

2010 Annual Merit Review Results Report

September 2010

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Introduction

The 2010 DOE Hydrogen Program and Vehicle Technologies Program Annual Merit Review and Peer Evaluation Meeting was held June 7-11, 2010 in Washington, DC. The review encompassed all of the work done by the Hydrogen Program and the Vehicle Technologies Program: a total of 271 individual activities were reviewed for Vehicle Technologies, by a total of 110 reviewers. A total of 1,333 individual review responses were received for the technical reviews.

The objective of the meeting was to review the accomplishments and plans for the Vehicle Technologies Program over the previous 21 months, and provide an opportunity for industry, government, and academia to give inputs to DOE on the Program with a structured and formal methodology. The meeting also provided attendees with a forum for interaction and technology information transfer.

The reviewers for the technical sessions were drawn from a wide variety of backgrounds, including current and former vehicle industry members, academia, government, and other expertise areas. In the technical sessions, these reviewers were asked to respond to a series of specific questions regarding the breadth, depth, and appropriateness of the DOE Vehicle Technologies Program. The technical questions are listed below, along with the scoring metrics (if appropriate). These questions were used for all Vehicle Technologies Program reviews, with the exception of the American Recovery and Reinvestment Act reviews, which used a different set of questions.

Question 1: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Question 2: Approach to performing the work: the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts. (Scoring weight for overall average = 20%)

Scoring: 4=outstanding (sharply focused on technical barriers; difficult to improve approach significantly); 3=good (generally effective but could be improved; contributes to overcoming some barriers); 2=fair (has significant weaknesses; may have some impact on overcoming barriers); 1=poor (not responsive to project objectives; unlikely to contribute to overcoming the barriers).

Question 3: 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. (Scoring weight for overall average = 40%)

Scoring: 4=outstanding (excellent progress toward objectives, suggests that barriers will be overcome); 3=good (significant progress toward objectives and overcoming one or more barriers); 2=fair (modest progress in overcoming barriers, rate of progress has been slow); 1=poor (little or no demonstrated progress toward objectives or any barriers).

Question 4: Collaboration and coordination with other institutions. (Scoring weight for overall average = 10%)

Scoring: 4=outstanding (close, appropriate collaboration with other institutions, partners are full participants and well coordinated); 3=good (some collaboration exists, partners are fairly well coordinated); 2=fair (a little collaboration exists, coordination between partners could be improved); 1=poor (most work is done at the sponsoring organization with little outside collaboration, little or no apparent coordination between partners).

Question 5: 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. (Scoring weight for overall average = 10%)

Scoring: 4=outstanding (plans clearly build on past progress and are sharply focused on barriers); 3=good (plans build on past progress and generally address overcoming barriers); 2=fair (plans may lead to improvements, but need better focus on overcoming barriers); 1=poor (plans have little relevance toward eliminating barriers or advancing the program).

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

Responses: excessive, sufficient, insufficient.

The following questions were used for the American Recovery and Reinvestment Act projects: these projects had focused on deployment, so a different series of questions were used.

1a. Relevance: Is the project effort relevant to the American Recovery and Reinvestment Act (ARRA) of 2009 goals: Create new jobs as well as save existing ones; spur economic activity and invest in long-term economic growth. (Scoring weight for overall average = 20%)

Scoring: 4 = outstanding (project is very relevant and will make substantial contributions to the ARRA 2009 goals); 3 = good (project is relevant and will make moderate but significant contributions to the ARRA 2009 goals); 2 = fair (project is somewhat relevant and will make some contribution to the ARRA 2009 goals); 1 = poor (project is not relevant and is unlikely to contribute to the ARRA 2009 goals).

1b. Relevance: Does the project's technology development plan and/or deployment plan address the VT ARRA project goals of accelerate the development of U.S. manufacturing capacity for batteries and electric drive components as well as the deployment of electric drive and alternative fuel vehicles and infrastructure? Does the project's development and/or deployment plan address the VT ARRA project goal to establish education projects that accelerate the mass market introduction and penetration of advanced electric drive vehicles, which includes light, medium, and heavy duty advanced electric vehicles (EV), plug-in hybrid electric vehicles (PHEV), and fuel cell electric vehicles (FCV)?

Scoring: 4 = outstanding (project is very relevant and will make substantial contributions to the ARRA 2009 goals); 3 = good (project is relevant and will make moderate but significant contributions to the ARRA 2009 goals); 2 = fair (project is somewhat relevant and will make some contribution to the ARRA 2009 goals); 1 = poor (project is not relevant and is unlikely to contribute to the ARRA 2009 goals).

2. Development/Deployment Approach: Are the project's technical and deployment milestones and schedule clearly identified, appropriate, and feasible, and are technical and commercial barriers and risks adequately addressed? (Scoring weight for overall average = 35%)

Scoring: 4 = outstanding (project team sharply focused on achieving milestones, overcoming barriers, and managing risks; difficult to improve approach significantly); 3 = good (appropriate milestones and schedule identified, and barriers and risks addressed. Effort likely to achieve project goals, but approach could be improved); 2 = fair (approach has significant weaknesses; but may contribute towards achieving most project goals); 1 = poor (unlikely to make progress towards project goals, and/or barriers, risks are not adequately addressed.)

3. Technical Accomplishments and Progress: What is the overall progress towards project's objectives and milestones? Is progress adequately reported and quantified (e.g., number of jobs, installations, etc.) as required by ARRA? (Scoring weight for overall average = 40%).

Scoring: 4 = outstanding (excellent progress toward objectives and milestones; barrier(s) likely to be overcome); 3 = good (significant progress towards objectives and overcoming one or more barriers); 2 = fair (rate of technical progress is slow, some progress made in overcoming barriers); 1 = poor (little or no demonstrated progress towards objectives, or towards overcoming barriers.)

4. Collaborations/Partnerships: Does the project team effectively use collaborations/partnerships with regional, state, local governments, industrial, commercial, university, research organizations, and similar organizations to achieve its objectives? (Scoring weight for overall average = 5%)

Scoring: 4 = outstanding (effective collaboration/partnerships that enhance probability of success of effort); 3 = good (some collaboration/partnerships exists that could enhance probability of success); 2= fair (minimal collaboration/partnerships exists; coordination/partnerships could be improved); 1 = poor (little collaboration/partnerships between partners, or collaboration with other organizations exist.)

Project Strengths

Project Weaknesses

Specific Recommendations

Responses to the questions were submitted electronically through a web-based software application, PeerNet, operated by the Oak Ridge Institute for Science and Education (ORISE). Database outputs from this software application were analyzed and summarized to collate the multiple-choice, text comment, and numeric scoring responses and produce the summary report.

The report is organized by technical area. Responses to the questions are summarized in the pages that follow, with summaries of numeric scores for each technical session, as well as text and graphical summaries of the responses for each individual technical activity. A list of the activities (and page numbers) for each section appears at the start of each section.

1. HYBRID AND VEHICLE SYSTEMS TECHNOLOGIES

Vehicle and system research provides an overarching vehicle systems perspective to the technology research and development (R&D) activities of the U.S. Department of Energy's (DOE's) vehicle research programs, and identifies major opportunities for improving vehicle efficiencies. The effort evaluates and validates the integration of technologies, provides component and vehicle benchmarking, develops and validates heavy hybrid propulsion technologies, and develops technologies to reduce the parasitic losses from heavy vehicle systems. Analytic and empirical tools are used to model and simulate potential vehicle systems, validate component performance in a systems context, benchmark emerging technology, and validate computer models. Extensive collaboration with the technology development activities is required for success. The results of hybrid and vehicle systems activities are used to estimate the national benefits and impacts of DOE-sponsored technology development, and successfully transfer developed technology to industry.

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1 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 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
Medium and Heavy-Duty Vehicle Field Evaluations	Kevin Walkowicz (National Renewable Energy Laboratory)	1-3	3.50	3.75	3.25	3.00	3.53
Truck Duty Cycle and Performance Data Collection and Analysis Program	Helmut E. Knee (Oak Ridge National Laboratory)	1-6	3.00	3.00	3.40	2.40	2.98
Boundary Layer Lubrication Mechanisms	George Fenske (Argonne National Laboratory)	1-10	3.67	2.67	3.00	3.33	3.04
DOE/DOD Parasitic Energy Loss Collaboration	George Fenske (Argonne National Laboratory)	1-12	3.00	3.00	3.25	2.75	3.00
DOE's Effort to Reduce Truck Aerodynamic Drag through Joint Experiments and Computations	Kambiz Salari (Lawrence Livermore National Laboratory)	1-15	3.67	4.00	3.33	3.67	3.79
Emissions and Fuel Consumption Test Results from a Plug-In Hybrid Electric School Bus	Jeffrey Gonder (National Renewable Energy Laboratory)	1-18	3.33	3.67	3.33	3.67	3.54
PHEV Engine and Aftertreatment Model Development	Stuart Daw (Oak Ridge National Laboratory)	1-20	3.50	3.25	3.00	3.25	3.28
Autonomie Plug & Play Software Architecture	Aymeric Rousseau (Argonne National Laboratory)	1-22	3.33	3.50	3.50	3.33	3.44
Tradeoff Between Powertrain Complexity and Fuel Efficiency	Aymeric Rousseau (Argonne National Laboratory)	1-25	2.75	3.00	2.13	2.50	2.77
Impact of Driving Behavior on PHEV Fuel Consumption for Different Powertrain, Component Sizes and Control	Aymeric Rousseau (Argonne National Laboratory)	1-28	2.88	3.00	2.88	2.88	2.94
Tradeoff between Fuel Consumption and Emissions for PHEV's	Neeraj Shidore (Argonne National Laboratory)	1-30	3.33	3.00	3.17	2.83	3.08
PHEV Engine Control and Energy Management Strategy	Paul Chambon (Oak Ridge National Laboratory)	1-32	2.17	1.67	2.17	2.00	1.90
Energy Management Strategies for Fast Battery Temperature Rise and Engine Efficiency Improvement at Very Cold Conditions	Neeraj Shidore (Argonne National Laboratory)	1-34	3.40	2.40	2.60	3.00	2.75

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
AVTA – PHEV Demonstrations and Testing	James Francfort (Idaho National Laboratory)	1-36	3.50	3.75	3.75	3.25	3.63
Advanced Technology Vehicle Benchmark and Assessment	Henning Lohse-Busch (Argonne National Laboratory)	1-38	3.33	3.67	3.33	3.50	3.52
Light-Duty Lean GDI Vehicle Technology Benchmark	Robert Wagner (Oak Ridge National Laboratory)	1-41	3.00	3.00	2.75	2.75	2.94
Plug-in Hybrid (PHEV) Vehicle Technology Advancement and Demonstration Activity	Greg Cesiel (General Motors)	1-43	3.33	3.00	2.67	3.00	3.04
Ford Plug-In Project: Bringing PHEVs to Market	Greg Fenette (Ford Motor Company)	1-45	3.67	3.33	3.67	2.67	3.38
Heavy Duty Vehicle Modeling and Simulation	Aymeric Rousseau (Argonne National Laboratory)	1-47	4.00	3.50	4.00	3.50	3.69
AVTA HEV, NEV, BEV and HICEV Demonstrations and Testing	James Francfort (Idaho National Laboratory)	1-49	3.67	3.67	3.67	3.33	3.63
CoolCab Thermal Load Reduction Project: CoolCalc HVAC Tool Development	John Rugh (National Renewable Energy Laboratory)	1-51	3.00	3.17	3.17	2.83	3.08
Plug IN Hybrid Vehicle Bus	Jan Friesner (Navistar International Corp.)	1-54	2.75	2.50	2.25	2.25	2.50
Standards for PHEV/EV Communications Protocol	Michael Kinter-Meyer (Pacific Northwest National Laboratory)	1-56	2.50	2.75	3.25	3.33	2.82
Integration Technology for PHEV-Grid-Connectivity, with Support for SAE Electrical Standards	Theodore Bohn (Argonne National Laboratory)	1-58	3.00	3.00	3.67	3.00	3.08
SAE Standards Development (J1711 PHEV, J2841 Utility Factor Definition, J1715 HEV Terminology)	Michael Duoba (Argonne National Laboratory)	1-60	3.60	3.60	4.00	3.00	3.58
J1634 SAE BEV Test Procedures	Michael Duoba (Argonne National Laboratory)	1-62	3.25	3.00	3.25	3.25	3.13
Integrated Vehicle Thermal Management	Matthew Thornton (National Renewable Energy Laboratory)	1-64	2.50	3.00	2.50	2.00	2.69
<i>Geographic Information System for Visualization of PHEV Fleet Data</i>	<i>Sera White (Idaho National Laboratory)</i>	<i>1-66</i>	<i>3.33</i>	<i>3.33</i>	<i>3.33</i>	<i>3.67</i>	<i>3.38</i>
<i>Advanced Powertrain Research Facility Vehicle Test Cell Thermal Upgrade</i>	<i>Glenn Keller (Argonne National Laboratory)</i>	<i>1-68</i>	<i>3.50</i>	<i>3.00</i>	<i>3.50</i>	<i>3.50</i>	<i>3.25</i>
<i>AVTA Vehicle Component Cost Model</i>	<i>Scott Ellsworth (Ricardo)</i>	<i>1-69</i>	<i>3.00</i>	<i>2.33</i>	<i>2.00</i>	<i>2.67</i>	<i>2.50</i>
OVERALL AVERAGE			3.15	3.07	3.07	2.94	3.08

NOTE: Italics denote poster presentations.

Medium and Heavy-Duty Vehicle Field Evaluations: Kevin Walkowicz (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

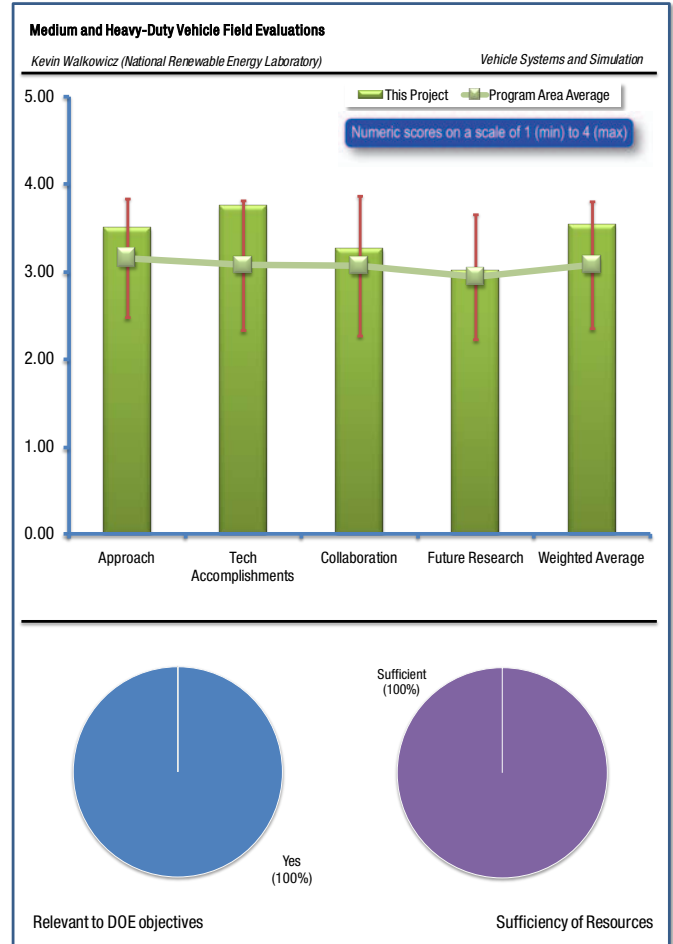
QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt that field evaluations are essential to verify system performance (efficiency). Some systems are marketed using data from “favorable” applications, therefore unbiased testing is important. Medium and heavy-duty vehicles represent an important sector. Another reviewer agreed that the data generated from this project provides real world usage data that will help the OEMs and Tier 1 suppliers understand the benefit and potential penalties (e.g. negative fuel economy improvement on FedEx trucks) of the new technology. The development and deployment of new systems and technology requires a good understanding of how the technology performs in the field under real world usage conditions.

Another reviewer stated that independent test and evaluation of new technologies that improve fuel economy and emissions provides critical information to those involved in the spec’ing and purchase of commercial vehicles. Fleet and operations in the commercial vehicle segment are rapid adopters of technology that can improve their bottom line, so the data being generated by NREL can be very effective to moving the industry to cleaner, more fuel efficient vehicles expeditiously. It was also added that improved efficiency in medium- and heavy-duty trucks offers the potential for significant petroleum displacement. Medium-duty vehicles, which have largely been untapped, especially offer potential advances through the use of hybrid and plug-in hybrid technologies. It was broadly agreed that data obtained from duty cycles provide invaluable assistance to OEMs and system suppliers in determining required sizing of components and expected duty cycle. Availability of such detailed data facilitates accelerates the development and industrialization of these technologies.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

It was felt that the technical approach was solid. Reviewers stated that data being collected is what fleets need to make informed decisions on new technologies. The team also provided detailed, quantified feedback to OEMs and system suppliers concerning the effectiveness of their systems, allowing for continuous improvement of products. Also within the scope of the program are efforts to quantify and define duty cycles and provide OEMs and system suppliers with information critical to the design and development process (example: defining school bus duty cycles to assist Navistar in development of next generation PHEV school buses). One of the questions is how new technologies are selected for evaluation. Recognizing that resources might be limited, a process for selecting the most appropriate technologies for evaluation could improve the overall process. (It is recognized that such a selection process might be in place, but was not mentioned in the slides or the verbal presentation). Another reviewer also noted that the team captures, processes, and presents the data to DOE and customers and where appropriate provides baseline comparisons. The inclusion of performance, maintenance and operational costs presents the complete picture for analysis and subsequent presentation of the technology payback. The approach also captures any issues associated with deployment of the technology.



It was also stated that after noting program cost, it was important to log as much data as possible, since it will have value in understanding transient operation. This data could be used for system optimization but presumably OEM confidentiality is a concern in pursuing / showcasing this.

Some final points that were made by a reviewer state that this project has a conventional approach for field and dyno testing of vehicular applications and follows a relatively time honored process of testing/evaluation (field and dyno), analysis, and publication. It appears to be evaluating a relatively broad slice of the medium and heavy duty vehicular market (medium-duty, heavy-duty day cabs, and school buses) with HEV, PHEV, and advanced battery technologies. It appears gradients have not been extensively studied; this is area for future work. Additionally, it is not clear if fully wireless data logging systems have been established. If not, this may be an area for future exploration. A more mechanized means (such as a database website) of publications may be in order when distributing testing/project results. Additionally, there has been a significant amount of information collected over the last decade on drive cycles and advanced technologies for medium and heavy duty vehicles. There should be a way to compile all this information into very user friendly formats for easy comparison, cross referencing, and tagging by interested parties.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Overall, it was felt by the reviewers that since data is available, there seem to be no major technical barriers. It was also agreed that the project appears to be making progress to schedule and it is good to see the extension of the UPS project beyond year 1 into years 2 and 3, which will add valuable durability data.

Another reviewer noted that the fuel economy improvements in real world use compare favorably with chassis testing. The FedEx gHEV conversion to diesel equivalent FE is a useful factor. However a negative fuel economy improvement figure is always hard to accept, however low. The comparison of KI with real world field data and chassis dyno derived data is a good correlation tool that will help the vehicle / system developers optimize the system for greatest benefit.

The third reviewer felt that a substantial amount of detailed data has been collected to date, analyzed and disseminated to concerned parties. Activity has been completed or is progressing on five key vehicle and drivetrain technologies, with detailed results concerning fuel economy, maintenance costs, and driving patterns. Correlation testing is now being done with most test fleets that include: (1) measure data in vehicle; (2) Chassis dyno test; and (3) Ongoing fleet test. Predicted results from chassis dyno test have fairly consistently fallen within the actual range of results from fleet testing, providing increasing confidence in chassis dyno results.

Other reviewers felt that funding for FY09 was relatively modest at \$300K and that results based on this funding level are reasonable. Several of the projects are new starts for FY10 while a couple of follow-ons to previous year's activities and they are now looking beyond fuel economy to durability and costs. Results clearly show that fuel economy improvements are often very cycle dependent. One concern is whether information gathered on maintenance costs is broken down to show costs specific to technologies under evaluation. In one case, operating cost of test unit was higher than baseline vehicle, but it was reported that maintenance issues were unrelated to hybrid components under evaluation.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer stated that there is clearly a strong liaison with industry partners, and that collaboration with fleets and OEMs appears to be strong and diverse. Participants appear fully engaged and their comments reflect collaboration with other agencies/departments in DOE but none were highlighted. It was also noted that there is significant involvement with fleets, OEMs and key suppliers, which is critical to the success of the overall program. NREL seems to be working close with first adopters of the new technology being evaluated and cooperation in setting up the test programs is excellent. It also appears that NREL is doing a good job of sharing collected data with other National Labs, OEMs and industry organizations.

Some reviewers were concerned with how fleets can easily access this information in order to assist in purchasing decisions. There may be a straightforward mechanism in place for fleets to obtain results, but it was not specifically discussed during the presentation. An opportunity for improvement is for NREL to collaborate with ORNL on their data collection activities. Historically, NREL has evaluated vehicles with new technologies, while ORNL has focused on capturing duty cycle information for conventional

vehicles. There appears to be some overlap and some opportunity for synergies between the two efforts. The final reviewer stated that the project coordinates/collaborates with a number of industrial entities including OEMs and fleets. It is not clear, however, how well this project collaborates with other DOE laboratories, including INL and ORNL which have extensive vehicular (light and heavy-duty) testing experience. Improved collaboration with these labs could identify areas to fine-tune the NREL medium and heavy-duty vehicular field evaluations, reduce redundancies, and improve cost-effectiveness across the labs. Specifically, INL could provide insights how to improve wireless data collection and industry/fleet cost share, while ORNL could provide insights on emissions testing components for heavy vehicles. Additionally, it is not clearly stated what the level of industrial cost share is for each project.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer noted that there will need to be an effort with large fleets to sift through data & remove erroneous points. An overall error/confidence analysis is needed because some differences between baseline vehicles and hybrids are small. The second felt that the class 8 truck project with Coke vs. conventional project should yield some very interesting results. The hybrid trucks are believed to be 2010 emissions compliant with SCR. The amount of SCR consumed during the study period should also be measured and factored into the FE, maintenance and performance costs.

Another reviewer stated that an outline exists for expected 2011 activity, although it appears that some of the details concerning what fleets, OEMs and technologies to focus on are not yet available. A certain amount of the future activity is “carryover”, a continuation of the data collection efforts initiated previously. Time limits may have prevented a more detailed discussion of future plans, but more information about some of the newer activities, such as the formation of the “voluntary user groups” to assemble and analyze vocational data would have been beneficial. The final reviewer felt that the proposed future research activities are reasonable but would benefit from additional clarity and prioritization. In addition, as alluded to above, more transparency and emphasis should be placed on industrial cost share.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The reviewers felt that funding appears sufficient, the project scope appears containable, and this activity seems well staffed to implement the identified current and future plans. It is also encouraging that spending for FY2010 was increased significantly over FY2009, and over the 10 year spending ranges. This may reflect more technologies and more vehicle types available for analysis, and a heightened interest in quantifying the benefits of alternative technology vehicles. As the number of fielded vehicles under evaluation grows, it will be interesting to see how NREL handles the projected heavier workload. The final reviewer added that overall, this is a solid task with compelling merits. There clearly is a need to field test prototype and early versions for advanced medium-duty and specialized heavy-duty vehicles. There is respectable industry collaboration and the appearance of some cost sharing typically via in-kind contributions. The task should explore expanding its scope to the next level in working very closely with fleets (including small guys) to help them overcome business barriers to widespread commercialization. It would be useful to see compelling information showing this that this task's activities are instrumental to fleets broadly adopting advanced technologies.

Truck Duty Cycle and Performance Data Collection and Analysis Program: Helmut E. Knee (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

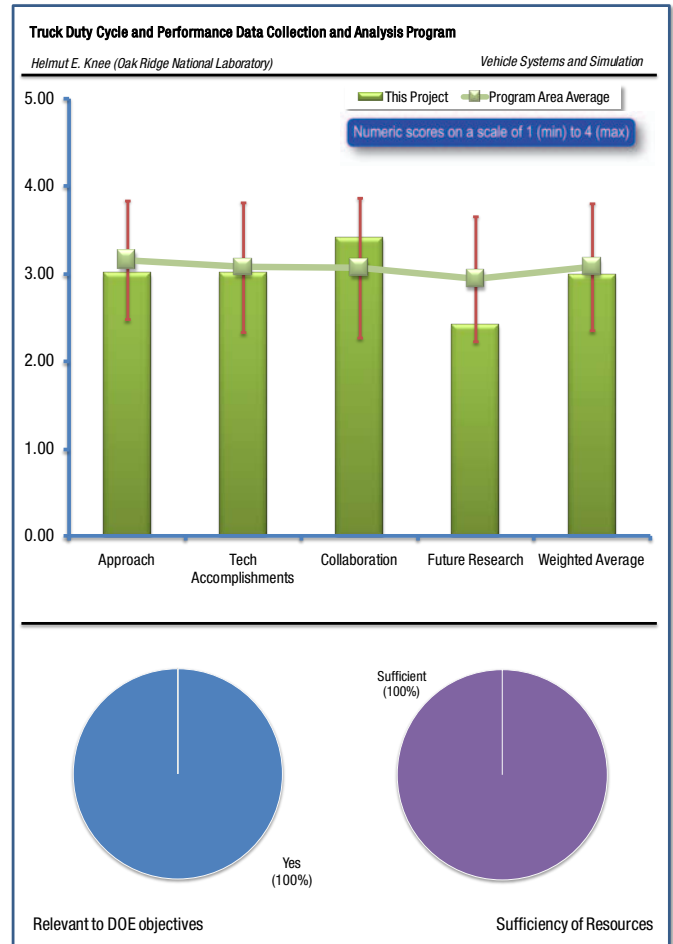
QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first commenter stated that understanding the details of vehicle activity is important for optimized design and for real-world evaluation. This program will also have benefits to a wider transportation community. It was also noted that the capturing real world data for traditional ICE powertrains will help the OEMs and Tier 1 suppliers optimize their system designs for maximum benefit and reduction in hydrocarbon usage. The use of the data to fine tune modeling tools such as Autonomie is an excellent way of sharing knowledge and improving system designs. Another reviewer agreed that the ORNL data collection effort facilitates modeling and simulation of commercial vehicles that allows up front analysis of new technologies offering improved fuel economy and reduced emissions. This data is expensive and time consuming to collect for private companies, so availability of this data will be very helpful to OEMs and component suppliers. This duty cycle data will help OEMs and suppliers accelerate the development or refinement of new technologies that directly address fuel usage. In addition, a better understanding of duty cycles by OEMs and fleets may allow modification of component spec'ing practices or driver techniques.

Overall, it was agreed that the first step in reducing petroleum displacement would seem to be understanding where and how the petroleum is used. This project supports that goal and is a necessary step. It was also stated that ORNL's activities are relevant in that considerable petroleum savings are achievable through efficiency advances in medium and heavy duty vehicles and development of rich data pools provide value across multiple areas. A number of areas are being addressed including quantification of efficiency benefits from advanced wide-based tires and brakes, development of medium and heavy vehicle duty cycles, and real world heavy-vehicle operational data for incorporation into PSAT/Autonomie.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer stated that both high density data from a few vehicles and low density data from many vehicles are contemplated. This is a good balance and a wide variety of vehicles is important. It was also felt that the range and types of data collected are impressive, and offer a rich source of information for OEMs and suppliers of many vehicle component types. It was also favorably noted that rather than focusing on a relatively few vehicles, with multiple channels of data collected, ORNL is engaging in a program to collect data on a much larger group of vehicles, but with an order of magnitude fewer channels. This should help improve the statistical significance of the data and also likely allow for data collection in a broader range of operating conditions. In general this is seen as a positive step, particularly in view of the fact that much of the data collected to date (though not all) has been from the general vicinity of Knoxville. This is certainly understandable from a logistics and cost perspective, but the new approach will presumably gather data literally from all parts of the country.



The reviewers noted that an opportunity for improvement is to make this data readily available to OEMs, suppliers, and fleet users. Currently, it is likely that the existence of such comprehensive data is largely unknown throughout the industry. A question arises concerning how candidate vehicle duty cycles are selected and prioritized. Some of the applications to be studied (wreckers, for example) are niche, and less “mainstream” than other applications. It would be interesting to understand the basis for vehicle/application selection. Another concern that was noted is that it is not clear that grade measurement is completely reliable and it needs evaluation of accuracy (perhaps using engine load data). The effect of auxiliary loads also needs to be understood. Another reviewer felt that it was disappointing to hear that there are only a limited number of units under test—six platforms, three transit bus and three Class 7 regional haul. However, it was good to see the proposed increase in number of units under test with the LSDC project. Working with voluntary fleets does mean that having to go with what can be obtained, which does result in some unusual vocations such as wreckers. This is a very small portion of the national Class 8 fleet and it is not clear if a more appropriate vocation could have been chosen (e.g. refuse).

Another commenter felt that there is a definite lack of available data regarding how vehicles are used (and thus the project addresses a real need). Much of the current work is useful, but a broader view is strongly needed. Researchers have done a good job in trying to get a broad range of applications, but there might be some further gains from a more rigorous design of experiments approach to selection of applications/regions/vehicles. However, it is recognized that a major obstacle is probably one that is non-technical; many companies might be unwilling to share data about their fleet operations. The final reviewer felt that the approach of this task suffers from an apparent lack of overall focus and unification. Many of the activities seem to be relatively dispersed and disconnected, almost unrelated. The approach does cover areas of value though with the potential for broad real world application, a notable example being single wide-based tires. Appropriate, real world performance measures are being collected as part of the project.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers agreed that a substantial database has already been assembled and that data points are at a high frequency, both of which are very useful. Reviewers also felt that given relatively modest funding levels, this project has collected a significant amount of real world data, established a number of partnerships, generated several reports, and provided significant support to PSAT/Autonomie development through heavy truck duty cycle data. ORNL has had success in addressing the first two identified barriers including “Obtaining voluntary fleets for data collection” and “Obtaining inter-agency cooperation for leveraged funding.” The third barrier identified by ORNL, “Getting data into industry,” has not been clearly addressed and it is difficult to assess whether progress has really been made.

A reviewer stated that understanding auxiliary loads for some vehicle types and data on advanced vehicle types (such as hybrids) are required. While this is slated for the future, it could have been obtained already. The limited scope of the data set was also a concern and it was felt that it is unfortunate that the data captured is limited to the Knoxville, Tennessee area, although this area does have a reasonable spread of terrain types including some large hills, with grade data coming from GPS. There was no accessory load data recorded so the source of energy usage was not identified. Perhaps this should be included as part of the LSDC project. Milestone progress appears to be to planned with the MTDC phase 1 complete in September and Phase 2 starting in July. Another commenter stated that he would like to see a list of applications and routes for which data exists (apparently 500 GB of data exists). It was reported, for example, that substantial data on Class 8 line haul and regional haul applications has been collected, but the means of accessing such information is not clear. Use of wireless data collection has allowed the accumulation of a substantial amount of data with only limited human resource intervention. This technology was clearly a program enabler. Reviewers also felt that items related to Class 8 data (confirming effectiveness of super singles) seem to be on point. More than a bullet or two discussing this, if this one of the major outcomes for this year, would have been beneficial. The class 7 data (which seemed to represent the majority of this talk) seems to be a little too narrow without much processing completed.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The reviewers felt that it was beneficial to be working with DOT FMCSA and supplying data to ANL with numerous fleet partners. They also felt that there were good connections with Argonne and Autonomie. Improving the modeling capability of this new tool will have a positive effect on the development of new vehicle technologies. Reviewers were also pleased to see the piggybacking of the

brake and tire investigations for FMCSA and it was thought to be a good use of funds. It was also stated that considerable success has been demonstrated in working with and obtaining cost share from DOT FMCSA and commercial fleets, and providing heavy vehicle data to ANL's PSAT/Autonomie modeling activities. Efforts are also underway to work with EPA and DOT FHWA.

Reviewers did feel that fleet choice seems a little unusual (as previously mentioned), but again with volunteers researchers must take what is available. Other reviewer felt that the program has required close cooperation with candidate fleets and securing their cooperation for instrumentation of their trucks. ORNL has apparently provided data to Argonne National Labs for development and refinement of the Autonomie modeling program. One observation is that these ORNL activities somewhat align with, if not overlap with, NREL vehicle data collection. An opportunity for improvement is for ORNL to collaborate with NREL on their data collection activities. Although NREL focuses on vehicles equipped with new technologies, it would seem that NREL/ORNL cooperation could perhaps streamline the efforts of both groups, especially given potential ORNL future work with hybrid vehicles. Another commenter felt that a good job was being done interacting with ANL and efforts extended outside DOE, namely TRB and FMCSA are very good thoughts. However, it was thought that more could be done here. Researchers from NREL and ORNL definitely need to work together. Some of the projects would seem to be related and as such they should be sharing data and analysis methods. Another area of concern is a perceived lack of coordination is with NREL for the development of heavy- and medium-duty drive cycles and vocations. NREL has done considerable work in this area and it does not appear that ORNL and NREL are sufficiently coordinating. Additionally, there may be synergy with regards to INL's light duty track and field testing activities which should be explored.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer noted that hybrids will be contemplated. The acquisition of less intense data from a large fleet will be challenging. The relationship between vehicle speed-time activity and factors such as power/weight ratio should be considered. It is not clear that this level of analysis is proposed (or whether the data are going to be used by others for this purpose). Another commenter stated that the LSDC pilot project dramatically increases the number of vehicles included in the study, which is a good thing. The desire to explore HEVs and PHEVs needs to be planned carefully and aligned with NREL to prevent overlap. The third reviewer restated that the means of determining which applications to focus on for data collection should be reviewed. It appears that some of the applications being considered are very niche or low volume. Future plans to obtain data on several thousand vehicles are perceived as a positive step, and a means of obtaining statistical significance. It was reported that future activity will include data collection of hybrid vehicles. This is perhaps very appropriate, but should be undertaken with collaboration, or at least communication with NREL, who has also been deeply involved in hybrid data acquisition. Future plans should absolutely include a means of making this data, available to OEMs, suppliers, fleets, and the general public. The data can only be useful if appropriate parties know that it exists. Almost as important is to use the technical expertise of the ORNL staff to analyze and summarize this data in way that it is of the most value to users. Making this data and meaningful summaries readily available may be the most significant improvement opportunity in the program. Another commenter noted that the overall results seem in order with funds used thus far. However, looking at original scope (~\$9.1M program with MTDC and LSDC phases), much of the work remains (as evidenced by the relatively small budget to date). The large scale data collection seems very appropriate as does the dual thrust—collecting some detailed data in addition to a much broader (albeit limited in depth) collection. Currently, it seems all of the class 7 data is collected in a narrow pool. The difficulties in obtaining a broad spectrum are recognized, but concerns exist about the abilities to use the data in making forecasts regarding national petroleum displacement. Also (especially lacking more large scale data), it is felt that the geographic scope of the class 7 data collection is limited. The final reviewer felt that the future work is fairly well defined and delineated, but suffers from a similar lack of overall focus and unification as current activities. This is especially evident when examining future work activities beyond FY11 which include a plethora of proposed activities including data collection for aerodynamics, parasitic energy losses, rolling resistance measures, and emissions. This project would benefit from a hard examination of which areas really should be addressed from a cost-benefit standpoint. ORNL also should explore means to publish results efficiently for a broad pool of users.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first commenter noted that funding is reasonable to high for the program. Hopefully the researchers will add considerable value through careful analysis of the data, and not just deal with the cycles for the funding. But the resources are sufficient to meet the objectives. Another reviewer stated that transitioning from a \$35k cost per platform to a budget target of a \$100k per vehicle is a huge leap forward; however, it is unclear if the quality and quantity of data can be recorded with the new budget target. Another reviewer felt that resources appear to be adequate, although the process has previously been somewhat limited by equipment. (Approximately 60 channels of data have been collected, with a per-unit-cost of \$35,000). The upcoming approach with limited data collection expands the number of vehicles for which data can be acquired to several thousand. Although the number of data channels is significantly reduced, this approach will be more manageable, and will enable data collection from a much broader cross section of vehicles and applications. The third commenter stated that he agreed with the large scale approach, but think that the sub-100 per vehicle may be optimistic. However, the overall budget seems appropriate. He did not see much summary data from data collection to data. In addition to collecting the data, post-processing and summarizing the data needs to be a part of this. The project does seem to include some research in those directions, but the reviewer interpreted the lack of much summary data to date as a sign that these resources are limited. (He recognizes that “post” processing means it is done after the data is collected, he just did not get a sense that there were enough efforts dedicated here.) Some efforts will be needed to try to “reconcile” the large scale data with the more detailed collection but not much was seen dedicated to this. The final reviewer felt that, overall, this is a solid task with a number of strong attributes including significant non-DOE cost share from several commercial and governmental entities, a broad-based demand for medium- and heavy- duty data for a variety of applications, and extensive intergovernmental collaboration. The project is starting to wring more efficiency out of the system through such means as wireless data downloads and ongoing exploration of new partnerships to assist and leverage funding. This task should continue to be funded at current levels with the option of expanded funding if a more unified focus be identified, continued strong levels of cost sharing are demonstrated, and the project successfully incorporates broad data collection efficiencies across vocations.

Boundary Layer Lubrication Mechanisms: George Fenske (Argonne National Laboratory)

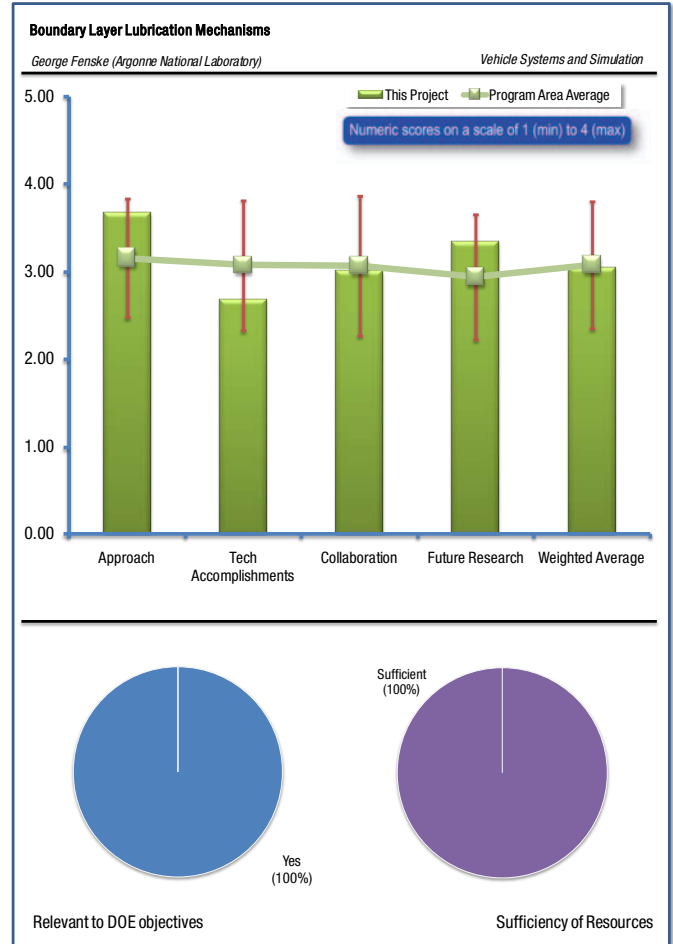
REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Overall, the reviewers felt that a better understanding of boundary layer structure and properties can suggest better lubricant formulations and provide guidance for material selection, resulting in better efficiency through reduced friction and reduced component mass. It was noted that, if the presenter’s information is correct, a 50% reduction in friction could result in 5-15% energy savings which would yield petroleum displacement.

Another commenter felt that the program to investigate “boundary layer lubrication mechanisms” directly supports the overall mission of the DOE to strengthen America’s energy security future. The work performed directly contributes to the DOE’s overall objective of petroleum displacement by investigating alternatives for fuels and lubricants that create energy savings. New efficiencies and energy gains may be achieved through the understanding and improved performance of lubricants (and the behavior of their boundary layers). Gaining an understanding of friction reduction in vehicle lubricated components and systems is directly related to improving VSS efficiencies. Lubricants can increase power density which results in size reduction and fuel savings. Lubricants can reduce and/or prevent high friction and high power density failures which can also lead to improved petroleum displacement efforts. This project achieves new information to advance sustainable friction reduction and increase power density in VSS, both critical to the DOE’s end goal of displacing petroleum.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers were impressed in particular with the use of the Advanced Photon Source, which provides opportunities to examine the boundary layer composition and structure to a degree not possible with other techniques. It was also noted that the technical barriers are clear and well defined. The methods presented show an appropriate focus on means to attack the problem. The overall objective of the work seeks to achieve sustainable friction reduction and increase power density in lubricated components and vehicle systems. The team uses a clear basic energy science and characterization approach at appropriate and critical boundary interfaces with respect to the appropriate applied R & D problem. The team takes a chemical and materials approach to the basic research, including investigating scuffing, surface coating, film formation, and mechanical and frictional properties. All tests lead clearly to support macroscopic property analysis and improved performance variables based on understanding of boundary lubrication mechanisms. Modeling results are not shown in the presentation; however, the team does an excellent job at detailed characterization and analysis including anisotropic behaviors in tribology, which is often overlooked. Also, the project is nicely coordinated with its commercial partner to demonstrate gain. Overall, it was noted that the approach includes materials and lubricating film studies, new diagnostic techniques, modeling, validation and a reasonable set of collaborations; all of which support a good, well balanced approach.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

It was felt by the reviewers that the project has made significant progress towards its objective to achieve sustainable friction reduction and increase power density in lubricated components and vehicle systems. The project has successfully developed and validated a scuffing model for metallic materials following extensive microstructural characterization, and this model is now being used by industrial partners as a design guide. The project team also evaluated the experimental (and modeling of) scuffing resistance of several materials pairs with high scuffing resistance demonstrated the use of multiple x-ray based surface analytical techniques for in-situ characterization of tribochemical boundary films. This is advanced characterization and should be commended.

However, reviewers did note that while scientific and technical accomplishments were evident, no specific numerical goals for this project were stated, but only a general objective to reduce friction, improve wear-ability, etc. Hence, no metric was provided to evaluate the project's accomplishments in terms of objective measurable milestones and goals. DOE has specific targets for Vehicle Technologies. The PI should quantify his goals and measurable contributions to meeting those targets. It was also felt that while the result showing that friction increases with the crystallinity of the film is intriguing, no information is given on the composition of the films and such information would be necessary to formulate better lubricants. It was also stated that the objectives could be more clearly defined and shown as "met" if more description of the link to new/better/more efficient high power density material were made. However the project is strong in content and demonstrates a continued need to understand better tribochemical boundary film structures, properties and performance for improved vehicle efficiency. Especially noteworthy is the paper produced by O. Ajayi [Ajayi O. O., Erck R. A., Lorenzo-Martin C., and Fenske G. R., "Frictional Anisotropy under Boundary Lubrication: Effect of Surface Texture" *Wear* 267 (2009), 1214-1219].

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers agreed that the collaboration on this project includes Caterpillar Inc., Eaton Corporation, Castrol-BP and Oakland University. This collaboration is commendable and appears coordinated, although the presentation does not demonstrate full details on management and coordination of the collaborators. Four relevant collaborations were identified, but only the general area of research was stated. More information on the nature, level of the collaborations, contributions and roles of each party would be useful.

It was noted that team lead George Fenske demonstrates strong leadership and management skills. It would be nice to see another university partner on the team. Some of the links to barriers such as reliability and safety are presented but not discussed. These results may be better coordinated with industry.

QUESTION 5: HAS THE PROJECT 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?

Overall, reviewers felt that the project appears well on the way to successful completion. They also agreed that the proposed research includes continued work on advanced characterization (FIB, TEM, GIXS at APS) etc. and continued measurement of nano-mechanical and frictional properties of other structurally different boundary films. Logically, the next year's work will (and should) concentrate as much as possible on the structure-property relationships for boundary layer films. Next characterization steps will include new investigations on contact temperatures and correlations to functional performance. These new results will surely be important findings for the commercial partners. It was also felt that the proposed future research is a continuation of the present direction of work. Targets and goals should be established to measure progress and accomplishments.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

It was felt that all of the resources for the project appear modest to adequate for the FY 2009 and FY2010 time frame. Much has been accomplished technically on a relatively small amount of funding. Across the full life of the project (beginning in 2004), \$2.5 M has been absorbed by the project.

DOE/DOD Parasitic Energy Loss Collaboration: George Fenske (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewers felt that lubrication/tribology studies have the potential to offer small percent reductions in petroleum use, but over a very large fleet. The program is also cognizant of emissions concerns (e.g., sulfur contamination of aftertreatment). This project is particularly relevant to increased use of EGR and impact of lubrication. Another comment made by a reviewer stated that improvements in lubrication and friction reduction have commercial implications beyond just reduction in fuel usage, such as increased durability and component life, reduced warranty costs, etc. Another commenter stated that improving engine and vehicle efficiency obviously will reduce consumption of petroleum and reduce emissions. This program will evaluate opportunities to reduce friction and parasitic losses in the engine and other drivetrain components. The program scope looks at surface finish, coatings, lubricants and lubricant additives. This activity takes on new importance as drivetrain components are downsized to increase power density, which results in a more severe duty cycle at the surface of rolling or sliding parts. This trend potentially increases parasitic losses, but also adversely affects surface life, which may indirectly affect efficiency.

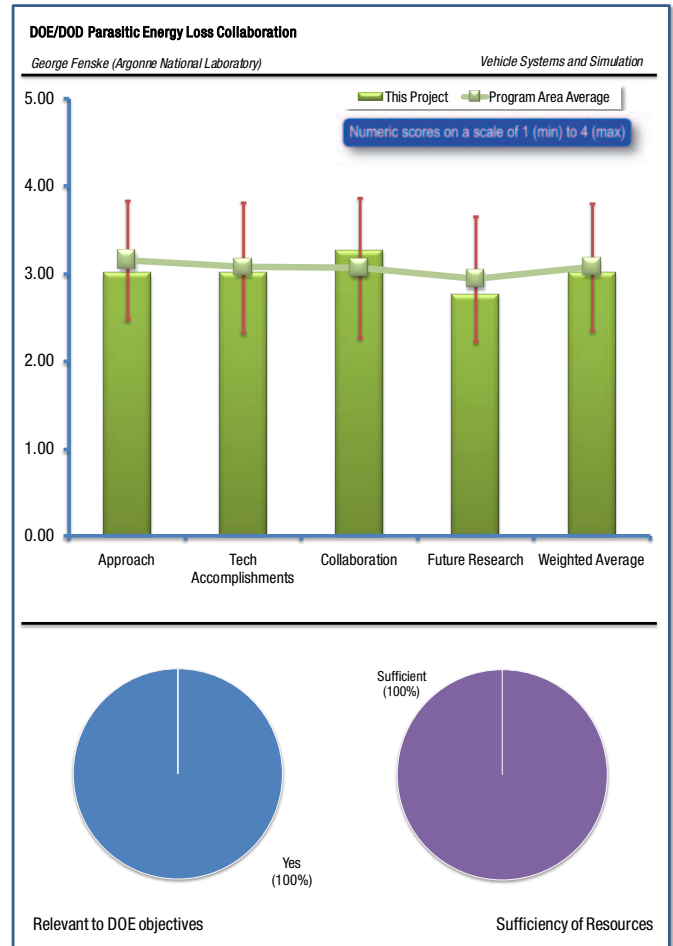
It was also felt that because engine and drivetrain friction account for 10-15% of fuel consumption in commercial vehicles, reduction of friction can lead to significant energy savings across all vehicle classes and vocations (commercial and military). Friction reduction could also be especially attractive for military applications given the high cost of deploying fuel and potential for increasing survivability in a lubricant-starved environment.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers felt that the project scope of work appears to be logically laid out with bench testing, analysis and engine validation (with vehicle OEMs, TARDEC, and lubricant suppliers). It was also felt that the technical approach is sound. The use of component or specimen level lab testing under very controlled operating parameters permits evaluation of multiple approaches to reduced parasitic losses (and also improved surface durability). Once a down-select is made of the most promising concepts, testing at the system level can be conducted.

It was observed by the reviewers that the differences between military and civilian vehicles are recognized. However, the discussion was very broad rather than technical but identifying pathways for success (as presented) is a required first step. It was noted that work is being leveraged, which is good, but makes the exact approach hard to define.

The second reviewer also felt that there do not appear to be alternative fuels and lubricity studies (fuel dilution etc) included in the project. The main focus is friction reduction and survivability after loss of lubricant. It was also noted that this is not a new project, but



an extension of a long running tribological activity at ANL with a new facet of military applications. The approach presented is conventional and consistent with past activities. The first two project objectives: 1) identify critical barriers ... and part of 2) “understand fundamental tribological solutions” should already largely be known and compiled. It appears the emphasis of this task should clearly be on objective 3) develop and implement advanced tribological solutions. It was also felt by the third reviewer that missing from the work plan is a discussion of evaluating friction reduction strategies for other drivetrain components, such as transmission and axle gearing. During Q & A, it was implied that such work will be conducted, but does not seem to be part of the current or future work plan. The final reviewer concluded that the approach is focused on the barriers. One thing that would be beneficial is greater clarity on the balance of R&D focus, whether on commercial or military applications.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

It was noted by the reviewers that the project started in FY2010, so progress and results are limited. Thus far, technical collaborations have been set up, partners identified, and teams formed. Preliminary work has focused on reducing the incidence of scuffing and evaluating the benefits of various lubricant additives. Given the short time since project startup, a fair amount of testing has been completed. It was agreed by another commenter that the ANL work with DOD for military applications is in relatively early stages. Some accomplishments have been presented including team building, impact of additives on scuffing in mil-spec mineral oil, identification of two commercial additives that extend scuffing behavior in fully lubricated and lubricant starved conditions. As always, given the evolutionary nature of tribology advancements, it would be of great value to elucidate (based on past experience) a potentially successful pathway to full implementation of advanced tribological systems in military or commercial vehicles.

Other reviewers felt that, so far, progress had been made on testing of oil additives and impact on scuffing loads. The presented data showed an interesting plot of friction loss after oil is drained. Further investigations to understand this phenomenon should be conducted. It was also felt that data is available for scuffing tests, but it is not clear how the additives are selected. It was also felt that the surface examination is forensic more than predictive. It was also mentioned that the study should include impact of additives in used oil vs. fresh.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

It was noted by several reviewers that the collaboration includes DOD, an OEM, a component supplier and representatives from the lubricant industry which covers the complete spectrum well. While the OEM was not named, the Tier 1 supplier, Mahle for pistons, bearings, and liners is a good choice. However, there was no mention of lubricant supplier(s). One reviewer also said that there were several questions and comments from the audience that indicated similar projects had been conducted at other educational institutes and would be worthy of further investigation (Ohio State driveline project as an example)

The program includes DOD/TARDEC as partners, but efforts are being made to address the needs of both military and commercial vehicles. It appears that collaboration with OEMs and lubricant companies is active, although they were not identified. A question that the team should ask (or perhaps already has): how much of this testing could be taken on by the lubricant suppliers themselves? This could be a means of accelerating progress. A major engine supplier has also not been identified as participating. This would seem to be an opportunity for improvement. Engine companies could supplement the testing program with their own evaluations. It was also noted that, although much of the early focus on the program is on engines, other drivetrain systems should not be ignored. In particular, there is a potential collaboration opportunity with transmission and axle manufacturers on efficiency improvements. Overall, it was felt by reviewers that this tribological task is showing improved collaboration and cost sharing which is much to the PI's credit. However, currently only one DOD ground vehicle OEM and one engine component manufacturer (Mahle) have been identified. It would be beneficial to increase this to at least two in each of these areas to stimulate competition and increase the odds of successful implementation of attractive tribological solutions.

QUESTION 5: HAS THE PROJECT 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?

Reviewers noted that future plans outline a continuation of the evaluation of lubricant additives, surface finish, and surface coatings. Based on a response to a question during the Q & A, some work will be done on super-finishing (chemical honing). Another commenter also stated that the results of bench testing will be used to update analytical models that predict parasitic losses in engines and drivetrain components. Following bench testing, complete system tests will be conducted on engines and other drivetrain components. Lacking in the future plans are any specific mention of evaluating transmission and drive axle parasitic losses. This is an area of significance that should be added to the forward plans.

Reviewers did mention that this is a new project, so future work is contained within scope. The reviewer did recommend, though, that this project be aligned with other ANL projects. It was noted that the project is only focused on friction/surface contact, not on viscosity and loss from churning. Perhaps this could be included as part of any further study.

The final reviewer felt that the proposed future work is reasonable, if uninspiring. This project would benefit from some new approaches to advancing tribological solutions whether it be through different relationships with industrial suppliers, aggressive competitive practices, or identification of revolutionary means (in combination with industry) to better validate tribological solutions in real world applications in shorter timeframes. For example, this could potentially be done by even further implementing ANL's advanced diagnostic techniques to improve understanding and confidence in wear and durability characteristics of advanced tribological solutions.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers agreed that overall, this is a good task with solid justification for continuation. Successful reduction of friction without compromising durability is very beneficial for military and commercial applications. In past years the task has demonstrated a number of technical accomplishments and is continuing to progress. However, an area of concern is that the task has been very evolutionary and ongoing for many years, leading to few commercial successes. Perhaps additional efforts should be made to further involve commercial users earlier in the process and demonstrate stronger interest and commitment to commercialization through additional private sector cost sharing.

While the reviewers found the budget and resources apparently sufficient for the project, they would like to see more contribution from the lubricant industry, as ultimately they are the organizations that will be commercializing and retailing the products developed from this study. It was also felt that the extent of resources contributed by the OEM and lubricant suppliers was not discussed in any detail. This appears to be an area, however, that could supplement the testing efforts of ANL, and perhaps accelerate overall progress. Drawing a major engine company, as well as transmission and axle suppliers into the program can also provide additional expertise and resource.

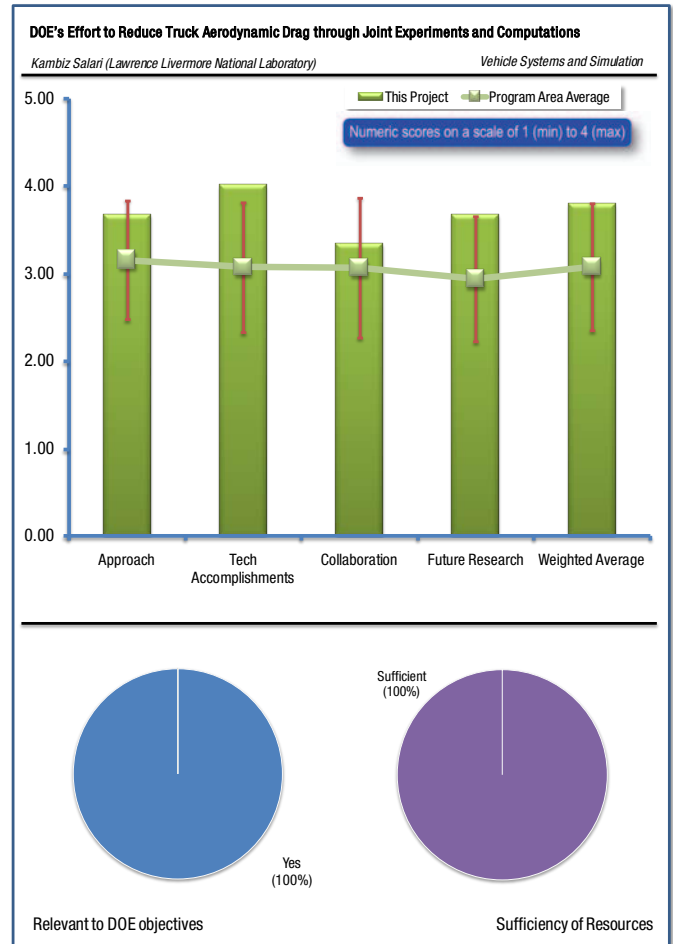
DOE's Effort to Reduce Truck Aerodynamic Drag through Joint Experiments and Computations: Kambiz Salari (Lawrence Livermore National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewers felt that this area is critical for reduction of diesel use by Class 8 over-the-road trucks in freeway use because realistic reductions of 10% are possible. Above 50 mph, aerodynamic losses account for more than half of the required horsepower for Class 8 tractor and trailers. A significant improvement in aerodynamics of the vehicle can dramatically increase the fuel efficiency of Class 8 vehicles, which account for approximately 12% of the petroleum consumed in the U.S. The output of these efforts could have a dramatic effect on reduction of fuel consumption in the Class 8 market. It was also stated by another reviewer that the primary goal of this project is to improve fuel economy of class 8 tractor-trailers through the use of aerodynamic drag reduction while satisfying regulation and industry operational constraints. Aerodynamic drag reduction is a very attractive area to achieve petroleum displacement due to the feasibility of significant fuel economy improvements (upwards of 10-15%), large and growing number of heavy vehicles on the nation's highways, and the fact that relatively little in-use aerodynamic advancements have been made with trailers which account for one third of the drag of a tractor-trailer combination.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers agreed that the overall task is well designed, logical, and follows a conventional progression from virtual testing, full-scale testing (NASA Ames Research Center), through on-road testing and evaluation of the most promising aerodynamic device combinations. Subsequently, the approach is to apply the best device combinations for implementation to the team consisting of tractor, trailer and third party device manufacturers; a wide-based single tire manufacturer; and large fleet. In the past year, the focus has been on full-scale wind tunnel testing at NASA Ames. This is a welcome advance from the more strictly modeling-based activities of the past and is an important step towards broad commercialization. This approach is helping to overcome the remaining barriers, winnowing down and fine tuning the most promising technologies, and putting these technologies near the cusp of successful commercialization.

It was also noted that investigators are linking tunnel testing and track testing, and that there is added potential if whole vehicle modeling were incorporated to understand the aerodynamic contribution during the track testing with higher fidelity. With track testing cooling differences may play a role as well as ground effects. It will be important to compare C_dA values from track testing and express those differences as a percentage, rather than using track testing to verify the differences in fuel consumption on the track (sensitivity issues). Reviewers also said that actual wind tunnel testing was preceded by "virtual testing" to sort out relative benefits of each device or configuration to be evaluated. This work utilized the largest wind tunnel facility in the world with minimal wind blocking effects, which affords an excellent opportunity to obtain clean, accurate data. From the presentation, it is obvious there was significant attention to detail in order to achieve the best possible accuracy. Another reviewer also mentioned that, although attempts

were made to reduce the effects of a “non-moving ground plane” and “non-rotating tires,” the suggestion was made to repeat testing of underbody components at a track facility, to improve confidence of results.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers were very impressed that full-scale wind tunnel testing involving a number of devices has been completed. More evidence of this came from other evaluators, who mentioned that LLNL and Navistar have successfully tested 23 aerodynamic devices using different combinations of two tractors and three trailers in a full scale wind tunnel. Base flaps, underbody and gap devices, and wide-based single tires have been tested and their range of fuel economy improvements quantified. Fuel economy improvements of 5-10% for base flaps, 5-8% for underbody devices, 1-2% for gap devices, and 4-5% for single wide-based tires has been demonstrated. Only a minimum amount of error has been introduced into wind tunnel calculations and which can likely be resolved upon completion of track and field testing. It was also noted that given the industry's focus on efficiency and cost control, these results can help to drive spec'ing and purchasing decisions that will translate into fuel economy benefits. This data should allow relatively quick adoption of the most promising devices.

Reviewers did note that the presentation could have included more detailed results from the testing, although this may have been restricted in order to preserve the confidentiality of the industry partners. Reviewers also mentioned that the presentation would have been improved by at least listing the 23 different tests, and at least providing a rank order of the measured reduction in aerodynamic drag. Data presented in this format would also be particularly meaningful for the fleets and owners that will have to make purchasing decisions on these devices.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers felt that this task is working closely with a number of industrial entities including aerodynamic device manufacturers, a tractor and trailer OEM, a fleet, tire manufacturer, and government entities. Good relationships seem to exist and the process is moving forward.

However, a reviewer did mention that there was no mention of collaboration with other National Labs. For example, it is anticipated that improvement results could be integrated into Argonne's Autonomie software for future analysis work. Again, it is unclear if this would have been restricted due to industry partner confidentiality concerns.

QUESTION 5: HAS THE PROJECT 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?

Reviewers agreed that the proposed future research and activities appear to be right on the mark with emphasis on bringing existing aerodynamic devices to commercialization. This is a sea change from some past years which emphasized extensive modeling with less focus on overcoming remaining barriers to commercialization. This is very refreshing. The proposed future research builds on past and current progress and is targeting remaining barriers. It also includes other work to improve aerodynamics of tankers which, while small in number, travel an enormous amount of miles each year. Additionally, the project will look at potential quantum leaps in aerodynamic improvements through integrated tractor/trailers.

Another commenter mentioned that future plans are in place for (1) evaluation of devices for tanker trailers; (2) optimization of various aerodynamic reduction devices; and (3) the aforementioned track testing. Additional aerodynamic devices will be evaluated as they become available. An optimized integrated tractor-trailer concept will be explored. While interesting to determine the absolute minimum aerodynamic drag of the tractor trailer combination, the “optimum” might be difficult to implement given the industry logistics of one tractor pulling a number of different trailers. Several reviewers also stated that while emphasis in the slide presentation was placed on “getting out the word” to the industry concerning benefits of these devices, it was not given much attention in the discussion of future activity. To maximize the impact of this meaningful research, efforts should be focused on how to make this information readily available to fleets and owners. Collaboration with OEMs, supplier, and key fleets is suggested in order to determine the best approaches.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers felt that based on the timely completion of the wind tunnel testing, it is obvious that sufficient resource was on hand to carry out the 23 tests efficiently. As noted in the previous section, it is also suggested that industry partners be brought into the process of determining how best to disseminate this information. Another commenter also stated that consideration should be given to increased funding should the task continue along its currently attractive trajectory. This would be especially true if the track and field testing proves successful and a handful of the aerodynamic devices achieve commercial success in the next year or two.

Emissions and Fuel Consumption Test Results from a Plug-In Hybrid Electric School Bus: Jeffrey Gonder (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

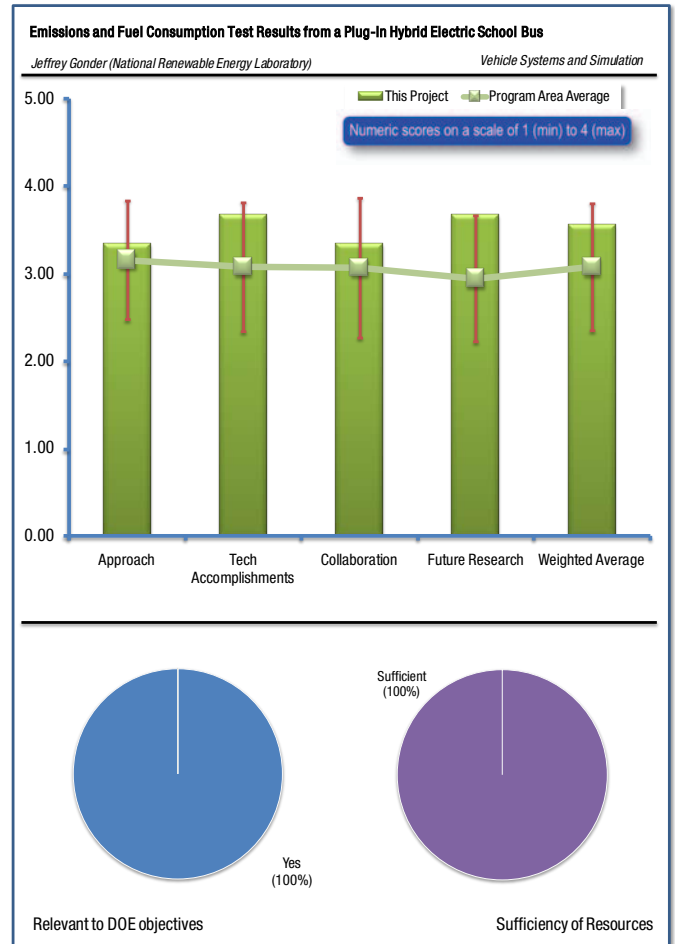
The first reviewer felt that testing vehicles which displace gasoline with electricity demonstrates the commercial readiness of alternative technologies. Reviewers also felt that EV and PHEV technology will play a major role in the effort to displace petroleum. The final reviewer was supportive of this project because thousands of school buses are on the roads every day, so technology that improves fuel economy can clearly make a meaningful reduction in petroleum usage. It was also agreed that the stop-and-go duty cycle of a school bus, and the relatively short operating interval, make this application an excellent fit for plug-in hybrids. Not only is the operating cost of the school district reduced, but the fuel usage can drop significantly, especially in larger fleets.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers felt that the technical approach was sound and that dynamometer testing of specific duty cycles compared the energy consumption of a plug-in hybrid school bus against a diesel baseline. Another reviewer felt that the choice of drive cycles on fuel economy assessment is very important and that the project addresses that issue by looking at different drive cycles and evaluating the impact. However, more work could be conducted to assess how well the cycles studied represented the entire population of vehicles. Another commenter felt that because three standard duty cycles were selected and the hybrid was evaluated in charge sustaining, charge depleting, and “transitional mode,” the effect of distance on the net fuel economy was easily discernable from the testing. It was also felt that the test program provided a clean, repeatable, controlled, thorough comparison of the PHEV vs. the standard diesel unit.

Other reviewers felt that this seemed like a good approach overall to testing; however, it did not seem that enough emphasis was put on understanding how electricity contributed to overall energy use. They were also surprised that total energy use seemed higher in the PHEV, and this did not seem to be adequately investigated. It was also felt that it is worth investigating how the usage patterns of the vehicle would change daily energy use, and not just cycle energy use because it is one thing to look at average daily travel, and another to look at the distribution and speed of these different cycles.

It was also noted by a reviewer that the baseline bus was somewhat different than the hybrid. Notably, it was a different OEM (Bluebird vs. Navistar), and a different engine (7.2L Cat vs. 6.4L Navistar Maxxforce) which somewhat affects the comparison. It was noted in the presentation that the smaller engine in and of itself was responsible for a portion of the improvement, so the improvements noted cannot be totally attributed to the hybrid feature. (Some may argue that the hybrid drivetrain is an enabler for smaller engines, since the hybrid can provide torque assist to the vehicle during situations requiring higher torque and power). It would have been interesting, and perhaps a bit cleaner to use the same OEM, and the same engine in both cases.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Overall, the reviewers felt that this seemed to meet testing goals well. As described above, it would be helpful to perform more analysis, but the data appears to be sound. The reviewers also felt that the results and analysis were very complete and insightful. In addition to providing the test results, this program took several “cuts” at the data to better understand trends, including effect of route distance, charge sustaining vs. charge depleting, and the “net energy” usage (diesel plus electric power).

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The reviewers felt that collaboration was sufficient for this project and including interface with Navistar, Enova, and several school districts. Another reviewer noted that the project has shown collaboration with both OEMs and end users. However, it would have been useful to discuss the actual data received in more detail. Because of the novelty of the technology, connecting the different players is critical to understand all ramifications of the technical choices made.

The final reviewer mentioned that in the supplemental slides, it was implied that this program team will assist other NREL groups if/when they perform a field evaluation of a PHEV school bus. Navistar is already working on a second generation PHEV for school buses and it is anticipated that the team will provide assistance and insight to Navistar in this second generation development.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer stated that the work seems to be on a good trajectory but he would like to see more focus on understanding the why instead of just the what. However, it seems like an excellent starting point. Another reviewer noted that the project is officially complete, although a back up slide itemized some proposed future activity, interfacing with other groups within NREL, and potentially assisting Navistar in their second generation PHEV development. The same reviewer felt that if a similar project is conducted for next-generation PHEV buses, it would be interesting to conduct the testing with a baseline vehicle from the same OEM and with the same engine size. This will provide the cleanest comparison.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

All reviewers felt that resources were apparently sufficient, as the project has been successfully completed, including not only the data collection, but a meaningful evaluation and presentation of the data.

**PHEV Engine and Aftertreatment Model Development:
Stuart Daw (Oak Ridge National Laboratory)**

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers felt that this project advances the PHEV agenda and analyzes certain parameters pertinent to the fuel use benefits of these systems. They also mentioned that knowledge of engine performance through modeling and trade studies is important for optimizing engine operation and fuel economy.

The final reviewer noted that HEVs and PHEVs offer significant opportunities for petroleum displacement, but potentially pose emissions challenges as a result of multiple engine start and stop cycles. ORNL is working to better understand and quantify the trade-offs between efficiency and emissions for gasoline and diesel hybrid vehicles using different engine and emission control strategies. In order to further their viability and increase their petroleum displacement potential, it is important to accurately assess and identify the most appropriate balance across these areas. This is the crux of ORNL's PHEV engine and aftertreatment model development efforts.

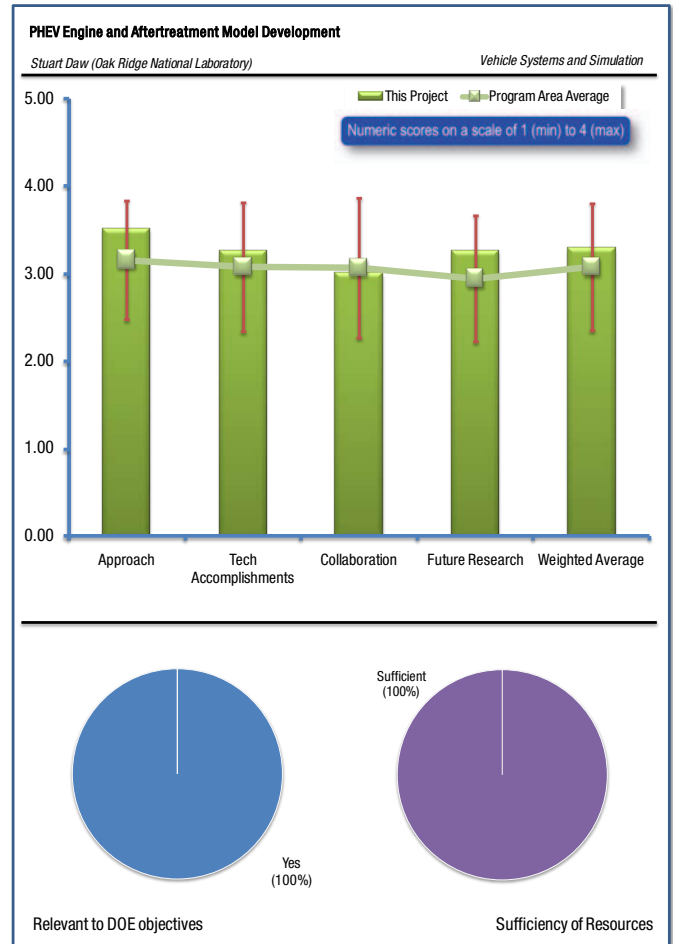
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer felt that the models should provide for good use in the private marketplace. The second agreed that the objectives are clearly stated with a specific quantifiable list of tasks and that all of the technical barriers are being addressed. New work largely entails fine tuning models and running a lengthy list of possible scenarios.

The final reviewer felt that there has been a noticeable improvement in the approach of this task over the last year. Previously, the task had a scope that was much too broad and was distinctly lacking in focus and priorities. This has been improved in the later part of 2009 and early 2010, to where the effort seems much more manageable and defined. It is evident that the crux currently is on stoichiometric and lean diesel and gasoline HEVs and PHEVs with different strategies and aftertreatment technologies. This is a good approach and it is recommended to continue along this path until resolution is achieved in these areas. The task still has a somewhat broad approach, hinting at exploration of unconventional/bio fuels and exhaust heat recovery systems. It was recommended to keep these efforts to a minimum at this point. The approach could also benefit from a more clear explanation of how the modeling activities and processes are conducted.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

It was felt by the first reviewer that the PI lists a good number of accomplishments and much past work has been done developing HEV models and performing associated analyses. PHEV engines and HEV engines are mostly the same and the primary goals appear to have now been largely accomplished. He also felt that a list of future milestones and dates would be helpful for evaluating the progress of this project.



Another commenter pointed out that the technical accomplishments over the last year seem to be solid including 1) transient engine simulation methodology, 2) LNT model for lean HEVs and PHEVs, 3) simulations of stoichiometric versus lean HEVs and PHEVs with lean NO_x and PM controls, and 4) transfer of TWC model from PSAT to AUTONOMIE, and initiation of other characterization studies. Overall, the reviewers felt that this is a respectable list of accomplishments over the last year based on existing funding levels.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer felt that the task has good coordination and collaboration mechanisms in place via Advanced Combustion MOU, Advanced Combustion and Emission Control (ACED) tech team, Diesel Cross Cut Team, CLEERS collaboration crosscut team and VSATT.

Other reviewers were unsure of what collaborators were contributing vs. what the core team was providing. They also felt that, while a significant number of parties were identified as collaborators through membership in relevant industrial groups, specifics of technical collaborations were not presented. They also pointed out that it would be helpful to explain the nature and role of each collaboration, at least in general terms.

QUESTION 5: HAS THE PROJECT 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?

Overall, the reviewers felt that the future proposed research is reasonable and should continue to focus on stoichiometric gasoline hybrids and lean diesel and gasoline hybrids. However, it was also noted that the proposed future scope exceeds the expected budget, but no case was made for the importance and urgency of increasing the annual scope. One reviewer also commented that he would like to see the effect of different performance/towing requirements on results.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

All reviewers felt that resources are currently sufficient; however, future increases may be required. One reviewer noted that if this task continues to generate models of high value to industry and stays more narrowly scoped and focused, consideration should be given to increased funding levels to accelerate conclusive determinations through simulation in the aforementioned key areas.

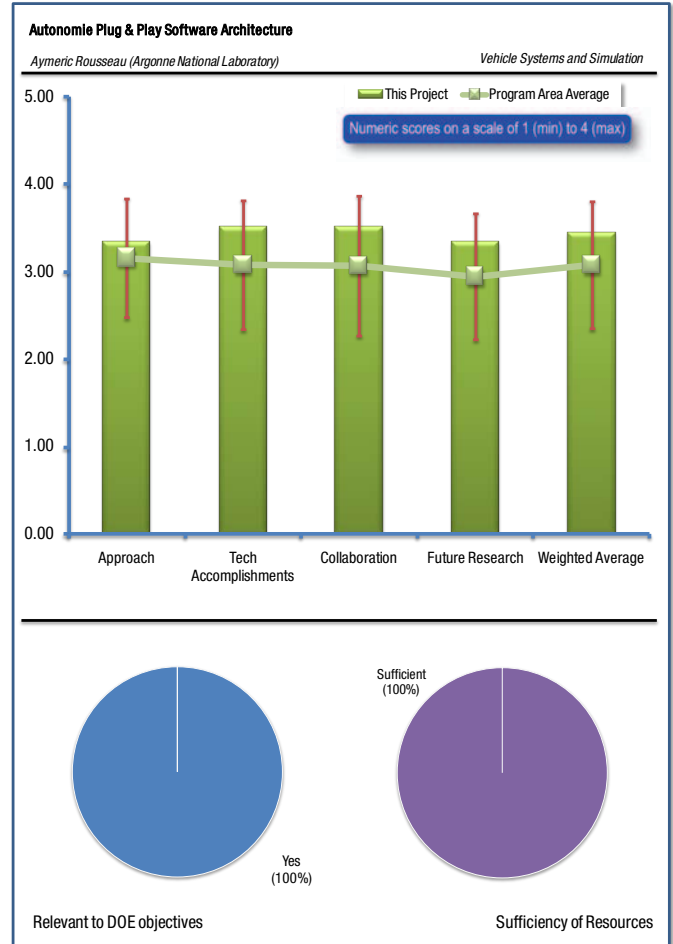
Autonomie Plug & Play Software Architecture: Aymeric Rousseau (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

All reviewers felt that vehicle modeling and simulation are central to evaluating technologies and developing the next generation of vehicles that use much less petroleum energy. This work is useful to DOE, OEMs, component suppliers, and researchers for advancing vehicle technologies. It was also pointed out that the model-based design support allows for optimization and component selection for efficiency and the flexible modeling architecture allows wider use by more industry participants. It was also agreed that detailed modeling and early simulation can reduce costs and time to market associated with new technology development. A tool like AUTONOMIE can be used on many projects and many technologies and is not limited to only one project. Another commenter felt that speeding the time of decisions by removing redundancies in data exchange and impact analysis will accelerate the deployment of the right advanced technologies. The third reviewer agreed with the presenter's slides and that efforts to facilitate the simulation process and allow studies to be conducted faster will help to identify better components/systems and develop better control strategies. He felt that all of these do lead to petroleum displacement.



The final reviewer pointed out that Autonomie provides a single platform that can be used to perform several different levels of simulation as well as component/hardware in the loop type experiments. The use of a single platform should promote consistency among the various DOE funded projects. This could be seen already in the presentations, where Autonomie was being used in several of the projects. While the intent is for Autonomie to be used in simulation of advanced powertrains, there is nothing to prevent it from being used for conventional powertrains as well. This would also facilitate future comparisons between conventional and new powertrain configurations.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer felt that the approach looks very good, and it looks like many of the concerns that a potential user of the software might have, have been addressed. However, it was felt that the 20 minute presentation was insufficient to judge whether all of the approaches are completely effective. Reviewers are looking forward to using the software when it is released in August, and will then be able to provide more valuable feedback that would benefit future development of the tool. The second reviewer feels that this combines the best from Mathworks, Gamma Technologies, LMS and Mechanical simulation in a time efficient and effective single package. Simulink has become the de facto modeling and simulation tool that almost every engineer has access to and with AUTONOMIE all phases of the development and validation processes are tied together in an enterprise wide approach. Another commenter stated that they are open source and working with established software vendors and GM: this takes the work from what would have been a national lab science project to the realm of impactful real results.

One reviewer fears that since it builds around a legacy model, links with components, controllers and simulations of the components, it may prove useful to an entity which is designing or assembling a product, but if corporate models/software are included, it will be limited to that user because of IP issues. He was also concerned that its role in verification of emissions or efficiency is not clear and believes that substantial human intervention will still be needed, rather than just “plug and play.”

Another reviewer has some reservations about a tool that claims to be everything to everyone, which may not be completely possible, and feels that perhaps some clear statement of scope would be worthwhile. However, the efforts to pull in other models (e.g. AMESim, CarSim, GTPower) seem to be well placed. Perhaps some additional electrical/electromechanical simulation packages should also be included. (AMESim has this capability, but does not seem to be a common industry tool in electrical/electromechanical modeling. In fairness, Simulink itself is probably a fairly common tool.) Another commenter did point out that the approach and work is focused on development of Autonomie of course, but is not so specifically focused on vehicle technical barriers (so not a criticism of the work).

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first commenter noted that it appears that the timeline is being adhered to. It was originally given to understand that the software would be released in June, but it appears that the official release has been pushed back to August. However, extensive use of the software for various MIL and CIL studies looks promising. A commenter noted that development has been published and the model has been built (90% complete program), but it would be good to see concrete examples of the simulation compared with realistic data. For it to be successful, each component manufacturer will need to provide a sufficiently accurate model. Another reviewer felt that the co-simulation combined with legacy code and processes results in a powerful, simple, technical solution that is totally customizable, allowing a single tool through the entire development process.

One reviewer stated that their progress seems very good and, as the project is nearly complete, this can be extended to say that overall program seems to have gone very well. Their proven ability to integrate with several commercial software packages is a very good effort. However, some metrics that tied back to original objectives would have been useful. More specifically, the goal was to allow researchers to quickly simulate various powertrains. Reduce cost and time to production by minimizing hardware iterations through Math-Based environment. So, either a summary of “stock” configurations that are available in the software should be provided, or if it is completely free form, perhaps some indication should be given of “typical” time to construct models, as experienced by partners at OEM, would be useful to assess progress towards this goal. Making allowances for previous models and including diverse tools are key to the final software system being widely useful. The flexibility designed into the system seems to work. (Not all software that claims to be able to do these sorts of customizations actually works in practice). It was also noted that the project timeline of three years is long but they have accomplished quite a lot. This reviewer would like to see more vision for the future on next steps, additional modules to hook to, etc.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer stated that it appears that there has been very good collaboration between ANL, GM, and Mathworks. Previous presentations by Mathworks engineers have made extensive use of Autonomie for studies involving HEVs. This seems to indicate good cooperation but it would have been good if the other OEMs (Ford and Chrysler) were more involved. However, credit must be given to the Autonomie team - they had investigated if there was any interest at Chrysler, but efforts to get the right people involved were not at all successful. Based on the information that was presented, it cannot be determined how well the integration of the other software - CarSim and AMESim - has proceeded.

One commenter feels that they need to continue outreach to vehicle OEMs to expand general acceptance. It is not yet clear how widely it will be adopted as an industry standard and many OEMs may have created their own complete modeling systems which will compete, even though Autonomie proposes to incorporate them into a larger package.

Another reviewer felt that the major participants in the project have been able to offer experience and guidance to steer the ANL team to deliver a fully rounded and robust tool. GM, as a major OEM participant, has provided the seal of approval by committing to use

the tool for all future control development activities throughout their company. The fourth reviewer pointed out that they seem to be working tightly with industry, but ideally the team would have a few OEM partners and maybe not be so tightly connected to one. However, this is probably a more minor point, in the big picture; researchers are actively working with vehicle OEMs and have tried to interface with other simulation tools. The final reviewer pointed out that there is an obvious collaboration with GM; however, this software will be open to others soon. He also noted that Autonomie development will be on-going, but the Software Architecture will likely be fixed going forward.

QUESTION 5: HAS THE PROJECT 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?

In general, the reviewers felt that overall proposed future research looks good (and perhaps a little ambitious). It was also noted that perhaps one other item that should be included is the linking of other specialty software to Autonomie. There was also a mention of the development of detailed models of batteries and other subsystems at ANL and other national labs. It is not apparent whether the validation and inclusion of these models in Autonomie is slated to happen, but that would be another potential future task. Overall, reviewers noted good forethought to how the tools would be used. Reviewers felt that the project is transitioning from development into a launch and maintenance mode. It was also felt that ANL would do well by exploring the use of Autonomie in the commercial medium and heavy duty truck arena.

One commenter did mention that the task “Define the industry standard for modeling and simulation to be adopted by the entire industry through SAE” is not under the sole control of the ANL investigators. There is a danger that if GM is the lone major first user, it may lose generic capacity.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The reviewers agreed that resources appear sufficient for Autonomie launch and maintenance activity because the project is nearly complete and seems to have met all goals. However, they did note that it was hard to evaluate.

Tradeoff Between Powertrain Complexity and Fuel Efficiency: Aymeric Rousseau (Argonne National Laboratory)

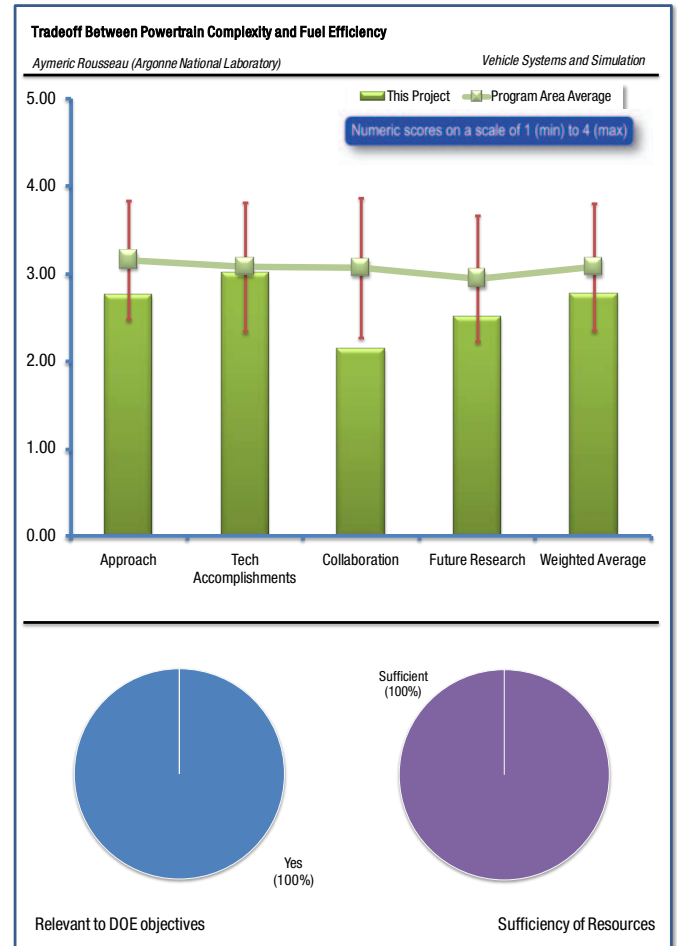
REVIEWER SAMPLE SIZE

This project had a total of 8 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers felt that since complex powertrains are continuously being studied and proposed, the study of the benefit of the added complexity is important to justify the usefulness of the technology. Another noted that making significant gains in fuel economy will require the use of hybrid vehicle technology. This project is looking at different hybrid (electric) vehicle configurations to determine the best return on investment. It offers another perspective on the various hybrid configurations that are being considered (besides the OEM viewpoint).

It was also noted that helping industry partners to understand potential benefits of more complicated systems will reduce overall design time and help industry to select optimal price/performance tradeoff. Designing the best system (that consumers will buy) will increase petroleum displacement. Overall, it was agreed that this knowledge helps in the selection and matching of technologies to their intended use for lowest cost.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer felt that in general the approach is valid. While the stated objective of the project is to compare different multi-mode hybrids, the exclusion of other types of hybrids does not appear to support the primary objective of petroleum displacement. Several of the European OEMs are heading towards other hybrid configurations, many of which represent a very viable transition from conventional automatics, and these hybrids are very likely to be marketed in the U.S. Also, the supervisory control for these hybrid configurations will be considerably simpler than those for the multi-mode hybrids. The choice of ratios in the multi-mode hybrids itself could constitute a separate project whose outcome would depend on the vehicle, prime mover, etc. Using the 'default' ratios for these transmissions may mask the true benefits of these multi-mode hybrids.

On a different note, the format of the review (20 + 10) does not allow a thorough understanding of the modeling approach, which is needed to provide meaningful feedback. In the absence of any other reports describing the project, a few more backup slides describing the approach in more detail may be warranted. For instance, it is unclear how the mechanical efficiency of the transmission is evaluated in the models. More information on some of these aspects would be very helpful. It was agreed by another reviewer that they used a fairly standard approach, but also required attention to detail. It would also be difficult to model the secondary issues such as clutch losses, gear losses, etc.

The third commenter noted that this was an interesting and useful program. Ultimately the component sizes and ranges (i.e. constant power ratio of electric machines) have an impact on coverage of transmission and overall results. However, a very clear definition of assumptions regarding performance conditions that govern initial component sizing and assumptions regarding component characteristics is needed to allow industry to properly interpret results. Without this, it is still a nice effort, but there are too many

unknowns to make much sense out of the results. Lacking this up-front structure/organization, the project reduces to coding different architectures in PSAT/Autonomie (which is useful, but probably not a task for more than \$500k).

It was also felt by another reviewer that this work forms a good basis for specific component sizing and fuel consumption assessment, but only for the power split class of hybrid powertrains. Please consider defining a sort of an “ideal hybrid” with the minimum-sized components to meet requirements, but with losses included, and an ideal simple control strategy. This idealized hybrid would perhaps never be realized, but it could serve as a benchmark realistic hybrid system to compare other possible (actual) hybrid architectures and component sizes with. This would be similar to a “Carnot efficiency” concept, but with real component sizing and losses. The current work, while perhaps relevant to some specific interests, is too specialized to be of much future general interest. The control complexities and approximations for a simulation require a lot of work, with perhaps not much return. Without any considerations for emissions, this level of control development may not be useful for evaluation of the potential. (The objective given is to size the engine to a minimum, yet get the most from the direct engine path; this may lead to engine loading issues and NOx, but this cannot be assessed.) Real component costs will be assessed by manufacturers for a particular vehicle.

One commenter did point out that there is a danger of oversimplification of models or use of insufficient Vehicle Technical Specifications which may drive erroneous conclusions. It is not a good idea to use material directly from GM/Allison hybrids presentations: at least mention the source on the slides. It was also pointed out that some of this work on transmission configuration has already been done in private industry, along with various transmission designs. One project looked at 20 different transmission configurations.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Overall, reviewers felt that good progress had been made so far, but there is much work to be done on the three and four mode hybrid controls before the project can be wrapped up. The main issue, pointed out by the reviewer, is whether the choice of the various supervisory control algorithms does justice to the true potential of these hybrids. It was also felt that modeling of single, 2-, 3- and 4-mode transmissions is a good accomplishment. The reviewer did not see any results (at least not for some of the more complicated transmissions), but the effort to size components and run all needed simulations is far from insignificant. There would still seem to be a lot of work to get to the final objectives. However, the original objectives were very ambitious, given the level of funding, and are as follows: “Evaluate the trade-offs between EVT system efficiency and EVT mechanical loss based on multi-mode powertrain complexity. Select the most promising configuration to support future DOE fuel consumption studies.”

Another felt that the objective statement was probably a little too broad; progress is on track with scope that the budget would seem to represent. Some efforts are needed to clearly spell out what this scope really is. It was stated that this was the first time that 3 and 4 modes were seen to be included in such an analysis where controls are also included. Brute force control optimization seems to be inconsistent with what was stated in presentation #9 regarding Autonomie's ability to capture and optimize interactions between systems. It was also asked by a commenter how complexity was measured and if it was one-mode, two-mode, and three-mode and how was it accomplished without taking into account the complexity of controls. The project could use some more work on costs of components and cost of developing the controls.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

All reviewers state that it is unclear from the presentation how much cooperation there has been with other institutions. It was noted that most collaboration was basically with DOE and GM. The question was also stated by a commenter asking what does GM and the DOE really want to get out of this.

QUESTION 5: HAS THE PROJECT 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?

Reviewers generally agreed with the proposed next steps, but noted that the presenter must consider other vehicle classes, different market requirements (luxury vs. standard for example) and their impact on component constraints and assumptions. It was also stated

that a reasonable and logical approach to completing the program is proposed. Answers will not be definitive, but will increase awareness of differences between architectures under varied operating conditions. It may not be necessary to go as high as a four mode, but rather refine the loss models for single, double, and three mode. “Expand study” seems like a wish list and lacks focus. Another commenter added that it would be interesting to see where the tipping point would be for the cost vs. benefit of the multi-mode configurations. Mechanical complexity aside, the higher mode hybrids would be a calibration nightmare and a consideration of the effort involved in calibrating the higher mode hybrids would also be instructive.

It was noted that statements about the future work echo those about this project. In principle, it has value and is of interest, however, some clear definition of scope is needed other than the “Future work will address the four selected multi-mode systems to assess their impact on fuel consumption and component sizing” scope that was given. Another commenter pointed out that the project is almost complete, yet there is a list of additional studies to be done including other vehicle classes, more modes, and more configurations. Perhaps focus on a general sort of ideal (not really the right word here) hybrid powertrain to compare to.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers’ comments here were basically the same as in earlier stages of the report. They agreed that this seems to be a very good project, but its scope seems almost limitless. It was also thought that some clear statements are needed regarding the desired scope and the assumptions which will underlie the final comparisons.

*Impact of Driving Behavior on PHEV Fuel Consumption for Different Powertrain, Component Sizes and Control:
Aymeric Rousseau (Argonne National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 8 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

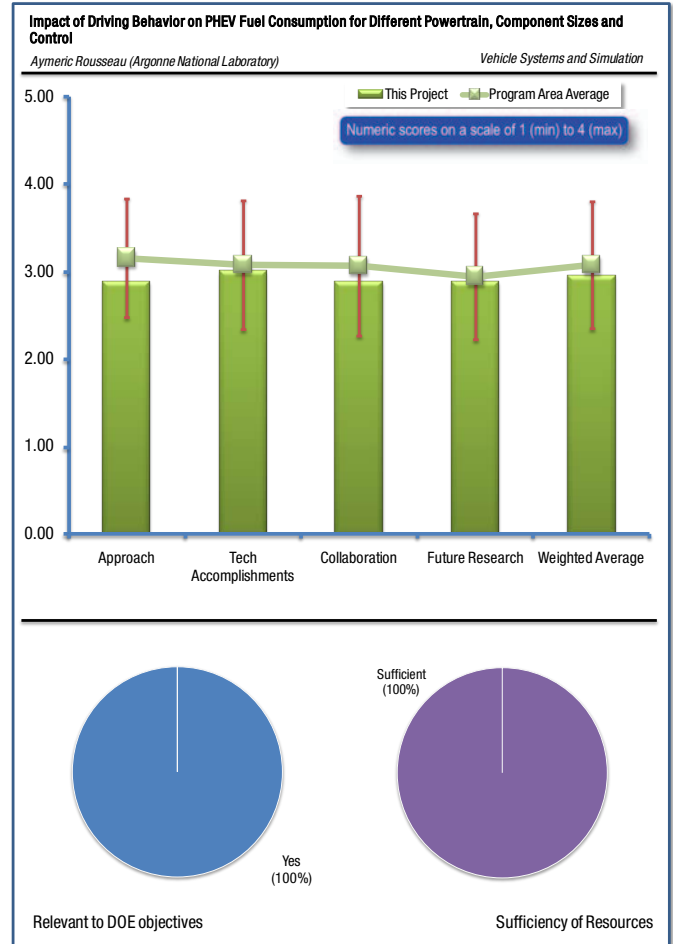
Overall, it was felt that this project fulfilled the objectives. The first reviewer noted that understanding how PHEVs will be used is of primary importance in determining how much impact they will have in the real world, and how worthwhile continued interest in them is. It was also stated that driver behavior has a significant impact on fuel economy for conventional powertrains and that this effect is even more significant for PHEV. Federal testing procedures currently do not take this parameter into account when evaluating fuel economy. Understanding the impact of driver behavior on fuel economy is hence critical to understand the real world benefit of the technology and hence the amount of petroleum displacement. The final reviewer commented that the assessment of the impact of driving cycle on petroleum displacement is on point since it helps to ensure that the final vehicle designs truly maximize the displacement of petroleum.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The main thing reviewers wanted to see is more of the same; more drive traces, more variation, and more days with the same drivers. The only real problem with the work is that by only studying driving in one place on one day, the overall significance of the work is somewhat uncertain. This can only be corrected with more data, which is difficult to obtain, but should be a future focus. Reviewers also found the additional slides are very helpful in understanding the various supervisory control algorithms. However, the structure of the various hybrid powertrains themselves is not clear from the presentation. Perhaps the project would also benefit by using more supervisory control algorithms to evaluate the fuel displacement. It was also noted that using the coefficient of variation instead of the standard deviation to report the impact on fuel consumption displacement may make the results clearer. The final reviewer also positively noted that the analytical approach of utilizing data captured from 110 trips in 1 day in 2007 in Kansas City and the method that the data was analyzed in many ways to determine optimum solution was beneficial.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

In general, the reviewers felt that this is excellent work towards evaluating the likely value of PHEVs and that the use of several real world driving cycles provides more credibility to the results. They were also pleased that the project appears to have made solid progress towards objectives and accomplished the technical goals set out at the start. It was mentioned that this was a good use of Autonomie to process data and model NPV. In particular, a commenter noted that in addition to the project design, the execution also seems very nice. The charts showing fuel saved (%) vs. distance (with several other elements of the cycle annotated) are exactly the information that the fourth objective would seem to require. (The fourth objective was: “Assess the impact of driving distance and driver aggressiveness on fuel displacement.”)



Another commenter noted that the cross correlation chart would seem to have a lot of interesting information. The reviewer liked the idea/approach, but needed a little more information/ discussion/description. One reviewer stated that many of the results generated are well-known to others in this research space. However, he was concerned with the table in the presentation that shows 2-3% FE benefit of HEV over conventional. An explanation is needed to understand why the benefit is so low, such as the model calibration.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers noted some good collaboration with other bodies, EPA, City of Chicago and University Davis. They were also pleased to see that The MathWorks were involved in the data processing and NPV modeling.

It was felt that although it was clear that data was obtained from EPA, the interaction appeared to be limited. It is also not clear what work was done with UC Davis or INL. The interaction seemed to serve the purpose, but likely could be improved. It was also unclear to at least one reviewer why the city of Chicago was a partner because the data is from Kansas City. It was also noted that NREL also seems to do quite a bit of drive cycle analysis and that some collaboration with NREL researchers could be useful. Other reviewer's comments included a perceived narrow collaboration with one software provider and concerns as to whether the results are shared with the right people.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer felt the prospects for future work look excellent. However, this particular commenter would prefer to see more focus on increasing the applicability of the work through the incorporation of more traces and vehicle variations rather than the creation of a location-aware control strategy, but this is a rich area of work, so it should all be valuable. In particular, a reviewer felt that the proposed next step of developing a test vehicle with trip recognition to test control strategies would be a good follow-on to this project. Further data analysis aimed at uncertainty would be another interesting avenue. One reviewer did not agree with the discussion that this should not be a DOE project, as the data was of significant benefit to OEMs. If a DOE project yields data for the benefit of all then the project should be regarded as a success, even if it is publicly funded.

Several reviewers also felt that the additional Monte Carlo simulations seem to be a nice extension (further explore sensitivities/variability) and conducting a similar exercise for medium/heavy duty vehicles is also a good thought, but needs some up front work to clarify scope (target vehicles to be studied).

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Overall, reviewers stated that the project is nearly complete (and seems that it will be completed on schedule) and the results seem consistent with the original scope and budget. They are also looking forward to what should be an interesting report.

Tradeoff between Fuel Consumption and Emissions for PHEV's: Neeraj Shidore (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers felt that by allowing the enhanced simulation of PHEVs, this project can contribute to petroleum displacement. It was also agreed that criteria emissions can significantly worsen when CO₂ emissions improve, making tradeoff studies important to develop a good compromise. Criteria emissions are particularly sensitive to aftertreatment temperature, and techniques that will allow faster temperature rise are of particular interest.

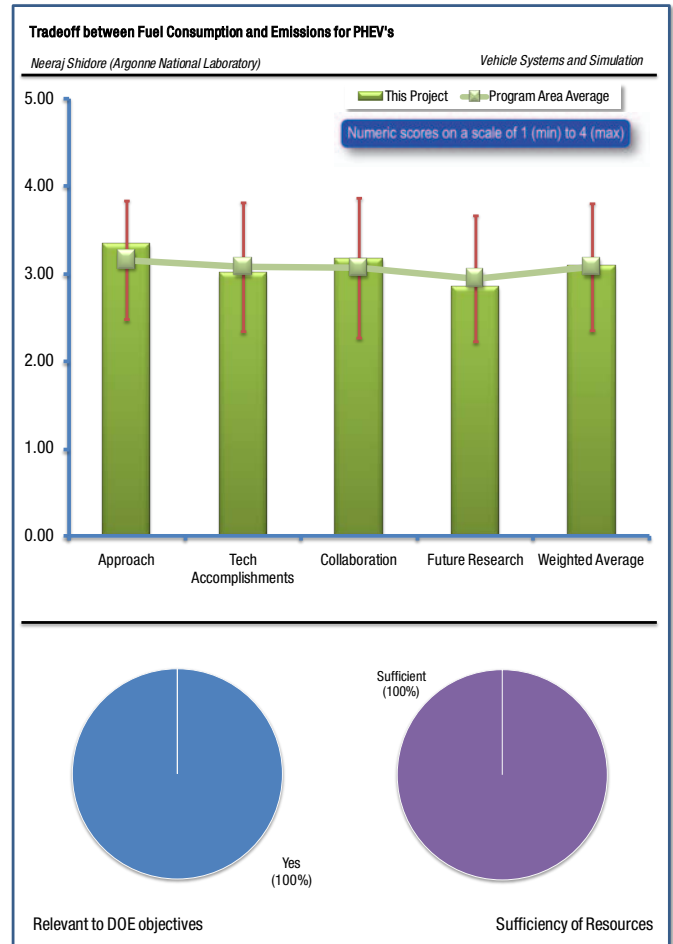
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first commenter stated that although the overall goal is admirable, it was not demonstrated that this work will be generalizable, or what the approach actually was. It was unclear if series, parallel, or a conventional technology was being discussed because at different points in the presentation all were mentioned. It seems that the intent is to prove the model in a simulation of a conventional vehicle, the most difficult application, and then to use this as validation for all other uses. However, it is not believed that this was done. Although it seems plausible that the difference in cold start fuel economy was due to a cold powertrain, it is unclear how this was demonstrated with data. This seems to be more of an assumption than an outcome, which is not a good way to approach validation. There was also no discussion of emissions validation, and although this was touched on in a previous presentation, it was not clear how these efforts would combine to result in a unified approach. Another reviewer remarked that the comment by the presenter that accuracy within 5% of reality is sufficient does not seem to address the needs of end users for more exacting virtual methods.

A reviewer noted that cold-start emissions are a significant issue for PHEVs and the results of this work should be integrated into Autonomie. It was also felt that while the model correlates for one set of points, more may be needed for full correlation (across temperature and other operating condition variables). It was also questioned what fidelity is deemed sufficient.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Overall, reviewers felt that very good progress on a complex system to implement engine in the loop and very good validation results had been accomplished. One commenter noted that the integration of the ORNL aftertreatment model into Autonomie was a good achievement. The data showed good correlation between the Autonomie model and Engine in the Loop. The differences on the EIL “preliminary cold start” appear to be understood (lower powertrain efficiency at cold start—not modeled). The simulation studies under way for power thresholds on fuel economy and emissions as well as engine warm up and torque transients should provide some interesting results. However, it was noted that although the progress was good, it's not clear whether the focus is on completing a



tradeoff study or adding a feature to Autonomie. If the study is the focus, the EIL setup should be ready to deliver interesting results now.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

It was agreed that there seemed to be excellent collaboration with Argonne and ORNL on the development of the engine emissions simulation. It was also noted as a very good example of using the strengths of ANL and ORNL integrated on a project. The project was also noted for good sharing of models with ORNL.

QUESTION 5: HAS THE PROJECT 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?

One reviewer remarked that future model-based work to evaluate other hybrid configurations and validation of vehicle level control strategies is a logical and valuable next step. Another noted that this work should also be integrated into Autonomie so that basic emissions considerations can be accounted for, including in control strategies that often only consider fuel consumption. It was also felt that there seems to be an excellent path forward for interesting results in a difficult area. Given the complexity of the setup achieved so far and the goals, it would be preferred to see the focus on using this setup to produce test results for one specific powertrain/setup. Although achieving generalizable results is admirable, it is going to be impossible to test a wide array of cases adequately; the approach should be deep instead of wide.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

It was noted by all reviewers that there seems to be adequate resources for excellent progress.

PHEV Engine Control and Energy Management Strategy:
Paul Chambon (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

It was agreed that the successful completion of this work would help make PHEVs more practical, which would decrease petroleum displacement. It was specifically noted that cold emissions are particularly important for PHEV vehicles because of the potential repeated cold starts. Understanding of the level of criteria emissions and the impact on fuel economy is critical to understand the real impact of PHEV on petroleum displacement. Another commenter remarked that engine-off operation does offer the capability to displace petroleum. However, as the researcher noted, initial emissions transients may not allow vehicle designers to exploit engine-off (it would not allow emissions regulations to be met).

The final reviewer agreed that the project meets the required objectives; however, he noted that the project appears to be chasing the same objective as every other OEM and major Tier 1 Engine Management System supplier, but without the support of either.

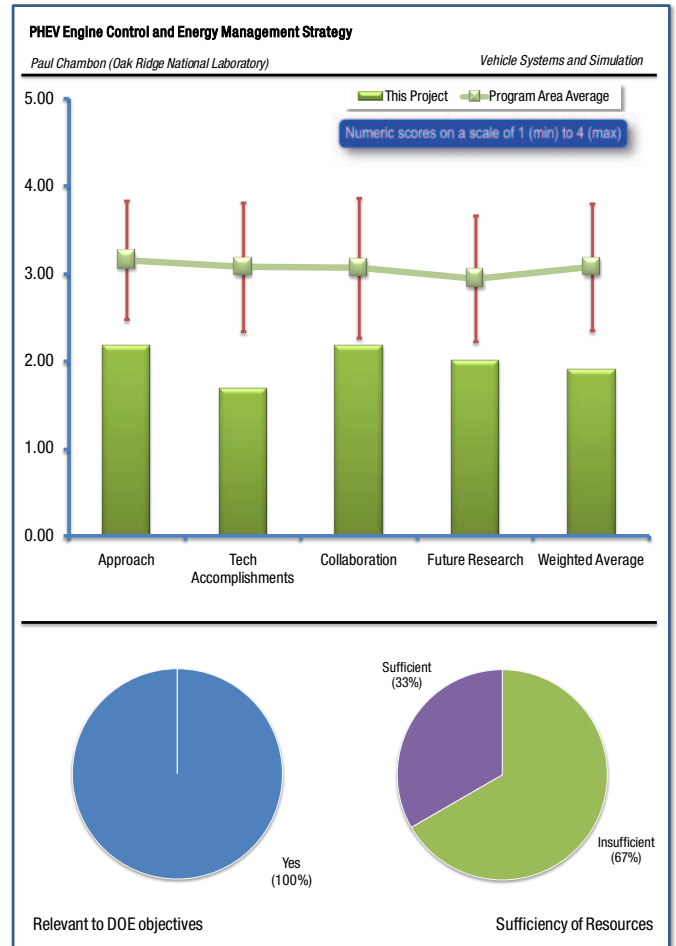
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One commenter noted that exploring the trade-offs between efficiency and emissions is something that can also be done in simulation. There is definitely value in exploring this in real hardware as well; however, there should be a very tight coupling between the simulation exercises and the hardware experiments. Researchers mention that they are working together, but from the presentations it was very hard to see that a fully integrated plan existed between the two projects. This fully integrated plan needs to exist or one of these efforts would seem to be largely wasted.

Another reviewer was concerned that this project does not seem to have a feasible project plan or specific goal and that it appears to be more of an aspiration than a project. The project team seems to be strong, but it is clear that they need to do more work to design a project that is feasible given the lack of OEM support and the need to do useful work within a reasonable amount of time. Some questions to consider include: What new strategies will be tested and how will this work be compared to OEM systems to ensure relevancy? These questions must be answered before the project can proceed in a useful direction. It was also noted that without OEM or Tier 1 support there has to be significant effort to characterize (map) the engine and even then the quality of the response surfaces generated will likely be poor due to the limited ability of proprietary control systems to perform major parameter sweeps. Another obstacle mentioned by a commenter is access to ECM code and control algorithms.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted that while this is a project in its initial stages, as noted above, it is not clear that the plan has been adequately rethought in light of changing circumstances. It was also mentioned that delays due to lack of cooperation by OEM caused a need for a robust back-up plan in place. It is good that graduate students from GATE are involved. Encouraging participation of graduate



students and helping them become the next generation of researchers and (practical) engineers is very essential to the success of the entire DOE initiative. One reviewer noted that the large number of slides dedicated to planning, purchasing and administration would seem to suggest a shortage of doing. Researcher correctly acknowledged that this has started slowly.

One concerned reviewer did note that there are very few knobs/levers to pull and all of these are well understood by the OEMs and Tier 1s. There was no evidence of a “brand new approach” or “silver bullet” that would succeed where all others have not.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first commenter felt that there appears to be good collaboration with relevant partners, given the status of the project. The second noted that while collaboration with UT and ANL appear to be going OK, more cooperation between ORNL and the OEM would contribute to the success of the project. Even though 2009 was a bad year for all the OEMs, it may be worthwhile to pursue that course in parallel once more, for the potential pay-off is significant. The final reviewer mentioned that there seems to be two projects looking at this, one is in simulation and one is on hardware. However, they appear to be progressing independently, which is not OK.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer noted, as mentioned above, that the project needs a much more well-defined plan. It is not clear what specific things the team hopes to accomplish, aside from getting an engine running with a modified controller. It is also unclear what strategy the team is hoping to try that hasn't been tried before. The comment that the team will not evaluate current hybrid systems because they do not wish to reverse engineer is not acceptable. One cannot advance the state of the art without first understanding the state of the art. Another commenter felt that, while the proposed research plan looks good, the success of much of the plan and preventing budget overruns may depend on cooperation with the OEMs.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The reviewers were torn on this topic because they did not want to redeploy what seems to be a well-qualified project team, onto another effort and canceling this one. However, if this project is continued it is under-resourced. Another reviewer agreed that a lot of work was required to actually get to the starting point due to lack of OEM, Tier 1 participation. It was also suggested that as this is a core business for a number of commercial organizations which spend many millions researching this topic, the project budget may be under estimated.

Energy Management Strategies for Fast Battery Temperature Rise and Engine Efficiency Improvement at Very Cold Conditions: Neeraj Shidore (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first commenter agreed that by improving the prospects for PHEVs, and improving the performance of those PHEVs, this project supports petroleum displacement. It was also noted that the quicker batteries and engines reach their optimum operating temperature the greater the fuel economy improvement and emission reductions are to be had. Other reviewers also added that PHEVs have a potential to displace a significant fraction of petroleum fuels and low temperature impacts on battery power and life are important considerations.

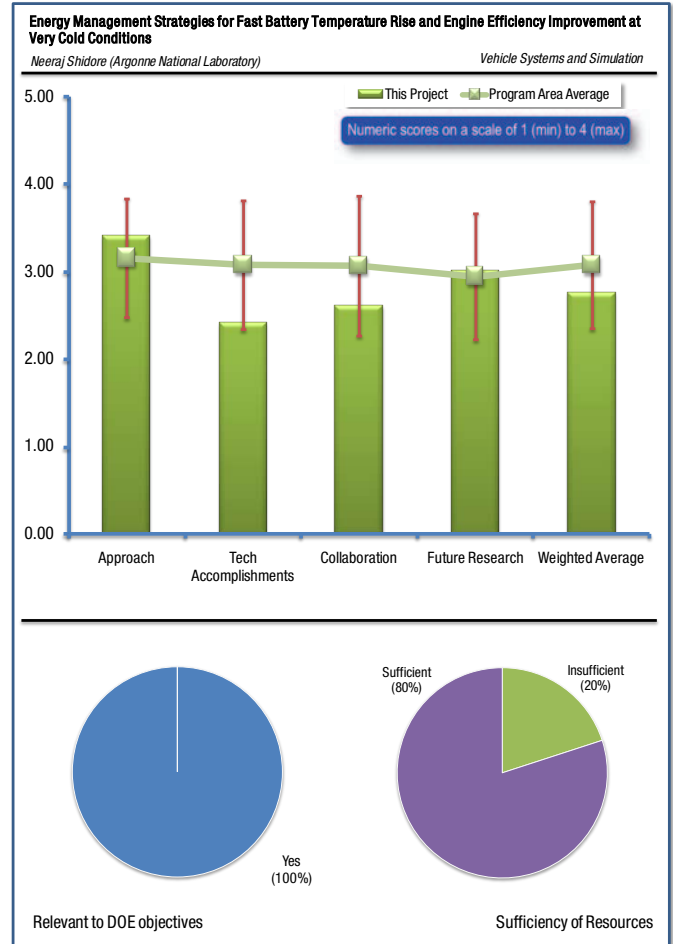
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The reviewers confirmed that the comparison of different energy management strategies to raise temperatures quickly is a logical approach and is a very good combination of battery-in-the-loop with the engine thermal model to get realistic yet workable ways to address the issues. The use of Autonomie is another example of the power of this development tool.

Another reviewer stated that while this project is interesting overall, it is not clear how much benefit is gained from having a battery in the loop. A battery should be much simpler to model than an engine in this regime, so developing a model instead of doing in-the-loop testing would allow rapid test restart, parallelization, and all of the other benefits of model-based design. It appears that the team does not think that battery makers are doing adequate testing of batteries at cold temperatures. However, it appears that they also want to treat the Battery Management System as a black box. The reviewer asked who developed the BMS, and the reviewer wondered how the team knows so much more about operating the battery in this regime than the battery maker. The reviewer has also consistently found the BMS to be the weakest link in the system. It was also noted that this project would be better if battery manufacturers were collaborators. It was not clear how industry may be addressing this issue which the battery manufacturers would know.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Overall, the reviewers felt that this project appears to be showing good progress towards its goal. Specifically, a reviewer commented on the fact that the use of battery in the loop and Autonomie is a well coordinated approach and the integration of the engine thermal model into Autonomie appears to be on track. It was also noted that it seems that base modeling work along the line of the intended outcome is progressing. It was described that more work needs to be performed before a solid outcome can be accomplished. One commenter did mention that the project is well along, but only preliminary results are available; this is due to the complexity of battery-in-the-loop set up time. Now that the system is working, the testing can be executed to generate the main results.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first commented noted that he didn't see strong collaboration, but it doesn't seem necessary for this project given the scope and approach. Another reviewer felt that the combining of other DOE projects (Autonomie and development of an engine thermal model) is a good use of existing work and one that builds upon previous funding exercises. The final reviewer stated that getting component suppliers involved should improve the outcome toward a potential use.

QUESTION 5: HAS THE PROJECT 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?

Overall, it was felt that this project appears to be well planned. It was advised to focus on understanding the different lithium ion chemistries in more detail or pursuing alternate strategies like battery heating while plugged in before focusing on using ultracapacitors. However, another reviewer felt that ultracapacitors have yet to establish a foothold and challenge batteries in the hybrid electric arena. This reviewer thought that exploring this technology on this project would be a valuable study. It was also noted that there's a lot of variation in "conventional" PHEV systems. The final reviewer pointed out that the project is for a one-year duration and is approximately 60% complete. The inclusion of a cabin temperature model is an interesting and novel extension of the project and one that explores the impact to vehicle driver / passengers.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Generally, it was agreed that the resources seem appropriate for the project. However, one commenter did add that the project completion is hampered by funding limits.

AVTA – PHEV Demonstrations and Testing: James Francfort (Idaho National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

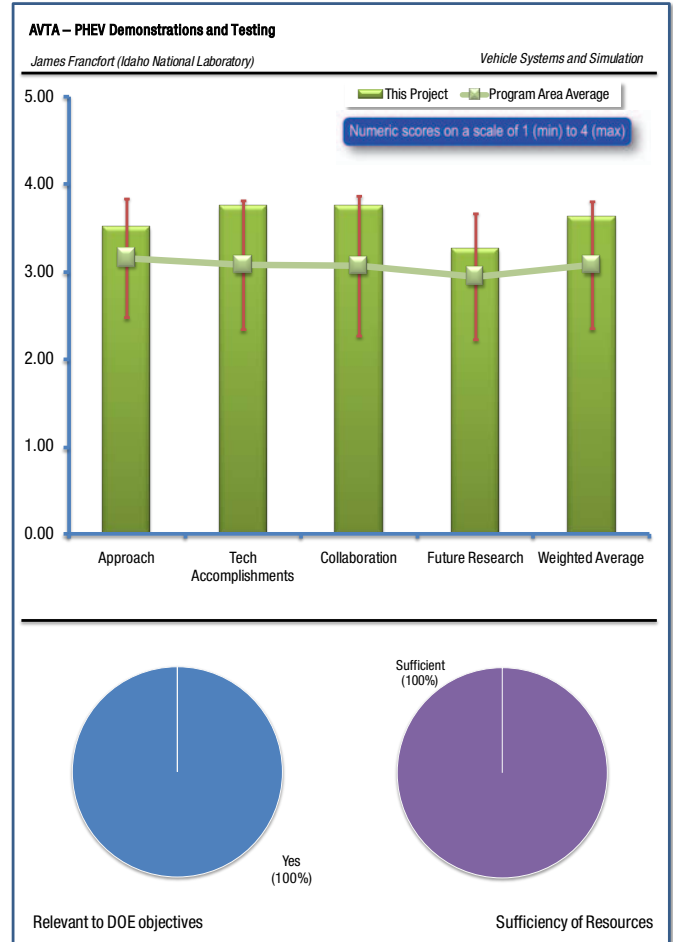
Reviewers stated that this is the most extensive data collection ever on these new technology vehicles. The data will be critical in evaluating assumptions made in the past and assess the real performance of those technologies. It will also serve to modify and tune the powertrain to address issues raised by the project. It will be beneficial to the OEMs and the general public for the successful introduction of these new technologies to the market place. Reviewers also felt that the development and high volume production of PHEV vehicles will help to achieve the national objective of reducing dependence on foreign oil. This program seeks to accelerate the development process and make available key data necessary to refine and bring PHEVs to market. Providing a consistent approach for evaluating vehicles and systems assists not only the vehicle OEMs, but key system suppliers. The program also provides insight to the general public as to progress and status of these developing technologies.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The reviewers stated that this program conducts testing on a variety of new technology passenger cars, including dynamometer, controlled track, accelerated field, and “unsupervised” fleet testing. The fleet testing relies on wireless data transmission and automated generation of test reports. The approach is highly leveraged, resulting in significant data accumulated with a relatively small staff. The fact that the vehicle testing is fairly well distributed geographically is impressive, so that a cross section of conditions and duty cycles may be obtained. The program includes focused testing to understand temperature effects on the battery and the fuel economy of the vehicle. It was also stated that there is some activity intended to understand PHEV charging strategies in the future. It was also agreed that the structure and specific objectives of this particular effort are not clearly understood, based on information provided in the presentation. There appears to be some good data generated concerning vehicle usage and charging times, but how this will be used by the program or the member utilities is a little vague.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

It was the general consensus among the reviewers that providing data and results on 1600 vehicles is nothing short of outstanding. As previously noted, this program is very efficient in generating results with a somewhat limited group of resources. It was also noted that the data also appears to be summarized in a meaningful way that provides insight into vehicle usage, fuel economy based on event or operating condition, and when and for how long vehicles are being charged. While it is clear that a variety of reports are generated, the reviewers were left with two questions: Are OEMs provided with reports and briefings on the results in order to maximize the potential benefit and usage of the data? What is the means of disseminating this information to the public? Such data could help individual consumers make wiser purchasing decisions, as well as assisting OEMs and suppliers in refining technology and systems.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The reviewers all agreed that collaboration and communication with other national labs appears to be effective. In particular, some of the required lab testing is done at Argonne. In addition, vehicle data related to temperature effects is being shared with the battery groups at INL and Argonne to facilitate their battery test and development programs. Other partners include government entities, clean air agencies, universities, and vehicle conversion companies. It is not clear from the presentation the extent to which vehicle OEMs are tied directly into testing, or if they are receiving detailed testing results. This would seem to be an opportunity for improvement. Importantly, a number of utilities are tied into this project, and there appears to be a focus on identifying vehicle to grid issues and helping the utilities to identify potential solutions. It was also noted that having OEMs, other labs and converters all working in a common space is an outstanding result in and of itself.

QUESTION 5: HAS THE PROJECT 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?

The first commenter mentioned that future plans include evaluation of new advanced technology vehicles as they become available. According to the presentation, future focus will be on evaluating OEM hybrid systems. It was noted by the reviewers that this is seen as a very positive move. Data on retrofitted or low volume conversions is interesting, but the future impact to national petroleum usage will be with OEM installed systems. A suggested future activity is continued collaboration with utilities to better refine recharge strategies that will be most cost effective and require the least amount of upgrade to the power grid. This was not specifically mentioned, but may already be part of the plan. Another reviewer also made the comment that flipping through slides that are not presented or explained is not really useful; the team should take the time to pare the presentation down to what can be presented in the time allotted.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

It was felt by all the reviewers that this program appears to be generating significant, meaningful data with relatively few resources, and is perceived to be very “efficient.” Obtaining data on several hundred vehicles and being able to report the results using an automatically generated test report allows for a much larger, statistically significant test program.

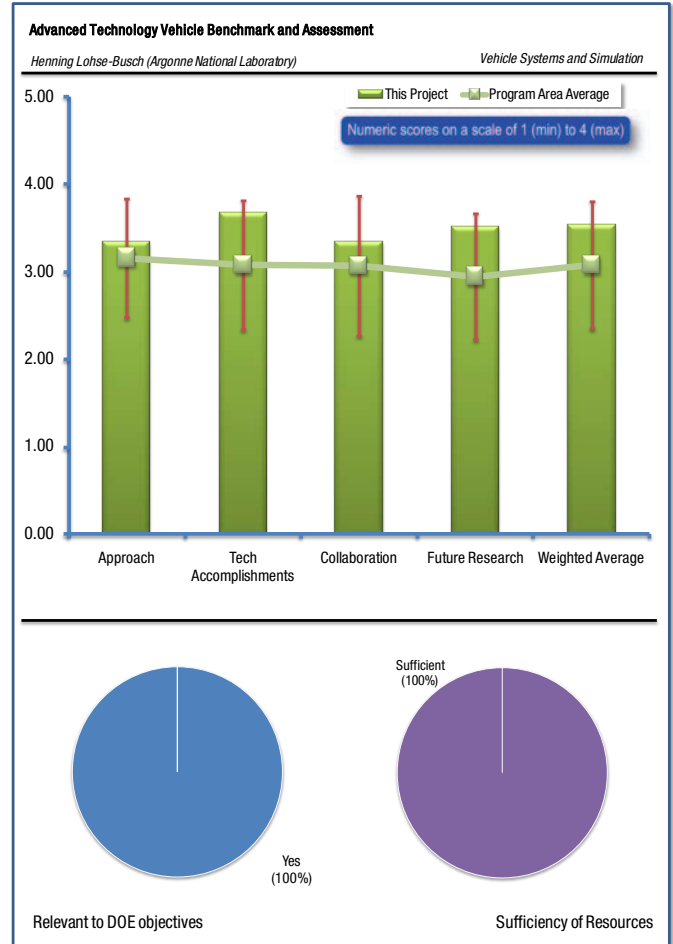
Advanced Technology Vehicle Benchmark and Assessment: Henning Lohse-Busch (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first commented stated that in part, this project provides the baseline testing for the prior project presented, VSS015. The project supports the DOE laboratory and field evaluations of HEVs, PHEVs and EVs, codes and standards development and continued support for model, development and validation (using Autonomie) with test data, EV testing and charging evaluation. All of these activities directly support the DOE VTP mission, and the administration's goals of improved fuel economy (fuel/electricity), reduced emissions, and improved performance in vehicle efficiency. DOE's VTP support of the understanding, improvement, analysis and validation of various EVs, HEVs and PHEV is directly supporting the overall DOE objective of petroleum displacement with new vehicles that will be using alternative forms fuel (electricity). The project objective includes the overarching goal of establishing the state-of-the-art automotive technology baseline for powertrain systems and components through data generation and analysis to displace petroleum.



Another reviewer pointed out that the benefits of new vehicle technology are hard to assess, as many varying factors can significantly impact the results. Having a third party doing a non-biased assessment of product delivered to the market by an OEM is a good way to first check on the claims done by OEMs and second on the real impact of the technologies.

It was also noted that clearly, the development and high volume production of PHEV vehicles will help to achieve the national objective of reducing dependence on foreign oil. This program can facilitate and accelerate the development of PHEV, HEV, and BEV vehicles through data collection and analysis. This effort is invaluable to move the technology to a production-ready state. Work performed under this program provides a consistent means for evaluating competing technologies and systems, and generates data necessary for development and continuous improvement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

It was noted by the first reviewer that the project team leverages a 10 year testing and validation approach working with INL collaborators. The project highlights use of the Advanced Powertrain Research Facility at ANL that carries the ultimate mission to benchmark advanced technology vehicles and disseminate that information to U.S. OEMs, National Labs, and universities. A set of standard test plans is being developed, adjusted for individual vehicles.

Reviewers also pointed out that the project performs laboratory (APRF) and field evaluations (INL,OEM) of HEVs, PHEVs and EVs affecting codes and standards development, development and validation (Autonomie), EV testing and charging evaluation with a set of strong partners including DOE, INL and eTec, USCAR, a variety of OEMs and vehicle components and suppliers.

Reviewers were wondering how coordination of individual systems development includes modeling and simulations is actually implemented. While Autonomie is used for modeling and simulation, it seemed like an enormous task requiring extensive dialog and data. Unfortunately, the presentation at the review was cut short, but reviewers would have liked to see more information on battery options, addition of cost effective, and life-cycle analysis may be helpful to improve the projects and analyses.

It was noted that testing approaches are well documented and rigorous (as noted in the presentation, “refined over a decade”). They provide for a consistent, objective means of evaluating hybrid and BEV technologies and systems. This initiative has access to state of the art instrumentation and test methodology. The Argonne facility is the “center of excellence” for controlled laboratory evaluations of hybrids and alternative powertrains. Two levels of dynamometer testing are available, depending upon whether the objective is basic characterization of the vehicle powertrain, or a more detailed data collection exercise to understand vehicle drivetrain efficiency and/or to evaluate operating parameters of specific system components. Data generated is used by other groups within Argonne and by other national labs. For example, data is used to help validate Autonomie analyses and simulations. Dynamometer data is used to compare with actual fielded vehicle data collected by Idaho National Laboratory. Procedures provide insight to industry organizations such as SAE for the purpose of writing test standards and procedures.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted that the technical accomplishment of the work and use of DOE funding is outstanding. The first accomplishment includes a comprehensive testing overview of various 2010 vehicle models from a range of OEMs, energy consumption and NEDC. The comparative presentation of the data and results is very effective. The selection of vehicles and point of interest for evaluation are complete, logical and appropriate. Value of the state of art hybrid, technology evolution, thermal recovery systems for example are studied in the Prius and Insight: fuel economy, and high speed EV operation are investigated in the Ford Fusion, and the Mercedes is used as the “modern” EV system benchmark, as it uses OEM lithium ion battery packs and associated SAE J1634 development. Fuel economy and energy consumption in label/conventional systems are demonstrated. The second accomplishment includes tracking power splits in hybrid vehicles (Fusion and Prius) and the third accomplishment investigates component life in more moderate hybrids. The accomplishments are met with detailed and appropriate variables for testing and modeling analysis, including details like driver aggressiveness and battery cycling. Another accomplishment of the work at the APRF included analysis of alternative fuels (hydrogen and liquid to coal).

Other reviewers mentioned that this project has completed the evaluation of 14 PHEV vehicles, as well as alternative fuel vehicles. Other accomplishments cited include a detailed evaluation of split power vehicles, understanding tradeoffs of mild hybrids, testing of alternative fuel vehicles, understanding effect of driver technique on fuel economy, and effect of accessories on efficiency (air conditioning). Results obtained in the lab are instrumental in establishing or modifying industry test procedures or standards. Test results have also provided invaluable assistance to vehicle OEMs. To show this, two examples were cited: an unnamed electric vehicle OEMs vehicle development, and Ford's latest PHEV vehicle under development.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first commenter felt that the collaborative team appears outstanding and comprehensive, led by INL, and including USCAR, eTec, OEMs, suppliers, Labs, etc. The only reason the rating is “good” is because access to data has been criticized, and d-cubed commented on difficulty in accessing the INL data. While this is not a show stopper, it has been observed by others and should be noted.

Other reviewers pointed out that this team worked closely with Magna and Ford in the development and refinement of their hybrid systems. As previously noted, collaboration with INL is readily apparent, with ANL performing lab testing on the vehicles subsequently field tested by INL. Some direct feedback is provided to OEMs that may improve system efficiency and/or robustness. This is viewed as a positive in terms of accelerating development and high volume production of these systems and providing a means for continuous improvement. This team has also contributed to the industry as a whole, through development or refinement of SAE test standards.

QUESTION 5: HAS THE PROJECT 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?

It was felt by the reviewers that the proposed future work is logical and appropriate and will no doubt be effective based on past year results. The proposed new work will extend and continue the benchmarking of Vehicles and Components in System Context, and include: possible EVs (Nissan Leaf, Mitsubishi iMiEV, Ford Focus, Ford Transit Connect, BMW, and Think); possible PHEVs (Toyota Prius, Chevy Volt); and possible HEVs (Honda CRZ, Chinese HEV). The future project would also include some APRF facility upgrades that will improve the analysis and testing capabilities, including adding a climate test cell upgrade and 5 cycle fuel consumption testing.

It was also advised that future plans include continued lab evaluation of new or developmental hybrid vehicles, refinement of Level 1 and 2 test procedures, and an upgrade to the climate controlled test cell. Some specific focus areas include a better understanding of temperature effects on vehicle performance and the impact of accessories (heating and air conditioning) on overall vehicle performance. It was also added that future plans should include, where appropriate, increased communication and collaboration with vehicle OEMs to hasten technology development and industrialization.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

All reviewers felt that the budget is strong and appropriate and recommended continued level of funding support for the work. The resources used in the past have been used successfully to achieve detailed and timely results.

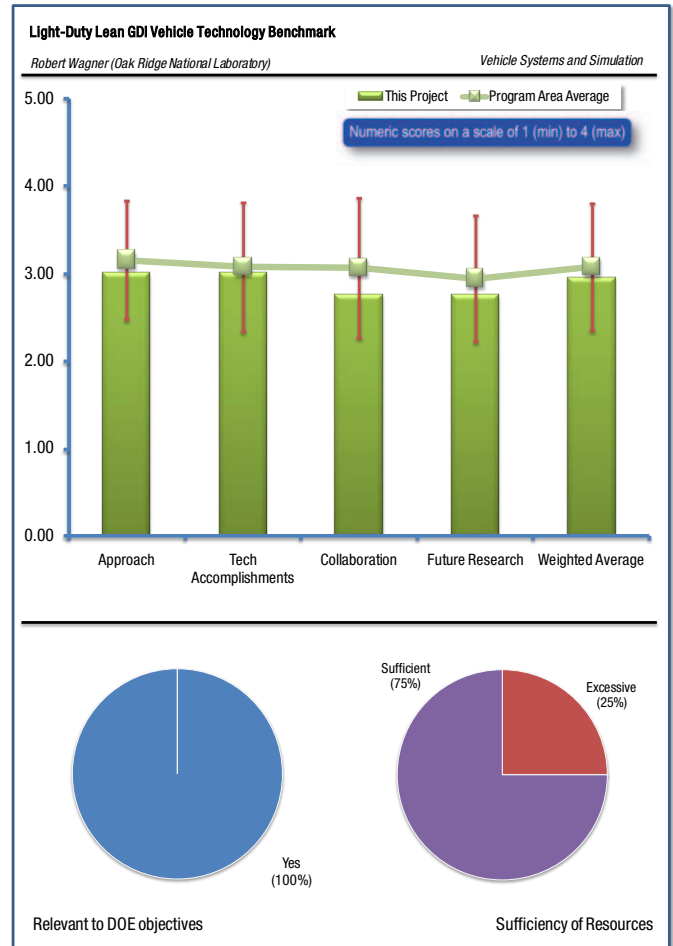
*Light-Duty Lean GDI Vehicle Technology Benchmark:
Robert Wagner (Oak Ridge National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Each reviewer had slightly different comments on this particular question. The first stated that stop-start systems have the potential to improve city fuel economy significantly. Benchmarking competitive stop-start systems would help in developing systems that offer a better return on investment. The second pointed out that the project presented appears to support the overall DOE mission of petroleum displacement by providing benchmark and validation data on performance and emissions of advanced lean GDI vehicles. This technology is not sold in the U.S. at the present time. This work, as presented, may or may not lead to a better understanding of if this technology will actually penetrate the U.S. market space if the technology becomes available here. Regardless, it provides useful benchmarking data for future analysis of performance and emissions of engines relevant to the U.S., and the ultimate displacement of petroleum. Another noted that it met the objectives by showing that lean GDI's benefits must be compared with fuel supply challenges, emissions impacts, and potential usage as lean GDI as a defeat device when users don't fuel with ultra low sulfur fuel. The final commenter stated that lean gasoline direct injection engines offer potential fuel economy benefits but pose emissions challenges in the U.S. This is a one-year characterization task to better understand advanced GDI technology from Europe and use this knowledge for development of simulations, augment dynamometer experiments, and advise future work in this technology area.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first commenter felt that he was not well qualified to comment on the lean GDI benchmarking. However, he was qualified to comment on the stop-start aspect of the benchmarking. He felt that in general the approach is good. However, there is a significant effort underway in the USCAR-TWG (Transmission Working Group) to evaluate stop start in at least two different vehicles. There has been extensive input from all the OEMs regarding the various driving state (and several other variables) under which the stop-start behavior would be studied. Even though the project is well underway, it would make sense to work with the TWG to maximize the potential benefits realized from this effort.

It was also mentioned that the approach to the work is logical and generally effective. The team negotiated and acquired a BMW on loan from GM and performed comprehensive instrumentation and full system vehicle testing. The characterizations and results were used to update PSAT/Autonomie models. The team will combine vehicle benchmark data with engine dynamometer experiments to develop and validate emissions control models for use with lean GDI advanced powertrain vehicle simulations. The approach to the work and process is sound, and will likely help understanding of barriers to widespread use of the lean GDI technology in US market. More discussion and focus of project activities to address barriers to be overcome if lean GDI is to be adopted would enhance this work. Another reviewer pointed out that this is a standard advanced vehicle benchmarking task following conventional testing protocols looking at fuel efficiency and emissions. The focus and procedure for the activity is clear with little task creep.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Many reviewers felt that the comprehensive testing performed is impressive. However, it was questioned if the approach to the testing and data is repeatable, so that the accomplishment can have full impact. The reviewer also questioned how one gets from one mode to another mode, and override to stop/start. It is still not clear whether this will make it to the U.S. market at this point in the project. It was also asked if more vehicles should be studied.

It was also pointed out that technical accomplishments are in line with standard vehicular benchmarking activities. Engine, aftertreatment, and hybrid features were instrumented; three iterations of three drive cycles were conducted; and fuel economy, emissions, and engine operation were characterized. Three different operating conditions were tested: stoichiometric, lean, and lean with stop-start. Lean NOx trap, start-stop, and intelligent alternator were also characterized. There are really no specific technical barriers to the continuation of this task.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer felt that the fundamental collaborations for this work are strong. The team collaborates also with INL testing facilities and ANL PSAT/Autonomie teams. Nicely, the VSATT-Data is available for use by the Vehicle Systems Analysis technical team and was already presented in other project presentations. The Lean NOx after-treatment data will be used in support of the CLEERS modeling activity. There is good coordination between experimental and modeling teams. Another reviewer also thought that the project team presents an interesting collaboration proposed on health effects, but it appears that the comprehensive study is not included in this project. However, it is thought that this might be a nice extension of this work. The third reviewer felt that the access to the data may be significantly improved. It is not clear whether there is a significant overlap with U.S. OEMs and feedback on data (besides the loan from GM). It may be important to consider more collaboration with the U.S. OEMs on data / findings.

Overall, it was felt that the coordination and collaboration seem reasonable with data available to the Vehicle Systems Analysis Tech Team, CLEERS modeling activity, and ORNL Advanced Combustion Engines Programs. INL provided advanced powertrain/vehicle testing support and data will be processed for use in ANL's PSAT/Autonomie simulation models. The project will publish results upon completion in September 2010.

QUESTION 5: HAS THE PROJECT 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?

A reviewer felt that future work seems logical and focused, targeting: 1) helping evaluate the potential of lean GDI engine operation and aftertreatment systems with advanced hybrid powertrains, 2) supplementing dynamometer experiments to develop and validate emission control models for lean GDI powertrains, and 3) exploring opportunities of ethanol use in lean combustion engines.

It was noted by another reviewer that the future work, as presented, was not very clear. However, the team proposes to combine vehicle benchmark data with engine dynamometer experiments to develop and validate emissions control models for use with lean GDI advanced powertrain vehicle simulation, and to focus on ethanol blends and potential opportunities presented by ethanol for lean combustion and emission control.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Overall, the reviewers felt that cost resources appear sufficient or perhaps slightly under-resourced. That said, the vision and impact of the project could be strengthened at which point a stronger budget could be recommended. With a stronger testing and coordination/collaboration plan, the project could potentially grow. Another commenter thought that the \$300K seems a little high for characterization of a single vehicle.

Plug-in Hybrid (PHEV) Vehicle Technology Advancement and Demonstration Activity: Greg Cesiel (General Motors)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

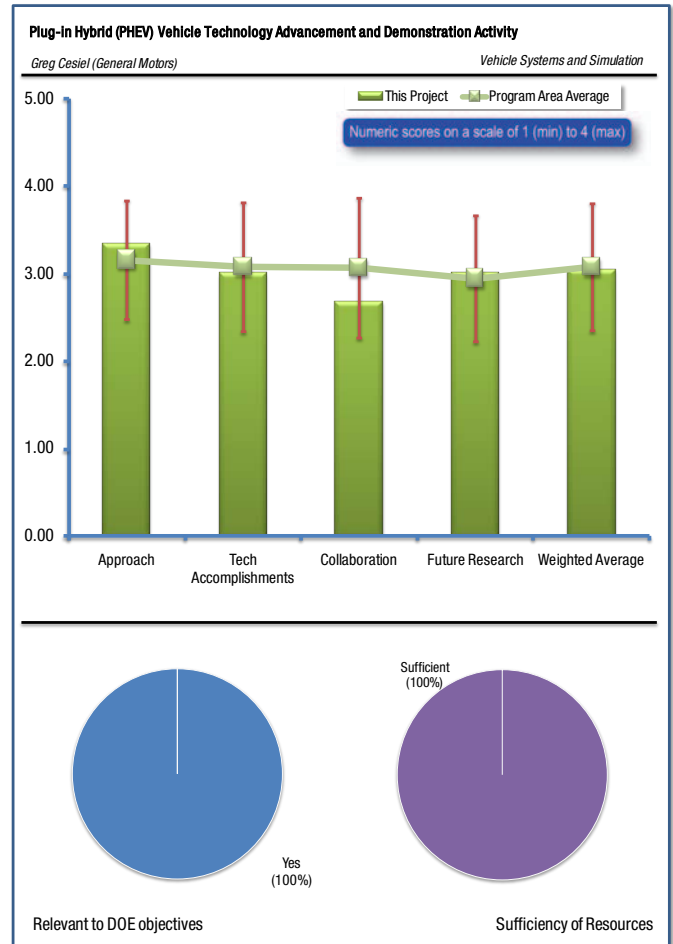
The first reviewer felt that the use of gasoline and E85 in combination with HEV technology definitely addresses the DOE objective of petroleum displacement. It was also felt by other reviewers that PHEVs have the potential to significantly reduce petroleum consumption in light duty vehicles. However, they face commercialization barriers including higher costs, consumer risk aversion, and electric infrastructure challenges. This task aims to address these barriers through development and deployment of 60 PHEVs in geographically dispersed areas with the goal of collecting fleet demonstration data. Information gleaned from demonstration will hopefully lay the foundation for broader penetration of PHEVs into the commercial market. The task incorporates lithium-ion battery technology and E85 flex fuel capable engine technology.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers pointed out that the project makes maximum reuse of Chevy Volt and Dual Mode technology and components. The inclusion of E85 technology appears to be carried across from other GM programs. The transition from NiMH battery technology to the Volt Li-Ion is a natural evolution. It was also noted that General Motors is following a well-proven early introduction strategy for new advanced vehicles. This activity is proceeding from development of mule vehicles, to integration, through validation, and demonstration fleet data collection. Every six months, deep dive demonstration reviews are being conducted with DOE. This PHEV demonstration activity builds upon GM's successful 2-mode hybrid vehicle family. An aggressive implementation schedule is being conducted with appropriate safety testing and user feedback mechanisms. The final commenter felt that this approach is straight-forward OE. However, what we don't see in this presentation is any of the details and targets of the vehicles being met.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first commenter did notice that the presentation contains very little technical and timing detail. Only events completed were discussed, and no future dates were included. Initial progress appeared to be on track until the issues associated with the dropping of the Saturn brand and the shift to a new platform introduced additional work to the project scope. Another reviewer felt that, currently, this task is significantly ahead of schedule. It appears all major development activities are so far on track or completed and have met or exceeded technical targets. Cold weather testing exceeded specs using both gasoline and alcohol fuels and the plug-in charging system has proven effective in both cold and hot temperatures. OnStar data collection has been customized to meet DOE reporting requirements and virtual modeling and simulation of vehicle hardware has been completed. It was also mentioned that reviewers would have liked to have seen more data on engines, fuels, fuel economy, and emissions.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first commenter pointed out that, clearly, this project is commercially sensitive and GM has kept the majority of the details of this project in house. The only collaborations are with University of Michigan-UMTRI for fleet feedback and ABCD for advanced research. The DOE 60 vehicle demonstration fleet was discussed during the Q&A session, but no timing or location details were provided. ANL was identified for future collaboration, although this looks like two weeks of testing rather than partner participation. It was also mentioned by a reviewer that they really liked the collaboration with U of M, and ANL.

It was also noted that this task has 80+ percent non-governmental cost share—no additional funds have been requested of DOE. The effort is coordinating with the Michigan Economic Development Corporation (MEDC) for funding, University of Michigan Advanced Battery Coalition for Drivetrains for research, and University of Michigan Transportation Research Institute (UMTRI) for consumer behavior research. The project is also coordinating with ANL for fuel economy and emissions testing in the fall of 2010. The final reviewer did point out that as a critical barrier has been identified as the interface and interaction with electric grid, an additional project partner such as an electric utility or EPRI may be of benefit.

QUESTION 5: HAS THE PROJECT 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?

