4. Electrification

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

The Electrification R&D effort focuses on early-stage research to support fast, secure, and resilient plug-in electric vehicle (PEV) charging on the nation's electric grid. Specifically, projects will increase the reliability of charging by focusing on smart-charging technology to support secure and cost-effective charging of large volumes of PEVs. Research will also focus on extreme fast-charging at power levels greater than 350 kW to support charging a PEV in 10–15 minutes and support heavy-duty truck charging as well. Impacts of PEV charging at scale for light-, medium-, and heavy-duty vehicles will be minimized through technologies that provide better flexibility and control, such as wireless charging approaches and chargers that use distributed energy resources, further supporting the Grid Modernization Initiative (GMI) and leveraging developments in battery energy storage technologies through the Behind the Meter Storage (BTMS) effort.

Electric Drive Research conducts R&D to reduce the cost of electric traction drive systems that can deliver at least 55kW of peak power to $7/kW by 2022, enabling cost-competitive technologies for vehicle electrification. Early-stage research focuses on extreme high-power density motor and power electronics technologies that have the potential to support radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability. This work emphasizes a 10-fold reduction in the volume of electric traction drive systems, which combine power electronics and motors using high-density integration technologies. Approaches include wide bandgap devices, dense power electronics packaging, novel circuit topologies, and new materials for high-density electric motors. Electric traction drive system integration based on power electronics and electric motor innovations are also be a priority.

Project Feedback

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

Table 4-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt089	Assessing the North American Supply Chain for Traction-Drive Inverters, Motors, and Batteries for Class 3-8 Hybrid Electric and Plug-In Electric Commercial Vehicles	Chris Whaling (Synthesis Partners)	4-10	3.00	3.00	3.13	3.00	**3.02**
elt091	Cost-Effective 6.5% Silicon Steel Laminate for Electric Machines	Jun Cui (Iowa State University)	4-13	2.88	2.63	2.88	2.75	**2.73**
elt115	Zero-Emission Cargo Transport I: Zero Emission Drayage Trucks	Phil Barroca (SCAQMD)	4-17	3.00	3.25	3.25	2.00	**3.03**
elt158	Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project	Seungbum Ha (SCAQMD)	4-19	3.00	2.00	2.00	2.00	**2.25**
elt187	Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid (SPIN System)	Sunil Chhaya (EPRI)	4-21	3.25	3.00	3.38	2.75	**3.08**
elt188	Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity	Steven Sokolsky (CALSTART)	4-25	3.50	3.50	2.75	3.25	**3.38**
elt189	Electric Truck with Range-Extending Engine (ETREE)	Jesse Dalton (Cummins-Peterbilt)	4-27	3.60	3.40	3.50	3.38	**3.46**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt190	Medium-Duty Urban Range Extended Connected Powertrain (MURECP)	Matthew Thorington (Bosch)	4-31	3.33	3.33	3.50	3.00	**3.31**
elt191	Medium-Duty Vehicle Powertrain Electrification and Demonstration	Wiley McCoy (McLaren)	4-34	2.88	2.88	3.25	2.75	**2.91**
elt197	High Power and Dynamic Wireless Charging of Electric Vehicles	Veda Galigekere (ORNL)	4-38	2.75	3.13	3.00	2.63	**2.95**
elt198	Cybersecurity: Securing Vehicle Charging Infrastructure	Jay Johnson (SNL)	4-41	3.36	3.29	3.21	3.57	**3.33**
elt199	Cybersecurity: Consequence-Driven Cybersecurity for High-Power Charging Infrastructure	Richard Carlson (INL)	4-48	3.50	3.42	3.50	3.17	**3.42**
elt200	Scalable Electric Vehicle Smart Charging Using Collaborative Autonomy	Steve Chapin (LLNL)	4-53	2.88	2.75	2.50	2.63	**2.73**
elt201	Charging Infrastructure Technologies: Smart Vehicle-Grid Integration–ANL	Keith Hardy (ANL)	4-57	3.67	3.50	4.00	3.67	**3.63**
elt202	Charging Infrastructure Technologies: Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE)	Andrew Meintz (NREL)	4-60	3.50	3.33	3.67	3.33	**3.42**
elt204	Charging Infrastructure Technologies: Development of a Multiport, >1 MW Charging System for Medium- and Heavy-Duty Electric Vehicles	Andrew Meintz (NREL)	4-64	3.50	3.25	3.50	3.13	**3.33**
elt205	Cybersecurity for Grid-Connected Extreme Fast Charging Station (CyberX)	David Coats (ABB)	4-68	3.00	3.25	3.00	3.00	**3.13**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt206	Cybersecurity Platform and Certification Framework Development for Extreme Fast Charging, Integrated Charging, Infrastructure Ecosystem	Sunil Chhaya (EPRI)	4-70	3.50	3.38	3.63	3.13	**3.41**
elt207	Enabling Secure and Resilient Extreme Fast Charging: A Software/Hardware Security Co-Design Approach	Ryan Gerdes (Virginia Tech University)	4-74	3.00	2.67	2.50	2.67	**2.73**
elt208	Highly Integrated Power Module	Emre Gurpinar (ORNL)	4-77	3.50	3.38	3.75	3.63	**3.48**
elt209	High-Voltage, High-Power Density Traction-Drive Inverter	Gui-Jia Su (ORNL)	4-81	3.25	3.25	3.38	3.63	**3.31**
elt210	Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain	Greg Pickrell (SNL)	4-84	3.30	3.40	3.20	3.10	**3.31**
elt211	Power Electronics Thermal Management	Gilbert Moreno (NREL)	4-89	3.50	3.75	3.00	3.50	**3.56**
elt212	Non-Heavy Rare-Earth High-Speed Motors	Tsarafidy Raminosoa (ORNL)	4-93	3.00	3.00	3.00	3.13	**3.02**
elt213	High-Fidelity Multiphysics Material Models for Electric Motors	Jason Pries (ORNL)	4-96	3.10	2.90	3.20	3.10	**3.01**
elt214	Electric Motor Thermal Management	Kevin Bennion (NREL)	4-100	3.33	3.17	3.50	3.17	**3.25**
elt215	Permanent Magnets without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density	Iver Anderson (Ames Laboratory)	4-103	3.17	3.00	3.00	2.83	**3.02**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt216	Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines	Todd Monson (SNL)	4-107	3.20	3.00	3.20	3.00	**3.08**
elt217	Integrated/Traction Drive Thermal Management	Bidzina Kekelia (NREL)	4-111	2.83	3.33	2.67	3.00	**3.08**
elt218	Advanced Power Electronics Designs–Reliability and Prognostics	Doug DeVoto (NREL)	4-114	3.50	3.67	3.83	3.50	**3.63**
elt219	Power Electronics Materials and Bonded Interfaces–Reliability and Lifetime	Paul Paret (NREL)	4-117	3.33	3.50	3.50	3.33	**3.44**
elt221	Integrated Electric Drive System	Shajjad Chowdhury (ORNL)	4-120	3.50	3.67	3.33	3.33	**3.54**
elt222	High-Reliability Ceramic Capacitors to Enable Extreme Power Density Improvements	Flicker, Jack (SNL)	4-122	3.67	3.67	2.83	3.67	**3.56**
elt223	Component Testing, Co-Optimization, and Trade-Space Evaluation	Jason Neely (SNL)	4-125	3.50	3.67	3.50	3.50	**3.58**
elt234	Soft Magnets to Achieve High-Efficiency Electric-Drive Motors of Exceptional Power Density	Matthew Kramer (Ames Laboratory)	4-127	2.90	2.90	2.80	2.70	**2.86**
elt236	Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture	Watson Collins (EPRI)	4-131	3.50	3.00	3.00	3.00	**3.13**
elt237	Enabling Extreme Fast Charging with Energy Storage	Jonathan Kimball (Missouri S&T)	4-133	3.00	3.50	3.00	2.50	**3.19**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt238	Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection	Srdjan Lukic (North Carolina State University)	4-135	3.00	3.50	3.50	3.50	**3.38**
elt239	High-Power Inductive Charging System Development and Integration for Mobility	Omer Onar (ORNL)	4-137	3.83	3.67	3.50	3.33	**3.65**
elt240	Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks)	Mike Masquelier (WAVE)	4-140	3.17	2.83	3.17	3.00	**2.98**
elt241	High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kW/1000-V/400-A Extreme Fast Charger for Electric Vehicles	Charles Zhu (Delta Electronics)	4-143	3.38	3.50	3.38	3.38	**3.44**
elt242	Heterogeneous Integration Technologies for High-Temperature, High-Density, Low-Profile Power Modules of Wide Bandgap Devices in Electric-Drive Applications	G.Q. Lu (Virginia Tech University)	4-147	3.25	3.00	3.50	3.50	**3.19**
elt243	Integrated Motor and Drive for Traction Applications	Bulent Sarlioglu (University of Wisconsin)	4-149	3.50	3.50	3.33	3.50	**3.48**
elt244	Next-Generation, High-Temperature, High-Frequency, High-Efficiency, High-Power Density Traction System	Robert Pilawa (University of California at Berkeley)	4-151	3.50	3.17	2.83	3.00	**3.19**
elt245	Integration Methods for High-Density Integrated Electric Drives	Alan Mantooth (University of Arkansas)	4-154	3.13	3.25	3.25	3.25	**3.22**
elt246	Implementation of Wide-Bandgap Devices in Circuits, Circuit Topology, System Integration as well as Silicon Carbide Devices	Anant Agarwal (Ohio State University)	4-157	3.00	3.25	2.75	3.00	**3.09**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt247	Cost-Competitive, High-Performance, Highly Reliable Power Devices on Silicon Carbide and Gallium Nitride	Woongje Sung (State University of New York Polytechnic Institute)	4-159	3.67	3.33	3.17	3.50	**3.42**
elt248	Multi-Objective Design Optimization of 100-kW Non-Rare-Earth or Reduced-Rare Earth Machines	Scott Sudhoff (Purdue University)	4-162	2.50	2.75	3.00	2.50	**2.69**
elt249	Rugged Wide Bandgap Devices and Advanced Electric Machines for High-Power Density Automotive Electric Drives	Victor Veliadis (North Carolina State University)	4-164	4.00	4.00	4.00	4.00	**4.00**
elt250	Design, Optimization, and Control of a 100-kW Electric Traction Motor Meeting or Exceeding DOE 2025 Targets	Ian Brown (Illinois Institute of Technology)	4-166	2.00	2.00	2.50	2.00	**2.06**
elt251	Device- and System-Level Thermal Packaging for Electric-Drive Technologies	Yogendra Joshi (Georgia Institute of Technology)	4-168	3.33	3.50	3.00	3.17	**3.35**
elt252	Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization	Lakshmi Iyer (Magma Services of America, Inc.)	4-170	2.00	2.00	3.00	2.00	**2.13**
elt253	Motor with Advanced Concepts for High-Power Density and Integrated Cooling for Efficiency Machine	Jagadeesh Tangudu (United Technologies Research Center)	4-172	2.67	2.50	2.50	2.50	**2.54**
elt254	Ultra-High Speed, High-Temperature Motor	Joseph Lyding (University of Illinois at Urbana-Champaign)	4-175	2.33	2.17	2.50	2.00	**2.23**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt255	Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque	Soma Essakiappan (University of North Carolina at Charlotte)	4-179	2.83	2.50	2.67	3.00	**2.67**
elt256	Amorphous Metal Ribbons and Metal Amorphous Nanocomposite Materials Enabled High-Power Density Vehicle Motor Applications	Mike McHenry (Carnegie Mellon University)	4-182	2.67	2.50	2.83	2.67	**2.60**
elt257	Directed Electric Charging of Transportation using eXtreme Fast Charging (XFC) (DIRECT XFC)	Tim Pennington (INL)	4-185	3.00	3.00	2.67	2.83	**2.94**
elt258	Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC)	Matteo Muratori (NREL)	4-189	2.33	2.67	2.33	2.50	**2.52**
elt259	Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions	Marcus Malinosky (Daimler Trucks North America)	4-193	3.25	3.42	3.50	3.25	**3.36**
elt260	Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management	Teresa Taylor (Volvo)	4-198	3.25	3.25	3.42	3.25	**3.27**
elt261	High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter	Ben Maruqart (Ricardo)	4-203	2.88	3.00	3.00	2.88	**2.95**
elt262	Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging	Brian Lindgren (Kenworth)	4-207	3.07	3.21	3.29	3.07	**3.17**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt263	Cybersecurity: Securing Vehicle Charging Infrastructure - Consequence Analysis and Threat Assessment	Rick Pratt (PNNL)	4-212	3.25	3.25	3.00	3.25	**3.22**
Overall Average				**3.19**	**3.16**	**3.17**	**3.08**	**3.16**

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

Presenter

Chris Whaling, Synthesis Partners

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

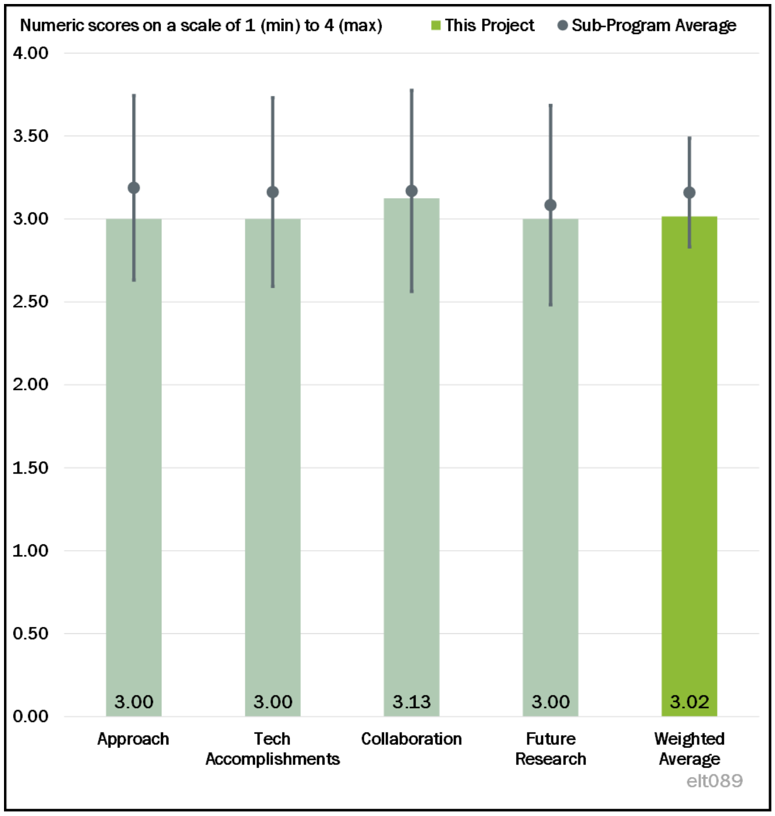

Figure 4-1 - Presentation Number: elt089 Presentation Title: Assessing the North American Supply Chain for Traction-Drive Inverters, Motors, and Batteries for Class 3-8 Hybrid Electric and Plug-In Electric Commercial Vehicles Principal Investigator: Chris Whaling (Synthesis Partners)

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

Reviewer 1:
The approach seems systematic and comprehensive.

Reviewer 2:
The approach includes logical steps; namely, data collection from primary and secondary sources followed by modeling of data and application of data analytics tools. Outcome of data analysis allows the project team to identify gaps. Key findings are included in the report. Fiscal Year (FY) 2019 findings are included in the report released to the public. This is an iterative process and a work in progress.

Reviewer 3:
It appears from the presentation that the majority of effort has focused on current state of the North American (NA) supply chain which addresses a barrier. Little information was presented on actionable intelligence for research and development (R&D) opportunities which should be of significant interest to the Vehicle Technologies Office (VTO) moving forward.

Reviewer 4:
Traction drive rare earth (RE) magnets are critical elements of which the majority of the current supply are controlled by a single country. Accessing the supply chain is very crucial for future R&D planning. It will be a value add to compare the cost and performance of heavy rare earth (HRE) magnets with reduced HRE magnets

versus HRE free magnets. The roadmap of these three technologies will decide the cost of the RE magnets too. This factor has to be taken into account in the model that is developed.

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

Reviewer 1:
The data collection method was clearly understood and implemented to understand gaps. Primary sources and contacts (hierarchy in source company) are categorized in the project report. The 2019 outlook of RE material mining from United States (U.S.) mines and global mines is stated in project report. Global distribution of RE reserves is provided in a bar chart. Price trends of RE are provided for the period of 20102019. RE oxides' average annual prices for the duration of 2015-2019 are outlined in the project report. U.S. government's RE stockpiles are outlined in the project report using a pie chart. For 2017, RE element applications are provided in the project report using a pie chart. For 2021, RE element applications are shown in the project report. Pie-chart based data visualization is quite easy to understand. Key RE supply chain bottlenecks are identified. Electric vehicle (EV) demand outlooks up to 2030 are provided in the report. In addition to the above, many outlooks are provided for various aspects of RE, oxides, and magnets.

Reviewer 2:
This project has tried to consolidate information about the current state of RE traction drive magnets and their supply chains in North America. Also, intelligence on R&D opportunities that can help strengthen RE supply chains, EVs, and autonomous vehicles in North America has been presented.

Reviewer 3:
There is reasonable progress made but the significance of the findings is not very clear.

Reviewer 4:
Considerable progress has been made in providing accurate information on the current state of the NA supply chain.

Progress against actionable intelligence on R&D opportunities appears limited from the presentation. This is supposed to be addressed in the January - April 2020 period.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was good collaboration with multiple entities.

Reviewer 2:
The project is led by Christopher Whaling in Synthesis Partners, LLC. For data collection, hundreds of contacts and touchpoints were made.

Reviewer 3:
In this project, efforts have been made to interact with numerous original equipment manufacturers (OEMs), Tier 1-4 suppliers, R&D organizations, universities, United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) Electrical & Electronics Tech Team members, the National Renewable Energy Laboratory (NREL) and Oak Ridge National Laboratory (ORNL).

Reviewer 4:
It appeared to the reviewer that there were Interactions with industry, universities, and National Laboratories as well as significant effort within primary and secondary research organizations.

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

Reviewer 1:
Potential pathways to NA RE-to-magnet supply chain renewal is included as a topic for future research, which is quite relevant.

Reviewer 2:
This is not a R&D project and no future research was proposed. The reviewer expects that this project will provide insight for future R&D opportunities.

Reviewer 3:
The go/no-go decisions were well in the past. The reviewer noted this project is about to end in about 3 months.

Reviewer 4:
The proposed future research and its significance are not very clear.

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

Reviewer 1:
RE supply chain assessment is very critical to plan future technologies and national security. The project supports U.S. Department of Energy (DOE) objectives very well.

Reviewer 2:
Understanding the RE market is critical moving forward.

Reviewer 3:
It is extremely relevant to know gaps in the supply chain of RE materials and magnets made thereof. Then, addressing RE materials supply chain gaps by carrying out targeted R&D project works. This project has the potential to support DOE-VTO in setting direction for future funding; therefore, this project and its findings may indirectly become quite relevant to DOE-VTO objectives and goals.

Reviewer 4:
This project supports the DOE objectives.

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

Reviewer 1:
Team is well organized with credible results presented.

Reviewer 2:
Project has necessary resources and funding to be successful.

Reviewer 3:
Based on the level of effort, the resources seem to be sufficient.

Reviewer 4:
From the presentation and principal investigator's (PI’s) comments, the project is expected to be completed within the proposed timeline and no additional resources are required.

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

Presenter

Jun Cui, Iowa State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers indicated that the project was relevant to current DOE objectives, 25% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers indicated that the resources were sufficient, 25% of reviewers indicated that the resources were insufficient, 25% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

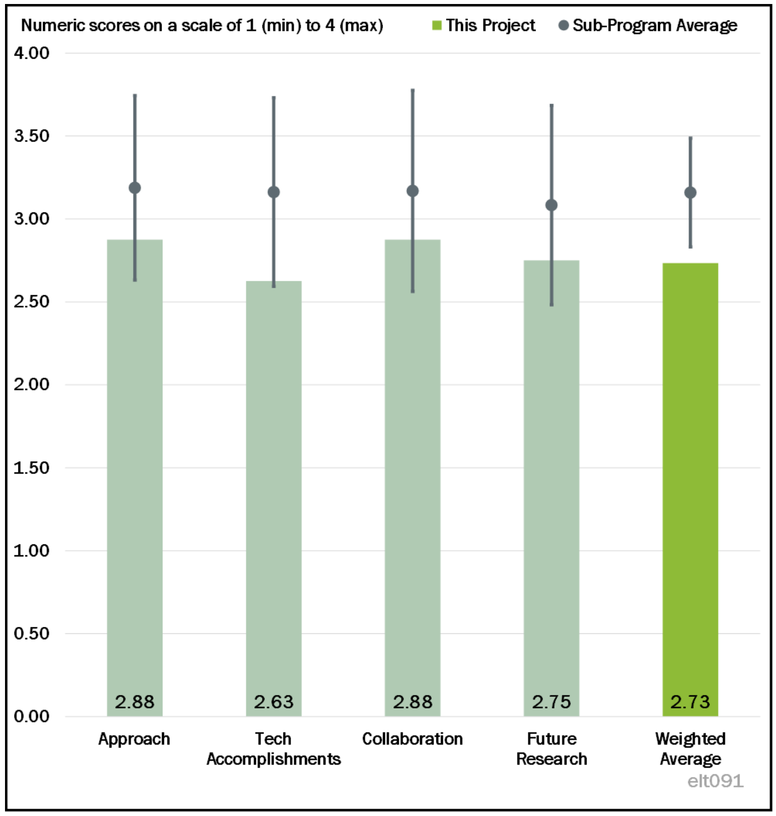

Figure 4-2 - Presentation Number: elt091 Presentation Title: Cost-Effective 6.5% Silicon Steel Laminate for Electric Machines Principal Investigator: Jun Cui (Iowa State University)

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

Reviewer 1:

It appears that the barriers are well understood.

Reviewer 2:

The reviewer was not familiar with the specifics of the metallurgical processes, but the approach seemed systematic and good progress was made.

Reviewer 3:

The reviewer is concerned about the scaling of hot press consolidation of the 6.5% silicon (Si) flakes. Is the hot press consolidation realistic for high volume production parts? The reviewer thought it depends how long the hot press process takes. The consolidation step to form a near net shape part concerns this reviewer in terms of the size of features that can be created or the overall size of the consolidated stack. This reviewer wished that this step had been examined more as part of the project.

Reviewer 4:

The reviewer's understanding from the presentation is that a new material has been developed but the presentation does not address any of the DOE targets that have been highlighted in Slide 2 (Cost and Power Density). As the project team states, the flux density of the 6.5% Si steel is much less when compared to conventional Si steel. Also, if the claim is reducing core loss at high frequencies, then a comparison of the state-of-the-art Si steel (used in automotive industry) should be compared with this 6.5% Si steel for flux density, core loss at different frequencies, and mechanical and tensile strength properties. The similar holds true for the manganese bismuth (MnBi) based non-RE magnet. A comparison of this magnet with a N42EH (for example or any other magnets which are widely used in the auto industry) must be compared for magnetic flux density and magnetic field strength (B-H) characteristics at 20 degrees Celsius (°C), 100°C, 150°C, 180°C and 200°C.

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

Reviewer 1:
The project is well on track.

Reviewer 2:
Good technical accomplishments have been made. While it appears that the MnBi coercivity increases with temperature in the plot on Slide 6, the romance appears to have a substantial drop. It is unclear if the overall energy product is increasing or decreasing with temperature. The rate of change with temperature is also unclear. It would be useful to compare these magnets to ferrite and automotive-grade neodymium iron boron (NdFeB). It is unclear how the calcium fluoride (CaF_2) insulation layer compares to standard C5 lamination insulation. The electrical resistivity versus melt spun wheel speed seems to have quite a wide error bar for some wheel speeds but not for others. The forsterite (Mg_2SiO_4) insulation coating appears to be very interesting.

Reviewer 3:
There is good progress made but it is not clear to this reviewer that the accomplished material properties and the test results of the prototype motor provide a path to meeting the DOE targets or surpassing the current state-of-the-art. There are some significant differences between predicted and measured results. The power density is far from the DOE targets. Also, the improvement in measured efficiency is not very clear. Lastly, more results around permanent magnets demagnetization should have been included.

Reviewer 4:
It is very difficult to understand how the magnet material, with much less energy density, and the 6.5% Si steel, with much less flux density and questionable core loss (as there is no comparison of core loss versus frequency between this steel and the conventional Si steel used in auto industry), will meet the DOE cost and power density targets. With limited time available in this project, it is very uncertain that the project objectives will be met.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is good collaboration in terms of materials development and integrating the new materials into a motor prototype and testing it.

Reviewer 2:
The coordination among the team partners appears to be good.

Reviewer 3:
The reviewer could not fairly assess from the slides, but the work seems to be well coordinated.

Reviewer 4:
Collaboration with OEMs, magnet suppliers, and steel suppliers would have been a big plus, which would have driven the project to attain the project goals in a timely fashion.

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

Reviewer 1:
The remaining barriers are really to scale the developed flake production processes for the magnet and 6.5% Si steel. This is a critical step and still quite high risk as the production of samples for this project were quite low in volume. It is encouraging that the project knowledge is being passed to Metglas who might scale it up and commercialize it.

Reviewer 2:
The project will be ending soon. This reviewer highly recommended continuation.

Reviewer 3:
This reviewer thought the proposed future research will require significant amount of resources and the path to meeting the DOE targets or surpassing the state-of-the-art is not clear.

Reviewer 4:
Based on the presentation it is very unclear how the technical barriers have been met or will be met. Can the project team compare the motor built (using the magnet and steel material developed), with an off-the-shelf electric machine (considering the stator diameter, stack length, voltage input, root mean square (RMS) current inputs, cooling, duty cycle all being the same), and claim that this motor can deliver much higher power density and efficiency with less cost?

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

Reviewer 1:
This reviewer described the project as one of the critical technologies for energy security.

Reviewer 2:
The development of a cost effective 6.5% silicon steel would be beneficial for the development of high-speed electrical machinery and the management of their losses. Increasing the ductility of the 6.5% silicon steel is also important. The work on MnBi magnets is also good, as a lower cost magnet alternative with a reasonable energy product would be a great alternative.

Reviewer 3:
It is relevant but it is not clear that it provides a clear path to meeting the DOE targets.

Reviewer 4:
The motor built with the materials developed in this project is going to give much lower torque density, power density, and efficiency and cost more.

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

Reviewer 1:
The project seems to be on track.

Reviewer 2:
About 90% of the project is done and the project seems to be wrapping up.

Reviewer 3:
It appears that the project partners mostly have sufficient resources for the completion of the project and milestones. The reviewer was concerned that some of the final milestones were not met and it is not clear if that was due to resource restrictions.

Reviewer 4:
Without support from OEMs and magnet and steel suppliers, it is very vague how the objectives can be met with the current resources.

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

Presenter

Phil Barroca, South Coast Air Quality Management District

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

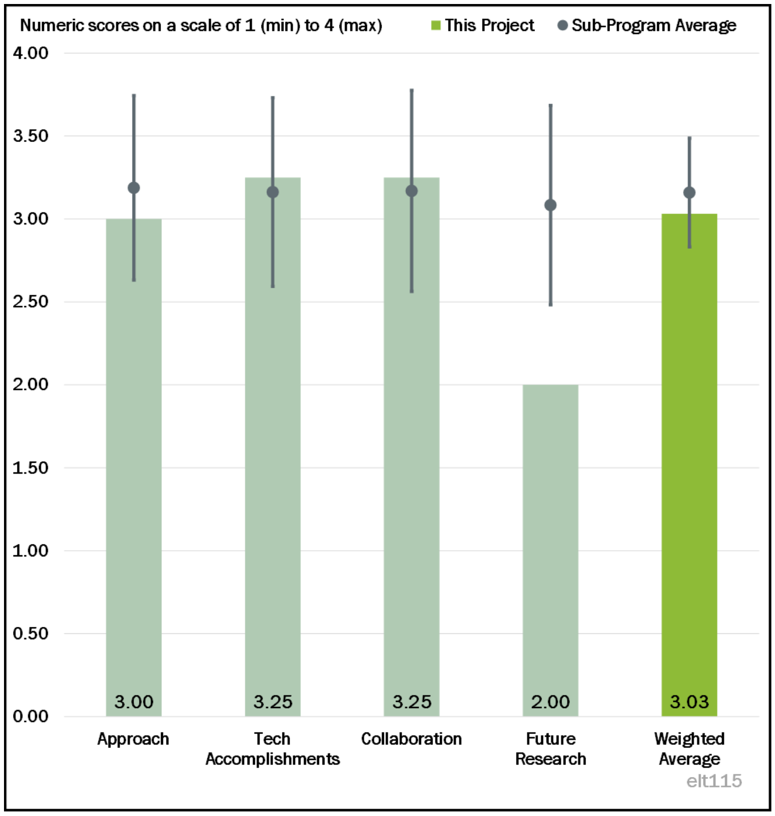

Figure 4-3 - Presentation Number: elt115 Presentation Title: Zero-Emission Cargo Transport I: Zero Emission Drayage Trucks Principal Investigator: Phil Barroca (South Coast Air Quality Management District)

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

Reviewer 1:

Laboratory work is important for development of new technologies, but successful demonstration in the field is the key element in commercialization. It is only by actually building and operating different types of trucks in the real world that experimental vehicles can be appropriately evaluated. This project did a very good job showing that electric drayage trucks could really work.

Reviewer 2:

The approach of testing the feasibility of all electric trucks using four platforms (two battery-electric and two plug-in electric) was a good idea. Certainly, the test site was a good choice: Ports of Los Angeles and Long Beach, the largest ports in the United States and also the most needed locations because they are in a non-attainment area and of concern to neighboring ethnic minority disadvantaged communities.

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

Reviewer 1:

Several different configurations were built and successfully operated under real-world conditions. Difficulties were identified and designs updated to overcome them. Results were clearly presented and will enable manufacturers and users to move forward. The reviewer would like to have seen a bit of discussion on which types of trucks were most likely to be successful in which types of operations, and what types of locations.

Reviewer 2:
The objectives could have clearer in specifying whether this was a proof-of-concept, exploratory, or otherwise a specific type of demonstration. The reviewer was expecting certain quantitative rather than qualitative goals and objectives to be specified at the onset. Also, it did not seem that the PI started out using the best state-of-the-art equipment, especially batteries. The PI needs to identify the particular problems besetting or preventing the use of all-electric drive trucks for drayage. For example, is it range? Is sufficient energy density storage a problem or something else? Another problem is that the PI was not using common units to compare fuel efficiency or fuel economy to allow for apples-to-apples comparison instead of apples-to-oranges comparison.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project required and achieved successful collaboration from a set of diverse industries, ranging from battery manufacturers to truck manufacturers to shippers. Without close collaboration, demonstrations could not have been achieved successfully.

Reviewer 2:
The reviewer did not have confidence that the project team looked at the best choices for the selection of electric batteries.

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

Reviewer 1:
The project is essentially complete.

Reviewer 2:
The reviewer really did not see much proposed future research in the area of all-electric drive trucks for drayage until a near-order-of-magnitude improvement in battery energy storage takes place. Otherwise, the reviewer thought it would not be of value.

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

Reviewer 1:
Drayage trucks are a significant fuel user and source of emissions in crowded port areas. There is a big opportunity to clean up our ports and reduce our use of diesel fuel if these trucks can be economically converted to alternative energy sources.

Reviewer 2:
Yes. It is necessary to examine all areas of transportation, including heavy-duty freight movement over the road to make sure all possible improvements in energy use are made.

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

Reviewer 1:
Without sufficient resources, the project team could not have invested the time required to design and redesign and build these trucks.

Reviewer 2:
The reviewer thought more than enough money was spent answering the question of whether all-electric drive trucks for drayage is feasible. This is an area not as suitable as, say, local pick-up and delivery.

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

Presenter

Seungbum Ha, South Coast Air Quality Management District

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

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

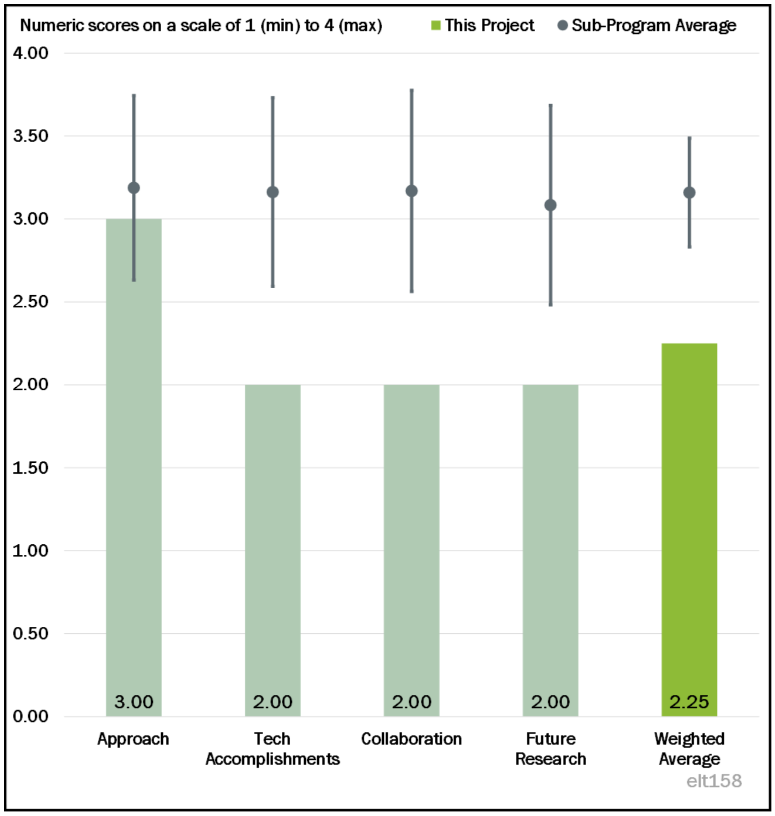

Figure 4-4 - Presentation Number: elt158 Presentation Title: Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project Principal Investigator: Seungbum Ha (South Coast Air Quality Management District)

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

Reviewer 1:

The reviewer did not think the goals and objectives of this project were defined well enough for anyone from the outside to decide whether the approach is good or not. There were no quantitative goals and objectives, so the reviewer wondered if this project is to just gather as much data as possible? If so, what is the purpose of gathering the data? Or is this a project to test feasibility of zero-emission range-extenders for drayage trucks? Or is the purpose to test feasibility of hydrogen fuel cells as an energy source for drayage trucks? Compressed natural gas (CNG) or liquefied natural gas (LNG) is perfectly suitable for use in auxiliary power units (APUs) for range extenders. It was not made clear how Zero-Emission Cargo Transport II (ZECT II) differs from ZECT I. Both are electric but it seems ZECT II relies on hydrogen.

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

Reviewer 1:

The reviewer was not happy at all that there were a lot of practical low-technology problems not even related to hydrogen fuel cells that have bedeviled the project, such as finding out the most optimum batteries for energy storage were not used at the beginning. Especially daunting to this reviewer was repeated failure of critical software updates, battery disconnects, power steering fluid pumps, motor inverters, traction motor resolver, transmission shift sensors, fuel cell coolant contamination, thermal management systems, and layout and packaging of components on the truck chassis, which should have been caught in the design stage rather than in testing. Most of the resources seems to have gone into addressing these "minor" problems.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team did not look well enough into analyzing and comparing different sources of hydrogen, such as: portable methane reformation (the largest natural gas filling station in the United States is located in Wilmington at or near the border between the Cities of Los Angeles and Long Beach); sharing with hydrogen fueling stations already in place for other vehicles, such as in Torrance, California; and hydrogen being used by neighboring oil refineries (hydrogen is being used to hydrogenate or convert many alkynes and alkenes to alkanes).

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

Reviewer 1:
A significant problem seems to be electric energy storage and the evolving nature of battery management systems. Until electric batteries are vastly improved, the reviewer would not fund any further research on ZECT II. While proof-of-concept or feasibility testing is worthwhile, the reviewer did not see future research on hydrogen fuel cells for drayage trucks as worthwhile until the cost of generating hydrogen drops and becomes competitive with fossil fuels. In the meantime, natural gas is a cleaner fuel than diesel fuel and could serve as a replacement for diesel fuel until hydrogen fuel cell technology and the cost of hydrogen both make hydrogen fuel cell trucks appropriate and relevant.

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

Reviewer 1:
It is important to examine every possible nook and cranny for potential uses of hydrogen fuel cell to reduce fossil fuel consumption, climate change impacts, and improve energy security.

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

Reviewer 1:
The reviewer questioned the team’s project execution.

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

Presenter

Sunil Chhaya, Electric Power Research Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

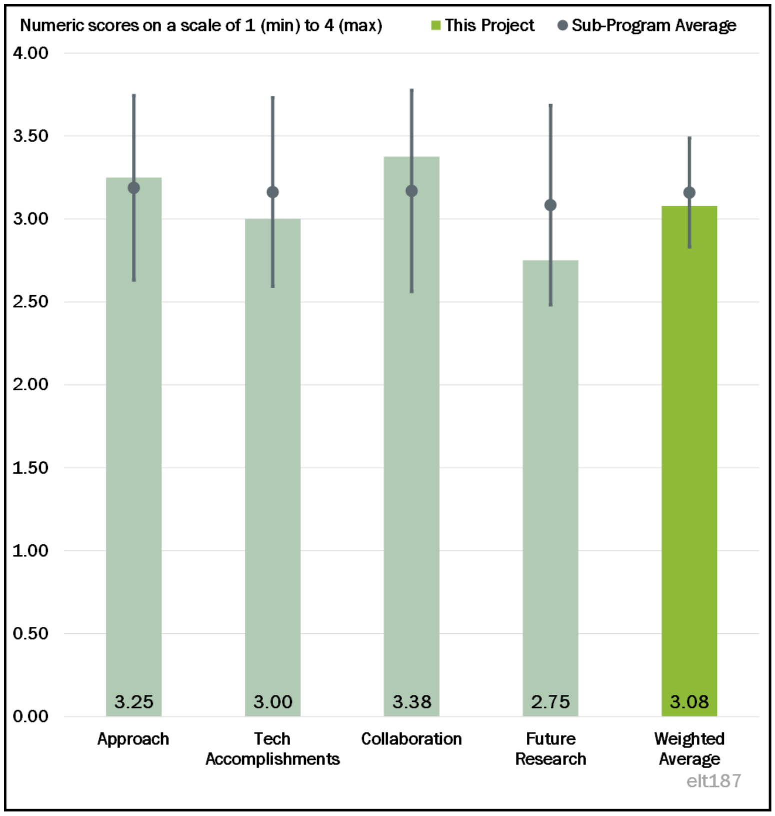

Figure 4-5 - Presentation Number: elt187 Presentation Title: Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid (SPIN System) Principal Investigator: Sunil Chhaya (Electric Power Research Institute)

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

Reviewer 1:

The technical approach addresses the project objectives in a reasonable fashion, given the hardware available.

Reviewer 2:

The project has a clear focus on enabling vehicle-to-grid (V2G) bi-directional flow integrated with solar and distributed resources. The plan is to impact open standards and enable greater use of V2G by focusing on the critical requirements for both on-vehicle and off-vehicle systems, key necessary elements for progress, and the strength of the approach. This project includes taking advantage of the Smart Power Integrated Node (SPIN).

Reviewer 3:

The approach toward achieving the technical goals is adequate. The project has been substantially delayed, and it is critical that important remaining tasks, such as the durability study, are not shortcut.

Reviewer 4:

The project appears well behind schedule and delayed. Some delays are cited on Slide 6 prior to the COVID-19 shutdown. More rigorous project management on timeline delivery would be beneficial.

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

Reviewer 1:
Open standards work is a valuable outcome which may lead to industry standards. An accompanying technology demonstration is also good to have.

Reviewer 2:
Most of the project tasks have been accomplished; however, there are critical tasks that will require significant time, beyond the expiration date of the project, to be completed.

Reviewer 3:
Overall, the project appears to be making solid progress, though the project team has seen some delays. On-vehicle technology demonstration is completed. For on-vehicle activities, the project team has completed some standards work and a look at grid stability and reliability. Off-vehicle integration is progressing. For off-vehicle efforts, the project team has completed some initial development work and set up for testing. In particular, to date, the project team has focused upon the development of the SPIN system (off-vehicle), both communication architecture and software. Remaining work will focus on verifying open standards. Two activities have been delayed from December 2019 and February 2020, and all testing was halted in March 2020 due to COVID-19. A year ago, their schedule was already noted as aggressive, so this is a source of greater concern. The project team appears to have a plan to do some work in parallel to catch up, and the project has already received an extension.

Reviewer 4:
Delays have put the project behind schedule. COVID-19 does not improve the matter; however, the project inception of 2016 should have yielded further progress than that shown.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project features an excellent collaboration across industry and National Laboratories. Presence of an automotive OEM with significant involvement in the project is a helpful step toward future development of the technology.

Reviewer 2:
The project has brought together a solid team of partners: the Electric Power Research Institute (EPRI) (lead); hardware vendors including a vehicle OEM; two National Laboratories; and the Society of Automotive Engineers (SAE). All appear to be focused on appropriate and key roles and contributing effectively to the project.

Reviewer 3:
Required partnerships with electric utility, EPRI, and auto OEMs are appropriate for this project.

Reviewer 4:
The project team has some very good and capable partners. The presentation did not specifically discuss collaboration and coordination effectiveness; however, delays would suggest it could be improved.

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

Reviewer 1:
The team has identified a clear path for research remaining under this project, as well as under future efforts. The team has several key elements planned to ensure the fully integrated system is built and tested under the remainder of this project as well as for impacting SAE standards. The project team does expect commercialization to continue through another funded research project.

Reviewer 2:
The future work outlined is an appropriate extension of the project work done so far.

Reviewer 3:
The project was slated to finish June 2020; however, it appears that this is unlikely due to current status and the COVID-19 shutdown.

Reviewer 4:
The remaining challenges are very significant and appear to have been slightly downplayed by the presenter. More clarity should be provided on how the PI will remediate the delays that have occurred during the project and what steps will be taken to ensure that the final tasks will be addressed appropriately.

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

Reviewer 1:
The project is focused on enhancing V2G for EVs, including coordination with critical industry standards, which will be needed to move EVs forward in the marketplace. By both improving charging and providing opportunities for load management through EVs as a distributed energy resource, the project supports displacing petroleum.

Reviewer 2:
The project supports DOE VTO goal of EV adoption for energy consumption reduction. EV users could see a customer-facing benefit of having an EV plugged in at home.

Reviewer 3:
In order to investigate energy savings and integration technology, V2G interoperability and benefits need to be defined, integrated, and tested. This concept is addressed in this project.

Reviewer 4:
The project supports the DOE objectives of expanding charging infrastructure for electrified vehicles.

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

Reviewer 1:
The project had sufficient resources and collaborators to achieve the demonstration.

Reviewer 2:
Resources appear to be adequate.

Reviewer 3:
There was no indication made that resources were insufficient. There is a concern that the project will not be completed on time due to delays even before COVID-19 shut down testing, though the PI seems confident the project should be close to completion and within the extension already provided.

Reviewer 4:

The organizations involved in this project have the competence and sufficient resources to complete the remaining milestones. Timing will be an issue, and very likely the project will have to be extended. Will the team members be able to continue the work with the remaining funding?

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

Presenter

Omer Onar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

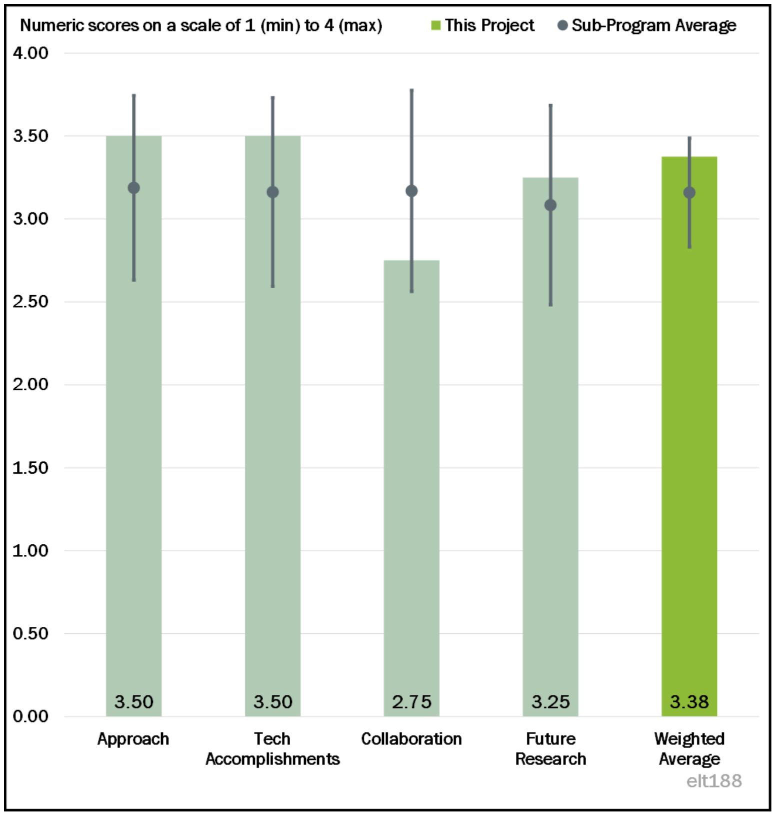

Figure 4-6 - Presentation Number: elt188 Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity Principal Investigator: Steven Sokolsky (CALSTART)

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

Reviewer 1:
The reviewer described the project as an excellent systematic approach.

Reviewer 2:
The project appears to continue to progress toward overcoming barriers outlined and approved previously, using logical framework and partners.

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

Reviewer 1:
Excellent progress has been made and a lot of hardware demonstrated.

Reviewer 2:
The reviewer had no additional comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is a reasonable level of collaboration.

Reviewer 2:
It would be helpful to have the background and the value proposition from a commercial partner, such as United Parcel Service (UPS), as guidance and metrics for project success.

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

Reviewer 1:
The future work is consistent with the overall project plan.

Reviewer 2:
The reviewer had no additional comments.

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

Reviewer 1:
Wireless charging is important for expanding future charging capabilities.

Reviewer 2:
The reviewer did not have the full history of this project or DOE objectives that may be related, so more information from commercial project partners to clarify the value of success compared to the value of alternatives would have been ideal.

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

Reviewer 1:
Resources are sufficient.

Reviewer 2:
The reviewer had no comment.

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

Presenter

Jesse Dalton, Cummins

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

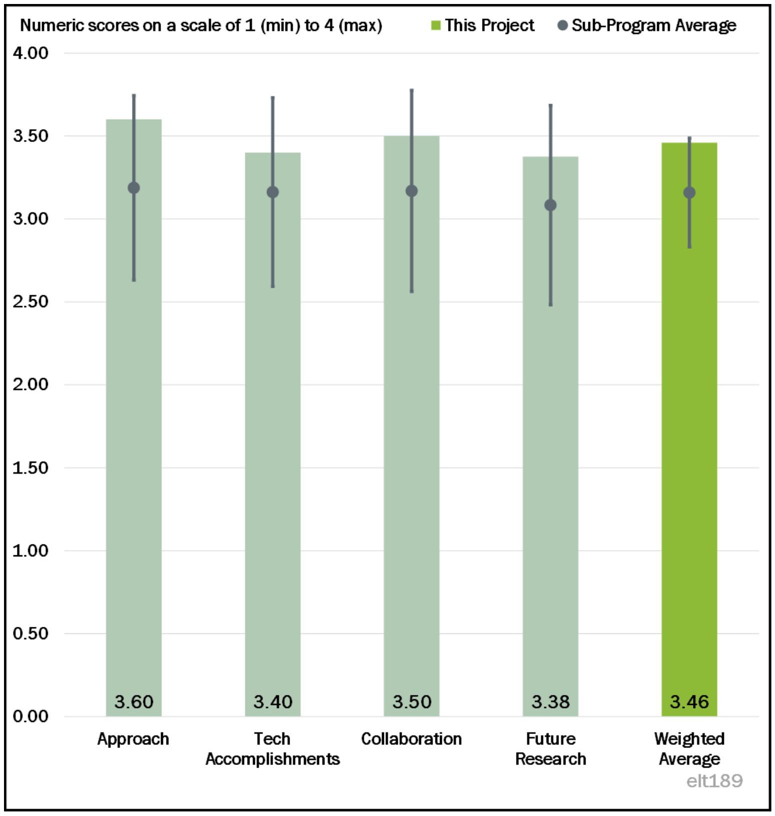

Figure 4-7 - Presentation Number: elt189 Presentation Title: Electric Truck with Range-Extending Engine (ETREE) Principal Investigator: Jesse Dalton (Cummins-Peterbilt)

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

Reviewer 1:

The reviewer was impressed with the approach. There was a good balance of effort, from dealing with changing industry expectations around hybrids (no belief in battery electric vehicles [BEVs] previously to now an almost over-belief or hype in them) to keeping total cost of ownership (TCO) or payback front and center to dealing with component issues, and so on. The reviewer did have a concern with using only the NREL Fleet DNA data. There are too few fleets involved in Fleet DNA. The project made great use though of the 80 and 100 duty cycles since they are representative.

Reviewer 2:

The project approach to understanding customer requirements for Frito-Lay was very wise. Frito-Lay operates class 5-7 pick-up and delivery trucks, comparable performance as conventional and, generally, desire flexibility provided by a range extender. These trucks also have the capability to operate in pure electric mode for a substantial part of route. Frito-Lay was a solid choice.

Reviewer 3:

The fact that the team has managed to get a truck on the road, with a large corporation seriously testing it for possible future use, demonstrates technical feasibility. The economic analysis shows competitiveness under certain conditions, and the PI has suggested improvements to extend the conditions to make it even more competitive.

Reviewer 4:

The project worked as promised.

Reviewer 5:
The project is nearly complete and the key technical goals have been met, which would lead to the conclusion that the approach was well thought out.

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

Reviewer 1:
The team persevered—good work. The project met the technical goals of zero emission operation and fuel consumption reductions. This reviewer liked using the trip to and from Indiana to Texas for analysis. There are many teams that would have missed this opportunity.

Reviewer 2:
The project accomplishments include a full powertrain demonstrated in test cell. The project team completed two truck builds as well as verification and validation activities for vehicle road worthiness. Additionally, the project demonstrated 65% fuel reduction over the conventional class 6 truck on a modified 80-mile work day duty cycle (NREL80). The project team is conducting on-road testing spanning multiple states and environmental conditions and undergoing a fleet trial with Frito-Lay in Indianapolis.

Reviewer 3:
The addition of a range extender was a key feature. Without it, range anxiety might preclude putting these trucks on actual routes. On the other hand, it is key to keep the additional power supply cost down. In the reviewer's opinion, battery vehicle with small batteries that cover most day-to-day needs, with a small engine backup, is the best of both worlds.

Reviewer 4:
The key vehicle efficiency milestone was met. For vehicle development, the reviewer would rate the project with an "Excellent." An overall rating of "Good" for progress was given due to delay in real-world vehicle testing based on impact of COVID-19. The real-world operation of the vehicle seems like a very critical step in the project and one that seems key to understanding the vehicle performance and the efficacy of the design that resulted from earlier project efforts.

