3. Power Electronics and Electrical Machines Technologies

Because they are essential to electric drive vehicles, improvements in electric traction drives have the potential to significantly reduce petroleum consumption in the transportation sector as well as help meet national economic and energy security goals. Hybrid electric vehicles (HEVs) can reduce petroleum use compared to average conventional vehicles by as much as 50%, while plug-in electric vehicles (PEVs) extend these savings even further.

Achieving these goals will require cutting-edge research and development (R&D) in several areas including:

- wide bandgap (WBG) devices
- advanced motor designs to reduce or eliminate rare earth materials
- novel packaging
- improvements in heat transfer and thermal management
- integration of power electronics functions in advanced vehicle architectures

The U.S. Department of Energy (DOE) Vehicle Technologies Office's (VTO's) Advanced Power Electronics and Electric Motors subprogram works to improve electric drive systems to commercialize new technologies in this area and reach VTO's goals for electrifying transportation. These improvements will also help DOE meet the *EV Everywhere* Grand Challenge goal of making the U.S. the first nation in the world to produce PEVs that are as affordable for the average American family as today's gasoline-powered vehicles by 2022.

VTO pursues two major areas of research under this subprogram:

- power electronics
- electric motors

The Advanced Power Electronics and Electric Motors' long-term R&D strategy recognizes that lowering cost is essential for consumer acceptance and technology breakthroughs are necessary to achieve R&D goals. Because of these considerations, it focuses on traction drive system R&D that:

- Reduces cost, weight, and volume
- Improves performance, efficiency and reliability
- Develops modular and scalable designs
- Improves manufacturability to enable commercialization

This research builds upon decades of work that DOE has conducted in power electronics and electric motors. Research supported by VTO led to the first production facility for electric traction drive motors from a U.S.-based manufacturer (General Motors) and the first U.S. based high-volume automotive inverter production (Delphi).

The major goals of Advanced Power Electronics and Electric Motors subprogram are to reach these levels for traction drive systems by 2022:

- Reduce cost from $30/kW in 2012 to $8/kW
- Increase specific power from 1.1 kW/kg in 2012 to 1.4 kW/kg
- Increase specific volume from 2.6 kW/L in 2012 to 4 kW/L
- Increase efficiency from 90% in 2012 to 94%

In August 2009, the Department announced the selection of ten projects totaling $495 million that will help accelerate the establishment of a globally competitive, domestic infrastructure for advanced electric drive vehicle manufacturing. American

Recovery and Reinvestment Act (ARRA)-funded Power Electronics and Electrical Machines Technologies activities support programs to enable production and commercialization of advanced electric drive vehicles, which help to reduce petroleum consumption. Activities include developing low-cost electric propulsion systems; supporting an increase in production capacities for electric drive components, manufacturing plants, and parallel hybrid propulsion systems; and supporting development of electric drive semiconductors. Additionally, AARA-funded activities that support commercialization include accelerating the launch of HEVs/PHEVs through efforts including localizing the design and production of transaxle systems, and developing a lower-cost, higher-control standardized platform.

Subprogram Feedback

DOE welcomed optional feedback on the overall technical subprogram areas presented during the 2013 AMR. Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area who volunteered to provide subprogram overview comments responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the subprogram area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year?

Question 2: Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

Question 3: Does the subprogram area appear to be focused, well-managed, and effective in addressing the DOE Vehicle Technologies Office's needs?

Question 4: Other Comments.

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc., as reviewer responses were optional.

Subprogram Overview Comments: Susan Rogers (U.S. Department of Energy) – ape00a

Question 1: Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year?

Reviewer 1:

The reviewer agreed that yes, the sub-program areas for power electronics and electric drive sub-systems had been covered well in the 2013 AMR presentations. In the program-summary presentation, the issues and challenges were clearly delineated from the program's point of view. The progress from the previous year was also clearly presented in several summary slides.

Reviewer 2:

The reviewer indicated that the sub-program understood the challenges well and was very focused on cost.

Reviewer 3:
The reviewer did not attend this sub-program session last year, but believed that Rogers had done a remarkable job bringing out relevant research questions and program definition, as well as selecting an excellent group of contract awardees who could apparently work together (or in lockstep).

Reviewer 4:
The reviewer reported that the sub-program area was adequately covered, and the most important challenge, which was cost reduction, had been identified. This reviewer added that the progress was documented with the commercialization activities in recent years and the key accomplishment in completed and ongoing projects.

Reviewer 5:
The reviewer concluded that the sub-program areas were adequately covered, the important issues and challenges had been identified, and the funded projects addressed them comprehensively.

Reviewer 6:
The reviewer stated yes.

Reviewer 7:
The reviewer voiced that the program needed a larger view of what constituted basic science. Investigators developing new technology needed to identify where the science that was developed fit into the broad goals of DOE. This reviewer added that it did no good for the DOE programs if the basic science was useless in reaching DOE's goals.

Question 2: Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

Reviewer 1:
The reviewer indicated that plans were identified for addressing issues and challenges.

Reviewer 2:
The reviewer reported that plans had been identified and gaps were not observed.

Reviewer 3:
The reviewer highlighted that there was a need to have resources available to validate the new technology and carry out the preliminary investigations of its utility. This reviewer added that the new Hub concept placed the National Laboratories in the position of carrying out the basic process of proving the ability of new concepts to meet market needs. In this process, scientists and technicians were trained in critical technologies. This represented a move away from the concept that good fundamental science was carried out for its own sake to advance the basic understanding of phenomena. This has long been the operating principal of industrial laboratories such as General Electric, Dow, Exxon, and so forth.

Reviewer 4:
The reviewer concluded that the plans seemed to be shifting from a technology focus to a systems development and optimization focus.

Reviewer 5:
According to this reviewer, the most important issue was cost reduction for electric traction drive systems, and basically all current projects in the sub-program area addressed this issue as their main target. Even though there were no obvious gaps in the project portfolio, the focus for funding in the future should be shifted toward the funding of complete system project proposals, as these offered a higher potential for achieving an optimized system design (in terms of both cost and performance).

Reviewer 6:
The reviewer stated that meeting the industry-driven cost targets seemed daunting. It was possible that some summary judgments, such as mature manufacturing and minimal potential for improvement (as listed within the tabular description of induction motors)

might be overlooking some of the more radical induction motor designs. In particular, reconsideration of newer types of induction motors (such as greater-than-three-phase ones) might lead to the marked cost reductions that were sought in the program goals. The direction set was to focus on WBG power electronic semiconductors, which were high-cost alternatives (at least for the present). It was appropriate that DOE-funded work be out in front of the industry. Furthermore, developments in special thermal packaging of WBG devices might also be valuable in applications to vertical metal-oxide-semiconductor (MOS) silicon devices as nearer-term alternatives by industry.

Question 3: Does the sub-program area appear to be focused, well-managed, and effective in addressing the DOE Vehicle Technologies Program's needs?

Reviewer 1:
The reviewer stated that the sub-program area was focused on the most important issue, which was cost reduction for electric drive systems. This reviewer added that it was well managed by the DOE representatives, who have the appropriate technical understanding and knowledge to evaluate and guide the projects in the sub-program area. It was effective in addressing DOE VTO needs.

Reviewer 2:
The reviewer felt that the sub-program area was focused and well managed, and that there was a good mix of fundamental-level and development work that would not be pursued as aggressively by the original equipment manufacturers (OEMs) without DOE support.

Reviewer 3:
The reviewer noted that the program appeared to be well focused on its stated needs. The program appeared to be well managed, with evident cross-discussions and peer-to-peer enthusiasm among the participants at the AMR meeting.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
The reviewer remarked that, for the common good, new technology should meet the needs of the country and assist in determining the ultimate value of that technology.

Reviewer 6:
According to this reviewer, the efforts at the labs seemed to be moving away from their strengths and were now more focused on architecture optimization and system development. While these areas were important, they typically did not lead to great breakthroughs in technology. This reviewer opined that the National Laboratories needed to be focused on technology development and not systems. The systems optimization and development were best left to industry, which was better prepared to make the appropriate tradeoffs in these systems while still meeting customer requirements.

Question 4: Other Comments

Reviewer 1:
The reviewer pointed out that, as the market accepted more and more electrical and electronic functions on vehicles and non-mobile systems, the investment in power electronics and electric drives seemed to be a sure-to-be-used technology. Whether the primary energy conversion system was an internal combustion engine (ICE) or a fuel cell (or a nuclear-powered utility charging a battery), the advanced developments in power electronics and electric drives would serve them all. Thus, funding for power electronics was a surer bet to be included in any eventual system, and seemed to justify greater investment in this multi-application technology area than in any one of the specific conversion/storage technologies.

Reviewer 2:
The reviewer observed that the APE program included an extensive collection of projects focusing on all aspects of electric machines and power electronics to meet DOE's 2020 targets. The projects focused on components as well as development of their key subsystems (capacitors, WBG and traditional silicon [Si] power modules, insulation materials, etc.). Many of the project presentations

did not reveal significant technical details relevant to the work, and this reviewer wanted to know if this was due to the projects being conducted with cost-sharing agreements. Projects fully funded, without an assertion of restrictions, would be delivered with unlimited rights to the government. In this case, the objective was not for the government to own all of the technological data, but rather to help the contractors develop key fuel-saving technologies to reduce dependence on imported oil and reduce pollution. The projects related to electric machines were particularly impressive. The reviewer asked if changing the name to include the electric-machines focus had been considered, and suggested Advanced Electric Machines and Power Electronics, Advanced Electric Drives, Advanced Electromechanical Systems, etc.

Reviewer 3:

The reviewer said that the industry-led projects were hard to evaluate, with the presenters invoking proprietary issues whenever asked technical questions. It would have been good to find a forum where the industry would have been more forthcoming with information so that the project progress could be properly evaluated. This reviewer added that, though a lot of universities were nominally participating in the research projects, the involvement of academia was relatively small in practice.

Reviewer 4:

The reviewer mentioned that systems work at the National Laboratories could lead to work that was no longer pre-competitive research and that would be difficult to move to industry. In a way, the labs appeared to be competing with industry solutions by creating their own optimized system solutions. This reviewer was not sure how or if those would ever move into the marketplace and actually help the DOE to achieve its goals.

Project Feedback

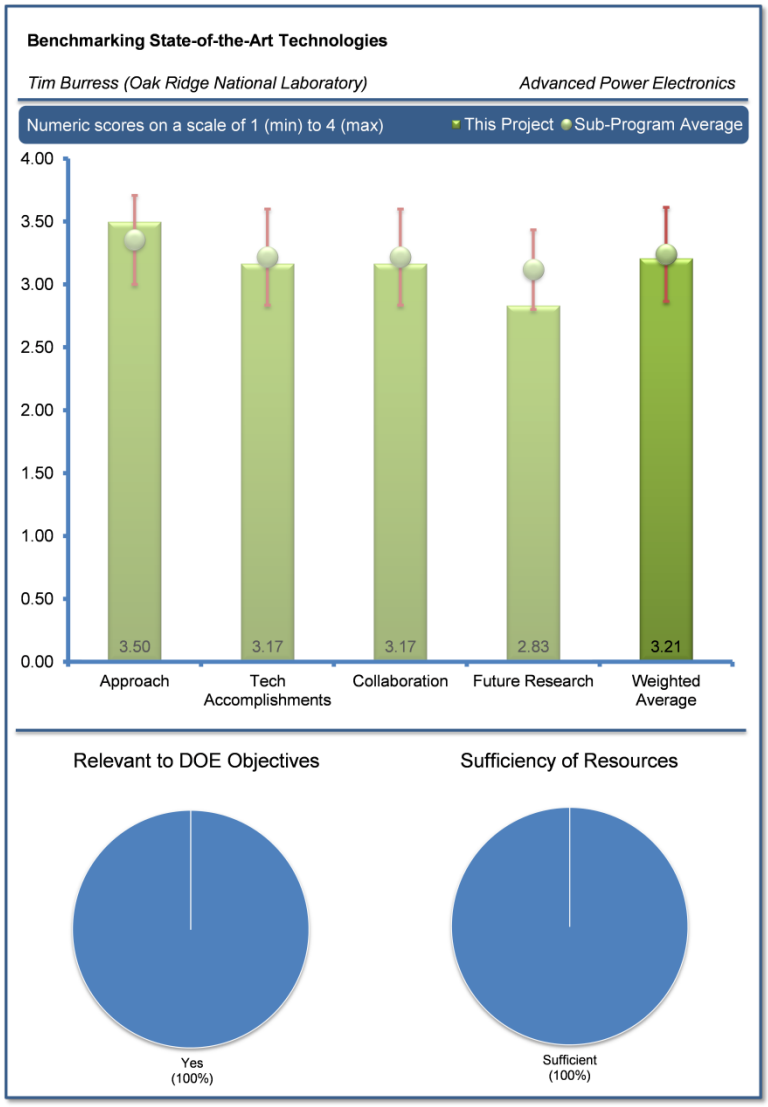
In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, as well as numeric scoring responses *(on a scale of 1 to 4)*. In the pages that follow, the reviewer responses to 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 summary table presenting the average numeric score for each question for each project is presented below.

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Benchmarking State-of-the-Art Technologies	Tim Burress (Oak Ridge National Laboratory)	3-8	3.50	3.17	3.17	2.83	3.21
High Dialectric Constant Capacitors for Power Electronic Systems	Uthamalingam Balachandran (Argonne National Laboratory)	3-12	3.67	3.67	3.67	3.33	3.63
Improved High Temperature Polymer Film Capacitors	Cy Fujimoto (Sandia National Laboratories)	3-15	3.50	3.25	3.25	3.25	3.31
† Glass Ceramic Dielectrics for DC Bus Capacitors	Michael Lanagan (Pennsylvania State University)	3-18	3.25	3.25	3.25	2.75	3.19
High Temperature Inverter	Ralph Taylor (Delphi Corporation)	3-21	3.40	3.40	3.40	3.00	3.35
Permanent Magnet Development for Automotive Traction Motors	Iver Anderson (Ames)	3-25	3.86	4.00	4.00	3.43	3.89
Air Cooling R&D	Jason Lustbader (National Renewable Energy Laboratory)	3-30	3.50	3.00	3.00	3.00	3.13
Characterization, Modeling, and Reliability of Power Modules	Allen Hefner (National Institute of Standards and Technology)	3-32	2.33	3.33	3.33	2.00	2.92
Development of SiC Large Tapered Crystal Growth	Philip Neudeck (National Aeronautics and Space Administration)	3-34	2.75	3.25	3.25	3.00	3.09
Reliability of Bonded Interfaces	Doug DeVoto (National Renewable Energy Laboratory)	3-37	3.75	3.75	3.75	3.25	3.69
Electric Motor Thermal Management	Kevin Bennion (National Renewable Energy Laboratory)	3-40	3.33	3.00	3.00	3.17	3.10
Interim Update: Global Automotive Power Electronics R&D Relevant To DOE 2015 and 2020 Cost Targets	Christopher Whaling (Synthesis Partners)	3-44	3.40	3.20	3.20	3.20	3.25
† Reliability of Electrical Interconnects	Doug DeVoto (National Renewable Energy Laboratory)	3-47	3.33	3.00	3.00	3.00	3.08
† Two-Phase Cooling R&D	Gilbert Moreno (National Renewable Energy Laboratory)	3-49	3.25	3.00	3.00	3.25	3.09
† Advanced Liquid Cooling R&D	Sreekant Narumanchi (National Renewable Energy Laboratory)	3-51	3.60	3.40	3.40	3.60	3.48
Next Generation Inverter	Greg Smith (General Motors, Advanced Technology Center)	3-54	3.50	3.25	3.25	3.00	3.28
Unique Lanthide-Free Motor Construction	Jon Lutz (UQM Technologies)	3-57	3.33	3.67	3.67	3.33	3.54
Alternative High-Performance Motors with Non-Rare Earth Materials	Ayman El-Refaie (General Electric Global)	3-61	3.14	3.14	3.14	3.14	3.14

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Integrated Power Module Cooling	Kevin Bennion (National Renewable Energy Laboratory)	3-66	3.33	3.67	3.67	3.00	3.50
Traction Drive System Modeling	Burak Ozpineci (Oak Ridge National Laboratory)	3-69	3.00	2.40	2.40	3.00	2.63
WBG Inverter Packaging	Zhenxian Liang (Oak Ridge National Laboratory)	3-72	3.17	2.83	2.83	3.50	3.00
WBG Gate Drivers for Power Modules	Leon Tolbert (Oak Ridge National Laboratory)	3-75	4.00	3.33	3.33	3.67	3.54
Electric Motor R&D	John Miller (Oak Ridge National Laboratory)	3-78	3.17	3.50	3.50	3.17	3.38
Integrated Vehicle Thermal Management	John Rugh (National Renewable Energy Laboratory)	3-82	3.25	3.63	3.63	3.25	3.48
† Inverter R&D	Madhu Chinthavali (Oak Ridge National Laboratory)	3-87	3.00	3.33	3.33	2.83	3.19
† WBG Converters and Chargers	Gui-Jia Su (Oak Ridge National Laboratory)	3-90	3.40	3.40	3.40	3.20	3.38
† System Integration and Validation	Tim Burress (Oak Ridge National Laboratory)	3-92	2.50	2.83	2.83	2.50	2.71
† Power Electronics Architecture R&D	Omer Onar (Oak Ridge National Laboratory)	3-95	3.00	3.50	3.50	3.17	3.33
† Electric Motor Architecture R&D	Curt Ayers (Oak Ridge National Laboratory)	3-97	3.33	2.67	2.67	2.67	2.83
† ‡ US Electric Drive Manufacturing Center	Judith Gieseking (General Motors)	3-99	3.75	2.50	2.50	3.67	2.96
† ‡ Low-Cost U.S. Manufacturing of Power Electronics for Electric Drive Vehicles	Greg Grant (Delphi Corporation)	3-102	3.25	3.25	3.25	3.33	3.26
† ‡ Electric Drive Component Manufacturing Facilities	Richard Thies (Allison Transmission, Inc.)	3-104	3.67	3.33	3.33	3.00	3.38
† ‡ U.S. Based HEV and PHEV Transaxle Program	Kevin Poet (Ford Motor Company)	3-106	3.67	2.33	2.33	3.00	2.75
† ‡ Providing Vehicle OEMs Flexible Scale to Accelerate Adoption of Electric Drive Vehicles	JJ Shives (Remy, Inc.)	3-109	3.25	3.50	3.50	3.25	3.41
† ‡ Electric Drive Component Manufacturing Facilities	Luke Bokas (UQM Technologies)	3-112	3.67	2.67	2.67	3.33	3.00
† ‡ Electric Drive Component Manufacturing: Magna E-Car Systems of America, Inc.	Brian Peaslee (Magna E-Car Systems of America, Inc.)	3-114	3.33	3.00	3.00	3.00	3.08
† ‡ DC Bus Capacitor Manufacturing Facility for Electric Drive Vehicles	Johnny Boan (Kemet)	3-116	4.00	3.67	3.67	3.33	3.71
Overall Average			3.35	3.22	3.22	3.12	3.24

† denotes poster presentations
‡ denotes ARRA funded projects

Benchmarking State-of-the-Art Technologies: Tim Burress (Oak Ridge National Laboratory) - ape006



Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer described that this is a benchmarking project. The reviewer noted that the presented emphasized that it is good that it is consistent with the past year's approach: taking the units apart to identify the subcomponents, such as heat spreaders and lower cost insulators; and efficiency mapping/identifying peak efficiencies.

Reviewer 2:

The reviewer acknowledged that this project continues to provide valuable benchmarking results for electric vehicle (EV)/ PEV state-of-the-art motor, inverter, and converters that provide a foundation for determining the relevance and goals for the other power electronics and electric motors projects within the VTO. The reviewer expressed that the project could be expanded to provide more complete coverage of propulsion and charger product offerings and more rapid turn-around.

Reviewer 3:

The reviewer expressed that the benchmarking effort is very important to the DOE mission. The reviewer cautioned, however, that because the team, on average, publishes one report every other year, it is a concern in terms of quick dissemination of the knowledge to researchers and industry. It was noted that the reviewers raised this concern previously.

Reviewer 4:

The reviewer described that this project has provided critical baseline information on the commercial electric drive vehicles in terms of current technology and cost. The information is important for developing advanced power inverter technologies to meet DOE's 2020 target.

Reviewer 5:

The reviewer affirmed that the project seems to be progressing very well and the approach for the tear downs and testing is very good. However, the reviewer did not see a clear use of the technical information within the presentation. It would have been helpful to have a data summary slide that showed the comparison of the Toyota and Nissan systems with Remy or other domestic power electronics manufacturers.

Reviewer 6:
The reviewer acknowledged that understanding the communication protocols of different manufacturer's products, to control their systems, can be a difficult task. The reviewer asked if this communication protocol is published and can be referenced. This work has been ongoing over the years, and the reviewer asked if it was possible to take the Toyota inverters and publish the advantages and disadvantages over design evolutions and describe what the enabling technologies are that provided those advantages.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer remarked that the project has made significant progress this year with accomplishments including the benchmarking of the Toyota Camry inverter, the Nissan LEAF inverter/motor and charger, and the Hyundai Sonata Hybrid starter/generator.

Reviewer 2:
The reviewer observed great technical accomplishments that were very well presented. It would be interesting to see a comparison, or evolution, of the power electronics in next year's presentation after all four vehicles have been analyzed.

Reviewer 3:
The reviewer noted that the project has made good progress, though it will be better if the test can be completed faster.

Reviewer 4:
The reviewer explained that a variety of parts from a variety of manufacturers had been taken and has provided useful information about their capabilities. The reviewer would refer to the evaluated systems as state-of-the-market, not state-of-the-art. The reviewer asked whether using vehicle simulators as opposed to dynamometer setups to speed up the work, had been considered.

Reviewer 5:
The reviewer noted that the project accomplishments are documented in a series of reports. The reviewer would have preferred a more technically-precise description of this this highly-detailed benchmarking work.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer expressed that there appears to be good coordination in working with materials analysts and with comparing to vendor efficiency plots. The reviewer acknowledged the good cooperation with those performing road-tests to better know how to mimic in-use conditions.

Reviewer 2:
The reviewer mentioned that in addition to the collaborations and coordination with Remy, the Argonne National Laboratory (ANL), and the National Renewable Energy Laboratory (NREL), this project provides a foundation for determining the relevance of and goals for the other power electronics and electric motor projects within the VTO.

Reviewer 3:
The reviewer pointed out that the team collaborated with ANL and other institutions to test the HEV and thermal management systems.

Reviewer 4:
The reviewer noted that it was good to see partnerships with private industry; however, the reviewer suggested that it would be better to have more private partners in this project to better compare where domestic suppliers stand compared to Nissan and Toyota suppliers.

Reviewer 5:
The reviewer suggested that a closer coordination with the OEMs may provide some of the information gathered in a more cost-effective manner. The reviewer observed that it was not clear what benefit the collaboration with Remy provides to the scope of the project. The reviewer added that the copper versus aluminum rotor issue is more of a research question.

Reviewer 6:
The reviewer pointed out that while the presenter provided information to NREL for thermal studies, the reviewer did not see any thermal study information in the presentation. The reviewer also mentioned that thermal stack information of the power stages would have been useful information.

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

Reviewer 1:
The reviewer asserted that the project continues to select and benchmark cutting-edge technologies that are most relevant to the program and proposed future product selections seem appropriate. However, the reviewer suggested that it would be appropriate for the project to define a strategy of how it will advance its capabilities and throughput as technology advances and the number of product offerings continue to increase.

Reviewer 2:
The reviewer agreed that the plan is good; however, the reviewer added that it will be interesting to see the performance of a U.S.-brand electric drive vehicle. The reviewer noted that past analyses have primarily focused on foreign brands such as Toyota, Lexus, Honda, and Hyundai.

Reviewer 3:
The reviewer indicated that future plans were clearly presented, but expressed that it would have been helpful to see the comprehensive expectations of the project as a whole.

Reviewer 4:
The reviewer expressed that it will be interesting to see how aluminum compares to copper for rotors in the Remy work. Perhaps, continued this reviewer, this analysis can be extended to the thermal diffusivity vis-à-vis thermal conductivity as best for transient vav steady-state. The reviewer was not able to comment on the volume of proposed work to be done.

Reviewer 5:
The reviewer criticized that it is not clear what benefit the characterization of the Remy machine provides to the benchmarking effort, since the machine is not in any production vehicle. The reviewer observed that this characterization may fit better with another project. The reviewer also suggested that faster dissemination of results should be a focus in the coming year.

Reviewer 6:
The reviewer asked if there is any planned future work on the direct current (DC) converters that are state-of-the-market.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer asserted that knowing what others are doing sets the standards for which we (in the United States) need to exceed.

Reviewer 2:
The reviewer explained that learning from competitive tear-downs and testing is very valuable. This information learned will be very helpful for domestic suppliers to be competitive, and ultimately will decrease the costs of vehicle electrification.

Reviewer 3:
The reviewer reinforced that benchmarking the EV/PEV state-of-the-art motor, inverter, and converters is a core function required for relevance of the overall VTO. The reviewer added that continuity of this project will result in a consistent comparison of performance and technology development over time.

Reviewer 4:
The reviewer indicated that the project work is very important for DOE.

Reviewer 5:
The reviewer explained that electrification of vehicles tends to decrease the need for petroleum for powering those vehicles.

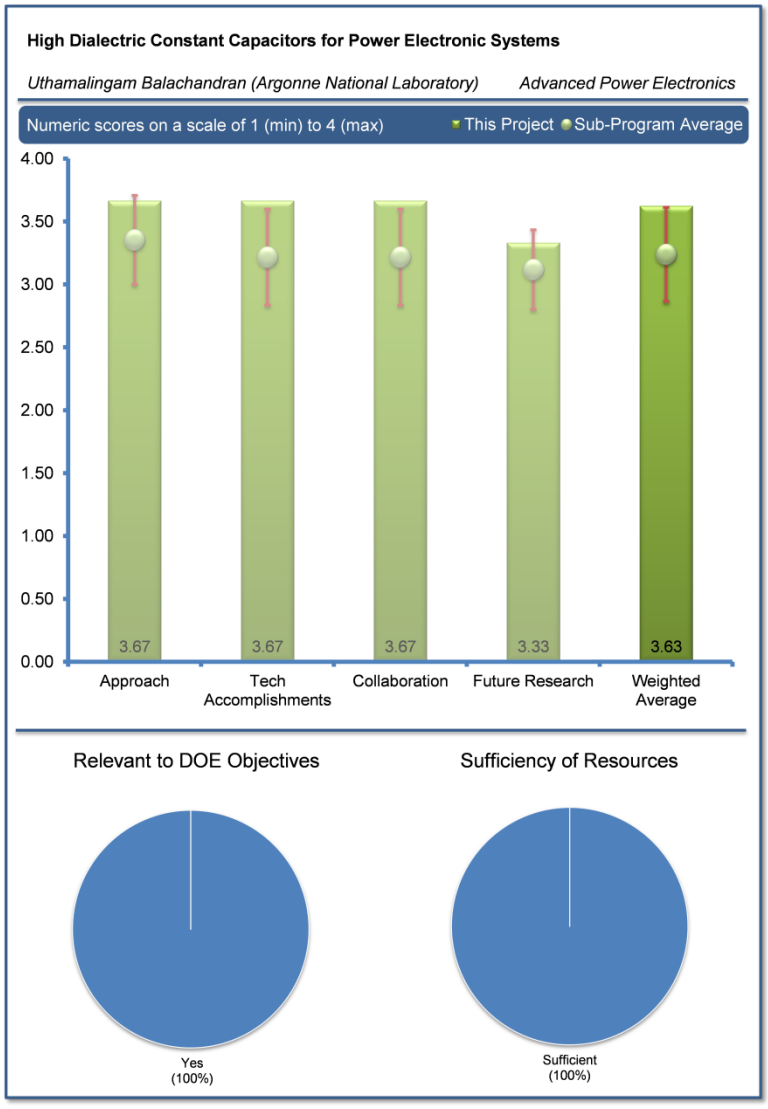
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the project support is sufficient to benchmark key cutting edge product offerings today, but that more rapid turn-around of results and more broad market coverage might be achieved with more resources.

Reviewer 2:
The reviewer stated that it appears the project is sufficiently funded and has the resources necessary to meet its milestones.

Reviewer 3:
The reviewer asked if there were more resources, people, or equipment, and whether more assessments could be accomplished.

High Dialectric Constant Capacitors for Power Electronic Systems: Uthamalingam Balachandran (Argonne National Laboratory) - ape008



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer explained that this project is focusing on the production process which will drive the cost down and result in a usable capacitor. The reviewer pointed out that early use of the capacitor in the Delphi project inverter enabled actual technical issues that were based on the in-circuit functionality to be discovered and addressed. The reviewer also highlighted that the volume reduction, ripple performance over-temperature, and thermal performance, in general, all look excellent.

Reviewer 2:

The reviewer affirmed that the project has made significant progress since last year's presentation. The researchers effectively utilized Delphi and Penn State as partners. The reviewer commented that the aerosol application of the lead lanthanum zirconium titanate (PLZT) dielectric needs to be optimized. It is not yet a production-ready process, but shows promise. The reviewer indicated that the presenter acknowledged having a patent to identify and eliminate dielectric defects, but this was not explained. The reviewer confirmed that this is critical for the capacitor manufacture to have high yields. The reviewer also remarked that the presenter also acknowledged having a method to decouple shorted capacitors from the inverter bus, but this needs further explanation with end-of-life of PLZT capacitor defined as loss of 10% capacitance. The reviewer pointed out that film capacitors self-heal, but this PLZT technology would just short out catastrophically. Therefore, the solution of decoupling capacitor from the inverter bus needs to be explained.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer observed that the performance of the capacitor, as shown, is very good. The thermal performance over temperature was good, and the equivalent series resistance (ESR) projections were good. The reviewer emphasized that it was very good that the researchers are addressing thermal issues early. The project focused on production processes and how they impact cost and performance, which this reviewer described as outstanding.

Reviewer 2:
The reviewer stated that while they were unable to attend last year's Annual Merit Review (AMR) meeting, based on the previous year's presentation information, much work has been done this year. The reviewer was most interested in the possibility of using the vaporization process to increase the thickness of the PLZT, thus increasing the voltage.

Reviewer 3:
The reviewer indicated that the DOE target volume goal is 0.6 liter, and the calculated PLZT volume is 0.5 liter. The reviewer also pointed out that the presenter indicated that a target is to be a lower cost than the polypropylene (PP) film solution, and the projection is to hit the DOE target of $30 for the DC link bus capacitor.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer applauded that the work with Delphi on the high-temperature inverter shows excellent cooperation. The use of the failure mode and effects analysis (FMEA), and root cause processes, should enable a solid corrective action plan and results. It appeared to the reviewer that the team was working well together based on the two presentations. The reviewer suggested that the researchers and Delphi need to update the FMEA after solving any technical issues, which will help in the transition to production.

Reviewer 2:
The reviewer simply stated that the researchers have worked very closely with Delphi and Penn State.

Reviewer 3:
The reviewer affirmed that utilizing Delphi as part of their partners is very good. The reviewer offered that the only thing that might be missing is a partner that is in the ceramic capacitor business.

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

Reviewer 1:
The reviewer expressed that the next steps seem logical and typical for solving production process related issues. The reviewer suggested that the researchers continue to use and update the FMEA after the root causes for future issues are determined.

Reviewer 2:
The reviewer observed that development of sub-micron PLZT powders and optimizing the aerosol process are critical to this evolving into a production process. The reviewer expressed interest in seeing the mechanism of culling-out the defects in the sheets, as well as decoupling shorted out capacitors from the bus explained, as these are critical for the capacitor manufacturer, the end-use application, and passenger safety.

Reviewer 3:
The reviewer expressed interest in the possibility of using the vaporization process to increase the thickness of the PLZT, thus increasing the voltage.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer reinforced that DC bus capacitor operating temperature is one of the limitations of inverters; they are also a significant cost driver. The reviewer affirmed that this project addresses both of these.

Reviewer 2:

The reviewer explained that one of the major ideas for this project is to find a capacitor that can be implemented in higher temperature applications where polypropylene film is unable to reach. The reviewer confirmed that this project fits the bill and is proving to be a viable solution.

Reviewer 3:

The reviewer explained that bulk capacitors are the second most expensive, and typically the largest component, in a traction inverter and represent a significant percentage of the cost. The reviewer added that the form factor of the capacitor and its thermal requirements drive the packaging of the design, and that this project addresses these issues.

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

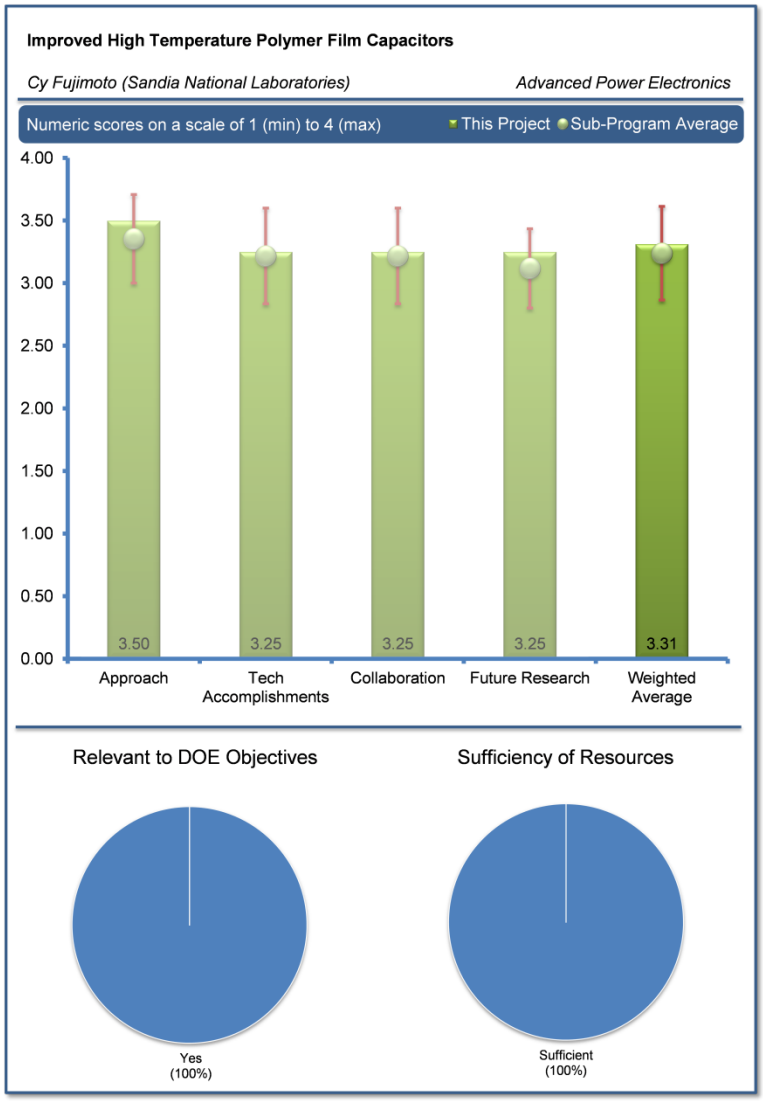
Reviewer 1:

The reviewer observed that the level of funding appears to have been sufficient. However, the reviewer added, the project funding is going down this coming year, so it needs to be seen if this will impact the progress.