The first commenter mentioned that the change in platform was identified as an additional challenge; otherwise, future work is contained within the program scope. It was also noted that, unfortunately, the elimination of the Saturn nameplate will require GM to rework a number of the activities under this task which has the potential to erase the schedule progress achieved to date. On the surface though, given that the task has been way ahead of schedule, it appears likely to meet the original schedule requirements using a different model as the vehicular platform. It was also mentioned that this program is continuing to move forward, but it would be nice to see some baselining compared to what DOE is collecting on competitive vehicles. It was expected to see 60 vehicles in test, but the reviewers were surprised not to have the additional details on expectations of consumer behavior and final placement of vehicles.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers agreed that it was difficult to determine how much funding was needed; it was assumed that it was contained within GM program resource commitments.

Ford Plug-In Project: Bringing PHEVs to Market: Greg Fenette (Ford Motor Company)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers stated that plug-in hybrid vehicles offer a significant opportunity for reducing fuel consumption, with a corresponding reduction in emissions. This project incorporates lithium-based battery technologies and flex-fuel engine capabilities in which a large percentage of the vehicle's energy consumption would come from domestically produced fuels. This program also supplemented Ford internal efforts to bring a plug-in hybrid car to market at an accelerated pace.

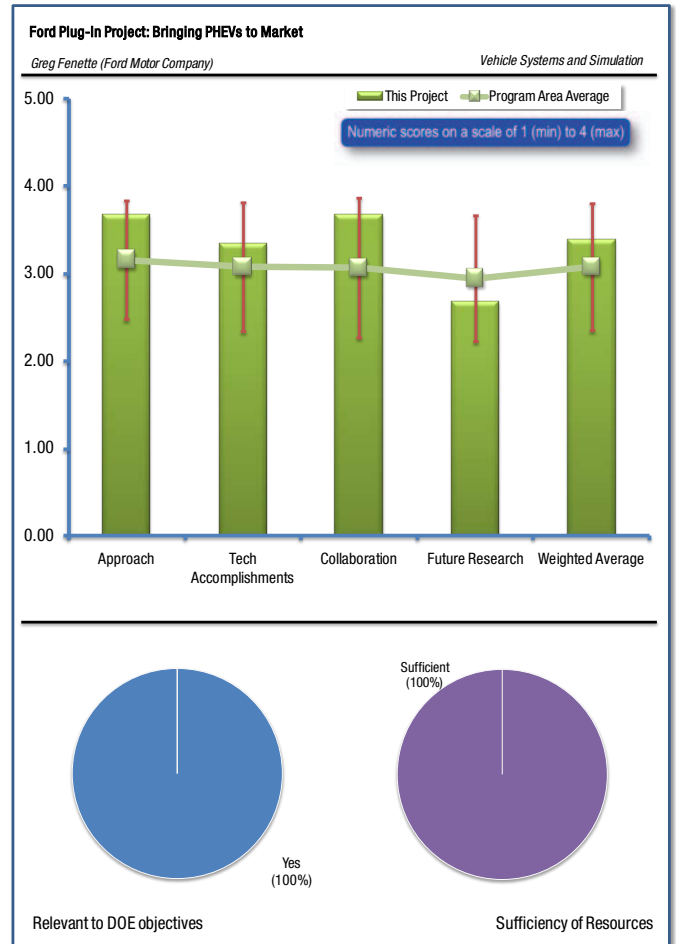
It was also noted that this project identifies a sustainable pathway toward accelerated and successful mass production of PHEVs to get to the 2012 launch. However, the reviewers would like to see how much petroleum this would displace at various volumes of vehicles and over what time period of expectation to sell into the marketplace.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers agreed that the technical approach appears to be sound, with the program working through a number of technical challenges in a very expeditious manner. The scope of effort included design of propulsion system, hybrid control system, development of vehicle to grid communications, selection of a battery supplier and subsequent development of battery control systems, laboratory testing to quantify fuel economy benefits, and finally, a fleet evaluation program, consisting of 21 vehicles released throughout the U.S.

Another commenter pointed out that Ford is following a logical, technical progression in developing and deploying their fleet of 21 PHEVs. The project's strong interest and coupling via deployment with various utilities is especially attractive. The active emphasis upon Smart Meter and two-way V2G and G2V communications as part of the deployment is excellent. Additionally, the human machine interface is very appropriate. Ford is also using their well-developed base of utility partners to conduct extensive public education. Ford recognizes that in many ways the successful development and commercialization of PHEVs is as much a consumer perception and marketing challenge as a technical challenge.

It was also stated that the first 10 vehicles were built with Ford built battery packs while the rest of the fleet has JCS batteries. Ford has also increased the Escape engine size from 2.3L to 2.5L, seemingly the opposite direction of what expected. The reviewer also had some questions including: How many different combinations of updates are you currently fielding? What was the increase in the weight of the vehicle that is PHEV vs Base vehicle? What are the metrics that are being monitored wirelessly? (that are also provided to DOE and what is DOE doing with this?) It would also be helpful to note how much it costs to field a vehicle.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted that it appears that excellent progress has been made to date, assuming that this activity began in 2008. Completing vehicle design, prototyping, lab performance testing, along with field testing of 21 units indicates that the efforts have been focused and well managed. The list of accomplishments aligns well with stated project objectives, and it appears that the project is tracking to an on-time completion.

Another commenter included that Ford is demonstrating a steady stream of technical and programmatic accomplishments including vehicle design and build, implementation of two-way communication on all vehicles, implementation of flex fuel calibration and strategy, and improved vehicle/battery robustness at cold temperatures. Broadband wireless data collection has been implemented. Additionally, the human machine interface displays are very appropriate. All 21 fleet vehicles are on the road racking up miles and have not demonstrated any battery problems. The feedback received from utility partners to date has been very impressive with regards to all electric range and drivability. The project is under budget and on schedule for completion in June 2012 and preparation for commencement of mass production that year. The detail included in this presentation was appreciated.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers noted that Ford has worked with DOE on aspects of development, although the specific areas of collaboration are not clear. Understandably, much of the development work has been conducted in-house. The only government activity specifically noted was the fuel economy testing conducted at Argonne Labs. It was also pointed out that Ford had identified battery cost and charge time as technical barriers. To address these barriers, Ford brought on Johnson Controls - Saft as their battery supplier during Phase 2 of the program and approximately half of the 21 vehicle fleet uses the Johnson-Saft batteries. A number of electrical utility companies are also listed as partners, presumably for the V2G and G2V development activities. Another commenter also mentioned that Ford's network of utility partners is especially impressive and is being leveraged appropriately. A strong outreach effort is being made with agreements reached with 10 partners for demonstration. Ford has also been working closely with Johnson-Controls / SAFT early on to improve and implement their lithium-ion based battery technology into the second half of the demonstration vehicles. The final reviewer reported really liking the fleet location map and mix of customers. What he didn't report seeing is the interaction with DOE on this project and what it means. He also had questions about what type of costs the fleets are taking on.

QUESTION 5: HAS THE PROJECT 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?

Future activities included additional fleet vehicle deployments, improvements to system and battery controls, continuation of V2G and G2V communications evaluations, collection of data from fielded vehicles, usage of data to guide design of production configuration. The program finish is noted as 2012; however, it is unclear if this equates to production implementation or completion of design phase. It would seem that a much greater number of field vehicles should be deployed to gain sufficient confidence in system reliability. It was also stated that lessons learned from this project will serve the next stage of PHEV mass production/marketing and feed Ford's full battery EV program. The final commenter pointed out that in 2012, the product vehicle design needs to be frozen to move into production. However, he had questions about whether it is the end game or if there are additional items that are for Future Research.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

It was noted by the reviewers that, apparently, significant resources have been devoted to this critical program from Ford. That said, funding amounts seems rather low, unless technology developed for other programs is being leveraged here. As previously noted, given the early-on production date, it would seem that the fleet testing must be significantly expanded. It was stated that the availability of DOE funding was a significant enabler for (or at least accelerated) the development of this vehicle. Another reviewer felt that resources for this task are sufficient and that overall, this is a well designed and implemented PHEV development and demonstration activity. The final reviewer did mention and a very good job was done on the presentation.

Heavy Duty Vehicle Modeling and Simulation: Aymeric Rousseau (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt that modeling and performance analysis of heavy vehicles provides insights into improving designs and operations leading to fuel savings. The second pointed out that a significant fraction of petroleum based fuels are consumed in HD vehicles, so technologies to enable lower fuel consumption directly support this DOE program objective.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

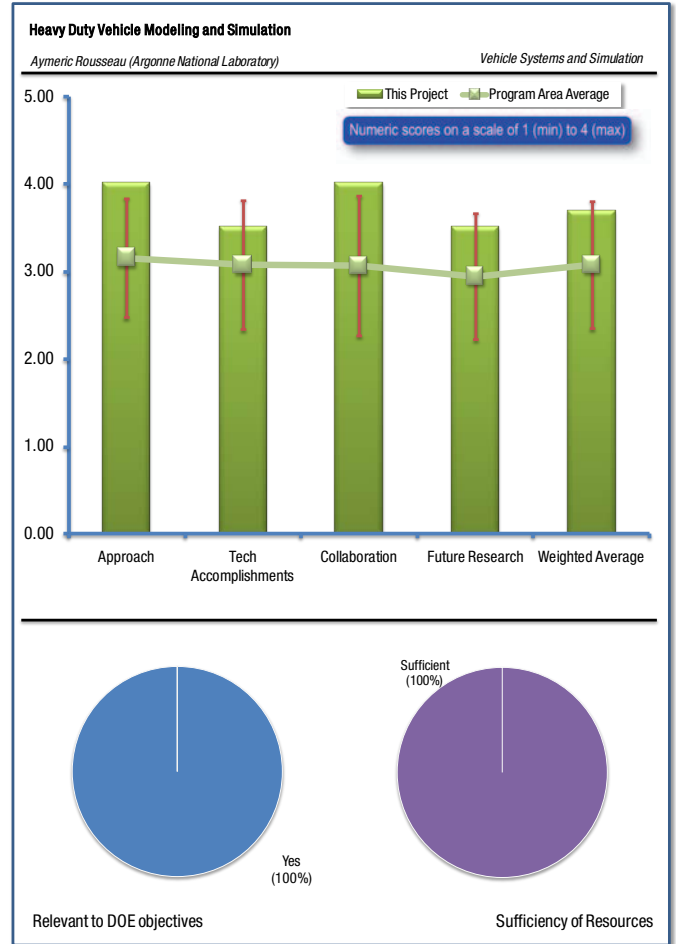
Reviewers felt that the modeling and analysis scenarios seem to be right on, tasks and milestones are clear, and accomplishments are specific and are aimed at addressing the barriers. It was also noted that collaborations are appropriate and both sides are providing value. There was also mention of a very good approach to integrate data, models, simulation, and validation to improve vehicle design and guide R&D efforts. However, it was requested that the project team identify the potential for fuel consumption reduction for each class of vehicle and each technology applied, including control strategies.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers felt that the team has made very good progress toward the end of this project on achieving objectives. Some early results are already identifying operational methods leading to fuel savings. Accomplishments are clear and measurable and provide value to DOE and the project's partners. Assessing the potential improvements in efficiency in terms of meeting the basic function/mission of the vehicle, air conditioning loads, hybrid component losses versus other improvements, and the impact of basic versus advanced control strategies would also be useful. Drive cycle and driver behavior are also areas of interest (as noted in future research).

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

It was felt that excellent use of partnerships for access to vehicles, component data, and validation data was executed. The list of collaborators is very reasonable, they appear to be working well with the PI to provide necessary modeling and operational data, and the project is providing useful information back to the collaborators. Reviewers also mentioned that, perhaps, the project team should consider more coordination with EPA to at least begin to assess impact of these technologies and control strategies on in-use emissions.



QUESTION 5: HAS THE PROJECT 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?

Reviewers felt that future work is expected to provide more of the same good work with specific accomplishments and milestones, overall very good work. Even though exhaust emissions are not part of the scope of modeling, it was requested that the project team consider partnerships that can address this issue, and include emissions where possible in any validation data effort.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers felt that the funding appears to be sufficient but at the same time somewhat modest for the new modeling and analysis area. Heavy vehicles are complex and cover a wide array of configurations. It was also mentioned that maybe this effort should be expanded.

AVTA HEV, NEV, BEV and HICEV Demonstrations and Testing: James Francfort (Idaho National Laboratory)

REVIEWER SAMPLE SIZE

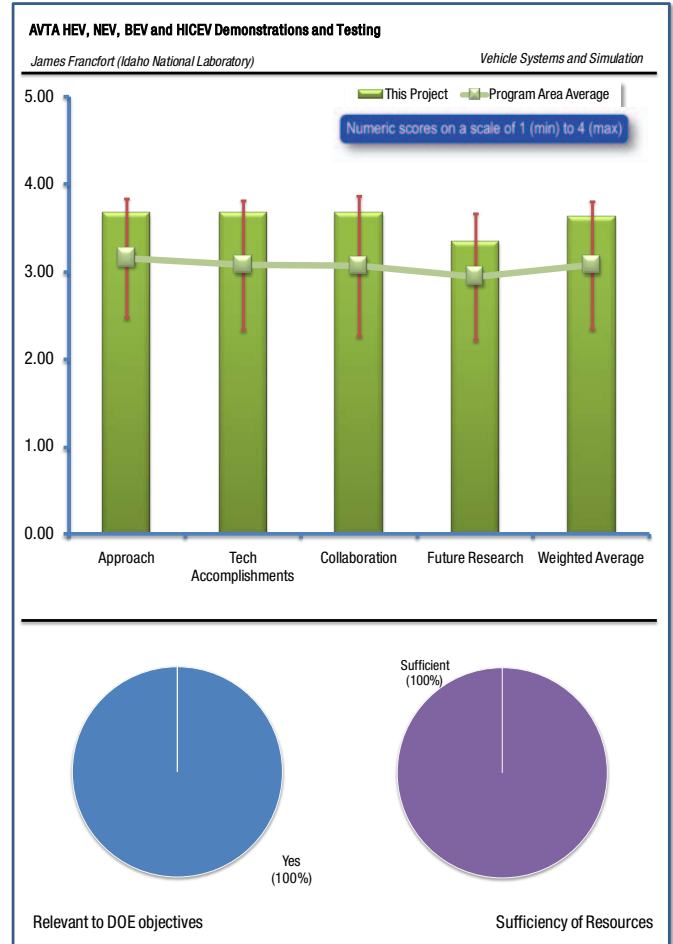
This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers felt that by providing accurate and timely test data, the project promotes the use of petroleum reducing alternatives. This project also provides the public with invaluable information to educate them on the performance and reliability of these new technologies.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first commenter noted that this project does not work on “reach” technology, so it is not particularly focused on technical barriers. However, the data warehousing and processing required to test this many vehicles is an under-appreciated challenge, and the project team is doing a good job of scaling with the needs. It was also stated that this is not a technically intensive project; the test protocols and how to manage the program are the greatest management challenges. Consistent application of the protocols seems to be the well done. Another reviewer has a concern when the answer is, “I don't have enough money to do the project.”



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

All reviewers agreed that the testing appears to be on target. Again, the focus is not on ambition but on execution, and the team appears to be doing an excellent job of keeping a diverse activity under control. The consistency of the information and its relevance are how the barrier of public confidence is being overcome to the use of these new vehicle systems. Again, the number of vehicles and the mileage accumulation is useful. It will be nice to see how the Leaf project progresses and if this can be compared to Nissan's project in Israel.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers felt that there is excellent collaboration with partners within DOE and with external partners. It was also noted that significant collaborations for funding and equipment exist here that leverages massive capability to generate the information that is being provided to the public. It was also felt that this information is useful as it gets disseminated. One reviewer would also like to learn more about the work that is being done with Canada, due to past experience there.

QUESTION 5: HAS THE PROJECT 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?

The first commenter mentioned that there appears to be a good plan in place to continue testing. Another reviewer also felt that the project team should look at a study that will show how real world driving may change battery system reliability and durability vs this

accelerated drive schedules. Accelerated mileage accumulation is a benefit to battery life and it would be of great interest to see if actual usage is in any way different from this accelerated mileage method. It was also stated that another commenter did not like to hear the complaint of being “budget constrained.”

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers felt that funding appears to be good and management seems to be adequate for funding increases already in the pipeline. It was added that it would also be nice to see the actual manpower on these projects.

CoolCab Thermal Load Reduction Project: CoolCalc HVAC Tool Development: John Rugh (National Renewable Energy Laboratory)

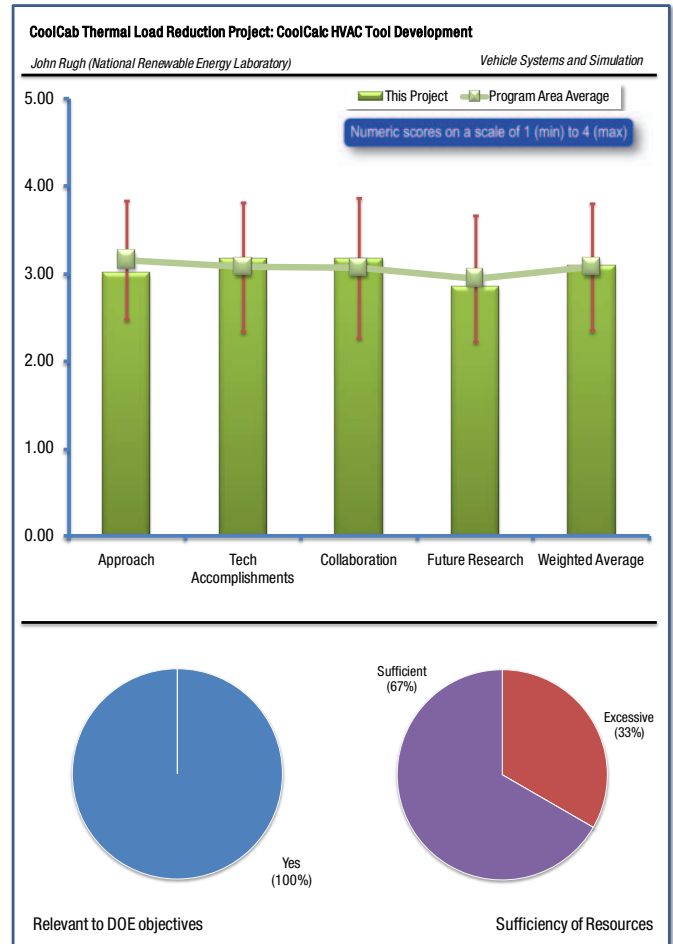
REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

All reviewers felt that this project fulfilled the objectives and that CoolCalc may prove to be a useful tool for evaluating thermal conditions in the truck cab leading to better thermal designs aimed at reducing fuel consumption by reducing truck idling periods. It was also stated that the main effort is to develop test methods rather than actually reduce load, so that it is a support effort.

Another commenter mentioned that reducing idling of heavy duty trucks can save millions of gallons of diesel fuel per year. One of the biggest barriers to reduced idling is the inability of some idle reduction technologies to meet performance requirements over widely varying temperature ranges. Especially challenging is the need to keep the truck cab cool in high temperatures over extended time periods. If the load can be reduced, via any of a number of thermal management strategies, the capacity and cost of idle reduction systems can be reduced thereby greatly increasing their market viability.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Overall, the reviewers agreed that the development of an easy to use tool with standard available software (freeware) is a great approach. One reviewer noted that this project makes use of existing code and tools resulting in an economical approach. However, it is not clear that the truck sketch is best approach; instead, the user could just be given an option of typical truck designs. The model does consider heat transfer coefficient and infiltration, but the user must “guess” at some values. It is evident that the presenter is aware of ways to expand the approach using more fundamental methods, but it is not clear how deeply the project will consider these. Another felt that the approach to this task is reasonable and methodical starting with the need to reduce the thermal load on the cab, identifying a modeling pathway, validating the model through field testing of actual truck cabs under varying thermal loads, integration of an air conditioning model, and sharing of the model with industry partners. The final reviewer pointed out that the project uses the top down approach, combining analyses and testing. The modeling system is physics based, no mesh modeling, with convenient input/output and the results are compared with experiments for validation. This modeling system allows modifications to designs to accomplish the thermal goal and it is linked to DOE database of weather for thermal boundary determinations.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first commenter noted that the importance of a user friendly interface to running the program tends to be underestimated in many of the research programs; however, it is quite the contrary here. The overall package looks very good. He also noted that he is looking forward to trying out the CoolCalc tool in the near future. Another noted that the project is on schedule.

The third reviewer felt that a real A/C model will be very complex, particularly when the heat rejection couples with the engine heat rejection & aerodynamic factors. Several test projects have been completed, and these are accomplishments, but a holistic model (as opposed to a vision of many options) is needed. However, the work done is still very valuable. It is good that CRADAS are executed.

The final reviewer pointed out that overall; the task has progressed but has taken a long time. The project was initiated in 2006 and only now a beta version of the tool is becoming available. For the length of time the task been active and funding expended to date (nearly \$2M), technical accomplishments have been somewhat sparse. Technical accomplishments surround CoolCalc tool development and heavy duty truck cab instrumentation and testing with results used to validate CoolCalc.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers felt that the project has a nice collaboration network with industries for testing and feedback. It was also noted that the partners have provided access to truck cabs enabling the project to measure thermal conditions and validate modeling efforts. One commenter did point out that the cooperation has been with trucking companies only. This tool is a general purpose tool that could be used for other applications as well. It may be worthwhile to consider involvement of the automotive OEMs as well. The final reviewer noted that the task has been coordinating with several heavy duty truck OEMs (PACCAR, Volvo, Freightliner, and International) and a fleet and idle reduction technology equipment manufacturer. It is disappointing that after five years it appears no industrial cost sharing has been procured, which lends doubt to how badly the truck industry is really interested in this tool. Primarily the truck OEMs are lending a couple of their vehicles to be instrumented in order to help validate CoolCalc. The project indicates that a primary barrier is the industry lacks key performance data on HVAC loads and truck cab thermal load reduction technologies, which may not be completely true.

QUESTION 5: HAS THE PROJECT 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?

The first commenter noted again that if some cooperation with automotive OEMs could be achieved, it would be worthwhile to use some of the passenger car/SUV information to validate the model as well. It was also mentioned that there is a need to define confidence of predictions, perhaps with a parametric study.

Another reviewer felt that the proposed work is appropriate to bring the development of CoolCalc to a relatively mature, validated and usable state. Other than any additional generic and essential improvements that may be identified, application of CoolCalc should be turned over to the OEMs and/or HVAC vendors for their use. NREL's long term scope should be to develop new essential models (if any more are really needed) and code validation. Specific evaluation and designing of truck cabs should be left to the OEMs. The extent to which the OEMs utilize and/or provide financial support for CoolCalc will substantiate its value to DOE and the OEMs for thermal load reductions leading to reduced fuel consumption.

The final reviewer stated that proposed future research includes applying CoolCalc tools to testing, and working with industry to improve idle reduction technology. The DOE is no longer in the idle reduction technology business as primary responsibility for this was transferred several years ago to EPA. As a force multiplier, thoughts should be given to transferring the technology to other vehicular applications such as transit and school buses. Efforts should be made to obtain cost sharing from non-DOE sources, to comprehensively identify (with truck OEMs) the universe of barriers to widespread commercialization of thermally enhanced tractors, and a task end game established bringing the task to conclusion no later than 2011.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first commenter mentioned that the budget is sufficient to large and that NREL has the ability to address driver comfort more precisely (model, spatial variation), and if this is done, resources are well matched.

Another reviewer felt that the project has produced reasonable results through its fifth year of an eight year schedule. The budget appears reasonable and adequate and the project should be looking for additional OEM support as CoolCalc matures and becomes a viable design tool. The project had a big increase from its FY09 budget of \$300K to its FY2010 budget of \$900K. Given CoolCalc's

apparent near-maturity, DOE should consider reducing the budget back to about \$300K to support additional essential model development and validation. It was also noted by another that this task is overfunded and should be scaled back significantly.

The final commenter pointed out that concerns surrounding this task include the lack of cost sharing from non-DOE entities, no definitive project end game, and questions as to what is really needed for industry to broadly implement thermal enhancements in heavy duty truck cabs. For example, even if a highly accurate tool (say CoolCalc) is available for determining HVAC loads and appropriate mitigation strategies—will this lead truck OEMs to broadly implement improved insulation strategies, glazings, IR reflective materials, and so forth? Or are there other business barriers such as cost and return on investment, weight, driver preferences, etc. which are the real show stoppers? A very frank dialogue with truck OEMs is necessary if it hasn't already been conducted in depth to truly understand the business barriers to widespread commercialization of thermally advanced truck tractors.

Plug IN Hybrid Vehicle Bus: Jan Friesner (Navistar International Corp.)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

It was noted by a reviewer that school buses are potentially attractive vehicles for electrification, given their start-and-stop duty cycle, consistent and centralized refueling pattern, and ability to accommodate hybrid-electric systems equipment. While school buses don't account for a significant fraction of the country's petroleum use, they offer the opportunity to clean up the air around some of the country's most vulnerable citizens (children) and provide a visible platform to promote awareness and acceptance of advanced vehicular technologies.

Another noted that if the claims made by Navistar of 1400 gallons per annum of fuel use reduction are realized, then it would meet the objectives; however, no info on how that may happen was provided.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

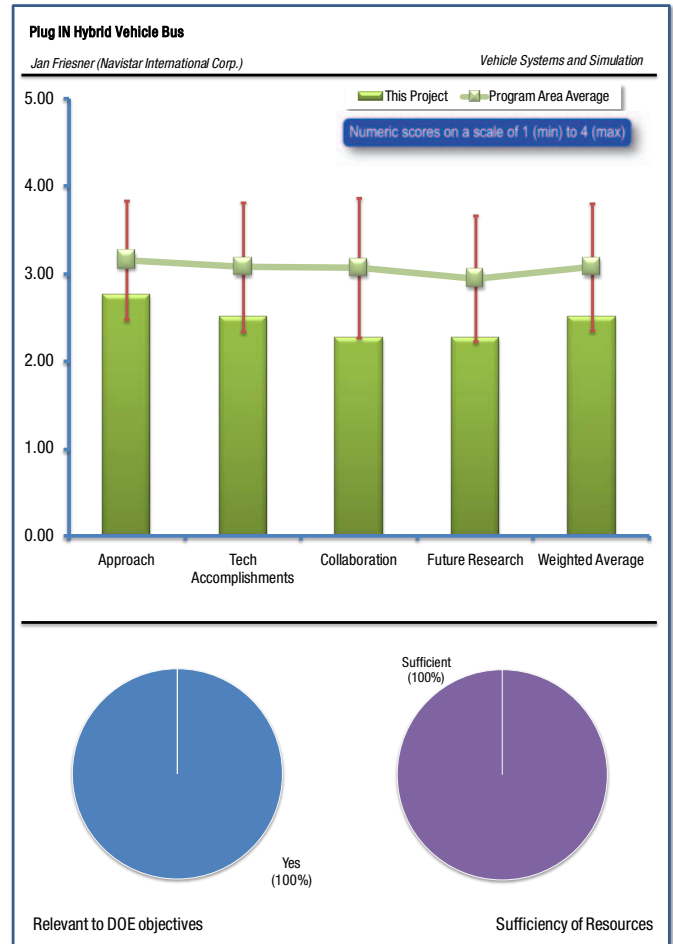
Reviewers felt that since the project has only been ongoing for the past few months, reasonable progress has been made. However, one reviewer did feel that not enough information was provided to evaluate it and the program has too much proprietary information to evaluate it to any degree of depth.

Another commenter noted that the overall approach of looking at both parallel and series configurations, constructing two buses of each, and testing at least two battery types in each configuration makes sense. Also, focusing on 30 miles electric range, from 0 - 45 mph, is appropriate to maximize the potential benefits for the majority of bus routes while minimizing storage requirements. The approach of publishing cost targets to promote competition from suppliers is especially attractive.

The final reviewer stated that the presentation listed the technical barriers but did not elucidate exact plans to address them and there was absolutely no discussion about addressing the cost barrier. PHEV battery packs for automobiles are estimated to add \$20,000 to the cost of an vehicle, so a much larger battery pack for a school bus will most likely cost a lot more. Not much was said about availability, integrations, and potential reliability problems that were identified, but no real plans were presented to address reliability. The reviewer also noted that it's not clear how many PHEV buses will actually be constructed and tested. Parallel- and series-hybrid configurations were stated and "at least two [unspecified] battery types." So this could be two buses, four buses, or maybe more.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

While the reviewers all agreed it may be a little too early to tell, accomplishments seem roughly in line with the current early stage of the project. However, it was noted that it does appear that the project may be slightly behind schedule.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers did note that other than stating that bids were received to test the batteries and perform emission testing and some uses of DOE lab simulation elements, no collaborations were cited. Another commenter pointed out that outside of battery and fuel economy and emissions testing, it is not clear who other project participants are. It may be appropriate to include another manufacturer experienced with hybrid/electric systems for medium-heavy vehicular applications, NREL for their intimate knowledge of duty cycles and recent PHEV school bus project with Enova, and possibly make exploratory inquiries with bus manufacturers about innovative bus construction designs that may facilitate application of advanced PHEV systems. A holistic approach examining not just application of hybrid electric systems but the entire bus structure could lead to advances or breakthroughs from a cost or functionality perspective.

QUESTION 5: HAS THE PROJECT 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?

Reviewers felt that the time frame for a point solution-based demonstrator program seems to be practical according to industry standards. It was also noted that the short-term planning for the next few months seems OK, but the long term planning was short on details. The final reviewer agreed by adding that the proposed future research is somewhat generic focusing on fuel economy, emissions, and durability testing as well as public awareness events, including ride and drives.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers had only limited information on the funds available for this project and as such were limited on their input. However, one reviewer noted that in the presentation it was never stated how many PHEV buses would actually be constructed (2? 4? More?). He also noted that the resources were not really discussed, but one would assume that Navistar should be able to convert a few buses into PHEVs and evaluate them for nearly \$20M. Another reviewer felt that the task is sufficiently funded and 50% industry cost-shared.

*Standards for PHEV/EV Communications Protocol:
Michael Kinter-Meyer (Pacific Northwest National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

It was widely agreed, by the reviewers, that the project as proposed will support the overall DOE objective to reduce petroleum displacement by proposing to improve standards and communications protocols for PHEV/EV vehicles. Such data on PHEV/EV could indirectly support the use and acceleration of new/more PHEV/EV into the US market space. Another added that greater integration and standardization of grid connectivity is essential as the number of vehicles increases.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

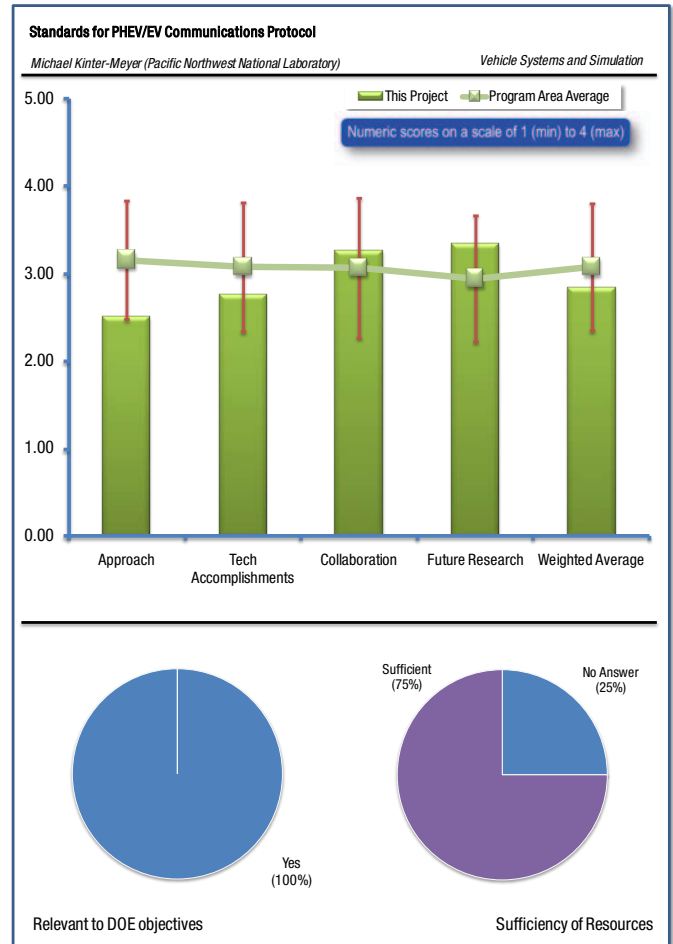
The first reviewer commented that there does not seem to be a clear goal or approach. Although contributing to the standard development is useful in itself, it is not clear what unique work PNNL is doing, and why this work is critical to the overall effort.

The second reviewer felt that the project attempts to make an important impact on the proposed project: developing standards for PHEV/EV communications and protocol. This could be important work including validation of standards, multiple data variables, and states of charge. Effectively communicating this data would also be critical and linking IEC with SAE activities. However, at present, while these important project objectives are stated, the approach to the work may not be as effective as necessary to achieve the planned results. The approach to the work presents a methodology but lacks a demonstration of the implementation of the approach. The project promises to build a “VGC Virtual Testbed” to test validation procedures for VGC. This requires collaboration with industry partners and it is not clear as presented that this will be accomplished.

Other commentators noted that it is a good approach but only focuses on the passenger car industry and has not given any consideration to commercial EVs. It was also mentioned that the project appears to understand the status quo and its short comings and has identified plans to correct them.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

It was noted that, given the early state of the project, it is difficult to evaluate progress, but it seems that adequate progress is being made. Another reviewer noted that, as stated above, while the methodology of the work proposed is fundamental, implementation strategies for the work appear weakly coordinated. This lack of implementation does appear to demonstrate and realize the potential impact of the work. There does not appear to be much data to support results yet in the project. Equipment is being purchased for the work. Perhaps it is still too soon in the project for comprehensive results. The work is certainly potentially important to document limitations and visions in EV distribution, and data would also be useful for medium-duty vehicles for SAE.



The final reviewer added that the project appears to have only considered individual vehicle charge situations and should be expanded to include multiple vehicle charge stations operating at same time, such as parking structures etc. Interesting use of ZigBee (something the reviewer had not come across previously). Subsequent research suggests that this technology is a good fit for this application.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers felt that the project team has put together a good collaborative team including a standards body, an OEM, a utility company an EVSE supplier, and a national lab. However, it was mentioned that collaboration and coordination is the core of this project, but it's not clear what the specific plan is to achieve this.

Another commentator noted that the collaborators on the work appear to be strong and include the Society of Automobile Engineers, Argonne National Lab, Ford, Echelon, Coulomb, and DTE Energy. However, as stated above the coordination and implementation of the project remains weak. The effectiveness and potential value of the collaborations is not realized.

QUESTION 5: HAS THE PROJECT 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?

Reviewers felt that the lack of a coherent plan is again a problem in evaluating this. It seems that there is a plan to create the test bench; however, reviewers were unsure how critical this is to the overall effort, and how the other partners will be incorporated into this process. It was also added that the project's stated future work ends at the end of this fiscal year with the expectations that it will all be completed.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

It was generally accepted by the reviewers that the resources seem to be adequate for the proposed work. One commentator did mention that it is difficult to determine; however, it is assumed as project duration is so short that resources are appropriate. Another reviewer agreed by adding that the budget and collaborations should be sufficient to complete the stated work scope as long as the collaborators all participate in a timely manner.

Integration Technology for PHEV-Grid-Connectivity, with Support for SAE Electrical Standards: Theodore Bohn (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Overall, the reviewers felt that by assisting the deployment of PHEVs, this work supports the objective of reducing petroleum use. It was also stated that adequate infrastructure, vehicle-to-grid integration and standards are important for success in PHEV acceptance and commercialization which leads to reduced petroleum usage.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer mentioned that this is a collection of projects and tasks that appear to be making good progress although it was difficult to evaluate because of the diverse nature and number of activities. However, the second identified barrier in part states "Alternative approaches exist..." If it is truly the case that alternative approaches exist, it is difficult to understand how this is a barrier. It was also noted that the development of clear industry standards is a must if the DOE is to manage the future power requirements for an increasingly electric national fleet.

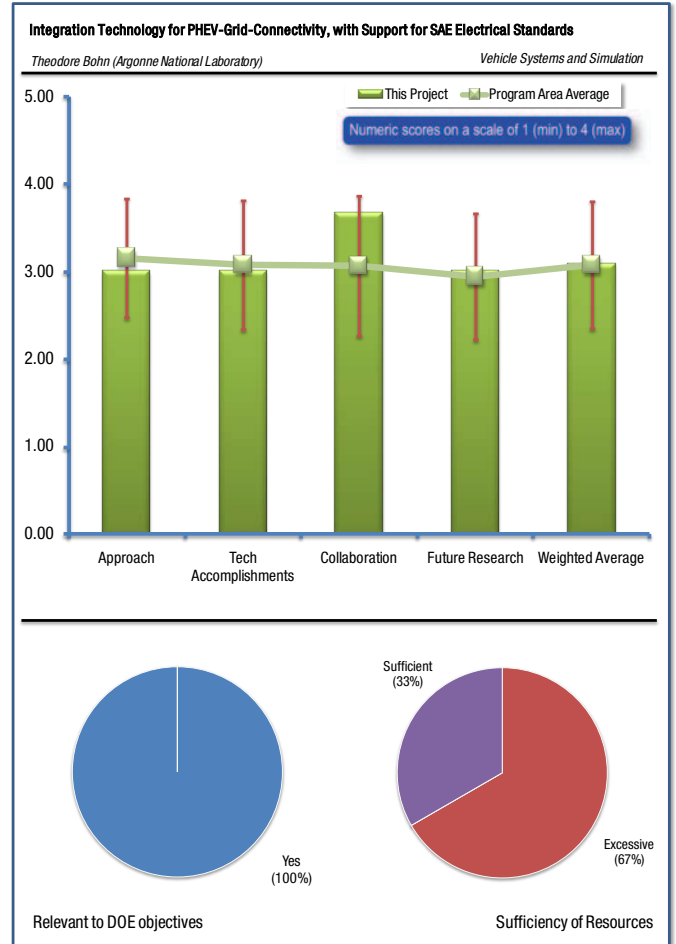
It was also stated by another commentator that this seems like a diffuse grab-bag of work. Some of the different parts seem interesting, but there is not a clear overall plan or defined goals. At some point, though, advanced research needs to happen this way, so it is trusted that the project funders are keeping track of the overall direction.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers felt that it is difficult to assess actual progress with the information given, but the different subparts appear to be on track. It was also added that the potpourri of projects appear to be making good progress. Another reviewer noted that the project has taken on many challenges: in fact, too many for a single presentation. However, the approach of defining electrical connector requirements, motor ratings, and charger efficiency metrics has resulted in some good consistent standards that will help manage the future growth. The reviewer was, however, disappointed that in this day and age we still find EU, US and Japan doing things differently. When will we see a global standard?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers felt that it appears that there is good collaboration. Another added that the project had compiled a vast list of collaborators from national labs, to OEMs, to utility companies and EVSE suppliers, an exhaustive list.



QUESTION 5: HAS THE PROJECT 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?

The first commentator felt that it seems that there are interesting ideas, but there is not a coherent plan with clear milestones. The second reviewer was pleased to see the proposed work for next fiscal year to include investigations on vehicle to grid communications technologies that emphasizes operations between countries as well as regions. The development of rating standards for Power Electronics and Energy Storage Systems are also a long time overdue. It was also noted that the stated future scope and general approach appear reasonable.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer pointed out that this work seems to be going in too many directions at once, which is an indication that funding exceeds the needs of the core research questions. It seems that more appropriate funding could improve focus. Another reviewer agreed by adding that the use of the second portion of the FY2010 budget was not adequately detailed nor adequately justified. Also, the second slide shows that \$470k is pending for new projects. There is concern that this funding may be excessive given the lack of a clearly identified scope. This is not a good way to utilize taxpayer funds.

SAE Standards Development (J1711 PHEV, J2841 Utility Factor Definition, J1715 HEV Terminology): Michael Duoba (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers felt that this project supported the overall objectives and that a fair and consistent measure of fuel economy is essential to consumer confidence in the published figures when selecting a vehicle. Another commentator agreed that this project enables the market penetration of electric vehicles which leads to displaced petroleum use. It was also added that the establishment of robust, flexible, technology neutral, and broadly accepted test procedures and standards are essential to the successful market introduction of PHEVs and other electrified vehicles. The development of test procedures and standards is an arduous, time consuming task that requires participation and cooperation from a broad spectrum of interested parties.

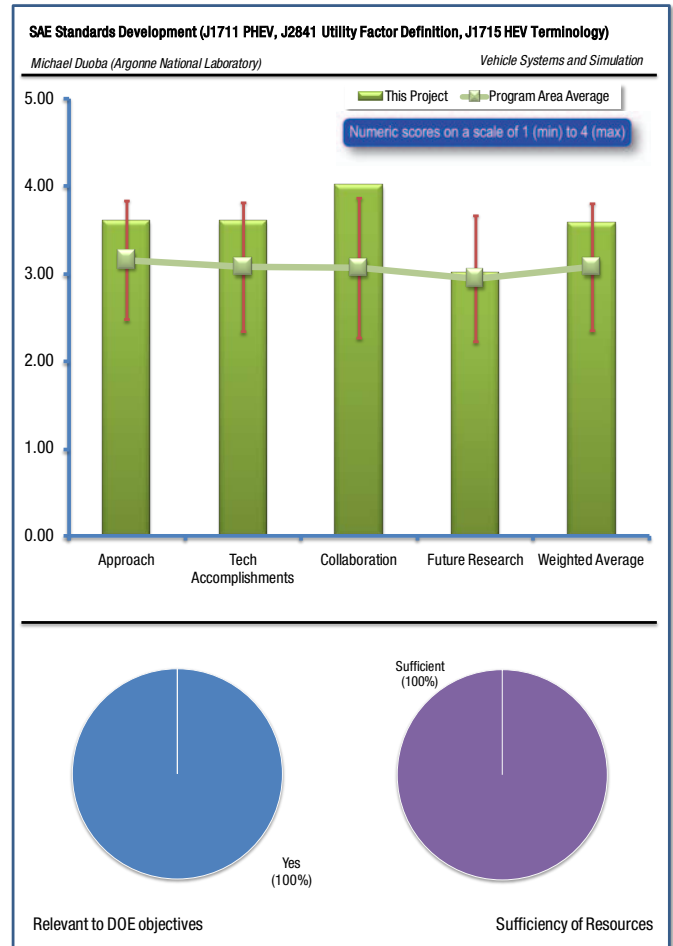
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers felt that the goals of the project have been achieved on a very tight timeline, in time for implementation. It was also agreed that the approach used was very good, and about the only way to get this work done in the time frame needed. The final reviewer added that the approach followed by this task is very robust, comprehensive, and inclusive. ANL chaired the J1711 Task Force and served as arbiter of competing interests. In the development of test procedures and utility factors, deep analysis has been conducted which has been augmented with the testing of many different PHEVs. This overall approach has led the finalization in a timely manner of the J1711 concept document which was sent to ballot in March 2010.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Commentators stated that the project is essentially complete, with all objectives met, and the J1711 process is near completion. It was stated that the standards are rigorous, and have now been published. Reviewers also felt that the project team did a great job of addressing the many issues that came up.

The final reviewer added that this task has demonstrated a number of new technical accomplishments including the completion of 1) multi-day individual utility factor (MDIUF), 2) rewrite of J2841 with MDIUF, 3) Definition of SOC corrections, 4) harmonized charge depleting range and end of test criterion, 5) alternative results calculations, and 6) updating of J1715 HEV terminology document. The knowledge gained through development of J1711 will be a key enabler in the development of the electric vehicle (J1634) standard.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Each of the reviewers agreed that the right participants were chosen and involved in getting an end product that addressed the needs of the industry. It was added that EPA, CARB, vehicle manufacturers are included and the involvement of JARI and Environment Canada is important. The final reviewer added that the collaboration for this task has been outstanding with input and participation from CARB, ISO, JARI, EPA, and DOT. Especially impressive is the harmonization and success in keeping J1711 compatible with CARB and ISO. Additionally, EPA and DOT will reference SAE standard J1711 for fuel economy labeling and CAFE. Furthermore, ANL is working with Idaho National Laboratory to investigate how J1711 test results compare to actual in-use fleet PHEV data. Additionally, CARB, Environment Canada, and Chrysler have provided early test data in support of J1711. ANL should be commended for all their efforts to draw in interested parties and bring nearly everyone to the table in the development of J1711.

QUESTION 5: HAS THE PROJECT 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?

Reviewers acknowledged that the J1711 standard program is near completion. It was also added that the proposed future activities are appropriate in substance and scope. A journal article will tie up the J1711 rationale and provide a learning tool for test engineers. Possible short cuts may be revisited and better understanding of PHEV in-use performance will be explored.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers felt that the end product appears well suited to the stated objectives and since the task ends in 2010, it has been appropriately funded. It was also felt that there was good sharing of resources from related activities.

J1634 SAE BEV Test Procedures: Michael Duoba (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers felt that this project supports penetration of electric vehicles. It was also noted by a reviewer that although this does not represent applied research, it is essential to develop uniform procedures to characterize new technology and to evaluate system design and control improvements. It was also added that the development of a BEV test procedure is a necessity to ensure an efficient and consistent approach across the entire space and prevent mis-selling or misrepresentation of the truth regarding range, power etc. BEVs are a significant component of fleet electrification plans.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

All of the reviewers felt that this project took a nice solid approach to the standard, with opportunity for comment and feedback included. It was also added that although BEV testing may appear straightforward, there are details which complicate the process and which ANL is addressing. This builds on SAE J1711 development, led by ANL.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

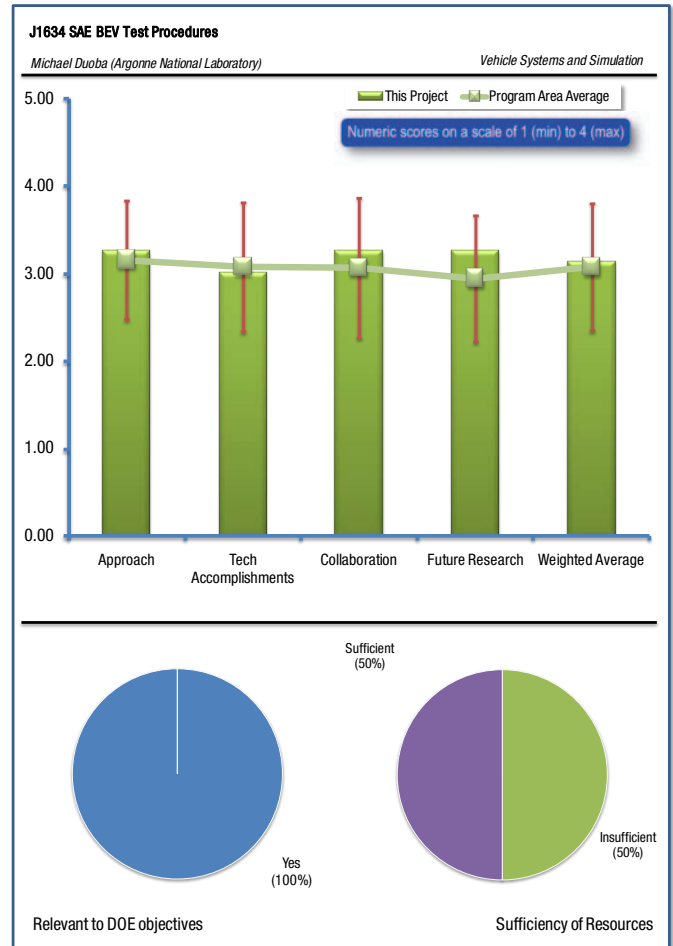
It is felt that even though vehicles have been tested and data is available, this still requires further development. It was also noted that the short cut approach and use of “Battery in the Loop” to test the viability of these ideas, is an efficient and quick method of getting some early results. Further “real” vehicle tests serve to validate the initial findings. Unfortunately no consideration appears to have been given to commercial EVs.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer noted that the SAE process assures wide participation resulting in major “traditional” auto manufacturers, plus JARI and Tesla are involved. It was also stated that as mentioned during the presentation, collaboration is essential as consensus must be achieved. There appears to be a good selection of collaborators including both US legislation bodies (EPA and ARB), overseas industry bodies from Japan, and many OEMs domestic and foreign.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer noted that the project team recognizes that the method must work for all BEVs. It is important that new technology is anticipated in the best way possible. Pursuing short-cut methods is important, and this has been recognized. It was also mentioned that a reviewer would like to see the use of cabin heaters included as this will also have a significant impact on range.



QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Commentators felt that, for the most part, funding was sufficient for this project. The first reviewer felt that \$150K appears reasonable to formulate the standard, but it will limit high volumes of testing. However, the final reviewer would like to see this work accelerated and given high priority.

Integrated Vehicle Thermal Management: Matthew Thornton (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt that reducing the complexity of thermal systems when adding vehicle electrification complexity is a goal that requires research. Reducing mass and complexity will improve fuel efficiency. It was also noted that it is possible that by integrating thermal management functions throughout the vehicle, cost/energy consumption parameters and space utilization could be improved. One difficulty of this is accurately quantifying and synergistically lining up the heat and cooling load requirements for key components including energy storage, power electronics and electric machines, etc. under various transient operating conditions.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer felt that this is a start and a good one where additional modeling and complex systems evaluation would be of great benefit. However, another pointed out that the principal weakness of the project approach is the lack of industry partners and early input into the task. It would seem that industry would be looking at options to integrate thermal management functions under their HEV/PHEV development programs, yet little mention is made of discussions with industry nor literature research as to what is going in the commercial world.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

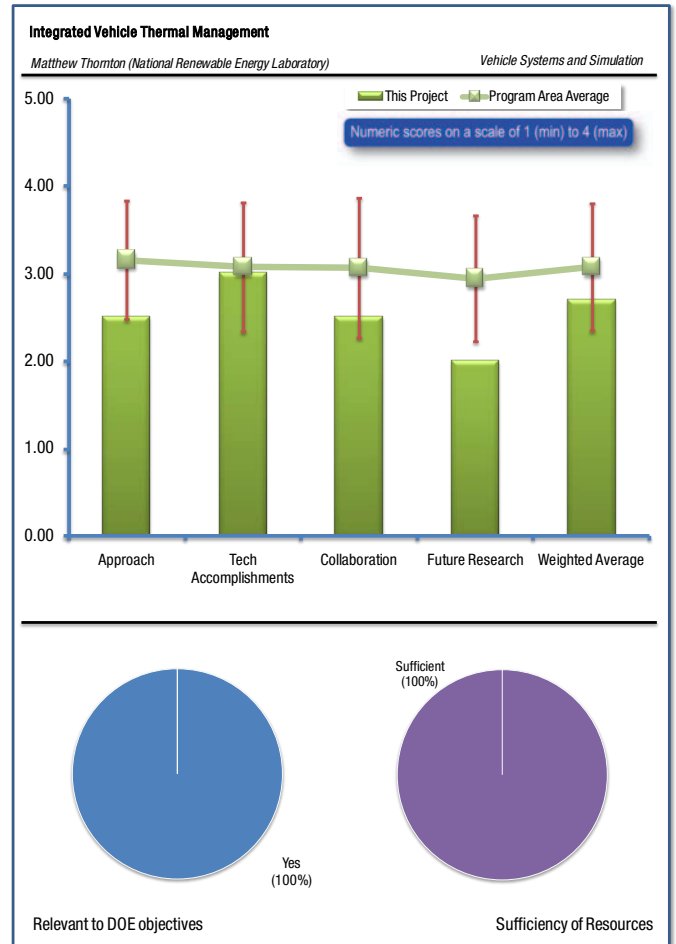
The first commenter stated that the two approaches being investigated are clearly understood and seem valid. Continued effort should bring positive results. The other reviewer felt that the task has made progress quantifying heat loads over transient operating conditions of individual components and integrated systems under real world in-use driving conditions. Some challenges as well as potential opportunities have been identified with regards to integrated thermal management for HEVs/PHEVs.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer noted that this project, if extended, needs a number of partners to join the effort in the thermal systems supply base. Bringing these results to industry would increase effectiveness. Another reviewer agreed by adding that this task would have benefited from increased and more transparent collaboration with other industrial and government entities. The task has not received any industrial cost share throughout its life.

QUESTION 5: HAS THE PROJECT 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?

Reviewers stated that no future work planned beyond this fiscal year. This may inhibit potential use of the outcomes.



QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

It was felt that this project has been sufficiently resourced throughout its life.

Geographic Information System for Visualization of PHEV Fleet Data: Sera White (Idaho National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers felt that the project supports the DOE’s goal of petroleum displacement by attempting to improve PHEV fleet performance using advanced GIS and visualization tools. The project looks at barriers in present GPS systems and looks for avenues to improve GIS tracking.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer felt that the project appears to have clear goals, and appears to be feasible. The project is well-integrated with the overall testing project. It was also added that the project appears appropriately defined for a student. The approach as presented appears sound and generally effective but might be improved. The project notes that GPS data from vehicles is not always transmitted, and therefore proposed targeted lab and field tests in large-scale demos to enhance the INL PHEV test fleet and improve INL QA.

Another reviewer also noted that the overlay of fleet data onto the Internet map server provides readable graphical trip data.

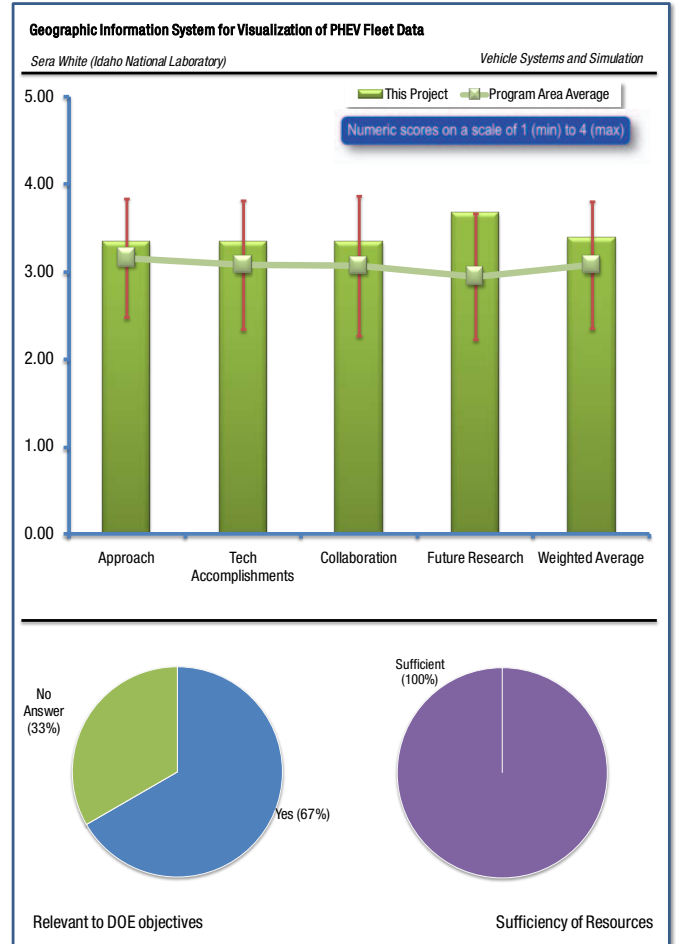
QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Overall reviewers stated that it appears that progress is being made, and that the project is on track to being a useful tool. Another reviewer also felt that the project team has made good progress on the work, and met numerous milestones including; (1) completion of development of web based map used to visualize PHEV fleet data (2) completion of a Digital Elevation Model (DEM) slope calculation (3) and integration of the new slope calculation into current aggressiveness algorithms. Future work will include complete city vs. highway trip type determination and a comparison of the results to current trip type determination and evaluate the new algorithms effectiveness. Next steps will include integration of map interface into current QA processes and a beta test and documentation. This approach is a very logical sequential process to achieve a path toward enhancement of the technology. It was also added that the ability to view the route graphically and zoom into different sections with selected parameters identified (e.g. speed) is a useful function.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A commenter felt that it is great to see a student lead project with strong leadership from INL. The collaboration with ISU and INL is strong and the relationship with eTec is not only important to achieve the project objectives but good exposure for the student.

Another added that it appears that there is a good coordination with the current project partners, but was concerned that the tool's focus is too narrow. It appears to be useful only to partners who have access to the full, detailed project data. Almost all partners will not be allowed to access this data due to privacy concerns. It will be very valuable to INL, valuable to individual project partners within the limitations, but it is difficult to see the value to organizations that are less tightly coupled.



QUESTION 5: HAS THE PROJECT 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?

The first reviewer stated that the project appears to have a good plan for future development. It was noted that it does not seem to have defined decision points, but given the nature of the project it seems that flexibility is more valuable. Another added that future work is strong, logical, and sound but may be improved by consideration of extended deployment. The final reviewer felt that the inclusion of slope/grade data is a very useful enhancement of the tool.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The reviewers agreed that resources seem sufficient for the given project goals. One reviewer added that the resources are excellent and matched to support a student project.

Advanced Powertrain Research Facility Vehicle Test Cell Thermal Upgrade: Glenn Keller (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt that this project promotes development of an experimental facility for very accurate efficiency determinations & efficiency research. The facility deals with powertrain configurations and provides for “real-world” thermal loads. Another reviewer also liked how this project ties into ANL's other DOE projects.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A commenter stated that this is a construction project based on design requirements and the requirements are either clear or standardized in each regard. A timeline is presented but the end date does seem ambitious. It was also added that the project may be tight on budget.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers agreed that it is hard to evaluate since program has only recently started, but poster shows that general contractor will be chosen this month.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

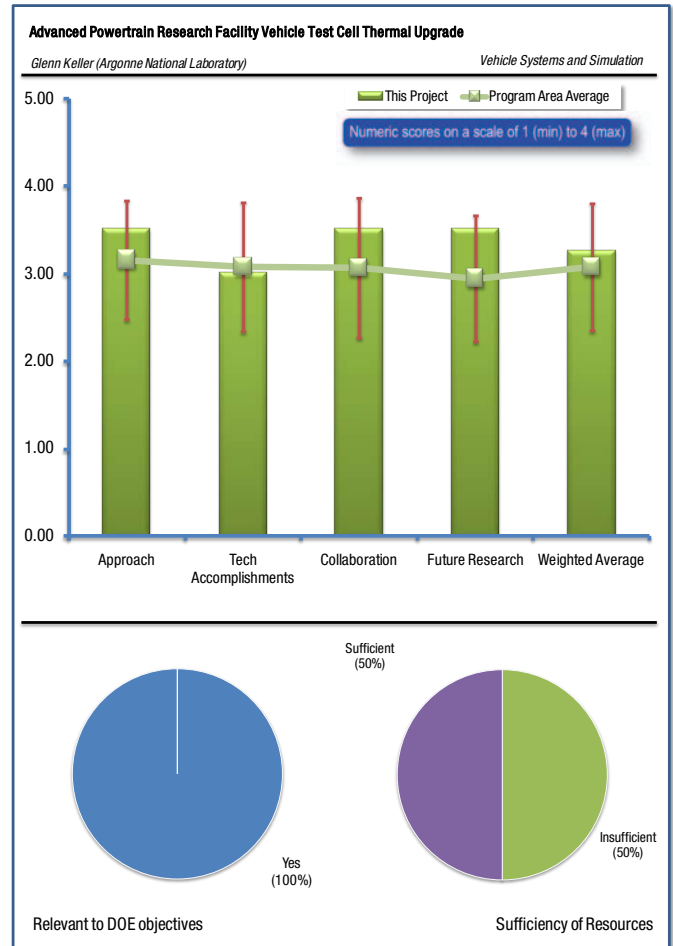
The first reviewer noted that ANL has many industry partners (generically), but the poster highlights collaborations only with INL, NREL, and ORNL. Another liked how this is tying into ANL’s projects and EPA's as well.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer noted that this is a research tool and ANL has identified cold effects on powertrain, accessory / air conditioning loads, and other areas for further study. These areas are important for vehicle design optimization and characterization. It was also felt that this can only lead to even better projects and understanding.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One commenter felt that resources will permit the stated development; however, future add-on improvements would require additional funds. Another commenter thinks that the budget will be short by 20%, based on experience of building a similar facility many years ago in the auto industry, including shoe-horning the design.



AVTA Vehicle Component Cost Model: Scott Ellsworth (Ricardo)

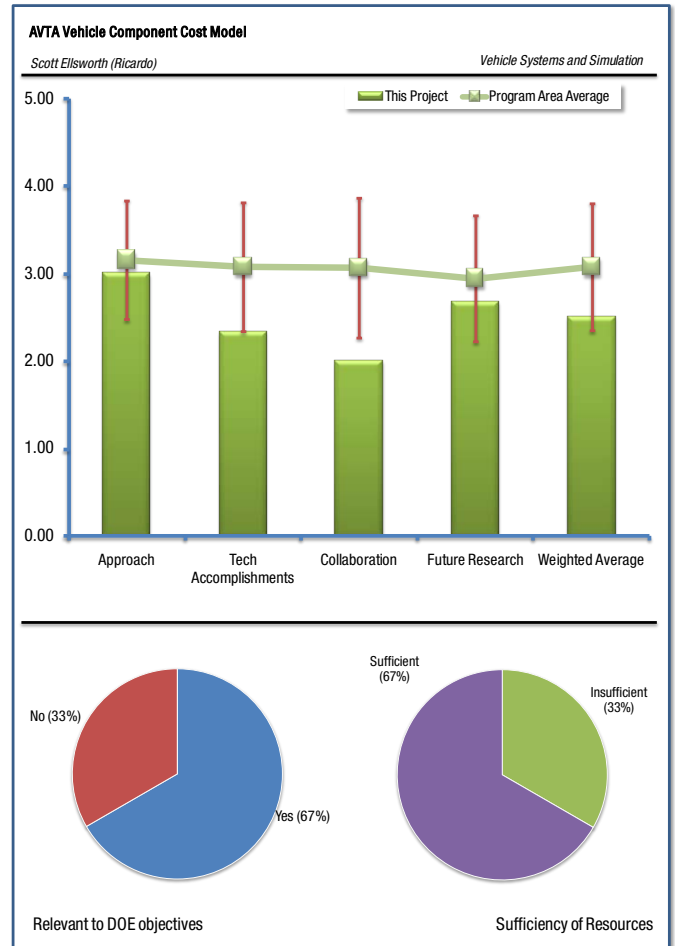
REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first commenter noted that in response to more stringent federal fuel economy regulations, a number of technologies are being considered for implementation. Currently, tools exist to predict fuel economy improvements, but determination of the “cost versus benefit” has been somewhat of an ad hoc process. This program seeks to provide a consistent approach to estimating costs of candidate technologies and providing a means of technology evaluation that considers not just performance but cost and commercial viability. Such a tool will facilitate and accelerate efforts to down-select the most promising technologies that can reduce petroleum usage.

Another reviewer stated that this one seems to be very borderline. Fundamentally, system cost absolutely matters, OEMs cannot produce systems that are not ultimately cost competitive (thus “yes” was checked). However, the reviewer reported having a hard time understanding the scope of this particular program. It seems to be focused on the current cost (with perhaps some assumed technology curves), instead of looking at how current research dollars could impact future costs. It is not thought that Ricardo intends to provide their cost data to other OEMs (they would have to pay, just as the government has), so it is not positive how this model is intended to be used. It almost seems that the government wants to independently verify cost estimates that OEMs provide. (Perhaps this is a needed step). It was also noted that while this project may be useful for policy making, it does not directly impact costs, or petroleum displacement.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first commenter noted that the tool to be delivered by this project takes a data-based, pragmatic approach to evaluating costs. Rather than basing estimates strictly on industry rules of thumb or more theoretical analyses to predict cost, this project provides a library containing actual cost data (where available), or refined estimates based on supplier input and well accepted means of cost estimating. The data used for analysis will be reviewed with key industry suppliers to validate its accuracy and appropriateness. This program will be a “post processor” of sorts to Autonomie analyses conducted to evaluate fuel savings potential of various methodologies.

The second reviewer is not completely sure what technical barriers this seeks to address. (Focus seems to be more on current cost of existing components as opposed to expected costs after government R&D investment.) The costing model seems reasonable—Ricardo does have some purchasing experience and the various assumptions regarding technology development and its impact on cost seem to be appropriate. He was also surprised to hear that the “cost” of lighter designs/materials is not included in this specific study. Ricardo indicated they had developed such models in the past (assisting with CAFE standards), but were not planning on incorporating the approach into the current project. In addition to more efficient components or alternate fuels, one way to decrease transportation fuel

use is to decrease the energy originally required to move the vehicle and reducing the vehicle's weight is a typical way to attempt to reduce the energy required.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted that this project just began in earnest a little over a month ago, so results are very limited at this point. It is expected, however, that the technical approach used here will yield a very useful tool for timely evaluation of candidate fuel economy technologies. Another commenter felt that the project seems to be on track, but difficult to tell from the poster.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first commenter felt that there has been significant interface with the analysis and simulation group at Argonne National Laboratories to ensure that this cost estimating program dovetails with the Autonomie analysis tool. He also noted that the program investigators envision significant interface with industry suppliers to obtain validation of the cost data included in the program. It appears once the tool is “test driven,” the predicted cost results will be compared with estimates generated by industry suppliers or technology users, in order to validate the approach.

Another reviewer noted that cost information is certainly useful to OEMs—but if they are not involved in this program, it is unclear how they will use the data. The final reviewer stated that the poster and discussions did not make it clear how coordinated the work is with partners, either for input to the process, or using the output.

QUESTION 5: HAS THE PROJECT 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?

Reviewers felt that a very clear plan has been laid out for implementation of the program. It does appear that the timeline has slipped just a bit due to a delayed project start. The program steps and projected timing are well defined. He also noted that discussions are already underway for the next phase of this program (funding for next phase not included in this program). Future plans include creating a similar database and program for medium and heavy duty truck technologies. In addition, there is a vision to incorporate the cost analysis tool directly into Autonomie, which will provide a seamless approach to evaluating both the technical benefits and commercial viability of candidate technologies.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first commenter noted that resources appear to be adequate for the program as defined. Several groups within Ricardo, including both the Strategic Analysis group and the technical group are engaged in this process. Support from Argonne appears to be adequate for the first phase of the program. He also stated that this is a relatively short duration program limited in scope, but the timing and resource requirements have been well laid out to ensure successful attainment of project deliverables.

Another reviewer felt that the time and cost do not seem to be consistent. (Relative to most of the modeling/simulation efforts, \$750K in 4 months is an aggressive spend rate.) His assumption is that the majority of this cost is to acquire rights/access to Ricardo's existing knowledge as opposed to funding additional work by Ricardo. However the rushed nature of the project would suggest that it will be hard to get a software tool that integrates well with the rest of modeling suite. (He does not doubt that Ricardo will fulfill their obligations, but cannot see how the end result will fit into the bigger picture.)

2. ENERGY STORAGE TECHNOLOGIES

Energy storage technologies, especially batteries, are critical enabling technologies for the development of advanced, fuel-efficient, light- and heavy-duty vehicles, which are critical components of the U.S. Department of Energy's (DOE's) Energy Strategic Goal: "to protect our national and economic security by promoting a diverse supply and delivery of reliable, affordable, and environmentally sound energy." The program's vision supports the development of durable and affordable advanced batteries covering the full range of vehicle applications, from start/stop to full-power hybrid electric, electric, and fuel cell vehicles. Much of this work will transfer to energy storage for heavy hybrid vehicles as well. Energy storage research aims to overcome specific technical barriers that have been identified by the automotive industry together with the Vehicle Technologies Program. These include cost, performance, life, and abuse tolerance. These barriers are being addressed collaboratively by the DOE's technical research teams and battery manufacturers.

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1 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 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
PHEV Battery Cost Assessment	Brian Barnett (TIAX LLC)	2-5	3.33	3.33	2.67	3.17	3.23
A High-Performance PHEV Battery Pack	Mohamed Alamgir (Compact Power)	2-7	2.80	2.60	3.20	2.00	2.65
HEV and PHEV USABC Battery Development Projects	Richard Holman (A123Systems)	2-9	3.20	2.80	2.60	2.60	2.85
USABC PHEV Battery Development Project	Cyrus Ashtiani (Enerdel)	2-11	3.20	2.40	3.20	2.40	2.70
JCS PHEV System Development-USABC	Scott Engstrom (Johnson Controls-Saft)	2-13	3.00	2.40	3.20	2.60	2.68
Advanced Cathode Material Development for PHEV Lithium Ion Batteries	Jamie Gardner (3M)	2-15	3.50	3.50	2.00	3.25	3.28
USABC Battery Separator Development	Ron Smith (Celgard)	2-17	1.80	1.20	1.00	1.20	1.33
Multifunctional, Inorganic-Filled Separators for Large Format, Li-ion Batteries	Richard Pekala (Entek)	2-19	3.80	3.40	2.00	3.00	3.28
Hybrid Nano Carbon Fiber/Graphene Platelet-Based High-Capacity Anodes for Lithium Ion Batteries	Bor Jang (Angstrom Materials)	2-21	3.40	3.20	2.80	3.40	3.23
New High-Energy Nanofiber Anode Materials	Xiangwu Zhang (NC State/NLE)	2-24	3.20	3.00	2.60	3.00	3.00
Stabilized Lithium Metal Powder, Enabling Material and Revolutionary Technology for High Energy Li-ion Batteries	Marina Yakovleva (FMC)	2-27	2.60	2.80	2.20	2.80	2.68
Protection of Li Anodes Using Dual Phase Electrolytes	Yuriy Mikhaylik (Sion Power)	2-30	2.80	3.00	3.00	2.60	2.90
Process for Low Cost Domestic Production of LIB Cathode Materials	Anthony Thurston (BASF)	2-33	2.40	2.40	2.40	2.80	2.45
Overview of Applied Battery Research	Gary Henriksen (Argonne National Laboratory)	2-36	3.00	3.17	3.50	3.17	3.17
Engineering of High Energy Cathode Material	Khalil Amine (Argonne National Laboratory)	2-39	3.33	3.33	3.20	3.17	3.30
New High Energy Gradient Concentration Cathode Material	Khalil Amine (Argonne National Laboratory)	2-42	3.00	3.00	2.50	3.17	2.96

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Design and Evaluation of Novel High Capacity Cathode Materials	Christopher Johnson (Argonne National Laboratory)	2-45	2.86	2.86	2.86	2.86	2.86
Search for High Energy Density Cathode Materials	Ilias Belharouak (Argonne National Laboratory)	2-48	3.00	2.57	2.57	3.00	2.73
Development of High-Capacity Cathode Materials with Integrated Structures	Sun-Ho Kang (Argonne National Laboratory)	2-50	3.00	3.00	3.00	2.86	2.98
Developing High Capacity, Long Life, and High Power Anodes	Khalil Amine (Argonne National Laboratory)	2-53	2.25	2.50	3.00	2.75	2.53
Lithium Metal Anodes	Jack Vaughey (Argonne National Laboratory)	2-55	2.75	2.75	2.75	2.75	2.75
Improved Methods for Making Intermetallic Anodes	Andrew Jansen (Argonne National Laboratory)	2-57	2.60	2.00	2.20	2.25	2.21
Novel Electrolytes and Additives	Dan Abraham (Argonne National Laboratory)	2-59	2.20	2.40	3.00	2.40	2.43
Electrolytes in Support of 5 V Li-ion Chemistries	Richard Jow (Army Research Laboratory)	2-61	3.20	2.80	2.60	3.00	2.90
Development of Advanced Electrolytes and Electrolyte Additives	Zhengcheng Zhang (Argonne National Laboratory)	2-63	2.75	3.00	2.75	2.75	2.88
Development of Novel Electrolytes for Use in High Energy Lithium-Ion Batteries with Wide Operating Temperature Range	Marshall Smart (Jet Propulsion Laboratory)	2-65	3.50	3.00	4.00	3.00	3.25
Novel Compounds for Enhancing Electrolyte Stability and Safety of Lithium-ion Cells	Kevin Gering (Idaho National Laboratory)	2-67	2.60	2.60	3.20	3.00	2.73
Screen Electrode Materials & Cell Chemistries and Streamlining Optimization of Electrode	Wenquan Lu (Argonne National Laboratory)	2-70	3.33	3.33	3.17	2.83	3.25
Materials Scale-up and Cell Performance Analysis	Vince Battaglia (Lawrence Berkeley National Laboratory)	2-73	3.00	2.83	3.50	2.83	2.96
Fabricate PHEV Type Cells for Testing & Diagnostics	Andrew Jansen (Argonne National Laboratory)	2-76	3.60	2.80	3.20	3.25	3.11
Electrochemistry Cell Model	Dennis Dees (Argonne National Laboratory)	2-79	3.50	3.50	2.75	3.33	3.39
Diagnostic Studies - Argonne	Dan Abraham (Argonne National Laboratory)	2-81	3.40	3.20	3.60	3.00	3.28
Electrochemistry Diagnostics at LBNL	Frank McLarnon (Lawrence Berkeley National Laboratory)	2-83	3.00	3.00	2.80	2.40	2.90
Diagnostic Studies to Improve Abuse Tolerance and Life of Li-ion Batteries	Xiao-Qing Yang (Brookhaven National Laboratory)	2-86	3.80	3.60	3.80	3.80	3.70
Develop and Evaluate Materials and Additives that Enhance Thermal and Overcharge Abuse	Khalil Amine (Argonne National Laboratory)	2-89	3.00	3.20	3.40	2.67	3.11
Abuse Tolerance Improvement	Peter Roth (Sandia National Laboratories)	2-92	3.50	3.17	3.00	3.33	3.25
Overcharge Protection	Thomas Richardson (Lawrence Berkeley National Laboratory)	2-95	3.67	3.17	2.83	3.00	3.23
High Energy Density Ultracapacitors	Patricia Smith (Naval Surface Warfare Center)	2-98	2.67	2.33	3.00	3.33	2.63
In Situ Characterization of Fatigue Behavior of Electrodes	Claus Daniel (Oak Ridge National Laboratory)	2-100	3.20	2.80	2.40	3.00	2.88

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Low Cost SiO_x-Graphite and Olivine Materials	Karim Zaghib (Hydro-Quebec)	2-102	2.86	2.86	3.29	3.14	2.95
Cathodes	Michael Thackeray (Argonne National Laboratory)	2-105	3.38	3.25	3.25	3.13	3.27
The Synthesis and Characterization of Substituted Olivines and Layered Manganese Oxides	M. Stanley Whittingham (SUNY-Binghamton)	2-107	3.00	2.71	3.33	2.67	2.86
Stabilized Spinel and Polyanion Cathodes	Arumugam Manthiram (University of Texas at Austin)	2-109	3.00	2.83	2.50	2.83	2.83
Olivines and Substituted Layered Materials	Marca Doeff (Lawrence Berkeley National Laboratory)	2-111	2.86	2.86	3.57	2.86	2.95
Cell Analysis – High-Energy Density Cathodes and Anodes	Thomas Richardson (Lawrence Berkeley National Laboratory)	2-113	3.43	3.29	3.57	3.00	3.32
First Principles Calculations of Electrode Materials	Gerbrand Ceder (Massachusetts Institute of Technology)	2-115	3.50	3.50	3.00	3.25	3.41
First Principles Calculations and NMR Spectroscopy of Electrode Materials: NMR	Clare Grey (SUNY-Stony Brook)	2-117	3.20	3.40	3.40	3.00	3.30
Development of High Energy Cathode for Li-ion Batteries	Jason Zhang (Pacific Northwest National Laboratory)	2-119	3.17	3.33	2.83	3.00	3.19
Inexpensive, Nonfluorinated Anions for Lithium Salts and Ionic Liquids for Lithium Battery Electrolytes	Wesley Henderson (North Carolina State University)	2-121	2.71	2.57	2.86	2.71	2.66
Molecular Dynamics Simulation Studies of Electrolytes and Electrolyte/Electrode Interfaces	Grant Smith (University of Utah)	2-123	2.57	2.57	3.00	2.57	2.63
In Situ Characterizations of New Battery Materials and the Studies of High Energy Density Li-Air Batteries	Xiao-Qing Yang (Brookhaven National Laboratory)	2-125	3.40	3.33	3.83	3.00	3.37
Solid Electrolyte Batteries	John Goodenough (University of Texas at Austin)	2-127	2.86	2.71	1.57	2.71	2.61
Nano-scale Composite Hetero-structures: Novel High Capacity Reversible Anodes for Lithium-ion Batteries	Prashant Kumta (University of Pittsburgh)	2-129	3.40	3.20	3.00	3.20	3.23
Intermetallic Anodes	Michael Thackeray (Argonne National Laboratory)	2-131	3.00	2.86	2.71	3.00	2.89
Nanostructured Materials as Anodes	M. Stanley Whittingham (SUNY-Binghamton)	2-133	2.75	2.50	2.88	2.50	2.61
Nanostructured Metal Oxide Anodes	Anne Dillon (National Renewable Energy Laboratory)	2-135	2.86	3.00	3.67	3.00	3.05
Development of High Capacity Anode for Li-ion Batteries	Jason Zhang (Pacific Northwest National Laboratory)	2-137	3.20	3.60	3.20	3.00	3.38
Electrolytes - Advanced Electrolyte and Electrolyte Additives	Khalil Amine (Argonne National Laboratory)	2-139	3.00	2.80	3.00	3.00	2.90
Development of Electrolytes for Lithium-ion Batteries	Brett Lucht (University of Rhode Island)	2-141	3.00	3.17	3.33	2.83	3.10
Bifunctional Electrolytes for Lithium-ion Batteries	Daniel Scherson (Case Western Reserve University)	2-143	3.00	2.60	2.60	2.80	2.73

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
<i>Performance and Safety of Olivines and Layered Oxides</i>	<i>Guoying Chen (Lawrence Berkeley National Laboratory)</i>	2-145	3.00	3.00	3.33	2.83	3.02
<i>Positive and Negative Electrodes: Novel and Optimized Materials</i>	<i>Jordi Cabana (Lawrence Berkeley National Laboratory)</i>	2-147	2.86	2.86	3.14	2.86	2.89
<i>Electrode Fabrication and Failure Analysis</i>	<i>Vince Battaglia (Lawrence Berkeley National Laboratory)</i>	2-149	3.20	3.00	3.20	3.00	3.08
<i>Microscale Electrode Design Using Coupled Kinetic, Thermal and Mechanical Modeling</i>	<i>Ann Marie Sastry (University of Michigan)</i>	2-151	3.00	3.17	2.50	2.83	3.00
<i>Analysis and Simulation of Electrochemical Energy Systems</i>	<i>John Newman (University of California at Berkeley)</i>	2-153	3.00	2.80	3.20	3.00	2.93
<i>The Role of Surface Chemistry and Bulk Properties on the Cycling and Rate Capability of Lithium Positive Electrode Materials</i>	<i>Yang Shao-Horn (Massachusetts Institute of Technology)</i>	2-155	3.20	3.40	3.00	3.20	3.28
<i>Interfacial Processes - Diagnostics</i>	<i>Robert Kostecki (Lawrence Berkeley National Laboratory)</i>	2-157	3.50	3.17	3.00	3.17	3.23
<i>Model-Experimental Studies on Next-generation Li-ion Materials</i>	<i>Venkat Srinivasan (Lawrence Berkeley National Laboratory)</i>	2-159	3.50	3.50	3.67	3.00	3.46
<i>Investigations of Cathode Architecture using Graphite Fibers</i>	<i>Nancy Dudney (Oak Ridge National Laboratory)</i>	2-161	2.80	3.00	3.00	2.80	2.93
<i>Block Copolymer Separators for Lithium Batteries</i>	<i>Nitash Balsara (Lawrence Berkeley National Laboratory)</i>	2-163	2.40	2.20	2.60	2.40	2.33
<i>Interfacial Behavior of Electrolytes</i>	<i>John Kerr (Lawrence Berkeley National Laboratory)</i>	2-165	2.60	2.40	2.60	2.40	2.48
<i>Advanced Binder for Electrode Materials</i>	<i>Gao Liu (Lawrence Berkeley National Laboratory)</i>	2-167	3.33	3.33	3.33	3.00	3.29
<i>Atomistic Modeling of Electrode Materials</i>	<i>Kristin Persson (Lawrence Berkeley National Laboratory)</i>	2-169	3.00	3.00	2.60	3.00	2.95
<i>Coupled Kinetic, Thermal, and Mechanical Modeling of FIB Micro-machined Electrodes</i>	<i>Claus Daniel (Oak Ridge National Laboratory)</i>	2-171	3.20	2.60	2.60	3.00	2.80
<i>Long-Living Polymer Electrolytes</i>	<i>Christopher Janke (Oak Ridge National Laboratory)</i>	2-173	2.20	1.80	1.20	2.40	1.90
<i>In-Situ Electron Microscopy of Electrical Energy Storage Materials</i>	<i>Karren More (Oak Ridge National Laboratory)</i>	2-175	3.20	2.80	2.40	2.80	2.85
<i>Diagnostic Testing and Analysis Toward Understanding Aging Mechanisms and Related Path Dependence</i>	<i>Kevin Gering (Idaho National Laboratory)</i>	2-177	3.50	3.25	3.25	3.50	3.34
OVERALL AVERAGE			3.04	2.92	2.93	2.88	2.94

NOTE: Italics denote poster presentations.

PHEV Battery Cost Assessment: Brian Barnett (TIAX LLC)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers noted that the cost of the battery, particularly the dollar per kilowatt-hour (\$/kWh) figure, is a key element in the success of the DOE’s program, as well as one of the most critical components to affect the success of automotive electrification. One reviewer praised the cost analysis is among the best he had seen in terms of a pure methodology, with its basis and findings essential to projecting market feasibility of PHEVs. The project was also characterized as a very timely topic with considerable value to researchers/developers engaged in this field.

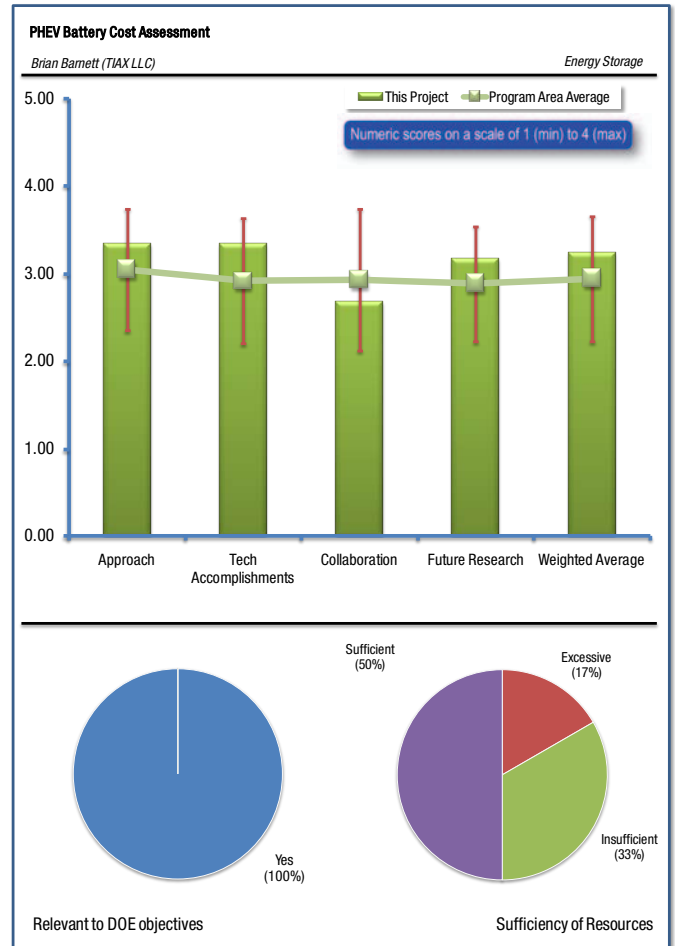
Two reviewers particularly lauded the project’s new approach to electric drive vehicle battery cost estimation, because the ability to accurately project the cost of different elements in the battery system provides the opportunity to concentrate activity in the areas that will bring the largest return, including accelerating the development in materials and other promising areas to meet cost objectives required for widespread adaptation of these technologies. A reviewer observed that this modeling can help accelerate development of most promising areas for cost reduction, therefore accelerating adoption of electric vehicles and accelerating the ability to meet DOE objectives of petroleum displacement.

One suggestion for fine-tuning the program was that because the costs are strongly affected by the production rate, two or more production rates should be included to quantify the effect of rate on total production cost of a battery.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The reviewers complimented the project, with one noting that it demonstrated very extensive work and methodology, with well-thought-out assumptions. Another similarly noted the sound unbiased methodology with a broad range of production variables. Another cited that the approach to developing a cost model for batteries builds on the previous successful efforts to develop a model to forecast fuel cell costs. A third reviewer deemed the approach to be very solid for identifying the major trends to impact costs in a direct, “apples to apples” comparison, as long as the details of things such as process yields and system costs per material are adjusted in order to make this approach more robust.

However, one reviewer noted that given that the first two high-volume PHEV/EV vehicles coming to the market (the Chevrolet Volt and Nissan Leaf) use batteries with mixed metal oxide cathodes and laminated pouch construction, it would be very instructive to extend the current work to those systems to allow a reality check for these kinds of studies which are often based on a multitude of assumptions and hypotheticals. Another reviewer pointed out that the relative cost of a prismatic cell and prismatic-cell-based pack system versus a cylindrical cell and cylindrical-cell-based pack system is an important area which is not addressed. Also, the reviewer who cited the potential for “apples to apples” comparisons above said that cell manufacturing yield assumptions of 100% are not realistic. Another current drawback indicated by two reviewers is that there needs to be validation of the model, which means that the



confidence level in the results would be low. For example, actual costs of cells compared to models should be integral part of this model validation.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers recognized the project as being high-caliber work that is providing excellent results, although counterintuitive, within its current scope. One reviewer noted how the model makes it possible to quickly estimate the effect of a new material on the final cost of the battery; because cost is a strong driver in the program success, the model will serve to assist in making better decisions on the various program elements. Another reviewer said that it was a major accomplishment that the program has identified several key areas to substantially impact battery system costs and also helped identify the relative weight of factors.

Suggestions for improvement included questions about how the aggressive yield assumptions were made, and addressing the issue that the validation information is not clear. It was noted that within the scope of this project, there is less technology derivatives but rather process-related optimization.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Several of the reviewers said that there was no specific evidence of collaboration or coordination with other institutions in the TiAx presentation, though two of the reviewers felt that the team has done a good job reaching out to collect information from the industry to utilize in their models. However, one reviewer suggested that TIAX could do much more by collaborating in the inverse fashion where they allow industry and academics to utilize their model to get the most value out of the work.

QUESTION 5: HAS THE PROJECT 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?

Reviewers cited TiAx's steady progression to the end deliverables and that its plans to explore prismatic cell costs are appropriate.

Feedback as to what TiAx should pursue going forward included:

- Additional studies should be continued on new materials as the program develops new higher performance materials to replace the ones used in this study as part of an add-on or a new contract. Plan to revisit and update costs of specific materials and the entire system are key
- Plan to explore alternate cell format
- For prismatic designs, estimated cost differences between stacked and flat wound rigid case and flexible packaging variations should be examined.
- Relative estimated cost differences between a prismatic cell and prismatic-cell-based pack system versus a cylindrical cell and cylindrical-cell-based pack system should be examined.
- The country of origin for various material and hardware data should be classified and identified in some fashion.
- Future research should include the validation of the existing model before starting the next phase.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer stated that the team has sufficient staff and resources to carry out the study. However, a second reviewer felt that it is not very clear the sources are available to provide models to the battery community to support models for stacked and flattened jelly roll prismatic and pouch cell this year or the next year. Three reviewers left no response to this section.

A reviewer advised that he would like to see this activity accelerated with the requirement that the actual model be made more available to the public, for example, with higher levels of funding, to give the best acceleration to the industry and DOE's goal of oil displacement.

A High-Performance PHEV Battery Pack: Mohamed Alamgir (Compact Power)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The consensus among reviewers was that the project is well-aligned with DOE objectives, as it addresses key technical issues for PHEV battery packs such as cell cycle life and calendar life, which are critical in reliably displacing ICE power in automotive use. One reviewer observed how low temperature performance aggravates these issues and was a key limiter of cell performance, especially for power-sensitive applications such as the HEV and PHEV. The development of new cell/battery pack designs for PHEV applications is critical for advancing such vehicles, according to one reviewer, and another cited the outstanding development of the safety reinforced separator (SRS) for safety and cell stability.

One minor point of dissent was that the target PHEV10 application limits the potential for petroleum displacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

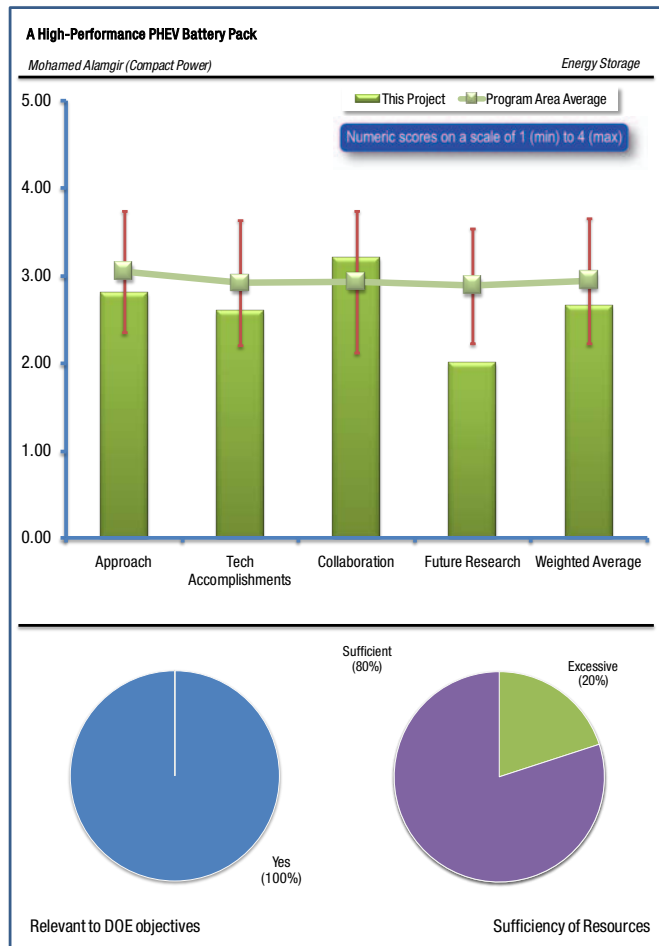
Overall, reviewers seemed to feel that the approach taken was reasonable, with barriers well-identified and logical progression made, though two reviewers wanted more details, such as on the real improvements and differences existing between the various cell generations. Three reviewers specifically commented on the analysis of thermal management as being very accurate with an interesting innovation, noting the achievements in the areas of liquid cooling versus refrigerant-to-air cooling with OEM constraints of packaging. Two reviewers also noticed the SRS work, though one remark was that this is safety-related and does not directly address the stated goals of petroleum displacement. Some specific feedback for improvement includes: the data about cycle and calendar life lack unit scale to effectively understand the progress; and solvent permeation was not directly addressed or characterized.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Though one reviewer said that progress was good, and another noted that the significant gains in the calendar life and shelf life of the battery pack should drive down application costs.

However, each of the four reviewers who responded to this question had feedback on what details were needed to better confirm improvements. Things that Compact Power should address include:

- Many presenters have used graphs without exact numbers. While it is not clear how these may impact confidentiality, this practice reduces the reviewers' understanding of the real process. However, the gap chart well quantified and clear, partially reducing the negative impact of the incomplete graphs.
- The refrigerant cooling is interesting, but some indications on the effective impacts (economical, technical, energy balance, complexity and reliability) would be useful.



- The refrigerated cooling thermal management (a refrigerant loop used to cool the air within the battery pack) appears to be an effective method to reduce/eliminate the need for high velocity air circulation (for air cooling), but, while this may maintain cell temperature during normal operation, it is unclear how helpful this would be to slow down or prevent thermal runaway during abuse conditions. How does this method of thermal management compare with liquid cooling during abuse.
- The safety reinforced separator (SRS) design in which an inorganic filler layer is applied to the surface of the polymer separator may not be optimal as indicated in the presentation by Entek (ES008). It is difficult to determine why the PLG2 design is “expected to meet the USABC target (cycle) life.” Very limited data is provided for this design and no numbers are given in the redacted plot.
- One reviewer observed that PLG2 doesn't seem significantly better than PLG0 in terms of cycle life. PLG0 has a bad impedance rise but overall, the reviewer did not feel that PLG3 is that much better than PLG0.
- The data for cycle life and calendar life do appear promising (relative to PLG1), but there is considerable variability in the performance of the three cells.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Most reviewers noted the effective collaborations with the national labs for independent evaluations, particularly for a commercial outfit. One suggestion was that CPI could have involved academic interests for system modeling of heat transfer for the thermal management research.

QUESTION 5: HAS THE PROJECT 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?

The project was completed in March 2010, so this is not applicable. However, one reviewer indicated here that he was unimpressed by the pack design/temperature control work, which he felt should be funded by LG/CPI rather than by the DOE.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers said that there were no obvious resource issues, though the information provided in the presentation was not sufficient for an adequate analysis of resources. Three reviewers did not answer.

*HEV and PHEV USABC Battery Development Projects:
Richard Holman (A123Systems)*

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewers agreed that the project was clearly focused on the improvements of Li-ion batteries that support the DOE objectives. One reviewer observed that life and safety/abuse capability are key aspects for the application of PHEVs, a technology that will displace petroleum. Another stated that the large-format 20Ah cell design for LiFePO₄ is a significant step in providing higher energy density in a safe pack design for PHEV-40 applications.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

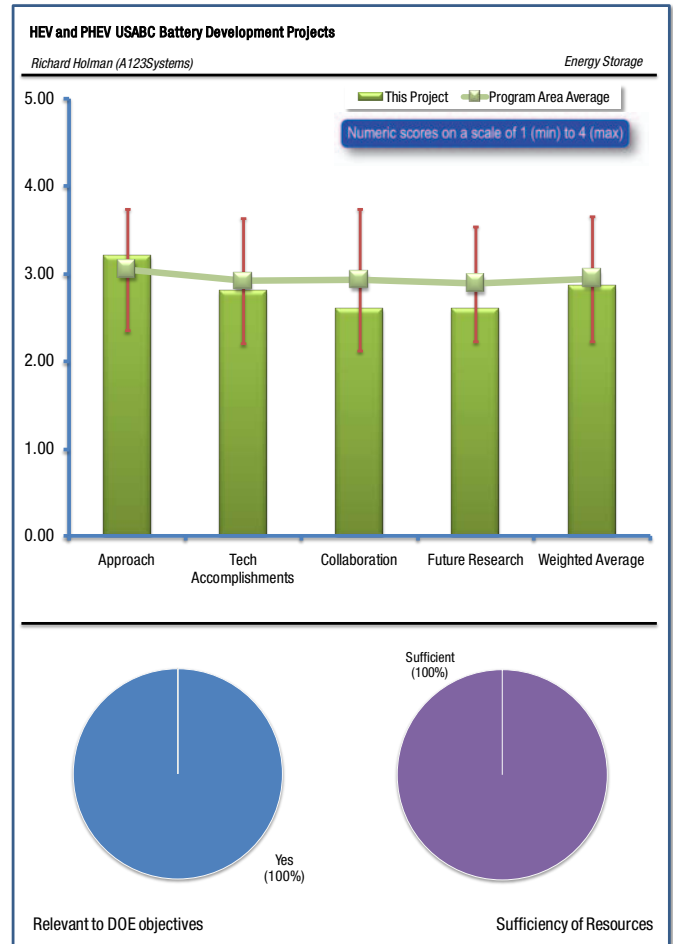
The reviewers felt that the standard product development processes were adhered to and that targets were within reach of production schedule, with a clear roadmap for meeting their deliverables. However, one reviewer felt that the approach was not explained in the description, although looking at project progress reveals the key steps to be improving cell design and BSF optimization. Another reviewer said that it was not clear what the technology actually is in its project to develop prismatic cells using A123's technology from cylindrical cells, presumably based upon a high voltage nanophosphate material with a high voltage electrolyte (although this is only implied from the future work). One reviewer gave feedback that he would have preferred to see Arrhenius plots of some of their data to indicate changes in failure mechanisms (if any) with increasing temperature. He felt that all A123 showed was performance at various temperatures, whereas Arrhenius plots can be really helpful in understanding the effect of temperature, especially when paired with known or estimated activation energies for typical processes and failure modes.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

All reviewers had specific points of feedback to provide here. Two reviewers noted that the progress is impressive and steady on both activity lines, and two others noted the impossibility of gauging how well these cells have done at meeting/exceeding the USABC goals due to the presentations being qualitative rather than quantitative (gap analyses with color coding instead of quantitative data). Another reviewer said that the prismatic cells meet most of the PHEV10 and 40 performance targets, but do not achieve the system volume and cost goals. A third reviewer cited improvements in calendar life, cycle life, and power (though cycle life is not expected to meet the program goals), and a final reviewer commented on the nice safety performance.

Other specific points of feedback are:

- It is not clear why abuse testing is only referred to the EUCAR procedure and not to the USABC Abuse testing tests.
- The abuse tolerance at EU 4 is not outstanding. This reviewer acknowledged that the final abuse control is at OEM system level, and said that A123 should have expanded upon external short-circuit protection (which A123 does well) with integrated fuse. Potential improvements could be gained by advanced shutdown separators and/or CID/PTC devices



- No information is provided regarding what the “doped nanophosphate” material actually is, although the presentation does indicate that this is a high-voltage cathode material.
- It is also not clear how far from the target the volume and cost metrics are. Redacted plots have been provided which give little information, but some short statements indicate that the cells have excellent capacity retention after thousands of cycles and have suitable abuse test characteristics.
- The SOC testing appeared to suffer from hardware issues (tightening of connections) which led to misleading data. The cells performed well for 80% SOC storage for 45°C and below, but not for the storage at 55°C.
- The cells cycle well, but the life is not expected to meet the program goals. For the HEV project with 32113 cells, the presentation indicates that most of the target goals will be met, except for the cost of the system.
- As color coding has been used, it is unclear how far from the cost goal the project is. No numbers are given in the redacted plots, so it is not possible to properly evaluate the cell performance.
- The A123 team don't seem to know what is their failure mechanism at 65°C, except that it's not iron solubility, which one reviewer did not find convincing.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Though collaborations were not specifically noted in the presentation, reviewers identified that the collaborations are reasonably limited to providing samples to independent national laboratories for testing and verifying project products.

QUESTION 5: HAS THE PROJECT 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?

A reviewer wrote that the project does not propose any real future research to overcome eventual barriers but is clearly concentrated on production targets. However, another reviewer opined that the team should do more to get a better understanding of their failure modes at 65°C. A third reviewer observed that A123 said that next-generation separators (already developed) will be tested. Cycle life and storage testing will be conducted in PHEV cells. Scale-up of high voltage cathode material will be done with selected high voltage electrolytes. Cell characterization will be continued along with external evaluations of cell, modules and packs. No information is provided regarding how the project can meet the USABC volumetric and cost goals. The HEV project appears to be completed as sample cells have been delivered and a final report will be provided in June 2010.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The reviewers' assessment was that A123 is well equipped to conduct all aspects of the projects, with its chemistry a viable option for HEVs and maybe PHEVs. Continued funding was recommended, even if a better evaluation would require the availability of quantitative data on the real number of products and complete planned activities.

USABC PHEV Battery Development Project: Cyrus Ashtiani (Enerdel)

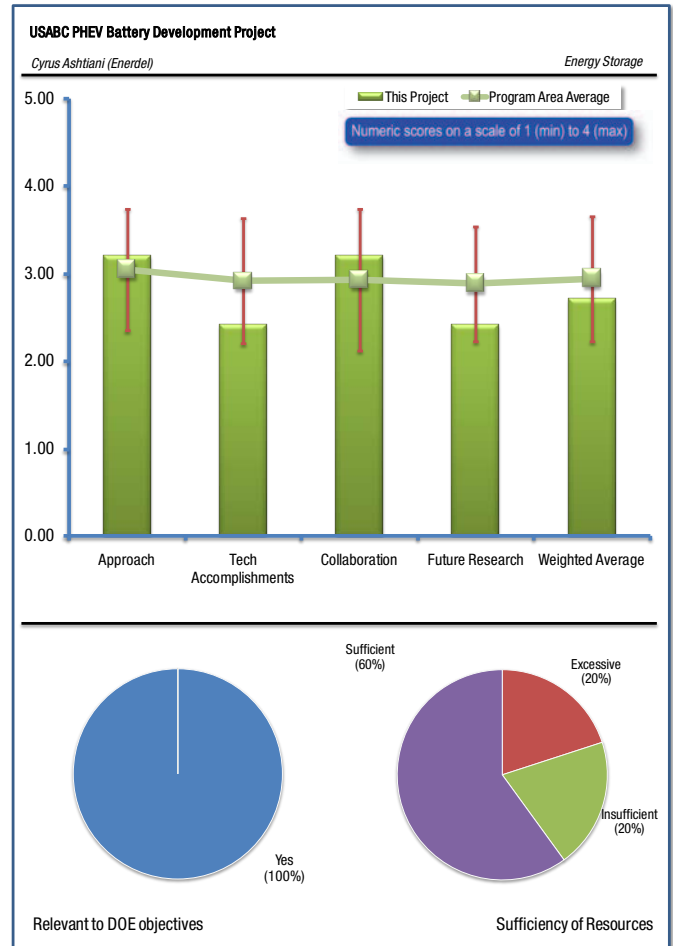
REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments on the titanate anode agreed that this can be a challenging alternative in low-cost systems if the project targets to have a high-voltage cathode and high-voltage electrolyte are successfully achieved. Also, the development of a titanate anode provides potential for improving both cycle life and safety within a PHEV pack. The focus on pushing to higher cell potentials begins to address one of the largest shortcomings of titanate vs. graphite/carbon anode materials. However, a dissenting reviewer stated that he did not believe the voltage penalty with Enerdel's anode can ever make this battery suitable for PHEV, and even an HEV would be a stretch.

Reviewers noted that developing a LNMO cathode from a surface coating could lead to significant energy density and lower production cost alternatives. Also, Enerdel's is a different approach to utilizing a high-voltage lithium battery cathode. By selecting an anode for which an SEI is not necessary for stable cycling, the remaining components (i.e., electrolyte composition) can be optimized to stabilize the cathode performance.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Most reviewers praised the approach, noting that the technical barriers are well identified with a clear approach towards handling the weak point of the LiTiO anode, the low working voltage of which must be counterbalanced by a large cathode voltage (provided by LNMO). Improved cathode materials and high voltage electrolyte formulations are likely necessary for this approach to be viable, but early demonstrations are promising.

One reviewer was more skeptical, however, stating that, in his view, many if not all of the electrolytes the Enerdel team are considering will have high viscosity and/or low conductivity that will effectively eliminate the high-rate performance of their battery, especially at low temperature. Without high rate, Enerdel does not really have much reason to use their LTO anode (except maybe safety), according to this reviewer.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewers agreed that progress has been modest at best. One reviewer said that it can't meet several of the DOE goals, opining that the high potential is a serious handicap that Enerdel has not been able to overcome, and that there has been no demonstrated advantage to offset their lower energy.

A reviewer characterized the various approaches to develop new high-voltage electrolytes (sulfolane-based solvents, ionic liquids, fluorinated solvents and SEI-forming additives) as appearing to have been ineffective as all of these electrolytes performed worse in

cells than the high-purity conventional electrolyte formulation. It was suggested that the quality of the cathode material (material processing) played a significant role in the cell performance. The lifetime, weight, volume and price of the cells continue to be a challenge.

Specific criticisms included:

- There is no experimental evidence of the selection process of the electrolyte.
- The specific performances of the cathode and electrolyte developed are not clearly shown.
- The Enerdel team could have proven greater mass production capability.
- It is unclear if the same attention was devoted to creating high purity materials for the sulfolane-based solvents, ionic liquids, fluorinated solvents, and SEI forming additives.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

All reviewers noted the collaborations with the national laboratories for both materials and testing. One reviewer suggested that Enerdel could have involved an academic entity as well.

QUESTION 5: HAS THE PROJECT 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?

The project is completed, but work will continue in-house by Enerdel, including cell design optimization, cathode surface coatings, and advanced high-voltage electrolytes. Though one reviewer stated that the key steps for future improvements are justifiable with a focus on novel electrodes and advanced electrolyte, another disagreed, expressing the opinion that this system is much better suited for load leveling applications where power and very high cycle life are needed rather than energy, rather than for PHEV or HEV programs, and should consequently be funded by programs supporting those applications.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers felt the resources were adequate and funding of future research should be considered. Two reviewers did not comment, and one reviewer recommended killing work on this system for HEV and PHEV and instead funding it under a program aimed at supporting stationary power conditioning/load leveling.

JCS PHEV System Development-USABC: Scott Engstrom (Johnson Controls-Saft)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers agreed that project is well in line with the DOE objectives because it is focused on PHEV design and optimization. In the project, prismatic cell lithium battery designs are being evaluated which utilize NMC as the cathode material and other lower cost materials that also have good energy for PHEV20 or 40 battery applications.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The consensus among the reviewers was that JCS was following appropriate cell development protocol with measurable output. JCS had utilized the same chemistry for cylindrical cells last year; the program scope was then changed to prismatic cells, leveraging existing Saft prismatic cell manufacturing capabilities. One reviewer felt that the approach is focused on some key aspects, but JCS needs to justify design choices better. However, another reviewer stated that he liked the shift away from NCA to less expensive NMC that also has higher energy than LiFePO₄, and also approved of the prismatic design for larger packs than cylindrical cells.

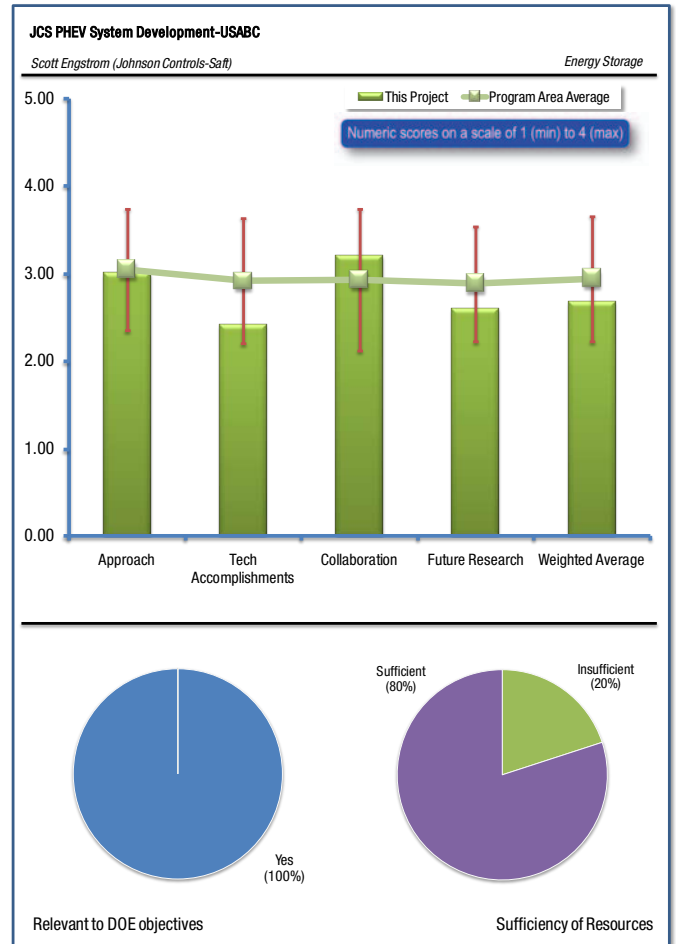
Specific places that could be improved included:

- Units would be nice
- The experimental results were more complete than in the presentations by other battery companies, but the planned work does not explain well how they really intend to significantly improve performance.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers noted that progress had thus far fallen short of DOE targets and would likely remain that way within the remaining time on the project. One reviewer noted JCS’s significant gains in the cost arena, which are typically greater than similar projects, though short of USABC goal. Another observed that with the recent shift to NMC materials and prismatic cells, JCS understandably do not have much actual data to share yet. He expected JCS to be able to say much more next time, so that a rating of “fair” is more a reflection of where JCS is in its program rather than any reflection on the team’s capabilities.

One reviewer did offer some specific critique, indicating that a plot was provided regarding packing efficiency in which it was noted that as the intra-cell spacing required for cooling increases, the packaging advantage of prismatic cells is reduced. It was not clear from this, however, whether or not the packaging advantage would be completely nullified. Redacted plots for cell performance were provided in which no values were given, which made it impossible to evaluate the performance thus far. It was verbally stated that the



current design is not yet close to the required USABC cost goal, but is approaching the goals for mass and volume. Very little specific information was provided.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers lauded JCS's collaborations on key components (for example, developmental separators from Entek and Celgard) and with national laboratories, though external evaluation at the national labs had yet to occur.

QUESTION 5: HAS THE PROJECT 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?

Three reviewers said that the plans seemed vague, with a lack of detail on what barriers are really addressed, though one conceded that this is not unexpected for a commercial unit. Two reviewers did not comment.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers said that their general impressions were that the resources are reasonable, though one questioned whether the DOE needs to fund the building and testing of large demonstration packs. A second reviewer noted that this is one of the largest capacity hard-canned/vented prismatic cells under development and stated that funding for this novel approach should be increased.

Advanced Cathode Material Development for PHEV Lithium Ion Batteries: Jamie Gardner (3M)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers unanimously agreed that this project supported the DOE objectives. Improved cathodes and anodes resulting in higher capacity and lower cost are crucial for advanced lithium battery development for EV and PHEV applications.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer lauded 3M's good understanding not only of materials but also of cell chemistry and interactions with electrolyte, etc. Another cited that although the approach is not well detailed, it seems quite reasonable because it is supported by interesting results. For the cathode development, new compositions (related to NMC which is the benchmark) with less Co content (expensive and costly) are pursued.

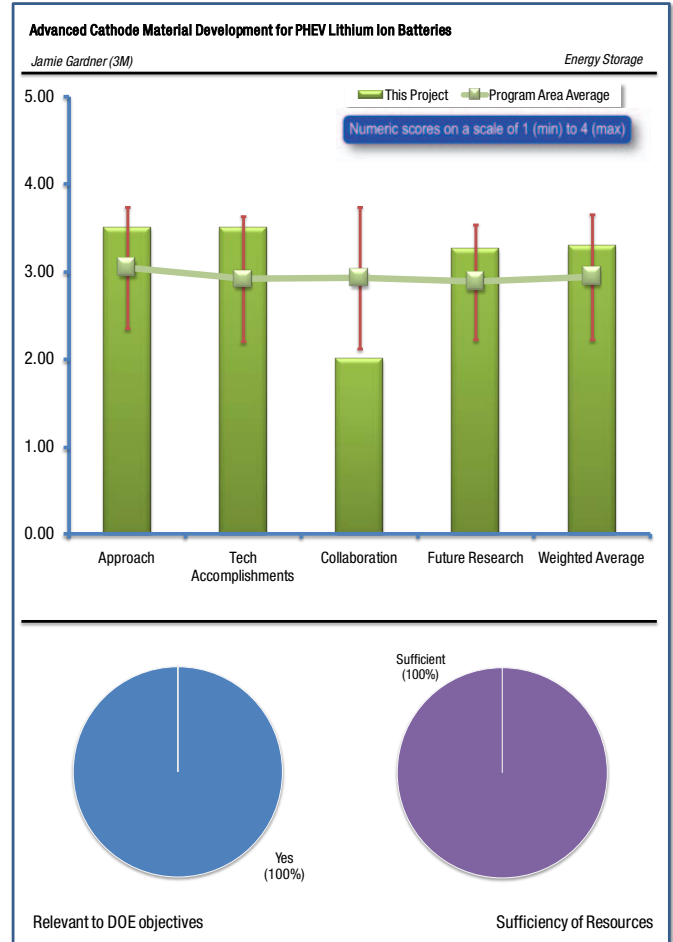
Some criticisms included:

- No indications are given about the real technical barriers to be overcome.
- The concentration of work on NMC materials does not seem supported by a comparative analysis of competitive materials.
- The same applies to Si-based anode materials.
- 3M's cathode goals are modest because they are basically looking at relatively minor changes in materials. The main thing here is manufacturability of the materials at a lower cost.
- The anode program is more challenging, although 300 cycles is not enough of a cycle life. Si-based alloys are being explored. The key to these is stabilizing the cycling behavior and electrolyte optimization.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewers were positive about the progress being made. One reviewer said that the quantitative data presented confirm the technical progress with gap analyses that show both the results achieved so far and where things stand with respect to the targets. Another observed that they have met most of their goals on energy and costing. While not a huge jump in energy for the cathode, the progress shows that they have done a good job in working within the framework of what is basically the known space of cathodes using industrial mixture design, etc. The thermal stability data in this reviewer's view shows no significant improvement, but he felt that this was to be expected unless 3M sacrificed energy and went heavily in the Mn direction in the mixture space.

Another noted that the two cathode materials (Adv NMC 1 and 2) appear to meet the project goals of capacity, thermal stability and reduced cost. Cycle life analysis is still underway, but seems to be very promising (it is anticipated that over 2000 cycles will be obtained with this prototype material). The processing conditions produce materials with an excellent morphology in large batches. 18650 cells are being studied rather than coin cells. For the anode project, two different prototype Si-alloy materials are being tested.



Melt spinning was used to produce the first material, while a proprietary manufacturing method is mentioned (low cost, high volume, quicker to scale) for the second material. Evidently, all is in order regarding the volumes of materials produced so there do not appear to be any issues with the scale of manufacturing. The materials also show promising results regarding their ability to meet the Year 1 targets for performance. Cycling data was not shown, but values are given for the cycle life (% fade) after 300 cycles (this did not include the initial 13% fade on the 1st cycle).

Two reviewers cited good anode results, particularly in view of the relatively early stages of such work. Overall, the anode materials provided a significant increase in volumetric and gravimetric capacity with reasonable cycling behavior.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers said they wanted to see more specific descriptions of any collaborations. One reviewer speculated that 3M has a large group and that confidentiality likely limits their ability to partner, so that lack of collaboration might be acceptable in this case. However, he would have liked to see plans to submit cell builds and materials to the national labs for testing and validation.

QUESTION 5: HAS THE PROJECT 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?

Reviewers felt that the remaining steps were reasonable with attention to coating and final material selection for the cathode (one cathode material will be downselected for development), while for the anode material the proposed future work (optimization of coating and electrolyte formulation, cell design and abuse tolerance) is too generic. The same reviewer wanted 3M to be supplying samples to DOE for validation as indicated in the previous section.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers agreed that 3M was well equipped and is working with other organizations as necessary for capabilities which they lack and external evaluations of their materials, so that resources are adequate. One reviewer specifically recommended continuing to fund this work through the DOE.

USABC Battery Separator Development: Ron Smith (Celgard)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The majority of reviewers were dissatisfied with how the Celgard addressed – or did not address – the DOE objectives. One reviewer noted that though the work on separators is important – as yet another reviewer noted, the high-temperature melt integrity of separators is a critical property for the safety of lithium-ion batteries – the technical issues mentioned in the project seem marginal. Another suspected that Celgard is working in a vacuum, working on the correct subject but with a questionable execution.

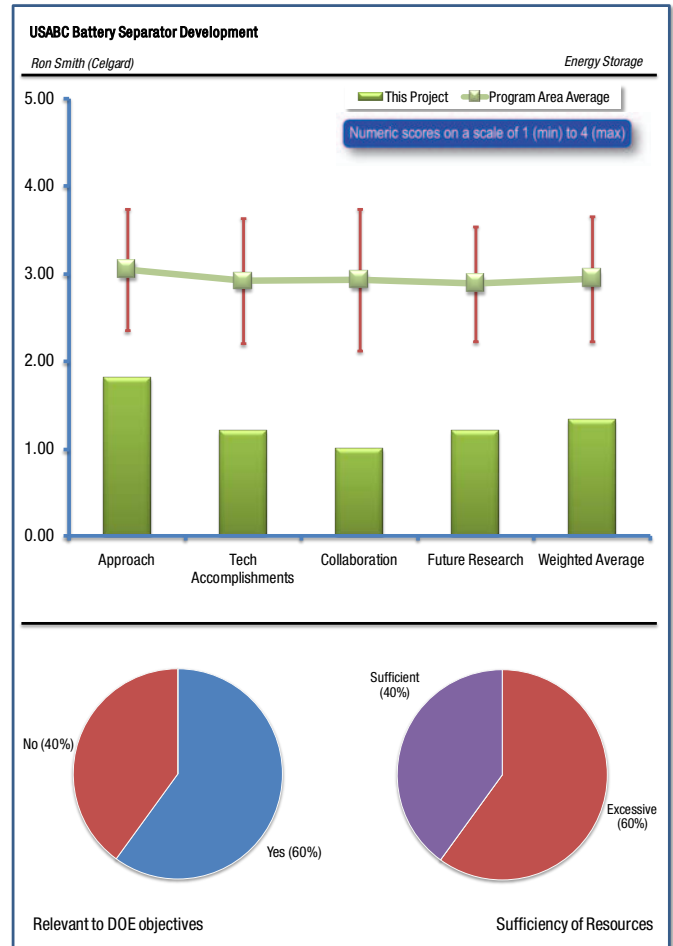
Other reviewers registered even stronger objections, noting that Celgard’s effort appears to be developing testing methodology that is closed or proprietary, and that this is a responsibility that should be left to Federal Agencies, the national labs, ASTM, SAE, or USABC and other consortia.

One reviewer was very unsatisfied with the completeness/level of information shared.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers generally expressed frustration with Celgard’s proprietary methods. One reviewer did say that from the limited information provided, the approach appears to be very reasonable for the development of a test method to measure high temperature melt integrity (HTMI) and to use such a method to design safer separators for lithium batteries. Another noted that the work on standards is interesting, but it lacked details and justification of the differences with existing standards and procedures. The stability versus various electrolyte materials would be an added value for battery applications.

However, there was no description of Celgard’s approach to its work on separator development. Another reviewer questioned whether Celgard should be attempting to define performance requirements outside of the scope of a potential customer. A third reviewer wrote that it doesn't seem appropriate to rely solely on Celgard's proprietary test methodology in a manner not subject to thorough review in order to set up a benchmark for future materials developed by Celgard. Finally, the last reviewer echoed this sentiment, pointing out that nothing in the Celgard talk addressed how they would actually make a better separator. The approach to coming up with a better test might have been useful, but for the fact that they are doing this alone and keeping it secret. For any new test to be useful, it has to be accepted and thus they would need to publicize the test and show why it is better than anything else out there. He indicated that Celgard will never get buy-in from others if they insist on doing their own thing, and said there's no (good) reason why they can't at least talk about test methods.”



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

All reviewers agreed that there was insufficient information to be able to rate progress, so that this was not an acceptable review. The most strongly worded criticism stated that Celgard “did not report any accomplishments except that they have developed a test that they like, but refused to describe it or even say why it was better.” There was no substantive information presented.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The reviewers all said that they saw no evidence of any collaborations, and two suggested that they should look to collaborate with the national labs.

QUESTION 5: HAS THE PROJECT 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?

No details were provided regarding future work for which a review can be made.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers were at best neutral or did not answer. The more outspoken reviewers noted that though this work needs to be done, Celgard may not be the best choice of contractors to continue with this project without significant additional oversight.

The most strongly worded reaction was from a reviewer who stated that the lack of project details made it impossible to provide a good rating.

Multifunctional, Inorganic-Filled Separators for Large Format, Li-ion Batteries: Richard Pekala (Entek)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers agreed that separator cost and stability are key issues for Li-ion battery development and applications. It is also very relevant and necessary, with the high temperature melt integrity of separators as a critical property for the safety of lithium batteries. The use of inorganic fillers to improve this property is widely viewed as one of the best and most practical methods of improving the melt integrity of membranes. One reviewer noted that this work mainly addresses safety by seeking to create stable films to high temperature (low shrinkage), while also providing a shut-down separator (other companies seem to have given up on doing both).

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

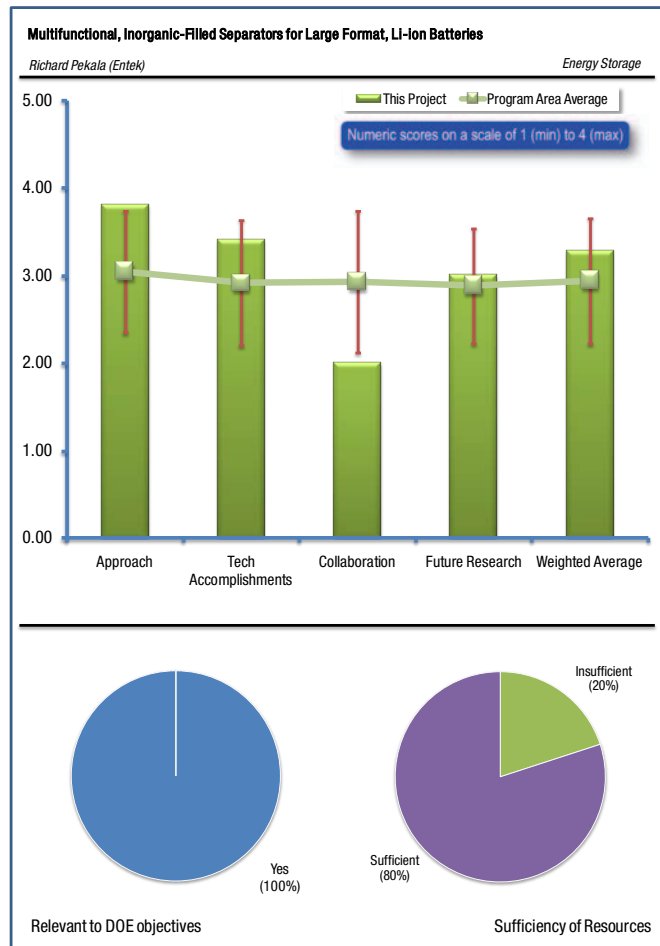
Reviewers recognized Entek’s approach as being clearly focused and organized with clear steps to meet identified technical and economical objectives, and that they possess very good expertise in separator development. One reviewer praised the company’s innovative technique (getting inorganic fillers into the bulk of the polymer) combined with a good appreciation of practicality and manufacturability.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers were impressed by Entek’s progress in the few months since the project started in February 2010. One reviewer characterized the progress as interesting and well-described with some quantitative data well aligned with expectations. He also judged that the technical and economical barriers are likely to be overcome, with another reviewer observing that Entek is very close to getting a practical material, although it is not really addressing the cost issue, and instead is more focused on safety.

Another reviewer praised how a sample was provided to the reviewer and audience to demonstrate the quality of the developmental material. Embedding the inorganic filler inside the membrane rather than as a layer on the surface (the competing approach) results in separators with much improved properties (low MacMullin number, low shrinkage, and excellent wettability). The heat treatment step may be a vital part of the separator processing.

In terms of feedback, the reviewer noted that the puncture strength of the membranes is still not meeting the program goal. It is unclear why the Process B membrane (with 69% silica) has a much better puncture strength than the Process A membrane (with 67% alumina). One concern is the possible difficulty in drying these membranes prior to battery assembly as both fillers are known to be hydrophilic (which has caused considerable confusion in the polymer electrolyte with filler scientific literature). Questions regarding how the prototype samples perform in preliminary cell testing would have been helpful in gauging the utility of these separators.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers stated that partners were listed: Rhodia (which is supplying the inorganic filler) and Portland State University (for the electron microscopy work provided). However, no other collaborations or coordination with other institutions was indicated. It is not clear if these separators will be provided to DOE labs or other organizations for external evaluation. A reviewer advised that more integration and collaboration with electrodes and electrolytes projects are highly recommended. The stability of the investigated separators should be analyzed with the electrolyte and electrode materials studied in the program. Another reviewer recommended more co-operation with Sandia who are also looking at separator safety and developing new tests.

QUESTION 5: HAS THE PROJECT 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?

Reviewers praised Entek's future plans as good. A reviewer noted that Entek seems to be moving forward aggressively and plans to get real samples into cell very soon. There were recommendations to improve collaborations and extend stability analysis to other materials sensitive to the program. Another reviewer noted that Entek's answers to questions show they are aware of and working on multiple issues not covered in the talk.

Another reviewer went into more detail in his assessment: For the future work, the concerns regarding the choice of filler will be addressed. New polymers and new process equipment may also be identified. Electrolyte compatibility and cell testing will be conducted. The project is listed as beginning in February 2010 so the progress thus far is very reasonable (it is assumed that the project has actually been on-going for a greater period of time).

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

All reviewers judged that Entek was well-equipped to conduct its project and using its resources efficiently. The reviewer who was most vocal in his disappointment about Celgard's presentation stated that Entek is "making great strides. I would like to see a separate effort on low cost materials."

Hybrid Nano Carbon Fiber/Graphene Platelet-Based High-Capacity Anodes for Lithium Ion Batteries: Bor Jang (Angstrom Materials)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewers all recognized that developing low-cost and high-capacity anode materials is an important step towards realizing higher energy density battery systems for electric vehicles. Three reviewers commented that the silicon (Si) alloys being investigated in this project were an attractive material for the goal of range-extending capacity for PHEVs, which would in turn reduce the petroleum consumption, demand and (national) dependence. Also, a reviewer added that this work represents a U.S. technology base rather than a Japanese or Korean technology development.

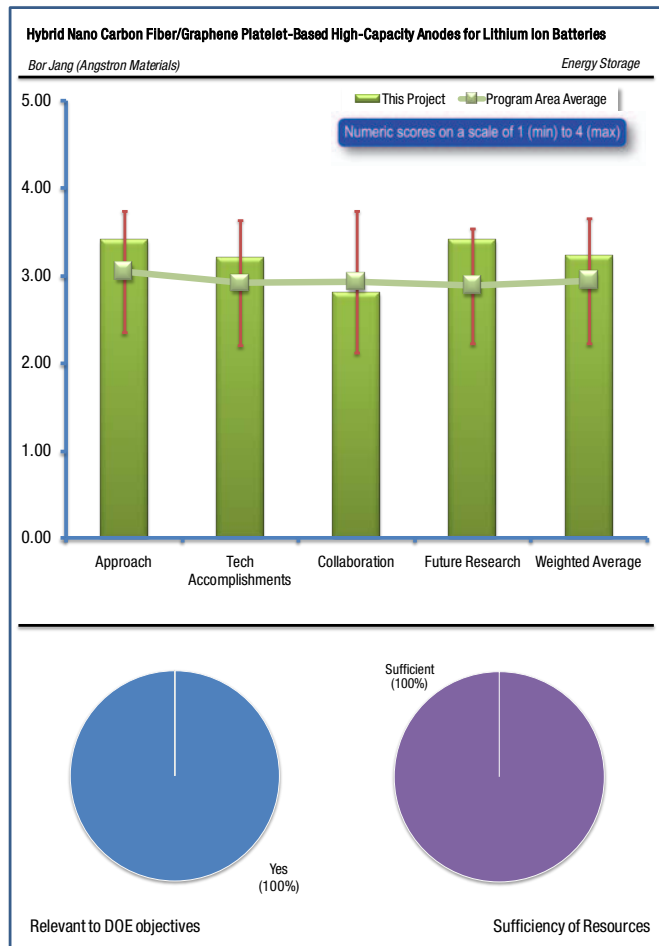
Cautionary notes were that Si alloys have been plagued by problems related to volume expansion and particle fragmentation, and another reviewer added that “everyone” seems to be working on Si, while noting that this group does seem to have a number of approaches and one or more could prove workable.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers welcomed the team’s approach, characterizing it as seeming effective, reasonable, and feasible to provide sufficiently high proportion of Si particles and thus high capacities exceeding 600 mAh/g. Another reviewer described the approach as well-presented, cost-effective, alternative, and well-defined with excellent variable considerations; he lauded that the approach is well-suited for manufacturing scale-up, in that both the nano graphene platelets (NGPs) and electro-spun carbon nano-fibers (CNFs) are low-cost nano materials and the Si deposition is being achieved by adopting the chemical vapor deposition system for mass production. A third reviewer conceded that though he was originally not excited about yet another way to form-C-coated silicon, the team at Angstrom Materials also appears to have a rather unique method and also the background expertise to meet their goals.

Cautionary notes included:

- The high surface area is good for delivering high currents when demanded but has a problem in the first cycle loss when the anode is charged for the first time. With graphite having a surface area of about 3 m²/g, this amounts to about 5% of the total capacity of the cell going to form the SEI protective layer. While the SEI layer may have a different structure on silicon nanowires, at 9 m²/g, the first cycle loss will significantly reduce the total cell capacity.
- There is still the lingering issue of high irreversible capacity, which may negate the benefits of high reversible capacity, unless other lithium sources (than cathode) are explored.
- A reviewer was concerned about the large volume (low energy density in Wh/L) and large amount of electrolyte required for at least some of the team’s approaches.
- The same reviewer also noted that costs don't seem too outrageous, but he was still not convinced that any of these manufacturing methods can really handle the huge scale and cost constraints of the auto business. In particular, he believed that while



electrospinning can be scaled up, its cost structure is simply too high for HEV/PHEV batteries. However, he noted that the team is looking at various methods, so it has options.

- The reviewer would also have preferred to see some more realistic and detailed cost estimates for a large-scale production system.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewers praised the project's progress in its first months, with a reviewer saying that the team had a very interesting approach, and another observing that the initial cycle life looks very good. One reviewer said that good progress has been achieved within one year both in terms of designs for suitable hybrid structures containing Si nano-particles during Li absorption and release and in developing low-cost materials and production methods. He also observed that the CNF or NGP geometry enables the supported coating to freely undergo strain relaxation in transverse directions, with NGPs providing a geometric confinement effect and a 2-D envelope maintaining good contact with Si particles. The resilience of such hybrid anode structures were demonstrated in half-cells, consistent with the DoE goals, according to this reviewer.

Another reviewer noted that the 650 mAh/g capacity for the silicon anode is about twice that of the graphite materials presently in use in Li-ion batteries, and that the team has designed a CVD process to produce a bed of amorphous silicon coated carbon nanowires and/or graphene sheets. The grain size is about 100 nanometers, a size which eases the strain when cycling as lithium enters/leaves the silicon alloy. The silicon loading can be controlled and the process is low-cost. The effectiveness of the anode has been demonstrated in half-cells. The team has developed the process for producing carbon nanowires, and the coated graphene sheets seemed to maintain capacity better on cycling.

A final reviewer raised a couple of concerns. He stated that the team needs to address costs more than they have done. Also, while there may be several ways to overcome initial irreversible capacity loss, they still need to demonstrate good coulombic efficiency after the first cycle or their cathode will run out of cyclable lithium with time.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Most reviewers felt that Angstrom had reasonable collaborations, and with the right mix of partners.

One reviewer noted that K2 Energy is a forward-thinking group and a good match for Angstrom. K2 presently has production in China as well as a new plant in Finland. Another reviewer observed that K2 Energy Solutions will assist in assessing these materials and in adopting them for various applications. A third reviewer stated that K2 is not what he would call a major player, however.

The first reviewer also characterized the Applied Sciences, noting that it will produce the vapor grown carbon nanofibers to go with Angstrom graphene sheets form a bed of carbon nanowires on graphene sheets. Another phrased this relationship as Applied Sciences will help in developing similar hybrid anode designs with vapor grown carbon fibers.

A reviewer said that though Angstrom appears to have good links to other carbon sources, it still needs to do more in establishing collaborations. He felt that the biggest problem is that they appear not to have linkage with any of the DOE Labs, and said that Angstrom should be providing samples to Argonne for characterization (and eventually to Battaglia at LBL), along with ANL. Cell builds at K2 should also include sampling to the DOE labs for an independent evaluation.

QUESTION 5: HAS THE PROJECT 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?

Most reviewers were positive about the plans, with one saying it was an excellent plan to progress to production feasibility. Another said the proposed future research is effectively planned and the future plans are consistent with the overall goals and include developing low-cost mass production methods, continuing the evaluation of these materials in half-cells, and later in button cells and 18650 cells. A third reviewer described the plans themselves, noting that a larger lab-scale CVD system will be installed to produce greater quantities of experimental anode materials. The parameters of the Si coating processes will be optimized to make reproducible

anode materials for experimental purposes. Also, safe operating procedures will be developed for the silicon coating process along with the MSDS of Silane, and the detailed personnel training and protection requirements. The morphology of the silicon deposition, thickness, crystal structure and the weight percentage of Si coating will be characterized and the evaluation of Si-coated anode materials by the half-cell method will be conducted at Angstrom and K2 during FY 2010. A fourth reviewer said that Angstrom will be pulling in their partners.

One reviewer was a bit more restrained, saying that he would have preferred to see some more realistic and detailed cost estimates for a large-scale production system. While this is not always easy to do, they should have enough information to at least make a stab at this. Also, Angstrom (and others) need to address the coulombic inefficiency that can cause the cathode to run out of cycleable lithium during cycling. Even 99.9% anode coulombic efficiency is not good enough or 20% cathode capacity is lost in just 200 cycles. Finally, this reviewer would require them to provide samples of cells for independent testing by ANL/Sandia - both materials and cells.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The reviewers felt that the resources were sufficient. One noted that the resources of about \$3.2 M with around 50% cost-share are consistent with the project scope in terms of developing new anode structures and scaling up the production methods. Another said that the budgeted amount should be ample.

A reviewer also agreed with the resource allocation, with some caveats. While he felt that Asian companies are ahead of the US in this area (cf. Panasonic's announcement of a 4Ah 18650 in the next year or two), the DOE needs to have someone in their own program to follow this approach and provide samples. He believes that Angstrom is well-suited for this job; however, he would not recommend funding more than two efforts in this area. He would want to see a path to a viable low-cost manufacturing method before funding work beyond that time frame.

New High-Energy Nanofiber Anode Materials: Xiangwu Zhang (NC State/NLE)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

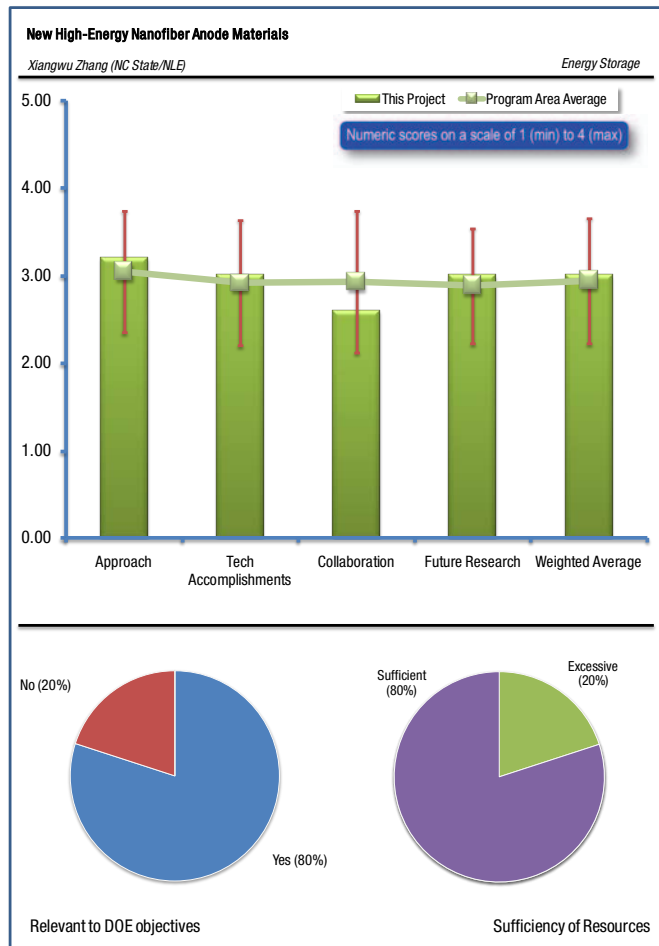
Reviewers generally felt that this project supported DOE’s objectives, as the drive for new higher energy battery systems is essential for meeting the goal of establishing electric vehicles as a viable transportation method that does not use petroleum as the energy source, according to one reviewer. He added that the silicon anode materials significantly increase the capacity, 670 mAh/g, and therefore will result in higher capacity batteries, and therefore higher energy storage capability. Another reviewer observed that the energy density improvement is needed to reduce the weight and volume of the battery systems. The anode capacity improvement will help with the goal of increasing cell energy density.

A third reviewer echoed this characterization, stating that the objective is to develop high-energy anode materials for Li-ion cells, based on silicon nano-particles embedded in a carbon nanofiber. Lithium alloys, especially Si alloys, are promising to provide 2-3 times the capacity of graphite anodes, but their use is being deterred by problems related to volume expansion and particle fragmentation of Si upon alloying with Li. Such anodes, if successfully developed, will contribute to an enhanced specific energy for Li-ion batteries to make them viable for PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement.

One reviewer offered some criticisms, however, stating that while they are aiming at high energy anodes and their approach does hold out the promise that they can maintain a Si-C conductive path during cycling, he did not believe that the team has anything significantly different from anyone else looking at C-Si anodes. He was also not convinced that spinning is commercially viable for the HEV or PHEV program, saying that just because it can be done on a large scale doesn't mean it is viable for the HEV program where costs are so critical.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

All but one of the reviewers responded favorably to the approach. One reviewer said that the approach looks effective, reasonable and amenable to scale up, and the plan to demonstrate the performance of these materials is also sound. He described the approach as addressing the three main barriers of capacity, cycle life, and cost with such Si composite anode. The approach involves the development of Si/C nanofibers that were prepared by the electro-spinning and carbonization of Si/Polymer (e.g., PAN) precursor nanofibers. A second reviewer had a similar response, reflecting that the project was about electrospun carbon fiber support for Si, and indicating that the team seems to understand the issues and has an interesting approach. A third reviewer said the systematic development starting with spinned fibers and embedding silicone makes it very encouraging.



Another reviewer recognized that preliminary results give 650 mAh/g capacity, and said that the approach is interesting and novel. However, he had questions: the exact details of the processing to produce Si particles in and on the various fibers were not clear. He also asked why there was an effect of surfactant on the nature of the final product.

Other criticisms logged by the reviewers include:

- There is still the issue of high irreversible capacity of over 20%, which may negate the benefits of high reversible capacity, unless other lithium sources (than cathode) are explored.
- The approach seems OK, but this came across as a “me-too” program. The reviewer did not find the approach especially innovative in that there are many ways to embed Si on C (basically C-coat) Si. He did not see why this approach should really be any better and the volume density of their fiber approach would seem to be really poor. While this reviewer considered Wh/kg to be the main metric, Wh/L is still very important and the volume and added electrolyte needed to fill these porous structures seems likely to hurt both energy density and cost.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

All reviewers approved of the progress made thus far. Comments included that the goal of twice the capacity of graphite was achieved with several different experimental configurations. The capacity was fairly constant during cycling. Another reviewer said that the progress achieved within one year is consistent with the project plans as well as with the DOE goals. Si/C nanofiber anodes, have been prepared using the electro-spinning technique, impregnating Si nanoparticles in carbon fibers made from PAN, and their performance demonstrated in coin cells, with a capacity of about 800 mAh/g, beyond the Year 1 Target of 650 mAh/g. Further, these materials have also been tested in 18650 cells, again demonstrating high stable capacity (of 600 mAh/g). A third reviewer said that good progress has been made in the first partial year, with improvements having been identified and applied (i.e. Si distribution).

Caveats included:

- A reviewer felt that the discussions should include more details and explanations of the experimental work.
- The fabrication of an 18650 cell was carried out to show the feasibility of the anode construction by American Lithium Energy. It was not clear why the cell voltage fell off at 150°C.
- Though the project has met the original goal, the cycle life may require additional development. Irreversible capacity may be limiting the energy improvement.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers noticed only two partners, one of which is a start-up focused on this work (Tec-Cell Inc., set up for transferring this spinning technology in the future, as one reviewer characterized it). The silicon-carbon/carbon composite anode - cobalt cathode cells were made by American Lithium Energy. A reviewer said the collaboration seems to be in good order as is the formation of a venture capital company to exploit the development. A reviewer speculated that possibly, other closer collaborations will be established with the DOE laboratories and other battery technologists in future.

QUESTION 5: HAS THE PROJECT 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?

The consensus among the reviewers was that the goals and milestones were reasonable, but there were some questions. A reviewer noted that the continued effort to establish the technology and improve the capacity to 1200 mAh/g and cycle life to 700 is absolutely needed. One reviewer said the future plans are consistent with the overall goals and include: i) optimizing the processing conditions and structure of Si/C nanofibers methods to achieve improvements in both capacity and cycle life, ii) continuing with their evaluation in coin cells and iii) fabricating 18650 cells with these Si/C nanofibers to demonstrate a capacity of > 600 mAh/g and cycle life of over 750 cycles with 70% depth of discharge. Another said that the effort to optimize the deposition process and optimize experimental parameters, such as flow rate, viscosity, surface tension and carbonization parameters is essential to success.

A skeptical reviewer commented that the team didn't really explain how they were going to hit the next density goal. How is the performance going to be improved? A second reviewer said that while the goals and milestones seem quite reasonable. However, he was not sure how they expect to meet their goals. Also, the team and others need to address the coulombic inefficiency that can cause the cathode to run out of cycleable lithium during cycling. Even 99.9% anode coulombic efficiency is not good enough or you lose 20% cathode capacity in just 200 cycles.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers were satisfied with the resources for this program. One explained that the resources of ~\$2.6M with ~50% cost-share are consistent with the project scope in terms of developing new Si/C nanofibers using low-cost electro-spinning and demonstrating their performance in sealed cells. Another reviewer commented that the team seems able to do the work with what they have. Though this was not bad at all, he however questions the advisability of funding this work in terms of novelty. He was skeptical that even if they succeed, that material processing method can compete on either a cost or a volume basis with other, simpler approaches. Because it seems like everyone is looking at various ways to coat Si with C, this reviewer did not believe that the DOE needs to fund yet another such project.