Reviewer 5:
The project is a little behind but that is expected. The project is ending soon.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
A strong team was assembled with industry, academia, and National Laboratories. Cummins, PACCAR, NREL, Argonne National Laboratory (ANL), and Ohio State University (OSU) are all great partners. Frito-Lay is a solid fleet partner.

Reviewer 2:
The project had good coordination with others.

Reviewer 3:
The vehicle developers made good use of the NREL trip data to avoid over-designing the power source. Similarly, operating data will be further used to optimize the size of future range extender units.

Reviewer 4:
The project team reporting of the achievement of key vehicle design specifications would indicate that the team performed well in the area of collaboration and coordination.

Reviewer 5:

The collaboration was strong among key partners. The reviewer perceived a missed opportunity to engage Frito-Lay more. Frito-Lay has much to offer with their detailed understanding of duty cycle data, their experience with all electric box trucks from Smith Electric, and both their interest and concern with BEVs ongoing. This would have been an outstanding place for this team and Frito-Lay to summarize how hybrids might fit in the full spectrum of options. Actually, the reviewer was hoping for such an analysis and slide here in this review.

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

Reviewer 1:

Future research includes: completing a fleet demonstration trial period with Frito-Lay; investigating use of electric-only operation in certain geographic areas ("geo-fencing") in Frito-Lay's delivery areas; analysis and future research of range extender sizing per class of truck, duty cycles, batteries, and geo-fencing requirements;, continued research on state-of-charge management using fleet management data, traffic, and weather; and continued industry education and outreach on range extender benefits.

Reviewer 2:

Future projects with smaller engines will improve the economics.

Reviewer 3:

The reviewer agrees with the PI's final future research comments on industry education and outreach. The benefits of true BEV medium-duty (MD) trucks will continue to dominate discussions in the trade press and with end-user fleets. Also, the drive to zero emissions, not less emissions, is also dominating consciousness. Hybrids will have a place and the industry needs the knowledge from this work. More explanations should be shared on the total cost of operation compared to both diesel and BEV alternatives. Can this still be done inside the budget of this project?

Reviewer 4:

The project is ending soon.

Reviewer 5:

The COVID-19 impact on vehicle field trials is a concern. The presentation did not make clear if the vehicle will be carried to a commercial platform, leaving the reviewer wondering how did the project impact electrified vehicle availability and viability? The field trial may help answer this question.

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

Reviewer 1:

Delivery trucks use significant quantities of diesel fuel, creating emissions and noise in cities. Reduction of fossil fuel use is a key DOE objective.

Reviewer 2:

Electrification of delivery vehicles seems promising from an environmental and energy standpoint. Furthering success in this area seems befitting of a DOE project.

Reviewer 3:

Yes, the project is very relevant, addressing cost of the batteries and return of investment (ROI).

Reviewer 4:
The project meets the DOE objectives by proving that large fuel economy improvements can be made while giving fleets the peace of mind to complete their routes without range anxiety.

Reviewer 5:
The project is more relevant now than in prior years.

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

Reviewer 1:
The reviewer observed a good job completing this work, given challenges along the way.

Reviewer 2:
The reviewer noted good management.

Reviewer 3:
Sufficient resources are allocated to this project.

Reviewer 4:
Based on successful development of the vehicle systems was indicated by this reviewer.

Reviewer 5:
The trucks got built and made it into commercial testing operations.

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

Presenter

Matthew Thorington, Bosch

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

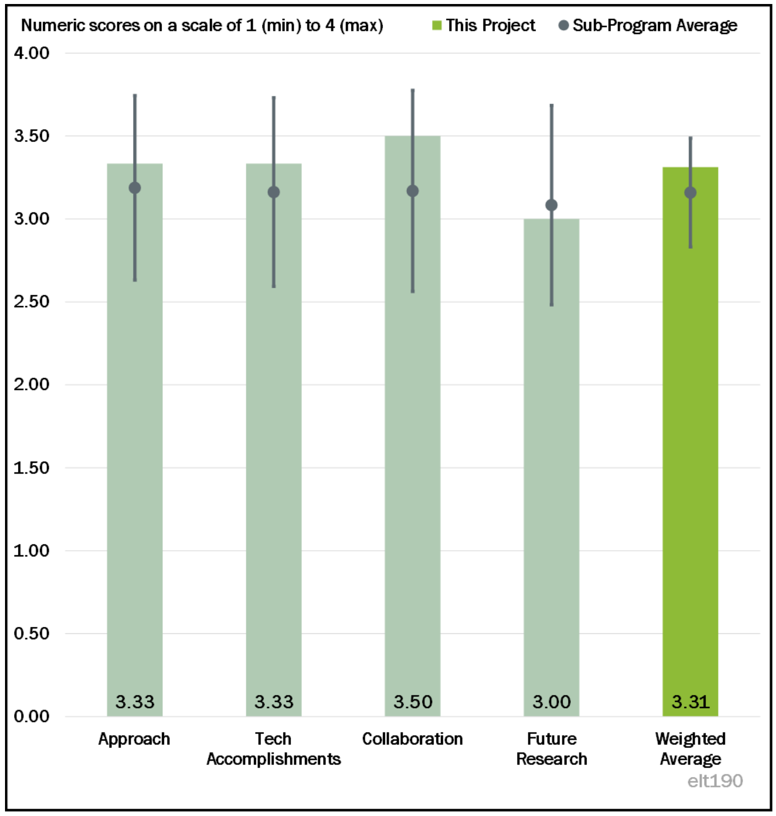

Figure 4-8 - Presentation Number: elt190 Presentation Title: Medium-Duty Urban Range Extended Connected Powertrain (MURECP) Principal Investigator: Matthew Thorington (Bosch)

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

Reviewer 1:

The approach was very good, from powertrain development to simulation and then the powertrain integration and demonstration.

Reviewer 2:

It was a good initial thought to reuse existing parts (two motors).

Reviewer 3:

Getting a truck designed, built, and tested is no small feat. However, since the other similar projects also included on-road testing in commercial operation, this project seems like it could have done more. The project seems more into analysis and theory than similar projects. That is not necessarily a bad thing.

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

Reviewer 1:

On the chassis dynamometer test, the PowerSplit Plug-in Hybrid Electric Vehicle (PHEV) system consumed 4.3 kilowatt-hours (kWh) of electrical energy, operating 46% of the time in single motor EV mode and 38% of the time in dual motor EV mode. This resulted in a 100% reduction in raw fuel consumed and 58% in diesel equivalent energy consumption (21 miles per gallon equivalent [MPGe]).

Reviewer 2:
Unfortunately, the poster for this project did not include technical details on vehicle and propulsion system architecture, so it is difficult to evaluate how innovative their work was, but the fuel reduction was impressive.

Reviewer 3:
The project team did some testing, but the project is not really different from last year.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Project partners and vendors are a strong team, which include Robert Bosch LLC; University of Michigan; Morgan Olson; VOSS Automotive; Ricardo; NREL; and Freightliner Custom Chassis Corporation.

Reviewer 2:
Getting a new technology design up and running can only be achieved with the collaboration of talented people from many disciplines.

Reviewer 3:
The project had a good partner list.

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

Reviewer 1:
Future research includes chassis dynamometer testing with fixed transmission temperature sensor and criteria emissions evaluation on the powertrain dynamometer. The project team will also include private test track validation.

Reviewer 2:
Perhaps with more money, the project team could test with a company on the road.

Reviewer 3:
The project scope was cut and is winding down.

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

Reviewer 1:
The project plans to demonstrate 50% fuel consumption reduction utilizing a PHEV powertrain with a dual-planetary gear transmission via deep integration of electric components based on high-volume light duty vehicles.

Reviewer 2:
Anything that reduces our use of liquid fossil fuels is of interest to DOE.

Reviewer 3:
The project indicated decreasing fuel consumption.

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

Reviewer 1:
There are sufficient project resources.

Reviewer 2:
This is a tough one, since some of the tasks were not completed. That may have been a COVID-19 problem.

Reviewer 3:
The project was a good try, but it seems like a dead-end for this propulsion architecture in the current form.

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

Presenter

Wiley McCoy, McLaren

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

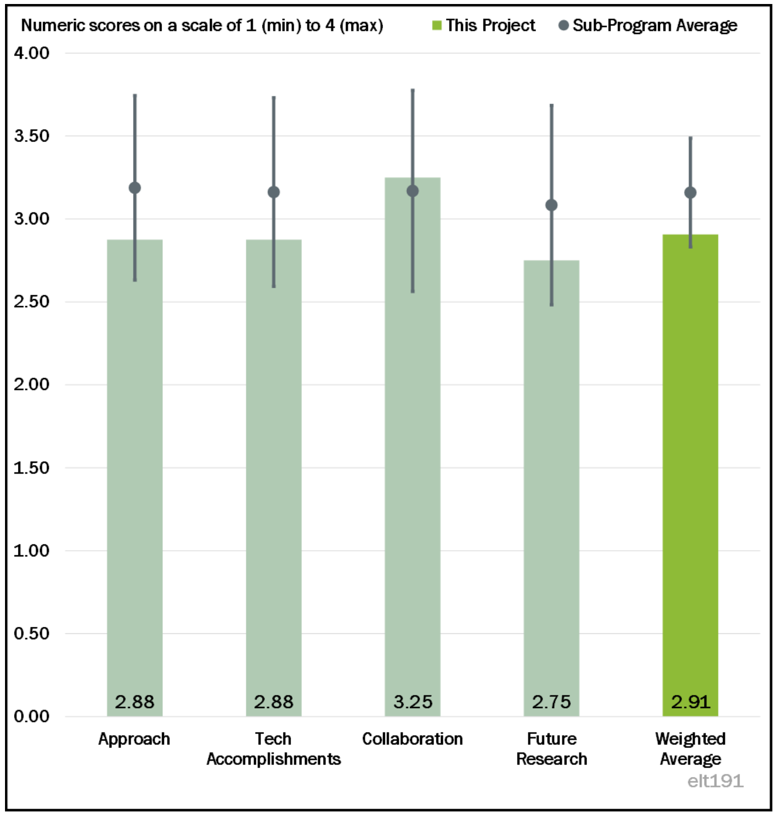

Figure 4-9 - Presentation Number: elt191 Presentation Title: Medium-Duty Vehicle Powertrain Electrification and Demonstration Principal Investigator: Wiley McCoy (McLaren)

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

Reviewer 1:

The reviewer thought the approach of E-motor, E-Axle, range extender, and battery was good. However, based on the results so far, the reviewer would suggest stopping any more work on the first-generation and continue developing or improving a second-generation electric powertrain for MD vehicles for use in the pick-up and delivery arena. Truck electrification has the greatest promise for MD vehicles used for pick-up and delivery, which are needed because such vehicles generally have a high stop-and-go rate and operate in congested areas where emissions are also highest.

Reviewer 2:

The team is very persistent in the face of continuing problems. It is, however, always a hard question whether to give up on a key component that continues to cause problems or to find an alternative and move forward. In this case, delaying replacement of the 2-speed unit caused significant delays. Certainly, much was learned, and something not working is as valid a scientific result as something working.

Reviewer 3:

The project has been impacted by several setbacks and by the shutdown caused by COVID-19. It seems that the timeline has been significantly impacted and DOE funds have been depleted. Since the original objectives will likely not be met, the project lead should focus on re-scoping the remaining objectives and highlight the impact of the work conducted so far.

Reviewer 4:
A number of system failures occurred by what appeared to be a combination of lubrication issues in conjunction with shift control strategies relative to vehicle loading. Although some miles were put on the system in real-world demonstrations, failures ultimately sidelined broader use. However, it appears many lessons in this process were gleaned and are being used moving forward into other potential product streams. This is a positive for potential future technology applications.

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

Reviewer 1:
The system was designed, developed, and tested in mules. This was favorable. Issues surrounding the design and controls, however, ultimately led to failure.

Reviewer 2:
The project team has made progress toward demonstrating electric trucks. It is really hard to tell how many of the problems were due to a combination of bad luck and trying something really hard, and how many were caused by poor choices.

Reviewer 3:
The project has been impacted by setbacks resulting from multiple breakdowns that occurred during the testing phase. Are there any "lessons learned" from the experience? Additionally, more emphasis should be put toward measuring and benchmarking the performance (fuel economy in particular) of the electrified powertrain.

Reviewer 4:
The reviewer really appreciated the fact that the vehicle had achieved 100% of the DOE's fuel efficiency improvement even though the reviewer was totally dismayed that the PI was not able to tell the audience what the fuel economy goal was or what the fuel economy of the current vehicle was with the improved electric powertrain. It is not clear what the causes of the failure of the remote oil supply/scavenging system, E-motor resolver, inverter, and E-axle shifting were, but the project team needs to be held accountable to explain those causes and assure reviewers that those causes are being addressed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration plan described is very good; the role of the different participants is relevant and well explained.

Reviewer 2:
It is highly commendable and noteworthy that the PI is working directly with an end-user—UPS.

Reviewer 3:
Sufficient collaborators were present to design and test the technology on-road from chassis supplier to technology, and, ultimately, demonstration partners.

Reviewer 4:
Again, so little can be included in such a presentation that it is really hard to know whether any of the issues with this project could have been avoided/ameliorated with better communication among partners. The team seems to have included the right people for the right tasks.

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

Reviewer 1:
The project needs to continue despite the recent setbacks. There is very high potential for this project to succeed, very high need for it, and it is very clear that the end-user supports it.

Reviewer 2:
In spite of setbacks, the team has a plan to actually get the job done, and the team should be commended for that.

Reviewer 3:
The project is completed relative to the funding and project timing. However, although targets were not met, it was stated that what was learned from the failures will be applied to future works.

Reviewer 4:
Given that the project is approaching completion, any effort should be directed toward demonstration and verification of benefits.

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

Reviewer 1:
The project aims at demonstrating a plug-in hybrid powertrain for MD delivery trucks and quantifying performance (fuel economy improvement), cost, and reliability.

Reviewer 2:
Delivery trucks use lots of fuel and pollute inner cities; successful completion of this project will help reduce both problems.

Reviewer 3:
Yes. DOE core objectives include energy efficiency and reducing reliance upon non-renewable energy sources. Technical research projects into transportation sectors currently not utilizing electrification are a key ingredient to these objectives.

Reviewer 4:
This reviewer indicated the same answer as prior comments.

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

Reviewer 1:
The reviewer strongly suggested, even urged, adding more funds as necessary and appropriate to allow the project to continue if the project is in danger of being underfunded.

Reviewer 2:
Given the challenges and setbacks that occurred during the project, significantly more resources should be allocated before the concept is translated into a product that can be commercialized.

Reviewer 3:
The team does plan to deliver the promised product, in spite of having trodden a bumpy road.

Reviewer 4:
The project is nearly completed without success, and additional funds were spent by the contractor to get to the final result.

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

Presenter

Veda Galigekere, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

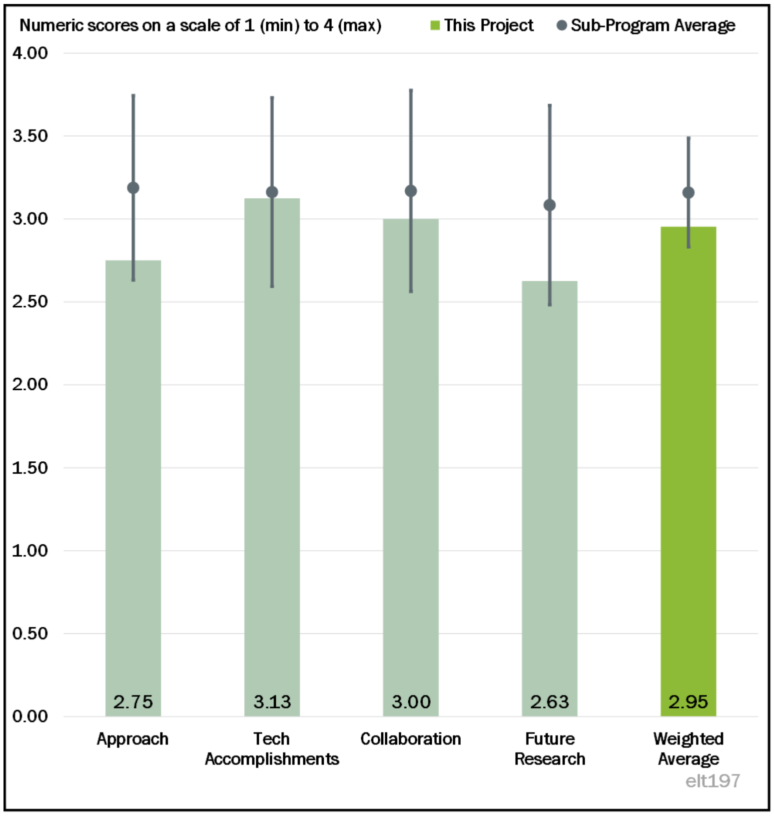

Figure 4-10 - Presentation Number: elt197 Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

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

Reviewer 1:

Going step-by-step is a very good way for the approach, and this project is doing that. The project culminates with a vehicle-level validation.

Reviewer 2:

The approach looks solid. It starts with targets, then laboratory-scale testing followed by real-world validation test. The project has demonstrated some success with the completion of the go/no-go milestone in September of 2019. The timeline on Slide 9 seems to be incorrectly marked as 2018 and 2019 rather than 2019 and 2020.

Reviewer 3:

There is a good approach, but some intermediate verification of the dynamic aspect would be helpful.

Reviewer 4:

The reviewer's comments hinged on the feasibility portion of this project and the lack of information (apparently) captured about cost, ownership, responsibility, funding, maintenance, automaker standardization, and others compared to present alternatives that leverage larger batteries with non-roadway fast charging locations, especially considering likely continuation of improvements in both battery density and cost.

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

Reviewer 1:
The project has accomplished a significant amount of technology. The simulation has been good as well as the hardware development.

Reviewer 2:
This may not be fair if the project team did not have control and/or input into the project objectives and barriers to overcome, but it does not seem that this project is adequately determining whether this approach can meet consumer expectations and needs with a value proposition that exceeds that of others currently in place for corridor fast charging.

Reviewer 3:
A lot of progress appears to have been made over the past year with 4 accomplishments from FY 2019 mentioned and 15 from FY 2020. There was no mention of impact on the schedule due to COVID-19 related closures. While it is understandable that many of the analysis tasks could have been completed remotely, the reviewer suspected there will be delays for the go/no-go decision point associated with the standalone test of 200 kilowatt (kW) power electronics and completing the overall FY 2020 phase of validating a 200 kW Dynamic Wireless Power Transfer (DWPT) systems in the laboratory.

Reviewer 4:
Good progress has been made but since most of the milestones are still in progress, it is hard to reach an accurate assessment at this point. More details about the dynamic aspect of charging should be included

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found good collaboration among participating organizations.

Reviewer 2:
Collaboration was comprised of three laboratories and three outside entities. Each team member had a clear and complementary scope.

Reviewer 3:
The teams seem to be gainfully working toward the same goals in a coordinated fashion.

Reviewer 4:
A key missing perspective here is that of consumers and federal and state agencies that would be integral partners for any deployment and maintenance of such assets.

According to the reviewer, there are key missing answers to these questions: Would this deployment materially affect EV adoption independent of other factors? Are deployments along federal and state transportation corridors physically, technically, and legally feasible? Who would need to fund this equipment and the accompanying installation and deployment, and what is the feasibility of such an investment?

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

Reviewer 1:
More focus on the dynamic aspects is needed.

Reviewer 2:
The future research looks appropriate and logical. It would be good to hear more about the work needed on the pavement side of the system and the implications (both technical and cost) to the roadways when that information is ready to be presented.

Reviewer 3:
Using a single active rectifier on the secondary side is a very good way to minimize the complexity. Has any thought been given to the reliability of the system and the backup for that reliability? Near future needs will need much higher power levels. The 200-kW level is high good for initial development and good for passenger vehicles. However, soon commercial trucks will need higher power to keep them moving, assuming this is a good solution. Any initial roadway developments should include higher power levels and just not be limited to passenger vehicles.

Reviewer 4:
The project seems to have continued beyond the feasibility portion without sufficient justification.

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

Reviewer 1:
This project supports DOE's overall objectives. If successful, it will provide cleaner, more efficient transportation options.

Reviewer 2:
Dynamic wireless power transfer is very relevant for the future of charging.

Reviewer 3:
This project is relevant. It needs to make sure that tearing up a roadway to install this technique is relevant for the future. In general, it seems as though it will be very expensive and cause significant maintenance for the road system. How much of the road system needs to be torn up? Do you put a half mile down every 10 miles? What is the duty cycle?

Reviewer 4:
Considering and vetting alternatives that enable long distance electric travel for consumers is important, and the reviewer believed that the project does support DOE objectives, but more attention is required on feasibility and value propositions.

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

Reviewer 1:
It appears to the reviewer that resources are sufficient.

Reviewer 2:
The resources seem to be sufficient for the work that needs to be completed.

Reviewer 3:
Great accomplishments with the given resource.

Reviewer 4:
The reviewer provided no comment.

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

Presenter

Jay Johnson, Sandia National Laboratories

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

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

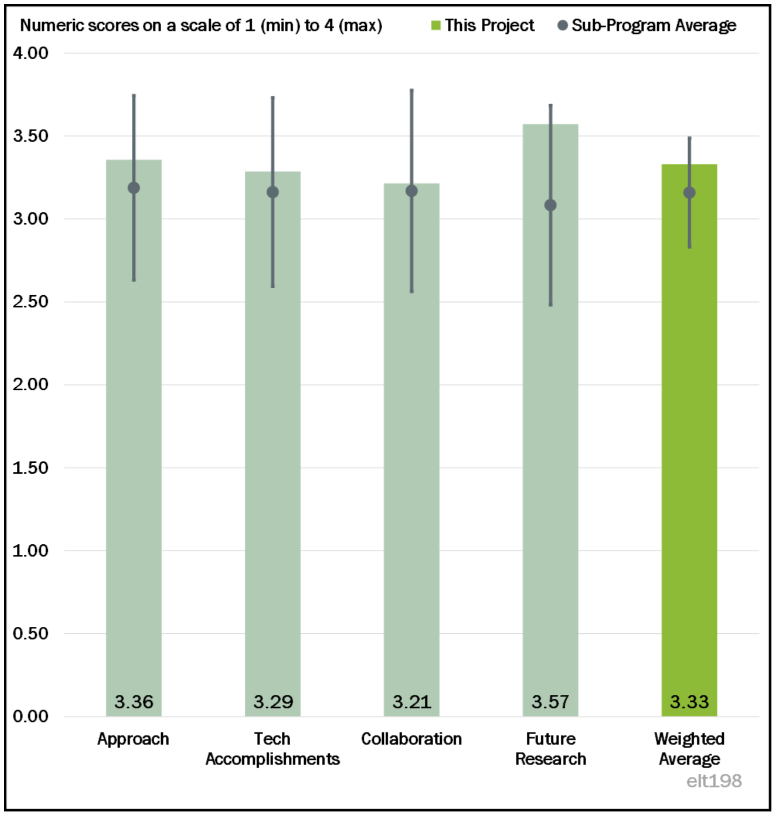

Figure 4-11 - Presentation Number: elt198 Presentation Title: Cybersecurity: Securing Vehicle Charging Infrastructure Principal Investigator: Jay Johnson (Sandia National Laboratories)

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

Reviewer 1:

By building models to quantify cybersecurity risks to electric vehicle supply equipment (EVSE) and establish actionable recommendations to protect charging infrastructure, automotive, charging, and utility stakeholders can better protect customers, vehicles, and power systems in the face of new threats. The project team approach is solid.

Reviewer 2:

The approach appears to be developed in a rational and detailed manner, with each element of the approach addressing the key issues. This is a complex area to address, and this project is only at the front end of research. It is also good to see that the project is designed to address security concerns covering multiple areas (not just technical, but also business, etc.) as well as various sources of attacks.

Reviewer 3:

This project represents a timely, first, fully comprehensive threat assessment looking at the entire EV and EV charging and grid ecosystem. It provides a high-level view of the risk landscape, interconnected assets, secure and unsecured interfaces, and attack surfaces. The project takes a two-pronged approach: (1) vulnerability assessment and threat model development and (2) investigation of consequences associated with charging/vehicle vulnerabilities with regard to the grid. The end goal is to create a risk-based matrix and prioritize mitigation strategies. The approach is very logical and clearly recognizes it is impossible to guard against all potential cyber-physical attacks and as such a substantiated and robust prioritization process is essential.

The presentation provides a clear objective and stated project milestones to provide timely and useful information for stakeholders to improve cybersecurity across the EV and EV charging and grid ecosystem, including OEMs, EVSE vendors, network operators and aggregators, utilities, and standards developing organizations (SDOs).

Overall, no specific weaknesses are noted in the project approach. The project approach is very well designed, logical, and directly addresses the technical barriers. This includes the reality that the EV and EV charging and grid ecosystem is a complicated system of systems which includes numerous stakeholder entities and interfaces, all of which pose potential cybersecurity risks. The project identifies a number of technical barriers and gaps, including the lack of a comprehensive cybersecurity approach, limited best practices, and incomplete industry understanding of attack surfaces, interconnected assets and unsecured interfaces. The project specifically addresses these barriers. On Slide 7 (EV Charging Attack Graphs), the presentation identifies the use cases for which the attack graphs were created. It would have been helpful to identify the logic and process used to determine the specific use cases to pursue.

Reviewer 4:
The use of spoofing, tampering, repudiation, information disclosure, denial of service, elevation of privilege (STRIDE) is an appropriate means of getting your hands around a difficult problem if one assumes no system is invulnerable. The approach helps to identify the wide spectrum of potential risks in a systematic way.

Reviewer 5:
Applying a threat model toward alternating current (AC) and direct current (DC) charging stations and then evaluating consequences and grid impacts are an excellent approach. This uses existing standards and then applies different teams to determine threat and vulnerability levels. This established a basis for the industry to evaluate their product and improve it along with providing updates to the standards.

Reviewer 6:
On Slide 11 it is difficult to quantify probability. How can the probability be related to accessibility of the attacker to insert vulnerability into the system? On Slide 18 under Demos and Experiments, these should be considered to be essential rather than optional to support a recommend solution.

Reviewer 7:
The reviewer observed a good start although some changes should be made. However, this can still be an excellent project and contribute real value. In terms of strengths of the approach, simply focusing on this problem is excellent; this is a difficult and consequential issue. Using an adversarial mindset and including partners (e.g., National Motor Freight Traffic Association, Inc. [NMFTA], which well understands a segment of industry and can provide their perspective and vision) to develop the threat model is excellent. Using attack graphs is excellent.

There are opportunities for improvement. The reviewer had two specific items which, if accepted, would strengthen the project team’s work product. The first is to embrace crypto-agility and work it into the project’s guidance and solution—the project can use public key infrastructure (PKI) guidance as a specific exemplar, but make sure the project team does not force a solution which might be irreparably compromised within the expected lifespan of the fielded equipment which are using your guidance during the design and development activities. The second is to accept the simple fact that the major enemy is a nation-state adversary—do not hand-wave away this likelihood (as currently done in the project risk matrix). It was en vogue in the 2000-2008 timeframe to hand-wave away the risk from a nation-state actor, but reports suggest that by 2018 over a quarter of all cyberattacks were state-actor backed. This completely changes the approach, concerns, and the threat matrix. It also makes the project research both valid and allows it to protect real-world systems, given the changing reality of the adversary. Similarly, please also consider organized crime strongly in the project risk matrix and the resources organized crime would bring to the hacks.

Regarding concerns, the project highlights PKI and has a specific milestone (FY 2021) tied to PKI. The problem with this is that Quantum Crypto is getting very much closer to being a serious threat and if the project does not have crypto-agility built into its recommendations and the solution set and if the project does not allow for crypto-replacement, the project will likely strand products developed under its recommendations.

The reviewer found two major weaknesses that should be corrected. The first is the appearance of a reliance on STRIDE; the reviewer believed this is a fault—not even Microsoft exclusively uses STRIDE and there are ample studies to suggest a hybrid approach (see Software Engineering Institute research) using things, such as Common Vulnerability Scoring System or Security Cards, and then applying STRIDE to the pruned results delivers much better results. While STRIDE minimizes false positives, the reviewer thought the real concern was false negatives and it is certainly less than clear that STRIDE is a good tool for that. STRIDE is excellent for inexperienced teams and provides a checklist approach, but the reviewer emphasized that the project really needs a significantly better system for something as important as design of product that will live for decades in the infrastructure.

The second major weakness is that the project has not brought in outside reviewers. For reference, the Department of Defense brings in commercial red teams to attach highly classified systems and help with design approaches. The project should rotate between companies so no one company performs more than one assessment. The project team is accepting real risk and, in the reviewer's opinion, probably compromising the overall value by not availing itself of outside parties

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

Reviewer 1:
There is excellent progress on identifying EVSE vulnerabilities and risk mitigation via red teamwork.

Reviewer 2:
This provides an excellent basis that will lead to next steps in this ongoing effort. The need to continue to improve, adjust, and understand new approaches is ongoing as the standards continue to be updated with more features and as more products come to market.

Reviewer 3:
The project has already begun to identify vulnerabilities in systems and standards, which will be critical for improvements to occur. The team has seemed to learn a great deal since the beginning of the project, and this learning will clearly expand the knowledge in this area. The accomplishments appear to be a clear result of the project design. The detailed Vulnerability/Consequence matrix is an interesting documentation approach.

Reviewer 4:
The project identifies a cascading sequence of activities, including red team testing of EVSE, identification of EV charging components and information flows, a comprehensive threat model, attack graphs, impact analyses with regard to grid distribution and transmission systems and impacts, and ultimately a comprehensive risk matrix and prioritization of mitigation actions.

In the last year, the project has made notable progress, including further development of the threat model, EV charging attack graphs, red team assessments of several chargers and International Standards Organization 15118-2 PKI requirements, and an update on power system consequences, including the potential for interarea forced-oscillations. A particularly notable element is that the project will have actionable results by the end of FY 2020, including attack graphs and hardening recommendations that will be useful to industry in the near term.

The threat modeling model of EV charging identified some findings, including that the energy sector cannot mitigate every extreme fast charging (XFC) threat on their own and that all XFC parties need strong coordinated cyber practices. This begs the question: what are recommended as the best methodologies to coordinate future cyber practices across the EV and EV charging and grid ecosystem?

Reviewer 5:
The team created attack graphs for the following use cases: Outsider to Business Network Presence, Deployment of Malicious Firmware, Physical Compromise of EVSE, and EVSE to Vehicle. The team has these models active and has discovered some weak points with this.

Reviewer 6:
On Slide 10 limited information was provided regarding actual results. The project team should consider alternative solutions to sharing the claimed sensitive results.

Reviewer 7:
The reviewer commented that excellent progress against meaningful goals as a strength. However, opportunities for improvement include the two weaknesses noted previously as well as the two improvement opportunities noted as part of the project team's goals list. This reviewer also stated concerns and weaknesses.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This has an outstanding collaboration across project teams from the National Laboratories, government, and industry partners along with the list of external collaborators. This mix of effort provides the balance needed to meet the goals of this project.

Reviewer 2:
Collaboration appears to be very good, with a really strong team of participants all with clear roles. The PI indicated that the list of partners has grown during the project. The team has been reaching out to the EVSE vendor community about the project and since the project team is having success at identifying threats, that has been useful in bringing new members onto the team. The project team is also coordinating with the other VTO cybersecurity project teams, as well as a number of federal offices and industry partners.

Reviewer 3:
The project maintains a strong and diverse team of Sandia National Laboratories (SNL), Pacific Northwest National Laboratory (PNNL), ANL, the U.S. (United States) Department of Transportation (DOT) Volpe Center, NMFTA, multiple DC fast charging (DCFC) vendors, and a large utility. It also identifies a number of external collaborations with DOE VTO-funded cybersecurity projects and government agencies. It would have been beneficial if the roles of Volpe and NMFTA were more clearly explained.

Reviewer 4:
On Slide 2 the presenter indicates two DCFC vendors (or multiple on Slide 13) and one utility not indicating their specific role and the expertise these partners bring to the project. The presenter did indicate the specific role of each identified supporting laboratory very well on Slide 12.

Reviewer 5:
There is a wide spectrum of partners, which is good. Idaho National Laboratory (INL) seems to be doing work on EVSE cybersecurity projects but the reviewer did not see them listed.

Reviewer 6:
The collaboration team is well assembled. However, as mentioned previously, the red team appears to be all National Laboratory employees. The project may benefit from using consultants with specialized expertise.

Reviewer 7:
The reviewer stated that one strength of the project is that highlighting different roles for the National Laboratories provided good insight. As for opportunities for improvement, the reviewer recommended providing more transparency for team coordination and work roles for future Annual Merit Reviews (AMRs). Given that NMFTA (specifically) would be able to present an excellent set of business concerns and priorities, their role should be highlighted as part of the threat description phase (especially if the project uses prior comments about stepping away from an exclusive use of STRIDE and begins a hybrid approach or some other better-than-check-boxes methodology).

The briefing included an excellent slide describing the different roles for each of the participating National Laboratories, but there was no chart describing roles for each team member nor was there much indication of how work was broken down among team members.

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

Reviewer 1:
Future work includes developing standardized policies for managing chargers and other assets in the charging ecosystem and designing effective perimeter defenses to protect the assets, such as firewalls, access control lists, and dat*a-inflight requirements (encryption, node authentication). This is solid future research.*

Reviewer 2:
The reviewer stated that a strength of this project is the excellent insight into needed next steps and future research projects and initiatives needed to secure this portion of the industry. Particularly, focusing on human understanding and practice will be very helpful. The reviewer suggested considering the addition of layers of defense beyond perimeter security as a future objective. Concerns and weaknesses were also stated by this reviewer.

Reviewer 3:
On Slide 14 the presenter identified well the specific contribution in the overall ecosystem of contributions.

Reviewer 4:
The project team has a clear plan for the remaining research required. There have been some delays due to COVID-19, but the delays do not appear to be significant so far.

Reviewer 5:
Next steps are appropriate.

Reviewer 6:
This is an ongoing effort and will continue to expand as new products and suppliers enter the market with variations on how these players implement security requirements. As vehicle charging and additional services continue to grow and expand, this effort needs to expand to match these needs.

Reviewer 7:
The project has clearly and logically laid out its future work as evidenced by a comprehensive and sequenced milestone listing. This includes publishing attack graphs and hardening recommendations (FY 2020), completing a draft threat model (FY 2021), completing the consequence study mapping EV and charging vulnerabilities to power system and infrastructure impact (FY 2021), providing a hardening guide for EVSE vendors (FY 2021), and completing PKI recommendations for SDOs (FY 2021). There is really no discussion of appropriate decision points nor discussion of mitigating risk by providing alternate development pathways.

However, given the relatively limited time available to present (20 minutes), it is understandable these areas really were not covered.

On Slide 14, the presentation provides a strong listing of remaining challenges and barriers, and additional work that should be targeted. This includes standardized policies, designing perimeter defenses, creating situational awareness and detection and prevention systems, researching response mechanisms, and creating contingency operating modes. It would be good to provide some thoughts on the next systematic steps to further the comprehensive approach to cybersecurity. For example, would it be beneficial to first set up a consortium and, if so, who would it include? The presentation mentions that the project team is reaching out to some industrial entities, such as OEMs, to better understand the real-world implementations of telematics systems for the threat models. But, more broadly, it would be good to know the overall plan for review of project results from the industrial and commercial perspective. Last year, a reviewer indicated it would be good to include a commercial cybersecurity firm(s), but SNL had indicated the sensitive nature of the red team assessments does not permit this. The reviewer wondered if somewhere in the overall review process (such as for the threat model and attack graphs) is there not potentially a beneficial role for a commercial cybersecurity firm which would not compromise the project's sensitivity?

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

Reviewer 1:
This project supports EV adoption by looking at ways to protect EV charging infrastructure. This is important to DOE VTO objective of wider EV adoption, which in turn reduces vehicle energy consumption.

Reviewer 2:
The project is focused on cybersecurity for EV charging, which will be a critical area of development to enable a move toward electrification, thus displacing petroleum.

Reviewer 3:
To quantify cybersecurity risks to EVSE and establish actionable recommendations to protect charging infrastructure allows automotive, charging, and utility stakeholders to better protect customers, vehicles, and power systems in the face of new threats. This is necessary to move electric vehicles into the U.S. market.

Reviewer 4:
This project is highly relevant. As the number of EVs and associated communications networks for EVs, EVSE, and external systems increase, attack vectors and cyber risks also increase for the charging infrastructure and the electric grid. This project represents the first truly comprehensive effort to understand the risk environment and provide a ground-up threat assessment for the EV/EVSE/grid ecosystem. It will provide the foundation to further a systematic approach to cybersecurity.

Reviewer 5:
The numerous actors and product will continue to expand, and providing a secure interface and response needs to match growth in electrification. By establishing a threat model and providing suggested approaches for cyber resilience, the grid, charging equipment, and vehicles have a better model to use in implementing security systems.

Reviewer 6:
The project identifies EV charging infrastructure cybersecurity risks.

Reviewer 7:
The reviewer found the task focus to be exactly aligned with critical DOE interests and concerns—security of both grid and the non-grid side of the vehicle charging problem are crucial for societal adoption and then for societal protection. There are opportunities for improvement and being even more relevant if the project team makes sure to respond to earlier comments. These will ensure crypto plan, red team results, and guidance

documents are the things that can provide protection to the infrastructure over at least 1.5 times the expected life of the charging stations. For example, if PKI will fail due to quantum crypto in 20 years and if the charging station has an expected life of 30 years or less, then a plan for crypto-agility is needed or the implemented project results are simply causing a massive vulnerability at the 20-year horizon—and that is obviously bad.

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

Reviewer 1:
Resources appear sufficient at this time.

Reviewer 2:
The resources ($3 million) are sufficient for the proposed task and deliverables.

Reviewer 3:
The work is on time with the provided resources.

Reviewer 4:
The resources are sufficient, but this is a small sampling of the product for AC and DC charging. More will be needed to expand to other products and functions for connectivity.

Reviewer 5:
There are very little data regarding resources other than money, which makes it impossible to conduct a meaningful estimate/evaluation of sufficiency, so the reviewer may have erred with the assumption that usage and availability were outstanding. The reviewer suggested to the PI, for future AMR sessions, to please provide equipment lists (including software) and also spend rates versus estimated spend rates so the reviewer can understand progress against schedule and cost goals as well as “tool” sufficiency.

Reviewer 6:
The utility and EVSE suppliers’ resources and contribution to project are not clear.

Reviewer 7:
The red team needs to be improved.

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

Presenter

Richard Carlson, Idaho National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

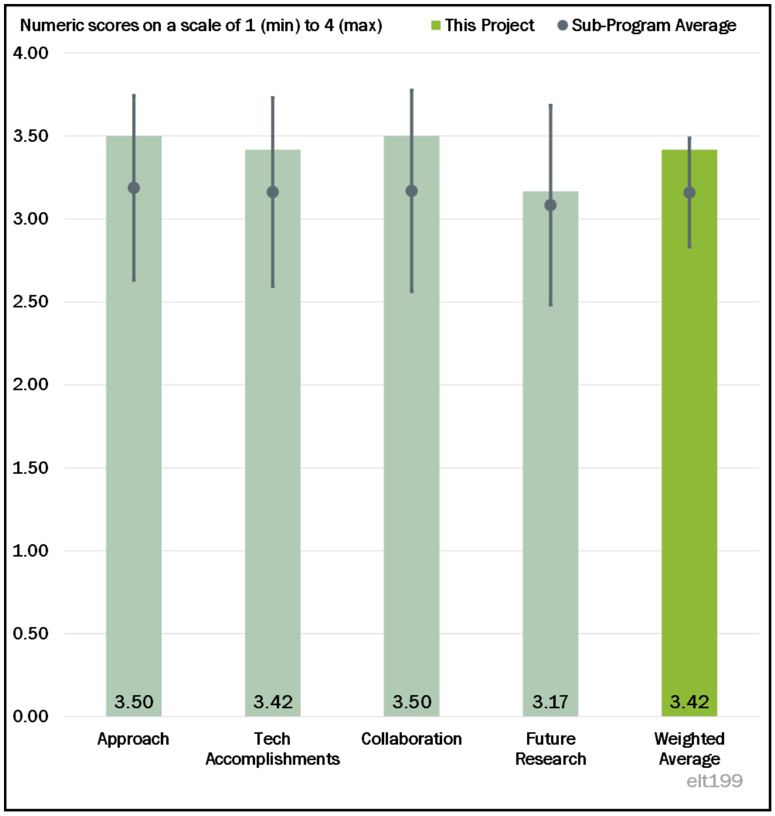

Figure 4-12 - Presentation Number: elt199 Presentation Title: Cybersecurity: Consequence-Driven Cybersecurity for High-Power Charging Infrastructure Principal Investigator: Richard Carlson (Idaho National Laboratory)

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

Reviewer 1:

The approach is well thought out and executed to meet this critical need for high powered systems. These are complex systems that must interface with more stakeholders than simple Levels 1 and 2 residential vehicle chargers. The broad-based interactions are being studied to assess high consequence events (HCEs). Included are conductive and/or wireless chargers and installations with many chargers on a site. The project is not covering grid “before-the-meter,” only after. That would be another project that eventually should be coordinated to this one. Not covering just hardware threats but working to identify HCEs that must be mitigated on a complex system, then developing mitigation strategies. This is a very comprehensive system engineering approach.

Reviewer 2:

A strength of this project is its clear, logical, and obviously relevant approach, which makes understanding this research and assessing both its progress and its relevance straightforward. The reviewer also found the Impact Severity Scoring to be clear, thoughtful, and relevant; indeed, it is one of the best scoring frameworks the reviewer had seen.

While this is not an actual recommendation, it is a request to consider something. It appears that the Impact Severity Scoring has equal weights across rows and columns, but is this sound? Perhaps the project could consider a sliding scale along the severity index, and perhaps even some of the rows are more consequential than others. The reviewer understood this adds complexity and, after reflection, might be valueless. However, the reviewer suggested to consider it and see if (for example) effect propagation should not be weighted a bit more strongly than duration.

Reviewer 3:
The approach includes high power charger providers and adds a ChargePoint operator for additional aspects. Leveraging other DOE projects and universities is also an excellent use of resources to complete the objectives of this project.

Reviewer 4:
The project appears to be clearly designed to address potential threats to the EV charging system. This includes a clear focus on the HCEs that can occur from a number of system vulnerability sources. The design specifically relies upon evaluation of both impact severity and complexity in order to develop more complete approaches to solutions.

Reviewer 5:
So far, the project seems to be moving in the right direction while approaching the testing of various ways to violate cybersecurity when it comes to charging.

Reviewer 6:
Based on the provided Gantt chart, it seems that there are some challenging issues with preparing laboratory equipment and laboratory evaluation. Some tasks are a bit overdue with no explicit justifications.

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

Reviewer 1:
The milestone-based report clearly states the path and the progress. The project has developed a scoring system that can be reused on many new systems. The project team will be evaluating strategies and solutions in laboratory environments that should take the end product of this project to a technology readiness level (TRL) of 5-6 by project end. The assessment follows a logical path to create positive outcomes. Detailed technical evaluations (i.e., thermal spoof and the multi-charger sudden stop) are excellently presented.

Reviewer 2:
The reviewer noted that there are excellent results, which are clearly presented and make sense. On the other hand, the PI needs to show (or convincingly argue) there is equivalency between a Raspberry Pi (reference Slide 10) and the objective hardware and software combination running on the actual EVSEs.

The reviewer's concerns were more of a request for clarification. Item 5 on Slide 7 is "feeder equipment damage," but it is listed under Grid Impacts rather than Hardware Damage. Is this just a typo (in which case the reviewer understood) or is there a nuance associated with hardware damage which the reviewer was missing? If there is—the reviewer was really missing it—so, please offer a bullet or sentence in the published materials explaining that nuance so everyone can understand the results.

Reviewer 3:
The project appears to be making progress largely in accordance with the plan. A large number of HCEs have been identified, with particular emphasis on grid impacts and safety, which is good to see. The next level of impact does indeed include impacts on EVs themselves. While perhaps a lower chance for occurrence, a significant impact on the confidence level of EV purchasers is possible.

Reviewer 4:
Because this project is 50% complete, it has the basis for positive results, but more time is needed to properly access how the ongoing evaluations lead to solutions.

Reviewer 5:
The reviewer was not sure that the project team has covered all of the possibilities. The project team seems to put a lot of emphasis on a direct entry point by actual contact and less on introducing a deviant over-the-air or transmitted through a communication apparatus.

Reviewer 6:
Based on the provided Gantt chart, it seems that there are some challenging issues with preparing laboratory equipment and laboratory evaluation. Some tasks are a bit overdue with no explicit justifications.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
All of the players are dispatched in what they excel. The project team members have experience in what they are dispatched to do.

Reviewer 2:
The partners and collaborators included have the background and experience to lead to positive results. This project varies from others as it focuses consequences, impact severity, and safety aspects.

Reviewer 3:
The team seems to have a good set of both laboratory and industry partners. Additional collaboration has occurred with DOT Volpe and the 21st Century Truck Partnership, as well as WAVE Inc., Utah State University, and the other VTO cybersecurity projects.

Reviewer 4:
It is great that collaborations are broad based and continue to expand. It was not clear whether there were new collaborations required to complete the project or if this group is sufficient. Expansion would be an excellent move.

Reviewer 5:
The project shows strong performers focusing on areas of their strength.

It would be helpful if the presenter showed how the team worked with and interacted with the other four DOE projects mentioned on Slide 14. It is not clear what the input paths are and how cross-task information is being used to accelerate or validate the project's work. Also, it would be helpful if the presenter provided a bit more detail about the different collaborators and how each was working on the different tasks (which the presenter did a great job of showing in the schedule slide).

Reviewer 6:
Collaboration is among National Laboratories (INL, NREL, ORNL), charger equipment manufacturers (Tritium, ABB), charge site owner-operator (Electrify America), and some additional EV charging infrastructure cybersecurity collaboration. Although the collaboration has been mentioned in general, the level of engagement, involvement, collaboration, or technical feedback of some mentioned collaborators is not clear.

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

Reviewer 1:
Future research is very well based on the accomplishments to date and follows the path that was originally defined for the project. It is good to see a project that has not had big hiccups! The approach is well thought out to meet this critical need for high powered systems. These are complex systems. The project is not

covering just hardware threats but working to identify HCEs that must be mitigated on a complex system, then developing mitigation strategies. Excellent work.

Reviewer 2:
The project has a detailed plan for future research for the remainder of the schedule, including extensive publication of results. There was no indication of any plans for any follow-on research after this project.

Reviewer 3:
As a strength, the reviewer said that the next steps are logical, completely reasonable, and comprehensive. The project team could describe if future study targets will be intended for production or actual "to be fielded" units and describe the benefits and drawbacks in each case. The presenter could show what the value is to both infrastructure and manufacturer if work is done with pre-fielded products and can influence final build products.

Reviewer 4:
Future work is expected to include laboratory evaluation to validate equipment capabilities. It is expected that this will lead to adjustments in security approaches to improve aspects and provide suggestions for updates needed for the industry in existing and future product.

Reviewer 5:
The reviewer believed the project team will have difficulty accounting for the grid through laboratory work. The reviewer also thought it would be hard to duplicate as not all grids are created equal across the country when it comes to resilience and a reaction to a cyber-attack.

Reviewer 6:
The future research has not been clearly mentioned. Also, since more than half of the time of project has passed, the main part of the project in preparing laboratory equipment and laboratory evaluation has not been completed. Furthermore, the barriers and solutions to the challenges have not been discussed.

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

Reviewer 1:
The objectives outlined here match well with the priorities of DOE and real issues to be addressed.

Reviewer 2:
The focus of the project is cybersecurity for EV charging, a critical area to address for a transition to EVs to be successful.

Reviewer 3:
As a strength, the project posed critical questions and offered solutions to an emergent and necessary DOE focus area. This reviewer also stated opportunities to improve, concerns, and weaknesses.

Reviewer 4:
The cybersecurity of the complex charging network is a critical enabler of the adoption of high powered EVs. The methodology developed is intended to be published for use by system developers for future use. It would be most relevant if the development would be continued and this process became a standard in partnership with the system developers and user groups.

Reviewer 5:
Results from this ranking and scoring of HCEs will help the industry and focus the effort into proper categories of impact severity and cyber manipulation. Generally, targets are focused on higher impact areas; however, even lower levels still need attention. Laboratory results will provide continuous improvement in security approaches.

Reviewer 6:
The review was on the fence with this experiment as the VTO deals with vehicle technology and not necessarily the infrastructure charging the vehicle. This deals more with the broad spectrum but does not bring it back to the vehicle in the real sense.

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

Reviewer 1:
Resources appear sufficient at this time, though the reviewer would anticipate follow-on efforts in this area.

Reviewer 2:
The maintenance of progress according to plan indicates that the resources are adequate and appropriate to complete the project.

Reviewer 3:
Everything seemed fine to the reviewer. There are no indications there were problems with resources or milestones. The reviewer particularly liked the presenter's openness about the schedule and where the project was on the list of tasks and subtasks. The reviewer also noted opportunities to improve, concerns, and weaknesses.

Reviewer 4:
The reviewer believed the project team has what is needed to finish this project.

Reviewer 5:
The provided resources seem to be sufficient to support the execution of the project.

Reviewer 6:
Collaboration with other laboratories, equipment manufacturers, and charge point providers provides a good balance of focus on the goals of this project and is expected to lead to positive results.

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

Presenter

Steve Chapin, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

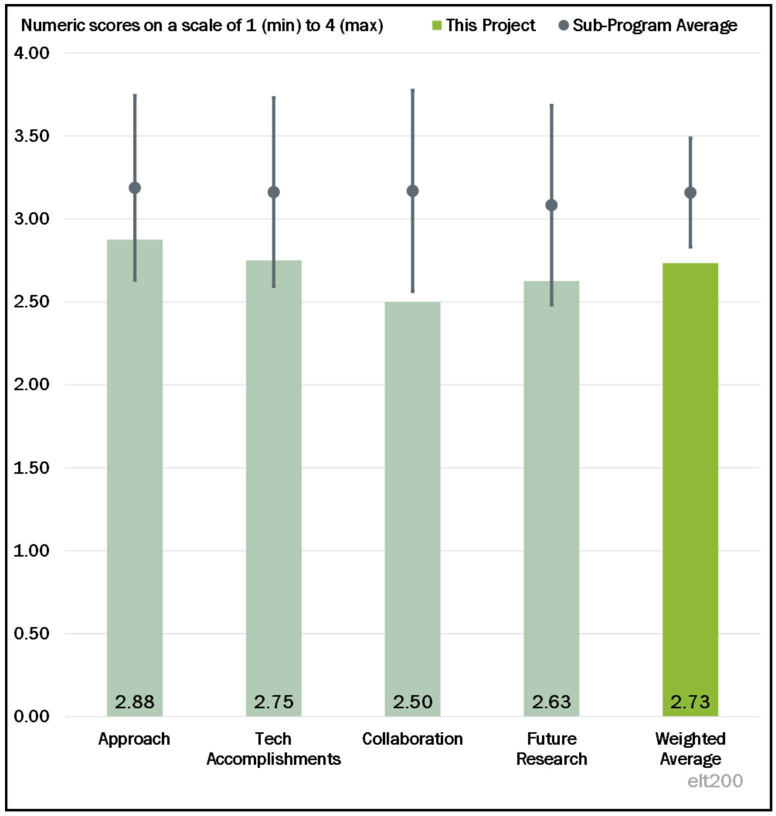

Figure 4-13 - Presentation Number: elt200 Presentation Title: Scalable Electric Vehicle Smart Charging Using Collaborative Autonomy Principal Investigator: Steve Chapin (Lawrence Livermore National Laboratory)

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

Reviewer 1:

The approaches look effective at this point. It should be able to overcome the barriers.