Reviewer 2:

The reviewer simply stated that, based on the progress reported, the resources are sufficient for this project.

Improved High Temperature Polymer Film Capacitors: Cy Fujimoto (Sandia National Laboratories) - ape009



Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer affirmed that the project is addressing both technical and cost barriers as the researchers discover new issues. The reviewer noted that the team addresses both the advantages and disadvantages of potential issues as they are evaluated, including the cost and reliability impacts.

Reviewer 2:

The reviewer summarized that the project has been developing a high-temperature polymer and film production process for high-temperature film capacitors. The reviewer described that different polymers have been developed and modified, and that both solvent casting and melt extrusion processes have been developed. The reviewer suggested that it would be great if the team can also develop an orientation process to improve the film performance, as commercial PP, polyethylene terephthalate (PET), and polyethylene naphthalate (PEN) films are produced with a biaxial orientation process.

Reviewer 3:

The reviewer stated that the researcher and team have approached this project methodically, and continue to do so with a forward path, and with production in mind. The reviewer indicated that the presenter claims that the material has a 150°C capability with higher K, at a cost of $0.015/µF. The presenter claimed the material has almost double the energy density with the plasticizer and voltage stabilizer, and can be extruded and metalized, although not optimized. The reviewer questioned the $0.015/µF claim, as this is lower than a polypropylene capacitor, and would welcome a capacitor manufacturer to validate the claim. The reviewer also explained that the researchers do not know if the material self-heals well. Although there are no studies planned for this self-healing, it still needs to be determined. The reviewer also reported that the researcher plans to increase the molecular weight in hopes to eliminate the need for the plasticizer, and explained that plasticizers are expensive and not suitable to oil immersion.

Reviewer 4:

The reviewer reported that the approach appears to be in order with the exception of one part; a cost analysis is missing.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer explained that the team has made progress to improve the temperature stability of the polymer, and that the film quality has been continuously improved.

Reviewer 2:
The reviewer commented that the researcher has made significant progress since last year.

Reviewer 3:
The biggest issue the reviewer observed, at the current state, is that the extruded film is cracking in larger windings. The reviewer explained that the researchers mentioned that this was primarily based on bad mechanical properties. The reviewer indicated that this is an important step, as it will allow for high capacitance values in larger windings. The reviewer looked forward to following this project.

Reviewer 4:
While significant progress has been made, the reviewer expressed that there are still issues that need to be overcome. The reviewer agreed that the goal of achieving a cost-competitive capacitor is great; however, the size projections are a concern, as the data indicate that the capacitor will be larger than the goal. The reviewer also cautioned that the performance of the capacitor at high temperatures and at typical bulk capacitance values remains to be seen.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer mentioned that the researchers have worked closely with Delphi, as well as Electronic Concepts, Inc. (ECI), Sandia National Laboratories (SNL), and Penn State.

Reviewer 2:
The reviewer highlighted that having a manufacturer of film capacitors as a resource, not only allows for increasing the technical ability, but it allows the utilization of the resource for testing purposes.

Reviewer 3:
The reviewer concluded that the collaboration among the team members appears to be very good and is working based on the results.

Reviewer 4:
The reviewer described that the Sandia team has been working with ANL, Penn State, and ECI during this project.

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

Reviewer 1:
The reviewer summarized the future research plans include the following: increasing molecular weight to hopefully eliminate plasticizers; and optimizing extrusion, metalization, winding, etc., for a production process. The reviewer identified the need to do two things: assess the self-healing ability; and have an independent capacitor manufacturer validate the cost claim, as it seemed too low.

Reviewer 2:
The reviewer stated that the plans were very basic in concept, but were still very important. The reviewer indicated that the researchers need to send material to ECI for building and testing prototypes; this important step is what will prove the process.

Reviewer 3:
The reviewer summarized that the future work will continue to expand the size of the devices, as well as address potential manufacturing issues. The reviewer observed that the team is addressing multiple issues in parallel, which is good, but may lead to difficulty if new issues pop up in trying to determine the root cause. The plan is appropriate for the project goal.

Reviewer 4:
The reviewer suggested that the future research should be focused more on film processing at a large scale.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer pointed out that higher temperature operation and higher K [with low dissipation factor (DF)] are needed to develop inverters that run hotter and that are smaller.

Reviewer 2:
The reviewer noted that high-temperature film capacitors are a critical component in electric drive vehicle (EDV) power inverters.

Reviewer 3:
The reviewer explained that one of the major ideas for the project is to find a capacitor that can be implemented in higher temperature applications that polypropylene film is unable to reach. The reviewer noted that this fits the bill, but still was unsure if it can be implemented in mass-production, or if it can meet the cost targets.

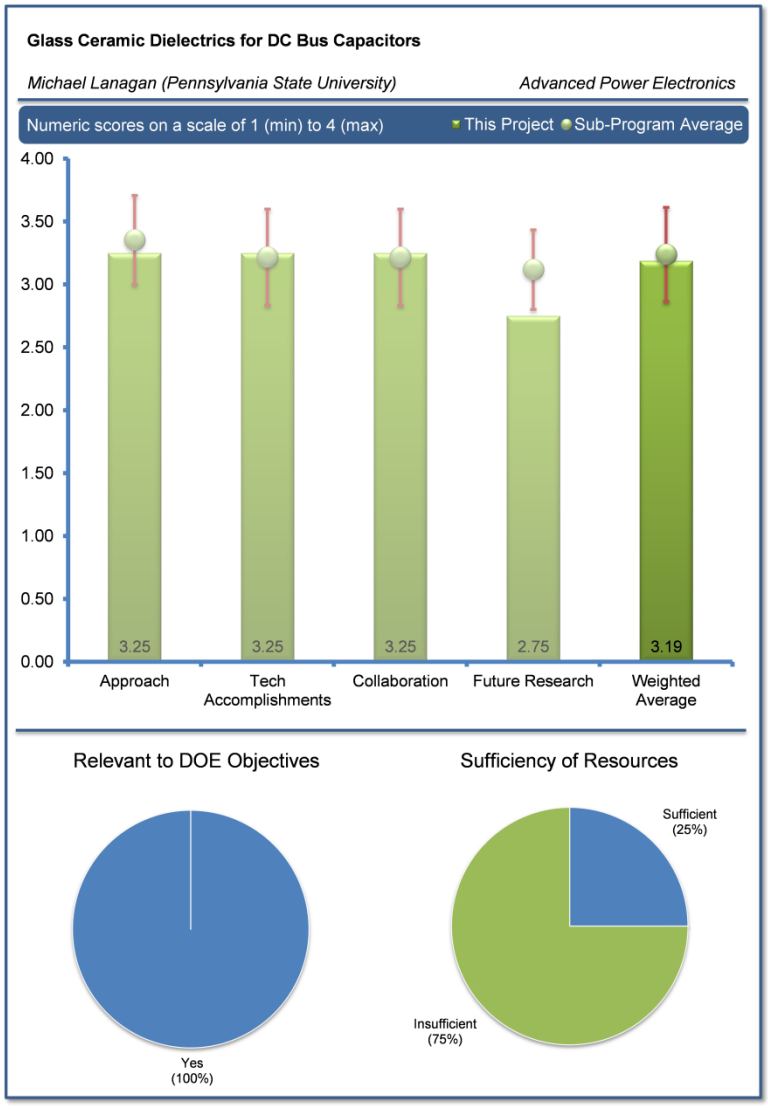
Reviewer 4:
The reviewer reinforced that bulk capacitors are significant issues in today's inverters in terms of size and cost, and are also limiting factors for high temperature use. The reviewer expressed that the proposed approach addresses most of the issues, with some concern that the size reduction will be significant enough, but acknowledging that any reduction is welcomed.

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

Reviewer 1:
The reviewer stated that resources appear to be sufficient, but may be on the light side. The reviewer expressed that there is significant progress to be made in the next few months. The goal is a 5-110 µF capacitor, which is achievable and sufficient to show viability of the film.

Reviewer 2:
The reviewer commented that availability of resources does not seem to be an issue for this project.

Glass Ceramic Dielectrics for DC Bus Capacitors: Michael Lanagan (Pennsylvania State University) - ape010



Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer agreed with the presenter's evaluation of using glass as a dielectric for DC link capacitors is valid for a higher temperature operation. The reviewer also explained that the presenter has proven that the glass can be wound. The reviewer expressed that the researcher needs to find out if the glass can be vapor-deposited and metalized, and also if it can self-heal.

Reviewer 2:

The reviewer commented that it was not clear from the presentation of the project's work, how the cost issue of capacitors is being addressed.

Reviewer 3:

The reviewer highlighted that leveraging suppliers of commodity available thin glass is an excellent approach for a PP replacement. The reviewer explained that the major barrier is how to get the suppliers of glass to provide thin enough material to compete with PP on a capacitance/volume basis. (Today the DC link suppliers are using 2.3-2.5 µm thick PP.) The reviewer described that using glass with a 200% improvement in permittivity, compared to PP, is possible. However, this reviewer asked whether the glass suppliers can provide a 6.6 µm thick glass to compete on a capacitance/volume basis with PP. The reviewer concluded by asking whether the supplied glass can provide a bend radius equal to that of PP.

Reviewer 4:

The reviewer applauded that it is outstanding that the researchers are taking advantage of the tremendous growth in flat panel displays to make a capacitor. The reviewer also thought that the approach of using Highly Accelerated Life Test (HALT) testing, to determine the viability, was extremely useful. The reviewer noted that the electrical performance potential is excellent. However, the mechanical performance has yet to be addressed. The reviewer noted that the flexibility of the glass has been shown, but not the ability to handle continuous vibration and shocks, such as are found in a vehicle. The reviewer expressed that this is not an insurmountable issue, but it will need to be addressed at some point.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer indicated that modest progress was made since last year due to minimal funding. The reviewer described that the project successes included: the materials passed the DC and alternating current (AC) electrical testing using painted palladium electrodes (replacing the previously used silver electrodes), and generated HALT data. The reviewer concluded by suggesting that the researchers need to migrate to vapor-deposited aluminum in order to be cost-effective.

Reviewer 2:
The reviewer commented that the pace is too leisurely, describing that the activities seem to have been done all serially, when they should have been done in parallel.

Reviewer 3:
The reviewer described that the work showed that a reliable glass-wound capacitor is possible. However, the reviewer suggested that it would be interesting to understand the compatibility issues of winding glass on the existing infrastructure used to wind PP. The reviewer asked several questions, including: whether the glass capacitor winding can be processed at the same rate as PP; whether there are handling issues that are unique to glass dielectric capacitors that could arise from the end spray or lead attachment process; whether clearing events cause other issues like fracturing the glass dielectric; and what rate of thermal shock can the glass based capacitors withstand.

Reviewer 4:
The reviewer reported that testing of the glass material for electrical performance and lifetime has shown the viability of the material as a high-voltage dielectric. The reviewer concluded that the results from the HALT testing indicate that the material choice was appropriate, and that it should become the choice for high-voltage/high-temperature dielectric material.

Reviewer 5:

Question 3: Collaboration and coordination with other institutions.
The reviewer explained that the collaboration plan is using the strengths of the team members. The reviewer believes that this team will meet the objectives of the project.

Reviewer 1:
The reviewer pointed out that the researchers are working with ANL, SNL, AVX, NEG, and Corning.

Reviewer 2:
The reviewer suggested that while there are a lot of capacitor industry partners, it may be beneficial to have an end-user partner to provide an end-user point of view. The reviewer also asserted that it would also seem reasonable that, with so many capacitor industry partners, the project team should be able to provide a relative cost for forming DC link capacitors made of glass, as opposed to PP and how that relative cost compares to the DOE 2020 targets. The reviewer asked whether that question has been asked of the 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.

Reviewer 1:
The reviewer indicated that extrapolation of the life model to larger capacitors is critical. This reviewer also offered that understanding the impact of sodium impurity in glass on life is critical (sodium mobility). The reviewer explained that the investigation of the level of self-healing (if any) is very important for potential adoption of technology since the lack of self-healing will be a major obstacle. The reviewer concluded by stating that the researchers will likely will need to use vapor-deposited aluminum electrodes.

Reviewer 2:
The reviewer noted that technical understanding of this capacitor type is progressing, but indicated that other areas need to be worked in parallel; for example, cost understanding and manufacturing processes need to be explored.

Reviewer 3:
The reviewer observed that understanding the fundamental limitations of glass dielectric is important and needs to be done. If there is no fundamental limitation to the dielectric, the reviewer queried how the glass suppliers could be motivated to deliver a thin enough material to meet the cost, size, and performance targets set by the DOE.

Reviewer 4:
The reviewer stated that the researcher's future plans are appropriate; material life issues need to be identified and addressed and this is the plan.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer commented that high-temperature, low-DF dielectric will become critical should wide bandgap develop, since it operates at higher temperatures than insulated-gate bipolar transistors (IGBT). The reviewer expressed that glass is a viable potential solution if it can be shown to have self-healing capabilities, and can be adapted to high-volume manufacturing.

Reviewer 2:
The reviewer explained that the current PP DC link capacitors used in EDV power inverters are big, heavy, thermally challenged, and costly. As a result, finding a PP replacement will help to lower the cost of EDV inverters and help to enable the market for EDVs.

Reviewer 3:
The reviewer stated that the project addresses the least rate-able, largest, highest cost component in a high-temperature inverter.

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

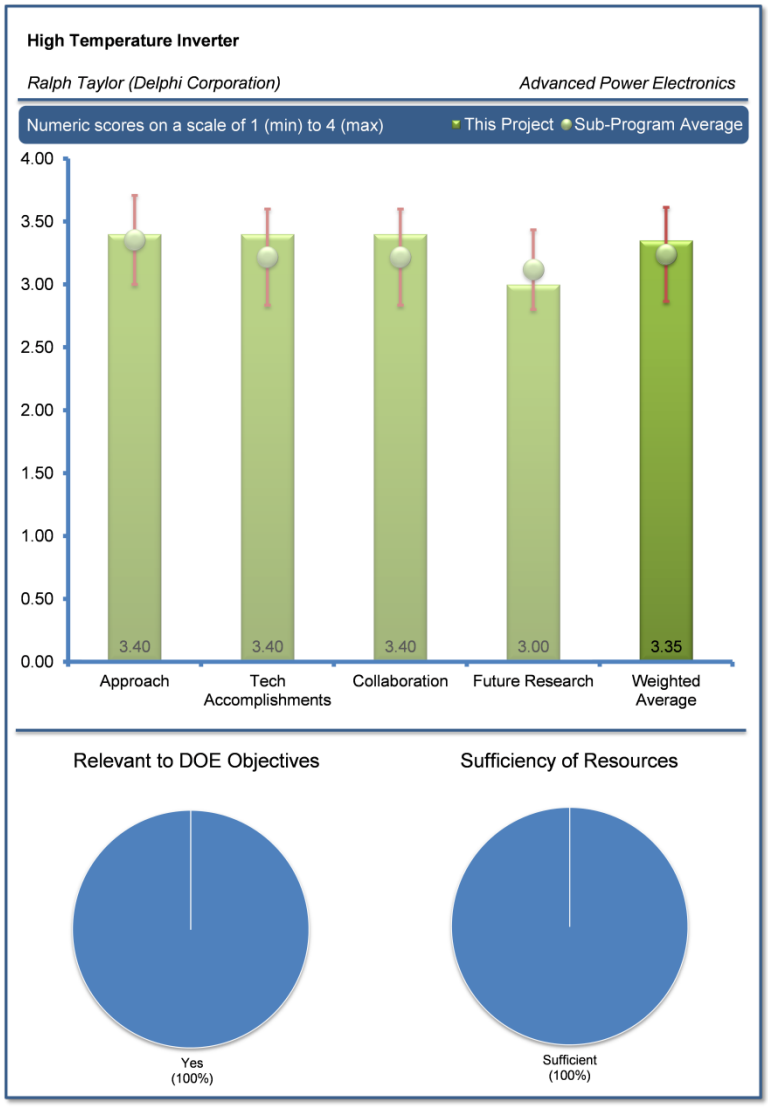
Reviewer 1:
The reviewer indicated that $50,000 for Fiscal Year (FY) 2013 is only enough funding to cover one part-time resource.

Reviewer 2:
The reviewer remarked that no information was provided on the funding level of this project, but given the pace that the work is being done, it seems that funding must be very limited.

Reviewer 3:
The reviewer expressed that the funding level was insufficient, only because the major barrier is finding a supplier willing to supply glass thin enough to enable this technology.

Reviewer 4:
The reviewer commented that the progress is indicative of adequate resources, and that those listed are correct.

High Temperature Inverter: Ralph Taylor (Delphi Automotive Systems LLC) - ape012



Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer reported that this project is wrapping-up a very successful multi-year effort that involved requirements-based advanced technology development to fill critical gaps needed for high-temperature inverters. This involved high- and low-risk options that, for the most part, were realistic given the short time frame of the project.

Reviewer 2:

The reviewer commented that the project's basic approach is good; however, it is based on a two-sided cooling method. No data was presented that indicates that a two-sided cooling approach is more cost-effective than single-sided with more silicon (silicon is relatively cheap today). The reviewer described that the program was developing two capacitors for high temperature operation in reality, which provides backup in case of issues that are not solvable in the time frame. The reviewer pointed out that no mention was made of what had to be done to provide accurate current measurements across the current/temperature range. This reviewer concluded by asking what the efficiency of the unit was across the temperature range, and how much did it degrade at hot temperatures.

Reviewer 3:

The reviewer commented that there seems to be two approaches. One approach is a sequential process development (e.g., try one idea; see if it works; if not, try another; eventually, one reaches the target, or not). The other approach is a design-of-experiment, which presumes that everything can be held constant across the long-duration matrix. The reviewer asserted that both approaches are reasonable and that learning occurs in both, but only some few succeed.

Reviewer 4:

The project has used different technologies to design and integrate high-temperature power inverters.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer reported that the project has met the final milestone and delivered prototype power inverter to DOE.

Reviewer 2:

The reviewer applauded that the double-sided cooling package approach is outstanding and the project exceeded all expectations on this aspect. The reviewer explained that the silicon carbon (SiC)-on silicon (Si) wafers, proposed as a way to short-cut the time required to reduce cost of proven 4HN-SiC wafer manufacturing, is not viable. The reviewer understood that the project explored this route given the allure of the breakthrough performance that has been demonstrated with SiC and the frustration that many have with time-scale required to scale up manufacturing SiC material. The reviewer commented that the capacitor technology development has proven to be difficult, as expected, but the capacitor work represents significant technology advancement, with good probability of impacting high-temperature inverters. Ultimately, the reviewer concluded that the project has met its overall goal of developing a high-temperature inverter that meets DOE's targets.

Reviewer 3:

The reviewer provided a brief project work summary, stating that some ideas worked and some did not; some few parts passed; some of those are still working; overall, the cost or volume targets were not met; and the presenter stated the project team ran out of time. The presentation left the reviewer looking for conclusions. The presentation indicated the researcher did accomplish making a high-temperature inverter. The reviewer was unsure about the reproducibility when only some few worked, but acknowledged that this is in the early stage.

Reviewer 4:

The reviewer commented that, based on the presentation, the performance of the unit was demonstrated over temperature but the test conditions were not mentioned nor were performance numbers presented. The reviewer also expressed reliability concerns related to operating a board at 123°C with 125°C parts where there does not appear to be much of a margin. The reviewer explained that the team did work well together to resolve the technical issues that were faced. The reviewer also pointed out that the original schedule to complete the project in July 2011 was overly optimistic. The reviewer added that the project team realized that the presentation time is limited, but it would have been beneficial to see all of the required issues that had to be overcome (e.g., current sensors) to enable high temperature operations.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer offered that the project has collaborated with various component vendors and developers to identify the best suppliers.

Reviewer 2:

The reviewer indicated that the project performed very well in working with partners and collaborations in many areas including capacitors, cooling system technologies, and electrical and thermal modeling,

Reviewer 3:

The reviewer praised that the team did an outstanding job working together to solve technical issues, and that the use of failure analysis and process FMEA should prove very beneficial when transitioning to production. The reviewer reported that the process was used for both capacitor designs, as well as a Design of Experiments approach. The reviewer also stated that there was very good active teamwork.

Reviewer 4:

The reviewer commented that the project seems rather completely dependent on National Laboratories doing materials development of ceramic capacitors, which may be too research-focused for economic production.

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

Reviewer 1:
The reviewer stated that the project will be completed this year.

Reviewer 2:
The reviewer indicated that, ultimately, the project has met its overall goals of developing high-temperature inverters that meet DOE targets by using alternate development pathways for each critical gap technology and appropriate down-selecting.

Reviewer 3:
The reviewer described that the development of the inverter was presented as complete, with the exception of the final report, but future work was described for the PLZT capacitor. The reviewer suggested that this should be moved to a separate project for that capacitor.

Reviewer 4:
The reviewer described that the future research plans include aerosol deposition with photonic sintering of PLZT materials; the reviewer cautioned that lots of novelty brings lots of risk.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that the high-temperature power inverter is critical to the DOE VTO.

Reviewer 2:
The reviewer explained that high-temperature inverters will provide substantial system cost, weight, and volume benefits in HEV propulsion applications.

Reviewer 3:
The reviewer stated that high-temperature inverters have been discussed for a while, and this project demonstrated that such an inverter can be built. A complete cost tradeoff will be required (at the vehicle level) that clearly shows that this approach is viable in terms of cost and reliability, before it will be accepted by industry. The reviewer affirmed that this inverter can be used as a baseline for a high-temperature inverter, but that the cost of assembly needs to be included. This reviewer's opinion was that some of the solutions presented will be useful in a typical temperature range inverter to provide a lower cost solution through the use of these techniques to handle the thermal excursions from transient operation, while still requiring less Si for normal operation.

Reviewer 4:
The reviewer observed that electrification of vehicles tends to decrease the amount of petroleum and other fossil fuels used for transportation.

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

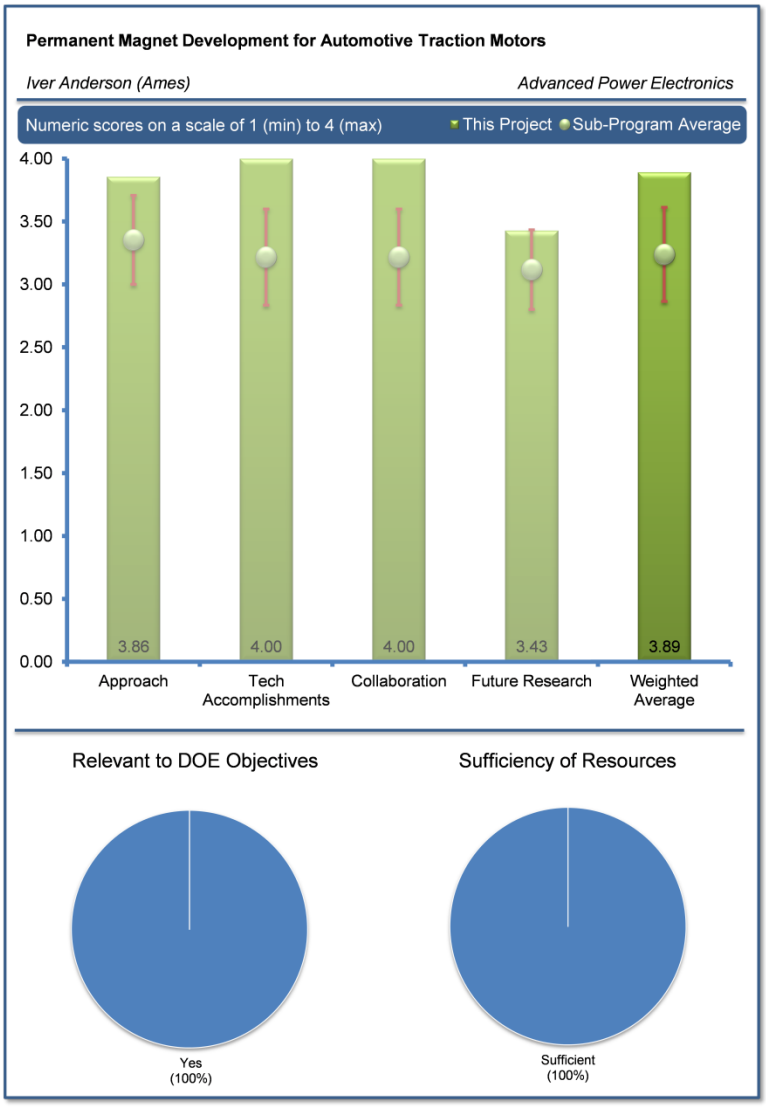
Reviewer 1:
The reviewer commented that work is ending.

Reviewer 2:
The reviewer believed that the resources were sufficient for the original plan, but due to the capacitor issues, the reviewer expressed that the resources were not sufficient to meet the original schedule. The reviewer highlighted that the fact remains that the goal of demonstrating a high-temperature inverter appears to have been met.

Reviewer 3:

The reviewer commented that the team has sufficient resources and partners to achieve the target.

Permanent Magnet Development for Automotive Traction Motors: Iver Anderson (Ames) - ape015



Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the extensive effort reflects that the approach provides confidence, and that the technical barriers are being addressed extremely well.

Reviewer 2:

The reviewer explained that the project involves the development of new permanent magnet materials with reduced cost and improved performance. The first approach is the reduction of the most expensive component in rare-earth magnets (dysprosium) with a new single-stage hot deformation (SSHD) method to fabricate fully dense anisotropic magnets. The second general approach is the "Beyond Rare Earth Magnet" initiative in which AlNiCo materials are improved and completely new material compositions are synthesized. The reviewer indicated that the overall approach is very well-designed and could be extended, or changed, if necessary, depending on the intermediate results of the sub-projects.

Reviewer 3:

The reviewer reported that the researchers used a well-planned research approach that systematically dealt with a broad range of magnet types, covering near-term rare earth (RE) and non-RE magnets, as well as long-term non-RE. The reviewer pointed out that the project also uses theoretical modeling as well as experimental methods.

Reviewer 4:

The reviewer indicated that, as could be said of all the motor development projects, the efforts are well-approached and seem to be highly collaborated by a select few. The reviewer also pointed out that the presenter is amazingly well-approached.

Reviewer 5:

The reviewer explained that reduced dysprosium and non-rare-earth work are both very important parts of this project. The reviewer applauded that the researchers have put much thought into the targets of the research to include the equivalent energy product (or flux density in the motor) at a relevant operating temperature.

Reviewer 6:

The reviewer summarized that the project approach is to develop new non-rare-earth, along with reduced-rare-earth, permanent magnet (PM) materials, which helps to ensure additional options in the near-term. The reviewer recounted that the reduction in

dysprosium, determined to be the most significant material in DOE's Critical Materials Strategy, is key to the reduced-rare-earth aspect of the project. The reviewer added that attention to both the material composition, as well as manufacturing steps, strengthens the approach.

Reviewer 7:

The reviewer warned that for the second milestone in September 2013, a more solid validation study is necessary before using Genetic Algorithm (GA) searching for the best structure based on computer simulations. The reviewer commented that the Principal Investigator (PI) showed a certain degree of agreement for a given structure from Slides 15 to 17; however, this does not mean the model is valid for exploring the new structure. As a consequence, the reviewer cautioned that the magnetic properties of the new selected Fe-Co-X alloys calculated from the model may mislead the material design.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer noted that numerous publications have resulted from this work.

The reviewer asserted that significant work has been done with modeling, simulation, analysis, manufacturing, and other novel methods to improve the coercivity of AlNiCo, which will make it a viable alternative to rare earth magnets.

Reviewer 2:

The reviewer highlighted that a significant project achievement towards the improvement of rare-earth magnets is the development of a new single-stage hot deformation method to fabricate fully dense anisotropic magnets with reduced dysprosium. The reviewer described that this method could potentially replace the more expensive method, with two-stage hot deformation (hot press and die-upset forging) in commercial anisotropic magnets, to produce fully dense magnets. The reviewer suggested that, as a next step in this project, the potential cost savings should be quantified, if this is possible, at this point in time. The reviewer also reported that significant progress has been made in the "Beyond Rare Earth Magnet" initiative, with the improvement of AlNiCo magnet materials. Commercial AlNiCo materials have been characterized, and pathways for improvements in composition and manufacturing were determined. A first pre-alloyed AlNiCo8H gas atomized powder sample was produced and tested on a hysteresis graph, and it shows a lot of potential, even though the process is not optimized at this point in time. The collaboration with an electric machine supplier, which is developing a new AlNiCo PM machine concept, will guide the work on both sides in the right direction. Lastly, the reviewer mentioned that the theoretical and experimental investigation of Fe-Co systems shows some promise, but the research is still in an early stage.

Reviewer 3:

The reviewer reported that the presenter showed very good progress with understanding AlNiCo structure and mechanisms for improvement. Also, the reviewer indicated there was very good use of modeling to investigate the potentially high energy product of non-RE alloys.

Reviewer 4:

The reviewer explained that this program topic was initiated with great urgency because of rare earth material costs. The reviewer highlighted that even though rare earth material markets have stabilized, this program has continued on this aggressive path and has demonstrated a very real potential that will not be as dependent on rare earth material markets.

Reviewer 5:

The reviewer observed that the demonstration of higher coercivity is positive (reduced dysprosium magnets), although processes that improve performance across a wide temperature range are needed. The reviewer suggested that it would be helpful to concentrate more on accomplishments that can be understood by non-experts, even if it means oversimplifying the research details. The reviewer described that it was useful to see that structure and roles of the different elements are being closely scrutinized.

Reviewer 6:
The reviewer reinforced that there is sufficient information provided for assessing this project, and that the technical accomplishments and progress meet the overall project and DOE goals and objectives.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer explained that a number of research organizations and universities are collaborating on this project, with the Ames Laboratory as a lead. The reviewer reported that the assignment of the separate tasks seems to be based on the specific expertise of the research organizations and is thus well-coordinated. The reviewer concluded by mentioning that collaborations with electric machine suppliers are aiding with specific focus on the permanent magnet material improvement needed for the different electric machine design concepts.

Reviewer 2:
The reviewer described that the presentation showed a very good use of the collaboration partners to explore a wide range of topics, and in an organized manner.

Reviewer 3:
The reviewer described that, as was obvious just among the presenters, this topic is well-collaborated (which the reviewer will repeat over again); however, the Ames Laboratory is at the front and center (lead).

Reviewer 4:
The reviewer commented that the project collaboration is broad, and it included a variety of institutions and experts that looked at the research issues from different angles. The reviewer clearly observed that the researchers are acting upon input from the collaborators.

Reviewer 5:
The reviewer highlighted that this project has extensive collaboration with its academic and industrial partners. Several other DOE-sponsored projects that were presented during the review included the materials and emerging results from this work. The reviewer noted that new grades of AlNiCo are fostering new motor designs, which leverage their best properties.

Reviewer 6:
The reviewer indicated that sufficient detail was provided on what contributions are being made by each of the collaborators, and that there are no issues identified with any of the collaborators.

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

Reviewer 1:
The reviewer reported that the project has well-defined milestones and that the plan for FY 2013 addresses the right issues. The reviewer expressed that the future research plans are based on the past progress, and that the barriers were identified as well as possible.

Reviewer 2:
The reviewer simply noted that the future work plan clearly builds on the success of the work to date.

Reviewer 3:
The reviewer acknowledged being unknowledgeable, perhaps, as to the needs that may remain.

Reviewer 4:
The reviewer expressed that the work is headed in the right direction, which bodes well for future research. The reviewer suggested that it would help to have more tangible goals (e.g., target magnet parameters) to allow industry to evaluate the impact of the new magnets may have on future motor designs. The reviewer suggested that even a rough idea of the possible improvements is helpful.

Reviewer 5:
The reviewer described that the further planned improvements in the coercivity of AlNiCo may make it a viable substitute to NdFeB magnets. The reviewer added that an ambitious plan was laid out for FY13.

Reviewer 6:
The reviewer observed that the proposed future work plan supports the project's objectives with adequate details.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer explained that the project supports the objective of petroleum displacement by developing non-rare earth magnet materials. The reviewer added that, if successful, these new materials would reduce the cost of PM machines, which would also enable a faster market introduction of HEVs and EVs.

Reviewer 2:
The reviewer affirmed that a sustainable supply of inexpensive, high energy product magnets is essential for low-cost, high-efficiency traction motors in HEV and EV applications.

Reviewer 3:
The reviewer expressed that reducing the reliance upon rare earth materials will allow for more stable electrified vehicle cost projections, thus allowing OEMs greater predictability of costs which will allow for market growth.

Reviewer 4:
The reviewer stated that alternatives to RE materials are important to the DOE's objectives, especially to those that retain the efficiency advantages of RE-PM motors.

Reviewer 5:
The reviewer summarized that the project will help reduce the cost of high-performance electric machines and ensure a steady supply of the included permanent magnets, while also reducing their price fluctuation. The reviewer emphasized that these machines are key components in HEVs which have demonstrated the capability to reduce fuel consumption. This work is especially critical to develop substitute non-rare-earth and reduced-rare-earth permanent magnet materials for future electric machines. The reviewer pointed out that this work is especially critical, considering the potential for supply disruption, cost fluctuation, and increased demand from new HEV and wind turbine applications.

Reviewer 6:
The reviewer indicated that statements in the presentation are positive that the work supports the overall DOE objectives of petroleum displacement.

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

Reviewer 1:
The reviewer reported that the presenter did not comment on any difficulties on resources.

Reviewer 2:
The reviewer expressed that the project has sufficient resources for the defined tasks.

Reviewer 3:

The reviewer acknowledged a lack of knowledge in this area to comment.