Stabilized Lithium Metal Powder, Enabling Material and Revolutionary Technology for High Energy Li-ion Batteries: Marina Yakovleva (FMC)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewers approved the project’s support of DOE objectives, noting the potential for improved battery performance, including improving the energy density and reducing cell manufacturing cost. More specifically, a reviewer observed that the project addresses one way to help utilize high-capacity anodes that have either a high initial capacity loss and/or lower than desired coulombic efficiency. It also could enable non-lithium-containing cathodes (make cells with a charged cathode such as V₂O₅ and discharged anode+SLMP).

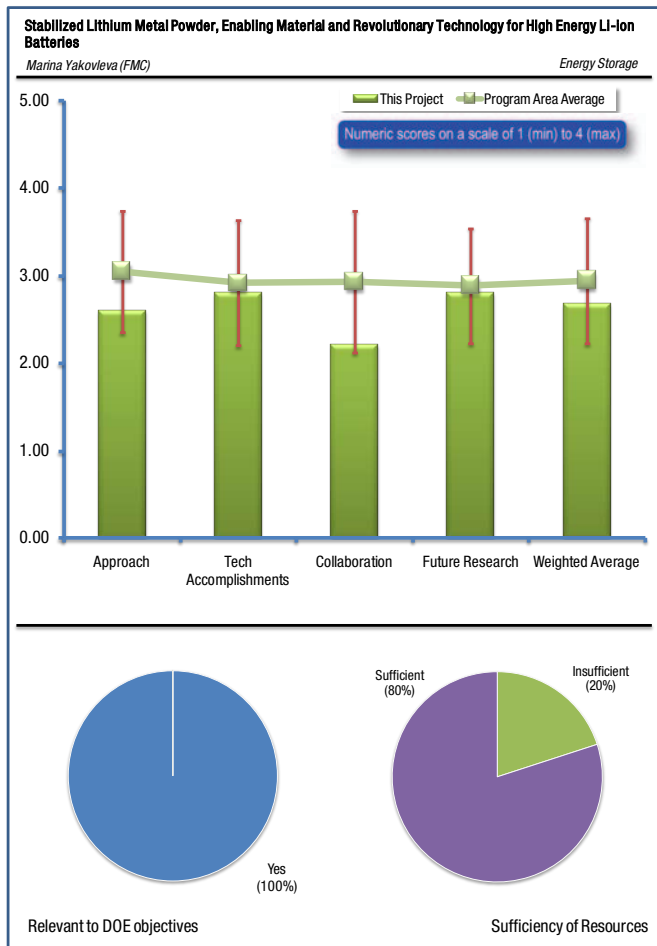
A third reviewer said that the lithium metal preparation developed by FMC is unique and offers a good, safe method to incorporate the lithium into cell constructions. As the press for higher energy density continues, lithium metal offers the highest energy density over the Li-Ion system.

Finally, a reviewer described the project as follows: The high capacity Li-alloy anodes (both Si and Sn) have the disadvantage of high irreversible capacities, for which the lithium source comes typically from the cathode, whose specific capacity is considerably lower. The objective of this project is to develop cost-effective manufacturing processes for SLMP (stabilized lithium metal powder), which will function as an independent source of lithium and thus enable the use of such high capacity anodes. The overall objective is to integrate the SLMP Technology into the Li-ion cell for PHEV application, and support high volume production of Li-ion batteries and to make available commercial quantities of SLMP that will enable higher energy, safer, environmentally friendlier and lower cost lithium batteries. Such batteries will contribute to the success of PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The reviewers had a mix of reactions to the approach. A reviewer said that this potentially addresses a number of issues. Another reviewer said that FMC has worked hard to develop a safer means to incorporate lithium metal anodes in advanced battery systems. The “slump” materials offer a more efficient, safer means to incorporate lithium metal anodes into the cell construction. It can be used to pre-lithiate the graphite materials for use in Li-ion cell constructions, but the more interesting fact is that it offers a new opportunity for lithium metal in the new push for lithium-air and similar lithium metal and lithium alloy anode systems being developed.

Another reviewer said FMC’s approach is to develop manufacturing methods for the SLMP. SLMP may be added to the anode to compensate for its irreversible capacity and even to lithiate the carbon anode such that it may be combined with non-lithiated cathodes. In either approach, the amount of SLM required to be added is considerably less, due to its high Li content, ~ 98%. The approach involves the development of a process and prototype unit for the commercial production of dry stabilized lithium metal powder (SLMP) and the integration of SLMP Technology into the a Li-Ion system, e.g., MCMB/LiMn₂O₄ system to demonstrate the



improvements both in the capacity as well as cycle life upon SLMP addition. A successful integration of the SLMP with the Li-ion chemistry is to yet to established, especially in the industrial production environment.

A couple of reviewers were more critical, however. One said that the use of stabilized lithium metal has not been successfully used in last 3-4 years and is not acceptable to most Li-ion battery developers. Another said that he is not sure why we need to have a pilot line facility at this stage. He recommended more lab work to demonstrate advantages and proof of concept of how you would actually implement this in a real battery production line needs to be done to assess practicality. He did not think a SLMP pilot line was needed to do this until and unless there are having trouble supplying samples. This reviewer still supported this work going forward, as it does open up new opportunities. Though he would much rather see lab work on using non-lithiated cathodes, he conceded that this needs to be done by others (such as LBNL/ANL).

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Progress achieved within the last two years was variously recognized as “excellent,” and consistent with the project plans as well as with the DoE goals. One reviewer said that FMC offers help to the developers to efficiently incorporate lithium metal into cell constructions. It offers a much safer and efficient method over lithium foil to incorporate lithium into cell constructions. A second reviewer said that FMC has shown that the SLMP has potential, and a third characterized the team’s activities as a prototype unit for the commercial production of dry stabilized lithium metal powder was designed, fabricated and tested and its process parameters have been optimized through design of experiments. Additionally, full pouch cell fabrication capability was developed. The benefits of the SLMP Technology have been successfully demonstrated in such pouch cells in the electrochemical system MCMB/ LiMn_2O_4 .

A final reviewer said that the timing for installation was pretty good for an industrial process in light of safety issues when dealing with high-surface-area lithium metal. However, he felt that a pilot line is “a nice-to-have” feature, not an essential program goal, because he is not yet convinced that SLMP is even necessary yet. Cell work shows the idea basically works, but the improvement is limited to the irreversible capacity loss, which is not that high with the cells investigated. So the project is leading to incremental improvements only (although using hard carbons is certainly better than graphite as an evaluation tool). This reviewer would like to see this used with Si and other anodes with very high irreversible capacity loss ASAP.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Most reviewers felt that FMC needed more collaborations. One said they need a battery producer as a partner for this project. Another said that FMC says they are working with lots of people, but he feared it may not be an in-depth relationship in most cases, and he felt this company really needs to have a real partner working with them on this so that they can get feedback. He suggested the DOE try to pair them up with the people looking at high-energy anodes as it seems that both groups need each other's help to come up with a practical solution. A third reviewer noted that no partners were specified, but FMC claims to be collaborating with major research institutes and universities in the development of non-lithium providing cathodes and in enabling advanced anode materials, such as Si/Sn composites and hard carbons and in the development of the application technologies. It is also engaging in joint development agreements with major Li-ion battery manufacturers.

A final reviewer noted that FMC offers their expertise to all who chose to use lithium metal anodes. This includes not only the lithium metal but the easiest and safest method to incorporate lithium metal in production of the cell. As new people get involved in lithium metal, they will need the expertise in handling lithium metal safely. This is not a trivial thing, as the metal can be very reactive and most have had experience with lithium fires in one way or another in the R&D as well as production operations.

QUESTION 5: HAS THE PROJECT 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?

Reviewers saw the future plans positively. One said that they had good plans and they seem to be working on the important areas as far as anodes go, though he was not so sure about non-lithiated cathodes. Good work but the reviewer would like to see it paired with DOE lab work on non-lithiated cathodes; they need help from the DOE labs on this. Another noted that the contract is based on the

use of lithium metal anodes in advanced battery development. FMC has the expertise and willingness to invest their efforts to assist in this important effort to develop new high-energy systems for vehicle propulsion.

A final reviewer said: The proposed future research is effectively planned and the future plans are consistent with the overall goals and include: i) Developing a process and design commercial unit to scale-up the production of SLMP dispersion in mineral oil (it is not clear how mineral oil dispersion is good for battery applications), ii) exploring the use of pilot scale alternative unit to produce dry SLMP powder directly from battery quality lithium metal and integrate SLMP Technology into the Li-ion cell using hard carbon/LiMn₂O₄ system.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The resources were seen as sufficient to meet the stated milestones. The resources of about \$6 million with around 50% cost-share over three years are consistent with the project scope in terms of developing commercial plant for the production of SLMP and integrating it into the Li-ion cells for improved capacity and life. One reviewer noted that the process is almost ready to go, so the team just needs a little help with scale-up and applications. As a result, he encouraged continued funding of this work, but would like to see it paired with DOE lab work on new non-lithiated cathodes.

*Protection of Li Anodes Using Dual Phase Electrolytes:
Yuriy Mikhaylik (Sion Power)*

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers agreed that the project supports the DOE objectives. One reviewer noted the potential for improved battery performance, with another noting more specifically that the Li-S cell has the potential to be the maximum energy density. Li-S system has excellent energy density and offers a light weight, high-energy source for consideration as the next generation vehicle system. The metal lithium anode will provide higher energy storage capability than the Li-ion system. Other strengths of this system noted by a different reviewer are that in principle, Li-S could address a number of issues. The reasons are that the raw materials are relatively cheap, and Sion Power has demonstrated good rate, safety, and low temperature performance in the past.

A reviewer described his reasoning towards his approval of the project’s alignment with DOE objectives as follows: the lithium-sulfur system offers high gravimetric and volumetric energy densities, due to the high specific capacity of the sulfur cathode. However, its advantages haven't been realized yet, due to the solubility of polysulfides from cathode in the electrolyte migrating to the anode and affecting its cycle life. The objective of this project is to develop an electrolyte system with two immiscible electrolyte solutions for the anode and cathode compartments, each with adequate chemical/electrochemical stability and impermeability for the polysulfides towards the anode. The overall objective is to incorporate such an electrolyte system in large format cells and demonstrate the improvements in specific energy, cycle life and safety. These studies, if successful, will lead to widespread use of Li-S in PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement.

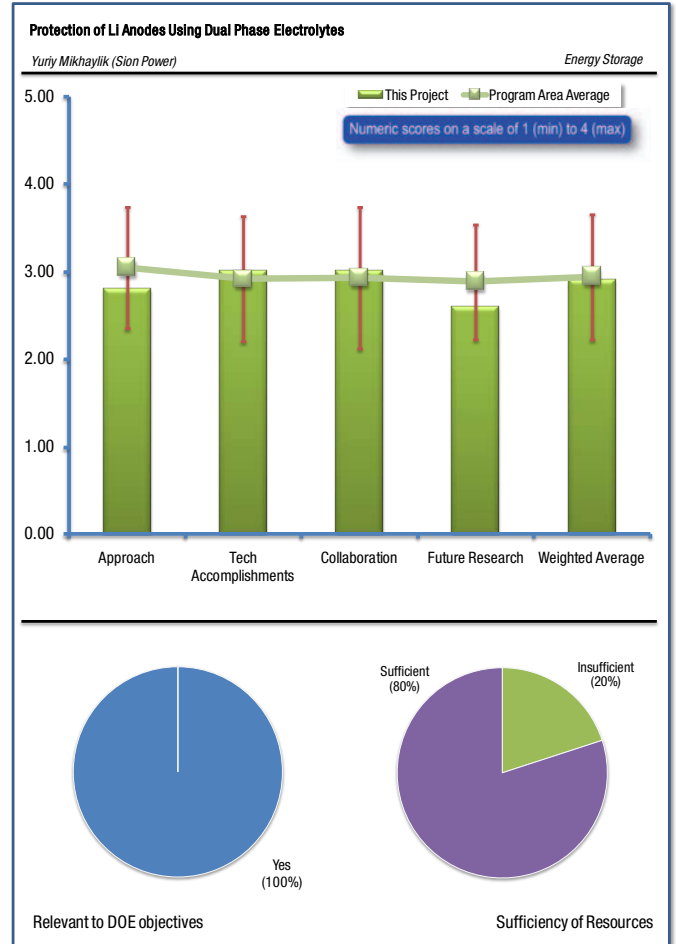
The objective of this project is to develop an electrolyte system with two immiscible electrolyte solutions for the anode and cathode compartments, each with adequate chemical/electrochemical stability and impermeability for the polysulfides towards the anode. The overall objective is to incorporate such an electrolyte system in large format cells and demonstrate the improvements in specific energy, cycle life and safety. These studies, if successful, will lead to widespread use of Li-S in PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement.

However, a caveat of Sion Power’s Li-S system is that cycle life and energy are “not that great,” according to a reviewer.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers expressed views that, in general, it was a good approach with good results so far, according to one reviewer. Another said it was a nice system and provides another option, and was interesting when viewed as a portfolio item. A third reviewer noted that the team has already surpassed the initial contract goals, and the key for initial success was the gel polymer developed to coat the lithium metal anode. The use of a two-phase cathode electrolyte solves several problems in the sulfur cathode formulations used in the rechargeable lithium metal anode.

Going forward, Sion Power should consider addressing the following: Sion Power needs to look at the impact of electrolyte on other performance/safety/cost aspects of cell. In particular, one reviewer pointed out that the lithium protecting layer using gel electrolyte is not robust enough to survive an automotive application. The cycle number should be equal to 5,000 cycles and the approach is targeted to 100 cycles. There is a big gap.



The approach is to develop a two-component immiscible electrolyte system, specific to anode and cathode environments. The anode electrolyte will be compatible with lithium, immobilized in a gel and also works as a separator. More importantly, it doesn't dissolve polysulfides from the cathode. The catholyte, on the other hand, is tailored to improve the sulfur cathode performance with high polysulfide solubility. Even though the approach looks elegant and feasible from the preliminary studies, it is not clear how rapidly lithium can migrate across two immiscible phases to provide high rate capability. As well, it is not realistic to assume that the anode will be free of dendrites with the proposed gel electrolytes in ether solutions, based on the vast number of studies with Li metal rechargeable systems.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers deemed the technical accomplishments and progress to be very good, with a couple of exceptions. One reviewer described it as reasonably good progress has been achieved within one year, consistent with the project plans as well as with the DoE goals. Improvements in both cycle life, beyond the modest target of 50 cycles, and in thermal safety have been demonstrated in small pouch cells with the proposed two-component electrolyte system.

Another reviewer said that the results demonstrate good promise for the system. The Wh/l and Wh/kg are essentially the same for the system. The two-phase cathode appears to be a good solution to the use of the sulfur cathode. The gel anode film gives good stability. Thermal runaway problems are under control and the demonstrated cycle life is twice that of the value targeted initially for this stage of development. A third reviewer echoed this, noting that Sion Power's team has exceeded durability and shown elimination of thermal runaway (up to 250°C).

Criticisms included that the DOE goal is 1,000+ cycle life, so that there is a big gap between the accomplishment and the goals. Another reviewer added that while the high-temperature safety data is very impressive, it's hard to understand how they can get above molten lithium without a problem. This was echoed in a different reviewer's statements as well, as he said the finding on the thermal safety beyond the melting point of lithium is unexpected and incomprehensible in a Li/metal gel polymer system. As for abuse tolerance, a reviewer said that he was still not sure about safety to crush Sion Power's cells either, but their nail penetration results are hopeful. Finally, a reviewer noted that though 350 Wh/kg sounds very good, although Wh/L is poor due to low density, making the battery pack quite large, which has cost and indirect weight implications.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

All reviewers recognized Sion's joint development agreement with BASF in Germany, where it has 14 scientists working on the project there. BASF has a working arrangement with Sion and works full time on the Li-S technology. A reviewer noted that the collaboration with BASF looks promising and adds strength to the team. However, another reviewer expressed that although the BASF chemical expertise will be very helpful in solving the polysulfide problem in the cell, he noted that there is no active development work discussion with them.

A couple of reviewers noted that there was no collaboration yet with any DOE laboratory, and one said he would like to see evidence of cooperation with Sandia on safety, especially for impact/crush work.

QUESTION 5: HAS THE PROJECT 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?

It was recognized that Sion Power has generally stated a path forward, though a couple of reviewers had some salient questions. One reviewer said that the development of a larger format 2.5 Ah cell structure will provide the opportunity to confirm stability of the anode coating and the dual-phase electrolyte system, and the testing to confirm the potential to meet the USABC goals is also a good step. Another reviewer said the proposed future research is well planned and the future plans are consistent with the overall goals and include: i) optimizing the cell hardware including the gel polymer and electrolyte, ii) develop a model to simulate performance for automotive applications and iii) develop larger format prototype 2.5 Ah Li-S cells to demonstrate >350 Wh/kg specific energy and longer cycle life under USABC test conditions.

Questions that some reviewers brought up about Sion Power's plan include that the lithium anode protection needs a robust Li-ion conducting barrier to last 1,000 cycles and the future research does not address the potential solution. Another reviewer said that he wanted to see a detailed cost estimate and volume/weight estimates, because he was wondering if Sion Power can ever meet the goals in any of these areas. One of the causes of low energy density is the relatively low percentage of actives in the cathode because they need a lot of solvent to solubilize the polysulfides, this reviewer opined. Work on improving the cathode actives should be pursued. Cycle life is poor as well.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The program has sufficient resources to establish the feasibility of developing the system for use in vehicle propulsion. An increase in resources will be in order when the initial work produces a system with potential for longer cycle life. The resources of about \$2.8 million with about two-thirds cost-share over three years are consistent with the project scope in terms of developing Li-S cells with dual-phase electrolytes for improved capacity and life.

A reviewer who was a bit more mixed in his response said that the overall LOS still seems low, but the team is making progress and this is a good use of DOE funding, if only as part of a portfolio approach to give more options. However, the DOE needs to keep a close eye on this program to ensure that they can continue to address the cycle life issues. This reviewer would like to see a projected design for a complete battery pack to judge whether even if they were successful it would be a viable system. In other words, the reviewer was unsure that DOE would actually want their battery system even if Sion Power fixed their problems.

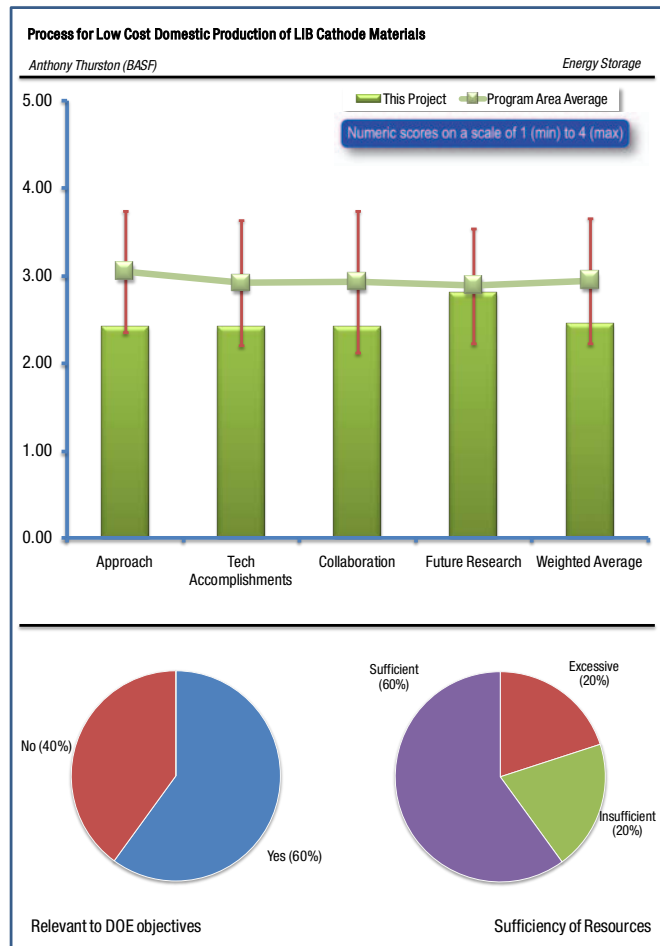
Process for Low Cost Domestic Production of LIB Cathode Materials: Anthony Thurston (BASF)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers saw this project as quite relevant to the overall DOE goals, though dissenters had questions about degree of need and timing. A firmer supporter said that it is essential to develop domestic supplies of all critical materials used in advanced batteries for electric vehicles. This project takes advantage of the newly developed materials from Argonne National Laboratory to develop an efficient production method. High-quality materials with controlled particle size and purity are essential. Another reviewer shared this view, noting that it is important to develop low-cost production methods for cathode materials being developed under BATT and ABR and BASF is well positioned to undertake these studies. Another objective is to validate the cost and quality targets are met via coin cells, pouch cells and 18650 cells, with final incorporation into a battery pack for complete testing and extensive material characterization. These studies, if successful, will lead to the incorporation of high-energy cathodes in Li-Ion cells for enhancing the PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement.



A third reviewer added that possible battery cost reduction and production capability were the goals here, and another reviewer echoed this, saying the perception was that BASF will synthesize high energy composite layered cathode. The objective of the project is to reduce the cost of manufacturing cathode material which will help with reducing the cost of the battery systems.

A final reviewer had a mixed take, feeling that this project maybe addresses a supply chain need for a domestic (albeit foreign) manufacturer of cathode materials. His biggest issue is the large cost and why do this now, as surely this can wait until we know what materials we eventually want to make?

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers noted that the project attempts to reduce the calcination time, which may reduce the cost of the current NMC cathode material. This will focus on improving one aspect of production and providing US production capacity. One reviewer built on this by saying that BASF already has expertise in the production of oxide materials. They are taking advantage of this expertise to develop the commercial production of the NMC cathode materials for advanced Li-ion batteries using advanced calcining operations in their Ohio facility.

Another reviewer phrased this sentiment in a slightly different fashion: The approach is to utilize BASF’s production and R&D facilities in the US to develop low-cost production process for the cathode materials developed in DOE laboratories and to produce at a few ton levels. This requires the selection of proper starting materials and adopting suitable blending methods and calcining schedules. In addition, BASF will work with Farasis Energy, Inc. (Hayward, California) to evaluate these materials in 18650 cells and

with commercial partners such as automotive OEMs and Tier I suppliers to validate BASF's cathode materials and finally test a Li-ion battery pack containing BASF's cathode materials.

A dissenting reviewer characterized this work as scale-up using their existing equipment, which is just looking at a faster calcining method. He stated that the industry should be funding this on their own.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers approved of the progress generally, with some caveats. A reviewer described that BASF has established a facility and is beginning to produce the NMC materials. The initial production gives good performance, close to the desired level. It would be expected as experience is gained in the production operation, the performance would be equivalent to the best materials from Japan and Korea. They have made arrangements to have production-type cells made by a third party to validate their internal tests.

Another reviewer said that reasonably good progress has been achieved within one year, consistent with the project plans as well as with the DOE goals. Improvements have been made in the synthesis of NMC-111 cathode with the process changes resulting in reduced processing time and increased potential production capacity, while maintaining product performance. The improvements in the pilot sample incorporated some of laboratory process improvements. Further experiments focused on optimizing the lithium stoichiometry, which helps reduce raw material costs and improves post-processing efficiency.

Questions included: What are their metrics? Any other improvements possible? Another reviewer noted that they have not started to synthesize the composite cathode material. A third noted that BASF seems to be making material faster and its performance is OK, but nothing very exciting or different. The cycle life of their best material does not look great.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The collaborations with Farasis Energy and Argonne were noted by the reviewers. One reviewer said that is a bit early to accurately question on co-operation as it is just beginning. Farasis is capable of making commercial cells. It always takes a few trials in making cells to arrive at proper formulations for the best performance. Each cathode material has its own particle size, shape, surface, and handling characteristics. Another reviewer expanded on this, noting the collaboration with Farasis energy to assist in the assembly and testing of 18650 cells and packs from BASF-produced NCM cathode materials and to provide guidance for design modifications in order to meet customer requirements. There is also collaboration with ANL via technology transfer.

In a more critical vein, a reviewer noted that Farasis seems to be a very tiny outfit, and that there is no real discussion on working with ANL. A reviewer was wondering who the customers for this work are.

QUESTION 5: HAS THE PROJECT 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?

Again, most reviewers approved of the proposed future research, though one reviewer said that he did not see what BASF was bringing to the program apart from manufacture/scale-up.

In the consensus view, one reviewer said that BASF is clearly focused on making the NMC materials and has the expertise to carry out the project to a successful conclusion. Another said that the proposed future research is well planned and the future plans are consistent with the overall goals and include: i) Completion of the Pilot Production Trials for NCM 111, NCM-A and NCM-B, ii) Validation of BASF Process Cost analysis for Production Customer evaluation and validation, iii) NCM production at Plant level and iv) Initiation of advanced cathode material lab phase in Pilot Trials for advanced cathode material. A third reviewer offered praise for the "good follow-on," but asked whether BASF have customers for production in 2011.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers deemed the resources to be sufficient to carry out the proposed work. The resources of around \$5 million with approximately 50% cost-share over three years are consistent with the project scope in terms of developing low-cost production methods for the next generation cathode materials for their incorporation in Li-ion batteries. Two reviewers did not comment.

However, one reviewer objected, arguing that this is something that can wait and that industry should be funding on their own, and recommended killing this project from the DOE program. He asked, “Is this work really transferable to other cathodes? Without having a clear winner in the cathode area, it seems premature to do scale-up work.”

*Overview of Applied Battery Research: Gary Henriksen
(Argonne National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

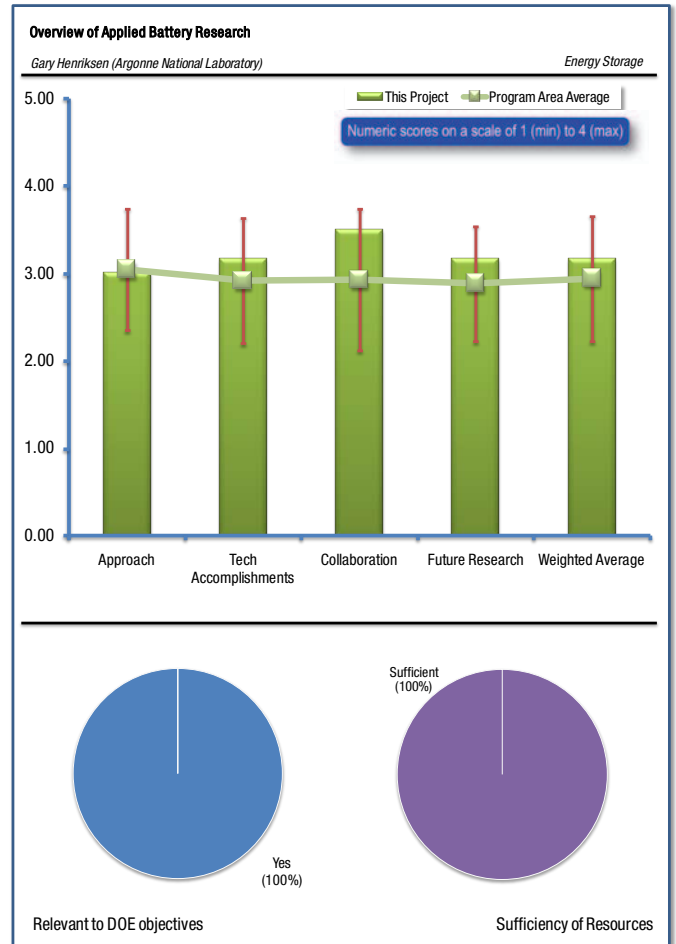
All reviewers were agreed that the project was very relevant to the overall DOE goals. Each pointed out a key part of the program. One reviewer noted that ABR was aimed at expanding its portfolio and addressing long-term needs, which he deemed was a critical part of the program.

Developing high-energy and low-cost batteries was recognized as a key aim by one reviewer, who also advised not to forget long life, because life and cost are linked. More specifically, another said that high-energy couples are the only way to make substantial non-incremental improvements in cost (\$/kWh). Reducing battery \$/kWh will be biggest enable to replacing petroleum. Another reviewer echoed this understanding, describing the program as: The overall objective is to develop advanced Li-ion battery technologies and to assist industrial developers of high-energy/high-power Li-Ion batteries to meet the FreedomCAR long-term battery-level PHEV energy density (~200 Wh/kg) goal, while simultaneously meeting the cost, life, abuse tolerance, and low-temperature performance goals. These studies, if successful, will lead to the incorporation of high-energy cathodes in Li-Ion cells for enhancing the PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

All supported the ABR program’s approach, but there were some questions. On the positive side, a reviewer noted that the bulk of the tasks are well thought out. Another reviewer approved seeing tests done in 18650 cells. A third reviewer noted that the approach is based a systematic advancement of Li-ion battery technology, from developing new materials through their incorporation in prototype cells. Specific approaches in this advanced battery research include i) development of advanced high capacity/voltage electrode and electrolyte (high voltage) materials which will enhance the energy densities and lifetimes of the batteries and reduce their cost, as required in the 40-mile PHEVs. This reviewer deemed the approach to be sound with the required emphasis both on the science and engineering of these new materials. A fourth reviewer called the approach excellent for the intention of this project. Additional positive comments came from a reviewer who wrote that ANL’s ability to integrate materials and approaches is key to reaching its goals. Its concept is very good and building ANL capabilities is also good.

On the other hand, reviewers also offered the following criticisms and suggestions: There are few items in the work plan which were quite a long shot and should have been transferred to the BATT program – as a case in point, the cathode work on silicates. The only deficiency in the approach is a lack of stipulated schedule for the incorporation of these advanced materials into the eventual products. One would like to see more rigid timelines for incorporating various generations of these new materials, especially with the automotive industry looking for such material advancements.



One reviewer said he would have rated the approach outstanding except that throughout presentation it was mentioned that materials are sought in Asia (noticeably ignoring U.S. advanced materials manufacturers) and also industrial partners are not US parent companies (although they are called U.S. companies). There is no problem with ANL working with these companies, but there should be some way to involve companies that are established as U.S.-based companies. It seems like an obvious error in the approach to have tight relationships with foreign entities and no significant effort with existing U.S. companies in this area. The reviewer added that he did not understand why ANL almost exclusively looks for new materials outside of the U.S., and then when it has new materials, gets them scaled up or produced at pilot stage outside the U.S. Besides previous very visible examples, the latest case was the use of Korean Daejung EM to do (TM precursor) in ES0019. This reviewer understands keeping a global perspective, but the balance does not indicate the US DOE perspective.

The same reviewer also noted that several repeated themes in many presentations that should be considered or addressed: often project objectives were high-energy materials and often the presenters showed high-capacity materials. Capacity and energy are not the same, and in fact, in a number of occasions the theoretical energy densities would not even advance DOE goals, even if all materials worked perfectly. There is a need to establish baseline calculations and nomenclature around Wh/g and Wh/L to determine if programs are relevant to DOE goals.

A reviewer likes the targeted solicitations that are open to all and appreciate that the program is trying to reach out into the battery community. However, he felt that the DOE labs are overly represented in these programs and would like to see more new labs in the program - acknowledging that you have limited control over the proposals you get. For example, several PIs are working on both anodes and cathodes on this program, and the reviewer would prefer to see more people and institutions in the program. In other words, spread the funding out more.

The reviewer also said, "A bigger issue to me is that I feel strongly that the three- to four-year timeline of most proposals is far too long for seed money. Far too many of the proposals are complete projects. I would instead prefer to see more proposals that just target the killer issues and do proof-of-concept work only. Then if these are successful, the workers can apply for follow-up funding. This would force PIs to focus on the critical issues and not get sidetracked with engineering details. Almost as important, it would shut down unproductive programs early and permit funding of a wider portfolio. Thus, I'd suggest most projects have an 18-month to two-year timeline but with much more limited expectations. Obviously, the timeline has to be made on a case by case basis, but many proposals could be partially funded on the basis that they do the critical work we want, rather than funding an entire three- to four-year proposal.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewers were positive, though one did characterize the presentation as being more forward-looking than a report on results report, making it hard to say anything about the progress.

The positive commentary included a reviewer deeming that in general Argonne's labs have done an outstanding job in all fronts. I can take issue with specific topics here and there but that does not take away the high quality of work coming out of the labs. Another wrote that reasonably good progress has been achieved in the last year at various DOE and National laboratories and industrial partners. Several new materials have been developed in all cell components, i.e., anode, cathodes, electrolytes, additives as well as separators. In each category, various types of materials are being developed and assessed. Both modeling and materials diagnostic studies are underway to aid in the development of new materials. In addition, several studies are being carried out to demonstrate both the performance and safety of these advanced materials.

Some feedback that was more critical included: Few of the authors in the program have the unnecessary tendency of prematurely promoting certain results which the reviewer would not see pan out in following years. He said he very much respected the scientific aptitude of the team members, and it would be OK with him just to see the data. However, it bothers and confuses him when he sees results which were strongly hyped in previous years but don't show up at all in this year's review.

Although this was about applied research, many of the programs project very long-term results. The reviewer said that he thought that more gains will be realized by having the researchers coordinate more of their efforts to meet tangible results and not just deliver excellent research papers.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers praised ABR’s collaborations highly, calling them “excellent,” “exemplary,” and “very good.” A reviewer noted that there are several fruitful collaborations among various partners in the ABR programs, i.e., among the DOE and national laboratories as well with the industrial developers.

Feedback included that a little more clarity on relationships in ABR’s network would be helpful. Another reviewer said that he thought that some better partnering would help improve results. A third reviewer said that it was difficult to say where the collaborations are aligned to serve all US interests best, however. A final reviewer recognized that ABR had some outreach to other institutions, but he still would like to see more new faces in the program.

QUESTION 5: HAS THE PROJECT 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?

Reviewers were positive, with one reviewer noting that ABR had plans for future projects that appear to support the barriers that are identified, though there were additional barriers to be addressed. Another deemed ABR to have a good portfolio looking at many key aspects. A reviewer described the proposed future research as to continue the material development for stable and low cost electrode and electrolyte materials and fabricate cells with the most promising candidate materials, establish the performance and abuse tolerance of the current PHEV-type cells, and continue detailed modeling and diagnostic studies in support of materials development. These activities are directed towards meeting the overall DOE goals to develop high specific energy, safe and low cost batteries for automotive applications.

Specific suggestions included addressing additional barriers such as recycling. A reviewer said that one key would be what next-generation technology is adapted beyond the NCA baseline system; once that system is selected and logic given for its selection, it would be better to assess. Another reviewer asked whether there should be any topics related to research on batteries/battery systems for addressing the stationary market. A different reviewer noted that there needs to be a focus on life in a sealed battery (18650 or higher).

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The reviewers were satisfied with the resources for the program, noting that they are sufficient to meet the stated milestones in the timeframe shown. One noted that the budget of about \$10-12 million per year over three years is well in tune with project needs and goals and the DOE objectives and are justified in the context multiple research efforts being pursued here. The emphasis is on basic research as this will place the United States in a leadership position in EV batteries globally and enable the US auto manufacturers to incorporate such batteries in electric vehicles.

However, one reviewer confessed to always being confused by the cell building facilities. Another reviewer expressed that he felt that additional resources may be needed to meet the additional recycling project suggested. Finally, a reviewer re-argued his point that though there is a need to keep funding this work, he would like to change the makeup of the projects and run many smaller ones as described above.

Engineering of High Energy Cathode Material: Khalil Amine (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The project was seen as being extremely relevant to goals for PHEVs and EVs, which do displace petroleum. Multiple reviewers agreed that the development of high-energy, long-life and abuse-tolerant Li-ion cathode material is absolutely critical to the commercial success of these batteries for automotive applications. In the words of another reviewer, the direction of program to produce disruptive cathode material at > 200 Ah/g and acceptable V is right on to enabling lower cost batteries, which are a key enabler to displacing oil.

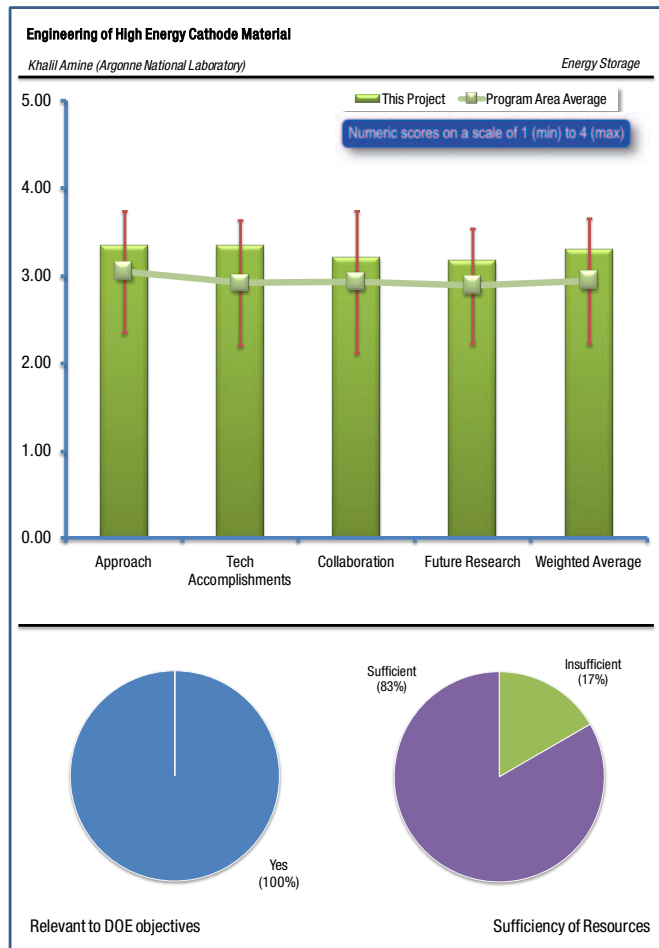
A wordier characterization was as follows: In order to successfully meet the needs of PHEV and EV batteries, the specific energy densities of Li-ion batteries are to be significantly improved. This mandates an increase in the specific energies of the active materials, i.e., anode and cathodes. The development of high-energy composite layered mixed metal oxide cathodes, as is being pursued here, is thus highly relevant to the PHEV goals and the overall DOE objectives. These studies, if successful, will lead to the incorporation of high-energy cathodes in Li-Ion cells for enhancing the PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

For the most part the reviewers approved of the approach, though there were some qualifications and criticisms. One reviewer said he thought the work is very solid, including that on morphology and composition to optimize rate and surface modification to improve rate and cycle life at high voltage. Another reviewer said that despite concerns about the stability of surface coating, he thought this approach is viable and should be pursued. He felt the group seems to have a very nice synthetic approach and the films look pretty homogenous.

A reviewer characterized the approach as appearing “sound and feasible,” based on composite, solid solutions of $xLi_2MnO_3 \cdot (1-x)LiNiO_2$, whose compositions are being optimized here and the morphology suitably engineered to improve the rate capability. Various synthesis processes are being explored to obtain high packing density and different surface modifications are also being examined to enable high rate and long cycle life at high voltages (4.6V). However, the progress with this class of materials is rather slow, especially on the power densities and cycle life, possibly due to their inherently poor power densities, more so at low temperature, as reported from laboratories. Further, due to their sloping voltage profiles, the improvement in the specific energy is not as significant as in the specific capacity.

A couple of reviewers suggested some new research directions, as one wrote that he thought it would be appropriate to show work with groups developing an electrolyte that is stable at high voltage. He also said he thought it would be interesting to focus on storage and self-discharge when cells are stored at high voltage. A second reviewer suggested that he would like to see some work aimed



getting a lithium ion conductive coating, either applied to the material or as part of changing the material's surface structure, though he was not sure this would be viable.

The criticisms included:

- While the surface-coated samples show initial good data, they oftentimes do not survive long cycle- or calendar-life tests. Hence he has general skepticism regarding the use of coating (AlF_3) to alleviate the issue of life. We have seen such an approach fall apart after prolonged life tests, and so the reviewer said he would not use it as his first line of attack.
- Another reviewer felt this project has too many approaches to reach the intended goal. He said he thought that a more focused approach is needed to overcome the technical barriers, as not enough attention can be given to a high potential solution.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers noted the progress as being “good,” “reasonably good,” and “very impressive,” though all had feedback and suggestions. A reviewer said that he hoped the authors do succeed in lowering the first cycle irreversible capacity as well as improving the rate capability using reproducible and inexpensive methods. Another reviewer noted that accomplishments are good working on addressing rate and stability, but that once performance is shown in larger cells, it will be more compelling. A third reviewer also identified the significant improvements in cycle life and stability, writing that though one can argue about the long-term stability of the coatings, he agreed with the PI that his work shows major improvements. The low impedance, better rate capability, and other features of these coated materials are also very welcome, which seem to be all around better rather than getting into the trade-off situation that is very common in the battery world. Still another reviewer commended the good progress, especially on capacity and density increase.

A reviewer characterized the team’s work in this way: Reasonably good progress has been achieved in the last year, consistent with the project objectives. Some of the significant accomplishments include: i) Development of continuous co-precipitation process based on carbonate precursors, for spherical particle morphology with high packing densities of 2.1g/cc, ii) Understanding the effects of Li concentration on the material morphology and performance, especially with non-Cobalt doped formulations, ii) Improvement of power (even at 55°C) and life of Co-doped formulations with surface modification with e.g., AlF_3 .

Suggestions included:

A reviewer said that he would have loved additional clarifications as to the reasons for the irreproducibility of the non-Co samples as well as the poorer cycling performance of the Co-based samples. A second reviewer commented on this as well, observing that the Co doping is promising but variability is still high. What is the confidence level that this can be solved? What is the mechanism of Co impact on capacity variability?

Scale-up seems to be challenging and will need close collaboration with materials manufacturers.

Reviewers addressed questions of battery life, with one stating that calendar life is as important as cycle life (and maybe even more important) and needs to be addressed as well. Another reviewer added to his concern about life issues, as he noted that the program is stated as being 40% complete. However, significant improvements are needed to reach the stated DOE EV and PHEV goals, in particular the cycle, power, and calendar life. A few hundred demonstrated cycles in a small cell format versus a minimum of 5,000 in a large format cell is a long way from being 40%. If the DOE EV and PHEV goals are not the intended goals of this work, then there should be a more clearly defined set of goals for this work.

A reviewer said that he still had concerns about the stability in real cells of a cathode that is being charged to such a high voltage. He suspected that major electrolyte work may be necessary down the road to successfully implement the cathode material.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers all lauded the several successful collaborations from this team with teams from other DOE laboratories, industry partners, and even with overseas universities and companies (e.g., ECPRO, which assisted in the scale-up of the gradient concentration material, though one reviewer knew nothing about this company). One reviewer did suggest that it would be nice to see more collaboration with a group working on electrolyte, as high-voltage material will work only if a solution to electrolyte oxidation is found: perhaps a high-voltage electrolyte, SEI, etc.

QUESTION 5: HAS THE PROJECT 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?

Reviewers indicated that the plans seem solid and look good, though they offered many suggestions. A reviewer characterized the proposed future research as to continue further optimization of these cathode materials in terms of composition, morphology (and tap density) and surface modifications in order to improve the specific energy, discharge rate capability and cycle life (at elevated temperatures), and to work with the industry partners to scale up these cathode materials for their incorporation and validation in 18650 cells. These activities are directed towards meeting the overall DOE goals to develop high specific energy, safe and low-cost batteries for automotive applications. Another reviewer said that he likes the approach to mixing particles of different sizes for better packing and higher density, which also can provide advantages in terms of using small particles for high rate and relying on the larger ones for energy.

One reviewer would recommend techniques other than coating to address the issue of life. However, another reviewer felt the work had too many approaches to the problem. The focus should be on life and scale-up, according to a different reviewer. The team needs to test its material in large cell format (18650 or higher). The team needs to get this material into real cells with a graphite anode as well. The team needs to look at long-term cycling and high temperature work as soon as possible to see if in fact these films can stand up to extended cycling. This work takes a long time so it's important to start it soon.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The reviewers agreed that this is a highly worthwhile program which is at the least being sufficiently funded, and could possibly be accelerated with further funding, according to one reviewer. This reviewer deemed it one of best-matched programs to the DOE objectives, and relative to others in this area this should be accelerated with funding while others are reduced. A second reviewer echoed this sentiment, saying that with a little more focus on the highest potential solution(s), the work will reach the DOE goals in a more timely fashion. Another reviewer said the budget of \$300K per year is probably low from the perspective of this task alone, but seems reasonable and justified, since multiple efforts on this class of cathode materials are underway at DOE laboratories and being supported by ABR.

New High Energy Gradient Concentration Cathode Material: Khalil Amine (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

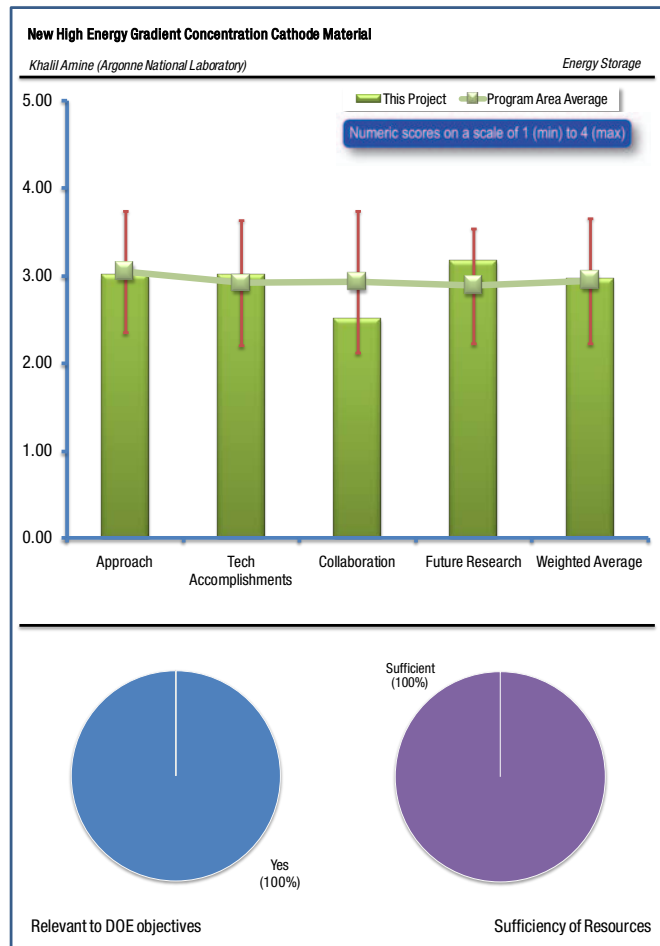
The reviewers uniformly recognized the value of high-energy, long-life and abuse-tolerant Li-ion cathode materials towards achieving the commercial success of Li-ion batteries for PHEV and EV applications. In further detail, one reviewer characterized the work as follows: In order to increase the specific energies of Li-ion batteries to meet the 40-mile range of PHEVs, new high specific energy materials are required to be developed. The development of high-energy mixed metal oxide cathodes, with specific capacities in excess of 200 mAh/g, high rate capability, life characteristics and abuse tolerance is thus highly relevant to the PHEV goals and the overall DoE objectives. These studies, if successful, will lead to the incorporation of high-energy cathodes in Li-ion cells for enhancing the PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers approved of the researchers’ approach, modulo some concerns and criticisms. A reviewer described the approach as based on achieving a desirable concentration gradient in the layered mixed metal oxide (NMC), such that the core of the particle is rich in nickel concentration, e.g., $\text{Li}[\text{Ni}_{0.8}\text{Co}_{0.1}\text{Mn}_{0.1}]\text{O}_2$ for maximizing the specific capacity, while the surface is enriched with manganese, e.g., $\text{LiNi}_{0.5}\text{Mn}_{0.5}\text{O}_2$ for cyclic and thermal stability. Such gradient composition across the core and shell is achieved by successive co-precipitation in respective solutions. The approach looks interesting and feasible, as demonstrated here. Also, it integrates well with the state of art materials and their processing. Another reviewer built upon this, noting that the team’s concept seems very sound and is a nice away to overcome the issue of cracks forming in two-phase/coated particles.

Concerns and criticisms included:

- A reviewer said that while this idea is certainly very elegant on paper, he was not sure how scalable, cost-effective the method is.
- The gradient core-shell approach type of material is very interesting. However, the reviewer wonders how easy it will be to control the consistency and quality of the product on large scale production, and believes this is a question to be addressed.
- The overall project has good clear focus, however there is a need to have clear, quantifiable goals and results, rather than just measures of “excellent” or “good.”
- There is a need to evaluate safety in cells relative to individual materials.
- The project team should work with credible materials manufacturers, as there are many nuances in producing materials that are ready for implementation. It appears that BASF and ECPRO are not experienced.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The progress was recognized to be good by most reviewers, though each had suggestions as well. One remained unconvinced, saying that he would like to see more data, because it was not clear that there was much change from the data that was presented last year.

A reviewer described the research as follows: Good progress has been achieved in the last year, consistent with the project objectives. Some of the significant accomplishments include: i) Development of a new gradient concentration cathode material with a high capacity of 209 mAh/g at 1 C rate when charged to 4.4V, ii) Verification of the gradient composition through analytical studies, iii) Demonstration of improved cycle life and abuse resistance relative to the core material (this was noted by another reviewer as well, who also expressed his hope that the results were repeatable), iv) Safety performance of gradient concentration material is excellent when compared to the bulk material and v) Further increase of Ni in the core and Mn in the shell. Another reviewer used the unorthodox word choice “very cute” to describe the results, especially the SEMs. He expanded upon this by saying that the pictures of the core and the shell are noteworthy as well as the data that showed the gradients for the respective elements.

Feedback included these comments:

- One reviewer found the abuse-tolerance data quite attractive but was not sure how comprehensive they are.
- End-of-Life abuse tests are very interesting to validate the beginning-of-life findings.
- A study of aging mechanism of this type of material would probably be very useful to understand how the core and the shell age.
- What is the impact of the shell thickness in performance? How easy is it to control?
- The work needs to get out of lab in order to be more credible.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

As with this PI’s other project, reviewers acknowledged good collaborations with universities and other DOE laboratories in the material optimization and characterization and with industry partners on the incorporation of these materials in 18650 cells and similar prototype cells. However, some feedback was that because an electrolyte stable at high temperature will be key to the success of this type of material, the program should have more collaboration with electrolyte studies. Another reviewer felt that stronger manufacturing partners would be helpful for validating the economic viability of this approach and the benefits versus cost over standard approaches.

QUESTION 5: HAS THE PROJECT 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?

A reviewer recognized that the steps outlined follow a progressive path to improving the performance and eventual production of the material as the deliverable of this project. The proposed future research is to continue further to scale up the synthetic process to obtain pure GCM in 100~500g batches, to optimize the composition and thickness of the outer layer of the gradient concentration to maximize the surface stability of the material, to carry out lifetime and thermal stability studies, and finally incorporate these materials in 18650 or similar prototype cells. These activities are thus directed towards meeting the overall DOE goals to develop high-specific-energy, safe and low-cost batteries for automotive applications.

However, reviewers were mixed in their feedback. One admitted that he was not fully convinced that this is the technique that would lead to the target material with the desired performance/cost metrics, but nonetheless, it would be interesting to use this technique on the composite cathode. Another asked why the team was not using a core material without Mn to increase the capacity even further. A final reviewer objected to the plan to scale-up the process, as it still seems to be in too early a stage of development to do that.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

It was felt that the resources were sufficient if the project keeps focused as outlined, with another reviewer judging that the budget of \$300K per year is adequate for the on-going as well as future studies. A different reviewer praised the good use of DOE funding, a novel approach, and the good results. He recommended that DOE keep funding at this level to continue progress, with the caveat that

he would not want to fund work at a chemical company to do scale-up because the technology not yet ready and this type of work should be borne by industry.

Design and Evaluation of Novel High Capacity Cathode Materials: Christopher Johnson (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Most reviewers felt the overall DOE objectives of petroleum displacement were supported, with an exception. One reviewer described the work as follows: in order to increase the specific energies of Li-ion batteries to meet the 40-mile range of PHEVs, new high specific energy materials are required to be developed, which are inexpensive and thermally stable. The objective of this project is to evaluate low-cost vanadium-based compounds with high capacity as cathodes in conjunction with a lithium source in the form of Li-rich Fe oxides. These studies, if successful, will lead to the incorporation of high-energy cathodes in Li-Ion cells for enhancing the PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement. Another reviewer echoed this, stating that the cathode is one of the key cell components to developing a battery that can provide the energy needed to support the PHEV and EV energy and power needs. This work supports that effort.

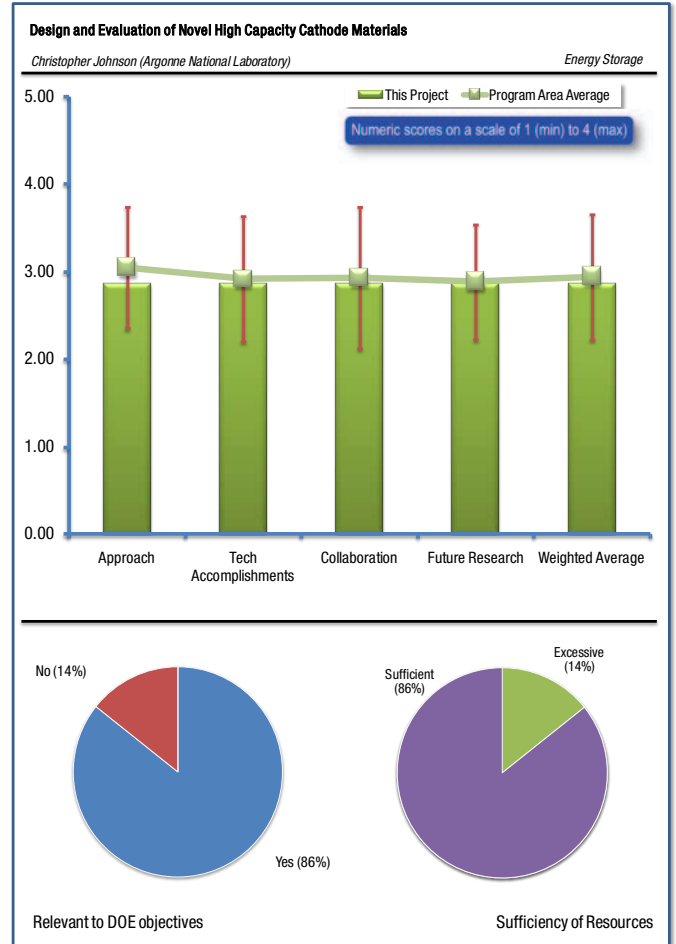
In support of the project, it was noted that the PI's focus on substantially increasing charge densities in LFO is appreciated. This reviewer recommended the use of energy densities instead of charge densities. Another reviewer praised the new approach to getting lithium into the cell and enabling the use of higher energy density cathodes.

However, a dissenting voice said that the energy density and cost profile of these materials are not appropriate, and that more basic research was necessary, but even so, the link to DOE objectives is not apparent. Finally, another reviewer admonished the team not to forget about life, which is a barrier.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers were split on this approach, described by one reviewer as based on blending Li_5FeO_4 , which has a large amount of sacrificial lithium ($5\text{Li}_2\text{O}$) functioning as the lithium source with a high capacity cathode, LiV_3O_8 . This strategy is expected to allow the use of ultra-high capacity anodes such as Si-C nano-composites with large first-cycle irreversible capacity and improve the thermal stability of the cathode battery, due to the presence of Fe. Inexpensive and abundant Fe and V oxides will thus be utilized for a widespread use of Li-ion battery technology.

This reviewer added that one uncertainty of this approach is the poor cycle life of vanadium oxides, in general, which has been a deterrent factor in their use. Another reviewer echoed this sentiment, stating that approaches using Fe are definitely worth pursuing for cost, abundance, and environmental advantages, but he was not sure about V in that regard. He added that the problem with this approach is that it leaves a lot of inactive material in the positive electrode and so a large irreversible capacity, and that this seems to be a long-term research effort that still needs to go through many barriers.



A third reviewer said there is a need to look at higher capacity cathodes, provide for safety, and address the cost concern as well, which he felt this work is attempting to do. There is a need to look at incorporating this material into a larger format cell. A fourth reviewer agreed, saying the approach gets high marks for being innovative and different. It could be an enabler for a whole new range of high-energy cathode materials, much in the same way that SLMP does. The emphasis on science, proof and understanding is very appropriate for this stage of development.

However, a dissenting voice said that he could not understand how this would move towards vehicle technology goals. Even if rate and fabrication constraints could be overcome, it is hard to imagine relevance based on very poor energy density and the commercial viability of vanadium.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Most reviewers felt there was good progress – but a few felt that when DOE goals were considered, this was less true. Good progress has been achieved relative to demonstrating the concept, according to one reviewer, but another reviewer felt that the results were only fair when judged with respect to the overall DOE goals. He noted that there were quite a lot of interesting results with the promise of high capacity that have been obtained, but these might not translate into high-energy systems because of low voltage. As a result, he would be tempted to place this type of research within the scope of a BATT program since these will need a lot of research/development time. A third reviewer noted the voltage range of LiV_3O_8 to be very large, and the average voltage is low, which may make utilization in automotive applications difficult. Another reviewer applauded the good progress at proving that there are other viable choices for cathode material, however a concern was about the large irreversible capacity loss and the implications of needing a much larger battery to meet the goals. Although high capacities were shown, the energy density is nowhere near where this should be to be funded as anything other than blue sky research

Suggestions include the following:

- It was suggested that this may be a good system for high-capacity advanced anodes such as Si/C to compensate for their high irreversible capacities.
- A reviewer said they have demonstrated the concept and more importantly to me have gained understanding of the fundamentals involved through the XAS work. The voltage profiles are always very sloping for these V-based materials where they go through several oxidation state changes. However, that by itself is not a big deal and could even be turned to an advantage in terms of fuel-gauging the battery pack. The use of the Li_3FeO_4 would seem less useful from a fuel-gauging perspective as it would only show up during deep discharge and typically you'd not want cells to cycle that deeply anyway.
- With two cathodes it would be helpful to be clearer when reporting data on mAh/g to state what the g are – are they referring to the V cathode, both active, or the whole electrode?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The consensus was that there are good collaborations within the DOE laboratories in the material characterization and with industry partners in the evaluation of Fe-oxides for pre-lithiation, though a couple of reviewers wanted it to be clearer who the industry collaborators were. A suggestion was that the team may need to get more involved with cell makers as they move forward.

QUESTION 5: HAS THE PROJECT 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?

Reviewers felt that the proposed future work looked clear and interesting, but two reviewers questioned whether it might better fit within the BATT program because of its long-term timeline. The proposed future research is to continue exploring new variable Fe/Co ratios for $\text{Li}_x\text{Fe}_{1-y}\text{Co}_y\text{O}_4$ as well as pure Li_6CoO_4 , and Li_6MnO_4 , understand the conditions of release of Li_2O and evaluating new charged cathodes such as V_2O_5 , MnO_2 and delithiated olivines MPO_4 (M=Fe, Mn, Co, Ni) in the blended cells. Also, the prelithiation precursor cathode system will be tested against high-capacity, high-energy anode. These studies are oriented towards the project goals of achieving low-cost and thermally stable high-capacity cathodes.

Feedback as to what other changes the team should consider include:

- Future research needs to look at life and the thermal stability of these materials.
- A reviewer would like to see more defined, quantifiable goals.
- The project really needs to address and get a better estimate of specific energy and energy density for a final cell. The reviewer is still very concerned about the low cell voltage of these V-based cathodes and also their density, which he believes may be quite low. One of the problems with a high-capacity, low-voltage approach to energy is that you need to pair it with a large anode to accept the capacity and energy/capacity estimates and data on just the cathode miss this effect.
- The same reviewer would like to see an energy density comparison of putting lithium in the cathode vs. the anode (SLMP) in combination with these non-lithium oxides. The PI is not expected to be an expert in SLMP or necessarily "attack" it, but a good faith comparison should be done, if not by this PI then by someone in the program using a consistent methodology (apples to apples as much as possible).

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers saw the resources as being sufficient, with one exception. The budget of \$300-400K per year is adequate for these studies, according to one, and another said that this is a new approach and needs continued support for a while at least. However, he would want to see a better estimate of possible energy density very quickly and certainly before the next review or funding decision.

The dissenting reviewer did not think this is a good use of funds for vehicle technology applications.

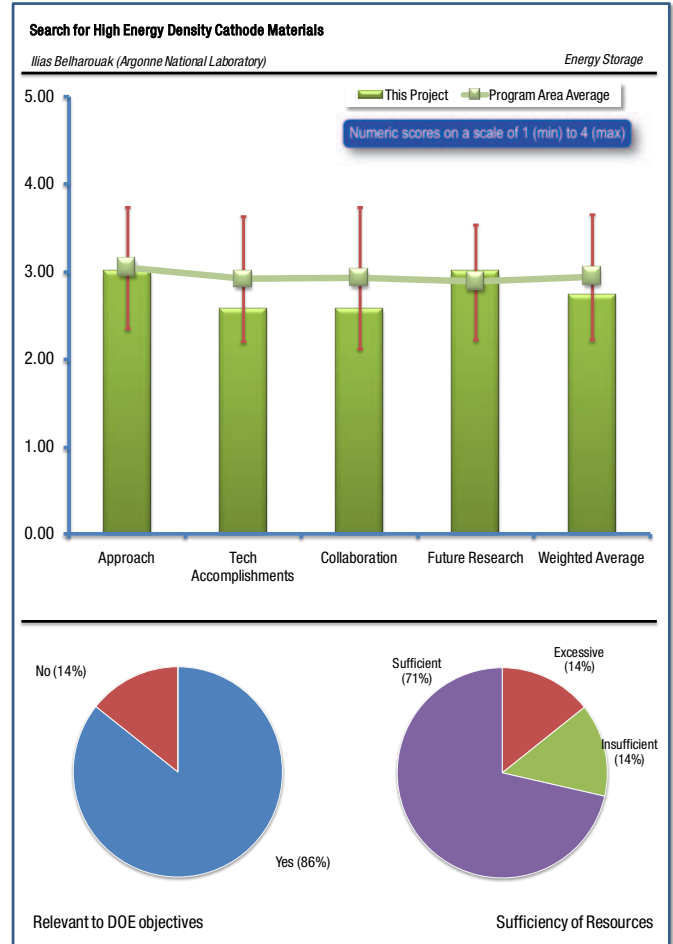
Search for High Energy Density Cathode Materials: Ilias Belharouak (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

As with the other cathode materials research projects, reviewers noted the need for the cathode as a key cell component to developing a battery that can provide the energy needed to support the PHEV and EV energy and power needs for use in an automotive application. In order to increase the specific energies of Li-ion batteries to meet the 40-mile range of PHEVs, new high specific energy materials are required to be developed. The objective of this project is to develop new cathode materials of the type, Li_2MSiO_4 ($\text{M}=\text{Mn,Fe,Co}$) materials, with the ability intercalate multiple lithiums and thus provide high specific capacity. Another related objective of this project is to overcome the barrier of poor electronic conductivity of these materials. These studies, if successful, will lead to the incorporation of high-energy cathodes in Li-Ion cells for enhancing the PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement. One reviewer did level the criticism that he believed that the theoretical energy density of this system (based on theoretical capacity, voltage, and theoretical crystal density) is lower than needed to make any useful impact to vehicle technology goals.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Two reviewers were lukewarm to this approach, while others approved of it. The approach is based on exploring the materials iso-structural to Li_3PO_4 for their ability to intercalate two lithiums (with ~ 333 mAh/g). Since the as-prepared $\text{Li}_2\text{MnSiO}_4$ is “almost” electrochemically inactive because of its large aggregates and low electronic conductivity, two different approaches are being adopted, i.e., to reduce the particle size to sub-micron level and to apply a suitable surface coating, e.g., carbon, to activate $\text{Li}_2\text{MnSiO}_4$. A reviewer said that the concept of trying increase capacity while still maintaining a high voltage is sound.

A reviewer said that through the strategy to look for multi-lithium-intercalating cathodes for an improved specific energy, the choice of $\text{Li}_2\text{MnSiO}_4$ is rather poor due to its sub-par electronic conductivity and low capacity even after milling to sub-micron size and with surface coating. Another reviewer felt the work is mostly exploratory in nature since these are new systems. He acknowledged that silicate would be a highly attractive material in case it can be made to work, but that this is a daunting challenge and will need years of R&D work. He added that the capacities are so negligible that he wouldn't waste his time building a Li-ion cell. A third reviewer was also a naysayer, saying that upfront theoretically-based work utilizing theoretical densities and best-case scenarios for energy densities would have indicated this was not a promising area of research against the primary objectives of DOE.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Several reviewers made distinctions between the good progress made towards the project's goals and progress with respect to the DOE's goals, which some felt the project did not address well. One such view was expressed by the reviewer who stated that good

progress has been achieved relative to demonstrating the concept. Specifically, successfully synthesized, characterized and evaluated the targeted structures of $\text{Li}_2\text{MnSiO}_4$ and integrated carbon nanotubes as conductive matrix during the synthesis. The project identified that the amorphization is responsible for the capacity fade of $\text{Li}_2\text{MnSiO}_4$ upon lithium removal, and proved that iron incorporation into the cathode results in structure stabilization, and promise in terms of capacity retention. Another said that significant improvement of electrochemical activity has been made, but capacity and voltage remain low. A third reviewer conceded that while the results are nowhere near the DOE targets, significant understanding has been achieved of the behavior of silicate-type cathode materials, especially understanding of amorphization using a slew of analytical techniques as well as ways to alleviate this issue. Of course, the achieved capacities are still insignificant, and the reviewer hopes the results thus far give the authors sufficient clues as to the future direction of the work. Yet another reviewer complimented the studies on degradation mechanisms, although not yet complete. However, he was still very concerned about low discharge voltage and poor cycling, and said it needed major improvements for this to be any good.

One reviewer who registered the greatest concerns about the project said there was no clear difference in the data presented this year and what was presented last year. Some of the SEMs presented did show some of the accomplishments, but the relevance to the DOE goals was not clear.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers felt there are good collaborations within ANL in the material characterization. However, collaborations outside ANL (and DOE) are yet to be established, with one reviewer asking whether anyone in the industry is being viewed as a potential collaborator.

QUESTION 5: HAS THE PROJECT 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?

Reviewers were generally mildly complimentary about the proposed work, with one reviewer saying it looks well thought out and two others saying the plan is OK. He added that a combination of mechanistic work and focused research on related materials might open up a new generation of stable/low-cost cathode materials. Another called the project as overall a very interesting approach. It is now needed to understand quickly the reason for the limitation of the capacity and find ways to lower the polarization between charge and discharge. Is the low capacity linked to a kinetics limitation?

Feedback and concerns included:

- It is now needed to understand quickly the reason for the limitation of the capacity and find ways to lower the polarization between charge and discharge. Is the low capacity linked to a kinetics limitation? As soon as this is understood, the life question should come next.
- The result goals need to be more clearly defined in quantifiable terms.
- One reviewer expressed that he was a little concerned about what he viewed as the low LOS for this material in view of all its problems. He would have liked to see plans to widen the search for materials, as currently it seems a bit too narrowly focused.
- Finally one researcher said that he thought the plan was OK if he thought the research was relevant, which he did not believe it was.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Opinions were split, with three reviewers saying the budget of \$300K per year is adequate for these studies. One suggested that working with an industry partner would help. However, other reviewers were more skeptical. One admitted that based on other questions he does not think this should receive more funding. The other reviewer was more measured, recognizing that this is quite a long-term commitment. This reviewer was OK with that as long as they reevaluate their progress and know when to pull the plug on a group of materials and move on to something else, and that there was a need to be vigilant and avoid the tendency to “study a dead horse to death.”

Development of High-Capacity Cathode Materials with Integrated Structures: Sun-Ho Kang (Argonne National Laboratory)

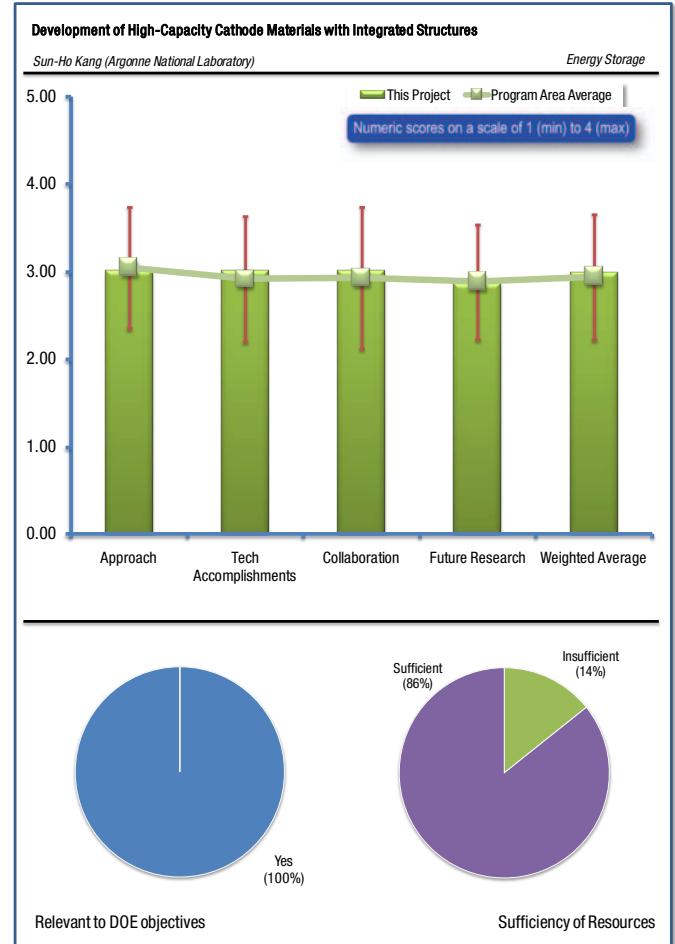
REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

As with all of the other high-capacity cathode materials projects, reviewers deemed the project to be highly relevant to DOE objectives. The specific energies of Li-ion batteries are to be increased to meet the 40-mile range of PHEVs, which mandates the development high-energy cathodes and anodes. The objective of this project is to develop low-cost and high-energy, and thermally-stable cathode materials with integrated structures with spinel components in the layered-layered nano-composite structure, based on manganese-rich formulations and demonstrate the performance enhancements relative to capacity, rate capability, cycling and thermal stability. These studies, if successful, will lead to the incorporation of high-energy cathodes in Li-Ion cells for enhancing the PHEVs, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement.

Another reviewer echoed that the cathode is the key cell active material component to developing a battery that can provide the energy needed to support the PHEV and EV energy and power needs. This project effort attempts to address some of the concerns associated with that component.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The reviewers were generally supportive of this approach, though there were caveats. The approach is based on embedding spinel component in the ‘layered-layered’ composite structure. Spinel structure may be created in the composite structure by controlling lithium content (e.g., 0.5<X). A reviewer said that of the overall approach, the stabilization of the surface is the most important. This is the only way we will get “5V” materials actually working. The electrolyte will play a big role as well and that work needs to have collaboration with electrolyte research. A different reviewer commended the systematic approach, which he thought was sound for studying this system.

Concerns raised included:

- A reviewer questioned why the manufacturing partner for this is not US-based but rather Korea-based. He commented that this seems consistent with Argonne's approach, but he felt that it was something that is not necessary.
- Another reviewer observed that the approach appears to address the stated goals of the project, but he had a concern that the DOE-specific goals were not receiving adequate attention.
- It is a pretty empirical mixing of materials, according to a reviewer, who would have liked to see more electrochemistry such as use of differential capacity (like the Hawaii Group) to really understand their cathodes. They need to compare performance with a simple physical blending of the component materials. This is in their plans but really it should have done right away to see if there is any real difference before continuing detailed studies on these integrated materials.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The responses of the reviewers were mixed in this category. Some reviewers were very complimentary, saying that these were excellent results in terms of a combination of data and analysis, with a very well-executed research plan. Another said that good progress has been achieved relative to demonstrating the concept, which confirms the high discharge capacities, and rate capability with the baseline chemistry ($\text{Li}_{1.2}\text{Ni}_{0.25}\text{Mn}_{0.75}\text{O}_y$) at 2.0-4.95 V. During extended cycling however, the voltage profile indicates increasing polarization. Demonstrated high capacity of ~250 mAh/g and excellent rate capability (>200 mAh/g at 1C rate), when charged to 4.6 V, but only after a few formation cycles. Understood the effects of Li and Co contents on the performance and successfully adopted X-ray absorption spectroscopy and HR TEM to confirm the integrated layered-spinel structure. A third reviewer commented that the results are good and the next step approach makes sense. A fourth complimented the good analytical results in trying to get an understanding, especially the TEM work.

However, some questions and criticisms included the following:

- As a general question, we need to understand how these high-energy cathode materials compare, in terms of performance vs. life vs. safety vs. cost. What is the life of these products?
- Another reviewer felt that it is not clear, from the data presented, on the progress made toward improving the cycling performance of the system. It also seems that there is a strong need to set quantifiable goals, especially as this is an on-going program.
- Work on larger format cells is also needed.
- Results look decent, according to another reviewer, who said that however he was not sure that the material performance is significantly greater than the sum of their parts, except maybe for the rate performance. The project needs to demonstrate material stability, and the hanging profile with even just a few cycles does not sound very promising.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Collaborations were judged to range anywhere from excellent to not obvious. A reviewer noted that there are a few collaborations within ANL and outside in the material characterization. However, there are no collaborations with any industry partner to evaluate these materials in 18650 cells, which are recommended, in view of the promising nature of these materials. Another reviewer agreed with the need for an industry partner. The reviewer who did not see obvious collaborations stated that collaboration with groups working on electrolyte is key to success. One reviewer wanted a better explanation as to why a Korean partner was chosen to provide a precursor over a U.S. partner.

QUESTION 5: HAS THE PROJECT 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?

Reviewers briefly noted the plans as being OK and solid, then quickly offered suggestions. The proposed future research is to continue these studies to i) identify the optimum chemistry in terms of Li-to-TM ratio and Co content, ii) develop close collaboration with industrial partner (good TM precursor), iii) investigate thermal safety characteristics, iv) further structural analysis with cycled and uncycled materials, v) explore physical blending of spinel and layered materials, and vi) finally assess in full cells with carbonaceous or advanced anode materials through collaborations.

Suggestions included:

- Please do not use the physical blend of spinel/layered materials, because that will hurt your calendar-life. Otherwise, you have a solid plan.
- A reviewer suggested more emphasis on high-voltage cathodes/sysetms.
- More life and safety data are needed.
- There is a need to set more definitive and quantifiable goals for future work, especially since this is an on-going program.

- A reviewer said there is a need to do the comparison with the simple blending ASAP. Also, look at cycled material to see if it stays an integrated material.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers varied in response to this question. One reviewer said that because it is a cutting-edge material, he would recommend allocating more funds. However, more common was the view that the budget of \$300K per year is adequate for these studies. Suggestions included that working with an industry partner would help, and another reviewer expressed that there is a need to push for a faster demonstration that the integrated material is significantly better than a simple blend before continuing to fund this work.

Developing High Capacity, Long Life, and High Power Anodes: Khalil Amine (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Two reviewers were positive about the relevance of this program to DOE objectives, two did not answer, and one reviewer felt that it does not belong as part of a vehicle technologies research program. A favorable reviewer described the program as follows: the specific energies of Li-ion batteries are to be increased for the PHEVs, while the HEVs need improvements in power density. The objective of this project is two-fold, i.e., to develop high power anode for HEVs and high-energy and long-life anodes for PHEVs. Both these anode systems are based on non-carbonaceous anodes, more specifically titanium oxides. These studies, if successful, will lead to the incorporation of high-power anodes and high-energy anodes in Li-Ion cells for enhancing HEVs, and PHEVs, respectively, which would in turn reduce the petroleum consumption, and pave the way towards petroleum replacement.

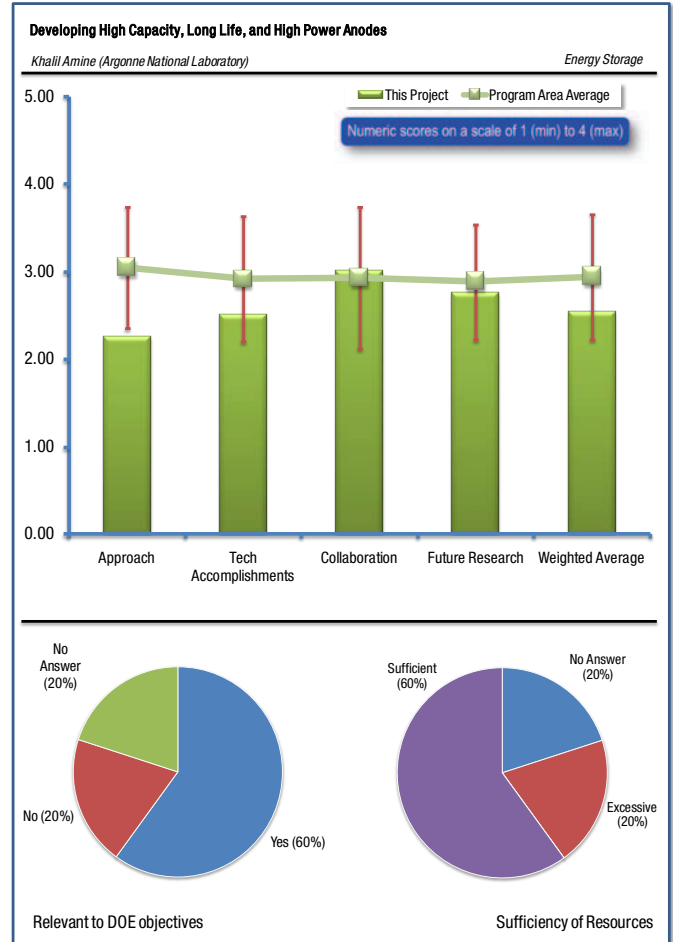
However, the reviewer who disagreed said that most of the work is on high voltage anodes. The reviewer just did not believe that we can afford the voltage penalty of these materials as it reduces both power and energy and places a larger stress on the cathode (to make up for the lower voltage both cathode and anode must run at a higher current, not a big deal for these anodes but it stresses the cathodes). Work like this has more applicability to load leveling and other stationary power needs and should not be funded under a Vehicle Technologies program.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers had some criticisms of this approach, even if on average they were tepidly positive. The approach for the high power anodes is based on $Li_2MTi_6O_{14}$ ($M=Ba, Sr, 2Na$) materials, which have lower-potentials (hence high cell voltages) and higher capacities compared to the traditional lithium titanate, $Li_4Ti_5O_{12}$ and can provide long life and enhanced safety, due to the absence of SEI. The high-energy anodes being developed belong to titanium oxides with a high theoretical capacity of 335mAh/g based on Ti_4+/Ti_3+ couple and new silicon-based composite system with a high packing density, low irreversible loss and long cycle life. This reviewer felt the proposed approaches appropriately address the barriers for HEV and PHEV batteries. Another reviewer agreed, but he also pointed out that there is also need a lower cost material.

Criticisms included:

- This work entails all current avenues of improving the anode. It thus lacks the focus of other similar projects.
- High-voltage anode for energy is more questionable. It will need to be coupled with high-voltage cathode, according to another reviewer.
- The reviewer who objected to the project in the previous category said that all the work on high-voltage anodes is irrelevant to Vehicle Technologies. The recent focus on Si is better.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewers described the results themselves, with only one characterizing it in any way (he deemed it “modest”). One reviewer noted that data on several novel materials were obtained, which really shed light on the titanate-type of anode materials. Another reviewer noted that capacity is still low, but rate capability looks great, but the voltage of the Sr material is not very different than titanate.

A third reviewer noted the modest progress that has been achieved relative to the standard LTO materials. Specific accomplishments include synthesis of $MLi_2Ti_6O_{14}$ anode materials, using sol gel and demonstration of their performance, especially the $SrLi_2Ti_6O_{14}$ material in half-cells and full cells. The results however do not compare well with those from the LTO anode. For the high-energy anode, nano-structured, high surface area and high packing density TiO_2 Brookite has been synthesized from a thermal decomposition of oxalate and demonstrated to have good cyclability, though the capacities are, once again, lower than LTO. The silicon composite anode, prepared from ball milling showed good cycle life with a moderate capacity of 500 mAh/g, and with a high irreversible capacity.

The dissenting view was that most of the results were not especially worthwhile, although the decent packing of their Si anode was useful; not enough people in this field appreciate the cost and performance implications of low packing.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Only two reviewers commented on the collaborations. There are a few collaborations within ANL and outside in the material characterization, assessment, and with FMC for the SLMP. A different reviewer commented that he would like to see this PI or someone work with Professor Kumta on the Si anode work.

QUESTION 5: HAS THE PROJECT 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?

Reactions to the proposed future research were mixed. A reviewer said that he did not think any of the titanate materials described here offer any significant advantages over Li-titanate to merit additional studies in full cells. Instead efforts should be directed at finding materials superior in capacity or slightly lower in voltage. Another reviewer described the proposed future research as to continue these studies on the high-power anode to evaluate $SrLi_2Ti_6O_{14}$ in full cells, improve its power capability through new synthesis methods and through CNT coating, and study its interactions with the electrolyte. For the high energy-anode, Si composite anode will be evaluated in full cells and with FMC as a Li source to compensate for the irreversible capacity. However, this reviewer did not judge it.

A third reviewer offered the feedback that surface area needs to be decreased. A fourth was highly critical, saying that only the silicon anode work that has a decent potential is worthwhile in view. Higher capacity, high potential anodes leads to a major loss in power and energy, especially when one factors in the impact on the cathode that has to match the higher capacity and increase in delivery current. This is what they stated they plan to do in the presentation. Though the reviewer is glad that they are looking to evaluate the SLMP approach, he cautions about sinking too much effort into yet another carbon-coating method for Si, as there are already ways to do that and many more will be coming out over the next year or two.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said that the budget of \$600 k per year (\$300 k for the high power and \$300 K for the high-energy anode) is adequate for these studies.

The only other reviewer who answered this question wrote that he recommended discontinuing funding for the bulk of this program under the Vehicle Technology program. (He was very skeptical in his responses to other questions above). Low-voltage anodes may well be deserving under a stationary power funding mechanism. He instead recommended continuing to look at Si as long as they are really doing something new, i.e., not just another way to carbon coat silicon. This should not be that costly.

Lithium Metal Anodes: Jack Vaughey (Argonne National Laboratory)

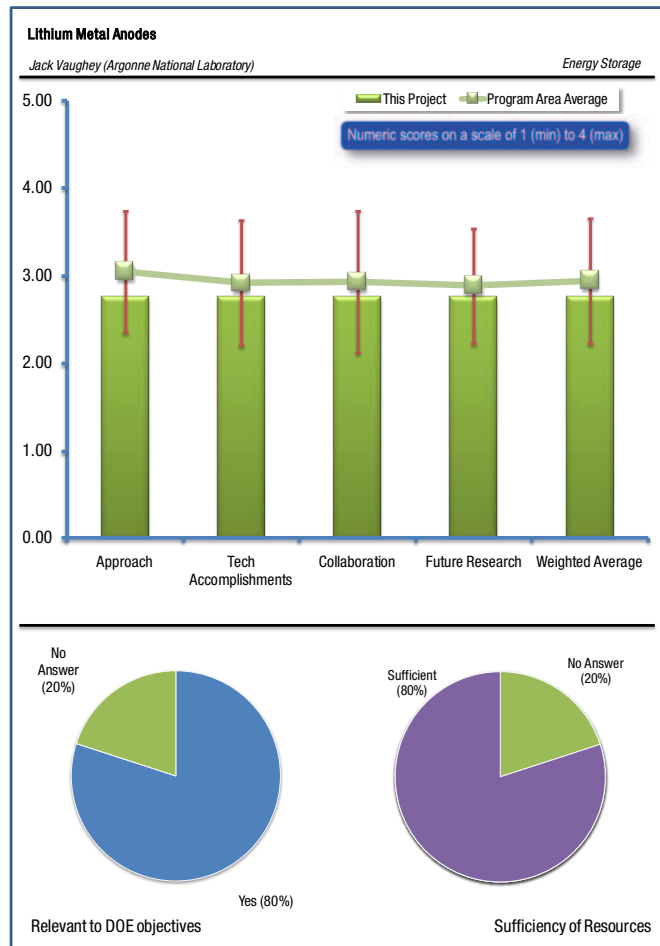
REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

All the reviewers approved of this project as supporting DOE objectives, but noted that it is a challenging project. One wrote that if one can find a way to have lithium metal anode work for long life and a safe system, this is great – but this is an extremely challenging task. Another reviewer echoed this notion, saying this is a very challenging project, but if successful it could enable a new class of higher-energy batteries for PHEV and EV applications. For EV applications Li-ion just does not have the energy and we need something like this to succeed to meet the longer-term EV goals.

A project description by another reviewer noted that the specific energies of Li-ion batteries need to be increased for meeting the range requirements of the PHEVs and the objective of this project is to develop metallic Li anodes in place of carbonaceous intercalation anode for enhancing the energy density of Li-Ion cells. These studies, if successful would lead to a successful Li-ion battery for PHEV, which in turn reduces the petroleum consumption, and pave the way towards petroleum replacement.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The approach was deemed very good by a reviewer who commended the very good microscopy work. Another said he techniques used to characterize the Li surface are state-of-the-art. However, the approaches used to alter the Li surface are not new, and that the authors should take rather bold and innovative approaches to come up with breakthrough results and not follow approaches which have already been tested by many authors. This is a 40-year-old topic. The approach involves a study of Li morphology to understand the morphological evolution upon cycling and to develop and characterize different coating technologies, including polymeric and ceramic coating, that robust during cycling in Li cell environments. The approach is appropriate to the stated objectives. One reviewer pointed out that one of the main issue is dendrite growth and wondered how this approach would solve that issue.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers generally commended the results, noting different aspects. The analytical results are cutting edge and quite impressive, according to one reviewer, who then added that data obtained to stabilize the Li surface are just fair, since the approaches used have been rather well-known (polymeric coatings etc) and the authors did not succeed in obtaining results that are not expected (weakness of polymer coatings, or even silane coating). Another reviewer noted good progress has been achieved in understanding morphological changes on Li upon cycling, i.e., the formation of dendritic subsurface layer which grows during low-rate cycling, which is covered by a porous mid-layer that grows during mid-rate cycling. It also accounts for the volume expansion. The coating studies reveal that that controlling the ability of the electrolyte solvent to reach the lithium surface while maintaining ionic conductivity is a key synthetic variable Amongst the coatings examined, Zintl coatings are too brittle, polymeric coatings are unstable, and the silane coatings not adequately protective.

A third reviewer complimented the nice study on the impact of the current on the failure mechanism. Unfortunately, that's not very optimistic for automotive applications. He also noted that it seems that the coating is a difficult approach because of the inherent reactivity of the Li. What about the new electrolyte approach?

The fourth reviewer said that the finding about loss of solvent in the dendrite growth process is an important new insight. He also said that it was nice SEM work, although he thought many of these features have been seen in many, many previous published studies on lithium plating in organic electrolytes.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said there are a few collaborations but suggested a much wider collaboration due to the complexity of the system. Another reviewer said that the current collaborations were OK in terms of doing the work, but he felt they are missing opportunities. They should be working with Ohara who made coatings for PolyPlus's protected lithium anode. Also, the reviewer said he believed that John Kerr worked with someone on using polymer electrolytes and also got great images of lithium dendrites growing through these films. The reviewer felt that Kerr should also be collaborating on this work.

QUESTION 5: HAS THE PROJECT 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?

Reviewers were mixed about the plan. One said that the plans seem OK, but he thought they need to get help from other collaborations as he outlined above. Another noted that this is a high pay-off research and the authors should take as unconventional an approach as possible to come up with novel ideas. He was not sure the proposed work is different enough to generate any new solution to this very important electrode work. A third reviewer said that he was not sure how working on a Li anode will really help the automotive industry (but acknowledge he may be wrong). Another question was whether we are really sure that we will find a solution to the more important issues of Li's safety concerns?

The proposed future research is to continue these studies to investigate the surface layer on Li with different coatings, cycling rate, and other additives, understand the effect of solvent on the protective nature of the silanes, evaluate the stability of ceramic lithium ion conductor in the cell environment and study the interactions between buffer layer and ceramic layer.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Three reviewers did not answer this question, but of those who did, one reviewer said the budget of \$300 k per year is reasonable for these studies. The other reviewer recommends continuing to fund this work, acknowledging that it will be very slow and many never in fact succeed. He views this as a high impact/low LOS program, and believes that the DOE needs to fund quite a few of this type of project in order to really make a difference in the long run.

*Improved Methods for Making Intermetallic Anodes:
Andrew Jansen (Argonne National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

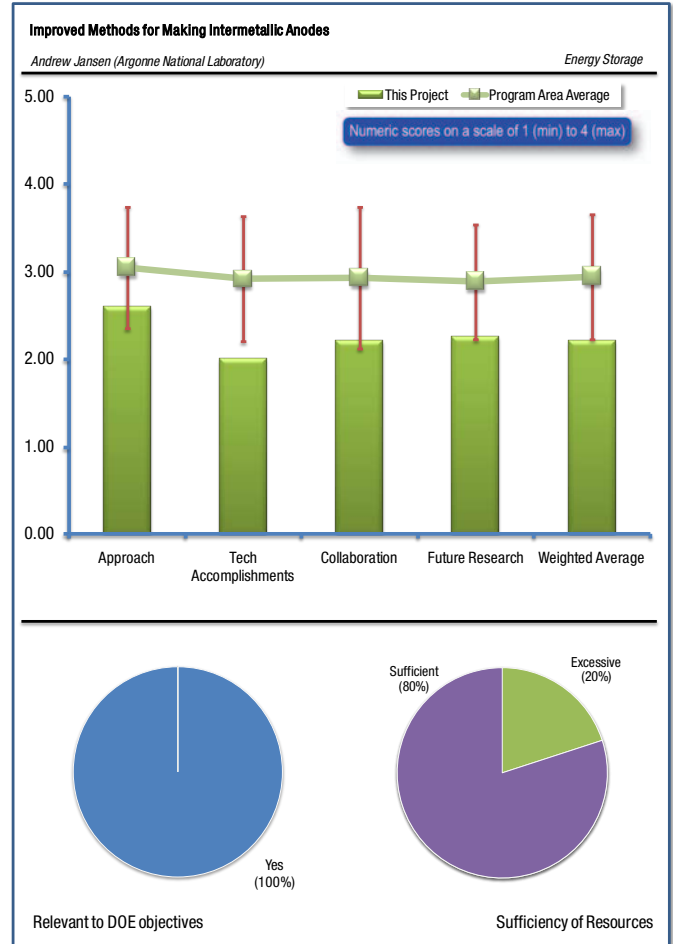
Reviewers agreed that this was a relevant project that supported DOE objectives. One reviewer said that high-energy, low-voltage, and safe Li-ion negative electrodes are definitely needed for the success of batteries in the automotive industry. A second reviewer agreed, saying there is a critical need for a low-cost anode that meets the life and performance requirements for PHEV and EV applications, and that this work is geared toward identifying an anode that will/may meet those needs. Another reviewer built upon this, saying the specific energies of Li-ion batteries need to be increased for meeting the range requirements of the PHEVs and the objective of this project is to develop inter-metallic Li alloy anodes, especially Cu_6Sn_5 in place of carbonaceous intercalation anode for enhancing the energy density of Li-Ion cells. These studies, if successful, would lead to a successful Li-ion battery for PHEV, which in turn reduces the petroleum consumption, and pave the way towards petroleum replacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The reviewers generally approved of the approach, though many offered criticisms. One reviewer said that Jansen’s approach is to limit electrode expansion of the alloy anode by working on binder or material synthesis. He felt the approach is good since the main challenge today is volume expansion. But in addition to that we need to work on limiting the volume expansion. Even if the electrode can accommodate the volume change, an electrode that expands by more than 100% is not practical. Another reviewer who was positive said that the approach to reach the stated goals of the project is sound, however, he was not clear on why a smaller size particle ($<0.5\mu m$) was not requested from supplier, based on the identified $0.2\text{-}\mu m$ particle size in Huggin’s model. Another reviewer liked the use of Huggins work but it seems that a theoretical understanding of how doping is likely to impact toughness, modulus etc. could be helpful - but he is not sure whether such a theory exists. However, he liked the paper estimate of what an actual battery would look like, and said that there is a need to do this more in other aspects of the program. The PI has a very good appreciation of the practical issues in getting from a material to a real battery.

Other reviewers were more tepid. One said the approaches are just fair and it is surprising that the authors spent so many resources on binders and electrolyte additives. These approaches are not going to solve the innate material issue. Another reviewer noted that the approach involves developing alternative methods of electrode fabrication with suitable binders and appropriate particle size for the intermetallic alloys, in particular Cu_6Sn_5 that was developed earlier in the BATT program. This alloy provides high volumetric energy, but hasn’t shown any compelling performance in the specific capacity to merit continued study /development. It will not truly address the technical barriers for intermetallic alloy anodes.

Another critic said that he would have liked a fresh look at new materials rather than an engineering-type study of ANL’s $CuSn$ anode, and said it seems a very limited approach to a very big area.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewers were lukewarm about the results. One said that work related to characterizations and understanding of the strain/stress properties of the materials is certainly appreciated. However, the actual data for solving the key task of stabilizing the anodes are not exciting and kind of expected. Another noted that volume expansion is still very high and difficult to handle in the cell. Another reviewer added that there appears to be a return (from last year) to the view that a binder that allows for extreme expansion, or alloys that prevent that expansion will be the solution. The appropriate particle size and process issues still remain concerns, as apparently they have not been fully identified. Reaching these decisions appears to be taking longer than originally planned. The Wildcat collaboration may help get the results faster.

More positively, reasonably good progress has been achieved in: i) understanding the mechanical properties of intermetallic alloys based on critical particle size, ii) identifying the metal suppliers, iii) developing coating processes relative to the conductive and resistive additive and in optimizing the binder.

Finally one reviewer allowed that while acknowledging that this is a very challenging high-impact/low LOS program, results to date are disappointing.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said there are only a few collaborations; it is probably worthwhile to collaborate with an industry partner to exploit the high volumetric energy density of these materials in 18650 cells. Another suggested that collaboration with a binder supplier should be initiated. A third thought that involving LBNL, for example, might open up the work to other anodes.

QUESTION 5: HAS THE PROJECT 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?

One reviewer wrote that the proposed future research is to continue these studies with small particle size materials containing various metals in a combinatorial way (with Wildcat Discovery) and revisit the critical particle size vs mechanical properties topic as well as reexamine the influence of binders and electrolyte additives. It is worthwhile to compare the final energy density against graphite, as is being planned here. These materials will probably address the volumetric energy needs of anode, but fall short of the gravimetric requirements.

Several reviewers offered suggestions for going forward:

- The authors should move away from the current approaches of using binders and electrolyte additives to counteract this fundamental material issue. Please focus more on altering material chemistry, morphology etc.
- Cost will need be lower than graphite to be competitive.
- Needs to do a lot of work on volume expansion and/or volumetric energy to be competitive with carbon.
- What about thermal stability and abuse tolerance?
- A reviewer liked the use of Huggins work but it seems that a theoretical understanding of how doping is likely to impact toughness, modulus etc. could be helpful, but he is not sure whether such a theory exists. He suggests talking to someone like Gerd Ceder about this, a better fundamental understanding of how dopants could impact the physical properties could be a big help in directing the synthetic work.
- The reviewer would like the scope widened to cover other materials, and he thinks this program needs to take a step back and see what other materials they should look at.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Only two reviewers answered this. One said the budget of \$300 k per year is appropriate for these studies. The other said that the effort is OK, but six years seems too long to fund this work without seeing more progress. Again, he would like to see work on something other than ANL's CuSn anode material.

Novel Electrolytes and Additives: Dan Abraham (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers deemed this to be very relevant and a critical area of research, with a couple of caveats. The specific energies of Li-ion batteries need to be increased for meeting the range requirements of the PHEVs. While there is a need to develop high-energy cathodes (and anodes), there is concurrent need to develop suitable electrolytes that afford safety and stability to the Li-ion cell, which is the objective of this task. These studies, if successful would lead to a successful Li-ion battery for PHEV, which in turn reduces the petroleum consumption, and pave the way towards petroleum replacement.

However, the caveats were that the stability needs to be higher than 50°C, and a different reviewer felt that though the program is trying to address cycle and calendar life issues, he does not believe the program is well focused to do this, as he outlines in a later section.

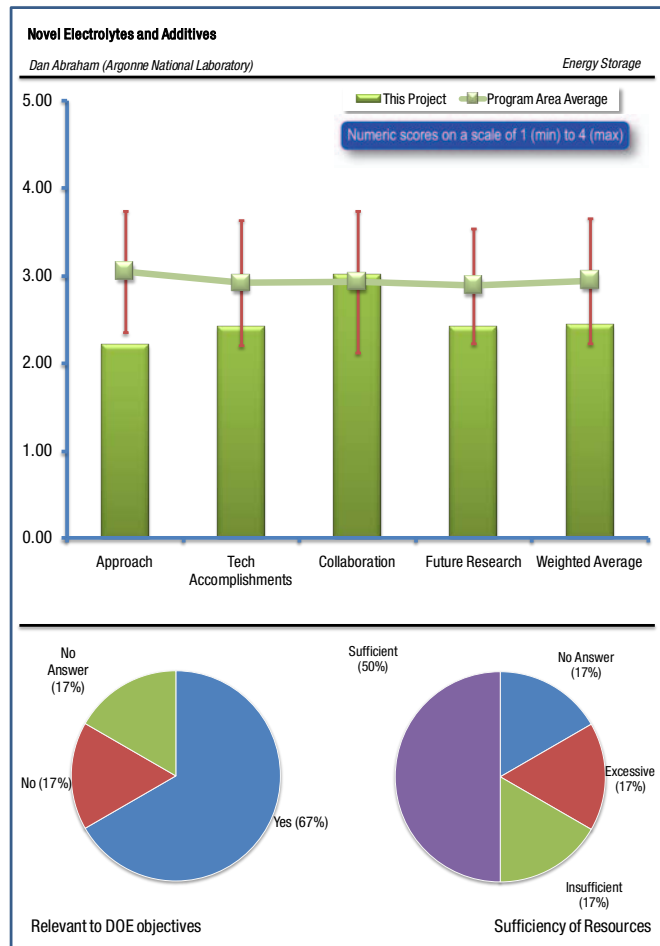
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers were generally critical of the approach. A positive reviewer commented that there were a number of attractive ideas being pursued to develop the next generation of electrolyte.

More commonly, the comments were critical. A different reviewer said that he didn't see any attempt in pushing the voltage to 5V. Even at 4.4 V the high fade rate in 4-5 cycles was pointing that we are not on the right path. Another reviewer stated that the reasons for the choice of glycol carbonate need to be better explained. It is not clear why that family of product has been chosen: thermal stability, cost, or what other reason? What are we trying to improve here? A third reviewer built upon this concern, saying that he has deep reservations about the approach to finding additives. What's the basis for trying to develop materials? I fear it may become a black hole that will suck up resources in a glorified fishing expedition among the 4 million+ organic compounds out there. If there was a basis for designing an additive I would feel more comfortable, but otherwise it would seem a never-ending, almost hopeless task.

A different reviewer noted that electrolyte is indeed a key component for the performance and safety of Li-ion cells. However, it not clear what advantages the GC-based electrolytes provide over the conventional EC-based systems.

A reviewer suggested that ionic liquids (IL) need to be looked at, but a couple of fundamental points need to be addressed in this area: low temperature performance and the problems of venting the cell in case of failure to essentially shut down the cell. This is an important safety feature in consumer cells and a high boiling point fluid may not be expelled well if the cell vents. Also ILs are hard to purify and Li-ion cells are exquisitely sensitive to impurities, so these need to be at least measured even if they can't be controlled very well.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers noted that much quality test data has been generated, but there are still concerns. One said the project has generated an immense amount of quality test data, some of which are novel and should lead to improved electrolyte system. Another reviewer agreed that some of the results looked OK, but usually this was only a partial data set. He was not sure that any of these materials are going to be useful overall. The use of differential capacity curves was nice, but the data do not suggest these materials are especially stable. My main concern is that I did not see any theory or experimental insight as to how these additives are supposed to work their magic.

A third reviewer characterized this as reasonably good progress accomplished in terms of: i) assessing the performance of graphitic anodes and metal oxides cathodes in GC (and its methyl ester version)-based electrolytes solutions, ii) identifying a couple for improved capacity retention and iii) examining a couple of ionic liquids based on pyrrolidinium, which performed well in half-cell, but not in full cells. Despite this progress, it is not clear to me what the GC-based electrolytes can offer. What is the rationale behind GC-based solutions except for being new?

Finally, a last reviewer said that he was not convinced about the explanation of GC oxidation that depletes the lithium reservoir. Based on the curve it seems to be more a reduction problem on the negative electrode than an oxidation on the positive electrode. What is the water content of this electrolyte? What about abuse tolerance? DSC?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers commended the collaborations with universities and other laboratories in this effort.

QUESTION 5: HAS THE PROJECT 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?

Reviewers had plenty of advice for the team. This included:

- The authors should carry out an exhaustive literature survey to minimize/eliminate redundant studies.
- Please pay attention to well-known functional groups such as acetates, ethers, etc., which have not proven to be stable enough for use in Li ion batteries.
- They need to include some thermal stability tests.
- I would suggest tearing down cells from the previous testing and looking in detail at the electrolyte and the electrodes to better identify the failure mechanism (for example, where is the lithium lost). That can be done in collaboration with other labs offering diagnostic capabilities.
- The proposed future research is to i) continue studies with GC-based electrolytes in terms of their electrochemical stability, SEI formation characteristics and electrochemical performance, ii) develop new electrolyte additives for stabilizing the electrode surfaces, and, iii) explore the use of ionic liquids. The proposed research is related to the overall project goals and the DoE objectives. The relevance of GC-based solutions is still unclear.
- A reviewer was not convinced that the glycerol additives are really that good. The team needs to develop an understanding of what you want additives to do and then design the additives (this means writing down proposed reactions, not just the desired results).

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer stated that the budget of \$300 k per year is appropriate for these studies. However, another reviewer said that he has huge reservations about this work because of the lack of a clear understanding of how they expect these additives to work. Industry can and does do this much better and faster than DOE labs. Also, major issues with the Ionic Liquids need to be addressed. Consequently, this reviewer has to recommend that the DOE stops funding this work, at least until the issues raised can be addressed. Three reviewers did not answer this question.

Electrolytes in Support of 5 V Li-ion Chemistries: Richard Jow (Army Research Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers unanimously agreed that this project is highly relevant to the DOE’s objectives. One reviewer described it as follows: High-voltage cathode materials are being developed to increase the specific energy of Li-ion cells to meet the range of PHEVs. Such cathodes would need electrolytes that are stable at these high (5 V) voltages. The objective of this task is to develop high-voltage electrolytes that enable the dreamed-of 5-V Li-ion chemistry. These studies, if successful, would lead to a successful Li-ion battery for PHEV, which in turn reduces the petroleum consumption, and paves the way towards petroleum replacement. Two other reviewers added that the use of a higher voltage system should reduce the number of cells needed for a system and consequently reduce the cost. Since cost is a key to moving the PHEV and EV technology forward, this project supports the overall DOE objectives.

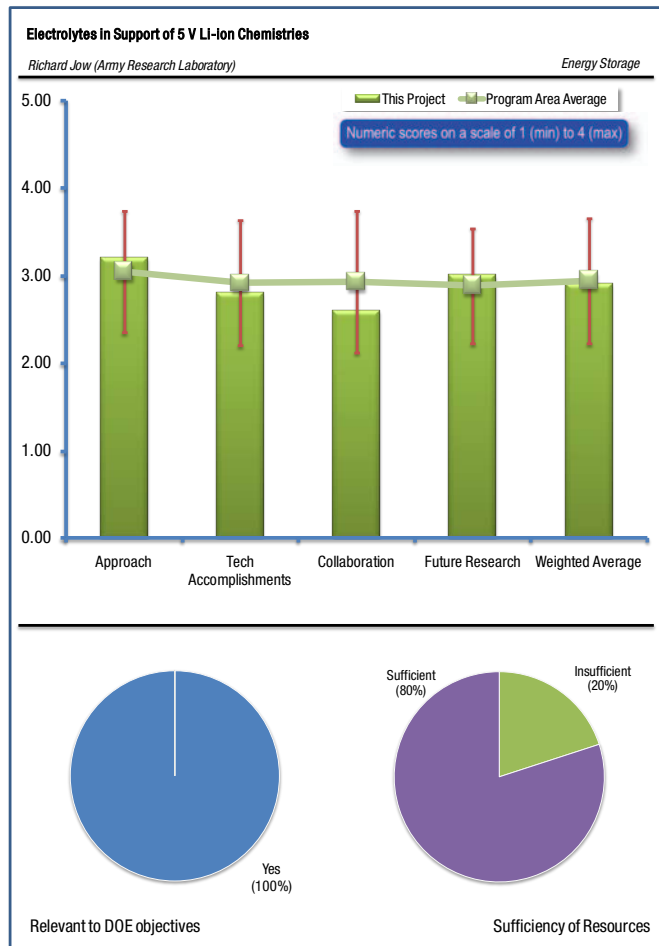
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers were positive about the approach, which involves developing new electrolytes based on i) unsymmetrical and unsaturated sulfones to be used a co-solvents or additives, ii) carbonate-based solutions with selective co-solvents and additives. A reviewer said that these approaches look quite reasonable, since sulfones are oxidatively stable at 5 V and the carbonate systems may be stabilized with proper additives that will form surface films on the cathode. The approaches address the technical barriers adequately. Another reviewer noted that the program seems to have the right approach by looking at key electrolyte families, isolating the issues associated with each, and determining the viability of eliminating those concerns. A third said that it is good to see high-voltage electrolyte studied, because this type of work is absolutely needed to make the high-voltage cathode application possible.

A concern is that the team will need to confirm compatibility with the other cell components. A last reviewer commented that this program is very challenging. Their approach of trying to use the sulfones is not bad, but they are known to be very extremely viscous, so low temperature would likely be very poor. The use of substitute materials for true 5V cathodes is good. He is also a little concerned about the “additive” approach unless there is a clear understanding of what the additives actually do - in detail. Basically, if one can design an additive to do something specific, then he is OK trying it out, otherwise this can turn into a fishing expedition and suck up valuable resources. But the group does seem to have some good ideas for what they want in an additive.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers commended the ARL additive results, but were mixed about other aspects of the project. One reviewer said that the ARL additive data look promising and provide very good clues as to the future directions for work. The current generation is definitely superior to conventional electrolyte systems, but he did not think they are stable enough yet to meet the demands of the 5V cell system



especially when data at high temperature have not yet been obtained. Another reviewer who commended the ARL results said that the team needs to look at the surface to see if there is any passivation film formed.

A third reviewer noted that good progress has been accomplished in terms of developing high anodic-stability electrolytes with sulfones. After evaluating several formulations (~ 80), it was concluded that the sulfone is unsuitable as a major solvent due to the issues connected with SEI on the anode, ion transport and electrode wetting. However, significant progress has been achieved in carbonate-based solutions, as demonstrated in cells with a spinel cathode. The progress achieved here is consistent with the DOE goals. A fourth reviewer also recognized that the project seems to have narrowed the test matrix by eliminating sulfones as an option. He mentioned the need to identify a collaborator for the next phase of work using the carbonate approach.

Concerns included the thought that it is not clear what the expectations/goals are for the program. Cost-reduction potential should be included in the goals. Also, low-temperature performance is a big problem with this chemistry, so LT performance improvement should be included as a concern to be addressed. Another criticism by a different reviewer was that the additives results look interesting, but he did not see any experimental understanding of how they worked, which bothers me.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

All reviewers noted the collaboration with ANL. One reviewer wondered where is the work with ANL high-voltage material, and another noted that he sees the same electrolyte being developed also at ANL (glycerol carbonate). One reviewer advised that in order to get at a real understanding of what these additives actually do, they may need more help from the other DOE labs. There is also a collaboration with a university and industry.

QUESTION 5: HAS THE PROJECT 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?

The proposed future research is to continue the i) Optimization of carbonate-based electrolytes, focusing on performances at elevated temperatures, ii) Studies on the characterization and diagnostics of the electrodes cycled with these electrolytes and iii) the design and development of new additives for improving performance of 5V cathodes.

One reviewer advised that while we do not know the nature of the ARLs, he thinks the work should continue in that regard because of the initial data. Another reviewer expanded upon this notion, saying he would focus on the ARL additives for now and especially in terms of understanding how they work. In fact, this understanding may prove more valuable than the additives themselves as it may direct future work in designing additives.

Other suggestions were:

- Characteristic and diagnostic studies are critical.
- The team needs to include calendar life tests at high temperature.
- There should be some planned work to establish low temperature performance.
- There should be a set of performance goals.
- There was very little cycle and calendar life work shown using existing additives.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers supported this work, as one stated that he believes this is very important work that needs significant funding. Another reviewer said the budget of \$200K per year looks insufficient for these studies, but may be justified if leveraged from DOD. Two reviewers did not answer this question. A third reviewer also supported the research, saying he remains concerned about the approach to “magic” additives. However, he agreed that they need to follow up on their promising findings, but only as long as they address the fundamental issue of what they are actually doing. If they can provide additives that have a clear basis as to why one would expect them to work and how, this reviewer is fine with continuing to evaluate new additives. However, the work should be focused. Funding level is quite modest though and should be continued at the present level.

Development of Advanced Electrolytes and Electrolyte Additives: Zhengcheng Zhang (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers were supportive of the relevance. High voltage cathodes materials are being developed to increase the specific energy of Li-ion cells to meet to the range of PHEVs. Such cathodes would need electrolytes that are stable at these high (5 V) voltages. The objective of this task is to develop high advanced electrolytes with high voltage stability, combined with high lithium ion conductivity, high thermal stability, non toxicity and non-flammability and also to identify electrolyte additive that provides a stable SEI on the electrodes for improved cycle life. These studies, if successful, would lead to a successful Li-ion battery for PHEV, which in turn reduces the petroleum consumption, and pave the way towards petroleum replacement.

One reviewer felt that ES024 and this program should be combined in some way.

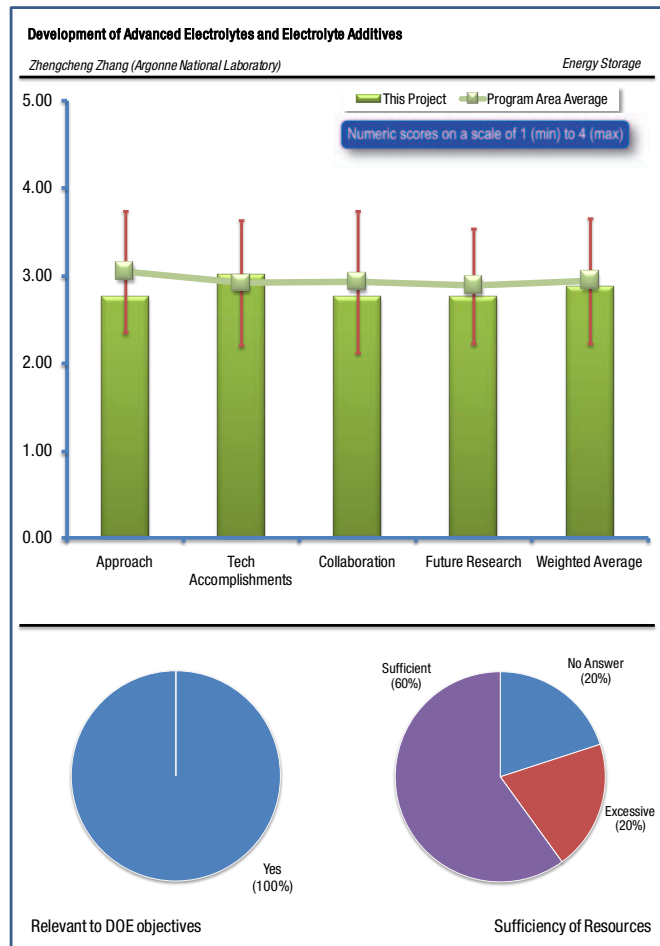
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said that the approach with sulfone has the potential drawback of poor low-temperature performance. Ionic liquids will have the problem of stability. Another reviewer described the approach as involving developing new electrolytes based on sulfone as a primary solvent or co-solvent, and ionic liquids, and investigating their compatibility with different battery chemistries. In addition, various electrolyte additives including compounds containing oxalic group, ester group, vinyl group et al. will be examined for their “filming ability” on the cathode surface. The approaches are thus aimed at developing stable and safe electrolytes for Li-ion batteries to enable their widespread use in PHEVs.

A different reviewer noted the approach in each area looked quite good, although the known viscosity problems of sulfolanes are likely to be very difficult to overcome at even modestly low temperatures. No low temperature work on this seems to have been planned.

Other reviewers had these questions and comments:

- Are these compounds the same as ARL?
- Why are they using LiTFSI, as it is well known to oxidize Al. The project needs to find another salt.
- Generally, a reviewer was concerned about work on additives without a clear rationale for evaluating them. They seem to be basically picking up on leads from others, which is better than just “fishing,” but have one's own rationale to design additives would be better.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers lauded the results thus far. One said that some of the additives look promising and this work should continue. Another agreed that there are quite a lot of very promising results. The LTFOP data at 55°C are impressive, and he hopes the authors can build on this success to develop the next generation of these additives/electrolytes.

A third reviewer said there is good progress accomplished in terms of developing high anodic-stability electrolytes with sulfones. The team has determined the wide electrochemical window and conductivities of trimethyl sulfone and ethyl methyl sulfone and demonstrated good cycling performance with spinel oxides in both TMS/ LiTFSI and EMS/LiTFSI electrolytes. They have also identified several new compounds with oxalic group as SEI formation additives and demonstrated their beneficial effect on both NMC cathode and MCMB anode at 55°C. They identified that succinic anhydride and maleic anhydride can form stable SEI earlier than EC, which might have several benefits. There is thus good progress towards the project and DOE goals.

Some advice and other feedback included the following:

- Someone mentioned that LiTFSI could work. Some corrosion and life studies are needed to prove it.
- The electrolyte work does not seem to be bearing much fruit. Wettability and viscosity issues with sulfolane were predictable based on its well-known properties. They may want to look a separator with surfactants such as Celgard 3501, if Celgard still makes it. The flammability comparison is flawed because of the different solvent ratios – one can't tell if the difference is due to the replacement of EC with Sulfolane or the fact that the EC formulation simply had a higher content of the much more flammable EMC.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The reviewers noted that there are a few collaborations within ANL and none yet outside ANL. It was suggested that they collaborate with industry partners as well.

QUESTION 5: HAS THE PROJECT 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?

The proposed future research is to continue investigating i) sulfone-based electrolytes to make them compatible with graphite anodes, ii) ionic liquids as new electrolyte solvents by screening existing electrolytes and develop new systems, and iii) electrolyte additives, in particular, succinic/maleic anhydride additives for thermal and morphological studies. These studies address overcoming the barrier outlined for this project, in the judgment of one reviewer. Another reviewer would propose evaluation of these materials at low temperatures also. A third reviewer was more critical, saying that he was not convinced that the sulfolane work justifies continuing and Ionic Liquids also have major issues with low temperature. Questions should also be asked about the acceptability of a highly non-volatile electrolyte as this would likely not effectively shut down the cell if it were to vent during abuse or malfunction. Only the additive work looks promising to me.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Three of the reviewers did not answer this question. One reviewer said the budget of \$300 k per year looks reasonable for these studies.

The final reviewer commented that the electrolyte work is not looking very promising, and even if they succeeded with sulfolanes or Ionic Liquids, the reviewer was not sure they could be used in practical cells due to low temperature and venting issues. The reviewer would scale this back to just look at the additives unless they can show a clear path to a viable high voltage electrolyte. The reviewer did not believe they have great expertise in electrolytes; basically the reviewer just questioned whether they are the right group in the DOE to be doing the electrolyte work.

Development of Novel Electrolytes for Use in High Energy Lithium-Ion Batteries with Wide Operating Temperature Range: Marshall Smart (Jet Propulsion Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer saw that this project is a critical component for long-life cells. The second reviewer perceived that barriers addressed at the electrolyte level are in line with DOE objectives, and life is clearly one of the main limitations today. Another reviewer said that this project in particular attempts to address the low temperature performance of the lithium ion chemistry without negatively impacting the high temperature performance.

The fourth reviewer saw that obviously JPL has an even stronger interest in low temperature cells than DOE, but this program does support the DOE goals, especially if low temperature power is really a design criterion. However, this reviewer is not convinced that the -30°C operation makes much sense, especially for initial market penetration and with the options to use heaters, engine power, etc.

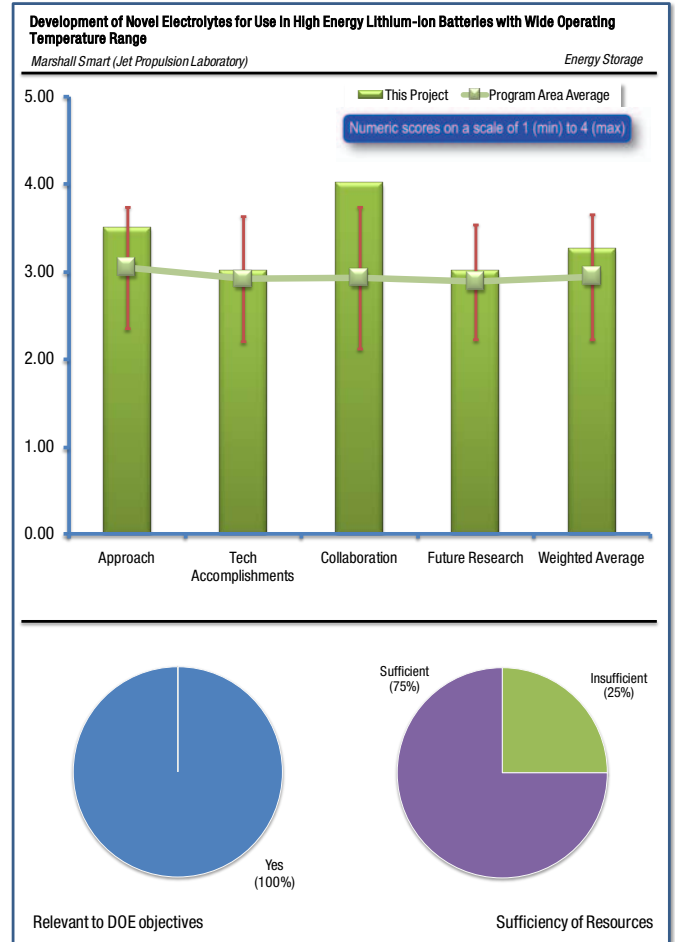
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer saw that many well-proven materials are being tested. The second reviewer felt that the approach is good because it combines fundamental work and studies in coil cells with evaluation in prototype cells. The third reviewer commented on the excellent approach to solving clearly defined objectives. Another reviewer liked their methodology a lot, including the use of harvested electrolyte and Quallion cells. The research generates a lot of actual test data that gives a good sense of confidence in the findings.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Several reviewers commented positively on the data. The first reviewer saw a great collection of data. The second reviewer noted that obviously a lot of work has been done with some nice results: overall, this is a nice work. Another reviewer felt the program met program goals of improving low temperature performance. The fourth reviewer saw good data and noted that some of the low temperature and ambient cycling results are quite impressive. The evaluation of additives is well thought out and showing some progress.

One reviewer was a little worried about the stability of these solvents at high temperatures. Another reviewer commented that it was a bit difficult to follow which of the results were the most promising. Also, some the results did not appear to be brand new. The third reviewer noted that high temperature performance did suffer. The fourth reviewer feared that these esters will not be able to provide good cycle or calendar life – JPL's own work shows problems at high temperature. This reviewer is not convinced that any amount of additives are going to fix this, and noted how Panasonic stopped using methyl butyrate in their cells a long time ago.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers had positive feedback about the collaboration. Specifically, the first reviewer was impressed by how everyone was really pulled together by the project team. The second reviewer felt that this seems to be a collaboration with lab and industrial partners. The third reviewer commented that many collaborators were used from various groups including different commercial battery suppliers: this is good, as it shows a wide range of interest from the industry in this program and the technology. The final reviewer noted that there was a “whole load” of impressive collaborators, and the team is also feeding work into modelers.

QUESTION 5: HAS THE PROJECT 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?

One reviewer felt that the program identified good potential solutions and proposes to build on that work and involve a wide range of battery suppliers by incorporating the electrolytes into their commercial cells. A second reviewer felt that plans going forward are good. The reviewer had concerns about the likelihood of ensuring adequate stability with the esters via additives, so this reviewer suggests much more emphasis be given to cycle life and high temperature testing. For the DOE program these are critical features and cannot be traded to get better low temperature performance (there may be room to do that for some of NASA's applications).

Another reviewer saw a definite need to wait for high temperature stability before a judgment can be made about these electrolytes. A third review saw that extreme temperature stability of esters has always been an issue. If it is believed this is the direction to go, this needs to be the primary focus for future research.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that annual funding seems low for this work, and this reviewer would like to see it doubled if and only if -30°C is really a “must have feature,” which this reviewer seriously questions. Otherwise, this reviewer suggests keeping the funding level as it is.

Novel Compounds for Enhancing Electrolyte Stability and Safety of Lithium-ion Cells: Kevin Gering (Idaho National Laboratory)

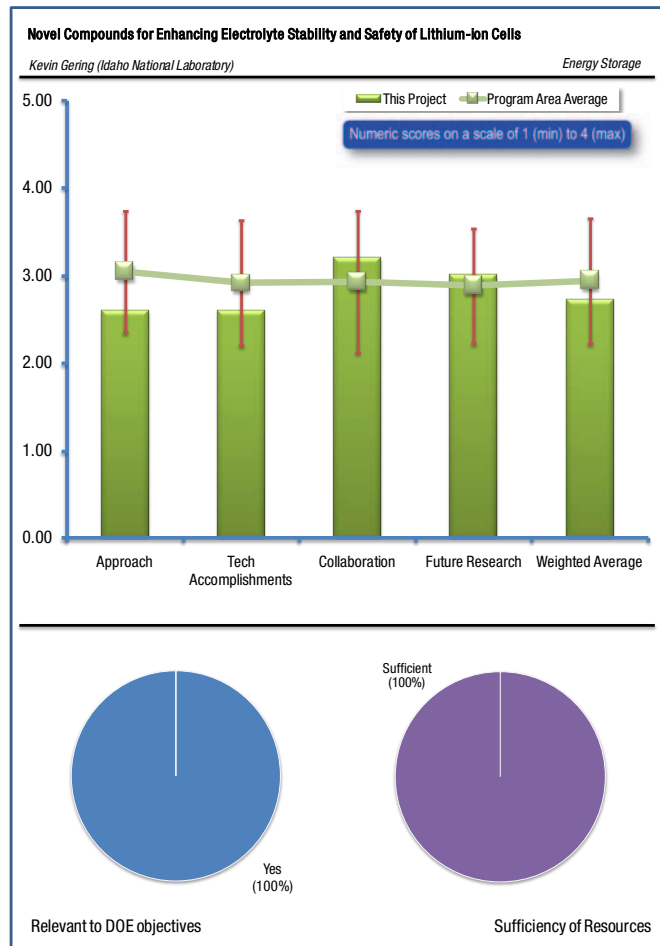
REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer commented that this project is relevant. A second reviewer also felt the project was relevant, and that working on improving abuse tolerance and cell life is the way to go. Another reviewer commented that both safety and longevity of Li-ion cells are inadequate for the current Li-ion cells, and this gets more challenging with the advent of high-voltage cathodes. The objective of this task is to develop new electrolytes based on novel solvents and on phosphazene additives. This would require an understanding on the effects of phosphazene additives on the other electrolyte components and on the SEI characteristics, as well as their tolerance to high and low voltages, which will be the topic of this study. These studies, if successful, would lead to a successful Li-ion battery for PHEV, which in turn reduces the petroleum consumption, and pave the way towards petroleum replacement.

The fourth reviewer commented that improved safety is key for this technology to be adopted into the vehicle market. A key goal of this program is to improve the electrolyte, which contributes to most of the safety issues. The final reviewer felt that safety is a critical area and this program represents an attempt to make the electrolyte non-flammable.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer felt that the project seemed to be aware of previous work by Bridgestone and others, and the team has access to experts on these materials. The project is looking at the flammability and performance together, and the reviewer likes the approach in general. The second reviewer commented that the program has selected one group on which to concentrate activity and this narrows the focus. The reasons for the choice are clearly outlined and understood.

The third reviewer noted how the project utilizes the expertise at INL on the phosphazene chemistry, and how the approach involves synthesis and characterization tests such as transport properties, flammability, and so forth, with electrochemical testing (in Li-ion coin cells) of a series of phosphazenes. These will be blended in different proportions with the carbonate solutions. Candidate electrolytes will be tested in LiCoO₂/graphite coin cells. One difficulty with this wide range of proportions for the phosphazenes is that it is unclear if the phosphazene is being utilized as an additive, co-solvent or primary solvent. The considerations are different for each application. The approaches are thus aimed at developing alternate and safe electrolytes for Li-ion batteries to enable their widespread use in PHEVs.

Another reviewer felt that the approach is good overall, but it is not very clear why phosphazene is the right chemistry, when it has “already failed.” There is probably good justification of that, but this is just not very obvious from the presentation. The final reviewer

was not sure this approach will work at all. The flashpoint did not increase, the substance is viscous, and it might be needed to be added in significant quantities to bring about any gain in stability (but will certainly be at the expense of power).

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer saw good progress has been accomplished in terms of evaluating various (about nine) phosphazene-based electrolytes in carbonate blends. Some of the effects of the phosphazenes are : i) to decrease the conductivity due to higher viscosity, ii) increase the SEI characteristics at the anode, probably causing higher interfacial impedance, and iii) providing moderate stability at the cathode and iv) overall causing considerable polarization over baseline. The CVs indicate considerable oxidative activity around 4.0 V, which suggest that they could only be used as additives, that too if the oxidation leads to a stable surface film on the cathode. In general, it is critical to determine the stability and compatibility of the phosphazenes at both the electrodes of Li-ion cells, before undertaking on an extensive study as this. The discharge capacity should be expressed as specific capacity to get an insight into the electrochemical compatibility.

Another reviewer felt that given the approach, the project has achieved some good characterization of the materials in question. This reviewer is very skeptical about any positive outcome of the project, as too many drawbacks are already coming to the surface. In fact, this reviewer feels that the original Bridgestone data were also not appealing to begin with from application point of view.

The third reviewer observed nice progress on developing additives with low viscosity, but conductivity is still affected. There is no change in flash point but the team needs to understand the true impact on abuse tolerance. This reviewer asked how much lithium is consumed during the first cycles. (What is the capacity loss?)

Another reviewer felt the work was good, but the overall results did not show any improvement in a key goal of the program-reduced flammability of the electrolyte. Relative to the stated benefit/strength of this additive, very little test data was presented to support the improved safety. It is good to know that cost is being considered as a concern for this process early on.

The fifth reviewer commented that the large amount of additive needed to reduce the flash point looks “pretty ugly” and was one of the problems with the original Bridgestone material. Good work, but the results to date don't look very encouraging.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first two reviewers saw very good collaboration, and the third reviewer commented that there are good collaborations with various DOE laboratories and with industry partners. Another reviewer felt that industry support/involvement is encouraging that the process has a great deal of promise.

The fifth reviewer saw good linkage with INL and SNL in the program. However, this reviewer adds, the team needs to talk with Sandia more about their battery test of Bridgestone's materials and devise meaningful tests going forward. Also, this reviewer suggests speaking to the US Navy, as they are very knowledgeable in this area and are currently doing aerosol flammability testing on all electrolytes used in their batteries.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer felt that future plans show that the issues identified will be addressed. One of these issues is determining the % level of phosphazene compounds that will improve flammability and what the resultant viscosity level will be. The second reviewer commented that if the authors can synthesize lower viscosity analogs, there might be some potential.

Another reviewer noted how the proposed future research is to continue investigating i) electrolyte systems having mostly phosphazene solvents, especially, non-cyclic phosphazenes with low viscosity, ii) selected phosphazenes as additives in volatile organic electrolytes for reduced flammability, and iii) the SEI characteristics (both on the cathode and anode) with the phosphazene

additives. Candidate solutions will be tested for abuse tolerance at SNL. This reviewer felt the proposed studies are consistent with the project and DOE goals.

The third reviewer commented that abuse tolerance is very important, as it is the main result expected from these compounds. To have good understanding of abuse tolerance, this needs to be done on large cells.

The final reviewer expressed some concerns about metrics for flammability. The PI needs to talk with Sandia more about Sandia's past battery test of Bridgestone's materials and devise meaningful tests going forward. This reviewer thought flash point is a pretty decent measure to start with, but it doesn't really address aerosol safety. The U.S. Navy is very knowledgeable in this area, and they are currently doing aerosol flammability testing on al electrolytes used in their batteries. This reviewer strongly suggested that the PI and Sandia get with the Navy to see what they can learn from each other. There is also an industry standard flame test measuring a burn length of a fabric-soaked cloth, although this reviewer does not like it. However, in that work (mostly in patents), a big benefit was seen from the LiPF₆ alone. Just a caution that going to a different salt could be a step backwards in their search for low flammability.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The budget of \$400 k per year (last year) looks reasonable for these studies, according to one reviewer. According to the second reviewer, the funding level seems low, but this is a low LOS high reward program and maybe that's appropriate at this stage. If they get anywhere, then significant additional funding would be needed to capitalize on their work.

Screen Electrode Materials & Cell Chemistries and Streamlining Optimization of Electrode: Wenquan Lu (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer commented that the stated objective of this project is to identify low-cost materials for the systems used in PHEV battery systems. The reduction of the cost of these systems is absolutely necessary for acceptance of this technology and consequently supports the DOE objective.

Another reviewer commented that with several advanced materials being developed and marketed by the vendors, it is essential to have their performance assessed for comparison in standard test vehicles and environments. The objective of this task is to identify and evaluate and understand the low-cost cell chemistries that can potentially meet the life, performance, abuse tolerance, and cost goals for PHEVs. Another objective is to understand the impact of the material physical properties and electrode formulation processes on the electrode performance. These studies, if successful, would lead to a successful Li-ion battery for PHEV, which in turn reduces the petroleum consumption, and paves the way towards petroleum replacement.

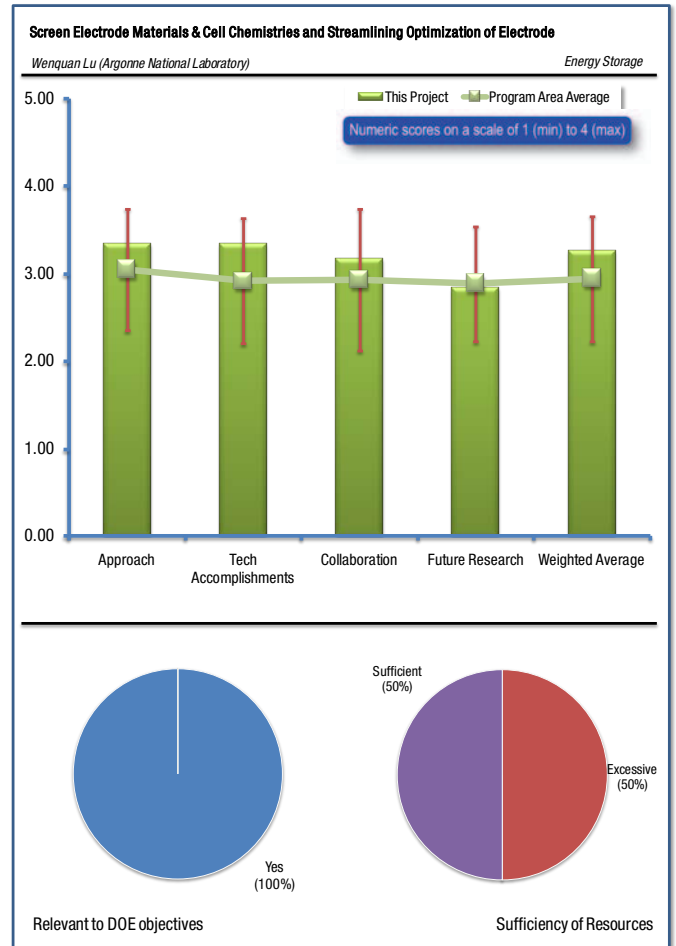
The third reviewer commented that evaluating the best materials available provides a valuable benchmarking feature to the program. Moreover, the fundamental work on particle conductivity and BCF electrodes provides greater understanding of how best to use and evaluate these materials.

According to the fourth reviewer, the stated goal of 100 Wh/kg (pack level) seems too low. Their understanding is that the pack level goal is 200 Wh/kg. The current technology for large format cells is already close to 100 Wh/kg pack and 150Wh/kg cell-level.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

According to one reviewer, the project is working with the right materials and a good evaluation methodology. This reviewer liked the work on fundamental aspects of making an electrode. The second reviewer liked the creative approaches to measure particle conductivities. The team should focus on how we can use this to make high energy and/or high power cells. The reviewer recommended examining Robert Kostecki's LBNL work where he shows that regional isolation of active material results in electrode/cell premature fading of power and energy. How can we use this knowledge to make better electrodes?

The third reviewer summarized how the current approach is to carry out a detailed assessment of various cell components, i.e., specifically high energy density LiMnFePO_4 , $\text{Li}_{1.05}(\text{Ni}_{4/9}\text{Co}_{1/9}\text{Mn}_{4/9})_{0.95}\text{O}_2$ from ANL, SMG graphite from Hitachi Chemical, and fluorinated electrolyte (FEC) from Daikin. The approach for the second objective is to study the distribution of the conductive additive and determining the effect of carbon coating and binder on the electronic conductivity. According to this reviewer, the approaches are thus aimed at evaluating the commercial materials and also understanding the electrode fabrication issues, as stated in the objectives.



Another reviewer felt that the approach allows for a broad level of investigation. There should be some constants identified at the cell and chemistry level to reduce the potential number of materials studied and to provide more useful information sooner. This reviewer thought it might be better to identify two or three chemistries and concentrate on the materials of two or three of the cell components.

The fourth reviewer was not completely clear as to the scope of this project. Are the team members evaluating materials or optimizing cell fabrication steps? In any case, the work is well organized and thought out.

For the fifth reviewer, the plot of capacity is valid for one type of material only. The working voltage will change that plot. That approach is what current battery suppliers are doing. Not sure about the added value. DOE should support work that lead to innovative solution. This reviewer is unsure if material screening needs to be a DOE funded activity. The second part of this work is much more valuable.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Several reviewers had positive feedback on the project's progress. The first reviewer saw that several important results with respect to characterization/optimization of the electrodes have been reported. These are very valuable to develop well-behaving cells for ANL and other labs. The second reviewer commented on the good work on various aspects of cell design and development with clear conclusions. It would be nice to tie up all the loose ends. E.G. insights on how to match electronic conductivity of electrode with the ionic conductivity to get optimum electrode ASI, or measuring particle conductivity and binder conductivity, etc. are all good. But now all the bits and pieces of information need to be tied together.

The second reviewer felt that good progress has been accomplished in terms of completing the evaluation of the selected materials, which showed interesting characteristics. Specifically, i) LiMnFePO_4 with high capacity of $\sim 160\text{mAh/g}$ at 4 V with $\sim 80\%$ capacity retention at 2C rate and good cycling performance, ii) ANL's $\text{Li}_{1.05}(\text{Ni}_{4/9}\text{Co}_{1/9}\text{Mn}_{4/9})_{0.95}\text{O}_2$ with high specific capacity of 180mAh/g and low irreversible capacity loss of $<10\%$, iii) the carbon coating in Hitachi's SMG improving reversible a capacity decreasing the irreversible capacity (SEI formation), and iv) the fluorinated electrolytes showing better oxidative stability and thermal stability with cathode. The second set of studies reveals that the contact resistance is a dominant contributor, and carbon coating on the NCM improves the thermal and conducting properties with expected improvements in the power characteristics. The results demonstrated good progress towards the goals of this project and DOE.

The third reviewer commented that the information provided on the materials tested was very good. The key performance aspects were identified. The results did give direction to suppliers on how their product can be improved. The final cell size used for endorsement and direction should be increased to a minimum of 4 Ah for power application and 10 for energy applications. Results can be significantly different when the cell size is scaled up.

Another reviewer saw great results of evaluations and new insight provided by the fundamental portion of the work. The 4-point conductivity measurements of single particles are very impressive. This reviewer wanted to repeat the audience's concerns that as the particles become smaller, the conductivity of the particle may reflect more and more surface conductivity rather than that of the bulk material - maybe the current doesn't even need to go through the bulk. 4-point methods overcome issues with making good contact to the particle - not surface vs. bulk conductivity, something this reviewer suggests thinking about.

The fifth reviewer felt it was a bit light on MnPO_4 . What are the real conclusions? SMG carbon: irreversible loss due to surface modification or decrease of surface area? This reviewer felt the work is assessing the obvious here. Most of the battery suppliers probably know about this. The second part of that work shows more promising results.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers provided positive feedback on the collaborations. The first reviewer suggests more effort should be put into bringing industry partners from the battery/cell manufacturing arena, and the second reviewer stated that there are several contributors to this study from different organizations and a few collaborations within ANL as well as externally. The third reviewer felt the project was very "linked in" with potential suppliers. There is good cooperation with fundamental scientists at ANL and modelers.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer felt that these studies are quite logical and help mitigate the barriers. This reviewer summarized how the proposed future research is to continue search for new, commercial materials to help meet the performance, safety and cost goals for PHEVs. Specific studies include assessment of i) LiNiCoMnO₂ (Phoenix), ii) hard carbon (Kureha), iii) aqueous binder (SBR), and iv) fluorinated solvent (Daikin) and carbon black (Cabot Corp). Likewise, studies will continue on the effects of carbon coating on cathode performance, on the contact resistance and optimization of carbon additives through modeling. Multiple workgroups at ANL work on very similar items. It would be nice to have a sharper division of workplans for a better appreciation of all the work currently underway at ANL.

The second reviewer felt that this project is generally very good, and suggests that any time a kinetic or conductivity issue (electrolyte or particles) is encountered, the impact should be evaluated at low temperature to more clearly see the impact.

The third reviewer suggests shifting focus toward more energetic materials and focusing the effort on how to achieve 250Wh/Kg, ~500Wh/L type of cells. The reviewer recommended the team look a bit more forward to more ambitious targets. Another reviewer questions how we can make best use of Dr. Lu's expertise to help the industry. The coating approach is interesting. It is developed by several companies but it seems to be difficult to control. This reviewer thought the study need to focus on this. Binder free is good. This reviewer asks why not work on a binder that lowers effects on conductivity. The fifth reviewer felt that the project was in line with objective, but would still like to see a more focused approach. The team could possibly work with a supplier to scale up the cell size and confirm the system performance.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer commented that the first part is just material screening. Resources need to be focused on second part. Another reviewer felt that the budget of \$650 k per year looks slightly excessive for these studies (~ \$400K would be appropriate). The third reviewer commented that combined funding level is quite high (\$750K), but they are doing a lot of work. This reviewer felt that funding still seems to be a bit excessive, and suggests DOE review and scale back their plans a little.

Materials Scale-up and Cell Performance Analysis: Vince Battaglia (Lawrence Berkeley National Laboratory)

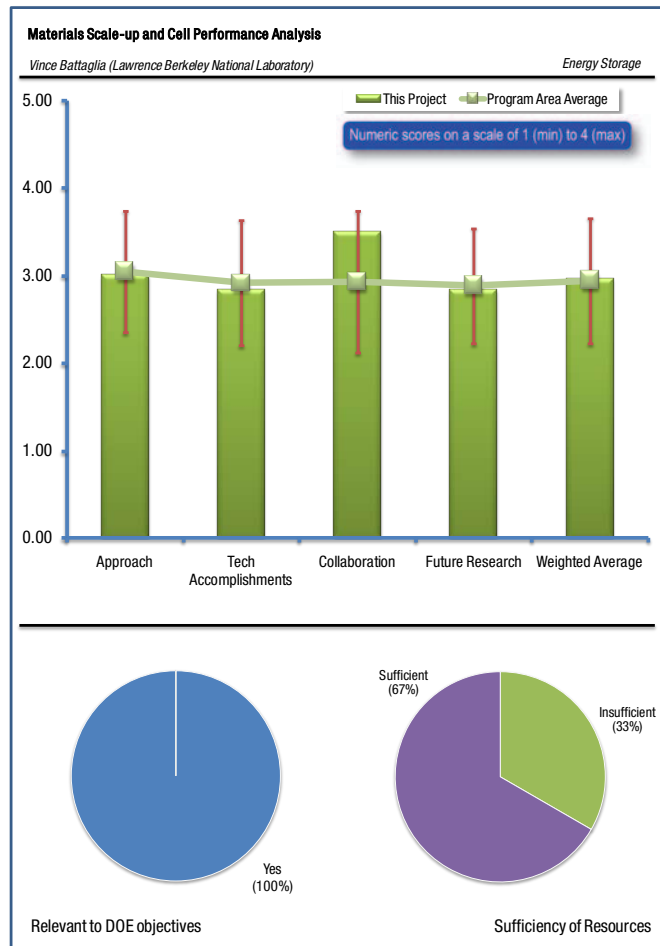
REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt that the project offers an important validation tool for the BATT program. The second reviewer felt the project was very relevant for developing next generation materials. Another reviewer commented that this project allows for a none bias evaluation of materials from researchers, which may be used to support the development of systems to meet the DOE goals. The fourth reviewer answered that the work is relevant, but do not forget about life improvement as well.