Reviewer 2:

This approach is viewing the generation variations to load variations. It appears the solution to increased demand from more EVs is to add spinning reserves instead of managing or planning EV charging needs with existing capacity. It also appears that partnering with ChargePoint has not been successful in sharing data for this project.

Reviewer 3:

This project has taken an appropriate approach by combining optimization modeling, distributed computing platform development, and hardware-in-the-loop and coupled simulations using the Hierarchical Engine for Large-scale Infrastructure Co-Simulation (HELICS) co-simulation platform and high performance computing (HPC) to develop, validate, and demonstrate decentralized algorithms for EV charge management.

Reviewer 4:

The reviewer had the following comments:

- The project goals and objectives are ill defined. The objective slide says, "to develop an algorithm," but that does not explain for what the algorithm is going to be used.

- What is so important about developing this algorithm? Will not having it make any significant difference to society, energy security, fossil fuel consumption, or climate change? Who is the end-user of the algorithm?
- The assumptions of both the model and the modeling scenarios are not well laid out and not clear. Whether the model and its results are realistic usually are predicated on the assumptions that go into the model. How realistic are these assumptions? Has a reality check been done on the assumptions?
- There is no clear indication about the makeup of EVs covered by this model and their range and travel patterns (origin, destination). The reviewer questioned the failure to include return-to-base, centralized charging for utility and municipal fleets, rental cars, etc. The reviewer also questioned the failure to include MD and heavy-duty (HD) vehicles in the modeling.
- Consumer input seems to be ignored in the model. What is the willingness of the market of EV owners to pay extra for extra fast charging?
- The PI does not say how the results of the modeling will be tested or corroborated.

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

Reviewer 1:
Simulation results looks promising. Simulation converges in a reasonable time frame with adequate accuracy. The reviewer was looking forward to some more simulation results to demonstrate how well the proposed smart algorithm can enable the frequency and voltage regulation. Is there any performance difference between different smart algorithms? What are the key merits that the project leader chose to evaluate the smart algorithm?

Reviewer 2:
The "Price Taker" model extended to operate at multiple levels: across vehicles at a charging station, behind the meter, and between meters in a single distribution feeder and between distribution feeders. The charging model implemented and tested is fully decentralized with no central coordination of any kind and supporting ancillary services and multiple competing parties. The Price Taker charging concept is modeled, and simulation results (graphics related to feeders, meters, stations, and EVs) are included in the project report.

Reviewer 3:
The slides on technical accomplishments merely tell us what the model can forecast or simulate depending on the parameters, such as number of iterations, number of feeders, and number of meters. The results of the modeling do not tell us how good the model (algorithm) is nor do the results tell us how close to reality the model (algorithm) is.

Reviewer 4:
The technical approach is good, but the progress appears to have some restrictions to moving forward. It is not clear why this project has ChargePoint as a partner as it seems unwilling to provide project data without being funded separately for this. It is also not clear how reserves and demand response signals are balanced to meet both grid and EV requirements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration with ChargePoint seems to be sufficient. The reviewer hoped that the data purchase process goes smoothly.

Reviewer 2:
Collaboration with Lawrence Livermore National Laboratory (LLNL) and ChargePoint is indicated. Also, an EVSE manufacturer could provide access to a testbed.

Reviewer 3:
Apparently, ChargePoint's data were expected and hindered due to specific funding, even though the project is funded. Data can still be collected on feeder circuits on EV charging to make some progress.

Reviewer 4:
The project team failed to include an end-user (other than themselves and ChargePoint).

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

Reviewer 1:
It looks like the model would be significantly improved and expanded. The reviewer looked forward to additional solid results to demonstrate that the project is delivering useful and insightful results.

Reviewer 2:
The following relevant tasks are outlined in the Proposed Future Research section of project report.

- Pairing Raspberry Pi proxy with Open EVSE for proof-of-concept
- Incorporating fixed-schedule EV into the model
- Incorporating client (EV) demand function (demand curve)
- Using more extensive simulations, including co-simulation with HELICS and ns3.

Reviewer 3:
It is not clear how using demand response and spinning reserves will meet the customer expectations for fast charging. Future research should include the customer's willingness to curtail fast charging from any demand response action.

Reviewer 4:
Until the project goals and objectives are clarified, the modeling assumptions are delineated, the end-users of the model are identified, the means for verifying the results of the model are proposed, the market for extra fast charging is known, and other shortcomings specified in the technical approach are addressed, the reviewer would not recommend future proposed research on this project.

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

Reviewer 1:
Yes.

Reviewer 2:
Smart charging that drives the cost of charging lower and faster access to charging station is very relevant to fast adoption of EVs.

Reviewer 3:
The need exists to model and predict fast charging requirements. However, it seems that more EVSE brands need to be included and then expanded to include more than 50 kW) stations.

Reviewer 4:
This reviewer emphasized that the project did not make a clear case for how the modeling is relevant to DOE objectives.

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

Reviewer 1:
This project has the necessary resources and research funds.

Reviewer 2:
The resources are sufficient, just not the available data from the EVSE resource.

Reviewer 3:
The purchase process between the collaborators makes the reviewer wonder if there is any other way to obtain the data. Can the project leader purchase from another operator to cross check with the results simulated from the ChargePoint data?

Reviewer 4:
The reviewer had no comment.

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

Presenter

Keith Hardy, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

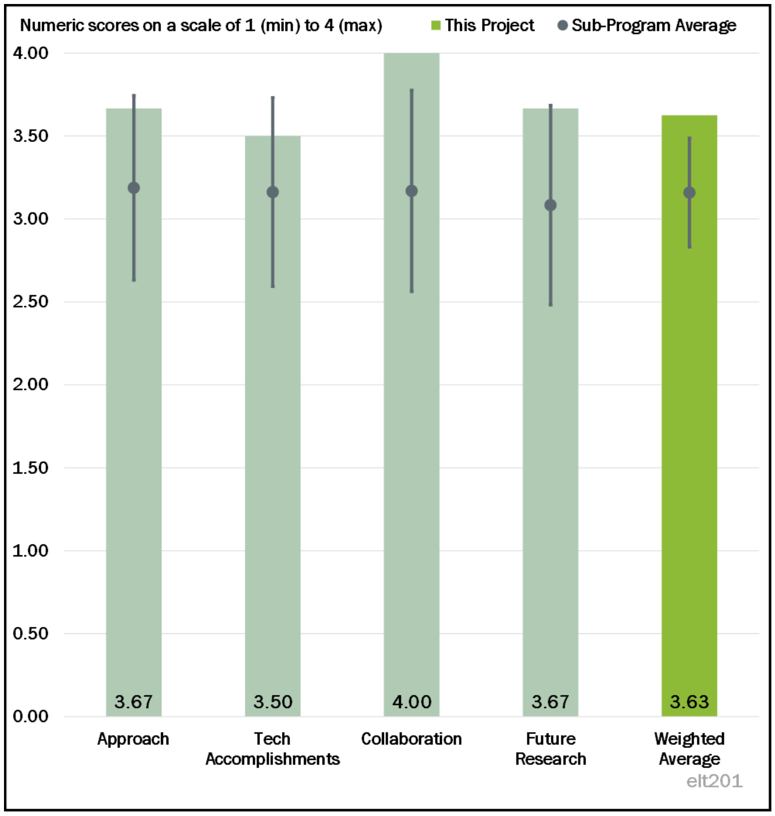

Figure 4-14 - Presentation Number: elt201 Presentation Title: Charging Infrastructure Technologies: Smart Vehicle-Grid Integration–ANL Principal Investigator: Keith Hardy (Argonne National Laboratory)

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

Reviewer 1:

The approaches look very solid.

Reviewer 2:

This project has an excellent approach since it builds on previous experience and continues to develop the Energy Management System for vehicle charging and controls for both AC and DC charging systems. This joint laboratory effort is able to demonstrate variations for managing charging systems. Both ANL and Joint Research Center (JRC) laboratories leverage both regions' strengths and allow utilizing systems that are better suited to each but offering common solutions to both regions.

Reviewer 3:

The project tasks (component development, standards work, demonstration) are all appropriate parts of addressing the barriers to smart grid energy management mixing EVs and other energy sources on the electrical grid.

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

Reviewer 1:

The technical accomplishments and progress are outstanding by addressing challenges of high-power charging to ensure the full capability of vehicle charging is included. This includes the development of the smart charge adapter to provide a full solution for monitoring the charging communication and grid quality aspects to provide features not included in other projects. The metering project includes validation of equipment and controls required for EVSEs and data to the vehicle OEMs to monitor grid quality items and responses to adjustments from distributed energy resources (DER) commands. The demonstration of various protocols is critical since alternative approaches are required for variations in regions, utility territories, and customer desires that will continue to evolve and change. The flexibility of multiple approaches provides a more viable solution for the results to be implemented to the industry.

Reviewer 2:
Some tasks were hindered by the laboratory closure but appear to be manageable within the current year. Good progress was made on communication and sub-metering hardware.

Reviewer 3:
It would be nice to see some simulation results after adding the XFC and battery storage to the distributed network model. For example, what kind of additional feature and function can this achieve comparing to previous?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project has an impressive array of collaborating companies and organizations, covering the gamut of potential stakeholders. International collaboration is outstanding.

Reviewer 2:
It can be seen that collaboration is coming from all different aspects, including OEMs, EVSE manufacturers, utilities, and many more. The annual update just cannot share all the great results this project has achieved.

Reviewer 3:
ANL has led the collaboration and coordination for North America and insured the teams in other regions are included in this effort. Information exchange of the approach and progress at ANL and JRC laboratories are used to mature and validate the standards for energy management communication and controls.

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

Reviewer 1:
ANL has an outstanding position for future research as high power charging systems are still evolving and the capabilities of the Energy Plaza will be able to validate updates to the standards and identify issues that need to be resolved for further updates to improve interoperability of charging systems. The Diagnostic Electric Vehicle Adaptor (DEVA) and sub-metering are continued items for complementing the project that offer OEMs and EVSE supplier tools for coordinating validation at their sites while leveraging ANL’s facilities.

Reviewer 2:
The next steps are appropriate for demonstrating the project's ultimate goals.

Reviewer 3:
It is always great to see any types of demonstration.

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

Reviewer 1:
Yes, this project supports the overall DOE objective. It is very important to develop and demonstrate the vehicle grid communication and solve the potential problems.

Reviewer 2:
The project aligns with the DOE VTO objective of removing barriers to more widespread EV adoption. Smart EV grid interaction is an important part of managing large numbers of EVs simultaneously connected to the grid.

Reviewer 3:
This project supports DOE objectives by providing a National Laboratory approach for development and validation to improve and expand the communication and equipment standards. Developing diagnostics and metering equipment complements this by providing solutions for the industry.

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

Reviewer 1:
ANL has sufficient resources for this project and is able to balance OEM and EVSE supplier needs.

Reviewer 2:
Resources appear to be sufficient to meet the outlined tasks.

Reviewer 3:
It looks like the project leader has sufficient resources to get the milestone achieved. The project leader mentioned the hardware-in-the-loop (HIL) engineer was absent. That might lead to some delay, but the reviewer would trust the team to solve that issue pretty soon.

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

Presenter

Andrew Meintz, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

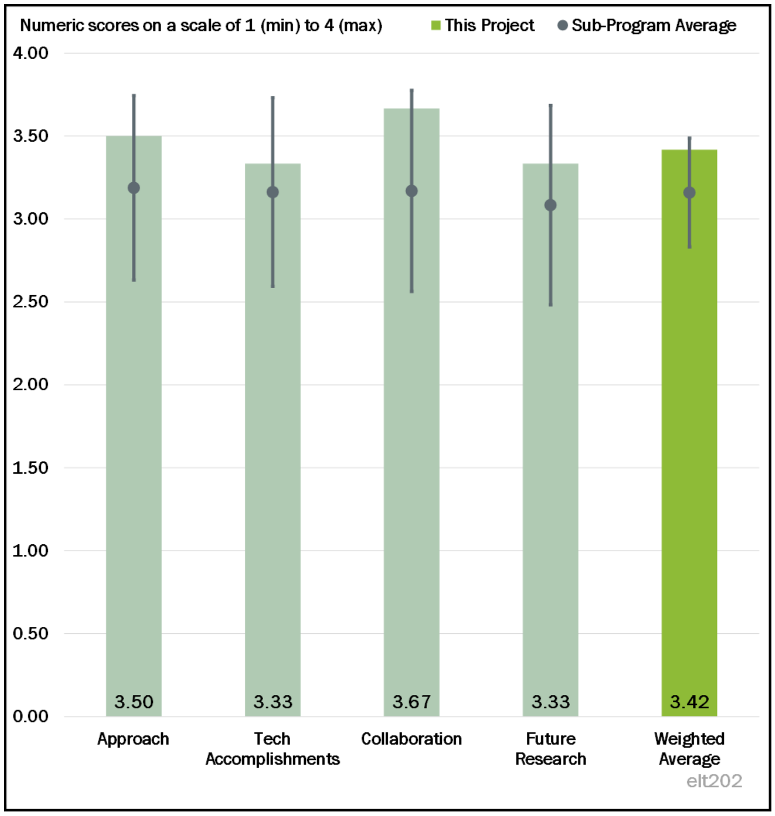

Figure 4-15 - Presentation Number: elt202 Presentation Title: Charging Infrastructure Technologies: Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE) Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

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

Reviewer 1:

This project has an outstanding approach for smart charging that is required to balance the grid and vehicle charging requirements. Distribution system modeling provides the background in charging installation to optimize the customer needs with infrastructure actions. This project provides a direct comparison of unmanaged charging against different level of managed charging for two major cities to clearly demonstrate the benefits with accurate data. This project is well designed since it also combines residential and fast charging needs to evaluate the impact of the entire systems.

Reviewer 2:

Using smart technologies, including geo-spatial mapping of grid infrastructure and EV location, the project team wants to understand plug-in electric vehicles (PEVs) at scale with unmanaged charging followed by investigation of managed charging with co-simulation of PEV in the electric grid. It is assumed that managed charging will be assisted by the high-level controls. Finally, using the new control technique, the project team will investigate advanced charge controls with co-simulation of PEV in the electric grid. This approach aligns with project goals to address barriers, which are mainly due to lack of data, such as when and how electric vehicles at scale will impact the grid and how electric vehicle load can “move” throughout the grid under various control and infrastructure scenarios. Once data are available, then reduced-cost electric charging infrastructure can be developed by optimal uses of resources in infrastructure, which is a key ingredient for the rapid adoption and deep penetration of PEVs.

Reviewer 3:
It is reasonable to first look at unmanaged charging and gradually move to more complicated and controlled scenarios. The approach covers a wide variety of tasks. Apparently, task 5 to task 10 will possibly generate some interesting insight and useful deliverables. The reviewer looked forward to seeing these results in more details.

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

Reviewer 1:
This project is using charging history as input to predictions on future needs. This balances the planning for additional and changing needs to include vehicle charging in infrastructure plans. Considerations that have included climate effects to grid loads have demonstrated a full approach for aggregators and planners to establish the optimal control and user benefits for balancing vehicle charging needs.

Reviewer 2:
The project team has obtained electric feeder models for Minneapolis and Atlanta and converted these models for simulation and validation in Open Direct System Simulator (OpenDSS). The project team has regular meetings with Xcel Energy and Southern Company to share results and get feedback, has quantified the impact of uncontrolled charging, has refined smart charge control strategies, and has integrated load profile resulted from controlled and smart charging with residential building loads.

Reviewer 3:
The project has successfully achieved the co-simulation between spatial and temporal models. Residential, commercial, and industry feeder examples have been looked into to identify the problem and opportunities. An uncontrolled scenario has been completed. The reviewer rated the project as “excellent” mainly because the detailed results of task 5 “refine smart charge control strategies” have not been well explained. The bullet points only show what has been added or what will be added in the future. The reviewer assumed that the work is still in progress, so rather than presenting an intermediate result, the project leader might just delay the results to show next time in a more complete way, which is fine. The reviewer thought the next year deliverable of this project will have more contributions and generate more novel ideas.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer rated the project as "excellent" because the collaboration seems to be well planned. The grid impact analysis for two different cities is carried out by two different teams, and each will focus on different aspects of the power system. In this AMR presentation, this advantage has not been observed yet. It seems like the two teams are doing identical work and putting out results for comparison. The reviewer is looking forward to the different insight each might have in the future.

Reviewer 2:
This project has demonstrated close coordination with other National Laboratories, utility partners, and vehicle OEMs and through United States Council on Automotive Research and the Grid Integration Tech Team (GITT) interactions. This has established the basis for smart charging and is adding distributed energy resources (DER) functions that will complete the system by adding solar and stationary storage along with DER functions for grid stability.

Reviewer 3:
Collaboration with multiple entities led by NREL team are as indicated:

- NREL— Project lead and developing PEV load profiles, as well as Minnesota OpenDSSmodels
- INL— Co-funded subcontractor to the project, responsible for developing aggregator model
- SNL— Co-funded subcontractor to the project, responsible for developing Atlanta OpenDSSmodel
- Xcel Energy— Providing data from Minneapolis distribution grid to assess loads and hosting capacity
- Southern Company— Providing data from Atlanta distribution grid to assess loads and hosting capacity
- INRIX— Subcontractor providing Minneapolis and Atlanta travel and vehicle data to assess PEV spatial and temporal charging loads
- EDF Renewables— Subcontractor for smart charging system supporting integration with building loads.

In addition to above collaborative activities, the project team also coordinates with the automotive and utility partners through the U.S. DRIVE GITT.

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

Reviewer 1:
The reviewer is looking forward to the future results for task 5 to task 10.

Reviewer 2:
Proposed Future Research topics include: identification of smart charging control strategies, quantification of implementation costs, distribution impact analysis for uncontrolled and controlled scenarios, transmission-level analysis, integration of smart charging with XFC and distributed energy resources, and integration and development into final tools.

Reviewer 3:
Future effort would be to include the DER advanced functions identified in Rule 21 and Institute of Electrical and Electronics Engineers (IEEE) 1547-2018, IEEE 1547.1, and SAE J3072 standards. This project has included the foundation for future research since it uses historical data to predict future expectations while including climate variations that effect loads and resources. This is not ready for advanced functions using DER approaches for grid stability with both AC and DC DER approaches.

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

Reviewer 1:
Yes, this project supports the overall DOE objectives.

Reviewer 2:
Successful completion of this project will demonstrate the value of smart charge management to reduce the impact of EVs at scale. Smart charging infrastructure will enable rapid adoption and penetration of PEVs.

Reviewer 3:
This project supports DOE objectives by including planning functions for grid stability. The planning and approach are expandable as the quantity of vehicles increase and the management approach is expanded to other locations.

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

Reviewer 1:
This multi-entity project led by NREL has necessary resources and enough research funds to succeed.

Reviewer 2:
It looks like this project has sufficient resources to achieve the proposed milestones in a timely manner.

Reviewer 3:
This project sufficiently steps through the actions needed to meet current needs while planning for additional growth of the electrification market. This project demonstrates the ability to dynamically adjust and adapt as conditions change due to climate and vehicle availability and usage varies while matching the grid stability functions. National Laboratory resources are imperative to establish the foundation for this analysis and tools that can be then used by aggregators and planners. No single or combined entities in the private sector can accomplish this task.

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

Presenter

Andrew Meintz, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

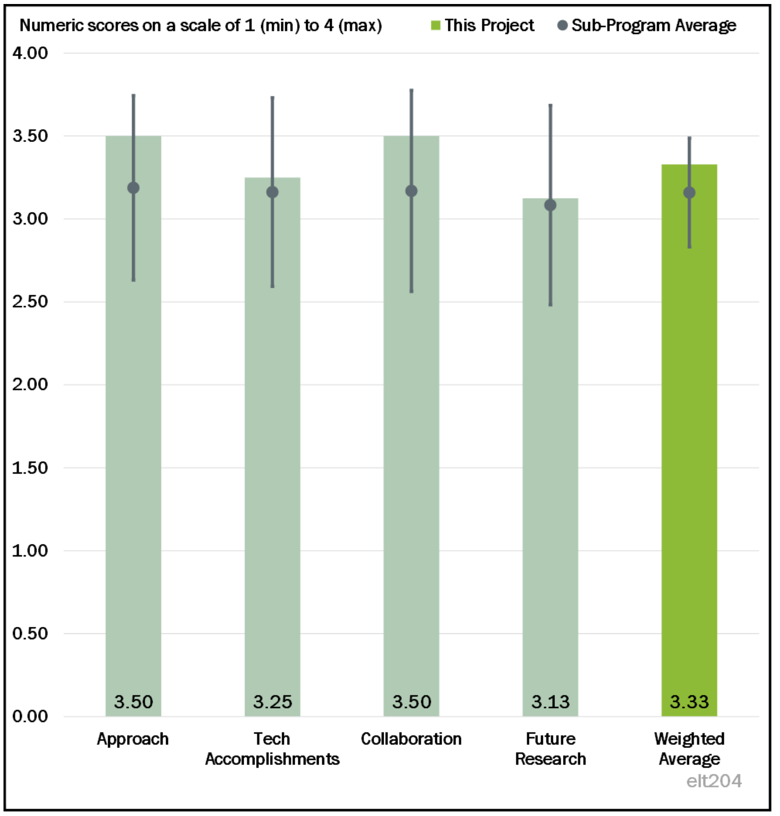

Figure 4-16 - Presentation Number: elt204 Presentation Title: Charging Infrastructure Technologies: Development of a Multiport, >1 MW Charging System for Medium- and Heavy-Duty Electric Vehicles Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

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

Reviewer 1:
The project's objectives and approach toward execution are outlined clearly. The project is currently on track, and the plan for completing the project appears feasible.

Reviewer 2:
The approach is very logical and straightforward.

Reviewer 3:
The project looks as though it has taken into account both MD and HD vehicles, which would be more than likely the ones accessing the truck stops for re-energization. Space seems to be a concern when it comes to the amount of charging equipment needed on site as well as the location of these filling centers, and the power need to sometimes get out to the middle of nowhere.

Reviewer 4:
This project develops an electrical model of distribution feeder with battery energy storage interface along with electric energy generated by a photovoltaic (PV) system. For aggregation of charging energy from three sources (electric grid, battery energy storage, and PV system), a variety of AC-DC and DC-DC and DC-AC power converters is required. The project has taken a collaborative approach with ORNL to develop necessary

power electronics infrastructure. Various industries and business owners of charging infrastructure are engaged by the project team for successful execution of approach taken by project team.

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

Reviewer 1:
Good progress has been delivered toward the final goals.

Reviewer 2:
The technical accomplishments reported for the current period of performance are considerable and well supported. The team has worked on several tasks in parallel and delivered compelling results. Most of the work done to date involved computation (simulations, virtual design, control design, and verification), and as the project approaches the demonstration phase, it would be helpful to get more information on what steps will be taken moving forward.

Reviewer 3:
This reviewer noted power electronics topology for energy sources interface with the battery charger. Power electronics systems such as this, with switching device level design considerations, are likely to result in efficient power conditioning systems to connect multiple sources, which are being reviewed, simulated, and selected by project team. The project team's concept of megawatt plus (MW+) charging equipment and its control systems has evolved to include placing a target for power conversion efficiency. Site utilization (6,284 possible locations were considered in the analysis) and load profile have been investigated by the project team. Based on outcome of the grid impacts analysis, best, mediocre, and worst locations on grid have been identified and marked on Slide 15 of the project report. It seems the closer the location is to the distribution feeder, the better the location is for the MW+ battery charger system. Battery load profile and optimal charge control related project activities were carried out by the team. Design considerations, including thermal management of 1+ MW connector, have been carried with evaluation planned in the fall of 2020.

Reviewer 4:
The reviewer believed the technical accomplishments are very good in concept. The question arises on how much scale can actually be achieved in what is being proposed. The reviewer thought scaling up to accommodate several vehicles at one time would need to be accounted for while attempting to dispense that much energy. How resilient would that be in the middle of the summer, especially for an air-cooled converter?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project has an impressive amount of entities giving input and all them from the industry that they deal in every day.

Reviewer 2:
The collaboration and coordination across project teams is excellent. The three National Laboratories involved have clear tasks, and a robust coordination plan is in place. There is a remarkable engagement of industry partners.

Reviewer 3:
It is good that many factions are sharing the effort. The team seems to be cohesive and working well together.

Reviewer 4:
Collaboration and coordination were a multi-laboratory approach with multiple industry partners.

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

Reviewer 1:
The proposed future research is clearly explained in the presentation. There should be more discussion regarding which parts of the project will be demonstrated in hardware and how the PI plans to execute the demonstration and evaluate and benchmark the results.

Reviewer 2:
There is a good list of future developments that are required. One development that the reviewer did not see on the list was the effect of high power/fast charge on battery longevity. This is an important effect as we move to higher power charging.

Reviewer 3:
In FY 2020, the proposed future research includes relevant tasks and topics, such as: developing switch-level and average value models to represent charging hardware, demonstrating of charging control optimization for integration with site controller, and supporting charging connector evaluation.

In FY 2021, proposed future research includes relevant tasks and topics, such as: integration of the overall control and virtual 1+ MW multi-port charging system evaluation platform; system verification through control HIL simulation of the charging system response to grid disturbances, effectiveness of site control, and grid interface control capability to mitigating grid impact; and evaluation of power transfer mechanism using prototype hardware.

Reviewer 4:
The steps seem logical, but the project still needs to address getting the power to the site and whether the grid can handle the massive amount of energy required. The grid goes down now without 1 MW fast chargers under light usage from vehicles.

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

Reviewer 1:
It supports the DOE objective to move toward cleaner energy. In order to support that objective, charging has to be outside of the home for wider use and for transportation use which has the most emissions.

Reviewer 2:
This project is quite relevant to DOE VTO objective for rapid proliferation of clean energy transportation infrastructure, and the project aims to develop research tools for a framework to design, optimize, and demonstrate key components of a multi-port 1+ MW medium-voltage connected charging system for EVs.

Reviewer 3:
It is important for the future of electric vehicles that we develop high charging and enable vehicles to be used as they are today. Many miles between stops and only short stops are the key to the industrialization of the trucks and commercial transportation.

Reviewer 4:
The project addresses the critical challenge to develop solutions for high power fast charging systems.

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

Reviewer 1:
The resources allocated by the partners are deemed sufficient to complete the project.

Reviewer 2:
This project has necessary resources and research funds, and execution of project is being carried out through collaboration and coordination among multiple DOE laboratories and key contributions from multiple industries.

Reviewer 3:
The reviewer did not know for sure, but it seems as though the project is moving forward: therefore, there are sufficient resources.

Reviewer 4:
The reviewer thought the project is well funded but needs to go into another phase after this one has concluded to figure out how to get the energy where it needs to be away from a metropolitan area.

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

Presenter

David Coats, ABB

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

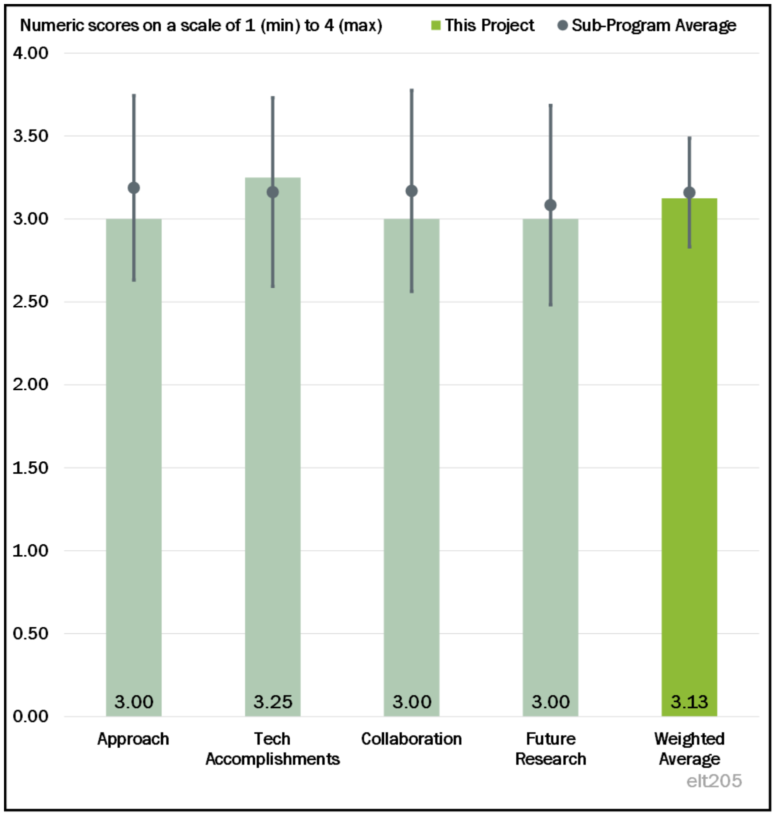

Figure 4-17 - Presentation Number: elt205 Presentation Title: Cybersecurity for Grid-Connected Extreme Fast Charging Station (CyberX) Principal Investigator: David Coats (ABB)

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

Reviewer 1:

The approach seems logical and systematic.

Reviewer 2:

The overall approach of cyber anomaly detection system (CADS) is good but is not robust enough. It needs to be extended to account for extreme environmental temperatures, sensor bias, and grid parameter anomalies such as voltage and frequency sag.

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

Reviewer 1:

The project technical accomplishments appear to be on track with the project plan.

Reviewer 2:

Good progress was made, but more hardware demonstration is needed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There seems to be a reasonable level of collaboration.

Reviewer 2:
The collaboration and coordination appear to be well executed.

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

Reviewer 1:
The proposed work is good and systematic.

Reviewer 2:
The proposed future work is logical.

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

Reviewer 1:
The project is highly relevant for addressing cybersecurity gaps for high power EVSEs. The project is characterizing threats and prototyping systems to identify and respond to EVSE cyber threats.

Reviewer 2:
Cybersecurity is a key challenge that needs to be addressed.

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

Reviewer 1:
Resources are sufficient.

Reviewer 2:
The allocated resources are sufficient for the planned work and timeline in the absence of a pandemic. However, it may be necessary to extend the timeline to account for mandated travel restrictions and supply chain interruptions.

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

Presenter

Sunil Chhaya, Electric Power Research Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

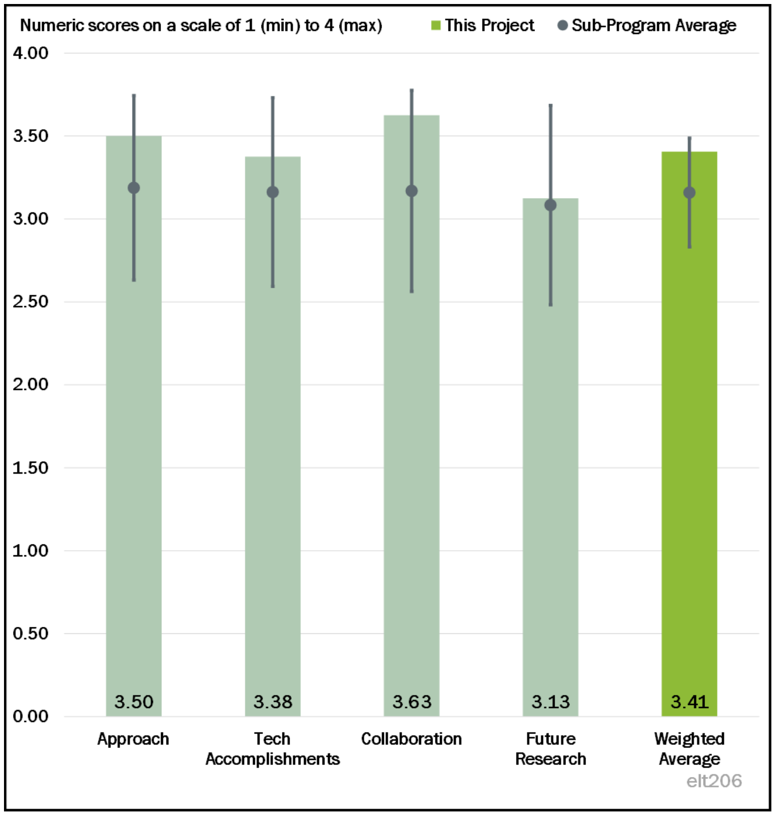

Figure 4-18 - Presentation Number: elt206 Presentation Title: Cybersecurity Platform and Certification Framework Development for Extreme Fast Charging, Integrated Charging, Infrastructure Ecosystem Principal Investigator: Sunil Chhaya (Electric Power Research Institute)

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

Reviewer 1:

This seems like a very well thought out and executed project with just the verification phase left. The project looks like it took a delay because of COVID-19. The reviewer was interested to see how it comes out.

Reviewer 2:

The work has an excellent diversity of focusing the effort at EPRI and the National Laboratories. Each work group has the ability to work both independently but also toward common approaches and solutions to improving security.

Reviewer 3:

The EPRI approach to this project was well laid out, had the proper perspective to impact the industry, and was flexible enough to be modified to still be productive, given the current environment.

Reviewer 4:

The project design appears reasonably straightforward, if not overwhelmingly innovative, at least as compared to other cybersecurity projects. The team is working with the EV Cybersecurity Working Group as well as federal, state, and utility groups using EPRI for coordination, which will be critical for getting the word out for the results. The project team is looking at much more than just the charging station, including everything attached to the chargers for opportunities for threats.

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

Reviewer 1:
The project and objectives at this point appear to have been met, and the project team is waiting for the verification stage.

Reviewer 2:
This adds value by including unresponsive service or injecting misinformation since that potentially leaves multiple customers stranded at charging stations or provides incorrect information as to the status and use of the charging stations. This project also includes attacks coupled with the customer's phone applications that are used and provided by the vehicle OEM or charge point operator.

Reviewer 3:
The risk matrix was completed, the working group created, and vulnerabilities and threats identified during BP 1. The current phase is focused on developing the security test plan. Some of the testing has been delayed due to COVID-19, but the PI does not expect that this will impact the overall schedule for the project as several activities are shifting around to attempt to keep the schedule reasonably on track. A key development during the project is the network interface card (NIC) for use in reducing cybersecurity risks, which the team plans to make open sourced to allow for greater adoption.

Reviewer 4:
There is a good foundation for cyber. A little more detail about subsystem requirements and industry acceptance would have been good to report out on.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
These project teams have an excellent history of joint effort and positive results. The teams have separated each task to complement their capabilities and maximize their contribution to successful completion of this project and will lead to future effort as security requirements continues to evolve.

Reviewer 2:
This project makes good use of partnership resources as well as bringing reviewers' comments into the process and has had industry impact with MD-HD cyber infrastructure. The internal review process helps to keep the project focused on advancing cyberstability.

Reviewer 3:
The makeup of the project team seems good, including laboratories, vendors, and a charging site supplier. Each organization appears to have clear assignments. The team's plan to coordinate through industry working groups and government/utility teams for information dissemination is a benefit. The team is also coordinating with the other VTO cybersecurity teams.

Reviewer 4:
All the proper people and groups are in play for the project. The reviewer wondered why it is only geared toward XFC cybersecurity and not all charging systems.

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

Reviewer 1:
This initial effort is applicable to expansion as other charging stations and more EVs come to market with more variations to consider. The foundations created on this project can be applied to other suppliers and expanded as the charging features also continue to grow and expand.

Reviewer 2:
The project team seems to have a plan for future research focused primarily on developing a NIC prototype and testing security controls in real-world applications.

Reviewer 3:
Looking at the future plans, the reviewer would probably test in a real-world scenario first before publishing outcomes.

Reviewer 4:
The project needs to have a proper test plan with appropriate asset impact levels of stability so that partner resources may be properly allocated.

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

Reviewer 1:
The project is extremely relevant as cyber impacts many parts of the next generation transportation systems.

Reviewer 2:
The grid and charging structure are very crucial to the security of the country, and it is very important to possibly come up with a standard for protecting it.

Reviewer 3:
The project is addressing cybersecurity for EV charging systems, a critical step required for success of EVs in the marketplace.

Reviewer 4:
This project allows the analysis of existing standards to be evaluated and improved upon. While each of the teams approach this from different angles or aspects, more solutions can be realized from a project with less diverse and smaller teams.

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

Reviewer 1:
Resources appear sufficient at this time.

Reviewer 2:
The project team has made good progress with resources available and is on track to meet project objectives.

Reviewer 3:
The reviewer saw no issues with how the project is proceeding with resources at this time.

Reviewer 4:

EPRI and National Laboratories have the equipment and resources to accomplish this task. Additional vehicles and chargers are always harder to include, but as production and diversity continues, this will be more sufficient in future projects.

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

Presenter

Ryan Gerdes, Virginia Tech University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

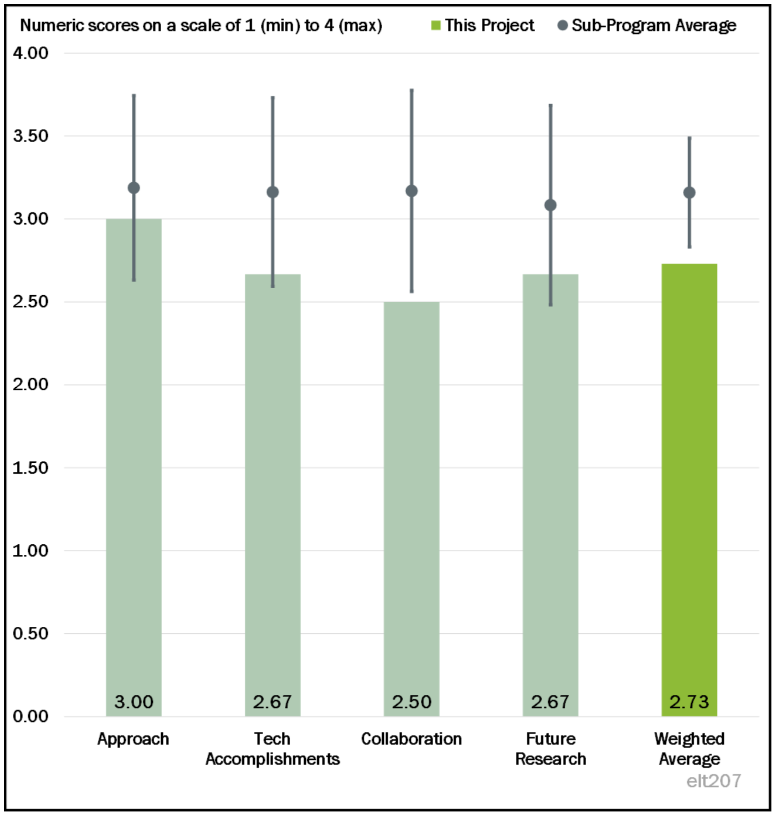

Figure 4-19 - Presentation Number: elt207 Presentation Title: Enabling Secure and Resilient Extreme Fast Charging: A Software/Hardware Security Co-Design Approach Principal Investigator: Ryan Gerdes (Virginia Tech University)

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

Reviewer 1:

The approach is excellent since it includes networked and centrally controlled charging stations that aggregate the power to multiple vehicles from a central controller. This adds the sub-controlled or micro-grid aspect to a charging station plaza that also includes multiple single charging stations. This scenario is highly likely with high power chargers and adds a level of security to this project.

Reviewer 2:

The project made good use of developing threat scenarios, identifying threat priorities, and use of threat assessments. The scope of the project seems to be very large for the team. This was noted by previous reviewers. Perhaps a remapping of goals would be appropriate, given COVID-19 impacts on the project.

Reviewer 3:

The approach seems promising. However, considering current progress of the project and proposed future research for the rest of 2020, it seems very challenging, even considering a 6-month extension due to COVID-19.

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

Reviewer 1:
This project has made excellent technical progress on the modeling and planning but is delayed due to equipment deliveries that could have been utilized earlier in the timeline. The models and approach are complete, but the demonstration and evaluation seem to be delayed from the initial planning.

Reviewer 2:
Good progress was made with simulation and software threat approach methods, but hardware (impacted by COVID-19) and through vehicle selection (a vehicle which is incapable of XFC charge rates) will reduce effectiveness of testing and the results will be biased. It will be interesting to see attack vectors prioritized based on impact to the system. Some hardening approaches should be evaluated by third parties on a separate system to see if approaches have merit.

Reviewer 3:
The progress is stated as 55% which is well behind schedule. The concern about the progress and being behind schedule was also raised during the previous round of reviews.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is excellent coordination across the teams since all members have diverse functions and focus. The combination of actors in this scenario provides an accurate and complete approach to completing the project goals. The effort of three universities along with industry sectors provides the mix of talent and approaches for positive results.

Reviewer 2:
This reviewer observed good member coordination, but as described there are still barriers with cross team knowledge of various domains. Because the scope is quite large, perhaps some focus on a specific (and reduced) attainable goal set would yield better results.

Reviewer 3:
The tasks, workload, level of involvements, and accomplishments of each collaborator need to be clearly and accurately mentioned, which are missing.

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

Reviewer 1:
Future effort is always needed to view new functions and features as these are applied to charging equipment and vehicles. Additional charging station suppliers and utilities along with more OEMs will add to the inputs to validate results of this project and lead to additional items that need to be considered.

Reviewer 2:
Linking proposed future work to changes in funding needs to be updated with background on project spends and missed milestones due to barriers or other challenges.

Reviewer 3:
The future research plans look promising; however, it seems very challenging to be completed on time, even considering 6-month extension due to COVID-19.

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

Reviewer 1:
The objectives outlined here match well with the priorities of DOE.

Reviewer 2:
This project is relevant since it combines existing DC charging stations with high power stations that aggregate loads within multiple dispensers. This mix of product is typical of current deployment of equipment and vehicles and sure to improve the approach to security for the industry to apply.

Reviewer 3:
The topics of the project are relevant, but the ability to complete objectives has impacted the project's relevance. Completion of focused milestones (a reduction from the original scope) would help the project have meaningful impact.

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

Reviewer 1:
The resources are sufficient for a reduced and focused goal set. The project team needs industry input to identify the most viable milestones, and effort should be focused on those.

Reviewer 2:
Resources are sufficient for the start of this approach. Expansion to other suppliers and charge point operators along with additional utilities is a key to maximizing input for a robust solution and needs to expand to include more of these variations.

Reviewer 3:
Considering the project objectives and future research and plans, the allocated budget seems more than enough.

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

Presenter

Emre Gurpinar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

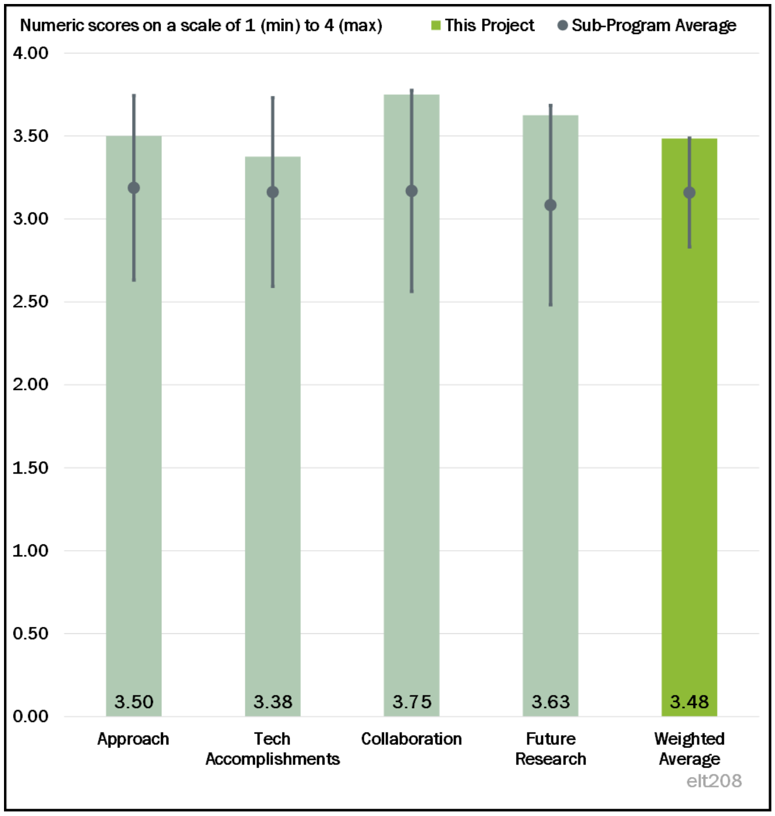

Figure 4-20 - Presentation Number: elt208 Presentation Title: Highly Integrated Power Module Principal Investigator: Emre Gurpinar (Oak Ridge National Laboratory)

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

Reviewer 1:

The presenter described a comprehensive approach tackling key aspects of design to enable reaching the target.

Reviewer 2:

Some of the previous work at ORNL is well utilized. Also good is that both silicon carbide (SiC) and gallium nitride (GaN) are considered.

Reviewer 3:

Thermal management is critically important to the performance, reliability, and cost of power modules. Thus, it is crucial to tackle the challenge by finding a materials solution to effectively extract heat away from the heat-generating device and transfer it to the environment through an efficiently designed heat sink. This project is aimed at finding solutions to both.

Reviewer 4:

To meet the DOE VTO 100 kW/liter (L) power-density target, a high-performance power-dense SiC power module is required. The project team is attempting to address 2025 power-density, cost ($2.70/kW), peak efficiency (greater than 97%), reliability (300,000-mile lifetime or 15 years operational life) targets by a SiC power module that has improved heat extraction, enhanced thermal and power cycling capability, low electrical parasitics, and integrated gate driver, sensor and protection circuits. It is a compelling approach to meet DOE VTO objectives and targets. Automated Design of Power Electronics and selection of one of best between GaN and SiC devices is also part of the project approach and strategy for a successful outcome of this project.

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

Reviewer 1:
The research team completed extensive simulations of the thermal performance of insulated-metal substrates with and without thermal pyrolytic graphite (TPG) as well as development of a liquid-cooled heat sink optimization scheme. The team has also made significant experimental progress to validate their simulation studies.

Reviewer 2:
The project team has completed the following technical tasks that will lead to successful completion of this project:

- Prototyping of direct bonded copper (DBC), insulated metal substrate (IMS), and IMS with TPG core (IMSwTPG) substrates
- Development of test setup for thermal and electrical characterization of half-bridge SiC power modules
- Comparison of steady state thermal performance based on experimental characterization
- Analysis of current capability and heat spreading of different substrates
- Transient thermal analysis of DBC, IMS, and IMSwTPG
- Electrical characterization of IMSwTPG
- Development of liquid cooled heat sink optimization scheme for automated design for power electronics
- Recommendation of multi-layer organic film based direct bonded copper (ODBC) substrate for optimized power module
- Analysis of layer thickness for multi-layer ODBC substrate
- Design of integrated heat sink for multi-layer ODBC substrate
- Development of a test board for characterization of GaN high-electron-mobility transistor (HEMT) and SiC metal oxide semiconductor field effect transistor (MOSFET) for traction drive systems.

Reviewer 3:
The project documented well the design, simulation, and experimental results. Experimental results are not reflecting steady state temperature similar to simulation results. It would be critical to identify for evaluation the impact on the reliability objective.

Reviewer 4:
Good progress is shown in analyses, design, and optimization task items. Also, some experimental characterizations have good progress. It may or may not be under the scope of this particular project, but the switching transient associated high-frequency oscillations on Slide 11 will sooner or later become a major concern. It might be a good idea to start giving specific thought to how to handle that from the packaging viewpoint (module parasitics and semiconductor capacitance).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Multiple National Laboratories, multiple universities, and multiple industries—collaborations are excellent!

Reviewer 2:
The complementary expertise of the partners and close interactions across the project team show a strong cohesive and synergistic collaboration.

Reviewer 3:
The project team was strong with well-defined independent roles.

Reviewer 4:
Many academic institutes, industries, and DOE laboratories are part of overall team with leading roles and responsibilities in successful execution of project tasks and completion of project milestones.

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

Reviewer 1:
Having completed extensive theoretical and simulation analyses and construction of a testbed for experimental implementation, the team's plan to focus on assembly, prototyping, and testing is logical and timely to further advance the goal of the project.

Reviewer 2:
The presenter defined milestones for FY 2020 and FY 2021.

Reviewer 3:
Future research topics that are going to make this project a successful one include the following:

- Complete assembly of test board for GaN HEMT and SiC MOSFET
- Complete the optimization of high-performance heat sink for multi-layer ODBC module based on GaN HEMT and SiC MOSFET
- Simulate the electrical and thermal performance of organic substrates with SiC and GaN devices
- Finalize the design for integrated module based on multi-layer ODBC
- Complete experimental characterization of SiC MOSFET and GaN HEMT
- Fabricate prototype integrated power module based on multi-layer ODBC
- Develop a segmented three-phase inverter based on proposed concept.

Reviewer 4:
The hardware prototyping and test plan are good. The reviewer looked forward to hearing about the prototype test results. It might be beyond the scope of this particular project, but it would be even better if specific consideration were given to extending the concept in this project to the double-sided cooling.

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

Reviewer 1:
Power-dense SiC and GaN power modules are closely tied to DOE objectives for cost-effective, high-reliability, high-efficiency, and miniaturized power electronics.

Reviewer 2:
The technologies developed in this project are key for achieving DOE Electrification Technologies' (ELT's) 2025 technical targets for electric drive systems.

Reviewer 3:
Yes, project ELT208 is relevant in order to meet the challenging inverter power density target in the U.S. DRIVE Electrical and Electronics Technical Team (EETT) roadmap.

Reviewer 4:
Power density and cost optimization were indicated by this reviewer.

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

Reviewer 1:
This project has necessary resources and research funds, and collaborations seem to be working smoothly.

Reviewer 2:
There are sufficient resources with no redundancies.

Reviewer 3:
Utilizing the outcomes and facilities handed over from the previous projects, it looks like resources are sufficient.

Reviewer 4:
The project addresses both scientific and technological challenges of a complex systems problem. More funding to the project team would ensure the highest possible quality of its performance.

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

Presenter

Gui Su-Jia, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

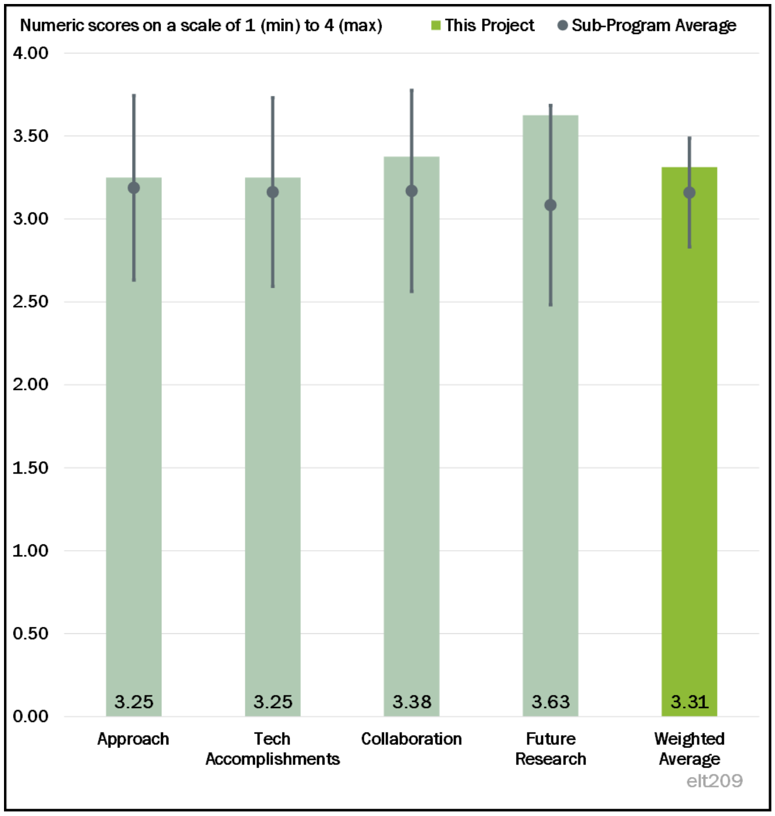

Figure 4-21 - Presentation Number: elt209 Presentation Title: High-Voltage, High-Power Density Traction-Drive Inverter Principal Investigator: Gui Su-Jia (Oak Ridge National Laboratory)

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

Reviewer 1:

The PI's previous work appears to be well utilized. As mentioned in the question and answer session of the oral presentation, the reviewer looked forward to hearing about the follow-up regarding comparative evaluation between the segmented inverter drive and the open-end winding dual inverter drive concept.