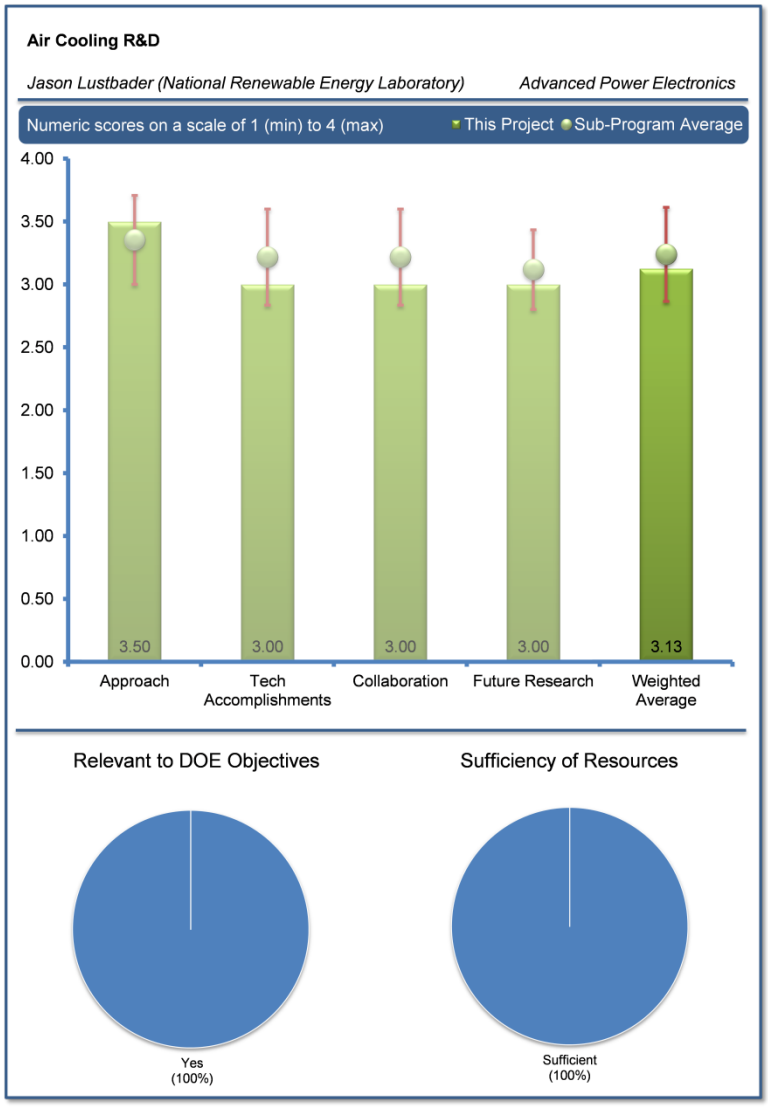
Reviewer 4:

The reviewer expressed that the team that is working on this project, is appropriate and sufficiently diverse to create useful outcomes.

Reviewer 5:

The reviewer commented that the project is going very well; a lack of resources is not apparent from the presented material.

Air Cooling R&D: Jason Lustbader (National Renewable Energy Laboratory) - ape019



Reviewer Sample Size

A total of two reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer expressed that the approach determined feasibility before proceeding with the design and construction. The reviewer noted that this is a well thought out presentation.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer explained that the prototype data confirmed that air-cooled inverters were possible, and so the concept was proven to be feasible.

Reviewer 2:

Question 3: Collaboration and coordination with other institutions.

The reviewer indicated that this is a good team, but felt that a vehicle manufacturer should be added to the team to get industry input. This reviewer suggested that this would help the project to become easier to manufacture and get industry acceptance.

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

Reviewer 1:

The reviewer suggested that future work should produce a proof-of-concept of a working prototype and address practical application issues.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

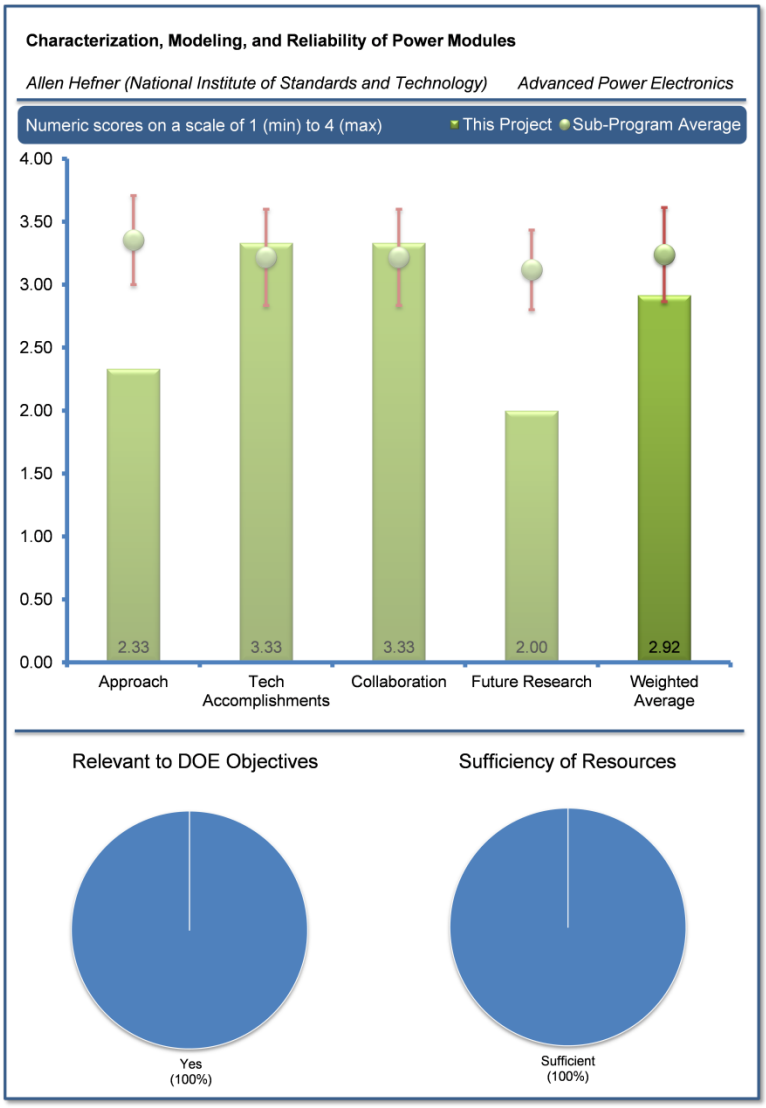
Reviewer 1:

The reviewer observed that this project is very relevant to future wide-band applications because cooling requires significant energy that reduces the EV drive efficiency.

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

No comments were received in response to this question.

Characterization, Modeling, and Reliability of Power Modules: Allen Hefner (National Institute of Standards and Technology) - ape026



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that certain items were deleted from original plan, and it was not clear why the items were deleted. The reviewer noted that the combination of making experimental test fixtures, and then modeling those fixtures, is desirable.

Reviewer 2:

The reviewer warned that the scope of the work seems to be too broad. The reviewer expressed a need to see a focus on identifying and understanding the vehicle thermal transient conditions effect on coolant temperature and ambient air. The reviewer also pointed out that component operating temperatures are dependent on the control strategy, which varies from vehicle to vehicle and from manufacturer to manufacturer.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer commented that the presenter had shown an interesting development for estimating the interior temperatures of metal–oxide–semiconductor field-effect transistors (MOSFET). The reviewer added that many parts of the simulation have come from other programs, so it was a little hard to detect which accomplishments are due to the present program. The reviewer admitted, however, that this is the nature of simulation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated that the researchers have interfaced with other programs.

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

Reviewer 1:

The reviewer cautioned that although the plans seem responsive to program needs, the plans seem broad and unfocused based on the presentation. The reviewer then noted relevant technologies included in the research plan, including the following: WBG; interconnect; electromagnetic interference; and bi-directional vehicle chargers.

Reviewer 2:

The reviewer cautioned that this work is too focused on specific devices, yet it was not clear to the reviewer that the simulation results will reflect real driving conditions. The reviewer suggested that understanding the physics of materials and packaging is more important than these particular applications. Also it seemed to the reviewer that several projects work that seems to be overlapping. The reviewer did not see was a clear understanding of what events during vehicle operation are creating stressful events for the electrification components and what the events characteristics look like.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

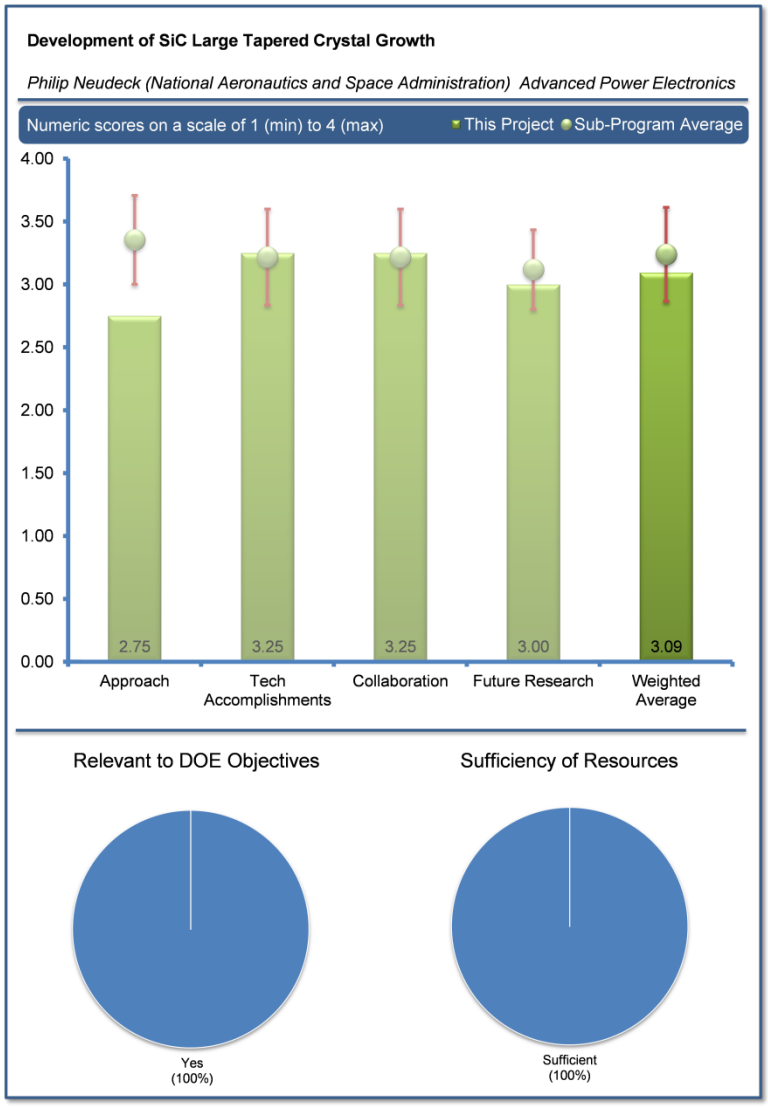
Reviewer 1:

The reviewer acknowledged that the electrification of vehicles will tend to decrease the use of petroleum for transportation.

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

No comments were received in response to this question.

Development of SiC Large Tapered Crystal Growth: Philip Neudeck (National Aeronautics and Space Administration) - ape027



Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer explained that this is deep-think work to address the very important problem of single crystals of 4H SiC. In spite of the many headaches, the reviewer found indications of the potential to operate. However, the timeframe of this project will not allow it to move far enough forward. Still, the reviewer acknowledged that the work is good and expected more in the basic funding area.

Reviewer 2:

The reviewer explained that the interest in the alternate SiC crystal growth method proposed, as a way to short-cut the time required to reduce the cost of proven 4HN-SiC wafer manufacturing, is understandable given the allure of the breakthrough performance that has been demonstrated with SiC. However, the reviewer cautioned that the new approach of this project is based on theoretical goals alone, without significant results that would indicate feasibility.

Reviewer 3:

The reviewer noted that the approach of this program seems to have morphed from the original objectives. The reviewer understood that this is a natural result of the research and development (R&D) results. The reviewer also expressed that the project is important and that the new approach supports the final longer-term objectives. However, the reviewer also opined that the project should re-evaluate what can be accomplished within the next seven months.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer praised that the project's technical accomplishments are great, and that it is nice to see progress on alternative development when the original accomplishments cannot be met. The reviewer expressed that progress will increase with the National Aeronautics and Space Administration (NASA) supporting it as a long-term project. However, the reviewer cautioned that there still need to be milestones and deliverable dates to avoid prolonging.

Reviewer 2:
The reviewer offered that it seems like a very reasonable amount of progress for a new critical materials development, but the work is not there yet, and the project is ending. The reviewer opined that the project objectives were idealistic, so falling short of meeting those objectives should not have been unexpected.

Reviewer 3:
The reviewer described that the project is growing some SiC crystals and is characterizing the material, but the reviewer criticized that the quality of the material is very poor and there is no indication that this will improve.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that the collaboration seems to be working well with analytical work in other laboratories.

Reviewer 2:
The reviewer asserted that the comprehensive team seems to be sufficient; however, the reviewer thought that it would be good to include more National Laboratories (if any are doing any of this kind of work). Also, the reviewer asked whether there are other companies, such as Dow, that could help with technical assistance and possibly funding.

Reviewer 3:
The reviewer affirmed that the project is coordinated with material scientists' need to characterize material, etc., but even if successful, the reviewer cautioned that this project would not have coordination points with other VTO projects for the foreseeable future.

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

Reviewer 1:
The reviewer expressed that this research is poised to answer the feasibility of further development. The reviewer also expressed that the NASA funding seems likely to allow some future progress, but that this is a new front of development.

Reviewer 2:
The reviewer noted that the proposed future work is fine, but was confused as to which future work is going to be done through 2013 (through the DOE funding), and which work will be done independently (without DOE funding). The reviewer suggested that it would be beneficial to make that more clear, or to align them. The reviewer also suggested that adding years, when the project looks to accomplish future research, would be helpful.

Reviewer 3:
The reviewer reported that the project has multiple alternate methods to produce the fiber and the epitaxial growth. The reviewer added that the project continues to innovate, but also expressed that there was little indication that the project will be successful.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer commented that electrification of vehicles will decrease dependence on petroleum fuels, and that lower cost SiC will be helpful.

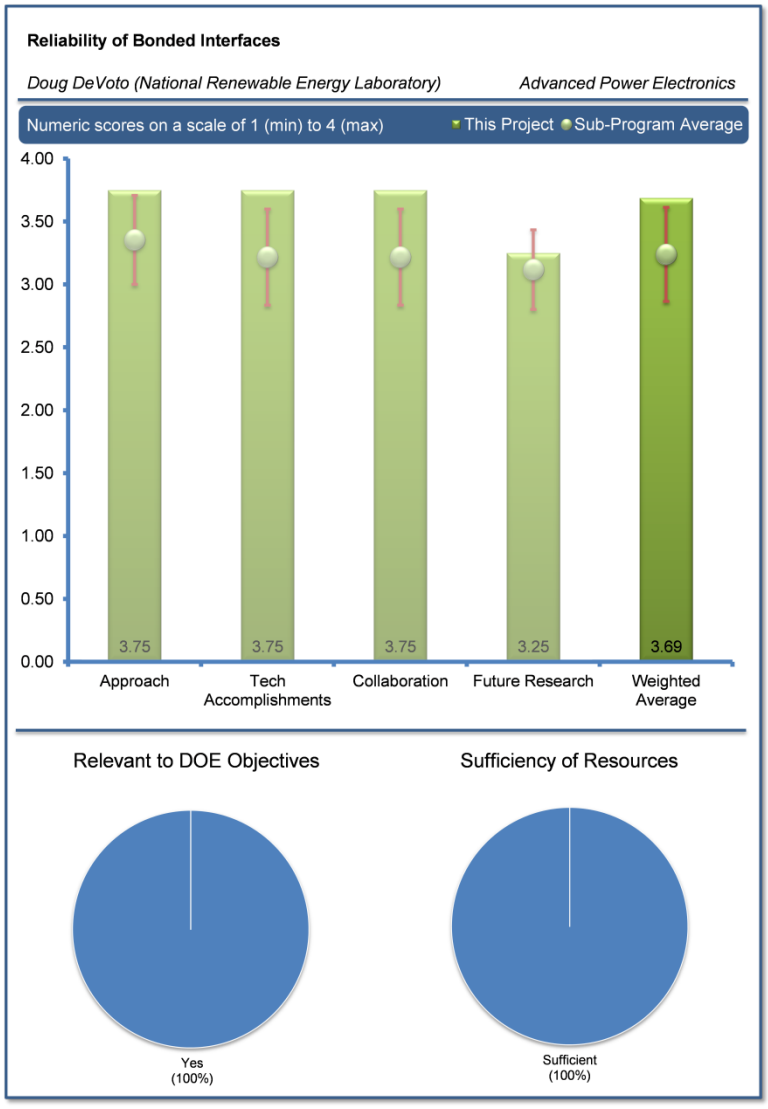
Reviewer 2:
The reviewer commented that, if successful in the long-term, this project has the potential to dramatically improve many of the crystal-affected industries, and not just the automotive industry.

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

Reviewer 1:

The reviewer indicated that the project team seems to have sufficient resources that may increase due to NASA money; however, the reviewer did not believe that the objectives will be met by the end of the program (2013).

Reliability of Bonded Interfaces: Doug DeVoto (National Renewable Energy Laboratory) - ape028



Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer explained that the interface, thermal interface material (TIM) or bonded interface material (BIM), between a power package and a heat sink is a limiting factor to the overall system thermal performance. As such, evaluating, TIMs or BIMs, to improve that interface performance, by testing and developing models that can predict their life, can be a valuable tool for the design of future EDV power electronics. The reviewer confirmed that the modeling holds the promise of shortening the testing time of materials, which can enable shorter time to market for EDV inverters and converters with improved thermal performance.

Reviewer 2:

The reviewer described that this project is addressing one of the barriers to developing a low-cost, reliable inverter for the transportation industry. The reviewer indicated that the method of attaching the die to substrates and to heat sinks is an important issue that must be solved for each application in a low-cost manner. The reviewer observed that this project is addressing the limitations of various types of bonding methods and that it should provide valuable insight into the strengths and weaknesses of each method, and hopefully help solve the weaknesses.

Reviewer 3:

The reviewer stated that the approach is logical and sound.

Reviewer 4:

The reviewer suggested the researchers need to look at other elements of creating a BIM.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer expressed that the progress towards understanding the manner in which the various bonding methods fail has been outstanding. The reviewer expressed that the use of modeling, followed by accelerated testing, is appropriate; defining failure limits up front was a requirement. The reviewer realized that lead-based solder is not acceptable now, but asked if it provides a good baseline to work from with years of use behind it. The reviewer concluded by stating that the choice for baseline was appropriate.

Reviewer 2:
The reviewer noted that the technical progress was good, but expressed that more comparisons were required to select the best bonding method.

Reviewer 3:
The reviewer stated that the modeling agrees with the tested results and is on track. The reviewer asked whether the researchers can take the next step and define the material properties for a BIM or TIM that will meet the stated performance targets.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer concluded that the collaboration was excellent with significant experts in the field being consulted.

Reviewer 2:
The reviewer simply noted that the project appears to be well-coordinated.

Reviewer 3:
The reviewer remarked that the project collaboration with team members appears to be very good to excellent; excellent regarding the involvement of team members assisting with the processes required to properly use their bonding material. It was not clear to the reviewer if the team members are being used to assist in identifying failure root causes for those that fail, but this reviewer would like to see the team members involved in this to improve their products.

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

Reviewer 1:
The reviewer opined that this project is important in the future to determine the best bonding for high-temperature WBG applications.

Reviewer 2:
The reviewer reported that the future work is in-line with what is currently being done. The reviewer asked whether the work can be expanded such that, based on the BIM or TIM's material properties, the BIM or TIM will meet the stated performance targets. Restated another way, the reviewer asked whether the material properties can be defined to enable a BIM or TIM to meet the stated performance targets.

Reviewer 3:
The reviewer confirmed that the proposed plan for next year is a logical extension of the current program. The reviewer would like the research team to add tasks related to the required plating quality of the substrate/heat sink, and to develop a standard for what is good enough. The reviewer indicated that experience has shown that plating quality has a large impact on the reliability of the bond joint.

Reviewer 4:
The reviewer suggested that other areas that contribute to the quality of the BIM need to be investigated in greater detail. For example, the manufacturing process and plating are critical to yielding high quality joint, and therefore, these areas need greater understanding and definition.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer agreed that this is an important project because bonding significantly affects the reliability and acceptance of EVs and bonding is one of the major reasons for industry electrical failures.

Reviewer 2:

The reviewer explained that this project can provide a tool to help increase the bonded interface reliability while at the same time, improving performance. The reviewer commented that better thermal performance of the bonded interface between the power package and the heat sink can increase power device reliability, possibly enable a smaller silicon (lower cost), or allow the EDV power electronics to operate at higher coolant temperatures (no secondary coolant loop, possible lower cost). This lower cost and improved reliability will help to enable the market for EDVs and lower our dependence on foreign oil.

Reviewer 3:

The reviewer reinforced that every inverter has devices that require bonding, and this project is solving issue with the various bonding methods. The reviewer felt the project should result in lower costs overall.

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

Reviewer 1:

The reviewer offered that there were adequate equipment and testing done for the scope of this project.

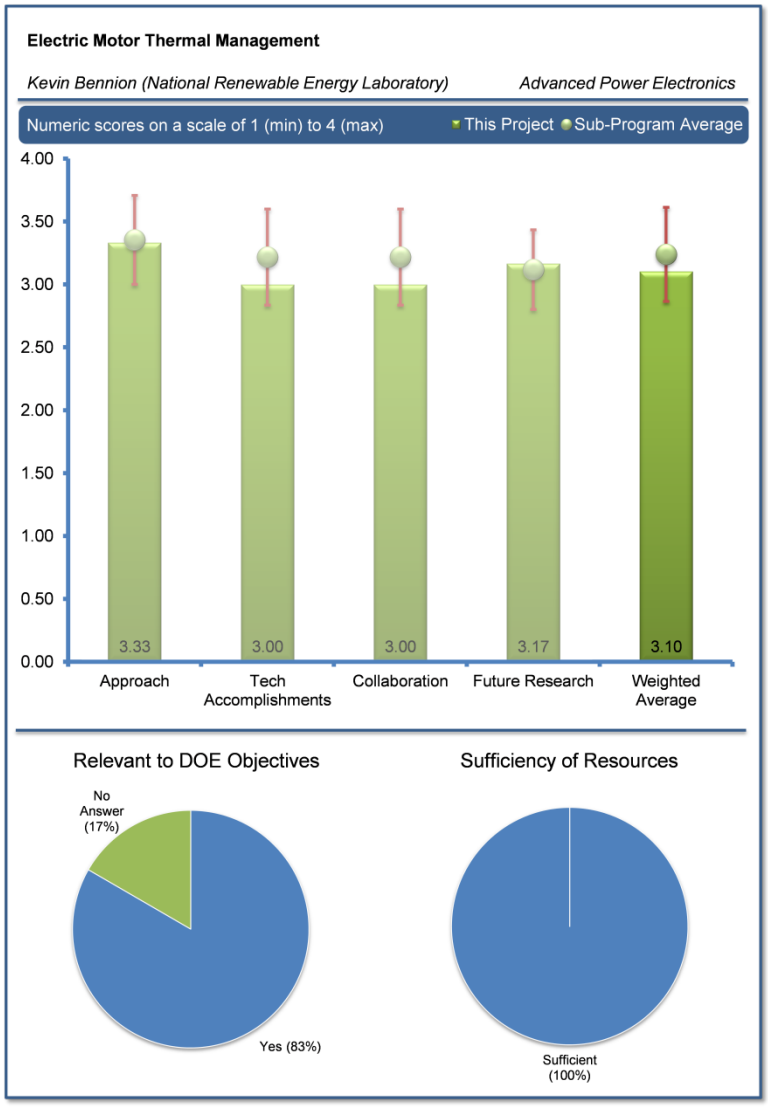
Reviewer 2:

The reviewer reported that the project results indicate that resources are sufficient to meet the program schedule.

Reviewer 3:

The reviewer noted that the team, with its partners, is well-coordinated and on track.

Electric Motor Thermal Management: Kevin Bennion (National Renewable Energy Laboratory) - ape030



Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer described that the approach, as presented, provides sufficient detail identifying the degree to which the technical barriers are being addressed. The project is well-designed, feasible, and integrated with other efforts addressing the barriers.

Reviewer 2:

The reviewer explained that the project conducted a cooling parameter sensitivity analysis for electric machines, both with experiments and simulations. The approach consisted of thermal finite element analysis (FEA) modeling for concentrated winding PM machines, and will be extended to induction machines in collaboration with another National Laboratory. The reviewer mentioned that the research was extended within the last year to investigate oil impingement cooling which is a very effective means of active cooling that is used elsewhere in the automotive industry. Therefore, the reviewer felt that a better understanding of this cooling technique is of high interest for automotive applications. The reviewer agreed that the overall research approach is well-designed and the technical barriers and limitations of the simulations models and test procedures were identified.

Reviewer 3:

The reviewer described that as thermal management of motors is a very diverse topic, it is a challenge to cover it all. The reviewer observed that the plan for this project wisely does not try to address everything, but rather focuses on the motor and cooling topologies and winding types that are most relevant to HEV and EV traction motors. The reviewer expressed that the researchers have covered these selected topics systematically, using both modeling and experimental approaches. The reviewer appreciated the clear aim to assist machine designers with the outcome of this research.

Reviewer 4:

The reviewer expressed that one of the main keys of the advanced motor development is to reduce size and cost of motors and improve performance; this project addresses this key issue. The reviewer added that the project's passive thermal design elements are a unique enabler.

Reviewer 5:
The reviewer affirmed that passive cooling, stator cooling jackets, and oil impingement are all relevant cooling techniques. The reviewer observed that studying these baselines, and their implications, are useful for the analysis and ultimate selection of the best cooling techniques for a given motor.

Reviewer 6:
The reviewer opined that the PI did not address the objectives very well as listed in Slide 4. First, the reviewer asked how the researchers quantify opportunities for improving cooling technologies for electric motors. The reviewer criticized that this objective is very vague and left the reviewer unable to judge the accomplishment of this objective. Second, the reviewer asked how the thermal improvements were linked to their impact on the Advanced Power Electronics and Electric Motors (APEEM) program targets. The reviewer asserted that the PI does not clearly address this issue either qualitatively or quantitatively. The reviewer indicated that the third objective was to increase information related to motor thermal management in open literature. The reviewer asked whether this should be a natural by-product of the project, and suggested that it is not appropriate to be treated as an objective. Additionally, the reviewer reported that no validation experiment was reported in Slide 12, other than the finite element analysis, which makes the findings relatively weak.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer indicated that the technical accomplishments are good and the results are important for the improved design of electric machine cooling techniques. The reviewer reported that thermal sensitivity analyses were conducted for different PM machines and their passive thermal design elements (e.g., for contact interfaces between slot liner and copper wire and laminations). The reviewer also described that an experimental set-up was implemented for the evaluation of transmission oil impingement cooling, and initial tests have been conducted. The reviewer noted that this part of the work is still in an early stage but will hopefully lead to interesting results.

Reviewer 2:
The reviewer acknowledged that good progress was made on FEA thermal and loss models. The reviewer also noted that very useful data regarding thermal resistances in the motor and parametric sensitivities, particularly for cross-slot thermal conductivity, was collected. The reviewer applauded the excellent and very original work on experimental measurement of convection coefficient for oil cooling.

Reviewer 3:
The reviewer offered that the technical approach is based on sound FEA, and appears to be correct.

Reviewer 4:
The reviewer commented that the analysis and test setups are useful, and it will be important that the researchers work with motor design experts to check the manufacturing and motor loss assumptions. The reviewer observed that the tasks and accomplishments, thus far in the program, are on target relative to industry usefulness.

Reviewer 5:
The reviewer stated that the technical accomplishments and progress, as stated, meet the overall project and DOE goals and objectives.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer pointed out the good use of the University of Wisconsin-Madison for modeling efforts and industry collaboration, and to make sure the most relevant topics are addressed and deliverables are useful to designers.

Reviewer 2:
The reviewer remarked that like all of the other motor research programs, the researchers appear to be well-collaborated with other National Laboratories and universities (e.g., University of Wisconsin-Madison).

Reviewer 3:
The reviewer commented that there are no issues identified with any of the collaborators, and that sufficient detail was provided on what contributions are being made by each collaborator.

Reviewer 4:
The reviewer indicated that the project includes one university collaborator, but no industry collaborators, even though industry feedback is being used to influence the research activities.

Reviewer 5:
The reviewer indicated that the researchers are collaborating with another National Laboratory and a university on this project. The reviewer observed that the collaborators' contributions are mainly in the area of electric machine design support. The reviewer criticized that, although it was mentioned that there has been some discussion with automotive OEMs, it seems that this area is still a weak point for the project. In the end, the reviewer reinforced that the goal should be that the developed simulation tools and experimental results are used by the OEMs for the improvement of their electric machine designs.

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

Reviewer 1:
The reviewer indicated that the proposed future work plan is consistent with the project objectives, with adequate details and specificity in supporting this assessment. The reviewer suggested that the rectangular wire cross-section discussed on Slide 15 may offer opportunities for future research work.

Reviewer 2:
The reviewer stated that the project will be finished in FY 2013 and the milestones for this year are well-defined. The reviewer described that the extended project scope to oil-cooled machines is a very good choice, as this cooling technique is of great interest for the industry due to the significant machine performance improvement. The reviewer also mentioned that the collaboration with the Oak Ridge National Laboratory (ORNL) will be beneficial for both projects.

Reviewer 3:
The reviewer reported a logical plan to build on previous work, and add thermal interface resistance measurements.

Reviewer 4:
The reviewer expressed that in this case, it is more important to continue the research into the project depth, rather than spawning new areas.

Reviewer 5:
The reviewer suggested working with industry on the inputs to the analysis and test work. For example, selecting realistic wire fill factors for motors, understanding the loss effects of bar windings (e.g., skin effect and the increase in AC losses that are caused by large winding cross sections), and the reduced loss effects of twist windings due to balanced flux linkage across all conductors (especially applicable for concentrated winding motors). The reviewer suggested that all of these items are motor loss issues that may not be known by thermal researchers.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer explained that the project supports the objective of petroleum displacement by improving the thermal performance of electric machines. If successful, this improvement would result in smaller machines with higher power density, which would enable a faster market introduction of hybrid and electric vehicles.

Reviewer 2:
The reviewer explained that improved thermal management in motors reduces the need for dysprosium in RE magnet motors and provides higher continuous output power density; both contribute to the adoption of HEVs and EVs.

Reviewer 3:
The reviewer commented that any improvements in the marketable feasibility of the motors for EVs will improve their viability and market acceptance, thus displacing oil.

Reviewer 4:
The reviewer indicated that the statements in the presentation are positive, and that the work supports the overall DOE objectives of petroleum displacement.

Reviewer 5:
The reviewer noted that thermal management affects the performance and cost of electric propulsion motors.

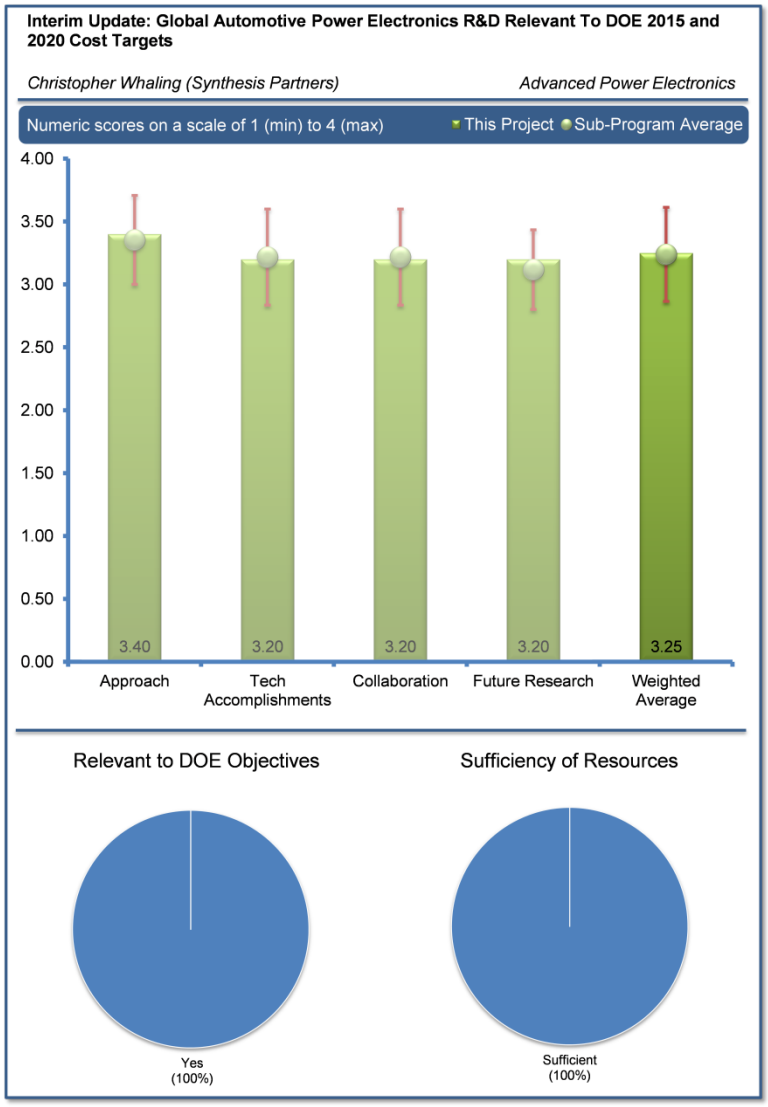
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the presenter did not comment on any difficulties on resources.

Reviewer 2:
The reviewer stated the project has sufficient resources for the defined tasks.

Reviewer 3:
The reviewer offered that the resources and logical progression of the program are on target to achieve program milestones.

Interim Update: Global Automotive Power Electronics R&D Relevant to DOE 2015 and 2020 Cost Targets: Christopher Whaling (Synthesis Partners) - ape032



Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer highlighted that this work is critical for understanding the industry trends. The reviewer observed that the researchers have done a very good job in compiling the data.

Reviewer 2:

The reviewer described that this kind of evaluation is different from experimental presentations. The reviewer cautioned that opinions of the speaker are influenced by analogies to examples that are far afield from the immediate data collected. The reviewer described that there is some structure in the choice of (foreign) paired companies and single, vertically-integrated companies, for study, which is a good approach.

Reviewer 3:

The reviewer noted an understanding from the presentation that a standardization of requirements is needed to reduce overall costs. The reviewer inquired about recommendations for achieving standardization [e.g., Society of Automotive Engineers (SAE) committees], as well as what could motivate the OEMs to do such a thing.

Reviewer 4:

The reviewer summarized that project has used several approaches to find and analyze, the information related to global automotive power electronics. The reviewer suggested that the project may invest more resources on other important components, such as switches and capacitors.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer explained that the project has gathered a lot of very useful information related to global automotive power electronics, and has provided a clear picture of the manufacturing and R&D.

Reviewer 2:
The reviewer described that the project accomplishments include data collection, which cannot be revealed due to licensing constraints placed by the information providers to the speaker. The reviewer also mentioned that the speaker reached some conclusions. For example, the DOE program cost goal will not be met without a radical change, presumably to some hub- or vertically-integrated structure.