The final reviewer noted that with several advanced materials being developed in the BATT program, it is essential to have their performance independently assessed against DOE/USABC performance targets in standard test vehicle and environment. The objective of this task is to identify and evaluate four new materials in this year. A successful verification will thus lead to their incorporation in prototype cells and/or redirect the research efforts under BATT. A successful development of Li-ion batteries for PHEV will reduce the petroleum consumption, and pave the way towards petroleum replacement.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer commented that the team has established and demonstrated a really good cell design for testing materials. This work is critical to moving the program forward, both from a validation point of view but also to ensure that we don't miss an opportunity because of poor cell-making by other PIs. The project is looking across the program and is very open. This reviewer thinks their ICL cutoff of 30% is a little harsh in view of possible fixes for this (SLMP, matched cathode, etc.). If they have already made the cells, why not continue to cycle or is this yet another result of insufficient testing capabilities. The second reviewer commented that this is a very interesting approach that links the work done in the labs to the real life.

The third reviewer wasn't sure comparing various materials based on one criterion (electrode loading as stated by the PI) will compare apples to apples. Even based on this one criterion, whether the loading density is measured in mAh/cc or mg active matl/cc or mWh/cc the team will get different electrodes and different results from cell testing. What about the composition of active material versus conductive carbon? binder? What if a material has carbon coating or has better conductivity than the other, would you use same composition to compare? In the end the cell should be optimized for the material; otherwise, just creating one leveling field will result in disparities in other areas.

According to the fourth reviewer, the approach is to get new materials from BATT PIs in 10g quantity, and test the materials in half-cells using electrode fabrication techniques developed in BATT program. The tests include capacity measurements and rate capability. Should the results be encouraging, full cells will be designed, fabricated and tested to identify performance attributes and limitations. Even though this approach looks good, it is not clear to this reviewer if this 'verification and validation' of the BATT materials is

necessary. Most of this assessment would be done by the BATT investigator, and with promising materials this should be done with an industry partner.

The final reviewer felt the approach as outlined is good. However, the presentation did not follow the approach presented. Good evaluation work was presented (particle sizing, XPS and Ion Sputtering work, etc), but none of this work was identified as part of the approach. On another question, is there any coulombic or energy efficiency evaluation work done in step two of the approach?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer saw good progress being made in benchmarking various materials in the same lab. Another reviewer felt that moderate progress has been accomplished in terms of evaluating several BATT samples both for performance and understanding their morphology/surface properties. Specifically, the team completed the assessment of four different materials from BATT and communicated the results to the PIs. They determined that both the MIT and HQ LiFePO₄ materials have coatings and perform well. HQ's has 100 nm primary particles with a 5 nm carbon coating, while the MIT's sample has 30 nm primary particles with a 1-2 nm carbon coating from oxalate precursor residue. These studies should focus more on high-energy materials than LiFePO₄, which is quite mature, to address the low energy density barrier of Li-Ion batteries.

The third reviewer felt that the work shows a great understanding of what it takes to optimize a cell construction and electrode fabrication to get the most out of a material to avoid missing opportunities - remember that missed opportunities are much worse than false positives as the latter will be corrected in follow up work. Missed opportunities may just get dropped and never reexamined.

The fourth reviewer saw good insights into composition of LFP from multiple sources (MIT, HQ, ANL, etc.) by XPS, and ion sputtering. LFP is a good material but cannot meet the needs of higher energy PHEV and EV applications. A single-minded focus on LFP will miss potentially better opportunities elsewhere.

Another reviewer commented that it was unfortunate that we did not see the very good results. The fifth reviewer was not sure how this program can be evaluated, since if there were no responses to the inquiry, there would be no work. This reviewer thinks there should be a minimum number of responses. There were eight responses and the work done was identified, but very little actual performance work was presented. Most of the data presented was descriptions of the particles and materials, which is more of a material characterization effort than performance testing. This reviewer can only imagine that the performance data could not be shared, and if so the program should be changed to reflect this 'no share' rule.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer saw excellent collaborations among many labs. The second reviewer felt that, as expected from the proposed work, there are several contributors and collaborators in this effort. The project will probably benefit more from some collaborations with an industrial partner in scaling up/verifying these materials.

The third reviewer was encouraged by work with MIT and others: this reviewer was looking forward to hear the results. It is worthwhile for DOE to make sure such collaborations are not used by the other party(ies) prematurely as a seal of approval of their work before substantive results are produced. Another reviewer concurred, noting that there appears to be good collaboration between the partners.

The fifth reviewer commented that the team was very open and working with other labs well. However, this reviewer thinks they could move from passively accepting materials to actively asking for them - including from suppliers outside the BATT program (coordinate with Lu's work). Another reviewer commented that we need to encourage more groups to participate in that collaboration.

QUESTION 5: HAS THE PROJECT 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?

One reviewer felt that there was a good plan, although they would like to see the team open up to evaluate materials outside the BATT PIs. The second reviewer remarked that if this can be accomplished before the end of the year, this is great. The most promising materials need to be evaluated in larger cells.

The third reviewer suggests for future presentations, please include more detailed plans for evaluating test conditions for various materials (test conditions, evaluation criteria, etc.) Another reviewer would like to shift focus to higher energy (voltage+capacity) chemistries. Even doped NCM material may not offer a big enough leap from commercial NCM. We need a quantum leap, not an incremental improvement. The fifth reviewer noted how the proposed future research is to continue the assessment of i) MIT high rate LiFePO_4 material, ii) ANL's high capacity NCM material, iii) H.Q. FePO_4 laminates and iv) low-cost, Al-substituted NCM from LBNL. These studies partly address the technical and cost barrier. Again, the relevance of this assessment between the developments under BATT incorporation by industry (if promising) is unclear. The final reviewer was not clear how these current materials performed. Only statements were made about the performance. This reviewer thought that further performance testing and validation should occur prior to the step of determining best automotive application. Performance results should be presented.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer felt that the budget of \$290k per year looks reasonable for these studies. Another reviewer commented that depending on how many labs are willing to participate and send their material, it could be good to provide more resources to Battaglia's team. The third reviewer commented that this project already can't keep up. This is critical work and the reviewer suspects test position limitations are slowing this down. This is a major strategic weakness that goes throughout the DOE programs (except maybe for JPL).

*Fabricate PHEV Type Cells for Testing & Diagnostics:
Andrew Jansen (Argonne National Laboratory)*

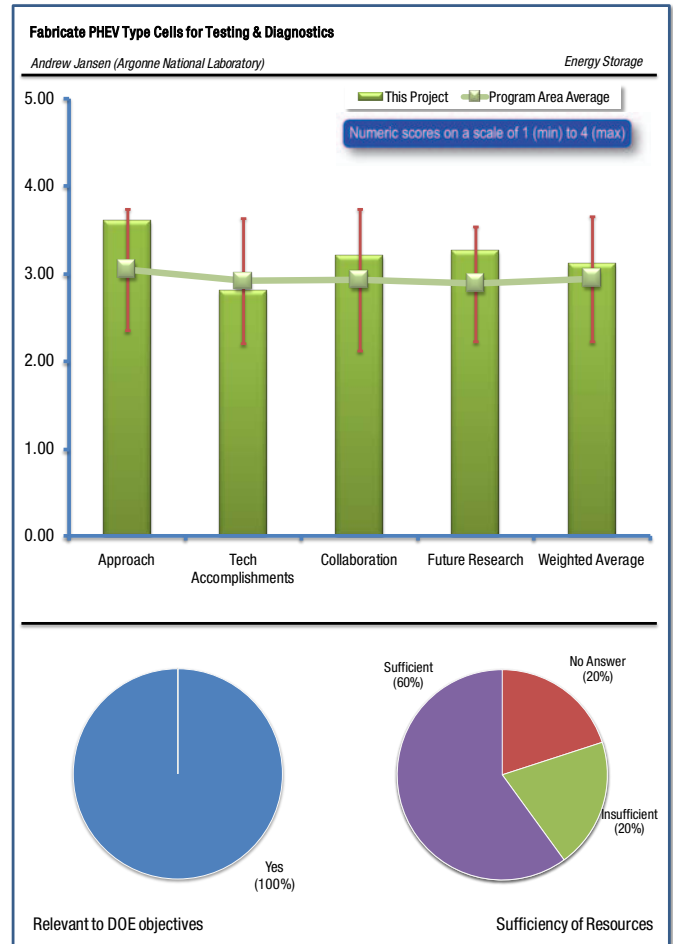
REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt this was very relevant for having in-house capability to manufacture cells. The second reviewer commented that there is a need for capability to design/optimize and build larger cells for material evaluation is well understood. This reviewer supports continuing this activity.

The third reviewer commented, with several advanced materials being developed and proposed for the PHEVs, it is essential to have their performance assessed as large-format or sealed cells. The objective of this task is to obtain test cells for calendar and cycle life studies in pouch cell or rigid cell (e.g. 18650) formats from industrial battery vendors. A secondary objective is to develop the capability in-house to fabricate 18650 cells. A successful development of Li-ion batteries for PHEV will reduce the petroleum consumption, and pave the way towards petroleum replacement. According to the fourth reviewer, the evaluation of materials in more appropriate cell size formats is critical to identifying materials that will be used to build cells for use in PHEVs. This project does that and consequently supports the DOE objectives. The fifth reviewer perceived that it is vital to get this effort going to make cells for the battery program.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer recognized that it is critical for the DOE labs to have their own real cell-making ability to test their own material and also to get decent cells. This gives them a very powerful tool to advance their own material programs and also as a side benefit will give them a great learning opportunity in the making of real cells. The second reviewer noted that the approach is to establish subcontracts with battery developers to produce large-format or sealed cells (18650) for the high-energy applications (with thicker electrodes) based on screened materials from suppliers and from the ABR and BATT programs. In parallel, efforts are underway to fabricate pouch cells and/or 18650 cells in Argonne’s new dry room facility with suitable electrode-fabrication equipment.

According to the third reviewer, the project was well thought through and contained a methodical approach by the PI to design and build cells, but this reviewer does not fully agree with the statement that thin electrodes result-in higher impedance cells. The reviewer agrees with the point that thinner electrodes have higher ASI. If an electrode is used that is twice as thick but has 1/2 ASI, at the cell level the same impedance is seen because twice as much electrode can generally be used (hence twice as much electrode area) in the cell. Cell optimization needs to be thought through more carefully.

Another reviewer noted the clear concise approach for Argonne developing the expertise to fabricate cells, in-house for testing. One concern is whether Argonne will be cost competitive for the material developers to come to Argonne to fabricate these cells.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted that there has been pretty good progress towards this long-awaited goal. Progress is impressive in setting up the facilities. The data on cell thickness and resistance is quite interesting. The second reviewer was encouraged to hear progress on building the dry room and installing electrode/cell fabrication equipment. However, how will this work be coordinated with the cell manufacturing and process development facility in Kentucky? The third reviewer saw excellent progress, and noted how the project obtained cells for initial evaluation as baseline performance barometer for cells produced by Argonne. The team has also procured equipment for cell fabrication.

Another reviewer perceived that moderate progress has been accomplished in terms of getting the prototype cells from industry partners and in setting up the cell fabrication facility at ANL. Specific accomplishments include: i) studied the effect of electrode thickness on performance, ii) identified electrode coating and cell fabrication vendors from high-energy electrodes and iii) initiated the design and installation of new dry room and iv) gathered information on the cell fabrication equipment. Surprisingly, there is not much done in terms of getting the cells made from the industry partners with any advanced materials. The progress is oriented towards meeting the project and DOE goals. The fifth reviewer thought the dry room layout looks good for what they have to do in the space available. The reviewer offered that this was a nice job and looks forward to seeing the results of cells made on this line. The team may need to at least think about adding a smaller version as a contingency if they find they have to separate one or more processes to avoid cross contamination (not sure DOE funding system really handles contingency funding very well). The reviewer hoped the new partners can make better baseline cells than before. This reviewer was not happy with the small scale of this work. This reviewer would have thought they could have made at least 300 baseline cells as most of the cost is involved in set-up/clean-up. The reviewer observed they can't test even the cells they do make: this is another issue.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Several reviewers generally saw evidence of collaboration. According to the first reviewer, as expected from the proposed work, there are several contributors and collaborators in this effort, including industry partners. The second reviewer saw multiple contributors. Another reviewer commented on how the project is working with better partners and seems to have a really good appreciation of the nuances of cell making and some of the pitfalls, learning from Sandia's and industry experience. The fourth reviewer thought the project would benefit from expanding relationship with other suppliers and OEM's.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer commented that with this ability now in place, ANL should now be well-positioned to carry out controlled testing. The second reviewer felt that the proposed future research is to continue the evaluation of baseline 18650 cells for quality and performance, procure 18650 cells with high energy cathode materials from approved vendors, order cell making equipment for fabrication of cells in Argonne's new dry room facility and fabricate cells at ANL with advanced materials in support of the BATT and ABR. The planned effort is in tune with the project goals. Another reviewer sees the project moving into the next phase of activity and is on a good time schedule. The fourth reviewer believes that other than the cell testing issue, their plan looks fine. In this reviewer's opinion, the "elephant in the room" is really the test position limitations and this drags down the reviewer's assessment of the future plans. The fifth reviewer thought that more focus on cell design and optimization is needed.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

For one reviewer, the budget of \$400 k per year looks reasonable for these studies. Another reviewer commented that this is a critical program but is being hampered by cost-cutting everywhere. This reviewer commented:

1. The dry room is too small.
2. They should have ordered at least 300 baseline cells and much more cathode so they could make their own cells (using JCS and their own cathodes) for validation purposes.

3. This reviewer's single biggest concern is that even with a too-small baseline sample, they are limited by test positions at both national laboratories. While acknowledging that no one ever has enough test positions, this team is not even close; the problem will only get worse. This reviewer feels that this is false economy in that inadequate data will result that will slow down the entire program and give false directions. We have some of the smartest and most expensive researchers in the world being hampered by inadequate resources. This program needs a massive scale-up of testing positions and associated temperature chambers ASAP - it's already too late to meet the program needs. As the cycle life improves and the team starts looking at varied test protocols, this problem will only get worse. Basically, the better you get, the more test positions become limiting. When things don't work well, you don't have to do much testing.

Electrochemistry Cell Model: Dennis Dees (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt the work was highly relevant. Another reviewer firmly believes that analytical models can shed light on and help in understanding the complex electrochemical phenomena. The effort should be supported. The third reviewer noted that identification of cell degradation mechanisms is key to the success of electric vehicle program. The fourth reviewer commented that modeling and fundamental work like this can be critical in understanding cell chemistry and directing future work.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

According to one reviewer, the project had very effective approaches to tackle many key issues. For the second reviewer, this is very challenging work and the approach taken in trying to really have a fundamentals-based rather than empirical fitting model is excellent. The third reviewer felt that definitely more work needs to be done to develop reliable models to link to experimental results and understand aging mechanisms.

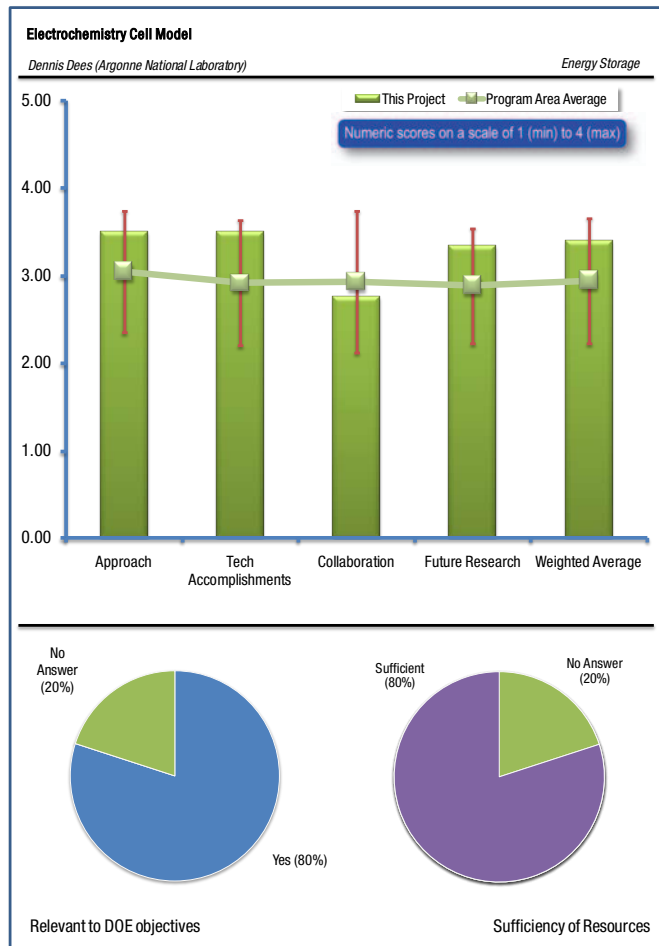
QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer commented that Dennis has been making significant contributions to our theoretical understanding of cell behavior. These are invaluable data and the reviewer is very pleased with the progress the author has been making. The second reviewer felt that good insights provided in graphite phase-transition during the lithium intercalation process. The third reviewer saw nice work on the modeling and understanding of the three stages of the graphite electrodes. Kinetics-limited mechanisms are very important to understand.

The fourth reviewer noted that the anode modeling work has shown great strides in a difficult area. Fitting models are fine when great precision is needed and the system is in a stable, mature state, but fundamental models like this work are the ones that can give true insight. (According to this reviewer, people often get too hung up on how well the model fits the data. In cases like this, it just has to be close enough so it can teach you something.)

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer saw good collaboration with experimentalists and seems to fit in well with other models. This is a critical feature where a lot of modelers fall down. The reviewer was very happy to see the close collaboration with and understanding of “real” batteries by the PI in his work. This reviewer was still a little lost on all the modeling initiatives that the DOE labs have going and have been done in the past - do they really support each other and/or are they competing? For example, does his proposed capacity loss model fit in with the work that Gering is doing on life analysis and modeling? Some of Dees’ slides address this, but it would be nice for someone



to show an overview of the various models and what they do next time (it is not necessarily Dees's job to do this of course). The second reviewer would love to see additional collaboration with other labs, especially universities. The third reviewer felt that collaboration between labs, universities (and maybe industry) should be encouraged. Why not a collaboration with LBNL?

QUESTION 5: HAS THE PROJECT 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?

A reviewer felt the project had an excellent plan of attack, and was very well focused. Another reviewer commented that an SEI model will be highly appreciated by the developers and scientists. We would also like to see how the electrode functions/degrades as a function of temperature, cycling regimes. Also, how about work on Li plating? Can the work be extended to include this issue also? The third reviewer would like to see modeling and simulation evolving to a point where they are used to predict the unknown rather than simply used to explain or map known phenomena. The reviewer understands the challenge, but thought the goals should be a lot loftier than the one set. For the fourth reviewer, the determination of the aging mechanism is critical to the process. A significant effort need to be put understanding these mechanisms.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer commented was that the project is doing well with the funding and should continue at the current level. It is critical to ensure that Dees continues to get the support from the experimentalists he needs.

Diagnostic Studies - Argonne: Dan Abraham (Argonne National Laboratory)

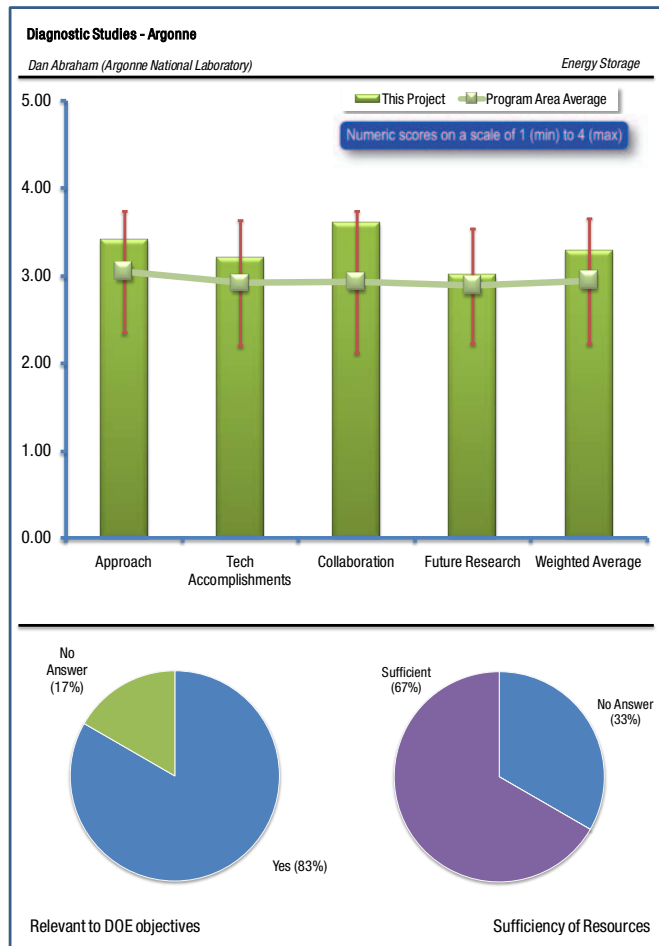
REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt that the work is very relevant, and the second reviewer commented that the focus on life is good. The third reviewer thought the project addresses lifetime issues of Li-Ion cells, especially the benchmark chemistries. The team is also looking at some new materials to improve lifetime.

Another reviewer noted that the current and advanced materials being developed for PHEVs do not quite meet the requirements in terms of calendar life and cycle life. The objective of this project is to gain a fundamental understanding of material changes and processes responsible for system performance degradation. Such an understanding helps in the development of improved materials by overcoming the performance limitations. A widespread use of Li-ion batteries for PHEV will reduce the petroleum consumption, and pave the way towards petroleum replacement. The fifth reviewer thought the work would be more relevant if the focus is shifted to where the industry is moving. The industry is moving away from NCA-based oxides towards NMC oxides. Even better, looking towards the future of high voltage/high energy cathodes will make the effort payoff much more pronounced.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer commented on how the project is using a whole range of techniques to study and truly understand what's going on inside the cell, which the reviewer liked very much. The second reviewer believed the approach is good but it would be helpful if it was better described. Especially what is the intent of that study, what does the investigator want to get out of it? Can we expect an understanding of failure mechanism and direction on materials and cell design? The third reviewer thought the project is doing good work, but can produce more substantial results if it were not so scattered. Several positive structures were looked at without fully bringing any one material to a significant conclusion. The reviewer was not sure what the selection criteria for the material is/was, but it's important to select one which is most relevant, e.g. NMC or one of the newer HV cathodes which are needed for PHEV.

According to the third reviewer, the approach is to adopting various electrochemical-and physicochemical-diagnostic techniques, such as spectroscopy, microscopy, diffraction, and chemical analysis at different laboratories to understand the structures of the electrode materials and their rearrangements upon cycling, repeat similar studies with the cell components harvested from the cells to characterize the interface at the electrode/electrolyte interface through in-situ electrochemical studies and ex-situ analytical techniques and to study the effect of moisture in the electrolyte on the performance to propose reaction mechanisms. These studies are quite relevant to the stated objectives of understanding the life and performance - limiting processes. However, it will be more beneficial and relevant to develop in-situ diagnostic technique, since the interfacial changes are more dominant than the bulk changes in the electrodes.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer was very impressed by the level of sophistication that has been brought to bear upon the diagnostic studies. A significant amount of very useful results has been generated from these studies, which are really helpful to understand Li ion battery chemistries. The second reviewer concurs, commenting that a lot of work has been done. The insights are good and tend to be more on the practical side of cell design and development. The third reviewer commented that a lot of work has been done, and hopefully more is to come.

According to the fourth reviewer, moderate progress has been accomplished in terms of understanding the structural aspects of Mn-based layered oxide materials of interest to PHEVs. In particular, it was shown that these composite oxides contain an intimate mixture of Li_2MnO_3 -like and LiCoO_2 -like areas with the Li atoms well-ordered both in, and normal to, the transition metal. Upon cycling, however, this ordering is lost after high-voltage cycling ($> 4.5\text{V}$). Similar diagnostics studies have been initiated on the PHEV baseline electrodes and cells. These studies are interesting, but the reviewer thought there is not much correlation with the performance loss or any feedback in the design of new materials. The progress is oriented towards meeting the project and DOE goals.

For the fifth reviewer, there were so many activities under this program that the reviewer found it very hard to assess progress from a 20 minute talk – which is a reflection on the review system, not the PI. Reviewing the slides helped and there seems to have been significant progress on a large number of areas, although several of the slides focused on activities completed and not enough on the actual gain in knowledge – basically some slides left the reviewer thinking “so what.” Nevertheless, despite the large funding amount, the reviewer was very impressed with both the quality and especially the sheer volume of this work.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

For one reviewer, this is a true collaborative effort. For the second reviewer, there are several useful collaborators in this effort, mainly from universities and national laboratories. Another reviewer commented that this group seems to have really good connections to many partners, both universities and other national laboratories. The third reviewer commented that partnership with the industry is recommended.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer summarized how future plans include performance and performance degradation studies of electrochemical couples identified for PHEV cells, by continuing to (a) examine the SEI formation on graphite electrodes in various electrolyte systems, (b) correlate the surface film formation and electrochemical performance of positive electrode materials, and (c) correlate of electrolyte composition and electrolyte additives to cell performance and performance degradation (i.e., effect on calendar life). The planned effort is in tune with the project goals. As this reviewer mentioned before, new in-situ diagnostics to understand the interfacial changes will be more beneficial.

A reviewer thought that plans going forward were not well spelled out, but they seem to be well-focused and the reviewer is optimistic they will continue to do good work. For the third reviewer, it will be very useful to draw conclusions (not only just mention what has been done) as much as possible to aid the audience on a slide or two. With so much data in place, it is easy to lose track. The fourth reviewer recommend focusing on the most relevant materials (high energy cathodes/anodes) with the objective of addressing or shedding light on the most urgent problems (safety, life, ..) Another reviewer commented that the proposed future research will be better described by the other collaborators of that program.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

According to one reviewer, the budget of \$600 k per year looks reasonable for these studies. The second reviewer thought the funding level is quite high but the quality and especially the quantity of their work justifies continuing funding them at this level. The team is doing a nice job as far as the reviewer can tell.

*Electrochemistry Diagnostics at LBNL: Frank McLaron
(Lawrence Berkeley National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

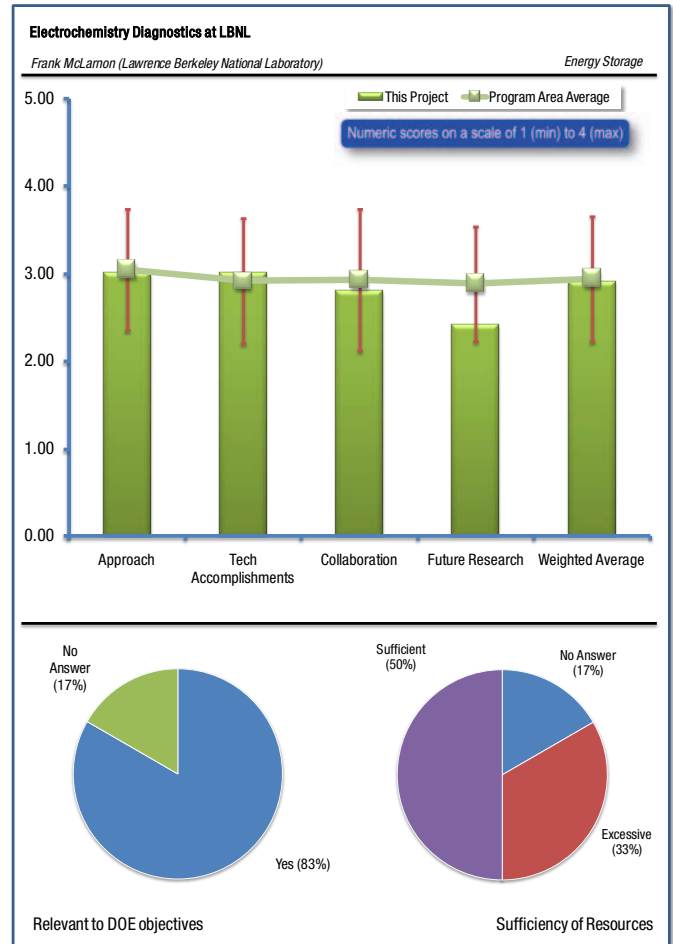
The first reviewer agreed the project is relevant. The second reviewer noted that diagnostics have provided invaluable insights into the inner workings of the material. The third reviewer commented that the project addresses lifetime issues of Li-Ion cells. The fourth reviewer noted that the current and advanced materials being developed for the PHEVs do not quite meet the requirements in terms of calendar life and cycle life. The objectives of this project are to understand factors that can enhance the stability of SEI layers from post-test characterization of components from ABRT test cells, ii) establish and investigate degradation mechanisms of PHEV cells, and iii) develop strategies to minimize irreversible cell capacity losses by developing surface treatment regimens to reduce side reactions. Widespread use of Li-ion batteries for PHEVs will reduce the petroleum consumption, and pave the way towards petroleum replacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

For the first reviewer, proper tools and methods were used and interpreted in a complementary manner. The second reviewer said the investigators are looking at diagnostic of the C anode to minimize irreversible capacity loss as well as the investigation of the failure mechanisms of PHEV cells.

The third reviewer said that the approach to functionalize the graphite edges was well thought out, even if it didn't work. Surface Raman showing degradation at both electrodes surfaces is also potentially very important. The reviewer thought the work focused too much on the Raman method and impedance alone. The reviewer would have liked to see other techniques used to get a more complete picture of what is going on in these electrodes. In particular, the reviewer thought they should get a better picture of the distribution of the effects they see on the bulk of the electrode - although the impedance data addresses this somewhat. Another reviewer commented that the analytical work is very useful. However, this reviewer is not so sure about the modification of the carbon surface work.

The final reviewer commented that the approaches include i) developing strategies to minimize irreversible capacity losses by a surface-modification of carbons, ii) carrying out diagnostic post-test diagnostic evaluation of components from ABRT test cells using spectroscopic, microscopic, X-ray, chromatographic, and related techniques, iii) understand factors that can enhance the stability of SEI layers and, iv) establish and investigate degradation mechanisms of PHEV cells, i.e., mainly through Raman spectroscopy and EIS techniques. Since the changes occurring at the electrode/electrolyte interfaces are dominant on the performance than the bulk characteristics, developing suitable non-electrochemical (more definitive) in-situ techniques will be more beneficial.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said that the earlier results obtained on carbon and metal-oxide electrodes are very useful. The second reviewer said there was excellent work on the graphitic anodes. The team needs to understand more about hard and soft carbons as they are more and more used in large format cells. Why do more amorphous carbons perform better in cycle life and even presumably in safety? What is the SEI layer differentiation between graphitic and amorphous carbons? The reviewer recommended that more work needs to be done with alternative anodes (LTO, Si-based...). Graphite is a good start but we should move on with newer materials.

The third reviewer commented the investigator gave a good view of how diagnostic techniques can help to understand failure mechanism of both positive and negative electrodes. Another reviewer felt moderate progress has been accomplished in terms of understanding the degradation mechanisms, mainly of the carbon anode. Based on the graphite anode structural degradation results, the team identified approaches to anode stabilization. Also, the team has identified candidate anode and cathode fade mechanisms in Gen-3 cells, which are similar as in gen-2 cells, i.e., contact resistances between primary particles and conductive carbon matrix, loss of available Li, and/or electrolyte starvation. Further, carbon disordering upon cycling, which is accelerated by complete delithiation from carbon, increases anode surface reactivity and causes SEI layer reformation, which shifts the cathode to a higher SOC and accelerates cathode degradation. Interesting that these findings are, it will be beneficial to see if similar failure occurs in a PHEV prototype cell with different designs, i.e., with different carbons (MCMB vs graphite) and electrode ratios.

The fourth reviewer thought the results shown were pretty good, but would have liked to see a better appreciation of how much of the anode is really being affected by this phenomenon. If the backside of the electrode near the carrier is basically OK, then it's hard to know how important the effect they find really is; maybe it would be less important for PHEV batteries as they are using thicker electrodes. Maybe the team should combine this with other techniques to try and get a better handle on how the effect they find varies with depth into the electrode.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer observed excellent collaboration with many labs. Another reviewer said to extend collaboration with industry/academia. The third reviewer wrote that there are several useful collaborations with the ABR partners from the DOE Laboratories. Collaboration with industry partners (with their hardware) will be helpful in developing a wide database on the failure mechanisms.

Another reviewer commented that we need to better understand how this work is connected to other groups work and what potential collaboration may look like. For example, the approach would very useful to understand surface chemistry and failure mechanisms of high voltage cathode and negative alloys. The fifth reviewer did not really see much evidence for cooperation aside from getting samples. The reviewer would have thought that bringing in other techniques in a combined effort would be more fruitful – the reviewer only saw the Raman and impedance studies done at LBNL.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer commented that the proposed future research is globally good. It would be interesting to apply this diagnostic approach to help the development of the most promising next generation materials (cathode, anode and separator). The second reviewer wrote that the analytical work should be continued at the same pace as before. The reviewer was not sure about the work to modify carbon: they thought some of this kind of work has been done before. The third reviewer said that the future studies are aimed at i) understanding the SEI layer formation and stabilizing the same, minimizing the irreversible capacity loss by changing the surface properties through pretreatments and ii) performing diagnostics tests of components from ABRT cells by examining electrode structures and surface films, establishing and investigating degradation mechanisms of PHEV cells and comparing them in ATD vs. ABRT cells. Again, developing in-situ techniques will be beneficial in understanding the interfacial changes. The fourth reviewer suggests going beyond graphite and old oxides (NCA). They are not part of the future. The final reviewer was not sure they saw or

heard a clear plan of where the team plans to go from here – little bit in terms of backing off on the fluorination reaction, but not much else.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer remarked that the budget of \$600 k per year looks slightly excessive for the scope of this effort (based on last year's progress). For the second reviewer, the funding level is quite high: the reviewer felt this is excessive in view of the effort being expended. The largely negative results and lack of a clear technology approach to fix the problem also suggests to the reviewer that this project is overfunded and could at least be trimmed back.

Diagnostic Studies to Improve Abuse Tolerance and Life of Li-ion Batteries: Xiao-Qing Yang (Brookhaven National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

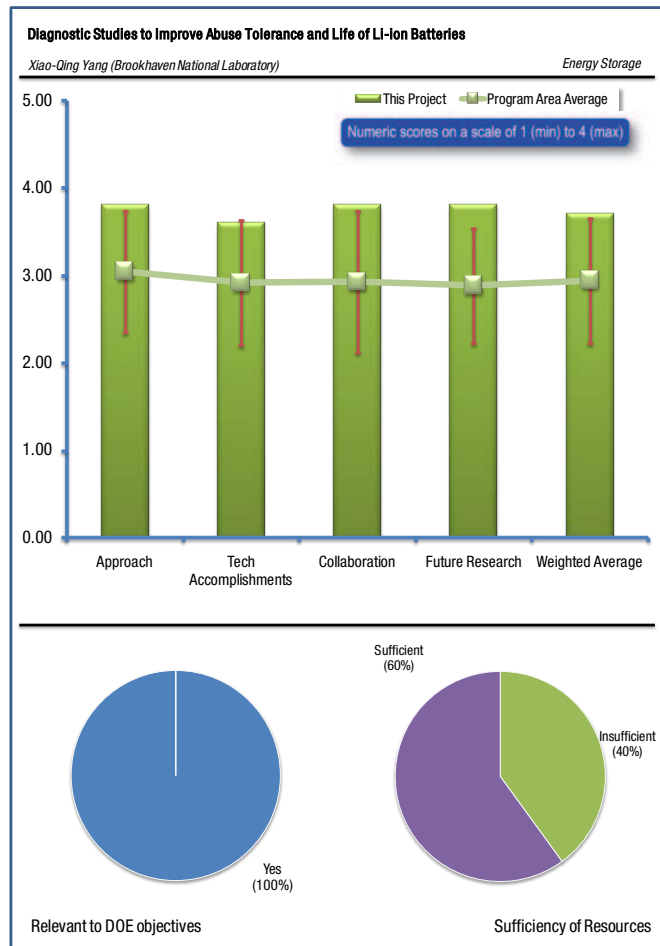
The first reviewer commented that the project is very relevant to understand how batteries fail, so that we can develop better batteries. The second reviewer stated that the project provides good in-situ understanding of structural changes in active materials during charge/discharge and thermal instability, and the third reviewer stated that this project addresses the fundamental stability and safety of critical materials of Li-Ion batteries.

The fourth reviewer stated that the current and advanced materials being developed for PHEVs do not quite meet the requirements in terms of calendar life and cycle life. The objectives of this project are to undertake diagnostic studies utilizing new in situ diagnostic techniques with surface and bulk sensitivity to understand the thermal abuse tolerance as well as performance degradation (capacity and power fading) of Li-ion cells. Such understanding is crucial in mitigating these failures and designing advanced materials. Widespread use of Li-ion batteries for PHEVs will reduce the petroleum consumption, and pave the way towards petroleum replacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer thought the work had very good approaches. Other comments focused on the benefits of in situ analysis. A second commenter wrote that tools are well-suited to provide structural insights into materials in-situ. The third reviewer commented that in-situ analysis during thermal heating is a very good approach as it allows actual observation of the mechanisms that lead to the failure and helps to develop a better strategy to prevent them.

A fourth commenter wrote the approach for understanding the abuse tolerance is based on the use of a combination of time resolved X-ray diffraction (XRD), in-situ soft and hard X-ray absorption (XAS), and in-situ transmission electron microscopy (TEM) techniques during heating of the electrode materials. For identifying the life-limiting process, the approach involves the use of in-situ XRD, soft and hard XAS studies of new electrode materials during charge-discharge cycling. These approaches are novel and sound and are expected to lead to good understanding understand of the advanced materials. A fifth commenter focused on how the team continues to leverage their surface/bulk XAS/XRF method by applying this to new materials and trying to address the coating approach to batteries. The ability to do in-situ work separates this group from many other groups in the world looking at these materials.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer thought the team gained very valuable insights into the various mechanisms that cause fade in batteries. This technique is proving to be an invaluable arsenal in probing the structure/structural changes of the various battery materials. The presentation was “simply brilliant and lucid,” according to this reviewer, who thoroughly enjoyed the talk.

The second reviewer commented on how this group continues to do world-class work and their results are always both impressive and trustworthy. They are showing insight into material stability that no one else is providing – both in the area of beam time and the TEM work. The third reviewer said there is a wealth of knowledge produced in understanding the role of various TM's in the oxides and how they actually work. Valuable insights are being developed into why layered, particularly nicklates are unstable and why NMC materials do better on safety. The fourth reviewer thought the presentation shows that Mn is very good to stabilize the structure, but because of stability of Mn the material has less capacity. This reviewer asked how to stabilize the structure without reducing capacity. Some nice results were developed about stabilization of LiNiCoAlO₂ structure with ZrO₂ coating.

The fifth reviewer summarized how good progress has been accomplished in terms of evaluating various materials for their structural changes during electrochemical cycling and thermal abuse. Specific accomplishments include: i) In-situ hard and soft X-ray absorption spectroscopy (XAS) study on charged Li_xNi_{0.8}Co_{0.15}Al_{0.05}O₂ (Gen2) and Li_xNi_{1/3}Co_{1/3}Mn_{1/3}O₂ (Gen3) cathode materials during heating, ii) Development of new in-situ diagnostic tool using high resolution TEM (HR-TEM) for thermal abuse studies, iii) In situ HR-TEM study of overcharged Gen2 cathode, iv) in-situ XRD studies of new Cr and F doped LiMn_{1-x}Cr_xO_{4-y}F_y spinel from ANL. Significant finds are: i) the thermal decomposition of Gen2 cathode occurs at the surface much earlier than in the bulk. The conversion of the layered structure the spinel and to the rock salt and its growth, occurs at the surface much earlier than in the bulk, which can be mitigates by a surface coating ii) Cr substitution in Cr and F doped cause structural changes in the spinel that account for the capacity loss and subsequent restoration, respectively. These studies demonstrate a definite progress to the stated objectives and are thus in tune with the overall goals.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer commented that the PI has involved “the entire world” in his collaboration, which is great. In comments, the second reviewer pointed out how the project has a good broad spectrum from DOE labs, industry, and academia. The third reviewer commented that there are several useful collaborations with the ABRT partners from the DOE laboratories as well as with industrial partners. The final reviewer remarked there is a long list of collaborators - very open. This is all the more impressive in light of their scheduling issues with beam time. The reviewer thought they must be a pleasure to work with.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer commented, “excellent!” The reviewer inquired, “can't probe SEI with this technique?” The second reviewer remarked this is one of the most exciting answers we are looking for. Does the coating really work? If yes, how does it work?

The third reviewer can't argue with the path that has generated a lot of good data so far. The reviewer thought it would be nice to plan a predictive tool for evaluating whether an active material will do well on safety, life, etc. Also, using these techniques to predict life or in general state-of-life of a material could be very helpful. The fourth reviewer really looks forward to seeing them continue to develop their in-situ TEM methodology and applying it to Li-Ion cells. This is especially important due to the surface reactivity of both electrodes and film formation at the anode and maybe cathode. In view of beam time issues, maybe the team should always ensure they have materials and plans ready to go so they don't miss beam time windows that apparently come and go. (The reviewer thought maybe the team does that already, but that wasn't the impression the reviewer got).

The final reviewer noted that the future studies are aimed at continuing the i) in-situ TEM studies on the thermal stability studies on the Gen and Gen 3 cathodes before and after surface modification (ZrO₂, AlPO₄, and Al₂O₃ etc) ii) In-situ XRD, TR-XRD, hard and soft XAS study of LiNi_xCo_yMn_zO₂ (x + y + z = 1) to correlate the compositional effects with performance loss, and iii) Apply these

new techniques to various electrode materials to probe their structural changes at the surface and in the bulk simultaneously. The planned studies are helpful in mitigating the technical barriers of life and safety for Li-ion cells.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer commented that the budget of \$350 k per year looks quite reasonable for this effort. The second reviewer thought it might be more productive to add resources in this area that has produced so much already. The third reviewer thought they do very well with their current funding, but would like to see this group get more beam time and more funding - although the reviewer was not sure more beam time is a funding issue or just a priority call at Brookhaven Lab.

Develop and Evaluate Materials and Additives that Enhance Thermal and Overcharge Abuse: Khalil Amine (Argonne National Laboratory)

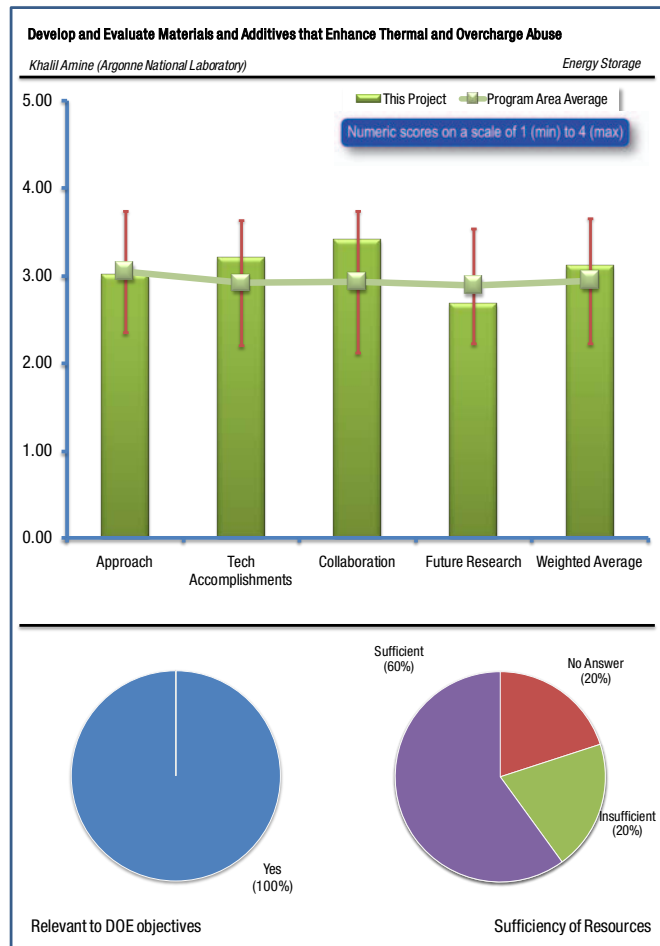
REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewer commented that this project is extremely important. Another reviewer had similar reactions, commenting that improving the safety is one of the most important characteristics in the development of PHEV and EV battery systems. This project investigates ways to improve the abuse tolerance of the Li-ion chemistry and consequently supports the DOE objectives. The third reviewer commented that it addresses safety and lifetime issues of Li-ion cells.

The fourth reviewer said that the current and advanced materials being developed for the PHEVs do not quite meet the requirements safety. The objectives of this project identify contributions from each of the cell components of different chemistries to the abuse characteristics and utilize this understanding to develop new abuse-tolerant materials and provide them to SNL for validation of safety benefits in 18650 cells. A widespread use of Li-ion batteries for PHEV will reduce the petroleum consumption, and pave the way towards petroleum replacement.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer thought the approaches were well thought out – a lot is going on at once, so they are covering a lot of ground in one program. The second reviewer noted that overcharge shuttles sound very attractive but the reviewer has yet to see a good, functional one.

For the third reviewer, a suggested change would be to concentrate on identifying and improving the key safety characteristics of one of the electrodes rather than looking at multiple areas of both. While identifying redox shuttles for overcharge protection may be good, from an automotive vehicle perspective, the most unlikely abuse situation is an overcharge event. The reviewer was not sure of the value of this work, unless there is another advantage developing this process, especially when done at the coin cell level.

The fourth reviewer commented that the approach targets improvements in all the cell components for increased safety, e.g., safer anodes and cathodes, additives for stable SEI, surface modification for cathode, safer electrolyte components (solvents and sat) and redox shuttles for overcharge protection. Materials are being secured from in-house researchers, partners and commercial sources and assessed for safety improvements, which are subsequently verified in 18650 cells. The approaches look reasonable and feasible and will lead to further understanding of safety issues of each component and later to safer cell components.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer commented that the results shown were pretty good overall. Nice use of activation energies to characterize and try to understand processes. It was gratifying to see that the fundamental material safety characteristics in many cases do carry over to full cell studies (although SNL has certainly shown that this is not always the case.) The reviewer thought rates for the overcharge additives were a bit low. The team needs to look at higher charge rates and impact of low temperature where diffusion limitations may be more problematic on these additives as well. Another reviewer said that work done to elucidate what takes place on the carbon electrode as well as finding ways to alter them have been quite impressive at the author's lab. Data presented in another section on additives combined with these efforts make it a comprehensive effort to tackle this important issue. The third reviewer noted that good progress has been accomplished in terms of evaluating various cell components for safety. For example, i) three types of MCMB carbons with different surface modifications were evaluated at the component level (DSC) and later in 18650-cell format (ARC) at SNL, which show that the type of carbon impacts the safety of lithiated carbon. ii) Three electrolyte additives were identified for SEI stabilization on graphite, including LiDFOB. iii) Four salts were evaluated, with LiPF₆ showing the least thermal stability (230C vs 310C). iv) Several 18650 cells made with NCA and Al₂O₃ coating were procured from industrial partners and being valuated for cycle life, abuse resistance and v) Three new redox shuttles corresponding 4.17 V, 4.2 V and 4.8V have been identified and demonstrated in coin cells. These studies demonstrate a definite progress to the stated objectives and are thus well in tune with the overall goals.

Another reviewer said that work presented was good, but results were not very clear, with respect to the objectives and the approach. Should present summarized results in line with objectives and approach. For example, what is the role of the anode and which anode provided the best safety in the chosen cell? If multiple areas are to be investigated, a test matrix with two cathodes and three anode types (or vice versa) would be more informative.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers commented on the collaborations. The first reviewer saw excellent linkages with external partners. The links to Asian companies are a very important advantage for this PI (obviously not something they cannot discuss openly in the briefing). Slides show results of working with Sandia, but PI's talk gave the impression that Sandia and ANL are not really talking as much as they need to. Just providing SNL and IDL with cells is not an accomplishment – it's what they did with them that matters. It seems to be a bit of a barrier, but the reviewer confessed that this is just an impression that may well be wrong. The reviewer suggests the SNL-ANL work at least be reviewed to ensure they are working together as well as they can since this linkage is critical for the program. The second reviewer thought that all the relevant labs have been included in the work. The third reviewer said that there are several useful collaborations with other DOE laboratories (SNL) and more importantly with the commercial materials suppliers and industrial partners. The final reviewer saw the good collaboration with suppliers, but there was no reference to the Fe phosphate provider.

QUESTION 5: HAS THE PROJECT 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?

One reviewer suggests that the efficacy of coatings should be checked over the entire life span of the cells. Making statements from initial data could be misleading, and hence it is recommended that data should be acquired both at the beginning of life and at end of life. The second reviewer thought that the plan going forward was good. This reviewer's main concern is with them trying to do too many things at once. This reviewer would like to see a little bit more focus and bring fewer concepts through the development stages into 18650 size cells for SNL and others to test.

Another reviewer said that future plans are too varied and extensive to be accomplished and provide data that could be used to drive decisions. The fourth reviewer said that the future studies are aimed at continuing to i) explore electrolyte additive to reduce heat flow from SEI decomposition at low temperature, ii) investigate the safety of anode without SEI, iii) quantify the thermal effects of LiPF₆, iv) investigate the role of none flammable electrolyte ionic liquids on the safety, v) investigate the effect of cathode composition, morphology and surface area on safety, vi) characterize of ANL's new redox shuttles, and continue exploring new shuttle structures. Efforts will be made to demonstrate the benefits with these cell components n 18650 cells made by an industrial partner. The planned

studies are helpful in mitigating the technical barriers of life and safety for Li-ion cells. One difficulty with this approach is that it is broadly diffused: it is more of evaluating what is out there vs. designing developing something new (except for the redox shuttles)

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers thought the funding level was appropriate, with one reviewer remarking that the budget of \$440k per year looks quite reasonable for this effort, and the second reviewer stating that the funding level is appropriate. They are doing a lot with what they get. The third reviewer commented the resources for the proposed work is insufficient. The reviewer would propose a much more reduced and focused work plan, however, rather than increasing the resources to this project.

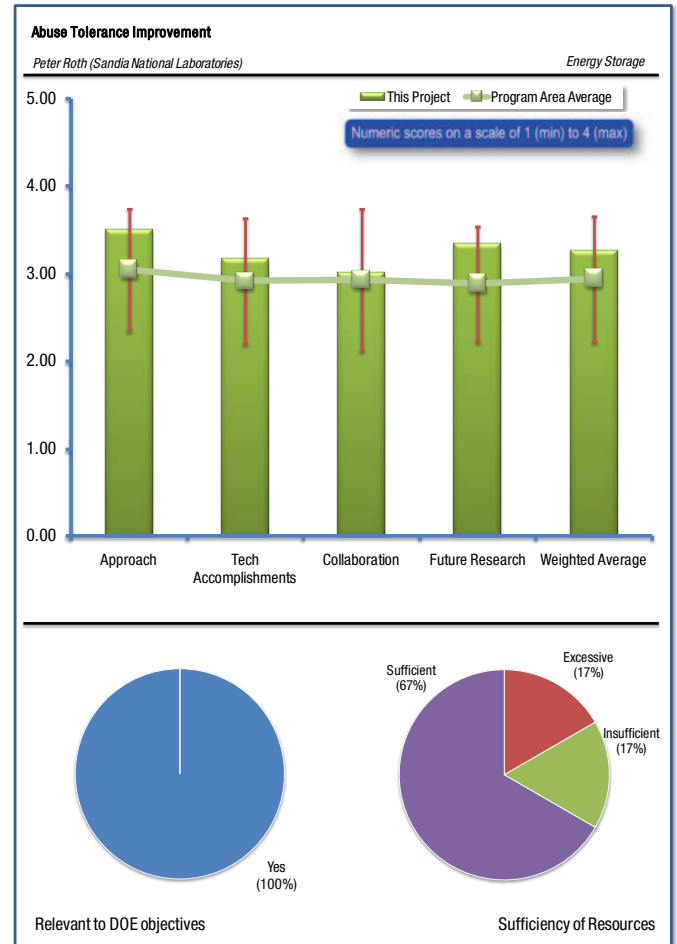
Abuse Tolerance Improvement: Peter Roth (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said that this is extremely important. Another reviewer said that of course developing intrinsically safe batteries is key to success for petroleum displacement. The third reviewer thought that improving the safety is one of the most important areas in the development of PHEV and EV battery systems. This project looks at materials and methods to improve the abuse tolerance of the Li-ion chemistry and consequently supports the DOE objectives. A fourth remarked that adequate safety is critical for successful implementation of DOE objectives (although when viewed against the huge number of existing cars that spontaneously burst into flames every year, the emphasis has to be on adequate, not perfect). A final reviewer wrote that Li-ion cells aren't tolerant to electrical or thermal abuse, which might lead to thermal runaway. The objectives of this program are to i) Identify degradation mechanisms of gas and heat-producing reactions in Li-ion cells, ii) develop advanced materials or combination of materials stable during abuse events, leading to enhanced safety, iii) demonstrate improved abuse tolerance in 18650 cells, and iv) develop techniques to understand and mitigate internal shorts. Improvement in safety is crucial to a widespread use of Li-ion batteries for PHEV will reduce the petroleum consumption, and pave the way towards petroleum replacement.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer remarked there were well-tested approaches to identify abuse-tolerance of various cell systems. The second reviewer commented that it is absolutely critical to find a method to properly simulate internal short circuits. The third commenter said the approach is very good toward accomplishing the goal of evaluating new materials from other labs and suppliers. This may have been done earlier, but it would be good to confirm that SNL can produce a commercial grade cell by making an 18650 cell from the same materials as a commercially available cell and comparing the abuse test results. The same procedure should be considered for the coated cell work. This reviewer thought that a project that establishes non-destructive ways to evaluate the potential of a cell's abuse tolerance and confirming the results by actual testing would be a good project for this lab. The project would most likely involve the collaboration with another lab(s). A fourth said they are looking at important key elements of safety in various chemistries. They have built up an impressive capability over the years. Their work on using low temperature molten metals looks to be an interesting way to generate shorts, although details were sketchy.

The fourth reviewer said the approach focuses on cell level abuse testing through ARC, which has been the main forte of SNL's safety studies. The approach includes building 18650 cells using SNL in-house cell fabrication facilities, using new anode and cathode materials and electrolyte and electrolyte additives and evaluate their thermal and overcharge tolerance, specifically the gas and heat generation, as well electrolytes and electrolyte additives from other DOE laboratories. In addition, the mechanical and thermal integrity of the separators and the effects of internal shorts contributing to the safety will be studied. The abuse test facilities at SNL

are established and are being used by all the DOE laboratories as well as industry partners. The approach is thus quite well-designed, feasible and well-integrated with the efforts of ABR partners.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer remarked the work is high quality and significant amount of test results were seen. The work is very impressive and, as always, very reliable data were shown. The second reviewer remarked that good progress has been accomplished in terms of evaluating several combinations of cell components for abuse tolerance. Specifically, i) Improved the peak heating rated in the prototyping test facility, ii) studied thermal stability of a variety of anodes and VC additives in Hitachi-built LiFePO_4 , iii) Developed a novel LiF/ABA anion receptor-based thermally-stable electrolyte, with $\sim 100^\circ\text{C}$ improvement in thermal stability and reduced gas generation, iv) established new coating capabilities for carbon anode and cathode electrodes, v) demonstrated the ability to initiate internal short circuits in coin cells using a low temperature alloy defect trigger, vi) established separator testing platform, viii) determined the amounts of gas generated with spinel, gen-2 and gen-3 cathodes, viii) determined the effects of fluorinated LiBOB ($\text{LiC}_2\text{O}_4\text{BF}_2$) additives on the thermal reactivity of 18650 cells with LiMn_2O_4 spinel and Gen3 cathodes. These studies demonstrate a definite progress to the stated objectives and are thus well in tune with the overall goals.

Another reviewer remarked that it was good to see that full size cells are being used for testing. The reviewer would like to see testing performed with larger cells, as response varies greatly as the cell size increases. It is not clear how the cell size effects can be captured accurately without going to larger format cells. Identifying a testing method that can be an accurate barometer for abuse tolerance determination with respect to cell size would be another good project for this lab.

The fourth reviewer asks if the failure mechanism on the overcharge test could be Li plating rather than incomplete shut down. For this kind of test, it would be good to have reproducibility tests. It may help to have a better understanding.

The fifth reviewer remarked progress seems good, although the methodology for internal shorts does not seem to have had much success this year (it's a difficult task, of course). The insight into gas generation is something that SNL is uniquely able to bring to the safety studies and their findings that heat output does not correlate with gas generation are very important. The reviewer thought the total amount of work they presented seemed a little low, but it's hard to judge from a 20 minute presentation. The reviewer suspected they do a lot of work for industry that they can't talk about, but we have to rate them on what was presented. Their cell capacity is very low for an 18650, even allowing for the fact that most cells for HEV applications have to be designed for high power, not high energy (maybe PHEV need to be a compromise construction). But with 2.8Ah 18650 cells being readily available, their input capacity just seems too low and needs to be increased.

The final reviewer commented on the good results in several areas. The reviewer was unsure about how the internal short mechanism is designed to work, but the reviewer understood the concept. The LiF/ABA electrolyte safety improvements are significant as well as AlF_3 coating. The reviewer would like to see an assessment of other attributes of these new materials/modifications.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers generally saw good collaboration. One reviewer remarked there was great collaboration by this lab. The second reviewer observed a broad range of collaboration with other labs. Enlisting suppliers and other cell manufacturers might help. The LiF/ABA electrolyte should be tested in collaboration with others to understand what trade-offs are made for power, cold-cranking etc. as its conductivity seems too low. A third remarked that there are several useful collaborations with other DOE laboratories and more importantly with the commercial materials suppliers and industrial partners. A fourth reviewer thought collaboration with different labs and suppliers is good.

The final reviewer saw a good link to customers. This reviewer added that it was hard to say from the presentations, but he questioned the quality of the link with ANL. These two groups have to work very closely together to understand how safety aspects of materials affect actual cell safety. Maybe this is happening, in which case this point is moot, but the impression the reviewer got was that once ANL shipped samples to SNL, ANL was not that involved any more (a "throw it over the wall mentality"). The reviewer suggested at least reviewing this linkage. This reviewer believes Sandia needs to work much more closely with the separator companies and

consumer standards organizations to help devise better test methods for resistance to internal shorting. While this reviewer believed they are involved in the auto safety standards committees, a lot of the science and understanding is still coming out of the consumer battery programs, fueled by the huge scale of the business and costly recalls (almost a billion dollars for Sony's and Panasonic's recalls alone). Also, the U.S. Navy is undertaking a major review of lithium batteries (primary and secondary) after several serious incidents. Sandia needs to be heavily involved in those efforts if they are not already. Sandia should be the "node" for all this safety stuff and this reviewer didn't think they are.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer commented that the internal short-circuit simulation is very important. It is one of the main concerns of the whole industry today and it requires a lot of focus.

Other reviewers made comments about possible future activities. The second reviewer remarked that the future plans are in line with the proposed objectives. The reviewer would like to see SNL concentrate on identifying test methods that can be used to accurately predict the abuse response of various cell formats based on the results of one cell size (i.e. 18650). Another project could involve a similar approach with soft pouch cells. Another reviewer said that all cells containing coated materials should be examined also at end of life to evaluate the efficacy of the coating.

The fourth reviewer remarked overall that this is a good plan, but the reviewer would like to see more emphasis on finding a good way to create and test for internal shorts. This is critical for the industry and developers, even though it may not be as glamorous as developing new materials. SNL is by far the best lab to do the former, not necessarily the latter. The team needs to work on reaching out more to various organizations mentioned above.

The final reviewer remarked, the future studies involve continuing efforts to i) improve the thermal abuse tolerance of Li-ion cells through cell-level abuse tests with different materials (e.g., AlF_3 -coated NMC and Al_2O_3 -coated Gen2, ii) improve overcharge abuse tolerance in full cells with new materials and additives, iii) demonstrate reduced electrolyte gas generation and improved thermal properties with LiF/ABA electrolytes, Fluorinated-LiBOB additives with different chemistries, iv) establish the electrode fabrication methods for new materials, and v) continue the internal short trigger tests, and support NREL's abuse model for Li-ion cells. The proposed studies address the technical barrier adequately.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer has visited this lab twice and, knowing that this is the premier safety-testing site in the U.S., would highly recommend additional funding, if possible, to make it the world's best lab in its category. The second reviewer thought that based on the stated goals, the resources are sufficient. However, given the level of interest in the larger format cells and the need for testing of the real cells the resources are limited. The third reviewer commented that this is a fairly costly program, but the work they do cannot be done cheaply. The reviewer recommended continuing at this funding level. A final reviewer remarked the budget of \$770 k per year looks marginally excessive (around \$550 K may be appropriate).

Overcharge Protection: Thomas Richardson (Lawrence Berkeley National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

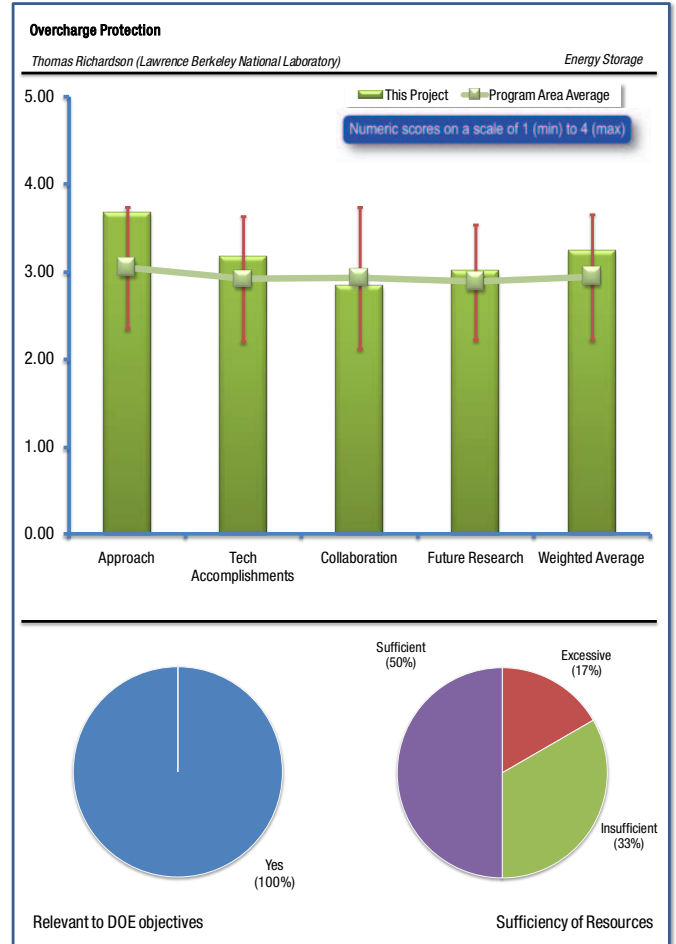
Several comments emphasized the importance of this work. The first reviewer said this could be an important contribution to the stability/safety of the packs. The second reviewer remarked that intrinsic overcharge protection is a critical safety aspect of Li-ion batteries. A third commenter remarked Li-ion cells do not have built-in overcharge tolerance and need to be balanced through external electronics. Attempts to achieve built-in overcharge protection through redox shuttle haven't been quite successful. The objectives of this program are to develop a reliable, inexpensive overcharge protection system using an electroactive polymer for internal, self-actuating protection. Improvement in safety is crucial to a widespread use of Li-ion batteries for PHEV that will reduce the petroleum consumption, and pave the way towards petroleum replacement. A fourth remark was that this could be developed into an important safety feature (and less importantly a charge leveling device for maintaining good pack balance).

A final reviewer remarked there is a concern about the potential of a PHEV or EV system being overcharged while connected to the grid, resulting in an abuse situation and decreased safety. This project attempts to reduce the potential for overcharging, which is in-line with the DOE objective of introducing this technology into the transportation market. The concern is that there is added cost for this at the cell level and the system cost in most cases will not be reduced, but more likely increased with the introduction of this agent into the system. The overcharge external hardware protection devices that are identified will most likely remain. The agent will become another protection device, rather than replacing existing ones-adding to the cost. Finally, the overcharge abuse condition, while one of the most undesirable in an automobile, it is also one of the least likely, because of the controls identified. It will be difficult to supplant something that is working.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer thought the approach to the stated objectives is right on line. The second reviewer remarked on the very interesting approach of electroactive polymers for cell balancing and overcharge protection. Another reviewer thought the project was a very well-focused work. The PI and his staff have clearly thought this through all the way to implementation, even though that will be a long way off course. Having a safety device that is sensitive to voltage rather than temperature opens up avenues for a new approach to overcharge protection.

The fourth reviewer has followed this field for a long time and still remains unconvinced that we will have any practical solution to this issue using this approach. The fifth reviewer thought this is an intriguing idea to impregnate the separator with an electroactive polymer that provides the bypass function during an overvoltage/overcharge. Questions to be addressed: What's the impact on round-trip coulombic and energy efficiency? What's the impact on cell self-discharge?



Another reviewer noted the approach focuses on incorporating a shorting agent, which is a reversible, voltage-activated polymer impregnated in the separator between the current collectors but is an external component connected parallel to the cell. Studies are being carried out to optimize morphology and improve utilization of electro-active polymer composite with tunable redox voltage windows, and to investigate high-voltage polymers that are suitable for overcharge protection, and to explore alternative cell configurations to achieve maximum protection. The approach is indeed novel, but it is not clear how the positive and negative current collectors could be shorted even externally through such a device. Instead, it should function as a bypass with low enough resistance, but should return to high-resistance phase upon interrupting the charge. Also, the switching speed of the polymer from the insulator to the conductor state and vice versa might be slow, which may make this device ineffective.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Many reviewers saw excellent progress. For instance, one commenter remarked the project was a highly qualified good approach based on the great progress made in the materials development front. These are very new classes of materials with new opportunities. This reviewer will keep an open mind and wait for these materials to be examined for their applications. A second reviewer remarked that very promising results were seen so far. Long life and robustness needs to be proven. It would be nice to show self discharge results to build some confidence on the concept. A third commenter saw excellent results, especially in view of the low funding effort. Their nanowire structures are very elegant and the conductivity results very good. This is important, because their conductivity goal is going to be fairly high if the safety device only occupies a small section of the cell volume, if they want to carry the high overcharge currents they are hoping to handle. The fourth commenter perceived that good progress has been accomplished in terms of demonstrating the concept with a few polymers with tunable redox voltages, external to the electrode/cell stack. Specifically, new electro-active polymers with different morphologies, using aligned and non-aligned polymer nanotubes, were evaluated. The sustainable current densities have been high and efficient configuration of the polymer is above the electrode stack, outside the electrochemical cell but within the cell housing. These accomplishments demonstrate a progress towards the project goals. The fifth reviewer said that it seems progress has been made at a slower pace since a few years ago; maybe the PI's need to elaborate on that more.

The sixth reviewer felt that the progress toward the goals is very good. However, based on the questions in Relevance, identifying another function for this agent would improve the potential of acceptance of this reversible soft-shortening agent at the commercial level. Has any testing been done to see how it performs under other abuse scenarios-in particular internal short circuit conditions, nail penetration, and crush? There appears to be a possible improvement in these areas using this agent and this should be explored.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said that all the relevant labs are involved. The second commenter saw several useful collaborations with other DOE laboratories. Reviewers also commented on the relationship with LBNL and potential relationships with other labs. For instance, a reviewer encouraged the PI to find partners outside LBNL in other national labs, but more importantly in the supply chain and cell manufacturing. This is a great idea and deserves a faster path to potential implementation. Another reviewer thinks that SNL should be involved to verify the results and evaluate its performance in other abuse tests. The fifth reviewer felt that a lot of people at LBNL are utilized, but would want to see them working with or at least talking with cell builders about proof of concept cell designs. It is probably hard for them to get much collaboration outside of LBNL since the funding level is so low. The sixth reviewer saw a good collaboration network, however it would be interesting to collaborate with a group that can build prototype cells.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer wrote that it is a good plan going forward. However, while recognizing their points about the need for nanowires (good conductivity and access to electrolyte ions), the reviewer wanted to caution the PI about the risk of letting perfection getting in the way of "good enough." The reviewer is not convinced that we need a true nanowire assembly and think that this would make the

device much more expensive. Also, the reviewer would like to see the team partner with a cell builder - some are already interested in this area judging by the questions the PI made.

The second reviewer noted the future studies involve preparing composite separators with electroactive polymer nanofibers and evaluating their rate capability and cycle life. This reviewer suggest investigating other high-voltage electroactive polymers and optimizing their morphology for maximum protection and exploring other cell configurations for improved protection and lower cost. The proposed studies address the technical barriers adequately.

Other reviewers provided suggestions for future activities. According to the third reviewer, so many aspects of these materials need to be tested before we can say that they really work (cyclability, calendar-life, low-temperature performance, cost etc.) and we can say this class of materials is suitable or not. Another reviewer suggests the need to talk to separator companies and to plastic and gasket companies as well. The sixth reviewer wrote that proposed future plans concentrate on evaluation of only one aspect of abuse tolerance. The scope should be expanded to evaluate the effect of this agent on other more likely abuse scenarios.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Some reviewers would like to see a funding increase, with one reviewer stating that it may be a good idea to “help” to scale-up that interesting concept. Another reviewer was really happy to see this concept resurrected from the BATT program. It is innovative and could provide an additional level of safety that is hard to do otherwise. For this reviewer, true safety comes from having redundant safety features - not just good cell designs. It could have implications even beyond the DOE's programs. Overall, this program needs a definite boost in funding and involvement of cell builders - would like to see this implemented in proof of concept cells ASAP. The current funding level is far too low for this project. They have shown good success and this work needs to be taken to the next level, which requires more time and money. Other reviewers felt the budget was sufficient, with one reviewer commenting that the budget of \$190K per year looks reasonable and adequate. Another reviewer agreed that resources for the work appear adequate for the future plans as stated. If work proposed in question 2 is addressed, more resources will be needed.

High Energy Density Ultracapacitors: Patricia Smith (Naval Surface Warfare Center)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Several reviewers saw this as a relevant project, with one reviewer commenting that higher energy supercapacitors may be a good combination with Li-ion batteries. Another reviewer stated that Li-ion batteries do not offer high power densities, as required for HEV and PHEVs, and it would be beneficial to combine them with ultracapacitors, to extend the battery life, enable cold engine starts and reduce battery heating. The objective of the present study is to develop electrode/electrolyte materials that will enable an ultracapacitor to meet power assist and regenerative braking goal, i.e., 15-20 Wh/kg, 650 W/kg at cell level, operational temperature of 30 to 50°C, 750,000 -1,000,000 cycles, and survivability temperature range of -46 to 65°C. Such improvements in capacitors will enable a widespread use of Li-ion batteries for HEVs and PHEVs, which will reduce the petroleum consumption, and pave the way towards petroleum replacement.

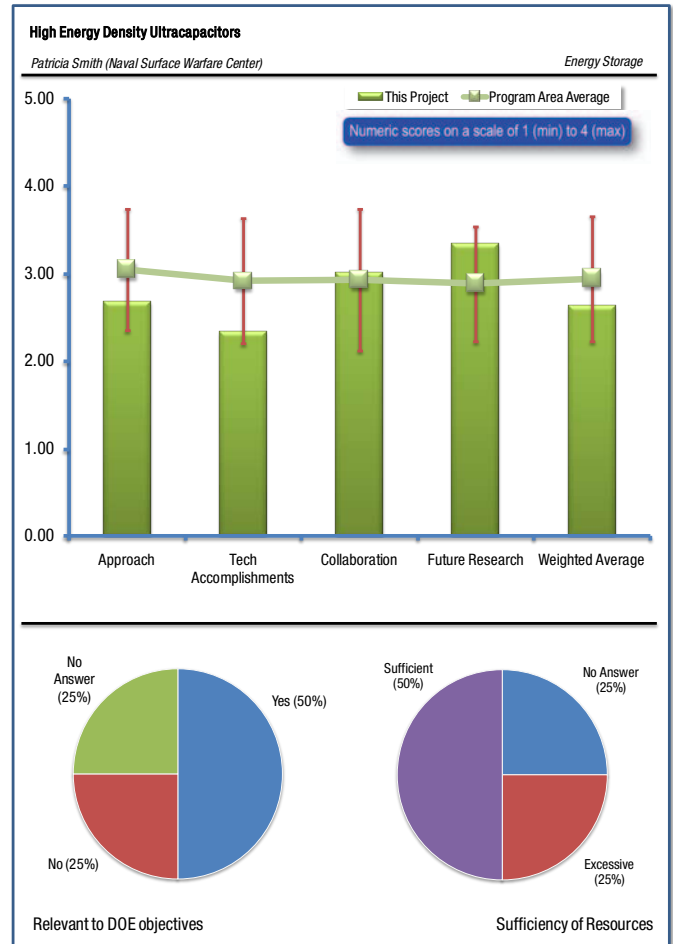
While the third reviewer felt that this may be good work, with the recent improvements in high rate batteries, this reviewer does not feel work on capacitors or even hybrids is justified for the vehicle program at all. This reviewer noted that a real battery will always be there, and the power ratings of these hybrid batteries are not that much better than high rate Li-Ion cells, especially when one factors in the larger size of the battery and the decrease in C-rate that they have to run at to handle the power peaks. If one needs a capacitor, which the reviewer did not believe to be the case, then just pair a conventional one with a battery; there is no need to try and do it all in one package - use a capacitor for power and a battery for energy. This reviewer believes this work might be fundable by DOE under a stationary power program for wind energy/load leveling/power regulation/spin-up support, but this should be funded through those programs not the Vehicle Technologies Program.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers felt the approach is good, though one reviewer commented that the power target looks low, and believes it should be much higher. Another reviewer felt these approaches adequately address the technical barriers outlined here, and summarized that the approach involves i) identifying high capacity/capacitance electrode materials to increase Wh/kg, ii) developing stable electrolyte systems with wide electrochemical voltage window, temperature range, good cycle life, and iii) fabricate and evaluate prototype capacitors in order to assess energy density, cycle life, self-discharge and safety. The third reviewer remarked that lots of people are looking at this, and this reviewer is not sure that they really have any special edge over anyone else.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer saw that good progress has been accomplished in terms of demonstrating specific energy ultra capacitors, specifically, i) Lithium ion asymmetric electrochemical capacitors show promise of significantly higher energy densities (>20 Wh/kg vs 5 Wh/kg) and low self-discharge (7% vs 17%) than conventional symmetric C/C capacitors, ii) Higher energy densities have been



achieved with lithium ion capacitor prototypes utilizing carbon negative electrodes than with lithium titanate electrodes, iii) however, their low temperature performance is poor compared to conventional ultra-capacitors (activated carbon/activated carbon). The progress is consistent with the project goals. The second reviewer questioned, what is the explanation why KOH activated carbons have higher capacitance than steam activated ones: higher surface area, higher functional group? Was it the impact on life of those two activations methods? Specific power needs to be much higher than 3000W/kg to be able to associate supercapacitors with Li-ion batteries. The third reviewer stated that power density ratings are not much better than A123 and other batteries. LICs seem to have many of the safety/reliability issues of Li-ion cells - truly intermediate between conventional EDLCs and Li-Ion.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

According to one reviewer, there are several useful collaborations with material suppliers and prototype capacitor manufacturers. The second reviewer felt that the project needs better links to industry, although they said they are getting in with Maxell.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer felt that the proposed studies address the technical barriers adequately. This reviewer summarized that future plans are to i) continue carbon functional group analysis to seek their correlation, if any, with the electrochemical performance, ii) complete the assessment of lithium capacitors (LIC LiTO), and iii) investigate the voltage delay and perform three-electrode measurements for low temperature performance, to understand the SEI on graphite, develop electrolyte with wide electrochemical window and temperature range and assess the safety at the material as well as device level. The second reviewer felt that the proposed future research was okay, but this reviewer just doesn't see the benefit to the program even if they succeed.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer stated that the budget of \$250 k per year looks reasonable and adequate, particularly due to leverage from the Navy programs. The second reviewer recommended killing this project or shifting the bill to a stationary power program. This reviewer does not see relevance to vehicle technologies. Basically, even if they succeed, this reviewer did not see anyone using it in cars/trucks.

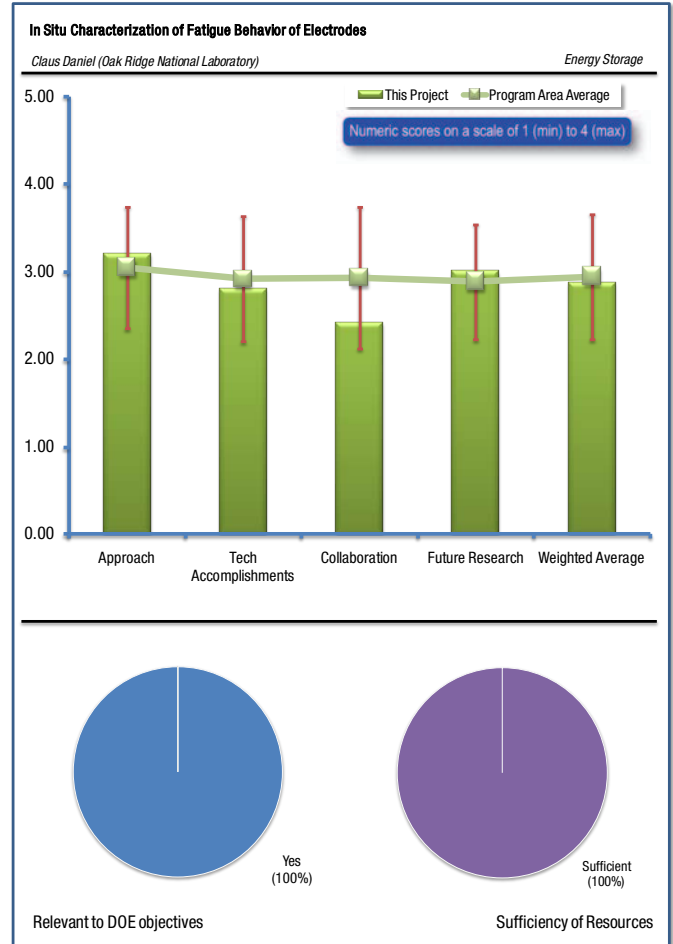
In Situ Characterization of Fatigue Behavior of Electrodes:
Claus Daniel (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers generally thought the project supports DOE objectives. The first reviewer stated that the project seeks to predict life performance for these PHEV and EV battery systems, and this goal supports the DOE objectives. The second reviewer states that we need good diagnostic tools to improve cell design. Cycle life is only one barrier, and this technique can help for calendar life as well. Another reviewer thought the project addresses one aspect of cycle life/lifetime, but is limited in scope. The third reviewer wrote that improvement in the cycle life will enable a widespread use of Li-ion batteries for PHEVs, which will reduce the petroleum consumption, and pave the way towards petroleum replacement. This reviewer also stated that Li-ion cell reactions involve intercalation processes, i.e., incorporation of lithium ions into lattices of carbon anodes and metal oxide cathodes, which results in an expansion of the lattice and the associated electrode degradation mechanically. The objective of this study is to develop in-situ tool to characterize mechanical degradation, such as crack initiation, crack growth, particle fracturing, particle loosening during cycling, gain fundamental understanding of accumulation of defects and resulting mechanical degradation and thus correlate the mechanical degradation to capacity fade.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers addressed the innovative technique. For instance, the first reviewer called the technique novel, and commented that there is need to explore its full potentials. Another reviewer commented that this is a very innovative approach that, combined with other methods or techniques, can give outstanding result, and suggested not focusing on cycle life only. Calendar life is very important too. The third reviewer felt these approaches adequately address the technical barriers outlined here, and summarized that the approach involves utilizing acoustic emissions stemming from mechanical events to probe degradation during cycling and additional characterization techniques such as XRD, neutron diffraction, optical microscopy, and Raman spectroscopy are applied simultaneously in order to validate understanding. The fourth reviewer stated that cell failure reasons were identified and areas that need work identified as well.

The final reviewer stated that the project was an interesting build on work at Case Western (Sherson and a Japanese post doctorate student). According to the reviewer, the approach is worthwhile as a single method. However, the reviewer was not seeing the benefit of combining this with other techniques that others have already developed. Just do the sound work first and then see how useful it really is. The approach is novel, albeit somewhat resurrected. More to the point, it could give an additional window into what's happening to the electrode materials.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers focused on the innovative nature of the project. The first reviewer said that the work is very innovative and good, and this reviewer would like to see if this method can be applied to evaluation and prediction of a cell's abuse tolerance. The second reviewer commented that this is a very exciting technology that can have applications in the field as SOH. This could be a powerful tool. The third reviewer thought it was too early to expect much, but results look as though they could be useful.

Because it is a new technique, the fourth reviewer was unsure if it will be really effective in elucidating all the key underlying failure mechanisms. However, there seems to be some potential out there to exploit this technique for better understanding of the electrode behaviors.

The fifth reviewer commented that progress is consistent with the project goals. This reviewer also wrote that moderate progress has been accomplished in terms of adopting and demonstrating acoustic emissions (AES) during cycling of carbon and silicon anodes, while also monitoring through XRD. Specific accomplishments include: i) Developed AES techniques using coin cells, which offer excellent signal transmission and cycling reproducibility, and ii) Added complimentary characterization methods (in-situ and ex-situ) in order to understand physical evidence of emission. Some of the useful scientific observations are: i) Emission frequency may allow for distinguishing the source of cracks, ii) Mud crack theory is not applicable to non-thin film electrodes; most cracking occurs during lithiation and cracks may initiate in the core of the particles, and iii) Brittle intercalation compounds may not need to be nano-sized to significantly reduce cracking.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Not a lot of collaboration was shown so far, but this reviewer was eager to see all the potential future collaborations. Another reviewer noted collaborations with ORNL, but external collaborations haven't been mentioned explicitly. The third reviewer was unsure if much collaboration is needed at this stage anyway. Another reviewer was not very clear about the collaborations.

QUESTION 5: HAS THE PROJECT 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?

Reviewers provided suggestions for additional future research. One reviewer would like to see future work to be done on thicker electrodes using the same materials; and, the results of a comparison of predicted performance using a new commercial cell and the same commercial cell type, but at its end of life. The second reviewer suggests that tests should be carried out at the beginning of life and end of life for cycled as well as stored cells, especially at accelerated test conditions, to see if the technique works. The third reviewer suggests looking at the effect of rate and especially temperature on the sounds they detect. Materials could become more brittle at low temperature and also greater diffusion gradients that build up at high rate might affect the processes that cause the sounds they are detecting.

The final reviewer stated that the proposed studies address the technical barriers adequately. The reviewer also noted that the future studies include: i) Validation of scientific observation on the crack initiation, ii) development of in-situ combination characterization, iii) gain an understanding of relationship between particle size and mechanical degradation, iv) extending the studies to cathodes, and v) develop New quantitative "fatigue" theory models will be developed in order to understand degradation accumulation and failure.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer stated that the budget of \$300 k per year looks reasonable and adequate for this effort. The second reviewer though the budget was okay for now, but this work should be limited to focusing only on the sound wave work and not let them expand the scope into other areas.

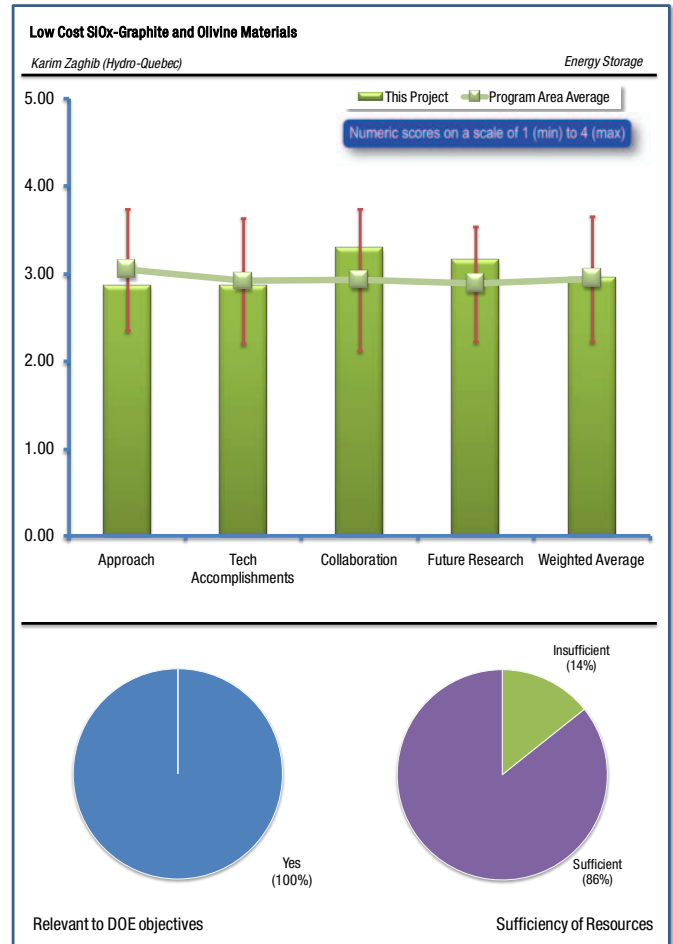
Low Cost SiOx-Graphite and Olivine Materials: Karim Zaghib (Hydro-Quebec)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers commented on the relevance of a SiOx anode. The first reviewer commented that Si and Olivine is one of promising materials, and another reviewer commented that a successful development of an SiOx anode would lead to an improved capacity lithium ion battery, which would be very desirable for the vehicle program. Also, a low cost olivine cathode with improved voltage would improve the cost per unit energy of the lithium ion system to good effect. The third reviewer noted that investigation of alternative higher energy anode materials and doped Mn phosphate cathodes could provide for lower battery costs for automotive applications. The fourth reviewer suggests that manganese phosphate would be a useful cathode material, and that silicon oxide anodes would be helpful. Another reviewer perceived that the project addresses the key DOE objectives on EV and PHEV batteries of low energy and life. The final reviewer mentioned that the project is focused on developing/evaluation of the promising electrode materials and diagnostics tools.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO

PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers had positive feedback on the approach. The first reviewer said the approach is clear and reasonable with acceptable steps, and that the work on SEI is important and requires effort and good collaborations. Another reviewer thought the approach is good in advancing the methods of making SiOx, but this reviewer would like to see some full cell work to give a fair comparison of the results with the state of the art. Likewise, the olivines work would be enhanced by the manufacture of 18650 cells at this point to see what difficulties might be encountered. The third reviewer stated that a lot of work is being conducted and a great progress shown in developing SEM/TEM capabilities and 18650 testing facility. Very important work has started on the electrode engineering. It is not clear if all these activities are within the project objectives or outside of the project objectives. Elaborating more on the activities covered by this program will help. Another reviewer commented that the PI is obtaining useful fundamental data using several different methods. The final reviewer noted that the binder study for SiO was done by several people already.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Several reviewers felt the progress is excellent. One reviewer commented that the progress is excellent and well-presented. The use of cycle life graphs with a few tens of cycles is not significant for the projected targets. It is suggested to give more acceptable results for the optimization and selection of the materials. The second reviewer commented that the PI is making progress and showing useful data. It appears that the blended cathodes have some promise as useful cathodes. According to the third reviewer, a lot of work is being conducted and a great progress shown in developing SEM/TEM capabilities and 18650 testing facility. Very important work has started on the electrode engineering. It is not clear if all these activities are within the project objectives or outside of the project

objectives. Elaborating more on the activities covered by this program will help. While the fourth reviewer thought progress is good, the comparison with this year's report and last year was somewhat disappointing in the level of accomplishment. In particular, the lack of data for anode efficiency may indicate that the anode is far from ready for development. The reviewer would like to see the SiOx anode used in a full cell to compare results with graphite directly. The cycle life data will also be much more meaningful. The olivine materials seem to be ready to be made into full size 18650 cells in order to make direct comparisons with other lithium ion systems. The fifth reviewer felt that although result details provided are too limited, dual material and dual layer activities seem quite promising.

The sixth reviewer commented that voltage cutoff for lithium extraction from charged SiOx was 2.5 V. It will result in too low cell voltage and is too far from practical. At voltage cutoff of around 0.5 V (a more practical value) the delivered capacity looks twice as low. Cycle life shown for SiOx is still far below from the approximately 1000 cycles typically achieved for commercial Li-ion systems. The role of SEI was not shown. Data on LiMnPO₄ mixed cathodes look promising. However, should be supported by improved safety data. Another reviewer commented that the advantage of multilayer electrodes needs to be proven.

The final commenter explained that this rating is based on evaluating the project against the objectives stated. Excellent work and progress must be noted for the work presented that is not stated under the objectives. Maybe the objectives have to be modified to better reflect the work being conducted? This reviewer makes the following queries:

Anode work:

- The objective of the project is to replace the graphite anode with lower cost and higher energy anode material. Replacing 50% of graphite with SiOx addresses energy increase objective. How does it address cost?
- Was the recipe for the electrode preparation kept the same for the study comparing the effect of the binder?
- How can you explain such significant difference in the 1st cycle efficiency?
- How can you explain such low cycle efficiency for the PVDF system in the 2nd cycle?
- Are you planning to study your selected anode/graphite/binder system performance at low/high temperature and at the higher rates
- Is the 1:1 anode composition is the optimum composition for the cost/energy objective?

Cathode work:

- The approach to improve performance of the cathode material requires additional process steps (wet milling, re-heating). How do these steps affect cost?
- The recipe for the electrode preparation has 25% inactive materials. How does this affect the energy density of the final cell?
- LiMnPO₄ synthesized by the hydrothermal method has reduced PSD, but it also has 30% irreversible capacity. How do you plan to mitigate this?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers generally saw good coordination. One reviewer felt there was a good network of really functional collaborations to meet project objectives. The second reviewer stated that all collaborators are strong. Their particular contribution was not shown well. Another reviewer saw excellent breadth of international collaboration, and the fourth reviewer stated that the PI is working well with his partners such as Sandia. The fifth reviewer stated that during the oral presentations, PIs have always complimented HQ on delivering samples, etc on time. The final reviewer commented that there are some collaborations but it is unclear how they work together.

QUESTION 5: HAS THE PROJECT 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?

A reviewer thought the plan for the next period is acceptable and reasonably structured, and the second reviewer commented that the PI's plans may lead to useful results. Their molten state plans may bear fruit.

Other reviewers made suggestions about avenues for future research. One reviewer stated that it is important to continue to develop the 18650 facility, but it would also be helpful to other BATT investigators to be able to take advantage of HQ coating, and calendaring equipment. The BATT program has never had much strength in this area and HQ could serve as important addition. The fourth reviewer stated that test of new materials in the 18650 cells has to show how well the objectives (cycle life and high energy) have been met. Low materials cost evaluation should be shown in more details. The third reviewer suggests that further exploration of LTO/LFP-based system, limitations, and benefits of elimination of formation process should be included.

The fifth reviewer commented it would help if future research is reflected in the project objectives, and the final reviewer stated the future work for SiO_x-graphite is not clear.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Respondents commented that resources seem sufficient. One reviewer commented that there are many results and activities well covered by resources and commitment, and the second reviewer commented that there are a lot of data and resources seem sufficient. Another reviewer suggests that the PI should work with Richardson at LBNL to try to gain a more in-depth understanding of the structure of his new materials.

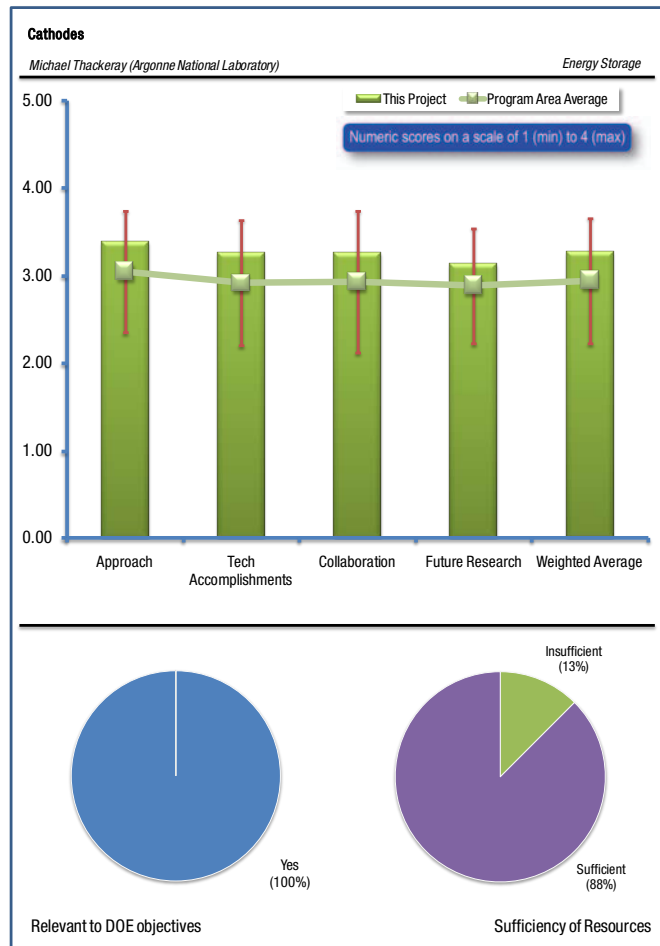
Cathodes: Michael Thackeray (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 8 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewers saw that the program meets DOE objectives. One reviewer noted that the program to develop new, high capacity cathode materials is very consistent with the increased energy density goals of the DOE program, and another reviewer commented the work on novel or improved cathodes is essential for the DOE objectives. The third reviewer stated that high-energy cathode is one of the main issues to achieve higher energy density. The fourth reviewer saw that the program is well balanced/ designed and focused on the objectives. Another reviewer commented that the layered-layered cathode is one of the more promising new technologies currently in development, and TiO₂ could be a means toward increased life and safety in line with automotive targets. The sixth reviewer stated that the project provides potential for fundamental advancement in energy capability of automotive battery active materials at both fundamental and applied levels. This work provides useful exploratory investigations of novel methods for improvement of active material synthesis/treatment/processing methods. The seventh reviewer noted that the PI is attempting to develop new cathode materials.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Several reviewers commented on the autogenic reaction. The first reviewer thought the PI’s approach may lead to useful results, and the autogenic reaction approach appears to be yielding useful results. The second reviewer commented that one of the barriers of previous work was the inability to charge and discharge the new cathode materials at higher rates. The approach to coat the surface of particles with an insoluble stable material is a good one to stabilize the interface with the electrolyte. Other approaches such as the use of autogenic reactions to produce carbon-coated TiO₂ for the anode material are newer and subject to further investigation. Finally the use of molecular modeling of spinel surfaces has promise to improve the stability of these materials in high temperature cycling. The third reviewer commented that the approach is well balanced between experimental material research, process optimization and modeling, and the fourth reviewer thought the approach was generally good, but autogenic synthesis does not seem to lead to a big win, at least in the field of battery materials. The fifth reviewer saw a clear, defined approach. The sixth reviewer commented that the program is focused on solving technical barriers very well; at least “back of the envelope” cost estimations/comparisons will be greatly beneficial vs. baseline chemistries. To the seventh reviewer, it seems object was too wide (high power, high capacity and low cost for PHEV and EV)

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers generally saw a useful technology and good progress. The first reviewer thought progress on cathode material protective treatment was particularly good in terms of meeting objectives. Modeling was helpful for understanding, but it needs experimental data supporting simulation results. The second reviewer commented that the accomplishment of obtaining a stabilized surface for the

composite high voltage materials is substantial. This has been a key barrier to acceptance of the material class. There remain several other barriers, however, which must be addressed before final acceptance of the material class can be accepted as battery materials for the PHEV program. Among these are the high irreversible capacity shown on the first cycle, which detracts from the cell capacity, the low temperature performance of the system, which has not been sufficiently investigated, the rate capability of the system which has been improved, but is still not as good as competing materials such as NMC, NCA, and others, and the cycle life of the system, which still needs demonstration in full cells, preferably in 18650 cell size. The third reviewer commented the research on various cathodes is giving extremely interesting results with real possibility to be close to the solution of technical barriers. Longer cycle life testing is recommended to better verify stability with respect to DOE targets. The fourth reviewer commented that the PI's nickel phosphate material appears to be useful. The fifth reviewer saw a very good quality of results, and asks the following: Is there is a plan to address high irreversible capacity in cathode and thus, energy density of the full cell? Is there is a strategy to eliminate the need for the formation cycles? Autogenic reaction was very interesting tool to screen different chemistries, could it be difficult to control/reproduce process parameters? The sixth reviewer stated the surface coating showed the performance improvement.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer commented that the increased collaboration with Northwestern University indicates an improved level of collaboration. A wider distribution of "best bet" cathode materials to others in the BATT program for competitive evaluation would be useful. The second reviewer stated that the PI is working with his partners. The basic modeling work may help him understand better the material he is developing. The third reviewer thought saw very interesting work on simulation of atomic structure of spinel: might contribute to the improvement of the first generation of the EV batteries. The fourth reviewer can see the collaboration successfully improve the powder.

The fifth reviewer perceived the coordination with other institutions is not clearly specified even if in the previous year it was mentioned. The sixth reviewer stated that the project needed more clarity on what collaborators are supposed to do and actually did, and the seventh reviewer states that a high-level (at a minimum) description of specific technical focus of collaboration with external active material suppliers is desirable and should be included in the future.

QUESTION 5: HAS THE PROJECT 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?

Generally, reviewers saw evidence of a well-defined plan. The first reviewer thought the plan for the next year is good and concentrates on key technical issues, and while the second reviewer also saw a well-defined plan, this reviewer commented that the project needs more clarity on TiO₂ anode improvement, particularly on stability increasing of highly lithiated TiO₂ anodes with autogenic synthesis. The third reviewer thought the PI's plan for future work is well-defined and will yield useful results.

The fourth reviewer also saw that future work is well-planned, and makes the following suggestions: might want to consider comparing doping vs. surface coating on cost and long cycle life; and need to do energy estimation for the TiO₂/Mn-cathodes systems. The fifth reviewer suggests that to achieve the 40 mile PHEV goal, the materials need to have high rate capability and safety as well as capacity.

The final reviewer would like to see the deficiencies noted above, namely low temperature performance, rate capability and cycle life, addressed in a systematic way so that better decisions on material acceptance can be made. The emphasis on surface studies to enhance the properties is well taken and should be pursued.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers thought the resources seemed sufficient for the planned work. One reviewer mentioned that the resources are well-developed and represent a fully-developed program, the second reviewer stated that the resources are adequate to the work and the excellent result achieved, and a third commenter noted that the work is high-quality.

The Synthesis and Characterization of Substituted Olivines and Layered Manganese Oxides: M. Stanley Whittingham (SUNY-Binghamton)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers perceive the project as supporting DOE objectives. The first reviewer stated that cathode material research is essential to support DOE objectives, and the second reviewer remarked the higher capacity cathode is one of the important milestones to achieve the PHEV goal. Another reviewer commented that the potential advancements are incremental relative to the current state-of-the-art. The fourth reviewer noted that the project focus is to develop new cathode materials which have high energy density as well as low weight and low material costs, using synthetic methods of low cost and to develop such synthetic methods. The final reviewer noted that the PI is producing new cathode materials.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer remarked that the PI’s approach is appealing because he is trying to develop materials that will intercalate more than one mole of lithium. Another reviewer commented that the approach is clearly centered on key barriers and with interesting proposed improvements.

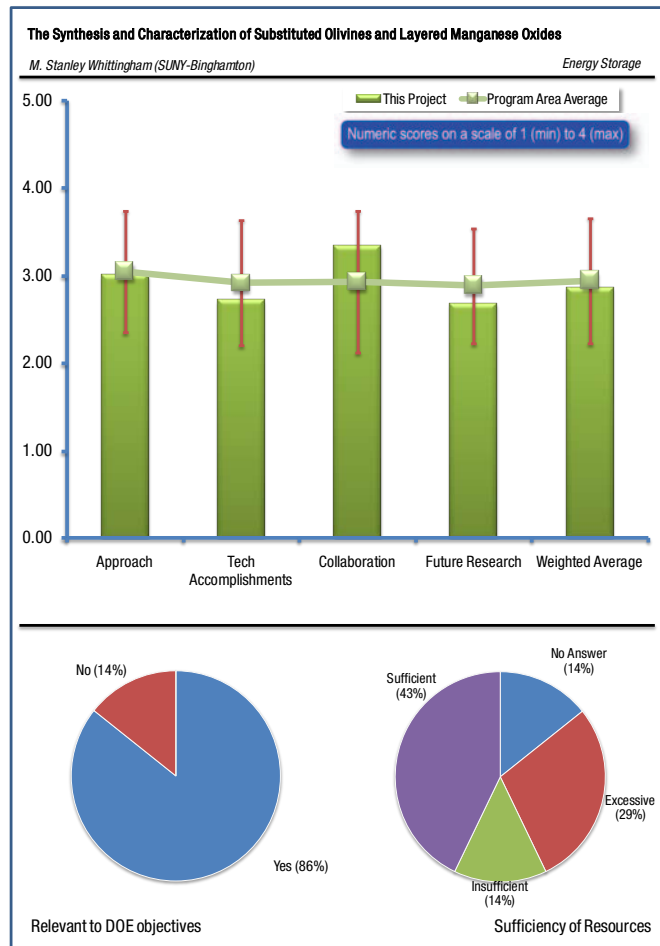
The third commenter remarked that the NMC ratio is well studied and issues have been identified already. According to the fourth reviewer, the search for cathodes capable of cycling two lithium ions promises higher energy. However, extraction/insertion of two Li ions typically happened at too wide range of charge/discharge voltages (from ~ 5 V to 1 V). This problem has to be addressed.

According to the fifth commenter, optimization of NMC composition for automotive or other applications is best left to viable materials suppliers at this stage of NMC implementation worldwide. The investigation of two electron materials is valuable.

The final reviewer remarked that all three approaches have the possibility of obtaining >200 Ah/kg in cathode capacity, which would meet DOE goals if successful. This reviewer summarized the approaches. 1) optimize the composition of NMC to minimize the cobalt proportion while maintaining capacity and rate capability, 2) investigate substitutions on phosphorus lattice of LFP to obtain better energy and rate performance and 3) investigate new materials that have the capability of intercalation more than one lithium ion per metal center.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers saw evidence of good progress. The first reviewer remarked that the progress is good and well documented. There is no specific activity described on abuse tolerance of the selected materials. The second reviewer commented there is good progress on LiMO₂ materials with ~200 Ah/kg and high rate. Two electrons materials (vanadium compounds) are at an infant stage. The third commenter wrote that the PI is making progress on developing novel, new cathode material.



The fourth reviewer stated that the 442 NMC material seems to be an optimum composition to maintain the rate capability of 333 composition and still reduce the level of Co. The goal of high capacity however, can only be met by charging to higher voltage levels which has caused capacity fading with cycling. The program should be extended on this family of materials by seeking methods to moderate the capacity fade when charging to 4.4 V or above. The final reviewer commented that people did not use high Ni content material because of the stability. PI should also focus on it, and should identify the pros and cons more clearly for each material.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers commented that collaborations are clear. A reviewer mentioned that the network of collaborations is clearly presented and justified, and the coordination seems to be very good. Another reviewer commented that the PI is working well with his partners.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer commented that the PI's plan to continue working on cathode materials with vanadium may yield useful material, and the second reviewer commented that the plan for each of the material class is reasonable. Some attention to stability tests and safety aspects is recommended. The third reviewer stated that oxides and olivines are already well developed at commercial scale. This reviewer asks if it would be better to concentrate on what is most promising and new. Two electron compounds? The fourth reviewer similarly queries if the focus should be on two electron materials. The fifth reviewer stated that the PI should identify the pros and cons more clearly for each material.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer stated that planned and required resources seem well justified by the work and the results presented, and the second reviewer commented that the PI's funding is sufficient. The third reviewer commented that they can do more failure mode analysis for each material.

Stabilized Spinels and Polyanion Cathodes: Arumugam Manthiram (University of Texas at Austin)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers generally perceived the work to be vital. The first reviewer commented the research and development of high voltage cathode materials would significantly impact DOE objectives, and the second reviewer stated that new preparations of existing cathode materials and new materials for cathodes for lithium ion batteries are important aspects of the lithium ion battery program. The third reviewer commented that the PI is producing stabilized spinels with high voltages that may be useful, and the fourth reviewer noted that the cathode is the most expensive materials in battery materials.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

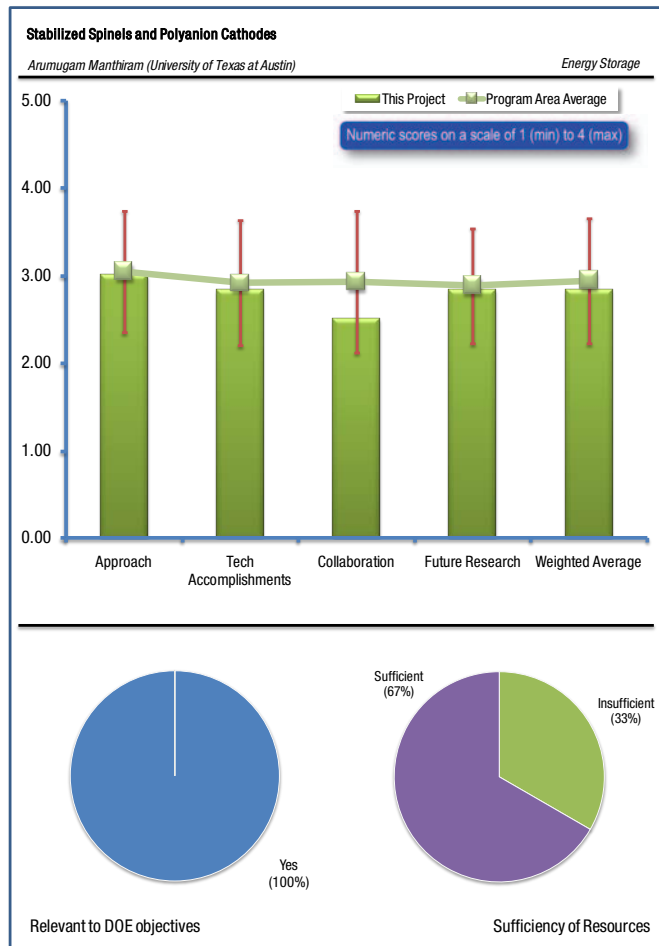
The first reviewer remarked that the approach is well focused on the selected barriers. All the steps from materials research to material preparation and characterization are clear and justifiable. According to the second reviewer, the PI's approach is useful and novel, and the third reviewer remarked that the cation's self-surface segregation improving cathode material stability looks interesting and promising.

The fourth reviewer stated that the approach varies for each material under investigation. The work with 4V spinel materials involves mainly cation substitution for manganese to reduce the solubility of manganese to as low a value as possible to address the cycle life problem with this material. The work with 5V spinel materials involves the substitution of cations in the nickel sites to try to stabilize the material and present a reduced surface to the electrolyte to minimize electrolyte decomposition. The work with polyatomic anions is more exploratory in nature and tries to develop ways to obtain higher than one electron per transition metal to increase capacity.

The fifth reviewer commented that the project uses a third element to stabilize Mn; spinel was studied many times and the difference from the previous study is unclear.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer remarked that progress is good and well demonstrated, and a second reviewer saw that the PI's ability to produce high voltage material is useful. The third reviewer remarked that oxyfluoride transition metal oxides have been found to have slightly better stability than pure oxide materials. It remains to show that the other properties of these materials are as good as or better than the oxides and that they can be made economically. The performance of spinels remains in a trade off situation that the cycle life can be improved, but only at the expense of the capacity of the positive. This is a serious shortcoming since the capacity of the spinel needs to be improved, even though it is a low cost material. Interesting results on iron substituted 4.8V cathodes have shown that the iron is segregated at the surface of the crystallites, which helps to stabilize the material against electrolyte oxidation. Some progress has been made in the mixed metal olivines to obtain better energy from some of the compounds. Also, some progress has been made in the silicate systems, but they do not approach the goal of two electrons per transition metal.



The fourth reviewer commented that silicate cathodes are at early stage of development. The team needs to show advantages over traditional Li-ion materials, and self-surface segregation during synthesis looks to be the most promising result. The final reviewer stated that it is very important to identify where the third element is in the molecular structure but it was not clear in the presentation.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer stated that collaborations have been useful in terms of analysis of materials and results. However, the reviewer would like to see some of the best materials supplied to the LBNL group for cell builds to compare the materials and formulations on an independent basis. The second reviewer commented that the collaboration network is acceptable even if key collaborations on specific materials could be improved.

According to the third reviewer, collaboration looks like analytical service support with exception of discussion with Professor John B. Goodenough, and the fourth reviewer remarked that the collaboration with Professor Goodenough has yielded useful results. Another reviewer stated that collaboration with viable industrial partners would be beneficial, and the final reviewer commented that collaboration seems only in-situ diffraction equipment.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer remarked that future work concentrates on most promising approaches, and the second reviewer commented that the PI's plan for future work is on target. The third reviewer would like to see a big push made on high voltage materials since this is the most promising program in BATT for this area. The use of TiO₂ or lithium titanate spinel as negative material will not succeed unless a high voltage positive of high capacity is developed in tandem. The other work should continue as well to map out the field, but with lower priority. The fourth reviewer commented that the spinel study needs to be improved, and the reviewer does not think this direction can solve the issue significantly. The final reviewer remarked that future activities are well organized, but recommended better focus on the activities to verify and present better improved specific energy and stability (cycle and calendar life) of the selected materials.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer commented that the work seems well covered by the planned resources. The second reviewer mentioned that the PI's funding is too low, and the third reviewer remarked that the project needs more resources to see the fundamental issues for the spinel.

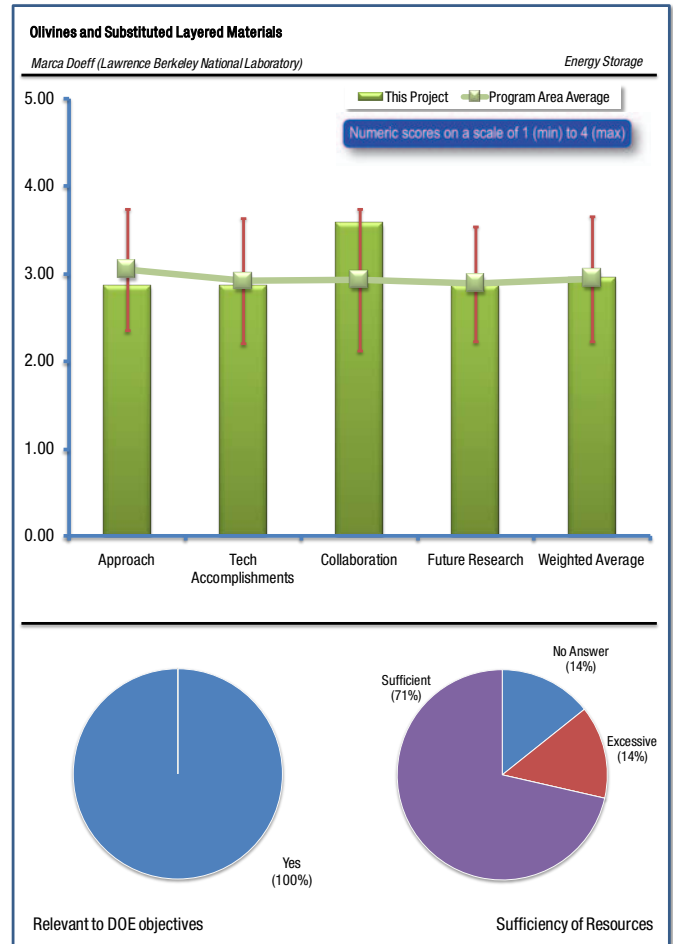
*Olivines and Substituted Layered Materials: Marca Doeff
(Lawrence Berkeley National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers remarked that the focus on lowering cost reflected DOE objectives. The first reviewer remarked that the project to prepare low cost cathode materials for lithium ion batteries with higher performance and low toxicity is well within the DOE objectives to improve battery performance for hybrid electric vehicles. The second reviewer also remarked that low-cost materials are well functional to meet DOE objectives. According to the third reviewer, low cost processing and reduced cobalt could help these materials move toward the USBAC cost goals. A solution to the known performance problems with LMP could result in a cathode with all the advantages of LFP but 10-12% higher energy, although the authors seem to be using LMP only as a test case. The fourth reviewer remarked that the project provides potential for improvements in automotive battery basic electrode material costs and energy density. The fifth reviewer remarked that olivine is one of most promising materials, and the final reviewer commented that the PI is trying to make new materials for cathodes.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO

PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer remarked that the project had a clear focus on technical barriers for the selected cathode materials. For the second reviewer, an important direction to lower cost is to reduce the amount of cobalt in NMC cathode materials without lowering the performance and cycle life. The approach to accomplish this is to replace some of the cobalt with main group elements that will not contribute to the capacity, but will improve rate capability in comparison to low cobalt materials without the additives. The preparation of LiMnPO₄, a promising higher voltage olivine with potentially improved energy, has been developed using spray pyrolysis. This gives the possibility of a low cost synthesis and easy substitution of other elements such as magnesium, which is known to improve the properties of other olivines. The second reviewer mentioned that spray pyrolysis looks as promising method, and queries, what about mass production with this technique? Approach to substitute Co looks reasonable. The third reviewer remarked the PI's approach appears to be of limited utility, and the final reviewer stated that it was unclear what the issues are for less Co and how the PI wants to overcome the issues.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer found that the Al and Ti substitutions in low cobalt NMC (Ni and Mn at 0.4) were beneficial to rate capability because the lamellarity of the structure was improved over the unsubstituted material. Fe was found to have the opposite effect and also had bad effects on rate. The effect on electronic conductivity was mixed so the structure effect was believed to be dominant. For still lower Co (Ni and Mn at 0.45), the Al substitution could be carried out to 0.05 (reducing the Co still further) without harming capacity or rate. A decision should be made to focus on a more limited range of composition at this point and to better characterize the

material for rate, cycle life, irreversible capacity and cost. Spray pyrolysis results were not too encouraging because of low efficiency of discharge. This indicates a side reaction for the Mn phosphate materials which is not simply electrolyte reduction. The second reviewer commented that work is progressing well, and the improvements of specific capacity would be a significant added value. The work of spray pyrolysis is valuable and is adequately recognized. Some general information about economical aspects related to new materials and processes would be an added value. The third reviewer commented that barriers and objectives are well addressed, and posed the question of what the achieved (or potential) cost reduction due to Co substitution is.

The fourth reviewer commented that the PI's accomplishments are not encouraging, and the final reviewer stated the material synthesis was well analyzed but the material after degrade can be analyzed more.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Several reviewers commented that collaboration was clear. The first reviewer remarked that a long list of collaborators was provided. In this kind of structure/property investigation, it is encouraging to see maximum use of collaboration and methodology. The second reviewer saw a well-structured network with balanced key contributions, and the third reviewer remarked that there was a very good and clear description of collaborators roles. The third reviewer remarked that collaboration is clear.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer stated that the plan is good for ongoing project, and asks if Al and Ti are the only possible options for Co substitution. According to the second reviewer, the work on low-Co NMC should be expanded to prepare more material, particularly for Al substitution for more thorough electrochemical evaluation. This could be an important result, but the effects need to be sorted out better for both Al and Ti substitution. The spray pyrolysis may have beneficial effects on mixed Fe/Mn phosphates such as found by Manthiram and should be considered. The third reviewer remarked that the future plan takes into account the results achieved and previous years' reviews. There is not yet enough focus on stability and cycle life, which was intended to be implemented with collaborations (Vince Battaglia). The fourth reviewer remarked that the PI should consider changing directions concerning material development, and the final reviewer suggests the PI should focus on the failure mode more.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers found funding sufficient. The first reviewer commented that funding seems fine for the amount of work and the challenging targets. There is only one doubt for this reviewer, related to the statement in the second slide that the funding "supports one postdoc and one student." The second reviewer stated that funding seems sufficient. The third reviewer commented that the PI's funding should be reduced to cover the in-situ XRD only.

Cell Analysis – High-Energy Density Cathodes and Anodes: Thomas Richardson (Lawrence Berkeley National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers saw that the work supports overall DOE objectives. The first reviewer remarked that work on cell analysis, cathodes and anodes are all valuable to the lithium ion battery program, and the second reviewer commented that key performances of Li battery electrodes are addressed and clearly support DOE objectives. The third reviewer remarked that the PI is developing useful experimental methods and anode materials. The fourth reviewer commented that high energy density and cathode is the most important milestone for the PHEV goal.

The final reviewer stated that high energy anodes represent a potential step change improvement in cell energy (Wh/L). The prelithiation looks promising, but the practical aspects of using prelithiated material must be addressed. Modeling/Li mapping work could also elucidate where to focus for improvements in formulation, electrode design, etc.

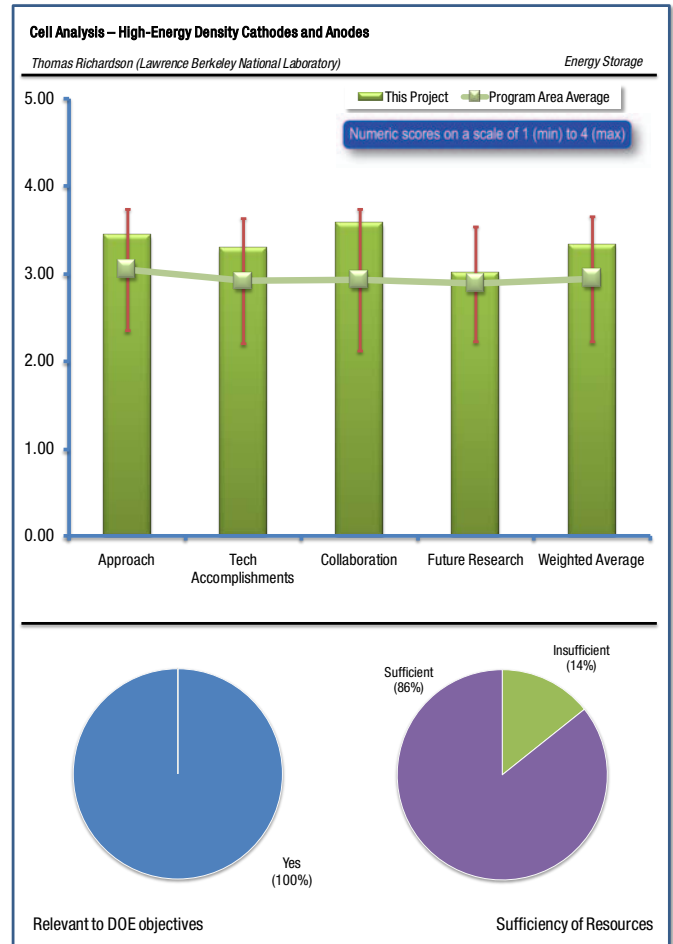
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer saw a good approach in terms of analytical techniques applied for new and known materials exploration, and the second reviewer remarked that the technical approach is acceptable even if mostly qualitative: no clear quantitative targets are defined. The technical barriers related to kinetics and structure are reasonable. The third reviewer noted that the PI has provided charge distributions on electrodes that will be very useful. The fourth reviewer commented that the approach to see the inhomogeneous current distribution through the electrode area is very interesting.

According to the final reviewer, the approach to better understand the reaction distribution in the cathode uses synchrotron radiation from the LBNL advanced light source with an in-situ cell technique. The approach to anode alloy work is to develop a method of prelithiating the alloy to eliminate the irreversible capacity normally found which will improve cycle life and cell balance. The approach to cathodes is to explore nonolivine phosphates of transition metals to seek high capacity materials. These approaches are all directed at current barriers in present materials and in understanding of cathode operation.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers had positive remarks about the experimental methods. For the first reviewer, particularly impressive was experimental visualization of charge distribution at microns scale in the real electrodes. The second reviewer remarked that the PI has developed experimental methods that should be used by others. The third reviewer commented that the results and the applied investigation techniques are impressive and valuable. The progress is evident and needs only better investigation in lab cells.



The fourth reviewer commented that the synchrotron work has yielded outstanding results in analyzing the distribution of reactions under high charge regimes. It would also be of interest to examine the distribution under conditions of high discharge rate after slow charge to a uniform highly charged cathode. The work on anodes is also novel and may be quite useful in developing high capacity anodes with good cycle life and high first cycle efficiency. The cathode work did not yield successful results to date, but is worthy of continued work.

The fifth reviewer remarked that the mapping was good, work was okay on the anode, but the cathode work has not had much positive progress. The final reviewer commented that the data indicate the failure mode for cell analysis, and if PI can suggest the improvement, it would be better.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The reviewers saw evidence of strong collaboration. According to the first reviewer, the collaborations are outstanding in both utilizing facilities for analytical work and in relating to models developed by Srinivasan. The second reviewer remarked that the collaborations are existing and well justified, and the third reviewer commented that the collaborators were strong with clear described contribution. The fourth reviewer felt the PI's collaboration with V. Srinivasan at LBNL is outstanding and useful, and the final reviewer felt the collaboration was clear.

QUESTION 5: HAS THE PROJECT 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?

Some reviewers perceived that the future work will be worthwhile. The first reviewer remarked that the PI's plans for future work will bear fruit. The second reviewer thought the future work is well organized with recommendations for more close-to-product work on both electrodes to confirm specific characteristics in lab cells. Cycle life and abuse tolerance should be more considered or at least analyzed, because they are project addressed barriers.

According to the third reviewer, the future work will include more cathode analysis which is likely to be quite fruitful in the opinion of the reviewer. Also, anode prelithiation should be continued with best bet preparations shown by other workers. The cathode future work was not fully described.

For the fourth reviewer, the future plan is too general without specifics even for exploratory project, and the fifth reviewer sensed that the future work is a little too general for cathodes. The final reviewer suggests an increased focus on extension of study to electrodes harvested from commercial cells.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers remarked that resources are sufficient. One reviewer remarked that the PI's budget should be increased based on his excellent progress in developing useful experimental techniques.

*First Principles Calculations of Electrode Materials:
Gerbrand Ceder (Massachusetts Institute of Technology)*

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer commented that theoretical activities are complementary to the research and development of new materials able to support DOE objectives. The second reviewer remarked that the project is using first principles methods in an attempt to identify materials that could offer step improvements over the state-of-the-art. The conventional approach (“fishing”) results in very slow advances in the field. The third reviewer commented that the rate capability decides the usable energy for the material. The final reviewer mentioned that the PI is working on developing materials and theory to help develop materials for cathodes.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer mentioned that the PI’s approach is bearing fruit, while the second reviewer commented that first principles are really instrumental in assisting material research work with the capacity of fast materials screening and selection. The approach is well focused in key technical barriers with fundamental studies. The third reviewer remarked that voltage and thermal stability is very important to improve the usable energy of the materials.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

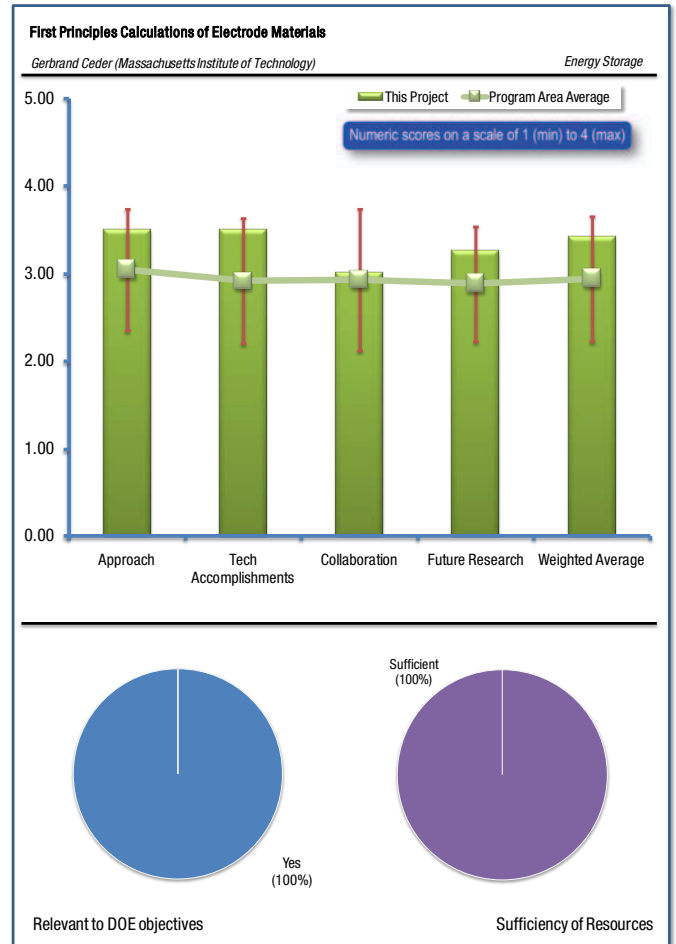
A reviewer saw excellent results with clear descriptions. The second reviewer remarked that the PI’s accomplishments in material development are valuable if they can be proven, reproduced by others. Their modeling efforts are useful. The third reviewer commented that it was interesting to see the results of the voltage and thermal stability. It was explained well why LFP has a bad rate capability in case of large particles.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers saw clear collaboration. The first reviewer saw well organized collaborations with key partners, and the second reviewer commented that the PI is collaborating with others in useful ways, especially having an exchange LBNL at MIT.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer felt that the PI’s plans for future work are appropriate, and commented that he may want to provide materials to others for validation of his results. The second reviewer agreed that the plan is fine, and commented that of course, the attention and the focus must be on the new materials announced and not yet disclosed. The third reviewer commented that the future plan seemed little bit too general.



QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Responding reviewers commented that the funding levels are appropriate.

First Principles Calculations and NMR Spectroscopy of Electrode Materials: NMR: Clare Grey (SUNY-Stony Brook)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers felt that this project definitely supports DOE objectives. The first reviewer remarked that this is essential research to support materials development for DOE programs. The second reviewer remarked that this is one of the few fruitful attempts at experimentally demonstrating what is happening in alloy anode materials and how it could affect performance. Extension of this work (including to other materials) could guide future work in this area. The third reviewer remarked that NMR is a good method to analyze the materials, and the final reviewer commented that the PI is using NMR to help develop and characterize new materials.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

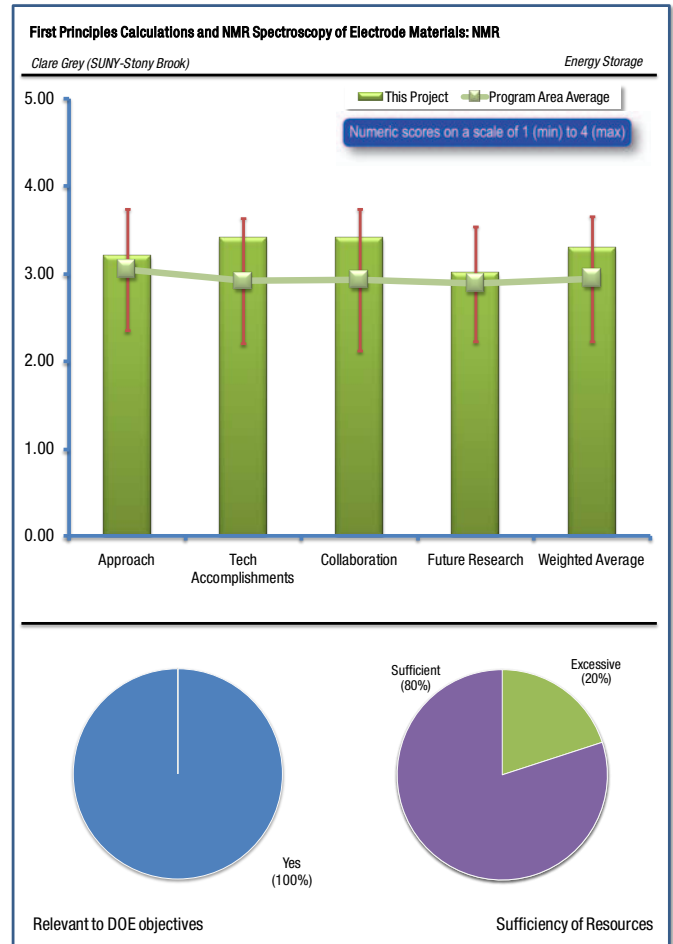
Reviewers generally remarked that the approach is useful. The first reviewer said that the use of different characterization techniques is a good approach to identify mechanisms during battery operations, and the second reviewer commented good simulation approach and powerful NMR techniques. The third commenter thought the PI's approach is useful for data generation; additionally, her Si work is interesting, but discouraging due to the law of reversibility. The fourth reviewer remarked that conducting a lithium dendrite study with NMR is interesting approach.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers saw evidence of progress in the work. The first reviewer remarked excellent progress with complete analysis of results. The second reviewer saw good insight into understanding of Si lithiation through simulations. This reviewer also commented that the NMR study on Li dendrites look interesting. However, it is not clear how it distinguished dendrites from mossy Li. The third reviewer thought the PI is making progress through her NMR work, but no useful new materials have been obtained. The fourth reviewer suggested that if PI can show some support data with different analytical technology for Li dendrite, it would be better.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer saw well established collaborations on key aspects of the work, and the second reviewer also saw very strong collaborators. The third reviewer remarked that the collaboration is clear. The final reviewer thought the PI's listed collaborators are sufficient. However, it is not clear how Ceder's modeling work is being used in her work.



QUESTION 5: HAS THE PROJECT 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?

Several reviewers thought future plans are appropriate. The first reviewer saw a good plan for exploratory project. The second reviewer thought the plan for anode is very good while for the cathode it may be recommended to look also to the materials that are more interesting in BATT program. According to the third reviewer, the PI's plans for next year are appropriate. It may be useful for her to limit the scope of materials investigated. The final reviewer would like to see Li dendrite studied more.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer remarked that the PI's funding is higher than needed to support her efforts. Another reviewer commented that resources seem sufficient.

Development of High Energy Cathode for Li-ion Batteries: Jason Zhang (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Several reviewers remarked that the work is relevant. The first reviewer remarked that high-energy cathodes are necessary to reach DOE objectives, and the second reviewer stated that alternative and new cathodes may accelerate the achievement of DOE objectives. The third reviewer remarked that the project is “out of the box thinking” towards supporting DOE objectives, and the fourth reviewer stated that the high energy cathode is most important milestone for PHEV goal. The final reviewer summarized that the PI is trying to develop new cathode materials.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

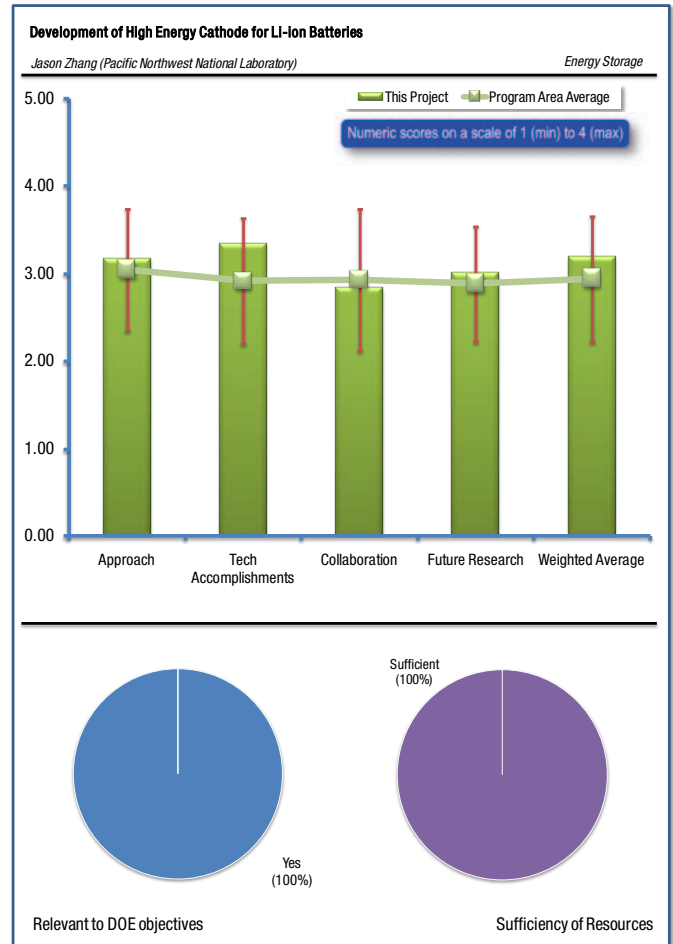
The first reviewer remarked that the PI’s approach to using organic chemistry to produce high capacity cathodes is useful. According to the second reviewer, the approach for the high energy cathode is clear. The PI should focus on the failure mode analysis also. The third reviewer remarked that the approach is clearly centered on key technical barriers of the materials investigated. The fourth reviewer noted that multiple routes are used to address the barriers, which is good, and also suggests using energy vs. capacity to support selection of the materials under investigation. At minimum, cost estimation vs. baseline chemistries should be provided. The fifth reviewer has a concern that organic cathode materials usually have very low densities and that the PI should consider this property along with the specific energy in reporting results. This reviewer also summarized the work thusly: 1. New synthetic methods for LiMnPO_4 and $\text{Li}_2\text{CoPO}_4\text{F}$; 2. Characterization of materials; and 3. Synthesis of organic cathode materials

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Several reviewers perceived that results are good despite the project being preliminary. The first reviewer saw excellent results, and commented that the stability tests are still preliminary but interesting: more cycles are needed. The second reviewer commented that the PI has produced interesting new materials.

The third reviewer commented that this is a new program, so the results are not expected to be substantial yet. The preferred orientation of LiMnPO_4 may have some interesting effects depending on the orientation. Since olivines are 1D conductors, the long dimension should not be the conducting axis since this could increase the polarization and decrease the capacity. Cycling data should also be emphasized since this is a shortcoming of this material. It is not clear to the reviewer what the excess lithium in LiMnPO_4 compositions means, whether a new phase is formed and what its electrochemical activity is. The work on pyrophosphate is interesting, but it is not clear what the electrochemical effect is.

The fourth reviewer stated that the material analysis after synthesis was done well, and that the PI should focus on the failure mode analysis also. The final reviewer said the team should focus on rate capability and columbic efficiency.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer saw acceptable collaborations for the work planned. Other reviewers made suggestions about future collaboration. According to the second reviewer, it would be useful to expand the collaborations of a new program such as this. Those described are certainly useful. The third reviewer suggests that the PI should develop collaboration with a group that could help him by using math modeling of the materials he is developing. Perhaps Ceder at MIT might be able to help. The final reviewer thought that the collaboration is clear but not much.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer saw a good plan for the prosecution of work, and recommends more focus on the investigation of life and stability of best selected cathodes. The second reviewer remarked that results for the work performed are well understood and considered in future work. The third reviewer commented that the PI's plans for the future are appropriate, especially his proposed vanadium cathode development work.

The fourth reviewer suggests that the workers should quickly assess the Wh/liter of the organic cathodes before investing a lot of work in this area. The nonstoichiometric LiMnPO_4 compounds are interesting, but need further structural work to better define them and interpret the electrochemistry. According to the fifth reviewer, PI should focus on the failure mode analysis also.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers thought resources are sufficient. One reviewer remarked that resources are fine, but this reviewer is not clear if the project will continue after September 2010, because future plan refers to 2011 also. Another reviewer commented that the quality of work is good.

Inexpensive, Nonfluorinated Anions for Lithium Salts and Ionic Liquids for Lithium Battery Electrolytes: Wesley Henderson (North Carolina State University)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers saw the project as relevant. The first reviewer remarked that low cost, better performing electrolyte salts would be very important for the DOE goals, and the second reviewer concurred that new electrolyte materials are essential to support DOE objectives. The third reviewer remarked that the electrolyte is important to improve the life of battery. The fourth reviewer summarized that the PI is working on developing new electrolytes.

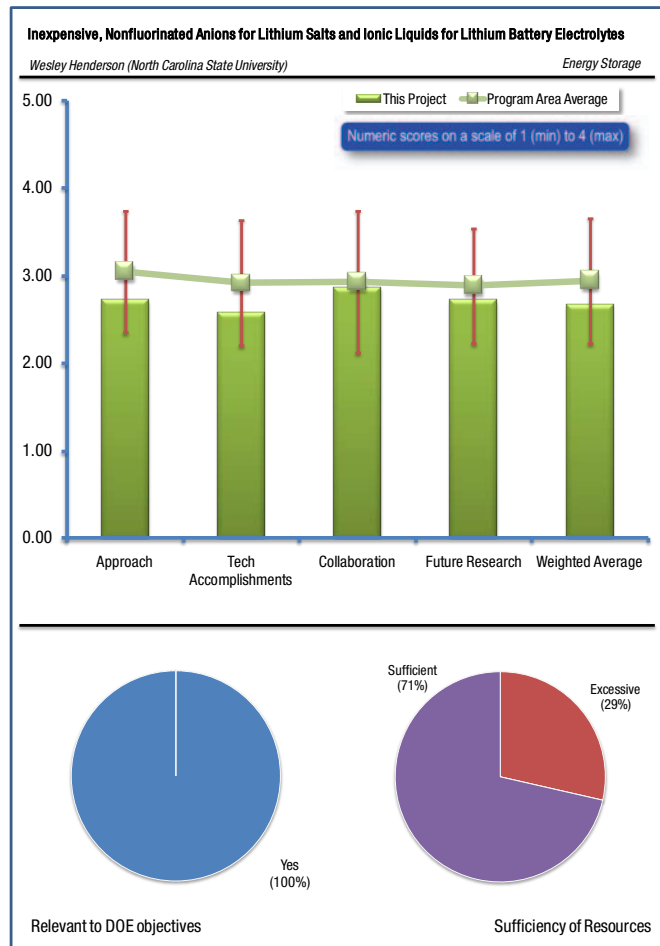
According to the fifth reviewer, electrolyte and electrolyte salt are an appreciable component of the total cost of Li-ion cells, and work is still needed to truly meet the demands of the automotive market in their entirety. That said, the work here seems to lack clear goals as to what is “success.”

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer remarked that the project had well-clarified barriers and approach, and the second reviewer commented that lithium salt typically is the most expensive part of electrolyte. It is particularly important to be introducing new, low cost salts. Ionic liquids are attractive due to their safe behavior at elevated temperatures. Reduction of their cost with new anions is important as well. The third reviewer stated that the two types of salts described in approaches have never been thoroughly investigated and seem to have a good chance of revealing some new structures which may be more stable than LiBOB. The comparison materials are very appropriate. The fourth reviewer thought the PI’s approach is appropriate in his approach to find new electrolytes, and the fifth reviewer stated that the material property characterization is very good basic research for university. According to the sixth reviewer, the project could benefit from more focused and targeted approach (fewer materials to be investigated, greater intuition in choosing path).

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewers saw the results of the work as useful. For instance, the first reviewer remarked that the results are interesting and timely, even if some more relation to the project objectives must be given. It is not easy to estimate the effective progress. The second reviewer remarked that LiBOB solubility observations are useful, and the third reviewer commented that replacement of fluorine based salts with boron and cyanide containing anions looks interesting and promising. It is necessary to address potential cyanide generation at abuse conditions. Phase behavior of ionic liquids with lithium salts should be studied in more details for better electrolyte formulation optimization. According to the fourth reviewer, the material characterization seems done very well. We want to see the relationship with the electrochemical performance.



The fifth reviewer remarked that this is a new program, so results are not expected to be as substantial. The recognition of solid solvate formation is important as it often limits solubility of a salt. The low solubility for most of the prepared materials indicates a problem with the approach. Certainly, the inclusion of aliphatic substituents goes in the wrong direction as it probably causes localization of the negative charge on the wrong atoms (O bonded to B instead of carbonyl oxygen). The investigator should develop some new concepts to increase delocalization of the negative charge. The final reviewer thought that the PI has made some new materials, but it is not clear that the materials will be used in cells.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer remarked that the PI has developed good collaborations, which is to be encouraged, and the second reviewer commented that there is a well-structured network of collaborations. The third reviewer saw a useful scope of international collaborators, and added that collaboration with viable industrial partner would be useful. The fourth reviewer thought the PI's interaction with ARL is potentially useful.

Another reviewer remarked that collaboration with lab/company producing experimental or commercial batteries and providing new electrolytes evaluation in the batteries will be helpful, and the final reviewer suggests the project can collaborate more for electrochemical study.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer commented the future work is well aligned with the achieved results, even if there is the recommendation to keep in mind some of the project objectives (low cost materials and processes, which require dedicated work to be more evidently showed). The second reviewer remarked it will be nice to see new electrolytes tested in the real rechargeable battery to prove their advantages. The third reviewer thought the PI's plans for the future are appropriate, but he should compare some of his new electrolytes to existing electrolytes.