Reviewer 2:

Passive elements, such as the decoupling capacitors of the electric-drive inverter, take up a large volume. To meet the ambitious 100 kW/L target prescribed by the ELT program, the team developed an innovative approach by segmenting the existing three-phase into a two, three-phase topology. As a result, the capacitor size is cut down by half, thus making a significant contribution to boosting the power density of the drive.

Reviewer 3:

The project PI assumes that DC capacitor cost can be drastically reduced by using active cooling of a segmented inverter DC bus bar. The segmented inverter allows interleaved pulse width modulation (PWM) switching of all devices in both inverters, resulting in significant reduction in DC bus current ripples. Capacitor elements are embedded, distributed, and direct cooled. The reviewer indicated a multiple prong approach from the standpoint of packaging, thermal management, and control of the segmented inverter, resulting in an inverter that could get closer to DOE VTO target for power density, cost, efficiency, and reliability.

Reviewer 4:

The impact to cost and power density is not clearly stated with proposed approach.

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

Reviewer 1:
The research team completed extensive simulations of their segmented three-phase inverter approach, developed a robust control methodology, and laid out a design of testbed for experimental verification.

Reviewer 2:
Good progress has been shown in particular about capacitor thermal analysis and simulation. As one of the future task items, cross-comparison between the analyses and simulations and a certain hardware measurement (at least some workbench measurements for several representative operating conditions) is expected.

Reviewer 3:
Technical accomplishments include: development of a switching timing-based method for computing the inverter capacitor ripple current and bus bar current and implemented in MATLAB, development of a driving cycle-based DC bus capacitor life-expectancy prediction and sizing tool, development of a capacitor transient thermal impedance model, and development of direct-cooled bus bar design concept. These outcomes show that the project is tracking as expected.

Reviewer 4:
Efficiency evaluation is not observed as an accomplishment nor stated to be part of the future work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is clear cohesion and synergistic collaboration across the project team.

Reviewer 2:
The presenter clearly stated collaborators and responsibilities.

Reviewer 3:
NREL and Virginia Polytechnic Institute (Virginia Tech) are collaborators with targeted roles and responsibilities in this project led by PI at ORNL.

Reviewer 4:
Collaboration with a National Laboratory (NREL) and a university (Virginia Tech) is well taken. It would be even better if there were some involvement from industry.

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

Reviewer 1:
The proposed future research plan is clear and sound.

Reviewer 2:
The reviewer was looking forward to hearing about the upcoming results of the directly cooled bus bar in 2020 and further looking forward to seeing the outcomes of 100 kW prototype!

Reviewer 3:
The future research tasks include valuation of the impact of the direct-cooled bus bars on the DC bus capacitors in various power modules; finalization of a direct cooled DC bus bar design for use in an inverter prototype in FY 2021; design of a 100 kW high voltage, segmented inverter using ORNL power modules; evaluation of the design against the DOE ELT 2025 targets; and fabrication of a prototype.

Reviewer 4:
The path to evaluating all of the DOE targets (efficiency and cost, specifically) was not observed.

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

Reviewer 1:
Yes, this work is very relevant to meet the challenging target of the power density of 100 kW/L.

Reviewer 2:
The technologies developed in this project are key for achieving DOE ELT's 2025 technical targets for electric drive systems.

Reviewer 3:
Project activities are related to DOE 2025 power electronics objectives and targets for power density, cost, efficiency, and reliability.

Reviewer 4:
Reliability was stated by this reviewer.

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

Reviewer 1:
Based on the budget number on an early slide in the presentation, the progress made thus far, and the future plan, the budget looks sufficient.

Reviewer 2:
This project has the necessary resources and research funds with appropriate level of collaboration.

Reviewer 3:
The project has sufficient resources with no redundancies.

Reviewer 4:
The project addresses key technological challenges of a complex systems problem. More funding to the project team would ensure the highest possible quality of its performance.

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

Presenter

Greg Pickrell, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

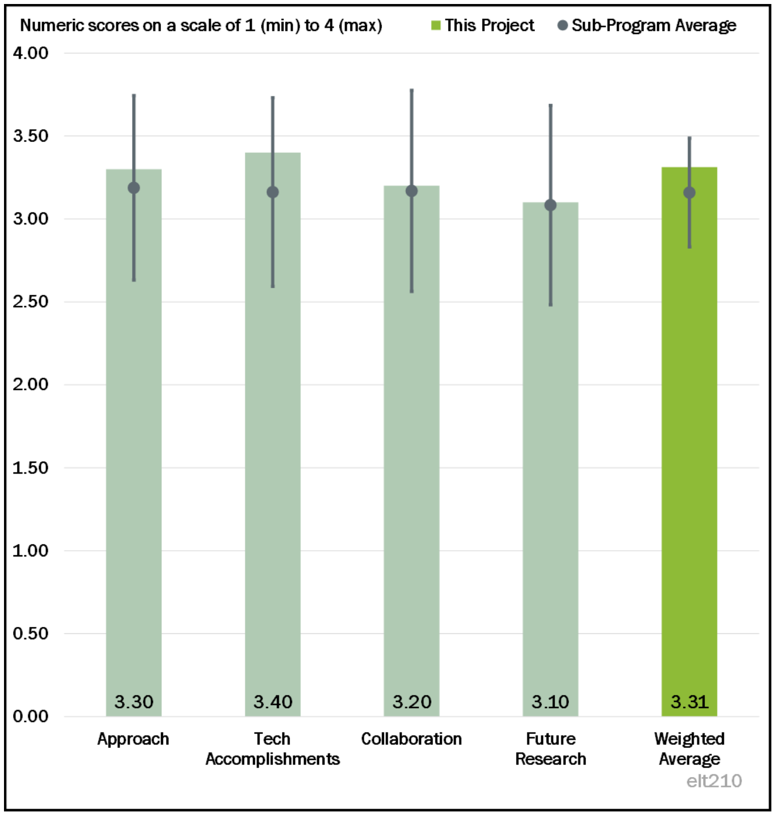

Figure 4-22 - Presentation Number: elt210 Presentation Title: Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain Principal Investigator: Greg Pickrell (Sandia National Laboratories)

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

Reviewer 1:

The step-by-step approach of a SiC MOSFET /SiC Schottky barrier diode (SBD)to SiC MOSFET/GaN SBD (or junction barrier Schottky [JBS] diode?) hybrid to GaN MOSFET/GaN SBD (or JBS diode?) is good. Developing vertical GaN SBD, JBS diode, and MOSFET are of very strong interest.

Reviewer 2:

The project PI has laid out the importance of enabling a power-dense, cost-effective electric drive system by improving power devices, passive (filter between inverter and electric motor) and rotatory (electric motor) components. Then, the PI down-selected impactful contribution made by the project team in the area of power-dense, wide bandgap (WBG) power devices. This contribution will be made in three stages:

- Stage 1: SiC MOSFET + SiC Diode
- Stage 2: SiC MOSFET + GaN Diode
- Stage 3: GaN MOSFET + GaN Diode.

At each stage, two key tasks are planned in approach taken for execution of this project: Task 1: Device modeling, circuit simulation at each stage and Task 2: Characterization and evaluation of device technology in test bed at each stage. This approach seems appropriate and closely tied with the final objective, “Development of Next-Generation Vertical GaN Devices for High-Power-Density Electric Drivetrain.”

Reviewer 3:
There is a three-step approach in characterization and evaluation.

Reviewer 4:
The team strives to reduce the size and weight of the inverter power electronics of electric drive systems by developing power device technologies based on SiC and GaN that have more superior performance characteristics than today's Si technologies. The SiC device technologies have been in development for over 30 years, and only recently, they are beginning to enter the transportation market. The primary reasons for the slow entry are cost and reliability, both are equally if not more challenging for developing the GaN device technologies. What would be great is if the team offered a value proposition of their vertical GaN devices in electric drive systems.

Reviewer 5:
It is not clear what or if any consultation has been performed with chip manufacturers and vehicle OEMs. This creates uncertainty that the approach is working on the issues that matter for vehicle electrification. The reviewer was afraid this work is focused on what the PI sees as issues, with the underlining assumption being that the chip manufactures not working chip issues currently.

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

Reviewer 1:
The reviewer found the technical accomplishments and progress to be comprehensive.

Reviewer 2:
SiC MOSFETs device gate oxide liability test results and short circuit capability tests are informative! Parametric study of new SiC MOSFET design is also good. Vertical GaN SBD, JBS diode, and MOSFETs study is also informative.

Reviewer 3:
Technical accomplishments of project are detailed out in Slides 7 to 17 of the project report with summary as stated here:

- The project team has pursued multi-path approach for power electronics keystone through development of SiC and GaN devices to meet Consortium targets.
- The project team has evaluated commercial SiC MOSFETs for reliability assessment while starting custom device fabrication at a commercial foundry (university partners). First round of custom SiC MOSFETs showed good device performance. Future designs will focus on automotive requirements.
- GaN device development is underway.
- Extensive device simulations for GaN diodes and MOSFETs have been completed.
- GaN Schottky diodes and JBS diodes have been demonstrated. Optimization is in progress.
- Process development for GaN MOSFET is underway.
- Implanted n-type source contacts for double-well MOSFETs have been demonstrated.

Reviewer 4:
In presenting the technical achievements and progress, the team had a large portion of the achievements made by its partners, OSU, State University of New York Polytechnic (SUNY Poly), and Lehigh University. Although this seems to show a close collaboration between the team and its partners, it obscures the team's own achievements on vertical GaN devices. The team clearly has made significant progress toward epitaxial growth of GaN on GaN and succeeded in fabricating vertical Schottky GaN diodes. Also, it would be great if

the team offered a comparison of their GaN devices with those reported in the literature to stress the significance of their achievements.

Reviewer 5:
Evaluation of off-the-shelf devices provides a good basis for components that are generally available, but the auto OEMs are provided components that are not available to anyone else. If the purpose of this work is for general education of the public, it has value. The reviewer would suggest that the PI contact the ELT082 PI.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Clearly stated collaborators and responsibilities were observed by the reviewer.

Reviewer 2:
This reviewer listed the following project collaborators with specific roles and responsibilities:

- ORNL–Collaborating partner for Electric Traction Drive integration and evaluation
- NREL–Collaborating partner for Electric Traction Drive integration and evaluation
- SUNY Poly (Woongje Sung)–Fabricating SiC JBS diode integrated with MOSFETs (sub-contractor)
- OSU (Anant Agarwal)–Designing for improved reliability for SiC electronics and, evaluating reliability and ruggedness of commercial and fabricated devices using realistic scenarios (sub-contractor)
- Jim Cooper–Working with OSU for SiC device evaluation and SNL for GaN power electronic device design and characterization (sub-contractor)
- Lehigh University (Jon Wierer)–Working with SNL for design, simulation, and modeling of GaN SB and JBS diodes (sub-contractor).

Reviewer 3:
Multiple National Laboratory and university collaborations are good. It would be even better if there would be some industry collaborators.

Reviewer 4:
There are close interactions across the project team to show a strong cohesive and synergistic collaboration. As the team has already realized, adding a partner with packaging expertise would further strengthen the collaboration.

Reviewer 5:
Collaboration with just universities and National Laboratories does not provide the reality/context of what is currently going on the industry.

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

Reviewer 1:
The next steps of both SiC and GaN are clearly defined. They are good. Also good are clear understandings of the upcoming challenges (automotive environment and cost). Looking forward to hearing about the upcoming year's progresses! Wondering if not only commercially available devices, but also the newly designed/developed devices are also put in the reliability tests. Also, would like to hear about details of gate dielectric material selection for the GaN MOSFETs in the future.

Reviewer 2:
The proposed future research on GaN are ambitious, but are logical continuation of the progress made thus far. This reviewer was confused by the future research for both SiC and GaN devices. Is this project supposed to focus on vertical GaN devices and the team's partners, SUNY Poly and OSU, on SiC devices? Do SUNY Poly and OSU have their own separate projects on SiC devices?

Reviewer 3:
The plan seems appropriate if the work aligns with actual needs from the chip manufacturers and vehicle OEMs.

Reviewer 4:
The reviewer offered the following comments for SiC MOSFETs:

- Focus on design and test for automotive reliability
- Fabricate and test second generation of devices
- Performance targets 1,600 volt (V) holdoff, Ron,sp is 5 mΩ-centimeter squared (cm^2), Vth = 2V
- Evaluate performance against Consortium targets
- Utilize devices in Gen1 prototype Electric Traction Drive.

Regarding GaN field effect transistors, the reviewer indicated the following:

- Iterate to improve GaN JBS diode performance to 600 V holdoff voltage, 0.5 A forward current
- Combine GaN JBS diode with SiC MOSFET in circuit for evaluation
- Demonstrate GaN MOSFET device performance (100 V holdoff voltage, 0.2 A forward current)
- Iterate to improve GaN SB and JBS diode performance against targets (1,200 V/100 A)
- Iterate to improve GaN MOSFET performance against targets (1,200 V/100 A)
- Combine GaN MOSFET and JBS diode in circuit for evaluation.

Reviewer 5:
This reviewer referenced Slide 21 regarding performance to 600 V hold-off voltage. This voltage level was unclear to the reviewer when the performance target is mainly at 1200 V and 1600 V.

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

Reviewer 1:
WBG devices are the key role players to meet the challenging power density target of the inverter. Yes, ELT210 is a very relevant project.

Reviewer 2:
To achieve DOE Electrification’s 2025 technical targets for electric drive systems, the device junction temperature will have to be elevated to 200°C or 250°C. This rules out the existing Si devices and awaits the development of either SiC or GaN devices.

Reviewer 3:
Vertical GaN power devices are very relevant for automotive applications and also as alternatives of SiC power devices. This project is striving to address this objective of DOE VTO.

Reviewer 4:
Reliability.

Reviewer 5:
The reviewer would be surprised if chip manufactures and OEMs are not already addressing the issues this project addresses. A detailed review should be held with chip manufactures and OEMs before moving forward on this project.

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

Reviewer 1:
For basic understanding and experimentation then the resources allocated are adequate. If the issues identified by this project are validated by the chip manufactures and vehicle OEMs and the goal is to have something that is usable by the OEMs then the resources for this project would be insufficient.

Reviewer 2:
Sufficient resources with no redundancies.

Reviewer 3:
Based on the progress thus far and the plan for the next step with the budget number, it seems sufficient.

Reviewer 4:
A serious development effort for vertical GaN devices, diodes, and switches, is an expensive endeavor. The private sector has already invested tens of million dollars, and the progress has been slow.

Reviewer 5:
Project has-necessary resources and research funds. A multi-entity collaboration seems like it is working in successful execution of project tasks.

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

Presenter

Gilbert Moreno, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

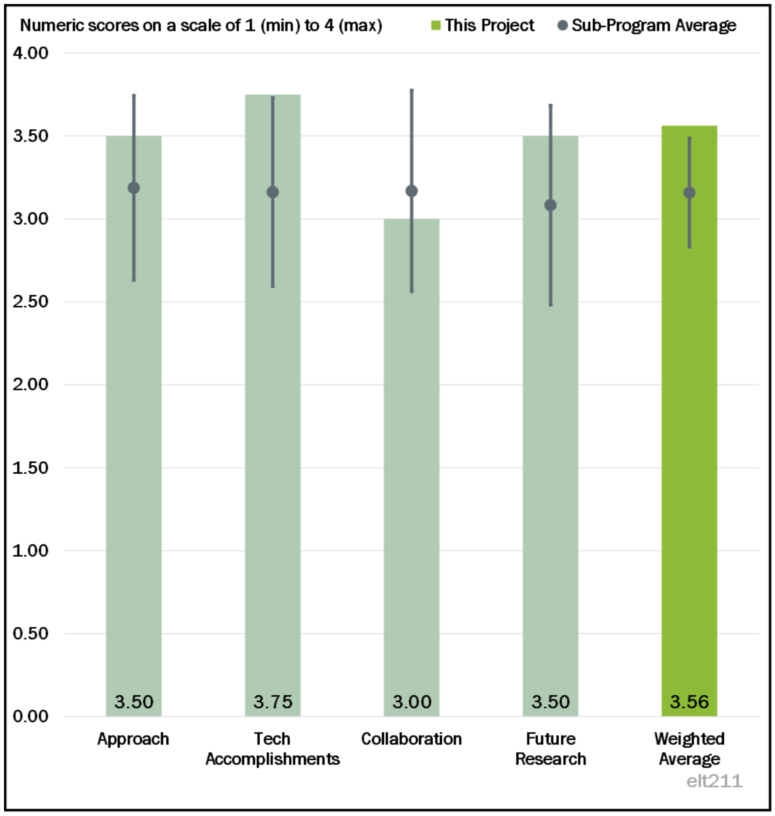

Figure 4-23 - Presentation Number: elt211 Presentation Title: Power Electronics Thermal Management Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory)

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

Reviewer 1:

Effective heat extraction from switching devices is critically important to the performance, reliability, and cost of power modules. The proposed approach offers an innovative strategy for heat removal by flowing a dielectric fluid directly on the device interconnect, either in a single-side or double-side cooling configuration.

Reviewer 2:

The approach seems reasonable and well thought out. The reviewer liked that the focus is outside of what one would expect most OEMs and their suppliers to pursue.

Reviewer 3:

The project is on track with the schedule; the technical accomplishments indicate that the technical barriers have been successfully addressed.

Reviewer 4:

The project team identifies that a compelling, yet practical thermal management strategy is required to achieve power density of 100 kW/L. This strategy includes packaging and convective cooling of power devices including use of the dielectric-fluid for cooling. From past works carried out by project team, it is stated that:

- By reducing the package thermal resistance, the total thermal resistance of power devices can be reduced by approximately 60% to 80% compared to conventional modules.

- Dielectric fluids enable a package re-design to decrease the package resistance, which is the dominant portion of overall thermal resistance.
- Use of dielectric fluids opens the potential of using automatic transmission fluid (ATF) or other new driveline fluids as the coolants.
- Dielectric fluids enable cooling of the bus bars/electrical interconnects to lower capacitor and gate driver temperatures, improved cooling (single-phase heat transfer) via jet impingement and finned surfaces, elimination of expensive ceramic materials, and improved thermal performance over conventional DBC-based designs.
- Using dielectric fluids results in reduced package/conduction resistance to 33% of total thermal resistance using a relatively high convection coefficient (17,300 W/[m^2·K]). Dielectric fluids enable easier realization of single-side and double-side cooled packages.

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

Reviewer 1:
The accomplishments presented are very encouraging, and the technical targets set for this year have been met and exceeded.

Reviewer 2:
The research team completed extensive simulations of their dielectric-fluid cooling approach and ran a large number of tests on the single-side cooled configuration to validate their simulation results.

Reviewer 3:
A dielectric fluid cooling system concept is developed with measured thermal performances; heat transfer coefficient of 17,300 W/(m^2·K) at a relatively low jet velocity of 0.3 m/s, (b) 22 mm^2·K/W junction-to-fluid thermal resistance (per device).

Also, it is determined that dielectric fluid cooling system leads miniaturization of power device package; achieved 120 mL total volume for conceptual 12-device module and heat exchanger; requires 4.1 L/min total flow rate; it is possible to dissipate 2.2 kW with 12 devices; junction temperature of 220°C at a heat flux of approximately 716 W/cm^2; and computed thermal resistance of 9 cm^3·K/W total resistance compared to target value of 21 cm^3·K/W.

The project team has fabricated the finned heat spreaders. The project team also designed a cartridge heater system to simulate the 12 SiC devices with heater blocks soldered to finned heat spreaders and measured the heat exchanger (case-to-fluid) thermal resistance. The project team also fabricated a polycarbonate prototype of the dielectric-fluid heat exchanger via three-dimensional (3-D) printing (cartridge heaters and insulation not shown) and completed fabrication of the dielectric fluid loop and measured the heat exchanger (case-to-fluid) thermal resistance at various fluid flow rates and temperatures.

The reviewer commented that the project team obtained a good match between experiments and the model and explained that changing fluid temperature has minimal effect on thermal resistance but does affect pumping power. The reviewer also indicated that the project team confirmed the heat exchanger low thermal resistance values and provided confidence in model predictions.

Additionally, the project team modeled performance of Alpha 6, AC-100, and ATF at 70°C and 40°C fluid temperatures at different flow rates (1 L/min to 6 L/min). The reviewer explained that changing fluids and varying temperatures has a minor effect on thermal resistance but has a big effect on pumping power when compared at the same flow rates. The reviewer also noted that the team predicted ATF performance to be similar to Alpha 6 because they have similar properties.

The project team has compared performance of ATF cooling with existing automotive systems, determined that higher viscosities at low temperatures may not be a problem if the correct fluid is chosen and coupled with a low pressure-drop system, and developed conceptual dielectric fluid-based double-side cooled module.

Reviewer 4:
The work is systematic. A cooling system design concept was created. A prototype was fabricated and tested. Results were compared to the simulated data and a good correlation was achieved.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There are close interactions across the project team that show a strong, cohesive, and synergistic collaboration.

Reviewer 2:
It looks as the technical accomplishments shown in the presentation have mostly been developed by the Lead Organization. In this sense, it is unclear what the role was of partners John Deere and Georgia Institute of Technology (Georgia Tech).

Reviewer 3:
Project collaborators with different types and level of contributions are stated:

- John Deere (industry)—Two-phase cooling for high-packaging-density planar inverter (via a cooperative research and development agreement [CRADA]).
- Georgia Tech—Collaboration to evaluate and develop advanced cooling technologies (two-phase and inter-device cooling)
- Elementum3D (industry)—3-D-printed metal parts to evaluate new heat exchanger concepts
- ORNL—Dielectric fluid manufacturers.

Reviewer 4:
The reviewer would like to have seen a passenger vehicle OEM involved; otherwise it seems to be a well-rounded team.

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

Reviewer 1:
The proposed future research is appropriate with the scope of the project. Given that the concept of jet impingement with dielectric fluid was proven so successful, could the project put more emphasis in the future on the optimization of the hydraulic circuit (designing the system to reduce pressure drops and opportunity to operate with different dielectric fluids), and conduct durability testing? These are critical aspects for a successful deployment of the technology.

Given that the technical targets have been addressed successfully with single-phase dielectric fluid, what would be the rationale behind exploring two-phase fluids? The risk/benefit proposition is unclear, in light of the results obtained. Perhaps this aspect could be de-emphasized, to focus more on the hydraulic system optimization based on the solution demonstrated so far.

Reviewer 2:
This reviewer looked forward to learning the team's progress of their future work on cooling modules in the double-side cooled configuration.

Reviewer 3:
The remaining challenges and barriers are right on target and the future plan addresses these issues.

Reviewer 4:
Project relevant future research topics include:

- Complete design of the double-side cooled, dielectric fluid concept
- Conduct experiments with AC-100 and ATF at various fluid temperatures and flow rates
- Collaborate with Georgia Tech to develop the advanced cooling technologies
- Fabricate a prototype of the double-side cooled concept
- Experimental demonstration/validation of the double-side dielectric fluid concept
- Evaluate the long-term reliability of the dielectric fluids
- Collaborate with Georgia Tech to develop the advanced cooling technologies.

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

Reviewer 1:
Advanced thermal management is extremely important for successful adoption of WBG power devices that have potential to meet 2025 power-density (100 kW/L) and efficiency (greater than 97%) targets of power electronics aspired by DOE VTO.

Reviewer 2:
The cooling technologies developed in this project are key for achieving DOE Electrification's 2025 technical targets for electric drive systems.

Reviewer 3:
The project aims at defining thermal management solution that are necessary to achieve the 2025 DOE power density of 100 kW/L for power electronics.

Reviewer 4:
A key factor in achieving power density will be thermal management.

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

Reviewer 1:
The funding level seems adequate.

Reviewer 2:
The resources allocated are sufficient so far. If the project emphasis shifts more toward packaging/design optimization and durability, more resources will have to be allocated to designing, 3-D printing, and manufacturing.

Reviewer 3:
This project has necessary resources and research funds in conjunction with result-oriented collaborations with industry and academia.

Reviewer 4:
This work is focused on cooling of switches/power modules. Cooling/thermal management of the other components will be critical in successfully achieving the project power density targets.

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

Presenter

Tsarafidy Raminosoa, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

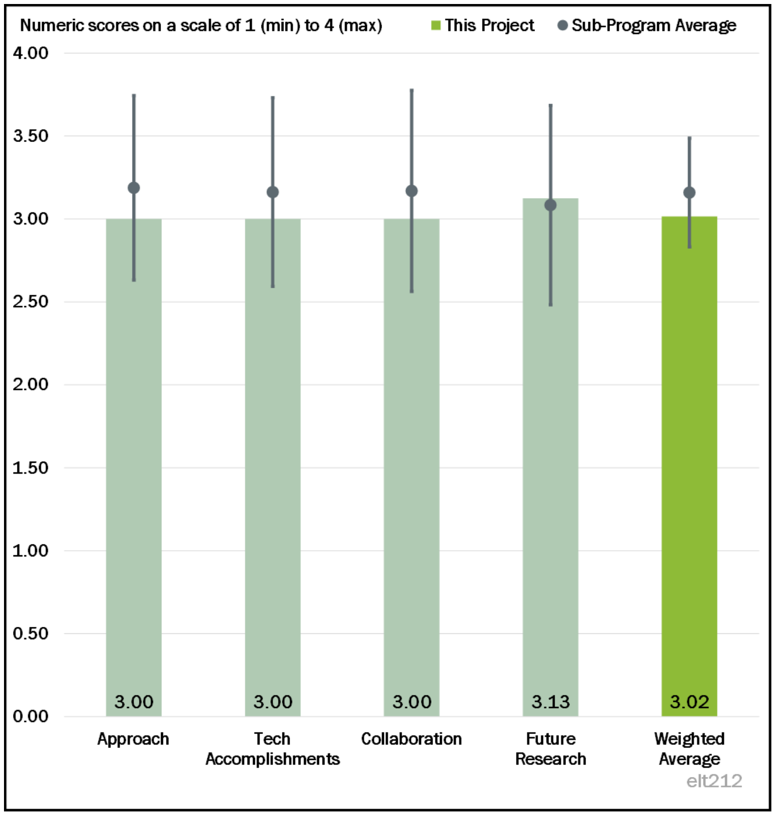

Figure 4-24 - Presentation Number: elt212 Presentation Title: Non-Heavy Rare-Earth High-Speed Motors Principal Investigator: Tsarafidy Raminosoa (Oak Ridge National Laboratory)

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

Reviewer 1:

The approach of down-selecting a drive design from many well-known options with the constraint of avoiding dysprosium (Dy) makes sense. Working all of the individual elements (motor, inverter) is important to achieving the most optimal design.

Reviewer 2:

Approach to project is sound. Technical barriers are being addressed adequately.

Reviewer 3:

Even though there might be potential benefits of the down selected topology especially in terms of system integration and thermal management, it is not very clear that it provides a clear path to meeting the DOE targets.

Reviewer 4:

High-density, non-rare earth (RE) permanent magnet (PM) machine design is of critical importance due to the high price of these magnets and control of these materials by a single country. However, outer-rotor PM machines have their own disadvantages. Stator cooling is an issue and this can increase the copper (Cu) loss and core loss. Outer-rotor PM machines have very high centrifugal forces which can increase the high-speed mechanical loss and core loss. How do these losses affect the magnet temperature? How is the surface PM contained?

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

Reviewer 1:
Progress is acceptable to date.

Reviewer 2:
The outer-rotor choice is interesting. Excellent progress has been made in addressing the design challenges of this configuration. One item that might need addressing is the growth of the motor volume to 3 liters (L) (if the reviewer heard that correctly) to get the inverter to fit. That seems directionally incorrect.

Reviewer 3:
Even though some mechanical stress analysis has been performed on the outer rotor design, a more detailed rotor dynamics analysis taking into consideration the bearings selection should be performed. The slides show a Halbach array, which is an expensive option for the application. Some justification for such choice should be included.

Reviewer 4:
At this stage of the project, it is very unclear how the performance indicators are met. What are the machine dimensions? What are the dimensions of the inverter? Is it single or dual inverter? Is the cooling common between the inverter and motor? How is the cost target met? Do Halbach array magnets tend to be cheaper than conventional magnets that are being currently used?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Good collaboration with other National Laboratories, especially NREL.

Reviewer 2:
Many lab teams are involved in delivering parts that must work together. The required design and data sharing seem to be in place.

Reviewer 3:
There seems to be proper collaboration and coordination among team members.

Reviewer 4:
Seems like a good collaboration between various National Laboratories. However, for this kind of project, it would be a value add if OEMs are a part of the advising team at least.

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

Reviewer 1:
Next steps are appropriate for achieving a successful design.

Reviewer 2:
Proposed future work is well aligned and planned per the project objectives.

Reviewer 3:
Integration of the thermal management of the motor and inverter is a critical aspect of this project. How is this addressed? A plan for thermal management of motors has been outlined.

Reviewer 4:
More analysis and experimental verification are needed.

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

Reviewer 1:
The project is relevant and well aligned to DOE objectives in 2025.

Reviewer 2:
Increasing power density and reducing cost are major factors for EV deployment and this project is aiming to do that.

Reviewer 3:
The project supports the DOE VTO objective of widespread EV adoption. Reducing drive cost and packaging size are critical to reducing EV cost relative to the current internal combustion engine (ICE) technology.

Reviewer 4:
Directionally, the project supports the DOE objectives but there are concerns about the level of improvement expected compared to the state of the art.

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

Reviewer 1:
Resources appear to be sufficient as the project is on schedule.

Reviewer 2:
Resources seem to be adequate.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
The project has experienced team members to complete the project on time.

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

Presenter

Jason Pries, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

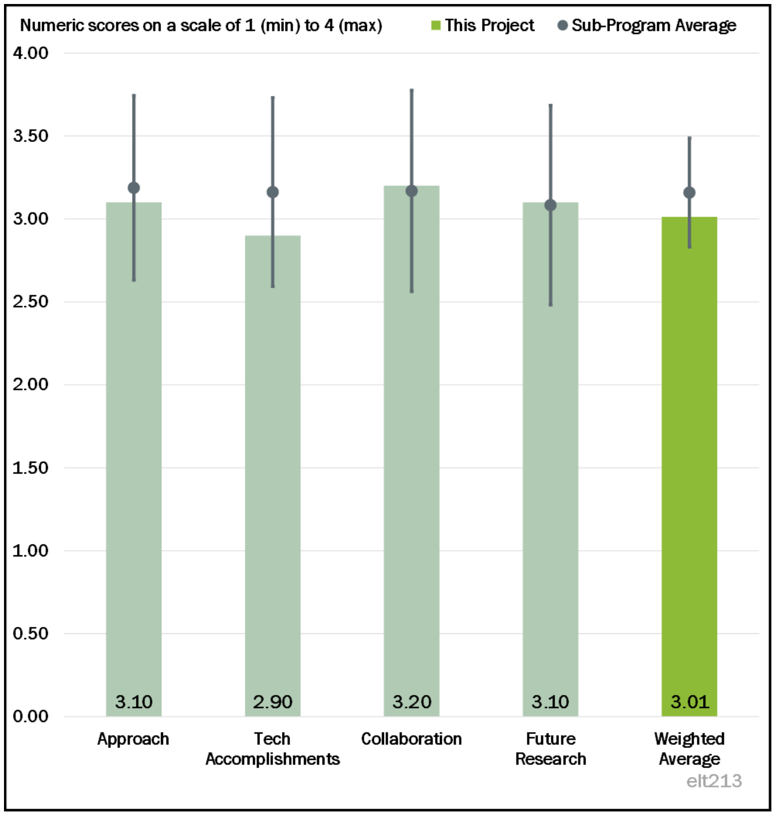

Figure 4-25 - Presentation Number: elt213 Presentation Title: High-Fidelity Multiphysics Material Models for Electric Motors Principal Investigator: Jason Pries (Oak Ridge National Laboratory)

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

Reviewer 1:

The need to obtain better material models by starting with more detailed measurements of physical properties is appropriate.

Reviewer 2:

Approach to project is sound. Technical barriers are being addressed adequately.

Reviewer 3:

The approach is logical and well defined. The approach includes three steps, including testing, post processing, and analysis. Research aims to improve the science and technology for HRE-free PMs and electrical steel core losses for motor design.

Reviewer 4:

Virtual analysis of electric machines has been a topic of interest for cost reduction and performance improvement, and this project aims to do that. With core loss there is a large discrepancy between finite element analysis (FEA) simulation data and actual test data. If a factor is introduced to match the core loss between simulation and test data, this factor varies by a large factor for various operating points in the machine. Also, different FEA tools have varying levels of discrepancy. The reviewer hoped that this project will be able to close this gap and give better estimation of these losses when compared to what present knowledge.

Reviewer 5:
Even though more accurate modeling of demagnetization and high-frequency losses is generally useful in electrical machine design, it is not clear how this is going to help meet the DOE objectives, especially since it was not shown in a clear way how the proposed modeling techniques are better than what already exits or have been previously explored in literature.

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

Reviewer 1:
Progress is acceptable to date.

Reviewer 2:
Many clever methods have been developed to effectively perform the material testing work. For example, comparisons of the actual measurements against current modeling predictions would have been useful as a gauge of the potential difficulties.

Reviewer 3:
There is some good progress made but still the differentiation compared to commercially available packages as well as other work presented in literature is not very clear. Also, the expected impact of the proposed/improved modeling techniques on the machine performance should be quantitatively presented.

Reviewer 4:
There has been some work done on characterizing the Halbach magnets. Estimating the PWM losses in the electrical steel with accurate hysteresis modeling is a major task that is yet to be performed.

Reviewer 5:
It is nice to see the development for PM test fixture and methodology for examining demagnetization curves. This is in line with the aims of the project. Project analyzed vector demagnetization requirements in Halbach outer rotor and a linear surface permanent magnet (SPM) motor. It would be nice to see other types of PM machines analyzed as well. Progress has been made to measure PWM core loss measurements.

How much will the predicted core losses be as a function of switching frequency for a given motor design? What is the trade-off between increasing the switching frequency of the inverter (higher losses for the inverter) and reducing core losses? How should the demagnetization analysis be extended for the Hallback array machine to interior permanent magnet (IPM) and SPM motors?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There has been significant collaboration between ORNL, Ames Laboratory, and NREL in this project.

Reviewer 2:
There seems to be proper collaboration and coordination among team members.

Reviewer 3:
The project requires inputs from three different labs to obtain the desired test data.

Reviewer 4:
The reviewer observed good collaboration among National Laboratories and these collaborations are well articulated and designed.

Reviewer 5:
There seems to be reasonable collaboration with other National Laboratories and teams even though there is no quantitative demonstration of the outcome of this collaboration.

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

Reviewer 1:
Proposed future work is well aligned and planned per the project objectives.

Reviewer 2:
One of the main aspects, which is accurate estimation of PWM loss, has been captured in the milestones and deliverables. This task has been organized systematically to prove the concept in smaller levels.

Reviewer 3:
The planned work is a logical follow-up to current testing. Instead of core-loss post-processing, would it be better to integrate the improved models directly into the FEA code?

Reviewer 4:
Future work is around PWM core testing and post-processing tools for FEA simulation for FY 2020 and improving PWM losses by improving second-order reversal curves for steels and permanent magnets for FY 2021. The reviewer found out that future work is in a logical sequence and addresses the aims of the project. In addition, please see prior comments for future work.

Reviewer 5:
More quantification of impact on machine performance should be presented. Clearer comparison with the state of the art should be presented.

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

Reviewer 1:
Electrical steel losses and PM losses and demagnetization are critical design considerations for optimizing the machine design and reducing the cost and volumetric power density of the machine. The high-frequency losses are tough to estimate, so make the losses in PM. For this reason, this project tries to close the knowledge gap in this area. It is nice to see detailed analysis and verification plans. This project is in line with DOE's goals to achieve high power density and low-cost traction motors.

Reviewer 2:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 3:
Better materials modeling should help the goal of designing improved motors, meeting the DOE VTO performance targets.

Reviewer 4:
Virtual modeling and analysis are relevant for reducing cost and having fast turn-around for product development. This aligns very well with the DOE objectives.

Reviewer 5:
More accurate modeling is helpful, but the extent it is going to help meet the DOE targets is still not clear.

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

Reviewer 1:
Resources are sufficient to meet the project milestones in a timely fashion. It is nice to see the test set-ups in picture to estimate the core and PM losses.

Reviewer 2:
Resources appear sufficient to execute the testing required.

Reviewer 3:
Resources seem to be adequate.

Reviewer 4:
Resources are sufficient.

Reviewer 5:
The team is very knowledgeable and can complete the project in time.

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

Presenter

Kevin Bennion, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

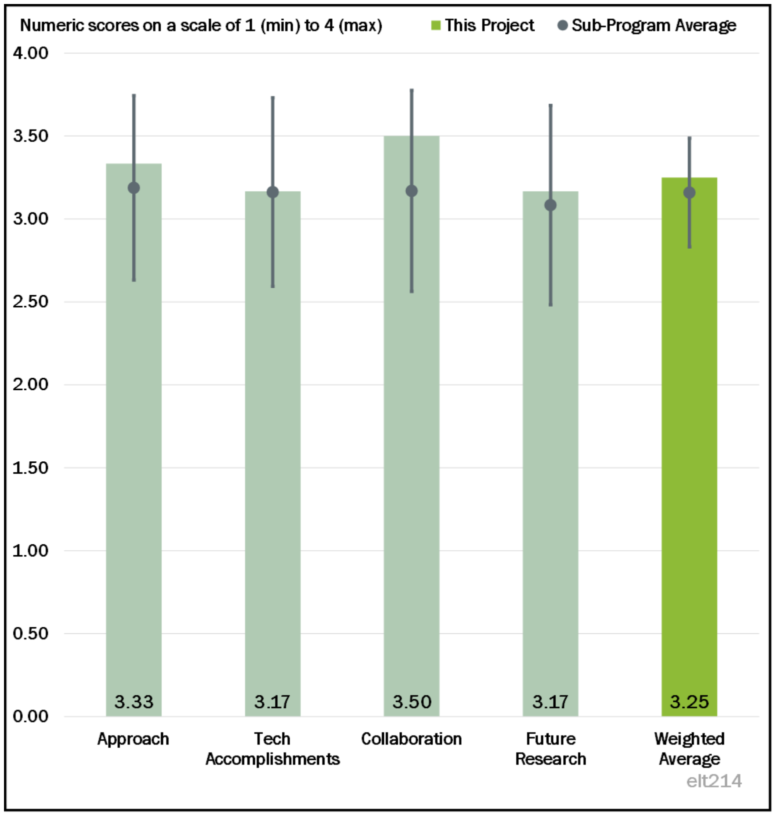

Figure 4-26 - Presentation Number: elt214 Presentation Title: Electric Motor Thermal Management Principal Investigator: Kevin Bennion (National Renewable Energy Laboratory)

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

Reviewer 1:

This project is about the material and interfaces of thermal and mechanical characterization and thermal analysis. The approach includes material and thermal characterization, including slot liners. Collaboration with SNL is carried out. Collaboration with Georgia Tech and ORNL for heat transformer technologies and advanced motor thermal analysis, respectively, are carried out.

The reviewer found that the aims of the project are timely, needed, and well defined. The project has a strong collaboration with ORNL, Georgia Tech, and SNL.

Reviewer 2:

The project appears to be well organized to provide the thermal management solutions for the motor being designed. The materials characterization is an important contribution to the thermal modeling accuracy.

Reviewer 3:

In general, thermal management is critical in terms of increasing the machine power density, and characterizing materials and interfaces is very helpful, but it is not clear that there are significant new technologies or approaches proposed.

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

Reviewer 1:
Significant progress has been achieved by developing an excellent approach for machine thermal modeling and analysis. Various cooling techniques have been evaluated, including the stator cavity cooling. Detailed analyses have been performed for stator cavity cooling. Other multiple approaches for stator cooling have also been well studied, including in-slot cooling for stator and stator teeth and high-performance potting compound.

The reviewer found that the project had made excellent progress and accomplished the goals of the project for this budget period.

Reviewer 2:
Progress is good. Are the six operating points used for the preliminary thermal analysis representative of what the motor would see in operation?

Reviewer 3:
Reasonable progress is made, but the novelty of the work done especially in comparison to the state of the art needs to be emphasized and clarified.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Laboratory and university collaborations appear to be working very well to achieve the test and analysis results.

Reviewer 2:
There is good collaboration between multiple team members.

Reviewer 3:
The project has significant collaboration with SNL, ORNL, and Georgia Tech. The reviewer observed excellent teamwork in the project.

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

Reviewer 1:
Next steps are appropriate in extending the work underway.

Reviewer 2:
More quantitative assessment of how the proposed research can affect the motor power density should be performed and presented.

Reviewer 3:
The project focuses on slot liner and interface contact resistance and developing system-level thermal validation and testing.

It would be nice if there were some articulation about the investigation of other types of cooling topologies and how collaboration will be achieved with other National Laboratories in future planning. What are the results and comparisons among different types of cooling topologies, and how does that compare to today's technology and best practices in the auto industry?

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

Reviewer 1:
Thermal analyses provided by this project are an important contribution to accomplishing the DOE VTO motor specification targets.

Reviewer 2:
Research support the goal of minimization of electric machines for traction applications.

Reviewer 3:
Thermal management is critical but novelty should be clarified.

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

Reviewer 1:
The reviewer found the overall project performance to be outstanding. Excellent collaboration, planning, and execution of project goals and milestones have been achieved.

Reviewer 2:
Resources appear to be sufficient.

Reviewer 3:
Resources are sufficient.

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

Presenter

Iver Anderson, Ames Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

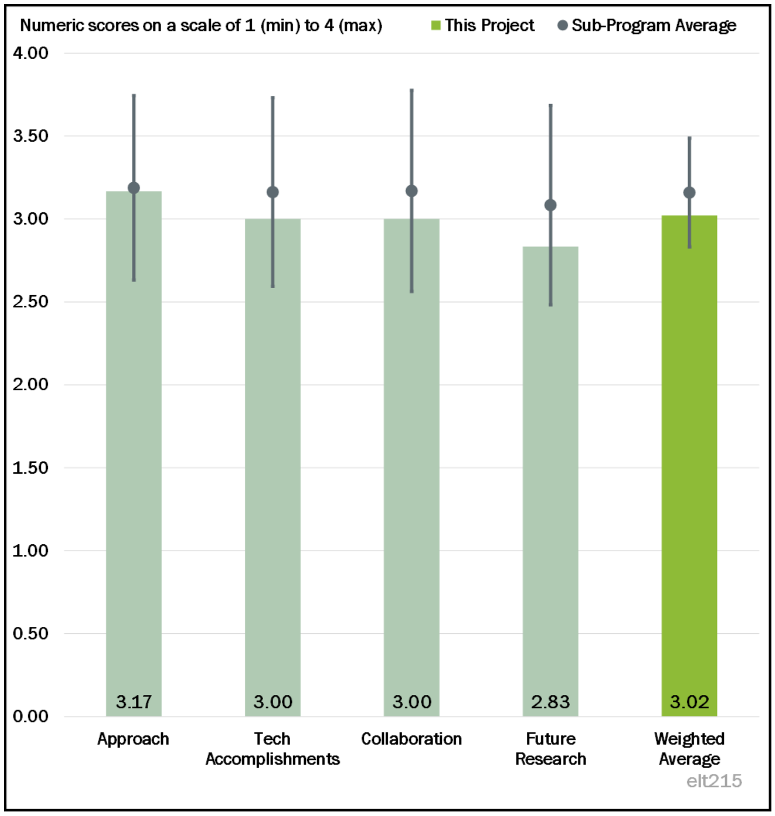

Figure 4-27 - Presentation Number: elt215 Presentation Title: Permanent Magnets without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density Principal Investigator: Iver Anderson (Ames Laboratory)

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

Reviewer 1:

This is fundamental work that needs to be done if HRE-free magnets are to become more effective.

Reviewer 2:

The project is about magnetic material development and processes for electrical steel loss and PM modeling. The project focuses on reduction of HRE metals and aims to improve the motor power density.

The reviewer observed that the project is well defined and aims to fill the knowledge gap in the materials area as applied to motors.

Reviewer 3:

The approach to project is sound. Technical barriers are being addressed adequately.

Reviewer 4:

The project is systematically exploring the barriers to achieving higher performance with lower RE content in sintered NdFeB magnets. The project has chosen to focus on controlling the grain size distribution as well as adjusting the composition of intergranular phases, which is a reasonable approach. The decision to prioritize the ultra-fine-grain approach over the gradient-magnet approach was appropriate, given the relative rate of progress between the two tasks.

Reviewer 5:
Eliminating Dy is very useful, but it is not clear that the proposed approach will lead to significant improvement compared to the state of the art in order to meet DOE's very demanding targets.

Reviewer 6:
Producing PMs having high energy density without the use of HRE materials is an important topic. This will reduce dependence on importing these HRE materials. Task 2.7 aims at developing high coercivity PMs at high temperature; it does not show how this coercivity compares with state-of-the-art PMs with HRE or reduced HRE materials. Defining the goals is one aspect but how it compares to the state-of-the-art PM materials is important. Also, it does not clearly compare the B values and the energy density values at different magnet temperatures. Without this information, it will be difficult to adopt these materials in real traction applications.

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

Reviewer 1:
The project has made noteworthy performance in exceeding the coercivity of commercially available NdFeb magnets using the ultra-fine-grained processing methods. The data generated while producing these samples are quite valuable and will accelerate future increases in performance.

Reviewer 2:
The approach is centered around processing ultra-fine grain size RE-PM without HRE. The project mainly aims to down-select exceptional powder production methods and validate the mechanism of enhancing coercivity through the fine-grain approach.

Project has great progress to achieve the milestones of the project.

Reviewer 3:
Progress is acceptable to date.

Reviewer 4:
There is a lot of good work being done but it is hard to judge the effectiveness of the results without knowing the targeted improvement. Researchers also note that the processes used could be more challenging to implement. Is there a cost/benefit target?

Reviewer 5:
25% improvement in coercivity is significant, but the impact on machine performance is not clear.

Reviewer 6:
There has been significant progress in the industry toward reducing/completely eliminating HRE materials while still maintaining high energy density. This project takes a different approach toward achieving the same goal. However, it does not compare how this material performs when compared to the state-of-the-art PM materials currently used in traction application. Comparison of magnetic flux (B) –magnetic field strength (H) characteristics at various temperatures (20°C, 100°C, 150°C, 180°C, and 200°C is needed). Thermal coefficient of remanence (Br) and coercivity (H_{cj}), and coefficient of thermal expansion of these materials should be compared to the state of the art.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Experts across several labs are engaged to produce the best outcome.

Reviewer 2:
There seems to be proper collaboration and coordination among team members.

Reviewer 3:
There seems to be reasonable collaboration with other National Laboratories.

Reviewer 4:
The project has collaboration with ORNL, NREL, and SNL. Collaboration strategy for motor design, thermal and mechanical properties of newly developed magnetic materials, and coordination with universities are well defined. The laboratories are complementary to each other's contributions and have a balanced shared amount of work.

Reviewer 5:
ORNL appears to have contributed expertise in motor performance simulation. The specific contributions of NREL and SNL were not called out in the presentation.

Reviewer 6:
The project team has strong collaboration with National Laboratories. However, the applicability of the materials developed and the commercialization aspects can be better addressed by the OEMs and magnet manufacturers (example, Arnold magnetics). Without the OEMs and magnet suppliers, it is difficult to benchmark the performance and cost, which are critical for adoptability of these materials in real applications.

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

Reviewer 1:
Next steps are appropriate; from the wording, the jet-milling work seems to be contingent on external actions.

Reviewer 2:
Proposed future work is well aligned and planned, per the project objectives.

Reviewer 3:
The proposed future focus on multi-jet milling and oxygen-free powder handling is a valid approach to solving the remaining technical problem. Given the lack of domestic availability of jet-milling equipment, alternate approaches for size refinement should be identified, if they exist.

Reviewer 4:
Future research is well defined and includes a multi-jet milling system to perform critical experiments, development of additive composition and quantity for HRE-free, RE-PM alloy powder, and validate the hypothesis that mechanical properties improve for the ultrafine-grain magnet. Future research is in line with the aims of reducing PM cost and the HRE element and increase the power density of the traction motor.

The reviewer questioned what are the predicted losses and efficiency comparison with proposed magnets and existing magnets on a motor design?

Reviewer 5:
Impact of achieved properties on machine performance should be evaluated, and more focus on scalability is needed.

Reviewer 6:
The presentation claims low-power density with non-RE PM machines. However, it is not clear how the project has addressed this barrier by showing experimental comparison between the HRE free materials developed in this project and the state-of-the-art PMs to achieve 50 kW/l at $3.30/kW.

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

Reviewer 1:
Work is critical to maximizing motor performance without resorting to HRE magnets. This goal is central to meeting DOE VTO drive unit metrics.

Reviewer 2:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 3:
Yes, this project supports the overall DOE objectives of enabling higher power density motors that minimize the use of critical raw materials.

Reviewer 4:
Eliminating HRE material is very relevant in terms of cost reduction and sustainability.

Reviewer 5:
The DOE goals require to increase power density and lowering the cost of the traction motor. HRE metals are costly. Hence, developing new magnets and processes are one of the critical elements to reduce the cost. Also, this work can improve high efficiency, which yields to reduce cooling. If cooling is reduced, there is an extra reduction of cost in the cooling system.

Reviewer 6:
Even though the DOE objective is supported, the performance metrics have not been showcased as of now in this project.

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

Reviewer 1:
Resources seem to be adequate.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
Resources are sufficient to carry out the work.

Reviewer 4:
The resources of the team appear to be sufficient. However, the lack of domestic availability of multi-jet milling equipment poses a risk if the Consortium cannot procure one in a timely fashion.

Reviewer 5:
Resources seem sufficient, but the comments about the jet-milling work under proposed future research leaves some doubt.

Reviewer 6:
Without collaboration from OEMs and magnet manufacturers, it is not an easy task to achieve the deliverables mentioned in this project.