Reviewer 3:
The reviewer asserted that it is very difficult to reduce thousands of pages of reports, timelines, technology road maps, business projections, etc. into a few relevant slides; but noted that the presenter made it work and interesting. However, the reviewer inquired as to who is responsible, or willing, to act upon the presented recommendations. The reviewer suggested that perhaps holding a workshop to bring OEMs together on EDV standards might be a starting point. The reviewer opined that from Slide 12 of the 2012 presentation (discussing technology road maps), if the road map does not support investment decisions, then it is not a good technology road map. From Slide 22 of the 2013 technology road map timeline, the reviewer did not see any investment decisions that enable the projected technologies. The reviewer also asked about the significance of the varying size and color boxes along the X-axis of the graph.

Reviewer 4:
The reviewer indicated that it was difficult to know the accuracy of the presented results. The reviewer, however, was not sure what else could be done to provide legitimacy to the findings.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer reported that many companies have contributed data for the study, which is evidence of collaboration. The reviewer explained that the information cannot be shared, which makes the product of the collaboration to be a bit obscure.

Reviewer 2:
The reviewer indicated that the researchers have talked to everybody, but suggested that perhaps the researchers should consider talking/working with the SAE to see how to establish standards committees.

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

Reviewer 1:
The reviewer noted that the work will continue, and highlighted that more China input is going to be valuable.

Reviewer 2:
The reviewer commented that continuing what the researchers are doing regarding standards is informative and that the researchers suggesting what should be done is also interesting. However, finding a way to make it happen would be great.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer explained that vehicle electrification will tend to decrease the need for petroleum for transportation.

Reviewer 2:
The reviewer stated that the presentation provided a snapshot of time where the technology is, and possibly where it is going. These insights may allow others to see opportunities to displace others and enable lower cost, along with reliable solutions for EDV products. The reviewer added that these lower-cost, reliable products will help to enable the market for EDVs, which reduce the reliance on foreign oil.

Reviewer 3:

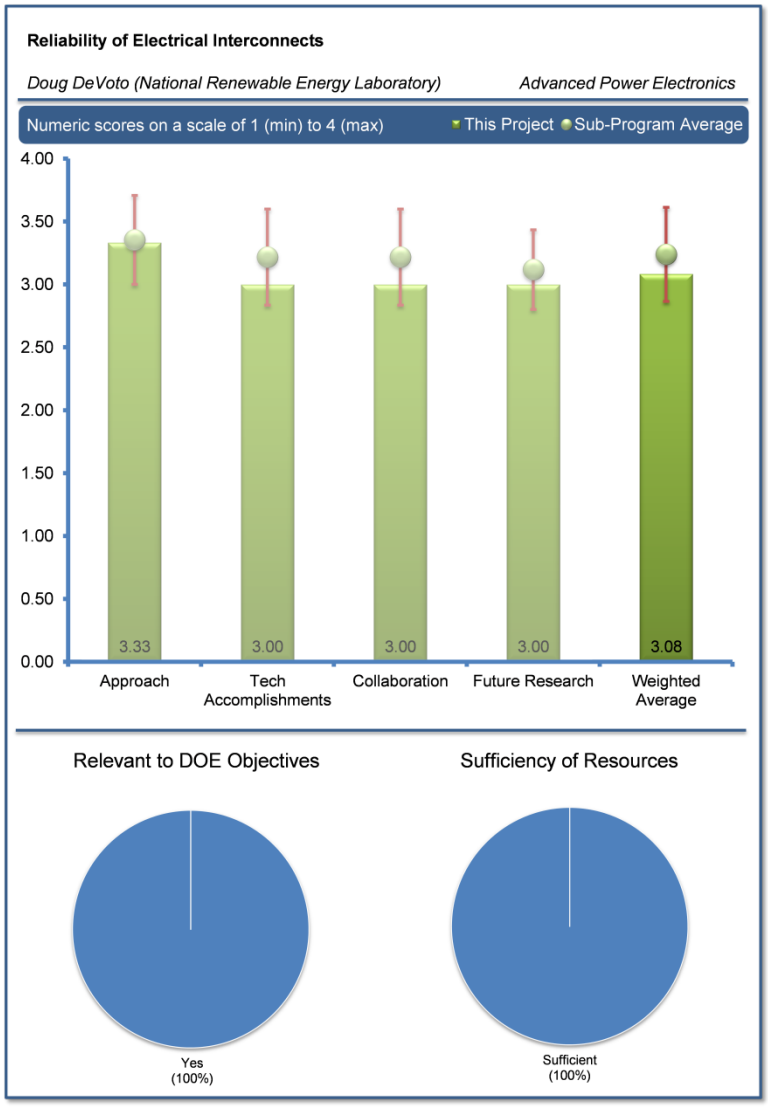
The reviewer emphasized that the information is critical for DOE to plan its future R&D efforts.

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

Reviewer 1:

The reviewer thought the work seems to be progressing with the resources provided.

Reliability of Electrical Interconnects: Doug DeVoto (National Renewable Energy Laboratory) - ape036



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the objective to determine failure modes in interconnect technologies was developed well. The reviewer requested that the summary provide general observations and conclusions.

Reviewer 2:

The reviewer described that the project is focused on characterizing the failure modes of ribbon bonding, as compared to industry standard wire bonding.

Reviewer 3:

The reviewer expressed that this was very appropriate for high-power inverters which require low-inductance interconnects. The reviewer anticipated that project results should enable improvements in the performance of ribbon bonding with the end result of being able to accurately model this interconnect method should provide a reliable component when ribbon bonding is used.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer asserted that the progress to date is outstanding, and that the approach has shown to be viable and has produced encouraging results. The reviewer indicated that the outcome should be usable by industry.

Reviewer 2:

The reviewer reported that the pull tests were planned well and demonstrated that wire bonds weaken under high temperature and humidity. The reviewer added that one of the stated project targets was to help designers to improve cost, weight, and volume; however, it was unclear to the reviewer how ultrasonic ribbon bonding labor and new equipment costs compares to standard wire bonding.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer summarized that the project collaborated with three technical partners on wire and ribbon bonding. The reviewer suggested that in the future an EV component manufacturer might be added to the collaborators.

Reviewer 2:
The reviewer cautioned that the collaboration appears to be limited to supplying parts and performing bonding. The reviewer would like to see involvement with root causing of the failure mechanisms.

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

Reviewer 1:
The reviewer noted that the future plans are a logical extension/progression of this project. The reviewer affirmed that industry will benefit if this plan is followed.

Reviewer 2:
The reviewer observed that making additional environmental testing of ribbon and wire bonds in the future is good, but suggested the project could also define the required temperature for WBG bonds and determine why higher temperature ribbon bonds are required.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

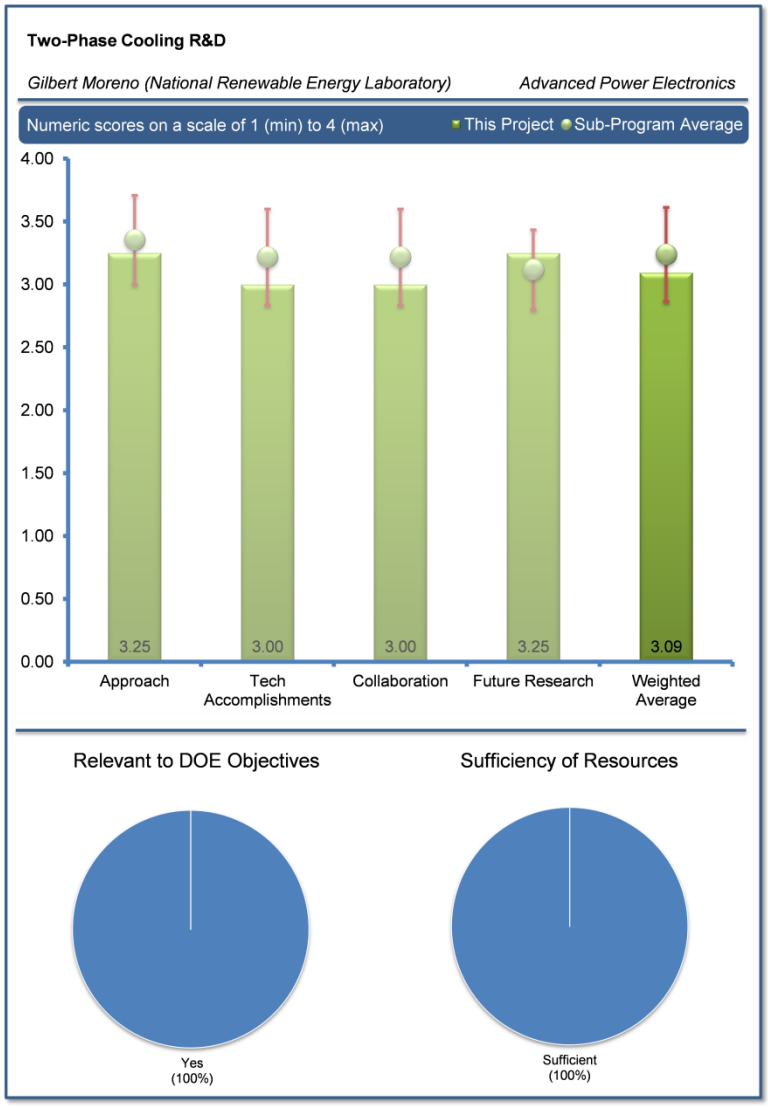
Reviewer 1:
The reviewer highlighted that this effort is an important part of the assembly of power modules, so it is imperative that it be correct.

Reviewer 2:
The reviewer offered that reliability and costs are relevant to acceptance of vehicle electrification.

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

Reviewer 1:
The reviewer praised the excellent results and progress to date with the resources allocated.

Two-Phase Cooling R&D: Gilbert Moreno (National Renewable Energy Laboratory) - ape037



Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that the two-phase cooling design is a potential low-cost solution to automotive power electronics.

Reviewer 2:

The reviewer applauded the excellent and very creative approach. The reviewer pointed out that this concept has some special requirements, such as condenser location above the evaporator and in a location with adequate air flow for the fan. The reviewer cautioned that these physical requirements could cause interference with other components and increase the space required.

Reviewer 3:

The reviewer explained that the project is aimed at solving one of the issues with traction inverters, cooling the power switches; however, the reviewer was not sure that this approach will provide the optimum solution as it needs to address the packaging/serviceability of the inverter once it is installed in the vehicle. The reviewer opined that the approach is novel and the results do indicate that it is technically capable of cooling the switches. The reviewer recommended that more involvement with the overall packaging of the inverter and the cooling system is needed to provide a solution.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer pointed out that the accomplishments and progress has been very creative and the science has been well researched.

Reviewer 2:

The reviewer described that the presented technical data showed a design that on the bench, provided outstanding performance with the potential to do so in a small size. The reviewer stated that methods of further improving the performance were implemented, and are either under extended testing or are planned.

Reviewer 3:

The reviewer explained that the project has demonstrated the concept of the two-phase cooling in prototype device.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed that the team is good, but suggested it might be a good idea to add an automotive assembly team member.

Reviewer 2:
The reviewer observed that the team has done a good job to date of working to their strengths and providing the appropriate hardware. What is missing from the team, according to the reviewer, is a system integrator that can help with the physical requirements for mounting this system in a vehicle, and that can determine what it needs, to be a viable commercial product.

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

Reviewer 1:
The reviewer stated the future plan was good, and that it includes the resolution of some practical issues.

Reviewer 2:
The reviewer remarked that the future plans are good to outstanding, depending upon the partner selected to assist in the demonstration. The reviewer pointed out the packaging issues related to the interface between the electronics and the cooling system, specifically the method of attaching the liquid supply and the vapor return lines. The reviewer highlighted that the orientation/method/location of the vapor return will be of interest as it may restrict the flexibility in allowable installation locations within the vehicle. The reviewer noted that the two-phase medium approach is good and should be reviewed with various OEMs to determine if a common fluid can be selected, or if multiple fluids need to be tested. The reviewer indicated that these issues are important, but are not overwhelming. The reviewer's biggest concern was the limitation of where the vapor return can be mounted and the cost of any disconnect method that may be required to support the installation.

Reviewer 3:
The reviewer asserted that the project will need to produce prototype for practical EDV power electronics.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer emphasized that cooling is a significant power loss and that this project has an interesting solution.

Reviewer 2:
The reviewer highlighted that cooling of power electronics is a big issue in vehicles, and that this method has the potential to reduce the volume required, as well as to provide an increase in performance.

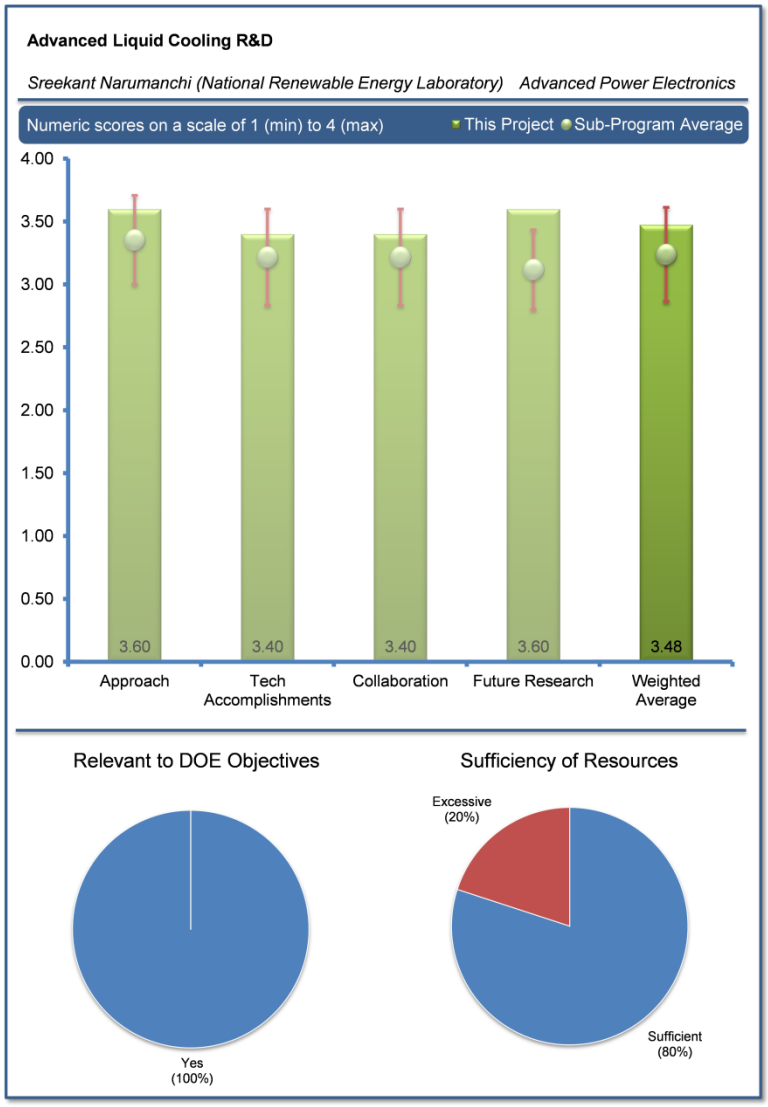
Reviewer 3:
The reviewer observed that thermal management is critical for reliable low-cost power electronics in EDV.

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

Reviewer 1:
The reviewer indicated that the resources are sufficient if an OEM is included.

Reviewer 2:
The reviewer said that resources have been sufficient to date as the results are impressive, but that vehicle level integration support is needed to move the project to the next level.

Advanced Liquid Cooling R&D: Sreekant Narumanchi (National Renewable Energy Laboratory) - ape039



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer summarized that the project will develop a single-phase liquid-cooled automotive inverter based on impinging jets, and enhances surfaces for improving thermal management for meeting the 2015 targets. The reviewer pointed out that the project will enable the use of high-temperature water-ethylene glycol coolant.

Reviewer 2:

The reviewer applauded that jet impingement was a great idea. This reviewer suggested that it would be interesting to compare adding channels to the plastic housing to direct the intake coolant toward the semiconductors. The reviewer also offered that the micro-surface and plastic container is a great idea.

Reviewer 3:

The reviewer commented that the submerged jet-cooling appears to be a means to reduce size of individual die and overall system, and that this was a good approach.

Reviewer 4:

The reviewer asked how this project impacts cost and added that no evidence was presented of what the cost is and could be with a new design.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer stated that the researchers had completed an initial design based on finite element analysis and modeling of three prototype designs. The reviewer also noted that the researchers had completed the design of the impinging jet configurations on a microfilm device.

Reviewer 2:

The reviewer summarized that the researchers demonstrated and imaged the cooling with the submerged jets.

Reviewer 3:
The reviewer simply noted that the project represented very good design and testing.

Reviewer 4:
The reviewer noted that the project is well-conducted, but criticized that the reliability characterization was weak. The reviewer expressed that no reliability modeling or system-level reliability testing is planned, which is crucial for demonstrating its real commercial value of this project.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer summarized that the collaborators included: UQM Industries (for inverter and power modules for dynamometer testing of the inverter); Delphi Electronics [for direct bonded copper (DBC) and DBA substrate for jet characterization]; and Wolverine Tube for micro-finned enhanced surface on a copper base plate and blocks.

Reviewer 2:
The reviewer agreed that this is a strong team for this phase of design and test, but emphasized that the next phase should include OEM vehicle input.

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

Reviewer 1:
The reviewer indicated the future research plans include characterization of the second and third prototype versions with jet impingement on a nickel-plated surface. The reviewer also mentioned that the research will address a cost comparison of mass production of the new heat exchanger as compared to the baseline aluminum heat exchanger.

Reviewer 2:
The reviewer reported that the plan to produce a prototype is excellent.

Reviewer 3:
The reviewer indicated that the future plans need to include a cost study that should include any cost impact to the entire system, if needed.

Reviewer 4:
The reviewer offered that the straight-through flow plan seems to have several benefits. The reviewer, however, asked whether it is possible that this positive in design may negatively affect the modularity of the overall system.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer explained that the EV battery will heat internally when used to power electric vehicles, so it will be necessary to provide cooling of the battery to prevent thermal runaway of the lithium-ion (Li-ion) battery and safe operation on public streets and highways

Reviewer 2:
The reviewer asserted that electrification of vehicles will lead to decreased use of petroleum, either through improved gasoline mileage, or through not using gasoline at all.

Reviewer 3:
The reviewer noted that this project could improve efficiency and reduce cost.

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

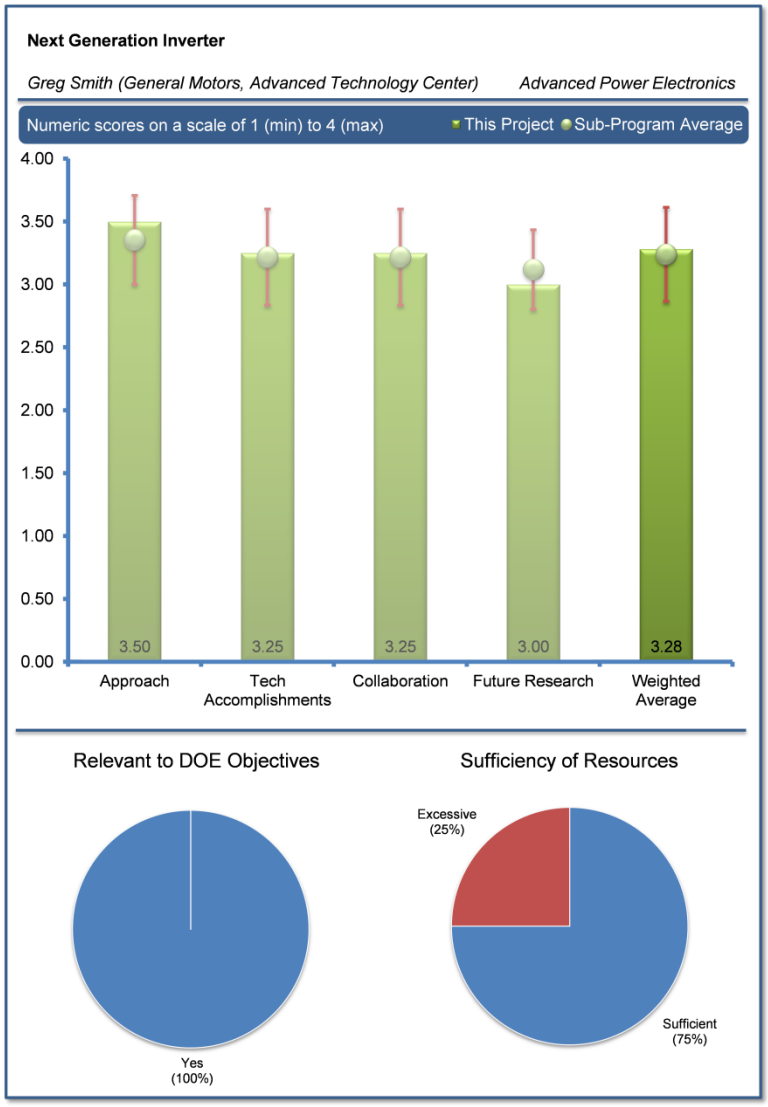
Reviewer 1:

The reviewer stated that the funding was appropriate for this project

Reviewer 2:

The reviewer observed that the resources were adequate for this phase of the project.

Next Generation Inverter: Greg Smith (General Motors) - ape040



Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that it seems appropriate that the focus is performance for the dollar, with commonality and worldwide manufacturing feasibility. The division into power modules, capacitors, gate drives, and control seemed appropriate to the reviewer. The reviewer applauded that the insight of the importance of cooling for cost reduction is leading the approach.

Reviewer 2:

The reviewer described that the strategy includes utilizing technologies that will be scalable to a wide range of vehicle applications, modular to enable cross-platform compatibility, and will be compatible with future technologies such as wide bandgap switches. The reviewer pointed out that the collaborations deep into the supply chain enable effective integration of advanced technologies. The reviewer noted that several collaborators for each key technical area (e.g., capacitors, gate drive, wide bandgaps, modules, and inverters) ensure that inverters can be specified consistently with multiple source supply chains

Reviewer 3:

The reviewer remarked that there is no doubt that General Motors (GM) has a practical approach to develop low-cost power inverter for commercial EDV, even though the project team can not disclose detailed technical information about the power inverter design.

Reviewer 4:

The reviewer criticized that the presented work was very vague and shared very little information with the reviewers. The reviewer described that the presenter essentially summarized that the last two years were spent collecting data internally. The reviewer acknowledged that even though there is an understanding that there is a need for protecting confidential information, this does not give reviewers the impression that much was done.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer reported that the program seems to be off to a good start, but with 2% done, it is too early to say much yet about accomplishments. The reviewer expected that significantly more will be accomplished by 2016.

Reviewer 2:
The reviewer summarized that a report on the technology and production cost was completed.

Reviewer 3:
The reviewer observed that GM has an integrated approach to achieve the target, though the details are not public.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer described that project collaborations deep into the supply chain, will enable effective integration of these advanced technologies. Several collaborators for each key technical area (e.g., capacitors, gate drive, wide bandgaps, modules, and inverters) ensure that inverter can be specified consistently with multiple source supply chains.

Reviewer 2:
The reviewer confirmed that GM has been working with various component suppliers.

Reviewer 3:
The reviewer noted that the list of vendor companies seems adequate.

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

Reviewer 1:
The reviewer recounted that a quote from the oral presentation (i.e., stepping through every single piece) reflects the careful detailed approach that is being taken. The reviewer summarized that integration decision choices were described as best fit for the application, as the vendor reliability is seen as being good, and providing those many choices.

Reviewer 2:
The reviewer expressed that little information was provided about future tasks and milestones, so suggested that a concept design go/no-go review would ensure adequate project planning and oversight.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that the electrification of vehicles helps to decrease the use of petroleum for vehicle propulsion.

Reviewer 2:
The reviewer explained that the project focuses on key VTO goals including cost, efficiency, performance and lifetime, and mass and volume to develop line of next generation propulsion inverters with a range of 55-110 kilowatt (kW).

Reviewer 3:
The reviewer asserted that GM is one of few companies that can develop integrated low-cost inverter technology and actually adapt it in a commercial EDV.

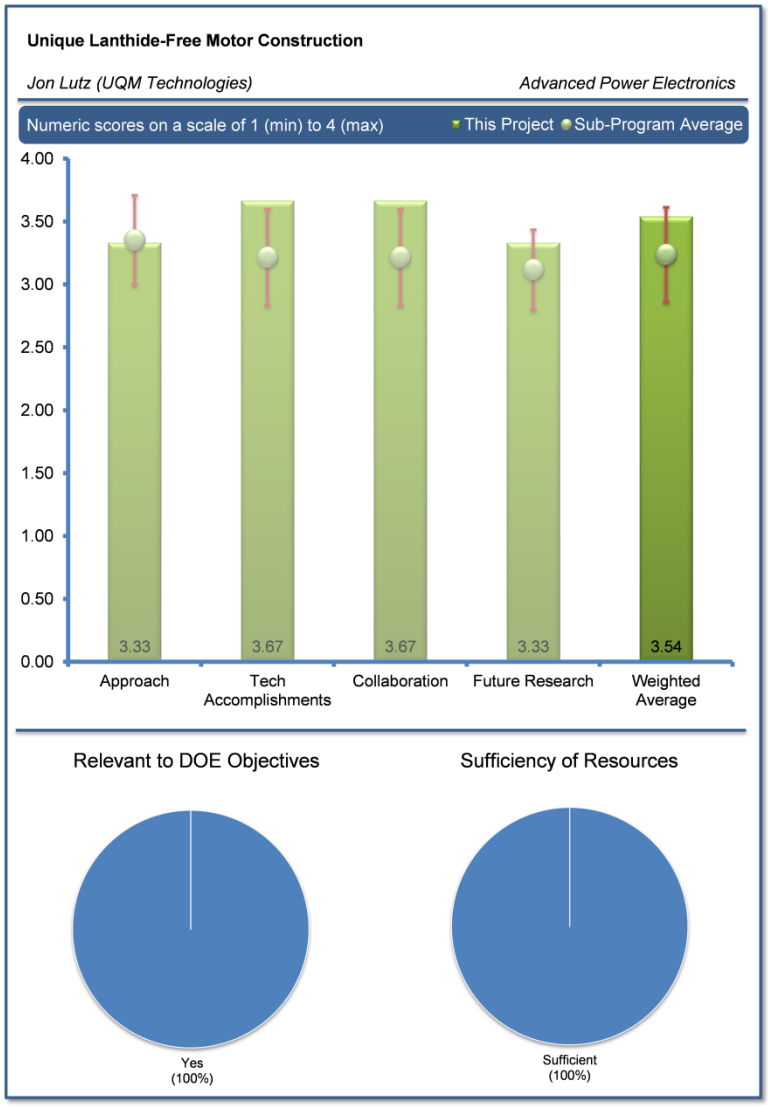
Reviewer 4:
The reviewer simply stated, yes, if successful.

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

Reviewer 1:

The reviewer cautioned that it was unclear what has been done for the $2 million spent so far, which goes beyond compiling the internally available data.

Unique Lanthide-Free Motor Construction: Jon Lutz (UQM Technologies, Inc.) - ape044



Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that the approach, as presented, provides sufficient detail to identify the degree to which the technical barriers are being addressed.

Reviewer 2:

The reviewer asserted that this project is another excellent example of motor development that does not rely on expensive rare earth materials.

Reviewer 3:

The reviewer summarized that a new electric machine concept with AlNiCo magnets, instead of rare-earth magnets, is being developed in this project. The reviewer described the justification for the approach being that AlNiCo magnets are significantly cheaper than NdFeB magnets, at least as of today, and the prices have been stable for a long time. The reviewer reported that electromagnetic modeling of the machine confirmed that AlNiCo magnets are usable without a significant demagnetization (this has been the main issue with this magnet material in the past). The overall approach is generally well-designed, according to this reviewer, and the technical barriers were identified. The reviewer pointed out that the milestones are well-defined and the manufacturing of prototype machines is coupled to go/no-go decisions based on simulation results.

Reviewer 4:

The reviewer observed that the research approach makes sense, focusing on a topology that results in large increase in permeance coefficient, and increasing coercivity of AlNiCo. However, the reviewer was concerned with the fact that, for PM machines, the design criteria for demagnetization was left to the discretion of the investigator. In the reviewer's opinion, this issue should be addressed in the DOE specifications for the project. The demagnetization criteria (current and temperature) can vary from normal operating currents at low temperature to transient 3-phase short circuit at high temperature. This has a significant effect on PM motor cost, as well as on feasibility of non-rare earth PMs. The reviewer asserted that whatever criterion is used by DOE, it should be applied consistently to all investigators. The reviewer cautioned that this issue is at the core of motor development using AlNiCo magnets, because demag is the Achilles' heel of this magnet type. The reviewer warned that UQM's self-imposed criteria of normal operating current level (the reviewer was not sure of what temperature) seems like a low standard.

Reviewer 5:
The reviewer explained that field weakening is not possible on this design, which requires an increase in voltage to meet the speed targets [750V required for 10,000 revolutions per minute (RPM)]. Current spikes are expected to demagnetize the edges of the permanent magnets (400A peak will result in approximately 2% demagnetization); so the only way to compensate for this loss is to increase the current to produce the same amount of torque, further increasing the demagnetization. The reviewer added that the loss of phase angle could result in more than 10% demagnetization. The reviewer noted that the approach was not described in sufficient detail during the presentation, adding that even a high-level discussion about the proposed rotor design was not included. The reviewer cautioned that the design has a high risk of not meeting the performance objectives due to demagnetization and the requirement for a variable DC bus voltage to meet the speed targets.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer stated that the technical accomplishments and progress, as stated, meet the objectives and goals, and the presentation provided sufficient detail to support this assessment.

Reviewer 2:
The reviewer applauded the excellent progress on concept development of AlNiCo usage.

Reviewer 3:
The reviewer expressed that given the high difficulty of basing the design on AlNiCo, the current design has reasonably good results so far (except for the demag criteria). It was not clear to the reviewer from the DOE specifications whether voltage-boosting was an allowable approach to meeting required performance. However, the reviewer admitted that this may just be the reviewer's misunderstanding of the specification. The reviewer added that good progress was shown by NREL and the Ames Laboratory on cooling and magnet improvement.

Reviewer 4:
The reviewer noted that the project is well-conducted, and also asked if the coercivity study results (Slide 13) were obtained from the simulation. If so, the reviewer indicated that an experimental validation study is necessary. In addition, the reviewer requested that the researchers please clarify how the results are related to the DOE requirements.

Reviewer 5:
The reviewer suggested that the reviewers may need to revisit current requirements since during the discussion it was revealed that some projects are targeting a 400 Arms system and UQM is targeting a 400A peak machine. The reviewer warned that the operative voltage range does not seem to be in compliance, despite a positive status on Slide 16. The reviewer noted that the magnetic, thermal, and controls analysis are helping to improve the machine design. The reviewer mentioned that no publications have resulted from the work to date.

Reviewer 6:
The reviewer observed that the technical accomplishments are generally good, detailing that the electromagnetic design simulations indicate that maximum torque and power is achieved within volume limits. However, the reviewer expressed that a drawback of this new machine concept is the fact that the machine cannot be field weakened. This fact leads to the need of including a boost converter traction system to obtain an only moderately high maximum speed (10,000 RPM) with a DC voltage of 750 volt (V). The reviewer reminded that this maximum speed is not even close to the DOE requirement of 14,000 RPM.

A second issue identified by the researchers is the significantly higher magnet mass in this type of machine (three times the mass of NdFeB magnets) for the same machine performance. The reviewer commented that it remains to be seen, if these drawbacks will increase the system cost significantly and may negate the cost savings with the AlNiCo magnets.

The reviewer noted also that researchers cannot reveal many details about the new machine concept at this point in time, as patent applications are pending, but hoped that this will be addressed in future review meetings.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that there are no issues addressed with any of the collaborators. The reviewer reported that sufficient detail was provided on what contributions are being made by each of the collaborators.

Reviewer 2:
The reviewer highlighted that the collaboration with Ames Laboratory for the development of improved AlNiCo magnets, is beneficial for the success of this project, as improved magnet materials can be implemented in the machine design when available. The reviewer also reported the other collaborations with NREL and ORNL will support the progress of the project.

Reviewer 3:
The reviewer commented that the work appears to be coordinated and that the researchers had used NREL well for thermal analysis and the Ames Laboratory for magnet improvements.

Reviewer 4:
The reviewer stated that, again, like most projects in this area, the project is very well-coordinated.

Reviewer 5:
The reviewer summarized that UQM has partnered with three government laboratories for aspects of the project, but that no relationships with academia or other industrial organizations were identified. The reviewer described that further improvements to AlNiCo coercivity in the Ames Laboratory research will have a significant positive impact on this development program.

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

Reviewer 1:
The reviewer indicated that the proposed future work plan is consistent with the project objectives with adequate details and specificity.

Reviewer 2:
The reviewer stated that the milestones in the project are well-defined and the barriers are identified as well as possible. The reviewer explained that the machine build, with standard off-the-shelf magnets, will be completed in October 2013, and subsequent testing will hopefully confirm the simulation results. In the next step, improved magnet materials will be implemented in the machine design, when available through the collaboration with the Ames Laboratory.

Reviewer 3:
The reviewer commented that the future plans seem logical and allow for multiple paths (e.g., oil- as well as water-cooling).

Reviewer 4:
The reviewer remarked that the next steps, of course, should be to integrate these various programs, especially the Ames Laboratory.

Reviewer 5:
The reviewer explained that UQM is working to reduce the required quantity of AlNiCo from three times to double the required rare-earth material required for similar power levels. End turn cooling is expected to improve thermal management performance compared to the existing water jacket design. The reviewer suggested that adding in the opportunity to refine/optimize the electromagnetic design of the machine after testing the first motor could strengthen the future plan. The reviewer asked if this will occur in Year 3.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer reported that statements in the presentation are positive and that the work supports the overall DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer explained that the project supports the objective of petroleum displacement by developing a new motor concept without the use of expensive rare-earth magnet materials. If successful, the reviewer noted that these would result in cost savings for electric drive systems, which would enable a faster market introduction of HEVs and EVs.

Reviewer 3:
The reviewer described that the project addresses the inherent sustainability problem with motors that use current rare earth magnets and creates a possible path for sustainable, high-efficiency sand EV applications.

Reviewer 4:
The reviewer repeated the need to develop better motor technology, which will lead to more stable costs and acceptance for OEMs to develop.

Reviewer 5:
The reviewer explained that this project will help reduce the cost of high-performance electric machines due to the primary PM material being AlNiCo rather than traditional rare-earth materials. The reviewer pointed out that these machines are key components in HEVs, which have demonstrated the capability to reduce fuel consumption.

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

Reviewer 1:
The reviewer stated that the presenter did not comment on any difficulties on resources.