The fourth reviewer suggests referencing questions under results, and recommends that IL work should continue to seek new structures. The fifth reviewer remarked that scope should be narrower and more focused, and the final reviewer wants to see the characterization continuously.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers remarked that funding is adequate.

Molecular Dynamics Simulation Studies of Electrolytes and Electrolyte/Electrode Interfaces: Grant Smith (University of Utah)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer commented that the project is theoretical work to support DOE objectives, and the second reviewer remarked this effort is mainly directed at better understanding the interfaces and interactions among phases in lithium ion batteries which should contribute to improving lithium ion batteries.

The third reviewer thought that while there is interesting learning here, it was not clear exactly how this work impacts the auto electrification goals. Another reviewer commented that the modeling seems more important for further material development. The final reviewer summarized that the PI is trying to understand better the formation of the SEI layer through modeling.

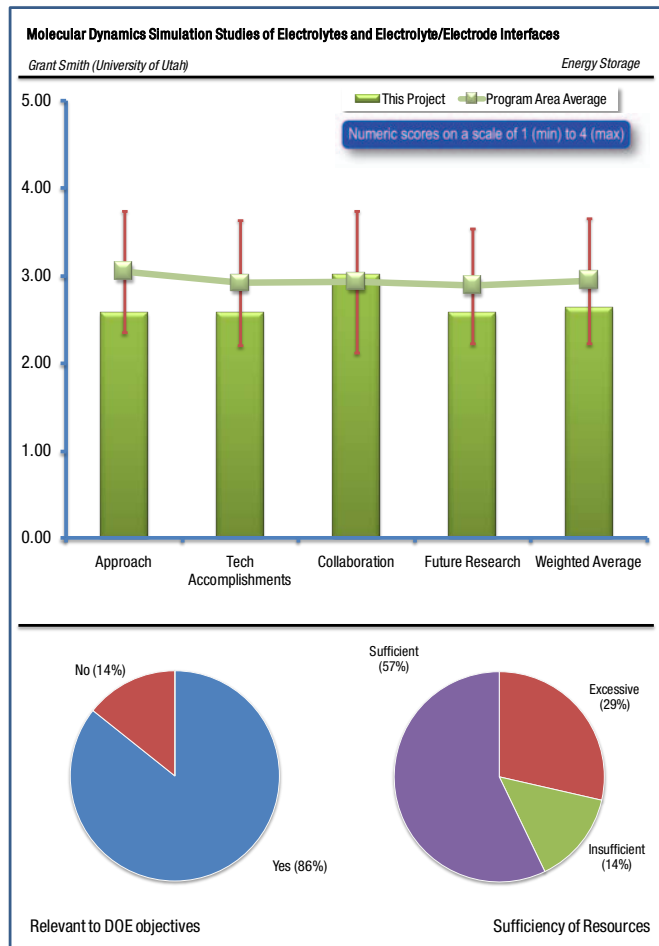
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer commented that the approach includes modeling the electrolyte phase, the SEI, the electrode-electrolyte interface and lithium intercalation/deintercalation. These are the key issues in lithium ion batteries. The second reviewer commented that molecular simulations appear to be a powerful tool for deeper understanding of battery related materials/electrodes performance. The approach needs more direct correlation with experimental data: at least, correlation was not well shown in the presentation. In response to the question, the third reviewer said this was a limited but key study to understand technical barriers in electrolyte effects. Another reviewer couldn't get how the breakdowns in the current performance of the working models would be overcome. The fifth reviewer remarked that project focus is too broad. The sixth reviewer stated that Smith's approach seems to be biased toward specifying the structure of the SEI a priori as opposed to not doing so. The final reviewer noted that SEI is very difficult to investigate so the modeling may be the good method.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer saw good results with clear progress. According to the second reviewer, the project shows good insight into materials performance for a wide (maybe too wide) range of conditions and areas. Again the data should be correlated with experiment at least semi-quantitatively. It will be nice to estimate area specific impedance for electrodes interface ($\text{ohm}\cdot\text{cm}^2$) and its activation energy. Too many items are under consideration, so analysis for every item can be quite shallow for the given time and resources.

The third reviewer commented that detailed QC computations show that the formation of the SEI is likely to be more complicated than previously thought. The opening of a PC or EC ring after formation of the anion radical at the negative electrode is the critical step



and it seems to occur in a different way. The predicted longer lifetime of the anion radical is a key finding and effects the way subsequent reactions occur.

Another reviewer remarked that the PI has not achieved a better understanding of the formation of the SEI as planned, and the final reviewer wants to see not only the current mechanism analysis but also new electrolyte system based on the modeling data. Also the SEI composition that is the goal for this project was not clear.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Some reviewers saw good collaboration, with the first reviewer remarking that the broad collaboration the PI has is very important for this project. To have an impact, the experimentalists need to have an appreciation of the results to direct further experiments. The second reviewer saw an acceptable collaboration network, and the third reviewer thought that collaborations are strong, but the presentation needs more clarity on collaborators' contributions.

The fourth reviewer suggests the PI should be collaborating with other theoreticians (G. Ceder or P. Balbuena, for example). The final reviewer remarked that the collaboration was not clear.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer remarked that future work plan looks promising, and the second reviewer concurred that the future work is well aligned to the achieved results. The third reviewer saw a good plan, with exception of whole-cell (anode/electrolyte/cathode) simulations. It is not clear what will be the whole cell simulations output (cycle life, energy density?).

The fourth reviewer suggests addressing shortcomings prior to moving to other systems. Another reviewer suggests that greater focus and more targeted effort is needed. The sixth reviewer suggests that the PI needs to focus on the SEI as opposed to attempting to model the entire cell, and the final reviewer stated that we want to see also the experimental data to compare with the modeling.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer commented that funding is too high for the amount of useful results. Another reviewer remarked that resources seem insufficient.

In Situ Characterizations of New Battery Materials and the Studies of High Energy Density Li-Air Batteries: Xiao-Qing Yang (Brookhaven National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said structural studies are important to understanding the operation of lithium-ion battery materials, while another said the lithium-air technology is one of the candidates for the next-generation battery. A third reviewer said the fundamental characterization work for most advanced materials in support of battery research and then DOE objectives. The final reviewer commented that Yang is trying to develop useful experimental techniques for studying potential material for cathodes. He is also working on lithium-air cells.

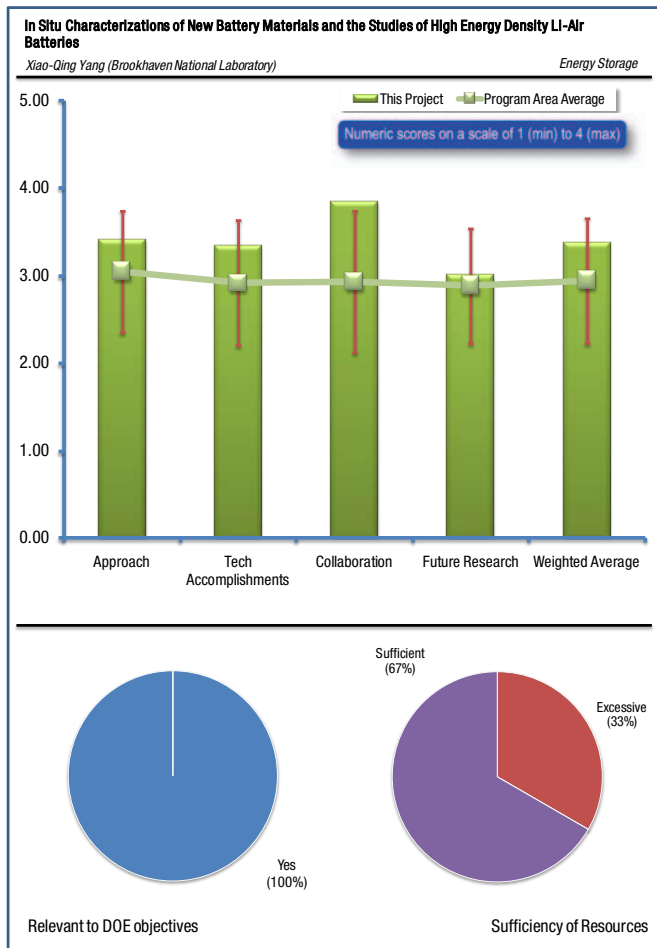
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments were mixed in this section. The first reviewer said Yang's approach is to use XRD to characterize electrode materials. Another said they suggested various X-ray analytical techniques directly address cathode materials performance issues. A third reviewer said the structural studies involve x-ray light sources at BNL, which gives unique capability to this group. In-situ work has proved valuable. TEM and SAED methods have also been developed to expand the structural determinations. New solvent types have been developed to affect the electrochemistry. A fourth commenter said a clear and complete approach is well focused on key technical barriers for assisting the overall BATT subprogram research on new materials for conventional Li and for Li/air systems. The complete characterization activities were finalized to also support internal material research.

Another reviewer said the degree of effort on lithium-air is not useful. The third reviewer said the objective of this test is very wide: this reviewer was not sure why the cathode characterization and lithium-air study were done in the same program.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the materials are characterized very well during charge and discharge, while another observed an impressive amount and quality of results and information giving significant inputs for further research and development. To-be-followed work is that on lithium-air and GDE. A third reviewer said studies have shown an unexpected two-phase region between the two plateaus of LiFeMnPO₄ materials. Studies of ANL materials are ongoing. The use of small pore carbons gives premature polarization of oxygen electrodes due to precipitation of lithium oxides and blocking of pores. Larger pore sizes and treated carbon to discourage immediate precipitation are recommended. This reviewer added that new anion receptor solvents have been developed, which are capable of forming a better SEI than previous solvents.



Another reviewer said that very useful knowledge has been generated on the behavior of various cathode materials. Boron compounds as SEI modifiers look promising. However, this reviewer added, their application for lithium-air to dissolve lithium oxides through complexation will require too high an equivalent weight of additives and dramatically reduce specific energy. The final reviewer commented that Yang has not developed exciting new information about materials or lithium/air cells.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. The first reviewer said the group continues with very wide collaborations, while another noted very strong collaborators and well-defined collaboration plan. A third reviewer said the degree and breadth of international collaboration is excellent. Another reviewer said Yang is working with others to help improve his results, while a fifth commenter said the collaboration was clear and well coordinated. The final reviewer said the project is extremely dependent on a well-organized network of collaborations, which are involved in many ways: sample suppliers, cooperation on novel material and systems.

QUESTION 5: HAS THE PROJECT 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?

Comments in this section were mixed. The first reviewer said the future plan seems well-established, while another said plans for further work are consistent with past results and should give meaningful experimentation. A third reviewer said the prosecution of work is logically related to the results achieved. This reviewer added that even if it does not seem necessary, increased effort on lithium-air is strongly recommended.

A fourth reviewer said good plan for cathode materials study, but added that the advantages of proposed boron materials/additives for lithium-air system are not clear. Another commenter said lithium-air should be a minor focus of the activity. The final reviewer commented that Yang's proposed work should be changed to exclude lithium-air so that he can spend more time on his other proposed tasks.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said the resources seem adequate and related to the large effort, while another added that the resources seem sufficient. The final commenter said Yang's funding is higher than needed, especially if the lithium/air work is dropped.

Solid Electrolyte Batteries: John Goodenough (University of Texas at Austin)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said solid electrolytes in combination with liquid electrolytes have opened new opportunities of high energy density batteries. Another commenter thought that advanced research for BATT subprogram in line with DOE objectives, while a third stated that Goodenough is trying to develop higher capacity cathodes and a better solid state separator. A fourth reviewer stated the solid state battery is one of the next generation batteries, while a final reviewer said yes, the project is supportive of DOE objectives but with huge barriers.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

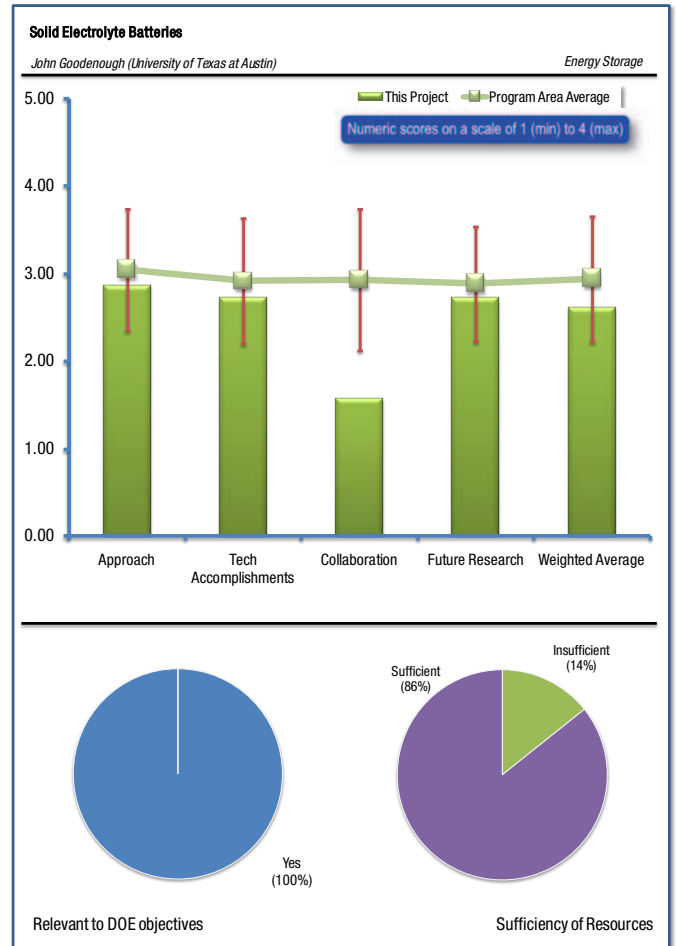
Comments were mixed in this section. The first reviewer said there was clear identification of technical barriers with interesting solutions to be verified. Another said the approach is to develop new solid electrolytes that will be stable in water to allow high energy liquid cathodes to be employed such as redox couples. A third reviewer said the proposed design does not solve the Li dendrites problem known for the Li/liquid electrolyte interface. Another said Goodenough has developed a very successful approach to meeting his goals in the past. It is not clear that he will be successful this time. The final reviewer said the approach for this study is not clear.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said Goodenough has not yet reached his goal of discovering a better solid electrolyte separator, while another doesn't see the sufficient test results and effort from this slide. A third reviewer said the results are mostly preparatory, showing good potential for improvements. However, the solid electrolyte identified is extremely interesting. Another reviewer commented that the work has proceeded to the stage of allowing a sealed cell to be made and optimized. A new finding is that the previously employed solid electrolyte (nasion) is not stable with acid solutions presently used with lithium air technology. Thus, the system will not be stable and unusable long-term in present status for rechargeable batteries. The authors have also found that water and air cathodes are quite inefficient in comparison to transition metal redox couples of ions in solution. The final reviewer said it is not clear how milestone "Optimize components of the cell (Apr. 10)" has been met. This reviewer added that there are no cycling data and confirmation of materials stability.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Commenters generally agreed in this section. The first reviewer said they have not yet identified any partners or collaborators for the work, and another added that no collaboration is envisaged in this phase. A third reviewer said there are no partners despite very challenging objectives. A fourth reviewer said no evidence of external collaboration, while another could not see any collaboration.



The final reviewer commented that Goodenough is not collaborating with others; however, in his case, he has proven in the past to be extremely capable without collaboration.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said Goodenough is planning to continue to search for a better solid electrolyte, which is good since he may discover such. Another reviewer said the PI proposes developing a new solid electrolyte that will not have solubility in the aqueous electrolytes that will carry the redox couples. This will necessitate revisiting the sealing on the anode compartment. A third reviewer said the focus on the solid electrolyte is reasonable, even if it is not much developed and clarified. Another commented that the future work is poorly written (figures instead of text). This reviewer added that it is not clear what will be done towards objectives and what will be actual author's contribution. The final reviewer said the future work is not clear.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said no specific risk is seen. A second commented that Goodenough's funding is sufficient, while the final commenter disagreed, stating that the resources seem insufficient.

Nano-scale Composite Hetero-structures: Novel High Capacity Reversible Anodes for Lithium-ion Batteries: Prashant Kumta (University of Pittsburgh)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said Kumta is trying to develop a better anode material, while another said novel anode research is necessary for DOE objectives. A third reviewer said a high capacity anode is important to achieve PHEV goals. The final reviewer said high capacity/alloy anodes potentially represent a large step improvement in the energy density (volumetric) of Li ion cells if the significant life issues, voltage/hysteresis problems, volume expansion complications (pack design), and safety can be sufficiently demonstrated.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

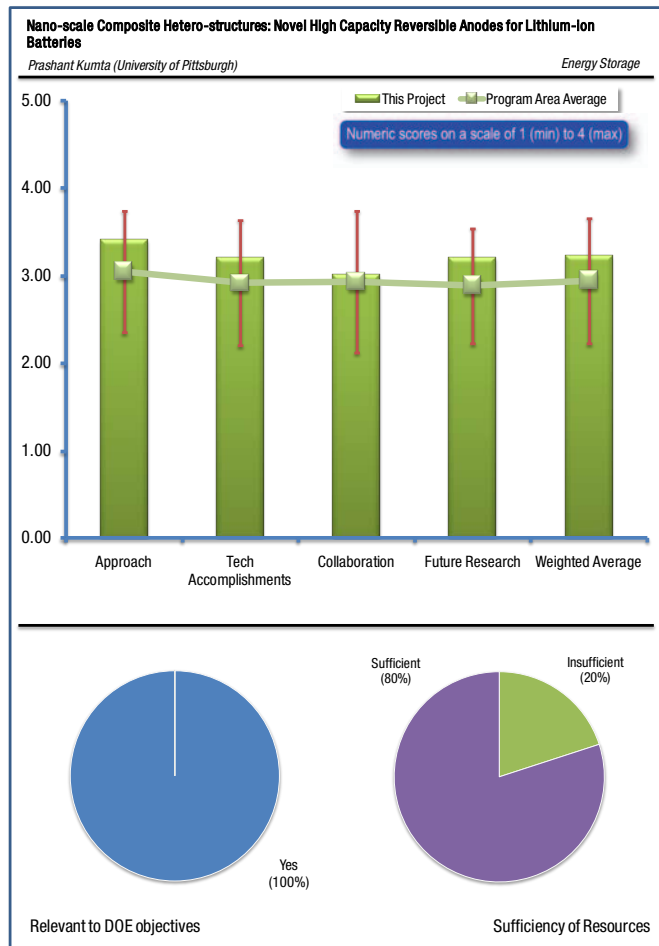
One reviewer said the focus is high on well identified barriers. A second commenter said there was an impressive range of proposed synthetic techniques to improve anode material performance, while another said Kumta's approach is attractive due to the high surface area per unit volume approach. The final reviewer said Si material is not novel, and added that it is not clear how CNT can improve the cons of Si materials.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer commented that Kumta has developed a useful material if it can be shown to cycle well. He needs to continue cycling his best material. It appears that the material does not have sufficient cycle life. He should compare his results to those obtained by others (Zhang at NC State, e.g.). Another reviewer said Si is a well-known material and it is important how Si can be used for a long time. PI should focus more on the life study. This reviewer added that 20 cycles is not enough. Another reviewer said relevant progress was made on novel anodes, and added that the stability should be verified well beyond 30 cycles. The final reviewer commented good progress on gravimetric and volumetric anode specific capacity. It is not clear what level of active material loading or capacity (mAh/cm²) can be reached with magnetron sputtering. Is it practical for mass production? Capacity loss of ~0.1% /cycle offers only ~ 200 cycles to 80%. It is too far from 5,000 cycles.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said the collaboration is clear, while another commented about the mixed collaborations with industry and national labs that were well described and motivated. A third reviewer observed strong collaborators, with a good description of their contribution. The final reviewer said Kumta should publish more with his collaborators.



QUESTION 5: HAS THE PROJECT 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?

One reviewer said this is quite an ambitious plan, and added that the good thing is that materials will be tested in the real cells. A second reviewer said the next period plan is well organized and aimed at solving defined barriers. The use of BATT cathodes is strongly recommended to increase comparability and support research progress of the entire subprogram. Another reviewer said Kumta's proposed work is acceptable. The final commenter said the plan is clear but added that Si is not a novel material.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said Kumta's funding is sufficient, while another said the resources seem sufficient. A third reviewer said the project is adequately supported. The final reviewer said that the budget/timeline slide is in contradiction with future plans. It looks that the project was 100% completed in 2009. This reviewer asked, what is the funding for 2011?

Intermetallic Anodes: Michael Thackeray (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said high-energy anodes are necessary to develop batteries for DOE goals, while another said a high capacity anode is important for PHEV goals. A third reviewer commented on the novel anodes that are relevant to DOE objectives. Another commenter said Thackeray is trying to develop better anodes for lithium ion cells. The final reviewer said new syntheses and electrode's design are keys for the commercial success of the Sn/Si based anodes.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

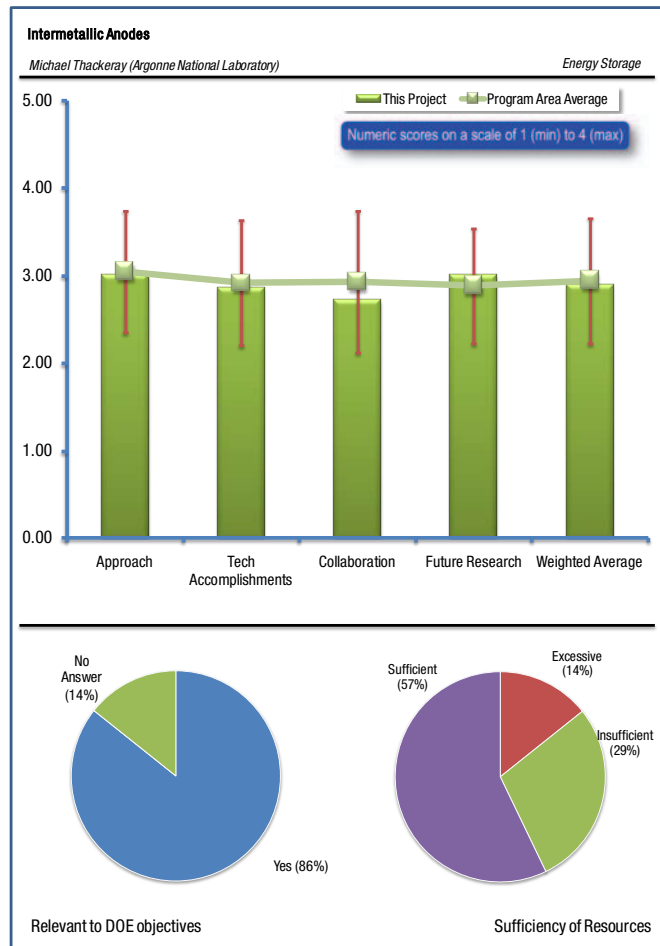
Comments were mixed in this section. The first reviewer said the approach is well focused on key barriers of metallic anodes, while another said the approach is very clear. A third reviewer said the approach is to develop anode materials with a few hundred millivolts EMF positive to Li. The purpose is to reduce the SEI formation and lithium plating problems. The emphasis is on tin and copper tin alloys on copper foam. This reviewer added that the specific energies are not much higher than graphite, however, and this will make it difficult to establish a benefit of the technology in the reviewer's opinion. Other work on autogenic reactions to form tin embedded in carbon may have a better chance at achieving high energy, however.

Another commenter said the approach is good in addressing cycling performance of the novel anode material, but does not address the irreversible capacity issue: this is a very important consideration for energy density of the cell. A fourth reviewer said electrodeposition is reasonable approach with high flexibility. In itself it is a very old and well known approach. The presenter needs to provide more clarity on what is new/unique with this approach for this particular application. The final reviewer commented that Thackeray's approach does not appear to be new or novel.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments were mixed in this section. The first reviewer said excellent progress was made on materials and preparation processes. Another commented that the test results are well analyzed, but wanted to see the comparison with the regular substrate. A third reviewer said that, while this is a new program, it follows from a previous program which developed the copper foam carrier. While the cycling appears to be good for certain mixtures, the electrode capacity is on the order of 200 mAh/g, which is substantially less than graphite. The autogenic method has produced higher specific capacity (up to 800 mAh/g), but the cycling data is preliminary.

Another reviewer said the higher anode capacity was achieved only for first few cycles. The foam Cu matrix looks helpful; however, can far overweight active materials. Is it taken into account? A fifth reviewer said Thackeray's success to date with electrodeposition of anode materials is disappointing. The final reviewer noted a very good overview of the work performed earlier, and very good initial results for the work performed under the current project objectives, but rate of progress seems low based on the results presented. This



reviewer is just curious about the possibility of using the team's 3-D Cu-foam for depositing lithium and evaluating such Li anode for the rechargeable applications. Are the autogenic reactions reproducible in terms of physical properties of the reacted products?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were mixed in this section. The first reviewer observed a good choice of partners, while another said some collaborations are mentioned but not evident in the presentation. A third reviewer said the role of collaborators is not shown, while another said the collaboration is not clear. One reviewer said that collaboration with viable industrial partner would be beneficial. The final reviewer said Thackeray may want to collaborate with Martin at University of Florida (for example) to obtain insight into production of high surface area electrodeposited material.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer felt there was very good understanding of the challenges and opportunities, while another commented that the future work is well defined. A third reviewer said the future work was good for exploratory project. Another commented that future plans will focus on the continued work with copper foams and electrodeposited alloys. The reviewer would like to see a greater emphasis placed on higher specific capacity alloys studied. The other work will continue on autogenic reaction preparations, which offer greater promise. Another commenter felt that the next period plan is not very specific. Stability of developed anode materials needs more attention. A final reviewer said Thackeray's plan should be modified to include help from others on the electrodeposition project, or it should be dropped.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Comments were mixed in this section. One reviewer said the resources seem adequate. A second commented that Thackeray's budget is excessive for this project based on the success to date. A third reviewer said the team might want to have more people to increase the rate of progress, and added that the team has a lot of potential and interesting ideas. The final reviewer said the resources seem sufficient.

Nanostructured Materials as Anodes: M. Stanley Whittingham (SUNY-Binghamton)

REVIEWER SAMPLE SIZE

This project had a total of 8 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said the search for low-cost, high-capacity anode materials is in the objectives of DOE for lithium ion batteries. Another added that anode materials must be improved to better support DOE objectives. A third reviewer said Whittingham is trying to find better anodes for lithium ion cells. Another commented the project is focused on developing materials with high gravimetric and high volumetric energy densities. The final reviewer said a high capacity anode is important for PHEV goals.

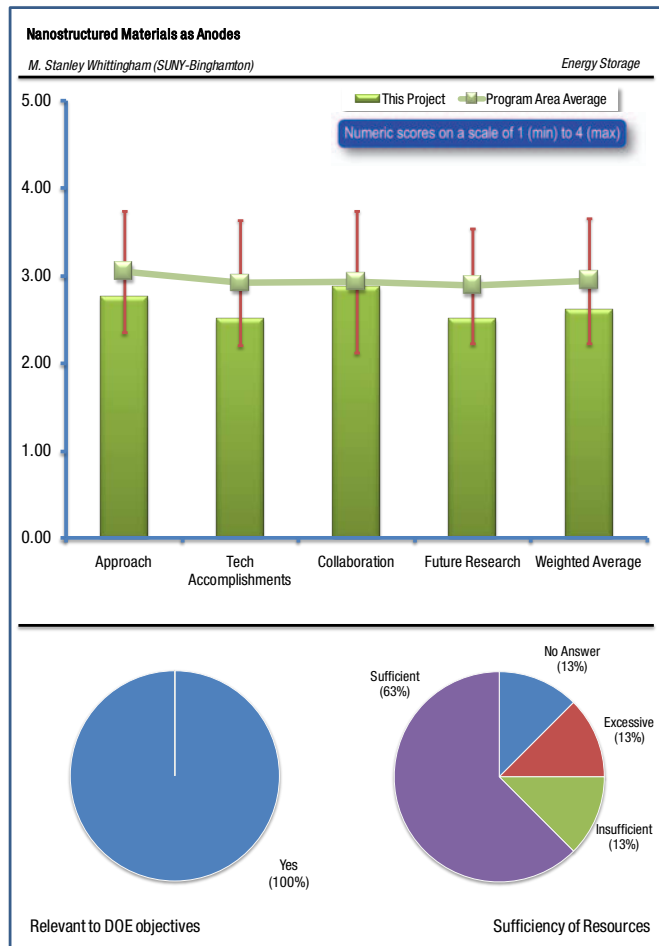
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said there is a good identification of technical barriers, while another stated the approach is well explained and allows for exploration of other than Si/Sn-based electrode materials. A third reviewer said the approach including amorphous, nanostructured, and composite materials for anodes is not brand new but still the most successful so far. It will be nice to show in some details how different is it from others in this project. A fourth reviewer said a lot of effort was expended on tin cobalt alloys, which has now been abandoned because of cost and material availability concerns. Also, it was noted that an effort on Al alloys has been abandoned because of poor efficiency and fade characteristics. This reviewer added that the present program will focus on pure nanophase tin and silicon alloys, and the reviewer agrees with this approach. Another said that Whittingham's approach could be focused more. The final reviewer said it is obvious that the PI should focus on the life for metal anode like Sn.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments were mixed in this section. The first reviewer said there were clear indications and excellent results aimed to drive selection and future work and choices. Another said good and clear progress was shown on Sn-containing materials. Well presented go/no-go criteria and data were seen. What is the expected cost reduction? A third reviewer said the results with Sn show the possibility of high efficiency cycling (at least with lower charge rates) and low cost. The right combination of properties still needs to be developed. Experiments resulted in the elimination of Sn-Co alloys and Al alloys from consideration as noted above. Si alloys formed by ball milling will probably need carbon protection to achieve the needed near 100% efficiency, however.

A fourth commenter said Whittingham's technical accomplishments are mostly negative, while another stated that the result is only charge-discharge performance. The reviewer thinks the PI needs more failure mode analysis to improve further. The final reviewer commented that the project end date is 12/31/10 and percent complete is "continuing" with more funding requested for FY11 suggesting low rate of progress vs. objectives stated for FY10. This reviewer noted interesting results for Li insertion/de-insertion rates for nano-amorphous tin. What was the electrode thickness (active material loading per cm²)? What is the density of these



materials (g/cm^3)? Also, this reviewer wanted to confirm that data presented on slides 8 and 9 is for Sn-Co-C. It will help to better appreciate results if the current density is translated into the C-rates or electrode thickness is referenced. What is the approach to mitigate the irreversible capacity losses? In general, the better the cycleability of the nano materials, the higher the surface area, the lower first cycle efficiency.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were mixed in this section. The first reviewer noted well established and reasonable collaborations, while another said the team had clearly shown collaborators' roles, but added the presentation needs more information on what they delivered. A third reviewer said Whittingham is working with others, and another said good partner selection. Another said the collaboration is not clear. The final reviewer would like to see more collaboration with others in the silicon field to take advantage of carbon-coating methods.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said the general focus is good, but would like to see more specifics. For example, this reviewer added, what approach is planned for nanoparticle protection to still meet cost/performance requirements? A second reviewer said adequate planning is observed based on results. The work on stability of anode materials needs more focus. Another noted most of the planned work is with tin, with little emphasis on Si. This reviewer would like to see a more equal balance with the two materials. Another reviewer said the plan is not clearly identified, while a fifth reviewer said the plan needs more specifics on protective layer: nature, method to create. The final reviewer said that Whittingham should consider ending this project.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said the resources seem unclear, and another said it is difficult to question on the resources as the objectives are very broad. The final commenter said Whittingham's funding is excessive based on the results obtained.

*Nanostructured Metal Oxide Anodes: Anne Dillon
(National Renewable Energy Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said high-capacity anodes are of interest for improved lithium-ion batteries, while another added novel anodes are functional to DOE objectives. A third reviewer commented on potential for improvements in both energy density and safety, which will accelerate implementation. A fourth reviewer said this work investigates alternative higher energy electrode materials, while another said Dillon is trying to find better anode materials for lithium cells. The final commenter said this kind of old material should be re-investigated with the combination of newer technology.

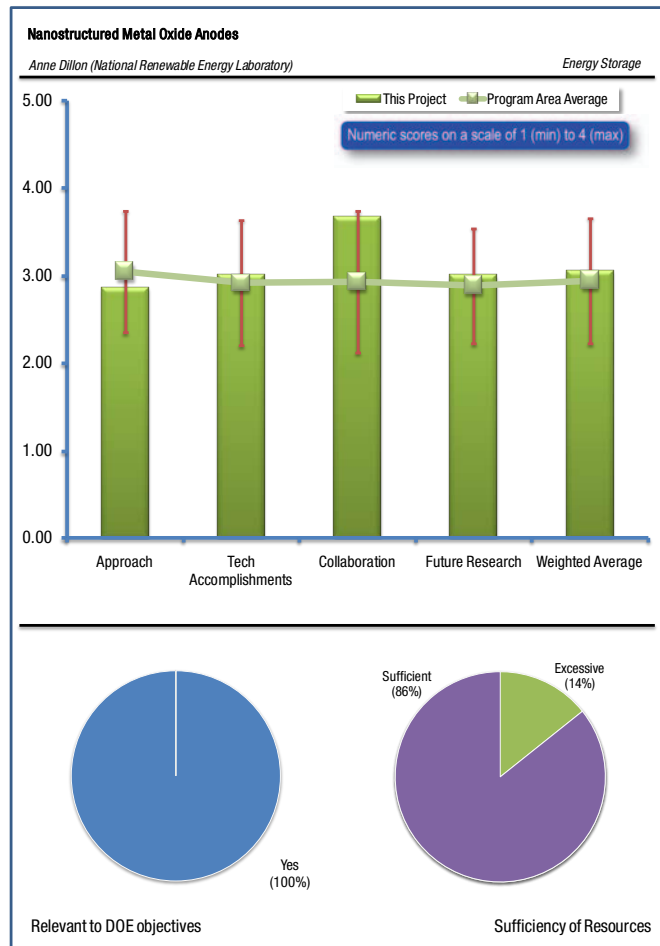
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments were mixed in this section. The first reviewer said that the atomic layer deposition approach, as well as hydrothermal process, looks very effective to meet objectives. Another reviewer said the team has well-defined the issue for the materials and is trying to apply new technology such as CNT. This seems to be a very good approach. Another said the approach is to use metal oxide nanoparticles to investigate displacement reactions involving many electrons for rechargeable anode materials. For MoO₃, hot wire CVD was used to prepare the nanoparticles and Atomic Layer Deposition (ALD) was used to coat the nanoparticles to achieve reversible reactions. This reviewer added that Fe₃O₄ nanoparticles were also investigated using a hydrothermal preparation and single wall nanotubes to construct binder free electrodes.

A fourth reviewer said technical barriers were identified but not clearly focused in the described approach. Another said excellent work was done towards novel higher energy materials / electrode structures. However, there seems to be little to no focus on the practical limitations in some areas of the approach (cost/practicality of ALD, etc.). The final reviewer said Dillon does not appear to be making progress on this project.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said relevant results well documented on both anodes. Iron-based anode is very promising. Cycle life is a key point and needs longer testing. Another commented excellent and well-presented progress. Specific capacity is great. Do these anode materials provide enough voltage differences with cathode to be practical? What was the average cell discharge voltage? Surface loading of surface capacity of electrodes was not shown. This reviewer added that, to get practical, it should be of 2 -3 mAh/cm². Another reviewer said there are more issues that remain, but added that we can see significant improvement for the life. The fifth reviewer said ALD coatings applied to the full electrode containing MoO₃ materials allowed cycling at higher rates than seen before while maintaining reversibility. The ALD coating seems to insure continued contact between the active material and the conductive phase. The full cell using MoO₃ anode with an Argonne National Laboratory cathode gave high capacity, but the voltage was



comparatively low. The specific energy of the cell was not reported, however. The use of SWNT with Fe_3O_4 gave very high capacity anode materials, but again the voltage is somewhat positive for an anode material and the hysteresis between charge and discharge is high. The final reviewer commented that Dillon has not produced useful material.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said the level of collaboration is very good and seems quite well coordinated. Another said there is good collaboration and it is clear, while a third reviewer said well-structured network of collaborations. The final commenter said there was a well-presented collaboration scheme with clear collaborator roles and deliverables.

QUESTION 5: HAS THE PROJECT 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?

Comments were mixed in this section. One reviewer said the future work is defined well, while another had no problems with future directions. A third reviewer said examination of practical trade-offs (cost of ALD, cost reduction? of binder-free) for actual implementation should have a more significant focus. Another commented that the work is heading toward a final test cell design and a decision to go or not with displacement types of anode materials. Some of the techniques developed in the program could be usefully employed with alloy structures and other anode types. A fifth reviewer said the plan is acceptable but requires more details. The final reviewer said Dillon is working with others, but this line of research does not appear to be useful.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Comments were mixed in this section. The first reviewer said the resources are sufficient. Another said the resources should be increased to extend material research with more cathodes. The final commenter said that Dillon's funding is excessive for this project, and added that it should be terminated.

*Development of High Capacity Anode for Li-ion Batteries:
Jason Zhang (Pacific Northwest National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said novel anodes are in support of DOE objectives, while another commented that Zhang is trying to develop a new anode material for lithium ion cells. A third reviewer said the project is focused on the search for the replacement materials for the matured Li-ion chemistry and the means of manufacture using low-cost production methods. The final reviewer said the high-capacity anode is important for PHEV goals.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

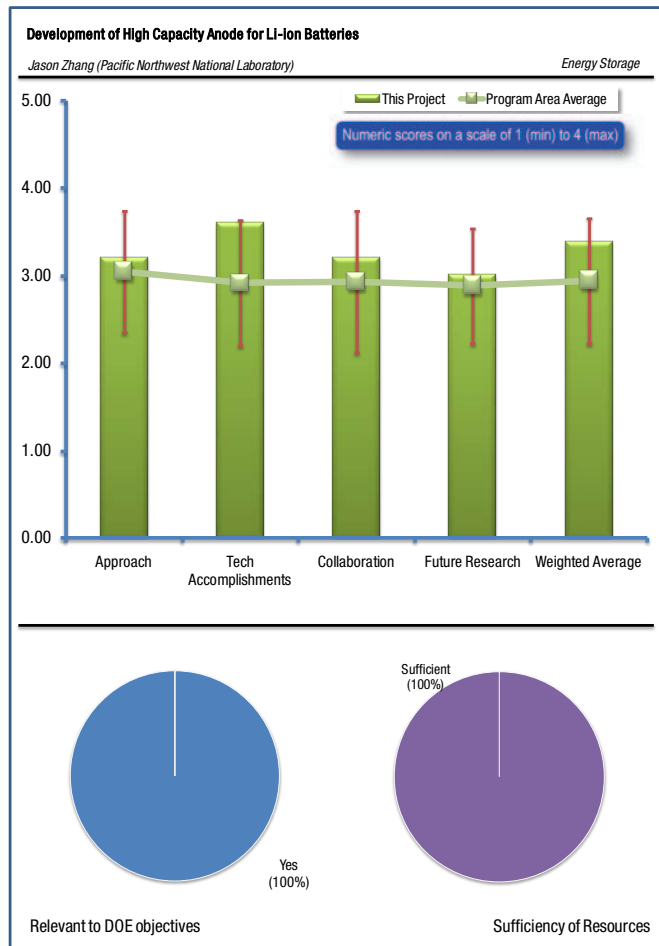
One reviewer said the approach is clear with well-identified barriers. Another stated that Zhang's approach is appropriate and novel. A third reviewer said clear understanding of the current technology limitations, and the project is well designed and integrated with other efforts. The final reviewer said using graphene sheet is new but Si+CVD was done by other groups also. This reviewer doesn't think this is new technology.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said excellent results were shown with interesting materials. A second stated that Zhang has made progress in developing new anode materials using Si and carbon. His success today is encouraging. However, he should try his material in a full cell with a cathode as soon as possible. A third reviewer said excellent work and progress are demonstrated. This reviewer's only suggestion is to compare cost of the production methods to graphite cost production, not to thin film deposition methods. In the presentation materials, this reviewer noted, capacity is shown to be close to 6000 mAh/g, above Si theoretical capacity. How can the team explain this phenomenon? Also, the first cycle efficiency is very low – does the team have a strategy to mitigate it? This reviewer suggests reporting specific capacity based on the composite material, not just Si, and also suggests translating the current density into the C-rates or provide thickness/loading of the composite material: difficult to compare to other results. The final reviewer said the data seems interesting but the reference data that the team chose is also not good.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer noted good coordination of a group of collaborations. Another said the collaboration is clear. A third said there was good outreach to allow people outside of the BATT/ABR to participate. A final reviewer said Zhang is collaborating with others. However, he should work with someone who can help him make a full cell.



QUESTION 5: HAS THE PROJECT 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?

One reviewer said the plan is consistent with the excellent results already achieved. It is recommended to analyze cost aspects and safety. A second reviewer said this is the right direction for the Si/Sn work, and added that it is very important to continue working on the binder P, important for the success of the commercialization of the Si-based technology. This reviewer would like to see more data in the future. Is the future work on SLMP as an anode targeting rechargeable or primary applications? A fourth reviewer said that Zhang's proposed work is fine except that he needs to add building full cells. Another suggested that the future work can be improved more towards to Si life issues. The final reviewer said Li-metal investigation should either be totally eliminated or should be a very minor aspect of future work.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first commenter said adequate resources were available. A second reviewer said Zhang's funding is sufficient, while another said the resources seem sufficient. The final reviewer said very good quality data and good progress demonstrated.

Electrolytes - Advanced Electrolyte and Electrolyte Additives: Khalil Amine (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said Amine is trying to develop better electrolytes, while another added electrolyte work is necessary to improve battery performances and support DOE objectives. The final reviewer commented that the electrolyte additive is a very critical key for the current lithium ion technology to improve the life and abuse tolerance.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said Amine's screening approach has merit, and another added that screening the additive by different reduction potentials is a good approach. A third reviewer observed a reasonable approach with some qualitative statement, but added that more specification of technical barriers would be preferable. The final reviewer said the proposed quantum chemical screening approach looks reasonable. This reviewer added that what is unique and innovative in this particular application is not clear.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

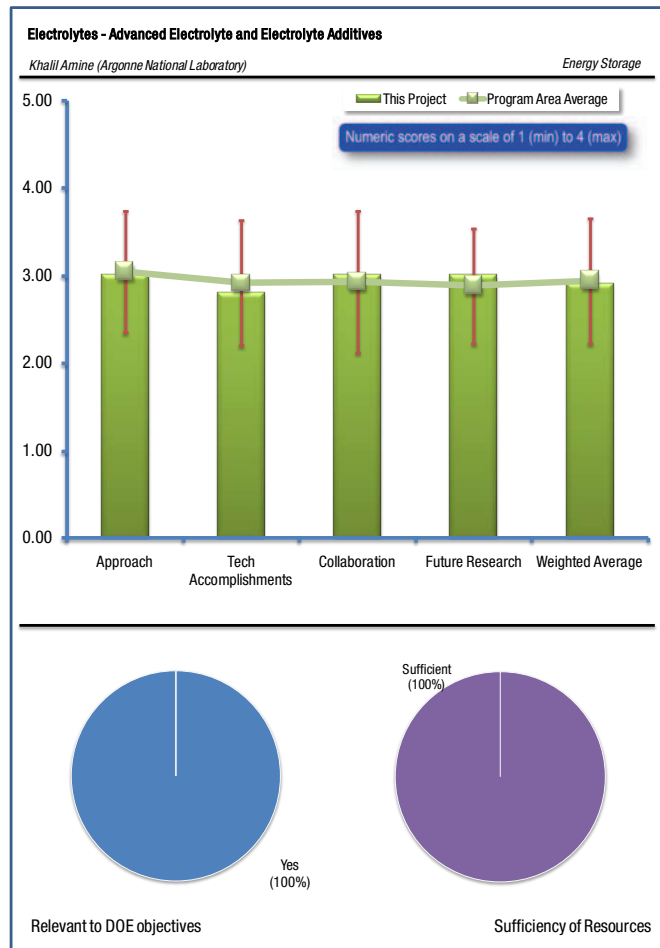
The first reviewer said Amine's discovery that LiDFOB has lower impedance and providing an explanation for same is very useful. A second reviewer noted a limited presentation with interesting results, while another stated that this is a long term program and this is just the first year, so not much progress is seen. The final reviewer said it looks like a very preliminary, early stage of the project. Does the number of 100 screened candidates really matter? What is the connection between material structure and quality of SEI formed?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said Amine is working closely with others, while another said the collaboration is clear. A third commented on the adequate collaborations. Another reviewer said there was a good collaboration plan and hopes it will result in experimental data feedback. The final reviewer said collaboration with a viable industrial partner is needed.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said the future work is defined well, and another said the future work is reasonable. A third reviewer said Amine's plans for next year are appropriate and it would be helpful to have a better understanding of the SEI formation as planned. The final



reviewer commented that the team needs better focus on objective: predict functional additives that form a stable Solid Electrolyte Interface.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said Amine's funding for this project is appropriate, while the other commenter said the resources seem sufficient.

Development of Electrolytes for Lithium-ion Batteries: Brett Lucht (University of Rhode Island)

REVIEWER SAMPLE SIZE

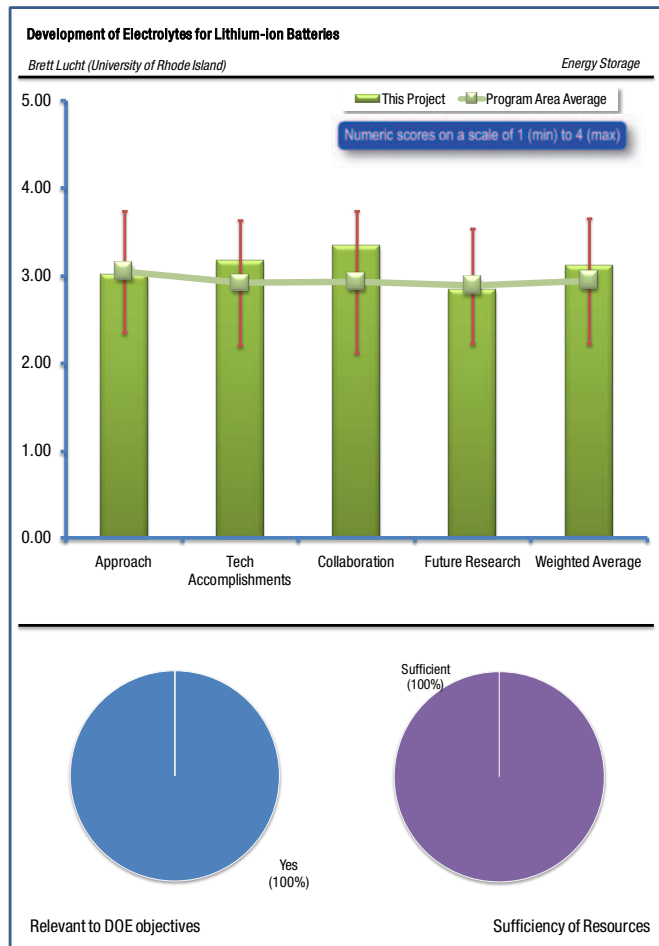
This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. One reviewer said electrolyte work is necessary to improve battery performances and support DOE objectives, while another commented that the project is attempting to address some of the key limitations with current electrolyte technology. A third reviewer said Lucht is trying to develop a better salt for use in high voltage cathode lithium ion cells, while the final reviewer added that new salt development is important to improve life.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said Lucht's approach is appropriate, while another said the approach is well focused on barriers. A third commenter noted this new salt was considered for a long time after LiBOB, but not a lot of work was done. So this is an interesting program. The final reviewer said new salt introduction is a relatively rare event for batteries and always gives more opportunities. What is the cost of new salt compared with traditional LiPF₆?



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments were generally positive in this section. The first reviewer said there were interesting results on a novel electrolyte composition. The excellent accelerated testing work should be suggested for extension to other BATT projects. A second reviewer observed a well-presented and detailed description on a novel salt. Aging and calendar life issue are well addressed. Difficult to question on additive X. Another commenter said Lucht's success in finding an additive to form a protective layer on the cathode to prevent electrolyte oxidation is interesting. The final reviewer said the result is excellent, and added that it is much better than LiBOB.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said there was a well-balanced network of collaborations, while another commented on the good description of collaborator roles. A third reviewer said Lucht is collaborating with the appropriate people, and another added that the collaboration is very clear. The final reviewer said that collaboration with a globally viable consumer electronics Li-ion cell manufacturer should be pursued.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said the future plans are defined well, while another said the future work is well aligned with achieved results. This second reviewer added that focus on stability, accelerated aging and coating effects is recommended to be maintained. A third

reviewer said the plan includes investigation of cycling behavior of $\text{LiPF}_4(\text{C}_2\text{O}_4)$ with Propylene Carbonate. Is PC the solvent beneficial for cathode? The final commenter said Lucht's plans for the future to improve further his electrolyte additives may be useful.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said Lucht's funding is sufficient, and another agreed that the resources are sufficient. The other remaining commenter said that the extension of accelerated testing to a large number of materials developed in BATT would require more resources.

Bifunctional Electrolytes for Lithium-ion Batteries: Daniel Scherson (Case Western Reserve University)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said electrolyte work with safety features is necessary to improve battery performances and support DOE objectives. Another commented that electrolyte development is important to improve the abuse tolerance. The final reviewer said Scherson is trying to develop flame retardant additives for electrolyte use in lithium ion cells.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

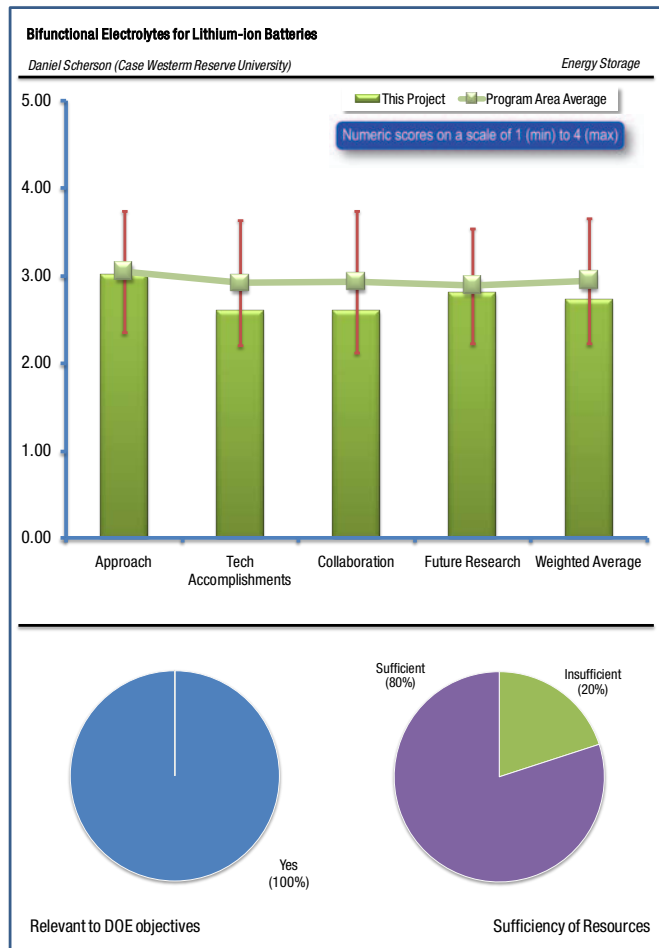
One reviewer said well-identified barriers were shown, while another said Scherson's approach to finding and testing these flame-retardant ions is appropriate. A third reviewer commented that phosphorous and boron moieties have been known as flame retardants. This reviewer asked, is the salt most effective way to introduce them into the electrolyte? The final commenter said the approach for this program is clear, but needs to confirm the other performance like life.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said Scherson's success in finding a candidate material for consideration for use as a flame retardant material is encouraging. His new spectroelectrochemical cell will be useful in this project and others. A second reviewer said they can work more with other groups to confirm the performance and abuse tolerance of the actual battery with this new electrolyte. Another noted complete characterization of the developed materials, with no evidence of the searched effect to improve abuse tolerance. Results of in-cells testing not clear. The final reviewer said development looks to be at an early stage, and added that more convincing data are needed on improved electrolyte/cell stability. It looks that salt's purity can be the issue. How is it addressed?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said there were reasonable partners and their roles. The second said there were good collaborations but the involvement of other BATT participants to verify the effect in different Li systems and materials. Another commenter stated that Scherson's collaboration with industry is useful. This reviewer added that he may also want to interact with ANL, e.g., to test his new salt in lithium ion cells being tested there. The final reviewer said they can work more to do the electrochemical test.



QUESTION 5: HAS THE PROJECT 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?

The first commenter said the future plan is defined well. Another said the planned future work is fine even if not clear, because there are undefined changes towards no presented completely new materials. A third reviewer said all bullets in the slide with the exception of the last one need more specifics. The final reviewer commented that Scherson's plans for the future are appropriate, but added that they seem to be limited in scope.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said Scherson's funding is sufficient, while the other commenter said they should have more electrochemical data to confirm the product.

*Performance and Safety of Olivines and Layered Oxides:
Guoying Chen (Lawrence Berkeley National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said novel materials for Li batteries are relevant to DOE objectives, while another noted that Chen is trying to find useful cathode materials. A third reviewer said there is definitely a need for high energy density, safe and cheap cathode materials. The final reviewer commented that this kind of basic research is very good for national lab work.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

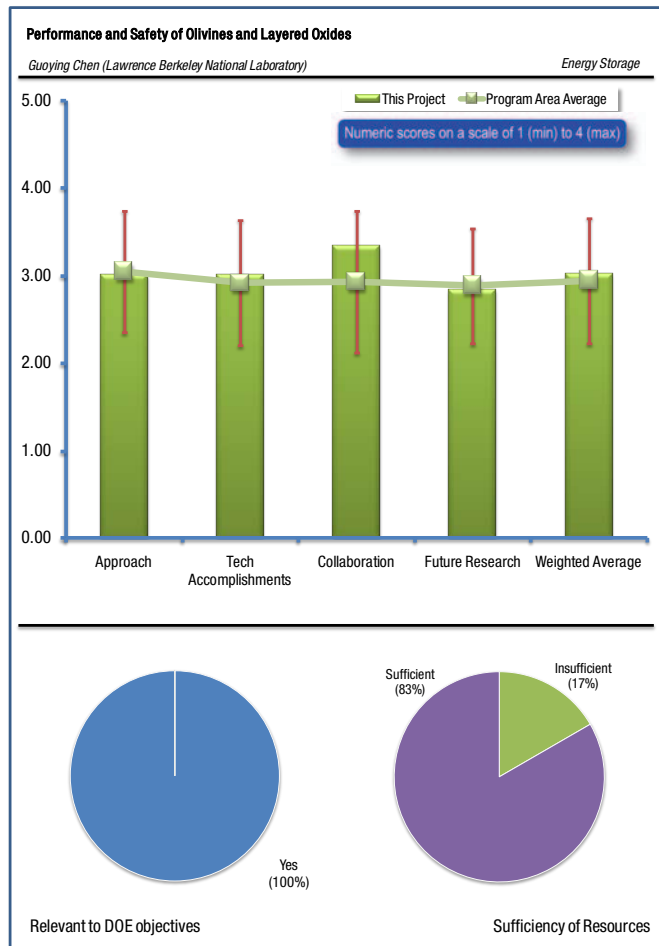
Comments were generally positive in this section. The first reviewer said that the approach is good with clear specifications on technical barriers of the selected materials. Another said this was a well-defined, classical academic approach correlating structure and performance. A third reviewer commented Chen's approach is appropriate. Another said the approach to improving the rate capability is traditional method such as Mg doping. This reviewer added that Mg doping sometimes works to improve the life. The final reviewer said very good use was made of the LBNL characterization equipment. Question: the team's approach to improve thermal stability of LMP is through substitution of Mn with Mg up to 0.5 moles. How will this approach affect the capacity of the material?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said good progress was made but more focus on the addressed objectives is necessary, and added that the key properties for Li cells should be more outlined. Another commenter said it was good from the point of knowledge gaining. More guidelines need to be generated on layered oxides improvement/stability. A third reviewer said Chen's technical accomplishments are acceptable, but it appears that LiMnPO_4 may not be a useful cathode material. A fourth commenter said milestones should better reflect the objectives; difficult to judge the degree of progress of this project. Overall, the work is very interesting and useful. This reviewer added that the team might want to consider focusing on fewer topics or add resources. The final reviewer thinks the PI will do more electrochemical study for NMC333. This reviewer added that we can see the effectiveness of Mg doping.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. The first reviewer noted well-organized collaborations, and another said that all collaborators are strong, and well organized. A third reviewer stated that Chen's collaboration is appropriate and she is publishing with her collaborators. Another commented on the good selection of partners, while the final reviewer said the collaboration is clear.



QUESTION 5: HAS THE PROJECT 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?

One reviewer said Chen's proposed future work is appropriate, while a second said that future work is defined well. A third reviewer observed a fairly good plan. A fourth reviewer said that future work is well outlined and will require significant efforts. The final reviewer said the plan lists activities but needs to be more focused on one of the objectives. Provide guidelines to design and develop electrode materials with improved energy density, rate capability, and safety, especially with regard to thermal stability.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer characterized resources as adequate, and a second reviewer agreed the resources are sufficient. Another said Chen's funding is appropriate. The final reviewer commented that the project is 30% complete, while the end date is September 30th, 2010.

Positive and Negative Electrodes: Novel and Optimized Materials: Jordi Cabana (Lawrence Berkeley National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said that high voltage cathodes and high capacity conversion reaction materials are useful in trying to achieve DOE goals. Another said new material development is important to achieve PHEV goal, while a third reviewer said novel materials for Li batteries are functional to DOE objectives. A fourth commenter said Cabana is trying to find better materials for lithium ion cells. The final reviewer said the program is focused on the development of the high voltage spinels and investigates anode materials based on the conversion reactions for higher energy density batteries.

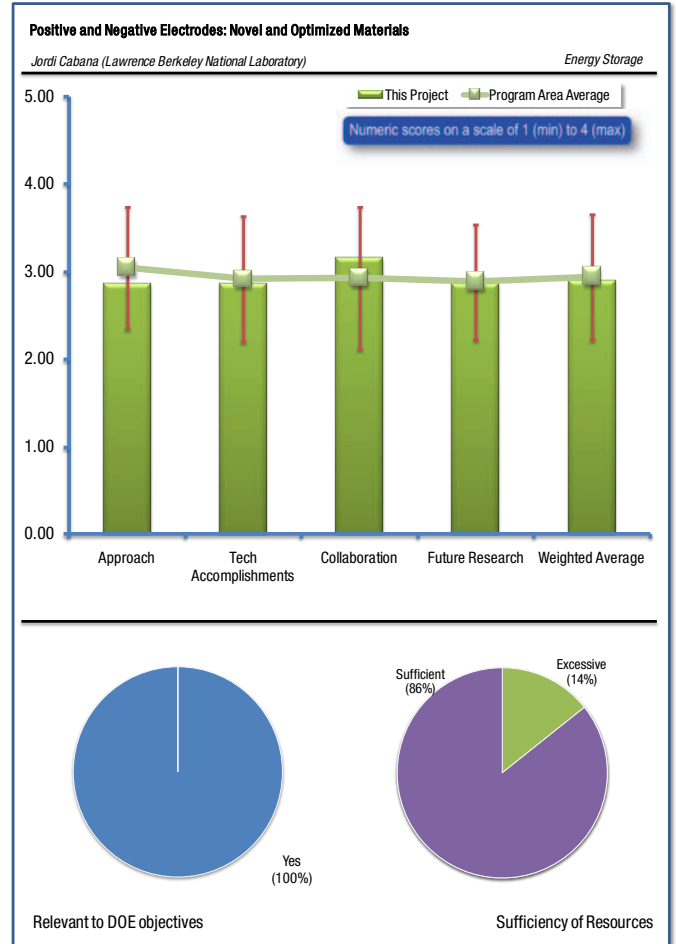
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said this was a good approach with well-focused technical barriers. Another commented Cabana's approach is appropriate. A third reviewer said there was a good selection of the characterization tools to understand the targeted correlations. This reviewer added that the team might consider partnering with companies specializing in high throughput sample production to have more effective use of the PI's expertise in characterization of materials. Another commented that the approach is fine but if the PI can work on more failure mechanisms, it would be better.

A fifth reviewer said the high voltage LNMO material is studied with structural methods which are linked to electrochemical properties. The conversion reaction of NiO and Cu-containing oxides and mixed metal oxides are studied with an emphasis on structural details of reactants and products. The final reviewer said the three bullets in the Approach slide offer certain advantages addressing the barriers, but each can be considered as a separate project. This reviewer asked, what are the connections between them in this one project?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments were mixed in this section. The first reviewer commented that this is a new program which involved setting up a new lab in the process. The structural work looks quite strong and the prospects for learning about reaction mechanisms are good. A second commenter said Cabana's finding that non nano scale particles perform better than nano scale particles is interesting. Another reviewer said interesting results even if better focus on project targets should be advisable. A fourth reviewer added that the work looks like analytical characterization, not development. This reviewer added that other items (NiO conversion and Cu-M-O) are at very rudimentary stage.



Another reviewer suggested that the PI should do more failure mode analysis for LMNO materials so the PI can improve the synthesis method even further. The final reviewer said significant progress against the objectives and milestones is demonstrated. This reviewer noted the important finding about particle's morphology on high rate performance, and added that it would be beneficial to do safety assessment as well vs. nanostructures. Conversion reactions; would be helpful to have a table of theoretical capacities vs. practical capacities for the purpose of assessing the progress.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. The first reviewer said the collaboration is clear, while a second commenter said Cabana's work with others is helpful. A third reviewer indicated a reasonable network of collaborations, while another said collaborators are strong with well-defined functions. Another commenter said good use was made of the NMR expertise. The final reviewer stated that it is useful to have substantial collaboration on a new program, and this one seems to fulfill the need.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said the plan looks comprehensive and is attacking important problems, while another said the future work is well related to the achieved results. A third reviewer said Cabana's planned future work is appropriate. Another said the future work outline is clear and supports the initial findings, while a fifth reviewer agreed the future work is clear. The final reviewer commented that the plan needs more quantified clarity about what is expected to be achieved in terms of the performance for high voltage spinel phases.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said Cabana's funding is sufficient, and another agreed that the resources are sufficient. The final commenter simply stated good progress was demonstrated.

Electrode Fabrication and Failure Analysis: Vince Battaglia (Lawrence Berkeley National Laboratory)

REVIEWER SAMPLE SIZE

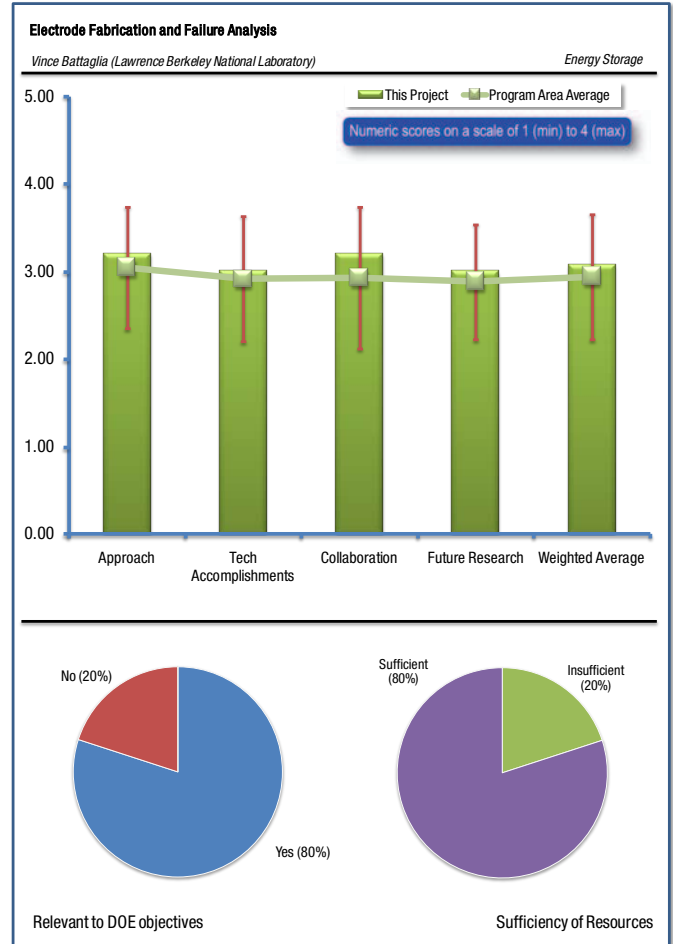
This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer said cell standards for materials characterizations for Li batteries is relevant to DOE objectives, while another commented that Battaglia is developing electrode fabrication techniques for lithium ion cells.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments in this section were mixed. One reviewer said Battaglia's approach is appropriate and useful. A second reviewer said the basic idea to have a common cell design and preparation for most BATT materials testing is the best approach to solve and verify technical barriers. Another reviewer said this was a very clear and well structured approach. However, failure modes may not be limited to those described in the approach. The final reviewer didn't believe this is national lab work, and commented that this is more engineering.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said Battaglia's results for his formation studies are very useful, especially since cell manufacturers do not reveal such information. Another commented on good progress with a clear service to the BATT subprogram. This reviewer added that it is useful to have a standard cell design (not necessarily the best one) for comparing materials and preparation processes. Another commented that the correlation of cycle life with anodes mechanical properties is impressive. Is it possible to generate quantified criteria for electrodes mechanical properties? Data/mechanisms on cathode dissolution are not clear. This reviewer added that high voltage and ordinary electrolyte showed differences but the mechanism is not shown. Is it simply different cathode cation solubility? The final reviewer said the result needs to be analyzed with more scientific method. This final reviewer asked, how does the mixing order affect the performance?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said that the networking is one of the scopes of the project and is well organized. A second reviewer noted the good collaboration slide with clear roles and contributions. Another commenter said Battaglia is working with several collaborators from different areas of expertise and interest. It would be useful if he could work with cell manufacturers who are doing cell formation. A final reviewer noted some collaboration relating to supplying materials.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said Battaglia's plans to work on stress effects will probably yield important information to assist in designing cells for maximum life time. Another said the plan related to the work already done and obviously connected to previous results. A third reviewer said "Work with Modeling group to figure out where stress is most important" sounds good for generation of quantitative criteria. The final reviewer suggested reconsidering the program.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said the resource's adequacy is strongly related to the effective collaborations and the number of samples available from BATT participants. Another commented that Battaglia's funding is at an appropriate level. It may be useful to consider providing additional funds for him to use to interact more closely with a cell manufacturer. The final reviewer could not judge if the resources are sufficient for this program.

Microscale Electrode Design Using Coupled Kinetic, Thermal and Mechanical Modeling: Ann Marie Sastry (University of Michigan)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer observed this was a modeling program to aid in electrode design to optimize battery performance, while a second commenter said modeling is useful to accelerate the development of Li technologies, which is required for meeting DOE objectives. A third reviewer commented that this kind of basic research is good for a national lab or university project. Another commenter said Sastry is trying to use modeling to help develop better electrodes for lithium ion cells. The final reviewer commented that the project is questionable, unless it enables 5V spinel, and even then, other materials are more promising.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

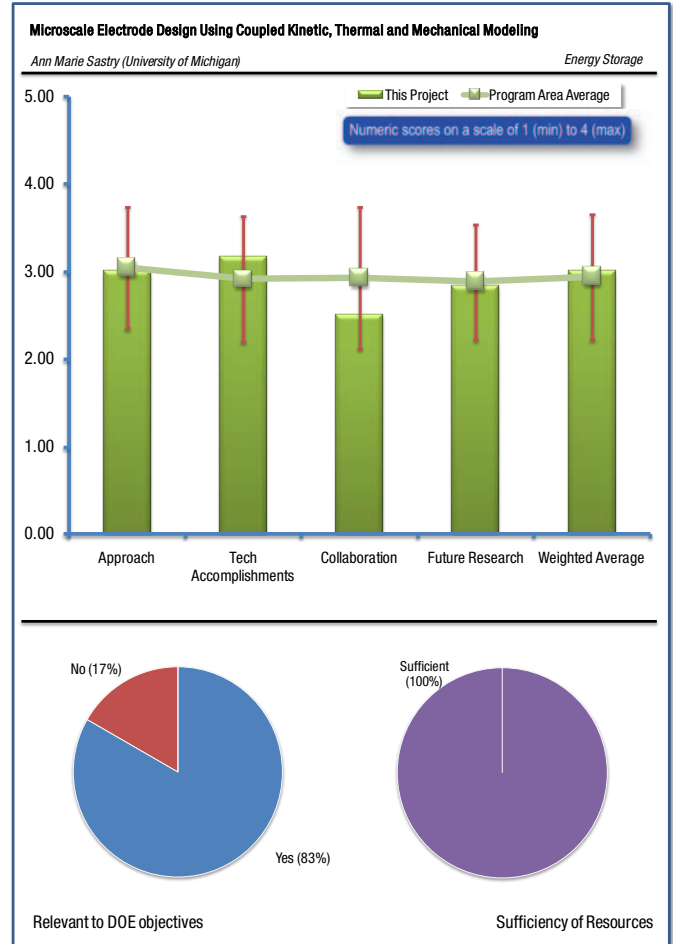
One reviewer said Sastry's approach is a valuable one because her results help cell manufacturers to understand better how their cells work. Another reviewer said the 3D microscopic electrode model is a very unique technique. A third commenter said both 3D and 1D modeling are employed to obtain the maximum information about electrode structures, including conductivity factors. Another reviewer commented on the good integration of different aspects in the modeling work. A final reviewer said multiscale modeling looks to be the most effective way to understand whole battery performance. Modeling SEI as a key player for stability is a necessary thing to do. Thermo-electrochemistry is part of approach. The role of “thermo” is not clearly shown in the presentation.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said Sastry's technical accomplishments are significant, and added that her findings for the diffusion coefficients will be useful to cell developers. Another reviewer noted the complete set of combined results with various applications in modeling work. A third commenter stated that the many variables in an electrode design result in various trade-offs in performance. This reviewer added that the results are quite reasonable in view of empirical electrode design studies and should lead to some optimal design criteria. Another reviewer said SEI layer experimental characterization looks important for further simulations. The tradeoff between ionic and electronic conductivities and its impact on porous electrode behavior and cell energy was well studied before. This reviewer asked, what did this development add to it? The final reviewer commented that the progress of this program is not clear in this presentation this year.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer observed adequate collaborations, while another noted that Sastry is collaborating with several groups. This reviewer added that she should be encouraged to work closely with GM personnel working on projects of common interest. A third commenter



said the slide did not show too much on collaboration and collaborators' roles. The final reviewer can see some company's name, but the collaboration is not clear.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said the plan is well related to the previous results, while another added that the plan is well focused on objectives. This reviewer asked if there are any plans to study nucleation mechanism and SEI forming new governing equations. A third reviewer said Sastry's plan to develop a model for the SEI formation is a good one, and added that it would be very useful to have a definitive explanation of how the SEI layers form on the anode and cathode. Another commented that the effects of SEI formation will be brought into the modeling considerations as it is known to have substantial effects on electrode conductivity. The final reviewer stated that the future work is too general.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The final reviewer said there are no budget-related slides, and cannot answer the question on resources.

Analysis and Simulation of Electrochemical Energy Systems: John Newman (University of California at Berkeley)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer said modeling programs are directed to improve performance of high energy lithium batteries, while another said the study of degradation mechanisms is helpful in supporting DOE objectives. A third reviewer said Newman is attempting to explain processes that occur in lithium ion cells. The final reviewer commented that SEI and Li dendrites need to be understood to improve the battery life.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

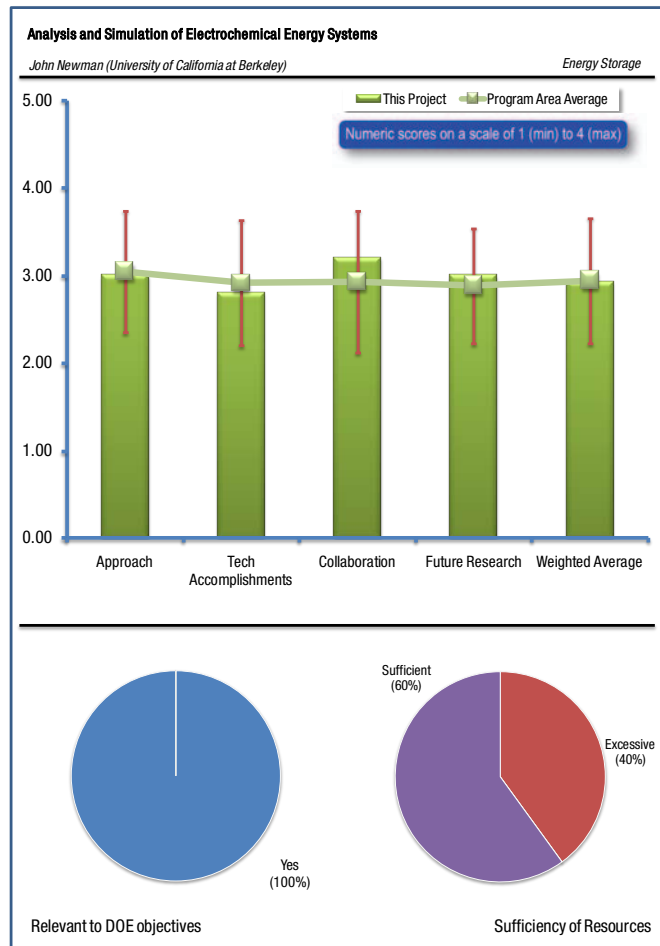
The first reviewer said there were well-identified technical barriers. A second commenter said Newman's approach is well established and useful, while another said it is an interesting approach to use redox shuttle for SEI study. The final reviewer said that rotating disk experiments are run to better understand shuttle mechanisms for overcharge protection. A new program was instituted to understand the effects of shape change of lithium metal electrodes.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said significant progress was made in mechanism comprehension, and added that the same analysis could be extended to other materials. Another commenter said Newman's explanation of how lithium plating can occur in cells is very useful. A third reviewer said that ferrocene-ferrocinium couple was shown to be a highly reversible shuttle reaction and used as a model system. It was shown that development of passivating films on the negative electrode cause a shift in the kinetics of the shuttle reaction. The model of lithium metal shape change shows that there could be a problem with this phenomenon in a lithium electrode. A detailed model will be constructed. A final reviewer said the results of ferrocenium reduction were not explained very well in this presentation yet.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said the collaboration level is outstanding, as models are applied to actual system studies in various laboratories. Another commenter said Newman's interaction with others is useful to his work. The third reviewer said some collaborations are in place, while another reviewer could see some collaboration. The final reviewer said inclusion of collaboration with external industrial partner is excellent, but shape change in Li metal anodes does not seem like a pertinent area in which to involve an industrial partner. This reviewer added, don't stop collaboration, but change to more pertinent subjects if possible.



QUESTION 5: HAS THE PROJECT 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?

One reviewer said Newman's proposed work is appropriate, while another stated that the future work is defined well. A third reviewer said future plans are adequate to the work already done, and said more focus should be placed on alternative materials where to apply the same modeling approach. The final commenter said the modeling in these areas is quite difficult, but progress does seem to be likely. A better model of shuttle behavior could be quite useful in developing a practical material. The shape change problem will be studied with a detailed model.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said Newman's funding is sufficient for this project, while a second reviewer commented that the resources are sufficient. The final reviewer said the presentation does not fully clarify the amount of work done in relation to the significant resources (budget?) used.

The Role of Surface Chemistry and Bulk Properties on the Cycling and Rate Capability of Lithium Positive Electrode Materials: Yang Shao-Horn (Massachusetts Institute of Technology)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

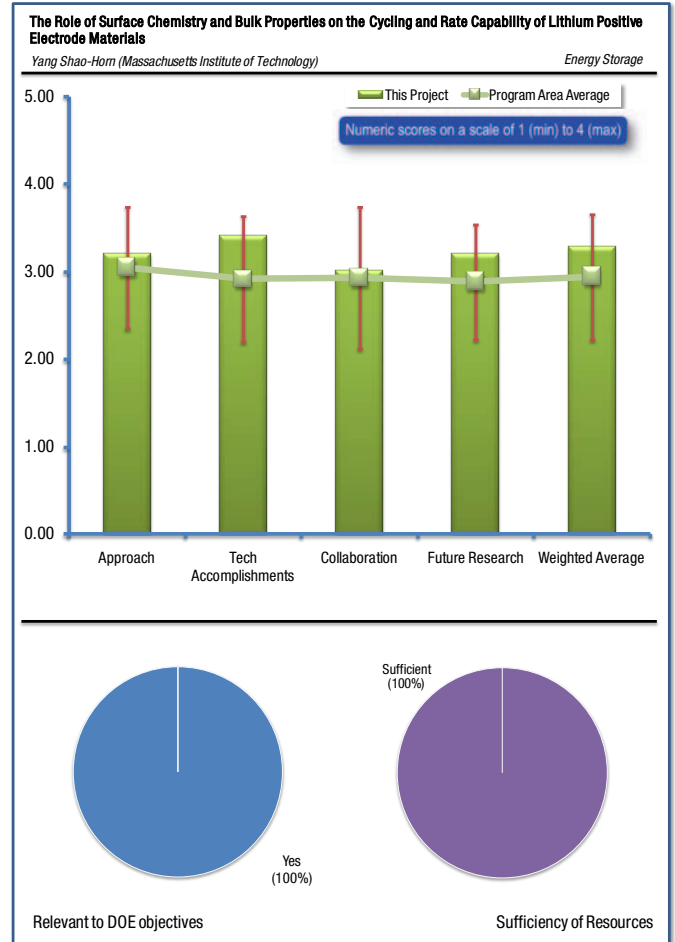
The first reviewer said structure studies emphasize the understanding of electrode problems with high capacity electrodes. They also lead to new materials. Another commented that the study of degradation mechanisms is important to favor the use of Li batteries, and a third reviewer said the cycle and rate is important performance for PHEV application. A fourth commenter said that Shao-Horn is using surface chemistry techniques to help understand better processes that occur on electrode materials for lithium ion cells. The final commenter said the current Li-ion commercially used chemistry is not only cathode-limited in terms of cathode-to-anode ratio, it is truly cathode-limited in terms of performance. Fundamental study of the surface chemistry of the cathode materials is very important to the further improvements.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said the approach is well-addressing key aspects, while another commented that Shao-Horn's approach is appropriate and useful. A third reviewer said the team is combining surface and bulk studies at the atomic level to try to understand the changes that take place in cathode materials and catalysts during operation. This seems to be a unique program in the BATT portfolio. Another reviewer said XPS is not so common to analyze Li-ion battery material. A final reviewer said the importance of the surface coatings was mostly studied in regard to the material safety performance. It has been also shown that doping materials has the same effect without the need to introduce an extra step in the manufacturing process. Limited data exist that show doping material with Mg and Ti improves both safety and performance (cycling at higher voltages and rate capability). It will be important to compare coating vs. doping. Also, could the formation of the metal fluorides be a "scavenging" of the acidic species? If a high quality, dry electrolyte is used, can the formation of the fluorides be observed?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said there was a good systematic approach and high quality work. Another commented that Shao-Horn's findings concerning annealing electrode materials are interesting and may lead to changes in the processes used to develop active materials. A third reviewer said good progress was made, but it should better demonstrated with some results on the improved life and stability. Another reviewer suggested that if the PI can provide the data other than XPS to support the results, it would be better. The final reviewer commented that the group has discovered that surface fluoride compounds are critical to good cycling behavior. To some degree, this can occur on bare surfaces if the salt is LiPF₆ (perhaps with a small amount of HF), but it can also be effected by surface coatings. In addition to enhancing cycle life, the charging efficiency is also improved. Test case materials include LCO, LNMO and



LMNO with excess Li. This reviewer added that additional work on catalysts for bifunctional oxygen electrodes has yielded outstanding efficiency in a very difficult area.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said the collaboration with Argonne has been very productive, while another agreed Shao-Horn's collaboration with Argonne personnel appears to be useful. A third reviewer said the collaboration is clear. The fourth reviewer noted only one collaboration of value, but the applications of the method to other materials are recommended. The final reviewer suggests the team look into the industry collaborations.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said there was clear understanding of challenges and proper tool selection, while another said the future work is defined well. A third reviewer commented that the plan to continue work on LMNO is a good one. This reviewer hopes that the work with ANL will continue, as the Argonne material needs better definition. A fourth reviewer said the plan is acceptable even if more materials would be preferable. The final reviewer said Shao-Horn's proposed future work is reasonable. However, it is not clear that the annealing and quenching work will be useful without guidance from a cell manufacturer.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said Shao-Horn's funding is sufficient, and another agreed that the resources are sufficient. The final reviewer commented that the progress is very good.

*Interfacial Processes - Diagnostics: Robert Kostecki
(Lawrence Berkeley National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said Kostecki is trying to develop methods for better understanding of the active material interface processes that occur in a lithium ion cell. Another reviewer said studies of important reaction mechanisms use spectroscopic techniques that are well developed by the group. A third commenter said that the study of mechanisms and diagnostics of Li batteries are functional to BATT subprogram to investigate new materials for DOE objectives. Another reviewer said this project provides valuable insight into fundamental understanding of several potential future higher energy or higher voltage Li-ion electrode active materials and identifies significant fundamental issues with these materials which must be addressed for further progress. The final reviewer commented that this kind of basic research is good for national labs.

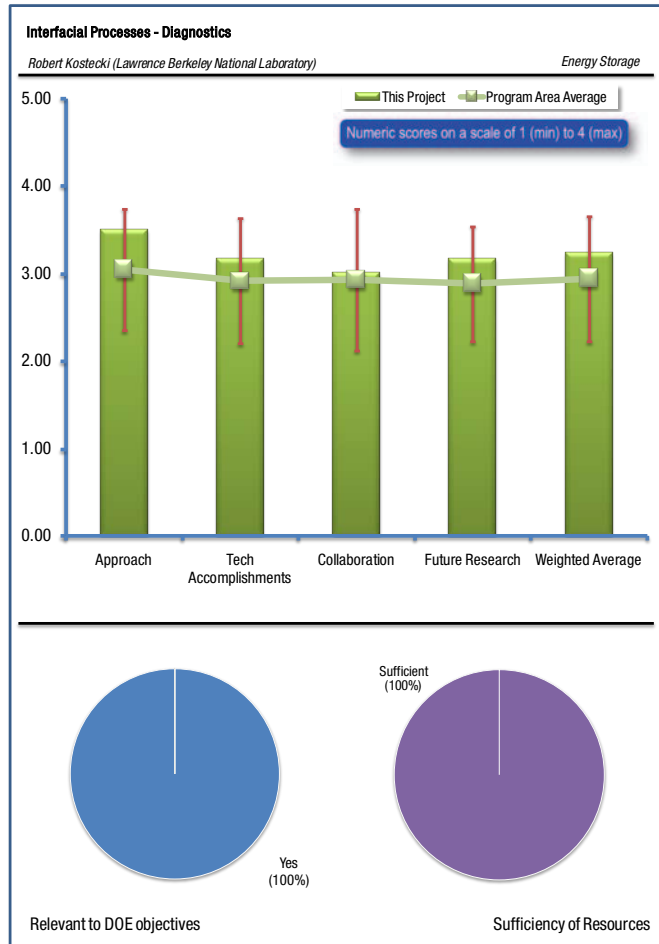
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments were generally positive in this section. The first reviewer said there was a well-focused approach to assist materials and cell development, while another noted the excellent breadth of techniques employed to investigate and characterize interfacial phenomena. A third reviewer said the approach was outstanding from point of applying various and most sophisticated analytical techniques. Another commenter said the approach is very clear, while a fifth reviewer said Kostecki's approach is adequate, and added that he may want to discuss his data analysis technique for this DS data. The final reviewer said in-situ methods have been developed to study the diffusion of lithium in Al and Sn for alloy reactions. The surface characteristics of LiMnPO₄, an important high energy cathode for lithium ion batteries, were studied by spectroscopic methods.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said excellent progress with clear indications on future improvements. Another reviewer said that observations and definitive conclusions regarding LiMnPO₄ stability in typical Li-ion electrolyte systems are of great value. A third commenter said that the SEI on Sn electrodes was found to be poorly formed for most electrolytes. The use of additives to improve this film was indicated. The oxidation of LiMnPO₄ on charge results in unstable surface species which cause degradation of the surface. This may be an important mechanism of degradation of these electrodes.

A fourth reviewer said the result is fine, and added that we want to have some improvement plan based on the phenomena that the PI observed. Another commented that Kostecki has presented interesting technical accomplishments. However, this reviewer added that it is not clear why he studied Li⁺ transport through Al. The final reviewer said the work was good for understanding of failure mechanisms. Recommendations for improvement, however, sound too generic and did not help. For instance, suggesting better additives or electrolyte to form stronger SEI without suggesting their chemical structure or nature did not help at all.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments in this section were mixed. The first reviewer said there were clear and well justified collaborations, while another said all collaborators are very strong. A third reviewer commented that Kostecki should work more closely with others around the country who are using similar techniques. The final reviewer can see a little collaboration with outside of team.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said future work is defined well, while another said future work was well related to the ongoing activities and, eventually, even better related to BATT progress. A third reviewer commented that they will study surface properties of other intermetallic electrodes and also other high voltage cathode materials. Another reviewer said Kostecki has reasonable plans for next year except for the DS experiments for electrode materials. The proposed work will probably not yield the desired diffusion coefficients for diffusion of Li⁺ in the active materials. The final commenter said the plan is excellent for understanding of failure mechanisms, diagnostics and analytical techniques development. However, this reviewer added, without better materials developed and their structures proposed, it is not clear how the project plan addressed and can meet the objective. Evaluate and improve the capacity and cycle life of intermetallic anodes and high voltage cathodes.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said Kostecki's funding is sufficient, and another agreed the resources are sufficient.

Model-Experimental Studies on Next-generation Li-ion Materials: Venkat Srinivasan (Lawrence Berkeley National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. One reviewer said modeling activities are complementary to the research and development of new materials able to support DOE objectives. Another commented this was excellent, practically based work, both from an understanding point as well as a materials design/guidance standpoint. A third reviewer thinks using the modeling for failure mode analysis is very useful. Another commenter stated that the modeling and experimental studies are carried out on next generation lithium ion electrode materials. The final reviewer said Srinivasan is using modeling to analyze data to understand better the phenomena that occur in the electrodes in lithium ion cells.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

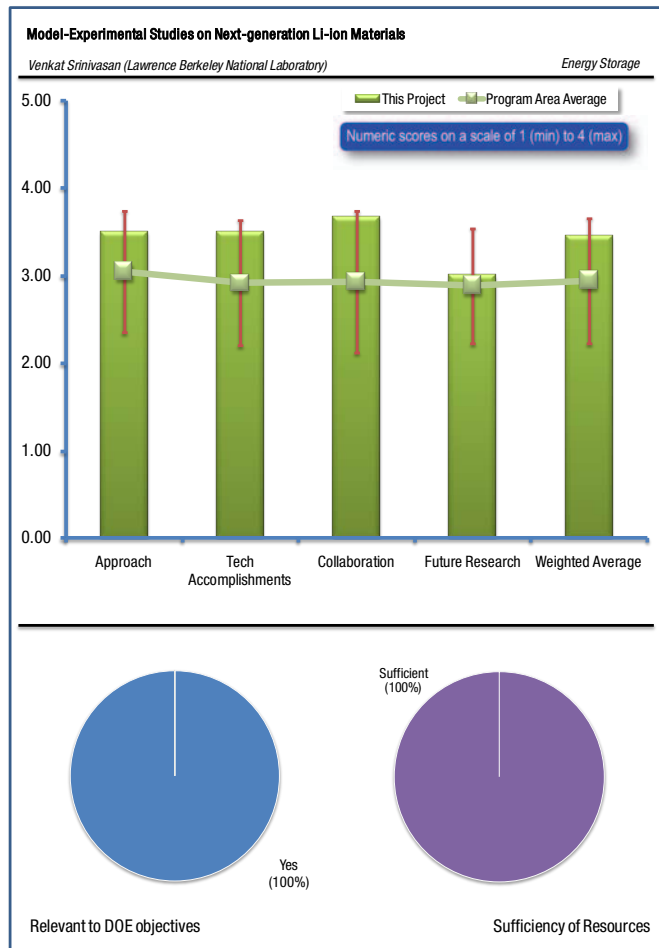
Comments were generally positive in this section. The first reviewer said the approach is well organized and addressing key barriers, while another commented that Srinivasan's approach is very useful since he is using detailed modeling to understand his experimental data. A third commenter thinks this method is a typical modeling study and very effective. The final reviewer said the approach on cathode materials is to try to understand various limiting properties on the reaction kinetics, e.g. particle size, electrode thickness, etc. This reviewer added that the approach on anode materials is to try to understand the effect of voltage hysteresis and other properties such as mechanical stress on Si cyclability.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer commented that Srinivasan's results associated with this silicon anode work are very helpful, while another said excellent progress was made in the study of the mechanisms by means of models. Stress test equipment is also interesting for general work on Li materials. A third reviewer said ultra fast LiFePO₄ electrodes are better understood as a result of modeling. Si anodes are limited due to stress factors and are aggravated at high rates of charge/discharge. This reviewer added that binder failure is an important phenomenon that should lead to careful binder selection. The final reviewer said the scope is wide but LFP results and binder-related failure analysis is very interesting. This reviewer wants to see the other materials results.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer noted the clear and well-coordinated network in BATT, while another said Srinivasan is working with others in a meaningful way. The final commenter could see a lot of collaboration.



QUESTION 5: HAS THE PROJECT 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?

The first reviewer said the plan follows the achieved results, while another commented the future work is defined well. Another reviewer said Srinivasan's proposed work is attractive, and added that understanding the stress effects in the proposed silicon anodes will be a useful result from his future work. Another suggested examining high rate cycling effects, examining a full cell Si/NMC cell and comparing to graphite negative cell, and extending stress analysis to Si electrodes to look for failure modes.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One commenter said Srinivasan's funding is appropriate for this project, and another said the resources are sufficient.

Investigations of Cathode Architecture using Graphite Fibers: Nancy Dudney (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

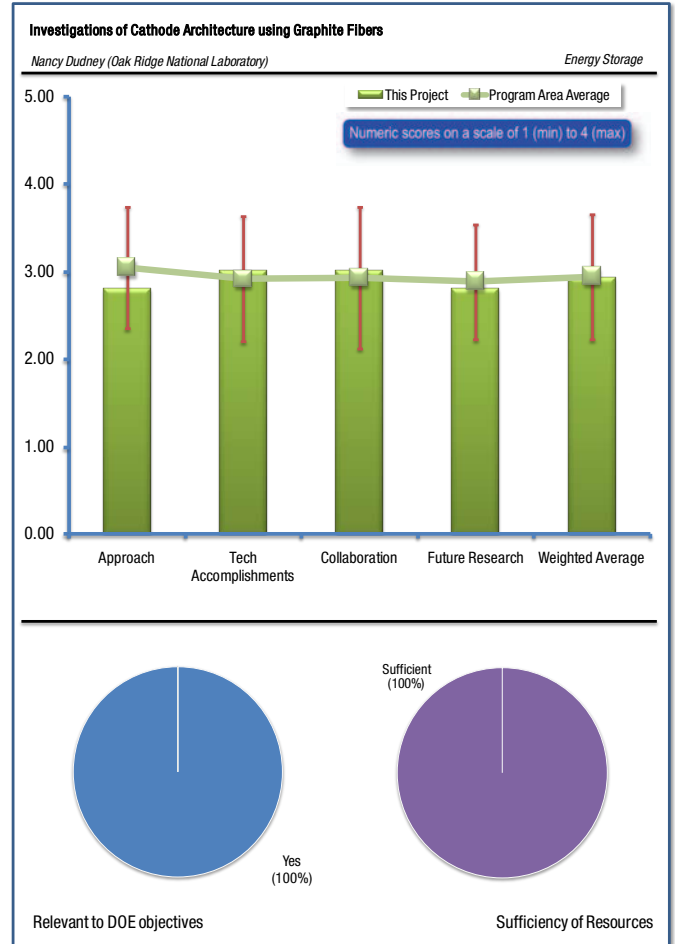
This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer said novel materials can improve performances and reduce cost to accelerate the introduction of Li batteries. Another commented that Dudney is trying to develop a novel approach to preparing cathodes for lithium-ion cells. The final reviewer said carbon fiber can be used for basic material research.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said the focus on the improvements in electrode non active materials is well motivated. The second reviewer said using a conductive carbon skeleton without blocking binder is attractive approach, but added that introduction of active material into skeleton is not an easy task and is difficult to scale up. Another commenter said Dudney's approach is appropriate for this project. However, this reviewer added the energy density appears to remain a problem. The final reviewer said this approach may be good to establish the basic material research method, but this reviewer doesn't see any benefit to using this much carbon fiber in the electrode. Practically we cannot use this much conductor in the electrode.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said significant progress has been made on novel carbon fiber support, while another commented that Dudney's novel cathode with HQ material is encouraging, but the low volumetric energy density is a concern. A third reviewer would recommend that the PI compares the power density results including conductor weight and volume. The final reviewer said full utilization of active material was achieved. However, it appears that the slurry technique applied for introducing active material into skeleton is not effective and has limitations in terms of volumetric energy density. Images of fibers filled with LiFePO₄ suggest also that due to high void volume the electrodes will be overweight with electrolyte leading to low battery specific energy.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said good collaborations in place, while another said collaborators are strong. Materials and test provided are adequate. A third reviewer commented that the collaboration is clear, while another added that Dudney is collaborating with HQ and others as needed. The final reviewer said collaboration with a viable industrial partner would be beneficial and should be aggressively pursued.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said there was an acceptable plan for future work. A second reviewer said Dudney's plans for finishing this project are appropriate. Another commenter stated there was a good plan to finalize project. To show the advantages of method explored, it may require a very different technique to fill carbon skeleton porosity with active material. The final reviewer said that just establishing the test method is fine but this solution doesn't seem practical.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said Dudney's funding is sufficient, and another agreed the resources are sufficient.

Block Copolymer Separators for Lithium Batteries: Nitash Balsara (Lawrence Berkeley National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer said new separators are also necessary to improve Li applications, while another commented that Balsara is trying to develop dry separators (block copolymers) for lithium ion cells. A third reviewer said the solid electrolyte is the next generation cells. The final reviewer said there is no evidence that success of this program will alleviate other basic limitations of Li-metal anode-based systems for long cycle-life automotive applications.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first commenter highlighted a clear focus on key specific barriers of separators. Another said this technology has a lot of barrier to be overcome: focusing on just material property is fine at this stage. A third reviewer said creating both active solid electrolyte separators and passive porous separators by block copolymer self-assembly sounds attractive. More details on nature of polymers will help for better understanding.

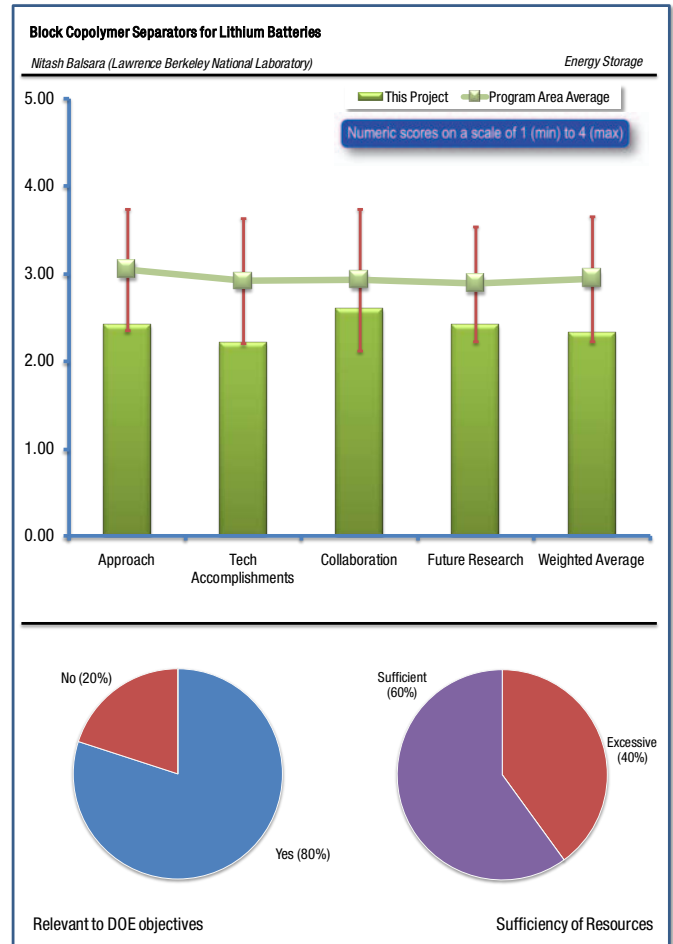
Another reviewer said Balsara's approach seems limited in scope. This reviewer added that it may be possible to make better time dependent measurements that would provide more useful information about lithium ion diffusion through block copolymers. It is probable that the materials he is studying will not be used in cells due to the very low diffusion coefficients he is report for Li+ ions. The final reviewer said insufficient technical content was provided to make a judgment.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said very good results, though another stated the gap between the target and the results needs to be clear. A third reviewer said the data presented look random and eclectic. It is difficult to conclude how they relate to battery performance. A fourth reviewer said insufficient technical content was provided to make a useful judgment. The final reviewer said Balsara's accomplishments seem to be a little thin. It is clear from his results that it is unlikely that block copolymers will provide the rate needed for lithium ion cells in vehicles.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were mixed in this section. One reviewer noted the strong collaborators with well-defined roles, while another said the collaboration is clear. Another reviewer observed acceptable collaborations. A fourth commenter said the apparent lack of involvement with viable industrial development partner at this stage is unfortunate. The final reviewer said Balsara's collaboration is weak relative to using his materials in cells for use in vehicles.



QUESTION 5: HAS THE PROJECT 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?

Comments were mixed in this section. One reviewer said the future work is defined well, while another stated the prosecution of the work is essentially related to the completion of characterization activities. Another said the plan for further evaluation in full cells is appropriate but is far overdue. A fourth commenter said Balsara's plans are reasonable, but added that it is unlikely that these materials will prove to be useful.

The final reviewer noted the PI's statement, "Complete measurement of diffusion coefficient and transference numbers of dry block copolymer electrolytes. Evaluate same in full cells." This reviewer said this statement needs clarity on what kind of cells will be tested. What are the targeted conductivities and at what conditions?

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said the resources are sufficient, while the other commenter said Balsara's funding is too large relative to the success of his program. He should be encouraged to consider some other separator material.

Interfacial Behavior of Electrolytes: John Kerr (Lawrence Berkeley National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said these activities are complementary to the research and development of new materials able to support DOE objectives. Another reviewer commented Kerr is trying to use polymers to improve the performance of lithium ion cells, while the final reviewer said the polymer is one of the key technologies for the next generation.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

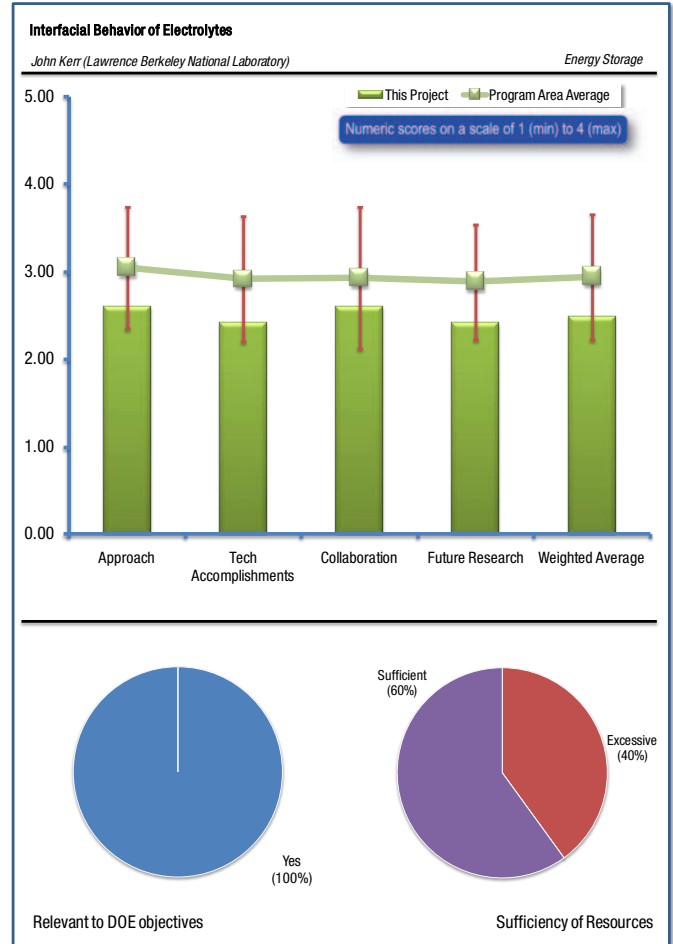
Comments in this section were mixed. The first reviewer said this is a clear and acceptable approach. Another said it is a good idea that polymers are used as binder also to reduce the polarization. Usually the interface between particle and polymer is the issue. A third reviewer stated the approach is good and includes a development of wide spectra of single Li ion conducting polymer electrolytes serving separately a variety of negative and positive electrodes. However, this reviewer added, adjustment and modification of polymers for planned electrochemical systems and particular electrodes may require resources and time far exceeding the existing project. The final reviewer said Kerr's approach seems to be of limited utility.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments in this section were mixed. The first reviewer said there were good results, and another said the characterization of material was done well. Probably PI can get more help for electrochemical study. The engineering work is sometimes important for a polymer study. A third reviewer said progress was slow because of too wide a range of materials and systems taken for investigation, and added that maybe it makes sense concentrating on something delivering more definitive knowledge and performance improvement. The final reviewer commented that Kerr's technical accomplishments are not stated clearly.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments in this section were mixed. The first reviewer said there was a well-organized network of collaborations, while another said the collaboration is done well. A third reviewer said all collaborators are strong. However, their number looks too high to be well coordinated and focusing on objectives. The final reviewer said Kerr is collaborating with others, but it is not clear that he is interacting with the right people who could help this reviewer direct his efforts.



QUESTION 5: HAS THE PROJECT 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?

Comments in this section were mixed. The first reviewer said future work related to the achieved results, while another said the future plan is defined well. A third reviewer noted too many goals for future work (3 slides) that are not necessarily focusing on objectives, while another commented that focus on a few areas of investigation is needed with specific limited number of targets. The final commenter stated that Kerr's plans to work on polyelectrolytes will probably not yield useful results.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said the resources are sufficient. A second reviewer said, taking into account the group presented and number of collaborators, the resources are sufficient but can be regrouped to meet the objectives on time. A final reviewer commented that Kerr's funding is excessive relative to his useful results.

*Advanced Binder for Electrode Materials: Gao Liu
(Lawrence Berkeley National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer highlighted new materials for improving Li cells, while another said Liu is trying to find a new binder material for lithium ion cells. A third reviewer said developing binders specifically for the use with Si-based anodes is necessary for the success of commercialization of the Si technology. The final reviewer said that new material development is important for the next generation.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

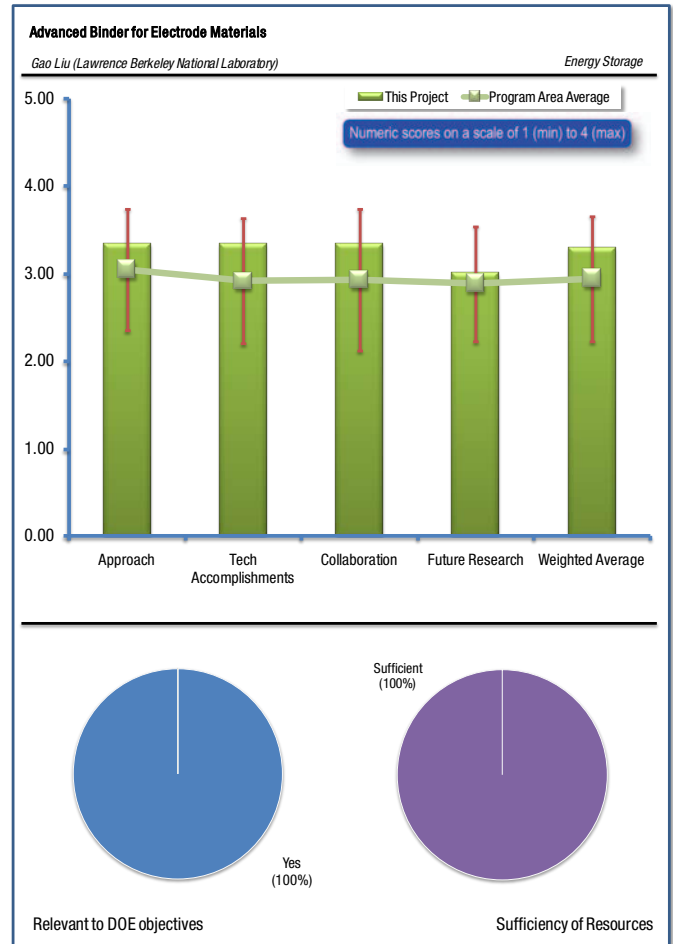
The first reviewer said Liu's approach is reasonable, while another commented that the conductive polymer for Si is an interesting idea. A third reviewer said the project is clearly focused on the effect of binder. This should remain the main activity of the project. Another commenter said the conductive binder approach for large volume changing materials looks innovative. Certain binder mechanical properties and chemical stability should be considered as well. The final reviewer said no information for the binder itself is provided, making it difficult to understand the approach in this regard.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted the excellent progress with complete experimental results, while another said Liu's results with the FMC material is interesting and may lead to useful material. Another commenter said the retained capacity looks impressive. Irreversible capacity loss and approaches to fix it did not promise a fast solution. This reviewer asked, is loss a function of binder amount? A fourth reviewer commented that steady progress towards the goals is demonstrated. This reviewer is interested in an explanation for the higher-than-theoretical capacity data. The final reviewer said the conductive polymer should work to improve the life. This reviewer wanted to see the comparison between regular polymer and conductive polymer, and also wanted to see the effectiveness of conductive polymer.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. The first reviewer said structured collaborations were shown, while another commented the collaboration is clear. A third reviewer said strong collaborators with well-defined roles were used, while another added that the collaboration with viable external industrial partners is excellent. Another reviewer said Liu's collaboration with others is acceptable. This final reviewer commented excellent choice of partners to include industry and academia.



QUESTION 5: HAS THE PROJECT 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?

The first reviewer said the future work is defined well, while another said Liu's proposed plans are reasonable. A third reviewer commented on the good plan with significantly extended life cycling. Another reviewer said that the proposed plan seems like it can overcome remaining performance problems. The final reviewer would like to see a more focused approach to developing binders, and added that this is very necessary research.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said Liu's funding is sufficient, and another agreed that the resources are sufficient. The final commenter noted steady progress, and good quality work.

*Atomistic Modeling of Electrode Materials: Kristin Persson
(Lawrence Berkeley National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said modeling activities are complementary to the research and development of new materials able to support DOE objectives. Another said that Persson is trying to use atomistic modeling to understand the processes that occur in lithium ion cells. This final reviewer said this kind of basic research is good for national lab work.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said Persson's approach is appropriate for this project, while another said that the approach to use atomistic modeling is clear, together with some related technical barriers of Li batteries. The third reviewer said the proposed atomistic modeling with calculated phase diagrams appears to be quite effective for batteries materials development. The final reviewer said people add the third element, mixed oxide or surface coated material, and those are already commercially available. This reviewer asks if the PI can work on these materials for modeling.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

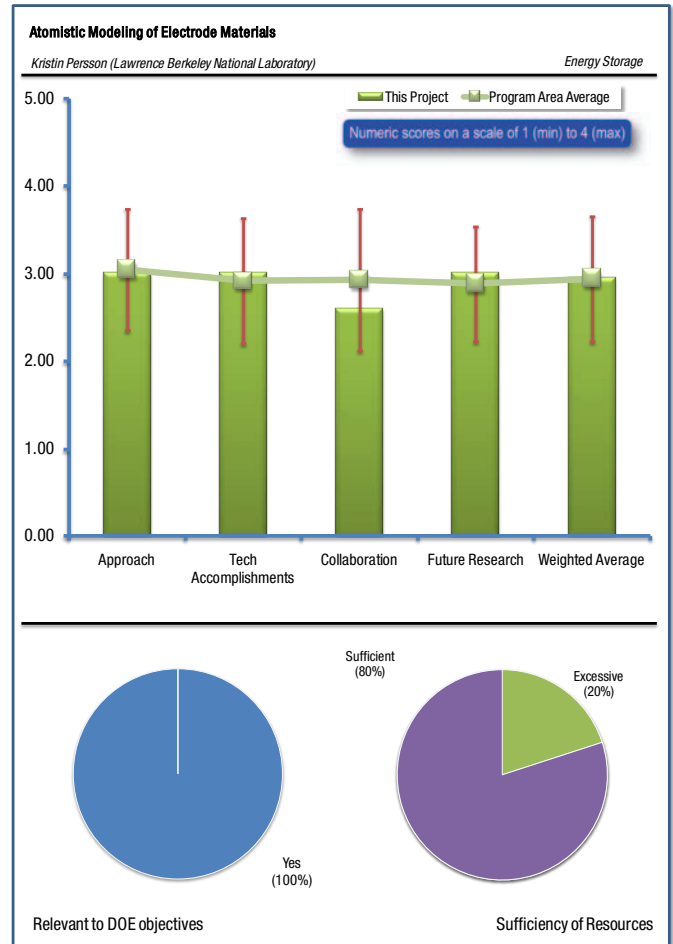
One reviewer said real progress has been made with possibility to improve materials and conductivity properties. Another observed the good accomplishments as a first step demonstrating that approach works. Particularly, Li graphite diffusion data are impressive. This reviewer added that the database development for accelerated materials design looks promising. Another reviewer said Persson's results are interesting, but it is not clear that she is providing useful information. This final reviewer asked if these modeling results can be fed back to the actual material synthesis.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments in this section were mixed. One reviewer said good collaborations with well defined collaborators' roles. Another reviewer said external (outside of VT) collaboration would be useful, while another reviewer can see a little collaboration. This final commenter said Persson should spend more time with other atomistic modelers such as Balbuena at Texas A&M University.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer felt there was an acceptable plan, while another said the future work is defined well. A third reviewer said future plans are good, but total effort should be more focused with reduced number of investigation areas. A fourth commenter said surface-effects studies are important for nano-sized materials, and added that typically all such materials are covered with SEI in the real



battery system. Any plans to include SEI surface effects? The final reviewer said Persson's plans for next year are reasonable except for the Cu work, which should be reconsidered since it is unlikely to produce useful materials.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said Persson's funding is sufficient for this project, while the other commenter agreed that the resources are sufficient.

Coupled Kinetic, Thermal, and Mechanical Modeling of FIB Micro-machined Electrodes: Claus Daniel (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer stated Daniel is trying to understand the effect of stress in lithium ion cells. Another said that theoretical activities complemented by experimental work are complementary to the research and development of new materials able to support DOE objectives. A third commenter said the project explores a novel approach to examining stress/strain behavior in Li-ion battery electrode materials, which may provide the potential for related optimization of usage conditions and increased cycle life in automotive battery systems. The final reviewer said this kind of basic research is good for national labs.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

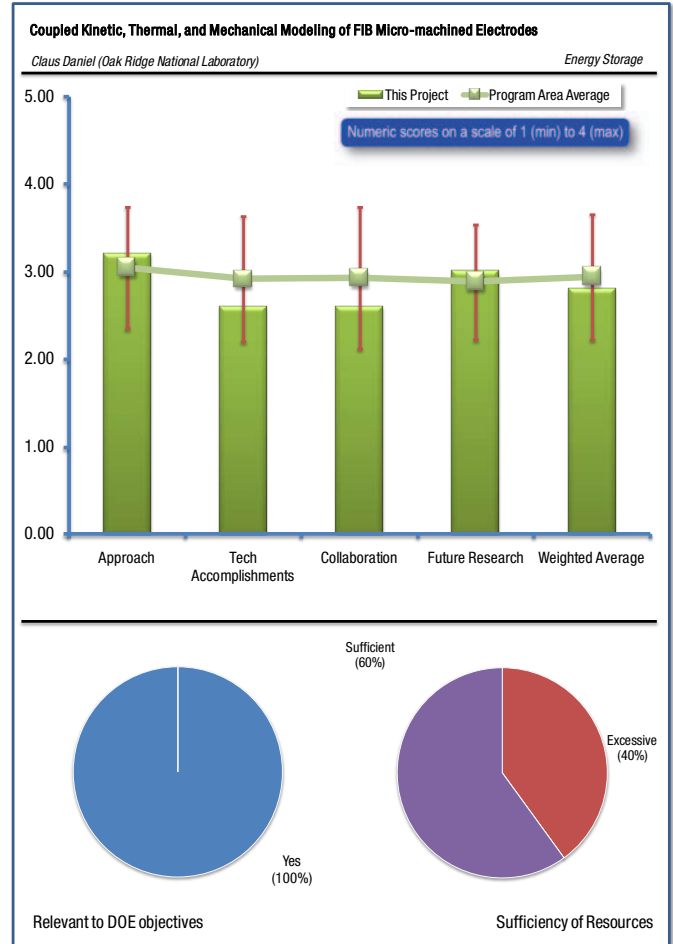
One reviewer said the work is clearly focused, while another said this seems to be a good method for fundamental understanding. A third reviewer said Daniel's approach is interesting and may lead to useful information. However, he should carry out more traditional experiments for comparison to his results. The final reviewer said the approach can deliver the most fundamental and direct understanding of stress-strain and state of charge relationships. It can be very costly expending such experiments on various cathode and anode materials and creating data base. This reviewer also asked about the influence of SEI generated on the sample surface. Can SEI affect mechanical response? SEI is a function of electrolyte nature, and it can add more complexity to data interpretation.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer felt there were good results with the possibility to be generally applied. Another reviewer commented that the project is at early stage, and added "nice images." A third reviewer said Daniel's accomplishments to date appear to be limited to establishing small-scale electrode materials and an apparent qualitative comparison to Sastry's simulation. A final reviewer said there are not too many results yet because this is a long-term project.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said Daniel's collaboration with others has been successful. A second reviewer noted only one collaboration, while another added that maybe one partner is sufficient for such an academic experimentation. The final reviewer said there was limited collaboration that could be extended to other BATT participants, contributing with materials and data for the full model.



QUESTION 5: HAS THE PROJECT 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?

The first reviewer said Daniel's plans for the future are appropriate, while another said the future work is defined well. A third reviewer said the plan addresses the objectives. The final reviewer said future work is well related to results achieved. More involvement of other BATT participants is recommended to enlarge materials analysis.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said Daniel's funding is sufficient for this project, and another agreed that the resources are sufficient. The final reviewer is not an expert in the equipment used. However, data demonstrated and normalized to budget suggest that it is a very expensive endeavor.

Long-Living Polymer Electrolytes: Christopher Janke (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

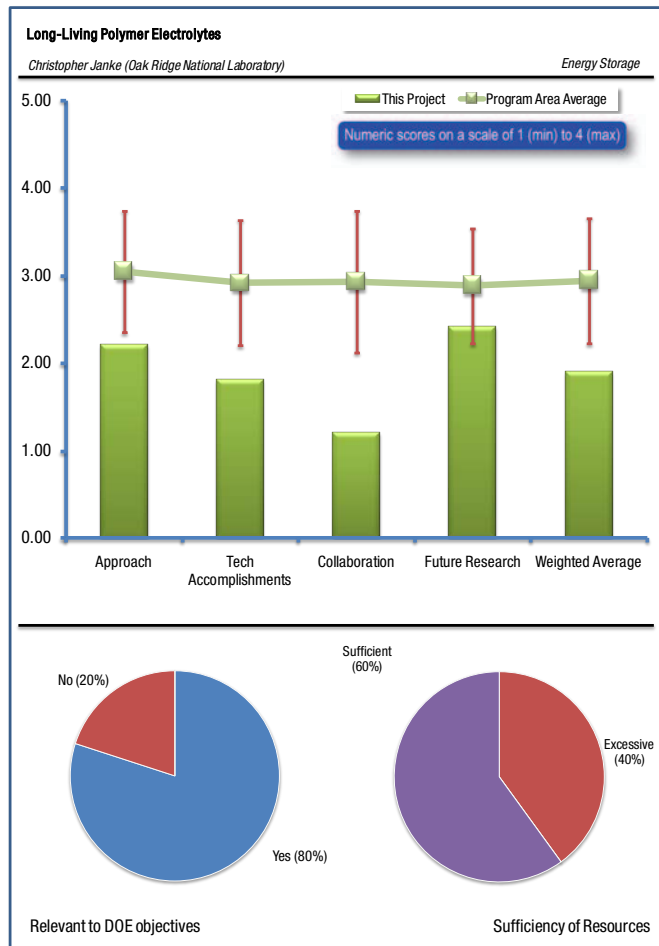
This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer said work on a polymer electrolyte may increase application possibilities for Li batteries, while another said the polymer electrolyte is key technology for next generation. A third reviewer said Janke's work appears to be directed toward preparing a better separator for lithium metal cells. The final reviewer said there is no evidence that success of this program will alleviate other basic limitations of Li-metal anode-based systems for long cycle-life automotive applications.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said this is advanced material, so the PI is focusing on the material property and general polymer issue such as Li dendrite and interface. A second commenter said Janke's approach seems to be limited in scope, while another said the interesting approach not clearly explained. A fourth reviewer said no description of the actual technical approach is provided, as any details are evidently proprietary. The final reviewer said the approach sounds innovative with possible big practical value. Is this hardening process applicable for mass production?



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said there were good results for a just-started project, while another said this project was just started, and not much progress is seen yet. A third reviewer stated Janke's accomplishments are not significant to date. Another commented said not too much data shown so far – only hardness data and no connection with conductivity or anode performance. The final reviewer said no evidence was provided to indicate that the hardened PEO films are viable (no ionic conductivity, interfacial resistance, or other electrochemical data provided), and no evidence was provided to indicate that the hardening process is viable.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The comments in this section were generally in agreement, with reviewers independently commenting that no collaboration envisaged, no collaborators shown, and no evidence of collaboration provided. A fourth reviewer said Janke is apparently not working with others, and the final reviewer commented that this project was just started and the collaboration is not seen yet.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said the future plan is defined well, while another felt that Janke's plans are not explained clearly. The third reviewer said the plan is fine, with recommendation to analyze the effect of ceramic additives in the PEO electrolyte. Furthermore, life

cycling test should be useful to confirm the effect of modified PEO on the performances of complete cells. The final reviewer said there are only iterations on formulations, treatment, etc. This reviewer asked, is the project objective to stop dendrites?

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said Janke's funding is excessive relative to his accomplishments, while the other commenter cannot judge it at this moment.

In-Situ Electron Microscopy of Electrical Energy Storage Materials: Karren More (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer stated that in-situ technology is very useful, while another commented this work is functional to new material and Li system development. A third reviewer said More is trying to understand the SEI formation using small scale electrodes with in-situ SEM. The final reviewer said advances in understanding of SEI formation processes and other processes at the electrode surface may aid automotive Li-ion battery development.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

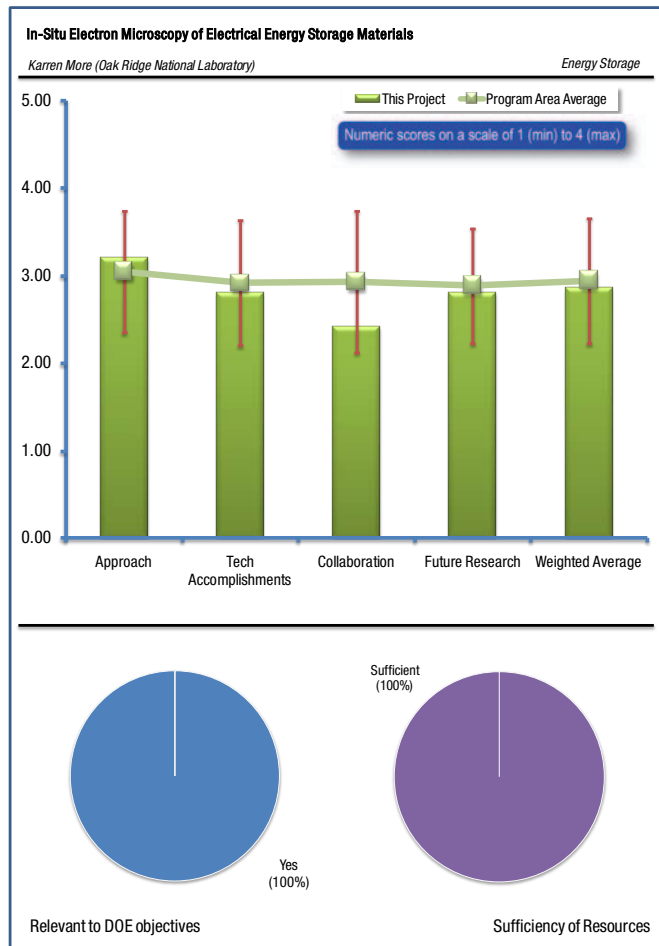
One commenter stated that the equipment will help in overcoming technical barriers. A second reviewer said More's approach is appropriate and may be extremely useful. Another thinks the approach is that the PI wants to establish a unique in-situ method for the basic research. A fourth commenter said in-situ electron microscopy characterization of electrodes and SEI can deliver valuable information, and added that it is a good approach for academic ongoing activity. The final reviewer said that, although there may be significant challenges in sample preparation, the ability to examine negative electrode carbon materials other than HOPG will be critical.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments were mixed in this section. One reviewer said More's accomplishments to date are exceptional, especially the observation of an apparent thin SEI layer on carbon. A second reviewer said the project is at an early stage and it needs more time to demonstrate the feasibility of the process, while another reviewer added that this project just started: the reviewer doesn't see the progress yet. The final reviewer commented that progress is still low and the collaboration process must be accelerated to extend the use of the proposed techniques.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said collaboration is part of the project activities. A second reviewer commented that the project is just starting, but future evidence of collaboration outside of ORNL will be desirable. Another said this project has just started, but the collaboration is planned. A fourth reviewer commented that most of the work was done by ORNL. This reviewer added that they are expecting to demonstrate better collaboration in future. The final reviewer said More should be working with atomistic scale modelers to help design her experiments and analysis of her data.



QUESTION 5: HAS THE PROJECT 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?

One reviewer said the future work is defined well, while another said the plan addresses objectives of this ongoing academic research. A third reviewer said More should add work with theoreticians. The final reviewer said the plan is described enough, and not enough clear actions are taken to address the possible collaborations to extend the use of the microbattery.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said More's funding is adequate for this project, while the other commenter cannot judge it at this moment.

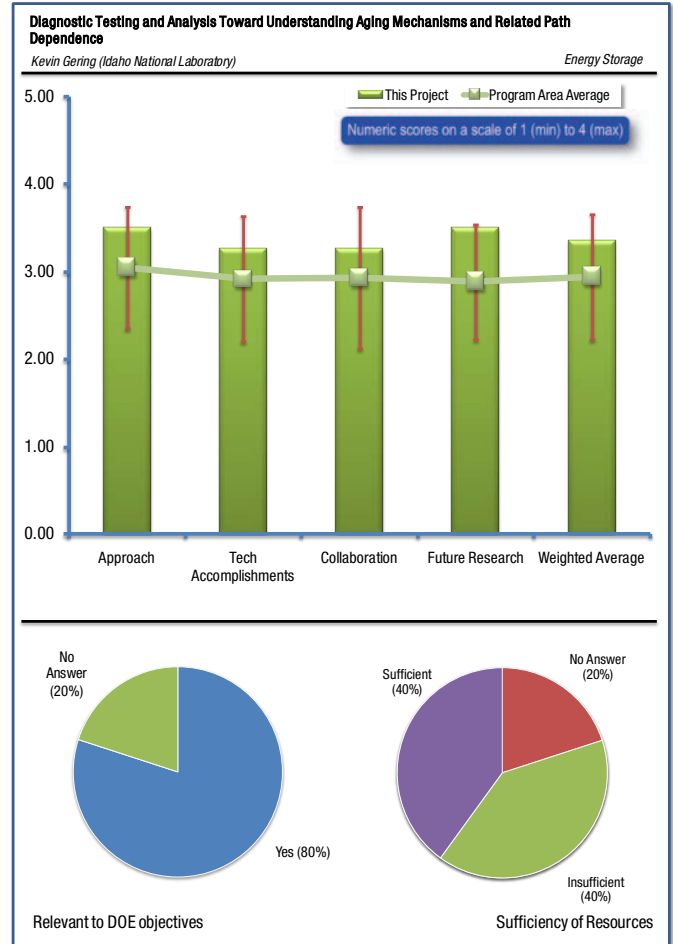
Diagnostic Testing and Analysis Toward Understanding Aging Mechanisms and Related Path Dependence: Kevin Gering (Idaho National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer said the work was very relevant, while another said this was a great attempt to develop a realistic method for estimating calendar life. The final reviewer said Li-ion batteries are yet to meet the life requirements of PHEVs and their degradation is strongly related to their usage. A quantitative understanding of this connection between degradation and use is still desirable. The objective of this study is to develop a platform of diagnostic testing (DT) that is geared toward specific issues in vehicular applications, and employ it to examine mechanistic contributions to cell aging. In addition, advanced modeling tools to complement DT will be developed and also an optimized operational protocol will be identified to minimize the generalized aging process (chemistry-specific). More specifically, the objective is to bridge the gap between ideal laboratory test conditions and PHEV field conditions. Improvement in the cycle life will enable widespread use of Li-ion batteries for PHEVs, which will reduce the petroleum consumption, and pave the way towards petroleum replacement.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments were generally positive in this section. The first reviewer said using commercially available systems to carry out the studies is an excellent idea. A second reviewer said it is very important to have work done on developing testing conditions to simulate real field conditions. We have too much gap today between laboratory tests and real life. These gaps may lead to over- or under-engineering the battery.

A third reviewer said the approach is to bridge the gap between the laboratory results and field observations by isolating the predominant aging factors, such as the nature and frequency of duty cycles, and the frequency and severity of thermal cycles. Such factors will be studied through DT in controlled and repeatable laboratory conditions to facilitate mechanistic evaluation of aging processes and path dependence thereof. Also, additional modeling tools will be developed and employed to promote diagnostic analysis over multiple domains, i.e., aging mechanisms as well as key performance issues. These approaches adequately address the technical barriers outlined here.

The final reviewer “loves the use of Sanyo cells,” as this takes out the high level of variability associated with lab cells that would likely torpedo this effort (too much “noise” from cell to cell variation in life). The methodology seems very robust and addresses some really important variables and especially how they interact in a relatively small set of batteries. This reviewer’s only concern is that this work needs to continue until a good portion of the cells actually reach end of life to capture any changes in degradation mechanisms as the cells age. However, the reviewer realizes that test position issues may preclude this. Work by Hawaii on understanding data and use of diff. capacity is also outstanding (this reviewer saw their paper in Vancouver ECS). The reviewer thinks

this work is really going to get a handle on a very thorny issue and provide an indispensable tool going forward when applied to HEV/PHEV batteries.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said this is a very timely topic and the progress made has been quite good, and recommended a focus on both. Another reviewer said it is too early to say yet, but results look very good. Programs looking at lifetime are inherently difficult to rate early in their progress; one cannot expect much at this stage and so such programs must be judged more on their approach than their 'progress'.

The final reviewer said moderate progress has been accomplished in terms of developing the Diagnostic Testing (DT) and combining with suitable models. Specific accomplishments include: i) Initiated path dependence studies with Sanyo Y 18650 cells (16) which are on-going and ii) Developed key computational methods and benchmarked on Gen2 and other Li-ion cell performance and aging data, e.g., capacity loss, cell conductance loss, performance over multiple domains, incremental capacity analysis, and equivalent circuit analysis. The early results obtained thus far are useful for assessing beginning-of-life trends and initial estimates of parameters for aging models. Finally, INL and HNEI have developed key computational tools used to model, diagnose, and predict performance and aging of electrochemical cell. The progress is consistent with the project goals.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said this showed excellent team work. Another commented that there are good collaborations within DOE, but also with external researchers. In particular, collaboration with the Hawaii Natural Energy Institute (HNEI) provides a synergistic basis due to the complementary histories of INL and HNEI in battery testing, research, and modeling. The final reviewer highlighted the good work with Hawaii. This reviewer still is not sure how this fits or doesn't fit with some of the modeling work on lifetime done at other DOE labs in the past. This reviewer asked, are they competing and/or complementary efforts?

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said the approach of pure calendar vs. aggressive and moderate cycle life is really good. The second reviewer said this was a great plan, although this work should be carried on for a lot longer than 18 months – want to get to the point where most cells “fail” or reach end of life. The third reviewer would recommend a sharp focus on developing models on failure/degradation mechanisms (how do you coordinate with Dennis Dees?). This reviewer asked, how about storing cells without any pulses?

The final reviewer commented that the future studies will include: i) monitoring the aging trends for the path dependence studies, ii) mechanistic analyses and modeling of mature data sets applying INL and HNEI modeling tools, iii) demonstration of INL diagnostic/predictive modeling capabilities through software integrating key modules regarding performance over life, iv) quantifying the impact of thermal cycling on Sanyo Y cell aging, v) extension to other duty-cycles (e.g., FUDS, DST), and other Li-ion cell chemistries. These studies will duly address the technical barriers outlined in the project.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said this is very important work that needs resources. Another commented that the budget of \$460 k per year (last year) looks reasonable and adequate for this effort. The final reviewer said again this effort is test position limited. This reviewer is also concerned that it is not going to run long enough in part because of this and the general "impatience" of a program with an annual review basis.

3. POWER ELECTRONICS AND ELECTRICAL MACHINES TECHNOLOGIES

Advanced electric drive vehicles such as hybrid-electric vehicles, plug-in hybrid electric vehicles, fuel cell electric vehicles, and pure electric vehicles, require power electronics and electrical machines (PEEM) to function. These devices allow the vehicle to use energy from the battery to assist in the propulsion of the vehicle, either on their own or in combination with an engine. Advanced technology vehicles such as hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), fuel cell hybrid electric vehicles (FCHEVs), and electric vehicles (EVs) can help meet important DOE goals, such as petroleum reduction. However, modern day PEEM technology is not sufficient to enable market-viable PHEVs, FCHEVs, and EVs. So, the Vehicle Technologies Program aims to develop these technologies by setting strategic goals for PEEM, and undertaking research projects that are carried out through collaboration among government, national laboratories, academia, and industry partners. Achieving the PEEM goals will require the development of new technologies. These new technologies must be compatible with high-volume manufacturing and must ensure high reliability, efficiency, and ruggedness. These technologies must also reduce cost, weight, and volume. Of all these challenges, cost is the greatest. PEEM project partners work together to ensure that technical attributes, vehicle-scale manufacturing, and cost sensitivities are addressed in a timely fashion and that the resulting technologies can be adopted by companies willing and able to supply products to automakers.

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

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Direct Water-Cooled Power Electronics Substrate Packaging	Randy Wiles (Oak Ridge National Laboratory)	3-4	2.40	2.80	3.40	3.00	2.80
Inverter Using Current Source Topology	Gui-Jia Su (Oak Ridge National Laboratory)	3-7	2.83	2.83	2.83	2.83	2.83
High-Temperature, High-Voltage Fully Integrated Gate Driver Circuit	Leon Tolbert (Oak Ridge National Laboratory)	3-9	3.50	3.33	2.50	3.17	3.25
A Segmented Drive Inverter Topology with a Small DC Bus Capacitor	Gui-Jia Su (Oak Ridge National Laboratory)	3-11	2.33	2.83	2.50	3.00	2.69
Novel Flux Coupling Machine without Permanent Magnets	John Hsu (Oak Ridge National Laboratory)	3-13	3.00	2.67	1.50	3.00	2.65
Benchmarking of Competitive Technologies	Tim Burress (Oak Ridge National Laboratory)	3-16	3.50	3.75	3.25	3.50	3.59
Wide Bandgap Materials	Mahdu Chinthavali (Oak Ridge National Laboratory)	3-18	2.75	3.00	2.50	2.75	2.84
High Dielectric Constant Capacitors for Power Electronic Systems	Uthamalingam Balachandran (Argonne National Laboratory)	3-21	3.00	3.00	3.50	3.00	3.06
High Temperature Polymer Capacitor Dielectric Films	Shawn Dirk (Sandia National Laboratories)	3-23	3.67	3.00	4.00	3.67	3.38
Glass Dielectrics for DC Bus Capacitors	Michael Lanagan (Pennsylvania State University)	3-25	3.00	2.50	2.50	3.00	2.69

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Advanced Soft Switching Inverter for Reducing Switching and Power Losses	Jason Lai (Virginia Tech)	3-27	3.50	3.60	2.67	3.50	3.45
Development, Test and Demonstration of a Cost-Effective, Compact, Light-Weight, and Scalable High Temperature Inverter for HEVs, PHEVs, and FCVs	Ralph Taylor (Delphi Automotive)	3-29	3.40	2.60	3.60	2.80	2.95
Scalable, Low-Cost, High Performance IPM Motor for Hybrid Vehicles	Ayman El-Refaie (General Electric Global)	3-31	3.20	3.20	3.20	3.20	3.20
Advanced Integrated Electric Traction System	Greg Smith (General Motors)	3-33	3.50	3.00	3.67	3.50	3.27
Permanent Magnet Development for Automotive Traction Motors	Iver Anderson (Ames)	3-35	3.25	2.50	3.75	3.50	2.97
Power Electronic Thermal System Performance and Integration	Kevin Bennion (National Renewable Energy Laboratory)	3-37	3.33	3.00	2.67	2.67	3.00
Thermal Stress and Reliability for Advanced Power Electronics and Electric Machines	Michael O'Keefe (National Renewable Energy Laboratory)	3-39	3.33	3.00	3.33	3.33	3.17
Characterization and Development of Advanced Heat Transfer Technologies	Gilbert Moreno (National Renewable Energy Laboratory)	3-41	3.00	4.00	4.00	3.00	3.63
Air Cooling Technology for Power Electronic Thermal Control	Jason Lustbader (National Renewable Energy Laboratory)	3-42	3.33	3.00	3.33	3.33	3.17
A New Class of Switched Reluctance Motors without Permanent Magnets	Tim Burress (Oak Ridge National Laboratory)	3-44	2.60	2.80	2.20	3.00	2.70
Bi-directional dc-dc Converter	Abas Goodarzi (U.S. Hybrid)	3-46	3.20	3.20	2.00	3.00	3.03
Novel Packaging to Reduce Stray Inductance in Power Electronics	Leon Tolbert (Oak Ridge National Laboratory)	3-48	3.50	3.00	3.00	3.00	3.13
Power Device Packaging	Fei Wang (Oak Ridge National Laboratory)	3-50	2.75	3.00	3.00	2.75	2.91
High Power Density Integrated Traction Machine Drive	Fei Wang (Oak Ridge National Laboratory)	3-52	2.60	3.00	2.40	3.20	2.85
High-Temperature Air-Cooled Traction Drive Inverter Packaging	Mahdu Chinthavali (Oak Ridge National Laboratory)	3-54	3.25	2.75	3.00	3.00	2.94
Electro-thermal-mechanical Simulation and Reliability for Plug-in Vehicle Converters and Inverters	Allen Hefner (NIST)	3-56	4.00	2.67	3.33	3.00	3.13
Development of SiC Large Tapered Crystal Growth	Philip Neudeck (NASA)	3-58	2.50	3.25	2.50	2.75	2.91
Thermal Performance and Reliability of Bonded Interfaces	Sreekant Narumanchi (National Renewable Energy Laboratory)	3-61	3.75	3.00	3.50	3.25	3.28

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
<i>Thermal Management of PHEV / EV Charging Systems</i>	<i>Kevin Bennion (National Renewable Energy Laboratory)</i>	3-63	4.00	2.00	3.00	3.00	2.75
<i>Motor Thermal Management</i>	<i>Kevin Bennion (National Renewable Energy Laboratory)</i>	3-64	2.67	2.00	3.33	3.33	2.50
<i>High Performance Permanent Magnets for Advanced Motors</i>	<i>Jinfang Liu (Electron Energy Corporation)</i>	3-66	2.75	3.00	3.00	2.50	2.88
<i>Low Cost, High Temperature, High Ripple Current DC Bus Capacitors</i>	<i>Ed Sawyer (SB Electronics)</i>	3-68	3.00	4.00	3.00	3.00	3.50
OVERALL AVERAGE			3.10	2.97	2.91	3.09	3.01

NOTE: Italics denote poster presentations.

Direct Water-Cooled Power Electronics Substrate Packaging: Randy Wiles (Oak Ridge National Laboratory)

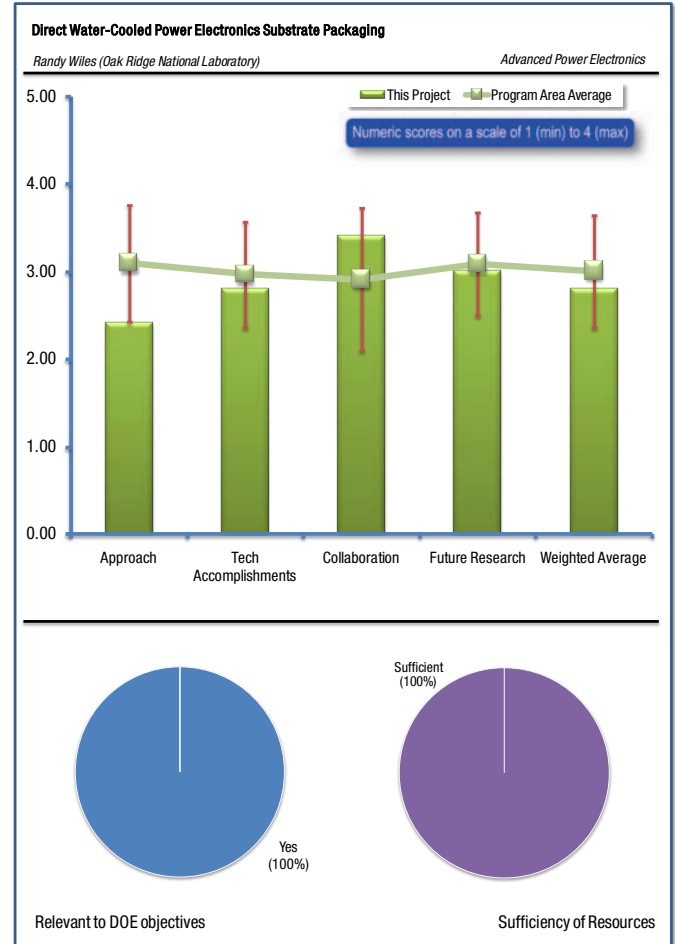
REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer commented that temperature reduction is critical for power electronics and the power devices, adding that the approach is to reduce the cost while maintaining the performance. This reviewer was not clear on the module testing, but stated that this is a good approach that, if successful, will be a game changer. A second reviewer said this project supports the DOE goals for power density and cost. It is a novel packaging method that improves thermal efficiency and improves device reliability. A third comment was that the smaller, lower-cost power stages for inverters help to enable lower-cost inverters for electrified inverters.

Another reviewer mentioned the reduced size and weight, adding that this may reduce material/manufacturing cost, but that this is not clear yet. The final commenter said that this potentially reduces thermal resistance from chip to coolant, noting a possible volume and weight reduction. This reviewer felt it was questionable whether it reduces system volume or cost.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer commented that this is a good approach and can reduce the weight and size of the cooling system. This reviewer added that more testing is needed on the system, as well as more information on cost reduction. Simulations were shown but the reviewer would need to see more testing to verify the performance of the design.

Another reviewer stated that this is a good novel approach to eliminating material layers and contacts, but there are issues with the geometric design. This may reduce cost and weight, but it is not clear how it is reducing the thermal resistance. This reviewer adds that uniformity of thermal resistance to different parts of the chip may be a major issue. If the thermal resistance to fluid is not uniform, it may accelerate the initiation of current nonuniformity and failure mechanisms. The lack of symmetry may also increase TCE mismatch stress. These issues could be evaluated using simulation. There are other ways to reduce thermal grease and thermal stack. The proposed method may result in a very thick ceramic and higher thermal resistance than other approaches. In the end, the chip area had to be increased to reduce thermal resistance. This defeats the whole purpose.

A third reviewer felt that this project is a novel idea, but may be more costly and have poorer performance than commercially available direct ceramic-cooled approaches, such as a direct liquid-cooled AlN chill plate. The results of this design should definitely be benchmarked/compared with existing products and other similar technologies published in the open literature. This comparison/benchmark should have already been done. The reviewer adds that the presenter did not appear to be aware of competing approaches and how this approach compared with them. If this approach does not yield a lower junction-to-coolant thermal resistance than existing approaches, further effort should be discontinued. This reviewer added that the assembly process (chip soldering,

wirebonding, terminal attach, dielectric gel potting, etc.) will be difficult and probably expensive. This should be evaluated as a part of future efforts.