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

Presenter

Todd Monson, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

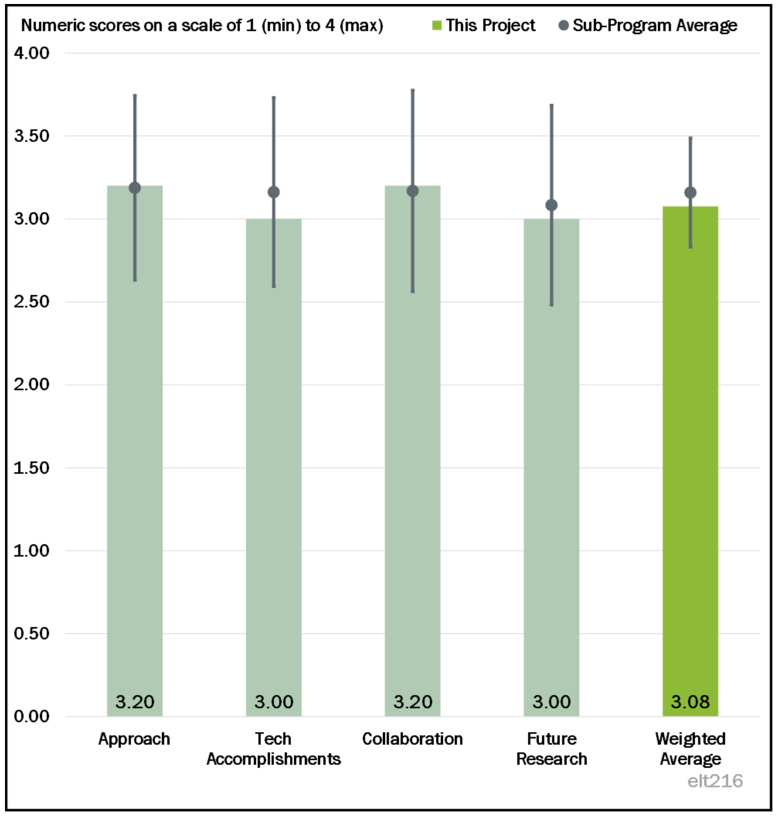

Figure 4-28 - Presentation Number: elt216 Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines Principal Investigator: Todd Monson (Sandia National Laboratories)

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

Reviewer 1:

The project aims to develop improved soft magnetics to achieve the DOE's cost and power targets. These soft magnetic materials are proposed to replace steel in PM motors. The project seeks to demonstrate 65 vol.% loading iron nitride (Fe_4N)/epoxy composite and 80 vol.% loading of Fe_4N. The reviewer found that the technical content of the presentation was excellent on the material science level. Milestones, aims, and approach are laid out.

Reviewer 2:

The project goals are compatible with the challenge of maximizing performance of non-HRE magnet motors. Engineering materials to maximize performance is a key task.

Reviewer 3:

Approach to project is sound. Technical barriers are being addressed adequately.

Reviewer 4:

The project addresses some, but not all, of the technical barriers involved in evaluating a new soft magnetic material for use in electrical machines. In particular, more focus should be given to benchmarking the Fe_4N composite performance to the materials conventionally used in motors, including Si steel and soft-magnetic-composites. Furthermore, the metallurgical characteristics of the γ-Fe_4N compound should be addressed as well. In particular, this is not a thermodynamically stable compound at room temperature and pressure and will decompose and off-gas nitrogen at elevated temperature. This may influence the lifetime of the soft magnetics components. The rate of nitrogen evolution at the maximum operating temperature should be assessed. The stability of the compound under the hot-pressing conditions should also be evaluated.

Reviewer 5:
Some analysis showing the expected improvement in performance with the novel proposed material versus Si steel laminations should be performed.

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

Reviewer 1:
There has been very good progress on material fabrication. It would be good to list targets to be met. For example, the reviewer appreciated the permeability improvements shown on Slide 14 but is there an expected limit?

Reviewer 2:
Progress is acceptable to date.

Reviewer 3:
There is good progress made but comparison to the state of the art is needed.

Reviewer 4:
The project has made good progress to meeting the goal of evaluating Fe_4N's performance.

Reviewer 5:
Fabrication of samples for thermal and mechanical testing and experimental set-ups are planned and shown. An epoxy sample has been produced. Mechanical testing has been prepared.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project has strong collaboration ties with Purdue University, Illinois Institute of Technology, ORNL, Ames Laboratory, and NREL. It is nice to see that there is a mutual connection and work share among different laboratories and academic institutions.

Reviewer 2:
The team is fairly large (six members), but the roles are well defined and well coordinated.

Reviewer 3:
The partners bring needed and complementary areas of expertise to the project.

Reviewer 4:
There seems to be proper collaboration and coordination among team members.

Reviewer 5:
There seems to be some level of collaboration, but it needs to be improved, especially in terms of evaluating the impact of the proposed material on the machine performance.

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

Reviewer 1:
Next steps are logical.

Reviewer 2:
Proposed future work is well aligned and planned per the project objectives.

Reviewer 3:
Future research includes soft magnetic material as applied to motor design and evaluates its saturation and eddy-current losses. Plans include improving the chemistry and demonstrating the new composite material in a motor design.

Reviewer 4:
The proposed future work will provide sufficient data to evaluate the performance of the Fe4N material in new motor designs. To be most useful, the new material's properties and estimated manufacturing cost should be compared to existing soft magnetic materials.

Reviewer 5:
More quantification of machine performance is needed.

It would be nice to include more details about the motor design in the presentation and future work. What kind of motor, what are the implementation challenges, losses, efficiency, etc.?

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

Reviewer 1:
Maximizing/optimizing motor component material properties is necessary to achieve the DOE VTO motor performance goals/targets.

Reviewer 2:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 3:
Yes, the project addressed the DOE goal of enabling higher performance electric motors with reduced critical material content.

Reviewer 4:
Yes, it does meet the overall DOE objectives for cost and power target because soft magnetic materials can be made more cheaply than laminated steels. In addition, there will be fewer losses in the core material and cost savings in the cooling system.

The reviewer questioned what the loss calculation and efficiency comparison are of the proposed soft magnetic component material compared to lamination-steel based design. If details are provided in the next budget period, that would be great.

Reviewer 5:
The project is relevant especially if more quantitative analysis of the machine performance is presented.

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

Reviewer 1:
The project is on schedule with given resources.

Reviewer 2:
Resources seem to be adequate.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
The resources of the project are sufficient to meet the stated milestones.

Reviewer 5:
Yes, resources are adequate, and testing for experimental set-up is shown in the presentation.

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

Presenter

Bidzina Kekelia, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

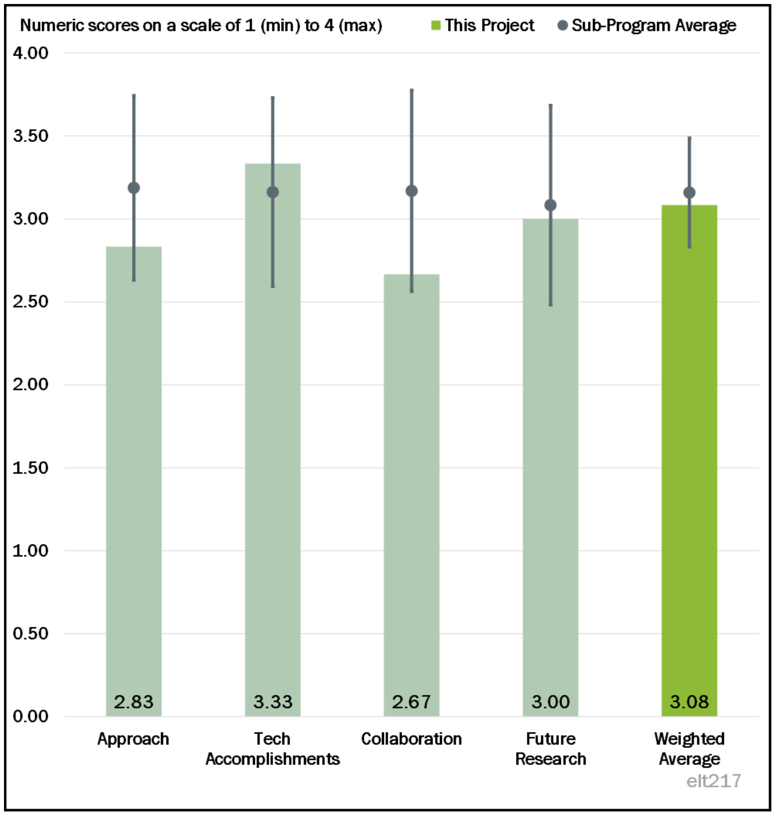

Figure 4-29 - Presentation Number: elt217 Presentation Title: Integrated/Traction Drive Thermal Management Principal Investigator: Bidzina Kekelia (National Renewable Energy Laboratory)

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

Reviewer 1:

The computational fluid dynamics (CFD) study of various jet types (circular, fan, off-center fan, oblique fan, etc.) and their characteristics is a sound approach to developing guidelines for direct cooling in electrified propulsion system design. Also, the planned future exploration and experimentation with different fluid types and characteristics will be useful in this regard.

Reviewer 2:

The approach makes sense. The reviewer would like to have seen some planning and provision for a practical implementation of jet impingement cooling techniques. The jet impingement devices depicted look large compared to the devices they are cooling.

Reviewer 3:

This is a very important project, but it does not appear to be advanced enough (as a second-year reviewer of this project).

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

Reviewer 1:

There is excellent technical progress in demonstrating the viability and effectiveness of the jet-impingement cooling technique.

Reviewer 2:
Technical accomplishments (CFD results) are strong. Steady progress is being made toward targets.

Reviewer 3:
Some progress was made.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
John Deere is part of the project team, but their contribution to the project is not well explained.

Reviewer 2:
Collaboration is not very evident.

Reviewer 3:
The second project partner (John Deere) is yet to show their contributions, as their tasks do not start until later this year. The team is well equipped.

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

Reviewer 1:
More quantification of the impact of the new materials on machine performance has to be performed. The impact of higher temperatures on efficiency has to be quantified. The proposed high-speed has to be proven to be practical.

Reviewer 2:
The plan to meet the project objectives is not well defined. The plan to develop the electromagnetic, thermal, and mechanical design of the motor is not presented. Go/no-go decisions points are not identified. The risks and mitigation plans are not identified. The scaled-up manufacturing capacity for the new materials is not demonstrated.

Reviewer 3:
Some of the concerns below have to be addressed at some stage of the project. This will help in realizing the proposed technology and also to check the go/no-go decision.

- Regarding the mechanical strength of the rotor and stator material, what is the tensile strength and yield strength of the SMC used in the rotor and stator?
- With respect to the core loss versus frequency, SMCs might have better core loss at high frequency. However, how do the B-H characteristics and the core loss versus frequency compare for the standard electrical steel used in traction application versus SMC material used in this project? If tB of the SMC material is relatively lower when compared to the electrical steel, then more current is needed to get the same torque.
- How does the resistance vary with temperature and what is the Cu loss at various regions of the machine? The high-temperature operation is going to create very high losses. How is this heat (due to the loss) going to be rejected? If there is an enhanced cooling system, then what is the cost of that cooling system? If the cooling system is going to be lot costlier, it can go against the DOE targets.
- What kind of inverter is planned in this project? Is it WBG-based? If so, what is the switching frequency? If the switching frequency is very high, how are the dv/dt and EMI issues addressed in this project?

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

Reviewer 1:
Novel materials are helpful, but there are concerns about practicality.

Reviewer 2:
Yes, this project meets the DOE objectives for high-speed motors operating at high temperatures.

Reviewer 3:
High-speed machines can increase the power density while reducing the volume and reducing the cost. All of these are important targets that are well aligned with what DOE is seeking.

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

Reviewer 1:
Resources are sufficient.

Reviewer 2:
The team has experienced personnel to deliver the tasks outlined in this project.

Reviewer 3:
The scaled-up manufacturing capacity for the new materials is not identified. The testing capability and performance metrics that need to be met are not specified.

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

Presenter

Doug DeVoto, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

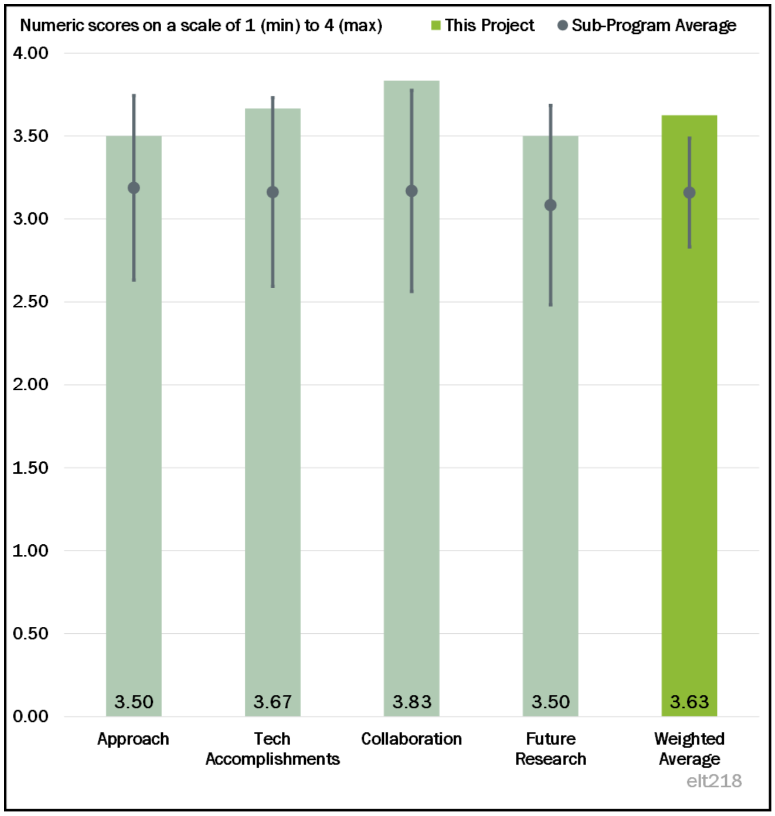

Figure 4-30 - Presentation Number: elt218 Presentation Title: Advanced Power Electronics Designs–Reliability and Prognostics Principal Investigator: Doug DeVoto (National Renewable Energy Laboratory)

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

Reviewer 1:

The quilt packaging via a chip to chip edge to the interconnect is novel, albeit risky, while the ODBC substrate as a replacement to ceramic substrate is promising. Both approaches are effective to tackle the barriers of thermal and reliability of packing power electronics.

Reviewer 2:

The PI has identified that new WBG package designs must address thermal and reliability concerns and be evaluated under accelerated conditions that approximate real-world conditions. This shows the PI has plan for commercialization of developed technology. Partnership with ORNL, Indiana Integrated Circuits (IIC), and DuPont is addressing supply chain issues of expert advice and material supply in development of quilt packaging of WBG devices via chip-to-chip interconnect technology for packages that are suitable for wire bond-less and double-sided cooling.

Reviewer 3:

The work is focusing on critical issues and new technologies that are needed. The reviewer would like to have seen this project take a broader look at interconnects, insulators, and conductors for power electronics.

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

Reviewer 1:
Thermal parametric analysis of quilt package and thermomechanical analysis of device-attach solder layer are good achievements for the year.

Reviewer 2:
This 4-year project has made quite a great progress, and the PI has the following technical accomplishments:

- Completed thermal parametric analysis of quilt package devices mounted onto ODBC substrates carrying device spacing, ODBC layers and their thicknesses, metallization thickness and heat transfer coefficient
- Found that substrate designs can maintain device temperatures under 160°C
- Completed thermomechanical analysis of device-attach solder layer
- Delivered first round of quilt-packaged devices from IIC
- Laid out sample characterization plan under accelerated thermal and vibration conditions.

Reviewer 3:
A broad range of variants were assessed for both the substrate and chip interconnect.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaborations with IIC and DuPont are critical to the project.

Reviewer 2:
The project team is appropriate and needful collaboration is underway in successful execution for project tasks targeted for milestones.

Reviewer 3:
The reviewer would like to see more involvement with vehicle OEMs.

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

Reviewer 1:
The proposed future work is appropriate.

Reviewer 2:
Full module assembly and evaluation are critical to success.

Reviewer 3:
Future work is sufficiently stated.

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

Reviewer 1:
A reliable and compact WBG packaging is important to deliver full potential of WBG semiconductors.

Reviewer 2:
This work will play a significant role in the next generation of power electronics.

Reviewer 3:
Sending out developed packages to industry with request to test these packages for a targeted application could accelerate commercialization of underlining technology.

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

Reviewer 1:
This work should be expanded to investigate other potential interconnects and substrates.

Reviewer 2:
The reviewer indicated that $350,000 for 2 years is reasonable.

Reviewer 3:
Appropriate resources are there in the project.

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

Presenter

Paul Paret, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

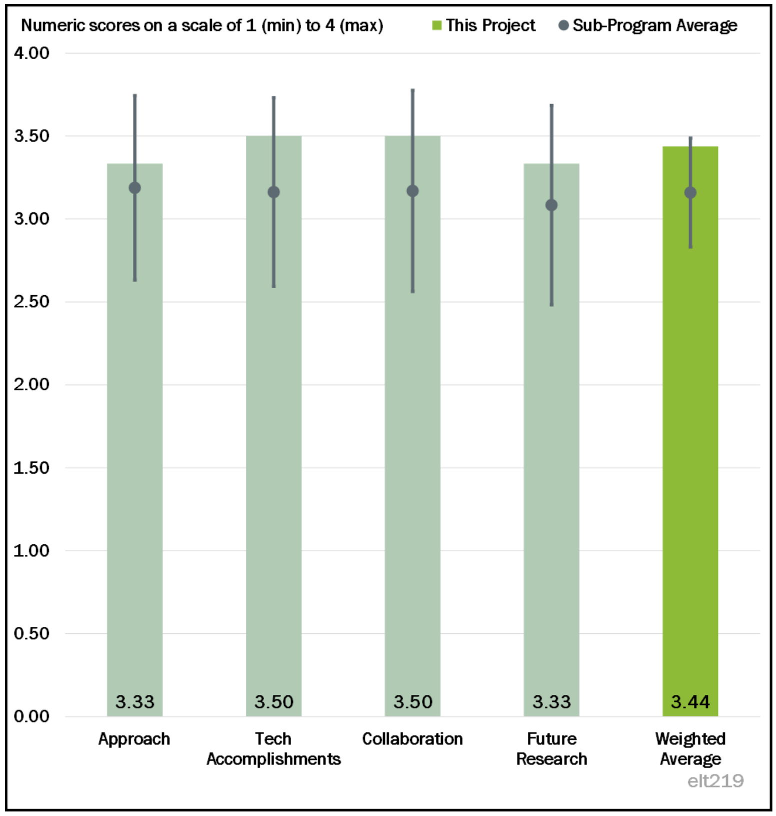

Figure 4-31 - Presentation Number: elt219 Presentation Title: Power Electronics Materials and Bonded Interfaces–Reliability and Lifetime Principal Investigator: Paul Paret (National Renewable Energy Laboratory)

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

Reviewer 1:

The approach, both experimental and modeling, is effective in terms of evaluating the reliability of the bonded interface materials for high-temperature power electronic applications.

Reviewer 2:

The experimental and modeling approach is quite relevant. Samples were developed, tested and characterized to prove that soldering method to attach two materials (Cu and Invar) leads to a far improved bind compared to low-pressure sintering.

Reviewer 3:

Both experimental and analysis effort will help with accuracy of the findings. The reviewer had no concern, though. When determining the performance of a joint, how does one know if it were the result of the material or how the samples were produced?

Question 2: B. Technical Accomplishments and Progress toward overall project - the degree to which progress has been made, measured against performance indicators.

Reviewer 1:

Samples with different and varying bonding diameter were fabricated, tested, and data plotted for comparison. Mechanical characterization and reliability evaluation of fabricated test samples have been carried out, and the failure mechanism is discussed in the project report. As per the PI, project milestones and tasks for future milestones are on track.

Reviewer 2:
The work and the results on sintered nano-silver are interesting. This is somewhat expected, but it is still nice to see the actual results. The results on transient liquid phase copper (Cu)/aluminum (Al) bonds are okay the reviewer looked forward to seeing the nickel-coated Cu results.

Reviewer 3:
Multiple samples were produced and evaluated.

Question 3: C. Collaboration and Coordination Across Project Team

Reviewer 1:
The project lead organization, NREL, is collaborating with Virginia Polytechnic Institute and State University (Professor G. Q. Lu), Georgia Tech (Professor Samuel Graham), ORNL, and Ames Laboratory. This collaborative teamwork is bearing excellent results.

Reviewer 2:
The collaboration with ORNL and Ames Laboratory is minimal, but with Virginia Tech and Georgia Tech, the collaboration is extensive. All the samples are from them.

Reviewer 3:
The project needs industry involvement, such as a power module supplier or a vehicle OEM that is heavily involved in the design and build of its power electronics. Also, equipment and manufacturing groups should be brought into the project.

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

Reviewer 1:
The quality of joints is heavily dependent on the manufacturing process and before performing characterization testing. The reviewer needed to have confidence that the test accurately reflects reality.

Reviewer 2:
Future research includes very relevant tasks, such as: investigate the effect of sample stiffness on reliability; develop a preliminary microstructural crack propagation model; conduct mechanical characterization of Cu/Al alloy at different strain rates and temperatures; synthesize Cu/Al alloy samples with high bond quality (less than 5% initial void fraction); conduct accelerated thermal cycling of Cu/Al bond samples under different temperature profiles; expand the microstructural crack propagation model to include physics at lower length and time scales and establish microstructure-property relationships to accelerate novel high-temperature material development; and investigate the reliability and failure mechanisms of alternate high-temperature materials, such as sintered Cu and Cu-tin (Sn) transient alloys.

Reviewer 3:
The proposed research is reasonable. The most interesting and impactful research is the synthesis of Cu/Al alloy samples with high bond quality. The failure mechanism study is somewhat phenomenological; it will be more impactful if it can be linked to materials physical properties.

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

Reviewer 1:
This work will significantly contribute to power density and cost.

Reviewer 2:
Reliable bonding is critical for all power electronics.

Reviewer 3:
Advanced materials and manufacturing processes for WBG power devices is a relevant and timely topic that the project PI is working in a collaborative research environment.

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

Reviewer 1:
The funding level is sufficient.

Reviewer 2:
The project has all necessary resources.

Reviewer 3:
Work needs to be broadened to have manufacturing and equipment providers involved.

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

Presenter

Shajjad Chowdhury, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

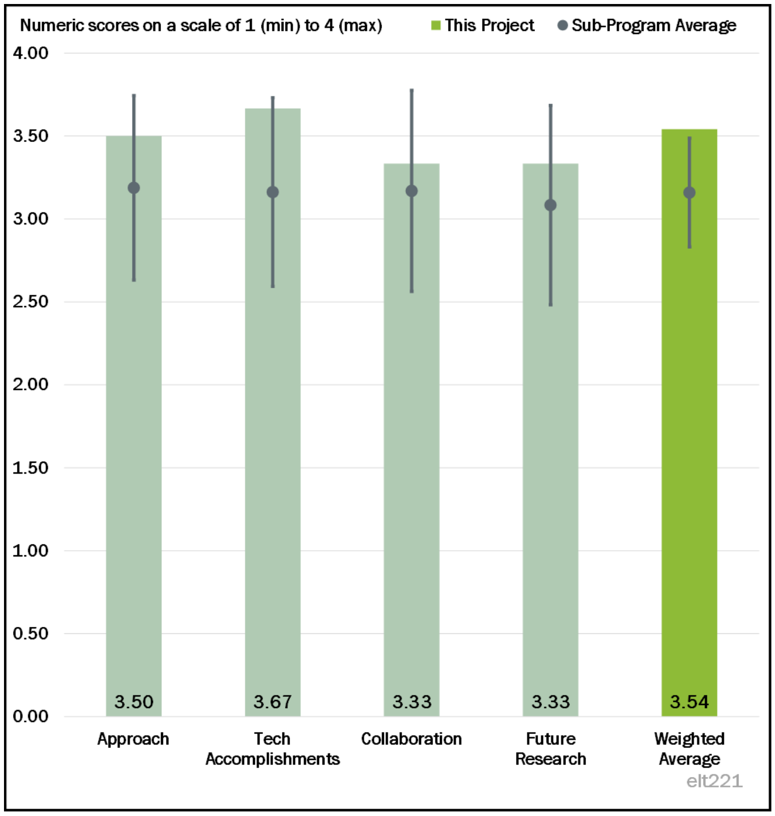

Figure 4-32 - Presentation Number: elt221 Presentation Title: Integrated Electric Drive System Principal Investigator: Shajjad Chowdhury (Oak Ridge National Laboratory)

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

Reviewer 1:
This is excellent and very relevant work.

Reviewer 2:
The project looks at the appropriate components to optimize and/or redesign to achieve the target inverter power density.

Reviewer 3:
The approach used to identify and select the candidate design (external rotor with inverter inside the stator hollow) is sound. The approach used to design and select the capacitor and heat sink (genetic algorithm) for the power module is also sound.

Question 2: B. Technical Accomplishments and Progress toward overall project - the degree to which progress has been made, measured against performance indicators.

Reviewer 1:
The reviewer said there is excellent work on evaluation of new capacitor technology. This is exactly what this type of project should be doing.

Reviewer 2:
There is excellent progress on capacitor selection, circular topology selection, and compact heat sink design.

Reviewer 3:
The project seems to be on track.

Question 3: C. Collaboration and Coordination Across Project Team

Reviewer 1:
There is very good collaboration.

Reviewer 2:
The reviewer noted good collaboration with NREL (thermal), SNL (WBG devices) and Ames Laboratory (new magnetic material) to design/prototype an optimal propulsion system.

Reviewer 3:
There is good collaboration. Would industry or university partners help the cause?

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

Reviewer 1:
The next steps are appropriate for this work.

Reviewer 2:
The team seems to know what needs to be done.

Reviewer 3:
Assessing the impact of stator heat on the inverter components will be a critical step toward successfully executing this concept architecture. Capacitor packaging will also be a key next step. So future plans as stated are sound.

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

Reviewer 1:
The inverter design is a key contribution to reaching the DOE VTO electric drive performance targets.

Reviewer 2:
This project is a key enabler for DOE's stated goal of a compact, efficient, cost-effective 33 kW/L drive system.

Reviewer 3:
This is very relevant research.

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

Reviewer 1:
The project needs more funding, according to the reviewer.

Reviewer 2:
Resources appear sufficient as the project work is on schedule.

Reviewer 3:
The allocated funds of $400,000 for 2020 are adequate for achieving the project goals.

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

Presenter

Jack Flicker, Sandia National Laboratories

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

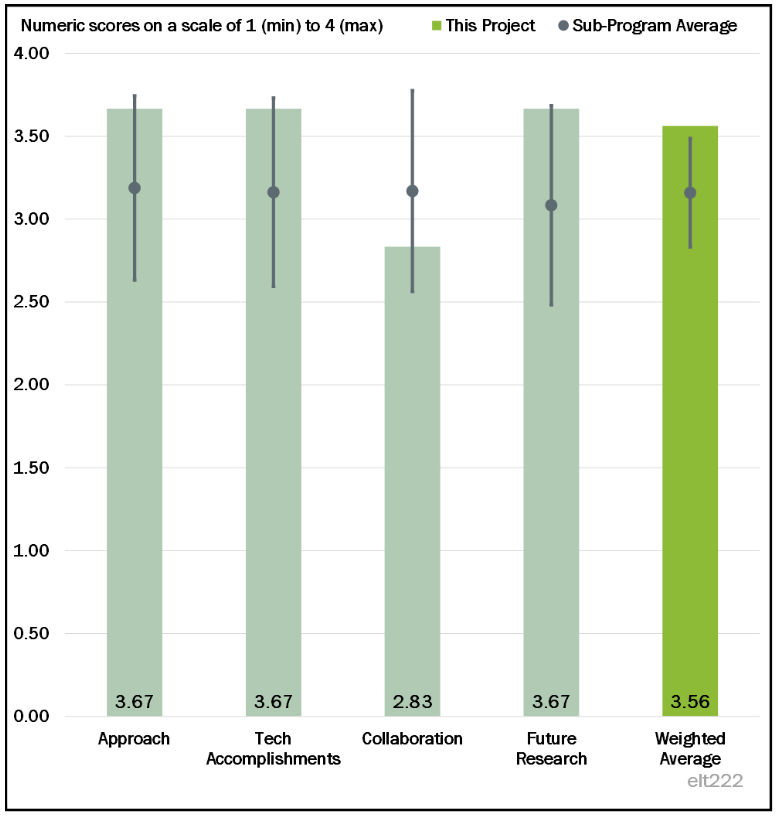

Figure 4-33 - Presentation Number: elt222 Presentation Title: High-Reliability Ceramic Capacitors to Enable Extreme Power Density Improvements Principal Investigator: Jack Flicker (Sandia National Laboratories)

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

Reviewer 1:

Oxygen vacancy migration is the main cause for failure at high voltage and high temperature. So, the total time the capacitor is subject to voltage above a critical value dictates its failure. For DC voltage, this is the total test time; for AC voltage, it is a small fraction of the test time. Slide 10 could be misunderstood as the AC field extended lifetime. To check the idea on Slide 9, a capacitor can be tested under DC voltage for 2 hours, then reverse polarity for another 2 hours, then repeat this procedure. The group might have been thinking of this already as the PI mentioned on Slide 16 “Evaluating long term voltage reverse bias healing step when vehicle is not in operation.”

Reviewer 2:

The project PI made the case that a ceramic capacitor could lead to increased power density of the traction inverter and could support meeting the DOE VTO power density target (33 kW/L) for electric drive systems. However, the highly accelerated lifetime testing (HALT) needs to be carried to understand failure caused by the build-up of oxygen vacancies at electrode surfaces and followed by devising mechanism to apply bi-polar voltage bias to clear-up oxygen vacancies at electrode surfaces. Therefore, this reviewer opined that the problem is well thought-out and a solution can be engineered by testing and experimentation of a large number of samples to capture failures caused by infant mortality and early wear-out mechanism.

Reviewer 3:
This project has an outstanding outline of objectives and properly placed proof of point experiments. The project is 30% complete and shows excellent demonstration of the technology and its ability to elongate the lifetime of capacitors.

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

Reviewer 1:
Excellent progress has been made. The data shown on Slide 10 are convincing and exciting.

Reviewer 2:
The HALT method is developed including dedicated test for large number (40) of samples. Capacitors tested for degradation observation at DC bias and bipolar switching of 0.1, 2.5 hertz (Hz), and 10 Hz. It is found that 10 Hz AC bias testing has raised life of the capacitor by a factor of 6 (100 hours) compared to DC bias testing at 10 times the voltage and above 125°C operating temperature. A mathematical model of lifetime estimation is under development.

Reviewer 3:
The project is 30% complete and gives a good demonstration of the technology as intended at this time in the project. The reviewer would like to encourage the researchers to include additional capacitors in their testing going forward.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration with NREL and ORNL is briefly mentioned.

Reviewer 2:
ORNL is being engaged to seek support in developing a circuit for bi-polar bias and implementing bi-polar bias circuit in a DC bus of a traction drive system, yet keeping the cost of drive system unchanged. The NREL team is supporting development of novel high-density integration and thermal management of ceramic capacitors and power modules.

Reviewer 3:
The project has not demonstrated much collaboration up to this time. A clear role for organizations mentioned as collaborators should be provided.

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

Reviewer 1:
The proposed research on more experiments on bipolar switching and evaluating switching schemes are important.

Reviewer 2:

The project plan in addition to X7R ceramic capacitor under study, plans to include KC-Link and CeraLink DC capacitors as these may have different activation energy and could vary significantly from X7R. Perform further experiments on bipolar switching. Evaluate bipolar switching scheme compatibility with drive train technologies.

Reviewer 3:
The project is at a critical stage and next steps and details related to a large study on failure analysis data are really outstanding. Including additional capacitors for large scale HALT studies would be very useful.

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

Reviewer 1:
This project will help meet DOE energy density targets as overall goal.

Reviewer 2:
A high-temperature ceramic capacitor is important for power electronics. Service life of ceramic capacitor has been a barrier. By simply implementing a bipolar switching scheme, one can 5x the service life is an impressive achievement. It will impact the future EV power electronic design in a very positive way.

Reviewer 3:
This is a very timely and relevant topic to meet the following DOE targets, goals and objective stated out for 2025:

- Power electronics density is 100 kW/L
- Power electronics target is greater than 100 kW (approximately1.2 kV/100 A)
- Power density target for drive system is 33kW/L
- Cost target for drive system is $6/kW
- Operational life of drive system is 300,000 miles.

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

Reviewer 1:
The reviewer asserted that $100,000 may not be enough to carry a comprehensive work.

Reviewer 2:
The PI has sufficient resources including collaborations with ORNL and NREL in DOE VTO's Consortium.

Reviewer 3:
Resources are sufficient for next steps. Role of collaborators should be provided in more detail going forward.

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

Presenter

Jason Neely, Sandia National Laboratories

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

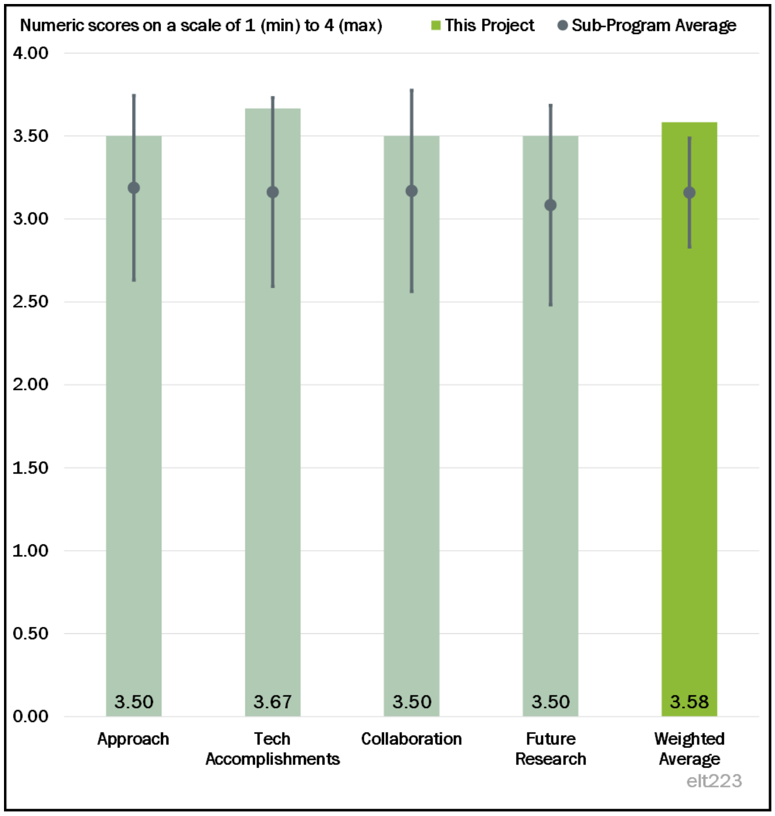

Figure 4-34 - Presentation Number: elt223 Presentation Title: Component Testing, Co-Optimization, and Trade-Space Evaluation Principal Investigator: Jason Neely (Sandia National Laboratories)

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

Reviewer 1:

The reviewer liked the approach to searching for the best design using optimization. A full exploration of the design is needed to figure out how best to meet project targets.

Reviewer 2:

The project is very well defined and connected.

Reviewer 3:

The approach is sound because it includes component testing, sub-system models, and full system optimization of the integrated electric drive system.

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

Reviewer 1:

Excellent work on creating and validating detailed circuit design tools.

Reviewer 2:

Accomplishments include a drive test bed for evaluating GaN devices, device level analysis of SiC versus GaN devices, boost converter optimization using Genetic algorithm optimization (GA), a novel inverter architecture, and a high-fidelity circuit model for inverter drive. This is an impressive list.

Reviewer 3:
Please continue this project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project pulls in expertise from different organizations to achieve synergistic results.

Reviewer 2:
The team is well defined and resources leveraged.

Reviewer 3:
Collaboration and coordination with Purdue (motor/drive co-optimization), Lehigh University (GaN devices), and SUNY Poly (fabricating SiC JBS diode) is proceeding well.

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

Reviewer 1:
These people know what they are doing.

Reviewer 2:
The hardware build is an important next step.

Reviewer 3:
Optimizing the system for 100 kW peak/55 kW continuous and building a scaled prototype is a good plan forward for 2020. Plans for 2021 include developing an advanced AC filter, co-optimizing inverter and homo-polar motor, and building an inverter using SNL's GaN devices are also sound.

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

Reviewer 1:
The project is important in finding an optimal inverter design to meet DOE VTO's drive unit targets.

Reviewer 2:
The reviewer found good research at the edge of commercialization.

Reviewer 3:
This project supports the overall DOE objectives of creating a compact, efficient, cost-effective 33 kW/L drive system.

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

Reviewer 1:
The reviewer would not hesitate to increase resources by 20%—good value for the money.

Reviewer 2:
Project appears to be meeting technical goals and timing with the funding provided.

Reviewer 3:
FY 2020 funding of $350,000 is adequate for the stated objectives.

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

Presenter

Matthew Kramer, Ames Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

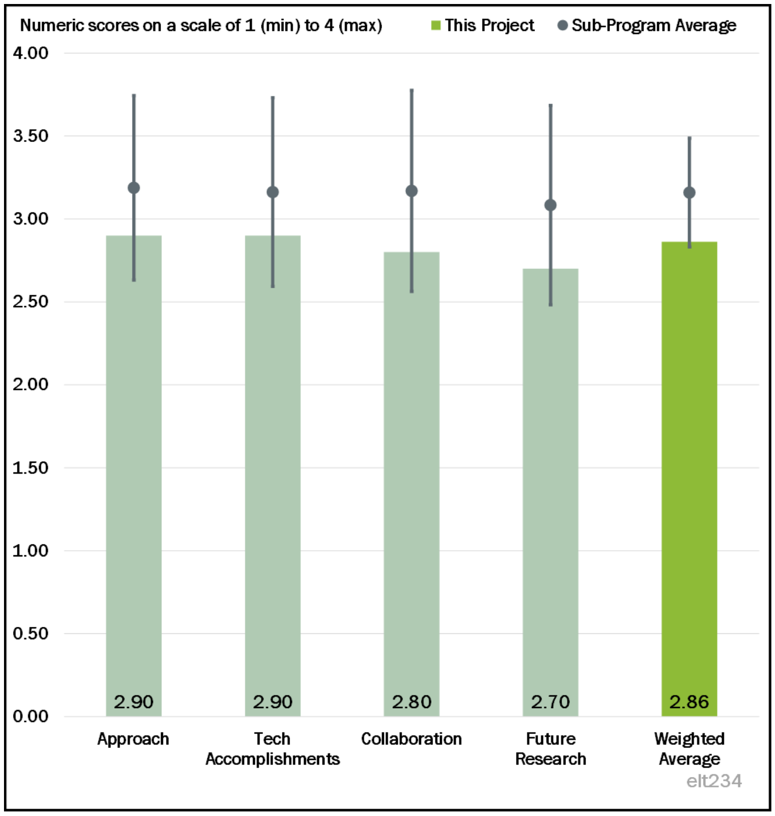

Figure 4-35 - Presentation Number: elt234 Presentation Title: Soft Magnets to Achieve High-Efficiency Electric-Drive Motors of Exceptional Power Density Principal Investigator: Matthew Kramer (Ames Laboratory)

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

Reviewer 1:

The approach to the project is sound. Technical barriers are being addressed adequately.

Reviewer 2:

The project has a very clearly defined target, and the approach to performing work clearly reflects that. The ability to fully manufacture test strips and characterize them provide sufficient proof points.

Reviewer 3:

In the overview slides, the PI mentioned that two barriers were addressed, Barrier 1: Magnet cost and rare-earth element price volatility, Barrier 2: Non-RE electric motor performance to meet the Targets—Exceptional drive motor power density and reduced cost (50 kW/l at $3.30/kW). However, in the presentation it is not clear how this material compares with the state-of-the-art 0.27 millimeter (mm) or 0.25 mm Si steel in terms of flux density, core loss at different frequencies up to 1000 Hz, and mechanical properties. Without this comparison, it is not possible to claim that the cost barrier and performance barrier are addressed.

Reviewer 4:

There seems to be overlap between this project and ELT091; this needs to be clarified.

Reviewer 5:

This project develops new soft magnetic materials to reduce iron loss and cost and improve power density for traction machines. The team has built some samples and tested the material properties. The loss and efficiency results show a greatly reduced iron loss indeed. The team will be working with an industry partner for large-scale production and to try to reduce the cost.

The reviewer had one question on the improvement of power density. It is not clear how the soft magnetic material developed in this project can compete with some existing material, such as Hiperco 50 in terms of saturation, permeability, and core loss. Hiperco 50 can easily go to 2.5 T. M19 can achieve more than 1.9 T. The material developed in this project targets to achieve 1.8 T, which is much lower than that of Hiperco 50. If the flux density of this material can only achieve 1.8 T, how can this material achieve better power density than Hiperco 50 or M19? No data in the presentation were shown about how the power density of machines can be improved using the materials developed in this project.

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

Reviewer 1:
The project has completed all the target milestone for this year. Technical targets have been met with clearly defined and sufficiently exhaustive experiments.

Reviewer 2:
Progress is acceptable to date.

Reviewer 3:
Overall, the team has made great progress in accomplishing the scheduled tasks. Four milestones are planned for year 2, and two milestones have been met, and one milestone is delayed, i.e., 35 mm ribbon. The original plan is to achieve this milestone by the end of quarter 3 of year 2. The presentation shows this task is 50% complete.

Reviewer 4:
Quantitative analysis of what can be achieved in terms of machine performance based on the achieved material properties should be performed.

Reviewer 5:
A sample of the 6.5% Si material has been prototyped. However, how does it compare with the standard Si steel to meet the power density, efficiency and cost targets is still not very clear.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seems to be proper collaboration and coordination among team members.

Reviewer 2:
There seems to be reasonable collaboration among the three National Laboratories involved.

Reviewer 3:
Each team member has its own expertise to contribute to the project.

Reviewer 4:
OEM partners and electrical steel manufacturing partners are very crucial for a project like this.

Reviewer 5:
The project has established ongoing collaboration with ORNL and NREL to support a system level property test. In addition, an industrial partnership provided needed support for manufacturability study. A deeper timeline and test details will help clearly understand the support needed from NREL and ORNL.

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

Reviewer 1:
This is really excellent. The manufacturing partnership will really help understand the requirement on scalability of the concept. More details from the NREL and ORNL study are needed to understand this part.

Reviewer 2:
Proposed future work is well aligned and planned, per the project objectives.

Reviewer 3:
The team identified three challenges: scalability of material, optimizing coreless while maintaining manufacturability, and cooling technology during material fabrication. The team's future plan proposes work to tackle these three challenges. The planned future work is reasonable and follows a logical manner.

Reviewer 4:
Quantification of machine performance improvement should be included.

Reviewer 5:
The prototype motor manufactured with the 6.5 % Si steel material has to be compared with off-the-shelf automotive grade traction motor having similar dimensions, voltage, current, speed, and cooling constraints. Without this validation, it is not clear the contribution of this project in improving the power density, efficiency, and cost reduction. Only some of these aspects have been addressed in the future research plan.

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

Reviewer 1:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 2:
This project claims to support the DOE objectives for power density, efficiency, and cost. However, without substantial comparison and validation, this is not confirmed.

Reviewer 3:
Yes. Efficient improvement in the motor will help meet the objective on energy density.

Reviewer 4:
This project supports the overall DOE objectives as this project develops soft magnetic materials for vehicle traction motors with reduced iron loss, improved power density, and low cost.

Reviewer 5:
The project is relevant, but its expected quantitative impact is not clear.

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

Reviewer 1:
Resources seem to be adequate.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
The project has sufficient collaboration and personnel support.

Reviewer 4:
The team has absolutely sufficient facilities and resources to achieve the stated milestones.

Reviewer 5:
The project might show a 6.5% Si steel material at the end. But is it going to be superior to the materials already available?

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

Presenter

Watson Collins, Electric Power Research Institute

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

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

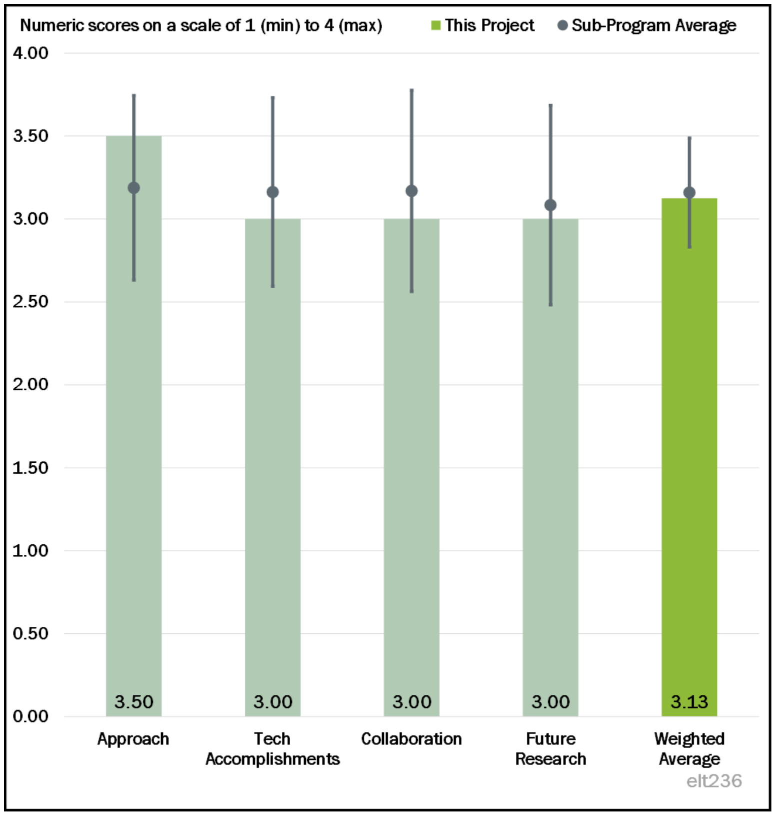

Figure 4-36 - Presentation Number: elt236 Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture Principal Investigator: Watson Collins (Electric Power Research Institute)

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

Reviewer 1:
The project is addressing cost of ownership, efficiency, and footprint which are critical for commercialization and scale of fast charging.

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

Reviewer 1:
Completion and status of milestones are not clear from the presentation. From information provided during the presentation, it appears that the project is on schedule.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Partner roles are clearly defined.

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

Reviewer 1:
Future research is outlined within project and is sensible, and challenges that could materialize in budget period two have been identified.

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

Reviewer 1:
The project addresses cost of ownership, efficiency, and footprint, which are critical for commercialization and scale of fast charging.

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

Reviewer 1:
The project is resourced sufficiently to achieve milestones in a timely manner.

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

Presenter

Jonathan Kimball, Missouri S&T

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

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

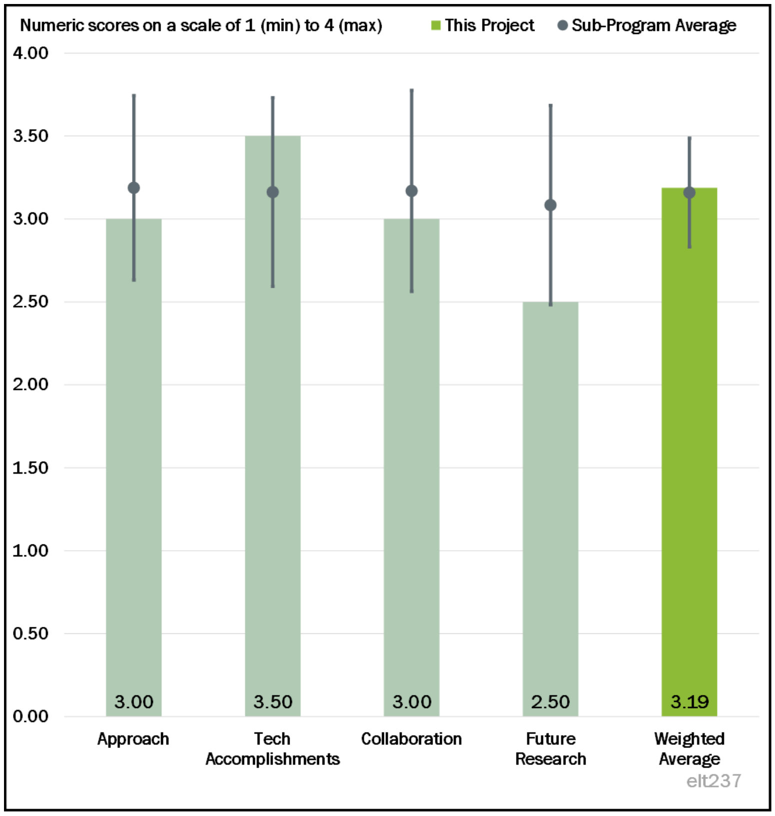

Figure 4-37 - Presentation Number: elt237 Presentation Title: Enabling Extreme Fast Charging with Energy Storage Principal Investigator: Jonathan Kimball (Missouri S&T)

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

Reviewer 1:

The project could better define a “business as usual (BAU)” scenario and compare the key outcomes and benefits of the work against this BAU case. The project should have better defined targets (capacity fade, lifecycle cost). The project could better highlight the tradeoffs between potential charge time and impacts on energy storage.

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

Reviewer 1:

The project seems to be on time and on schedule to reach its goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project could benefit from more collaboration with a power electronics manufacturer or supplier to better set real-world expectations.

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

Reviewer 1:
The project would benefit from showing better alternative options or at least comparing the chosen approach to the others.

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

Reviewer 1:
This project will help define possible solutions to advanced and low-cost vehicle charging.

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

Reviewer 1:
Resources seem sufficient.

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

Presenter

Srdjan Lukic, North Carolina State University

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

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

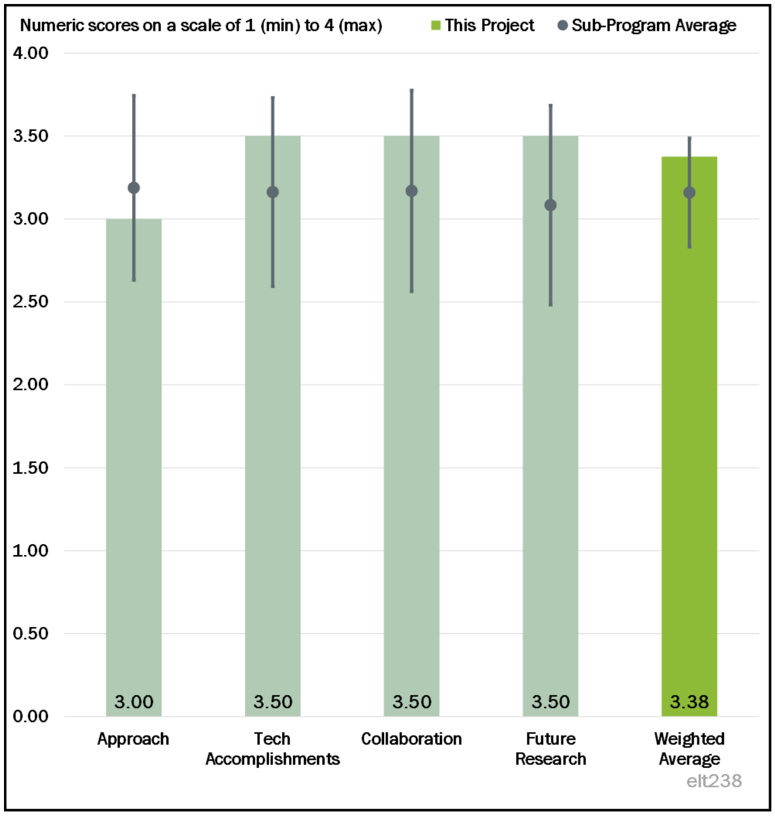

Figure 4-38 - Presentation Number: elt238 Presentation Title: Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection Principal Investigator: Srdjan Lukic (North Carolina State University)

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

Reviewer 1:

It would be helpful if the review explained the reasoning behind the 480 V versus high voltage—economic or technical benefits of this approach. It would also be helpful if the review clearly explained why a solid-state transformer was chosen or beneficial over conventional approach.