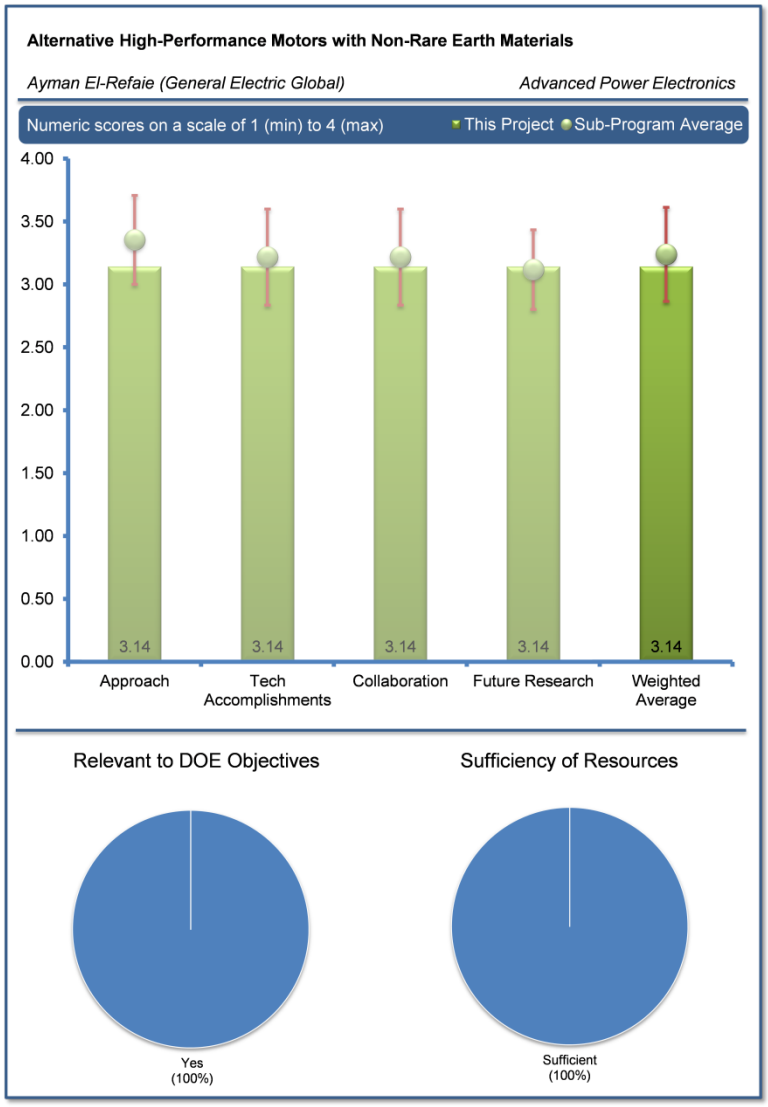
Reviewer 2:
The reviewer indicated that the project has sufficient resources for the defined tasks.

Reviewer 3:
The reviewer stated there was good team selection.

Reviewer 4:
The reviewer stated that the project is on track and that a lack of resources is not apparent from the presented material.

Reviewer 5:
The reviewer asserted being unqualified to elaborate to detail.

Alternative High-Performance Motors with Non-Rare Earth Materials: Ayman El-Refaie (General Electric Global) - ape045



Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the project is well-conducted and planned.

Reviewer 2:

The reviewer offered that trade studies on a variety of motor topologies is a good starting point, and when married with improved soft and hard magnetics, may result in overcoming barriers. The reviewer acknowledged that the organization and the PI are very familiar with the requirements and challenges of the DOE targets.

Reviewer 3:

The reviewer explained that the main goal of the project is the development of new electric machine concepts with non-rare earth magnets, or with no magnets at all. The approach is to investigate 10 different motor topologies and to identify promising new materials. A downselection of three most promising machine concepts for further investigation and prototype build, will focus the project resources on the best candidate concepts. The reviewer reported that a weak aspect of the approach is that a cost model will be developed only for the final concept with the best performance. The reviewer explained that this approach somewhat ignores at first the main challenge for future electric traction motors, which is the high cost. For example the best concept in terms of performance might end up being the most expensive too.

Reviewer 4:

The reviewer stated that the research approach makes sense, with attention to improving machine topology and materials. However, the reviewer was concerned with the fact that, for PM machines, the design criteria for demagnetization was left to the discretion of the investigator. In this reviewer's opinion, this issue should be addressed in the DOE specifications for the project. The reviewer explained that the demag criteria (current and temperature) can vary from normal operating currents at low temperature to transient three-phase short circuit at high temperature; this has a significant effect on PM motor cost as well as on feasibility of non-rare earth PMs. The reviewer thought that General Electric (GE)'s self-imposed criteria of double the maximum operating current at 150°C seemed to be reasonable. Regardless, the reviewer thought that whatever criterion is used by DOE, it should be applied consistently to all investigators.

Reviewer 5:

The reviewer observed that the PI has a strong understanding of the project requirements; however, the approach was not described in sufficient detail during the presentation. The reviewer, however, warned that the approach leverages the use of an industrial motor

frame which may not represent the thermal performance of the machine integrated in its target automotive environment. The reviewer asked whether the use of reduced-rare-earth magnets in this project meets the DOE targets.

Reviewer 6:

The reviewer stated that the approach, as presented, lacks detail to identify the degree to which the technical barriers are being addressed. It was difficult for the reviewer to judge from the presentation if there is sharp focus on these technical barriers.

Reviewer 7:

The reviewer remarked that of the motor programs, this one seemed a bit less advanced or along the process.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer described that the evaluation of 10 motor topologies has been finished and a down-select of three most promising topologies has been done: one has reduced RE magnet content; one has no RE magnets; and one has no magnets at all. No further information was provided about the motor topologies, but the reviewer hoped this would change by the next annual review meeting. The reviewer also mentioned that, regarding the new material developments, new magnet materials are being evaluated and that new high tensile strength lamination steel shows promise. Finally, a new dielectric for use as insulation material at high temperatures has been developed. The reviewer summarized that all of the above are good technical accomplishments and the progress is significant compared to last year.

Reviewer 2:

The reviewer commented that the program is already building a prototype. Building hardware early is good; too many programs save hardware build until near the end of the program. The reviewer remarked that higher strength laminations have value for all motor topologies, so it is also positive that this activity occurs early in the program.

The reviewer believed that more details regarding the downselect process for the three motors would be helpful. Light load efficiency is very important (in this reviewer's opinion, perhaps more important than weight), so it would be useful to discuss why some of the heavier, yet more efficient, designs were eliminated from contention.

Reviewer 3:

The reviewer observed evidence of progress on all fronts, but not much detail given on accomplishments, and added that it was difficult to evaluate. The reviewer noted very little quantitative information about material developments. Topology downselection had some quantitative data, but sketchy about details. The reviewer expressed understanding that some of this may be necessary because of intellectual property (IP) pursuits, but it seems that non-proprietary designs/topologies (e.g., conventional induction, switched reluctance, IPM) could be shared in more detail. The reviewer inquired about why the locations of these conventional topologies on the efficiency and performance graphs, at least, were not shown. Reviewers do not even know if these conventional topologies were part of the evaluation (apart from induction, which was mentioned verbally as being evaluated, although no mention was made of which metrics corresponded to induction. The reviewer thought the balance between IP interests and accountability could be improved.

Reviewer 4:

The reviewer observed development of new soft magnetic lamination and insulation materials in addition to the permanent magnets and machine development helps further advance the state of art in motor technology. The reviewer asserted that the motor topologies were not described in the presentation. Topologies are being developed to minimize the likelihood of demagnetization. The reviewer believed that no publications were identified in the presentation material.

Reviewer 5:

The reviewer expressed that, when compared to the other similar projects, this one seems a bit behind.

Reviewer 6:
The reviewer commented that the technical accomplishments and progress, as stated in the presentation, meet the project objectives and goals. However, the reviewer explained that insufficient detail was provided as to how well and very little technical detail is provided beyond statements.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that all of the programs are well-coordinated and compliments to DOE.

Reviewer 2:
The reviewer noted that this project has an extensive group of collaborators from universities and National Laboratories, along with an industrial partner for fabrication of the machine. In total, seven contracts are in place with the project partners.

Reviewer 3:
The reviewer acknowledged that a number of collaborations with universities were set up for the motor development. The reviewer also thought the collaboration with Ames Laboratory and Arnold Magnetics and their work on alternative magnet materials was a good choice. The reviewer added that it seems as if the researchers are doing a good job to assure that all modeling assumptions are the same for all different motor designs.

Reviewer 4:
The reviewer expressed that there is very good talent included in team, and that the teams made good use of the various material experts and a variety of machine design experts. It appeared to the reviewer that most parties are now actively engaged and it was encouraging to see that all of the legal contracts had been worked out. (It did not surprise the reviewer that this took a long time to do.) The reviewer wondered if it would be possible for DOE to establish a standard collaboration agreement that parties have to sign before being awarded a project, so that more time can be spent on collaborative research. Alternatively, DOE could make having a signed agreement (not necessarily DOE's) a condition for getting the award. The reviewer admitted that this may be overkill where the team consists of only a few parties, but it might make sense for projects like this with eight different groups that have to come to a legal agreement.

Reviewer 5:
The reviewer noted that the long list of partners is good, as long as the work is coordinated and each company's role is understood. The reviewer cautioned that the risk is fragmented work if the partners are not well-managed. The reviewer commented that how each partner contributed was not covered during the presentation, so it is difficult to assess how they are being managed.

Reviewer 6:
The reviewer reported that there are no issues addressed with collaborators. The reviewer also noted that there was very little detail on what contributions are being made by each of the collaborators and how well the coordination is working.

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

Reviewer 1:
The reviewer explained that the future research plans include the completion of testing the proof-of-principle motors/materials. Moreover, the reviewer noted that final selection of motor topology/materials will be based on test results of the proof-of-principle motors, which will take place within the next year. The reviewer indicated that the project is well-coordinated regarding future plans, but as mentioned above, the implementation of cost models should not be postponed until the final, best performing motor topology is selected. This might lead to a great motor topology, which is far from meeting the cost target.

Reviewer 2:
The reviewer explained that the future research includes multiple builds, materials testing, and continued downselection, which are all appropriate. The reviewer emphasized that GE needs to be highly involved in the prototype build process, and that oversight of McCleer Power and the prototype challenges should be monitored closely.

Reviewer 3:
The reviewer described that the future activities include builds of two or three proof-of-principle motors and then a final motor that leverages the best aspects of the proof-of-principle designs along with scaled-up fabrication of new lamination and insulation materials.

Reviewer 4:
The reviewer remarked that, in general, the future work plan looks good; however, it was not clear to the reviewer how increased insulation temperature ratings would help attain the goals of this project. It seemed unlikely to the reviewer that operating with winding temperatures at 250°C will meet DOE's efficiency requirements.

Reviewer 5:
The reviewer noted that the proposed future work plan is the same as promised, but lacks details and specificity.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer indicated that statements in the presentation are positive that the work supports the overall DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer explained that the project supports the objective of petroleum displacement by developing new motor concepts without the use of expensive rare-earth magnet materials. If successful, the reviewer believed that these would result in cost savings for electric drive systems, which would enable a faster market introduction of HEVs and EVs.

Reviewer 3:
The reviewer commented that this project addresses the sustainability problem of motors using current rare earth magnets, as well as evaluates machine, material, and control approaches that could reduce system cost for HEV and EV powertrains.

Reviewer 4:
The reviewer expressed not being qualified to make this judgment in this area.

Reviewer 5:
The reviewer affirmed that the PI understands the 2020 DOE objectives and their impact on petroleum displacement.

Reviewer 6:
The reviewer described that this project will help reduce the cost of high-performance electric machines through reduction/elimination of rare earth permanent magnets in the design. These machines are key components in HEV which have demonstrated the capability to reduce fuel consumption.

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

Reviewer 1:
The reviewer indicated that the presenter did not comment on any difficulties on resources.

Reviewer 2:
The reviewer thought the project has sufficient resources for the defined tasks.

Reviewer 3:

The reviewer expressed that the resources are certainly sufficient, but observed that the challenge may be organizing them to work together in a timely manner.

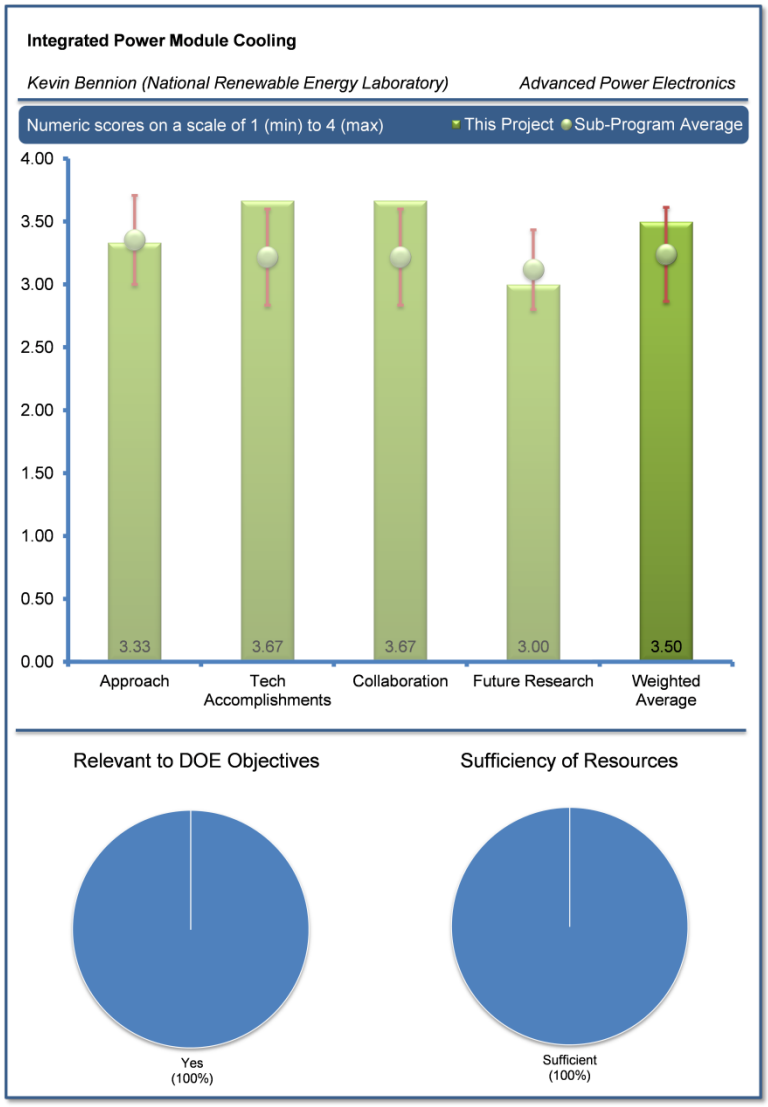
Reviewer 4:

The reviewer indicated that the resources appear to be sufficient and appropriate, as long as they are managed and understand their roles in the program. The reviewer highlighted that Program Management is key to this multi-faceted program.

Reviewer 5:

The reviewer reported that the project is on track, and that a lack of resources was not apparent from the presented material.

Integrated Power Module Cooling: Kevin Bennion (National Renewable Energy Laboratory) - ape047



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the objective was clear and well and understood and the approach was straight forward and effective.

Reviewer 2:

The reviewer commented that the use of an extruded heat sink for power modules is very good, noting low cost, small, and high performance. However, the reviewer expressed that it does not address the other components that require cooling such as current sensors and bulk capacitors. Additionally, heat sinks are also used as part of the chassis and for mounting other components, which may increase the size or at least add some constraints to allow for machining to support these needs. The reviewer stated that the basic approach is fine and can be expanded to include the complete inverter.

Reviewer 3:

The reviewer indicated that the extruded heat exchanger enables multidimensional heat transfer and under the project guidelines of doubling the heat flux this approach has potential. Extrusions are typically a low cost production process; it is not clear from the presentation what the cost of the extrusion would be.

One example the reviewer noted was that the planarity requirements of heat sinks could affect costs. Also, for a double sided cooled system, too much camber across the surface could require thicker BIMs, which reduce cooling performance and possibly offset the gains of the heat exchanger. The reviewer expressed that both costs and how planarity, flatness, and camber affect performance and cost need to be discussed.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer commented that it was a good concept using low tech solution to get a significant gain in efficiency.

Reviewer 2:

The reviewer indicated that the initial test results of the heat exchanger are meeting or exceeding goals of the project.

Reviewer 3:
The reviewer opined that the accomplishments to date are outstanding. Performance modeling at typical flow rates is a very good approach because the potential performance can be seen based on the modeling results. It is very important that extrusion supplier design rules have been used. The reviewer liked the flexibility and scalability of the design to support additional modules and double sided cooling.

The reviewer indicated that there is a need to address the mounting of the heat sink within the inverter chassis and possible use as a part of the chassis; the heat sink's mass is also an important consideration because it would lead to using the extrusion as part of the chassis as opposed to mounting it in the chassis depending on the weight. The reviewer would like to see what the limit is for this design in terms of its ability to remove heat; specifically, at what point is the limiting factor the ability to spread the heat quickly enough from the die.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that developing a design and having a commercial partner that can make the design is a very good approach.

Reviewer 2:
The reviewer indicated that collaboration with Sapa is excellent, suggesting that their knowledge could be used to provide design rules. The reviewer stressed the need to continue this type of collaboration with power switch/module industry partners in order to arrive at an optimal solution.

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

Reviewer 1:
The reviewer felt that it is a good plan to apply this design to existing semiconductors.

Reviewer 2:
The reviewer expressed that the future plans are good but do not go far enough. There is a need to determine the limits of the heat sink's ability to dissipate heat and spread it from a small point source such as a die. The reviewer also suggested including performance with no flow, but with coolant, and then to investigate what happens with no coolant.

Reviewer 3:
The reviewer indicated that the future work should include looking at cost or stating tolerances required for fabrication that could allow this approach to be used in a double-sided cooled application and how these tolerances might affect cost.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that effective cooling saves energy and improves reliability; with WBG comes products that run hotter and require better cooling. This project is very relevant to the success of electric vehicles.

Reviewer 2:
The reviewer indicated that the potential benefits of this heat exchanger are possibly smaller die size for an EDV inverter or higher inlet cooling temperatures for the EDV inverter; both results could lead to lower cost systems. This lower cost approach will help to enable the market for EDVs and lower our dependence on foreign oil.

Reviewer 3:

The reviewer commented that heat sinks are an important part of solving the cost/performance issue related to power electronics. A high performing low cost part is highly desirable.

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

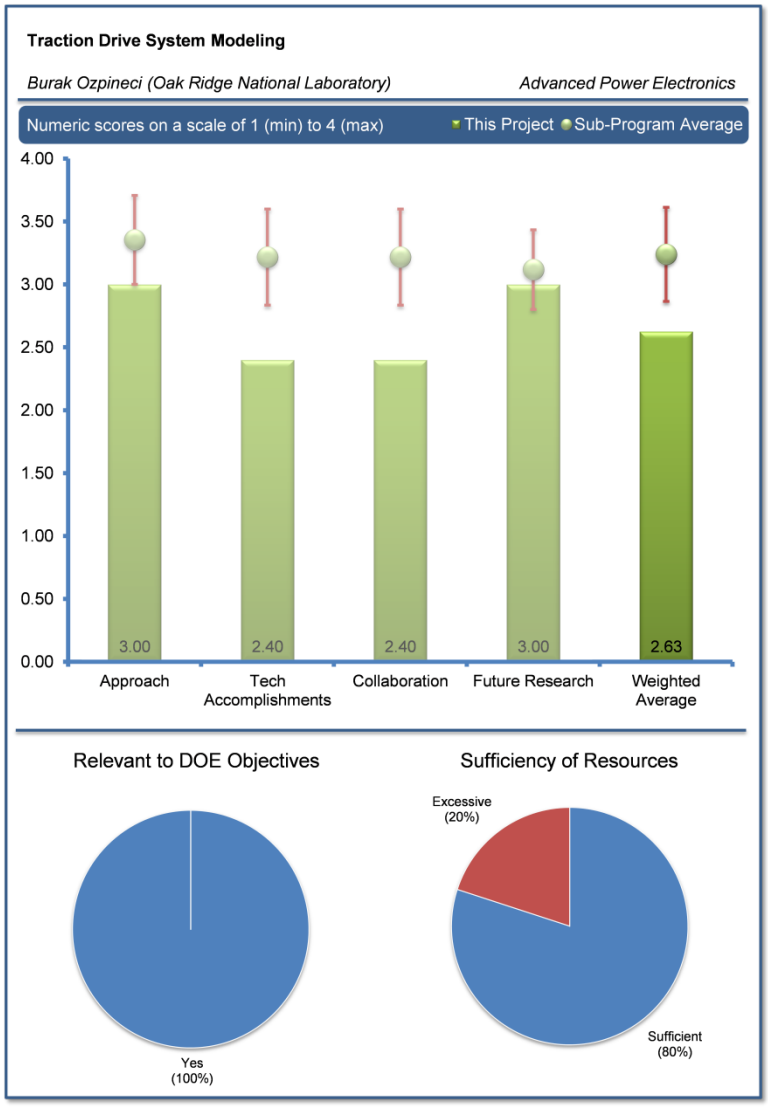
Reviewer 1:

The reviewer indicated that there is no mention of lack of resources or the need for more time to complete the project.

Reviewer 2:

The reviewer noted that the resources are sufficient to this point. The reviewer noted that there is a need to add industry team members to provide device/module expertise for future plans.

Traction Drive System Modeling: Burak Ozpineci (Oak Ridge National Laboratory) - ape048



Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that a lot of work has been done considering that this is a new project. This work is very important, as it ties a number of other initiatives into a detailed system-level model.

Reviewer 2:

The reviewer noted that using a vehicle system model to determine the optimum traction drive parameters to refine the component performance requirements is a good approach. Getting an agreement from an OEM to use a combined drive cycle to specify component performance would be useful. The reviewer noted that it would be interesting to find out what the worst case conditions that drive component performance requirements are and if those worst case conditions are common to other combined drive cycles.

Reviewer 3:

The reviewer indicated that the approach and objectives of this project were clearly presented. The reviewer did feel that, for program tracking, it might be better to have more milestones defined.

Reviewer 4:

The reviewer expressed that it is not clear where this project is heading, what is unique, and why industry and the VTO needs ORNL to do this other than it is adding to modeling competency at ORNL.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer noted that the work is on track.

Reviewer 2:

The reviewer noted identifying regions of clustering to identify most common regions of operation. In many systems, the transient responses, rather than the steady state (most time spent) regions are most important to vehicle customer satisfaction, such as entering a highway. The reviewer opined that some steps should be taken to address the transient responses.

Reviewer 3:
The reviewer noted that there has been some progress toward analyzing what the best simulation operating points are to determine efficiency and cost optimization based on statistical analysis of driving cycles, development of simulation models collecting tools, and identifying trade-offs to study such as bus voltages and speed impact on efficiency and cost.

Reviewer 4:
The reviewer commented that the progress of this program is excellent, especially with the program just starting this year. The reviewer indicated looking forward to seeing more simulations throughout the program.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the links are to other modelers and the links to experimental workers are often valuable to provide checking of model performance.

Reviewer 2:
The reviewer commented that there are some partners for models and software including ORNL, NREL thermal models, and ANL, but there does not yet seem to be sufficient partners to provide guidance on vehicle industry need.

Reviewer 3:
The reviewer indicated that, to do the modeling and the circuit simulations, the resources are there. The reviewer expressed that it would be interesting to have an OEM comment on the approach and results, as the program is progressing.

Reviewer 4:
The reviewer noted that this project does not have sufficient collaboration with private industry, especially as the future is looked at to work on optimizing cost.

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

Reviewer 1:
The reviewer noted that the approach to the future work is logical and aggressive.

Reviewer 2:
The reviewer commented that the proposed future work for 2013 is good. The reviewer did indicate that it would have been helpful to see some details of future work and milestones beyond 2013.

Reviewer 3:
The reviewer expressed that asking of the audience for suggestions on what to do is diplomatic, but seems weak in form, from a presenter who is presenting himself as the expert.

Reviewer 4:
The reviewer commented that the future plan is not specific other than to do more of the same for other power electronic systems and components.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that electrification of vehicles tends to decrease need for petroleum and other fossil fuels.

Reviewer 2:
The reviewer commented that the project is on the topic areas that are important to meet DOE objectives, but it is unclear how the specifics of the project will lead to meaningful outcomes.

Reviewer 3:
The reviewer stated that a more efficient, lower cost propulsion system would help to enable the market for EDVs and lower our dependence on foreign oil.

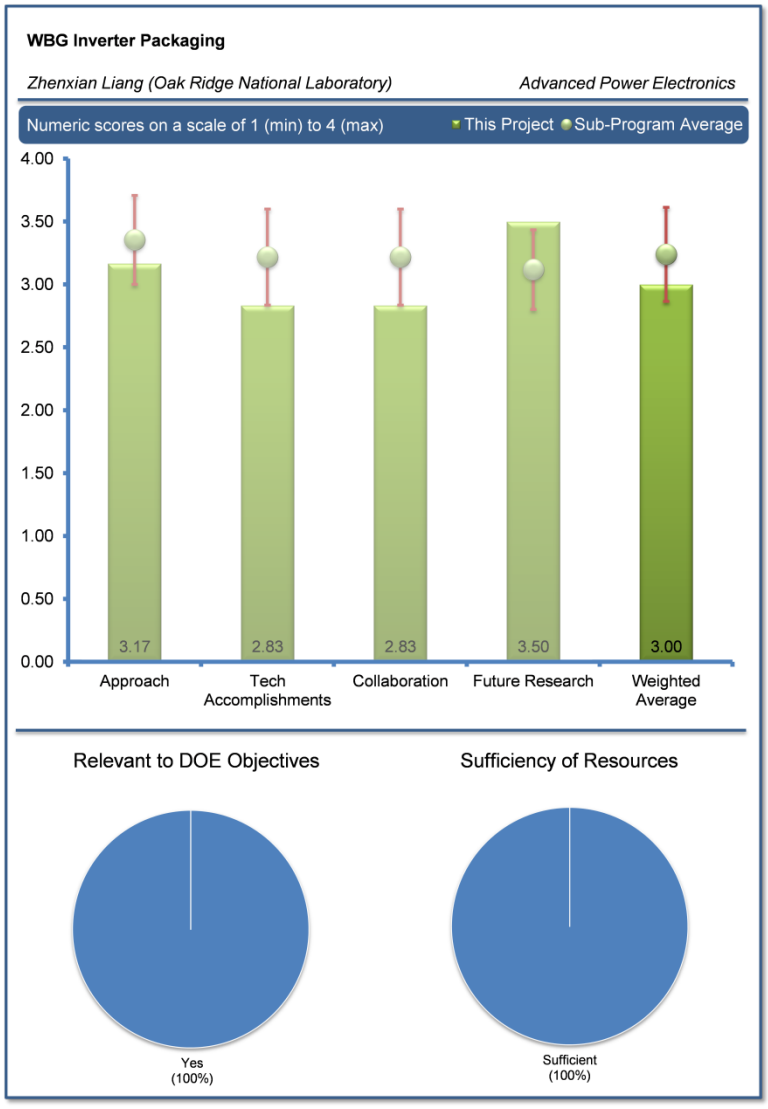
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that the team is very small, but based on the accomplishments for this first year, seems to have sufficient resources.

Reviewer 2:
The reviewer observed that the project is on track with the resources allocated.

Reviewer 3:
The reviewer commented that the resources seem high relative to other projects given the level of effort required to achieve the goals and apparent lack of planning and demonstrated need.

WBG Inverter Packaging: Zhenxian Liang (Oak Ridge National Laboratory) - ape049



Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that the approach of using a binary comparison of SiC MOSFET Schottky diode assembly with same assemblies in Si MOSFET and diodes seems likely to lead to a clear comparison.

Reviewer 2:

The reviewer commented that the approach to compare the Si and SiC as well as the cooling method is a well-balanced number of variables. The reviewer wanted to know if double sided cooling was planned for a future generation, and if there were plans to test this method of cooling in the future.

Reviewer 3:

The reviewer commented that it was a very important goal to develop 100 Ampere (A)/1200 Volt (V) SiC and hybrid SiC/Si modules using mostly commercially available die and including both thermal grease baseplates and integrated cooling modules, and to compare the performance with silicon modules. However, there are published studies using dynamic electro-thermal analysis to size die in 10 kilovolt (kV) SiC half-bridge modules and 4.5 kV Si/SiC hybrid modules. The reviewer indicated that it would be a significant step backwards, and would provide meaningless results, to select the die sizes for modules based on what is optimal size for Silicon devices of a different type, rather than doing a proper analysis of optimal die size required to meet the same current and thermal performance as the silicon modules.

Reviewer 4:

The reviewer indicated that hard attachment, soldered, of the DBC substrate to the cold plate is very good from a thermal point of view as indicated on Slide 5. But the hard attach of the large area of the DBC with a low coefficient of thermal expansion (CTE) to the higher CTE copper base plate may not be a reliable solution. The reviewer noted that, if it is purported that this soldered hard attach approach is good for automotive – as Slide 6 indicated – data should be presented that shows the hard attach approach is also reliable. Additionally, the reviewer was interested in knowing the assumptions used for flow rate, pressure drop and convection coefficient for the heat exchangers used to determine allowed current density.

Reviewer 5:

The reviewer noted that the project develops packaging for WBG inverters for EDV and an integrated approach to improve the inverter performance. The WBG will improve the power density of EDV power inverter. However, the team may provide more information on the potential cost reduction with WBG switches.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer commented that 55% reduction of die size was good progress, which may mean lower cost, with the more expensive material, SiC. The reviewer noted that it was seen as significant toward the program objectives; the technical accomplishments include 55% reduction in die size, 60% decrease in conduction power loss, and 20% in switching power loss.

Reviewer 2:
The reviewer indicated that the progress of this program is very good, especially at such an early stage of the program. The reviewer suggested it might be prudent to make sure that module prototypes are not over-designed, as this may increase costs of manufacturability and end up not being representative of real world components.

Reviewer 3:
The reviewer noted 50A/1200V SiC modules were developed, fabricated, and performance tested; 100A modules are underway.

Reviewer 4:
The reviewer stated that, within a short period of time, the project has produced various WBG switch packaging devices and performed systematic test on the performance.

Reviewer 5:
The reviewer commented that providing parts for testing in ORNL power electronics is on track. However, nothing in the slides suggests that any reliable work has been done or what the reliability targets are.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer indicated that the team has excellent collaboration with several suppliers, universities, and National Laboratories.

Reviewer 2:
The reviewer noted that many suppliers are working with the investigator.

Reviewer 3:
The reviewer reported that multiple device vendors and package partners are included, and that package assembly lead and partners are excellent. The reviewer noted that it would be best to include a partner to perform electro-thermal analysis of module optimal die size.

Reviewer 4:
The reviewer indicated that it was great to see collaboration with the University of Tennessee. However, it would be good to also include private industry partners in this program beyond simply sourcing materials.

Reviewer 5:
The reviewer commented that, from the collaborations, it looked like published work of others is incorporated but there is no industry or other DOE laboratory collaborators that are part of the team.

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

Reviewer 1:
The reviewer noted that the goal of addressing high temperature capable package next year is a critical goal.

Reviewer 2:
The reviewer noted that the proposed future activities are very well explained and seem appropriately aggressive for the program timing and resources, while maintaining the leap frog objective.

Reviewer 3:
The reviewer remarked that the proposed future work approach looks reasonable.

Reviewer 4:
The reviewer commented that the project has a well-defined plan for future research.

Reviewer 5:
The reviewer noted that moving up to a specific size is representative of a clear direction in future work, but concerns about costs remain. While the smaller part will be less expensive than a larger one of the same material, the comparison here is for two different materials. It is possible that the larger of the lower cost material may be lower cost than smaller of the more expensive material. The reviewer observed that making this comparison clear would be helpful.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that electrification of vehicles is seen as decreasing the need for using petroleum based fuels for transportation.

Reviewer 2:
The reviewer indicated that assessing the benefits of SiC for vehicle propulsion inverters is very important, especially if high temperature capability is included in the study.

Reviewer 3:
The reviewer commented that the increase in power density appears to be on track and achievable in this project. This will dramatically assist the vehicle electrification goals of the DOE.

Reviewer 4:
The reviewer observed that helping to lower the cost of power electronics devices can enable the market for EDVs, which will lower our dependence on foreign oil.

Reviewer 5:
The reviewer indicated that WBG switches are critical for next generation EDV power electronics and packaging is important.

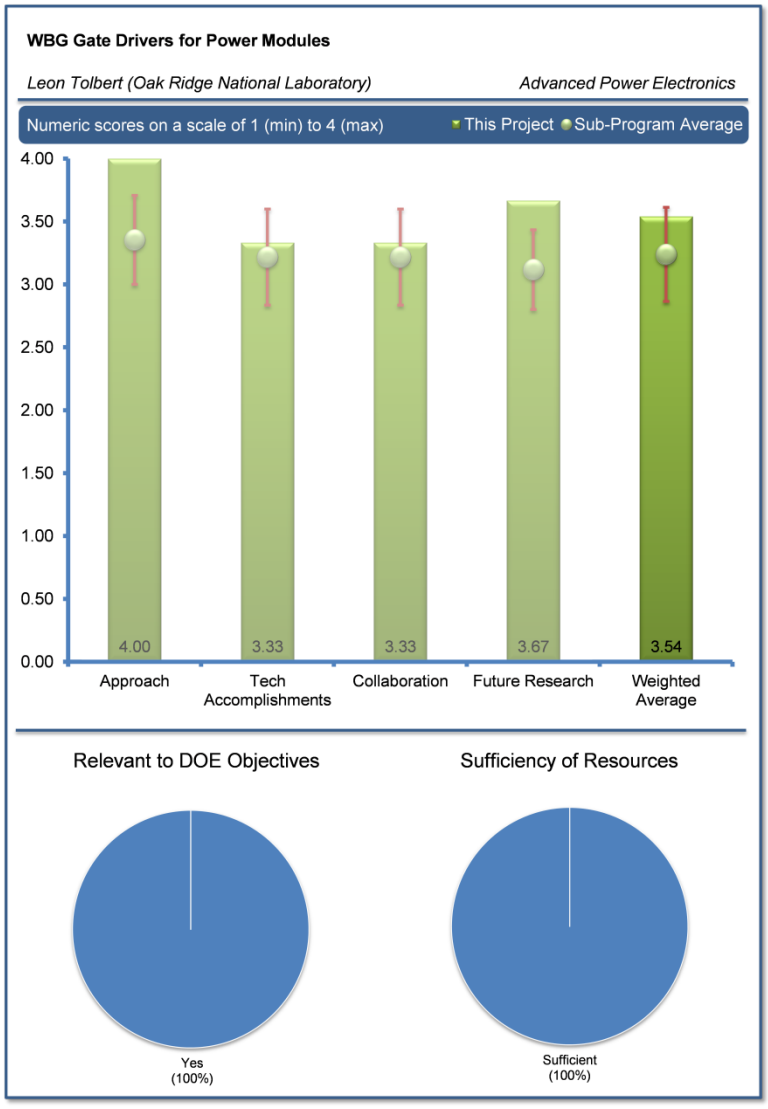
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer did not observe on the presentation how much the total budget beyond 2013 was for, but for 2013, the resources and funding seemed to be sufficient, but on the low side for all of the future activities that the project team has planned.