Another commenter felt that the concept to eliminate the heat sink and baseplate has merit in terms of thermal effectiveness. The conceptual model shown should function on the bench, but it needs more design work before it would be robust enough for automotive applications. The major drawbacks that this reviewer sees for this concept are: 1) sealing of the ceramic cylinders to the manifold under shock and vibration, 2) performing die attach and wire bonding using standard manufacturing equipment, 3) potentially large parasitic inductances since currents may have to travel around the cylinder, 4) large mass of the substrate, and 5) ineffective cooling due to small surface area of the coolant cavity. This reviewer added that other cooling technologies, such as indirect jet impingement (Danfoss Shower Power, for example), use submerged impingement jets to increase turbulence and surface area, and would be more thermally effective in addition to using standard planar substrates and manufacturing techniques.

One final reviewer stated that it is not clear how much silicon area is required to meet the group's junction temperature claims. Adding more silicon increases cost, and the reviewer asked that in the future the group please state the silicon area. Also, for the junction temperature claims, the group showed the power but not the current required for that junction temperature. Please state device current that creates the power losses. Also, this final commenter asked about the flow rate and pressure drop required for these junction temperatures.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the project is on track for transitioning the new approach to sample and system demonstrations. Another reviewer stated that the program seems to be on schedule, adding that just assembling this mechanical configuration and obtaining experimental results is a significant achievement. It is important to calculate the overall thermal resistance from junction to liquid for each switch and each chip from the experimental results and compare/benchmark with other similar technologies as a go/no go criteria. A third reviewer added that progress has been good considering the novel technique and new processing steps. However, there is much more to be done to make this a commercial automotive product.

Another commenter stated that the team met the 13.4 kW/L target, which is good. This reviewer felt that it was not clear what the goals were for the design, adding that there were no calculations on the inductance for the buss. The team needs to conduct temperature cycling testing and evaluation, and should also conduct transient testing on the modules and in simulations.

A final reviewer stated that more work is required – thermal shock on the bonded ceramic, -40°C to 175°C. This reviewer added there are many internal seals in the inverter. How does the team address the long term possibilities of leaks? Over time and temperature, what is the expected degradation of the cooling channels? How is the bus bar attachment made to the power stage? Is there some strain relief between the bus bar and the power switch? Is there a plan to thermal cycle the power switch module with the bus bars attached?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said that there is a good team and set of partners working on the project. Another commented that the industry team members are good selections, adding the team really needs to keep a close eye on their plater. They are all problematic from time to time, since it is a process that is typically hard to control.

A third reviewer indicated that the team needs a good collaboration with simulation and reliability efforts for this new geometry and material configuration. A final reviewer believes that most of the work has been with subcontractors to resolve issues with die attach and wire bonding. This reviewer doesn't believe that other institutions are heavily involved.

QUESTION 5: HAS THE PROJECT 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?

Reviewers offered a number of suggestions here. The first indicated the need to address some issues of buss structure and uniform temperature of the devices, adding that overall the plan is good and will address some of the technical barriers. Another reviewer said that the project's goal of producing a circuit demonstration is good, but it may be better to take a step back and perform simulations of temperature uniformity, thermal resistance, and to perform thermal cycling and thermal shock experiments on the new thermal stack even with dummy device samples, rather than moving forward with making full-up modules. A third reviewer offered the following recommendations: 1. Investigate using high-temperature plastics for the manifolds like those used in auto radiators. 2. Perform 3-D inductance analysis to determine parasitic. 3. Remove center mass and fill with non-porous material. 4. Determine how to coat substrates with soft-gel.

Another reviewer suggested that the team is approaching the immediate problems, but should also consider some of the longer-term potential problems. Will filtering be required for long-term performance of the coolant channels? Also, their junction temps over time will increase; do they expect to be under 175°C at end of life for these junction temperatures? When they showed their power stage there was no controller; is there a plan to include the controller in their inverter package? What is the size of the finished inverter package?

A final reviewer stated that a comparison / benchmark of the experimental and simulated thermal results with other approaches must be completed as soon as possible, and a go/no-go decision made. If the performance is comparable / superior to other approaches, then this reviewer recommends that some reliability evaluations be conducted on: 1) ambient temperature cycling, and 2) thermal (power) cycling. The team also needs to look at actual temperature uniformity across each diode and IGBT chip experimentally and relate to long-term reliability. They need to assess effect of this octagonal geometry on overall system size, terminal/busbar placement, inductance, etc. and compare with existing designs. This reviewer added that the assembly process (chip soldering, wirebonding, terminal attach, dielectric gel potting, etc.) will be difficult and probably expensive. This should also be evaluated as a part of future efforts.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

There were no comments for this aspect of the research.

Inverter Using Current Source Topology: Gui-Jia Su (Oak Ridge National Laboratory)

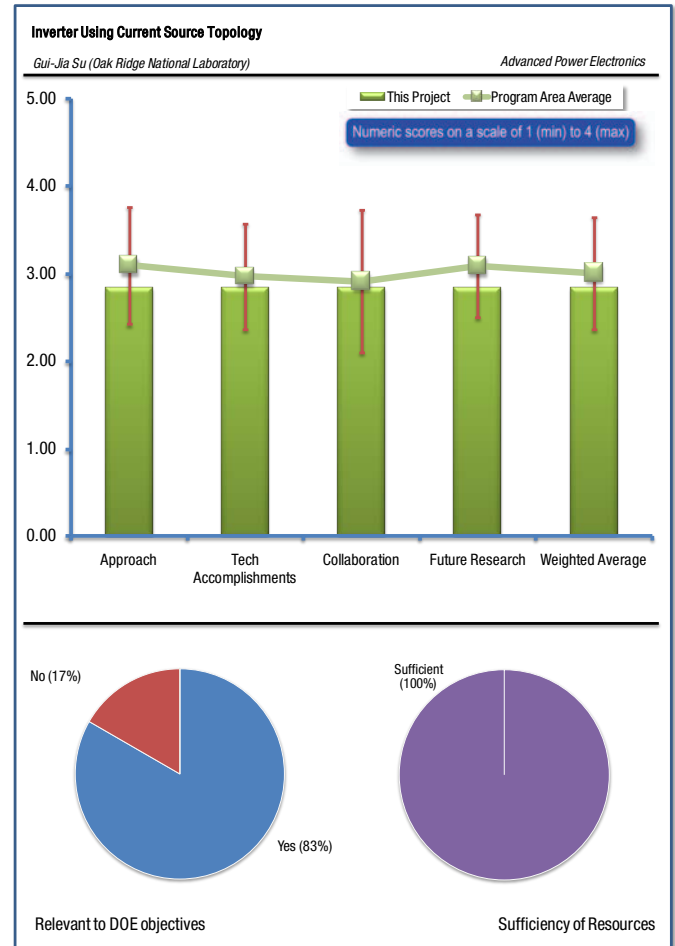
REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer stated that the reduction of cost and volume on electrical inverter are clearly defined as main objectives for PEV applications. Another stated this has the possibility of reducing capacitor requirements compared to voltage source converters, as well as voltage boost capability and battery charging. This also has potential of dual use as a charger. A third commenter felt that this is a very innovative topology study into ZCSI. It attempts to reduce ripple current and capacitor volume to meet DOE's goals. Another said the claim is to reduce size, weight and cost of inverter. This can enable the market for future inverters used in electric drive vehicles.

One reviewer stated that this can reduce the need for the DC bus capacitor, which will reduce the cost and weight. The capacitor is a big part of the volume of the power electronics system. For high temperature operation the size of the capacitor can increase significantly. The capacitor can be reduced but an inductor is added. The inductor performs better at high temperature than the capacitor. A final commenter stated that the project is hard to justify without showing better efficiency and fewer capacitors used in the circuit.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer stated that this is a novel approach, and that teaming with MSU on topology design is effective. Using prior work on associated programs as a foundation is a plus. This reviewer added that it was difficult to assess the quality of the approach since actual circuit architecture was not discussed. Another reviewer commented that one of the issues of the current mode convert is the step-up voltage. The current mode converter is limited in step-up voltage; therefore, bi-directional operation is limited. The use of the quasi-Z network can help with the bi-directional operation. What is the size of the inductor? What is the operating frequency and is that frequency limited? This reviewer would like to see a study of the reliability of the system with the added parts.

A third reviewer said that the approach is inventive, as it explores a new topology space that combines a quasi-Z source and current-fed inverters. It does require reverse blocking IGBTs, which are not available right now. That may make this approach costly as these are new devices that are not widely available. It also requires an input inductor which adds cost and weight compared to a capacitor. This trade-off needs to be carefully weighed. The overall effect will be higher device and inductor losses compared to reduction of losses in the anti-parallel diodes. This reviewer recommends that efficiency be analyzed.

Another said that the claim is a smaller inverter by reducing the bulk x cap. Adding a trans-qZ network adds more component R, L's and C's. In their 10kW prototype picture, these extra components for the quasi-qZ network look large. What are the expected values and ratings of the components in the trans qZ network? This reviewer understands this is under patent review, but asked if some quantifiable information on size and weight could be shared.

A fifth commenter stated that there are apparently some issues with the current source inverter, so the Z-source is brought in to allow low speed, defeating the purpose. A final reviewer said the project efficiently addresses the major technical barriers but sometimes does not mention new issues coming from the new approach such as the reliability and cost of the three big contactors placed on the machine phases to switch from motor to charger (slide 7).

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted the improvement of the new current-fed Trans-ZSI, but added that there were only simulation results at this time. Another stated the need for more information on the trans-qZ network. A third commenter noted that a new qZSI was shown that can reduce the size of the inductors. This reviewer would like to see the waveform through the devices and inductors. What is the efficiency of this system and how does it compare to the capacitor system? Another commenter noted that they are currently they are in the analysis stage and it shows promising results. This reviewer thinks that the really big issues are ahead in developing hardware and controls. One reviewer stated that: (1) The circuit has fundamental issues. In the previous year’s review, a “blank” block marked confidential was placed between the input and the CSI for the purpose of low-speed operation. This year, the block is changed, and a Z-source network is added. No explanation was provided to make a connection between this year’s effort and last year’s presentation. (2) No system performance and efficiency were presented. The presentation did not show distinctive features and results, rather staying at the same level as last year’s qualitative comparison between VSI and CSI. It should show apple-to-apple comparison with solid numbers, not just qualitative explanation; that should not be the purpose of research. One final reviewer said that not much was presented for FY10 accomplishments, so it is difficult to determine if the program is on schedule and how well it is proceeding. This reviewer added that nothing was presented about inverter efficiency capability with this architecture. Reverse blocking IGBT/MOSFET switches are crucial to the future of this type of system. Series connections of IGBTs and blocking diodes will lead to lower efficiencies and increased power dissipation.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were mixed in this section. The first reviewer stated that the team is made up of some of the leaders in the area and there is a good balance between industry and academia. Another added that this is an effective teaming arrangement with university and industry. A third reviewer said that the team uses MSU’s early work as a baseline and all the protagonists seem to be involved in their respective field of expertise. This reviewer added that there was not a lot of material presented to judge this question. Another review noted some collaboration, but the group did not show clear linkage. One commentary suggested that the group possibly could use some collaboration with industry on power inductors and capacitors – can they be combined to reduce the packaging size? A final reviewer stated that they need the power module with reverse blocking IGBTs to be successful and convince others that this can be done.

QUESTION 5: HAS THE PROJECT 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?

Comments were mixed in this section. The first reviewer stated that there is a good plan for future work, while another stated that he or she thinks that the proposed technical work plan is well thought out and should be meaningful. A third reviewer felt that the research showed a good plan which included more design and simulation and construction of a 55 kW prototype system. This reviewer would like to see the voltage and current stress on the power devices. Another reviewed added that the team has a clear path but added that it was too early on in the program to fully appreciate the focus on barriers. One reviewer felt that not much result was presented. A final reviewer stated the logical next step is to build and test the inverter, but asked, why two? Are they different inverters or just in case one fails? (FY11 bullet)

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

There were no comments for this aspect of the research.

High-Temperature, High-Voltage Fully Integrated Gate Driver Circuit: Leon Tolbert (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

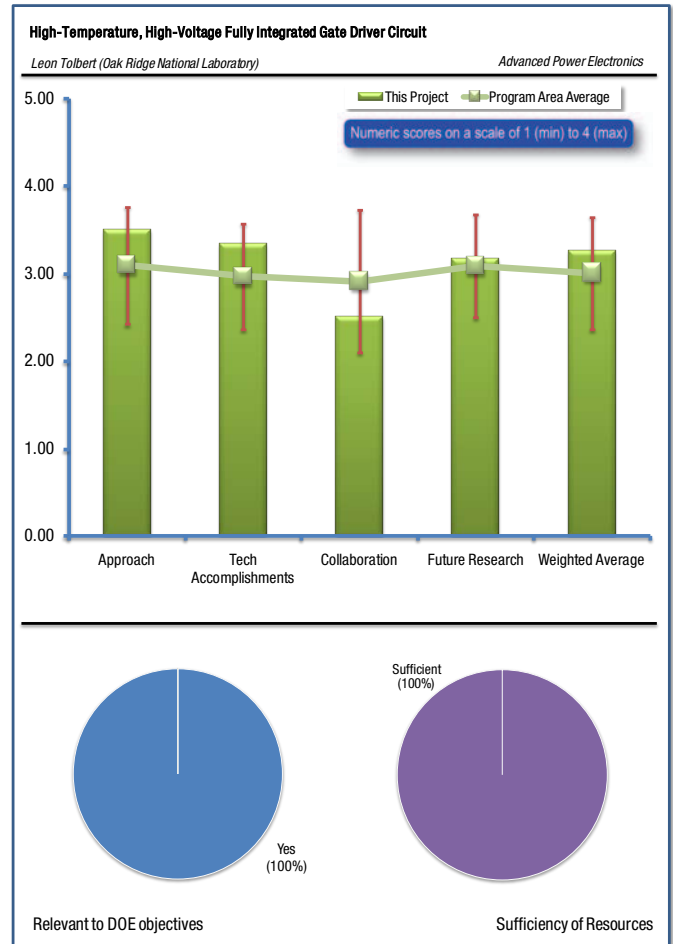
Comments were generally positive. One reviewer noted that this is relevant for electric vehicles and possibly military applications, while another commented that the project enables and supports other projects that reduce size, weight, and cost by developing a high temperature gate drive to be used by other projects that supports the use of high temperature coolant. One person stated that, to the extent that a gate driver ASIC can assist the introduction of important power semiconductors based on wide bandgap materials, the answer is yes. Another reviewer added that the idea of building a gate driver for driving high currents at high temperature in SOI technology is a useful one for SiC and GaN based power electronics. This will greatly benefit the drilling operations where the electronics need to operate at temperatures exceeding 200°C.

One commenter said that in order to utilize high temperature power devices, high temperature gate drive circuits are needed. This project investigated the design of a gate drive circuit that can drive a SiC MOSFET or JFET. A final reviewer said that the integrated, high temperature gate drive is a critical aspect of the efforts to deploy and implement robust power electronic technology based on silicon carbide power devices. The ability to fully leverage the performance entitlement of silicon carbide power devices depends on the availability of driver technology with similar operating environment capabilities. The generic nature of the subject driver is also highly relevant to multiple switch technologies being developed.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments were generally positive in this section. The first reviewer stated that the PI's grasp of the technical nuances of the integrated circuit design and the target application are beyond question, while another indicated an excellent integration of analog and mixed signal expertise with power device subject matter experts resulting, in a highly relevant project with outstanding attributes. A third commenter stated that the approach of using BCD on SOI technology is a sound one. It leverages an existing technology platform while building on the strengths of the team in clever circuit design and access to wide band gap devices which can act as a test bed for the gate driver. Another reviewer said that the approach for the project is good. The use of the CMOS process with SOI is great and will allow for compact high-current gate drivers. This reviewer added that the approach of adding a protection circuit into the gate drive is good for protection of the power devices.

One reviewer stated that this is a development project with little novel research content, adding that it is beneficial, however, for ORNL to have a high temperature gate driver available to aid other projects. A final reviewer stated that the approach seems to have produced a viable design and good results. However, most power electronics systems use H-Bridge configurations with low-side and high-side switches. This gate driver would be enhanced by having drivers and the associated isolation for both the high-side and low-



side switches. Although they may already have done so, it is recommended that the team canvass industrial power module users to determine features they value in gate drivers and incorporate them into this effort.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments were generally positive in this section. One reviewer stated that the gate driver appears to meet the objectives, while another added that the gate driver was tested on both a SiC MOS and a JFET device and was operated at temperatures up to 200°C. A complete test chip was developed which showed that the devices can be constructed with a very small footprint. A third reviewer said that multiple iterations of the IC design have been accomplished, each one adding useful functionality while resolving limitations of earlier designs (often intentionally accepted as early spirals of an evolving design). This is great work. Another said that the integrated gate driver has already been successfully demonstrated which is capable of supplying 2.2 A at 200°C (without any cooling mechanism) and a voltage up to 30 V. A next-generation driver is being designed which will add more features. The final commenter said that, with the exception of the lack of input isolation functionality, due to difficulty in identifying robust components, the project is considered to be highly successful.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were mixed in this section. One reviewer stated that the very good coordination with power device manufacturers enabled accomplishment of a majority of the project milestones. Another commented that good collaboration and a good team were put together for development and testing. This reviewer added that they may need to add a SiC device manufacturer to the team. A third reviewer felt that the team may want to have other industrial users test the gate driver or review the results for more feedback.

One reviewer said that no evidence of any contribution by GM is seen in the presentation so far. A final reviewer commented that this project is focused, for collaboration, on technology support relationships, most obviously the foundry making the prototype IC chips. This reviewer added that it is unclear how much collaboration was forged with manufacturers in the wide bandgap semiconductor industry. However, at this late date in the project's life, it is probably a moot point.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said that limitations of the developed technology are well-understood and viable solutions recommended, while another commented that the next generation of the gate driver will be completed and tested with SiC MOSFETs and JFETs. A third reviewer said that not much is left to do unless the project was extended with additional funding. The generation 5 chip might be worth funding by the DOE.

One reviewer stated that the team has plans for testing the new board in FY10. This reviewer added that no plans were stated for integrating the driver circuit into the power device package. The final commenter felt that no plan is evident as to how this technology actually gets commercialized or what the logical next step is.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were provided for this section.

A Segmented Drive Inverter Topology with a Small DC Bus Capacitor: Gui-Jia Su (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said this approach can reduce the volume, weight and cost of the capacitor. This reviewer noted a reduction of cap ripple current by 60%, adding that this approach can increase the efficiency of the system. Another commenter said that reducing bus capacitance by 60% will be a valuable accomplishment, if indeed there is no other significant cost related to the new VSI technique used. A third reviewer noted that reduction of ripple current, motor current, lower costs, and inverter reliability benefits were covered in the presentation. Another commented that reducing the size of the bus caps can reduce the size and cost of the inverter, adding that the lower cost / smaller size inverter can enable electric drive vehicles.

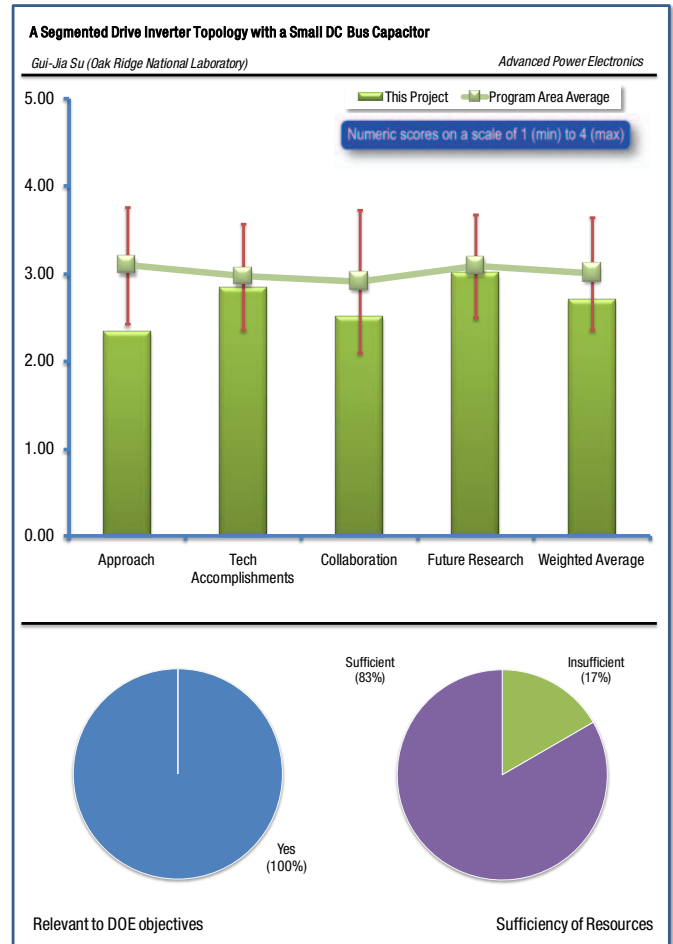
One reviewer said that this project is aimed to reduce DC bus capacitance and meet the DOE goals for cost and volume. The final reviewer commented that the proposed technology involves modifying the standard drive topology and optimizing the PWM scheme to significantly reduce the ripple current flowing into the capacitor without additional silicon or passive (L or C) components, additional sensors, and control complexity. The reviewer added that this can substantially reduce the bus capacitance (at least 60%) and thus inverter volume and cost, and hence reduce the battery loss and improve battery operating conditions.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer stated that the project involves simulation and prototyping, adding that it is feasible, while another found it hard to understand the speaker, which took away from the quality of the slides. Another reviewer said that there were not many details on the approach because of patent issues, adding that the simulation shows the reduction in the ripple current for this approach. A fourth reviewer said that, because the work is under patent review, it is not clear what changes would be required to implement this approach. This person asked, if silicon area is the same but the number of switches doubles, is there a twofold increase in gate drives? Also, how does the new control strategy affect throughput requirements?

One reviewer said that the process is fine with simulation, prototyping, and testing, but the reviewer did not see a lot of effort in terms of production intent. If the new technique will double the number of switches, even if the current rating will be lower, the increase in cost will be significant (which was not mentioned in the study). A better cost evaluation should be part of the approach to justify the study itself.

The final reviewer stated that the concept will reduce bus ripple and allow smaller input DC bus capacitance. The concept of phase interleaving is well known and has been applied in multi-section DC-DC converters. It has also been applied in various types of inverters such as multi-phase motor inverters, dual winding inverters and double ended inverters. Much of that work was done at GM



for the past six years, including optimal control algorithms. For the proposed topology the additional set of switches, gate drivers, and motor windings adds a lot of complexity and cost to the inverter. Drawbacks include: 1. Six more drivers, 2. Six more switches, 3. Three more windings, 4. Three more motor cables, 5. Motor windings have to be wound with identical electrical characteristics, and 6. Ripple is non-zero for high and low modulation indices.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer thought that the speaker slides were well done, while another commented that the simulation showed 60% reduction in current ripple, adding, if it is validated by experiment, then it will have importance. The prototype is underway. A third reviewer commented that results to date show that bus ripple can be reduced and the size of bus cap reduced by 60%. That shows a dramatic reduction in inverter volume. The work on optimizing PWM techniques is valuable. This reviewer recommends that the PI look at other topologies other than the dual winding motor that may have additional advantages. One such example is the open ended winding motor where each end is fed by a half-bridge. This has the advantage of full voltage rail utilization.

One reviewer would like to see more information about the control strategy, while another felt that a year to build 90% of a prototype seems long. This reviewer wondered if there may be some issue with resources or budget. The final commenter said that the team did not show many results on the technical accomplishment such as waveforms. Some simulation waveforms were given showing the motor current and the ripple current. A 28 % reduction was shown in simulation. Because the approach was not shown, it was not clear how the reduction in ripple current was achieved. The team needs to address the efficiency of the system.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer did not see other institutions as a partner, while another added that no collaboration was presented. A third commenter stated that there was no collaboration at this time, but the team has plans to work with others on aspects such as packaging. Another reviewer said that collaboration was not mentioned that much. This person added that maybe talking about custom IGBT modules will help to recognize collaborative efforts. The final reviewer said that the prototype is done at ORNL. It might be beneficial if it can be collaborated with a motor company to expedite the prototype and testing process. It may also make sense to have academic participation to investigate the drawbacks of the proposed algorithm.

QUESTION 5: HAS THE PROJECT 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?

Comments were mixed in this section. One reviewer said that either they do or should show a clear path to get to a 55kW system by the end of FY10. Another said that the future tasks are appropriate, adding that some advancement of the research objective is desirable. A third reviewer said that this is a logical way of proceeding but that this project appears to be behind. One final reviewer said the project has potential in the claims but needs more information. Noting the smaller cap but more switches, more gate drives, and more complexity for control, this reviewer said that it was hard at this time to quantify the benefit.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received on this question.

Novel Flux Coupling Machine without Permanent Magnets: John Hsu (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer stated that reduction of permanent magnets can reduce the cost of the system and can reduce the motor size for high operating temperature, while another said this project aims to replace the permanent magnets found in electric motors, and added that this supports the DOE cost and power density goals for machines. A third reviewer said that by trying to eliminate the magnets, if successful, this approach will allow the achievement of a significant price reduction compared to actual PM machines used on EV and PHEV.

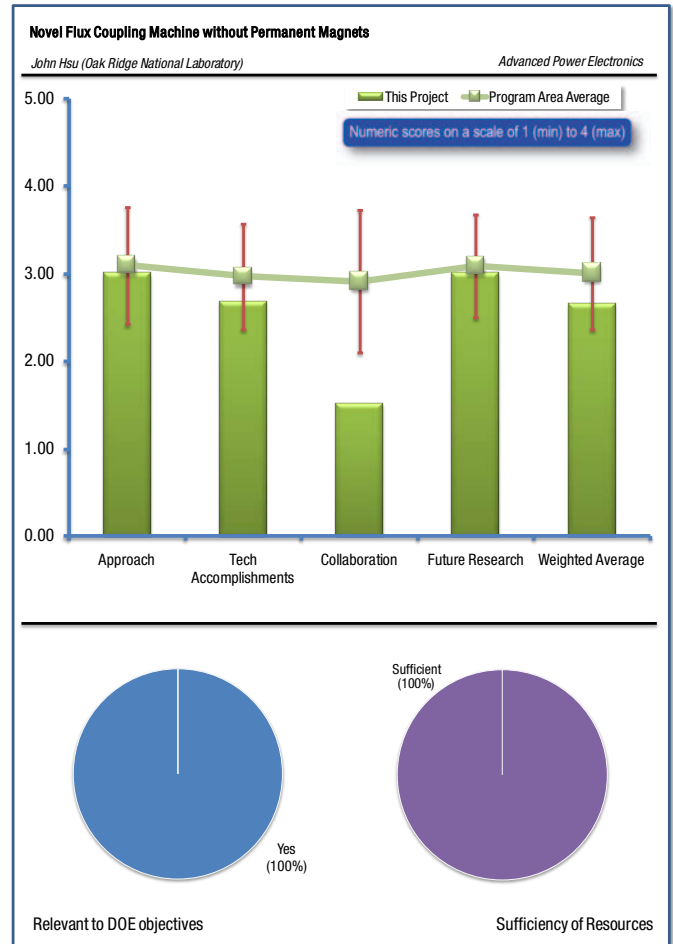
A fourth reviewer said electric traction motors are critical to the adoption of electric vehicles that displace petroleum. New topologies deserve to be explored through laboratories, especially ones that do not replace one dependency for another (this technology eliminates rare earth permanent magnets that presently create dependency on China). Another commenter said that, if successful in meeting the 2020 targets for the traction motor, this can be a key enabler in meeting the overall 2020 electric traction drivetrain targets. The final reviewer commented that the novel electric machine design concept

addresses a major issue of today's electric machines, which is the high cost of permanent magnets. If the project is going to be successful, the novel electric machine design could potentially accelerate the implementation of electric drive systems in the automotive industry. This would support the DOE objectives of petroleum displacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments in this section were mixed. One reviewer said a good approach was shown which utilized FEA modeling and design; the approach also investigated cooling of the system. Another stated that the approach is good but needs to move faster to building a prototype and verifying analytical predictions. Also, accurate efficiency predictions are needed. A third reviewer commented that the project is ambitious, possibly to a fault. For example, an externally excited machine that exhibits the novel flux path is sufficient without the exploration of novel stator winding. This reviewer added that what is most important is the need to assemble a proof of concept machine that can be used to refine the understanding of the machine before attempting optimization and folding in additional innovations.

Another commenter said the proposed novel electric machine design has a 3-dimensional magnetic flux path, which is different than in most of the electric machine concepts in use today. The researchers tried to avoid the very complex 3-dimensional modeling of design iterations because this takes a lot of time and computing power. But the real advantages of the novel machine concept can only be proven with full 3-dimensional FEA modeling. Additionally, this reviewer added, a new stator winding structure is proposed, which is independent from the general design concept of implementing a stationary field excitation for the rotor. The risk of this approach is that too many independent novel ideas are put into one project, and the differentiation between successful and unsuccessful ideas will be difficult. A fifth reviewer commented that there are several ideas expressed to achieve the objective (novel winding structure, field



coil to eliminate magnet, hybrid cooling, field control optimized...), but at this time, there is no simulation or estimation of hybrid cooling and field control optimized. This reviewer asked if it is really necessary to have them for this machine.

The final reviewer stated that John Hsu is to be commended for a novel machine that has no permanent magnets and high power density. Separately excited motors and the wound field machine have been around for a while. But this motor is statically excited and has no slip rings. Because there is no rotating coil, it is capable of very high speeds. This reviewer also liked the ability to reduce field current at high speeds to improve efficiency. Drawbacks to this design are: 1. Complexity in the mechanical assembly, 2. High field losses, 3. No solution to mechanical stresses in the rotor, 4. Four air gaps, and 5. Double cooling.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said that a proof-of-concept, simplified motor is a better approach than attempted optimization at this stage of the program. This would accelerate the hardware build and allow for model calibration to create a second generation prototype that is more likely to fare well against DOE targets. Cost analysis should show more details about how the calculation was performed. In addition to material differences (additional iron and copper, elimination of magnets), manufacturing processes and tolerances need to be factored into cost calculations. With these factors, cost may become higher. A second reviewer said that, since the last time this project was reviewed, there has been a lot of effort to overcome some mechanical problems and to address rotor magnetic imbalance. However, there still remains an issue of high stress concentrations within the rotor at high speeds. Several attempts have been made without a solution. Another issue is the complexity of mechanical assembly and multiple airgaps.

A third reviewer said the team should show operation of speeds up to 1400 RPM, and added that comparisons of modeled results were compared to Camry with good results, but the weight was greater. The work did not meet the 2020 target. Does the research plan to address the weight issue? Another commenter said the simulation is encouraging, but questions concerning feasibility need to be answered by a prototype. It doesn't appear that anything was done on thermal and control this year. It was hard to judge the progress made. The increase in weight is understandable but is still a negative effect of the technique used. A fifth reviewer said significant progress has been made so far, but the researchers have to prove their claims with measurements of a prototype machine, which is already planned for the future. But it is necessary that detailed loss and efficiency simulations will be conducted before a prototype is available. The weakest point in the accomplishments so far is that no efficiency simulation results are available, e.g. eddy current losses in the solid steel core for the excitation field could be a big problem. Moreover, it has to be proven that the package volume claim is reasonable.

This final reviewer stated there is good progress but there are still several risks and questions to be answered. Also some of the assumptions need to be rechecked:

- (1) The claim that this is a higher temperature machine is questionable since insulation is still a limiting factor.
- (2) The novel winding method that can increase the fill factor by 50% is applicable also for PM machines.
- (3) Efficiency maps especially along the rated power envelope should be evaluated.
- (4) The assumptions for cost should be double checked. Do they also account for manufacturing cost or they are solely based on materials cost?
- (5) Torque ripple results do not have enough resolution. The figure showing torque ripple over one mechanical cycles doesn't properly capture torque ripple/electrical cycle.
- (6) It is not clear whether the design meets the 105°C coolant inlet temperature requirement based on the proposed cooling scheme.
- (7) Are the masses based on active mass or total mass?
- (8) Detailed mechanical and rotor dynamics analysis should be performed to ensure the machine can be spun safely up to 14000 rpm.

(9) It would be beneficial to scale the design down to the 55 kW to check if there are any issues with scalability as well as provide better comparison with the 2020 specs.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said no collaboration is seen at the moment, and another said no industry or laboratory partners are shown at this time. A third reviewer added, as already mentioned in the presentation, there is no sponsor for this project. Involvement of an industrial partner is needed. Another reviewer said there are no collaborations at the moment, as this is a pure research project in an early stage. This reviewer added that a bigger interest from the industry will be there, if a successful prototype testing has been conducted.

Another commenter believed most of this work is being done at ORNL internally, and added that perhaps some better collaboration could be made with a university that specializes in electric motors. One final reviewer said there is little collaboration within this project, which hopefully will change if the prototype motor shows promise. It is important for the electromagnetic and mechanical engineers and designers to work closely before building the first unit, and it is also important to consider the controller that will be used to drive the motor and to have their involvement. It is not clear that ORNL internal collaboration is sufficient.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said building the prototype and experimentally verifying the analytical results is a critical step. Another commented that the future work plan is generally good. As mentioned above, more detailed simulation work has to be done to prove some of the claims before a prototype is available. A third reviewer said proving the concept through experimentation is the logical next step. This reviewer is curious to see results from the prototype and is sure that it is the case of eventual partners.

Another reviewer said the team needs to address the issues of going from simulation to prototype. The team also needs to investigate the losses with this design. A fifth reviewer commented that risk mitigation is not a strong point with this program. It is an ambitious program that should consider pathways to reduce the complexity of the prototype. Assuming that suggestions from past and present reviewers are heeded, this reviewer looks forward to the prototype results. The final reviewer recommended trying to cast the Zip Lock fasteners using aluminum much like the rotor bars in an induction motor. This will eliminate complex machining, and precision assembly.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this section.

Benchmarking of Competitive Technologies: Tim Burress (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said that, by analyzing what is done in this arena, this study gives a good understanding of the state-of-the-art and constitutes a good knowledge base to build upon. A second commenter said the comparison has good reference value. The industry and research organizations have a basis for comparing their target system performance. The way that Toyota designed their power electronics can be the initial reference to some design teams. A third reviewer said that benchmarking electrification technologies that are now commercialized will help others incorporate “lessons learned” through the careful evaluation of those technologies. It will help those who are not as far along to catch up and speed the commercialization of new systems, and hence, vehicles that displace petroleum. The final reviewer said it is very important to understand the marketplace for power electronics, and added that this benchmarking activity attempts to understand recent technology.

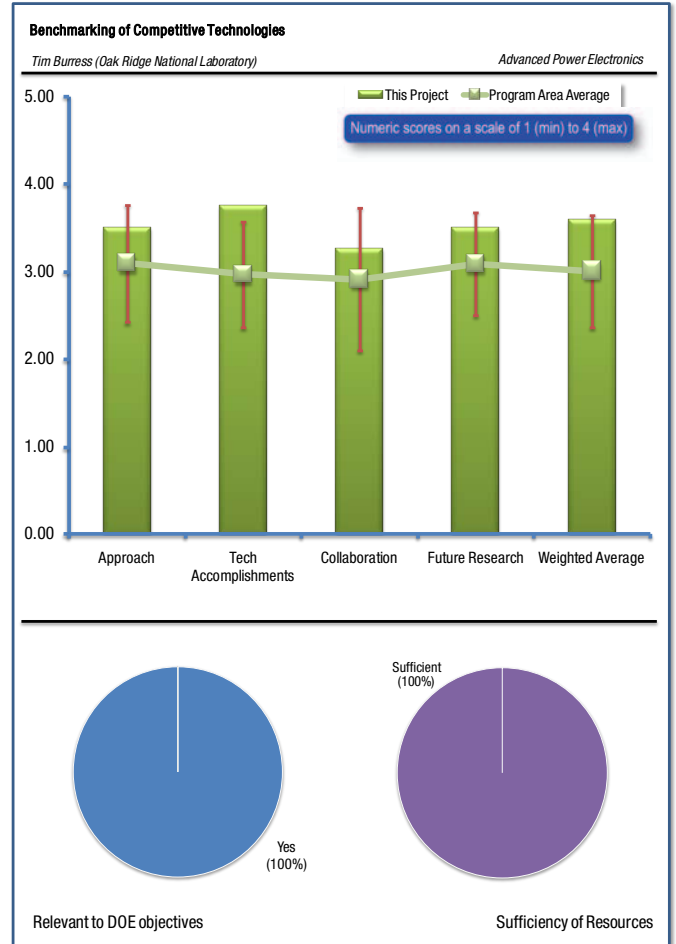
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer really liked this intelligent approach, and added the team was doing an excellent job. Another said the research team did a good job to understand how Toyota designed the system when they took the components apart. There was a very good explanation for what they found. Further improvement is possible by injecting design expert in the field, so the design philosophy can be explained better. This is apparently beyond the current research team capability, but it would be good to incorporate more design experts who can provide more insight to the design philosophy.

A third reviewer said the approach is to do a detailed tear-down of Toyota hybrid electronics and motors. These are considered the benchmark standard today. The final reviewer said expansion of the work to evaluate the communications system, signal processing, and approach to achieve compliance with standards would be useful. For example, is dual processing used to ensure that undesired torque is not produced? Materials evaluation (lamination steel, magnets, aluminum grade, potting compounds, PC board layers, processor selection, etc.) would also be worthwhile. Some of this may already be in the detailed reports. Improvements to the power electronics, machine, and cooling technologies are evaluated well through this effort.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments were generally positive in this section. The first reviewer said the team has provided very detailed results of the production system, and added that they took pictures and explained how each component works. A second reviewer said the work is timely and relevant. Work on used systems (160,000 miles) was good to see and should continue whenever possible. Following observations with confirmed or educated guesses as to reasons should continue. Another commenter said that, so far, the results are very enlightening to



see how much progress is being made. It shows some dramatic reduction in wires and heat sinks. The final reviewer said there was excellent analysis of the 2010 Prius, and pertinent comparison with previous models for the drive and motor.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said this work is being done in connection with other DOE participants, while another noted that there are numerous collaborators that are doing their part of the job, along with good management from ORNL. A third reviewer said generally collaboration is good, and added that more power electronics and motor design experts can be brought in to further exploit design philosophy. The final reviewer said collaborating with manufacturers would also be appropriate, especially to help answer and document the deduced reasons for the design choices observed.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said this project seems to have reached its end of life as defined and hopes that some decision to continue it will be taken in September. This project is valuable for the EV/PHEV community as a knowledge database. It will be valuable to extend the study to emerging vehicles. Another stated that, although there is a comment from the audience about evaluating the U.S. manufacturer's design, the team has done an excellent job so far and should keep on doing the good work. The final reviewer said to see comments above for suggestions on future research to dig more into the details that will help U.S. manufacturers close the gap with foreign manufacturers. Evaluation of the controller and driver boards to a deeper level would be useful future work.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this aspect of the research.

Wide Bandgap Materials: Mahdu Chinthavali (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

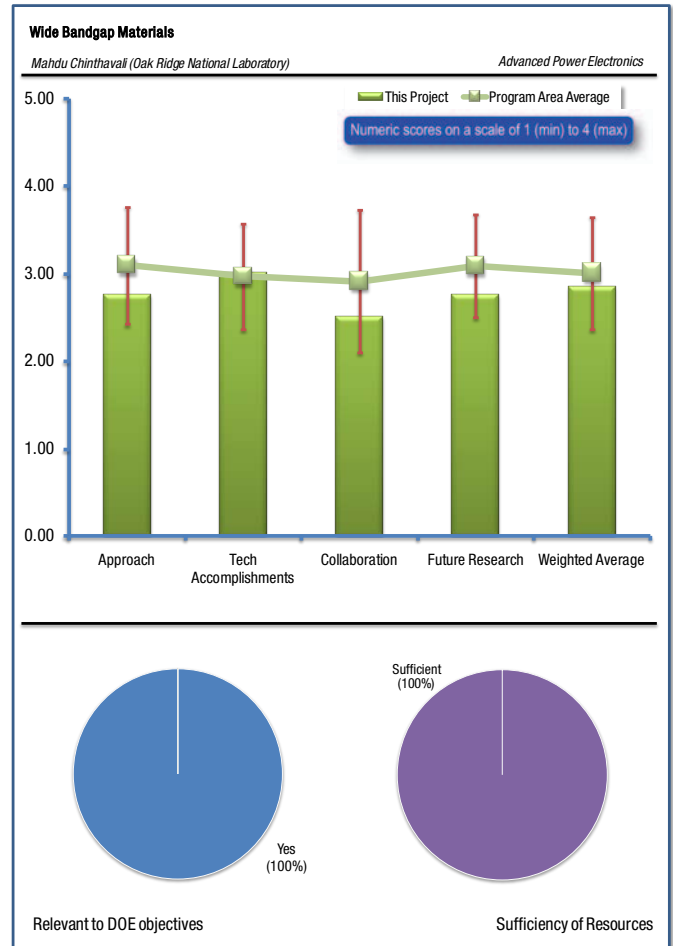
The first reviewer said this work is extremely relevant to the mission of DOE for petroleum displacement or at least petroleum reduction. The main objective is to evaluate the use of wide band gap devices such as SiC or GaN diodes and FETs in hybrid and electric vehicles. It is anticipated that the inverter efficiency can be increased, thereby improving gas mileage and reducing cooling infrastructure by use of wide band gap devices in the boost and inverter sections. Another reviewer commented that most automotive OEMs have active R&D efforts to increase efficiency and thermal flexibility in EV power electronics using emerging commercially available SiC power semiconductor devices (FETs and Schottky diodes). This reviewer added that it is recognized throughout the HEV/PHEV/BEV industry that wide bandgap semiconductor technology is relevant to future petroleum displacement through consumer adoption of HEV/PHEV/BEV. A third reviewer said high temperature devices offer the promise of eliminating a coolant loop and/or using higher current densities. This may reduce weight and size in the future, leading to fuel economy savings. However, cost is the barrier at this point. The characterization/modeling/system impact work is important to track progress.

The final reviewer said the performance entitlement of the wide bandgap class of semiconductor materials has been demonstrated to be capable of significant power conditioning and distribution equipment efficiency advantages over state-of-the-art Si power device technology. The subject project is appropriately quantitatively evaluating the device performance characteristics to validate the terminal performance characteristics to assess technology maturity and suitability for system utilization. In addition, the development of SPICE models for the evaluated device technologies is a necessary thrust to enhance and accelerate implementation of these technologies by making available applications engineering design tools.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments in this section were mixed. The first reviewer said the overall goals are good: characterization, modeling, and system simulation to benchmark and monitor progress of wide bandgap device development and potential impact on EV. A second reviewer suggested they consider including power dissipation curves for use in determining forward SOA space evaluation/determination. This reviewer added that implementation of a single package for comparison and benchmarking would also be appropriate for this and other characterizations in order to evaluate the differing switch technologies. Very good project structure and execution was also observed. Efforts were made to evaluate and characterize gate drive response needs when considering threshold voltage shifts with increasing temperatures (especially for e-JFETs).

A third reviewer stated that the approach is seriously flawed. Obtaining devices from vendors and measuring dc and dynamic characteristics and building models is simply duplication of the data already being provided by the vendors. Minimizing thermal



impedance is attacking the wrong problem because the losses with wide band gap devices are already lower. Minimizing inductance is useful but it is at the level of module design where the PI has no experience. A better approach would be to design an inverter using commercially available wide band gap modules, increase the switching frequency in the boost section to reduce the size of the reactor and reduce the size of the cold plate and number of silicon IGBTs in the inverter section. This should be done just for wide band gap diodes as a first step. Benchmarking should be done with all silicon modules.

The final reviewer commented that, clearly, as this project has progressed, the team has dramatically improved their familiarity with the technology, and their evaluation of the technology is approaching the quality of the manufacturers of the devices themselves. The comment made by the presenter in response to the question about characterizing gate energy, etc., to the effect that creating a data sheet is not the goal of the project is a welcome reflection on the true contribution that this project can realistically make. In that spirit, this reviewer encourages the presenter in the future to take care when making comments about the true rating of devices. The reviewer knows and agrees with the presenter's intended technical context, and also knows that taking care in the choice of words will avoid the possibility of confusing the audience. The future work involves creating behavioral models and making system relevant conclusions about the technology. This final reviewer commends the project team for this choice, which is a good use of the team's expertise and better reflects the needs of the community for understanding the value proposition that wide band gap semiconductors might have in a very cost sensitive industry.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments in this section were mixed. The first reviewer said good progress has been made in developing and obtaining equipment for basic tests and in performing basic characterization of a number of samples from different sources. Another commented that the static evaluation of devices appears to be essentially complete and to be largely done well. Dynamic evaluation was not reported as that work is still in progress (gate driver board “sent off”). The behavioral modeling effort appears to be embryonic, as no progress was reported. A third reviewer said that validation of SPICE models in relevant topologies would be appropriate and a good subtask to accomplish to compare to inverter topology being planned. The final reviewer said that, assuming the project has been ongoing since October 2001, the progress is extremely slow. This reviewer noted that there is no detailed calculation of higher efficiency of an inverter based on wide band gap devices, despite the fact that these devices have been available for a number of years.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer noted the inclusion of GE (MOSFETs), United Silicon Carbide (BJT), and Northrop Grumman (JFET including cascades), while a second reviewer said the project has identified sources and obtained samples from a number of sources. However, this reviewer added, coordination with other labs that do SiC/GaN device testing and modeling seems to be lacking. Another reviewer said there is poor evidence of any collaboration with the partners. The devices that have been measured are not state of the art, no significant effort has been made to acquire recent devices, and the testing could have been easily done at the University of Tennessee-Knoxville, whereas ORNL could have focused on building an inverter. The final reviewer said it is unclear how much this project collaborates with the applications engineering support of the wide bandgap vendors. This reviewer's guess is very little, which could be improved. University of Tennessee may or may not be the best choice for behavioral modeling of wide bandgap semiconductor devices. Other academic institutions are further along in that technical area. This final reviewer asks whether the team reached out to any of these institutions.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said reasonable objectives seem to be set for future research. Again, risk might be reduced by improving the collaborations. But the future research is clearly aimed at the most valuable contribution that this project can make, which is helping to answer the question “Do wide bandgap semiconductors have a value proposition in the automotive industry?” Another reviewer said completing the design of an air-cooled inverter is a good goal, and added that an even a better goal should be to build and test the

inverter. Simulations are useless in such applications. A third commenter suggested the team might consider evolving this project or a follow-on activity to include a packaged (multi-chip type module packages) wide band gap technology assessment.

The final reviewer stated that this project would be more effective if it produced a comprehensive list of tests needed for evaluation of devices. Similarly, a comprehensive list of device performance metrics that can be used to evaluate device suitability for vehicle applications would be beneficial. Some theoretical analysis of how the characterized device performance would impact inverter performance should be provided and updated as the device technology evolves. Near-term suggested changes to the evaluation procedure include addition of basic measurement methods like gate and gate-drain charge. Also, each device should be given an independently derived current rating based on watts/cm², package thermal resistance, and SOA modes. Reliability and qualification tests: HTOL, HTRB, HTGB are difficult long term measurements and may be beyond the scope of the work. However, it may be appropriate to perform specific reliability tests for known SiC/GaN device specific concerns (for example, forward bias degradation and gate voltage drift). This final reviewer added that more comprehensive device characterization will be needed before accurate modeling and simulation results can be obtained.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

High Dielectric Constant Capacitors for Power Electronic Systems: Uthamalingam Balachandran (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt this project did support the overall DOE objectives of petroleum displacement based on the research and findings presented. The other said the project proposes to reduce the size of vehicle inverters by ultimately incorporating the DC link capacitor function within a printed circuit board. While there are several challenges that need to be addressed, this work is worthy, as it is a different approach to solving the problem compared with traditional wound film or electrochemical capacitors used for this application.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

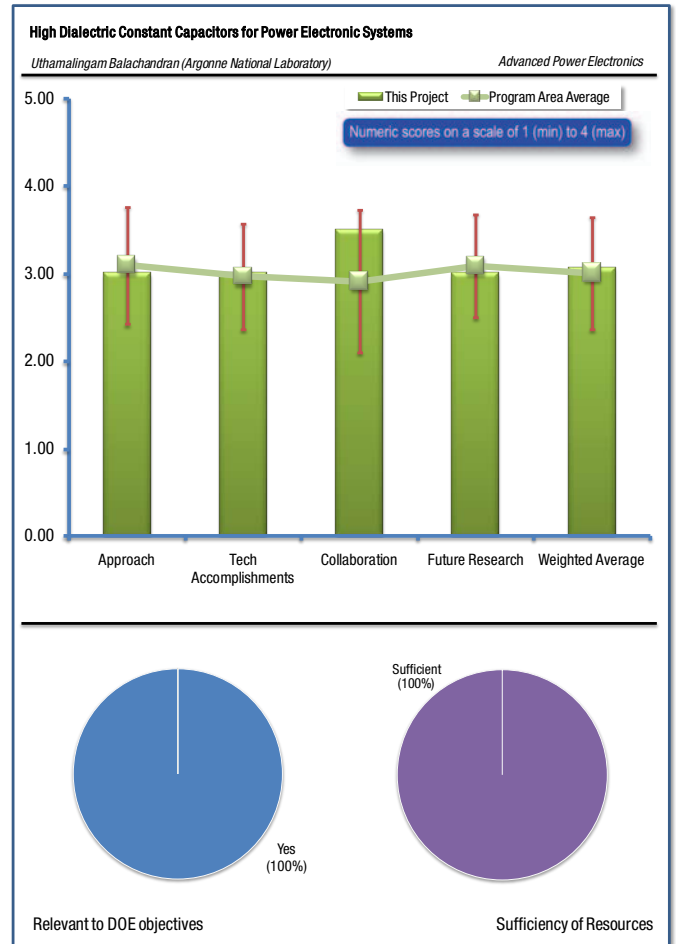
The lone commenter stated that technical barriers should be carefully worked out with the direct customer for the capacitor technology the team is working toward: the inverter design engineer. For example, the capacitance measured by a bridge with zero bias is meaningless for the intended application. The capacitance while biased at the DC bus voltage is what is important: dQ/dV at 450V for the target application. Presented results should relate to that condition, not at zero bias. The graceful failure mode is critical to the viability of this technology, especially as fabricated in a multilayer device.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The lone commenter said the increased size of capacitor elements and the improved breakdown strength were positive signs. This reviewer suggests that dielectric withstand be reported in volts/micron, which is more typical of how dielectric strength is measured in the capacitor industry. Clear reporting of results is necessary in conditions relative to the application, such as leakage. What is the leakage per μF at a given dielectric stress? This is more relevant than leakage/cm² with no voltage stress indicated.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said very good collaboration on this project was demonstrated. The other reviewer said one area that was not addressed was the method used to connect the stacked layers in parallel. This reviewer does not know if a separate institution would have value in this regard: possibly a leading edge PCB manufacturer would be able to assist for that planned implementation. For discrete multilayer capacitors, would talking to a manufacturer of multilayer ceramic capacitors add any value there, or has Sandia National Labs a state-of-the-art expertise?



QUESTION 5: HAS THE PROJECT 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?

The lone commenter said that for such high DC link capacitor currents (100ARMS), interconnect such that active electrodes are able to share this current will be a non-trivial portion of the technical development. This reviewer did not see any planned activity in this area for future work. This current has significant magnetic interaction implications that can cause unexpected heating. For example, the current through a stacked film capacitor will cause a magnetic field that will have components perpendicular to the electrodes, generating eddy currents. These have been shown to be non-trivial effects. As the capacitor volume is made smaller (enabled by high K materials) current density uniformity and magnetic effects become more important.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

High Temperature Polymer Capacitor Dielectric Films: Shawn Dirk (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer commented that the high-temperature polymer capacitor dielectric films are needed in the industry if they can be produced in volume and at competitive pricing. Another commenter said the higher temperature smaller capacitors can make an inverter smaller. However, solvent casting is not a low cost process. This reviewer indicated a need to move to an extrusion process as suggested in the team’s presentation.

The final reviewer said that one important attribute of this research is that low-cost polymers are being studied. If cost is not comparable to the current polypropylene solution, it has little hope of being adopted. The goal of a cent and a half/ μ F appears to this reviewer to be a “pipe dream.” It would require a break-through in capacitor technology far more significant than a new capacitor film, but the reviewer adds that that is not to be construed as a criticism of this work, and is more of a comment on an unrealistic goal set by DOE.

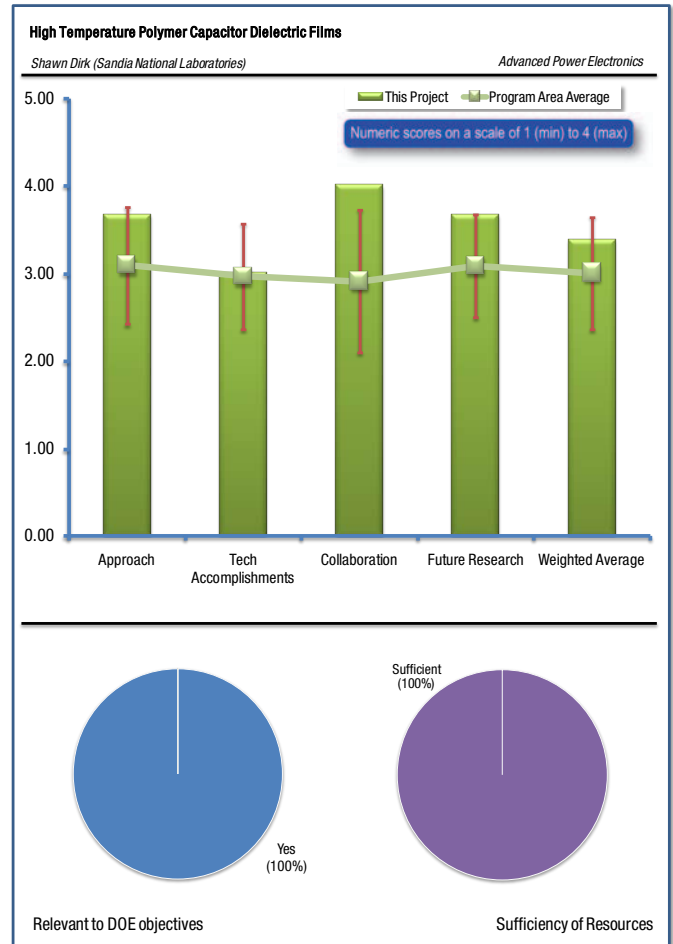
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer thought the speaker did a very good job in presenting the information and the research was excellent. This reviewer’s experience in the field questions the high heat capability, and is concerned that the costs will be high due to being a specialty film in low volume. Another reviewer said that the work needs to move to an extrusion process, with thinner films and higher breakdown voltage. Also, will this material be comparable with the existing metalization processes for PP, or is more invention required?

The final reviewer stated that a well-focused effort is seen here, with what appear to be relevant players. This reviewer expects to see more “capacitor results data” in the future. This reviewer was not qualified to comment on the organic chemistry aspects of this work, although the reviewer can appreciate the difficulties in going from “the lab” to “a pair of film rolls from which capacitors can be manufactured.” It is one of the biggest barriers for a “new film.” The ECI connection is a “natural.” This reviewer continues to encourage characterization of self healing capability relative to the 450V DC bus requirement and the dielectric stress level one would expect to use for that application.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said this was a great technical concept, but needed to see more quantified data to verify progress and product availability as well as true costs. This will be an excellent technical project if desired results can be achieved for market and product use. A second reviewer commented that the team needs to show the finished capacitor size, weight, and projected cost. Does it meet the capacitor targets? The final reviewer said it was encouraging to see more interaction with ECI. Several problems were solved. This



reviewer had the following questions: for the higher K formulations, does capacitance change with applied voltage? (dQ/dV at the applied bias $V/\mu\text{m}$, should be referred to DOE target 450V bus voltage.) Have any leakage tests been made relative to the above target voltage and temperature stress?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. The first reviewer said the collaboration with outside institutions looked very good (Penn State, ECI, Argonne), while another said it was hard to criticize, adding that it looks like the right organizations are involved. The final reviewer said working with industry, national labs and universities, this project has an excellent team.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said the concept of thinner extruded films with higher dielectric constant is directionally correct. The team needs to demonstrate this. The other commenter said this is right down the alley as to what is needed. This reviewer asked: has the team explored other possible sources for doing the “stacked” capacitor? Would the traditional “stacked film” approach be applicable? Graceful failure is a major requirement. Consider the power that is available should a capacitor not fail “gracefully” (i.e., 450VDC bus with several hundred amps available for fault current.) This reviewer is glad to see this program better funded in 2010.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

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

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said that glass as a capacitor dielectric could substantially reduce size/weight, especially considering other advantages with respect to thermal management. The other commenter said low cost, high temperature bulk capacitors are needed for power electronics inverters to help enable the market for electric drive vehicles.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer stated there are some magnetic aspects of a high current stacked capacitor design not addressed here, but considering the funding level this reviewer didn't think they need to be in this particular research effort. However, some thought should be given to losses if large electrode areas are connected to terminals: metal thin enough to allow self healing has limited current carrying capability and limited current density before it vaporizes in a similar fashion as around a dielectric fault during the clearing process.

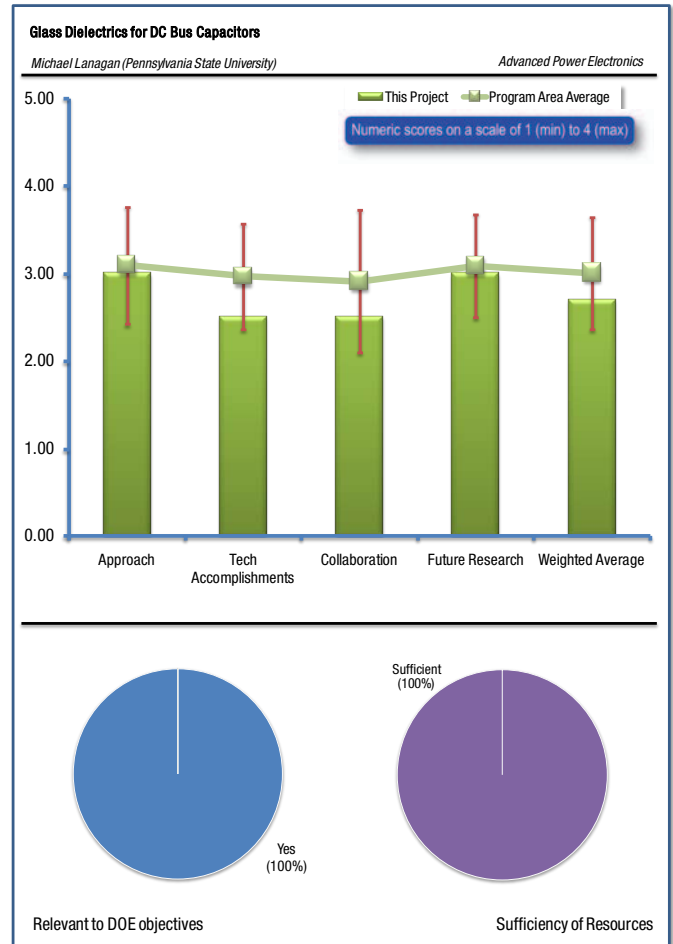
The other reviewer asked whether there is a supplier of glass that can provide less than the 10µm thickness needed to make a comparable size capacitor. Is this thickness of glass, less than 10µm, required for the flat panel displays, or is this a specialty item which may make the cost of the capacitor non-competitive?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer commented one supplier has been found that is making glass “wire” of the required thickness but are interested in making sheets in high volume to lower the cost and enable the technology. The other stated this work is tightly focused on self-healing effects. This reviewer would like to see the same after the capacitor is in the stacked arrangement. The proof of graceful failure is in a “usable” capacitor, where a dielectric failure and self healing succeeds without involving adjacent layers. Is there a possibility of obtaining this glass in “rolls?” A wound glass capacitor would have several advantages over a stacked form. Depending on dielectric strength, this may be useful in really thin “films,” say 3µm. Is there a possibility of that? At what voltage stress did the glass fail and self heal? This reviewer would say that these self healing experimental results appeared expensive, but more work may have been done than was presented.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer was not sure how, for the work presented, all of the collaborators were involved. This is likely to improve for the next phase of the project. This reviewer added it was very hard to tell with a short presentation and conversation what activity was done by collaborators. The other reviewer asked how effective it is for the team to introduce glass manufactures to capacitor manufacturers.



Would it be better to have someone who represents the market, possibly someone from the EE tech team, to work with the group and the manufacturers to help establish market size and help persuade the cap manufacturers to help develop this product?

QUESTION 5: HAS THE PROJECT 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?

The first reviewer referred to the comments under the approach question. The other reviewer said the plan is good, and will see next year what progress is made. The team could look at availability of the thickness of glass that would be optimal for the 450VDC bus requirement. This reviewer suggests also looking at capacitor electrode thickness as well as for an optimal material.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No responses were received for this question.

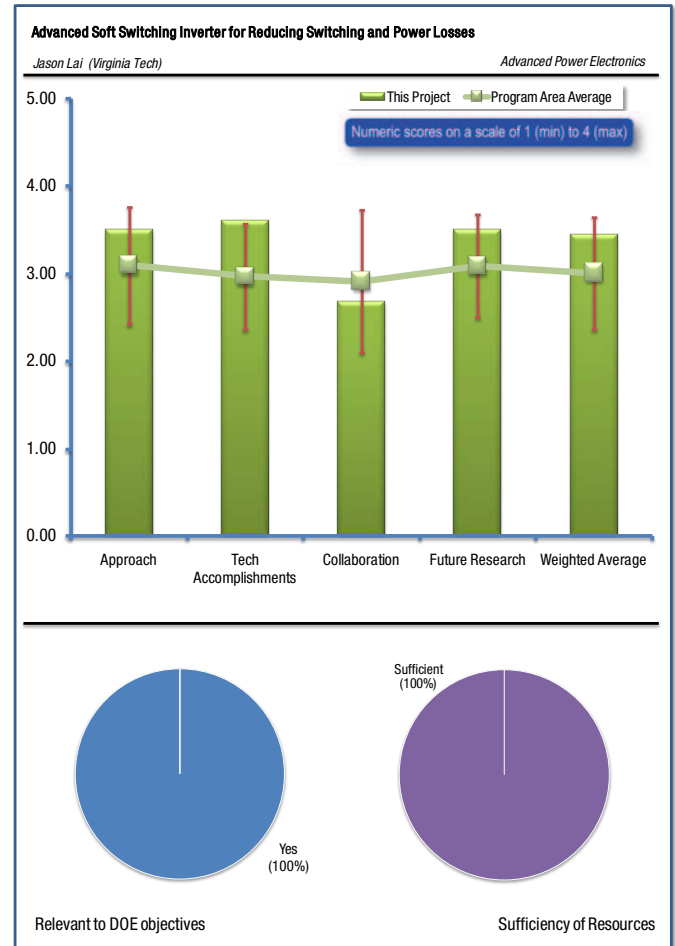
Advanced Soft Switching Inverter for Reducing Switching and Power Losses: Jason Lai (Virginia Tech)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said that the objective of this program is to develop soft switching inverter for traction applications with 98% efficiency or higher. This is highly relevant for hybrid and EV applications as it will lead to lower losses, and higher coolant temperatures. Another reviewer said the project is looking at reduction of cost volume and weight. Also, the project is looking at increased efficiency. The project is investigating advanced packaging that can lead to more improved system performance. A third reviewer said developing power drive technology (soft switching) to improve its efficiency is perfectly relevant. Another commenter said that the project will develop extremely high efficiency converters based on CoolMOS and soft switching. It will benefit the future electrified vehicles by saving energy. One reviewer said the project aims to improve overall inverter efficiency of 98% and peak of 99% to reduce cost, weight, volume and thermal management. The final reviewer said higher efficiency inverters allow electric drive vehicles to go farther on the same amount of energy, providing more range, or possibly less batteries for an equivalent range.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer liked the approach of having three generations, with the next one based on lessons learned from the previous one, while another reviewer said the research involves modeling and simulation, prototype manufacturing, testing and validation, and added that the approach is appropriate. A third reviewer said the idea of using a silicon IGBT in parallel with a CoolMOS is a very good approach to reducing conduction losses at light loads. The idea of reducing loop inductance within the module is a good idea. It will be worthwhile to discuss how this was achieved. The presented material shows efficiency rising almost 1 % over a time period of 5-6 hours. This reviewer asks how this is possible. It casts doubt on the accuracy of the calorimeter. It will be nice to see a plot of inverter efficiency vs. output power.

Another commenter said there was very good work in showing efficiency and EMI improvements, but added that the cost data for the power module is questionable for the automotive environment. A fifth reviewer said the approach is technically outstanding but very complex to manufacture. The team is able to get 99% efficiency. Hybrid switch Mosfet/IGBT is made possible due to soft switching but adds additional cost. Variable timing is very innovative. Low thermal impedance module is good work but not really needed. The final reviewer commented that the module does not include the resonance inductors. The development of a soft switch hybrid module using the IGBT and MOSFET is good. The highly integrated soft-switch is good for reduction of switching losses. This reviewer would like to see the peak current through the devices.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the project is right on target, with experimentation that supports simulation: a lot was accomplished this year. This reviewer is eager to see how Generation 2 performs in a vehicle. A second commenter said prototypes have been made and preliminary testing have concluded, and added that the progress is excellent.

Another reviewer stated that calorimeter test measurements were needed to determine accurate measurements. This reviewer added that the Gen 2 module is very complex to build but the inverter looks compact. Cost models project lower future cost, which need some more work to be believable. A 4°C rise in T_j is outstanding. A fourth reviewer said significant volume reduction has been achieved in the Gen-2 inverter. Efficiency of 98% has been consistently achieved. Authors claim > 99%, although only one figure in the presented material shows that after 6 hours – efficiency increase with time needs to be explained if really true. One table in the presented material shows <99%. Nevertheless, the team should be congratulated in making a piece of hardware which works great.

One reviewer said the group can get a reduction in the cost of the modules. This reviewer said very significant reluctance was seen in parasitic inductance from the advanced packaging, and also reluctance in the output EMI. It is not clear at what power level the EMI plots were taken. One final reviewer said demonstrating the high efficiency and low EMI is good, but the cost comparisons need more work. The team compares their modules to a standard six pack module; the comparison should be made to an automotive qualified power module, plus the inductors that are required for the team’s soft switching power module should be included into the cost.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said there was a small well-focused team, while another indicated there was good collaboration with partners for the study. As already mentioned, an industrial partner will be a plus. A third reviewer mentioned Powerex, NIST, and Azure Dynamics. Another commenter said the collaboration between the PI and Powerex is clear, but added that it is less clear between the other partners. One reviewer noted that further collaboration with industry for future commercialization is important. The final reviewer said the team did not show any outside collaboration.

QUESTION 5: HAS THE PROJECT 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?

Comments were generally positive in this section. The first reviewer said the plans to test the inverter in the vehicle are outstanding, while another said the future research is appropriate. A third reviewer said to continue testing and integration into a vehicle, and added that it is good that the researcher will address the EMI issues; this reviewer would like to see the tradeoff between the hard switched and the soft switched circuits. Another commenter said that putting the inverter on the road is an excellent test. The cost model for the Generation 3 module should be an automotive qualified module, including the cost and weight of the inductors vs. an automotive qualified power module. The final reviewer stated, according to the milestones slide, Generation 2 will be tested in vehicle. This reviewer asks, what about Generation 3?

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No responses were provided to this question.

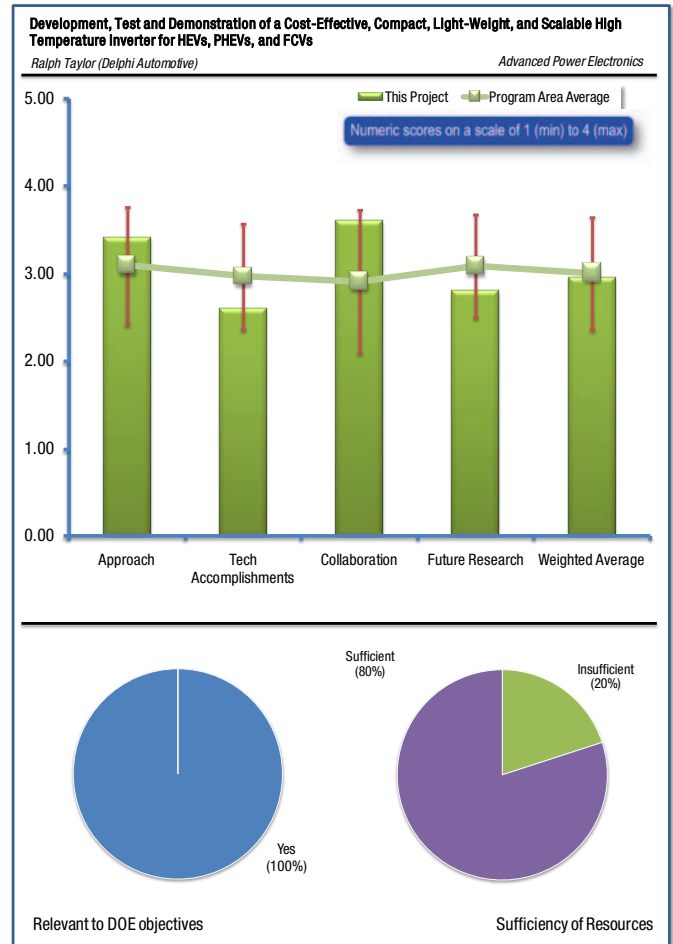
Development, Test and Demonstration of a Cost-Effective, Compact, Light-Weight, and Scalable High Temperature Inverter for HEVs, PHEVs, and FCVs: Ralph Taylor (Delphi Automotive)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. One reviewer said reducing cost, weight, and volume of an inverter is definitely a relevant objective, while another said that the novel packaging and possible low cost construction make this effort very relevant to the DOE objectives. A third reviewer said this supports DOE objectives for cost, volume and weight, and added that this is a broad multi-discipline approach that looks at many components. Another reviewer noted the project investigates low cost, volume and weight of the inverter circuit. The approach to reduce wire bonds can increase the reliability of the system and reduce long-term cost. The final reviewer said that the reduced weight and size, and eliminating the need for a cooling loop addressed by this project would help reduce petroleum consumption. This reviewer added that the proposed manufacturing approach would be consistent with cost effective high volume production.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said this program considers the broad spectrum of inverter technologies that together may have significant impacts. Specifically, the novel double-sided cooling IGBT and the circuit board integration may lead to substantial improvement. Another reviewer noted the project uses a Delphi Viper power switch with double sided cooling, and added there was great experimental work on GE extruded polycarbonate film capacitor. A third reviewer said the approach is good but challenging due to the amount of new components involved. Another commenter stated that the dual high-risk, high payback and low-risk approach is commendable, but delays in the high-risk efforts seem to have resulted in overall program delays.

The final reviewer commented no wire bonds and using a circuit board approach, which will minimize the buss bars. A very compact system was designed that can have both top and bottom cooling. Improvement on film capacitors was seen. The team is also investigating the film-on-foil caps to reduce cost and volume. Also, the team should investigate SiC devices to replace Si. There is a need to double current handling capability of SiC to keep the cost the same.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments in this section were mixed. The first reviewer said the team has good progress toward the objectives and has shown good results in the package and capacitor development, and added that they need to overcome the issue with SiC material. Another said congratulations for the effort but has to admit that it is hard to evaluate the progress accomplished due to the lack of information. A third reviewer commented that November is when hardware is available, and added that the SiC on Si work is progressing, but is not a success yet. Another reviewer was disappointed that even a preliminary inverter design has not been fabricated and tested with the

Viper IGBTs using existing state of the art Si diode and capacitor technologies. This reviewer added that it appears that the original problems associated with growing SiC on Si seem to have been solved – this is encouraging.

The final reviewer said progress is generally good on the broad set of individual tasks and on the integration of the overall project. There remains uncertainty about progress on one of the high risk, non-critical path, tasks involving SiC on Si wafers. Progress was previously made on wafer thickness and bow, but N₂ contamination is still too high. The stated goal for Q2/2010 (shortly after this Merit Review) is to determine if the new material is suitable for fabricating test devices. Although material test structures indicate progress, this reviewer eagerly awaits quantitative demonstrations of the status of this task and how it might impact the overall project.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. The first reviewer said there was good collaboration with leaders in the market of devices packaging and circuits, while another said that there appears to be a strong team. A third reviewer said there were different partners with critical involvement. The final commenter said Delphi has put together an outstanding team of experts and companies incl. Dow Corning/GeneSiC, GE, Argonne, ORNL, and NREL.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said that many paths can be explored with these technologies. Another stated a concern that there are still a lot of unknowns, and the reviewer isn't sure that they will be addressed and solved in the small amount of time left. Backups are planned but will not plainly satisfy the expectations. A third reviewer said to investigate film caps and foil caps. The team should continue to look at 3C SiC. The team did not show many results for system modeling. The final reviewer stated that it may be too late in the program, but an inverter should be fabricated and tested with the existing Viper IGBTs and “low-risk” state of the art diodes and capacitor technologies, as well as building an inverter with the “higher risk” technologies once they become available. This final reviewer said the team seems to be betting on all of the “high-risk” technologies being successful.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

Scalable, Low-Cost, High Performance IPM Motor for Hybrid Vehicles: Ayman El-Refaie (General Electric Global)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said this project seeks to meet very aggressive targets for motor cost, efficiency and weight, while another said propulsion motor technology is key to electrification success and improvements to the technology affect vehicle performance, efficiency and range. This reviewer added that efficiency and range affect petroleum displacement. A third reviewer said the work was to achieve high efficiency (greater than 95%), high speed of 14,000 RPM, and high coolant inlet temperature. The final reviewer commented that the novel electric machine design claims a significant increase of efficiency. If the project is going to be successful, the novel electric machine design could potentially accelerate the implementation of electric drive systems in the automotive industry. This would support the DOE objectives of petroleum displacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL

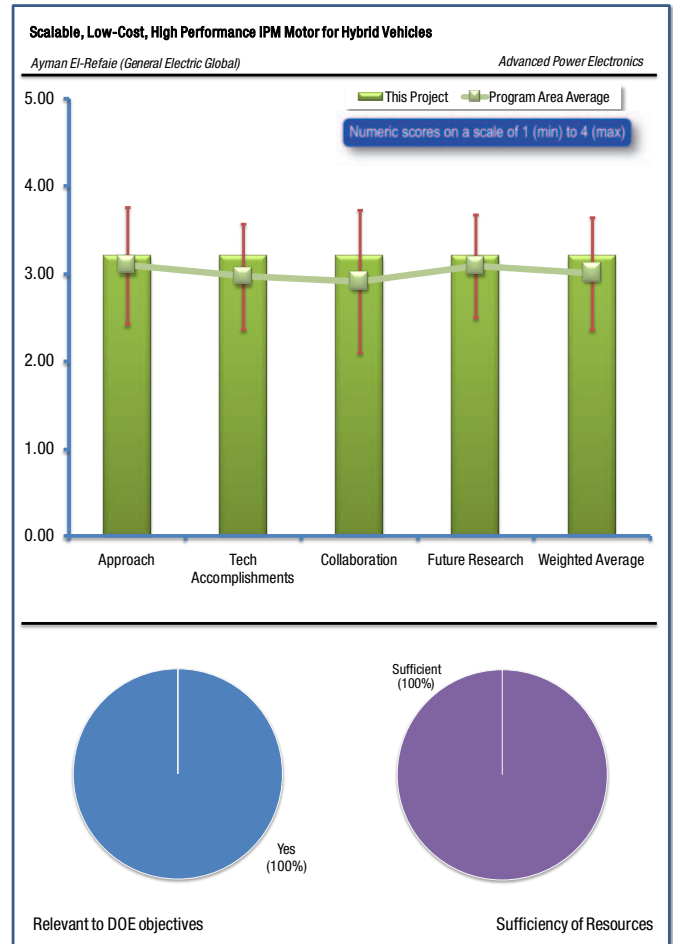
BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said improving each main component of the PM is certainly a good approach, while another said GE has taken an innovative approach to simultaneously meet all the goals. The design uses concentrated windings and an interior PM rotor. Another reviewer commented the approach is to reach high power density IPMs. A fourth reviewer said the researchers are addressing one of the most important technical barriers in electric machine design, which is the increase of efficiency. But it has to be checked in how far the focus on fulfilling the very tough DOE requirements for efficiency at high speed might sacrifice the efficiency at lower speed operation, which is usually more important for the overall fuel efficiency in a vehicle application.

The final reviewer said few details are provided, but the motor technology appears to be innovative. High resistivity magnets are required due to spatial harmonics created by the stator, so more evidence that the topology justifies the rotor heating would be useful. Rotor heating tends to become worse as motors are scaled up to higher power, this final reviewer added, so the team should consider this when the 120 kW version is designed.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the test results of first generation machine are encouraging. This reviewer is impressed by the amount of work done this year. Concerning the thermal study, concerns are raised about the thermal exchange between stator and cooling jacket. This reviewer is curious to know what the liquid temperature was during these tests, and the extracted thermal power. A second reviewer commented that the team has received and tested the first proof of principle machine and has received the second proof of principle machine. There was a good approach on the stator winding to reduce the losses. The team has completed full testing at various speeds



and tested up to 1400 RPM. The team has tested the machine up to full power. The machine was also tested up to 105°C inlet coolant only up to 7500 RPM.

A third reviewer said that significant and partly excellent progress towards the objectives has been made. All issues have been named and for most of these a path leading to the solution has been shown. The manufacturing and testing of prototype machines gives credibility to the claimed achievements. Some of the proposed improvements for the IPM machine design can also be applied separately to other machine concepts. This reviewer adds that the concentrated stator winding concept chosen leads to higher harmonics, and therefore potentially higher losses in the rotor. This problem is addressed by a part of the project which deals with the development of new magnet materials with higher resistivity. The researchers should make sure that this part of the project is not consuming too many resources, because this specific topic is also studied in two projects from other researchers.

Another reviewer said the motor meets most of the goals except for high speed efficiency. This reviewer believes that this requirement is not a real world need since there is very little time spent at high speeds for most drive cycles. The final reviewer said proof of principle test data shows progress, but the test results are limited and more characterization should be available. For example, an efficiency map and continuous output capability curve should be presented at this time (preferably with a high accuracy torque cell like HBM).

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said there was good collaboration with academia and industry to meet the requirements, while another said the collaboration between the different partners seems good. The third reviewer said that the partners are appropriate, and another added that GE has many good partners. The final reviewer said the collaboration with university and industry partners seems to be well coordinated. This gives the project the advantage of receiving input from multiple sides, which should contribute to the success of the project.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said there was a good approach to scale up of the motors and meet the required goals, while another said the proposed future work addresses the majority of the remaining issues very well. A third reviewer said there is a good plan to cross the finish line, but asked if it will be on time. The final reviewer said evaluation of the current status and how that influences the next steps appears to be appropriate and in place. More detail for the purpose of evaluation is desired to help review the technology and determine its advantages relative to available motors.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

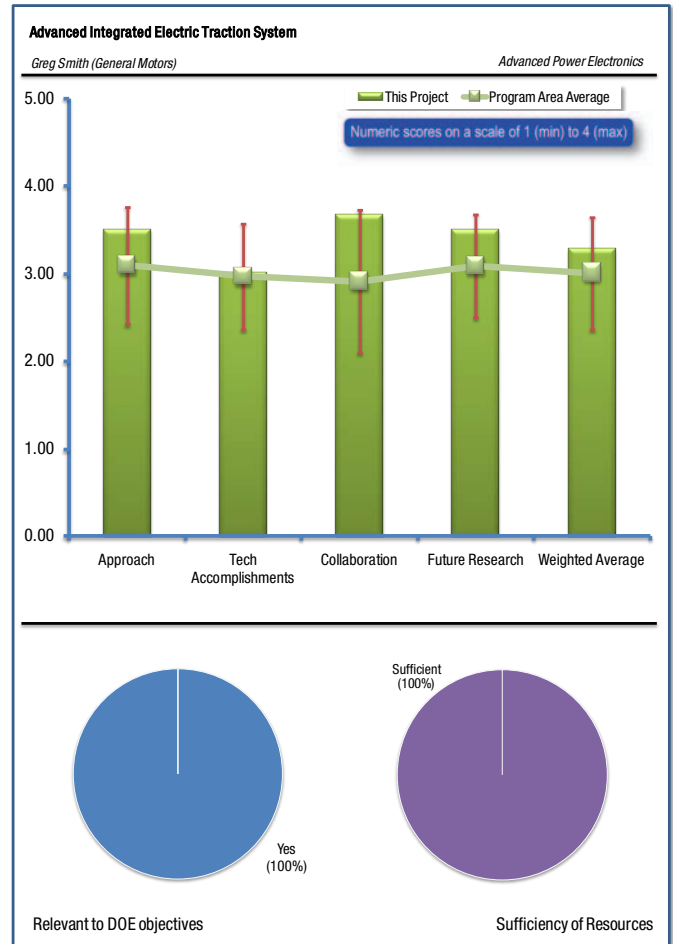
Advanced Integrated Electric Traction System: Greg Smith (General Motors)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said this project will reduce cost with high power density and high efficiency. Also, this project addressed the increase in reliability. Another commenter said that this project, if successful, will help meet the 2015 electric drive train targets. A third reviewer said the work is directly relevant to implementation of EV or hybrid EV application; real world, right now. Another commented that integrating the inverter into the same housing as the motor is an avenue that needed investigation. A fifth reviewer said this technology ventures into areas that stray from conventional, and, if cost advantages are proven out, it will help vehicle electrification adoption. Another said smaller size, lighter weight, and cost improvement are directionally correct to enable market acceptance of electric drive vehicles. The final reviewer said this is different from university/national labs based research, but this comment is not to imply that this final researcher thinks research projects are not important. DOE funded projects often allow discovery and correction of problems otherwise uncovered by customers. This benefit may not always be appreciated.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said the trade studies performed to arrive at design decisions appear to be well thought out and executed. The team recognizes the issues relevant to propulsion system optimization. Another reviewer said this approach looks at components in the system such as the motor, thermal, circuits, chargers and the system integration. A third reviewer said multiple challenging innovations are sequenced in this approach (multi-phase machine, heavy layer circuit, new switches, bus caps...). Another commenter said that, given the results will be a “real product,” known barriers have to be knocked down, or at least addressed. Without this focus, that wouldn't happen. Another reviewer said the work was focused on technical barriers, but adapting requirements to “real world” environment. Can the team share those real world requirements by updating the original specifications? The final reviewer said (1) It is not clear what the key quantitative benefits are of going to 5-phase system in terms of meeting the 2015 specs, and (2) Even though the project is targeting the 2015 specs, according to the presenter, it seems that some of the components are sized based on GM's required ratings and not the 2015 specs.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer was impressed by the accomplishment realized this year in this project. Each sub-system looks under control. Another reviewer said the pace of progress is impressive, and added that it would be helpful to quantify the improvements achieved based on the design decisions (publishing the trade studies). For example: capacitance reduction due to 5-phase with 3rd harmonic current, inverter kVA rating for 5-phase versus 3-phase approach, pros/cons of thermal solutions, and why the copper baseplate came

out on top. A third reviewer said the progress has been excellent, but added that, considering the funding level, it should be. Cost remains a challenge, and this reviewer thinks it will be for considerable time. Cost is a real barrier to success in this market. Even with the federal subsidies for a plug-in EV, the cost differential between say a Chevy Volt and an equivalent internal combustion-only vehicle enables purchase of a large amount of gasoline. It appears that cost has been addressed in several areas.

Another reviewer said the project started at the component level, and developed a heavy copper board and press fit pin, which is done with a solder-less joint. The team also investigated high temperature solder. They tested power module joint up to 1800 cycles. They reviewed several types of thermal heat sinks and selected the copper heat sink. Another reviewer said (1) The project is tackling many areas and it is not clear how the progress accomplished compares to the 2015 specs, (2) Test data is needed and clear comparison to the specs is needed, and (3) It is not clear what the next steps are in order to meet the 105°C coolant inlet temperature requirement as well as efficiency requirements for the motor. The final reviewer said hardware is becoming available to test – perhaps for initial systems, soldering can be used as opposed to press fit pins. All targets may be difficult to make; can these “targets” be revisited as part of the task team roadmaps – Or is there a path to address these shortfalls? The presenter made the comment that a five phase motor would be something they would not put into production but they would use a three phase machine, why? What are the cost drivers that are making it difficult to meet cost?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said the team has good collaboration for the different components and a good plan to integrate the team, while another said there was a very ambitious coordination effort with all the collaborators involved in this project: good job. A third reviewer said lots of suppliers were present. Another commented that other institutions are mentioned, but their influence is unclear. Regardless, this reviewer added, the design decisions are thoughtful as mentioned above. A fifth reviewer said there are many entities involved, but it is not clear what is the specific contribution of each of them. The final reviewer commented no project like this can be successful without the collaboration of suppliers and National Labs.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said future work will involve testing at the component and the system level. It should also include EMI testing and thermal cycling of the components. Another reviewer looks forward to the test results, and, hopefully, more details about the gains achieved with this architecture. Future efficiency mapping was mentioned, which is important to compare and contrast the performance of electric propulsion systems. A third reviewer said the development plan is well constructed up to the final report, while another said there needs to be experimental verification of the predicted performance as soon as possible. Another commenter said this work is to build, test and validate: not exactly research, but it is needed to verify all the previous work. The work looks good. The milestone chart says the work will be done in March 2011, the strategy chart says done in May 2011 – what is changing? The final reviewer said the proposed work appears to be sufficient to “finish the project.”

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

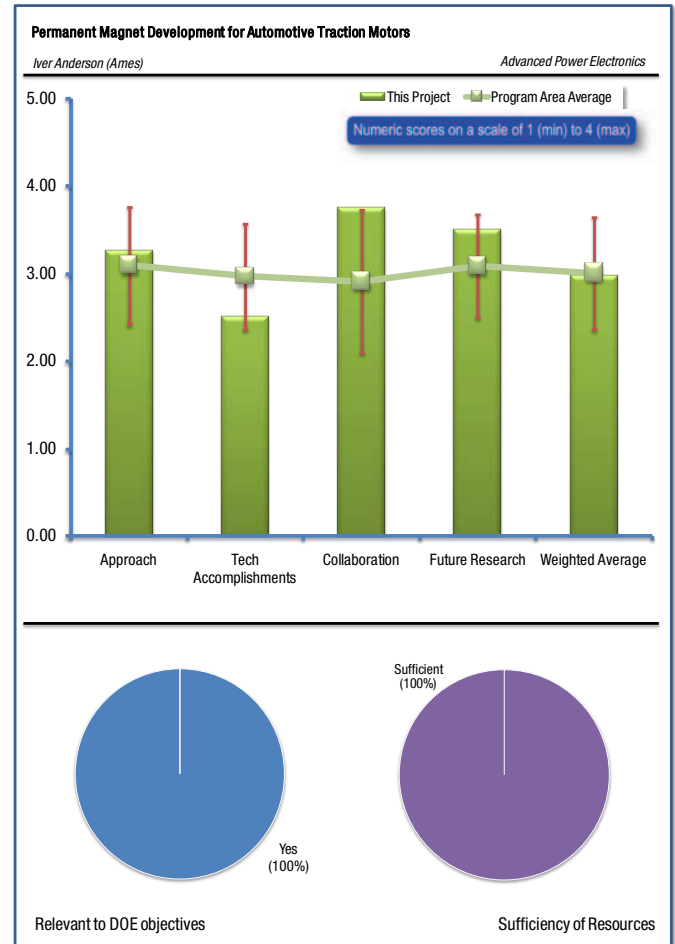
Permanent Magnet Development for Automotive Traction Motors: Iver Anderson (Ames)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said this project focuses on the reduction of the cost of permanent magnets, and achieving higher operating temperature while maintaining magnetic performance. The goal is to increase magnetic energy density at reduced manufacturing cost. Another reviewer said the project addresses a major issue of today's electric machines, which is the high cost of rare-earth permanent magnets. If the project is going to be successful it could potentially accelerate the implementation of electric drive systems in the automotive industry. This would support the DOE objectives of petroleum displacement. A third reviewer said (1) High energy product high-temperature permanent magnets are needed to achieve high power density motors, and (2) Non-rare earth permanent magnets are needed to minimize the risk of price and availability of rare earth permanent magnets in the future. The final reviewer said current and future work is relevant to finding alternative materials, or at least reducing dependence on materials that may become difficult to obtain as vehicle electrification takes place. China's monopoly over rare earths may threaten electrification activities.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said this project has a good approach of developing anisotropic magnets for compact high torque applications, and added the approach using nano-crystalline powder is good. Another reviewer said that the technical barriers for the improvement of permanent magnet materials are clearly addressed by the researchers. The great bandwidth of possible improvements for rare-earth magnet material, both sintered and bonded, is covered in the approach to perform the work. Beyond that, also the improvement of non rare-earth magnet material will be investigated in depth. A third reviewer commented that past work has provided a basis to achieve results that may have a high impact going forward. Dysprosium reduction, higher strength/temperature magnets to reduce rare earth magnet content per motor, and non-rare earth technologies are important goals that are part of the future approach. The final reviewer thinks all the areas that are pursued are important but is concerned that pursuing all these in parallel might not be the way to go. Even though the presenter indicated that more resources are available, the reviewer thinks that picking one or two areas to focus one might be more productive. This reviewer is also concerned about the pursuit of bonded magnets because they have lower energy product and there are some significant practical issues that does not allow taking advantage of injecting these magnets into IPM rotors.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the project showed good technical accomplishments in the area of simulation and development of the materials and in investigation into beyond rare earth magnetic. A second reviewer said a significant progress has been made towards the goal of improving anisotropic magnets both with intrinsic and extrinsic sintering. The main focus for this part of the project is an increase in energy density and coercivity with the reduction of the most expensive rare-earth materials. The second part of the project which deals

with the improvement of the magnetic properties of bonded magnets has to overcome some technical hurdles at this point in time. The last part of the project, which is the development of non rare-earth materials, is in an early stage now and the evaluation of the technical accomplishments will be clearer next year. This reviewer added the researchers should make sure that the improvement of ferrite magnet material will be investigated in detail.

A third reviewer couldn't quantitatively evaluate the technical accomplishment and progress. This reviewer believes that clear quantitative comparison to the state of the art is needed. The final reviewer said past work has been slow to show results that impact magnets used in motors. For a program that has been going for many years, it is disappointing to see the problems encountered for achieving the fundamental goals. This is difficult science, however, which should be considered. Future work, as described in this year's presentation, and with some successes, will change this assessment.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. The first reviewer commented that there were great collaborations and the workshops on the projects helped focus the project, while another said it seems there is good collaboration with various entities. A third reviewer said an impressive network of collaboration partners has been set up for this project. Both industry and university input will be collected in the project. This is the best approach to initiate a competitive permanent magnet research activity in the U.S. The final reviewer said collaborators are appropriate and numerous. Ames is proactive in discussing their research and soliciting input. This will continue to be important with the new directions being pursued, and input from motor manufacturers beyond those listed as collaborators is encouraged.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said the project showed a good path forward to reach the goals. Another reviewer said that the future research for the improvement of sintered and bonded rare-earth permanent magnet materials is well planned and builds upon the achievements so far. The investigation on non rare-earth magnets is in an early stage, but the next steps for a more defined definition of the project are well described. A third commenter said, as previously mentioned, more focused approach is recommended. The final reviewer said past activity provides the experience to create high-impact work by reducing dysprosium and rare earth content required by high performance motors. Substantial reduction in dysprosium would be a successful result. Making AlNiCo work, somehow, would be an even more successful result. The future research proposed is important, and this final reviewer hopes next year's presentation will show progress in these areas.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received in this section.

Power Electronic Thermal System Performance and Integration: Kevin Bennion (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said high temperature operation is critical for power electronics and high power density. Also, the package is critical for heat removal and low losses. A second reviewer said the capability to perform system studies is very important to assess the impact of different package and cooling designs on the inverter, motor, etc. The final reviewer said that competitive assessments provide a benchmark against which other approaches can be compared. These comparisons raise the bar for cost, performance, and innovation.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

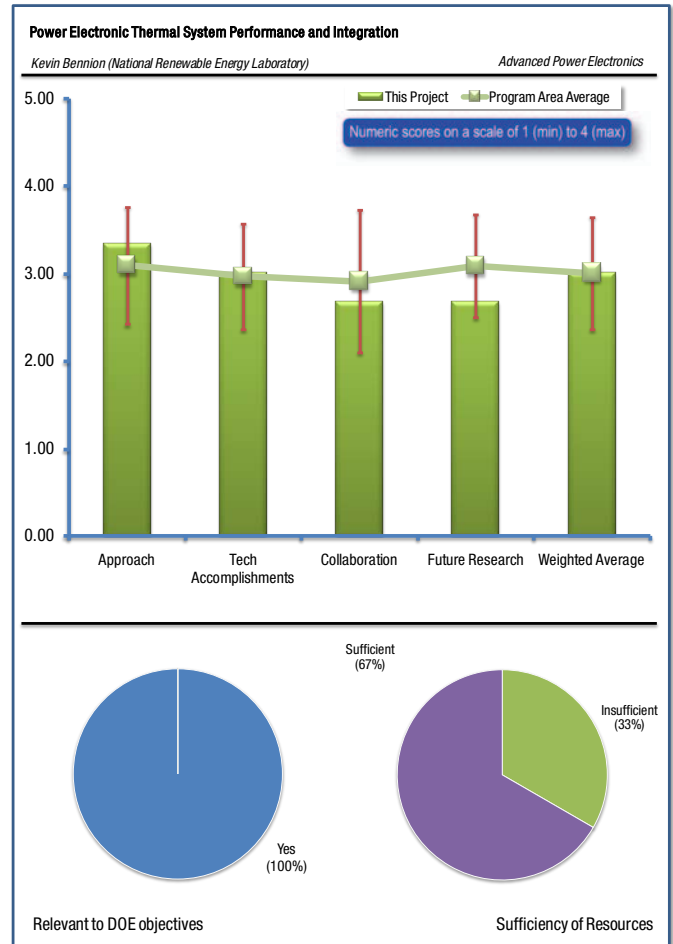
The first reviewer said there was a good understanding of what is needed and a good approach to developing a system-wide understanding. Another commented that the project is to identify system knowledge gaps and then develop a process. The project also investigated the comparison of baseline cooling to a direct cooled base plate and directed cooled DBC. The final reviewer said performance, weight, thermal management, and volume in some ways are being addressed. Cost and life analysis are missing. This reviewer asked if these analyses can be quantified to the goals of this program (dollar savings, weight savings, and long term reliability) with respect to how they apply to an inverter or DC-DC converter or a power stage.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer referred to comments from questions 1 and 2 above, while another observed that the team made significant progress towards the integration of the package and also implemented lessons learned.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said there is collaboration with industry and government labs, but not research with universities. The other commenter said more interaction with industry would be welcome. This reviewer asked whether the team can use their techniques to come up with “better ways” to do what they are benchmarking. If so, can some of their concepts find a commercial partner to use the technology?



QUESTION 5: HAS THE PROJECT 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?

The first reviewer said there was a good plan to integrate thermal systems to meet the stated goals. Another said good work has been done establishing this modeling capability. This reviewer asks how it can be made available to government or industry in the future. The final reviewer asked if the team can come up with better ways to do what they are currently benchmarking.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

Thermal Stress and Reliability for Advanced Power Electronics and Electric Machines: Michael O'Keefe (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said the project focused on the development of reliability of power electronics and motors, while another said this project begins the process of understanding joint technology for power modules. The final reviewer commented that reliability evaluation of advanced technologies is essential to determine suitability for vehicle applications. Technologies evaluated in this project may aid in reducing size and weight, and in eliminating a cooling loop. This would lead to petroleum displacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

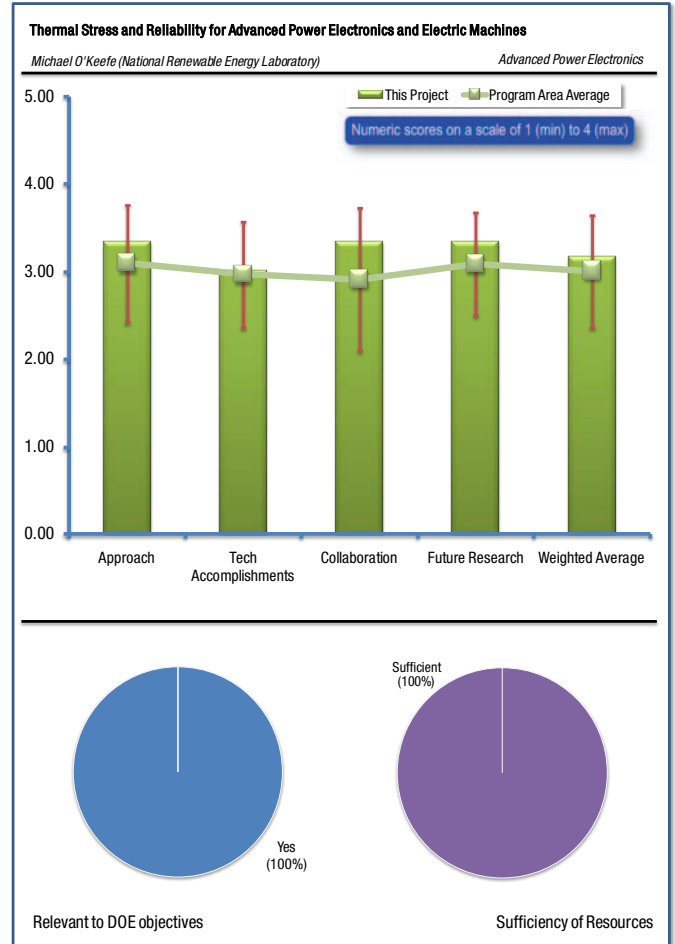
Comments were generally positive in this section. The first reviewer said the approach to compare the three APEEM packages and compare the results with the FreedomCar EETT is a good approach. Modeling was done to compare the different packages; however, some actual data is needed. Another commenter stated that this project is providing a strong theoretical and measurement foundation for package technology reliability studies within the Vehicle Technologies Program. The final reviewer said that the work is well planned, and added that the team may want to consider how best to make the data generated usable to industry.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said the concepts have been demonstrated and results are described clearly. Another reviewer said good models were developed, but more test data is needed for collaboration of the models. This reviewer stated the need to show the thermal cycling of the system.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. One reviewer pointed to a good mix of industry, academic, and other national labs, while another said the project has a strong effort to coordinate and build links between various device, package, and cooling efforts within the Vehicle Technologies Program. The final reviewer stated that there was good collaboration with industry and universities, and mentioned the collection of data from research partners to help with the generation of models.



QUESTION 5: HAS THE PROJECT 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?

One reviewer stated that future plans to validate model with test data will enhance the results of the research. Another said the program is well thought out with good future plans. Coordination with other projects within the Vehicle Technologies Program should continue to identify critical reliability issues and advanced structures being considered. Issues related to funding ramp up (and increased level of effort) next year should be a focus. The final reviewer said this work has a great plan, but the team needs to be timely with getting tasks done and information out.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this section.

Characterization and Development of Advanced Heat Transfer Technologies: Gilbert Moreno (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 1 reviewer.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewer said that improving thermal performance of inverters for electric drive vehicles can help to reduce their cost, adding that lower cost inverters can help to enable the market for electric drive vehicles.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The reviewer said that the team is looking for the “best” performance, but the reviewer did not see a target(s) for performance they are trying achieve. Have they considered that the best performance might be too costly, while something with lower performance may achieve the targets at lower cost?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewer said that performance at start of life does not equate to performance at end of life. How will this be quantified? Can the team also look at robustness – diameters vary over time, distance between objects have a tolerance, coolants degrade – how does that affect the initial performance?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

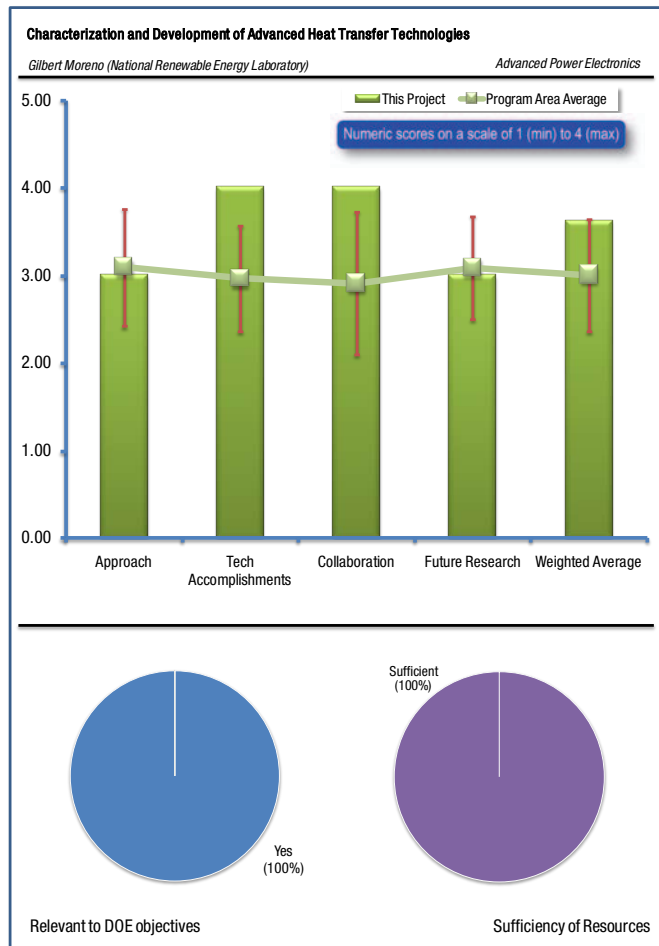
The reviewer stated that there is a good set of partners.

QUESTION 5: HAS THE PROJECT 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?

The reviewer said to see the comments above. Can the team find a partner to implement one or more of their best concepts to show cost and performance results?

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comment was provided for this question.



Air Cooling Technology for Power Electronic Thermal Control: Jason Lustbader (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said the project supports DOE goals for cost and mass, while another said that finding a lower cost cooling system for power electronics can help to enable electric drive vehicle systems. The final commenter said the elimination of costly secondary cooling systems in HEV and PHEV vehicles is a primary goal of the overall vehicle power technology program. This reviewer added that this project is focused on optimization of air cooling approaches, with an outstanding systems integration approach, which may significantly impact these objectives.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

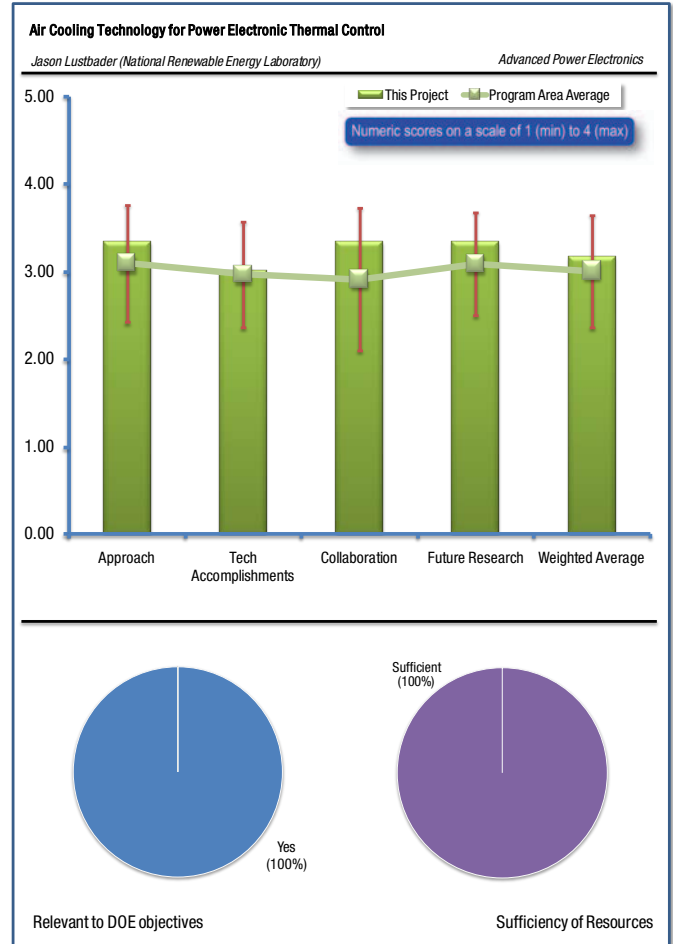
The first reviewer said there was an excellent project focus and approach toward evaluating leading air-cooling technology approaches with an emphasis on the systems-level boundary conditions and impacts. This reviewer also observed a very well structured approach with well-defined milestones and solid technical underpinnings. Another reviewer commented that prior work on micro-fin coolers was not as practical due to issues with clogging and high pressure drop. The new work on synthetic jets looks promising to improve thermal transfer. The final reviewer said novel micro fins may give the best performance, but asked how the group addresses fin fouling or clogging. Will this require additional filtering of the air and also additional costs? Would it be possible to look at what could be done with radiator fin stock as opposed to micro fins? This reviewer added that radiator fin stock is currently used in automotive applications; its cost and properties are known and may provide a quicker path to automotive customer acceptance.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the project is on schedule with identified milestones and go/no go metrics satisfied. A second commented that so far there is only analysis and no experimental results. This reviewer is very interested in the results: this reviewer was involved with some work on submerged oscillating liquid jets, and it showed improvement over stationary jets. It should work the same with air. The final reviewer asked how air cooling affects mechanical packaging in an inverter. Does the power stage packaging, switches, need to change to accommodate these concepts? Will that add cost to the overall inverter? How flexible can the design be; is it quiet enough to put in the passenger compartment, will it require filters that require changing?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said working with ORNL to integrate the team's cooling system with an inverter is a good start. Another reviewer said the only recommendation would be to closely evaluate the work which has been done and is ongoing across DoD. This reviewer adds that DTIC reports would be an excellent resource for reference.



QUESTION 5: HAS THE PROJECT 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?

The first reviewer said that difficulties in implementing air cooling technologies appear to be well understood and the project structured to address and evaluate the proposed approach effectively. The close coupling with system level aspects will lead to a project focused on the key elements to overcoming the technical barriers present. Another reviewer said to include integrating the team's air cooling system with an inverter. The presentation should show all parts required for the team's system to work. The team should compare cost and size of all components required for air cooling.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

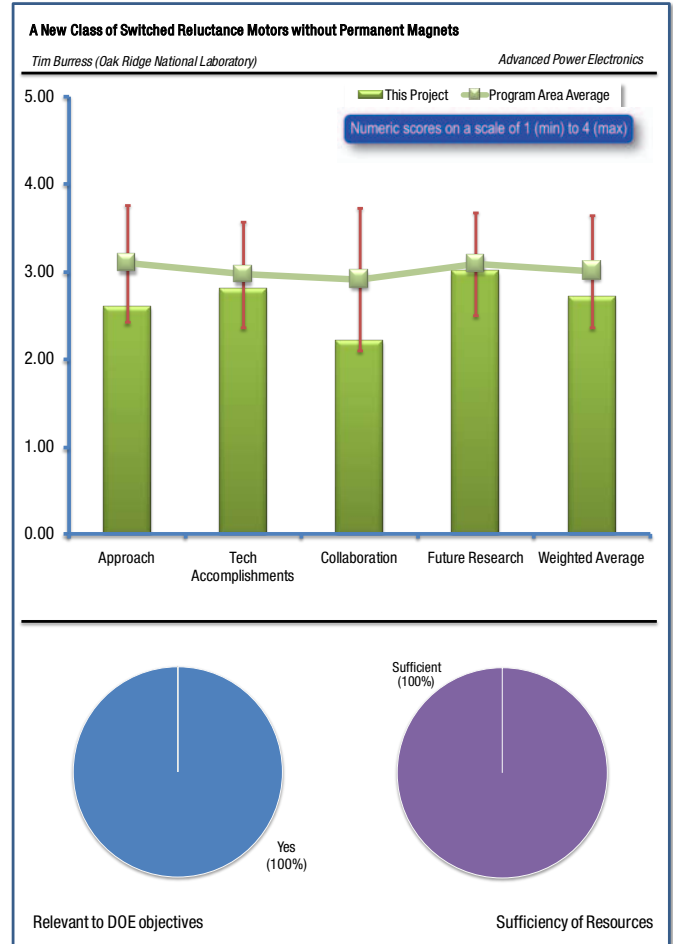
A New Class of Switched Reluctance Motors without Permanent Magnets: Tim Burress (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. One reviewer stated that, if successful, this project can provide a cheaper alternative to PM machines. Another commented that the study of a new type of switched reluctance motor is part of the contribution of new EV and PHEV. This reviewer added that the switched reluctance motor should not be neglected. Another reviewed stated that the novel switched reluctance motor design concept addresses a major issue of today's electric machines, which is the high cost of permanent magnets. If the project is going to be successful, the novel switched reluctance motor design could potentially accelerate the implementation of electric drive systems in the automotive industry. This would support the DOE objectives of petroleum displacement. A fourth reviewer said switched reluctance motors are candidates for electric propulsion and deserve to be considered if their performance problems can be overcome. They eliminate the need for strategic materials and could increase vehicle electrification if successful. The final reviewer added that this project supports the DOE cost and power density goals for electric machines. It strives to eliminate the costly NeFeB rare earth magnets.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said the researchers want to address the well-known disadvantages of switched reluctance motors, which are vibration/noise and controllability. The proposed design approach features some novel ideas which require a detailed investigation through simulation and testing. Another commented that, from simulation to prototyping, the approach is good, even though not a lot of detail provided. The third reviewer added that the approach seems well conceived, but results are short on details. For example, this reviewer adds that design studies of different architectures are mentioned, but the results of these studies are not published.

Another commenter stated that Tim's investigation into a new switched reluctance motor proves that there can always be new discoveries if one takes a fresh approach. This reviewer is not a big fan of switched reluctance, but this motor appears to have good torque density and low ripple. The stator poles look very simple to wind and assemble and the rotor is simple and robust. The large number of poles should help reduce modal vibrations in the stator to reduce acoustic noise. Drawbacks this reviewer sees are: 1. potential acoustic noise if the stator poles are not rigidly held in place, 2. unique power module with unidirectional current (same for all SRs), 3. twice the number of motor cables compared to 3-phase, and 4. difficult current profiling.

The final reviewer was not sure that the proposed concept can fundamentally solve the well-known issues of switched reluctance motors in terms of acoustic noise, vibration, and torque ripple. This reviewer is also not sure that the proposed concept will be competitive with permanent magnet machines in terms of efficiency and power density.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer stated that the analysis of the chosen design is progressing at a good pace. This reviewer added to make sure to consider the mechanical challenges associated with the separate stator segments, as the forces on these segments could create challenges, and possibly prototype failure, if not addressed. Another said the project seems to progress properly but added that there is not a lot of information to judge it other than promising investigations. This reviewer would have appreciated having a brief description of challenges and issues solved on the motor control side.

A third reviewer said that the technical accomplishments so far are more of a theoretical nature, although some simulations have been conducted. The main claim of noise reduction is not yet proven, either in simulation or with testing. But this is fully in line with the project schedule and therefore not a point of criticism. This reviewer added that a common problem with switched reluctance motors is that if the controls are optimized for low noise, the efficiency is reduced too. The researchers have to make sure that this is incorporated in their design process. Another reviewer added that so far this project has only done simulations and no machine has been built. The technical results look promising; however, this class of machine seems to always have certain issues around torque ripple and acoustic noise that only surface after the hardware is built. This reviewer will wait for the experimental results to see how well this motor works compared to the simulations, and hopes it works well.

The final reviewer stated that, even though the project is almost 50% done, there is a lot of work to be done and significant risks to be addressed. The reviewer indicated: (1) Detailed thermal analysis should be performed. There might be significant cooling challenges with the proposed stator structure and winding configurations. (2) Detailed structural analysis should be performed. (3) Evaluation of the efficiency and power density should be performed. And, (4) It is not clear how does the machine performance compare to the specs

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments in this section were mixed. The first reviewer stated that the collaboration with university and industry partners seems to be well coordinated. This gives the project the advantage of receiving input from multiple sides, which should contribute to the success of the project. In contrast, another said it's not really a collaboration, but more on the level of sanity-check partners. A third reviewer said it doesn't seem that there is a lot of collaboration. Most of the work is done at ORNL. Another commenter stated that collaboration is light and deficient of industry/manufacturing involvement. Switched reluctance controls will be highly important to showing useful results, and partners with this experience under their belt are encouraged. A final reviewer thought that collaboration with Newcastle University or Aachen University would be very useful as both of these institutions have extensive knowledge of switched reluctance motors

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said the team has planned well for the project and future hardware, while another stated that the next steps in this project are well planned. The researchers are aware of the many hurdles they have to overcome to significantly improve the existing switched reluctance motor concepts. Prototype testing will be necessary for a final conclusion because an accurate simulation of the noise in electric machines is still a challenge.

A third reviewer hopes to see results from experimentation next year. Another commenter said that the detailed analysis should be finalized, then a prototype should be built and tested as soon as possible to prove the concept feasibility. The final reviewer stated that, as with any motor, and the switched reluctance motor in particular, the proof is in the testing. This reviewer would encourage a path that creates a proof-of-concept unit faster than planned, performing control optimization with hardware rather than through computer modeling.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

Bi-directional DC-DC Converter: Abas Goodarzi (U.S. Hybrid)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said the work supports the DOE goals for cost, mass and weight, while another said it meets or exceeds DOE targets for PHEV bidirectional DC/DC converters. A third reviewer said DC/DC converters are and will be more and more necessary on EVs and PHEVs due to the multiple DC voltage sources necessary. The final reviewer said bidirectional DC-DC converters are becoming more popular in HEVs and PHEVs due to their importance in reducing battery current ripple, maintaining power capability of the motor, and increasing battery life time.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

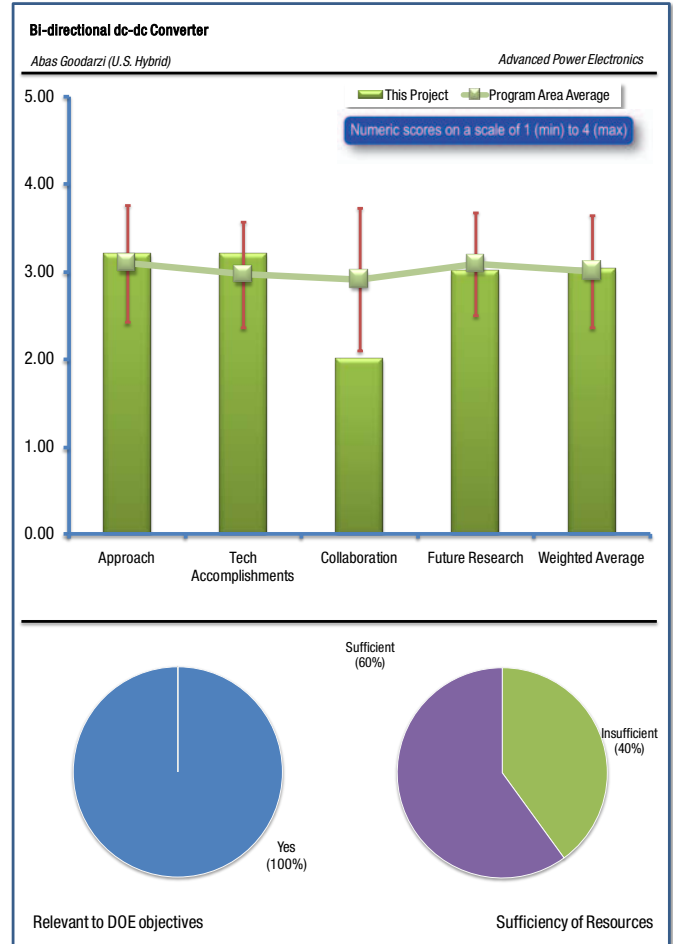
One reviewer said moving from simulation to prototype is a classical approach, but still very appropriate to that type of development. Another said current PHEVs do not advertise a dual battery approach, and asked if there is an OEM that is interested in the team's concept. A third reviewer said the concept of combining a power battery and energy battery makes sense until a better battery comes along. The key to this approach is a high power, high efficiency DC-DC converter. This converter uses SiC and multiple sections to increase efficiency. The final reviewer said the approach uses two kinds of battery packs with one directly connected to the motor DC bus while the other uses a DC-DC converter. It might work in some way, but why aren't all batteries connected through the DC-DC converter?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the measured data shows very good results in improving vehicle range, converter efficiency, and cost. There are few details about the converter design, but it is obvious that careful details of magnetics, thermal and power flow were completed. Another reviewer said a lot of simulation has been done at vehicle level and also at the component level. Test realized at component level on units is a good accomplishment so far, especially when results appear clearly; this reviewer can appreciate that. A third reviewer said the progress seems to be slower than expected. The final reviewer saw no comments on the power density and specific power targets, and this reviewer asked, were they met?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said it appears that most of the work was done at US Hybrid, while another reviewer cannot see any collaboration or partnership in the presentation. Another reviewer indicated no obvious collaborations, and added that the team seems to be seeking a partner for vehicle testing. A fourth reviewer said the team does not seem to have true partners for implementation of the developed converter. It is important that the researchers work with an OEM and a Tier-1 supplier in order to validate their research results. The final reviewer asked if the team can find an OEM and a battery supplier who are interested in supporting this architecture.



QUESTION 5: HAS THE PROJECT 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?

The first reviewer said the future research objectives are okay, while another commented that the intent is really to fully validate the product and bring it to production: that's an excellent objective. Another reviewer said they seem to have a commercialization plan for multiple applications, while a fourth reviewer referred to previous comments above. The final reviewer said that based on the current results, this project should continue into the pre-production phase or at least additional applications.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

Novel Packaging to Reduce Stray Inductance in Power Electronics: Leon Tolbert (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said this project is designed to reduce stray module inductance. This has a minor effect towards meeting DOE goals. It is a good way to increase module reliability. Another commented that the poster was not presented during the review. The final reviewer said power modules with low internal inductances reduce voltage stress levels on the semiconductor die as well as other components and materials in the system. However, the reviewer added that most power module suppliers already have low inductance package designs.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said this was a novel concept, but added that there is a problem with the “proposed” configuration shown in the presentation materials. This configuration implies that the Si PiN diode has the anode connection on the bottom of the chip and the cathode on the top. The opposite is true for silicon PiN diodes. Although this issue is not unsolvable, this reviewer added, the solutions may not be very practical. The concept of P and N cells is relatively new to the next reviewer, and it makes sense that it can reduce the parasitic loop inductance in a module. The simulations look very promising for the one case shown. In this reviewer’s opinion, the investigators should be working with a module manufacturer to understand their needs, standards, and barriers. They may be doing this already. Drawbacks are: 1. difficulty scaling up to multi-chip switches with current sharing imbalances, and 2. DC bus pads are located in the center of the substrate which makes it difficult to wire bond to a lead frame. This reviewer believes that this is a good idea, and is anxious to see test results.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

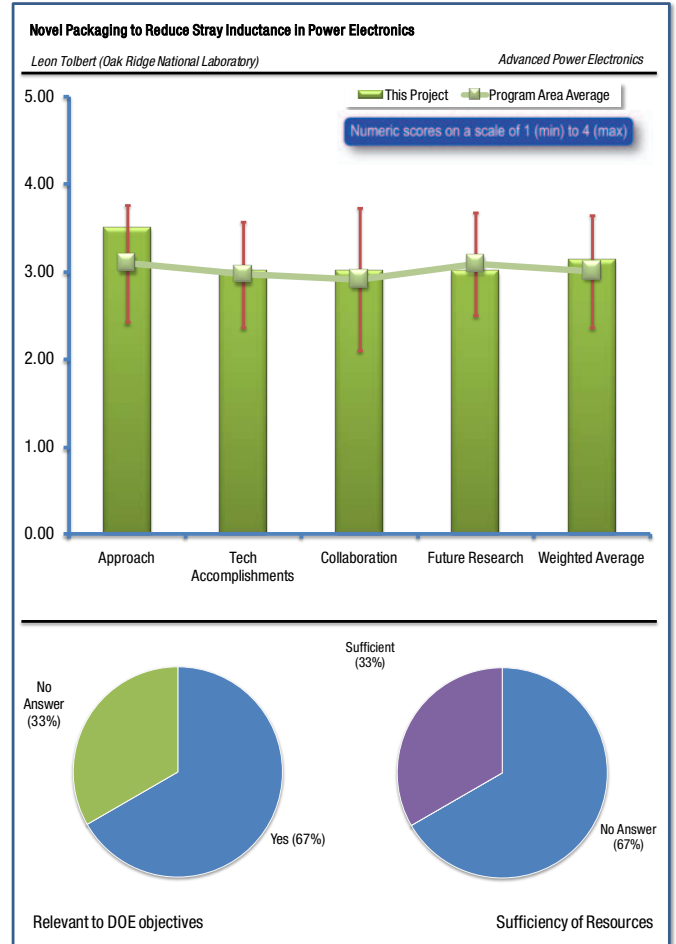
The lone commenter did not see any evidence of design sensitivity studies, i.e. internal inductance variation with conductor width/spacing/length, length and number of wirebonds, etc., different chip layouts to drive design of test module.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

There were no comments in this section.

QUESTION 5: HAS THE PROJECT 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?

There were no comments in this section.



QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

There were no comments for this question.

Power Device Packaging: Fei Wang (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said this project looks at power device packaging, which is important to meet the DOE goals of cost, volume and mass. Another stated that developing new power packaging can lead to smaller size lower cost inverters, helping to enable the electric power train market. A third reviewer commented that advanced high temperature power device packages with high reliability may impact the size and weight of the vehicle inverter and eliminate the need for an additional coolant loop. The final reviewer said the power switches are going to be one of the biggest challenges to overcome for inverters.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

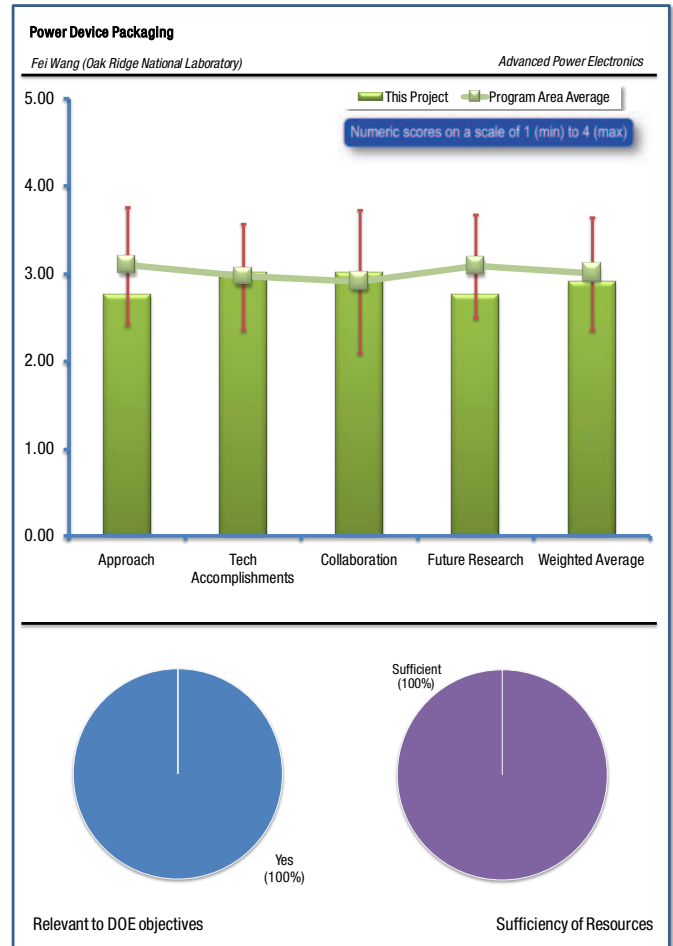
The first reviewer said benchmarking to establish a baseline before studying new solutions is a smart approach, while another commented that this is a new start-up that seems to be entirely exploratory and open ended without a clear predefined technical approach. A third reviewer said it is good to benchmark the best of power devices available today, and added that this benchmarking activity is just starting. The final reviewer said that, since the project is under patent review, it is difficult to evaluate. The approach to benchmark existing designs, improve on their performance with new designs, build and test those new designs is good.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments in this section were mixed. One reviewer said the project has made progress on performing some tests on state-of-the-art vehicle power devices. Another commented that no new concepts for a novel packaging method were shown. A third reviewer said the project is in its early stage. This reviewer noticed that some results extracted from other projects already mature, but “that’s fine” to use previous work to move forward faster. The final reviewer said this was a new start – since the project is under patent review, it is difficult to evaluate. Work shown has many coolant seals, this reviewer noted; how are leaks prevented?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said ORNL is used to managing programs with diverse collaborators, while another said appropriate collaboration partners are identified, but not much strategic collaboration has been demonstrated yet. The other commenter asked if the team should be working with a semiconductor supplier to provide die for their packaging work.



QUESTION 5: HAS THE PROJECT 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?

The first reviewer said this was a new start and referred to previous comments, while another was curious to see how the new package concept will go. This reviewer would have appreciated some status of development or research in progress concerning the new package concept. Another commenter said this project needs to continue to develop a more definite plan for addressing identified technical challenges. This may improve as the project progresses. The final reviewer hopes that the team comes up with a workable power concept, and added that there needs to be tight cooperation with commercial vendors to understand production costs.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this question.

High Power Density Integrated Traction Machine Drive: Fei Wang (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer stated this work supports the DOE goals of system cost, volume, and mass, while another said methods to decrease the cost of electric drive vehicle traction drive systems can help enable the electric drive vehicle market. A third reviewer commented that integrating the motor and the power converter can have a significant impact on reducing the drive train weight and volume. Another commented that integrated motor/electronics solutions are desirable for vehicle electrification and could increase consumer adoption. The final reviewer said this project concerns the electric propulsion system, which is necessary to the petroleum displacement objective. The limited power capability of such integrated drives is, however, a concern.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

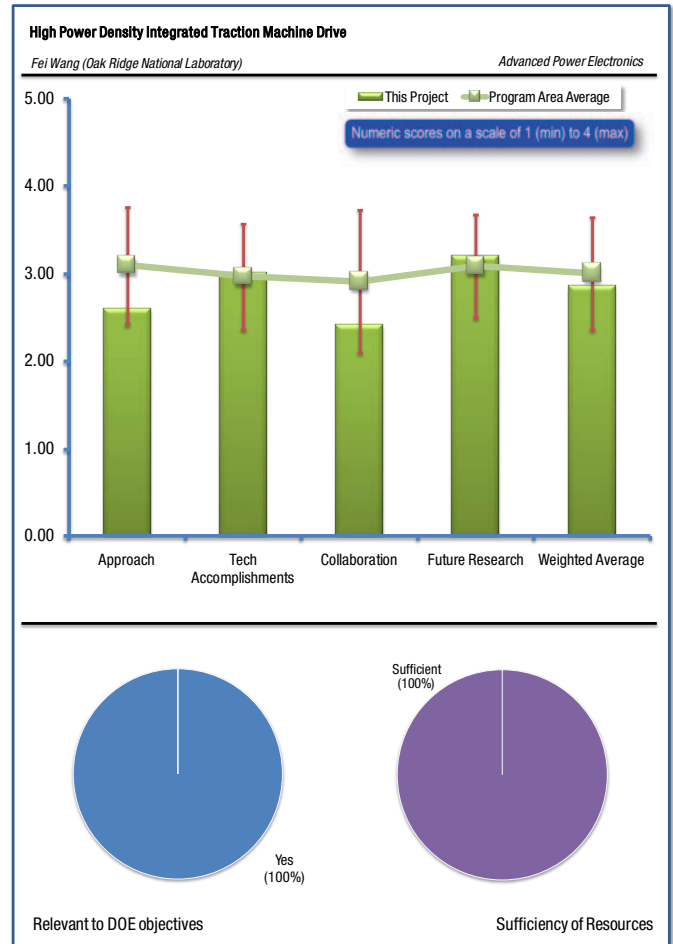
The first reviewer noted this project has just started and a prototype is already on its way. This reviewer cannot see any proof of concept or simulation, however, and asked if this project corresponded to the continuation of previous work. Another reviewer commented that an integrated traction drive is appealing, but this project takes on a lot of challenges that make it difficult to envision a manufacturable approach. Even if only some parts of this work are taken forward, this program will be worthwhile.

A third reviewer asked if the team can explain how packaging design and optimized cooling systems will extend operating junction temperature to 200°C. Are they saying this concept will work with all IGBT devices? Why oil cooling, why not use water-ethylene glycol and get better performance? How does this 200°C junction temperature affect the life of the device? What does the team feel is limiting the current Si device junction temperature?

Another commenter said the objective of this project is an integrated motor inverter. This is a unique approach because it also uses a multi-phase motor with a separate inverter per phase. This brings redundancy to the system, but also adds parts and complexity. If integration was not enough of a problem, they are also attempting to operate at 200°C junctions. Drawbacks are: 1. low B_{max} for the soft magnetic composite pole piece, 2. difficult cooling of the system, and 3. no thermal margin on power devices. The final reviewer said the scope of the project is not well defined. It is not clear whether the project is only focused on the integration and packaging issues, or if it will also include motor development. Also, it is not clear whether fault tolerance is one of the objectives or not. This final reviewer said many things still need to be decided.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer was really impressed by the progress made on this project in a short period of time, and said “good job.” Another commented that this was a new start, and to see comments above. A third reviewer said having hardware early on as a demonstrator is



a real positive. This reviewer added that more information and results are encouraged, but as a new program, this should not be expected during this review.

Another reviewer recommended they investigate 3D laminations that are now being done by several Japanese lamination suppliers. They use progressively stamped laminations of various shapes to create a laminated stack with 3D features. This can give them the desired 3D pole piece made of thin magnetic steel material. Another recommendation is to either reduce the coolant temperature or consider air cooling for the power electronics.

The final reviewer said one of the key accomplishments is developing control for the 5-phase system, and added that this might not be very relevant if it is decided not to pursue a 5-phase system. It seems that the main reason why 5-phase was pursued is mainly legacy and the existence of a 5-phase machine. This reviewer added that the other accomplishments, in terms of device evaluation and device packaging, still seem to be at a relatively preliminary stage. Experimental results are needed. It is not clear what is being done on the motor side.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said the work load is well distributed between universities used as subcontractors: “smart play.” Collaboration with a semi-conductor company would have been a plus for this project. Another reviewer said it seems that most of the new work is taking place at University of Tennessee, and added the main contribution of University of Wisconsin seems to be providing the 5-phase IMMD that has been previously developed. A third reviewer said collaboration with organizations that have hands-on experience in some of the key innovation areas would be helpful. The final reviewer would like to see an Si supplier supporting this work.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer simply said this was a new start, while another stated that the high rating is due to the approach of building prototypes early on, becoming progressively more representative of the desired propulsion system. A third reviewer said that second generation planned to build upon lesson learned from prototype 1 is the way to go. However, this reviewer added, there’s not a lot of proposal on research concerning power switches to deal with thermal constraints. The final reviewer suggested targeting a 55 kW IMMD that will meet the specs instead of targeting a 10 kW IMMD for legacy reasons. This reviewer added that it is not clear what the plans are for the motor, including the number of phases and machine topology.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this section.

High-Temperature Air-Cooled Traction Drive Inverter Packaging: Mahdu Chinthavali (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer indicated this supports the goals for DOE cost, while another noted the need to understand if air cooling can be reliably used to reduce power electronics cost. A third reviewer commented that low-cost inverters will help to drive the EDV market. The final reviewer stated that packaging of the power converter is always an important issue in HEV/PHEV. This research deals with the packaging that uses air cooling. It will help achieve meaningful results that can help reduce cost and increase reliability in these systems.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

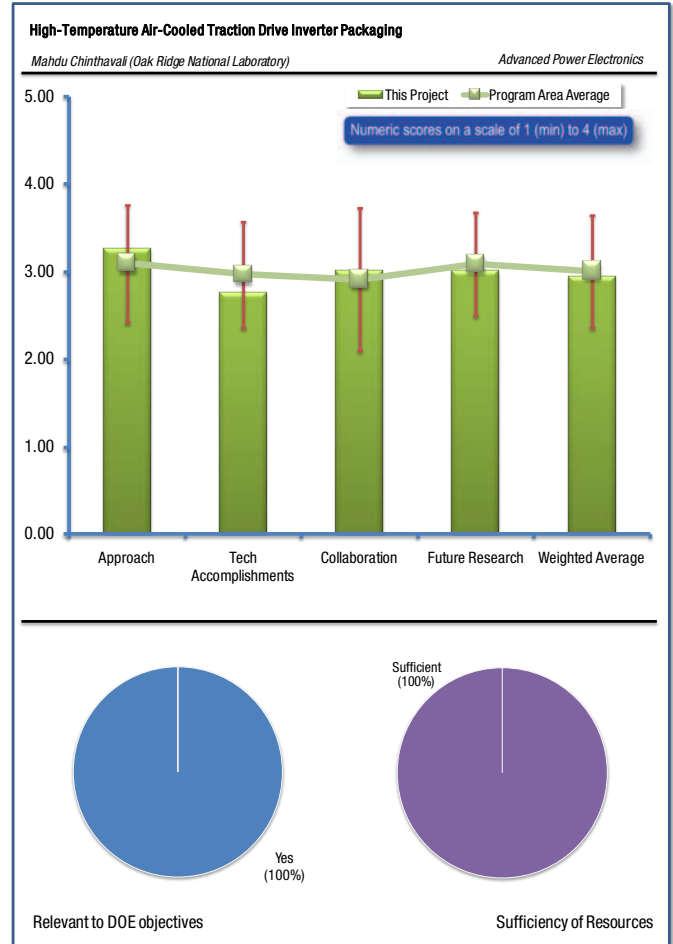
One reviewer stated that the approach is excellent, while another said it would be useful to see concepts of an air-cooled power stage that can illustrate how the heat is removed and the cooling is presented to the power stage. The final reviewer said this project was re-scoped to develop an understanding of the requirements and boundary conditions for air cooling of a traction drive. This reviewer added that there is not enough information yet to evaluate the approach.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said there have been some preliminary results, while another added that so far there has been good progress made to understand air cooling. It seems that a general model is difficult to achieve devoid of specific design details. The final reviewer said new start and referenced comments above. This reviewer noted the team did not mention high temperature interconnects as a gap; is there a commercial die attach process for a 275°C junction temperature device?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said it is not clear what modeling is performed at ORNL and what is performed at NREL. It seems that most of the thermal modeling should be conducted at NREL given their expertise. Another said the work is mainly performed by the collaborators, adding that the PI is a program manager. The final reviewer asked if the team has suppliers of these high temperature devices that are willing to work with them.



QUESTION 5: HAS THE PROJECT 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?

One commenter said the future research topics are appropriate. Another reviewer asked if the exit criteria are that, if the models from NREL show it's not feasible, the project ends?

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received on this aspect.

Electro-thermal-mechanical Simulation and Reliability for Plug-in Vehicle Converters and Inverters: Allen Hefner (NIST)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said the project allows optimization of the inverter cooling system based on usage and reduces overall volume, mass, and cost, which directly supports the targets. Another indicated that the research deals with thermal issues in power converters in HEV and PHEV. It is an important subject. The final reviewer said that combining physics-based electro-thermal and reliability modules to optimize performance and reliability of power modules is of great importance for vehicle, industrial, and military systems.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer stated the proposed approach is appropriate. Another commented that it builds on past work at NIST, but also adds the reliability modeling capability developed at the University of Maryland, applied to actual modules and validated by testing. The final reviewer stated that there is very good methodology in addressing the problem; however, it needs to be validated against a known standard or benchmark. Going after soft-switching may not be the best choice for initial focus.

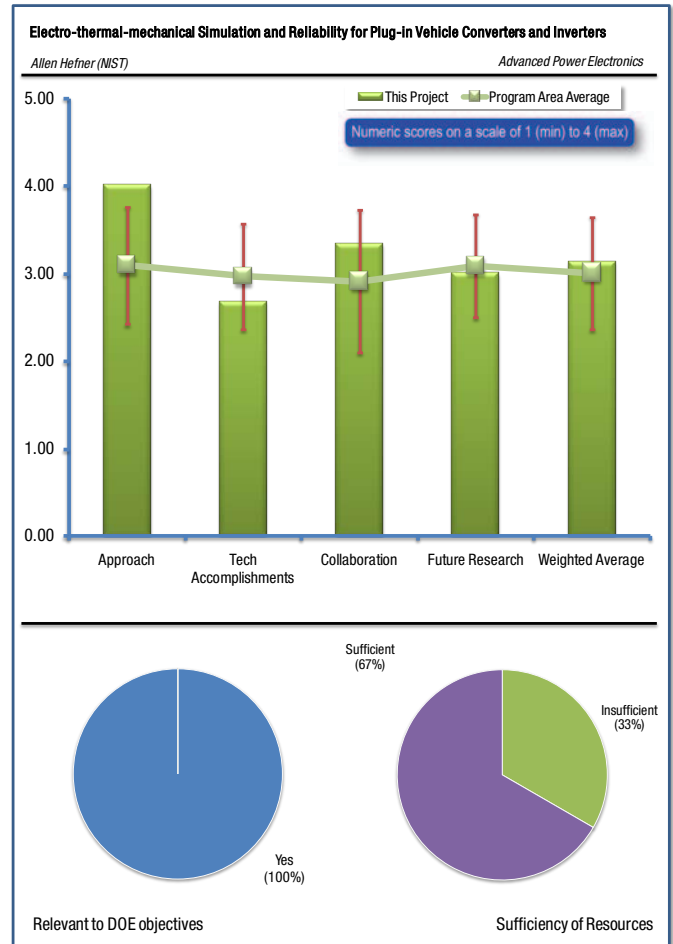
QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer stated that the progress is good, while another indicated good progress for the first 1.5 years of effort. The final reviewer said that it is relatively early in the project for accomplishments.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said NIST and CALCE are pioneers in their respective areas, adding that industrial companies are supplying vehicle modules/designs for modeling/testing. Another commenter stated that the project collaborates with OEMs and suppliers as well as ORNL. It is a good approach to follow. This reviewer added that it would be also desirable to have plans for implementation in actual vehicle systems.

The final reviewer said this development is for a valuable analytical tool, but it does not have a clear customer in the end. This tool should be an enabler for system optimization; however, where this tool ends up and who is going to own it is not understood. This reviewer would like to see some longer-term plans for its development and application in one of the National Labs or have it available for industry in one form or another (work with tool supplier Synopsis to have capability added).



QUESTION 5: HAS THE PROJECT 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?

One reviewer stated that the future research is appropriate, while another indicated that long-term plans for how this methodology will be used for future research were not well understood.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this aspect.

Development of SiC Large Tapered Crystal Growth:
Philip Neudeck (NASA)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

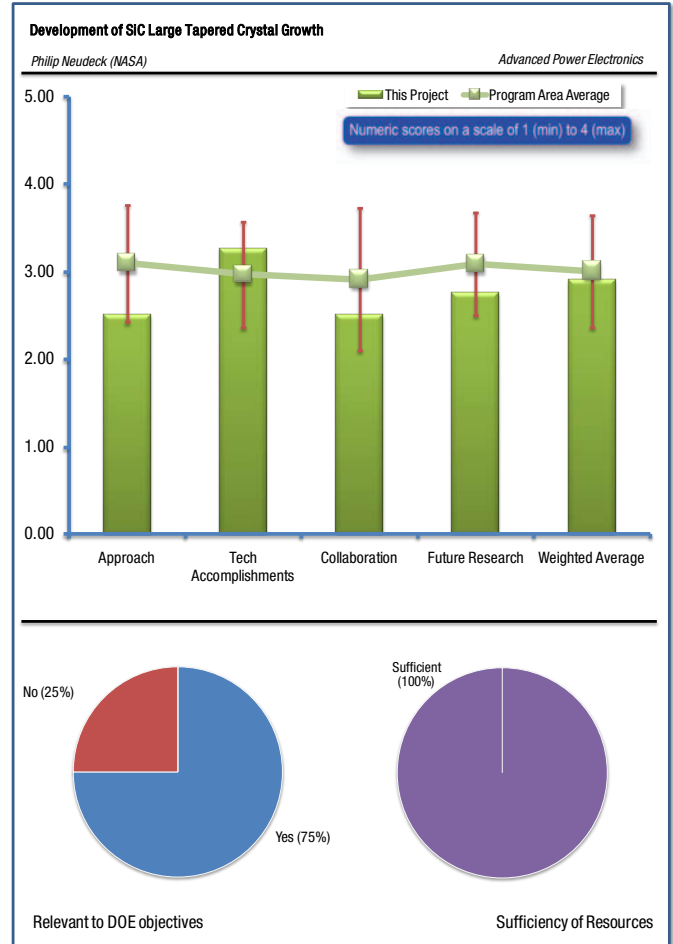
The first reviewer said that, to the extent that this high-risk technology development actually develops into a usable product that in turn makes silicon carbide more affordable, then the answer is yes. A second reviewer said that a new SiC substrate growth method may be successfully demonstrated using the proposed novel approach, although this is a high risk project. If successful, the new SiC substrate growth approach may be scalable and manufacturable, and the new process may successfully compete with existing approaches that will also improve while the novel approach is being developed. If all of the above is successful, devices made in the new material may be suitable for vehicle applications and may lead to reduced size and weight thus reducing petroleum consumption.