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

Reviewer 1:

It seems that good progress has been made.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Coordination and communication across partners seem good, but a work breakdown structure or some type of system work plan would help communicate this (i.e., who is working on what piece).

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

Reviewer 1:
The project seems focused on a real and upcoming issue.

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

Reviewer 1:
This project will help lower charging costs and enable increased EV adoption.

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

Reviewer 1:
Resources seem sufficient when compared to similar efforts that are being funded.

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

Presenter

Omer Onar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

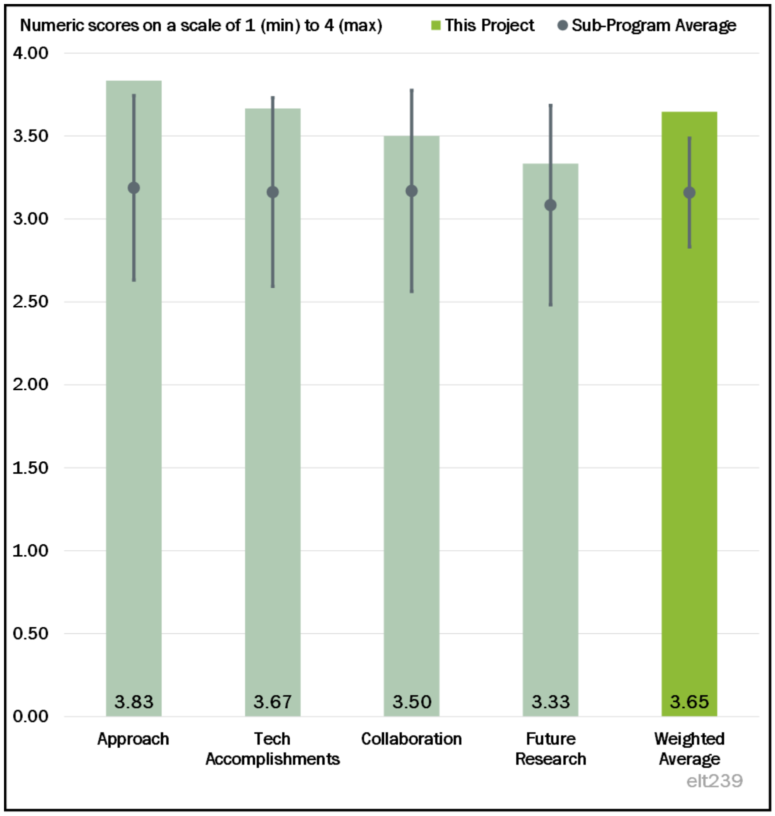

Figure 4-39 - Presentation Number: elt239 Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility Principal Investigator: Omer Onar (Oak Ridge National Laboratory)

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

Reviewer 1:

The approach is solid with design, testing, modeling, and validation. The integration into a vehicle is key. The project has demonstrated some success with the completion of the go/no-go milestone in October of 2019. There was no mention of impact on the schedule due to COVID-19 related closures which seems unlikely. The reviewer suspected there will be delays for the go/no-go decision point associated with the demonstration at 100 kW on a Hyundai-Kia vehicle.

Reviewer 2:

The project is focused on both 100 kW and 300 kW inductive charging system, designed to be small with electromagnetic coupling. The team seems to have a very specific and detailed approach very well aligned with accomplishing the necessary activities to achieve project goals. In particular, the team has worked to take an approach to overcome shortcomings of existing systems. They have also included analysis of design alternatives, in order to minimize risk.

Reviewer 3:

The approach is logically organized. Initially doing the soft requirements like iterative design and modeling. Later in the project there is demonstration of the 100 kW and the 300 kW systems on actual vehicles.

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

Reviewer 1:
A lot of progress appears to have been made over the past year with 4 accomplishments from FY 2019 mentioned and 18 from FY 2020. The laboratory benchtop test setup shows impressive results.

Reviewer 2:
Overall, the project has appeared to achieve significant accomplishments. The team is now working on validating 100 kW operation. So far, they are showing 95% efficiency. The team compared their system against state-of-the-art systems, showing much higher power transfer at a larger air gap and at higher efficiency. During this budget period, they have developed the simulation model and thermal analysis. By conducting detailed analysis, the team has been able to significantly reduce component sizes. Assembly initially turned out to be an issue, so they analyzed alternative designs and chose a different approach. They have also analyzed the vehicle-side equipment - with overall efficiencies at 97%–98%. In addition, the team looked at ways to minimize the misalignment issues.

Reviewer 3:
Good accomplishments occurred including the design and prototype, simulation and analysis of the components, and inverter design.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Partners include ORNL (lead), ChargePoint, Hyundai, and Seres—pretty much all the types of organizations needed for this project. The team has very specific duties assigned to each team member. The Hyundai vehicle will be tested up to 100 kW, while the Seres vehicle will be used for 300 kW.

Reviewer 2:
Collaboration was comprised of the National Laboratories, a charging provider, and two automotive companies. Each team member has a distinct piece of the project that compliments the other components. There was not much discussion on the larger vehicle manufacturer since that work is not until the next fiscal year. Look forward to hearing more about that company and its contributions.

Reviewer 3:
It looks like a lot of coordination is occurring and that the right groups are available to do the project.

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

Reviewer 1:
The future work described seems like the next logical steps with this effort. Two areas for future consideration are interoperability with SAE Standard J2954-2, and evaluation of system costs for commercial implementation.

Reviewer 2:
The team appears to have very specific activities left to accomplish, primarily focused on validating up to 100 kW and scale-up to the 300-kW power level. The only concern is that this scale-up may be a significant effort.

After this project, they are also interested in looking at MD and HD applications, which would appear to be a very promising opportunity for this technology. In fact, this technology might actually have greater applications for MD-HD vehicles, particularly delivery trucks and buses. Another future effort identified by the PI was to convert this system from a prototype to a commercial unit.

Reviewer 3:
Future plans are significant. These plans will show and demonstrate the technology.

Will this technology be interoperable with the technology that is occurring with SAE J-2954-2? Several manufacturers are to have the 250-kW wireless charging in small fleets. And new demonstrations are now occurring at the 1000 kW level. It is so important that interoperable mechanisms be used. All wireless vehicles should be able to charge at any wireless interface. It is also important that the 100-kW system be compatible with the 300-kW system.

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

Reviewer 1:
This project supports DOE's overall objectives. If successful this project will provide a prototype for cleaner, more efficient transportation. Work will still be necessary from a cost perspective to get it to commercial market.

Reviewer 2:
The project is focused on improving performance (efficiency and power level) of inductive charging systems, which could add options for charging EVs. This would therefore enable greater use of electric transportation technologies, thereby displacing petroleum and reducing emissions.

Reviewer 3:
The commercial industry needs high power charging. Wireless is one way.

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

Reviewer 1:
The resources seem to be appropriate for the work to be completed.

Reviewer 2:
Funds appear sufficient for this project as currently designed. The technology does seem to have strong potential for follow-on activities.

Reviewer 3:
The reviewer commented so far, so good.

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

Presenter

Mike Masquelier, WAVE

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

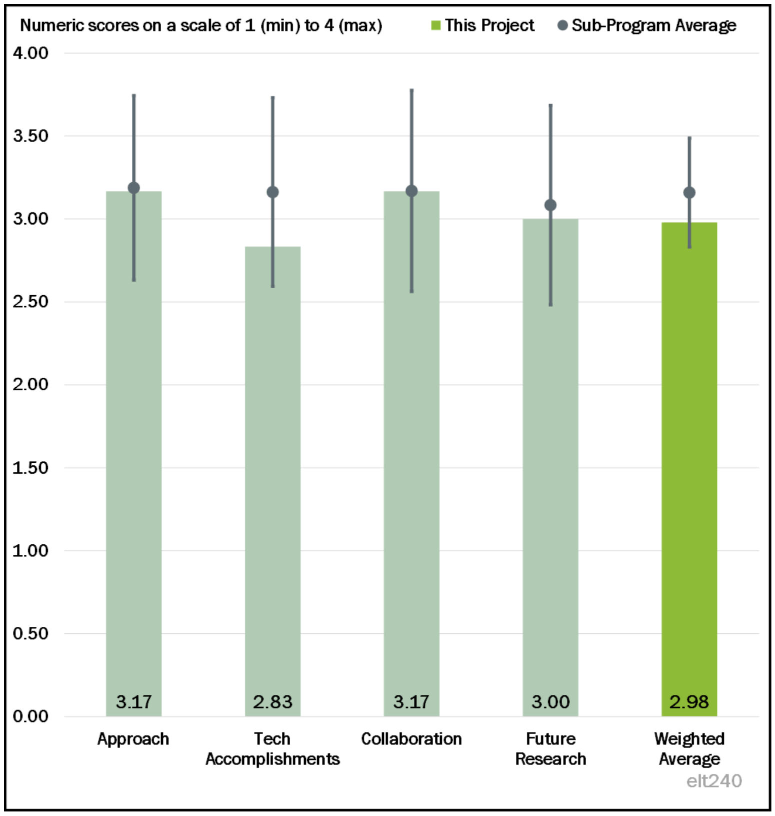

Figure 4-40 - Presentation Number: elt240 Presentation Title: Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks) Principal Investigator: Mike Masquelier (WAVE)

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

Reviewer 1:

The scope of work is sound and it appears that the right project steps and requirements are addressed. One complication appeared to be working with the Port of Los Angeles; however, another location was selected to overcome some of those issues.

Reviewer 2:

The planned approach was sound, but the re-scoped project still focuses on a 500-kW wireless extreme fast-charging (WXFC) unit that has not been fully developed and the project in nearly halfway complete. The team is still making substantial changes to 500 kW hardware. The new plan of moving the 500-kW testing to the third period raises the risk for completion of major milestones.

Reviewer 3:

The approach is directly addressing several XFC technical barriers to include high power wireless power transfer to enable shorter charge times, thermal management, interface to Medium Voltage distribution feeder, and multi-C charge rate of the vehicle battery pack. An improved approach feature would be to have included an initial requirements definition phase prior to the design phase.

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

Reviewer 1:
One of the seven converter modules have been developed and tested for full-power operation. Other subcomponents of the high-power charger have been designed, built, and tested. Truck demonstrator #1 already 90% completed (with COVID delaying final completion until July 2020).

Reviewer 2:
As stated above, project looks to adjust its plan based on hardware progress for the grid side, and there has been some good progress there. Recognition of the lack of progress of a 3C-capable large energy storage system (ESS) pack suitable for a HD application is not a sufficient plan to ensure a properly developed vehicle will be available for testing required to show system capability.

The test site is nearly ready and the first truck should be available next quarter. The estimated date for full system testing start was not clear.

Reviewer 3:
Progress on critical standalone battery tests have been delayed which indicates that significant project risk exists halfway through the timeline. The future work to validate that Medium Voltage (MV)-related high voltage isolation requirements from UL field evaluation also indicates that significant project risk remains. The project is only 35% complete nearing second year of work. However, the work completed to date is valuable to overcoming some technical barriers and meets or exceeds the target measures of performance for those components.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The presentation indicates that the partners are meeting regularly to communicate and resolve issues.

Reviewer 2:
There appeared to be some issues with the primary site partner; however, that has been addressed and moved to a new Carson location. This is not without issue as it will entail facility modifications; however, the team appears ready to tackle this barrier.

Reviewer 3:
With the exception of the previously noted ESS subsystem development issues, there seems to be a good representation of the partners needed to make good progress and have an impact.

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

Reviewer 1:
The presentation does a nice job of ordering the proposed future research by criticality of the needed advancement to the long-term success of this high-power charging capability.

Reviewer 2:
The proposed future research topics listed in the slides are important; however, this question is more directed at the current project (and not future ones). The slides do not directly address how these issues are to be planned around (for instance, thermal management at such high battery charging power).

Reviewer 3:
The difficulties in getting the site ready for a pilot project should be identified as a barrier that needs better understanding within the future work. Similarly, the lack of ability to test the entire subsystem prior to truck installation and operation deserves attention. Completing subsystem testing and reporting data regarding systems parameters and performance in various operational scenarios would yield valuable information for future project.

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

Reviewer 1:
This project is highly relevant to DOE's objective to advance transportation electrification technologies with regard to developing high-power charging technologies and EVSE infrastructure capabilities.

Reviewer 2:
Fast-charging, whether for HD or light-duty (LD) applications, is a critical technology to tackle in order to gain better penetration in the EV market. This project directly goes after this.

Reviewer 3:
As explained in the project intro, there is a great deal of energy consumed (and carbon dioxide [CO_2] emissions created) by this portion of the transportation fleet. Efforts which may expand electric mobility into the HD industry are worthy of investigation.

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

Reviewer 1:
The delayed progress and extended development timeline are likely indicators of insufficient project resources. The technology scope of this project is broad and therefore there is more opportunity for unanticipated development costs.

Reviewer 2:
It is a bit early in the project and the project is relatively aggressive; however, good progress has been made (about 35% complete).

Reviewer 3:
Good partnership members having adequate experience and providing substantial cost share—and hardware, which will allow the project to have substantial impact even if the ultimate milestones are not achieved.

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

Presenter

Charles Zhu, Delta Electronics

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

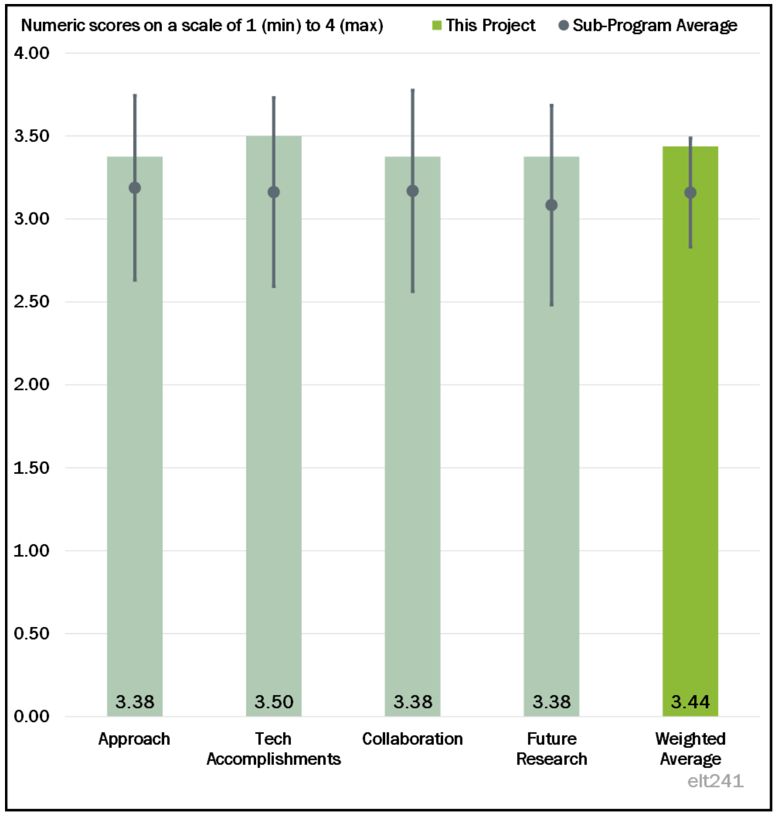

Figure 4-41 - Presentation Number: elt241 Presentation Title: High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kW/1000-V/400-A Extreme Fast Charger for Electric Vehicles Principal Investigator: Charles Zhu (Delta Electronics)

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

Reviewer 1:

The team has a reasonable project design, going through an interim-level charging system first (135 kW). Time will show if the scale-up from 135 kW to 400 kW can be properly accomplished. The team understands that higher-level systems have increased transmission and distribution requirements, and they are working to reduce some of that need by converting electricity down to the medium level for this charger. Eventually, the system will handle 200-1,000 VDC, though right now they're looking at 400 VDC. They are shooting for 60% charge in 10 minutes at a maximum of 400 amps. The system is also designed to integrate with storage, to address potential demand charge concerns.

Reviewer 2:

The project milestones for BP 1 have all been met and all but the final demonstration of the 400-kW laboratory test for BP 2 have been met. Partial demonstration of the 400-kW test demonstrates compliance at partial power.

Reviewer 3:

The concept is excellent, but not far along enough to give a legitimate observation. The concept would solve a lot of charging time issues for a quick fleet turnaround.

Reviewer 4:
This project is relying upon compelling technologies and hence adopted approach for project is likely to lead to a successful project outcome. Medium-voltage AC input, 4.8 kV or 13.2 kV. Solid state transformer-based technology to reduce the size and weight, and to increase scalability and flexibility. Cascaded multilevel converter topology as medium voltage interface to reduce the total number of power cell. Multilevel resonant converter for medium voltage isolation, operated at high frequency with soft switching. SiC MOSFET devices for high voltage and lower loss. Interface to an ESS and/or a renewable energy generation system (e.g., photovoltaics [PV]) for energy back-up.

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

Reviewer 1:
So far, the team has completed the 135-kW charger integration—this is the interim step. This was demonstrated at a higher efficiency level than required. They have also completed the 400-kW mechanical design (early, as it was projected for August 31, 2020) and will be starting testing soon. (There have been some testing delays due to COVID-19.) General Motors (GM) has been working on a retrofitted vehicle with an 800V battery pack (a luxury SUV) to enable faster charging. The requirement is 50% state of charge in 10 minutes, and the project team is already seeing around 67%.

Reviewer 2:
Partial demonstrations are already complete with plans for the final demonstration well underway. The project appears to be on time.

Reviewer 3:
So far, conceptually, it appears to be on track with accomplishments and timelines.

Reviewer 4:
Parts for the 135-kW charger system are under development and likely to be tested as per the project plan. Test conditions for 135 kW charger system are stated out during presentation as well as in project report. It is proved by the PI that resonant converter used in isolation stage will lead to higher efficiency and proved out by measured data indicating charger efficiency greater than 98%. Buck converter efficiency at various charging voltage (200 V to 990 V) is measured. Measured data on efficiency and system waveforms (current and voltage) indicate that the project team has established functionality of parts used in the proposed charger. Proposed prototype of charger is retrofitted in vehicle and charging profile results are included in project report. Also, the project has completed numerous milestones showing outstanding technical progress and accomplishments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project has a good group of team members—an EVSE manufacturer lead with a vehicle manufacturer, two utilities, a state energy office, a university, and a city. Each seems to have a clear role and have been contributing significantly.

Reviewer 2:
Project targets and deadlines were met; the collaborative team appears to be functioning very well.

Reviewer 3:
It appears like all the right groups are lined up to make a successful trial at this stage.

Reviewer 4:
This project lead by Delta Electronics Americas Ltd. includes many relevant collaborators, such as GM, DTE Energy, the Center for Power Electronics Systems at Virginia Tech, NextEnergy, and Michigan Energy Office.

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

Reviewer 1:
Overall, the project team appears to have a straightforward plan for the remainder of this project. Their plan for future research is to scale up to the 400-kW unit—this may turn out to require a significant effort versus the 135-kW system tested so far. They will test with DTE next year, and then would like to approach the market—this is a market-intended design. There was no indication as to whether any follow-on efforts are planned or even contemplated.

Reviewer 2:
Hardware demonstration of the concept in the third budget period will serve as an excellent technology demonstration of the proposed fast charging system.

Reviewer 3:
The future research seems to go in logical order from this time standpoint.

Reviewer 4:
The proposed future research includes relevant tasks and topics such as test vehicle high voltage distribution system)/rechargeable energy storage system (RESS) with sub-topics; Test 400 kW XFC system with vehicle emulator, test 400 kW XFC system with Chevy Bolt car. Also, included the proposed future research are build test vehicle and test 400 kW XFC system with 800 V retrofit vehicle.

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

Reviewer 1:
The project is focused on increasing the charging rate for EVs, to make recharging closer to the gasoline-level experience. That will be important to assist market penetration of EVs.

Reviewer 2:
In order to increase adoption of non-petroleum energy sources for transportation, development and integration of fast-charging systems will be key. This project will demonstrate such a technology.

Reviewer 3:
This would definitely aid in a business case for electric transport vehicles with the concern about charging times.

Reviewer 4:
The project aligns with DOE VTO objectives and successful completion of this project will accelerate adoption of battery powered passenger cars in the United States.

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

Reviewer 1:
Resources appear sufficient at this time.

Reviewer 2:
The team appears to be hitting targets on time; funding and resources seem appropriate.

Reviewer 3:
At this moment it seems like the team has what they need to complete the project.

Reviewer 4:
Resources for project seem appropriate.

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

Presenter

G.Q. Lu, Virginia Tech

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

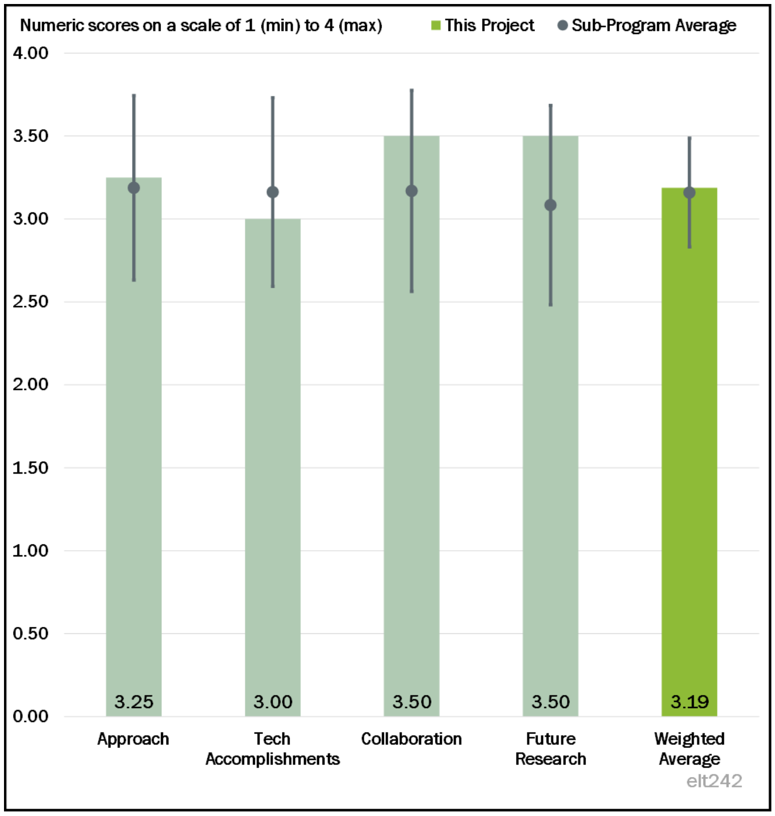

Figure 4-42 - Presentation Number: elt242 Presentation Title: Heterogeneous Integration Technologies for High-Temperature, High-Density, Low-Profile Power Modules of Wide Bandgap Devices in Electric-Drive Applications Principal Investigator: G.Q. Lu (Virginia Tech)

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

Reviewer 1:

The project aims to produce power modules with high-temperature reliability. Experimental approach is designed very well. However, the project does not provide any details on key issues, such as mechanical and thermal simulations. Without details on actual and operational temperature distribution within the module, it might not be possible to exclude some components.

Reviewer 2:

The project addresses the technical barriers from a design perspective. The concern the reviewer had is that manufacturing methods and processes significantly influence performance of a part. There really needs to be production scale manufacturing involvement in the project to ensure results are usable by industry.

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

Reviewer 1:

The design work and testing show progress, but testing needs to be performed over the full operating temperature before saying the work contributes to overcoming barriers.

Reviewer 2:
The project has finished its first set of designs and experiments; however, there is a significant lack of detail on thermal and mechanical simulation work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Various project collaborators are listed, and there appears to be good testing and characterization planning embedded in the project.

Reviewer 2:
This is a good team, but the project really needs industry involvement from a power module manufacturer.

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

Reviewer 1:
A thorough test plan needs to be developed and testing performed in order to prove these designs have merit.

Reviewer 2:
This is a very relevant topic with well-defined future research targets.

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

Reviewer 1:
This work is needed to increase power density and fully utilize SiC switches.

Reviewer 2:
The project will contribute significantly in meeting DOE goals.

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

Reviewer 1:
Resources are sufficient.

Reviewer 2:
This area of work is critical, but the reviewer believed the funding level is the contributing factor for why testing is limited and industrial involvement does not exist.

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

Presenter

Bulent Sarlioglu, University of Wisconsin

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

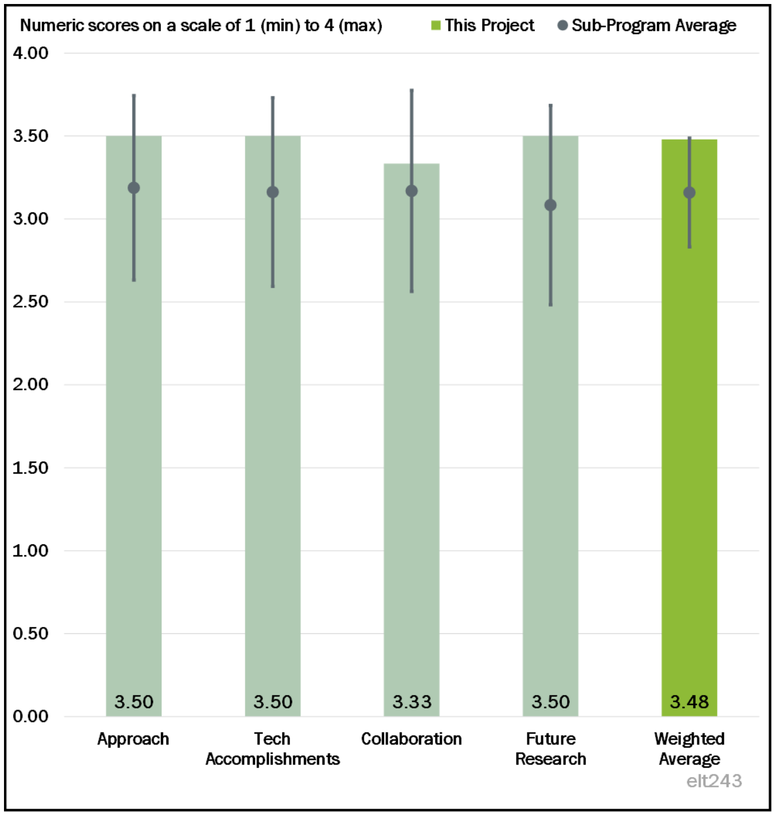

Figure 4-43 - Presentation Number: elt243 Presentation Title: Integrated Motor and Drive for Traction Applications Principal Investigator: Bulent Sarlioglu (University of Wisconsin)

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

Reviewer 1:

The project looks at a wide variety of options and attempts to rationalize the down-selection of the “best” design.

Reviewer 2:

The approach in this project of evaluating various machine and inverter topologies, prototyping the most promising design, and testing to validate the concepts is sound.

Reviewer 3:

The approach is very relevant to industry.

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

Reviewer 1:

Excellent progress has been made on analyzing the options and picking a best candidate motor and inverter.

Reviewer 2:

The trade-off study showing the SPM motor and the 2-level current source inverter with DC/DC converter as being the leading candidates is well executed and impressive. The integrated motor drive architectural study as well as the test-bed design are also well executed.

Reviewer 3:
The project just started.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team seems to be gearing up to engage.

Reviewer 2:
Collaboration and coordination with NREL and ORNL are proceeding well.

Reviewer 3:
The reviewer found good collaboration with the National Laboratories. It is interesting that the "National Laboratories" keystone project is focusing on a different design. Did the various parties have a discussion about the "best" option?

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

Reviewer 1:
The next steps are appropriate.

Reviewer 2:
The project is going in the right direction.

Reviewer 3:
The future plan to complete the hardware prototypes and validate the proposed concepts is sound.

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

Reviewer 1:
This is a highly desirable project from the industry perspective.

Reviewer 2:
Wisconsin Electric Machines and the Power Electronics Consortium's effort act as a good point of comparison for a bake-off between IMD concepts. This is needed to achieve the technical knowledge required to meet the DOE VTO electric drive targets.

Reviewer 3:
This project attempts to create a compact, cost-effective, and efficient integrated drive to meet DOE's 33 kW/L and $6/kW targets.

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

Reviewer 1:
The project appears to be on schedule with the existing funding level.

Reviewer 2:
FY 2020 funding of $300,000 is adequate to meet the objectives.

Reviewer 3:
This reviewer commented that resources seem appropriate if the collaboration does not extend significantly.

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

Presenter

Robert Pilawa, University of California at Berkeley

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

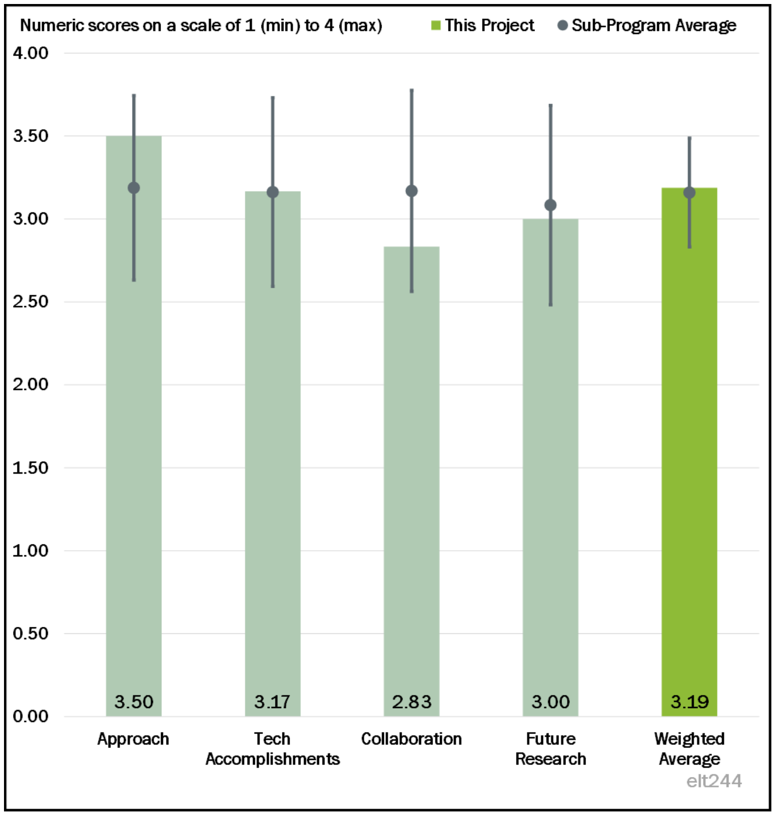

Figure 4-44 - Presentation Number: elt244 Presentation Title: Next-Generation, High-Temperature, High-Frequency, High-Efficiency, High-Power Density Traction System Principal Investigator: Robert Pilawa (University of California at Berkeley)

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

Reviewer 1:

The project team has proposed a novel way to increase the power density of the inverter while reducing the cost at the same time. The barriers have been addressed through novel circuit topologies, component identification and characterization, and packaging. Very interesting work with high potential for commercialization.

Reviewer 2:

The PI states that the Flying Capacitor Multilevel (FCML) converter could be a better power converter topology compared to conventional two-level converter. Distributed heat generation in FCML converter could mitigate reliability issues. Also, the FCML converter could operate under failures, only faction of capability could be compromised under single point failure. The FCML converter with lowest possible inductance in current loop produces less than 1% total harmonic distortion (THD) and could be quite useful for a low-inductance light-weight electric motor drive system. Up to 100 kHz switching frequency allows appropriate voltage balancing in passive components used in the FCML.

Reviewer 3:

The design has potential, but the reviewer asked how it impacts cost. This needs to be addressed before moving forward.

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

Reviewer 1:
Assessment of the preliminary design has been completed, verifying the electric drive inverter with power density. More than 100 kW/L is achievable.

Reviewer 2:
FCML converter start-up has been verified for voltage ramp-up verified 0 V to 1000 V in few seconds and voltage balancing of passive components achieved by novel PWM control for switches (active elements) and capacitors (passive elements). Fault mitigation method by sensing rate of rise of current through output inductor is investigated by project team. Component characterization including use of automotive qualified part is thought out by the project PI. Based on design and test data, it is stated by PI that projected power density could significantly increase if liquid cooling including immersion cooling is used for the FCML converter.

Reviewer 3:
The work being performed is of high quality and technically interesting, but the design complexity makes it unlikely to be useful for automotive.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project showcases very good collaboration with Consortium members: Purdue University and the University of Wisconsin for machine integration, SNL for WBG expertise and packaging, and ORNL for vehicle integration aspects. Lots of collaboration is shown with components suppliers: GaN Systems, EPC, Infineon, Texas Instruments, TDK, and Murata. Efforts have been made to touch base with OEMs as well.

Reviewer 2:
Input from Industry that could use FCML converter is lacking, else PI collaborates and seeks input from SNL and ORNL

Reviewer 3:
There is little to no evidence of collaboration.

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

Reviewer 1:
A very clear plan has been outlined on the proposed future research with go/no-go decisions. The main issues on the high-power density, high-efficiency inverter is electromagnetic interference (EMI), thermal management, and novel control development. All these aspects have been planned well at this stage.

Reviewer 2:
Future research includes the following relevant topics: EMI testing, hierarchical control development, development of liquid heat-exchanger or immersion-based thermal management, accelerated lifetime testing of modules, improvement in module's assembly process, development of on-line fault detection and mitigation, and synthesis top-down and bottom-up failure models during design stage.

Reviewer 3:
Without a cost assessment and an understanding that vehicle OEMs concur with this approach, the reviewer would not move forward.

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

Reviewer 1:
Achieving a very high-power dense traction inverter, which is highly efficient with low cost, is the main objective of the DOE, which is addressed in each and every aspect of this project.

Reviewer 2:
The FCML plans to meet $2.70/kW cost target and 100 kW/L power-density target. This reviewer suggested that the PI must develop metrics and methods by using bill of material and part dimensions to track cost and power-density targets.

Reviewer 3:
The technology is interesting, and it is clear that advantages can be yielded, but the reviewer was really concerned if this project has merit for automotive use.

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

Reviewer 1:
The team is very well organized and capable to deliver the required tasks.

Reviewer 2:
The project has necessary and sufficient resources.

Reviewer 3:
If the DOE objective is to have some projects to explore really different approaches, then this level of resources is sufficient.

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

Presenter

Alan Mantooth, University of Arkansas

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

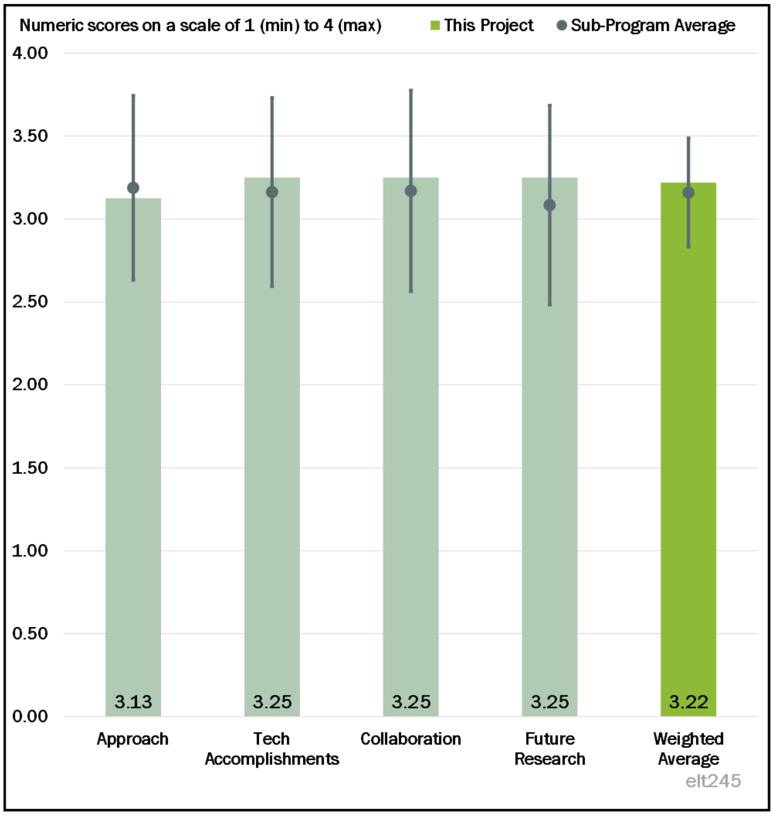

Figure 4-45 - Presentation Number: elt245 Presentation Title: Integration Methods for High-Density Integrated Electric Drives Principal Investigator: Alan Mantooth (University of Arkansas)

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

Reviewer 1:

The approach to designing a high-power density power module by integrating gate drivers, current sensors, filtering, and cooling is well received.

Reviewer 2:

The reviewer noted that this is a good project, it has just started, and it seems to be going deep enough.

Reviewer 3:

Since SiC devices are currently on the market, the purpose of the SiC complementary-symmetry metal (CMOS) fabrication task could be made clearer.

Reviewer 4:

Increasing the inverter power density and efficiency, and at the same time reducing the cost, is a very critical area of interest to reduce the cost of EVs and for their market penetration. One aspect is doing the prototype and evaluating the high-temperature gate drive, high power density power module design, and the integration aspects of the power module. The second aspect is whether this is going to deliver the same performance in the field. A series of design validation is needed to prove that the components developed for a traction inverter delivers superior power density and efficiency with lower cost when compared to the off-the-shelf traction inverter. How is this validation going to be performed?

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

Reviewer 1:
Excellent progress has been made on characterizing SiC low-voltage devices at very high temperatures.

Reviewer 2:
Research is on track with year 1.

Reviewer 3:
The research team has shown evidence of excellent technical progress in characterizing high-temperature operation of SiC CMOS, creating double-sided power module architectures, and exploring various integration components and cooling methods.

Reviewer 4:
A literature review on the power module integration aspects, gate drive design, and integrated circuit design with some FEA and prototype results have been shown. In the trade-off study, has any analysis been done on the effect of the high switching frequency of these devices and the corresponding EMI issues?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project tasks are well coordinated across the project team.

Reviewer 2:
The reviewer commented that there is sufficient collaboration and engagement.

Reviewer 3:
The team has shown solid collaboration with Virginia Tech and ORNL.

Reviewer 4:
The team has been very collaborative with Virginia Tech and ORNL for the power module and integrated circuit design, and heat sink design and system integration aspects, respectively.

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

Reviewer 1:
The next steps are appropriate in achieving the project goals.

Reviewer 2:
The reviewer found good vision for future research.

Reviewer 3:
Proposed future work on high-temperature CMOS fabrication and continued development of the integrated power module are well motivated.

Reviewer 4:
The milestones and deliverables of each collaborator and the PI have been mentioned clearly. However, the go/no-go decision points have not been listed.

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

Reviewer 1:
Device design for the integrated power inverter is an important contribution to the DOE VTO electric drive targets.

Reviewer 2:
Yes, it is highly desirable.

Reviewer 3:
A compact power module will be critical to DOE's stated goal of creating a 33 kW/L electric drive system.

Reviewer 4:
This project aligns very well with DOE objectives of increasing inverter power density and efficiency while reducing the cost.

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

Reviewer 1:
The project appears to be on track with the given funding.

Reviewer 2:
Sufficient resources have been allocated.

Reviewer 3:
FY 2020 funding of $300,000 is adequate.

Reviewer 4:
The team is well experienced, having worked on similar projects in the past.

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

Presenter

Anant Agarwal, Ohio State University

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

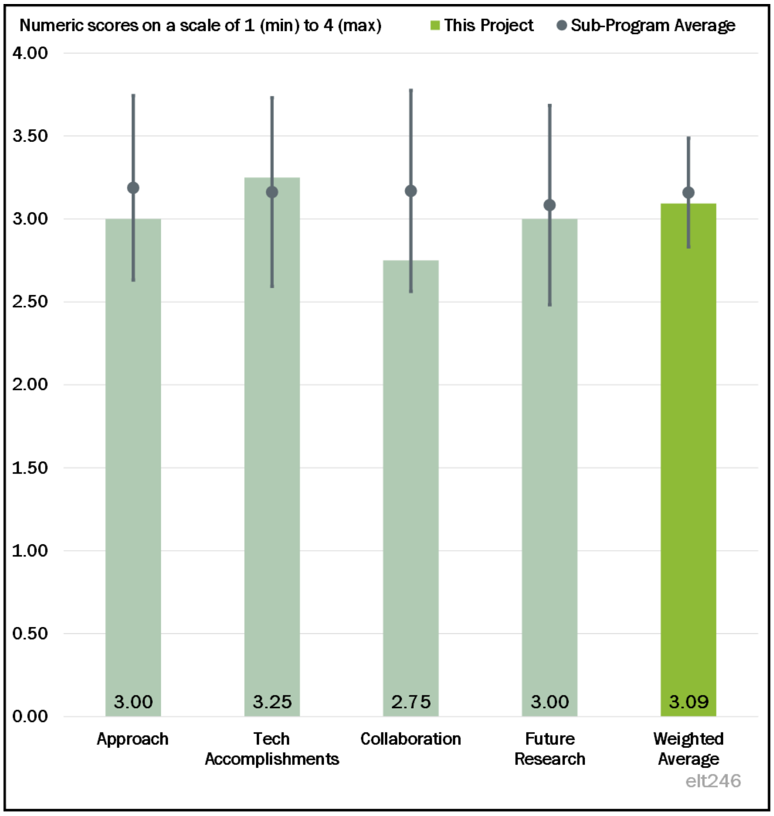

Figure 4-46 - Presentation Number: elt246 Presentation Title: Implementation of Wide-Bandgap Devices in Circuits, Circuit Topology, System Integration as well as Silicon Carbide Devices Principal Investigator: Anant Agarwal (Ohio State University)

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

Reviewer 1:

Generally, the project seems to be addressing issues that exist, but the reviewer was uncertain that these issues have not been already addressed when they compare to ELT082. Usually the auto industry has access to new devices years before the general market.

Reviewer 2:

The project hits the right target application for achieving energy density goals in power electronics. However, there is a clear lack of background understanding. There are SiC based inverters in operation in commercial vehicles today (Tesla for example has a discreet SiC device). Additional study of the reliability data from the past must be included.

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

Reviewer 1:

The work is interesting and educates the project, but the reviewer was not sure this will contribute to auto industry adoption of WBG devices.

Reviewer 2:

The project has accomplished initially set targets.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project has excellent collaboration.

Reviewer 2:
No device manufacturers or vehicle OEMs are on the team. Without alignment with industry, this work is limiting its potential.

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

Reviewer 1:
No evidence has been provided other than from the perspective of the current team that the issues being addressed are appropriate and their resolution would allow industry to deploy WBG in mass. The reviewer cannot say future research will be effective without this evidence.

Reviewer 2:
The project must include additional background study.

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

Reviewer 1:
The project aims to achieve power and energy density objectives as set by DOE.

Reviewer 2:
This work seems to address WBG device issues, and there is a logic behind the project team's thinking. There is quality in the work being performed, but the reviewer did not believe this will enable exploitation of WBG by the auto industry.

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

Reviewer 1:
Based on what this project is, it has appropriate resources.

Reviewer 2:
Sufficient resources have been included to complete the project plan.

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

Presenter

Woongje Sung, State University of New York Polytechnic Institute

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

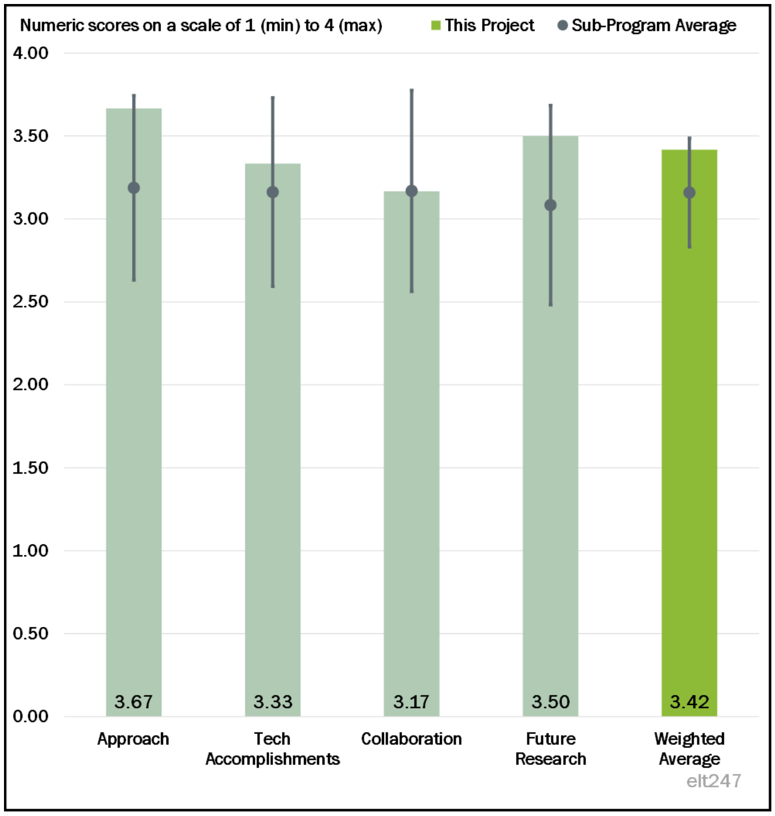

Figure 4-47 - Presentation Number: elt247 Presentation Title: Cost-Competitive, High-Performance, Highly Reliable Power Devices on Silicon Carbide and Gallium Nitride Principal Investigator: Woongje Sung (State University of New York Polytechnic Institute)

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

Reviewer 1:
Both BP1 and BP2 plan are well designed, comprehensive, and mostly feasible.

Reviewer 2:
All relevant barriers to technical target are well summarized, and the project has a well-timed staged execution plan.

Reviewer 3:
Generally, the project seems to be addressing issues that exist, but the reviewer was uncertain that these issues are a complete list or the ones the auto industry believes are important.

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

Reviewer 1:
The project has met all technical targets for the current year.

Reviewer 2:
The cell optimization, the edge termination design, and non-isothermal simulation of a narrow junction field effect transistor (JFET) width, and mask design of floor plan show good progress toward the final deliverable. The reviewer hoped that Lot 2 can be finished before August. The evaluation of Lot 1 is satisfying.

Reviewer 3:
The work is interesting and educates the project, but the reviewer was not sure this will contribute to auto industry adoption of WBG devices.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project is a collaboration between ADI, Ohio State University, SNL and the Army Research Laboratory, which is an excellent distribution of capabilities.

Reviewer 2:
Collaboration with ADI is extensive.

Reviewer 3:
No device manufacturers or vehicle OEMs are on the team. Without alignment with industry, this work is limiting its potential.

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

Reviewer 1:
The proposed research on process, device, reliability assessment, and packaging research are good topics and carry far-reaching impact.

Reviewer 2:
The proposed future research is well planned and staged according the various intermediate targets.

Reviewer 3:
No evidence has been provided other than from the perspective of the current team that the issues being addressed are appropriate and their resolution would allow industry to deploy WBG in mass. The reviewer cannot say future research will be effective without this evidence.

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

Reviewer 1:
A large project like this one to ensure next-generation WGB with reasonable performance is directly related to VTO's 2025 target on power electronics power density and cost.

Reviewer 2:
This project is well aligned with DOE targets of energy density in WBG based devices.

Reviewer 3:
This work seems to address WBG device issues, and there is a logic behind the project team’s thinking. There is quality in the work being performed, but the reviewer did not believe this will enable exploitation of WBG by the auto industry.

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

Reviewer 1:
Based on what this project is, it has appropriate resources.

Reviewer 2:
The project is sufficiently resourced.

Reviewer 3:
Funding of $300,000 per year for 5 years is more than sufficient.

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

Presenter

Scott Sudhoff, Purdue University

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

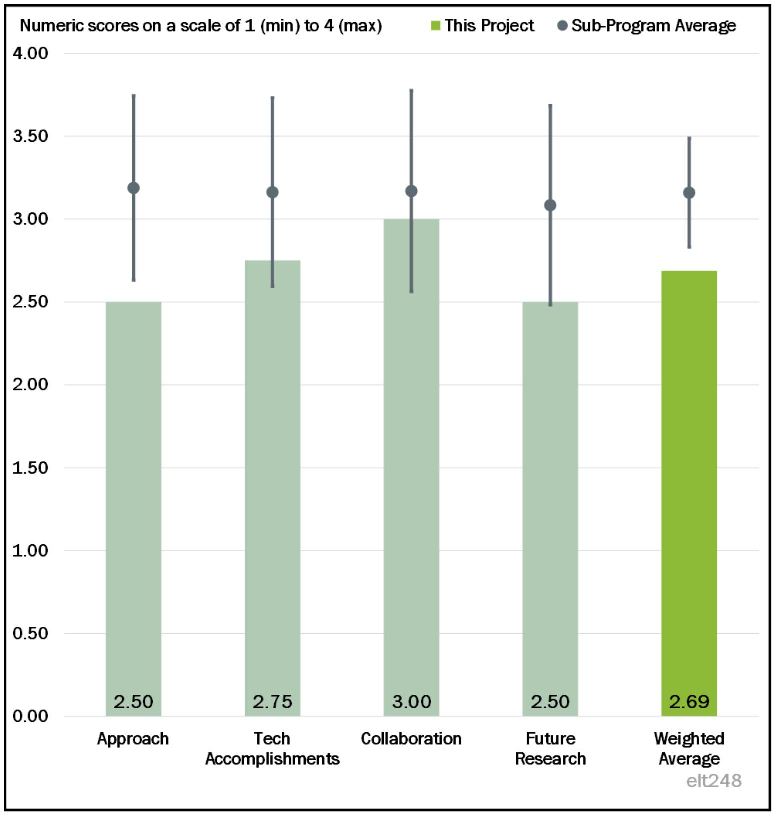

Figure 4-48 - Presentation Number: elt248 Presentation Title: Multi-Objective Design Optimization of 100-kW Non-Rare-Earth or Reduced-Rare Earth Machines Principal Investigator: Scott Sudhoff (Purdue University)

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

Reviewer 1:

This project started 12 months ago. At this point, the team has finished the development of the numerical tool, method of moments, to analyze the electromagnetic performance of electric machines. Research results have shown that this numerical tool takes a tremendously reduced time to get similar enough results as a FEA tool. This tool has not started to address the technical barriers stated in the presentation. However, this tool lays the foundation for the team's future work to address the technical barriers, i.e., non-RE machines, reduced cost, and the system-level trade-off between cost, performance, and materials.

Reviewer 2:

The focus has been more on modeling tools, but there has not been enough justification of the selectin of the homopolar topology or how it evolved. Also, not enough information has been provided to quantitatively show the expected improvement compared to the state of the art. In addition, it is not obvious that this topology provides a path to meeting the DOE requirements.