Reviewer 2:
The reviewer indicated that, while the resources appear sufficient, there may be help available at NREL that has done work on bonded interfaces and their reliability. It may be better to expand on NREL's work than to start from scratch on another reliability assessment.

Reviewer 3:
The reviewer noted collaboration with the University of Tennessee.

WBG Gate Drivers for Power Modules: Leon Tolbert (Oak Ridge National Laboratory) - ape050



Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that working to solve detailed level circuit issues, which may arise with the SiC substitution, with very fast switching seems appropriate.

Reviewer 2:

The reviewer observed that the goal and strategy of developing a highly integrated power module with integrated gate drive, input isolation, and integrated power supply in a high temperature package has significant potential to advance VTO goals.

Reviewer 3:

The reviewer noted that the availability of high performance gate drivers that are capable of operating at high temperatures is a key technology that needs development if the WBG devices are to be incorporated into vehicle power electronics. An impressive job has been done in the first year of the project.

Reviewer 4:

The reviewer indicated that the approach seems very comprehensive and runs in parallel paths with Zhenxian. The protecting factors for the fast switching are very important and will be very beneficial to the industry.

Reviewer 5:

The reviewer indicated that creating separate chips based on function is a low risk approach for evaluating new concepts. Having backup processes to evaluate process uncertainties also helps to increase the possibility of a successful first turn of chips. The reviewer added that it would be helpful to learn more details of the active current balance scheme. In particular, the reviewer was interested in the WBG chip requirements for making the balancing circuit work including current sense (i.e., what is the accuracy and repeatability, and number of additional pins required to perform the balancing).

Reviewer 6:

The reviewer commented that this project will develop a highly integrated power module incorporating WBG power electronic devices to reduce power density and cooling requirements by using high temperature packaging and components. The driver will include an integrated gate drive, isolation chip, power supply on a chip, and special protection features to enable fast switching of WBG devices.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer indicated that a great job of moving forward with the designs and simulation was done while awaiting Zhenxian's program deliverables to incorporate into the module. Getting all of those prototype designs out for fabrication by April was a great accomplishment.

Reviewer 2:
The reviewer noted that the project is on track and that barriers are being addressed.

Reviewer 3:
The reviewer noted that the interactions and choices are clearly being identified and potential issues are being addressed. The reviewer also noted that the project was able to reduce switching loss, which the reviewer expressed was good. In addition, the reviewer noted that, for paralleled SiC MOSFETs, experimental recognition of concern with variable threshold voltages led to simulation of a circuit to adjust the pulse width modulation (PWM) timing and, now more recently, confirming circuits with demonstrations in hardware.

Reviewer 4:
The reviewer commented that the input isolation device schematic and layout were designed, simulated, and submitted for fabrication in two technologies. Also, the power supply chip was designed and simulated. Additionally, the short circuit and overcurrent protection circuits were designed.

Reviewer 5:
The reviewer indicated that, in the first year, designing and sending the gate driver chips for fabrication was accomplished. Going forward, multiple fabrication techniques to mitigate the risk associated with the isolation requirements for the on-chip transformer are being looked at.

Reviewer 6:
The reviewer noted that circuit design has been completed, the circuit has been fabricated, and circuit modeling has been performed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that there was an outstanding team and collaborations.

Reviewer 2:
The reviewer observed that the project seems to be working well with vendors for integrated chip fabrication.

Reviewer 3:
The reviewer noted that the project has collaboration with several suppliers and other groups in DOE.

Reviewer 4:
The reviewer noted that there seems to be a strong collaboration within ORNL and the other programs. That is a great use of funding to piggyback on the different research programs. However, the reviewer observed that it would be beneficial to include private industry beyond just supplying components.

Reviewer 5:
The reviewer noted that another partner for the fabrication of the chips could be of use.

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

Reviewer 1:
The reviewer noted that the reduced cross-talk and de-saturation protection seemed appropriate. The reviewer indicated that the plans to integrate and test the developed devices and circuits within the module are well defined. However, a simulation study of gate drive requirements for fast switching SiC and Insulated Gate Bipolar Transistors (IGBTs) in this module using physics-based power device models would be helpful in optimizing gate drive buffer. Simulation of electro-magnetic interference by including transmission line models for power module package interconnect parasitic would be helpful in eliminating the concern listed in the assumptions charts and evaluating the impact of parasitic capacitance of the gate isolation device.

Reviewer 2:
The reviewer indicated that the future research plans were well thought out, noting that the coming year would be challenging.

Reviewer 3:
The reviewer noted that the approach was logical and well stated.

Reviewer 4:
The reviewer commented that the project has a good plan to complete the driver design, modeling, and testing in the future.

Reviewer 5:
The reviewer noted that the explanation and amount of future activities for 2013 and 2014 was great. The future activities would have been more clear if more milestones were defined and if they were expanded beyond 2013.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer indicated that electrification of vehicles tends to lead to decrease in use of petroleum fuels.

Reviewer 2:
The reviewer commented that the goal and strategy of developing a highly integrated power module with integrated gate drive, input isolation, and integrated power supply in a high temperature package has significant potential to advance VTO goals.

Reviewer 3:
The reviewer indicated that, this, in combination with Zhenxian's project, will significantly improve the power electronics industry in both performance and cost goals.

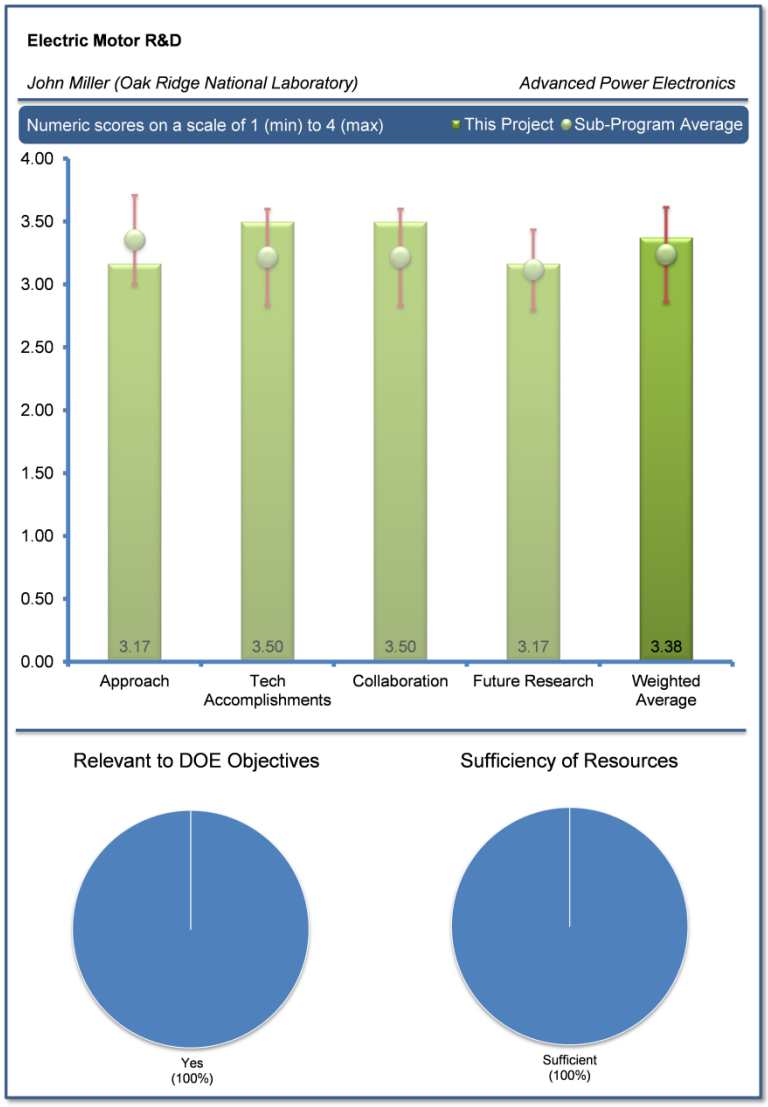
Reviewer 4:
The reviewer noted that WBG devices may enable lower cost power electronics for EDVs. WBG devices will need a gate driver that can take advantage of their capability, and lowering the cost of the power electronics helps to enable the market for EDVs, which reduces our dependence on foreign oil.

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

Reviewer 1:
The reviewer indicated that the amount of resources and funding seems sufficient for this project. It is great that the University is also utilizing other funding sources to help this program and that it would be great to see that on other ORNL projects as well.

Reviewer 2:
The reviewer noted that the progress is on track with resources provided.

Electric Motor R&D: John Miller (Oak Ridge National Laboratory) - ape051



Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that the approach, as presented, provides sufficient detail identifying that the degree to which the technical barriers are being addressed. The reviewer noted that the project is well designed, feasible and integrated with other efforts to address the barriers.

Reviewer 2:

The reviewer observed that the project was well-conducted and planned.

Reviewer 3:

The reviewer noted that the project was a well-structured program with well-defined assessment criteria.

Reviewer 4:

The reviewer noted the appropriate focus on improved low loss steels and how to leverage these in non-RE topologies.

Reviewer 5:

The reviewer stated that the approach provides a good high-level view of baseline technologies, but higher speed has drawbacks that need to be honestly addressed to weigh the pros and cons. The approach pays little service to these issues, and glossing over them is the risk with this program. The reviewer noted that it will also be important to accurately quantify the costs of the various topologies: magnet costs, high speed bearing costs (also considering the typical tight tolerances required for other parts that drive up costs), high silicon lamination costs, etc.

Reviewer 6:

The reviewer commented that the main assumption for the approach in this project is that electric traction motors require a shift to a significantly higher maximum speed in order to meet the 2020 cost target. It was attempted to prove this assumption with a motor speed over time curve, which should describe the historical trend of automotive traction motor speed, as a surrogate for cost. The linear interpolation of the data points seems quite random and other interpolation curves are definitely valid, too; this could lead to a different conclusion like the curve is flattening over time. The reviewer also observed that the selection of the data points for interpolation was questionable. For example, the EV1 electric vehicle in the 1990s and all fuel cell vehicles from different manufactures over the last 8-10 years have maximum speeds around 10,000 to 12,000 RPM.

Additionally, the reviewer stated that, besides this general flaw in the approach, the other aspects of the project approach are well defined, as the selected motor topologies for investigation are valid choices and the improvement of materials for electric machines, especially in terms of loss reduction, and the improvement of thermal management are beneficial for any type of electric machine.

The reviewer also noted that the research in the area of high speed machines requires an evaluation of the complete drive system including transmission and inverter. This seems to be addressed with another new project.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer stated that the technical accomplishments and progress meet the overall project and DOE goals and objectives. The reviewer noted that sufficient information was provided in support of this assessment.

Reviewer 2:
The reviewer stated that the reasons for this work are sound, and exploring how fast is too fast is a worthwhile question. Documenting speed trends, the effect on motor size, and enabling technologies to push the speed envelope higher are all good research questions. The reviewer noted that the framework was set and it would be important to be thorough in evaluating all the implications of both low and high speed motors.

Reviewer 3:
The reviewer indicated that this was good progress, but the reviewer would have liked more detail on comparing specific motor performance curves under same conditions. The reviewer expressed concern that simply focusing on power density glosses over significant differences in speed range and efficiency. The reviewer was also not clear on what the rules of comparison were between benchmark motors and new topology designs.

Reviewer 4:
The reviewer observed that it was still too early to observe great gains in progress.

Reviewer 5:
The reviewer noted that the technical accomplishments are generally good, but not without flaws. The reviewer did feel that it was positive that suitable motor topologies have been selected for further investigation of high speed designs and the materials development has made progress, even though the latter topic needs more specific details about the obtained improvements. Also, the cost breakdown for the baseline permanent magnet (PM) motor from the Nissan LEAF was a very good accomplishment.

Additionally, the reviewer commented that a high speed induction machine has been designed and a cost breakdown has been derived, too. Unfortunately, this cost breakdown has errors. For example, the casting of the housing has been ignored and the cost assumptions for high speed bearings seem to be very optimistic.

Finally, the reviewer noted that that the high speed induction machine can easily meet the 2020 cost target was a very bold statement. Considering the mistakes in the cost breakdown and overly optimistic assumptions, the reviewer perceived that this statement was very questionable.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that, like all of these motor programs, there appeared to be great collaboration on this technical question.

Reviewer 2:
The reviewer commented that there are no issues identified with any of the collaborators; sufficient detail was provided on what contributions are being made by each of the collaborators.

Reviewer 3:
The reviewer noted collaborations with several divisions within ORNL and other National Laboratories are set up and seem to be working well, and the collaboration with material suppliers from the industry will surely benefit the project. The reviewer remarked

that it would be beneficial if collaboration with an electric machine OEM could be established in order to provide guidance for the project about what is of interest for the industry and how a high speed machine could be integrated into a transmission.

Reviewer 4:
The reviewer stated that the list of collaborators is good, but it would be outstanding to see a motor manufacturer on the list. A motor manufacturer, for example, may be the only type of collaborator that would be able to translate the tight tolerances required for high speed bearings into part costs.

Reviewer 5:
The reviewer indicated that collaboration is evident and well-coordinated with steel researchers. The reviewer expressed that it was not as clear if or how collaboration on thermal analysis is being done.

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

Reviewer 1:
The reviewer stated that the proposed future work plan is consistent with the project objectives with adequate details and specificity supporting this assessment.

Reviewer 2:
The reviewer noted that, as this project scope goes through the 2015 fiscal year, there appears to be a great definition of future work and deliverables.

Reviewer 3:
The reviewer commented that a good approach was planned; the reviewer hoped to see more apples-to-apples performance curves and efficiency map comparisons going forward.

Reviewer 4:
The reviewer remarked that, overall, the milestones in the project are well defined. New developments in the material area will be integrated into the next iterations of the motor designs. The reviewer noted that this specific project has made many twists and turns in its approach and focus since it was started, even merging two other projects into one; the reviewer expressed hope that the researchers now have a clear plan for the remaining duration of the project.

Reviewer 5:
The reviewer listed some important questions to address in future presentations. Regarding low loss laminations, the reviewer was interested in the tradeoffs in costs and saturation flux density. For high speed motors, the reviewer would like to know the transmission implications. Regarding high speed bearing, this reviewer inquired about the cost implications for bearings, end bell tolerances, and shaft tolerances. For heat rejection, the reviewer noted that very high power density motors, especially induction motors, have real issues with heat rejection, which will also affect bearing performance and life. For motor life, the reviewer explained that service intervals and premature failures are almost always driven by bearings and seals, not insulation systems; as such, the reviewer suggested addressing bearing and rotating seal service and lifespan in the analysis. Finally, for magnets, the reviewer recommended an attempt to use real prevailing cost per pound numbers.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer indicated that the statements in the presentation are positive that the work supports the overall DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer commented that the project supports the objective of petroleum displacement by developing new motor concepts without the use of expensive rare-earth magnet materials. If successful, these would result in cost savings for electric drive systems, which would enable a faster market introduction of Hybrid and Electric Vehicles.

Reviewer 3:
The reviewer stated that the project addresses inherent sustainability problem in motors that use current rare earth magnets and offers a potential path to sustainable, low cost, and high efficiency motors for HEV and EV applications.

Reviewer 4:
The reviewer noted that, by developing better motors that are less dependent on rare earth materials, the market can mature at a more stable rate.

Reviewer 5:
The reviewer stated that better motors for EVs and HEVs supports the objectives of petroleum displacement.

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

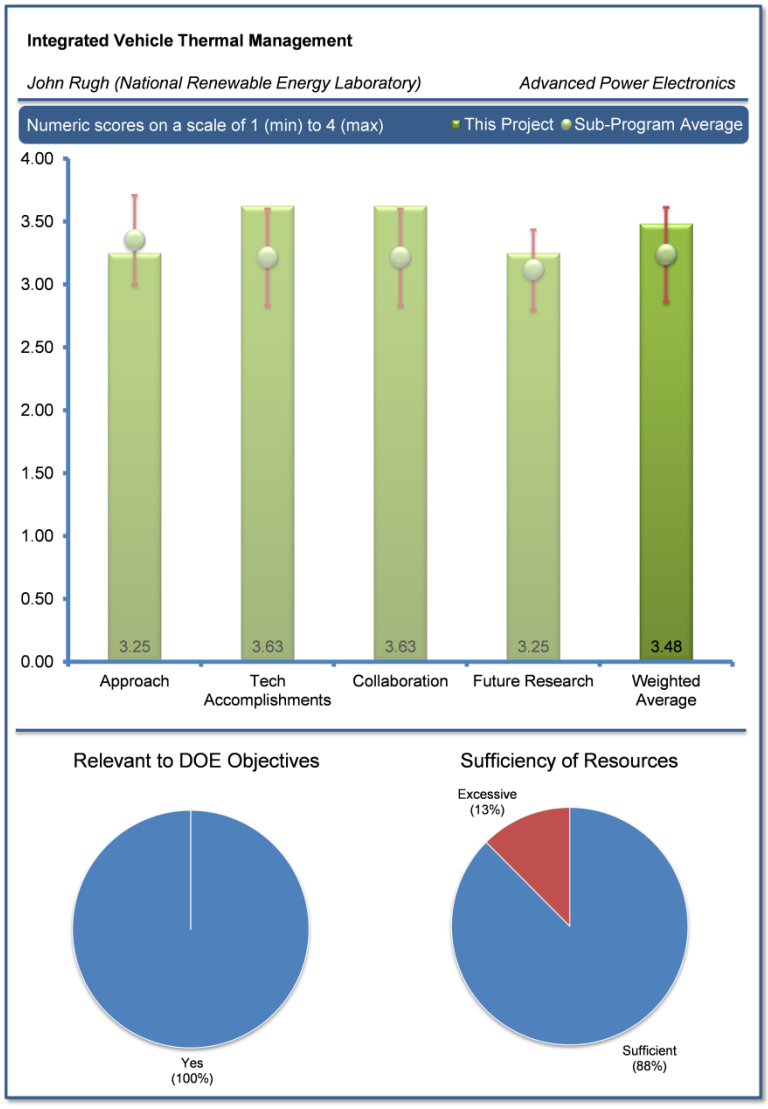
Reviewer 1:
The reviewer indicated that the presentation does not comment on any difficulties on resources.

Reviewer 2:
The reviewer commented that the project has sufficient resources for the defined tasks.

Reviewer 3:
The reviewer opined that there was no way to qualify whether or not the resources were sufficient enough for the project to achieve the stated milestones in a timely fashion based upon the information received.

Reviewer 4:
The reviewer noted that the resources were sufficient, but there were additional details that had not been addressed that needed to be considered when performing design trade studies.

Integrated Vehicle Thermal Management: John Rugh (National Renewable Energy Laboratory) - ape052



Reviewer Sample Size

A total of eight reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that the approach, as presented, provides sufficient detail identifying that the degree to which the technical barriers are being addressed. The project is well designed, feasible and integrated with other efforts to address the barriers. A system level look is the right approach for optimization.

Reviewer 2:

The reviewer noted that the approach in this project is to start with the implementation of thermal one-dimensional (1-D) models for all thermal components in an EV. In a second step, the most promising combined thermal management system concepts are selected and assessed in detail and tested on a bench test set-up.

The reviewer expressed that this is a very good approach and it will support the automotive industry in their effort to simplify the cooling systems for EVs and the collaboration with automotive manufacturers and suppliers on a vehicle-level should provide helpful insights in achieving this goal.

Reviewer 3:

The reviewer commented that designing a cooling system based on all of the heat loads and optimizing it for optimum overall performance is a great objective. The reviewer opined that an important issue that remained to be addressed was how to convince the various separate design responsible entities to do this, but that issue was beyond the scope of the project. The reviewer thought that the combined approach is very good and would significantly reduce the overall cost and mass of the vehicle.

Reviewer 4:

The reviewer noted that the project includes the vehicle as a whole, including energy storage and the propulsion system, beginning with modeling and moving to bench testing. The reviewer noted that relevant scenarios, cooling combinations, and routing were addressed. The reviewer was surprised that vehicle OEMs are not designing thermal management from a vehicle systems standpoint; even if some are already doing so, this work will educate those who are not, and perhaps provide new ideas for those who are.

Reviewer 5:

The reviewer indicated that the project provides logical design and test approach, including complete system thermal/fluid model. Approach progresses from modeling, to bench tests, to vehicle level tests.

Reviewer 6:
The reviewer stated that the project is well conducted. The reviewer's only suggestion is to also include comparison of the cost, weight, and life to the baseline thermal management system if possible.

Reviewer 7:
The reviewer commented that thermal management synergies were another excellent DOE objective to working towards a fringe objective.

Reviewer 8:
The reviewer commented that there were many qualitative statements but nothing is quantified. The reviewer observed that, by stating combined cooling loops will save cost, the potential cost savings should have also been indicated, especially with so many suppliers involved in the project. The reviewer also did not feel that the barrier to be overcome was established.

The reviewer noted that modeling is performed. However, the modeling does not establish how much performance is taken from the individual cooling systems. The amount of performance lost through combining the systems was not noted.

The reviewer also indicated that the worst case cooling conditions that would establish the worst case heat transfer requirements that typically size the cooling systems were not established. Without that exercise, the reviewer was unsure how the combined cooling system is assured not to end up being a larger combined system that provides just a modest cost reduction.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer commented that it was very good progress in adding or updating component thermal models, including inverter and battery. The reviewer also noted that the project demonstrated the benefit of utilizing waste heat of power electronics to reduce electric heater requirements and improve battery warm-up in cold conditions.

Reviewer 2:
The reviewer noted that there the model and hardware tools were well defined and that the project brings a practicality to the solution.

Reviewer 3:
The reviewer commented that the technical accomplishments and progress, as stated, meet the overall project and DOE goals and objectives. The reviewer noted that there was sufficient information provided in support of this assessment. Additionally, the reviewer remarked that the results from a system level approach are encouraging.

Reviewer 4:
The reviewer noted that the baseline EV thermal systems models have been completed and combined cooling loop strategies have been investigated. The reviewer added that combining fluid loops can offer advantages, indicating that strategies have been identified to evaluate with bench testing.

The reviewer also expressed that it is very important to investigate the current DOE requirement of 105°C coolant temperature for the power electronics and electrical machine components in more detail. This requirement might make sense in hybrid vehicles with an existing cooling loop for the ICE, but in EVs without the legacy high temperature cooling loop, this might not be the best choice. The reviewer was hopeful that the project could help clarify the issue.

Reviewer 5:
The reviewer commented that the work to acquire the appropriate model inputs across many different groups is commendable. The work to create a realistic baseline was also time well spent. The reviewer indicated, relative to this research, the effects of combining systems were quantified for both power consumed and transient effects on the vehicle and passenger. Pros and cons are both disclosed as well.

Reviewer 6:
The reviewer indicated that the technical progress to date is very good; the data and models justify the approach and conclusions. The reviewer noted that there was probably need to determine the impact of the slightly higher energy storage system (ESS) temperatures mentioned on the performance of the battery (mostly life) to be able to answer questions from the battery responsible group. The reviewer queried whether the modeling took into account the length of coolant hoses due to various component locations with the vehicle.

Reviewer 7:
The reviewer commented that the technical accomplishments listed were weak. The listed accomplishments: completed baseline EV thermal systems model, investigated combined cooling loop strategies, identified advantages of combining fluid loops, and identified strategies for bench testing are very qualitative statements. The reviewer wondered, from a technical standpoint, what of the accomplishments was new.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that sufficient detail is provided on what contributions are being made by each of the collaborators. There are no issues identified with any of the collaborators.

Reviewer 2:
The reviewer commented that the collaboration set-up with industry partners and the other VTO tasks is excellent.

Reviewer 3:
The reviewer observed that it is good to see industry involved and so it must have some value.

Reviewer 4:
The reviewer indicated that there was good use of industry collaboration including OEMs, component producers, and software.

Reviewer 5:
The reviewer expressed that it was very good to see Ford, Visteon, Magna, and VTO together, which will drive the practical solutions.

Reviewer 6:
The reviewer noted that the appropriate industry partners and groups within the VTO are included in the program. This looks like a well-organized program.

Reviewer 7:
The reviewer indicated that the collaboration among team members appears to be working 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.

Reviewer 1:
The reviewer commented that the proposed future research work plan is consistent with the project objectives with adequate details and specificity.

Reviewer 2:
The reviewer commented that the future research will mainly focus on the final bench test implementation and verification of the simulation models. The project is well planned and milestones will support the decision if vehicle level tests are necessary.

Reviewer 3:
The reviewer stated that the future work was a logical follow-up to modeling work, namely successively higher level verification of modeling through bench testing, and bench testing through vehicle testing.

Reviewer 4:
The reviewer commented that the future work for design, bench test, and vehicle level testing was good. The reviewer explained that it would have been useful to provide a little more detail on projected or desired outcome. The reviewer remarked that it was important to integrate cost impact into this program whether positive or negative. The reviewer expressed that a systems-level approach should have a net positive cost impact and it is important to highlight this during briefings.

Reviewer 5:
The reviewer found that the future work is logical for the next steps. However, the reviewer suggested adding some analysis investigating the life/reliability impacts of a single loop including failure mode and effects analysis (FMEA) for the system. The reviewer also wanted to know if the bench system will be able to vary the ambient conditions such as temperature, humidity, etc. and the various loads from the power electronics and ESS.

Reviewer 6:
The reviewer indicated that this project represents an incremental improvement. However, the reviewer did not see barriers overcome with this project and or any new technology being developed. The reviewer noted that Audi announced the e-Tron that will be released next year that will combine the battery and power electronics cooling loops. That will provide a nice incremental improvement, but it is hardly breaking down any barriers.

Additionally, this project is an integration effort; the reviewer observed that no technology has been defined that would warrant further involvement by the best minds at our National Laboratories. The reviewer stated that technology breakthroughs are needed by the laboratories, not integration efforts, and that integration should be left to industry to perform. Research would be better served to find new materials and/or more efficient heat transfer mechanisms that the supply base does not have the sufficient R&D capability to develop.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer commented that the research work supports the overall DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer stated that the project supports the objective of petroleum displacement by improving the cooling systems of EVs. If successful, these improvements would result in reduced costs for the electric drive train, which would enable a faster market introduction of Hybrid and EVs.

Reviewer 3:
The reviewer indicated that the goals of project are to better utilize waste heat energy and common cooling loops to reduce mass, cost, and range of hybrid and EVs.

Reviewer 4:
The reviewer commented that looking at the entire vehicle relative to subsystem cooling is useful so that the appropriate synergies and tradeoffs are evaluated.

Reviewer 5:
The reviewer indicated that cooling is an integral part of the vehicle and reducing the number of separate lops should reduce vehicle mass and cost.

Reviewer 6:
The reviewer commented that, from the qualitative statements, it should support petroleum displacement, but the reviewer wanted to know how much displacement might occur. While it may be relevant, it may not be that significant.

Reviewer 7:
The reviewer expressed having no qualification for this question.

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

Reviewer 1:
The reviewer indicated that there was no mention of difficulties on resources.

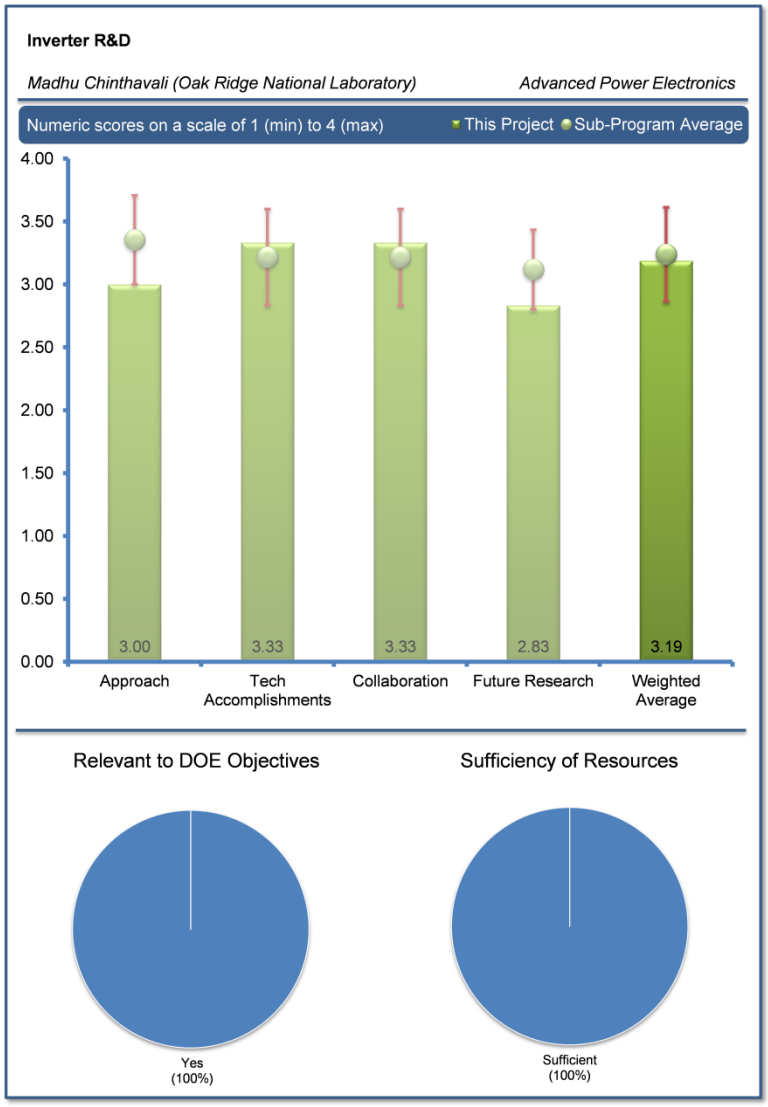
Reviewer 2:
The reviewer expressed that the project has sufficient resources for the defined tasks.

Reviewer 3:
The reviewer remarked that the resources for this program are appropriate and sufficient.

Reviewer 4:
The reviewer commented that the results indicate that resources are sufficient.

Reviewer 5:
The reviewer noted that the modeling effort to understand what is possible would be more than sufficient for the DOE to spend money. Spending additional money on testing and hardware is best left to industry partners. The reviewer commented that if value exists by doing this work, then industry will pay for the hardware and testing and did not see $1.25 million worth of research that is showing how barriers are broken.

Inverter R&D: Madhu Chinthavali (Oak Ridge National Laboratory) - ape053



Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that benchmarking is ongoing and that the work appears to be done in a detailed manner.

Reviewer 2:

The reviewer stated that the WBG device cost is mentioned and benefits of cost reduction on other subsystems is a focus but it is unclear that analysis cost break points have been determined.

Reviewer 3:

The reviewer stated that this is an important project for the DOE. It helps quantify the potential benefits of the emerging SiC devices. The reviewer noted that a lot of progress in the first year towards demonstrating the full scale system was reported. The reviewer noted that it would be interesting to quantify next year, once the 10kW system has been built, where the power density improvement comes from, as well as an efficiency comparison to the state of the art.

Reviewer 4:

The reviewer remarked that the project presents a clear integrated approach on how to use WBG inverter to achieve the size, weight, and cost goals. Slides of particular note to the reviewer included Slide 6.

Reviewer 5:

The reviewer commented that the availability of WBG die in the voltage and current range needed for the application is a barrier. The reviewer indicated that working with the WBG supplier to understand their road maps to get an idea of costs and what is their plan for automotive qualifications for application specific devices will be necessary. Additionally, off the shelf WBG materials that would use all the capabilities of the in-house WBG gate driver may be even harder to get. For example, active current balance to share current evenly between paralleled devices may be difficult to find. From the design review in August, it would be useful to state the conditions under which the inverter could meet the 20/20 targets and what is included in that inverter design. The reviewer observed that this was a good first step to understand how WBG power devices can be used to meet the DOE 20/20 targets.

Reviewer 6:

The reviewer did not see a plan on how to accomplish the cost objectives. The reviewer commented there were no studies of cost trade-offs to determine how to balance the system cost.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer was glad to see a website to make the information about WBG transistors and diodes more widely available.

Reviewer 2:
The reviewer commented that the project has completed the initial design of a 10 kW inverter using commercial SiC 1200 V, 100 ampere (A) MOSFET modules. The project has also tested the power module in the Nissan LEAF as baseline. Additionally, the cooling design has been improved.

Reviewer 3:
The reviewer commented that there are quite a few subsystem development efforts each with alternate approaches but it is not clear how this will be pulled together to meet program goals.

Reviewer 4:
The reviewer noted that the designs are moving forward. The design review of the inverter will determine if there is a path to the 20/20 targets. At this time it is difficult to assess the progress toward objectives without more knowledge about the completed design.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted many connections with suppliers that are being benchmarked.

Reviewer 2:
The reviewer noted that the project has collaboration with several suppliers, power inverter companies, and several other groups in DOE.

Reviewer 3:
The reviewer remarked that, with regards to awareness of who to talk to in the industry about WBG materials, the project team is well covered. The reviewer noted that there was nothing mentioned about the project team's plans for capacitors, but there were three capacitor manufactures listed as collaborators. The reviewer wanted to know if there was a custom capacitor that was part of the design or if it was just a repackaged PP capacitor.

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

Reviewer 1:
The reviewer noted the ongoing nature of the benchmarking project.

Reviewer 2:
The reviewer commented that the project steps are reasonable, but a detailed cost study of what needs to be accomplished in the design to meet the 2020 goals and objectives is missing. The reviewer noted that good work is being done, but without focus on the cost issue it does not really provide any justification for using WBG technology in automotive applications.

Reviewer 3:
The reviewer expressed that it would be a very good thing if the project team can show a path to the 20/20 targets in August using WBG materials, but WBG may be one of many challenges needed to overcome to meet the targets. For example, if an air cooled WBG inverter is chosen to meet the 20/20 targets the costing should also include a fan and ducting. The reviewer asked what might happen if the fan and the inverter location required a twisted route to duct the air.

Reviewer 4:
The reviewer commented that the project has a clear path to 30 kW WBG power inverter with 55 kW peak power.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that electrification of vehicles tends to decrease petroleum use.