A third commenter said the idea of growing a lower-defect SiC sounds “grand and big.” However, the reality is very different. There are commercial suppliers of SiC wafers which have supplied high quality SiC wafers in large quantities. These are 100 mm substrates where defect density is very low to begin with and greater than 50% yield of 10 kV, 1 cm² devices has been consistently shown in PiN devices. When one looks at the yield of 10 kV MOSFET devices, the average yield drops to 25-30%. Most of this drop in yield is attributed to processing induced defects (12-15 mask process) due to the lack of automated manufacturing equipment for processing 100 mm substrates. Therefore the focus should be to increase the diameter of the substrates to 150-200 mm rather than a totally untried new technique of crystal growth when it is clear that the defect density on the current substrates is extremely low. Increasing the diameter of the wafer with currently used and well-established techniques will lead to lower cost of the devices which is exactly what the industry needs.

The final reviewer said the efficiency benefits of silicon carbide power technology are well established. One of the primary impediments to a more rapid implementation of this technology is the concentration and types of intrinsic defects in the bulk substrate material, which act as nucleation sites for epitaxial defects and stack fault formation in bipolar devices. If successful, the proposed approach would enable the realization of very low defect density wafer material, which would have a significant impact on the reliability and performance of devices fabricated on them.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said this is a well-structured project with the approach clearly defined, as well as the potential barriers to implementation. The team should include more information on the characterization methods to be used in evaluating the grown material. Another reviewer said that this is about as high risk of a technology project as has ever been reviewed in the DOE VTP. As such, the approach almost defies “measuring” with the simple check-off descriptors above.



A third reviewer said that, within one decade, existing approaches to manufacturing SiC substrates for power devices have made tremendous progress, resulting in a rapidly growing SiC power diode market with rapid reduction of cost. Rapid progress has also been made in using existing SiC substrate growth approaches to produce advanced SiC power switching devices including high voltage devices with excellent performance. It is not clear that a new approach to growing SiC power devices substrates is needed, but it may be a good fall back if progress does not continue with existing approaches.

The final reviewer said that the process has been clearly divided up into the two aspects: lateral expansion of the fiber and original growth of the fiber. Both aspects are technically challenging and will require significant work before a commercially viable technique evolves. It should also be expected that a number of technically limiting problems will arise as the programs advance that may affect the overall objectives. However, that is to be expected in any new growth technique. Specific comments and questions on each aspect are listed below.

Lateral growth on a SiC fiber:

- (1) Cost – more detail on aspects on the efficiency of gas deposition would help here, a typical SiC epitaxial system only utilizes a small fraction of delivered gas to grow the material – the rest flows past the deposition area and exits the system. The use of cheaper source gases than are typically used in the SiC industry may be possible, but are the desired high growth rates achievable with these lower cost gases?
- (2) Parasitic depositions in the growth system – how are these avoided if the process reaches its potential to deposit many kilograms of SiC crystal. Typical epitaxial systems require maintenance after growing a few hundred grams of SiC.
- (3) M-axis growth is a largely unexplored field, though significant work has come out of Japan in recent years. What problems do the authors anticipate when growing layers that are essentially 50 to 75mm thick in the different a-axis directions?

SiC fiber growth:

- (1) The technology shown in the presentation material is for laser melt of sapphire; however, SiC will not melt under standard conditions. Instead it is suggested that a solvent approach can be used. Do the authors have data on what growth rates have been achieved for the solvent approach?
- (2) Have low diameter rods of SiC been grown with a solvent approach, and if so, are these defect-free (except for the center screw dislocation)?
- (3) Is it required that the two growth systems be linked as shown in the presentation materials. This may lead to a very complicated total growth system. Or can the thin seed crystals be grown in one system, and then the best seed crystals transferred to the lateral growth epitaxial system?

Overall this final reviewer finds the concept a fascinating one and one with great potential if the technical challenges can be overcome.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the majority of the progress that has been made is in the design and procurements for modification/build-up of laboratory hardware needed to initiate the novel growth experiments. Another said the project has only recently received funding, adding the progress is as expected (mostly, setting up equipment to get underway on future empirical work). The final reviewer said this is a new project with little progress to date. Parts and materials ordered and system fabrication initiated.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said there is little collaboration with other organizations; it's a NASA experiment. Another commented there needs to be more clearly defined, especially with respect to detailing the contributions of collaborators. The final reviewer said that, under direct questioning, the presenter said that key crystallographic diagnostics are being outsourced to organizations recognized by the

reviewer as highly competent, which is a good thing. The “when,” “why,” and “how” of the collaborations was not clearly expressed in the presentation, and the presenter answered the question in a way that did not clarify the details of collaborations.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said the project is well structured, although significant unknowns remain to be determined. The second reviewer said there is a big gap in going from a successful demonstration of the growth experiment to a manufacturable product that could be used to produce devices suitable for vehicle applications.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were provided for this question.

Thermal Performance and Reliability of Bonded Interfaces: Sreekant Narumanchi (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said wiring bonding is the most potential area of power electronics failure. Therefore, the research has importance. A second reviewer commented that this is a critical area of power electronics that needs detailed study. Another reviewer said that better thermal performance of inverter power stages can reduce their cost. The reduced cost can help to enable the electric drive vehicle market. A final reviewer said interfaces with improved thermal performance and reliability enables use of high temperature coolant and/or air cooling, thus enabling reduction in cost, weight and volume of power electronics.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said the proposed approach is appropriate. Another commented that bonded interlaces are a major weak link in reliability of power packages and present a major constraint on thermal cycling application of power devices. The project is well integrated and includes all aspects (including stress, characterization, technology development, modeling and analysis, and technology transfer) needed to provide meaningful results.

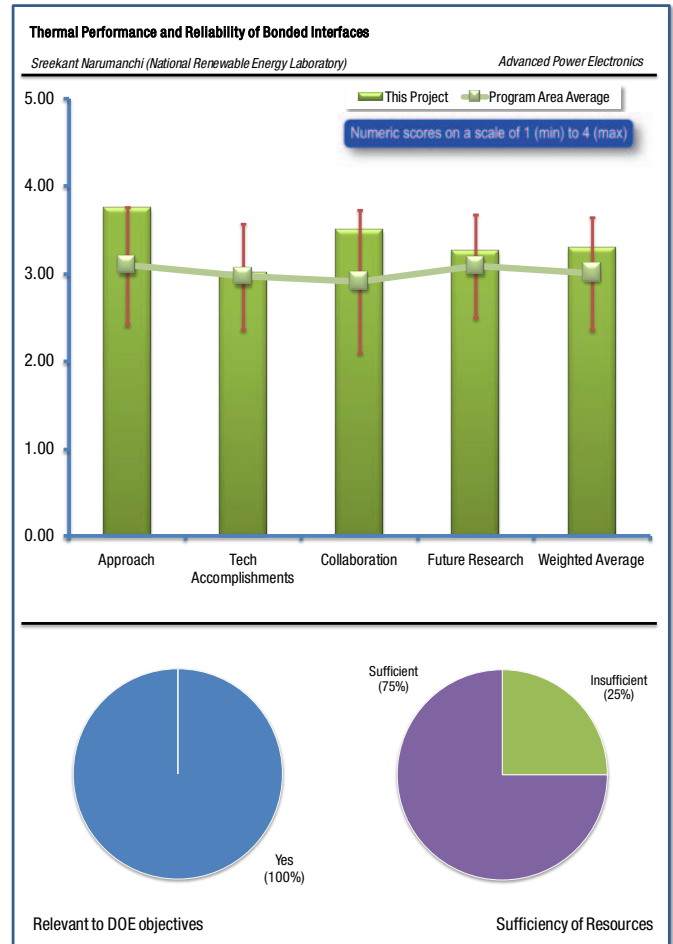
A third reviewer said this is a key element of power module construction that needs this type of focus. Other areas need the same amount of attention such as interconnects, bus structures from die to inverter bus structure, and heat sinks, but these need to be done separately. One thing that needs to be included is a relative cost of each type of interface. The final reviewer said the team may want to consider adding thermal cycling for some of the parts as well as a destructive pull test to test the bond line strength at various endpoints. Also, can the team also consider using the BIM's for die attachment?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments were generally positive in this section. One reviewer said the progress is good, while another said the new start approach is good. A final reviewer said the team worked closely with the auto industry to establish the work plan. They executed the comprehensive plan to evaluate existing and advanced approaches. They also investigated new approaches consisting of sintered interfaces with silver nano-particles and thermoplastic adhesives with embedded carbon fibers.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said the collaboration is with OEM, ORNL, and others, adding that it is sufficient to carry out the tasks. Another said the team collaborates with government, industry, and academic organizations and makes good use of assets of partners in characterization, manufacturing of bonded interfaces, simulation and modeling, and application for vehicle packages. A third reviewer



said working with suppliers as well as potential end users helps to focus the research. The final reviewer said the project needs more coordination. This reviewer sees some more opportunity to be better integrated into ORNL packaging work.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said this was a new start, while a second said the proposed future research is appropriate. A third reviewer commented the work needs to be timely for it to be relevant to industry, so the speed of work is very important. The final reviewer said the project is well planned and is focused on areas of potential high impact. This project could be expanded in funding level and could evolve into a center of excellence in advanced package bonded interface approaches for high reliability packages necessary for electric vehicles, grid inverters, and other high priority applications. Note: this reviewer marked the resources as “Insufficient” because this project could be expanded to have even more impact, not because the goals are not being met as is.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were provided for this question.

Thermal Management of PHEV / EV Charging Systems: Kevin Bennion (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 1 reviewer.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewer stated that this supports the DOE goals of cost and mass.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The reviewer stated that chargers are often an afterthought, and this project addresses the thermal issues involved. This looks to be a solid attempt to understand where the charger should reside and how to handle the heat load. This is a real issue since an onboard charger will require cooling that will have to come from the vehicle which is not running.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewer said that so far this is a new project and there are no accomplishments.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

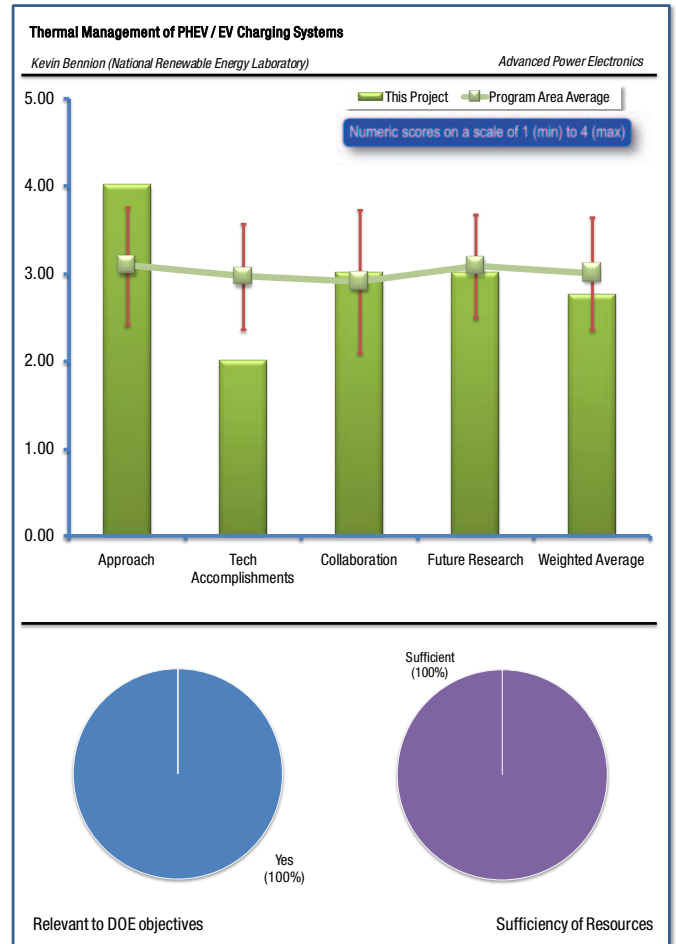
There were no comments.

QUESTION 5: HAS THE PROJECT 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?

There were no comments.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

There were no comments.



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

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments were generally positive in this section. The first reviewer said that motor thermal control is a key enabler to achieving high power density. Another commented that higher coolant temperatures are desired for electric propulsion systems (from a vehicle standpoint), and improved thermal solutions help achieve that goal. This would help enable more electrification architectures. A final reviewer said that motor thermal aspect is important in HEV and PHEV. Hence it is important to understand the issues and find solutions to solve them.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

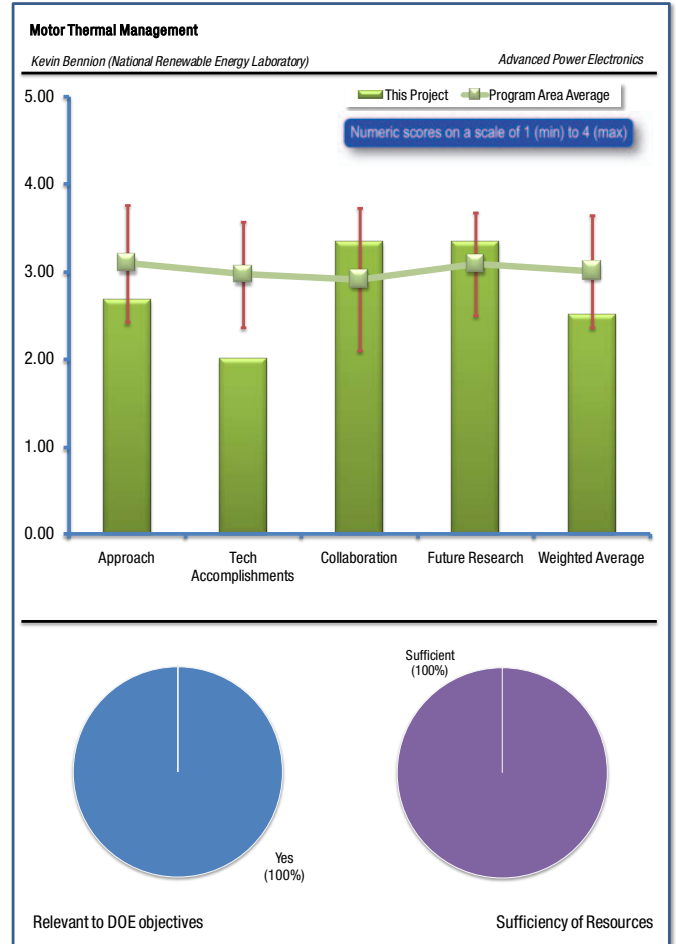
One reviewer stated that the approach is fine, while another said the novelty of the project is not clear, adding that a thorough literature review is needed to decide what can potentially be a novel cooling scheme.¹ A final reviewer said, as a new program, the detailed approach tasks have yet to be formulated. NREL has established many possible cooling technologies, and selecting and focusing on these items will be important.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

All three reviewers stated that the project is new and either that there are not significant accomplishments yet or that technical accomplishments cannot be evaluated yet.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer stated that it seems to be good but that it's too early to tell. Another noted NREL solicits input from researchers, developers, and manufacturers. Their proactive approach and persistence will help to structure useful work. The final reviewer commented that the work is being carried out with participation of a university. It is suggested that they work with more suppliers of motors, OEMs, and additional institutions who have already demonstrated expertise and experience in this area.



¹ DOE note: This is actually the main focus of the first year of this project. Instead of jumping directly into proposing a specific motor cooling scheme, DOE is currently working with the University of Wisconsin to conduct a literature survey to identify the size of the contribution of motor cooling to the overall system thermal management to determine the relative value of effort in this area, and to identify promising areas for cooling technology development.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer stated that the future research tasks are appropriate, while another reviewer commented that NREL is proactive and is proposing appropriate focus areas. This reviewer encourages a focus on winding cooling and encapsulation materials that remove heat from end windings effectively. This would have the highest impact in increasing the rating of electric motors. The final commenter said the proposed future work is common practice in industry when it comes to machine design, adding that novelty needs to be identified. This reviewer added that focusing on developing an accurate lumped parameter thermal model can be potentially of value in terms of speeding up the design process instead of relying on FEA.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were provided.

High Performance Permanent Magnets for Advanced Motors: Jinfang Liu (Electron Energy Corporation)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

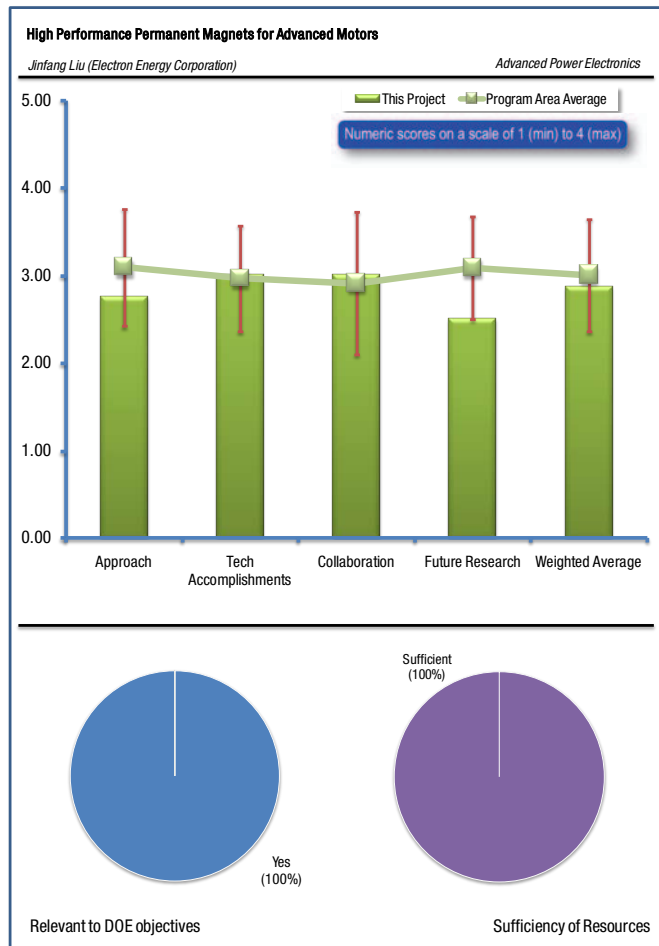
Comments in this section were mixed. The first reviewer stated that higher energy product and higher resistivity magnets help increase the motor power density and efficiency. Another reviewer said the magnet characteristics are critical on PM machine development. Improving them is always appreciated as long as it is not accompanied by a big cost penalty. A third commenter said the project addresses a major issue of today's electric machines, which is the high cost of rare-earth permanent magnets. If the project is going to be successful it could potentially accelerate the implementation of electric drive systems in the automotive industry. This would support the DOE objectives of petroleum displacement. A final reviewer stated that the project is somewhat relevant, since the program does not appear to address issues relevant to many industry participants.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said the technical barriers for the improvement of permanent magnet materials are addressed by the researchers. This reviewer added the focus is on the improvement of temperature stability and increase of electrical resistivity, which would enable a wider range of potential applications for permanent magnet machines. Another reviewer added that the approach seems okay, but admits to not being an expert on the subject. A third reviewer said the project is pursuing several important areas. This reviewer is, however, concerned about the focus on SmCo magnets, which are not really practical in the automotive market. The project should show that the proposed concepts are applicable to Nd magnets. Also, focusing on one or two tasks might provide better chance of success instead of spreading the project resources over several areas. The final reviewer stated that low resistivity is not a significant problem with existing magnets, aside from motors that have high stator-induced harmonics, and much of the research focuses on SmCo magnets, which are not being used by industry for vehicle electrification motors. SmCo magnets consist of expensive and price volatile materials.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments in this section were mixed. One reviewer said that some major milestones were accomplished this year: good job. Another commented that several samples of the various materials have been produced, adding that some methods are showing more promising results than others. A third reviewer stated significant progress has been made towards the goal of gradually improving the properties of permanent magnets, both for SmCo and NdFeB types. The targeted temperature range of 200-240°C seems to be higher than what the automotive industry might need for the widespread application of electric drive systems. But there might be a niche market for magnets with this temperature capability in specific applications like high speed electric compressor drives. This reviewer added that the claim of a cost reduction in the manufacturing process of magnets needs more proof. A final reviewer said the program appears to



be meeting project goals, but mainly using the technologies that have the least commercial promise, and how this assists with DOE goals is unclear.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer said good collaboration was observed based on the project size, while another stated that collaboration with academia and industry is occurring. Another commenter said that the collaboration with another company that is working on a DOE funded project for the development of IPM machines is important for a clear understanding of the specific requirements for permanent magnets in electric machines. The final reviewer said that having the customer's involvement is excellent, but the collaboration of the University of Delaware was not described at all.

QUESTION 5: HAS THE PROJECT 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?

Comments in this section were mixed. The first reviewer stated that the DOE-funded part of the project will come to an end soon, but the researchers explained that the project will be continued as part of their own research. The proposed future work is comprehensive. Another commenter said efforts to give more maturity to the product is the right way to go for this particular project. A third reviewer noted there are several methods proposed to increase magnet resistivity. They are showing a wide range of improvement. They should be down selected to the most promising approach and this should be pursued further. This reviewer added that a cost model for estimating the magnets' cost should be developed. The final reviewer commented that the relevance of this work is questioned due to the focus on magnet resistivity and SmCo as a candidate material.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received.

Low Cost, High Temperature, High Ripple Current DC Bus Capacitors: Ed Sawyer (SB Electronics)

REVIEWER SAMPLE SIZE

This project had a total of 1 reviewer.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewer said that high temperature / low inductance capacitors are a gap in inverter designs. SBE is trying to fill the gap to help enable the electric drive vehicle market.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The reviewer stated that cost and temperature are still a challenge. This reviewer asked if material changes and extended life testing will address the cost and temperature challenges.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewer said that the low inductance of the capacitor is very good. The size and the configuration of the capacitor may be a packaging concern for inverter designs. Should inverters be designed around the bulk cap or should the bulk cap be designed around the inverter? Show some examples of the latter: i.e., how to connect to a 3 phase power stage, power module, without intermediate connections.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

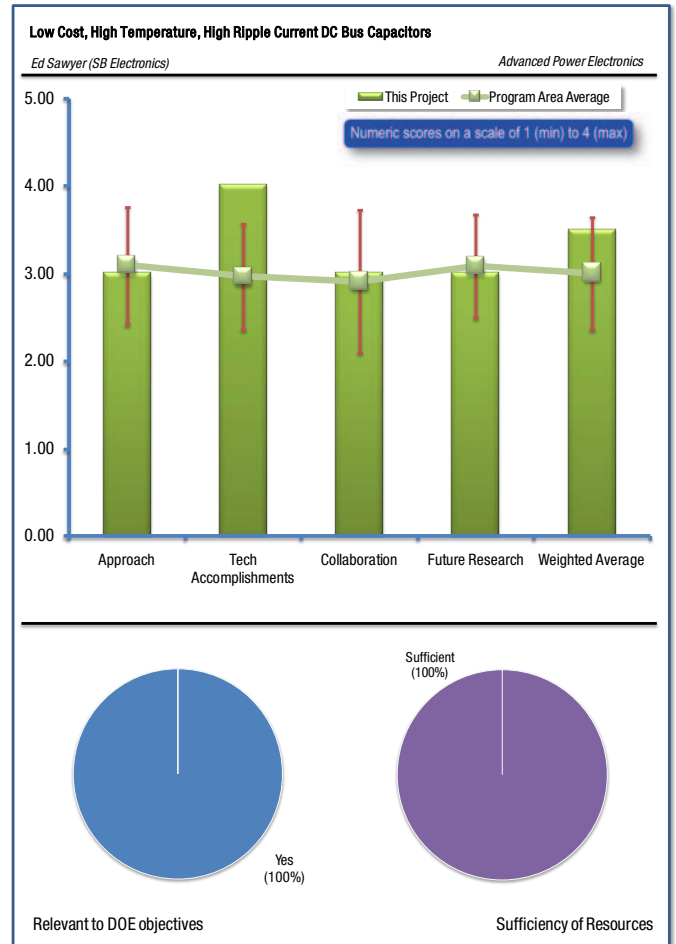
The reviewer commented that the team has a capacitor, puts it in an inverter, and shows performance improvements vs. a more “traditional” bulk cap design.

QUESTION 5: HAS THE PROJECT 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?

The reviewer stated that changing materials and platings may reduce cost, but the team could use an inverter partner to evaluate their capacitor.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were received for this section.



4. ADVANCED COMBUSTION ENGINE TECHNOLOGIES

The Advanced Combustion Engine subprogram of the U.S. Department of Energy's Vehicle Technologies Program (VTP) is improving the fuel economy of passenger vehicles (cars and light trucks) and commercial vehicles (medium-duty and commercial trucks) by increasing the efficiency of the engines that power them. Work is done in collaboration with industry, national laboratories, and universities, as well as in conjunction with the FreedomCAR and Fuels Partnership for passenger vehicle applications and the 21st Century Truck Partnership for commercial vehicle applications. Research and development (R&D) efforts focus on improving engine efficiency while meeting future federal and state emissions regulations through a combination of: combustion technologies that minimize in-cylinder formation of emissions; aftertreatment technologies that further reduce exhaust emissions; and understanding fuel property impacts on combustion and emissions. Technologies that improve the overall engine performance are also pursued.

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1 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 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
Heavy-Duty Low-Temperature and Diesel Combustion & Heavy-Duty Combustion Modeling	Mark Musculus (Sandia National Laboratories)	4-4	3.69	3.62	3.69	3.38	3.62
Low-Temperature Automotive Diesel Combustion	Paul Miles (Sandia National Laboratories)	4-7	3.46	3.08	3.58	3.31	3.27
Sandia Optical Hydrogen-fueled Engine	Sebastian Kaiser (Sandia National Laboratories)	4-10	2.80	2.40	2.80	2.70	2.59
HCCI and Stratified-Charge CI Engine Combustion Research	John Dec (Sandia National Laboratories)	4-13	3.92	3.69	3.85	3.38	3.73
Low-Temperature Diesel Combustion Cross-Cut Research	Lyle Pickett (Sandia National Laboratories)	4-16	3.67	3.50	3.67	3.17	3.52
Automotive HCCI Engine Research	Richard Steeper (Sandia National Laboratories)	4-19	3.27	3.55	3.27	2.90	3.36
Large Eddy Simulation (LES) Applied to LTC/Diesel/Hydrogen Engine Combustion Research	Joe Oefelein (Sandia National Laboratories)	4-21	3.33	3.00	3.25	3.08	3.13
Free-Piston Engine	Peter Van Blarigan (Sandia National Laboratories)	4-24	2.67	2.25	2.25	2.75	2.42
Optimization of Direct-Injection H2 Combustion Engine Performance, Efficiency, and Emissions	Thomas Wallner (Argonne National Laboratory)	4-27	3.11	3.00	2.89	2.78	2.99
Fuel Spray Research on Light-Duty Injection Systems	Christopher Powell (Argonne National Laboratory)	4-30	3.67	3.33	3.42	3.00	3.39
Visualization of In-Cylinder Combustion R&D	Stephen Ciatti (Argonne National Laboratory)	4-32	2.92	2.92	2.91	3.00	2.93
Computationally Efficient Modeling of High-Efficiency Clean Combustion Engines	Salvador Aceves (Lawrence Livermore National Laboratory)	4-35	3.36	3.42	3.45	3.36	3.40
Chemical Kinetic Research on HCCI & Diesel Fuels	William Pitz (Lawrence Livermore National Laboratory)	4-37	3.69	3.92	3.85	3.54	3.81
KIVA-4 Development	David Carrington (Los Alamos National Laboratory)	4-39	3.29	3.50	3.50	3.29	3.42

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes	Stuart Daw (Oak Ridge National Laboratory)	4-43	3.27	3.00	3.18	2.82	3.07
High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Diesel Engines	Robert Wagner (Oak Ridge National Laboratory)	4-46	3.38	3.38	3.46	3.15	3.37
Achieving and Demonstrating Vehicle Technologies Engine Fuel Efficiency Milestones	Robert Wagner (Oak Ridge National Laboratory)	4-49	3.58	3.55	3.42	3.25	3.50
Emissions Control for Lean Gasoline Engines	Jim Parks (Oak Ridge National Laboratory)	4-52	3.38	3.38	3.13	3.25	3.33
A University Consortium on Efficient and Clean High-Pressure, Lean Burn (HPLB) Engines	Dennis Assanis (University of Michigan)	4-54	3.08	3.08	3.67	3.27	3.18
Optimization of Advanced Diesel Engine Combustion Strategies	Rolf Reitz (University of Wisconsin)	4-57	3.71	3.79	3.64	3.57	3.72
Flex Fuel Optimized SI and HCCI Engine	Gouming Zhu (Michigan State University)	4-61	3.10	2.67	2.55	3.00	2.80
CLEERS Coordination & Joint Development of Benchmark Kinetics for LNT & SCR	Stuart Daw (Oak Ridge National Laboratory)	4-64	3.83	3.33	4.00	3.50	3.56
CLEERS: Aftertreatment Modeling and Analysis	Darrell Herling (Pacific Northwest National Laboratory)	4-67	3.43	3.57	3.71	3.71	3.57
Development of Advanced Diesel Particulate Filtration (DPF) Systems	Kyeong Lee (Argonne National Laboratory)	4-70	2.86	3.00	3.14	2.86	2.96
Combination and Integration of DPF-SCR Aftertreatment Technologies	Kenneth Rappe (Pacific Northwest National Laboratory)	4-73	2.86	2.86	2.83	2.86	2.85
Enhanced High Temperature Performance of NOx Storage/Reduction (NSR) Materials	Chuck Peden (Pacific Northwest National Laboratory)	4-76	3.50	3.33	3.71	3.29	3.42
Degradation Mechanisms of Urea Selective Catalytic Reduction Technology	Chuck Peden (Pacific Northwest National Laboratory)	4-79	3.71	3.33	3.57	3.29	3.45
Experimental Studies for DPF and SCR Model, Control System, and OBD Development for Engines Using Diesel and Biodiesel Fuels	John Johnson (Michigan Technological University)	4-82	3.43	3.14	3.71	3.57	3.34
Development of Optimal Catalyst Designs and Operating Strategies for Lean NOx Reduction in Coupled LNT-SCR Systems	Michael Harold (University of Houston)	4-84	3.60	3.33	3.67	3.33	3.44
Three-Dimensional Composite Nanostructures for Lean NOx Emission Control	Pu-Xian Gao (University of Connecticut)	4-87	2.67	2.86	2.43	2.57	2.72
Efficient Emissions Control for Multi-Mode Lean DI Engines	Jim Parks (Oak Ridge National Laboratory)	4-90	3.50	3.00	3.57	3.00	3.20
Cummins/ORNL-FEERC CRADA: NOx Control & Measurement Technology for Heavy-Duty Diesel Engines	William Partridge (Oak Ridge National Laboratory)	4-92	3.50	3.43	3.57	3.29	3.45
Pre-Competitive Catalysis Research: Fundamental Sulfation/Desulfation Studies of Lean NOx Traps	Todd Toops (Oak Ridge National Laboratory)	4-95	3.33	3.33	3.33	2.83	3.27
Advanced Engine/Aftertreatment System R&D CRADA with Navistar, Inc.	Josh Pihl (Oak Ridge National Laboratory)	4-97	3.50	3.33	3.50	3.67	3.44

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Development of Chemical Kinetic Models for Lean NOx Traps	Richard Larson (Sandia National Laboratories)	4-99	3.20	3.20	2.80	3.00	3.13
Development of High-Efficiency Clean Combustion Engines Designs for SI and CI Engines	Kenneth Patton (General Motors)	4-101	3.83	3.67	3.33	3.83	3.69
Advanced Boost System Development for Diesel HCCI/LTC Application	Harold Sun (Ford Motor Company)	4-103	3.00	3.20	3.00	3.00	3.10
Development of Enabling Technologies for High Efficiency, Low Emissions Homogeneous Charge Compression Ignition (HCCI) Engines	Scott Fiveland (Caterpillar)	4-105	3.60	3.80	3.40	3.60	3.68
An Engine System Approach to Exhaust Waste Heat Recovery	Richard Kruiwyk (Caterpillar)	4-107	3.40	3.20	3.20	3.20	3.25
Advanced Diesel Engine Technology Development for HECC	Donald Stanton (Cummins)	4-109	3.60	3.60	3.80	3.20	3.58
Exhaust Energy Recovery	Chris Nelson (Cummins)	4-111	3.80	3.80	2.80	3.40	3.63
High Efficiency Combustion and Controls	Kevin Sisken (Detroit Diesel)	4-113	4.00	3.33	3.33	3.33	3.50
Low-Temperature Combustion Demonstrator for High-Efficiency Clean Combustion	William de Ojeda (Navistar International Corp.)	4-115	3.67	3.67	3.67	3.00	3.58
Advanced Collaborative Emissions Study (ACES)	Dan Greenbaum (Health Effects Institute)	4-117	4.00	3.50	3.75	4.00	3.72
Measurement and Characterization of Unregulated Emissions from Advanced Technologies	John Storey (Oak Ridge National Laboratory)	4-119	3.75	3.75	3.67	4.00	3.77
Collaborative Lubricating Oil Study on Emissions (CLOSE Project)	Douglas Lawson (National Renewable Energy Laboratory)	4-121	3.50	3.25	4.00	3.25	3.41
Thermoelectric HVAC for Light-Duty Vehicle Applications	Clay Maranville (Ford Motor Company)	4-123	3.25	3.33	3.75	3.50	3.39
Improving Energy Efficiency by Developing Components for Distributed Cooling and Heating Based on Thermal Comfort Modeling	Gregory Meisner (General Motors)	4-125	2.75	2.75	2.50	2.75	2.72
Thermoelectric Conversion of Waste Heat to Electricity in an IC Engine Powered Vehicle	Harold Schock (Michigan State University)	4-128	3.75	3.50	3.75	3.50	3.59
Develop Thermoelectric Technology for Automotive Waste Heat Recovery	Gregory Meisner (General Motors)	4-131	3.25	2.75	3.00	2.75	2.91
Automotive Waste Heat Conversion to Power Program	John LaGrandeur (BSST LLC)	4-134	3.50	3.50	3.50	3.25	3.47
OVERALL AVERAGE			3.39	3.28	3.36	3.20	3.31

Heavy-Duty Low-Temperature and Diesel Combustion & Heavy-Duty Combustion Modeling: Mark Musculus (Sandia National Laboratory (SNL))

REVIEWER SAMPLE SIZE

This project had a total of 13 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

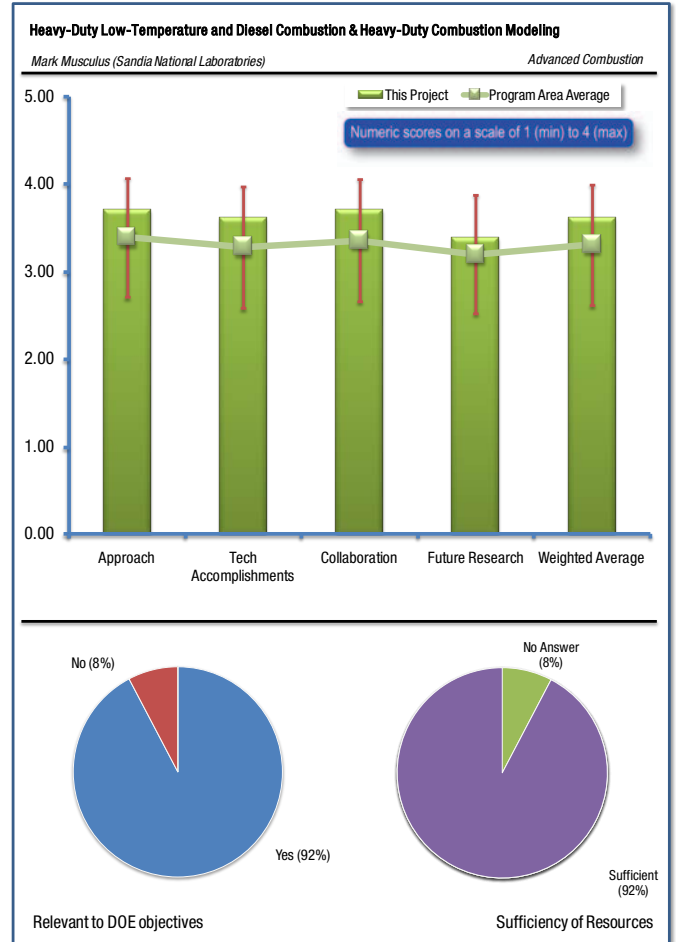
Comments were generally positive in this section. The first reviewer said very fundamental analyses are required for the more advanced demonstration and implementation of LTC for commercial applications. Project goals are being modified and changed on an expedient basis - shifting from purely an emissions focus to more of a focus on fuel efficiency. A second reviewer said minimizing engine-out emissions addresses a key roadblock for improved efficiency, while another added that fundamental understanding of heavy-duty diesel combustion processes is necessary for future engine developments. A fourth reviewer said the data being generated leads to improved understanding, and is very relevant. We need to ensure this understanding is captured and translated into a tool that aids the industry. Another commented that, to the extent that LTC can be utilized at light load to control emissions, it can reduce the need for fuel to maintain adequate aftertreatment temperatures. If we can control LTC at high load with optimal timing, engine efficiency can be increased. A sixth reviewer said that this enables the construction of low emission, high efficiency diesel engines. This work will help with the development of CFD models to match engine results. This is an understanding necessary for the construction of high efficiency clean engines. The team could show a better picture of how this ties into higher efficiency engine work.

Another reviewer said the work addresses soot, HC and CO emissions problems with low temperature combustion. The work also addresses the lack of understanding multiple injection processes in advanced combustion systems, which have the potential of reducing soot and HC emissions. One reviewer said this project does support the DOE objective of developing a fundamental understanding of low temperature combustion that will enable the use of less engine aftertreatment and thus potentially increase engine thermal efficiency. At this point in time it is unclear what type of indicated fuel consumption improvement is possible with this approach versus other more conventional approaches that may include additional aftertreatment technology.

Another reviewer said that there are certainly a lot of efforts that are focused on improving fundamental understanding of diesel combustion and this information is being well shared with a large diverse industry group. The final reviewer said a shift is needed from emissions formation to reducing fuel consumption and CO₂. Two objectives are related to soot formation and oxidation. Another is on HC+CO oxidation. Fourth is flame propagation. This reviewer submits that given the emerging tight CO₂ regulations, which will be much more difficult to meet in the future than reducing criteria pollutants, the emphasis shifts to efficiency with little emphasis on emissions formation. Movement into GDI and efficiency is right on target.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments were generally positive in this section. The first reviewer said this is a useful merge between modeling and experimentation. Another said this team has done a great job of identifying key technical issues, and applying “best in the world



capabilities” to study those issues. A third reviewer said the team has made good measurements showing effects of post injections and good measurements showing difference of LTC and conventional operation. Another reviewer noted the excellent overall focus on the forefront of LTC investigation. The combined core competency of SNL and UWM researchers offers unique opportunity to advance the state-of-the-art. A fifth reviewer said the combination of modeling and state-of-art measurement is superb. This reviewer added: ability to adapt to new needs; use of new tools is cutting edge and critical for public programs like this; apply this approach to efficiency gains.

Another reviewer commented that planar laser imaging diagnostics are applied to a single cylinder optical engine with very good optical access. Data and knowledge is combined with modeling efforts at the University of Wisconsin. One reviewer said, scientifically, this is a great project. The PI is developing PM formation and oxidation understanding in free jets that currently doesn't exist today for real world direct injection combustion devices. The only possible improvement in this project is the current lack of quantification of any possible fuel consumption improvement versus more conventional combustion approaches. Another reviewer said the team had pursued excellent technique development, but still the main focus is on emissions rather than efficiency. The final commenter asked if these techniques can be applied to GDI cold engine soot formation.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments were generally positive in this section. One reviewer said good results were shown on reduction of UHC and promising methods were presented, while another reviewer said the results shared are interesting and with good explanation and understanding given to the optical data. A third reviewer said, once again, new findings in LTC are discovered. The dual laser approach and the dual injection investigations have uncovered new characteristics of the LTC. A fourth reviewer said this group is ahead of the world in understanding the combustion process in ways relevant to engine design and development. Another commented “nice work on new methods.” The soot formation comparison of LTC with conventional engines is enlightening. The impact of post injection on main injection soot is a new finding and important. This is a good plan on GDI, according to this reviewer, who also suggested that the team remain flexible as knowledge develops, focusing on improved efficiency rather than emissions.

Another reviewer said, scientifically, this project is aiding in the community's understanding of in-cylinder soot formation/oxidization. The optical aspects of this project are truly outstanding. Again, it would be nice to see some type of experiment or simulation that shows how this combustion approach would impact fuel consumption. One reviewer said very interesting insight is being discovered on the rate of formation of soot in LTC combustion with the use of two different laser wavelengths. Also, post injection has been verified to reduce soot from the main injection. The exact reason for this is still being probed. For now the formation of OH late in the cycle is thought to oxidize the soot. This reviewer added that progress has been made to understand post injection's potential to reduce UHC. One final reviewer commented on the good incremental improvement and advancement that is necessary to lay the groundwork for industry's application of these technologies. Areas of investigation are closely related, but this reviewer queried to what extent this is a scattershot approach.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. One reviewer said that SNL is a key part of a large team that includes other labs, industry, and academia. This integration results in first-class transfer of new learning to those who need it. Another reviewer said this project has been well coordinated with industry and the University of Wisconsin through AEC working group meetings that includes input from key engine OEM partners. A third commenter noted that the team is dealing with a large working group, and this reviewer cannot imagine a program that could do better on collaboration, specifically with pulling together a large group to share the output and lessons of both this program and similar at the universities. Another reviewer said the collaboration with the University of Wisconsin is outstanding. This reviewer added that there is also a solid connection with the Advanced Engine Combustion Working group.

One reviewer sees more sync between SNL and UWM this year and a good team, and recommended that the team not add to the MOU membership. This reviewer felt the project's membership is already large enough to barely reach a consensus. Sooner or later, the work will be leveled at the least common denominator and SNL may be challenged in maintaining harmony. Another reviewer said this is a very well-established multidisciplinary project that has extensive industry backing. This reviewer added that closer

interaction with modeling partner (UW) would be more advantageous to the project. The final reviewer said the work is very broad and cross-functional. Lund and the University of Wisconsin bring in more academic inputs. This reviewer didn't see evidence of bringing in industry researchers, and added that this is critical for rapid communication and implementation of latest results.

QUESTION 5: HAS THE PROJECT 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?

Comments were mixed in this section. The first reviewer observed good steady progress. Project goals are updated as experimental results and modeling results shape the future directions to lead to further efficiency improvements. A second reviewer noted a good plan, while another said keep going; there is more to do and to learn. A fourth reviewer said future work is very relevant. It will be focused on dual fuel concepts proposed by University of Wisconsin for high efficiency. Work will also continue on the reduction of HC emissions with multiple injections.

A fifth commented that the team mentioned an intent to evaluate a dual fueled engine, but there is no clear plan for what to look at. Another reviewer said that it would be interesting to broaden the range of speed / load cases investigated, especially as the area of research extends into multiple injections, and dual fuel. One commenter thinks that the program needs to shift emphasis from emissions to efficiency. The work on LTC is interesting and by reducing emissions the team may indirectly impact fuel consumption. However, the investigators need a mind-shift into how to improve combustion processes to reduce CO₂ emissions. The move into dual fuels and GDI is right on target. Explain experimental results from Wisconsin and use the fundamental understanding to improve efficiency. The final reviewer commented that overall, the approach is sound scientifically, if focused on continually seeking fundamental understanding of PM formation in free jets. As mentioned above, it would be beneficial to include some type of consideration for fuel consumption impact with LTC strategies.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said there is an appropriate level of effort, while another said overall this is a good project with promising techniques and useful results. The final reviewer commented that too many publications can be a distraction.

Low-Temperature Automotive Diesel Combustion: Paul Miles (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

This project had a total of 13 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said LTC has promise to reduce efficiency losses due to emissions control and provide high efficiency combustion if well controlled. Another said fundamental understanding of advanced combustion modes helps drive engine design of the future. A third reviewer said improved emissions measurement techniques in cylinder can confirm modeling. These models are needed for future engine designs. Another added that the team is gaining fundamental understanding of the combustion process in question, which should help in optimizing the system to our advantage. A fifth commenter said this project applies optical diagnostics to understand the processes due to which combustion in diesel engines is inefficient, and how exhaust pollutants are formed, which offers insight into reducing combustion inefficiency by changes in engine design.

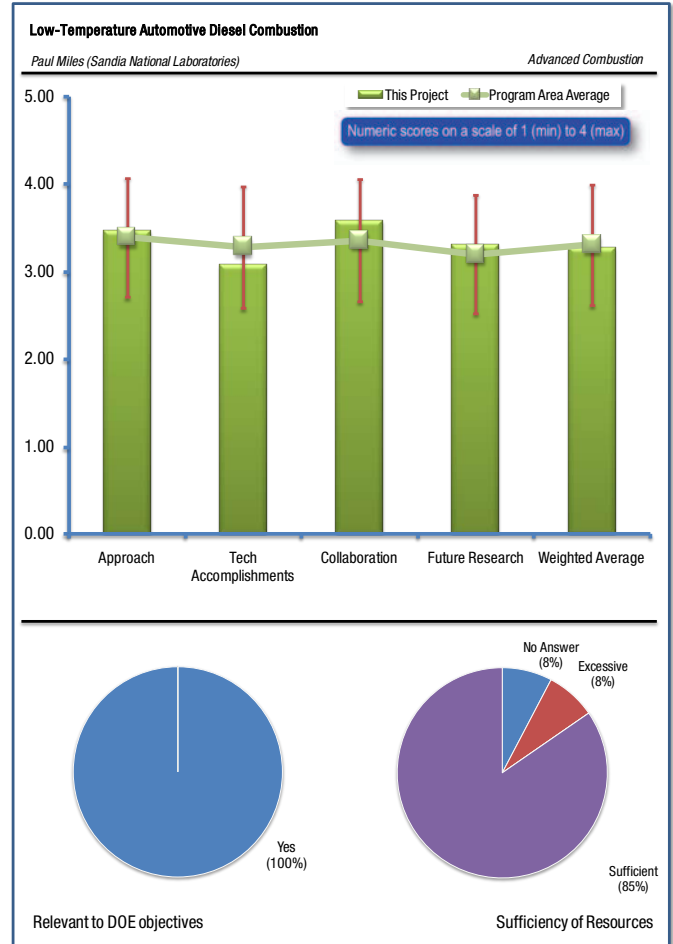
One reviewer said LTC is critical to engine efficiencies because LT emissions are costly to light-duty diesels. This reviewer would like to see a closer tie directly to improving combustion efficiency. The reviewer doesn't see many domestic OEMs moving into diesel.

Benefits would be valuable to Germans and Japanese, for domestic and international sales. This reviewer supposes this is OK. Another commenter said this project partially supports DOE objectives—it addresses combustion schemes that may reduce engine-out emissions, but doesn't seem to include an element that addresses the impact of such combustion schemes on fuel consumption. The final reviewer said improving diagnostic techniques will be required for the further development and understanding of fundamental combustion processes in light-duty engines, in addition to heavy-duty engines. This reviewer added that this project needs to enunciate exactly why the processes studied are different from HD.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer noted the significant work on developing techniques to evaluate combustion, while another commented on the top-quality work with leading-edge facilities. A third reviewer said this is a great combination of optical and metal engines, and CFD/kinetics modeling to address CO and unburned hydrocarbon formation. It methodically develops an understanding of the impact of spray targeting and bowl design on CO and unburned hydrocarbon that may be of value in designing next generation small bore diesel combustion systems. Another reviewer said using optical engine, modeling and metal engine work for feedback loop is impressive and valuable. The approach is well-refined over the years. The team needs to emphasize developing new analytic tools to cover deficiencies.

Another reviewer commented that in-cylinder optical measurements are the focus of this work. The results provide knowledge for model improvements and developments at the U of W. The engine is similar to the metal engine at the U of W. Care has been taken in the details of the optical engine design to mimic that of the metal engine. Emissions and cylinder pressure measurements are also used in the overall analysis. One commenter said that, to use a predictive model, the team will need to establish confidence that it is robust.



Hopefully when the discrepancy between model and testing is resolved, it results in a model improvement that increases robustness for other conditions and engine geometries. Another reviewer said the project is reactive in its objectives, which is not a bad thing, but the motivations for changing directions and goals needs to be better motivated.

The final reviewer said that a balance is probably needed in the time/effort spent on “improving the techniques” versus running investigation experiments. This reviewer suggests less of the former and more of the latter. Is running a “broad range of operating conditions” with this hardware set a good choice? Should the work focus on a selection of high priority points? This reviewer is recommending a deeper and narrower forward planning, instead of the broad and necessarily shallow testing. This reviewer suggested that the team should consider limiting the time and resources spent on developing a “library of data” and run focused tests to iteratively validate simulations. The reviewer suggested that the team run statistically designed test matrices.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the new diagnostics seem to be very useful and help clarify the processes. Another commented on the nice matrices. The team is looking at operating conditions, and impact of changes. There was good correlation with results and nice development of theory. The team is getting an understanding of deficiencies on measurement and model. A third reviewer said the experimental database that is being developed for CO and unburned hydrocarbon formation as a function of targeting is of value to modelers for designing future small bore combustion systems. Again, the missing element is fuel consumption impact. Another commenter said the results and progress shared were of good interest and showed helpful understanding of some of the contributors to combustion inefficiency. It would help to have a design matrix of some combustion system parameters that are being studied so that the output could be of more direct help in the designing of real life combustion systems ... injector tips, bowls, swirl, etc.

The fifth reviewer would like to see more results that can be applied to engine development, while another said the presentation did not really show a \$1 million accomplishments level, especially on the experimental side. Another said that the project highlights that the 'marriage' between fundamental engine measurements and computational modeling is a tricky one - how can differences between the results seen be ascribed to problems with either one of the techniques? For example, it is possible to “see” something in the model results that is not seen in the physical results—is it a modeling problem, or a failure of the diagnostic technique? The benefits of modeling are known and are obvious, but we need to admit that we will never see truly fully predictive modeling capability.

The final reviewer said a wide array of experiments sweeping several relevant parameters has been completed. Deep-UV laser diagnostics have been developed to measure CO, C2 and PAH fields. There is no evidence seen of CO or unburned hydrocarbons leaving the bowl, as the modeling has predicted in the past. The mixture leaving the bowl is clean. Thus it looks like the modeling is incorrect. The modeling has been exercised to check the sensitivities of various parameters, but none so far explain the discrepancy between model and experiments. It seems more likely that the problem is with simulating the mixing processes rather than chemical kinetics or grid size issues. This reviewer added that experiments have also been conducted that verify that CO and unburned hydrocarbon emissions can be decreased by reducing squish height and targeting the spray deeper within the bowl.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. The first reviewer said collaborations are well established and productive, while another observed great integration with academia, industry, and other labs. This reviewer added that this was a good example of collaborative research. Another reviewer said the UW and GM collaboration is important. It is nice to see industry (GM) so intimately involved. A fourth reviewer noted that the PI is collaborating with GM, the Lund Institute, and UW-ERC. That brings together optical engine measurements, metal engine measurements, and kinetics/mixing simulation—outstanding collaborative team. Another reviewer commented that very close ties with the modeling efforts exist with the University of Wisconsin. Indirect ties also exist with several industrial companies and national labs via the Advanced Engine Combustion group. A final reviewer said the list of the collaborating groups is impressive, as is the case with all the SNL projects under the MOU. This reviewer added that the team should capitalize more on it. Is this work coordinated with other related efforts within the SNL Combustion Facility? How so? This reviewer recommended not adding to the MOU membership. The team’s membership is large enough to barely reach a consensus now. Sooner or later, the work will be leveled at the least common denominator and SNL may be challenged in maintaining harmony.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer said keep up the good work. Another said there was nice movement into changing geometry given current understanding, and added that the team will be able to corroborate model and check hypotheses. Another commenter offered no comments—logical future plan for next year. A reviewer stated that the future plans are somewhat ad-hoc, perhaps by necessity in order to respond to changes or modifications in the industry's research directions. The final reviewer said the search for the model's shortcomings will be pursued by doing more experiments that increase understanding of mixing processes by varying injection pressures, swirl ratio and injector hole sizes. This reviewer added that multiple injections will also be investigated.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said seems like an appropriate effort level, while the other commenter said funding seems to have been a bit on the high side for this year's result. This reviewer added that too many publications can be a distraction.

Sandia Optical Hydrogen-fueled Engine: Sebastian Kaiser (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

This project had a total of 10 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

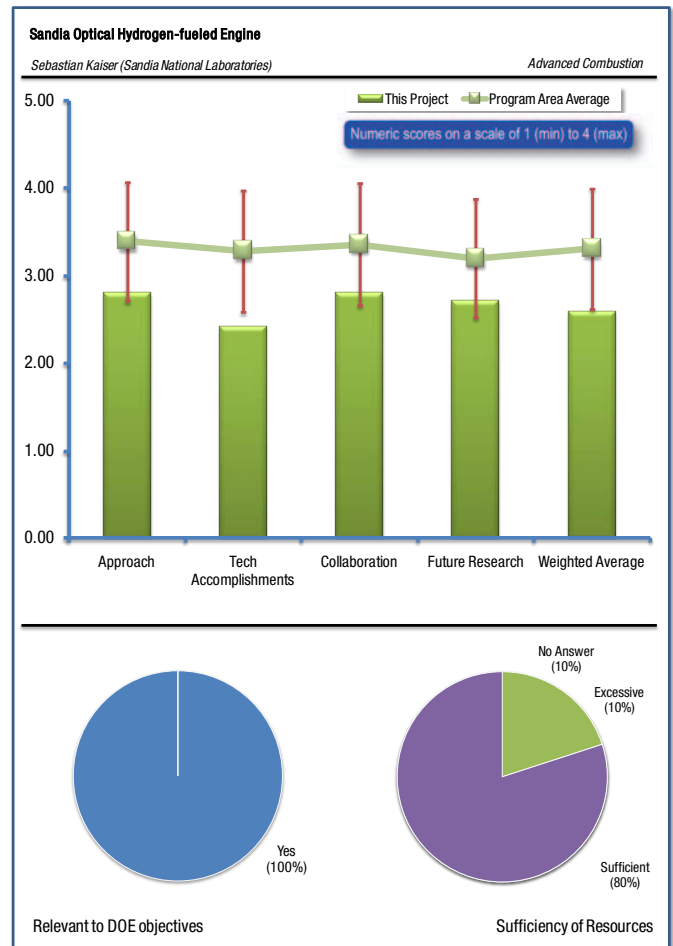
Comments were mixed in this section. The first reviewer said this work has a conceivable use should H₂ ever become viable as a fuel. Another commented that the overall efficiency gains justify the work. Longer term perspectives provide balance with shorter term vision of other projects: we need to understand fundamentals. A third reviewer commented that it uses H₂ instead of hydrocarbons, and added that this assumes the H₂ is not coming from oil. One reviewer said hydrogen-fueled IC engines have promise for very large increases in vehicle fuel economy. Modeling results at Argonne National Labs has recently shown this benefit. Other benefits are high power density and low NO_x. This reviewer added that one significant concern is the hydrogen fuel infrastructure, without which this project ultimately cannot be successful.

Another reviewer asked where hydrogen currently fits in the DOE's energy mix. The industry is receiving mixed signals about whether hydrogen is being considered for the future or not. This project is quite esoteric—investigating a single jet flow in a cylinder for DI of H₂ is quite far removed from our current emphasis on fuel efficiency for diesel and gasoline engines. Another reviewer commented that this project was more relevant in prior years when the H₂ “hype” was at its peak. The final reviewer stated this project weakly supports the DOE objectives of understanding fundamental combustion phenomenon toward improving engine fuel consumption. This reviewer added that the latter portion of the objective is being weakly addressed in this project.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said the combination of optical, metal engines and modeling is the correct approach. Another agrees with the need to increase the understanding of the combustion, fuel, air and combustion chamber. This reviewer added that fundamental investigations of interactions are important and well worth investigating, and the method used in this program to try and isolate these effects does seem like a logical approach. A third reviewer said the early emphasis on modeling is key, but added that it seems like time to move on and get more correlations. Modeling needs to push beyond hardware limitations and recommend best configurations.

A fourth commenter said, to date, optical engine measurements have been informative and the limited CFD has shown that mixing issues still require quite a bit of attention. The presentation did not include metal engine measurements, which are critical in this type of research project. An integration of optical engine, modeling, and metal engine results is necessary to develop continual understanding of hydrogen DI engine combustion behavior. Another reviewer said an optical engine is used to measure in-cylinder processes of H₂ fuel injection, mixing and combustion. These are combined with results from the metal engine at Argonne and numerical simulations at three different national labs to get the total understanding. Technical barriers related to engine performance should be spelled out and the plan to address those barriers should be clearly outlined.



Another reviewer commented that the greater focus on simulation is good, but added that the quality of simulation leaves much to be desired. The same “quantity” of simulation will yield significantly better results if (and only if) it is done by a national lab or an academic partner who has an already-established core competency in engine simulations. A few of the experimental results slides are repeats from last year's work. The focus on the single-hole injector is a step in the right direction. Another reviewer said there was good use of measurement and simulation. However, the reviewer thinks the team should have partnered with Fluent for the Fluent CFD. The CFD results are more a result of the individual doing the work than the code itself. This reviewer doesn't know how much interaction there was with the Fluent CFD writers. Another reviewer said, again, the use or relevance of H₂ needs to be better motivated. Isn't ethanol use in DI engines more relevant, or the direct injection of CNG, for example? The final reviewer said the team needs to consider more than one speed-load condition as part of the injector evaluation process, and subsequent combustion work.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the models are developing well. There is not much correlation, but information flow is just beginning. Models should contemplate the impact of lube oil, as this reviewer would expect this to be a significant practical issue that will emerge—more related to ash and PM/PN emissions than HC emissions. A second reviewer said there was good progress with the data and model, but there was not full agreement so far. Covering a broad-based investigation domain from fundamentals all the way to the Ford metal engine is a tall order. It requires critical competencies and multi-faceted teaming that are not available to this project. This is reflected in the quality of results. A fourth reviewer said the team needs to address the discrepancy between simulation and experiment. Another reviewer said it is unclear that there were significant advancements made in the testing last year that improved our fundamental understanding of the combustion process and that would give some good insight into better methods to optimize the combustion process for improved engine performance. Clearly efforts were made in the testing and simulation, this reviewer added, but it was not clear what fundamental advancements were made.

Another reviewer said progress is slow and the results scattered. Results purport to show the inadequacies of KIVA versus FLUENT. Shouldn't the KIVA modelers be told? Better description of the “time to complete injection” versus in-cylinder bulk flow motion should be more fully described. One commenter was suspicious of the CFD results and curious if an expert Fluent user could have done better. This reviewer thought a good KIVA user would have done better. With the coarse grid, it makes this reviewer wonder if there was a computer resource issue. Another reviewer said limited combustion understanding has been generated to date. For example, it would be nice to see more study on injector targeting, wall effects, and bowl design on mixing and combustion. Metal engine results would help address these shortcomings. The final reviewer said only one operating condition and three injection timings have been studied this year. When integrated over a three year period, the amount and scope of knowledge generated from this work seems to fall below expectations. This reviewer added that the motivation for the selection of hardware (like the single-hole injector), the selection of operating conditions, and the selection of flows should be based on improving engine performance, not necessarily on what is easy to model with numerical simulations.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were mixed in this section. The first reviewer said it is encouraging to see that collaborations with simulation and metal engine researchers have improved this past year. Another said industry involvement from Ford and connection with the MOU group is good. A third commenter said collaboration seems okay at this early stage: ANL and LLNL. This reviewer would like to see more industry involvement later in the project.

Another reviewer didn't know what the mixing objective was, and queried if the team was trying to achieve a homogeneous mixture at TDC. A fifth commenter said that, though the presentation suggested a collaboration element with Ford, there was no data shown for metal engine experiments. This reviewer added that the collaboration with LLNL and ANL is obviously very good, given their recent CFD modeling results. Another asked why there is no mention of Cummins Westport, who has done a fair amount of work in the area of direct injection of H₂ in HD engines. The final reviewer said, if not already done, this work should be compared with the (robust) NG fundamental investigations, nationally and abroad, and similarly for H₂ work. (H₂ and NG have many similarities and differences too.) This reviewer also suggested increasing the level of experience and core competency of the collaborators who are carrying out DOE-funded activities.

QUESTION 5: HAS THE PROJECT 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?

Comments were mixed in this section. One reviewer said the work is worth continuing, and added the team should perhaps consider potential future fuel sources; will H₂ come from a reformer and thus perhaps be mixed with CO and/or CH₄? If so, what are the implications to this work? Another reviewer said that they need to push the envelope on injection and parameters. This is a very different fuel and the investigators need to model the various independent variables and recommend hardware directions. A good example would be low pressure and large nozzle diameters, or using different cone angles (impingement on crown seems like a non-issue). A third reviewer said the focus should be on in-cylinder emissions formation, understanding and identifying ways to reduce, then on power density. Another commented that it would be nice to see more spray targeting elements included in future work, including more metal engine work to address mixing issues seen to date.

One reviewer stated that it is imperative that the metal engine work at Argonne is the driving force for this work at Sandia. Design issues, injector selection, and efficiency and emissions performance issue generated at Argonne (with advice from the OEM partner involved) on their metal engine should drive investigations on this optical engine work. This reviewer added that validation of the simulation, while very necessary and important, should not be the sole focus of this work. Another reviewer commented that the future plans are somewhat random—why the emphasis on single jet injection? At some point with single-hole injection, single injection and low pressure, we would be better off with port injection. The final reviewer said Fluent simulation at ANL should be stopped. It is an exercise that a junior engineer at an industrial partner can do well. The value of running a simulation at LLNL is TBD. Model tuning is elementary. This reviewer added that the work needs to rise to be on par with a national lab-type research activity.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer commented that, given the relatively low likelihood of H₂ ever being a major transport fuel, this is an appropriate and perhaps generous funding level. Another reviewer asked if we should find a source for the fuel first. It would make more sense to this reviewer if the team used methane; we know how to get that, both out of the ground and renewable. The final reviewer asked, has the team surveyed the ICE H₂ work done in Germany, Europe (especially TNO), and Japan? This reviewer added that it may be worthwhile for the PI to spend a couple man-months on this, then re-examine the future plans. Should the project be scaled down, considering the emerging “realities” of the H₂-based transportation value proposition?

HCCI and Stratified-Charge CI Engine Combustion Research: John Dec (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

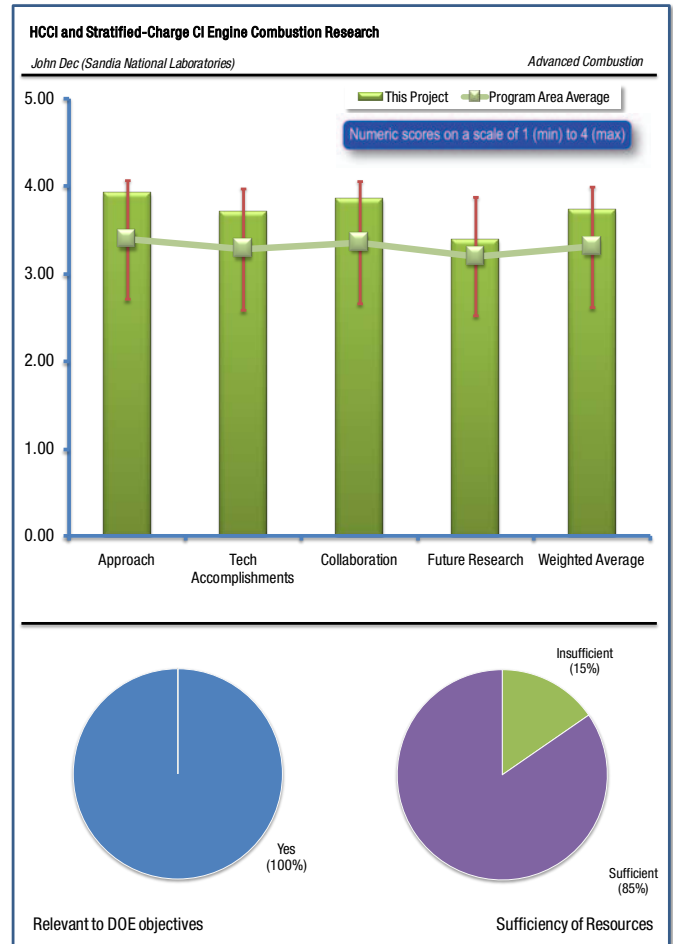
This project had a total of 13 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that HCCI/LTC efficiency improvements are “right-on,” and that improving range can lead to improved CO₂ if gasoline is used. A reviewer commented that the focus on extending range and efficiency of HCCI directly supports goals. Similarly, a reviewer said the increased load range of LTC addresses a key barrier to implementation.

A reviewer said this is a very good fundamental project aimed at advancing the understanding of HCCI while pushing up IMEP and exploring possible ISFC improvements. The fundamental understanding of these combustion systems will drive future engine design. A reviewer noted that the project seeks to provide fundamental understanding of LTC combustion. Very specific issues like thermal stratification, and the potential of intake boost to extend the high load limit of HCCI combustion is being investigated.

A reviewer observed that higher load levels of HCCI engine operation will be critical to allowing the widespread implementation of HCCI in real-world commercial applications. Expanding HCCI to alternative fuel usage (ethanol and other biofuels) will serve to allow for conventional petroleum-based fuel displacement. A final reviewer said this supports efforts for higher efficiency at usable loads on a light duty diesel; also showed how to improve thermal efficiency by a significant margin.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer said there was excellent work at using the measured results in cylinder to lead the LES simulation work: good job of using boost and EGR to get higher BMEP levels for HCCI. A reviewer said that the PI has further expanded last year's very good fundamental work to address both high load operation and impact of HCCI strategy on ISFC. The team is uniquely suited to tackle a difficult problem. John Dec has chosen TS and methanol HCCI as the focus of his current studies. This is endorsed by the MOU members and others, so this reviewer took it as a “best-in-class approach.” A reviewer said this work is leading the world in understanding quasi-homogenous combustion systems, and this group has defined the opportunities for control through stratification.

A commenter observed this is a good, comprehensive approach with well-motivated goals and modifications to the project on the fly. Another reviewer also noted this is a comprehensive approach—optical, models, metal, and said it was nice to see good transfer of information to industry (GM); the modeling of stratification and in-depth variable is impressive. A reviewer also noted the combination of data from metal and optical engines. The metal engine is allowed to set the agenda for the optical engine. This is a very sound approach. Also, CFD models are applied to gain further understanding that experiments cannot provide. A reviewer felt this approach is using the best available tools to focus on key HCCI issues.

The final reviewer would like to see a clear summary of the assumptions for the engine testing, and would like an assessment if any of these assumptions present future roadblocks to implementation of these techniques.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer noted there is good progress on a wide front, and increased boost for HCCI and the use of ethanol in HCCI engines are both very useful project goals. Another said there was a good deal of high quality progress made over the last year, including enough detailed work to understand the causes and give good insight to the value and reasons for the behavior observed with HCCI. The work on thermal stratification was very helpful and directly relevant to HCCI understanding. Further comments were that important findings/confirmations were made on showing the importance of thermal stratification on progression of auto-ignition: this is an important discovery on early ignition impacts from boost on combustion stability. This is nice work as are the results on improving efficiency via boost and reduced EGR. A commenter noted the team is gaining good fundamental understanding of thermal stratification plus other interesting results, plus interesting data on boosting. The presenter demonstrated the importance of TS, but they now need to determine how to impact it. This reviewer also had questions on the impact of thermal versus concentration stratification, as well as TS correlation with concentration gradients.

A reviewer observed that more details on thermal stratification in the bulk gas and the near wall region have been obtained. Thermal stratification reduces the maximum heat release rate, which reduced knock. The correlation with combustion is excellent and now provides confidence in our understanding of the effect of thermal stratification. In addition: the effect of residuals on thermal stratification in a low residual situation has been shown to be not significant; the effect of intake boost in extending the high load HCCI limit has been observed for a range of speeds; the loss in maximum IMEP is not a huge issue.

A reviewer commented on the very good results on the impact of increasing BMEP on engine pressure rise rate limits and peak firing pressure limits based on fundamental thermal stratification optical engine measurements and modeling. However, more work still needs to occur addressing further increasing load and qualifying ISFC impact, and also addressing control issues for transitioning from one steady-state to another steady-state operation point.

Final comments were that everyone waits to read the papers coming from this work, and that the PI has achieved the objectives set down and added to them as the project proceeded.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first comment was that this is very important work that has resulted in a breakthrough - impact of boost on extended HCCI range. It is nice to get this moving into industry through closer collaboration. Another recommended keeping up the great collaboration. A reviewer said everything seems to be working together to achieve the project objectives. The third reviewer said that the presenter is dealing with a wide range of participants and John does an excellent job sharing his work across a broad range of the diesel engine community.

A reviewer noted a wide range of collaborations with industry, national labs and universities. Similarly, a commenter stated that they are working with many key universities and industry partners. This project has a good collaboration of strengths of optical and metal engine work at SNL and Stanford, and HCCI kinetics modeling work at UM and GM. A reviewer highlighted the close integration of academia, labs, industry, and sets an example for other research programs.

Good coordination with other institutions was noted by a reviewer, who further commented on a good, real-time technology transfer to GM. In addition the sixth reviewer stated, "Do not add to the MOU membership. You have large enough membership to barely reach a consensus now. Sooner or later, the work will be leveled at the least common denominator and SNL may be challenged in maintaining harmony."

QUESTION 5: HAS THE PROJECT 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?

A reviewer said “keep going.” Another observed that expanding future research to biofuels, high efficiency boosted HCCI and closer integration with computational modeling are all useful areas. Future direction modifications are an expedient approach and a good use of DOE funding. Plans are appropriate to address some key HCCI issues.

The fourth reviewer thought the plan moving forward is solid, although it would be good to run some simple transient evaluations (engine load and speed changes) to see how HCCI would perform with changing engine conditions to understand combustion stability and the potential requirements to make this work over a real drive cycle. Another observation was that the future challenge would be to demonstrate this on a multicylinder engine. The PI should do a study of the work to show how variability effects would be a challenge on a multi cylinder: the PI should also study transient effects for a multi cylinder.

A reviewer noted the direction on improving TS and major impacts. There is a need to move towards impacting TS to improved performance: how will this be accomplished? The PI may need to move into interplay with concentration gradients. The final reviewer asked if the PI has considered the effect of air motion and the gas total kinetic energy on TS.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Funding level was generally judged to be appropriate. A comment was offered that this project appears to support post-docs and other personal at SNL and LLNL. The funding seems reasonable. A reviewer would like to see more resources being spent on this project: these are excellent results that are well-aligned with DOE and industry objectives, and are a good investment. The last commenter would fund this more and put in multi-cylinder work and transient operation work.

Low-Temperature Diesel Combustion Cross-Cut Research: Lyle Pickett (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

This project had a total of 12 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer noted that the project included fundamental studies of spray mechanics, spray combustion and soot models for conventional and alternative fuels which are important areas of research for fossil fuel displacement. A separate reviewer noted that the Engine Combustion Network is quite important for transmission of data and to develop common understandings with non-DOE researchers. The reviewer added that this was a central tool for propagating information and that cross-cuts like this develop broadened understanding and corroboration. A separate reviewer stated that the project was gaining a fundamental measurement under controlled conditions to advance inputs to better models. One reviewer said that the project provides excellent data for in cylinder modeling calibration and development.

One reviewer said that the project addresses the sources of unburned hydrocarbon and CO emissions, and thereby also addresses efficiency barriers for low temperature combustion processes. The reviewer added that load limit issues for LTC combustion are also addressed.

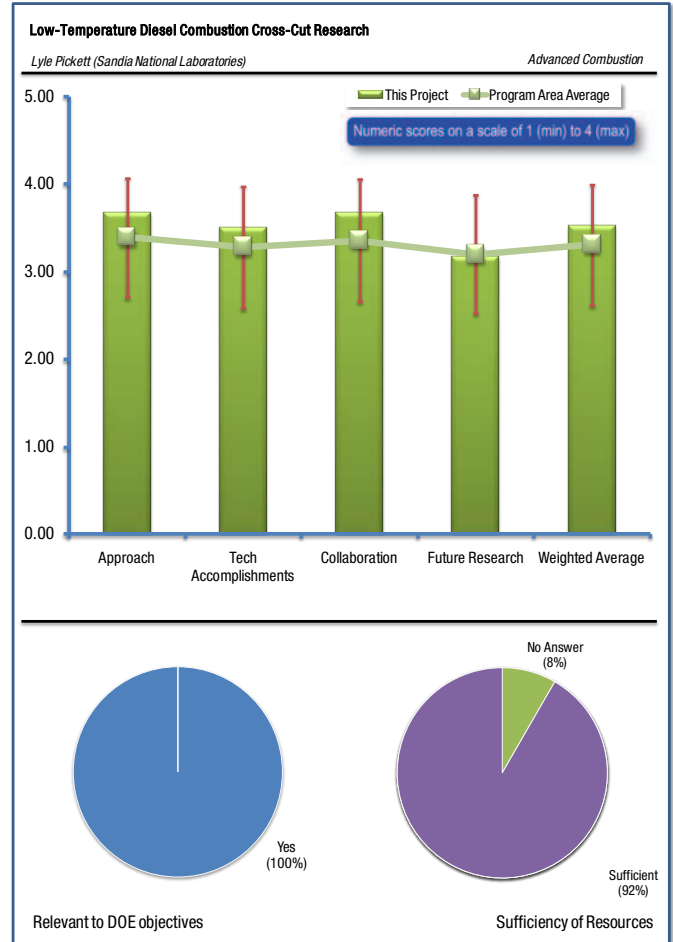
A reviewer said that this was a multi-faceted project which provides a great baseline fundamental spray formation and combustion database for engine combustion system modelers to calibrate their models to reduce engine-out emissions and addressing spray-targeting issues for DPF regeneration. The reviewer added that fuel consumption improvement is addressed in this project in the form of a method to reduce fueling during DPF regeneration and this is a tie with DOE goals, but a little weak.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said that the approach of establishing baseline injection equipment, nozzles, and operating conditions for experimentation at various worldwide labs is wonderful. The reviewer added that with time, the measurements taken by the various partners can be readily compared and used by combustion modelers to improve existing spray/kinetics models in comparrison to gathering published data that will include a huge variety of boundary conditions that are difficult to resolve by modelers.

A reviewer described the project approach as well designed and an expedient experimental direction. A separate reviewer stated that it was a unique approach to managing variability while maintaining applicably to real engines. A reviewer stated that the project capitalizes on a long standing SNL experimental setup and core competency.

A reviewer sated that the quantitative optical diagnostics are used in a combustion vessel to generate data useful for the improvement of numerical models of fuel injection processes. The reviewer continued that this is done via the Engine Combustion Network, and the study of a standard injector common to many labs around the world. The reviewer added that the laboratory setup allows for very



careful control of the experiment and boundary conditions adding that the effect of high pressure and temperature on spray character can be studied.

A reviewer thought that the stated objective of this project is good, and having a large group of injectors spread across the world is a great effort for correlation, especially if people are willing to share some of the interesting results, beyond the basics required for collaboration.

A reviewer noted that the project was starting with spray, adding that this was a good start with identical injectors. The reviewer also said that the work on soot understanding is a good application for collaboration, however, future engines will operate at high NO_x and low PM and this becomes less critical. The reviewer saw a need to focus on efficiency drivers.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer thinks this is one of the best overall projects, adding that it provided fundamental data to develop combustion, spray, and emissions models for designing engines of the future.

One reviewer said there were good findings on late post injection and biodiesel impact. A reviewer described good applications in spray geometries as well as the biodiesel soot investigations. A separate reviewer observed good systematic progress, adding that the project was pushing the boundary of fundamental engine combustion understanding.

A reviewer noted that the initial test and evaluation of the commonality of spray boundary conditions is promising, though much work still lies ahead of all the involved partners in this study. The reviewer added that the most tangible contribution to date is in the area of spray penetration at very low charge density and high temperatures where DPF regeneration spray targeting has potential over-penetration issues. To date, the reviewer said, there is little demonstration of what type of ISFC improvements could be made during DPF regeneration through more optimal spray targeting, adding that this possibly could be addressed in the future.

A reviewer described the data set from the injection penetration work as fairly impressive, especially the collaboration between lab data and simulation work. The reviewer added that it would be good in the future to have this work expanded to include the other injection parameters, meaning injection pressure, hole diameter (and other injector hole descriptive items, e.g. L/D, radius, etc.) to build an ever larger and potentially more helpful data base to be considered in injector/combustion system design.

A reviewer said there was a very good agreement of boundary conditions and spray penetration data between Sandia and IFP, adding that in the case of combustion, lift-off lengths also were the same between the two institutions. The reviewer continued that liquid penetration for late injection has been studied and this condition is relevant to DPF generation. The same reviewer noted that new information has been generated as follows: biodiesel sprays are shown to penetrate 25% more than standard diesel; and soot morphology as a function of downstream position in the spray has been studied.

A reviewer said that the characterization of injector A shows good correlation with others. The same reviewer also listed jet penetration with biodiesel and ULSD comparisons and soot formation and characteristics as having very interesting results. The reviewers added that these were nice preliminary results and direction.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer described a widespread collaboration with a wide range of stakeholders and investigators. A separate reviewer said there was an excellent cooperative network.

One reviewer said that the Engine Combustion Network is an interesting concept and it needs to be kept pre-competitive. The reviewer added that the quality of work and results will be dependent on where the experiments are carried out, as not all the combustion labs and researchers are equal. The reviewer added that this would affect the overall results, as they rely on others to provide some of the building blocks to supplement project results. The reviewer urged the project not to add to the MOU membership,

suggesting that their membership is large enough to make it difficult to reach a consensus now. The reviewer added that sooner or later, the work will be leveled at the least common denominator and SNL may be challenged in maintaining harmony.

A reviewer described the collaboration as excellent so far, noting there was nice collaboration with IFP, Bosch, etc. and that this is a central objective to make sure a valuable tool is being developed. A separate reviewer stated that the Engine Combustion Network is a great idea.

A reviewer said that this is a huge collaborative effort among numerous global research institutions with outstanding effort by the PI is setting up this huge collaboration.

QUESTION 5: HAS THE PROJECT 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?

A reviewer noted that the project direction is on a year-to-year basis and is modified as required to investigate new areas of interest. One reviewer described strong focus parameters that can affect HCCI management. A reviewer said that GDI is good addition to portfolio of planned work.

A reviewer stated that the future work is very logical and will be beneficial to modelers and engine development companies. The reviewer added that the only missing piece revolves around quantifying fuel consumption improvements associated with more optimal DPF regeneration spray targeting. A separate reviewer said that several items needed for model development have been put on the list.

A reviewer suggested that the project needs to move towards high-efficiency objectives, giving the example that we are seeing a very strong movement towards high-NO_x and low PM operation (low EGR), and very high injection pressures. The reviewer continued that it was also very important to move into LD gasoline DI, adding that these will be the bulk of US engines in the next 5-10 years and we need much more understanding here.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

There were no responses to this question.

Automotive HCCI Engine Research: Richard Steeper (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

This project had a total of 11 reviewers. HEYWOOD

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that HCCI combustion, once implemented on a large commercial scale, will have a positive effect on fleet fuel efficiency. A separate reviewer stated that it is very important to advance understanding in efficiency of gasoline DI engines adding that there was a novel approach with high NVO levels.

One reviewer said that the experimental work described is an important bridge between modeling and multi-cylinder engine demonstration of high-efficiency engines. A separate reviewer noted that fundamental knowledge of low temperature combustion is being generated, adding that these include the areas of thermal and residual stratification, ignition, heat transfer and mixing.

A reviewer said they could not make the leap to better efficiency with this one, adding that they need to see a 1-D cycle simulation that shows how this concept of NVO injection for HCCI is going to improve efficiency.

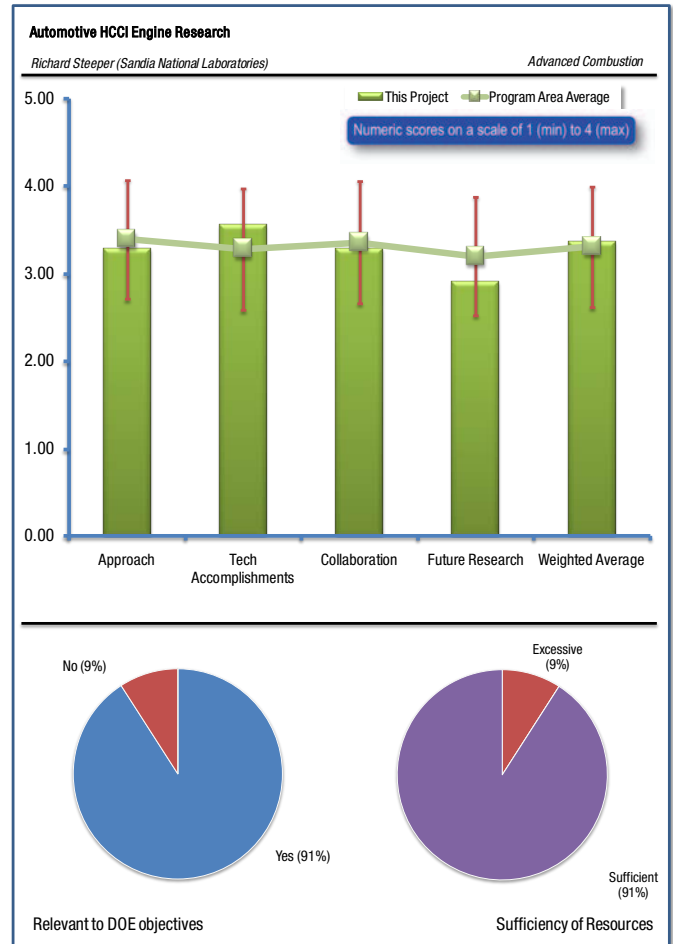
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said this was one of a few gasoline combustion based projects and there was a good balance with diesel fuel based combustion. A reviewer said the experiments are performed in an optical engine and new diagnostics are being developed as necessary. The reviewer added that computer models are being exercised for further understanding.

A reviewer commented that investigations of chemical kinetics of early stages of heat release in HCCI combustion are a key to controlling it, continuing that from today forward, gasoline will contain at least 10-15% ethanol. The reviewer suggested that the oxygenate components might have an important effect on CO production, as well as other potentially relevant intermediate species (e.g., aldehydes), and so this might be an important element to consider in the chemical kinetics work. The reviewer would like to see the work include a fuel effects/sensitivity study.

A reviewer stated that the use of NVO is not well motivated other than to drive internal EGR, and wondered why study this particular phenomenon versus any other “interesting” conventional DI, SI or pre-mixed combustion effect. A reviewer suggested that the project team should consider running 1-D global cycle simulation models such as GT Power or WAVE to supplement the detailed KIVA analysis. This would give much insight especially when NVO is the focus of the study. A reviewer said that the optical engine with modeling is impressive, but it needs more metal engine work. The team needs to focus on efficiency gains.

One reviewer missed the fundamental importance of this work and how it will benefit IC engines moving forward. The reviewer understood what was being examined, just not how this really advances the state of the art in system design.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said that the experiments to determine the relative influence of thermal and chemical factors on heat release are of critical importance to LTC. A separate reviewer said that the experiments that distinguished between thermal and chemical effects and revealed chemical effects are very valuable.

One reviewer said there were nice correlations of SOI NVO and performance and a good interpretation of observations. The reviewer added that it was an interesting discovery on NVO impact on heat release. The reviewer also commented on the good work done on diagnostics and CO impact and the excellent work on developing new diagnostics and better S/N.

A reviewer said that the accomplishments are good, but that this project does not offer a holistic view of any particular part of HCCI engine operation that is useful, timely or lasting.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this was a good collaboration with a range of institutions. A separate reviewer said that the work is well coordinated with modeling efforts, and industry interest is sufficient to maintain technical relevance/significance. One reviewer stated that the collaboration was very impressive with UW, LLNL, Ford and GM and that it was nice to see inputs from OEMs helping to set direction.

One reviewer urged the team not to add to the MOU membership. The reviewer believes the project's membership is large enough to barely reach a consensus now. The reviewer added that sooner or later, the work will be leveled at the least common denominator and SNL may be challenged in maintaining harmony.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that while HCCI is important, this project seems to be in better position than some others to shift emphasis toward other types of combustion such as lean burn. This may be more important for light duty in the next 10 years or so. A separate reviewer said that there was a need to continue developing understanding of this operating principle and added that the project should continue getting OEM direction. The reviewer suggested the project needs to move towards advancing efficiency gains. A reviewer made the general comment that the proportion spent on facility upgrades and expansions at SNL appears to be excessive.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer made the general comment that the proportion spent on facility upgrades and expansions at SNL appears to be excessive.

Large Eddy Simulation (LES) Applied to LTC/Diesel/Hydrogen Engine Combustion Research: Joe Oefelein (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

This project had a total of 12 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer commented that fundamental studies of injector characteristics are important for novel engine concepts to displace conventional fuels and engines. A second reviewer remarked that LES can be a powerful tool for better understanding of combustion and for the helping with the development of the traditional CFD tools. The third reviewer expressed that this project provides simulation capabilities for the development of high efficiency, clean, low temperature combustion engines.

The fourth reviewer stated that the work is an important longer-term step toward including experimentally-observed effects on engine modeling. Similarly, the fifth reviewer opined that it is important to push modeling foundations, and added that models are so critical to understanding.

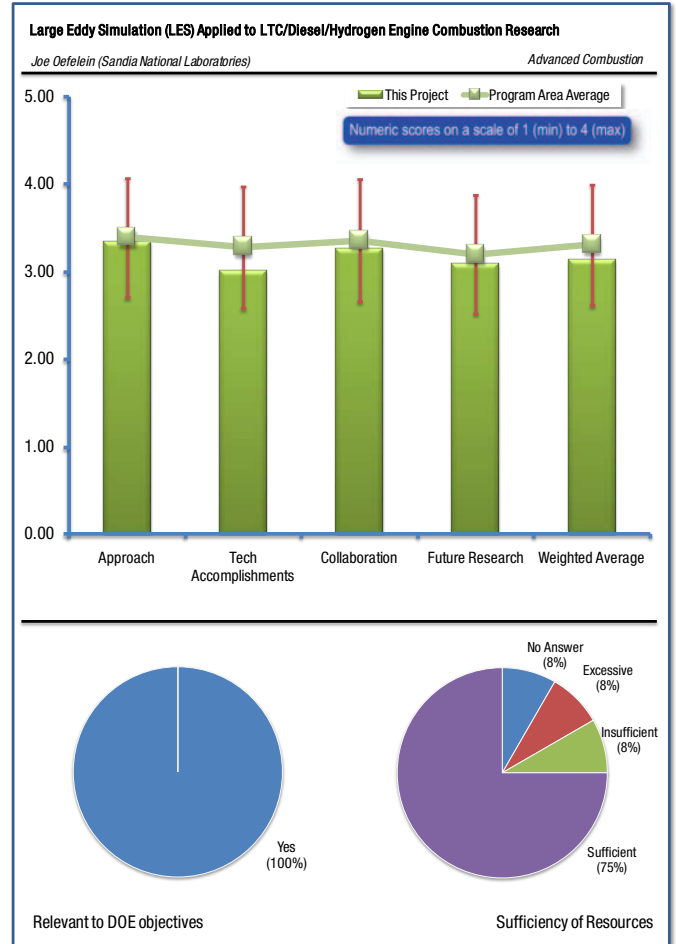
The sixth reviewer noted that this project indirectly supports DOE goals of advanced combustion development and improve fuel consumption characteristics. This reviewer explained that the net output of this project is essentially the translation from high fidelity CFD analysis of DI combustion into engineering models, and added that it is important that this work continues given the possibility for improved engineering models based on high density computational meshes.

A seventh reviewer responded both positively and negatively to the relevance of this project to overall DOE objectives of petroleum displacement. This reviewer remarked that this project should be totally funded by BES, and it is indeed a fundamental work that falls outside of the VTP charter. Additionally, the “link” should exist without providing VTP funding support.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer stated that the computational power behind this project is very impressive. The second reviewer noted the project’s use of cutting edge components, and interesting dissection of effects via the interface envelope choice, and that it was nice to see multiple fuels and engines being modeled to develop common fundamentals. This reviewer added that it is very important to correlate with reality. A third reviewer offered that the project has good use of computer resources, and the focus on modeling and improving this area of expertise is an excellent area in which to focus. Furthermore, this reviewer remarked that obviously, collaboration is hugely important in this project to make sure there is a broad data set that can be used for simulation calibration.

The fourth reviewer opined that this project comes across as a solution looking for a problem, and added that relevance to real engine practicalities is obvious, but needs to be better motivated.



A fifth reviewer commented that the approach is aimed toward a significant improvement in more computationally-intensive methods, and is an important step in bringing this closer to eventual “desktop” calculation. This reviewer warned that the broad scope may be getting ahead of the tool’s capabilities, and suggested that stepping back and validating the basic models against experiment would be a better use of time.

The sixth reviewer indicated that the project is fascinating as always, but offered concern that the techniques cannot be employed by only a select few with this computing capability.

A seventh reviewer recommended that an area of improvement is in validation versus experimental measurements. Additionally, to date, there has been little effort in validation against practical engine type measurements, though future work is focused on this validation issue. Otherwise, the approach has been very good.

The eighth reviewer remarked that this is a “nice to do” project.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted that the work beginning on HCCI experiments at Sandia will be particularly important and relevant. The initial results are encouraging. The work on modeling liquid HC sprays is also very critical. The second reviewer commented on the nice interface analyses and mixing, and added that it is important to push state-of-art and expanding time on looking at unexplored territories. The third reviewer remarked that this is the frontiers of simulation, and noted that it is fully dependent on the future computing platforms capabilities. Additionally, this reviewer offered that there were too many “nice pictures” reflecting the progress made.

A fourth reviewer queried whether there is more to this than impressive visualization to the layman. This reviewer also pondered how good the visualization is, other than as measured by gross parameters and variables like jet penetration length and large scale structure development.

The fifth reviewer stated that progress is relatively slow in going from base validation cases to “real world cases”. This reviewer questioned how the evolving jet simulations in the presentation compare with fundamental experimental measurements of scalar dissipation rates. Additionally, this reviewer offered that the only concern is that the impression given is that validation is done on a macroscopic scale, comparing to parameters such as jet penetration rates and cylinder bulk temperature, and not on a microscopic scale, which is more relevant to accurate prediction of mixing and heat transfer processes. For example, the comparison with HCCI scalar fields seems to suggest that the turbulence length scales are too large. The reviewer also queried whether there is sufficient experimental temperature and/or concentration field data for validation, to give better agreement going forward.

A sixth reviewer expressed that milestones in the presentation are largely “ongoing” projects, and further added that the milestones are not clear. The seventh reviewer commented that this project needs much more validation against experimental measurements in order to aid engine designers.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer opined that the project has an amazing list of collaborators. The second reviewer commented that collaboration both inside Sandia and beyond is well represented. A third reviewer indicated that the project has done excellent work in having an LES working group that involves uses of various CFD codes. This reviewer hoped that the lessons learned are available to these CFD code companies.

The fourth reviewer noted that the CFD side of the equation is very collaborative in nature since it includes a number of groups that are either software developers or researchers who have expertise in engine CFD. This reviewer did explain that more collaboration is necessary with those who have experimental data available for validation, and suggested possibly UW-ERC or GM.

A fifth reviewer commented that collaboration is sufficient to steer the project in the right direction, but recommended that the model needs more validation data. The sixth reviewer stated that more in-depth understanding of the underlying combustion phenomena will help the modeler understand the results.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer recommended continued analysis of the less-well understood cases of highly diffusive gaseous fuels (hydrogen) and liquid fuels, as a means of better identifying the gaps in fundamental understanding that would be required to get to the next level. The second reviewer praised the project as great work, but added that the challenge will be to turn this into a practical tool for industry.

A third reviewer noted that future research needs to have a long-term vision and not merely be reactive to suggestions from existing Sandia research; otherwise the significance of this work will be dilute. For example, the long-term goal of investigating a very high pressure, multiple-injection DI process would be a good basis for ongoing, background work.

The fourth reviewer commented that the future work does include possible validation against Lyle Pickett's combustion network database, but possibly this effort could also include any experimental data from UW-ERC and/or GM. Additionally, this reviewer stated that the more validation the better chance engine design companies will be able to reap the benefits toward developing less computational intensive engineering models.

The fifth reviewer explained that generating reduced but practical computing capability for common engine designers at the PC and workstation level is required next.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer commented that the gap in investigators is now filled, and added that it is important to get training done and progress. A second reviewer recommended that DOE's BES fund the project.

Free-Piston Engine: Peter Van Blarigan (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

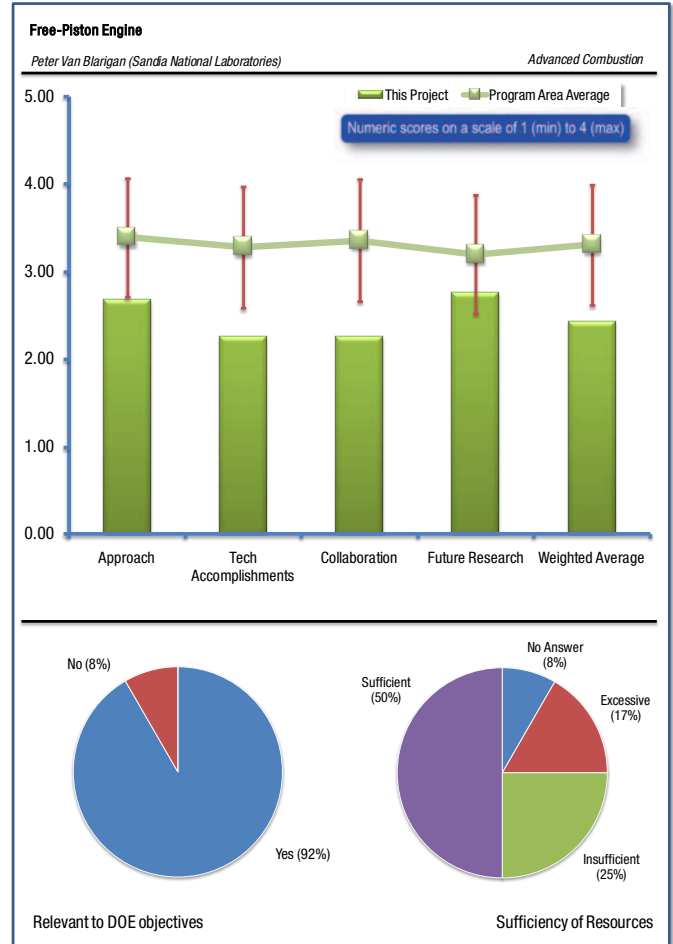
This project had a total of 12 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer noted that this is an interesting engine concept that deserves to be pursued. Similarly, the second reviewer expressed that this is a good, innovative project that really would advance the state of the art. This reviewer did add that there are some obvious challenges with the variety of new devices being combined, but the reviewer gave good marks for thinking outside the box.

A third reviewer indicated that the FPE program remains an important long-range technology as a cost-effective and efficient powerplant for PHEVs. The fourth reviewer remarked that the free piston has very high efficiency potential and could be an alternative to fuel cell. Furthermore, it can easily adapt to a broad range of fuels. The fifth reviewer supposed that one could “burn a lot of stuff in this thing.”

The sixth reviewer explained that, theoretically, this project supports DOE goals for pushing peak engine thermal efficiency above 50% while attempting to meet emission standards in-cylinder. A seventh reviewer noted that the project promises very high efficiency (>50%), via high compression ratios (20-40:1). The eighth reviewer offered that this project is best fit for a SBIR-type program and not VTP funding.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer really liked the innovative ideas behind this free piston engine, and added that this has the potential to generate a lot of very interesting data that could be of great interest as we move forward.

The second reviewer noted the interesting design approach, but commented that there is still a lot of work to get a working device. A third reviewer indicated that much credit is deserved in assembling a functional prototype. The reviewer did query whether the approach taken is meant to prove out the capabilities of the LEG-FPE under fired conditions, or to examine two-stroke, ultra-high CR, lean HCCI with various fuels. Additionally, the reviewer noted that if worked separately, each would be a substantial effort, and that taken together, this is a highly ambitious undertaking for the resources proposed.

A fourth reviewer explained that the major technical barrier is practical implementation, and suggested that this should be addressed via a meaningful prototype. Furthermore, this reviewer expressed that funding has been increased in 2010 to build parts and assemble a prototype.

The fifth reviewer opined that the project seems to have gone backwards rather than forward, although reconsidering a number of previous assumptions and engine features is a good idea.

The sixth reviewer commented that the elusive free-piston, 2-stroke engine has been researched and studied to a great detail by DOD, DOE, Daimler Benz, AVL, FEV and many others. This reviewer felt that this project is “beating a dead horse.”

A seventh reviewer expressed doubt that the engine will ever run, adding that the planning is so poor, and that it was built without knowing how to get it started, the reviewer could not begin to imagine all the potential failure modes. If you have HCCI near constant volume combustion, you will “wake all the neighbors for miles” when this engine runs. This reviewer did comment that none of the other researchers care about noise either. This reviewer further noted the need to do a safety review with this, as there are unrestrained pistons (projectiles) and high voltages.

The eighth reviewer indicated that the project seems to be spending a lot of time on the start mechanisms and synchronization routines, and questioned whether mechanically coupled pistons would more quickly allow for combustion development (and concept assessment).

A ninth reviewer said that the steps undertaken in the project during the last couple years have been logical, as the PI has slowly developed a prototype engine. One point of concern was expressed by this reviewer concerning the air system, which must supply a significant amount of pressure (work) to compress the charge. A suggestion was made that possibly more attention should be given to reducing this parasitic loss and improving engine power density.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer indicated that progress is being made toward a working prototype, although it seems that mechanical difficulties such as the lock/release mechanism and bounce chamber design have unnecessarily impeded the progress toward gaining an understanding of the fundamentals (i.e., high CR HCCI combustion, and continuous control of a running engine). A reviewer remarked that too much effort is being expended on nuances to arrive at an operating concept. A reviewer declared that the team has some hardware, but cannot run it. This reviewer questioned whether any time has been spent doing DFMEA's, and whether some experienced engine design people have been looking at this.

A reviewer commented that the project seems to have been re-commenced with a more rigorous approach to the design. This reviewer also noted that the design of the gas bounce chambers (and the required latching mechanism) seems to be a retrograde step, and queried how this may give a better free piston engine. Further, this reviewer questioned what thought has been given to other bounce mechanisms.

A reviewer opined that the project still has a long way to go to get results that might progress development of a free piston engine. While this reviewer explained that fuel fired results will be most critical, they did question whether engine control can be maintained.

A reviewer expressed that the project is an interesting concept, but that it was unfortunate that the controls challenge and effort seem to be on par or greater than the combustion effort. A reviewer acknowledged that there are certainly challenges/obstacles being encountered, which are being addressed, but it does seem that overall progress is moving at a fairly slow pace. The reviewer queried whether it would be good to accelerate the design and troubleshooting phase of this program and get to the longer term testing program. Similarly, the sixth reviewer stated that progress still seems slow, and that, while funding has increased for 2010, full staffing has still not occurred in June of 2010. Further, this reviewer noted that HCCI combustion, promised in last year's review, has still not been tested with other fuels. This reviewer did question whether the high efficiency of the HCCI combustion will be lost in the alternator and in the energy needed for the enabling subsystems.

The final reviewer observed that most of the work to date has been in analysis and design with the former under most ideal conditions. The reviewer added that there are many obstacles in front of the PI, including meeting brake thermal efficiency above 50%. This includes taking into account air system parasitic losses, maintaining a high efficiency linear alternator, addressing in cooling issues with the linear alternator, and properly controlling the effective compression ratio.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer commented that the level of collaboration is appropriate for this stage of development. A second reviewer expressed that the list of collaborators is very good, adding that the “subjects” of collaboration are engineering developments, not research. The third reviewer remarked that there should be other collaborations with universities, and offered the European Volvo/Chalmers University collaboration as one to follow. A fourth reviewer recommended that the project work to pull together the small community of free piston developers. The fifth reviewer mentioned that there has been a small modeling collaboration with UM and GM, and that otherwise, this is a standalone project that could benefit from more interaction with GM concerning the real world issues with this engine.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer indicated that plans seem appropriate to determine if the design is feasible. The second reviewer noted that the approach to the future seems clear—to make a free piston engine and to run it on a number of fuels. However, this reviewer remarked that the pathway to get there is not clear.

A third reviewer observed a need to accelerate the troubleshooting phase of this program and move into the testing phase, as a lot of good data could potentially be derived via testing with this unique engine. The fourth reviewer commented that the PI needs to take actual real brake thermal efficiency measurements on this engine before proceeding any further with this project.

The fifth reviewer opined that the scope is very ambitious for a program of this size.

The sixth reviewer does not see a value to this research project. Eventually, this will be realized and the project will be terminated without significant accomplishments.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer indicated a slow start was seen, but more appropriate effort is shown now. The second reviewer acknowledged the adequate funding, but saw a need for more directed support, as it seems like Peter is a one man show. A third reviewer commented that, given the long-term nature of the research, the level of funding is appropriate. Yet, it appears to be insufficient to cover the outlined project scope.

The fourth reviewer noted the novel engine design is a very expensive enterprise, and that this budget still does not seem adequate. Although budget is increasing, the fifth reviewer remarked that it may not be sufficient to move the technology forward. Further, this reviewer questioned whether spending a small fraction of the effort on free piston (rather than fuel cell) could be a quicker route to high efficiency mobile electricity supply.

The fifth reviewer stated that the PI might be “a few million away from making this work.”

Optimization of Direct-Injection H₂ Combustion Engine Performance, Efficiency, and Emissions: Thomas Wallner (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 9 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer observed that H₂ fuel can displace petroleum. The second reviewer remarked that this project directly addresses DOE goals for improved engine thermal efficiency and while address emission standards.

A third reviewer commented that hydrogen IC engine use will be a useful bridge to a more “hydrogen intense” alternative fuel future. The fourth reviewer indicated that IC engines are at the very least a bridge technology to the long-term vision for use of H₂ in transportation. The fifth reviewer stated that this was more relevant in prior years when the H₂ “hype” was at its peak.

The sixth reviewer explained that hydrogen certainly could have potential to improve the greenhouse gas situation, assuming it can be produced in a manner that is CO₂ free (clearly outside the scope of this project).

A seventh reviewer shared that while hydrogen is a fuel that will provide a pathway to the DOE goal of 45% brake thermal efficiency, the infrastructure for hydrogen production and distribution and onboard storage remain huge issues.

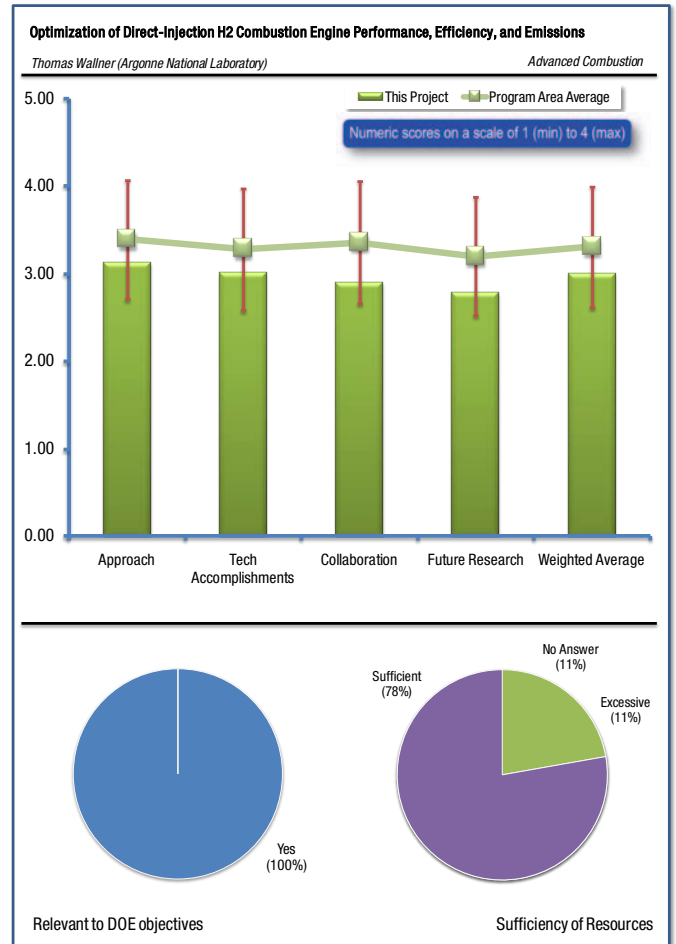
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer acknowledged that the project team has been very responsive to previous reviewer comments and criticisms. Additionally, this reviewer noted that project modifications over the past year have been very well thought out, useful and relevant. The second reviewer observed that the project is using single cylinder engine to evaluate realistic conditions.

A third reviewer commented that overall, this is a well thought out, methodically executed project. Further, the only area that is missing is work on any thermal efficiency losses associated with fuel preparation that are considerably higher compared to other engine alternatives.

The fourth reviewer indicated that it is important to be building a base understanding of H₂ combustion in ICs, but would like the focus of this work to be exclusively on achieving high efficiency with H₂.

The fifth reviewer stated that this is not a fundamental investigation effort but is more like an industrial development work. This reviewer declared that Fluent simulation at ANL should be stopped, adding that ANL carrying this task and reporting on it may reflect negatively on both the Lab and the VTP program. Rather than having a local post-doc do it, this reviewer suggested engaging acknowledged experts that can design an effective simulation plan and carry it out. Examples abound in many other programs reported during this annual AMR. Additionally, this reviewer opined that the model tuning is elementary, and that the work needs to rise to be on par with a national lab-type research activity. This reviewer also commented that experimental investigations of H₂O and EGR



injection for lower NO_x are looking at an old technology. The underlying phenomenological explanation is well-studied and has been documented in the public literature for the diesel engine. This reviewer questioned why the researchers expect these “diluent” to behave differently in an H₂-fired engine, and queried whether they have applied Chemkin and KIVA to it. Briefly, this reviewer offered that the studies are experimental hit-and miss. A revamp of the philosophy, approach and strategy of this effort can lead to significant improvements.

The sixth reviewer observed that the project includes single cylinder investigation, as well as a focus on NO_x emissions and injector development. The reviewer also noted the effort to trying water injection and EGR to reduce NO_x emissions, as well as investigating different injector designs, location and nozzles designs, and multiple injection strategies. This reviewer suggested that the focus should be on more generic issues like increasing efficiency and reducing NO_x, rather than local optimizations like trying different nozzle designs.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer remarked that good progress was made and a good assessment of the practicalities and potential of the methods considered was performed. The second reviewer commented that the PI has made much progress in the last year in addressing and improving thermal efficiency at two load points. There is still much more work to be done since this effort has not fully reached DOE thermal efficiency goals, though there is great promise that the next generation combustion system will meet this goal. The third reviewer observed that they did a good job getting this engine up and running and producing data. Additionally, this is much preferred over getting caught up in the many mechanical issues that certainly could have dominated this type of program. The fourth reviewer acknowledged the good progress in addressing engine efficiency and emissions, but noted there are still concerns with overall H₂ cycle efficiency.

The fifth reviewer questioned whether 45% is a good enough efficiency goal. This reviewer also queried whether there should instead be an indicated efficiency goal (since this is likely not a near or mid-term technology) rather than using best-case extrapolations for PMEP, FMEP. Moreover, the uncertainty in NO_x requirements for 2030+ and in technological advances in aftertreatment (particularly with regard to H₂, the perfect reductant) makes any focus on NO_x seemingly unnecessary. This reviewer questioned what the technical barriers would be if the NO_x constraint were the removed (e.g., temperature issues, heat loss).

A sixth reviewer indicated that the work required to compress H₂ to injection pressure is not included. A rough estimate for large scale high pressure H₂ should be provided.

The seventh reviewer commented that the project should have been rated lower but was given “fair” to help with the overall score. Additionally, the reviewer commented that piece wise investigations of selected options yield narrow application results. Finally, this reviewer questioned whether the team has surveyed the ICE H₂ work done in Germany, Europe (especially TNO) and Japan, and suggested that it may be worthwhile for the PI to spend a couple of man-months on this, then compare the program approach and results to prior work.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer commented that the project is a good combination of national lab, industry and academic partners. The second reviewer explained that this project appears to leverage work at both SNL and LLNL in the areas of optical H₂ engine measurements and CFD modeling of the spray formation process. This reviewer noted that it would be interesting to compare any of the metal engine results with any recent work at Ford Motor Company.

A third reviewer recommended that, if not already done, this work should be compared with the (robust) NG fundamental investigations, nationally and abroad, as well as for prior H₂ work. This reviewer stated to increase the level of experience and core competency of the collaborators who are carrying out DOE-funded activities.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer explained that future plans are well thought out and reasonable for the budget and effort reported. A second reviewer commented that there is a good plan as far as engine work, but questions the overall H₂ strategy and where the H₂ engine fits in. The third reviewer noted that, overall, the future work is addressing the current combustion system limitations of the metal engine. This reviewer added that it would be helpful this coming year to collaborate with Ford and compare any experimental measurements available from past Ford H₂ engine research.

A fourth reviewer recommended that emphasis should be on efficiency alone, and not engine-out emissions controls. Ultimately, the life-cycle efficiency benefits of H₂ ICE's will have to compete against other options (e.g., fuel cells), and placing the focus instead on reducing engine-out NO_x may confound future efforts to sort out best technology options for H₂.

The fifth reviewer stated that a significant revamp is highly recommended.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The single reviewer whether the project should be scaled down, considering the emerging realities of the H₂-based transportation value proposition. If not, a pragmatic "peer review deep dive" may improve the resource utilization if the involved research staff are open for it.

Fuel Spray Research on Light-Duty Injection Systems:
Christopher Powell (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

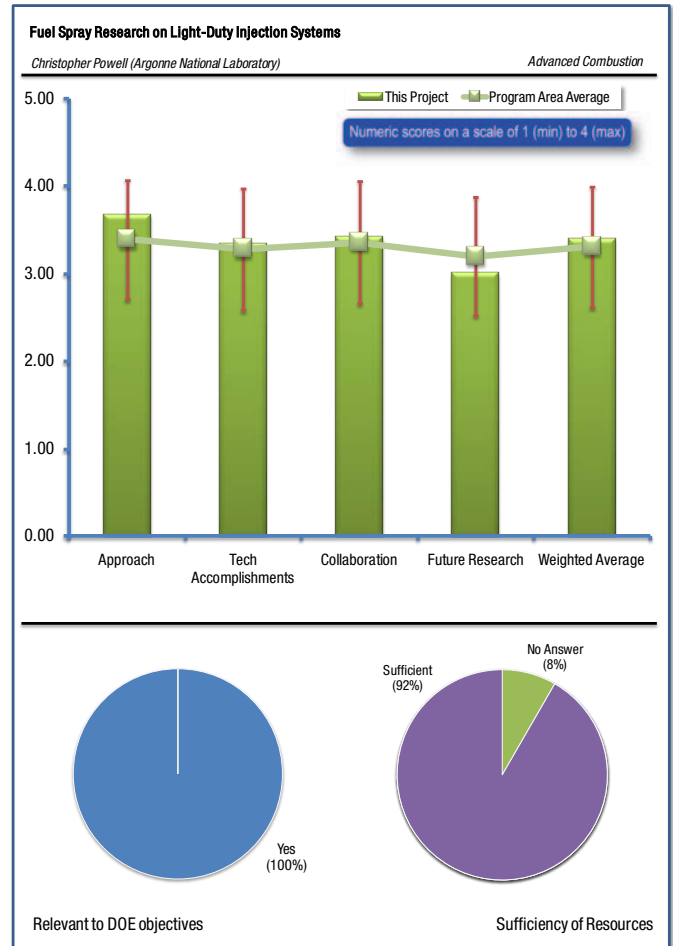
This project had a total of 12 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers commented that the project is highly relevant. One reviewer commented that the project’s fundamental studies of injector performance and the fluid dynamics of fuel injection are important for a wide range of engine operation. A second reviewer remarked that this project supports LTC and other combustion mode research aimed at improving engine thermal efficiency while meeting emission standards.

Another reviewer said improved injection can increase efficiency and decrease losses to emission control, and a fourth reviewer remarked that the project leads to basic understanding of fuel injector nozzles and their operation which is critical to diesel engine performance and modeling. The fifth reviewer remarked that especially with the dedicated space, focused research to understand fuel sprays can be conducted. Fuel sprays are at the heart of most advanced combustion concepts.

The final reviewer felt that diesels offer reduction in petroleum use, but more emphasis on GDI systems may ultimately be more important to petroleum/CO₂ reduction.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers had positive feedback about the use of ANL facilities. One reviewer remarked that the project possesses unique capabilities that capitalize on a specific ANL facility and core competency, and a second reviewer also remarked good use of available facilities and new information produced to help refine injection design. A third reviewer remarked that the approach is rigorous and well thought out, but progress has been slow (possibly due to construction at the Argonne APS).

Another reviewer noted that this project has come a long way since 2005 when vessel boundary conditions were nowhere close to actual engine conditions. After years of patience, this diagnostic is now providing very valuable internal spray measurements. The approach is outstanding and development of the near facility to allow more rapid experimental execution should provide a dramatic increase in the development of knowledge in near injector spray dynamics.

Two reviewers had positive feedback about the use of x-rays. According to one reviewer, x-rays offer unique insight, and opening the beamline to general user proposals will also be important for collaborative efforts with academic institutions. However, this reviewer would like to see more emphasis on high pressure gasoline sprays, including integration with experimental work in this area. Another reviewer remarked that using X-rays to study sprays is certainly an interesting topic, but had questions about using a 2-D method to study what is clearly a 3-D event. However, still a lot of good information can be gained from this type of work. Certainly the ambient conditions in the test chamber are also an item to be strongly considered; potentially up to and including reacting sprays.

The final reviewer commented that this may be the only method for studying needle motion in some common rail injectors where this measurement is extremely difficult. Spray visualization is good stuff but not as important.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers saw evidence of progress. The first reviewer remarked that technical progress has been good but slow. A second reviewer remarked that the project has created a very useful tool for fuel system makers, one that they could not have done individually on their own. The third reviewer said this looks like a good start, but we did not see very many results. Hopefully, now that the technique is proven, we can see more interest and more results. According to the fourth reviewer, overall, very good progress was made since 2005. It would be nice to more liquid distribution measurements over a larger variety of charge density and temperatures indicative of DI engines. According to another reviewer, certainly a lot of good progress was made relative to the facility and taking of data. High marks were given for this progress, and the results do indicate the potential for learning a good deal about spray development.

The sixth reviewer remarked the validation of other efforts in this field is of fundamental importance, and the seventh reviewer noted that progress is slow due to the commissioning of the new facility. Another reviewer summarized that the team is explaining some of the observed results by others, such as the SNL work. The team is showing some discoveries and confirming other observations via the X-ray approach. They have completed the new fully dedicated facility. They are supporting the GM work.

Remarked the final reviewer, seems like the volume of work being done is low. Can the scope and volume of work done be expected to increase in the future due to the dedicated facility?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers had positive feedback on the collaboration with industry and labs. Said one reviewer, collaboration is good and fairly comprehensive. It will presumably increase in the next project period due to projects that can be conducted at the new beamline facility. A second reviewer remarked collaboration with industry is good, and a third reviewer thought it was good to see the team is working with industry. The reviewer thought the fuel injector makers will continue to be interested. A third reviewer noted that the project is collaborating with two leading fuel injection system companies, and remarked that SNL, GM, and UWM are great stakeholders to engage and to benefit from this work. Another reviewer remarked the project has benefited from collaboration with industry (Bosch and GM) and universities (modeling) throughout the years. The new collaboration with Delphi should provide new insights into post injection spray dynamics. The final reviewer questions if there are any new resource bottlenecks with the new beamline that might limit the potential for expanding cooperative efforts.

QUESTION 5: HAS THE PROJECT 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?

Reviewers had suggestions for future work plans. According to the first reviewer, future plans are quite wide open, which is both good and bad. The second reviewer would like to see a more focused plan. Probably this needs more communication of the capability and opportunity to get inputs and ideas. The third reviewer would like to see a high-pressure injection (3000 bar) into a high density charge (65kg/m^3). This is what the modern engines will soon be doing in a few years. The fourth reviewer remarked overall, the proposed research is very good. It would be nice to see a larger database of near injector behavior versus variances in charge density and temperature. The fifth reviewer suggests put the Vehicle Technologies X-Ray beamline to a good use: measure the quality and quantity of its output. Harvest the current capabilities while embarking on adding more. The final reviewer questions if multiple injection events can be studied with this apparatus and technique.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The responding reviewer remarked there was adequate funding, unless cooperative efforts are expanded.

Visualization of In-Cylinder Combustion R&D: Stephen Ciatti (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 12 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt that improved PCCI combustion would allow for the deployment of high efficiency engines in the LD arena. According to the second reviewer, the focus on more practical implementation of LTC in a multicylinder engine is an important part of transferring this technology to industry, and the third reviewer saw significant potential for increased efficiency vs stoichiometric combustion. The fourth reviewer felt the PI made a good case that he can burn gasoline much more efficiently than today's gasoline engine. The fifth reviewer remarked diesel like efficiencies with gasoline like fuels and lower NOx is a worthy goal.

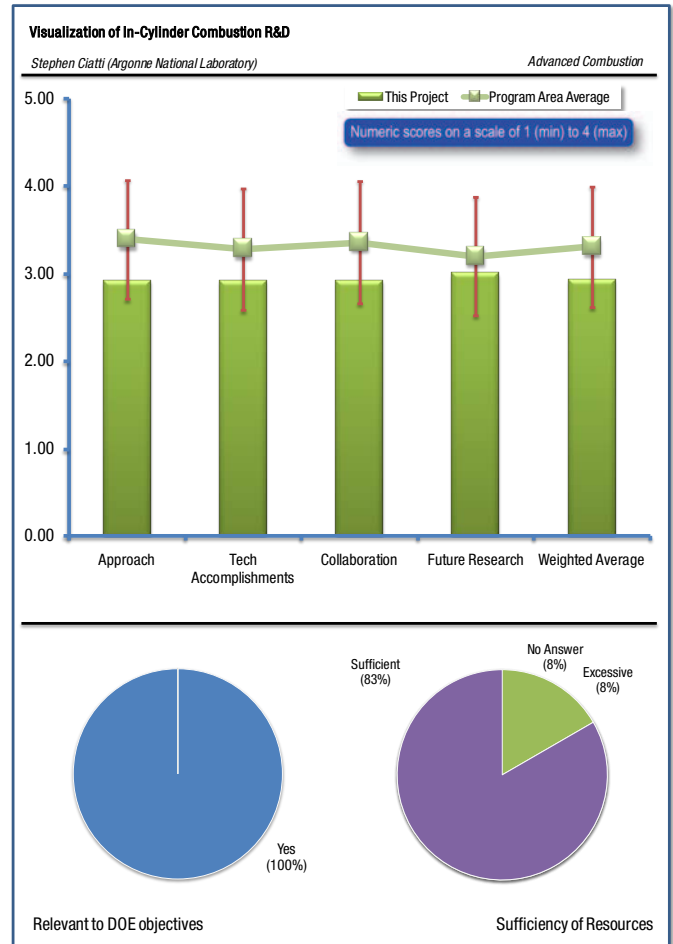
The sixth reviewer would prefer to further explore commercially available fuels, before moving into custom blends. According to another reviewer, the project does support overall DOE objectives of reducing petroleum usage. But there is some uncertainty regarding the focus of the project. It is stated that the barriers addressed are all related to control of low temperature and transient combustion. However, most of the work (except of course for the same-cycle control work) being done is related to combustion and fuels development.

Another reviewer remarked that the project kind of supports DOE's objectives, and elaborated this project is evaluating non-standard fuels under LTC/PCCI operation and it is unclear if any of these fuels are practical as we look out in the future. The hope is that this effort will lead to fundamental understanding in ignition behavior of these various fuels toward helping design LTC/PCCI injection strategies for conventional fuels. The main value of this effort is in assessing the impact of gasoline type fuels on diesel engine performance which is important.

The final reviewer said they partially missed the point on why running a diesel engine on gasoline is desirable, but the data are interesting. Granted, high compression ratio is run and reasonable efficiencies obtained, but the reviewer was not sure there is real value to this.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer saw a good approach to HCCI control with interesting results. The second reviewer felt the approach of testing and evaluating fuels with non-standard diesel or gasoline fuel properties is good toward establishing the effects of ignition quality and evaporation rate on PCCI approaches. It would be nice to eventually translate this work to include production available gasoline fuels. According to the third reviewer, the approach holds good potential for demonstrating the project goals for power density, efficiency and emissions. But if the goal were to help bring the technology closer to commercialization, then more focus should be placed on system cost, with attention to the fuel injection system and combustion controls, and possibly on acceptance factors such as combustion noise. If the engine "runs better with lower injection pressure", then why not resort to a lower-cost fuel injection system?



The fourth reviewer remarked that the approach is somewhat ad-hoc. Exactly what is the final goal, and what are the intermediate results that have to be achieved along the way? “We wanted to see what was possible” seems like an enjoyable voyage of discovery, but this is not the best way to plan or conduct an experimental process or procedure. According to the fifth reviewer, the work is OK, but it seems like a “let’s just dive into it and see what happens.” This reviewer can see a whole lot of issues on the horizon: sensitivity to things like intake manifold temperature, ambient temperature, fuel cetane variability, etc. This all needs to be considered. Is one of these a show stopper? Then address it from the start, or stop the show and work on something else.

The sixth reviewer remarked that this overall approach is industrial-type development work. The National Lab brings little expertise to bear on the work, with uncertain value-added. Using the Converge code and its application is better suited for a graduate student exercise. What would the simulation approach be if, for example, Rolf Reitz or Dennis Assanis is challenged with the objectives of this project? The effect of the CR variation can be well studied and characterized by a 1-D (GT Power or WAVE) cycle simulation with a KIVA combustion analysis support. Further, introducing the fuel chemistry into the KIVA analysis would yield substantially more robust results and insight that cannot be attained by the prescribed testing. The engine platform can then be used for model validation, etc.

Another reviewer thought the objectives were not clear and could be laid out more clearly. Known roadblocks and approach to overcome need to be laid out more clearly. The final reviewer remarked there seems to be uncertainty regarding the focus of the project. Is it control system or is it combustion system development? Perhaps it is both?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

According to one reviewer, very good progress was made on controlling HCCI combustion, and the project is demonstrating real potential. The second reviewer felt that progress has been relatively modest, but 2010 appears on track. The data provided so far are strictly steady state, but transient performance using this strategy would be interesting and insightful. The third reviewer saw good progress on a number of fronts—increased power density for HCCI is a good goal, but this project needs more direction and oversight.

The fourth reviewer noted that some PCCI data has been generated to date though much work lies ahead of the PI. It would be nice to see more engine speed and load points included in the test matrix. The fifth reviewer remarked that results show much effort and investment went into lab and instrumentation setup, as has been the case in prior reporting periods. This is not “technical accomplishments and progress.” The experimental setups at GM, other industry companies (Cummins for example) and academia (UWM & UM for example) are still superior to that described in this project. Why continue investing in a “me too” effort and report the progress on the status of lab construction? The endoscope feature is nice, but not necessary or critically needed. Cut-and-try results were shown. The team should design an experiment and validate the results with a statistical significance. The summary slide reflects the results: it provides generic statements with lack of progress.

According to the sixth reviewer, the approach appears to be a bit haphazard. The final reviewer remarked the presentation does not clearly spell out the progress in emissions reduction or efficiency gain relative to a known baseline. How do we know we are making progress? Some effort should be expended to compare fuel consumption results on a more familiar basis to a PFI gasoline baseline.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers saw good collaboration. According to the first reviewer, good collaboration and apparent buy-in from an OEM (GM) was shown. The second reviewer remarked this appears to be well coordinated project with GM and BP as a fuel supplier. According to the third reviewer, industry collaboration is appropriate for successful technology transfer. However, this reviewer would like to see a more coherent plan for coordination with other labs that will clearly contribute to the project’s success.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer felt that the optical work is the most useful part to explain how this works. The reviewer is looking forward to seeing how it works. According to the second reviewer future plans need better consideration. Engine control is a good avenue for further study, but it needs to be well-planned. The third reviewer said that the project goals are worthwhile and feasible, but would like a more clearly defined plan for coordination with other labs that could help this project be even more successful. Another reviewer would like to see a clear plan on how to address key roadblocks. The fifth reviewer said that we expect a substantial amount of the progress during the next year including fuel system timing studies, EGR sweeps, and comparison with fundamental spray data from SNL. The final reviewer said that it really needs a review and a major revamp.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

According to one reviewer, too much investment was made in lab setup, hardware, and instrumentation.

Computationally Efficient Modeling of High-Efficiency Clean Combustion Engines: Salvador Aceves (Lawrence Livermore National Laboratory)

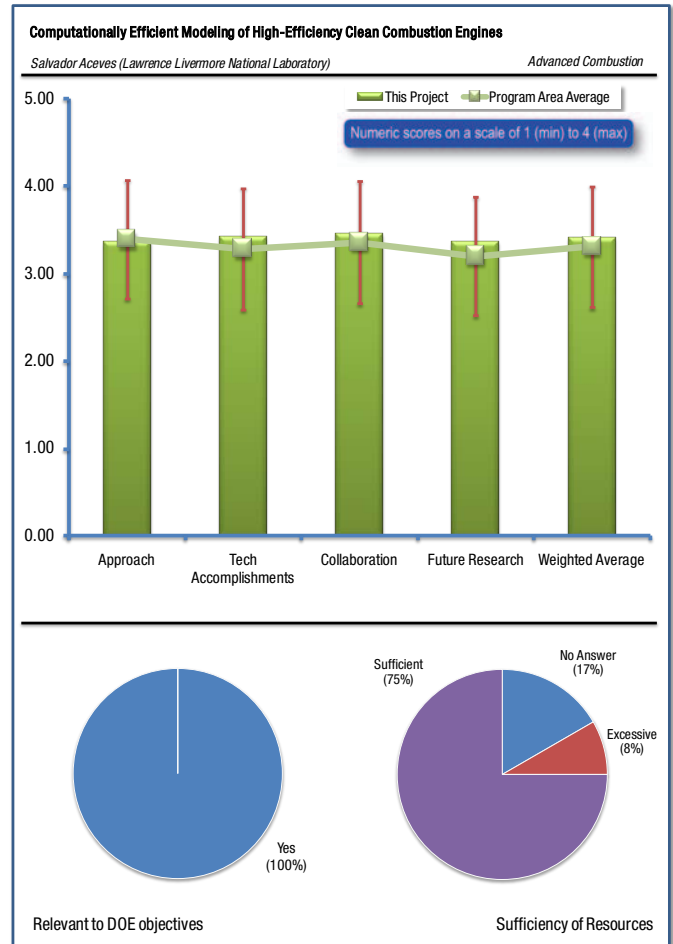
REVIEWER SAMPLE SIZE

This project had a total of 12 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers saw that computation modeling is relevant. According to the first reviewer, computational modeling is important to evaluate and control new combustion regimes, and the second reviewer concurred that modeling is a critical part of relating the single-cylinder testing to eventual multi-cylinder approaches. The third reviewer remarked that computational models that couple fluid mechanics and chemistry are a must if advanced low temperature combustion concepts are going to be brought to fruition. Another reviewer remarked this project indirectly supports DOE engine efficiency goals by providing designer with simplified models that help speed up the development process.

The fifth reviewer noted that advanced modeling is useful to improve engine development for efficiency. Unfortunately, this reviewer did not feel competent to evaluate progress in modeling development at this level. Work should be shared with software developers for commercialization. The final reviewer remarked the work supports objectives indirectly by showing how to create better and faster CFD models for simulating engine combustion.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

According to the first reviewer, this is an outstanding utilization of unique national lab capabilities that is focused on pushing the state-of-the-art of robust simulation. It combines applied math, Chemkin and KIVA into a user friendly package. Using neural net also is a plus. There is a good bridge between BES and VTP. The second reviewer noted that transferring these tools to the public domain is a major step toward future advancement of LTC technology. The third reviewer remarked overall the approach is good; the only lacking element is more detailed validation. The fourth reviewer said simulation work is clearly important as we move forward, and this program will certainly make advancements in the simulations as we move forward, especially the work focused on improving computational speed. According to the fifth reviewer, it is very important that these codes can be run on a desktop PC and thus enable the engine designer to use them effectively.

The sixth reviewer commented that approach seems scattershot, and the team is trying to do many things across many fronts. The final reviewer would like to see more correlation to engine results at various operating conditions. This would include a more conventional diesel operation condition with near TDC injection and diffusion burning. This is how diesels operate today and probably will for a long time.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers generally saw good progress. According to the first reviewer good progress was made in overcoming barriers to the quasi-real-time calculation of coupled CFD and chemical kinetics on a grid-intensive basis. The second reviewer said continued validation with experiments is helping to build invaluable tools in this area. The third reviewer thought the project pushed the envelope further, and is validating engine data from other labs. Reasonable results were obtained, both correlation and probing of differences from experimental data. A reviewer asked if the team is publishing too many details, to the point that others may get to where the team is today and leapfrog with little investments in money and resources. The fourth reviewer commented that the PI is showing impressive results. Not sure how these get translated to industry. The fifth reviewer also saw very good progress to date. The only shortcoming is lack of experimental validation. The sixth reviewer remarked that results of applications shown are very encouraging.

According to another reviewer, it looks like very good work but this person was not able to evaluate this modeling effort. The final reviewer commented that perhaps it is just difficult to explain the improvement in numerics that is being worked, but it is just not easy to understand the level of progress that was made on this program.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer saw a wide range of collaborators—this is to be encouraged. The second reviewer also commented outstanding integration with efforts within DOE and universities. The third reviewer remarked that this project historically has included outstanding collaboration between LLNL, other national labs, and various universities—great job.

The fourth reviewer said that it could be outstanding, but asked if the team has too many partners, beyond the point of diminished returns. The team has added new offshore collaborators: how much is gained from this versus what is given away. Does “public release of the code” reflect the best stewardship for DOE and the U.S.-based industry? Should there be a tiered cost to give the code to users and others abroad? It is great that the team is giving a software license to a U.S.-based company, but will they market it as well, or will the team be able to have some control on it? The final reviewer would like to see collaboration with the CFD industry. This is how it could better get into the hands of users.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer commented Keep up the good work, and suggests consider paring down the “partners” and collaborators: maybe limit it to ORNL, SNL and one or two industry partner(s). The second reviewer said commercialization of the multi-zone model is wonderful. The only recommendation is to continue validation.

According to the third reviewer, future plans are ambitious—the use of teraflop GPUs for example. Is this not just a distraction from what should be the main objectives of this work? The final reviewer commented that continued efforts to make these tools available on the desktop will significantly improve university contributions in this area.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer commented that \$1 million is a large sum. What would the team do if you have only \$800K? What will the team do if you have \$1.2 million? According to the second reviewer, this seems like a lot of funding for the little amount of engine test correlation. If ERC is doing a lot of this, is this just to support ERC KIVA? If the government is funding this, it should go to the whole CFD industry, which would provide more benefit to making better engines. To the third reviewer, it is not clear how the money was spent and this program seems borderline excessive. Having said that, the reviewer does understand that projects such as this do require a fair amount of technical experts running and working on the code. This reviewer would like a bit more detail on some of the specific advancements in the future.

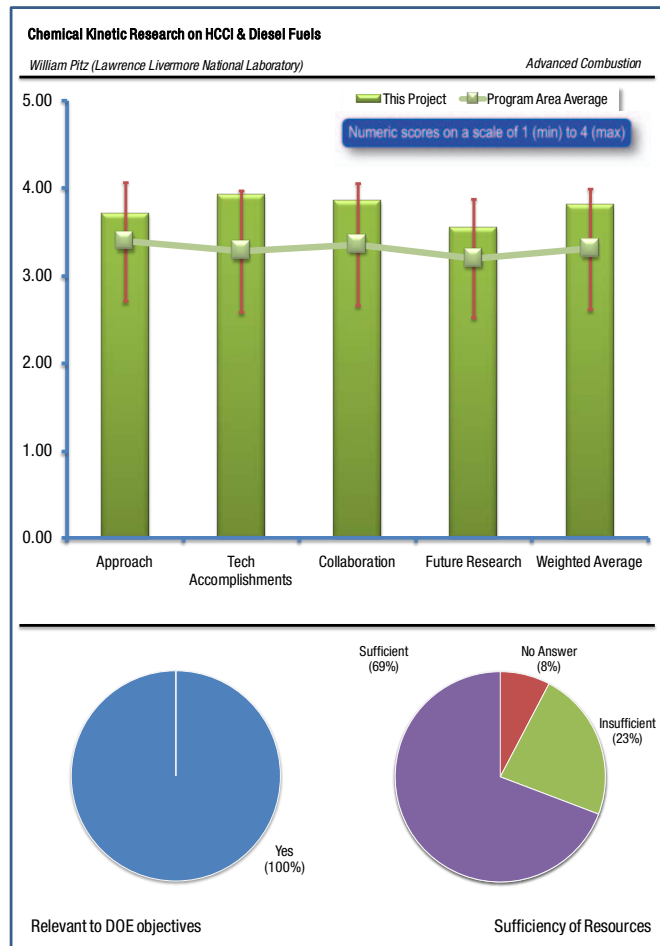
*Chemical Kinetic Research on HCCI & Diesel Fuels:
William Pitz (Lawrence Livermore National
Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 13 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

According to the first reviewer, reduced order computational models are critical for reducing the computational time required for fully predictive combustion modeling. The second reviewer commented that chemical kinetics input is key to combustion modeling and can accelerate progress, and the third reviewer remarked this is important work on basic chemical reactions of fuels that is needed to supply models for combustion modeling which is needed for investigation of efficient engine combustion systems. The fourth reviewer said this project indirectly supports DOE goals by providing engine designer with more accurate diesel and gasoline fuel surrogates for modeling ignition and intermediate heat release rate, and an outstanding effort has been seen to date. Another reviewer remarked this project investigates important effects for understanding and predicting the start of combustion in compression ignition engines. The sixth reviewer said having fundamental kinetic mechanisms for combustion is very important for modeling and simulation efforts to improve the fuel efficiency and reduce emissions of vehicles. The focus of this work is on components found in nonpetroleum fuels as well as petroleum based fuels. The final reviewer commented recently, the role of fuels and their reactivities are being appreciated greatly in the pursuit of high efficiency. It is very important that chemical kinetic models for fuels are developed to enable the design of high efficiency clean engines.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

According to the first reviewer, this is a very well focused and directed program, and the second reviewer commented on an outstanding utilization of unique national lab capabilities. The team is focused on pushing the state-of-the-art of fuel models and has established a good bridge between BES and VTP. For the third reviewer, developing reduced order mechanisms with the functional group method is good news. The fourth reviewer said overall, this is a good approach. As usual, it would be nice to see additional validation of the newly developed diesel and gasoline fuel ignition mechanisms at engine relevant boundary conditions. The fifth reviewer saw excellent focus on working on the important components first, and good use of experimental measurements to create surrogate models of the fuels. The team has made good use of experiments with these fuels to create computer models. The sixth reviewer remarked that the approach of first developing fundamental kinetic mechanisms for individual components and then comparing to existing experimental data is excellent. In addition, the approach also includes reducing the size of the mechanisms to significantly reduce computational time.

Another reviewer questions, if more attention should be given to oxygenated reference fuels (E10) as well as future fuels such as E15 or E20. The final reviewer remarked the work looks good, but was mostly beyond the reviewer’s area of expertise.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers generally saw good progress, with the first reviewer commenting on good progress year-to-year, and the second reviewer remarking on excellent progress, especially in kinetics modeling, directly leading to improvements in early heat release predictions for HCCI combustion. The third reviewer saw significant accomplishments, including developing mechanisms for 2-Methylalkane isoparaffins that are present in diesel fuel, improving the mechanisms for toluene and benzene resulting in better agreement with experimental data, and development of a diesel PRF model, which demonstrated the big effect that cetane number has on the low temperature portion of reaction. The fourth reviewer thought model comparisons seem to show very good agreement and results look impressive. The fifth reviewer remarked the project pushed the envelope further. The team extended the usefulness by adding more components to the mechanism library: improved toluene and benzene mechanisms, high and low temperature mechanisms for selected higher molecular weight iso-alkanes, high and low temperature mechanism for a high molecular weight alkyl-benzene. The development in reduced mechanisms is encouraging. The sixth reviewer felt there was good progress on reducing the mechanisms to reduce the computational times needed. This makes this work more usable to industry and useful for achieving DOE targets. This reviewer thought the correlation of simulation to experiment is quite impressive. Another reviewer remarked that much progress has been made in the last five years in the area of developing surrogate fuel ignition chemistry for automotive fuels. Nevertheless, we need more validation. The final reviewer commented that the good agreement with Dec's data of cool flame heat release is very encouraging.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer saw a well-respected group with a wide range of collaborators. The second reviewer thought the collaboration was appropriate for a more scientific project, and the third reviewer remarked on good work at using the various labs. The fourth reviewer approved of working with a good cross section of people working in similar areas. The fifth reviewer remarked that the project includes representation from many partners including national labs, U.S. universities, and European universities. There has been much collaboration among these various partners in developing full and reduced mechanisms for various heavy hydrocarbon fuels and surrogates. Another reviewer summarized that main collaboration mentioned was with Sandia, but also some collaboration with industry via participation in AEC/MOU and CRC. The final reviewer remarked this is a difficult area to find competent collaborators. The team has connected with SNL.

QUESTION 5: HAS THE PROJECT 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?

Reviewers generally saw clear plans. According to the first reviewer, future path is fairly clear - increase number of components for an increased number of fuels useful in current and future combustion regimes. The second reviewer commented on plans to continue to fill the gaps that exist by developing mechanisms for other isoalkanes and alkyl aromatics and to develop more accurate surrogates for diesel and gasoline is very worthwhile. The third reviewer remarked there was outstanding work to date, but had no input on how to do it better.

Another reviewer suggested the team consider increasing the effort of development of reduced mechanisms for use in multidimensional engine simulation codes, and consider joint efforts on a "real-life" engine validation effort, maybe with ORNL. The fifth reviewer questions if future work should include a sensitivity study of fuel effects with gasoline containing 10-20% ethanol. Another reviewer commented the proposed modeling advances are great, but more validation is needed. The final reviewer's only comment is that it would help to better understand how this work gets us better kinetics on the fuels we use in production, but this is probably more a result of the reviewer's lack of understanding.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer remarked a task that could consume a much larger budget and still be incomplete. According to the second reviewer, this is exactly the kind of basic research the government should do. If more funds would speed it up then spend it here.

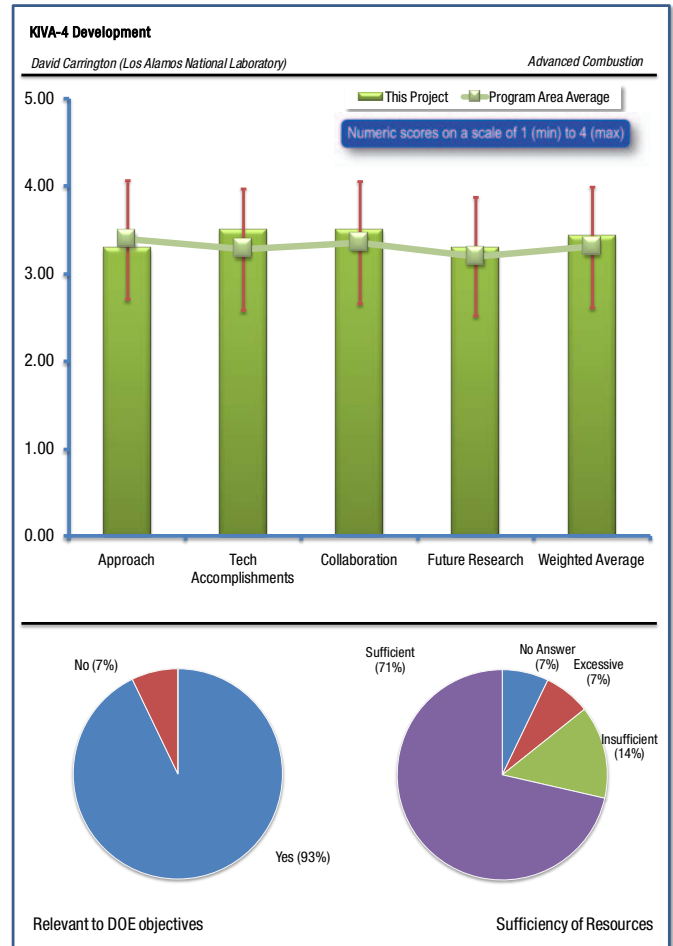
KIVA-4 Development: David Carrington (Los Alamos National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 14 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers generally saw the work as highly supportive of DOE objectives. The first reviewer commented KIVA has evolved into a very important engine development tool that is widely used by industry, national labs and universities alike. It is an integral part of the engine and emissions research “palette.” The second reviewer remarked KIVA has become a standard tool for engine simulation calculations and used by researchers the world over, in industry, government and academia. Thus, this program supports the development of advanced combustion and high efficiency engines, which can lead to petroleum displacement. To the third reviewer, development of improved modeling and simulation tools such as KIVA-4 is important for improving capability to better model combustion and to develop engine designs for better fuel efficiency and reduced emissions. The fourth reviewer observed continuous improvement of this important combustion analysis tool is key to efficient advancement of combustion technology. The fifth reviewer remarked that this is a pioneering work in simulation that gives a viable tool to design more efficient powerplants. The sixth reviewer commented that even though KIVA is not prominently used by industry, it is definitely needed and required by the labs and universities. They need the open-source tool that KIVA provides, and which is lacking in commercial codes. The seventh reviewer remarked good work on the continuous improvement of KIVA, a tool that is of great significance as we move forward with new combustion system designs.