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

Reviewer 1:

The team has finished all four milestones as planned in the proposal on time. The major accomplishment in Year 1 is the development of the numerical tool for electric machine analysis. The results predicted using this new tool are compared against the results from using a finite element tool. The two produce very similar results. The numerical tool runs significantly faster.

Reviewer 2:
The choice of the homopolar topology is not clearly justified. The proposed design seems fairly complicated, and it is not clear that it can provide a practical path to meeting the DOE objectives.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
All team members run bi-weekly conference calls to follow up on the project. The collaboration and coordination are excellent. The reviewer encouraged the team to publish together.

Reviewer 2:
There seems to be reasonable communications among team members and good collaboration with the team at SNL.

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

Reviewer 1:
Future research is effectively planned and has a logical manner. The team did not discuss project risks for the future work.

Reviewer 2:
Even though design and modeling tools are important, more emphasis on proving the merits of the proposed topology is needed.

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

Reviewer 1:
This project supports the overall DOE objectives as it develops non-RE vehicle traction electric machines and tries to reduce the cost and improve the system reliability.

Reviewer 2:
The project is relevant, but the value proposition is not very clear.

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

Reviewer 1:
The team consists of leading universities and National Laboratories in the field of electric machines and power electronics. Every organization on the team has excellent facilities and resources to conduct the research tasks in this project.

Reviewer 2:
Resources are sufficient.

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

Presenter

Victor Veliadis, North Carolina State University

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

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

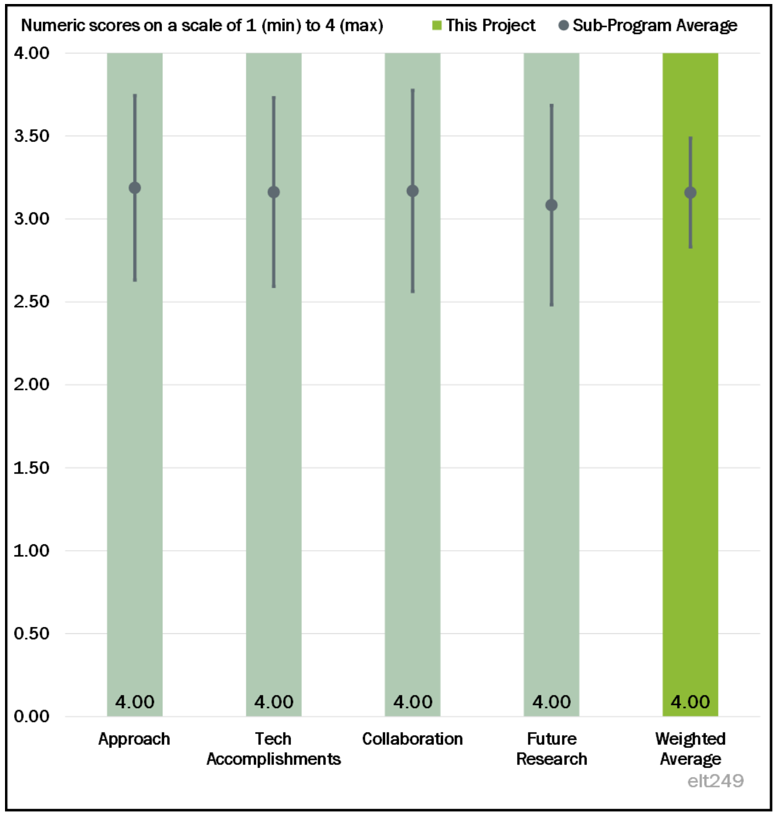

Figure 4-49 - Presentation Number: elt249 Presentation Title: Rugged Wide Bandgap Devices and Advanced Electric Machines for High-Power Density Automotive Electric Drives Principal Investigator: Victor Veliadis (North Carolina State University)

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

Reviewer 1:

This is a comprehensive project consisting of two part: WBG power electronics and a non-HRE high-power density motor. It is impressive to see the team tackle two different topics with equally innovative and effective approaches. The modeling of GaN device validated the impact of high frequency on power density. Going for higher frequency is the only way to achieve 2025 target power density; the motor design evaluation is extensive. Three designs were evaluated using FEA. This is the right approach before building anything.

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

Reviewer 1:

Both modeling of GaN device and motor designs made good progress. The use of NEOREC45MHF is a reasonable choice for now. However, its high-temperature performance is worrisome. Ames Laboratory has been pursuing high-temperature non-HRE PM via fine grain approach. They reported better performance with an N45 grade magnet than that of the N45UH. Please contact them for high-temperature data. Ultra-conductive Cu conductor improvement in conductivity should be limited to 8% or less. Overall, there has been great progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is one of the projects for the EDT Consortium. The team appears to be periodically reviewed by four National Laboratories.

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

Reviewer 1:
The proposed efforts on GaN and a demagnetization check on N45MHF are all necessary.

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

Reviewer 1:
The work this team has been doing directly addresses VTO's 2025 target on system power density.

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

Reviewer 1:
The reviewer asserted that $300,000 per year for 5 years is sufficient for either power electronics or the motor; at least $200,000 per year more is needed for the team to run at full speed.

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

Presenter

Ian Brown, Illinois Institute of Technology

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

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

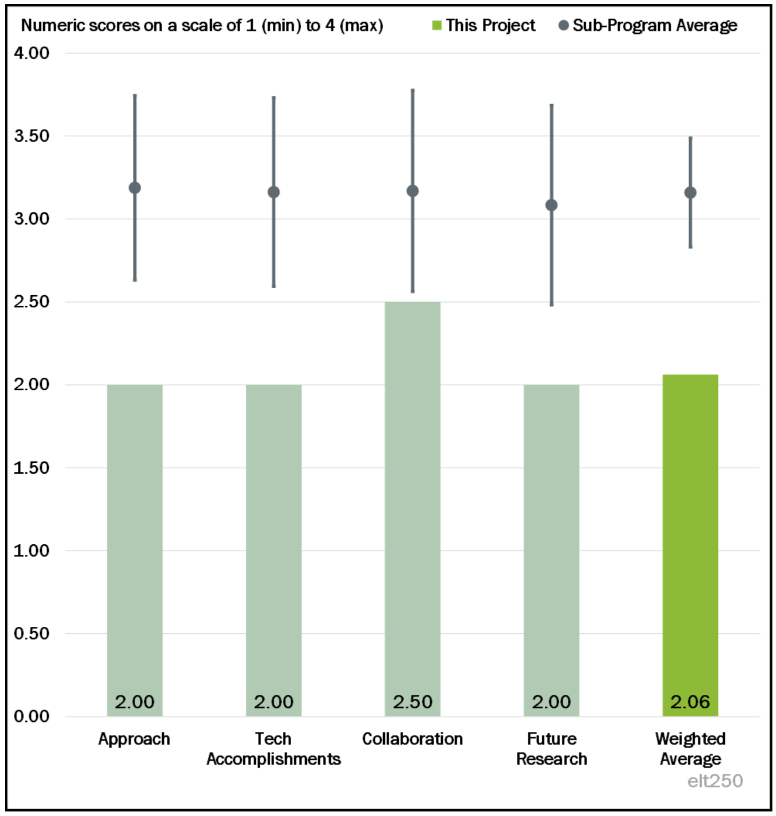

Figure 4-50 - Presentation Number: elt250 Presentation Title: Design, Optimization, and Control of a 100-kW Electric Traction Motor Meeting or Exceeding DOE 2025 Targets Principal Investigator: Ian Brown (Illinois Institute of Technology)

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

Reviewer 1:

Even though the proposed approach includes multiple technologies, none of them is really novel and it is not clear how this approach can lead to an eight-fold improvement in power density. More clarification of the novelty in the proposed approach is needed as well as how it compares to the state of the art and what has already been covered in literature.

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

Reviewer 1:

The IPM topology presented is not novel. A current density for up to 42 A_{rms}/mm^2 seems to be assumed and this is more than 2X higher compared to the state of the art. There was not enough information about how such a significant increase can be accomplished. The system voltage and flux-weakening capability has also to be taken into consideration. Also, if higher speed is assumed, the mass and efficiency of any additional gearing should be included.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There seems to be some collaboration, but more information should be provided.

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

Reviewer 1:
The novelty of the proposed approach needs to be the focus of future research. Based on what was presented, it is not very clear that the proposed approach can lead to a practical solution to meet the DOE's targets. More details and analysis are needed to build more confidence in the proposed approach.

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

Reviewer 1:
The project tries to pursue few technologies that are relevant, but the novelty and expected performance improvement are not very clear.

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

Reviewer 1:
Resources are sufficient.

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

Presenter

Yogendra Joshi, Georgia Institute of Technology

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

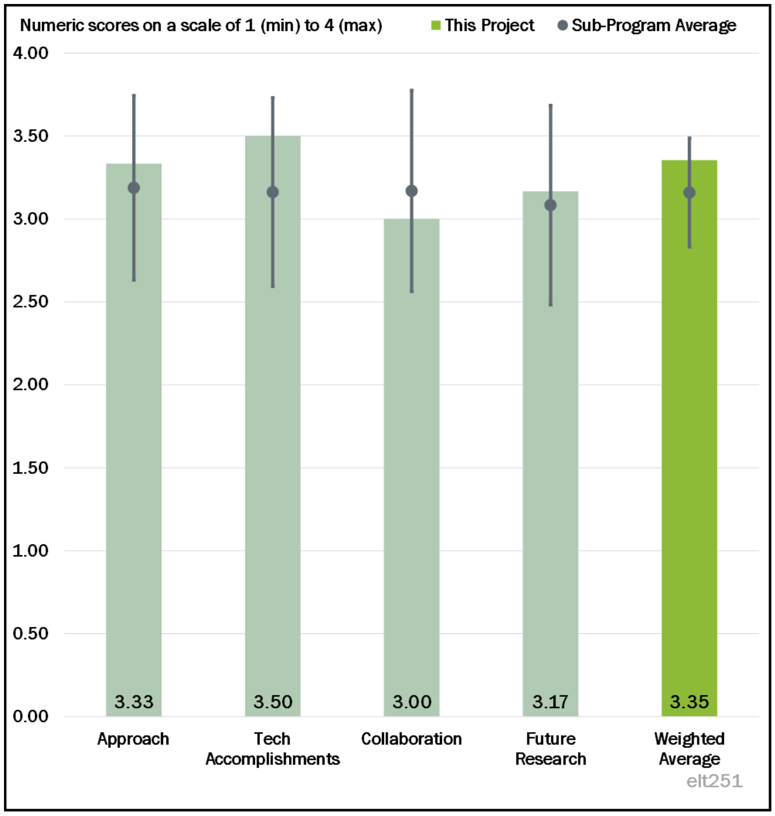

Figure 4-51 - Presentation Number: elt251 Presentation Title: Device- and System-Level Thermal Packaging for Electric-Drive Technologies Principal Investigator: Yogendra Joshi (Georgia Institute of Technology)

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

Reviewer 1:

This novel approach to dissipate heat looks promising. Combination of simulation and experiment is appropriate to doing proof of concept.

Reviewer 2:

The reviewer found this to be a good approach and methodology.

Reviewer 3:

The proposed use of metal foam and transient liquid phase (TLP) are interesting approaches to electric drive system thermal management and packaging.

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

Reviewer 1:

CFD heat transfer modeling of the cold plates with metal foam, 500 W/cm^2 heat flux removal, and exploration of bonding materials via TLP are all excellent advances in the area of electric drive thermal management optimization.

Reviewer 2:

This project just started, but it is good.

Reviewer 3:
The correlation between computational and experimental results looks very good for power inverter module metal foam. Reduced order motor thermal model looks like a good time saver.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaborations with NREL, ORNL, and SUNY Poly are all going well.

Reviewer 2:
There is good collaboration between government laboratories and academic researchers. Have the researchers been able to attract industry collaboration? The reviewer was under the (possibly mistaken?) impression SiC devices are available today.

Reviewer 3:
The reviewer did not see much collaboration.

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

Reviewer 1:
This is a very important project to understand the thermal properties of an EV drive.

Reviewer 2:
Future work steps are logical next steps for this work.

Reviewer 3:
The FY 2020 and 2021 objectives of thermal packaging and electric motor thermal management with various sub-tasks as listed on Slide 25 are well structured and appear quite promising.

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

Reviewer 1:
The project investigates novel techniques to improve power electronics heat transfer. This is critical to meeting the power density targets set by DOE VTO.

Reviewer 2:
This reviewer indicated that thermal is important.

Reviewer 3:
Optimal efficient thermal management is a key enabler for the DOE stated objective of creating a 33 kW/L electric drive system.

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

Reviewer 1:
The FY 2020 budget of $300,000 is adequate for the planned research tasks.

Reviewer 2:
The project is on time with the given budget.

Reviewer 3:
It seemed to the reviewer like enough of the resources have been allocated.

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

Presenter

Lakshmi Iyer, Magma Services of America, Inc.

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

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

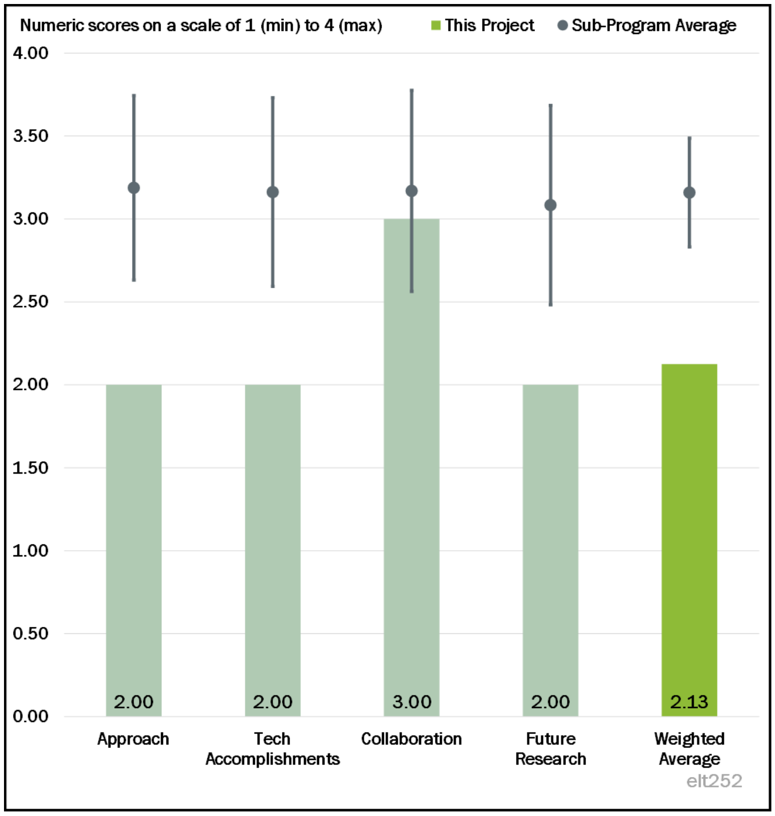

Figure 4-52 - Presentation Number: elt252 Presentation Title: Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization Principal Investigator: Lakshmi Iyer (Magma Services of America, Inc.)

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

Reviewer 1:

The novelty in the project is not very clear. The presented stator thermal management is fairly standard and there was no information shared regarding rotor thermal management. Regarding the optimization and the rotor excitation, there is significant overlap with other previously and currently funded projects by the DOE. It is not clear that the proposed approach can lead to eight-fold improvement in power density.

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

Reviewer 1:

The thermal management scheme presented does not address the rotor cooling, which can be more challenging compared to the stator, and even the proposed stator cooling scheme does not justify significant increase in power density. More analysis and details are needed.

Regarding the optimization results, it is not clear how the presented designs compare to the DOE targets. The key curve that shows efficiency versus torque is not sufficient.

Regarding the rotor excitation, it is not clear if there is any novelty there or the approach is leveraged from previous developments. This needs to be clarified.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seems to be good collaboration between the three involved organizations.

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

Reviewer 1:
More analysis and details are needed to justify the approach and build confidence that there is a realistic path to meeting the DOE targets.

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

Reviewer 1:
The project is relevant, but more information is needed to better assess the approach and the progress made.

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

Reviewer 1:
Resources are sufficient.

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

Presenter

Jagadeesh Tangudu, United Technologies Research Center

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

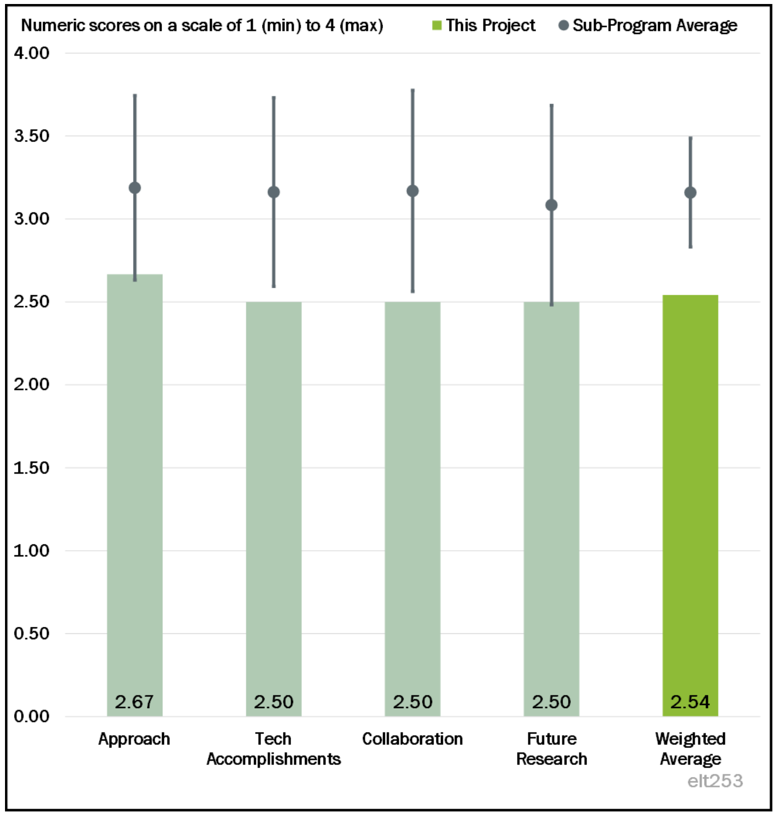

Figure 4-53 - Presentation Number: elt253 Presentation Title: Motor with Advanced Concepts for High-Power Density and Integrated Cooling for Efficiency Machine Principal Investigator: Jagadeesh Tangudu (United Technologies Research Center)

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

Reviewer 1:
The approach to the project is sound. Technical barriers are being addressed adequately.

Reviewer 2:
The project is in early stage with technical work starting at the beginning of the year. The organization of the project seems appropriate. The PI and the team have adequate background to address all tasks. The major thermal and electromagnetic barriers have been identified, and the project plan appears able to address them.

Reviewer 3:
There are no clear novel technologies proposed to meet the eight-fold improvement in power density. There is not enough information to evaluate the in-slot cooling. Also, with higher speeds, additional gearing should be evaluated and considered.

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

Reviewer 1:
Progress is acceptable to date.

Reviewer 2:
The project seems to be at a relatively early stage and since the results presented are in per unit (PU), it is hard to assess the extent of the progress made. Even on PU basis, it is not clear that there is a path to meet the eight-fold target.

Reviewer 3:
At this early point in the project, not enough technical progress has been made to evaluate.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seem to be proper collaboration and coordination among team members.

Reviewer 2:
The project is a seedling and thus a small team is appropriate. The collaboration with John Deere for application specifications is appropriate.

Reviewer 3:
There seems to be no collaboration at the moment outside the sponsoring organization.

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

Reviewer 1:
Proposed future work is well aligned and planned, per the project objectives.

Reviewer 2:
The novelty, especially in comparison to the state of the- art, should be clarified.

Reviewer 3:
The project has a detailed schedule with appropriate phases and decision points for an effort of this scope. One risk that is not explicitly addressed is the sensitivity of the motor performance to variation in material properties. This risk may be significant for less well-characterized materials, such as high-Si low-loss electrical steels and additively manufactured plastics. The reviewer encouraged the team to send ring cores of the electrical to an independent testing laboratory to verify the core loss and B-H curves. The reviewer also encouraged the team to send additively manufactured plastic coupons out for testing of thermal conductivity and thermal aging tests.

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

Reviewer 1:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 2:
The project is relevant, but the extent of performance improvement is not clear.

Reviewer 3:
The project is appropriately focused on meeting the Electric Traction Drive Systems performance targets.

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

Reviewer 1:
Resources seem to be adequate.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
The project appears to have sufficient resources within the project team to complete the milestones. The PI should, however, indicate if Raytheon is going to build the sectional stator prototype itself or sub-contract it to a vendor.

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

Presenter

Faraz Arastu, University of Illinois at Urbana-Champaign

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

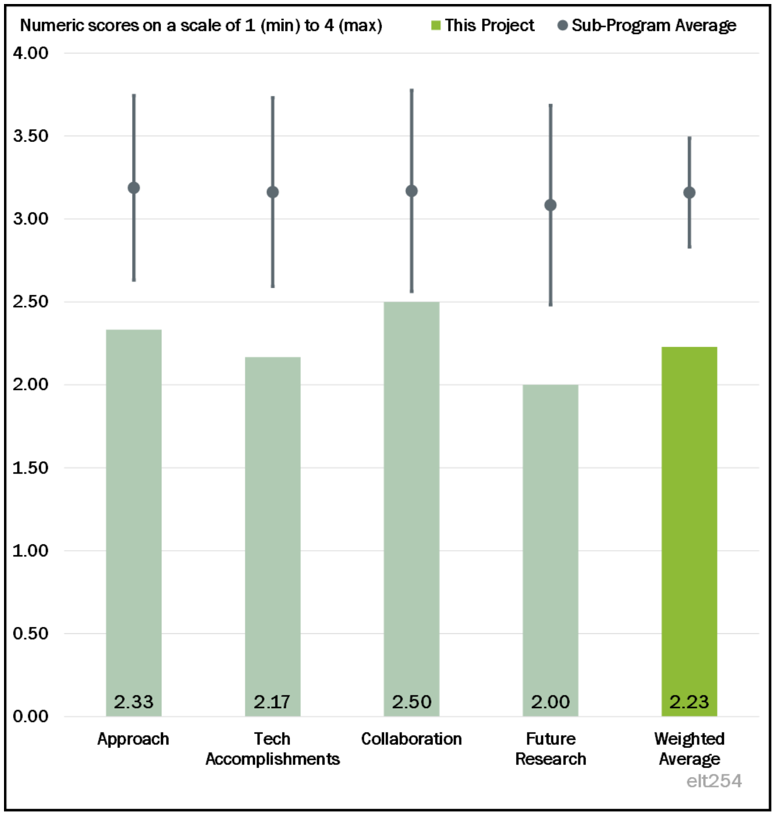

Figure 4-54 - Presentation Number: elt254 Presentation Title: Ultra-High Speed, High-Temperature Motor Principal Investigator: Joseph Lyding (University of Illinois at Urbana-Champaign)

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

Reviewer 1:

The project has just started and early experimental work has been completed on the insulation and magnetic materials. Dielectric test data are presented on the insulation, and a solenoid prototype and soft magnetic composite stator have been shown. However, it is not stated what other thermal, electrical, magnetic, and mechanical properties must be met to enable the materials to operate in a motor with the stated performance targets (125 kW, 50 kW/L, and 60,000 revolutions per minute).

Reviewer 2:

Even though high-temperature insulation can enable higher power density, there are several issues that need clarification:

- The focus seems to be on the wire insulation. What about the other components of the insulation system including slot liner, phase separator and (potentially) vacuum pressure impregnation resin?
- Higher temperature leads to lower efficiency, which can have significant impact on performance. This needs to be quantified.
- The proposed ultra-high speed is not practical for a motor of that size. Any additional gearing needed has to be evaluated and taken into consideration. Also, analysis and evaluation of the bearings has to be performed.

Reviewer 3:
Operating the motor at very high speeds can reduce the motor volume to deliver the same power. This can help with cost reduction. However, at high speed operation, there are several issues:

- Regarding the mechanical strength of the rotor and stator material, what is the tensile strength and yield strength of the soft magnetic composites (SMC)] used in the rotor and stator?
- With respect to the core loss versus frequency, SMCs might have better core loss at high frequency. However, how do the flux density and magnetic field strength (B-H) characteristics and the core loss versus frequency compare for the standard electrical steel used in traction application versus SMC material used in this project? If the B of the SMC material is relatively lower when compared to the electrical steel, then more current is needed to get the same torque.
- How does the resistance vary with temperature and what is the Cu loss at various regions of the machine? The high temperature operation is going to create very high losses. How is this heat (due to the loss) going to be rejected? If there is an enhanced cooling system, then what is the cost of that cooling system? If the cooling system is going to be lot costlier, it can go against the DOE targets.
- What kind of inverter is planned in this project? Is it WBG-based? If so, what is the switching frequency? If the switching frequency is very high, how are the dv/dt and EMI issues addressed in this project?

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

Reviewer 1:
Only limited test data are presented and no calculations are presented showing how the materials will enable a motor with the stated performance targets are being met. The relevance of the solenoid test, as an alternative to a motor test, to assess the performance of the insulation is not clear.

Reviewer 2:
A test stand and a small motor prototype have been built. However, a lot of progress is expected to happen later this year, as per the plan outlined. The team’s response to the above concerns can help to evaluate the project better.

Reviewer 3:
The reviewer referenced prior comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
John Deere is part of the project team, but their contribution to the project is not well explained.

Reviewer 2:
Collaboration is not very evident.

Reviewer 3:
The second project partner (John Deere) is yet to show their contributions, as their tasks do not start until later this year. The team is well equipped.

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

Reviewer 1:
More quantification of the impact of the new materials on machine performance has to be performed. The impact of higher temperatures on efficiency has to be quantified. The proposed high-speed has to be proven to be practical.

Reviewer 2:
The plan to meet the project objectives is not well defined. The plan to develop the electromagnetic, thermal, and mechanical design of the motor is not presented. Go/no-go decisions points are not identified. The risks and mitigation plans are not identified. The scaled-up manufacturing capacity for the new materials is not demonstrated.

Reviewer 3:
Some of the concerns below have to be addressed at some stage of the project. This will help in realizing the proposed technology and also to check the go/no-go decision.

- Regarding the mechanical strength of the rotor and stator material, what is the tensile strength and yield strength of the SMC used in the rotor and stator?
- With respect to the core loss versus frequency, SMCs might have better core loss at high frequency. However, how do the B-H characteristics and the core loss versus frequency compare for the standard electrical steel used in traction application versus SMC material used in this project? If tB of the SMC material is relatively lower when compared to the electrical steel, then more current is needed to get the same torque.
- How does the resistance vary with temperature and what is the Cu loss at various regions of the machine? The high-temperature operation is going to create very high losses. How is this heat (due to the loss) going to be rejected? If there is an enhanced cooling system, then what is the cost of that cooling system? If the cooling system is going to be lot costlier, it can go against the DOE targets.
- What kind of inverter is planned in this project? Is it WBG-based? If so, what is the switching frequency? If the switching frequency is very high, how are the dv/dt and EMI issues addressed in this project?

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

Reviewer 1:
Novel materials are helpful, but there are concerns about practicality.

Reviewer 2:
Yes, this project meets the DOE objectives for high-speed motors operating at high temperatures.

Reviewer 3:
High-speed machines can increase the power density while reducing the volume and reducing the cost. All of these are important targets that are well aligned with what DOE is seeking.

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

Reviewer 1:
Resources are sufficient.

Reviewer 2:
The team has experienced personnel to deliver the tasks outlined in this project.

Reviewer 3:
The scaled-up manufacturing capacity for the new materials is not identified. The testing capability and performance metrics that need to be met are not specified.

Reviewer 4:

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

Presenter

Soma Essakiappan, University of North Carolina at Charlotte

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

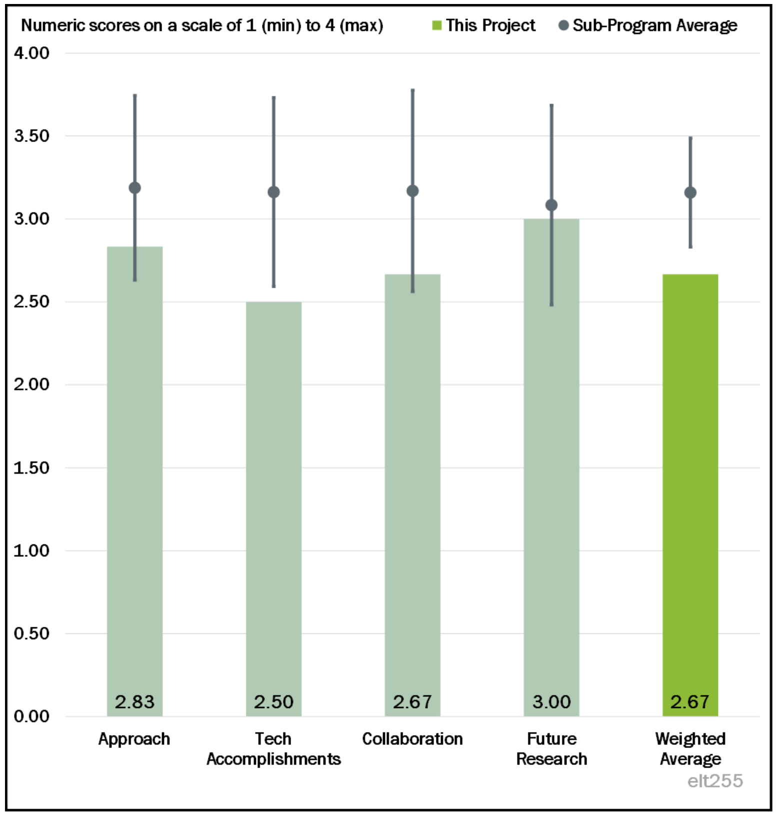

Figure 4-55 - Presentation Number: elt255 Presentation Title: Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque Principal Investigator: Soma Essakiappan (University of North Carolina at Charlotte)

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

Reviewer 1:

The project is in its first year of operation. The project approach is comprehensive and seems appropriate for the new technologies being introduced (the high-speed motor with a novel topology with advanced cooling methods).

Reviewer 2:

It was unclear to the reviewer not only if the proposed motor topology is novel or building upon previously developed technology but also why the proposed motor topology can achieve significant improvement in power density. The proposed topology has some analogy to flux-switching machines and seem to be a high reluctance topology, so it is difficult to see from where the power density improvement is coming.

Reviewer 3:

A new concept has been proposed on the motor technology by moving the magnets from the rotor to the stator. It has been claimed that there is flux doubling, torque double, and an eight-fold increase in power density. However, even the simulation results have not been presented to prove the claim.

The reviewer proposed considering an IPM motor used in traction application (for example, the Bolt motor). If a comparison is made with the same stator diameter and stack length, with the same voltage and current inputs, how is it possible to double the torque? Also, when the windings and magnets are placed in the stator, it is definitely going to over saturate the stator lamination (we have to consider the same stator diameter when we compare). In that scenario, the losses are very high and the torque drops.

When the torque is doubled, that means the no load back electromagnetic force (EMF) increases by the same scale. That implies the base speed is reduced by half. However, the claim is a threefold increase in base speed while doubling the torque at the same time. This claim is contradictory.

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

Reviewer 1:
The project has met the objectives it had planned for the early tasks but is not yet advanced enough for a full evaluation.

Reviewer 2:
The reviewer made the following observations:

- The optimization results showing losses versus size and power density are not very clear. More details about how the optimization was done and what assumptions went into it should be included.
- Since the windings are effectively directly exposed to the airgap harmonics, more details about winding AC losses should be included.
- More details about torque ripple should be included.
- A 3:1 constant power speed range might not be sufficient. Some traction applications require up to 5:1.
- The proposed motor stator topology is fairly complicated and will be difficult to mass produce with the required tolerances while also maintaining the stator roundness.

Reviewer 3:
This project has some claims without any proper justification or technical backing. No information is provided regarding the motor dimensions, DC input voltage, maximum RMS phase current, FEA simulation results on the speed-torque characteristics, or efficiency maps. The most important aspect is there is no evidence of how this machine can double the flux and torque at the same time increasing the power density by eight-fold.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team appears to have all of the capabilities needed to complete the project. The roles of each team member are well defined. The contributions of each team member to the project goals are well explained.

Reviewer 2:
There seems to be reasonable collaboration.

Reviewer 3:
QM Power has some experience with this motor technology. But sufficient technical evidence is lacking regarding power density improvement and cost reduction.

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

Reviewer 1:
The proposed work is reasonable but previously mentioned questions need to be addressed.

Reviewer 2:
The project plan is well structured and has appropriate go/no-go decision points. The major barriers to progress have been identified. The risks and mitigation plans are adequately explained.

Reviewer 3:
The project may showcase a motor-inverter system capable of delivering certain torque and power. However, is it really going to have the power density improvement and cost reduction? A baseline has to be established when a claim like this is made. Without simulation and dynamometer test results, and comparison with state-of-the-art IPM machine having the same dimensions, voltage constraints, current constraints and cooling strategy, it is hard to prove that the target metrics have been met.

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

Reviewer 1:
The project directly addresses the targets on the Electrical and Electronics Technical Team Roadmap.

Reviewer 2:
The project is relevant, but the approach needs more clarification and supporting analysis.

Reviewer 3:
As pointed out earlier, this project claims superior power density with significant cost reduction. However, unless it is supported with sufficient simulation data and dynamometer test data, and compared with a current baseline motor (like Tesla or a Bolt motor), it cannot be said that this project supports the DOE objectives.

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

Reviewer 1:
Resources are sufficient.

Reviewer 2:
The resources the project have seem appropriate to meet the stated milestones.

Reviewer 3:
It is feasible that the project may deliver a motor and inverter. Is it really going to outperform the current state-of-the-art traction machines? That is the big question.

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

Presenter

Mike McHenry, Carnegie Mellon University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

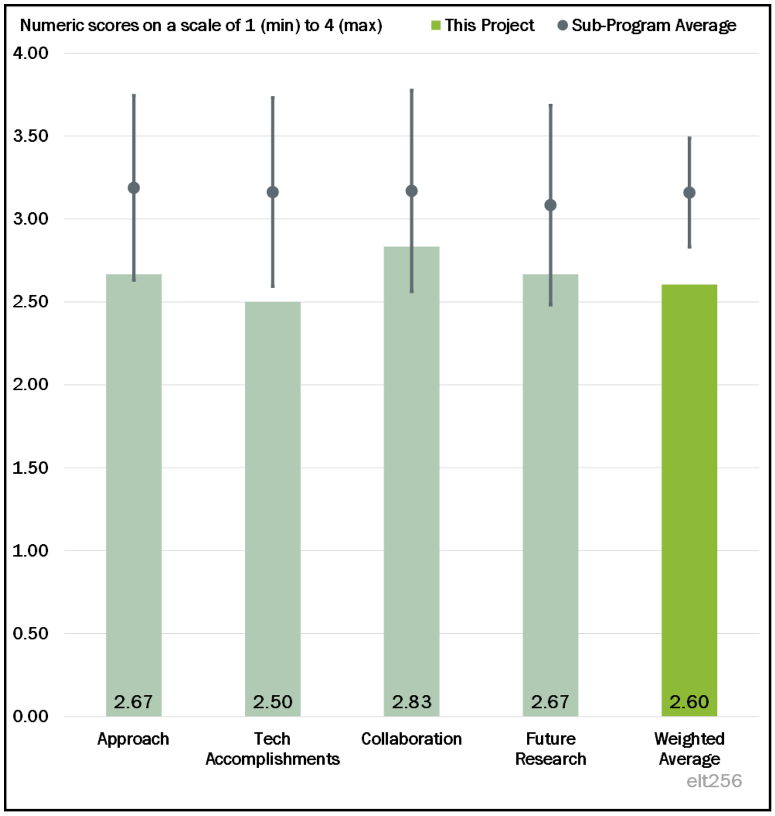

Figure 4-56 - Presentation Number: elt256 Presentation Title: Amorphous Metal Ribbons and Metal Amorphous Nanocomposite Materials Enabled High-Power Density Vehicle Motor Applications Principal Investigator: Mike McHenry (Carnegie Mellon University)

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

Reviewer 1:

The approach to the project is sound. Technical barriers are being addressed adequately.

Reviewer 2:

It is not clear what the bases are for choosing the presented 2.5 kW topology. It is not clear that the proposed approach can lead to an eight-fold increase in power density based on the state of the art of traction motors.

Reviewer 3:

At the time the review slides were written, the project had been in operation for a few months. The approach consists of comparing the performance of a new metal-amorphous nanocomposite alloy to the performance of a commercial iron-cobalt (FeCo)-Metglas, Inc. and conventional electrical steel. The benchmark will be done in a flux switching motor topology that enables high power density with lower coercivity magnets. The comparison will include FEA simulations of the electromagnetic, thermal, and mechanical performance of the motor, as well as evaluation of motor components built with the new materials. The project scope does not appear to include testing of a completed motor. This approach is sufficient to meet the goal of benchmarking the performance of new soft magnetic materials to the degree needed to assess if they should be developed to a higher technology readiness level.

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

Reviewer 1:
Progress is acceptable to date.

Reviewer 2:
The technical accomplishments meet expectations for the initial stages of the project. All the required resources appear to have been retained, and the initial work is systematically evaluating material performance in an existing motor design. Initial design studies of a novel flux switching design appear to have been completed, and initial casting trials and characterization of the new soft magnetic alloy have been completed.

Reviewer 3:
The presented comparison between the 2.5 kW and 20 kW designs is confusing. Since there is a significant difference in the slot fill factor as well as the assumed current density (which is mainly dependent on cooling), it is not clear what the contribution is of the expected improvement in material properties. Also, 20 kW does not represent the typical rating of a traction motor.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seems to be proper collaboration and coordination among team members.

Reviewer 2:
There is reasonable level of collaboration.

Reviewer 3:
The team is well coordinated, and the roles and responsibilities of each team member have been well defined.

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

Reviewer 1:
The proposed future work is well aligned and planned, per the project objectives.

Reviewer 2:
A practical baseline of a traction motor should be used moving forward.

Reviewer 3:
The proposed future research is effectively planned to meet the goals of the project. The evaluation of the FeCo-Metglas alloy adequately mitigates the risk of unforeseen problems arising during development of the new metal-amorphous nanocomposite alloy. The manufacturability of the new alloy and the new motor design will be considered. To be most impactful, some consideration should be given to the interface between the novel motor design and the balance of sub-systems in an EV, such as what kind of power supply and motor controller will be needed. What voltage will the motor operate at? Will conventional bearings and thermal management systems be usable, or will new sub-systems need to be designed? Finally, the capacity of the supply chain to produce the new alloy should be calculated in order to determine what fraction of the EV market can be addressed.

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

Reviewer 1:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 2:
The project is relevant, but the level of expected performance improvement is not very clear.

Reviewer 3:
The project supports the overall objectives because its goal is focused on enabling higher performance motors that can meet the DOE roadmap's performance targets, as well as minimizing the use of HRE elements like Dy.

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

Reviewer 1:
Resources seem to be adequate.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
The resources of the project team are adequate to meet the goals of the project.

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

Presenter

Tim Pennington, Idaho National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

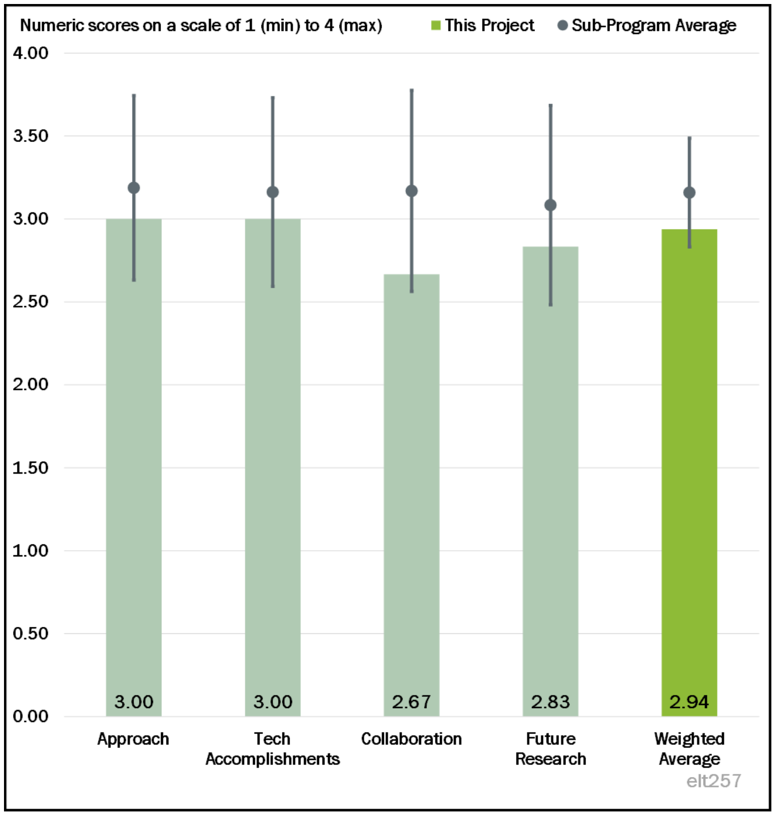

Figure 4-57 - Presentation Number: elt257 Presentation Title: Directed Electric Charging of Transportation using eXtreme Fast Charging (XFC) (DIRECT XFC) Principal Investigator: Tim Pennington (Idaho National Laboratory)

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

Reviewer 1:

This approach is excellent because it considers the baseline with no controls in the system and sequentially adds stationary storage, communication, and reservations for evaluation of result combinations. This also includes both AC and DC charging and fleet and private EVs.

Reviewer 2:

The plan seems well thought out. It will be critical for the project team to establish the baseline case of unmanaged charging in order to fully understand value and impact of controlled scenarios. It was not clear if/how driver behavior was going to be assessed in the project flow—that is, what if drivers are reluctant to be rerouted to other locations as a means of optimization? To some extent, the valuation exercise planned in task 1.4 may help address this by at least providing some baseline value as seen from the driver's perspective. The concern would be that even with a clear value to the driver, consumers may not choose a low-cost scenario based on inconvenience issues. Will the project address driver behavior as a counter to the most "sensible" control scheme?

For grid impacts, it was not clear if the OpenDSS simulations would be used to calculate potential cost impacts to distribution for the unmanaged case and then compare a simple grid upgrades path as a mitigation strategy to the cost of a fully managed system.

The project approach relies on a control system that must span multiple charging locations—having a regional component. It was not clear how, in a competitive market, where some portion of charging stations might fall outside this "controlled" system of chargers, will be accounted for in the work. It was also not clear if the project would attempt to account for competitive pricing's impact on consumer behavior, where competitive pricing strategies are driven by factors not accounted for in the simulation tools. Might this undermine the optimal scenario for system performance, and can the impact be quantized?

It was not clear from the presentation if the AC level 2 simulation capabilities of Caldera™ would be exercised in the project. It was not clear from the presentation if driver behavior related to use of public (XFC) versus lower power public and private charging would be accounted for in modeling efforts. Is there a plan to look at actual driver behavior to inform the Caldera model? Will the impact of site level optimization that is done independently on the regional optimization strategy be studied/simulated? Is all optimization cooperative?

Will results of HIL testing and any limitations encountered be fed back into the Caldera modeling tool to optimize its behavior?

Reviewer 3:
The reviewer provided the following comments:

- The objective is to determine the value of directing when and where EVs will use XFC to minimize cost and grid. The major problem with the approach is that it assumes there is a growing demand for EVs but that does not mean the growth in XFC of such vehicles will be in parallel. It will not be a one-to-one correspondence because XFC will cost more. What is the willingness of the market of EV owners to pay extra for XFC? There was no discussion of that issue—on which this project is predicated.
- The project fails to identify the end-user of the determination made by the modeling. Is the end-user a fleet, individual EV owner, an XFC station owner/operator or an electric utility?
- The assumptions of neither the model nor the modeling scenarios are not well laid out and clear. Whether the model and its results are realistic usually are predicated on the assumptions that go into the model. How realistic are these assumptions? Have the assumptions been tested for realism?
- Of particular primary importance, nobody knows where the future XFC stations will be located. There is no guarantee that they will be evenly distributed across a metropolitan area. There may even be an unforeseen tendency of competitors to cluster because of the effect of real property cost and real property availability.
- Of particular secondary importance is that consumer input seems to be ignored in the model. How much are owners of EVs willing to pay extra for XFC? How many owners of EVs are willing to pay for XFC?
- Of particular tertiary importance, how willing are owners of EVs to drive to an unfamiliar neighborhood or location, perhaps, across town, to XFC their vehicles? It may even take more time than it is worth depending on travel conditions, such as traffic congestion. Or, the XFC station was not on the route the driver already had in mind for his travel that day. A lot of driving involves trip-chaining in which a driver expects to make certain stops in a certain order (buying groceries, going to a medical appointment, picking up dry cleaning, dropping off children, etc.). Was trip-chaining taken into account and the inconvenience imposed on trip-chaining or even normal commuting patterns when a driver is directed to an XFC station out of his way?
- Of next importance is that there is no clear indication about the make-up of EVs covered by this model and their range, their travel patterns (origin, destination). The reviewer questioned the failure to include return-to-base, centralized XFC for utility and municipal fleets, rental cars, etc. The reviewer also questioned the failure to include MD and HD vehicles in the modeling.

- The project team needs to tell the reviewers how the results of the directed charging model will be corroborated against reality, .

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

Reviewer 1:
Since this is the first year of the project, the contributions of each lab are clear and complementary to each. The initial operation and approach are clear and seems to be on target.

Reviewer 2:
The team seems to have made good progress on early tasks even with the impact of COVID-19. Accomplishments to date were based on isolated lab efforts.

Reviewer 3:
The results so far only indicate what the model can do and what the model can forecast. There is no way for anyone to determine whether the results of the directed charging model are (rather will be) realistic at all; in other words, there is no way to confirm the model. The reviewer would evaluate technical accomplishments and progress by comparing it to reality or improvement of what is already real.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The labs have variations to their expertise and their contribution is a good match to success of this project.

Reviewer 2:
To date, much of the work completed has been segregated across the project lab teams, requiring minimal cooperation between the participating labs, so it is difficult to assess how well the teams will handle the complex coordination tasks to come later in the project.

Reviewer 3:
No end-user was identified. Not even the local electric power utility was included as a collaborating or cooperating organization. The local metropolitan transportation planning organization, which is required by the U.S. Department of Transportation (DOT) to be involved in approving highway/transit projects for federal funding and collects travel demand data and travel pattern data for different surface modes, was also not included as a collaborating or cooperating organization.

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

Reviewer 1:
The first-year data are expected to provide results to guide planning of grid usage and benefits of balancing stationary storage needs with communication and reservation requirements to meet EV charging needs.

Reviewer 2:
From the milestone list, it appears the project team has a good plan for addressing their future work. One concern is that project results will not be published until late in 2021, while lessons learned from the effort might benefit near-term system planning and station deployment. Is there any plan to report results prior to the final report to benefit real-world infrastructure deployment?

Reviewer 3:
This project is premature. There are no data on market demand for XFC of EVs, nor are there data on where future XFC locations will tend to be. No data were furnished that use of data on specific travel patterns of EVs was made.

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

Reviewer 1:
The project is very relevant since it provides information on how and where to add resources and communication at charging locations.

Reviewer 2:
The project studies optimization strategies that stand to benefit a wide audience of stakeholders. This seems befitting of a DOE sponsored activity.

Reviewer 3:
The PI did not make a case for what is so important about developing this model for directed XFC. Will not having it make any significant difference to society, energy security, fossil fuel consumption, climate change?

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

Reviewer 1:
The noted team sizes and schedule seem reasonable. This assessment is also based on progress the project team has shown to date which also seems in line with project plans.

Reviewer 2:
These laboratories have the resources to accomplish this project goals and provide guidance on how to balance the grid and vehicle charging needs.

Reviewer 3:
The reviewer had no comment.

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

Presenter

Matteo Muratori, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

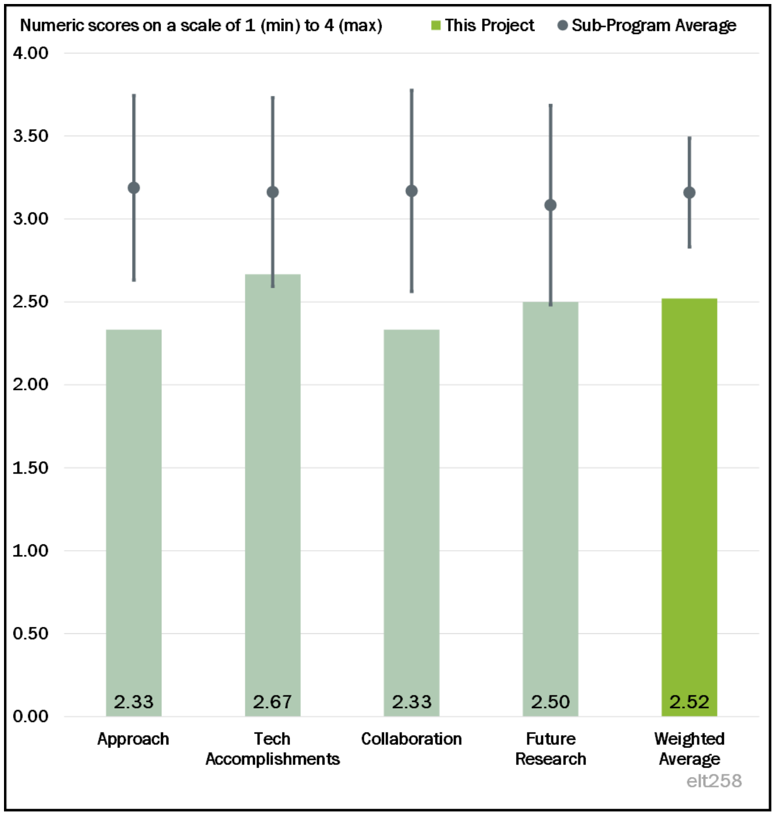

Figure 4-58 - Presentation Number: elt258 Presentation Title: Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC) Principal Investigator: Matteo Muratori (National Renewable Energy Laboratory)

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

Reviewer 1:

The project goals seem very broad. It was not clear what bounding conditions would be used for the key questions listed on Slide 10—who will optimization benefit? For example, if smart charging can reduce voltage variation from solar production, but requires a control technique that hinders EV drivers with a high level of inconvenience, how would driver behavior be accounted for?

The presentation did not mention engagement with utilities that serve the area being simulated. It seems like this effort would benefit from utility engagement. Will grid scenarios be reviewed by utilities?

The models planned have broad coverage and very complex inputs. How will the models be vetted, given the goal of covering disruptive scenarios in the transportation field? It was not clear that there is a baseline case that can be simulated to test the model's outputs.

Reviewer 2:

The project focus is on larger vehicles because they do require XFC. This also depends on the usage because if the vehicles are only operated at one shift, rather than continuous, slower fast charge should be considered.

Reviewer 3:
It is unsatisfactory that there were absolutely no slides indicating the explicit goals or objectives of this project. There was an approach slide, but approach to what? Widespread electrification is mentioned but for what (as if there was no electrification) already in-place?

Second, any and all modeling requires making assumptions. The assumptions underlying the modeling were not laid out. There was no mention of whether any kind of reality check was performed on those assumptions. The project team's assumptions include high EV adoption, the make-up of the kinds of EVs assumed in the model (their range), travel patterns (origin and destination) of EVs, how many EV owner/operators would be willing to pay more for the higher cost of XFC, distribution of XFC EV charging stations, and where the XFC stations are to be located (if as claimed, they will be in downtown for ride-hailing EVs, land value will be very expensive—how is that taken into account?).