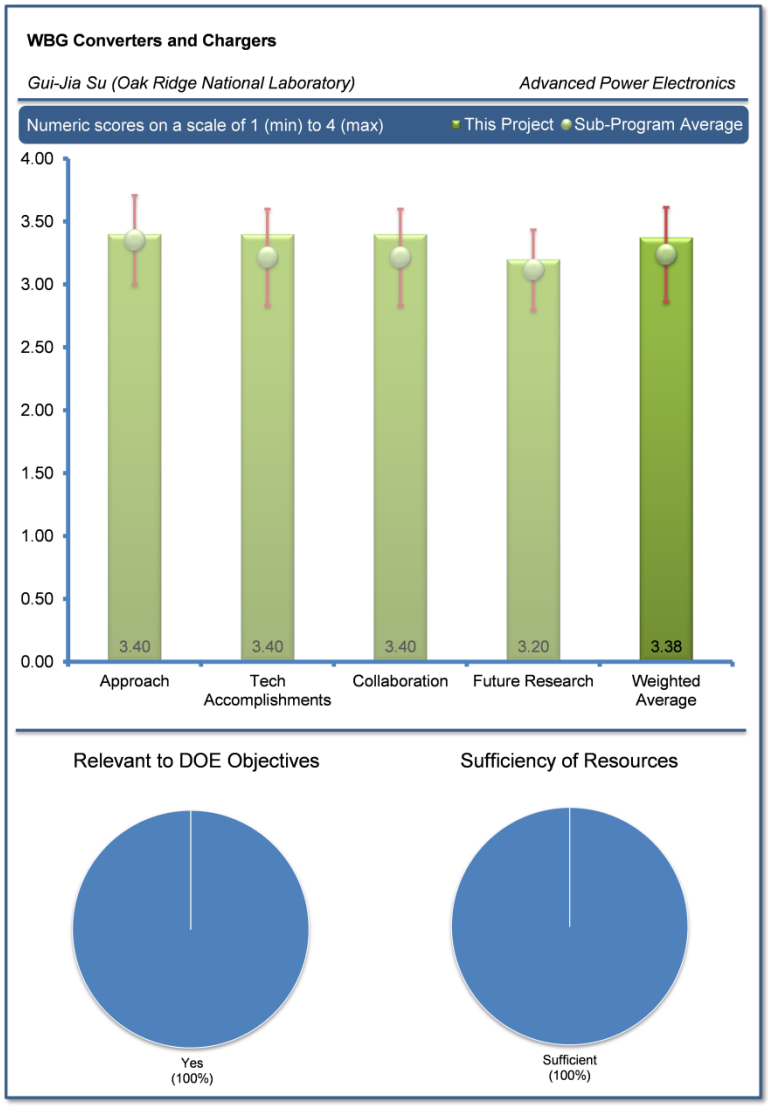
Reviewer 2:
The reviewer stated from efficiency only.

Reviewer 3:
The reviewer commented that, if the design can meet the 20/20 targets, this would enable the market for EDVs and reduce our reliance on foreign oil.

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

Reviewer 1:
The reviewer commented that, for where the project team is at today, the resources are sufficient.

WBG Converters and Chargers: Gui-Jia Su (Oak Ridge National Laboratory) - ape054



Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the benefits from switching mode are becoming clearer.

Reviewer 2:

The reviewer stated that the strategy to utilize high frequency WBG on-board chargers and converters to reduce size, weight, and cost and increase efficiency is good. Bidirectional charger capability is also good, but roaming grid inverters face grid integration standard and regulatory changes which are being address by the Smart Grid Interoperability Panel (SGIP) Distributed Renewables, Generation & Storage (DRGS) and the Vehicle to Grid (V2G) Domain Expert Working Groups (DEWGS). The reviewer noted that ORNL and NREL are becoming members of SGIP so it might be appropriate for this project to monitor these efforts or to coordinate through National Institute of Standards and Technology (NIST).

Reviewer 3:

The reviewer commented that this project overcomes the limitations of present semiconductor and magnetic materials with WBG devices, advanced magnetic materials and novel control strategies to significantly increase power density, specific power and efficiency at lower cost. Additionally, the reviewer noted that the project can reduce the cost of the power inverter by using smaller capacitor.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer noted that isolation converter architecture selection and design modeling was performed, and testing was performed using silicon devices. SiC and Gallium Nitride (GaN) switch for vehicle converter applications were also evaluated.

Reviewer 2:

The reviewer remarked that cost needs to be looked at and justify why this approach is better than a conventional solution.

Reviewer 3:

The reviewer commented that the team has done quite a bit of work in the first year. The reviewer observed that, though the new devices provide some interesting opportunities, a lot of work has been done on the topology tradeoff by others. It would be a good

idea to focus on the improvements that can be made with the conventional topologies using the new devices rather than spending too much effort on topologies tradeoff. The reviewer noted that it appeared that the goal was to complete the tradeoff analysis this year, but there was no indication which topology was chosen.

Reviewer 4:
The reviewer commented that the project has significant achievements up to now and several technical tasks have been performed. The project has simulated several converter architectures and developed a battery ripple current reduction control strategy for the isolation converter to reduce the bulky DC link capacitor. The project also identified one isolation converter candidate and completed testing of a 5kW Si-based integrated DC-DC converter and charger using the candidate. In addition, the project has completed DBC design for WBG switch phase-leg modules for CREE, Inc. SiC MOSFETs. The project also conducted tests of efficient power conversion (EPC) eGaN switches for possible use in the 14V DC-DC converter.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the industry WBG and magnetic material partners were outstanding. ORNL, NREL and the University of Tennessee were also listed as 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.

Reviewer 1:
The reviewer commented that the detailed future plans seem reasonable.

Reviewer 2:
The reviewer indicated that the project has a clear plan to achieve the milestones in the future.

Reviewer 3:
The reviewer commented that a cost rational of how this lowers cost was needed.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that electrification of vehicles tends to decrease petroleum use.

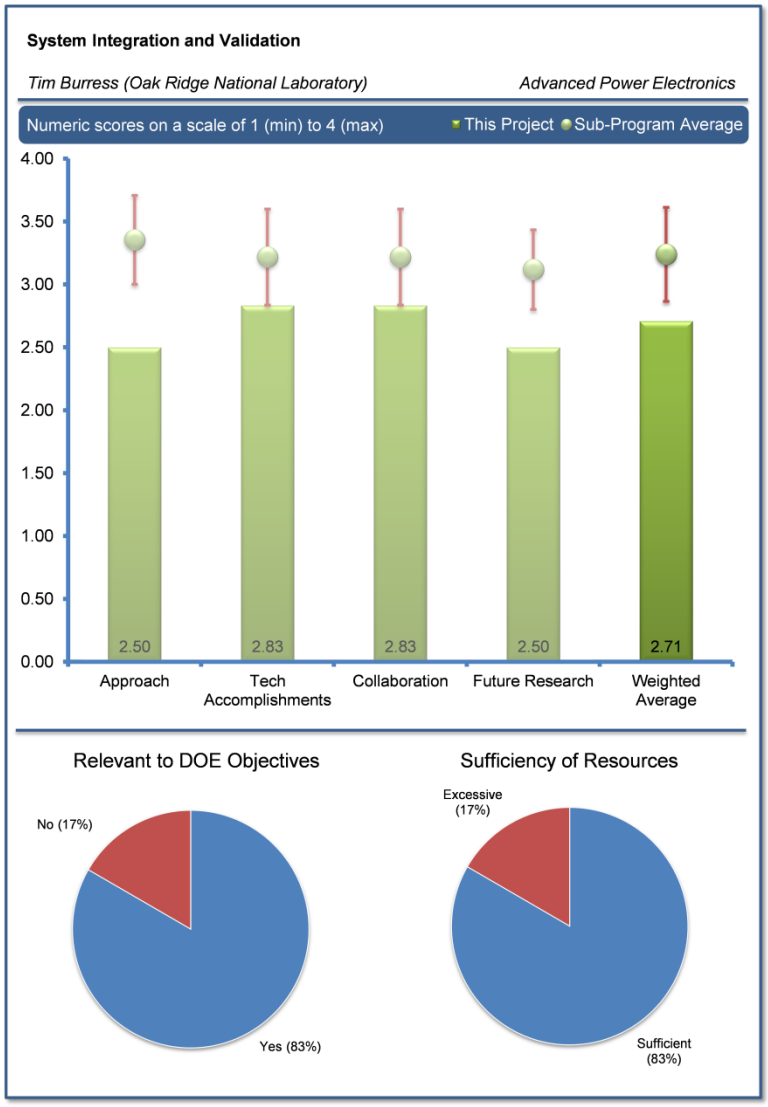
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?
No comments were received in response to this question.

System Integration and Validation: Tim Burress (Oak Ridge National Laboratory) - ape055

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.



Reviewer 1:

The reviewer commented that the system modeling seems appropriate.

Reviewer 2:

The reviewer remarked that this was an interesting project that will give the DOE capabilities to study the interactions between various electric driveline components.

Reviewer 3:

The reviewer commented that developing a vehicle hardware-in-the-loop (HIL) simulation system is an excellent approach to better quantify requirements as well as the possibility of shortening design cycles. Additionally, the reviewer noted that developing a universal controller with a dynamic control system and high speed data acquisition system should provide useful information on system behavior somewhat independent of hardware. However, the reviewer noted that a plan for incorporating the Glidcop material into an IM rotor was not addressed.

Reviewer 4:

The reviewer commented that this project does not develop the technology to overcome barriers. The reviewer noted that this project is developing testing capabilities to perform verification work.

Reviewer 5:

The reviewer commented that the desire to test traction drive system performance is necessary, but wondered if the development of a facility to do this cost effective when compared to using existing facilities such as those that are available from AVL. The reviewer noted that the use of combined test profiles is very good and will provide usable data. An additional requirement to fully evaluate the system that was noted was to be able to test over temperature for the various components. The reviewer also wanted to know if the system will be able to test motors only or if it will be able to also test motor/gear boxes to determine the efficiency of the retransmission function.

Reviewer 6:

The reviewer commented that it was unclear why this was being done when it seemed to be more of an OEM task.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:
The reviewer commented that the system modeling work based on component-by-component simulation appears to be appropriate.

Reviewer 2:
The reviewer indicated that the development is on track from a hardware standpoint with barriers identified. However, some mention needs to be made about how the software development is going for the software that glues this system together and analyzes the results.

Reviewer 3:
The reviewer stated that the progress is very good in terms of supporting an in house HIL system capable of testing individual components from various suppliers. However, the reviewer noted that if the goal is to test only systems then these components might not be required and that the development of these components will support other uses such as motor testing and/or inverter only testing, if required. The reviewer asked if there is the capability/plan to test ESS subsystems in this facility.

Reviewer 4:
The reviewer stated that this project is not applicable to achieving the DOE goals. The reviewer indicated that this project is developing a HIL system in a dynamometer, building up ORNL to perform testing.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that it looks like a good team to develop the hardware in the loop vehicle simulation system.

Reviewer 2:
The reviewer noted that the collaborations with the DOE and the National Laboratories community are outstanding. The reviewer was interested in knowing if industry had been contacted to determine what facilities already exist and to find out what kind of issues and solutions that they have implemented.

Reviewer 3:
The reviewer commented that this project should not be an Advanced Power Electronics and Electrical Machines (APEEM) project, noting that this is a capital expenditure project to acquire test equipment.

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

Reviewer 1:
The reviewer noted that, in discussing future work, the year by year delineations are clear. The reviewer mused that perhaps it is only in modeling work that such precise plans can be formulated. The reviewer was heartened that the modeling in out-years will include hardware-in-the-loop.

Reviewer 2:
The reviewer noted that the hardware future development is well defined. More information about software development and how it plays into this development would be useful.

Reviewer 3:
The reviewer indicated that future plans are appropriate for the project as defined.

Reviewer 4:
The reviewer was unsure of how much value the data generated will be. Every vehicle's operating modes are different. It seemed to the reviewer that this project will not generate data that will be real.

Reviewer 5:
The reviewer stated that there is no research here.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer commented that the increased electrification of vehicles tends to decrease petroleum use.

Reviewer 2:
The reviewer noted that, if successful, there is potential for reducing design times and improving system efficiency and lowering system cost, all of which help to enable the market for EDVs, which in turn helps to lower our dependence on foreign oil.

Reviewer 3:
The reviewer stated that these functions are required to meet the DOE goals but wondered if this is the most cost effective method to achieve it. The reviewer stated that it might be, in the long run.

Reviewer 4:
The reviewer commented that this project is just a capital expenditure project.

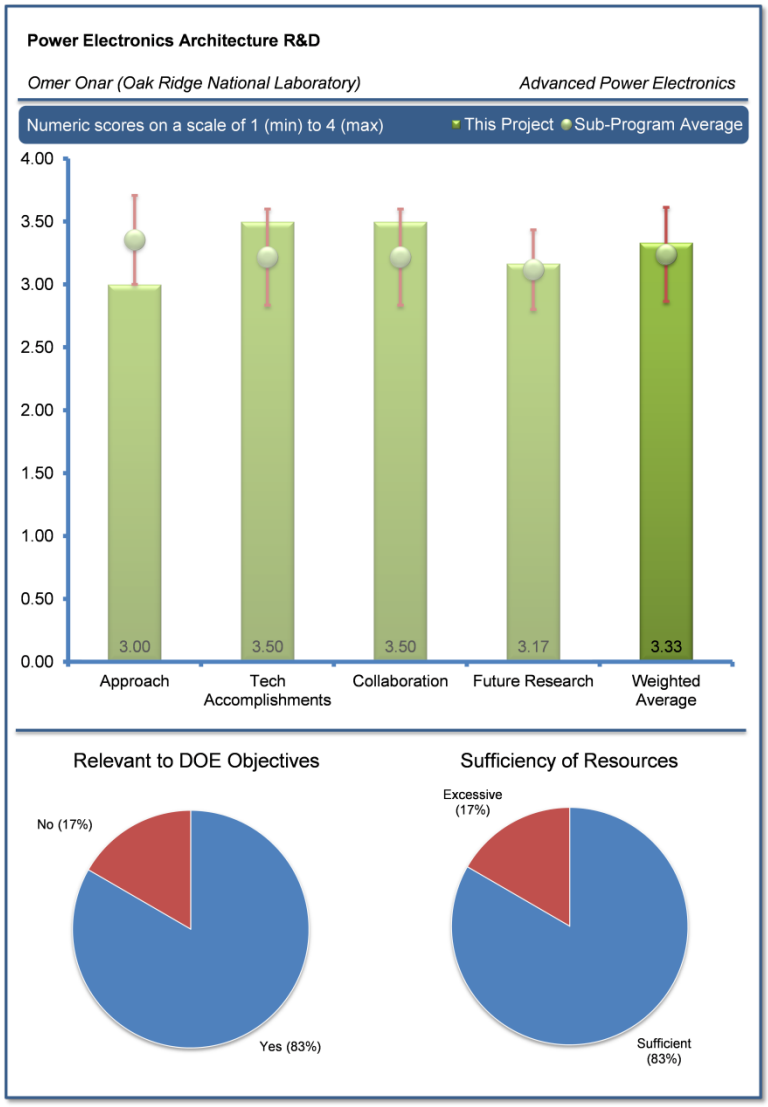
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that the project is on track with resources defined.

Reviewer 2:
The reviewer commented that the resources are appropriate for the project as defined.

Reviewer 3:
The reviewer noted that hiring a company that specializes in dynamometers and HIL systems to deliver a turnkey system to the lab would be better. This project will be slow to develop, will be highly customized, and will have to walk through a long debug process to get up and running.

Power Electronics Architecture R&D: Omer Onar (Oak Ridge National Laboratory) - ape056



Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that high voltage bi-directional conversions appear to be important to higher efficiency.

Reviewer 2:

The reviewer indicated that this is a new project, and the researchers have made good progress on meeting project goals.

Reviewer 3:

The reviewer stated that this project proposed a hybrid energy storage system with both batteries and ultra-capacitors. A modular and reconfigurable bi-directional buck/boost DC-DC converter will be designed and developed to be placed between the regenerative energy storage systems (RESS) and the DC link (traction drive inverter). The reviewer noted that the use of ultra-capacitors in the energy storage system may increase the vehicle energy storage cost as ultra-capacitors are more expensive than batteries.

Reviewer 4:

The reviewer commented that modeling many topologies for DC-DC converters, building one or two based upon the model results, and decoupling energy and power from the energy storage system is a good approach. Recognition that system cost could increase based on choices is an excellent observation. The reviewer noted that, if system cost increases, there needs to be a discussion on the expected system benefits that could justify the cost increase.

The reviewer indicated that the decision point on whether to proceed is not clear. It states change if the hybrid system outperforms the reconfigurable system, but it was unclear what would be changed if this occurred.

Reviewer 5:

The reviewer was not clear on why and how this work addresses the technical targets.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer believed that the work was still at an early stage, but the planning appears to be detailed.

Reviewer 2:
The reviewer commented that the project has a good start in analyzing architecture options.

Reviewer 3:
The reviewer stated that the progress is on track, noting that downselection of architecture needs to be finalized to see if costs are in line with DOE targets.

Reviewer 4:
The reviewer noted that the project has designed and modeled different designs.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the linkages with Maxwell and Chrysler were good.

Reviewer 2:
The reviewer stated that having Chrysler and the ultra-capacitor companies as collaborators with the ORNL team was positive.

Reviewer 3:
The reviewer noted that the project has collaborations with both energy storage experts and power electronics experts.

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

Reviewer 1:
The reviewer commented that the plans seem clear and logical; first a test bed and then systems integration. The reviewer stated that this was good.

Reviewer 2:
The reviewer noted that the plans are based on progress; a decision point on cost versus performance needs to be included.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer indicated that electrification of vehicles tends to decrease petroleum use.

Reviewer 2:
The reviewer commented that the possibility of using active energy management to reduce the size and cost of power electronic converters helps to enable the market for EDVs, which decreases dependence on foreign oil.

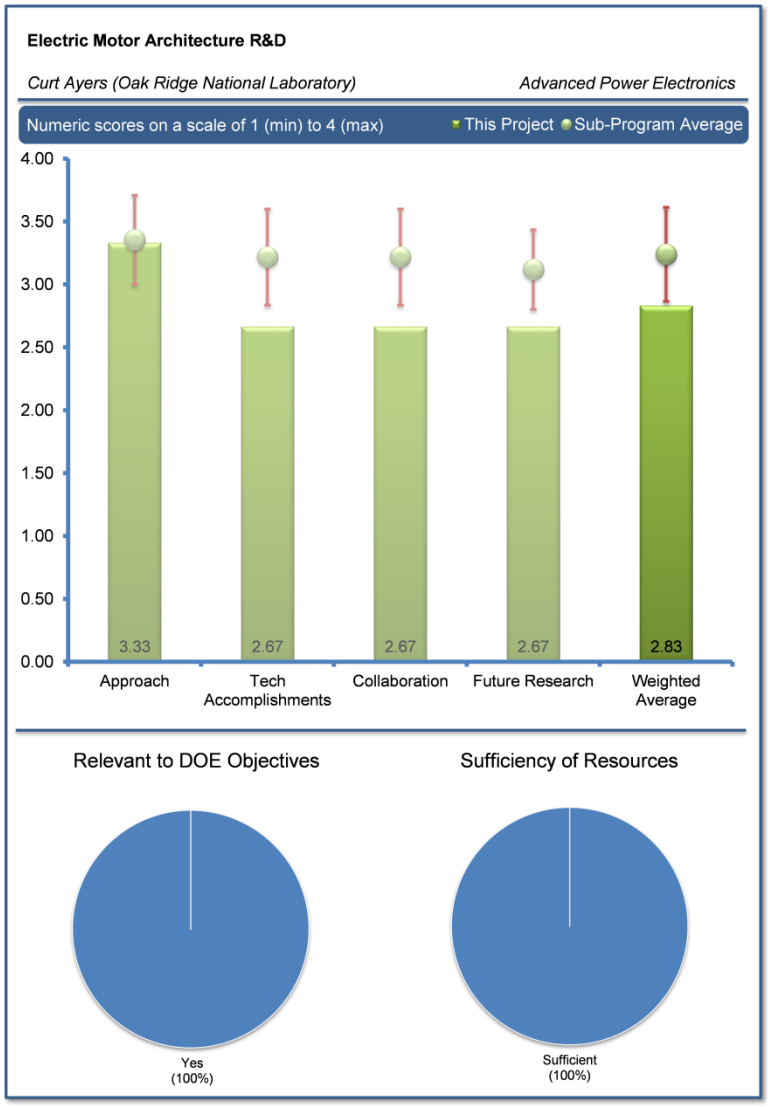
Reviewer 3:
The reviewer commented that the hybrid energy storage system may balance the energy density and power density, and improve regenerative braking.

Reviewer 4:
The reviewer commented that it is not clear; system baseline performance and proposed system performance are not quantified.

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

Reviewer 1:
The reviewer remarked that the project is on track with resources on hand.

Electric Motor Architecture R&D: Curt Ayers (Oak Ridge National Laboratory) - ape057



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the approach in this project supports the assumption from the Electric Motor R&D project, that electric motors need significantly higher maximum speed to meet the 2020 cost target. Although the validity of this assumption is questionable, the approach to include the transmission or gear box components into the overall system evaluation is good. Additionally, the reviewer noted that the evaluation of material limits regarding high speed operation is of interest for the automotive industry.

Reviewer 2:

The reviewer indicated that understanding current technology and utilizing information from other benchmarking and development programs is a good start to the approach. Analyzing these machines, their associated transmissions, and looking to address the issues found through these analyses are also appropriate. The reviewer noted that it will be important to understand not only the architecture, material, and component selection, but the tolerances and American Gear Manufacturers Association (AGMA) gear grades required for high speeds, as these affect cost.

Reviewer 3:

The reviewer indicated that the project is well conducted and planned.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer noted that the project was started in FY 2013. The initial accomplishments are good with the benchmarking of existing traction systems.

The reviewer was unclear on the benefits of the investigation of starter motor designs for high power traction drive systems. The usage profile and thus the requirements for a starter motor are very different compared to a traction motor. The reviewer thought that future accomplishments might make the benefits of investigating starter motors more obvious.

Reviewer 2:
The reviewer indicated that this is a relatively new program. The technology teardown, technology evaluation, and FEA modal analysis are good early accomplishments. The reviewer commented that motors are designed for their speed of operation, and suggested not to conclude that higher speeds are limited by copper bar or magnet retention because retention systems can be improved by trading off performance, which is why retention systems are not highly over designed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that collaboration with an industrial motor supplier is in an early stage, but will hopefully lead to good results. The reviewer commented that the involvement of transmission suppliers or automotive OEMs would strengthen the project focus.

Reviewer 2:
The reviewer noted that Regal-Beloit Corporation is an industrial motor supplier. The reviewer questioned their knowledge regarding traction systems for transportation.

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

Reviewer 1:
The reviewer stated that analyzing possible gear solutions for high speed motors, complementing other ORNL work, is worthwhile. It will be important to look at gearing cost (materials, grades, and tolerances), gearing and bearing losses at high speeds, and total traction system specific power and power density. Most of these issues were already noted, leading the reviewer to believe there was a good understanding of what needs to be analyzed.

Reviewer 2:
The reviewer commented that the future research plans are not very detailed at this point in time. The reviewer hoped that the planned benchmarking activity will support the future definition of more specific plans.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer indicated that the project supports the objective of petroleum displacement by investigating driveline components with the focus on higher speed. If successful, this could result in cost savings for electric drive systems, which would enable a faster market introduction of Hybrid and EVs.

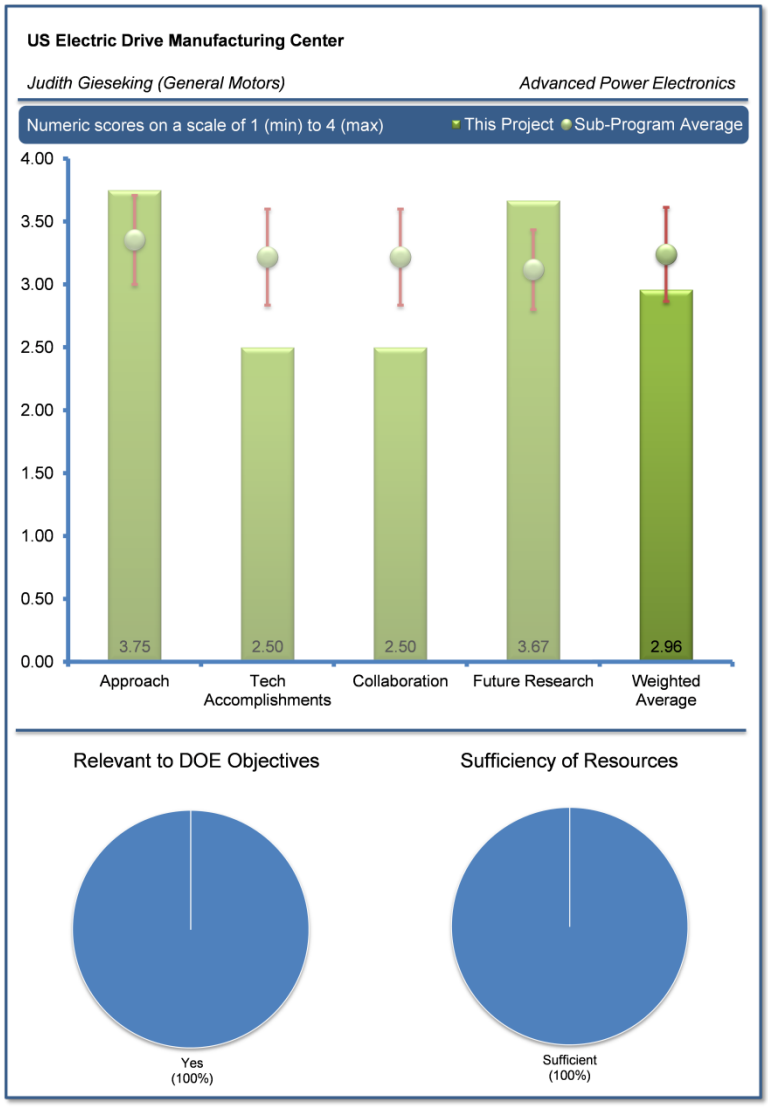
Reviewer 2:
The reviewer commented that better electric propulsion systems support the DOE objectives of petroleum displacement.

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

Reviewer 1:
The reviewer remarked that the project has sufficient resources for the defined tasks.

Reviewer 2:
The reviewer indicated that resources at ORNL are appropriate and there is industry involvement in this program.

US Electric Drive Manufacturing Center: Judith Gieseking (General Motors) - arravt021



Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that GM has built the first U.S. factory for electric motors in Maryland. The facility also makes electric drivetrains. Both components will be part of the Spark EV. The equipment for both components has been installed and validated. The factory began making electric motor units in May 2013.

The reviewer indicated that the aims are to develop domestic electric motor design, engineering, and manufacturing capabilities, as most key electric drive components are currently built in East Asia. GM reported that prototype and production builds of both motors and electric drive units were delivered on time, with hundreds of units of both parts built through the first quarter of 2013.

Reviewer 2:

The reviewer commented that creating more jobs and building a new factory to make EV motors in three years is very good.

Reviewer 3:

The reviewer indicated that the program was responsive to the requirement of adding production capacity for electric motors and drives.

Reviewer 4:

The reviewer noted that the facility is up, running, and producing parts.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer noted that the equipment for both components has been installed and validated. The factory began making electric motor units in May 2013.

Reviewer 2:

The reviewer noted that the project made good use of automation and technology.

Reviewer 3:
The reviewer stated that production in the facility has been launched. The production line strategy and the product qualification were provided. However, there was little detail regarding the system being manufactured.

Reviewer 4:
The reviewer noted that consumer acceptance is the last barrier that needs to be overcome. The market for EDVs is growing and GM is well positioned to capitalize on that expanding market.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that GM reported that there were no external collaborations beyond the DOE assistance. The reviewer presumed that construction contractors were involved at some point.

Reviewer 2:
The reviewer noted that GM used in-house expertise.

Reviewer 3:
The reviewer stated that no collaboration on this program is noted. The reviewer indicated that little collaboration for this type of program is required.

Reviewer 4:
The reviewer indicated that there are no other partners.

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

Reviewer 1:
The reviewer expressed that it was great that plant production in 2013 was on budget and on schedule.

Reviewer 2:
The reviewer noted that the program is concluding, so there is no future work to evaluate.

Reviewer 3:
The reviewer stated that the project is on track for close out.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer commented that GM's new factory supports the manufacture of PEVs in the U.S. This will make it easier for GM to deliver PEVs to U.S. consumers, who can then drive these vehicles instead of conventional ICE vehicles that run exclusively on petroleum-based fuel.

Reviewer 2:
The reviewer indicated that the project gives the United States a leadership position in electrifying vehicles into the future.

Reviewer 3:
The reviewer stated that manufacturing infrastructure is a key element in the sale of electrified vehicles.

Reviewer 4:

The reviewer noted that the project enables the U.S. manufacturing of EDV powertrains and creates and retains U.S.-based manufacturing jobs. The reviewer noted that 29 advanced manufacturing jobs were created at the new facility. The reviewer was unclear regarding the number of jobs that were retained at the facility.

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

Reviewer 1:

The reviewer indicated that the project was completed with the resources provided by DOE and GM.

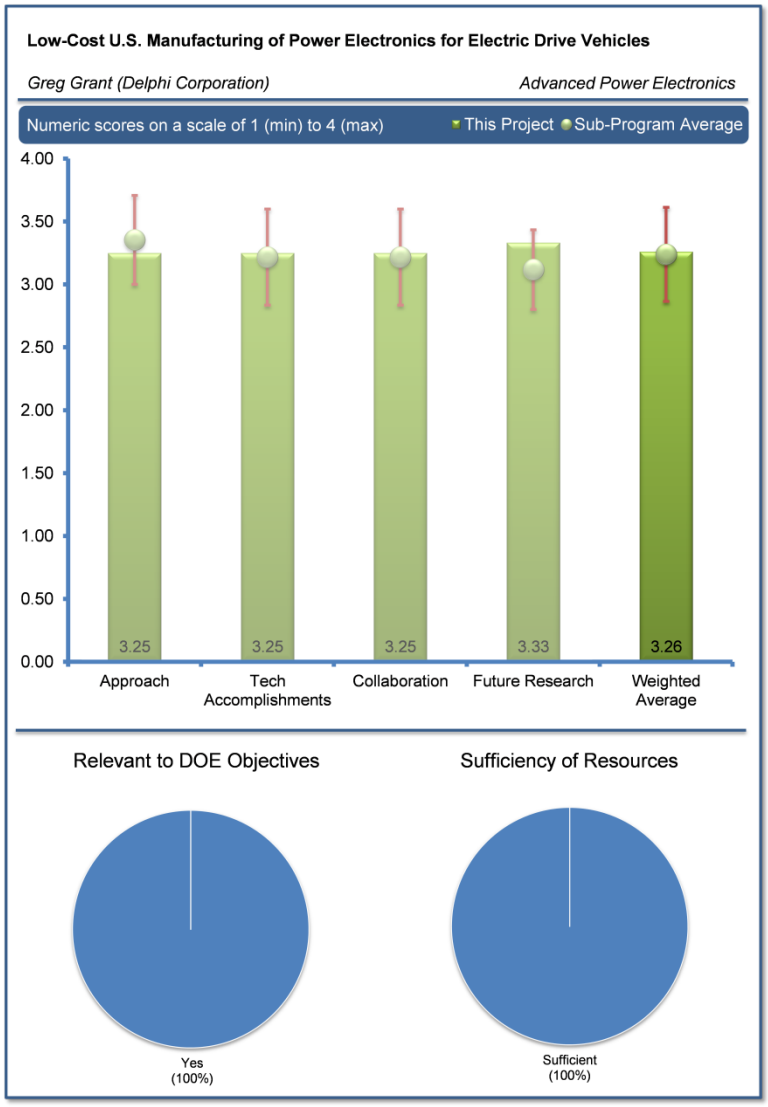
Reviewer 2:

The reviewer stated that GM has the resources to execute this program.

Reviewer 3:

The reviewer commented that the project is heading to closure with the resources available.

Low-Cost U.S. Manufacturing of Power Electronics for Electric Drive Vehicles: Greg Grant (Delphi Automotive Systems LLC) - arravt022



Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated that robust power management of power electronics is critical for the success of electric vehicles. The approach here is based on the considerable background available at Delphi.

Reviewer 2:

The reviewer noted that the work seemed to be concluding with some measure of success.

Reviewer 3:

The reviewer commented that the goal to develop low cost manufacturing and produce a trained workforce in this country for manufacturing electric vehicle components was achieved. Over 900 jobs were created and electric components were developed.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer stated that a model system was developed and tested that meets the needs of electric vehicles. It is ready for distribution.

Reviewer 2:

The reviewer remarked that Delphi seemed to have made reasonably good use of ARRA funding to make inventions necessary for high volume manufacturing of power electronics.

Reviewer 3:

The reviewer indicated that the project created technology and manufacturing facilities for electric vehicles which can supply the industry for many years. The reviewer noted that increasing acceptance of EVs requires low cost and efficient manufacturing.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that collaborators included several car manufacturers and the State of Indiana.

Reviewer 2:
The reviewer commented that the level of collaboration and coordination was appropriate for manufacturing work.

Reviewer 3:
The reviewer noted that the collaborators included several industry leading companies.

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

Reviewer 1:
The reviewer commented that the various electrical devices, inverters, chargers, control algorithms, etc., have been created. New job creation goals were also met.

Reviewer 2:
The reviewer hoped that the project effect will live on in future Delphi products.

Reviewer 3:
The reviewer noted that the project is nearly complete.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that power electronics are the base for electric vehicle propulsion. Electric vehicles use electrical energy to power the system. The demands on power electronics range from milliwatts to megawatts for the various systems, especially to deliver the high power essential for vehicle operation. The reviewer noted that electric vehicles are a key element in meeting the goals for petroleum displacement.

Reviewer 2:
The reviewer commented that the project was relevant to create an incentive for manufacturing EV equipment.

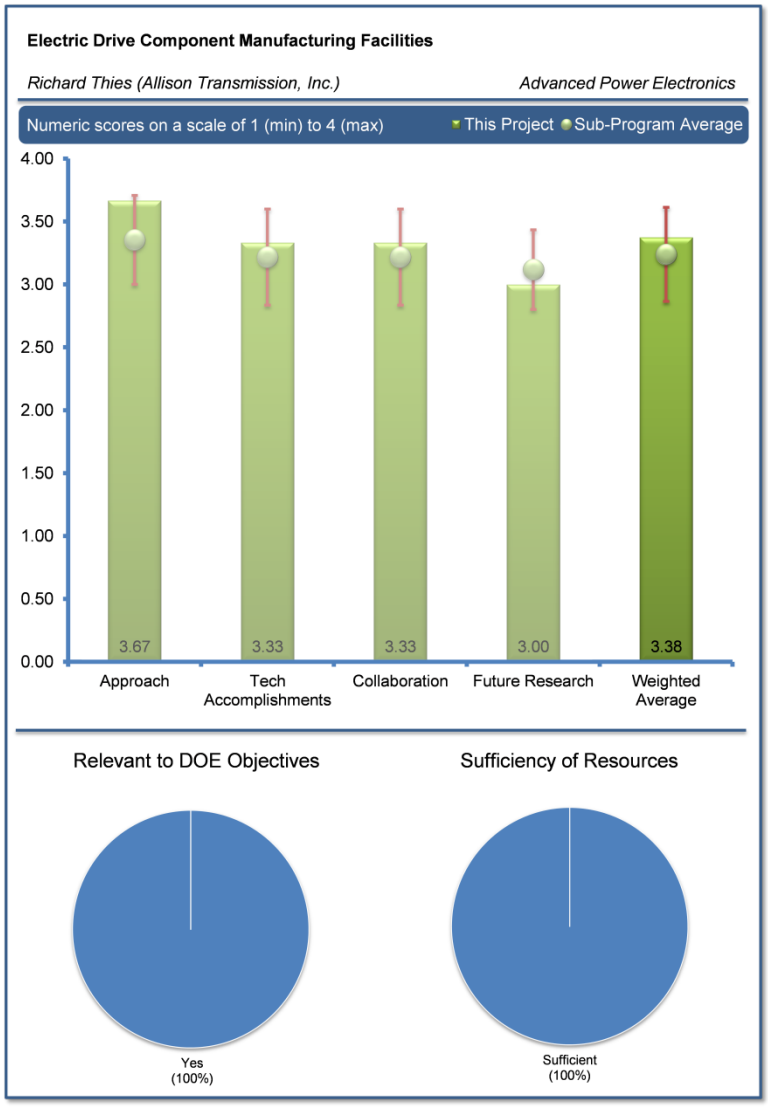
Reviewer 3:
The reviewer noted that vehicle electrification will decrease petroleum use in transportation.

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

Reviewer 1:
The reviewer stated that sufficient resources were available.

Reviewer 2:
The reviewer noted that the resources were sufficient to achieve the goals.

Electric Drive Component Manufacturing Facilities: Richard Thies (Allison Transmission, Inc.) - arravt023



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that ARRA dollars were directed to setting up manufacturing of utility vehicle hybrid motor transmissions.

Reviewer 2:

The reviewer stated that the goal to produce a hybrid commercial drive for buses, trucks, emergency vehicles, and motor homes was well understood. The project was planned with schedule milestones and it was completed on schedule.

Reviewer 3:

The reviewer commented that Allison has been able to mitigate schedule and technical risk due to their integration experience and controls and communication background. The reviewer noted that Allison has a separate program with Office of Naval Research (ONR), which packages a generator inside a modified bell housing around the torque converter, maintaining the same driveline length. The reviewer remarked that that system is ideal for retrofit applications assuming no interference with the additional radial diameter and no need for power take off (PTO), and wanted to know if this packaging approach was considered for this project.

Also, the reviewer added that providing more detail on the need for the engine disconnect clutch and when it is used would be helpful.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer commented that the manufacturing line was set up and products are now in mass production. The reviewer exclaimed that this was the best kind of success for a manufacturing project.

Reviewer 2:

The reviewer stated that this was an excellent achievement to design and built a commercial grade hybrid drive train for large vehicles.

Reviewer 3:
The reviewer indicated that, due to the high overall budget, a high-level breakdown of significant subcontracts and costs would be helpful in the project assessment. The reviewer noted that the accomplishments were excellent leading toward the start of production (SOP) in October 2013, including low rate initial production (LRIP) in November 2012.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the collaboration with Delphi Electronics (a power electronics and energy storage system company) and Remy, Inc. (a motor-generator company) was outstanding.

Reviewer 2:
The reviewer expressed that the collaboration and coordination was appropriate for a manufacturing type project.

Reviewer 3:
The reviewer noted that several other companies collaborated on the project.

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

Reviewer 1:
The reviewer commented that the ARRA work is concluding, and the product is already being sold. The reviewer commented that future research may be in directing other power needs to such successes, probably in other projects.

Reviewer 2:
The reviewer indicated that the goal is be able to produce 20,000 units by the end of this year and the project is on schedule.

Reviewer 3:
The reviewer commented that the future plans were not specified in detail; however, the timeline from Slide 17 indicates that SOP is scheduled for October 2013 for the H3000-based system and continuation of the design validation (DV) for the H4000-based system.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer observed that the project is very relevant because savings are estimated to be 29 million gallons of fuel and 291 tons of Carbon Dioxide (CO_2) eliminated.

Reviewer 2:
The reviewer noted that the electrification of vehicles will tend to decrease petroleum use.

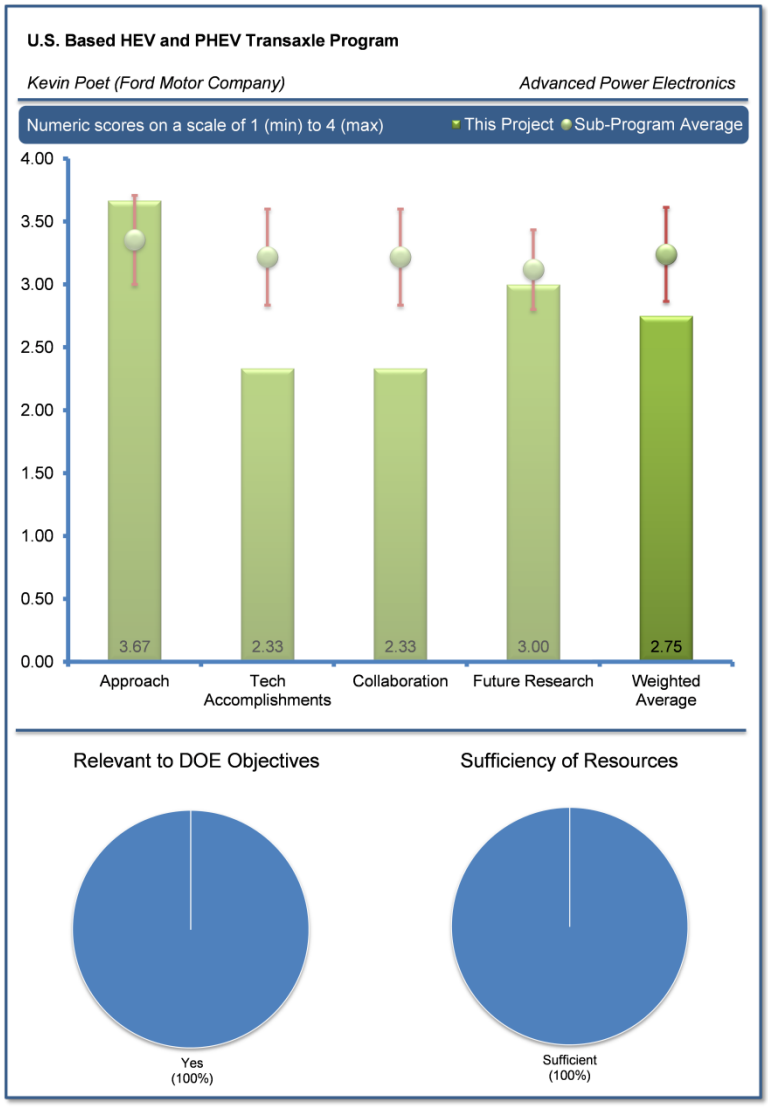
Reviewer 3:
The reviewer stated that Allison's existing fleet of H 40/50 hybrid transit busses has saved more than 29 million gallons of fuel over more than 553 million miles. The reviewer noted that the project has a 25-35% fuel economy improvement goal.

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

Reviewer 1:
The reviewer commented that the resources were adequate for the project to complete the scheduled milestones.

Reviewer 2:
The reviewer stated that the project is on track. A lack of resources was not apparent.

U.S. Based HEV and PHEV Transaxle Program: Kevin Poet (Ford Motor Company) - arravt024



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the goal to build a U.S.-based transaxle was broken down into four phases with milestone completion dates and the project was completed on time. The reviewer commented that this was a job well done.

Reviewer 2:

The reviewer indicated that the program is responsive to the requirement of adding production capacity for components. In this case, the production capacity was for a transaxle system for HEVs and PHEVs.

Reviewer 3:

The reviewer noted that Ford's new facility was built to make the HF35 transaxle, which is its first one to be internally manufactured. Its cost is mitigated by using components that are common to other Ford transaxle products. The HF35 is made by Ford's first transaxle assembly process that offers flexibility for tailoring the unit for each of several models of vehicle that Ford makes or will introduce. The reviewer commented that lessons learned through prototype testing and simultaneous engineering were applied to the design leading into Phase IV and ultimately the production launch of the product.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer noted that the project was executed over four phases, with various go/no go decision points. Each of those phases was completed, and the production line is almost completely ready. Some automation on the assembly line is still being completed. However, it is anticipated that these will be complete by the end of August 2013, which is the official end of the project. The reviewer also noted that the HF35 transmission is in full production.

Reviewer 2:

The reviewer stated that the project produced the first Ford transaxle manufactured by Ford and is compatible with other Ford drive components. This enabled PHEV and HEV vehicles to be made on the same assembly line with other Ford vehicles. The transaxle was extensively tested during Phase IV.

Reviewer 3:
The reviewer noted that production in the facility has been launched. The details regarding the development process, phased project plan, and installed equipment shows that the program has been successful.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that Ford identified no partners, but contractors were used in the process of constructing and outfitting its facility. Ford also credited partners in the community, machine tool suppliers, and production component suppliers in achieving its goals here.

Reviewer 2:
The reviewer indicated that this project did not officially have collaborators but Ford worked with several other companies and experts to complete the project.

Reviewer 3:
The reviewer noted that little collaboration was required for this program.

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

Reviewer 1:
The reviewer indicated that the project was near completion.

Reviewer 2:
The reviewer noted that the program is concluding and Ford will react to market demand going forward.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that the plant is in full production of the HF 35 transaxle. The reviewer remarked that the project is a real success story for fuel saving hybrid vehicles already on the road. This project has already had a major impact on reducing petroleum production.

Reviewer 2:
The reviewer indicated that the facility enables the mass customization of electric drive vehicles, which do not yet appeal to a broad enough market to enable large-scale series production. Plug-in electric vehicles appeal to a variety of niche markets, and if Ford can meet the needs of each of these niche markets, it is likely to sell more vehicles than if it chooses just one model and ramps up to volume manufacturing. The more PEVs on the road, the fewer vehicle miles traveled (VMT) on petroleum; the reviewer concludes that this project supports the DOE objective of petroleum displacement.

Reviewer 3:
The reviewer noted that manufacturing infrastructure is a key component to selling 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 reviewer commented that the funding was sufficient to build this facility that enables Ford to have the capability of mass customization for its EDVs.

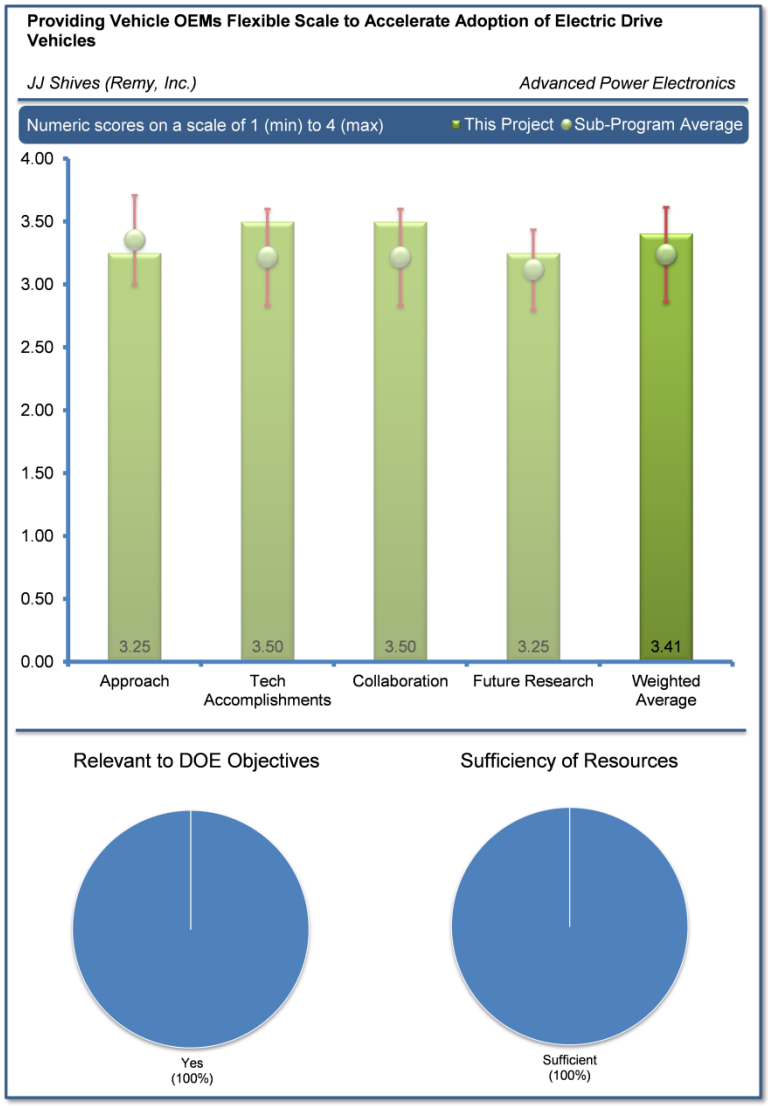
Reviewer 2:

The reviewer indicated that there was sufficient funding for the project goals to be achieved since Ford contributed half of the funding.

Reviewer 3:

The reviewer observed that Ford has the resources to execute this program.

Providing Vehicle OEMs Flexible Scale to Accelerate Adoption of Electric Drive Vehicles: JJ Shives (Remy, Inc.) - arravt025



Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that developing a standard, scalable platform for EDV motors and controls has been demonstrated. The barriers of market acceptance are based on performance and cost of their product. The reviewer noted that Remy and Phoenix are well positioned to capitalize on the expanding market for EDVs.

Reviewer 2:

The reviewer commented that the idea of providing a cost effective source of scalable electric drive traction systems is attractive. The reviewer indicated that the main question is when the market will be able to support multiple sources. The approach of improving existing facilities first is good and then building new facilities for high rate production is logical, but the reviewer needed more information regarding the definition of high rate and the limits of an improved facility.

Reviewer 3:

The reviewer stated that the approach to make non-OEM-specific and high-voltage variants of the motors will help reduce cost and promote wider adoption. The torque curves on Slides 11-12 show the continuous and peak torque curves for both the HVH410 and HVH250. For the HVH410, the continuous torque and peak torque are nearly the same, while for the HVH250 they have a difference of approximately 50 Newton-meters (Nm) of torque. The reviewer wanted to know if the continuous torque and peak torque ratings for the HVH410 motor were the same.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer expressed that the accomplishments were excellent. These included the completion of the Phase 1 production facility for both the electric machines (Remy) and inverters (Phoenix). This work also facilitated commercialization of multiple variants of the HVH250 and HVH410 motor families, including oil and water cooled variants with multiple lengths and winding patterns.

Reviewer 2:

The reviewer noted that products have been developed, can be manufactured, and are for sale.

Reviewer 3:
The reviewer commented that the plan to provide a matched set of inverter and motor is very good. The use of the same facility to recycle the parts is also good. The reviewer believed that both of the partners are capable of delivering working production parts, but had concerns that market could provide enough demand for them to be successful.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that the team members are doing a great job of collaborating on the plan and the requirements from their customers. If the market supports the project team, the reviewer believes that the project team will be successful.

Reviewer 2:
The reviewer indicated that it appears that Remy and Phoenix are working well together.

Reviewer 3:
The reviewer noted close collaboration with Phoenix on the associated power electronics as well as collaboration with multiple customers.

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

Reviewer 1:
The reviewer commented that basing expansion on market demand is outstanding and recommended not to spend money unless it was needed.

Reviewer 2:
The reviewer noted that a second manufacturing site in Indiana is presently under investigation. However, Remy is waiting on additional booked business prior to moving forward.

Reviewer 3:
The reviewer indicated that implementing phase two of the program based on increasing demand is a good approach. The reviewer wanted to know if market demand, at this time, does not necessitate the increased capacity does the program end in December 2013 or does something else occur.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that low cost EDV powertrains help to enable the market for EDVs which, in turn, lowers our dependence on foreign oil.

Reviewer 2:
The reviewer commented that the project supports the DOE goal of developing U.S. suppliers which, if cost effective, should support the overall goal of displacing petroleum.

Reviewer 3:
The reviewer commented that this project will help reduce the cost of high-performance electric machines and power electronics through production at high-volume manufacturing facilities supporting multiple OEMs. These electric drives are key components in hybrid electric vehicles, which have demonstrated the capability to reduce fuel consumption.

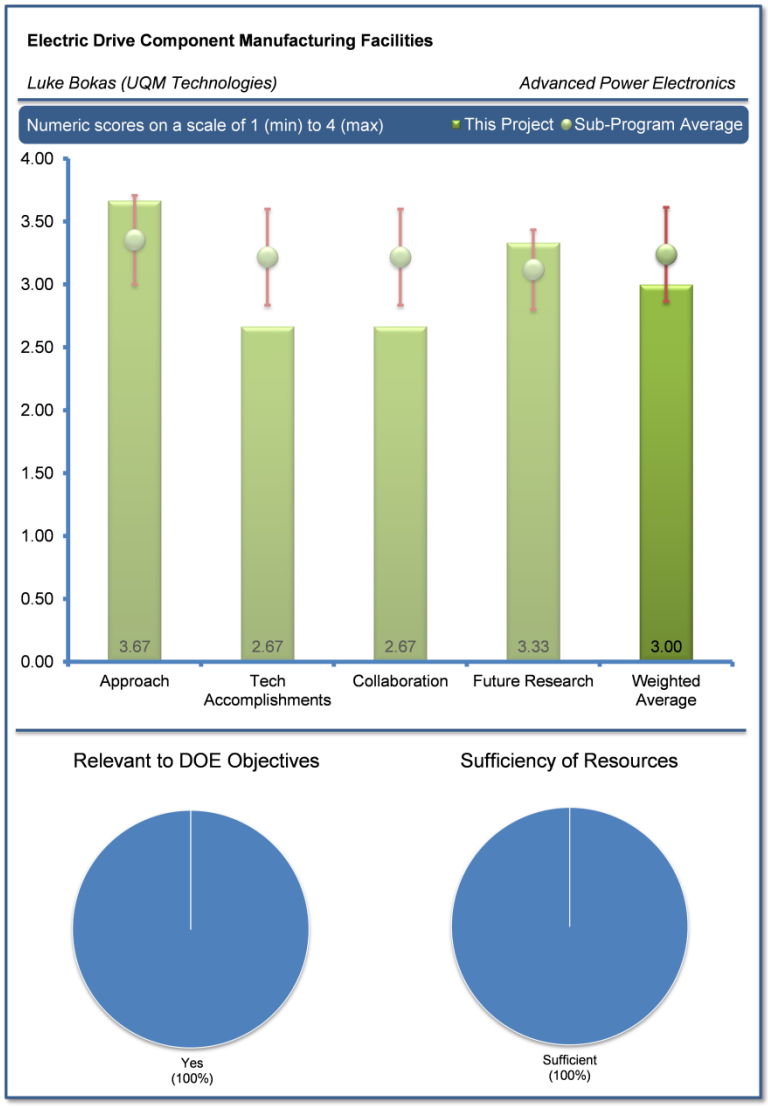
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the project is on track. A lack of resources is not apparent.

Reviewer 2:
The reviewer noted that the product developed with the available resources, and that resources and money appear to be available for the facilities. The reviewer noted that there still remains a question as to the need for increased manufacturing.

Reviewer 3:
The reviewer commented that it remains to be seen if the market will justify the expense of upgrading the facilities.

Electric Drive Component Manufacturing Facilities: Luke Bokas (UQM Technologies, Inc.) - arravt026



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that the project is directly addressing the issue to reduce costs in manufacturing.

Reviewer 2:

The reviewer indicated that the approach addresses high volume manufacturing of electric machines and power electronic components for both passenger and heavy duty vehicle markets. This will help reduce the cost of these components.

Reviewer 3:

The reviewer commented that the project produced a new manufacturing plant and improved electric components for bus, truck and car electrification.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer remarked that the results were great, including motors produced and passed to meet automotive standards.

Reviewer 2:

The reviewer commented that the project improved plant automation and increased the plant's capacity to produce more components. Components were improved in numerous ways including reducing weight, volume and cost.

Reviewer 3:

The reviewer noted that the project supported relocation to a larger 140,000 square foot facility. New controller and motor lines have been established and are operational at the new site, capable of 20,000 units annually. Components from the new assembly line have completed automotive qualification. Additionally, a second generation interior permanent magnet (IPM) motor of 100kW and a new heavy-duty motor of 220kW have been developed under this effort. The reviewer noted that a next generation motor controller which is 50% of the size of the original has been developed. Finally, over 1,000 units have been manufactured on the new production lines.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that the project was well-coordinated, with capable suppliers for both product and production.

Reviewer 2:
The reviewer noted that UQM Technologies collaborated with customers.

Reviewer 3:
The reviewer indicated that no collaborative arrangements were identified.

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

Reviewer 1:
The reviewer indicated that there were plans to increase product capabilities to improve production line utilization.

Reviewer 2:
The reviewer noted that most of the milestones are complete except for final validation of some automotive system components.

Reviewer 3:
The reviewer commented that new variations of the heavy-duty motor are planned, including a high-torque, low-speed variant and a high-voltage variant. UQM Technologies is still working to leverage the additional capacity through higher volume production contracts.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that UQM Technologies understands the fundamental issue very well and is attacking the problem with improved manufacturing and customer acceptance which will lead to petroleum displacement.

Reviewer 2:
The reviewer commented that efficient, high production manufacturing is required to produce low cost, reliable electric and hybrid vehicles which will reduce the use of petroleum.

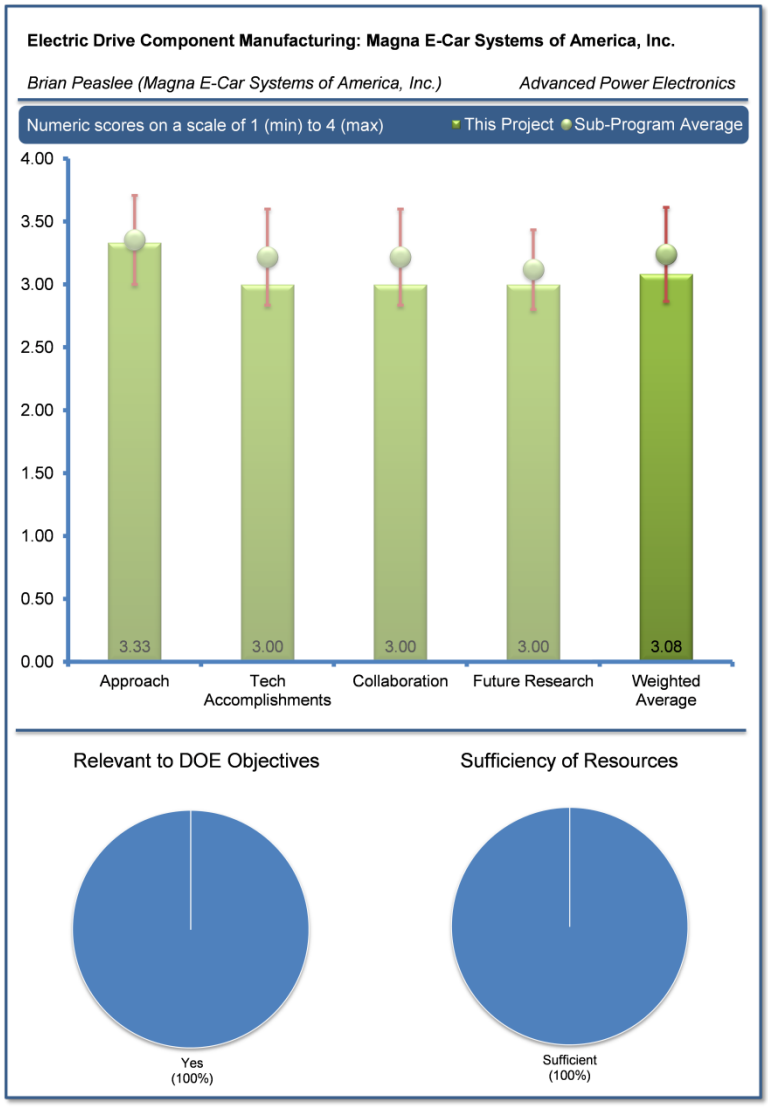
Reviewer 3:
The reviewer indicated that this project will help reduce the cost of high-performance electric machines and power electronics through production at high-volume manufacturing facilities supporting multiple OEMs. These electric drives are key components in hybrid electric vehicles which have demonstrated the capability to reduce fuel consumption.

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

Reviewer 1:
The reviewer commented that the objectives were achieved on schedule with the available resources.

Reviewer 2:
The reviewer noted that the project is on track. A lack of resources was not apparent.

Electric Drive Component Manufacturing: Magna E-Car Systems of America, Inc.: Brian Peaslee (Magna E-Car Systems of America, Inc.) - arravt027



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that this project produced an efficient manufacturing plant to produce electric vehicle components.

Reviewer 2:

The reviewer observed that the program is responsive to the requirement of adding production capacity for components.

Reviewer 3:

The reviewer indicated that the project is well designed to meet the goal of increasing U.S. production of electric drive system components as it relates to this project. The facility supports a variety of components by sharing resources. The reviewer expressed uncertainty surrounding market demand being acceptable enough to be profitable.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

The reviewer commented that the manufacturing plant was designed to be highly efficient using the latest in technology in robotics and automation. The plant also included a laboratory and test areas.

Reviewer 2:

The reviewer remarked that the program is ambitious in terms of the number of different products that are being released to production. The reviewer noted that most of the large systems have been production launched, and the small control modules will be launched within the next year.

Reviewer 3:

The reviewer observed that the technical accomplishments are good, but the volume is relatively large compared to DOE specifications. The performance is very good and supports the upper end of the DOE range of 75 kW to 150 kW.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that in-company collaboration was used.

Reviewer 2:
The reviewer stated that no collaboration is mentioned; the reviewer expressed that collaboration was not likely to be required for this type of program.

Reviewer 3:
The reviewer expressed that collaborations among the various divisions of the company should be good and it appears that they are.

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

Reviewer 1:
The reviewer noted that the project is nearly complete except for final testing and evaluation.

Reviewer 2:
The reviewer expressed that the program has reasonable time left to complete the launch of the remaining products.

Reviewer 3:
The reviewer commented that future plans are based on meeting viable milestones.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer opined that the project is relevant because reducing cost and improving quality are required to get public acceptance of electric and hybrid vehicles. This project achieves both reduced cost and improved quality and testing.

Reviewer 2:
The reviewer indicated that manufacturing infrastructure is a key component to selling electrified vehicles.

Reviewer 3:
The reviewer commented that there is a need for U.S. based suppliers. The reviewer expressed that the market needs to expand to support this.

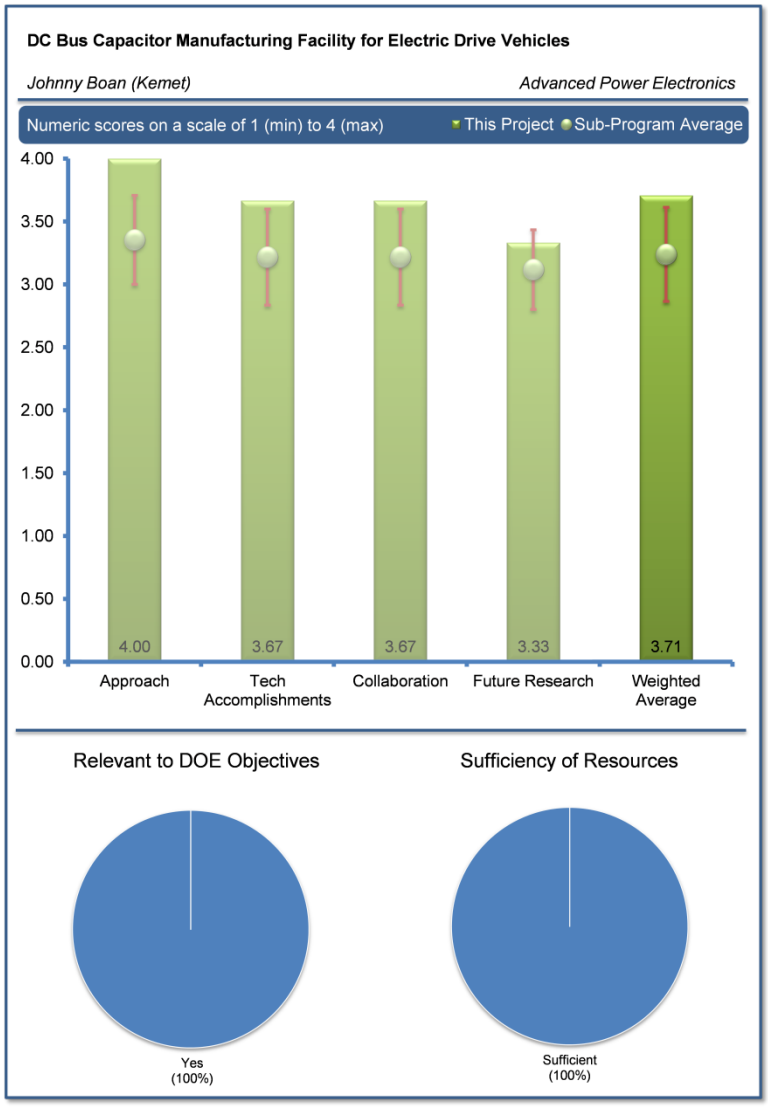
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that the resources were adequate to meet the schedule milestones.

Reviewer 2:
The reviewer remarked that Magna has the resources to execute this program.

Reviewer 3:
The reviewer stated that the resources appear sufficient to date.

DC Bus Capacitor Manufacturing Facility for Electric Drive Vehicles: Johnny Boan (KEMET Corporation) - arravt028



Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that the goal is to produce a plant for high volume capacitors in electric vehicles. KEMET upgraded an existing facility with additional automated equipment. The project team made a decision to make soft wound film capacitors based on customer input.

Reviewer 2:

The reviewer commented that KEMET is one of the largest capacitor manufacturers with products from capacitor film metallization, capacitor winding/stacking machining, and finished capacitors for various applications.

Question 2: Technical accomplishments and progress toward overall project and DOE goals – the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals.

Reviewer 1:

KEMET will build and equip a factory to manufacture DC buss capacitors for 100,000 EVs. The reviewer noted that the factory made its first shipment of DC bus capacitors and will support about 110 new jobs. The project is 29% complete.

Reviewer 2:

The reviewer indicated that the project is 32% complete. Machines and equipment for the first of three lines necessary to increase production have been purchased. More people have been hired and DC bus capacitors have already been shipped. The reviewer believes that the project will be completed on time.

Reviewer 3:

The reviewer noted that film capacitor manufacturing facilities have been set up in the United States, even though the current EDV market is affecting their project plan due to business issues.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that participants in the project and project monitors were adequately informed.

Reviewer 2:
The reviewer noted that collaboration was in-house.

Reviewer 3:
The reviewer indicated that the project has close collaboration with various customers and the project is also discussing with potential future dielectric materials.

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

Reviewer 1:
The reviewer noted that the project completes in 2015 and the project will install two more high volume lines.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that high volume production and automation will reduce the cost of the electrification of vehicles.

Reviewer 2:
The reviewer commented that a DC bus capacitor is one critical component in EDV power electronics. The film capacitor manufacturing is mainly related to polypropylene capacitors. The reviewer noted that some high temperature capacitor products may also be explored to achieve the 140°C target.

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

Reviewer 1:
The reviewer indicated that adequate resources are available.

Reviewer 2:
The reviewer observed that the resources have been adequate for KEMET to meet scheduled milestones.

Reviewer 3:
The reviewer commented that KEMET has all the resources for EDV film capacitor manufacturing and marketing.

Acronyms and Abbreviations

Acronym	Definition
1-D	One-Dimensional
°C	Degrees Celsius
A	Ampere
AC	Alternating Current
AGMA	American Gear Manufacturers Association
ANL	Argonne National Laboratory
APEEM	Advanced Power Electronics and Electrical Machines
ARRA	American Recovery and Reinvestment Act
BIM	Bonded Interface Material
CO_2	Carbon Dioxide
CTE	Coefficient of Thermal Expansion
DBA	Direct Bonded Aluminum
DBC	Direct Bonded Copper
DC	Direct Current
DEWGS	Domain Expert Working Groups
DF	Dissipation Factor
DOE	U.S. Department of Energy
DRGS	Distributed Renewables, Generation & Storage
DV	Design Validation
ECI	Electronic Concepts, Inc.
EDV	Electric Drive Vehicle
EPC	Efficient Power Conversion
ESR	Equivalent Series Resistance
ESS	Energy Storage System
EV	Electric Vehicle
FEA	Finite Element Analysis
FEMA	Failure Mode and Effects Analysis
FY	Fiscal Year
GA	Genetic Algorithm
GaN	Gallium Nitride
GE	General Electric
GM	General Motors
HALT	Highly Accelerated Life Test
HEV	Hybrid Electric Vehicle
HIL	Hardware-in-the-loop
ICE	Internal Combustion Engine
IP	Intellectual Property
IPM	Interior Permanent Magnet

Acronym	Definition
IGBT	Insulated Gate Bipolar Transistor
kW	Kilowatt
kV	Kilovolt
Li-ion	Lithium Ion
LRIP	Low Rate Initial Production
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
Nm	Newton-meters
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer
ONR	Office of Naval Research
ORNL	Oak Ridge National Laboratory
PEN	Polyethylene Naphthalate
PET	Polyethylene Terephthalate
PEV	Plug-in Electric Vehicle
PI	Principal Investigator
PLZT	Lead Zirconium Titanate
PM	Permanent Magnet
PP	Polypropylene
PTO	Power Take Off
PWM	Pulse Width Modulation
R&D	Research and Development
RE	Rare Earth
RESS	Regenerative Energy Storage System
RPM	Revolutions Per Minute
SAE	Society of Automotive Engineers
SGIP	Smart Grid Interoperability Panel
Si	Silicon
SiC	Silicon Carbon
SNL	Sandia National Laboratories
SOP	Start of Production
SSHD	Single-Stage Hot Deformation
TIM	Thermal Interface Material
U.S.	United States of America
V	Volt
V2G	Vehicle to Grid
VMT	Vehicle Miles Traveled
VTO	Vehicle Technologies Office
WBG	Wide Band Gap

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