Lastly, when the model runs from the computer produce results, how are those results going to be validated and verified? How realistic are the results?

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

Reviewer 1:
The project is in the initial stage, so more time is needed to see how the various approaches are combined and used.

Reviewer 2:
Progress noted seems reasonable but is very preliminary (3-year project that has only been underway for a few months). For that reason, it is difficult to assess the longer-term efficacy of the project.

Reviewer 3:
The reviewer asked how progress or technical accomplishments can be measured where there are no goals or objectives explicitly stated. It would be unfair, impartial, and non-objective of the reviewer to use implied goals and objectives.

Moreover, what has been presented as technical accomplishments are really what the model can do and forecast in different limited scenarios. The reviewer questioned how model results could be validated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project does not appear to have progressed to the phase where integration of the simulation tools from NREL and LBNL will be merged into a system. Based on this, it is difficult to address the status of collaboration across the project teams.

Reviewer 2:
The project appears to be well organized, but specific items for each team is still not clear in this early stage of completion.

Reviewer 3:
No end-users were identified. The reviewer questions the project value without an end user identified. No collaborating or cooperating organizations outside themselves and DOE were specified. The reviewer was disappointed because the reviewer would have expected as critical collaborating or cooperating organizations: the local electric utility, which is Pacific Gas and Electric (P&GE) and the Metropolitan Transportation Commission (MTC) for the nine-county San Francisco Bay area. PG&E is critical because it is the utility that has the monopoly over the distribution of electric power in the San Francisco Bay area, over which the model is being applied. MTC is critical because it is the federally and state-recognized metropolitan transportation

planning organization involved in recommending all local highway and transit projects for federal funding. The MTC is responsible for collecting data and forecasting transportation patterns including origin and destination of trips by mode and frequency. While the PI did not know the answer as to whether MTC provided input to the model that is the subject of the project research and a staff member had said he did have contact with MTC, the fact that MTC is not a collaborator and the slides do not mention MTC input made the reviewer skeptical about the extent the local experts on data on travel patterns and travel demand were consulted and asked to cooperate on a project relying on important local travel data.

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

Reviewer 1:
The specific focus of high-power charging and within the area of San Francisco should be expandable to other areas and a broader range of vehicle charging power levels. More time in this project will lead to a better conclusion on future research potentials.

Reviewer 2:
With broad goals, complex models that consider future looking (and disruptive) scenarios, and the need to integrate output from the models into a coherent picture, a key challenge will be to develop baseline scenarios that allow assessing model efficacy. How will researchers know that the Transportation Energy & Mobility Pathway Options (TEMPO) is providing valid results? This question becomes even more complex when the various models are combined to assess regional results. It was not clear from presentation how researchers will validate models to show that results presented from disruptive scenarios will be valid.

Reviewer 3:
This project is premature. There are no market data on the numbers or proportion of owner and operators of EVs who would pay for XFC knowing that it costs more than conventional charging. There are no data on where and how many XFC stations will be located. The reviewer was skeptical that the project actually made use of data on travel patterns (origin and destination) and travel demand by mode and frequency from the MTC for the nine-county San Francisco Bay area for input into the project's model.

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

Reviewer 1:
Understanding regional impacts of disruptive changes in transportation systems is vital to enable sensible future planning for utilities, cities, and other stakeholders in the transportation field. Advancing understanding in this area seems befitting of a DOE project.

Reviewer 2:
While passenger cars need XFC, that usage may be less than once a month so the timing of this needs to be considered.

Reviewer 3:
The project team does not make a case for the relevance of this project to DOE objectives. The team needs to answer the question: what is so important about developing this model—will not having it make any significant difference to society, energy security, fossil fuel consumption, climate change?

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

Reviewer 1:
Because the project is very "early-in" it is difficult to assess team sufficiency. Reasonable progress has been made since project inception which leads me to rate this as sufficient.

Reviewer 2:
The predictive part of when EVs need to be charged is not included at this point, but there may be data available from other projects and used in this project as needed.

Reviewer 3:
This reviewer had no comment.

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

Presenter

Marcus Malinosky, Daimler Trucks North America

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

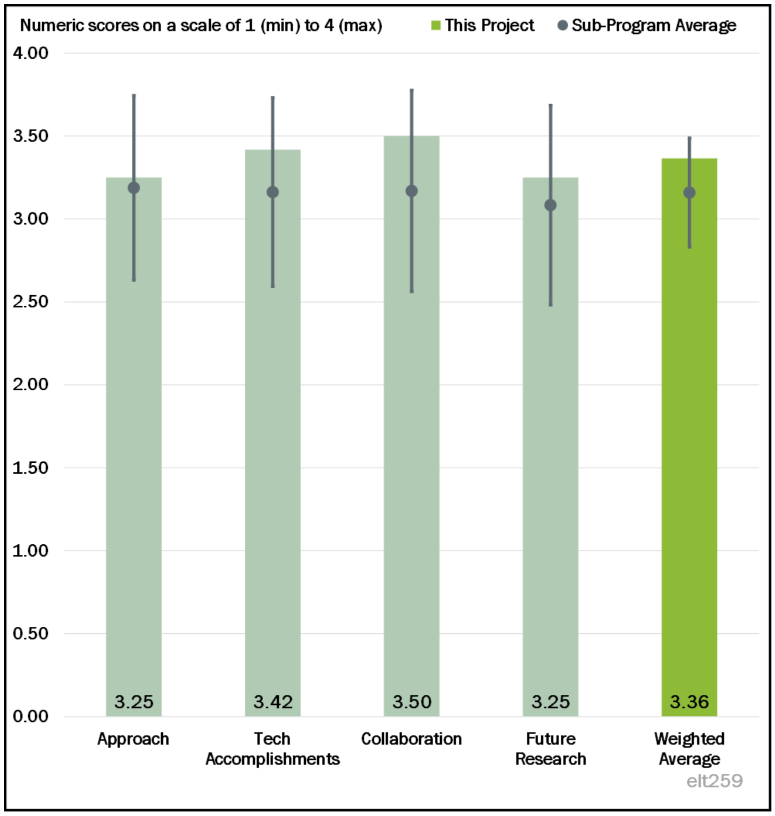

Figure 4-59 - Presentation Number: elt259 Presentation Title: Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions Principal Investigator: Marcus Malinosky

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

Reviewer 1:

The project is leveraging global design, engineering, sourcing, and vertically integrated production capabilities to quickly achieve economies of scale and reduce product costs. Through a "co-creation" approach with fleet partners, the project will collect operator feedback and determine best practices for continuous improvement.

Reviewer 2:

In spite of delays due to the COVID-19 outbreak, the project appears on track from a timeline that is relatively aggressive.

Reviewer 3:

The barriers to short-term progress have been listed related to the manufacture, delivery, and testing of the B sample units at Meier and UPS. However, barriers that are no doubt already recognized for C and D samples have not been listed. For example, the presentation implies that the powertrain design may change from using wheel motors to an e-axle arrangement (reduction in motors). This kind of powertrain change may present some barriers not seen in previous samples. The presentation also states a goal of achieving 2.0 kWh/mile to increase range with the battery pack—this seems like a very tall order, given the likely duty cycle of the two fleet partners. The reviewer assumed there are significant barriers related to that goal.

Reviewer 4:
It is very difficult to do an evaluation with so little information. The reviewer would have liked to see information about how many trucks, what type and size of battery, what types of duty cycles proposed, and how the designs were/will be decided. This difficulty is at least in part caused by the format and content requested by the system. However, the reviewer did not think it is very useful. Additionally, note the title mentions weather but the presentation does not.

Reviewer 5:
The project is being executed by a highly capable organization with excellent partners. Good product development processes are being used with critical milestones clearly laid out. The reviewer's main concern was with respect to details on customer requirements for the target segment. Other than a 250-mile range, no customer requirements including charging time or weight are specified. While it is possible that many routes could be fulfilled with a 250-mile capable BEV, customers may use the same truck on multiple back to back routes which limits charging times.

Reviewer 6:
Daimler Trucks North America LLC (DTNA) E-Mobility Group (EMG) is leveraging global design, engineering, sourcing and vertically integrated production capabilities to quickly achieve economies of scale and reduce product costs. Through a "co-creation" approach with fleet partners, DTNA EMG will collect operator feedback and determine best practices for continuous improvement. Changing eMachine for increased efficiency will allow the project performer to overcome barrier of range anxiety.

This approach will allow commercialization of battery powered electric trucks, preferably adopted by fleet owners such as UPS.

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

Reviewer 1:
The vehicle mule is together and all targets appear to be on track in spite of COVID-19 delays. The B-sample build was completed in April of 2020 and testing is in progress.

Reviewer 2:
It is encouraging that B sample delivery and testing are underway as they will provide invaluable input to the remainder of the project. Other completed and in-process steps appear to show good progress toward achieving objectives.

Reviewer 3:
The project team has made significant progress and achieved critical project milestones for Phase 1a: Research, Design, Building and Commissioning—Vehicle Design and Specifications, including completion of the B-sample build.

Reviewer 4:
The team has accomplished much in a very short time, including the B-sample build and 75% completion of C-sample design documentation. This is highly impressive, given the short time since the project began.

Reviewer 5:
There is quite great progress, as outlined by the PI: The B-sample build was completed April 2020; B-Sample vehicle testing in process; C-Sample vehicle design and integration is in process with approximately 75% of the design documented; C-sample vehicle simulation is ongoing; D-Sample vehicle design is in process; and D-Sample development supplier selection in process.

The project team has made significant progress and achieved critical project milestones for Phase 1a: Research, Design, Building and Commissioning—Vehicle Design and Specifications, including completion of the B-sample build.

Reviewer 6:
The project has just started. Subsequently, the reviewer referenced prior comments and indicated that it is hard to know whether the team is doing a good job. The reviewer would really like to see some information about what different truck versions were included. The presentation includes minimal information.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team has excellent partner organizations that have demonstrated a commitment to increasing freight efficiency. To date, the bulk of the work is likely to have occurred at DTNA (the prime). Partner participation should increase significantly once testing is under way.

Reviewer 2:
Collaborators are Meijer, UPS, and SCAQMD for various aspects of the project.

Reviewer 3:
Strong fleet partners and SCAQMD is a great agency to work on these types of projects.

Reviewer 4:
The appropriate mix of OEMs in conjunction with testing partners appears well coordinated relative to the current project timelines.

Reviewer 5:
Coordination between Daimler and listed partners looks to be productive and effective. Short term schedule risks have been identified and highlighted.

Reviewer 6:
Once the trucks are built, the team will have very good partners to test them, but the reviewer was not so sure about build, design, and process data.

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

Reviewer 1:
The reviewer noted that future research includes the following: continuing B- Sample vehicle testing; completing C-Sample vehicle design, integration, and simulation; and beginning C-Sample vehicle procurement. In period, the team will also complete D-Sample vehicle development supplier selection and begin D- Sample tooling supplier selection.

Reviewer 2:
The project is aggressive and timelines appear met. However, the reviewer would like to have seen more detail relative to the technology used to address the diverse climate conditions the vehicle will operate under (hot/cold). A number of studies show the issues associated with EV range loss relative to heating, ventilation, and air conditioning requirements. Some technical details in the vehicle design and approach would be appreciated.

Reviewer 3:
The proposed future work is logically laid out. The reviewer's main concern was with respect to time allowed for testing of the hardware and software. C-sample build and go/no-go approval are both shown to occur in the same month (milestones slide). It is also not clear what regulatory approvals are required prior to production release.

Reviewer 4:
The plan outlines the steps and schedule in a logical way, but details of future technical challenges have not been outlined. One objective of the project is to test under diverse climate conditions, but this objective is not reflected in the presentation material. There are a number of diverse climate conditions that will not be demonstrated by Michigan and California climates.

Reviewer 5:
The project aligns very well with field testing of B, C and D samples.

Reviewer 6:
This progress report does not include enough information to enable the reviewer to properly evaluate the work. There is no technical detail provided. So, this reviewer cannot adequately address the questions posed. It was unclear to the reviewer how to ask questions of the poster presenters.

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

Reviewer 1:
This project advances state-of-the-art HD electric truck technologies to full commercialization and provides a platform for the market to reduce maintenance and energy costs, diesel consumption, carbon, nitrogen oxides, particulate matter (PM), and emissions.

Reviewer 2:
The significant testing of vehicles in customer operations and duty cycles is a great way to support overall DOE objectives. This testing should provide invaluable information as electrified vehicles start to be implemented in the marketplace.

Reviewer 3:
Battery-powered vehicle are relevant to DOE VTO goals and objectives.

Reviewer 4:
The goal of reducing petroleum needs requires a reduction across the vehicle spectrum, both LD and HD. This project approaches the HD transportation sector via electrification and if successful is cited to serve the needs of 75% of the marketplace.

Reviewer 5:
This project is accelerating development of BEVs in collaboration with customers. There are no BEVs on the market today from major truck OEMs that meet the needs of 70% of the freight hauling market. While new entrants can be exciting and innovative, many customers want to continue to purchase from OEMs with which they have built a long relationship and where they know what to expect from the service and support network. One concern here is that commercial feasibility (i.e., cost and fleet ROI is not addressed.

Reviewer 6:
All projects aimed at replacing fossil fuel use with electricity are consistent with DOE goals.

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

Reviewer 1:
The project team has demonstrated excellent use of the available resources to date. The COVID situation will strain all organizations as the team has pointed out. If the team is able to continue to access and leverage global resources, they should be able achieve their milestones as planned.

Reviewer 2:
The project has sufficient resources.

Reviewer 3:
The project appears funded sufficiently to overcome barriers and hit the targets of a relatively aggressive timeline.

Reviewer 4:
At this point, resources appear to be sufficient.

Reviewer 5:
The project has enough funding and resources. The project report looks quite different compared to other DOE VTO-EDT projects.

Reviewer 6:
There is not enough information provided to answer this question meaningfully.

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

Presenter

Sam McLauglin, Volvo

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

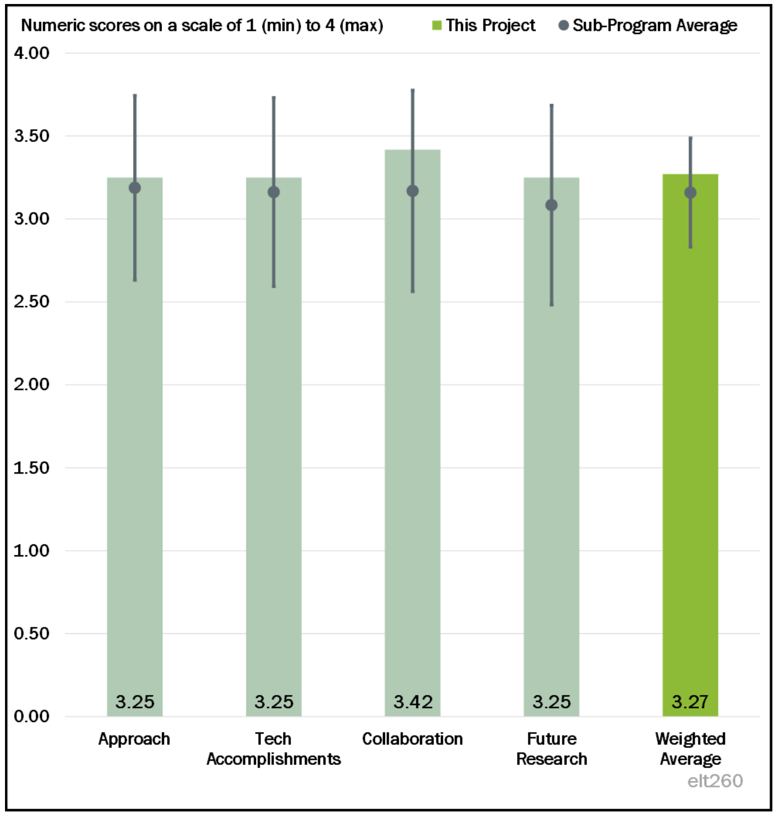

Figure 4-60 - Presentation Number: elt260 Presentation Title: Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management Principal Investigator: Teresa Taylor

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

Reviewer 1:

This project has a limited, clearly-defined mission that will improve the operating performance of existing electric trucks. The improved efficiency will substantially improve the economics of owning an electric truck. The energy management system (EMS) will reduce the TCO at minimal added cost.

Reviewer 2:

The reviewer observed a solid project approach by understanding fleet partners' baseline operations and establishing project duty cycles. The team is combining a physics-based truck model, battery information, utility demand charges, and database parameters as inputs to a machine learning algorithm that will predict energy use, operational energy cost, and battery performance. The reviewer also noted installing vehicle charging locations at fleet partners and demonstrating intelligent energy management system in daily operations with fleet partners covering both cold- and hot-weather conditions.

Reviewer 3:

The approach of combining real-world usage data and vehicle modeling to suggest the best energy efficient route is reasonable. The machine learning component seems a bit unconvincing.

Reviewer 4:

Although the reported completion percent is only 5% at this time, the reviewer thought the approach is somewhat vague in terms of objectives. The baseline is not well defined, so progress against that baseline would be very hard to measure. In addition, no milestones or tasks were listed for calendar year 2022 in the slides. The claim of achieving 20%–30% in battery driving range would appear to require many improvements in vehicle component integration as well as improvements in the management of vehicle operations. These kinds of improvements in energy consumption are few and far between in today's diesel world.

Reviewer 5:
Conditional route optimization can play a role in energy consumption reduction. The project is relatively early in its stages, so it is difficult to ascertain how much of the physics-based model development, duty cycle development, and systems integration have occurred.

Reviewer 6:
The project is logically laid out with data from multiple vehicles in use at a customer location, and a baseline vehicle has been defined. The only weakness the reviewer saw is if the project were reliant on driver behavior as a significant source of efficiency gains, it will be difficult to assess the real-world effect of those gains. The reviewer did not believe one can assume 100% compliance from drivers as is stated in response to the question on driver behavior.

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

Reviewer 1:
Work streams are in progress and appear to be on track based on project timing chart.

Reviewer 2:
The project is just getting started, but the project team seems to have made significant progress toward understanding the duty cycles, routes, etc., of the vehicles they will be equipping with EMS.

Reviewer 3:
Accomplishments include the baseline of fleet partners' operations: 10 Vehicles have been identified at Murphy Logistics, and the VIN # information is being collected. Understanding fleet partners' baseline operations and establishing project duty cycles. Physics-based truck model is completed. University of Minnesota has identified all of the model parameters, their descriptions, and current values for the electric truck model.

Reviewer 4:
The project is too early to determine if it is behind schedule or requires additional project management to overcome the inevitable issues.

Reviewer 5:
Progress listed on the milestone chart does not show any completed items in the six or so months since the contract award. The milestone chart does not outline dates within the year that tasks should be completed. No milestones for year 3 are listed.

Reviewer 6:
The project is in the very early stages. Work on the truck model has begun though much of what has occurred to date is planning and analysis. Two quarters feels like a long time to spend characterizing duty cycles for 10 trucks (Accomplishment and Gantt chart from Proposed Future work slides).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
In addition to being led by the truck manufacturer, which is important, the team has two partners that will actually run the trucks in commercial operation. That is good; it is also key that a university was included to deal with the key feature: machine learning.

Reviewer 2:
This reviewer described the team is very strong:

- Volvo (PI)—contract management, project management, and engineering resources for truck operation, data collection and route simulation
- University of Minnesota—vehicle to capture cloud data management, algorithm development, data analytics, and secondary driver display
- Greenlots—electric charging support and installation of chargers
- HEB Companies—fleet testing, operational data, and driver feedback
- Murphy Logistics—fleet testing, operational data, and driver feedback.

Reviewer 3:
Partners are appropriate to meet the project objectives.

Reviewer 4:
A sufficient blend of OEMs, academia, and site partners are available for a proper cold/hot (Minnesota/Texas) demonstration of the technology.

Reviewer 5:
Partners have been identified and the roles seem fairly clear. The specific areas or teams within Volvo are not identified in the presentation.

Reviewer 6:
Duty cycle data have been collected from the fleets and the modeling work by the University of Minnesota has been kicked off indicating that all parties are engaged.

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

Reviewer 1:
Future plans and research include the following:

- Collecting and analyzing fleet customers' baseline duty cycle
- Creating a baseline database using all collected parameters for chosen duty cycles and deciding representative duty cycles for the project
- Creating the project verification plan
- Placing purchase order for build of truck demonstrator
- Creating physics-based, battery electric truck model
- Creating initial machine learning
- Defining locations for on-route charging
- Determining optimal on-route charging locations for fleets.

Reviewer 2:
The team proposes to get even better supporting information and modeling results before they actually operate the trucks; that means that many of the potential glitches will have been foreseen and can be avoided.

Reviewer 3:
Current and upcoming project tasks make sense.

Reviewer 4:
As stated earlier, the project is early and it is hard to ascertain the future steps due to the completion of the current steps. Once the models are complete, simulation should provide a solid framework and estimate of the potential savings utilizing intelligent holistic battery management within the boundaries of the test vehicles and locations. Details on the type of environment would be helpful (cities, suburbs, rural delivery routes in Texas and Minnesota, or a combination?).

Reviewer 5:
The presentation indicates that attempts will be made to modify routes for greater efficiency. However, modifying routes is a much more complex question than just trying to optimize energy efficiency and charging points. Delivery deadlines, driver hours of service, vehicle utilization for the next shift, and many other factors are needed to determine optimal routes.

Reviewer 6:
The proposed future research follows a logical progression. The reviewer’s concerns were that work for the final year has not been detailed which will include testing and validation. Since performance validation is listed as a barrier (Slide 2), this should be a major emphasis for the team.

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

Reviewer 1:
It supports DOE VTO objectives of more energy efficient freight movement and EV technology adoption.

Reviewer 2:
This project will address a major barrier to electric truck operation: inefficiencies that raise costs. In addition, better understanding of how the system works should do much to reduce range anxiety.

Reviewer 3:
Intelligent routing will play an increasing role in petroleum reduction and transportation efficiency.

Reviewer 4:
Energy efficiency, regardless of whether it comes from diesel pump or a charger, is in line with DOE objectives. This project addresses efficiency and can lower the cost of the truck itself through smaller batteries which will also help with adoption. The approach is likely to be commercially feasible because the gains are through algorithms and software development, which can be implemented cost effectively.

Reviewer 5:
This project is quite new and further refinement of the project objectives is necessary to assure support of DOE objectives. The reviewer thought the project has very good potential to provide learning that will further DOE objectives by having a practical demonstration of HD EV implementation in a real-world environment.

Reviewer 6:
The project plan is to research, develop, and demonstrate life cycle cost-effective Class 8 BEVs equipped with an intelligent EMS capable of commercial operations of greater than or equal to 50 miles per day as well as increased efficiency and productivity when compared to baseline 2019 Mack and 2015-2020 Volvo HD battery EV fleet performance.

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

Reviewer 1:
There are sufficient resources to complete the project.

Reviewer 2:
Resources appear adequate as the project is on track.

Reviewer 3:
The project appears appropriately funded for the work outlined.

Reviewer 4:
This is always hard to evaluate without much more detail, but funding levels seem reasonable.

Reviewer 5:
The project team has not identified a deficiency though the current COVID situation will strain all resources.

Reviewer 6:
Given the very early state of this project, this is hard to evaluate at this time.

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

Presenter

Elton Rohrer, Ricardo

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

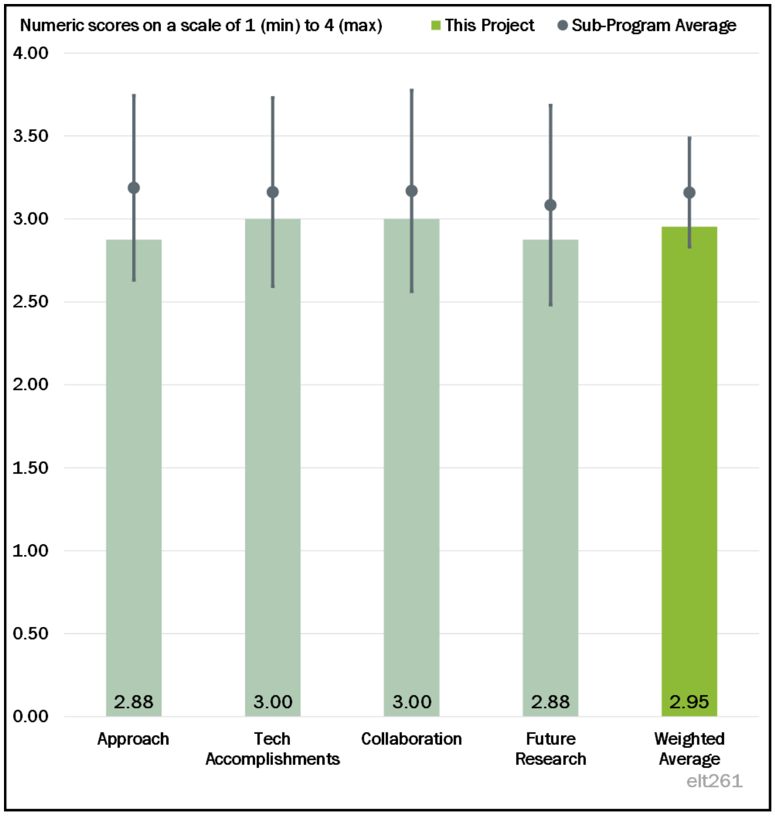

Figure 4-61 - Presentation Number: elt261 Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter Principal Investigator: Ben Maruqart (Ricardo)

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

Reviewer 1:

The project is well designed and feasible to design and develop a class-leading, high-power density, highly efficient 250 kW continuous SiC inverter. Inverter development and drive system component development, subsystem development and system testing, system integration development, and vehicle build vehicle integration and demonstration of two Class 8 trucks are part of the approach.

Reviewer 2:

Prototype design and testing of the 250 kW SiC inverter with efficiency greater than 92.5% in year 1 followed by a greater than 98.5% efficiency SiC inverter in year 2 will lead to quite appropriate hardware for in-vehicle testing in year 3; this is a good approach. This approach allows for overcoming the learning curve, technology risk mitigation, supply chain, and capability build-up followed by prototype hardware testing of a 250 kW SiC inverter in the powertrain for HD trucks.

Reviewer 3:

Technical barriers are mentioned in the presentation, but it seems that little time is devoted to them or how they will be solved. For example, the goal from A samples to B samples is to increase efficiency from 92% to 98.5%. However, the presentation does not mention how this increase will be accomplished. The battery system operating voltage is mentioned as a big barrier, but not why this presents issues or how they will be solved. Integration with the powertrain and testing on vehicles is mentioned as a task, but not how the numerous challenges this presents will be covered.

Reviewer 4:
The reviewer's impression was that the overall project is lacking a systemic approach. The stated objective is to develop and demonstrate a Class 8 BEV but the focus is inverter development. Other than packaging, there is no discussion on integrating and optimizing the system to take advantage of the SiC technology which might include trade-offs in battery size and the traction motor for performance and reliability nor is there a target efficiency for the whole system. Prior work on LD EV applications points to systemic benefits when implementing SiC inverters. The work related to the rest of the vehicle appears to only serve as a demonstration of the inverter which then makes the diesel baseline inappropriate (as opposed to a baseline utilizing Si inverters).

The stated efficiency and power density goals are aggressive though whether the efficiency is peak or average over a duty cycle is not specified.

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

Reviewer 1:
Proof of concept inverter design has started, and several different simulation scenarios have been completed.

Reviewer 2:
It appears from the presentation material that progress has been made to execute the A sample inverter design and software. Will there be any A sample testing at the vehicle level to start to iron out some of the integration challenges with the first samples before the B sample parts are available? This step is not mentioned in the presentation that the reviewer saw.

Reviewer 3:
The team appears to be making good progress on the stated approach.

Reviewer 4:
The team is making progress; however, there seems no indication that technical progress aligns with the approach. This reviewer doubted that, by end of September 2020, the project team will have a prototype of a 250 kW SiC inverter. Vital parts of inverter are evaluated and selected.

The 250 kW SiC traction inverter system simulation and design tasks seem completed including soft switching scheme simulated in PSIM. Performance of Wolfspeed's SiC power module with part number CAB450M12XM3 for 250 kW power application is understood by project team.

Common-mode and differential-mode (DM) noise generated by inverter as understood by the project team. The project reviewer doubted that the proposed shunt-based current sensing method will lead to any solution that will support targeted high efficiency greater than 98.5 in the SiC Inverter B-sample. This will be quite problematic when battery voltage is 656 V nominal contrary to current sensor simulated at 1000 V DC bus for 250 kW SiC inverter. There is no novelty in the proposed current sensing circuit.

It seems like the team is developing a vehicle, it has electric drive systems and eAxle in collaboration with project partners. It is hard to assess progress from the project report. Looks like the PI is proposing more than he could finish in a year even in collaboration with project partners. This reviewer has high doubts about successful completion of this project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team consists of Ricardo Inc. as the prime and leading the SiC inverter development, North Carolina State University providing simulation and design expertise support, and TransPower Inc., a wholly

owned subsidiary of Meritor Inc., as a leader in developing and supplying integrated drive systems and full electric truck solutions. This team is collaborating and achieving results.

Reviewer 2:
North Carolina State University's Freedom Systems Center and Trans Power/Meritor are collaborating with the lead organization, Ricardo. All partners have their role identified. It is extremely important that the 250 kW SiC inverter is fabricated and tested in the vehicle platform developed by Meritor.

Reviewer 3:
The presentation articulates activities ongoing with North Carolina State University, but little with Meritot/TransPower so far.

Reviewer 4:
The project team focusing on the SiC inverter appears to be collaborating well as evidenced by their good progress and accomplishments. However, the fact that the chosen battery voltage is a challenge and the lack of details on aspects of the vehicle not related to the inverter are concerns. The slide listing Technical Accomplishments and Progress on the Meritor eAxle (Slide 16) are nearly word for word from the Meritor website, which may indicate that the team working on the remaining powertrain is not entirely engaged.

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

Reviewer 1:
Future project activities will be focused on the development of the 250 kW SiC inverter to achieve 98.5% efficiency and the system level integration and testing to allow the demonstration of two Class 8 trucks operating for 250 miles daily.

Reviewer 2:
In the proposed future research, relevant topics are stated out in the project report.

Reviewer 3:
The plans for integrating the designs with the e-axle on chassis need to be fleshed out in more detail.

Reviewer 4:
The steps related to the inverter are well documented though there is not much detail on vehicle integration. The challenges listed on Slide 19 (Research Challenges and Barriers) primarily relate to vehicle integration and test issues which are not addressed in the future research.

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

Reviewer 1:
This project will develop highly efficient electric powertrain to allow the acceleration of U.S. truck fleet electrification, which is closely tied with DOE VTO objectives.

Reviewer 2:
Yes, it meets the objectives of improving the efficiency of driving EV powertrains in a much more efficient manner as well as doing so in a much smaller package.

Reviewer 3:
The project does support the overall DOE objectives; however, the 250-mile range is a very limited sampling of Class 8 trucks on the road today. The goal should be much higher: a typical Class 8 truck can run 600 miles on a single load of diesel, a typical route would be 55 miles an hour for 4 hours, stop and then 55 miles an hour

for 4 more hours. So, each leg of the driver's day would be 220 miles, for 440 miles per normal work day. This project should set higher mileage goals on a single charge.

Reviewer 4:
The project is advancing development of the SiC inverter with very aggressive efficiency and power density goals which should contribute to large scale commercial adoption of BEV technology. Missing is discussion on a cost target or commercialization potential and there is limited effort in integrating or optimizing the overall BEV architecture to take advantage of the inverter technology. There is limited innovation apparent relating to the work to integrate the whole vehicle.

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

Reviewer 1:
Project has sufficient resources to complete the project.

Reviewer 2:
This early in the project, it is hard to tell if resources are sufficient. They appear to be so at this time.

Reviewer 3:
The team does not state that additional resources are needed. The non-integrated approach the team is pursuing may be related to resources, but this has not been stated.

Reviewer 4:
The project has all necessary resources except slow progress made to date. It seems like the project team has promised more than they could deliver.

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

Presenter

Brian Lindgren, Kenworth

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

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

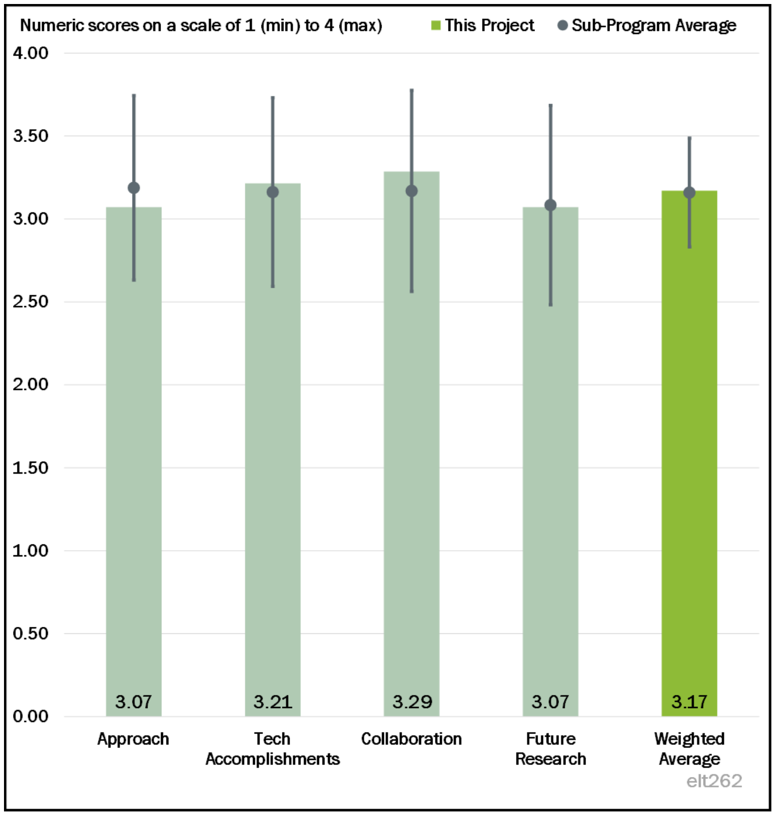

Figure 4-62 - Presentation Number: elt262 Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging Principal Investigator: Brian Lindgren (Kenworth)

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

Reviewer 1:

The project is in the early stages so it is difficult at this point to ascertain the success of the approach. However, the appropriate mix of collaborators appears present for the project.

Reviewer 2:

Will the project incorporate what is learned from SuperTruck to improve vehicle energy consumption? That was not stated in the approach but would be a big enabler to making this work. It is also not clear why a wireless charging approach would be preferred at this level of power transfer and vehicle specialization.

Reviewer 3:

The project team has taken a customer focused approach with a detailed route analysis as a starting point for the technical specifications. The milestones and timeline are logical and well planned. The reviewer’s only concerns are around product cost and customer ROI. The cost of the battery and the incremental wireless infrastructure looks very cost prohibitive.

Reviewer 4:

This project clearly includes all of the pieces needed to address wireless charging of electric trucks and then demonstrating. The reviewer wished the poster contained information on what the team was doing to make the charging happen fast.

Reviewer 5:
The high-level approach seems reasonable but not enough details have been provided. Also, it is not clear why wireless charging is chosen.

Reviewer 6:
It is early on in the project—and understanding the issues with other projects—it is good to see the timeline preparing for subsystem testing in a variety of areas. Still, the approach seems to lack robustness as most milestones are sequential. It may be wise to plan for some parallel task options for the sake of time compression.

Reviewer 7:
The reviewer thought most barriers were at least articulated verbally, but not all were mentioned in the presentation. For example, a 660-kWh battery pack was selected with a "worst case" power consumption on the trip of 450 kWh. However, the 30-minute fast charge could only deliver a maximum of 500 kWh using a 1,000-kW charger. That assumes the full power can be delivered for the full 30 minutes and battery deterioration is not a factor. It seems like that factor of safety may be too small, but testing results will provide direction. The reviewer appreciated that the data gathering process to set the battery pack size was very representative of real-world conditions.

In addition, the EMI aspects of wireless charging at that power level may also be a very large technical barrier. The reviewer thought the project is well designed and feasible as it gets at many aspects of putting this kind of technology into practical service. The reviewer looked forward to reports as it progresses.

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

Reviewer 1:
The technical work to date is a great start. Real-world data will prevent underestimating the propulsion requirements.

Reviewer 2:
The team has run the route with a range extended electric truck to establish power requirements for all of the major systems and subsystems and determined key parameters including battery sizing which defines the charging requirements. The fact that this was established early using an EV should give the team confidence to continue down its path.

Reviewer 3:
The layout for the tractor hardware is complete. The components and weight limitations can be met allowing for future project implementation.

Reviewer 4:
Considerable thought has obviously gone into design of the charger; the reviewer would like to have seen more detail and maybe schematics of how the on-board charger was going to be laid out.

Reviewer 5:
It is early on in the project, and though the route has been identified and evaluated, vehicle performance information will have a great impact on component selection and evaluation. There was not much in the presentation about vehicle parameters.

There is good work with the magnetics simulation—validating when the vehicle is completed will be late if the model proves to be inaccurate for the new higher power levels.

Reviewer 6:
Progress to date, given the very recent start of the project appears, to be very good. Many partners have been identified and seem on board with the various aspects of the project.

Reviewer 7:
The project is at an early stage and not enough information has been provided.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
All the stakeholders in this type of technical project are represented.

Reviewer 2:
There is reasonable level of collaboration.

Reviewer 3:
An appropriate project team is apparent for this project. A tractor OEM, wireless charging, academic, and public sector team members are coordinated within this project for the demonstration. It is an appropriate blend of partners to complete a demonstration.

Reviewer 4:
The team seems to cover all the bases.

Reviewer 5:
Good representation of team members from needed industries. Because some of these team members are on multiple projects, it will be interesting to see what they learn from other projects and how they will communicate to assist the progression of the technology.

Reviewer 6:
The project is in the very early stages, but the fact that the route was established and tested demonstrates good collaboration among the partners.

Reviewer 7:
The partner selection covers all aspects and appears to be a big plus.

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

Reviewer 1:
The next steps are appropriate.

Reviewer 2:
There are a lot of good questions to be answered in this project, particularly, the grid impacts and occupant safety of such high-power wireless charging demonstrations. Additionally, determining the battery thermal requirements for high powered charging and use will prove insightful during the demonstration.

Reviewer 3:
The milestone chart outlines key decision points and seems to represent reasonable timing. The reviewer was sure that some barriers will come up over time that may dictate alternate development.

Reviewer 4:
The slide deck was a bit brief in this area, but it is very good to see the references to testing for thermal, high-frequency interference (an industry concern at large air gaps and power levels) as well as leakage field recognition. These are all valuable areas of interest, but no real-world use also means understanding environmental aspects of the operational domain as well as the impacts charging at high rates on a large ESS pack at possible high ambient temperatures will have on pack degradation. It is perhaps wise of the project to focus on power transfer and not have too broad a scope.

Reviewer 5:
Again, information presented is very sketchy. Next year, please specify what information is being collected about power levels, rates, temperature, etc.

Reviewer 6:
The proposed future research addresses critical issues. Not addressed is a question on the efficiency of wireless charging versus a physical plug or where wireless charging is appropriate, given the costs of the hardware and in charging efficiency.

Reviewer 7:
It is difficult to judge until more progress is made and more information provided.

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

Reviewer 1:
EVs in this size are a final frontier and advance the DOE VTO goals of greater EV adoption.

Reviewer 2:
Projects which expand fully electric operation into the MD-HD realm deserve to be investigated for commercial readiness and parameter development.

Reviewer 3:
Fast charging and extended range of large trucks are relevant.

Reviewer 4:
Wireless fast charging would certainly contribute significantly to ease of operation and versatility of electric truck operation.

Reviewer 5:
Development and demonstration of electrified power and charging systems for freight will provide key pieces of information relative to grid needs. Additionally, results from such a project can validate or invalidate the current state-of-the-art electrification charging and powertrain technologies relative to heavy truck freight transportation.

Reviewer 6:
This project is a very practical demonstration of implementing battery technology for HD applications and definitely supports DOE objectives.

Reviewer 7:
The project is addressing the charging infrastructure for BEVs, which is one of the barriers to BEV adoption. One concern is that commercial feasibility is not addressed, nor is there involvement or mention of any standards bodies and how a proprietary solution may limit wider adoption.

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

Reviewer 1:
Resources appear adequate at this stage of the project.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
The project is early; however, the funds appear sufficient for the project.

Reviewer 4:
It is early on in the project, but based on other projects, the funds should be sufficient to have substantial results to report out to the EV MD-HD community.

Reviewer 5:
At this early point in the project, resources appear to be sufficient and partner involvement seems excellent.

Reviewer 6:
Given the good progress to date and a good mix of partners, the team appears to have sufficient resources.

Reviewer 7:
Again, it is hard to say much here with no cost numbers provided.

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

Presenter

Rick Pratt, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

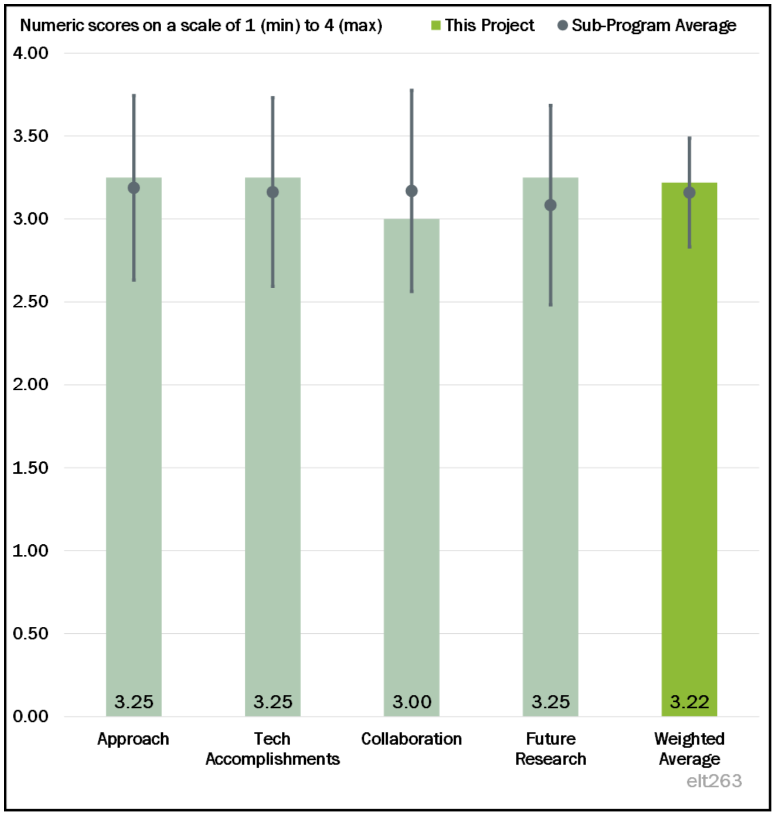

Figure 4-63 - Presentation Number: elt263 Presentation Title: Cybersecurity: Securing Vehicle Charging Infrastructure - Consequence Analysis and Threat Assessment Principal Investigator: Rick Pratt (Pacific Northwest National Laboratory)

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

Reviewer 1:

The STRIDE methodology being applied is a proven cybersecurity approach. The project approach is selectively addressing several technical barriers yet appears to have appropriately focused the scope of the project in order to attain practical and feasible progress.

Reviewer 2:

Previous studies have not focused specifically on quantifying the potential cyber effects of compromised XFC on the distribution grid, so this is somewhat novel, and beneficial to the mission of VTO and the national security interest. The STRIDE model produced is comprehensive and insightful, providing a valuable perspective on the critical data/power flows, actors, and components relevant to XFC charging (this STRIDE model has been presented by SNL, and framed as an SNL-led project: it is not clear if this is the same project (novel), or borrowed from a separate VTO-funded project). The modeling and simulation efforts are a valuable exercise, but could benefit from going “bigger,” e.g., SNL showed that a 10,000 MW static load has minimal effect on WECC—therefore there may be greater value in modeling significantly more than 500 MW. Additionally, the relevance, accuracy, and transition value of the project would be substantially increased if real assessments were performed against XFC ecosystems and distribution components (recognizing the challenges in getting access to systems that this testing can safely be performed on).

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

Reviewer 1:
The progress to date has created meaningful results with respect to each of the barriers being addressed.

Reviewer 2:
Project appears to be on schedule. Stated goals of developing threat models and dynamic simulations have been met, and improvements on both are underway. Likely knowledge transfer goals are being met through multiple publications and presentations, increasing awareness of the risks posed by XFC. Milestones stated in the slide deck appear to have been met. However, threat and vulnerability assessments, as stated, appear to be a paper exercise (e.g., an analysis)—better technical achievement could be gained from practical assessments. These are suggested to have occurred by other project partners, but it is not clear if these are part of the PNNL project based on presentation contents and limited DOE funding.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project appears to have good coordination with the other National Laboratories (ANL and SNL) and very good communication of the work with domain relevant R&D forums such as the GITT and an EPRI working group.

Reviewer 2:
Collaboration is not highlighted in the presentation. Low involvement and retention of industry partners is apparent (e.g., early stage involvement of new industry partner, Florida Power & Light—just now executing a non-disclosure agreement.

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

Reviewer 1:
Threat models and consequence events identified have good potential transition value for OEMs/product security organizations, and for DOE in follow-on funded research focused on validating and measuring threats through practical assessments. Modeling and simulation of adverse effects on WEC have likely transition value for commercial utilities and regulators, as well as other DOE National Laboratories and DOE-funded research.

Reviewer 2:
The proposed future work is logical to the realization of the proposed advancements, especially in the inclusion of validation and verification work for the threat analysis and mitigation strategies. However, this reviewer was concerned that the threat analysis may be exposing electric grid vulnerabilities to the public with the potential to educate bad actors and to the detriment of grid security. Please consider limiting dissemination of the results until they can be evaluated by DOE and the U.S. Department of Homeland Security regarding possible national/grid security implications.

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

Reviewer 1:
This project is directly relevant to DOE's Cybersecurity Multi-Year Program Plan objective to "Complete end-to-end threat informed and consequence driven vulnerability assessment of EV/charging/grid interactions. (FY 2020)".

Reviewer 2:
Alignment of project goals with DOE objectives is apparent. DOE stated in 2018 (?) the goal of understanding threats that XFC pose to critical infrastructure and national security—project goals and vision directly contribute thereto. However, to maximize transition value, practical assessments should be included, best practices and design recommendations should be produced, and models should be released and licensed as open-source and be reusable by industry.

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

Reviewer 1:
The project is generating productive results with the allocated resources.

Reviewer 2:
According to the reviewer, $1 million and a 3-year project between three National Laboratories plus industry seems insufficient to produce quality results; however, the apparent progress (gained exclusively from the presentation contents) exceeds expectations for the level of funding provided by DOE. Perhaps the competitive lab model struggles here, where multiple laboratories now share specialties (e.g., in EV/EVSE cybersecurity) and must split very limited funds for collaborative research.

Acronyms and Abbreviations

°C	Degrees Celsius
3-D	Three-dimensional
AC	alternating current
Al	Aluminum
ANL	Argonne National Laboratory
AMR	Annual Merit Review
ATF	Automatic transmission fluid
B	Magnetic flux density
BAU	Business as usual
BEV	battery electric vehicle
BP	Budget period
CADS	Cyber anomaly detection system
CaF_2	Calcium fluoride
CFD	Computational fluid dynamics
cm	Centimeter
CMOS	Complementary-symmetry metal
CNG	Compressed natural gas
Cu	Copper
DBC	Direct bonded copper
DC	Direct current
DCFC	DC fast charging
DER	Distributed energy resources
DoD	Department of Defense
DOE	U.S. Department of Energy
DOT	Department of Transportation
DSS	Distribution System Simulator
DTNA	Daimler Trucks North America LLC
DWPT	Dynamic Wireless Power Transfer

Dy	Dysprosium
EETT	Electrical and Electronics Technical Team
ELT	Electrification Technologies
EMG	E-Mobility Group
EMI	Electromagnetic interference
EMS	Energy management system
EPRI	Electric Power Research Institute
ESS	Energy storage system
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
FCML	Flying Capacitor Multilevel
Fe_4N	Iron nitride
FEA	Finite element analysis
FeCo	Iron-cobalt
FY	Fiscal year
GaN	Gallium nitride
GAO	Genetic algorithm optimization
Georgia Tech	Georgia Institute of Technology
GITT	Grid integration technical team
GM	General Motors
H	Magnetic field strength
HALT	Highly accelerated lifetime test
HCEs	High consequence events
HD	Heavy-duty
HELICS	Hierarchical Engine for Large-scale Infrastructure Co-Simulation
HEMT	High-electron-mobility transistor
HIL	Hardware in the loop
HRE	Heavy rare earth

Hz	Hertz
ICE	Internal combustion engine
IEEE	Institute of Electrical and Electronics Engineers
IIC	Indiana Integrated Circuits
IMS	Insulated metal substrate
INL	Idaho National Laboratory
IPM	Interior permanent magnet
JBS	Junction barrier Schottky
JRC	Joint Research Center
kW	Kilowatt
kWh	Kilowatt hours
L	Liter
LD	Light-duty
MD	Medium-duty
Mg_2SiO_4	Forsterite
mm	Millimeter
MnBi	Manganese bismuth
MOSFET	Metal oxide semiconductor field effect transistor
MPGe	Miles per gallon equivalent
MTC	Metropolitan Transportation Commission
MV	Medium Voltage
MW+	Megawatt plus
NA	North America
NdFeB	Neodymium iron boron
NIC	Network interface card
NMFTA	National Motor Freight Traffic Association, Inc.
NREL	National Renewable Energy Laboratory
NREL80	80-mile work day duty cycle developed by NREL

ODBC	Organic film based direct bonded copper
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
OSU	Ohio State University
PEVs	Plug-in electric vehicles
PG&E	Pacific Gas & Electric
PI	Principal Investigator
PKI	Public key infrastructure
PM	Particulate matter
PM	Permanent magnet
PNNL	Pacific Northwest National Laboratory
PU	Per unit
PV	Photovoltaic
PWM	Pulse width modulation
R&D	Research and development
RE	Rare earth
RMS	Root mean square
ROI	Return on investment
SAE	Society of Automotive Engineers
SBD	Schottky barrier diode
SCAQMD	South Coast Air Quality Management District
SDOs	Standards developing organizations
Si	Silicon
SiC	Silicon carbide
SMC	Soft magnetic composites
SNL	Sandia National Laboratories
SPIN	Smart Power Integrated Node
SPM	Surface permanent magnet

STRIDE	Spoofing, tampering, repudiation, information disclosure, denial of service, elevation of privilege
SUNY Poly	State University of New York Polytechnic
TCO	Total cost of ownership
THD	Total harmonic distortion
TLP	Transient liquid phase
TPG	Thermal pyrolytic graphite
U.S.	United States
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UPS	United Parcel Service
V	Volt
V2G	Vehicle-to-Grid
VDC	Volts of direct current
Virginia Tech	Virginia Polytechnic Institute
VTO	Vehicle Technologies Office
WBG	Wide bandgap
WECC	Western Interconnection model
WXFC	Wireless extreme fast charging
XFC	Extreme fast charging
ZECT II	Zero-Emission Cargo Transport II