Another reviewer remarked this project indirectly affects DOE engine efficiency and emissions goals by providing engine designers a higher fidelity combustion system modeling tool that eventually might be used to explore advanced combustion strategies. A reviewer remarked that improving the tool will especially help advance LTC modeling efforts in industry and academia. A reviewer commented that the base of modeling program is key to productivity. Continuous improvement is critical. The reviewer recommended to keep pushing the envelope. The project should be careful not to compete with private sector programs, but to push the level of technology to the benefit of all. A reviewer noted that the project aims to develop more robust and efficient algorithms for understanding and predicting combustion processes and emissions from engines. The KIVA-4 code will also be used as a tool for engine design. The cut cell method of grid generation should reduce the time taken for grid generation to around 30 minutes (currently it is on the order of days).

Another reviewer said good combustion modeling tools are needed for development of high efficient engines, but what this project is providing is being provided by commercial companies. This is just supporting a government code that competes with an established and growing CFD industry. The final reviewer would like to see a concise list of current KIVA users in industry.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Several reviewers had positive feedback on the approach. According to the first reviewer, this is a core competence that is really unparalleled. The second reviewer remarked the code features being added are well-considered, and significantly enhance the usefulness of the tool. The third reviewer said this was a good cooperative effort with other researchers and industry to identify key issues and target solutions and used an excellent approach to verify outcomes. The fourth reviewer saw a good focus on providing improvements to KIVA that will improve the code. Some of these features are already commercially available in other codes. The fifth reviewer said the well established protocol does not need changing. Emphasis should be on pushing the envelope on modeling and transferring the technology to the private sector.

The sixth reviewer remarked that physical and numerical methods are developed to get high accuracy. The code is designed to be user-friendly so the user can make changes to grid and geometry relatively easily. The seventh reviewer highlighted the work on grid algorithm improvements, adaptive finite element approach (cut cell) and conjugate heat transfer. These all serve to improve capability to model engines and specifically advanced combustion strategies with faster and more accurate calculations.

The eighth reviewer thought the approach is very comprehensive but the emphasis on certain areas (over or to the exclusion of others) is not well motivated. Another reviewer remarked the approach sounds reasonable. This reviewer continues, as mentioned, it is important to understand fundamental processes. The reviewer mentioned importance of getting feedback from users, although it is not clear how that is being done at this point other than collaboration between LANL and the several universities mentioned. Another reviewer remarked that this project is one of those that elicits flexibility in exploring non-standard modeling methods for combustion system modeling in the hope of providing engine designers a better design tool. The only concern is that it is difficult to validate the new submodels and it would be beneficial to explore ways to ensure such new models are truly predictive and trend wise accurate. The final reviewer remarked the improvement work on improving the numerics is certainly impressive and well directed. What this reviewer struggles with is a clear KIVA vision for the user community. This is not the fault of this program, but more a lack of a single (perhaps commercial) body driving the long term direction the code.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers saw good progress. The first reviewer remarked on the outstanding progress with added features to the model and solver, and especially to the grid flexibility and moving body algorithms, and the second reviewer said real progress was delivered in some key problem areas that are immediately useful to engine developers. The third reviewer thought the team persistently addressed the various building blocks to advance the state-of-the-art of engine combustion simulation, and the fourth reviewer saw impressive improvement in performance. It is nice to see the blend of technical progress and addressing of customer needs. The fifth reviewer saw progress in several areas, including better heat transfer model, modeled the piston crevice which has resulted in better HCCI modeling, and developed 2D and 3D CBS codes. The sixth reviewer thought the project covers both fundamental developments and applications: hp-adaptive CBS FE method; parallel KIVA-4mpi beta version released; cut-cell technique for grid generation is improving and is helpful; and Iowa State work seems helpful too.

The sixth reviewer remarked that code improvements to support LLNL HCCI simulations and enhancements to code include ability to use unstructured meshes via third party software. KIVA 4 beta has been released. Conjugate heat transfer capability is in the code and being tried on test cases. The seventh reviewer remarked there seems to have been good progress made. Unsteady turbulence modeling has progressed. Heat conduction is being modeled. Cut cell strategy work has progressed to create grids quickly. Sprays and spray-wall interaction has progressed. The eighth reviewer remarked clearly a lot of high powered very smart people are working on improving the KIVA code and KIVA-4mpi.

Another reviewer commented that this is very important work, but has been poorly presented and motivated, which is a disservice to the investigators. The tenth reviewer thinks the barriers are missed. The problem with combustion CFD codes is their lack of getting good results—KIVA included. Making them run faster isn't going to help. This reviewer thought there needs to be a concentrated effort on modeling some engine results as exactly as possible, and studying all the reasons why the modeling is wrong and address these

issues. The reviewer thought better progress would be made in this area if there was a collaboration effort in doing this with the CFD code companies. Combined, they have way more resources than this project has. The final reviewer commented the PI and partners have obviously spent much time and effort developing and incorporating new submodels into KIVA-4, which is difficult for a reviewer to quantify from a software modification viewpoint. Nevertheless, this project needs some level of validation which has been weakly addressed at this point...possibly next year or later on?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers generally saw good collaboration with a variety of stakeholders. The first reviewer remarked KIVA development and usage is widely promoted through user groups and collaborations, and the second reviewer thought the project is working closely with four different university groups on test cases to try out additions to the solver. The third reviewer remarked it is good to see national labs and academic collaboration. It is key to get students and the next generation trained and productive in these tools. The fourth reviewer remarked this project includes an excellent partnership between the PI (LLNL) and three other U.S. universities with expertise in various portions of CFD including software development. The fifth reviewer focused on collaboration with higher education, commenting that very good collaboration exists with Iowa State University, University of Nevada, and Purdue University. The work is being immediately transferred to these universities.

The sixth reviewer remarked KIVA is a fairly unique and successful collaborative group within DOE, but it may help overall progress if some of the code support can be offloaded to others (unless there is value added in customer interaction). According to the seventh reviewer, collaborations are limited to several universities and Los Alamos. No collaboration with industry is indicated—perhaps appropriate at this stage. Another reviewer remarked that this is a difficult area to find competent collaborators. The team is connected with the relevant community: more is not necessarily better. The final reviewer commented there is no tangible link to industry other than the MOU.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer saw a good plan to further verify changes and to look at remaining areas for improvement, and the second reviewer remarked future work is evolutionary by nature, necessity and design. The third reviewer thought it seems like a good emphasis on advancing the technology. The fourth reviewer summarized plans include further validation of recent additions to gridding and solver capabilities. The team is continuing development of new methods, refining the cut cell grid approach and improving the moving body meshing capability.

The fifth reviewer remarked generally the future research is very good; the only concern is lack of validation looking into the future.

The sixth reviewer suggests it may help to tackle a real-life engine combustion system model and progressively exercise it to demonstrate progress. The seventh reviewer remarked chemical kinetics will be brought into the code. The cut-cell method will be perfected. Also immersed and moving body algorithm. The final reviewer understands the focus on numeric improvements, but KIVA continues to suffer from being very non-user friendly. At some point it needs to be “dumbed down” so a wider range of CFD experts, who are not KIVA experts, could be active users and use this tool for industry combustion system development.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

According to the first reviewer, “increase the funding if LANL can provide a robust increased effort proposal.” The advancement in this area helps DOE's mission. It also has significant positive impact on its industrial benefactors, if they know how to capitalize on it. Consider protecting the investment by avoiding the “knowledge dump” via publications, open forum “exchanges” that exploit the good work reported here, etc. Somehow, IP protection is needed. The second reviewer said the development of fundamental tools could always garner more support but this is probably not feasible in a resource-constrained funding environment. Another reviewer commented the team could do with more funding to increase staffing to get the work done more quickly.

The fourth reviewer remarked that this is a valuable program. Many of the technical issues described by the speaker were well beyond the understanding of this reviewer. It may be valuable in future presentations to provide more introductory discussion of the nature of the improvements to KIVA. The final reviewer commented there is no indication that resources are not appropriate.

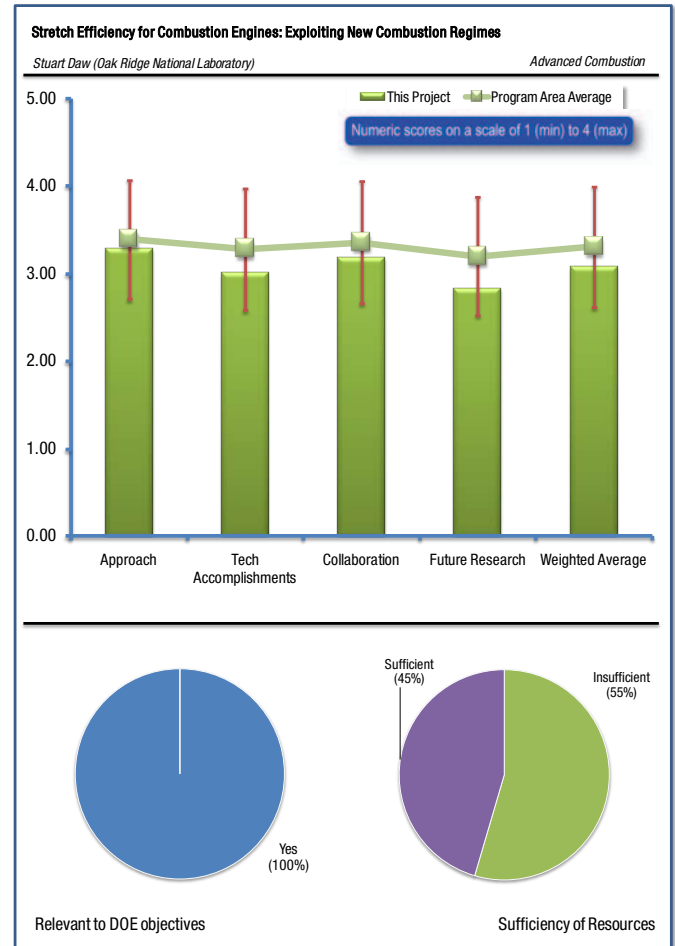
Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes: Stuart Daw (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 11 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

According to the first reviewer, fundamental studies (and reassessments) of our most basic thermodynamic and physical assumptions about engine design are to be encouraged. The second reviewer commented breaking ground on these new areas will only help in the development of future programs, and the third reviewer remarked the focus is on identifying ways to reduce fuel consumption (and thus lower petroleum usage). The fourth reviewer said pushing the boundaries of engine efficiency is an important fuel saving opportunity, and the fifth reviewer commented it is very important to fund out-of-the-box exploration of combustion. The sixth reviewer noted the work is looking at long-term, high risk concepts to increase the efficiency of the internal combustion engine. This is the kind of work that a National Lab should be expected to do. It is estimated that brake thermal efficiency can be improved to 50-60%. The seventh reviewer remarked the team is trying to demonstrate how to recovery waste heat in the exhaust. The final reviewer commented on the limited LD vehicle application.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

According to the first reviewer, it is great to see really free thinking, even if it may stretch the state of the art. According to the second reviewer, general approach of engaging experts to generate ideas on improving efficiency, downselecting and then conducting some proof-of-concept experiments is a good one. The third reviewer remarked that the USCAR workshop is impressive. It is a great idea to leverage the expertise of the field and use this to push the limits. Use of reforming is great out-of-the-box thinking based on thermodynamics fundamentals. It also fits nicely with today's engine base and can be phased in very nicely. The fourth reviewer thought that the team is looking at some interesting technologies and likes that this includes a fair amount of experimental testing to validate real potential.

The fifth reviewer pointed out a second law analysis is being pursued, which points to sources of irreversibilities. Combustion irreversibility is reduced when syngas is burned relative to a more a complex HC molecule. The sixth reviewer remarked that the project is modest in scope due to budget constraints, but jumping into hardware-based experiments before all theoretical options have been considered is unnecessarily risky from a project direction point of view. The seventh reviewer understands the basic concept, but has little idea on how it would be put on an engine. Another reviewer remarked that the long-range approach is appropriate for extending beyond near-term efforts. However, the approach must also consider how the vehicle system, especially hybridization, will determine the degree to which these long-range technologies will be effective. The final reviewer commented that the team needs to clearly outline assumptions (barriers) to practical implementation.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Some reviewers saw some excellent progress, with the first reviewer remarking the progress with the design and development of the TCR system is very good, and establishes a good building block for future work in this area. According to the second reviewer, modeling of TCR is intriguing and excellent. The results set the framework for experimental verification. Also, work on 6-cycle engine is exciting and results are forthcoming: ditto on RAPTR. The third reviewer saw great progress considering the small budget.

According to the fourth reviewer, this project's move into hardware-based experimentation seems to be a post hoc justification of what was deemed to be the most important area of potential benefit, namely thermochemical recuperation. But what about other areas of engine design such as split cycles, for example? New (or rediscovered) thermodynamic cycles offer far higher potential efficiency gains. Exhaust energy availability in real world applications is very low on a cycle-integrated basis, due to low exhaust enthalpy with LTC or drive cycle demands. What about the complexity versus WHR as an alternative? Reformate will have to be used immediately with no capacitance or storage capability, unlike WHR.

The fifth reviewer remarked meeting with experts to generate ideas was held. This reviewer was not sure that the idea of thermochemical recuperation including reforming to produce syngas that is being pursued has enough potential to significantly improve efficiency or that it is different or better than what others (including OEM's, national labs, and universities) are working on. According to the sixth reviewer, good ideas were shown but much is to be done to show the real potential on TCR. The colloquium is a good idea and should be repeated perhaps with better guidance. The seventh reviewer remarked it looks like the RAPTR project is needed to provide needed chemical reaction data, but then the team jumps into this 6 stroke engine with hydraulic actuated valves. Is the RAPTR data needed? It appears the team does not think so. The eighth reviewer thought the project is an interesting area to explore, but power density cannot be ignored. The team should keep looking for efficiency gains, but keep in mind that a 100% efficient cycle that produced no power is of no value. The final reviewer said that work has progressed on thermochemical recuperation, particularly on reforming methanol into syngas using exhaust energy. A concern is the nature of the duty cycle for light-duty applications, where the energy in the exhaust is being reduced via increases in engine efficiency due to other concepts.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers generally saw good collaboration, with the first reviewer remarking the PI has gone to great efforts to get a wide range of inputs and this is an example of outstanding collaboration. The second reviewer remarked on good use of the industry working group, which is to be encouraged, and the third reviewer said collaboration with the combustion “community at large” is a promising start. Sustaining the collaboration with industry as the program develops will be important going forward. The fourth reviewer remarked there was good outreach to a broad spectrum of the engine community. According to the fifth reviewer, partners include GTI and several universities. Industry partners limited to mainly one OEM and catalyst supplier through GTI. The final reviewer remarked that universities are well-represented, but industry is lacking. The PI should bring in engine companies, Sturman, reformer companies, etc.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer saw a good plan to further evaluate TCR. According to the second reviewer, resources are quite limited, so future work needs to focus on setting the stage to justify further resources. Focus on modeling and analyses to make thoughtful decisions on where to spend the bigger money that should come.

The third reviewer understands how the 6-stroke engine will run, but the reviewer did not know how the team plans to run an engine with a fuel reformer. This reviewer was not much of a fan of the 6-stroke engine: displacement was downsized by 50%. The fourth reviewer remarked future moves into hardware-based experimentation can be seen to be premature—it locks in one particular physical setup rather than retaining flexibility. The final reviewer suggests the focus on TCR catalyst development and demonstration is appropriate, but perhaps greater emphasis on dilute (vs. lean) combustion would be a better long-term strategy.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Several reviewers thought funding was insufficient. According to the first reviewer, funds are probably insufficient now that real-world experiments are being contemplated. The second reviewer remarked funding seems too low for achieving a successful project outcome for the experimental work in timely fashion. The third reviewer commented there is nowhere near enough money to pursue this work, and the fourth reviewer remarked “not enough to do all you want.” The fifth reviewer remarked the team is yearning to move into experiments to verify the excellent modeling foundation. There are not enough resources to do hardware. The final reviewer doesn’t recommend spending more than \$250K on this specific idea, although that funding will quickly be consumed when experiments are started.

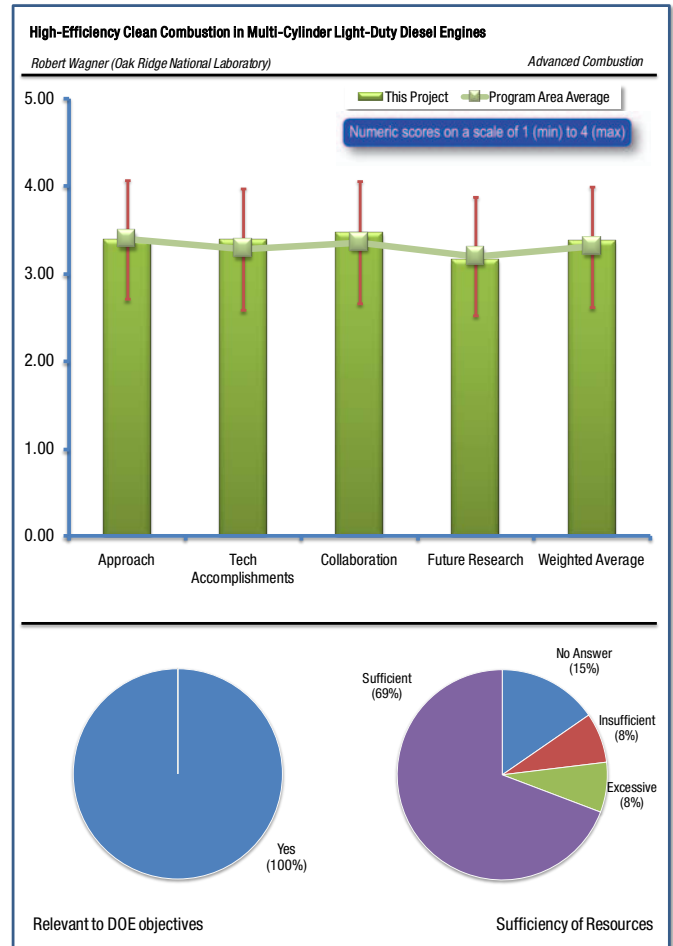
High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Diesel Engines: Robert Wagner (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 13 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

According to the first reviewer, advanced combustion strategies specifically address improving efficiency and lowering emissions. The second reviewer remarked this is of particular relevance to light duty trucks, for future CO₂/fuel economy compliance. The third reviewer commented that the focus is on evaluating advanced combustion concepts to improve efficiency and reduce emissions. The fourth reviewer said light-duty uses the majority of petroleum based fuel and offers the biggest fuel saving opportunity. According to the fifth reviewer, these high-EGR gasoline engines are showing much promise in both HD and LD: efficiency high, CO₂ low. This is a very nice project that is demonstrating real improvements. The sixth reviewer remarked the project demonstrated significant thermal efficiency improvement. The seventh reviewer saw very good use of multi-cylinder hardware to explore advanced combustion schemes including dual fuel to increase the thermal efficiency in advanced engines while meeting emissions targets. The final reviewer commented the engine efficiencies reported from this work has been tracked for several years. Advanced concepts proposed by several workers in the field are demonstrated on a multi cylinder platform.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer remarked on the good mix of analysis and experimentation. There is appropriate use of available hardware. The second reviewer commented on the classic evolution of development. The third reviewer remarked, the approach is multi-faceted—experiments, modeling and control-based. The fourth reviewer thought the approach of combining modeling, experiments, and analysis is appropriate. The fifth reviewer remarked that the combination of modeling, experimentation, and collaboration is excellent. The project addresses current barriers. What new barriers are created? This could be outlined. The sixth reviewer said this project is a great combination of experimental and modeling activities for studying dual fuel combustion approaches or other combustion approaches. Eventually other speed and load points should be explored to give a more modal approach toward assessing the capability of the dual fuel concept for truly meeting EPA emission standards.

The seventh reviewer said, by using a multi cylinder engine, real-world challenges and issues are kept in the forefront. Results are better related to commercial applications. The eighth reviewer commented that the barriers are emissions and combustion control. Approach includes modeling collaboration, multi-cylinder engine work and thermodynamic analysis. This overall dual-fuel approach seems to have serious practical limitations because filling a vehicle with two fuels is not a practical option in the marketplace. Could this be accomplished with reforming the primary (diesel) fuel and putting that reformat into the engine? The final reviewer is concerned that the dual fuel approach may be relatively expensive for much of light duty, except perhaps in Class 2b and 3 trucks, where diesels are widely used. Would more emphasis on larger displacement engines therefore be appropriate for this work? Also, the load/speed points chosen for this work should be revisited in light of future powertrain systems.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Several reviewers saw excellent progress. According to the first reviewer, excellent progress in evaluating the dual fuel concept on a light duty engine, and the second reviewer also saw very good progress in several areas: testing the University of Wisconsin dual fuel concept on a multi-cylinder engine, and exploration of expanding range of PCCI operations. The third reviewer commented that results are impressive out of the chute: good progress and confirmation/conflicts with modeling. The team should keep plugging away to address discrepancies. The fourth reviewer commented on the very good progress on verifying dual-fuel concept on 1.9-L multi cylinder. Indicated thermal efficiency of about 42% has been obtained, but this gain is not being seen in brake efficiency mainly because of cylinder balancing. By improving cylinder balancing this should be improved in the future. The fifth reviewer remarked that the project is making good progress in a number of areas, and certainly has some interesting test data. It would be good to try and get a better feel toward BSFC. The reviewer understands the need to start with ISFC, but there is certainly a need for the dual fuel approach to get out to a BSFC number just to make sure there are no unexpected big hitters on efficiency.

Another reviewer remarked the initial experimental results are very important for assessing differences between predicted fuel consumption gains with the dual fuel approach versus real world multi-cylinder actual fuel consumption impacts. Nevertheless, the future work is necessary to fully explore the capability of the dual fuel approach to improve thermal efficiency. The sixth reviewer remarked on quantifying the efficiency/emissions potential of a dual-fuel advanced combustion approach, and characterizing transient/practical issues of using such a mode in a practical engine. There is a sophisticated engine test stand with a heavily instrumented engine to support thermodynamic analysis. Results are informative of the potential of dual fueling with a liquid gasoline or equivalent fuel. The work shows that the practical benefits are more strongly related to emissions, rather than efficiency. The seventh reviewer thought it was nice to see real engine results, but efficiency is not that encouraging.

The eighth reviewer questions if this project is designed only to check and confirm UW's recent modeling and dual fuel experimental results. This is a limited and derivative scope of work. The final reviewer questions how well would the diesel engine have done if timing had been optimized for efficiency? A NO_x vs BSFC plot of the diesel compared to a NO_x vs BSFC for this dual fuel engine would be helpful. Also, the diesel can be equipped with more EGR, remapped turbos, higher pressure injection, etc and achieve some pretty good fuel efficiency. This is out of your scope, but this could be modeled and compared to test results.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Most reviewers saw good collaboration, with the first reviewer noting good use of collaborations, especially with University of Wisconsin, and the second reviewer observing direct and active collaboration with University of Wisconsin, Delphi and others. The third reviewer remarked on the good cooperation with industry and universities. The fourth reviewer saw a well-rounded team with much involvement: top caliber. The fifth reviewer commented this effort historically and also within the last year has included clear collaboration with universities and various industry partners. According to the sixth reviewer, the main collaboration seems to be with Wisconsin (at least for dual fuel concept). There is some collaboration with Delphi that appears to be related to supply of injectors. Other industry collaboration was vaguely referred to as "industry tech teams" and "one-on one" interactions. The final reviewer suggests the project should be more engaged with Class 2b and 3 OEMs, who might be first adopters of this technology in light duty.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer generally saw a good approach. This reviewer added that there are so many areas to explore in the future but exploring pushing up thermal efficiency while relaxing NO_x levels would be beneficial and also exploring other engine speed/load operating points would be very helpful to the community. According to the second reviewer, plan is in place for necessary further evaluation. The team needs to see how to get real benefit relative to diesel to make this engine system competitive. The third reviewer commented the presentation proposed continued effort to explore other advanced combustion concepts such as partially premixed combustion and Dec's HCCI concept.

The fourth reviewer suggests to keep moving on refining and improving performance and see where we can go. Focus on BTE with no emissions constraints for now. The team needs to move from indicated to brake measurements to really account for losses. They might overwhelm everything and makes this look non-competitive. The team needs to move into testing and use modeling only to supplement direction. The fifth reviewer thought it looks as though future work will be responding to advances of others, or is there some other plan? The sixth reviewer remarked on expanding the range of conditions considered, and integration of oxidation catalysts. The work would benefit from including different fuel types or formulations. The seventh reviewer questions if the emissions goals should be stretched to something more aggressive, like Tier2/Bin2, for this work.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Responding reviewers commented that resources may be insufficient. The first reviewer remarked funding seems to be ok, but may be insufficient as development progresses. The second reviewer commented as more experimentation is used, more resources might be needed. The sense is that this is well within UW budget. The third reviewer remarked it takes money to test and the team does not seem to have a lot. Also, with more resources the team could look at the re-optimized diesel.

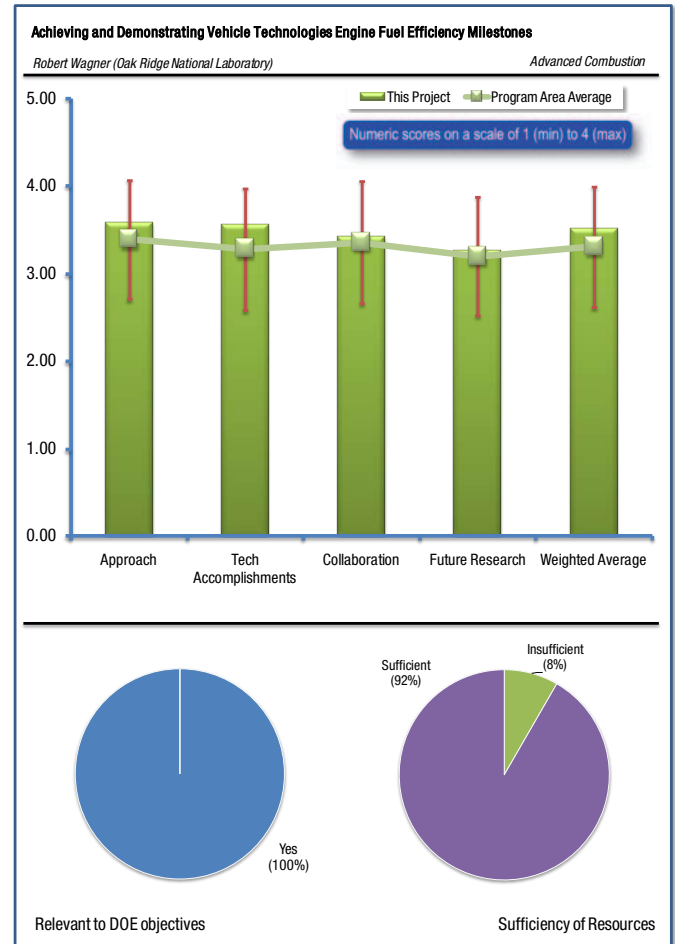
Achieving and Demonstrating Vehicle Technologies Engine Fuel Efficiency Milestones: Robert Wagner (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 12 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Many reviewers saw the work as supporting DOE objectives. According to the first reviewer, increasing the efficiency of engine-based vehicles is a critical need for fuel consumption reduction and petroleum displacement. The second reviewer remarked the project is seeking to improve thermal efficiency through turbocompounding and bottom cycling and is directly responsive to displacing/reducing petroleum use. The third reviewer remarked the project supports DOE goals of shorter-term efficiency improvement goals (45% BTE). The fourth reviewer commented this part of the ACE program is possibly the area of greatest direct relevance to the goal of reducing petroleum use, and the fifth reviewer commented that exhaust energy recovery is important to boost engine efficiency. The sixth reviewer thought bottoming cycles will be a key new technology in 2016+. It is very critical to set the stage and find obstacles. The work is cutting edge. The seventh reviewer thought the project does a good job of showing the tremendous effort and cost of a bottoming cycle on a diesel engine. The eighth reviewer remarked this is the only project which directly addresses a 45% BTE demonstration. The ninth reviewer remarked the exhaust heat recovery aspects of this work are very interesting and highly relevant to work being performed in many places. The final reviewer commented that this is the main project in the DOE portfolio that directly addresses and is devoted to meeting the Vehicle Technologies goal of reducing petroleum usage by increasing engine efficiency. The engine efficiencies reported from this work have been tracked for several years. Advanced concepts proposed by several workers in the field are demonstrated on a multi cylinder platform in order to meet the goals.



The first reviewer commented seems to be very focused in 2010 on assessing whether the organic Rankine cycle can achieve 45% BTE. The second reviewer saw a good mix of analysis and experiment, but would like to see more focus on vehicle integration and duty cycle. The third reviewer commented that the approach is outstanding. It is a comprehensive approach that includes simulation, experimentation, thermodynamic analyses, and collaboration with other researchers in universities, national labs and industry. The key is the willingness to incorporate concepts and progress made by many collaborators on one test site. This gives this project great value. The fourth reviewer commented it is very good to look at modeling and thermodynamics to look at opportunities and then turn it into hardware. It is nice to see the tight collaboration and development of analyses on the engine, incorporating cutting-edge thermal management. The fifth reviewer commented about incorporating turbocompounding and bottoming cycle in a multicylinder engine, including experimental and modeling studies. The team has clearly identified that typical road load operating conditions are low efficiency and need to recover thermal energy or reduce exergy loss.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer commented seems to be very focused in 2010 on assessing whether the organic Rankine cycle can achieve 45% BTE. The second reviewer saw a good mix of analysis and experiment, but would like to see more focus on vehicle integration and duty cycle. The third reviewer commented that the approach is outstanding. It is a comprehensive approach that includes simulation, experimentation, thermodynamic analyses, and collaboration with other researchers in universities, national labs and industry. The key is the willingness to incorporate concepts and progress made by many collaborators on one test site. This gives this project great value. The fourth reviewer commented it is very good to look at modeling and thermodynamics to look at opportunities and then turn it into hardware. It is nice to see the tight collaboration and development of analyses on the engine, incorporating cutting-edge thermal management. The fifth reviewer commented about incorporating turbocompounding and bottoming cycle in a multicylinder engine, including experimental and modeling studies. The team has clearly identified that typical road load operating conditions are low efficiency and need to recover thermal energy or reduce exergy loss.

The sixth reviewer remarked that the focus on WHR, and specifically ORC, limits the potential application and scope of this project. The seventh reviewer thought the approach was outstanding, but would like to see consideration and prioritization of these advanced technologies relative to the anticipated improvements in conventional and hybrid vehicle technologies over the next decade or so. Another reviewer remarked that implementing an ORC on a LD vehicle is problematic, but it is OK for proof of principle. The final reviewer wanted to know what the team would recommend to help with the road load efficiency.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer saw outstanding peak performance. 45% BTE is the highest the reviewer has seen: the reviewer suggested to keep pushing. The second reviewer commented that against a goal of 45%, a peak brake thermal efficiency of 44.3% has been demonstrated. This was achieved with experimental results from the organic Rankine cycle that was designed, constructed and tested during this period that moved the overall brake thermal efficiency from 41.8% to 44.3%. Modeling of the organic cycle for transient application has also been completed. This effort is setting expectations for application of the organic Rankine cycle to road load conditions.

The third reviewer remarked the use of WHR adds an enormous increase in complexity for a small potential increase in efficiency (from say 42% to 44%). What about looking for other cycle-based improvements from a holistic point of view? The fourth reviewer commented the progress with bottoming cycles is very good, but how might this technology benefit from vehicle hybridization, especially with PHEVs? The fifth reviewer summarized that the project is studying organic Rankine cycle system and demonstrating increasing BTE on a multicylinder engine. The team has identified where in a typical range of operating conditions there is availability in the exhaust and EGR gases. The team has completed benchmarking of the organic Rankine cycle system (>11%) and identified difficulties in operating the device and key components to optimize (evaporator).

The sixth reviewer thought the concept was demonstrating some potential in the lab, but it is disappointing to see such low potential at road load. The final reviewer was concerned that the ORC offers no benefit at light load. Is this the best path forward for light duty?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Generally, reviewers saw excellent collaboration. The first reviewer remarked on good, widespread collaborations with industry and universities. The second reviewer commented that interactions are focused with organizations that could provide ORC hardware and software. The third reviewer remarked on the good cross section of people involved and liked the team's willingness to share GT Suite models relative to bottoming cycle. This would be very helpful and is an example of excellent collaboration. The fourth reviewer remarked, as mentioned already, collaboration with other researchers, OEMs and suppliers for hardware is excellent. The fifth reviewer believes that system modeling is key / good to see. Also the interaction with Gamma is good. It is a way for the knowledge from this work to be available / useful to industry.

The sixth reviewer saw close collaboration with component suppliers, but saw no identified university involvement, even though this project and the supporting analyses would be ideal educational opportunities. The seventh reviewer saw good use of industry inputs and collaboration with industry, and suggests that the project could broaden collaboration with more industry effort now focused on Rankine WHR. The final reviewer saw good collaboration with state-of-the-art components, and suggests that moving forward, the team will need OEM involvement for technology transfer and for addressing practical issues.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer commented future work is on track towards the 45% peak thermal efficiency goal. Simulation tools will be used to assess the potential of thermal storage for better utilization of thermal heat recovery. The second reviewer remarked that the goal of continuing to assess various technologies to improve efficiency is appropriate, although no specific plans were discussed. The third reviewer remarked keep working on the modeling and experimental interaction. Key will be to answer the question: Where should the aftertreatment go, pre-turbo or pre-ORC? Can the engine be run for high-exhaust manifold temperature to deliver aftertreatment needs,

but counting on the turbo and/or ORC to minimize losses? The fourth reviewer summarized that the project is pushing to 45% BTE in the engine stand, understanding matching of the organic Rankine cycle to match the available energy. The team is expanding consideration of energy storage and recovery to enable full effectiveness during transient operation.

The fifth reviewer suggests that WHR is better suited to heavy duty applications. Hybridization, downsizing and engine cycle modifications would be a better potential fit for light duty. The sixth reviewer thought more emphasis on vehicle-level modeling with these technologies may be warranted, using representative 2020+ baselines (conventional and hybrid). The seventh reviewer commented that there are still many barriers to make this a productive approach to real vehicles. It might be worth a colloquium on key issues to address. The eighth reviewer would be “visiting the super turbo guy and finding out if they actually have made one that really worked.” The final reviewer remarked that project appears to be drawing to a close.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers had no comments on resources.

Emissions Control for Lean Gasoline Engines: Jim Parks (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 9 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Several reviewers saw lean-burn gasoline as relevant. The first reviewer remarked that lean burn engines may be a critical part of future light-duty engines. The second reviewer commented lean gasoline is an attractive and viable approach to meeting future CO₂ requirements. Lean NO_x is problematic and significantly limiting. The third reviewer remarked that lean gasoline is an interesting item to study and the results do have relevance to fuel consumption goals. For the fourth reviewer, cost is the primary barrier, so this reviewer is pleased to see it expressly stated. The fifth reviewer agreed that lean burn gasoline engines provide fuel economy benefits and thereby can lead to petroleum displacement, but their emissions control presents challenges that must be overcome in a cost effective manner. The sixth reviewer remarked this is work to enable lean burn operation in a gasoline car to meet Tier 2 Bin5. This is a more efficient operating mode.

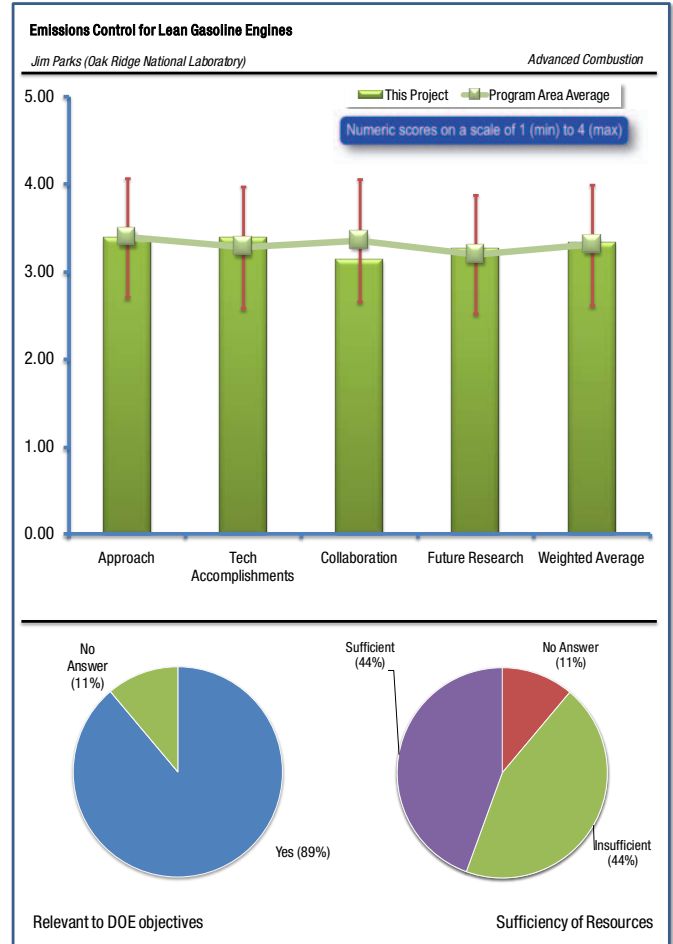
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer commented that the vehicle benchmark testing is thorough, and a useful reference for future comparisons. The second reviewer remarked the approach does focus on some of the fundamental questions, and this is a good thing as there are a lot of unknowns here. The third reviewer summarized the PI is studying exhaust from an LNT equipped lean burn gasoline vehicle initially. They are looking at a combination of technologies (LNT, SCR, TWC and combinations LNT+SCR). Complementary bench flow reactor studies and integrated results with CLEERS were performed.

The fourth reviewer would have liked to see what speeds and loads the engine sees when running these cycles. The 3500 rpm data is very interesting and shows the challenges faced, but this is faster than the reviewer runs a personal car engine (which is a 2.0L 4 cylinder.) The fifth reviewer observed that the team has the car, the analytical equipment, and access to devices. The reviewer presumed the project will have calibration control. Everything seems set for a survey-type study aimed at approaches to meeting very tight (Bin 2) emissions levels. The final reviewer commented not being a turbo is fine.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer saw outstanding progress in characterizing the performance of lean burn vs. stoichiometric operation. The second reviewer felt the results are very interesting and provide a nice base of understanding how the current system works, with limitations and gaps to meeting Tier 2 Bin 2. The reviewer is anxiously waiting for more results to yield even more understanding of the system characteristics. The third reviewer remarked on the good job of collecting useful engine data for the project, but asked if BMW would have given this data if they were asked. That would have “sure saved time.” The fourth reviewer observed that benchmarking



information is being generated by chassis dyno tests of the BMW vehicle with LNT. Some important dynamic and regeneration behavior was observed, although shouldn't much of this information have been available from BMW since they engineered the vehicle? The team is performing LNT flow reactor studies and has installed an advanced lean burn engine for further studies.

According to the final reviewer, the fuel economy improvements shown are impressive, but it would help to have some comparison to diesel. The reviewer's basic question is this: is the desire to improve efficiency of gasoline engines, or try and get better than diesels as the benchmark? In any case, this is good technical work with very interesting results.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer remarked that sharing data with CLEERS is a great thing and the reviewer appreciated this contribution to basic understanding of the aftertreatment device. The second reviewer saw little inputs coming from outside ORNL. The team may wish to pull in a catalyzer for LNT understanding so to avoid re-inventing anything. Also, vehicle calibration work from OEMs might help: this can come later. The final reviewer saw interaction with GM and CLEERS.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer believes it would be interesting to compare the benefits of lean vs. dilute (EGR) in future work. The second reviewer remarked the general direction is certainly valid and leaves room for flexibility. The final reviewer commented the PI will continue vehicle studies, flow reactor studies and development of advanced lean burn gasoline engine test stand with capability to study various lean NOx strategies.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Responding reviewers thought the budget is too low. The first reviewer remarked that the budget seems low for such a commercially relevant program that could have near term benefits in the marketplace. The second reviewer said if this is to extend much beyond benchmarking work, and the reviewer thinks it should, more resources will be required. The third reviewer commented this was not much of a budget for doing test work.

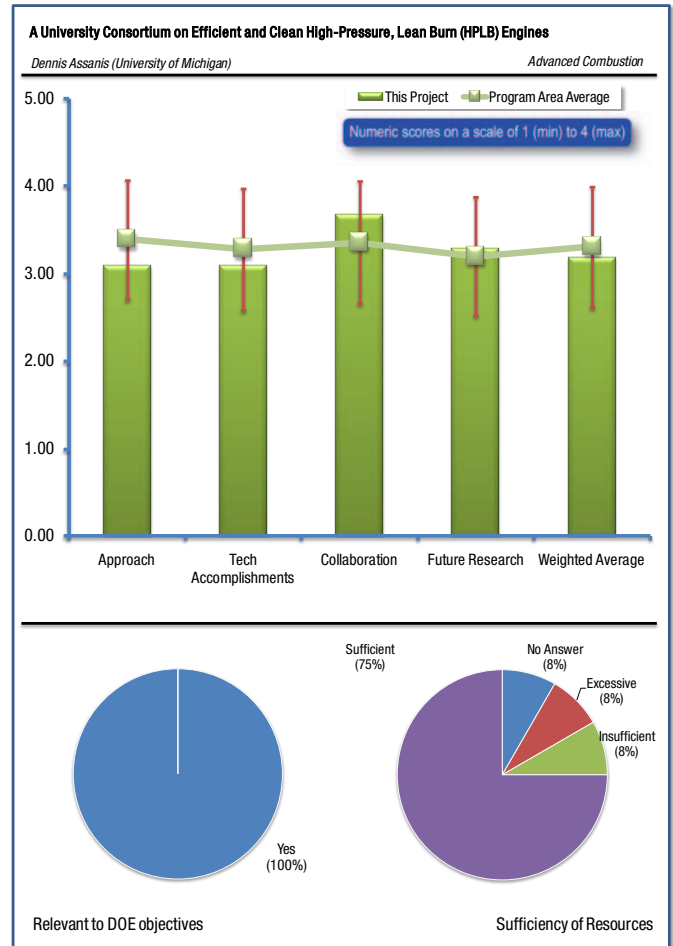
A University Consortium on Efficient and Clean High-Pressure, Lean Burn (HPLB) Engines: Dennis Assanis (University of Michigan)

REVIEWER SAMPLE SIZE

This project had a total of 12 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers generally saw the project as supporting DOE objectives. The first reviewer remarked about the focus on high-efficiency new combustion approaches with multiple parties and the consortia split of efforts, judged to be excellent. The work has the objective of maximum efficiency without emissions constraints. The second reviewer commented it is useful to explore long-range potential for advanced multi-mode combustion. The third reviewer commented there are a lot of good items being worked in this program. The fourth reviewer remarked this coalition of universities provides a combination of advanced combustion strategy exploration and engine duty/vehicle level fuel economy assessment; the emissions modeling portion of this effort will be challenging, but at a minimum, this project can provide DOE with feedback on vehicle level impacts of the various combustion strategies. Another reviewer stated that the work is trying to push HCCI operation (which is efficient) into higher power operating conditions. Work is being done on the transition from SI to HCCI (using SACI).



The sixth reviewer noted the goal of the program is to demonstrate the pathway to achieving a 25-40% improvement in light-duty vehicle efficiency in order to reduce petroleum use, and the final reviewer remarked that the project focuses on pushing the boundaries of engine efficiency and emissions reduction to reduce petroleum consumption.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer saw a good focus on simulation that is appropriate to early evaluation of technology. The team made good use of available engine test equipment. The second reviewer saw very good progress, and excellent coordination; covering many bases. The third reviewer remarked the overall approach is a good basic and applied research effort that covers fundamental combustion studies of gasoline/ethanol SACI and HCCI, includes metal engine experiments, optical device experiments, and engine system/vehicle simulation to assess potential fuel economy gains. It wasn't clear how wide an actual engine operating range was going to be addressed in this project—it would be valuable to cover a very broad region of an actual engine operating map.

The fourth reviewer suggested pursuing high pressure lean (dilute) burn, building from past HCCI consortium and final in-vehicle fuel economy gains. Combustion is a spark assisted compression ignition process, using charge/fuel stratification and using fuel tailoring to improve efficiency. Multiple modeling tools are being employed to support the experimental efforts. The fifth reviewer summarized that the PI split tasks among competency centers and highlighted interaction pathways. The work covers the keys: dilution, stratification, fuels, multi-mode, and spark.

Other reviewers commented on the project's complexity. The sixth reviewer remarked it was a very complex project. It is difficult to understand all aspects from a 20 minute presentation. It is nice to see the vehicle integration as part of attribute demonstration. The

seventh reviewer remarked that maybe it was the presentation, but the reviewer could not discern the real focus on this program; there were 6-8 different areas being discussed and the reviewer was unclear as to what was the real focus. The eighth reviewer said the work was a broad-fronted scattershot approach to engine efficiency improvements and novel combustion regime investigation. For the ninth reviewer, the approach is a bit concerning. There is a long list of things to investigate, but no clear integration of the tasks. Emissions are the challenge, more so than any incremental thermal efficiency gains. There were no specific emissions tasks listed.

The final reviewer remarked that the demonstration of a path to 20-40% will be on a FFVA single cylinder engine and via the use of models based on concepts and data. Also, work will possibly be done on a multi cylinder project jointly with Bosch. The pathway to be explored contains several elements. These include assessing the potential of novel engine cycles, stratification strategies, multiple ignition, and fuel chemistry opportunities.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewers noted that the project is in its early phases. The first reviewer said results reflect the excellent managerial skills of the PI and the solid core competency of the collaborators. The second reviewer noted it is early in the project, but the previous consortium demonstrates a winning track record. There is a high probability of achieving 45% BTE using practical approaches. The third reviewer said it is early days in the life of this project. It has a wide range of programs, and it is not clear what the focus is. It seems to be a catchall – methods, tools and procedures. What does 'demonstrate' mean in the context of this project: on an experimental platform, on an engine, or in a vehicle? The fourth reviewer summarized that the work done over the past years under the previous consortium has been extended by developing a vehicle fuel economy assessment tool, improving the CFD models, and identifying and demonstrating the SI, SACI, and HCCI combustion regimes on the FFVA single cylinder engine. The sixth reviewer observed that the team developed a framework for assessing vehicle efficiency improvements with advanced combustion. They have developed and applied a new wall function heat transfer model to improve heat loss calculations. They have demonstrated distinct combustion mode operation in an engine platform, permitting shifting between modes for optimal combustion and efficiency. Another reviewer remarked that the project is pulling together work in multiple combustion regimes. It is always hard to see how all these elements will come together. The eighth reviewer commented this follow-on effort to past HCCI has contributed to the understanding of load limits for HCCI and now is pushing in a direction to address multi-mode combustion in “gasoline” SI type engines. The work is in its early stages, but it would be nice to see some type of projected vehicle analysis fuel economy improvement analysis based on this early SACI and HCCI work. The final reviewer remarked that it was hard to tell what the progress was. There seemed to be a lot of topics touched upon for two minutes without a real explanation of technical progress.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers generally saw good collaboration. The first reviewer characterized the good, wide collaboration, and the second reviewer remarked that strong cooperation is fundamental to the project plan. The third reviewer observed a strong multi-university effort, with national labs and numerous industrial partners (component suppliers and OEMs). The fourth reviewer remarked it doesn't seem to get better than this. Top-notch academic centers are included, and incorporating UW, MIT, and UCB will help develop these centers for training scientists and engineers, and yet bring high-probability results. There is a nice mix of industrial partnerships. The fifth reviewer remarked the PI is dealing with a good cross section of individuals. The sixth reviewer also commented that good collaboration with a number of industry, national lab and university organizations exists. The final reviewer questioned, “are there too many chefs and cooks in the kitchen?”

QUESTION 5: HAS THE PROJECT 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?

The first reviewer commented that plans look appropriate to moving forward. Focus on control strategies should be included. The second reviewer remarked on the good plan with much involvement. It is nice to focus on efficiency, with some biofuels work. Turning concepts into hardware will be key to get at issues. The third reviewer commented the team will do further development of experimental capabilities in engine and RCM facilities to consider fuel and charge stratification.

The fourth reviewer suggests that future research areas need to be refined or focused down to a select few areas, or else this project comes across as merely a means to fund the University of Michigan to do the sorts of projects that it already finds the funding to do. The fifth reviewer asked if the plans need narrower but deeper coverage of the topics, or are the team members satisfied with the depth of coverage within the broad areas being addressed. The sixth reviewer's only suggestion is to consider setting up a vehicle level simulation such that any generated engine results could be readily integrating a duty cycle simulation that could quickly assess any potential fuel economy gains. The final reviewer remarked the project needs to have more clear focus on specific topics.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer saw a nice blend of fundamental and applied experiments, yielding new knowledge and engineering outcomes. The second reviewer was not clear that the money will be well-spent and what the actual deliverables will be. The final reviewer does not recall that it was stated what the resources were. It is therefore hard to make a call on if the resources are sufficient or not.

Optimization of Advanced Diesel Engine Combustion Strategies: Rolf Reitz (University of Wisconsin)

REVIEWER SAMPLE SIZE

This project had a total of 14 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A researcher said that the project has the potential to show significant fuel efficiency improvements in engines and that this is an example of how fundamental engine research should be conducted at universities. A separate reviewer said that the work at UW is important fundamental combustion work, leading to advancements in LTC. A different reviewer said that there was good potential for increased engine efficiency. One reviewer said that this project focused on improving engine efficiency by focusing on the combustion process directly.

A reviewer said that improving fuel economy will be enabled by developing improved advanced combustion modes will displace petroleum. One reviewer said that the focus is on development of high efficiency ICE's with 20-40% improvement in fuel economy for light duty vehicles and achievement of 55% brake thermal efficiency in heavy-duty vehicles. The reviewer added that if successful, these achievements would decrease the consumption of petroleum.

A reviewer said that this was a large comprehensive project aimed at maximizing efficiency using practical methods and that there was excellent transfer of technology with broad collaboration. The reviewer added that this is one of the better DOE projects that will deliver fruitful results. A reviewer said that the project supports modeling of efficient combustion systems and is investigating more efficient combustion systems.

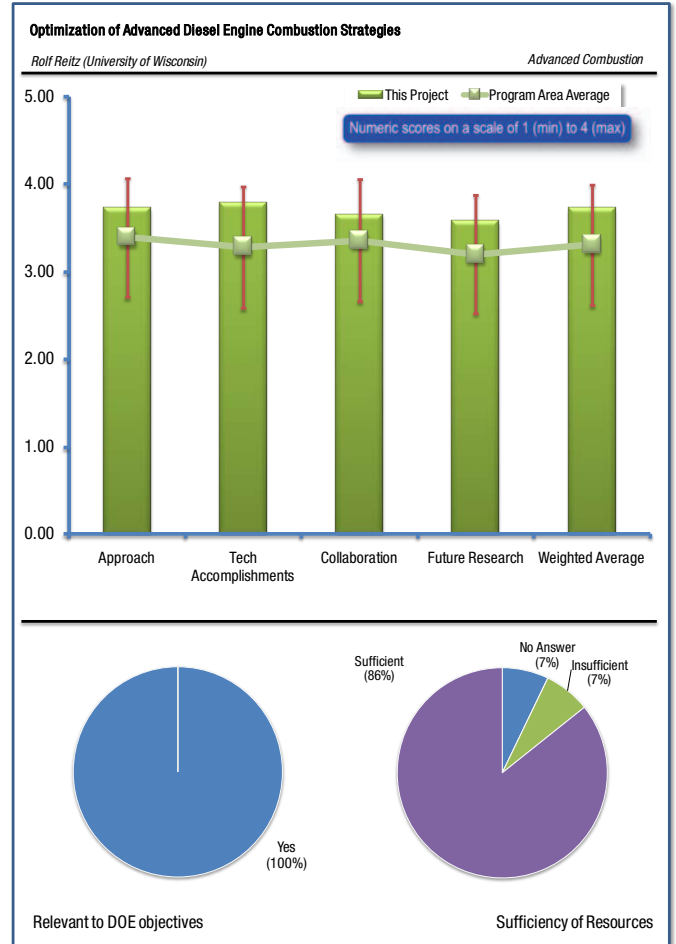
One reviewer said that this project does support DOE fuel efficiency and emissions goals by detailed combustion research on dual mode approaches combined with engine system simulation. The reviewer added that portions of this project are pushing the limits of understanding in dual fuel combustion approaches. A separate reviewer said that the work is being done in a number of areas with good direct relevance to improving engine operating efficiency.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that this work was a comprehensive yet well-thought out approach to engine research. A separate reviewer said that the approach is well-integrated with efforts of DOE and industry, and is significantly contributing to tangible advancements in LTC. A different reviewer noted that the project is focused on key barriers to implementation, not just a narrow area, and there was good use of analysis tools and experiments. A reviewer said they were great projects.

A reviewer noted that the approach of combining experimental work with modeling/simulation was excellent. The reviewer added that the project was also exploring alternate concepts such as dual fuel.

One reviewer said that the team was applying high fidelity engine simulation and high-resolution engine experiments to create and employ advanced tools for development of high efficiency low emissions engines. The reviewer continued that the barriers identified are combustion phasing and heat losses.



A separate reviewer commented that the project took a sound and thorough approach capitalizing on best-in-class scholars and engine research experts. The reviewer continued, commenting that the team is using high fidelity computing and high-resolution engine experiments synergistically to create and apply advanced tools needed for high-efficiency, low-emissions engine combustion design—cannot do better than that.

One reviewer commented on the project's broad approach with much complexity. In general, the reviewer felt, it was very balanced between combustion, efficiency, fuels, aftertreatment, metal engines, modeling, and optical. The same reviewer felt that the results were very impressive. The reviewer did feel that SCR injection and optimization were a "fish out of water" here. The reviewer added they still felt the work was complimentary, but that this consortium might be better spent on combustion. The reviewer added that the project is very worthy, but unless there are unique challenges presented here, this one might be moved.

One reviewer felt there was "too much stuff." The reviewer added that the technical approach is OK, but they were not sure the baseline performance is well established.

A reviewer said the work is being focused on areas of direct interest to industry and getting higher efficiency out of IC engines. The reviewer suggested that at some point soon, there needs to be more focus on BSFC of the dual fuel engine, just to understand if there are any unexpected losses on a full engine.

A reviewer commented that a comprehensive approach has been taken as outlined in Tasks A, B, C and D. The reviewer added that combustion strategies to improve thermal efficiency are undertaken with experimental as well as CFD tools. The reviewer continued that fuels are recognized as being a key enabler for combustion strategies and reducing emissions are recognized as being an integral part of any high efficiency design. The reviewer also noted that system-level optimization and demonstration is also undertaken to address real-world challenges.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said there was outstanding progress in all areas. A separate reviewer commented that the efficiency improvements shown through dual fuel injection processes were very exciting. Another reviewer said that there were outstanding results, especially in tasks A3, dual fuel engine: 55% efficiency. One reviewer said that there were a very good number of accomplishments in several areas and that the project had demonstrated that 55+% brake thermal efficiency could be achieved while meeting U.S. EPA heavy-duty emissions standards without using an aftertreatment device. A reviewer said that the ISFC numbers being shown are very impressive, but the project needs to show more on stability and transient operation, adding that the progress to date on this program is just outstanding.

A reviewer said that the project had uncovered new frontiers / grounds in optimization and control of diesel combustion for maximum fuel efficiency with minimum penalty to meet emissions mandates. The reviewer added that the state-of-the-art of diesel combustion and efficiency had been advanced.

A reviewer commented that an outstanding accomplishment of the project has been the demonstration of a dual-fuel concept that has achieved 55-60% indicated thermal efficiency in a heavy-duty engine. The reviewer added what is particularly impressive is that EPA 2010 emissions regulation have been met simultaneously. The reviewer continued that the key is to introduce reactivity gradients with the use of dual fuel and multiple injections. The gradient in fuel reactivity broadens the heat release, which generally is expected to decrease efficiency. The same reviewer noted that this is thought to be more than offset with the efficiency that comes from the low temperature combustion, on the order of 1600-1700°C. The reviewer also commented that low temperature combustion reduces heat loss and results in a net large increase in efficiency.

A reviewer noted that it was a new project but milestones included the development of 55% BTE engine operating conditions using simulation through combustion chamber and spray optimization. The reviewer also said that the project had found that fuel type is less important at high load than at low load, while optimizing injection strategy. In addition the reviewer said the project was upgrading the LES model for simulation of multi-mode combustion. The reviewer noted that the team had performed a dual fuel strategy study

and met US 2010 emissions while achieving 53-59% thermal efficiency at a 10 bar operating condition. The reviewer noted they had looked at fuel effects in light duty engine and ran fuels similar to the FACE fuels. The reviewer continued, saying the project had compared optical and metal engine behavior in 1.9L engine platform and developed reduced mechanisms for model fuel mixtures including ethanol. The reviewer commented that modeling behavior within exhaust aftertreatment systems including urea sprays. The reviewer also commented that the project team had made length scale measurements within an engine to study mixing control.

A different reviewer said that the work on comparing gasoline and ethanol as the second fuel in a dual fuel approach is outstanding and that much insight is being generated from this work. The reviewer also said that as such, approaches show ISFC levels near 60%. An assessment needs to be made of what type of BSFC can be anticipated once this combustion approach is actually implemented on multi-cylinder engines; it would be beneficial to address this looming issue. In addition, the reviewer said, it is not clear how the turbulence scale engine experiments will tangibly contribute to this overall effort.

One reviewer said it is tough to evaluate so much work in a short presentation, adding that accomplishments seem impressive with good promise.

One reviewer was not sure about some of the performance numbers quoted. The reviewer added that this gets back to establishing a baseline. The reviewer believes the baseline operating conditions need to be established somewhat. The reviewer gave that example that the project had shown some cases of 40-50% EGR, yet run a very low intake manifold temperature. The reviewer wondered if this is realistic and how the project was handling all the condensation.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this was good cooperative work with industry and others. A different reviewer described a strong cooperative effort with collaborators within industry and academia. One reviewer said that this was the right combination of collaborators and partners. A separate reviewer commented that this multi-disciplinary approach appears well coordinated between various UW-ERC members and GM when appropriate.

One reviewer said that this work is being widely shared and a lot of participants are aware of this work, showing excellent collaboration. A separate reviewer said that collaborations exist with a host of industry and national lab partners. A different reviewer commented that the membership was the right size. A separate reviewer commented that the work was being performed under the existing consortium which has many members.

One reviewer noted this was an industry collaboration mainly with GM and Woodward and also through members of their DERC consortia. The reviewer added that input and collaboration through the latter may primarily be limited to annual meetings.

A reviewer noted that this is a huge program with many collaborators. The reviewer suggested that, although the project is fresh and refunded, please consider longer term how to shift resources from “mature” projects to more optimistic ones.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said the plan is complete and thorough. A separate reviewer said there were good plans for continuing to build on the results that they have already obtained. One reviewer said that it was good to see a systems approach to evaluating emissions with LTC (including transient behavior). A reviewer said that the future work planned is right on and is focused very well.

One reviewer commented that the future research plans are ambitious, suggesting they might need to be focused down somewhat in the future to ensure success on a wide range of fronts.

A reviewer said that there were excellent accomplishments and plans are to extend and continue this ongoing work. The reviewer also suggested that the project needs to address the practicality of dual fueling strategies with gasoline and E85 as a supplementary fuel.

One reviewer said the project planned a broad look at many aspects, adding that it is difficult to judge how well focused the objectives are. A separate reviewer suggested that Task A1 be moved to LTC only if efficiency gains are objective and Task A3 should have the emissions limitation removed and the project focused to really push efficiency. The reviewer suggested a decision can be made later on aftertreatment fuel penalties and optimization. The reviewer believed the team needs to know efficiency limits.

A reviewer felt that the presentation did not include a detailed future plans effort, though it did include a general plan, adding it would be nice to see more detail.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that progress has shown a good return on investment so far. A separate reviewer noted their belief that last year's budget was low: there was a good increase this year, and we should see substantially more advancement at the next AMR. One reviewer said that it looks okay but difficult. One reviewer said that progress seems good and there was no indication that resources are not sufficient. Another reviewer said that it looks okay, but there it is difficult to assess as there is so much on the plate.

A separate reviewer suggested that there was a need to address the practicality of dual fueling strategies with gasoline and E85 as a supplementary fuel. Another reviewer said that the dual fuel work is somewhat a duplication of the work on ACE16.

Flex Fuel Optimized SI and HCCI Engine: Gouming Zhu (Michigan State University)

REVIEWER SAMPLE SIZE

This project had a total of 11 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer stated that a dual combustion mode engine that is optimized for flex fuel has the opportunity to be more efficient and allow use of alternative fuel, providing multiple ways to displace petroleum. One reviewer added that flex fuel efficiency can both displace petroleum with ethanol and reduce total energy consumption. The value of ethanol can be increased if it is used in dual mode to improve gasoline efficiency. One person commented that the project's efficiency objectives are consistent, adding that it was nice to get funding into MSU with the need to develop an engineering base outside of the larger centers. MSU has advantages of location and access to OEMs.

A reviewer commented that this project supports DOE thermal efficiency goals by exploring gasoline-type HCCI in metal and optical engines toward pushing up thermal efficiency.

One reviewer simply stated that the project was learning how to run an engine in a more efficient mode (HCCI) and was using ethanol. Another reviewer believed that this project aims to further develop the HCCI concept by demonstrating a dual combustion engine that operates in both an SI and HCCI mode. In the process, real world issues with regards to controlling this complex mixed-mode combustion process will be surfaced and addressed. The reviewer added that the only downside of this project is that some of this work is duplication of work already done at Oak Ridge National Lab. The new feature of this project would perhaps be the inclusion of E85 and addressing of a flex fuel engine. The researchers involved should use the work already done at ORNL as a starting point to avoid duplication.

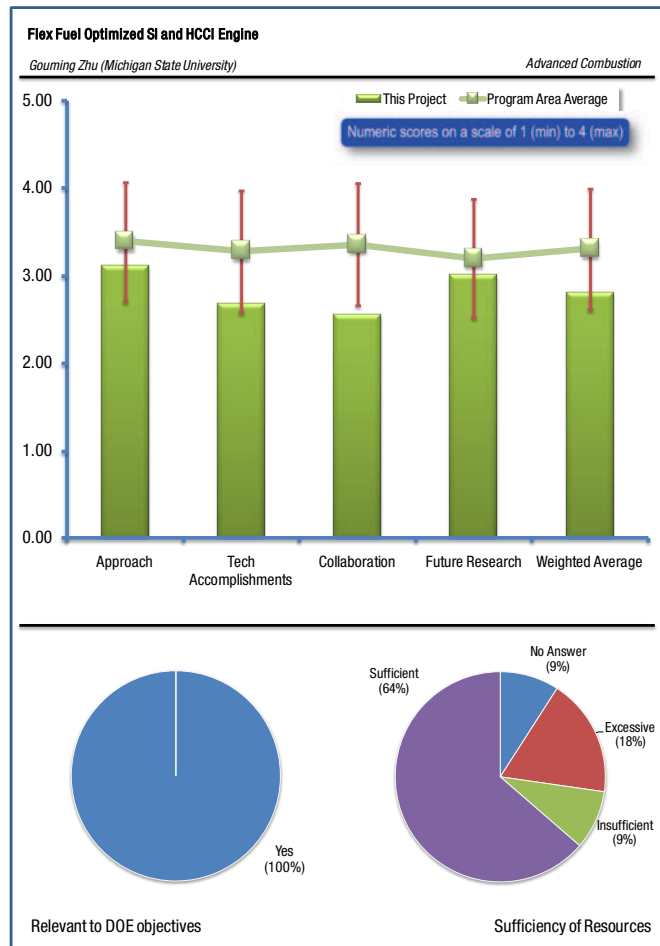
One reviewer concluded that the project only had tenuous relevance and that this project looks a lot like others that are better thought out, planned and executed.

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QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer was of the belief that the barriers are robustness and cost effectiveness of a dual combustion mode engine, developing a control-oriented combustion model that can be included in active engine control, depending on fuel composition and operating conditions, using GT-Power simulation to develop tools that can be used in engine control while developing a combustion model, developing design of single cylinder optical engine, and the combination of metal and optical engine studies with an emphasis on monitoring spray behavior as fuel composition changes.

A separate reviewer felt there was a good use of modeling to guide the work and liked the cycle simulation work being done to get early guidance. The reviewer added that the modeling of transitions between SI and HCCI is good work and that it will be interesting if the results agree with the models.



One reviewer noted a multifaceted approach of modeling, metal, optical, control. The reviewer believed there was good feedback and on-the-fly optimization using multiple methods and that it was nice to see milestones and go no-go decision points.

A separate reviewer was of the opinion that the means for a practical approach to transitioning between LTC and SI combustion is good. Another reviewer stated that working on a dual fuel engine seems like a good approach and a good item to investigate. The reviewer continued that the overall approach seemed relaxed and appears to have room to have major milestones moved forward. One reviewer was of the belief that model-based controls and hardware-in-the-loop control strategies will be employed by the project. Also, the reviewer added, an optical engine will be included to investigate in-cylinder flow, mixing and combustion. The same reviewer went on to state that it seems like the design of the HCCI combustion system is going to start from scratch and that it seems like the project is not just going to focus on controls. The reviewer expressed that it could be that the scope of the project is more than what one single project can handle.

A reviewer opined that the approach is ambitious but naïve, and that the investigator is not very well informed about the current state of the art or of the potential pitfalls (of attempting to predict the transition between conventional SI-initiated combustion and HCCI, for example). A separate reviewer concluded that the project held nothing new and had no innovation. That reviewer continued that this “project” barely qualifies for a master degree student’s work at any other university and that most, if not all, of the subscribed work has been already done by academia, auto companies, and leading first tier suppliers like Bosch, Delphi, Continental, Denso, Matlab, dSpace and others.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer stated that modeling of SI and HCCI combustion using GT-Power has progressed to a good extent. The hybrid mode of combustion, where an engine cycle starts out in the SI mode and ends in the HCCI mode has been accomplished. This control feature will allow smooth transition between SI and HCCI modes of combustion. The reviewer also stated that the design of the optical engine is complete.

A separate reviewer commented that there was progress toward engine simulation, control based model development and single cylinder engine design and fabrication. Another commenter described the modeling results as providing good direction to the hardware part of the project. The same reviewer also saw interesting limits and opportunities for SI-HCCI.

A reviewer commented that if the modeling of the transient mode switching turns out to be accurate, this project will have achieved quite an accomplishment.

One reviewer stated that the simulation shows good potential, but added that it was still too early to assess how well the system will work in actual engine. The reviewer continued that caution is in order as modeling SI-HCCI transition is not proven. Two reviewers were of a similar mindset: one stated that the project was at very early days, while another said the project has only started so progress is thus minimal.

One reviewer stated that while the exercises presented were nice, the project activities and results have been completed a few years ago by various entities. A separate reviewer said that for what appears to be a multi-year project with a couple/few years of history, the amount of progress seems slow. The reviewer commented on a basic design being laid out, the control system being roughed out, and some modeling done, but felt that there should have been more progress. The same reviewer added that they were especially concerned about the real life transition between SI and HCCI and that does not seem to yet be considered.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer remarked that because of collaboration with an industrial partner (Chrysler), technology transfer should occur rapidly. A separate reviewer stated that the parent company in Torino, Italy has the results of the project objectives, at least in the advanced research organization "Centro Ricerche Fiat." A different reviewer commented that Chrysler seems interested. One reviewer commented that there had been efforts to collaborate with Chrysler, but it appears that an agreement is not in place as yet. The reviewer went on to state that they have received engine hardware and some technical support and have gotten some support from GT-

Power. Another reviewer noted that the collaboration was only with Chrysler and that this has apparently not been finalized yet. One reviewer said this is an isolated project focused on MSU and that even Chrysler is an unknown at this stage. The reviewer added that the project is important and should strive for more collaboration in the future.

A different reviewer opined that some of the work looks like duplication of the University the Michigan combustion R&D and wondered if the PI has coordinated with UM to ensure complimentary versus duplication of work. The reviewer went on to say that LLNL and UM have done a lot of work on simplified modeling of premixed combustion including HCCI and SA HCCI/PCCI and asked if the PI has coordinated with these researchers to ensure their GT Power combustion model is giving reasonable results. The reviewer concluded that the project has pending support from the Chrysler group, but otherwise seems to be operating in a vacuum.

QUESTION 5: HAS THE PROJECT 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?

A commenter stated that the program seems to be on time and that Phase II of the program will involve optical engine tests to visualize combustion and modification of the cylinder head for VVT actuation. The reviewer added that other subsystems include ignition feedback and the HIL simulator development with the inclusion of a real-time engine model. A separate reviewer suggested that the project continue work on engine, modeling, sensing and control developments. One reviewer felt that the plan was impressive and now needs execution. The reviewer added that transients and mode-shifting will be very interesting.

Another reviewer commented that a better acknowledgement of the barriers would instill more confidence in this project and that there needs to be a more frank assessment of the tremendous hurdles to be overcome in building HCCI control expertise. An additional reviewer concluded that this project covers old bases.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer stated that they were not sure the team can get this all done and that doing a new optical engine sure seems like a large investment in itself. A separate reviewer wondered why DOE is funding another school to build an optical engine and a green field ICE lab. The same reviewer also asked if this is an objective of the EERE VTP.

CLEERS Coordination & Joint Development of Benchmark Kinetics for LNT & SCR: Stuart Daw (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

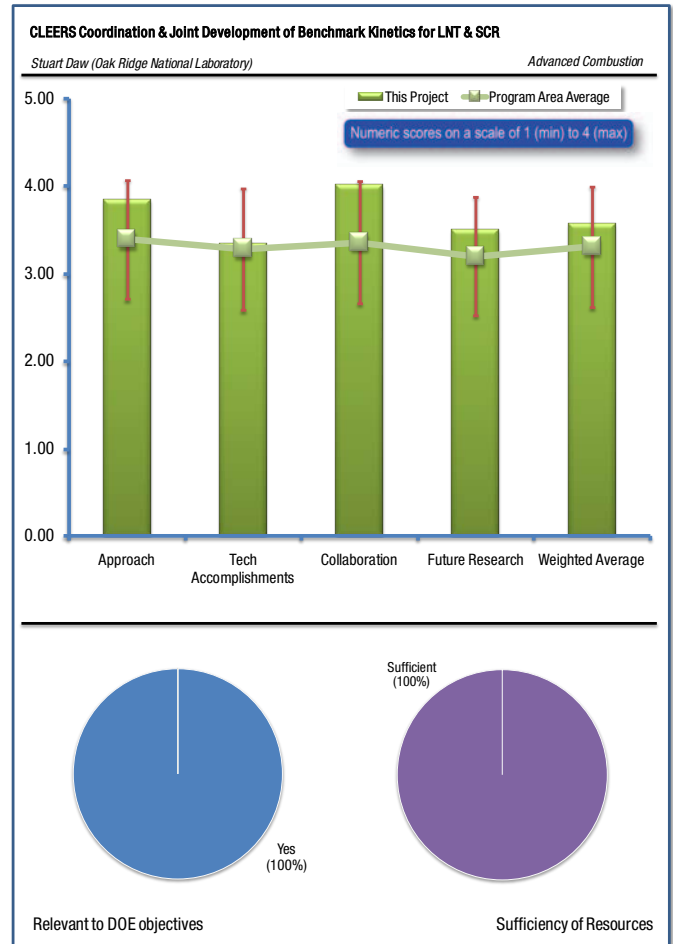
A reviewer stated that this was a key group to stimulate cooperative catalyst modeling development. Another reviewer added that this project supports DOE objectives strongly by bringing together the people who work on efficient emissions control with a wide range of fuels and technologies. Another reviewer noted that this work enables the implementation of lean burn engine capability and that it seems clear that the future requirement of higher fuel economy will require lean burn engines. The reviewer added that the implementation of lean gasoline technologies is especially relevant. The same reviewer continued that gasoline engines account for approximately 95% of all the light duty vehicles and consequently are providing the emission technologies that all the implementation of lean gasoline engines goes a long ways towards reducing the overall vehicle petroleum consumption.

One reviewer said that moving forward deNOx means high efficiency for diesel engines. CLEERS provides a solid baseline for pushing the envelope. A separate reviewer maintained that in terms of petroleum displacement, diesel and lean gasoline are the key powerplants, here but more work could be done to push it further with advanced fuels such as biodiesel and ethanol, as examples.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that this was an amazing success in bring many researchers together in common efforts. Another reviewer noted that the implementation of a global LNT mechanism will help with the implementation of this work. Another reviewer commented that the approach of developing models for “generic” catalysts is very instructive for most of the issues in developing these models. The reviewer added that the CLEERS conferences and webinars are excellent. A separate reviewer opined that good fundamental items are being researched and that they are a huge fan of the workshops and working groups. A different reviewer said that they have no new comments for improvements and the project should just keep doing what it is doing. A different reviewer commented that the project had a comprehensive approach with an advisory committee, modeling, correlations with experiments and communications/workshops. That reviewer added that this was a model program.

One reviewer concluded that the development of the understanding of the spatiotemporal chemistry of the LNT is very important in assisting in the development of engine control strategies that reflect the actual condition of the LNT catalyst. It is interesting to understand the toluene poisoning of the SCR catalyst. The reviewer believes the difficulty is providing a range of hydrocarbon materials that can have an effect on the SCR catalyst. The reviewer added that there was also more emphasis on hydrocarbon species emitted from lean gasoline systems.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer stated that developing the relationship between the oxygen storage and the NO_x storage on the LNT is a major accomplishment and will have a significant impact on the efficiency of the device. The reviewer continued that since there is a significant growth in the coupled device technologies such as LNT-SCR, the understanding of the conditions in which a LNT produces ammonia is clearly on track with the needs of industry. One reviewer commented that the ability to build communication between active players in the field is excellent and that this will lead to the development of protocols for testing at different laboratories and the evaluation of the effect of the various approaches on fuel economy is evaluated. The reviewer continued that LNT work has been a staple of the activity in the past, but now SCR is being much more fully explored. The same reviewer added that HC poisoning of urea-SCR is an example of an area of research that has received attention. That reviewer ended that the effect of sulfur has been studied along with the explanation of why more ammonia is made after S deposition in LNT and that ammonia production under rich regime has been studied and the formation of N₂O from it has been examined. One reviewer commented that there had been good results already and more on the way. A separate reviewer found the Fe-zeolite reaction paths quite interesting and that it sets the stage for optimization by industry. LNT modeling and NH₃ is delivering new understanding that will move field forward.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer was of the belief that this project involves more collaborative work between industry, national labs, and universities than almost any other project. Another reviewer commented that the effort is by nature collaborative and the leaders are very good in fostering the team effort. A third reviewer commented that all key sectors represented and that tech transfer and advisory committees were excellent. Another commented that this was just an outstanding job in getting a broad-range collaboration.

A separate reviewer said that the sharing of results with industry through CLEERS is a very good method to get this information into the industrial sector. The reviewer continued that it is also clear that the interaction with the work going on at PNNL and SNL is solid and that it does not appear that “fiefdom issues” are occurring, which is very good. A different reviewer commented that coordination with the industry is very important and that they see that some projects may be studying out-dated catalysts. The same reviewer suggested that more catalyst information from catalyst suppliers and auto companies would be helpful.

QUESTION 5: HAS THE PROJECT 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?

One reviewer urged the project to keep up the good work. Another reviewer commented that a focus on the unburned fractions of gasoline as possible poisoning agents for SCR would be helpful and that continuing the work on SCR protocols and comparing the results from other laboratories is very beneficial. A separate reviewer believes that there was a strong focus on LNT and SCR, but it would be good to include HC-SCR in the overall modeling approach, especially in the determination of effects on fuel economy between the technologies. The same reviewer added that there has been an increase in interest in new developments with Ag HC-SCR by some in the catalyst industry, which is not covered in this program. The reviewer felt that this could offer an interesting new direction, since there may be mechanistic similarities to what happens in LNTs, especially surrounding NH₃ formation.

Another reviewer said that they think it is time to move away from the current Umicore benchmark LNT catalyst. The reviewer would like to see a laboratory comparison/benchmark of commercially available LNT and SCR catalysts under the CLEERS protocol. This would help determine what issues have been solved. For example, HC poisoning is likely to be less of a problem on the newer CuSCR catalysts. A separate reviewer commented that key gaps include a major trend towards integrated components. LNT+DOC; SCR+DPF; which are leading concepts. The reviewer saw that models form a basis of understanding, but there is no evidence here of tying all this together (the PO_x material being added to LNT for NH₃ and desulfation). The reviewer concluded that there seems to be a gap here and highlighted PM oxidation by SCR catalysts. Base metal catalysts show dual functionality and this might be worth modeling and exploring.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said more funding certainly could be helpful; however, this laboratory has been very effective in the utilization of their resources in addressing these problems. Another reviewer commented that they do not recall any requests for further resources to evaluate, but could be supportive for them depending on what they were. A separate reviewer commented that there was appropriate funding and staffing.

CLEERS: Aftertreatment Modeling and Analysis:
Darrell Herling (Pacific Northwest National Laboratory)

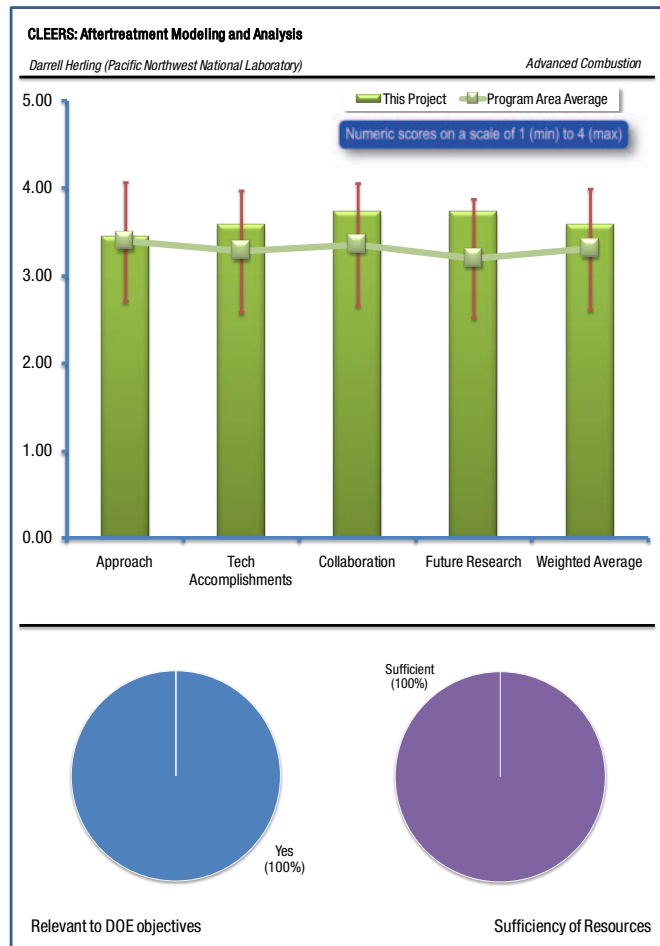
REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that the development of the fundamental science to enable high efficiency emissions control for high efficiency engines will further the DOE objective of displacing petroleum, since high efficiency vehicles must meet stringent emissions standards. Another commenter said that both SCR and LNT catalysis is very relevant to the implementation of lean engine technologies. The reviewer continued that the focus on the factors that limit the implementation of these emission technologies assists in the implementation of these technologies. What is especially interesting are the effects of hydrocarbons on the SCR performance. Another reviewer said that the relevance of the CLEERS-related program appears high, as it supports the goal of identifying efficient after treatment systems to support efficient engine systems. Yet another reviewer said that the project displayed useful leadership of team work on catalyst modeling.

One reviewer said that technology transfer is important, and that industry inputs are being taken into account. The same reviewer added that the work on ASCR and LNTs is fundamental to several high-efficiency engine types.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said that some good fundamental studies are being performed. Another stated that the mix of modeling and experiment is especially strong, especially with the range of specialized experimental tools at PNNL. A reviewer stated that the “science to solutions” framework for achieving advanced cost effective emissions controls is a sound approach that is much more likely to yield successful product development in the end. The reviewer continued that this project builds from elementary measurements, e.g., morphology changes as reactants adsorb on the barium- alumina support interface, to yield guidance for enhanced material design.

A reviewer said that the project was showing reception to shifting work to areas of interest. Modeling foundations seem responsive to needs. Another reviewer commented that the kinetic analysis of the SCR catalyst is very appropriate. The same reviewer continued that most of the modeling work on these catalysts in industry is via global models and there was little discussion of discussion of the forms of the global reactions that will be needed to describe these kinetic effects.

One reviewer commented that it seems the H₂O impact on the SCR catalyst is not very important: the reviewer recommended to stop chasing after this one. Another reviewer noted that they were not interested in modeling FeSCR catalysts. Please quickly move on to available CuSCR catalysts. These are the ones industry cared enough to put in production.

Another reviewer said that there seems to be some fuzziness about the plans and efforts: is this an effort to support modeling, or work to learn about catalysts surfaces and reactions? Both are useful, but CLEERS is nominally about modeling and not surface science. Of course, the surface science is very interesting and worthwhile on its own.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said that evaluating the possible poisoning effect of hydrocarbons on the SCR catalysts is important, since hydrocarbon poisoning will most likely occur when there is hydrocarbon slip from upstream devices. Another reviewer commented that the structural analysis of gamma alumina is very interesting and provides a good basis for future understanding of the LNT kinetic behavior. A separate reviewer commented that there were very interesting results on alumina surfaces etc.

A different reviewer was not convinced that the H₂O inhibition studies were necessary. The SCR mechanism shown in the presentation is a global mechanism. Consequently the water inhibition effect will most likely roll into the global ammonia kinetics.

Another reviewer commented that this was very interesting work on a range of HCs and showing the effects are different for NO-SCR vs. NO₂ SCR. It provided valuable insights into SCR and HC adsorption effects. The same reviewer said that the critical issue going forward is that 95%+ efficiency SCR systems are in demand, and a key foundation moving forward was adsorption. Learnings are interesting, but perhaps lack practical clarity. The reviewer added that research feeds the knowledge base and adds to the portfolio interesting “what-if” scenarios.

A separate reviewer said that the determination of the surface structure of gamma alumina is very useful to build models, adding there are five-fold species at surface and that there is a 1:1 match between Ba and 5-fold sites, about 16% of surface, more like 100 gamma alumina. (Isolated Ba atoms are seen). The reviewer also stated that they could see isolated Pt also.

A reviewer said that the project identified inhibitory interactions between species, identified detailed interactions between barium and alumina support, and identified dispersed individual Pt atoms on alumina (results in Science article).

One reviewer commented that a successfully LNT must be durable. The reviewer questioned whether a link could be drawn between the penta-coordinate alumina ion to activity/storage? The reviewer also wondered what happens to the penta-coordinate alumina ion and the catalytic phase with aging and sulfur poisoning.

A separate reviewer noted that there has been a shift to working on urea-SCR, and that there is a DPF, SCR, and LNT subgroup work, but focus has been on SCR and LNT this past year.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer commented that there was extensive collaboration with component suppliers and OEMs. Another reviewer commented that the collaborative aspects of the CLEERS-related programs are excellent between industry, national labs, and some universities, particularly for programs at ORNL and PNNL and one program at SNL-Livermore. The same reviewer wondered if there might also be groups in Illinois or New Mexico that may have skills that would support these programs as well.

A separate reviewer commented that there was excellent collaboration with industry, academia, and other labs. One reviewer noted an excellent flow of information and that there were inputs to direct work and workshops and website to transfer knowledge.

One reviewer said that it would be good if there was a more direct collaboration with an OEM. A separate reviewer said it was not clear if there is an OEM partner on these work.

QUESTION 5: HAS THE PROJECT 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?

A reviewer stated that future programs look excellent, adding that continuation of the studies of urea and its surrogates and their ability to form ammonia should be a priority. The reviewer continued that there has been an increase in interest in new developments with Ag HC-SCR by some in the catalyst industry which is not covered in this program. The reviewer suggested that this could offer an interesting new direction, since there may be mechanistic similarities to what happens in LNTs, especially surrounding NH₃ formation.

A reviewer was in favor of continuing work on surface interactions, aging, kinetic modeling and fundamental materials studies. A separate reviewer stated that this was an important to move into Cu-zeolites and that competitive adsorption of NO₂ and NH₃ (Yezerets 2010 SAE paper comparing Fe- and Cu-zeolites) is very interesting with significant practical application. The reviewer believed that this is in need of fundamental understanding. The team needs to supplement with Fe-zeolite comparisons. A reviewer said that the work continues to be good. The reviewer would like to see more detail about the SCR kinetic mechanism and especially would like to see inhibition terms for hydrocarbons. The reviewer added that they would also like to see the ammonia storage handled by an isotherm. Both of those advances would be very good for the modeling community.

A reviewer commented that the future work points are very good except the one on further modeling on the Fe/zeolite catalyst. The reviewer recommends very quickly finishing this work and moving on to the commercially available CuSCR catalysts as a higher priority. Another reviewer stated that each of the proposed efforts sounded interesting, but felt some don't seem to fit the CLEERS modeling charter.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer stated that many of these results grow on previous accomplishments, so consequently as long as the rate of accomplishment continues then the funding is sufficient. The reviewer continues that it is not clear to them that there are many problems that are not being addressed due to lack of funding.

Another reviewer noted that the funding was appropriate to the work being done. The reviewer continued saying perhaps CLEERS funding could be trimmed and some of the funding shifted to another program to cover the non-modeling part of the work. The reviewer would not like to see that work cut since it is also very interesting.

Development of Advanced Diesel Particulate Filtration (DPF) Systems: Kyeong Lee (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer commented that diesel particulate filters do support the effort to implement clean diesel engines. With the higher fuel economy, diesel engines do support the overall object of petroleum displacement. Similar comments came from a separate reviewer who said diesel particulate filtration and trap regeneration are essential to advanced technology high efficiency diesel and DI gasoline vehicles, which by providing higher fuel economy will displace petroleum. Another reviewer added that efficient use of DPFs will improve efficiency of diesel and lean gas emission control systems. One reviewer said that there is a continuing need for improved DPFs.

One reviewer stated that the project’s relevance was marginal. The reviewer continued that DPF is fundamental to diesel engines and is migrating to gasoline adding that the shift is more towards passive operation with high NO_x/C exhaust from efficient engine operating points and that PM soot membrane is becoming obsolete in favor of ash/catalyst/soot/gas interactions. The reviewer feels there has been a shift to instantaneous PM oxidation and dynamics. The reviewer continues that the results are still significant to LDD and optimization of them over next five years and that very few HD applications (Navistar is the only one) build soot membranes anymore.

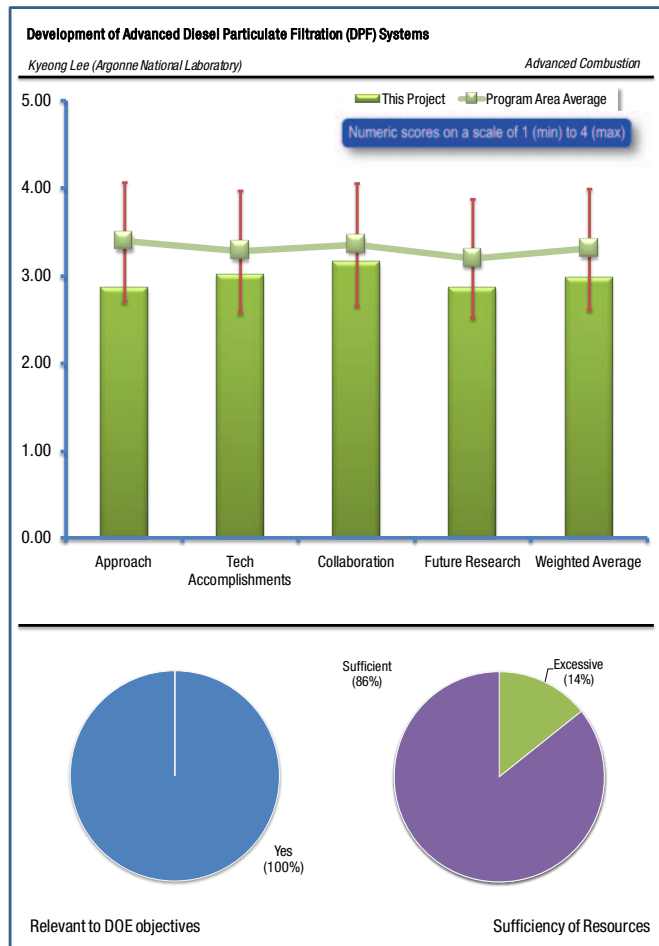
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said that the development of fundamental understanding with base experiments and model fit was within the realm of DOE/NL work. The reviewer continued that the work on plug changes is creative, but is more applied research and seems out of scope with fundamental understanding and more in line with product development. The reviewer continued that base understanding now lays a foundation and may be important for improving initial filtration.

A reviewer thought the approach to addressing rate constant determination is outstanding, and the reviewer thinks the future work looks exciting. However, the same reviewer did not fully understand the approach to the modified DPF changes and how that testing would help the understanding of what is going on that leads to improvements at least at low loading times.

One reviewer commented that they fully support development of an improved fundamental understanding of the DPF performance, especially during oxidation of the trapped soot. The reviewer remained unclear about using graphite vs. diesel soot. The reviewer added that that they assume this is acceptable, but would prefer using actual diesel soot. The reviewer also noted that it was not clear if the reaction rates were done on a filter or just on the soot itself in a free state.

One reviewer commented that the project was performing TGA and DSC analyses on carbon and soot sample and determining reaction kinetics for soot oxidation and relative contributions to DPF back pressure from different fluid flow phenomena.



Another reviewer said that it was a nice procedure, but they did not see any information on generation of CO vs. CO₂. The reviewer added that they were unclear how this is handled since some potential heat from CO is not accounted for in the TGA measurements and wondered if the project planned to test with NO₂ as well.

Another reviewer commented that it sounds as though some parts of the program are successful but not available for review, continuing that based on what was shown, much of the work duplicates work others have previously published.

One reviewer said that this project has shown some relevant data on the oxidation kinetics for soot, but the reviewer felt that the unusual proposed DPF structure appears to have very little possibility of producing an improved DPF activity.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer stated that the project contained impressive fundamental work on reaction dynamics and activation behavior, but needed to delineate fresh soot properties, as this will be the future soot in passive DPFs. A separate reviewer said that the project measured the transient heat release from diesel soot oxidation using DSC. The team is determining permeability behavior of DPF materials and modified DPF material configurations. The reviewer continued that the invention disclosure submitted for defining pressure drop and soot mass relationship in the DPF.

One reviewer said that it was very good to get activation energies for graphite and soot with preexponentials, and noted the presentation showed that most of the pressure drop is from flow through wall in wall-flow monoliths. The reviewer added, that even after our discussion, the reviewer still not sure they understood the assumptions in the Modified DPF model (unless there is a block at the front of the lower channel in the Modified DPF). The reviewer added that of course then, the flow would go through two walls, so the basis of the benefit was unclear.

A separate reviewer commented that the project has demonstrated an oxidation rate for soot that reproduces previous work from Cummins, however, the reviewer added that he author did not even comment on that comparison.

One reviewer said that a question was raised on oxidation rate constants staying the same or having two zones.

A reviewer said that activation energy needs to be compared to published literature and wondered what the H/C ratio was for the soot used, what the conditions of the collected soot were, was biodiesel used anywhere, and how much sulfur was in the fuel. The same reviewer said that 1/2 PP DPF has higher back pressure than conventional DPF up to about 4 hours. The reviewer continued that 60 miles per hour for 4 hours is about 240 miles and that this corresponds to most of the soot loading, especially for applications where there is high passive regeneration. The reviewer stated that 1/2 pp system would always have higher back pressure compared to the conv. DPF.

A reviewer said it was hard to judge since the team states there is a control algorithm but it can't be described. The reviewer added that what was described seemed to repeat previously published work. The same reviewer said that it would rate higher if the control system is really successful. The reviewer was not clear on the concept behind the central-plug filter and why it would behave as it does; this may be a limitation of the short time for presentations. The reviewer finished by commenting that the different DPF structure seems to have very little physical reason to be more effective and that this seems like a waste of time.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer noted that there were collaborations with component suppliers, materials developers and OEMs and academia. Another reviewer said that it is good there is an OEM and a substrate supplier involved while a third commented that there was good industry NL interaction and feedback.

A separate reviewer stated that the partners seemed very appropriate adding that it would be good to be clear about the involvement of Corning and Caterpillar in the project and the issues that they found to be most important.

One reviewer said that a number of collaborators were reported; however, there was no evidence in the presentation that the partners were active.

QUESTION 5: HAS THE PROJECT 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?

A reviewer stated that continuing the soot oxidation work appears to be worthwhile; however, it would be appreciated to discuss it with the CLEERS industrial community and make sure that the work is complementary and not simply repeats of work already in the literature.

Another reviewer said that it seemed there was a need to improve the rate constant determinations for soot oxidation, although the approach seems appropriate. The reviewer continued that it would seem best to use more fresh soot as an element in the testing, especially as the contract is ending in 2011. The reviewer added that this should be available off engines at Argonne. The reviewer also said that active regens are very unlikely as we go forward in time, as OEMs are running more in the high NO_x, low PM regimes. The reviewer suggested that partially blocked DPF results need clarification. It would be good to include measurements and evaluations of alternative approaches relative to particle number improvements. The reviewer would look forward to the optical studies of oxidation and location of heat release.

A reviewer suggested the project continue soot oxidation studies with more practical exhaust gases, continue DPF membrane studies and analyze soot structure and morphology at various stages of oxidation. The reviewer continued that the soot study should include the engine operating condition as an experimental variable, since soot nanostructure and particle morphology should be influenced by load, EGR level and fuel type.

One reviewer saw a need to shift to passive DPF operation, noting that reaction kinetics with various gases is important, especially under “marginally passive” operation wherein NO₂+C reactions are limited. The reviewer asked if there is enough NO₂ and kinetics to burn the small amounts of soot under low load operation. The reviewer also suggested shifting away from active regeneration quantification because this has been studied significantly. The same reviewer state that much work is needed on the “new DPF” which hold individual soot particles for a short period of time and soot-catalyst-ash interactions become key.

A reviewer stated that it was somewhat hard to judge without understanding more about proposed modified membranes etc.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that resources were appropriate assuming there really were successful control results. Another reviewer felt that this seems like an enormous amount of money for the limited results at this point. One reviewer noted that optical studies of heat release were mentioned, and assumes the equipment is available. The reviewer also assumed that particle number studies can also be addressed.

Combination and Integration of DPF-SCR Aftertreatment Technologies: Kenneth Rappe (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer stated that this work is directed toward enhanced packaging effectiveness for the after treatment devices. The reviewer added that the value of this is that high catalyst volumes can be employed, which improves the ability of heavy-duty trucks to more effectively meet stringent emission standards. A separate reviewer saw potential for significant cost and size reduction of a key emission component.

A reviewer said that the project advances more efficient aftertreatment systems that enable high efficiency engines and thereby displace petroleum use. A different reviewer said that using a more compact system, like SCR-DPF, to accomplish NOx and particulate removal is clearly a more efficient way to do emissions control.

Another reviewer said that high efficiency deNOx is the future and getting extra deNOx off a DPF is an important step. Also, LDD and non-road have space constrictions, so combo systems help. A separate reviewer said that the coating of an SCR on a DPF structure is certainly of interest, and directly relevant to potential needs moving forward.

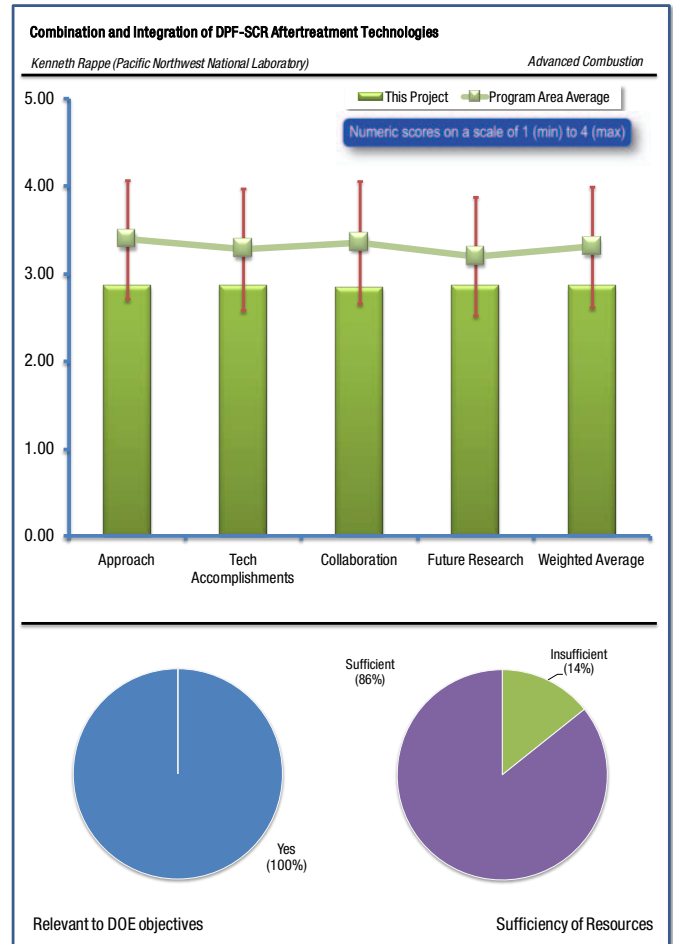
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said that this was a good approach and study of the DPF+SCR integrated system. The reviewer added that certainly there is strong interest in the impact on passive regeneration of soot on the DPF, with the assumption that active regeneration might well be required to make the system sustainable.

Another reviewer said that the project was studying the interaction effects between DPF and SCR combined operation, such as effects of active site blockage, thermal nonuniformity and other issues; integrating SCR active materials into DPF wall flow support and addressing NOx conversion with accumulated soot.

One reviewer said that the tools available appear to be quite effective, although things are very basic so far using Jetta soot and smoke number analysis for soot exposures. The reviewer added that they hope more quantitative measures of the loading of soot mass and number will be used. The same reviewer noted that PACCAR has brought the University of Utrecht into the project, but it was not clear what they were evaluating from the one slide of capabilities.

A separate reviewer said that the approach would have been rated outstanding, but since the team planned to do the coating themselves the reviewer must rate it as fair. The reviewer continued that they have to absolutely involve a catalyst washcoat supplier in the project. The reviewer added that the project team has been optimizing their latest SCR technologies for each of the DPF substrate



types for years, and they know how to apply the SCR within the DPF wall and avoid the overlayer that is responsible for high back pressure. The reviewer believes that this work is out of the team's scope. The reviewer added that a catalyst supplier can then provide commercially interesting SCR formulations.

Separate reviewer stated that apparently the CRADA partner PACCAR does not want to include an experienced catalyst coater into the CRADA. The reviewer continued that this leaves PNNL in the position of having to learn how to coat various types of flow-through catalysts: this is not an effective use of National Laboratory expertise and resources. The same reviewer also asked if a smoke meter is an effective method of loading these samples. This is especially of concern since the back pressure of these monolithic cores is dependent on the coating density and the porosity of the monolith.

One reviewer expressed similar concerns, stating that there were key issues of substrate strength versus washcoat loading versus pressure drop are hard to evaluate in a realistic way without a real washcoater involved. The reviewer continued that the approach taken seems to be to make pieces; this may be best left to washcoaters and substrate suppliers. The reviewer added that few plans seem to be in place for theoretical understanding of pressure drop fundamentals; that is the sort of area where labs can make real contributions.

A separate reviewer said the approach seems reasonable. The reviewer continued that emphasis needs to be on increasing loading while reducing back pressure. The reviewer continued that this is being addressed, but what is missing is a quantification of washcoat loading in pores (x% goes into Y-size pores). The reviewer continued that once established, this can be used to evaluate materials, processes, performance, etc.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that there was a good preliminary foundation, included single sided, double sided, etc. Another reviewer said that the project had completed detailed substrate evaluations, was defining attributes for integrated system and defined cordierite as the primary substrate candidate and SiC as a secondary option.

A reviewer said that they would certainly like to see data on SCR conversion efficiency as well as soot loading rates compared to current production type DPFs. A separate reviewer said that the objectives for the project are well laid out and next year should show the fruit of many of the efforts on the best location for the NO_x catalyst washcoat, e.g., if having it on more than the exit channels is effective or even helps in soot lightoff.

One reviewer said that it is disturbing that one of the accomplishments is to develop coating technology which is done routinely at various suppliers. The reviewer added that given the partnership constraint, they believe that this work was well done.

One reviewer said that the laboratory cores do not have a skin and that this will be very difficult to accurately determine back pressure due to possible leaks. The same reviewer questioned how the team knows that the SCR formulation is durable enough. The reviewer suggested the project team determine the hydrothermal stability of all SCR candidates ahead of time before picking one for coating and drop Fe/zeolite SCR formulations.

A reviewer said that the lack of suitable catalyst materials is a major problem, and that washcoating required significant art that may be lacking here. Another reviewer added that the collaboration with a coater would seem very important.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that working with the University of Utrecht should be very effective. The same reviewer expressed concern that the lack of a quality coater in the CRADA is a major disadvantage and that it was not at all clear what direct interaction was going on with PACCAR. Another reviewer said that there was direct collaboration with PACCAR as a potential user and technology transfer path, in combination with DAF and University of Utrecht.

One reviewer saw a direct need to develop a partnership with a coating company to perhaps tailor the washcoat of the NO_x side of the wall flow surface with the most appropriate structure for current SCR catalysts to function. A separate reviewer said that the team needs a catalyst source, and that involvement of OEMs is valuable but perhaps of limited direct utility.

A separate reviewer said that expanding the collaboration to a coater of SCR catalysts and catalyzed DPFs or obtaining vendor-supplied samples will enhance the timeline and credibility of this important project. One reviewer believed that there was a need to bring in a substrate supplier and coater and that they will know what's known and where the gaps are. The reviewer added that the team can also get the latest materials designed for these applications.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that the proposed future research looks excellent. The reviewer added that hopefully the impact of beneficial or negative impact of a NO_x catalyst in the inlet channel, walls, and exit channel could be explored.

A separate reviewer stated that it is clear that the PI would prefer to use the coatings from a supplier. It would be helpful to know what is preventing this from occurring. Another reviewer said that the project will configure combined function samples, age and examine performance with an internal formulation developed by PNNL.

A reviewer suggested that the team include other interesting information such as the changes in mechanical strength and the pore size distribution changes of the filter wall. A separate reviewer suggested the team will want higher porosity substrates, and then mechanical strength becomes an issue. The reviewer also stated that the team will need representative catalyst sources and fears that without a catalyst source and substrate source they may have limited success.

One reviewer suggested the team drop active regeneration quantification and efforts, and move towards fundamental characterization of the coating and back pressure contributions. The review also said there were limited resources, so focus on critical understandings.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that most of the tools for a good study are there, but there is a need for more impact-based particulate measures for mass determination and other methods for number determination, if the project can move that far. A separate reviewer said that resources are far short if you have to make your own substrates and catalysts, and perhaps excessive if the team does not have sources for those items. One reviewer said that it would be very helpful to see the extent of the contribution that has been supplied by PACCAR. Another reviewer said that the team needed a major washcoater involved in project.

Enhanced High Temperature Performance of NOx Storage/Reduction (NSR) Materials: Chuck Peden (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that this was a very significant program to develop catalyst technology. A separate reviewer commented that extending the range of NSR catalysts can allow the highly lean engine technologies reach application and reduce fuel consumption. One reviewer said that LNT catalysts with good performance at high temperatures are important for emissions control in newer diesel and lean gas systems that may be closer to the engine.

One reviewer commented that NOx control may be one of the most critical functions to enable 55% BTE engines for high efficiency vehicles, so this work can be highly relevant to petroleum displacement. A separate reviewer said that HT means HL, which means high NOx flux and as such HT LNTs are important.

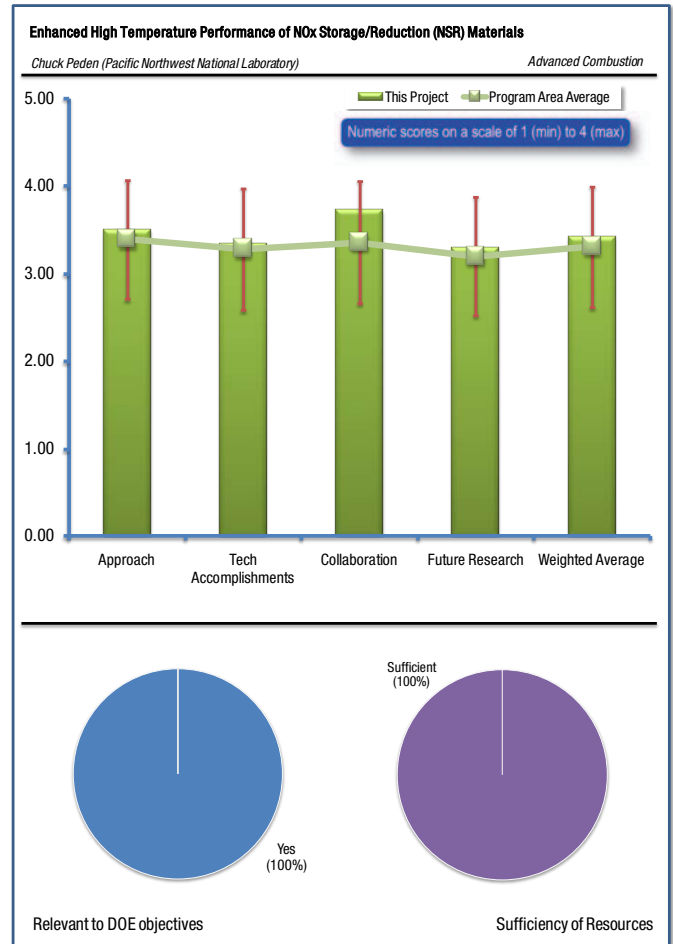
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said it is helpful that this work has debunked a wide range of NSR materials that have been floating around in the literature. The reviewer continued that potassium has been known as the high temperature storage material for quite a number of years and expanding the study of it to other support materials is the logical way to circumvent some of the deficiencies of the alumina based potassium oxides. The reviewer continued that having a supplier-produced high temperature NSR provides a very good benchmark for the work. A reviewer said that a team of lab, industry, and supplier with a history of good research has laid out a program and is very likely to make excellent progress.

One reviewer saw the project as looking at cutting edge industrial materials for benchmarking in developing “model” materials from PNNL and looking at gaps in commercial material and use information to develop a model is a strong approach. The reviewer added that the use of advanced analytical tools is important and needed to offer new insights.

A reviewer said that the characterization tools are more than appropriate. Another commented that the barrier to improved NOx storage capability for LNTs might require better support or storage materials, SOx stability/instability or develop a whole new concept. The reviewer added that working to develop a fundamental understanding for NOx storage materials for high temperatures for lean burn engines, by examining roles of precious metals, storage mechanisms, regeneration mechanisms and other topics and that this is done by studying commercial model materials using PNNL's catalyst characterization facilities.

A reviewer warned to try not to focus too much on fresh catalysts, and that there is a real need to understand the deactivation of aged catalysts but, most importantly, improve the thermal durability, SOx suppression, and DeSOx efficiency.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer commented that this program is just starting but there has been good progress so far. Another reviewer said that the project was starting to get some good results, and is looking at some areas of interest. The reviewer continued that it is very good to see results already for a project this is still relatively new; well done.

Another reviewer said that there was a good base of understanding on current formulation. The reviewer continued that this was very interesting progress on changing support material and added that this was an excellent direction.

A reviewer said that the novel area was looked at first, asking if NO_x decomposition occurs at higher temperatures with new materials. The reviewer continued that the project has shown that this is not the way to go: even for BaO/MgO cat, there is less than 2% conversion at reasonable conditions. The same reviewer added that the high temperature JM material shifts peak conversion without S to 400 to 450°C vs. 100°C lower in previous material. The reviewer also said that this was a very interesting result to understand. The reviewer also wondered what the lower temperature desulfation at 500°C means. The reviewer noted that here the NO_x adsorbed peaked for desulfation at 600°C and then fell with temperature. The reviewer felt that it would be good to see the amount of sulfur still on the catalyst in these studies along with precious metal and Ba particle sizes.

A reviewer stated that the technical accomplishments seem to just reinforce what we already know in the literature. The reviewer added that K is known to improve high temperature storage but the key open issues have been stabilization and deSO_xing at lower temperatures. The reviewer said that the interaction and characterization of K on the various supports is interesting and hopefully that will provide insight on how to stabilize it.

A separate reviewer commented that most of this work has been background work so far. Mostly the work is duplicating and validating what is already in the literature. A reviewer said that the project has surveyed recent reports of recent materials developments, but that these materials have too little activity. The reviewer continued that new materials are needed. The same reviewer also said that the project studied commercial catalysts for high temperature NSR and found some J-M work well in 400-450°C, but sulfur exposure and desulfation at elevated temperature degrades the material dramatically, and improved performance is seen for model Pt-BaO on MgAl₂O₄.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that the collaborations with Cummins, JM and BNL are well designed and should give this project the best possibility of success. A separate reviewer stated this collaboration with Cummins appears to be very strong, while a third commented that there is obviously a close and valuable working relation between the lab and industrial people and that the trust indicated by availability of state of the art commercial catalysts is a sign of the close collaboration and earned trust.

One reviewer said that having Cummins and JMI as partners will really enforce what is really important for high temperature NSR applications and determining realistic formulations that can be manufactured. Another said this was a perfect collaboration with OEM and catalyzer. The reviewer continued that this looks like a close collaboration with catalyzer. They know much.

A separate reviewer noted the project has had regular contact with Cummins, Johnson-Matthey and Brookhaven Nat Lab through a CRADA arrangement. The reviewer continued that there was no involvement of universities, which is a weakness of the project since this involves in part such fundamental, precommercial concept development.

QUESTION 5: HAS THE PROJECT 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?

A reviewer stated that working with both new materials and the best materials from a supplier plus the high powered instrumentation at the national labs is the best approach for this project. Another reviewer said that the plans are excellent and they have already commented on how nice it would be to have more details from the desulfation studies. The reviewer continued that looking at role of

K & Mg-aluminate in HT performance are important issues. The same reviewer continued that this is an opportunity also to see if there are ways to understand what the materials PNNL is making have to offer.

One reviewer said that the program direction seems solid and the program seems to be heading in a direction that should provide further interesting data moving forward. Another reviewer said that continuing studies of new NSR materials and characterization of NSR materials from J-M. A reviewer said that K migration must be solved for this type of NSR to work and suggested a focus on thermal stability and that the project should consider using Oxygen Storage Components in the formulation development and that they hoped the formulation information can be made available. Another reviewer added that there were excellent plans.

Another reviewer noted that a continuation of baseline understanding is proposed here. The reviewer felt that this was more of the same, and that while this might be called for, fundamentals on support/adsorbant seems warranted as well to set future direction. The same reviewer added that POx material to generate hydrogen will separate HT NOx capacity and HT sulfur adsorption.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer saw no evidence that this project has no studies that are not being done because of a lack of funds. A separate reviewer noted an appropriate level of effort for this valuable effort.

Degradation Mechanisms of Urea Selective Catalytic Reduction Technology: Chuck Peden (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that understanding of the degradation of DOCs and SCR catalysts is important for efficient diesel emissions control. A separate reviewer said that this was useful support for emission system development. Another reviewer said that examining the ageing of an SCR catalyst is of direct relevance and could have significant impact on the current state of the art in SCR design and development.

One reviewer commented that it seems that urea SCR will be a major part of future emission control systems and that understanding the degradation mechanisms is important to satisfying the long term durability requirements of the aftertreatment system.

A reviewer said that high-efficiency deNO_x is the future: the reviewer continued that aging dynamics and test protocols are critical to this. The reviewer concluded that the project is right-on target to high efficient diesel engines.

Another reviewer said that SCR NO_x control is an essential component of 2010 emissions compliant diesel vehicles and is potentially a critical component of 55% BTE engine systems. So, mitigating aging of the SCR catalyst supports deployment of high BTE vehicles which will displace petroleum.

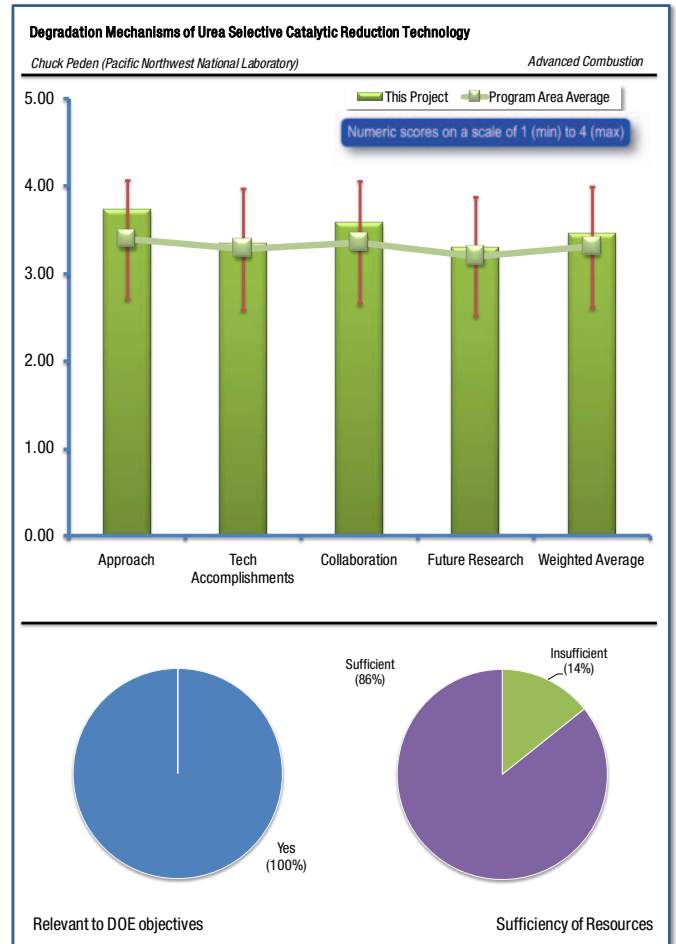
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said that in their view this is exactly the correct use of National Laboratory facilities where the unique instrumental techniques of the laboratory are used to investigate production-like materials. The reviewer added that in this case, GM acquires and ages the catalyst samples in the manner that they evaluate all their samples and PNNL uses instrumental techniques to determine the degradation mechanisms.

A reviewer said that the approach to work seems appropriate. Another reviewer saw this as a useful application of PNNL's analytical capabilities to up to date commercial catalyst with product relevance. One reviewer commented on the simple logical approach taken, noting the procedure of "age, test and analyze." The reviewer concluded that there were mutual benefits of OEM collaboration with NL analysis and that good teamwork is critical here.

A reviewer noted that the project was using model and commercial, fresh and aged SCR samples for analysis using PNNL's characterization tools to define the deactivation mechanisms, and to relate the performance to specific physicochemical changes in the materials.

A separate reviewer commented that on the DOC aging, stating that PGM sintering is interesting, but not really helpful. The reviewer continued that examining the SCR aging for root cause is also interesting, but it would really help if there was a component about



what can be done about this. The reviewer ended that without quantifying how to improve the catalyst, this is just a materials project to show what changed; not why or what can be done about it.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that this work seems to be well on its way to showing a direct relationship between PGM crystallite size and aging conditions. The reviewer added that this has long been predicted anecdotally, but this may put a clear functionality to it. The same reviewer continued that for the SCR aging there is evidence of a loss of zeolite cage structure with aging and that again, this has been long postulated and inferred from other work. Hopefully, this will give a direct functional relationship for this aging behavior.

One reviewer commented that considering the size of the project, a considerable number of results have been found, adding for DOCs, PNNL finds that the performance degrades because of sintering of DOC particles and their alloy formation. The same reviewer also stated that for SCR the work looks interesting with non-linear performance drop off in slide 13 and linear change in zeolite structure parameter in slide 14. The reviewer continued that the aging conditions are spelled out, so it is impossible to correlate the results. The reviewer does not believe this was asked during the presentation.

A reviewer noted that for DOC's, severe sintering of PGM is seen up to 100 nm crystallites, with a rapid size increase followed by a more gradual but continual increase and Pt-Pd alloying. The reviewer continued that for SCR catalysts, dramatic loss of function was shown over 40 hours of operation under aging tests. The reviewer continued that XRD shows some structural changes in the zeolite and there is sintering of the active phase particles.

One reviewer said that it seems very interesting; although with enough being confidential, it is hard to judge fully. Another reviewer said that DOC aging is quantified nicely. The same reviewer continued that NO₂ formation is tied to HC light-off quite strongly (need to eliminate CO/HC before NO₂ can form). The reviewer added that quantification should be done together with NO/HC/CO gas mixtures. The reviewer was not sure Pt/Pd alloying is causing the aging. Some formulations are alloyed purposefully. The reviewer concludes that grain growth is the culprit and needs to be quantified.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer commented that there was an active collaboration with GM with regard to materials preparation, characterization and performance analysis. A reviewer said that it is clear that GM is a direct and active participant and produces the optimal samples for investigation. The reviewer added that it would be helpful if this work were regularly reported on the CLEERS conference calls. Another reviewer said that this is a close collaboration with key companies, and that the willingness of industry to supply current state of the art catalysts reflects a high level of trust in the lab personnel. A reviewer said that they will assume the collaboration with GM is excellent, because of the quality of the people, although there is little evidence at this point of work done with GM.

Two reviewers were of a similar mind, one stating that it would help to have a catalyst company tied into this. However, the collaboration is good to see and synergistic. A separate reviewer suggested that the team needs to get the catalyst supplier involved so you can start to look at why the aging occurred and what can be done about it.

One reviewer said that correlation of laboratory vs. vehicle aged catalysts is very important and that they believe the right approach is being taken.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said that the team appears to be headed in a direction to develop those much needed aging relationships for each device. Another reviewer commented upon the complete characterization of lab aged samples, the opportunity to potentially modify aging protocol and define best tools for characterization.

A reviewer noted that the conclusion of Pt/Pd alloying appears to indicate sintering of the two metals. The reviewer wondered if in the fresh DOC, the Pt and Pd were completely independent of each other or were they already alloyed but very dispersed. The reviewer continued that the low temperature SCR deactivation involved the destruction of the zeolite and wondered if the acidity or NH₃ storage capacity could be checked. Was there a linear decrease? In addition, the high temperature deactivation was non-linear. A good understanding of the active component would be very interesting.

One reviewer said that there was a good plan in place, suggesting that an emphasis needs to be on characterizing and confirming aging mechanisms because this will set future direction on improvements. The reviewer urged the team to make sure they have this confirmation. (Is it really Pt/Pd alloying that is causing the problem?)

A reviewer suggested that for DOCs, it would be good to evaluate the ability of DOC to supply heat as well as NO₂ to the SCR and that it would also be good to independently, to the extent possible, vary the agglomeration of particles and their alloying. The reviewer asked if there is an explanation for why an alloyed particle is less effective. The reviewer assumed the aging conditions in the SCR will be done at temperatures and humidities that will bring out those effects explicitly.

One reviewer said to keep up the good work. A reviewer said that it would help to have the proposed work examine why the changes that were seen in the catalyst occurred and what can be done to make it more robust. Expand the scope and funding if need be.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said that the funding limits this to a small effort; it might be useful to expand the effort. A separate reviewer recommended an increased scope of work to include what can be done to make catalysts more robust, and this change in scope would certainly require increased funding. A separate reviewer saw no evidence that any part of this study is not being accomplished with this level of funding.

Experimental Studies for DPF and SCR Model, Control System, and OBD Development for Engines Using Diesel and Biodiesel Fuels: John Johnson (Michigan Technological University)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that this is an effort to develop a system integration approach which uses experimental information and system state software. The reviewer added that ultimately this type of approach will be used for control strategy development for these complex aftertreatment systems. Another reviewer said that the project addresses a significant gap in technology – OBD, adding that these are expensive and can take away from efficiency. The reviewer noted that better models and fundamental understanding is critical.

A reviewer said that improving exhaust system controls and OBD for biofuels will enable higher efficiency diesel vehicles that meet emissions standards and tolerate biofuels, all of which will displace petroleum. A separate reviewer commented that this project covers a range of topics that are relevant to efficient emissions control. OBD is an important topic that impacts on DOE objectives in terms of meeting them over the life of the vehicle. One reviewer said the project supports emission system needs. A reviewer said that it is also important to support this lab to maintain a core competency of the industry—modeling of cutting edge DPF and emissions systems.

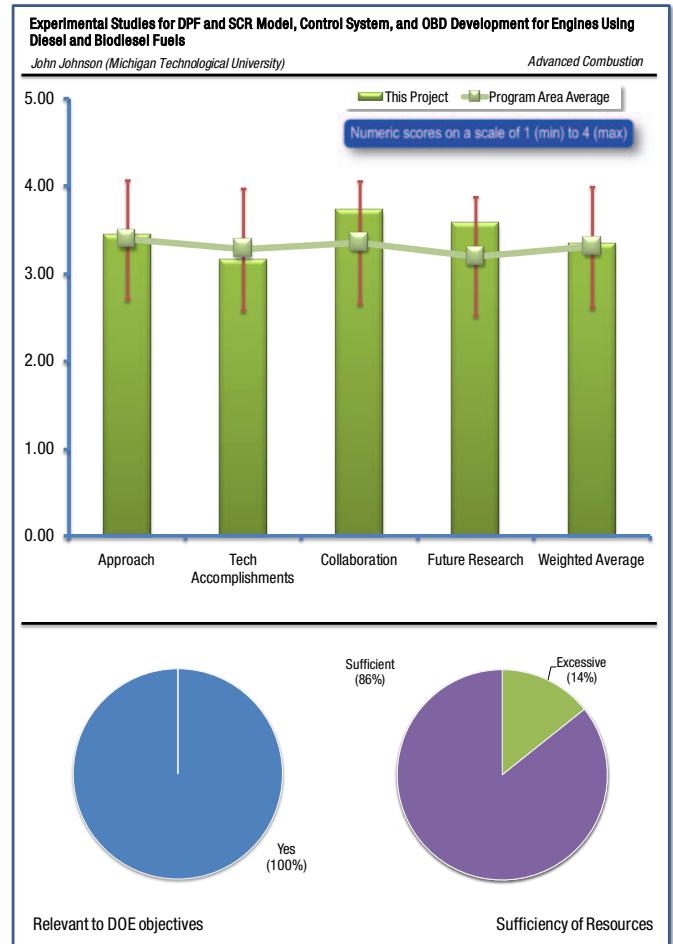
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said that developing an integrated software approach to predicting the state of the aftertreatment devices is absolutely crucial to full system modeling of these aftertreatment systems. Another reviewer said that this seems to be the start of a very good project.

A separate reviewer stated that it was a large collaboration and that key issues are being addressed. The reviewer continued that there was a good advisory committee and resultant approach. The reviewer also said that the approach of fundamental spatial measurements feeding into models was a good approach.

A reviewer said that the hypothesis is that if OEMs can access information on the “state” of aftertreatment devices (e.g., species storage), then system performance can be improved and understood to enable more frequent passive regeneration events which will save fuel.

A reviewer said that the focus is on DPF and SCR, but with the system view the DOC is very important to work on as much. Another reviewer commented that the ammonia will be measured in collaboration with Oak Ridge, but how is not clarified. The reviewer wonder if that will be done at Michigan Tech and would Watlow also be capturing temperature and species.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that it was a good start, but still early in the program. Another reviewer said that data is just coming in making it too early to comment. The reviewer added that the set-up seems ready for productivity. A reviewer commented that the preparation work seems to be completed, but there are no major accomplishments at this point.

One reviewer said that there are enhanced existing test cell facilities, and that protocols have been developed. The reviewer added that they have started engine testing for baselining of system performance.

One reviewer said that it is very early in this project and it has many ambitious deliverables and that several of the needed tools have been set up, but that it is too early to really evaluate the accomplishments.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer says that a good team has been brought together for a successful project. Another reviewer said that the interaction with ORNL is especially needed to make this project successful and that PNNL is very experienced in DPF loading and evaluation. The reviewer concluded that this is a highly integrated program and hopefully will be effectively coordinated.

A reviewer commented that there was a large team of collaborators with extensive experience and they were using a data inventory system to enable collaboration. One reviewer said that there was exceptional communication in place and the right players on board—multiple OEMs and approaches.

One reviewer said that this project has many important collaborators and that it will be important for them all to participate fully. Another said that it seems this project has many very important collaborators. It seems like a good team of industry, academia, labs, but the actual level of collaboration remains to be demonstrated

QUESTION 5: HAS THE PROJECT 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?

One reviewer said that it looks like a very good plan. One reviewer said that this seems to be a well focused future plan and they hope that delivery follows the plan. Another said that there was a good plan in place and that it was moving in a very impressive direction. The reviewer added that the work emphasizes passive DPF and characterization. The reviewer asked if soot will burn fast enough at low temperature and if there are mal-distribution issues.

Another reviewer said that the plans for research are very good, adding that it might be good to reconsider the importance of active regeneration of DPFs as a major topic, since more OEMs are using passive regeneration. A separate reviewer said that the team should complete model development, deploy soot morphology determination instrument, and complete ammonia storage study.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said there was an appropriate level of funding. A separate reviewer said that the budget seems very large for the potential benefits that are likely from this program.

Development of Optimal Catalyst Designs and Operating Strategies for Lean NOx Reduction in Coupled LNT-SCR Systems: Michael Harold (University of Houston)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that development of advanced lean NOx control is enabling of high efficiency vehicle systems and thereby can directly lead to petroleum displacement. A separate reviewer commented that this is designed to enable the implementation of non-urea SCR for either gasoline or diesel engines and that both of these engines are lean with higher fuel economy and consequently assist in the objective of petroleum displacement.

A reviewer said that LNT-SCR systems are ones we need to understand as non-urea systems that can still show excellent emissions control. A separate reviewer commented that LNT+SCR systems are a very interesting and promising approach to high-efficiency deNOx low cost systems for smaller HD and LD applications. Another reviewer said that SCR/LNT systems are clearly relevant as we move forward with diesel catalysts and there are certainly a lot of open questions on this subject.

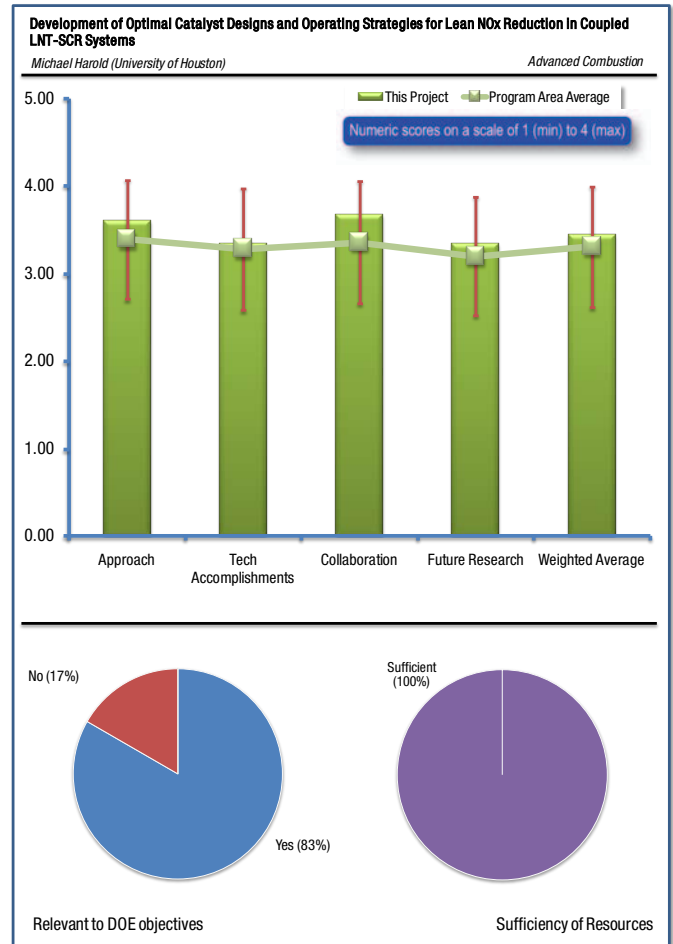
One reviewer said that this project does not support petroleum displacement and that it is aligned with the ACE 2009 goals posted on the DOE website. The reviewer concluded that at best, there is only a very remote connection between the output of this effort and petroleum displacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that the tools being brought are excellent and the involvement between the partners appears to be well thought out. One reviewer stated that this project has gained access to a very new supplier technology and that the connection to Ford who is planning to implement an LNT/SCR lean gasoline technology is the best way to transfer the technology.

Another reviewer saw this as a fundamental/academic study of chemistry of LNT-SCR. The reviewer added that toward this purpose, some progress has been made but it is hard to assess the impact of the program or recent results as no strategy or risk mitigation plan was presented. Is the goal of this work just observations and hypotheses to drive suggestions for catalyst design? The reviewer continued that the approach stated (use noble metals in the SCR instead of LNT and generate NH₃ in LNT) is good, the presentation does not focus on this...program and presentation needs focus toward goals that are measurable and time driven.

One reviewer said that the team is examining LNT/SCR reactor and catalyst coupling, looking to learn what specific species are emitted by the LNT that assist the SCR to function and that the objective is to reduce or eliminate the need for urea.



A reviewer said that the project was heavy on fundamental kinetic measurements and modeling, with some vehicle testing. The reviewer also said to work closely with CLEERS to avoid duplication of work already done and that it is important to focus on fundamental chemistries, as this will drive innovation in the private sector.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that for a project that does not start until this October and is already 10% complete, this project is doing very well. The reviewer continued that the project is ambitious, but all of the pieces have the potential to get excellent results. The reviewer also said that the LNT-SCR system shows considerable promise and is important to understand. The reviewer also commented that the Ford results suggesting organo-nitrates are formed along with ammonia are very interesting and that ethylene ammine may exist at mass 42 in this work. The reviewer ended by saying that the data and understanding will come from ORNL and UK. The modeling at UH will provide much of the ultimate benefit.

A separate reviewer commented that was a very impressive array of data and implications on directions. The reviewer was really looking forward to more data coming in and also said that this is quite a complex system and the team has the tools and demonstrated analytical capability.

One reviewer said that project was producing kinetics of ammonia based SCR and storage and regeneration of LNT and produced and surveying evidence of ammonia release from the LNT that reacts in the SCR to reduce NO_x. The reviewer suggested that to verify the HCNO formation mechanism, the team should consider using an isotopically labeled HC reductant.

Another reviewer suggested that there are a large number of observations that are very provocative. The same reviewer expressed concerns that there does not seem to be closure on a number of the observations. The reviewer gave the example of the propylene NO_x reduction observation being quite interesting; however, there was no closure on this observation. The reviewer suggested that perhaps there would be more clear accomplishments if there were more focus to the work.

One reviewer said that it seems that even after a year of work, this is still at an observation stage, adding there was some speculation, some early pathway proposed, but it seems like it could be behind schedule. The reviewers said that it was hard to tell without visible time driven goals in the presentation.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this incorporates an OEM, catalyst supplier, national laboratories and academic institutions and that this work has been reported at the CLEERS workshop and the conference calls. The reviewer concluded that clearly this work is regularly held up to scrutiny by a number of high expertise parties.

One reviewer said that there was an excellent choice of collaborators, making a very strong project. A separate reviewer commented that all key players are in place with good communications and project planning. The reviewer added that technology transfer is in place as well as checks and balances.

A separate reviewer said that there was a good cross section of participants which seems to cover all the main technical areas in question here and that thought was clearly given to get participants with varying areas of expertise.

A reviewer said that the project had multi-university, national lab, supplier and OEM involvement and that there was an exchange of materials, sharing of testing expertise and capabilities, and exchange of information to support modeling efforts. One reviewer stated that from the results presented, the synergistic impact of the collaboration is not obvious—appears partners are acting a bit independent.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that the plans are well thought out and continue in the direction laid out already. Another reviewer said that the plan is right on target for accomplishing meaningful results. The reviewer suggested that the team should be careful on spending too much time on interesting but low impact kinetic studies, for example on the complexities of the non-NH₃ route unless warranted.

Another reviewer commented that there were continuing spatiotemporal studies of species to support model development, and suggested in-situ DRIFTS studies to better understand mechanisms.

A reviewer was concerned that the project has gotten too unfocused due to the large number of collaborators and felt that the presentation did give the feeling of a number of experiments that were not tightly coordinated. A separate reviewer commented that there were lots of parallel paths—too broad and fundamental in scope. The reviewer added that future research does not show a path of down selection which drives the effort to a goal or deliverable.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer commented that there were lots of resources and wondered if they are creating synergies. Another reviewer said that there are quite a number of partners in this project and that funding of this level is necessary to accomplish the goals. The reviewer added that they did not see evidence that this project is not accomplishing its goals.

Three-Dimensional Composite Nanostructures for Lean NO_x Emission Control: Pu-Xian Gao (University of Connecticut)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that new materials for lean NO_x control could make NO_x control easier and more cost effective for high efficiency lean burn engines. Another reviewer commented that exploration of novel catalyst materials is important to make sure we have the best nanostructured catalysts.

One reviewer said that there was a very appropriate expenditure of some funds on new classes of catalysts for deNO_x and that this is an interesting approach for a class of materials that have interesting deNO_x potential. A separate reviewer said that a goal of reducing the precious metals in the emission control systems assists the DOE objective of petroleum displacement by reducing the costs of the emission control systems.

One reviewer stated that this project is very removed from having direct impact on petroleum displacement and that this is a fundamental research program on catalysts and emission reductions. A separate reviewer stated that the relevance of this seems strange, especially since there is not a substrate or catalyst supplier involved. The reviewer understands the importance of this type of work and will call it relevant, but without engine catalyst/substrate supplier involvement, this really is “borderline.” The reviewer also said they supported the development of new materials, as there are certainly deficiencies with today's systems.

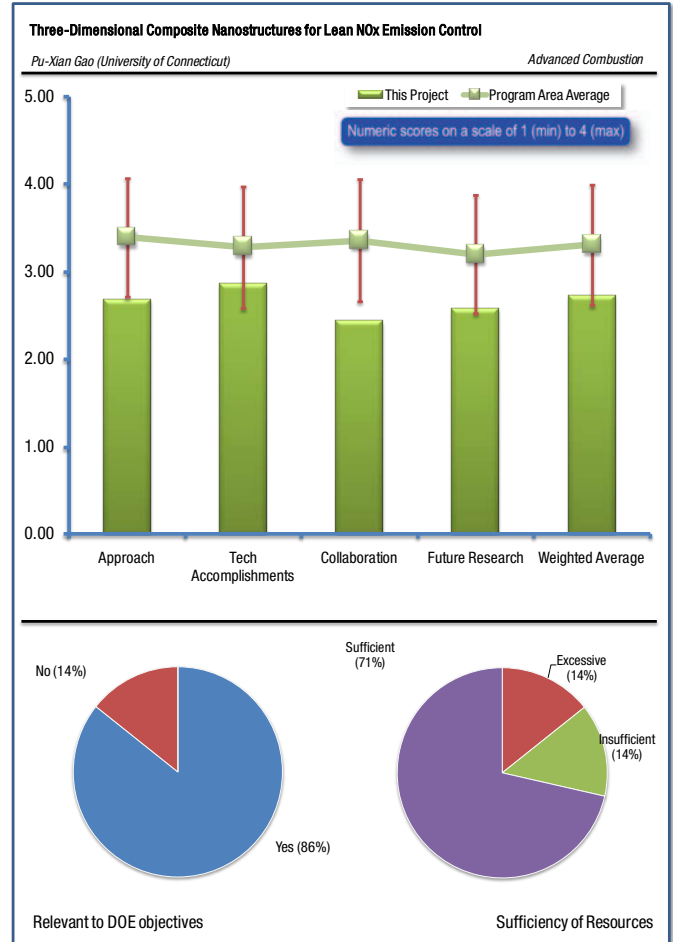
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that the approach described in the presentation is ambitious, but chooses correct things to study. The reviewer added that for this new project, if they can be achieved, it will be very successful. The reviewer continued that one major goal is ultrahigh surface area for the catalyst and that it was not clear what method(s) would be used to show that. The reviewer continued that the 3D structures shown are like overlapping dendritic arrays, which still have large open spaces relative to the surface area available.

One reviewer said that this was an interesting plan and that they support the development of new materials and uncovering what could be a potentially new direction for catalysts.

A reviewer said that the project was looking for non-precious metal emission control catalysts and synthesis of nanostructured metal oxide arrays. The reviewer added that there was characterization and performance analysis as well as atomistic simulation of catalytic reactions.

One reviewer said that the approach is all about synthesis, but gave very little information about how it would affect engine emission reduction. The reviewer continued that the project has spent a lot of time in developing and characterizing the various material



compositions. The reviewer was hoping for some performance data by now and didn't see any evidence the team will meet the overall objective of lower or no PGM usage and an enhancement in the activity and durability of lean NO_x catalysts.

Another reviewer said the approach dives right into synthesis without a pre-screening step on determining what to make. deNO_x functionality seems to be missing or coming in a later stage.

A reviewer said that the concepts for catalyst design do not evidence a path to displace use of noble metals or a mechanism as to why the design was considered and that there were too many materials growth approaches. The reviewer added that it seems like the background research was weak and that the work would benefit from experimental design approach.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that there was very impressive synthesis range and ability and that one can see how these structures might have strong catalytic activity. The reviewer suggested that perhaps a surface area measurement is needed, as this is what drives catalyst activity, particularly at low temperatures.

One reviewer said that they had begun the synthesis activities. The reviewer added that the team had made 3D nanostructures of various oxide materials, such as shell layers and nanowire arrays, and coated these nanostructures with surface layers of LSMO. The reviewer added that some catalyst surface modeling had been completed.

A reviewer noted good progress on creation of structures, but that the project does lack some direction of what they are going to do with this and which catalyst is truly required and how it would fully interact with these structures. The reviewer added that the substrate and the catalyst need to be very well integrated to operate at high efficiency and this requires program direction.

A reviewer said that there was a fantastic job of characterizing the materials but no catalyst performance accomplishments are shown yet.

One reviewer said that it is very early in the life of this project and they have shown several materials that may be interesting and there also is modeling on some of those surfaces. The reviewer suggested the project needs to focus on demonstration of all the criteria listed on slide 5 - Approach. It was also said that it was not clear how enhanced surface areas would be demonstrated.

A reviewer stated that this group is very good at design and synthesis of perovskites, but there is no indication of engine exhaust emission reduction.

One reviewer said that no cause-effect learning reported, no alignment to a materials specification or properties goal that would give desired catalytic performance, and there were many random, unrelated results reported, not obvious to catalysis. The reviewer felt that the project organization is poor and that the vision is not supported.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this is an interesting fundamental synthesis study but practical direction will be critical to get good return on investment. The reviewer added that UT provides practical synthesis and Honda on practical application, noting that the UConn lab has very interesting analytical and modeling capability but may be lacking in application to catalytic application to automotive. The reviewer suggested the team leverage Honda strongly on making sure the right experiments are performed to link back to the application.

A separate reviewer stated that there was collaboration with Honda Research Institute (catalyst testing) and United Technologies (materials characterization). One reviewer stated that Materials Development was inspired by Honda support with further support from UTI, but the actual capabilities of partners to fit with responsibilities are not spelled out in detail.

Another reviewer said that obviously Honda has shown interest in this project, but they have not shown any obvious interaction on this project. The reviewer added that it almost feels as if this is a fishing expedition and indicated they would like to see more indication

that Honda is directly involved in showing why this is a good set of materials to investigate. One reviewer was not clear on what Honda has contributed yet and a separate reviewer saw no evidence that Honda or United Technologies is doing anything and where their activities kick in. The reviewer added that this program would benefit from a group experienced in materials characterization for catalysts.

A reviewer commented that there was no involvement of major catalyst suppliers. Another reviewer said that the major partner is Honda, and wondered why DOE is funding a project where there is only a 20% cost share with a Japanese supplier. The reviewer felt that this project collaboration absolutely needs to be broadened to include U.S. based companies, and this absolutely should include a catalyst and substrate supplier. The reviewer added that this poor collaboration is a gray cloud over what could be a very interesting project.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that they like the modeling aspect of the project. The reviewer felt that an answer, by the team, to one of his questions was clearly “hand waving.” The reviewer would like to see more application input for this project.

One reviewer commented that the plan is good and very necessary right away, adding there was a need to know how the material behaves as a catalyst, what the durability is, and what the cost looks like. The reviewer asked if there any benchmarks that could be used to compare the activity and durability of the material and show how it is better.

A separate reviewer commented that it is key to get performance results ASAP to help guide synthesis and material choices. The reviewer continued that NO_x testing on planar surfaces would be a good start and needs to be implemented for feedback, asking if this process can yield improvements over current materials. The reviewer concluded that this is key and direct feedback from performance is critical.

One reviewer noted testing of catalyst performance and behavior, continuing simulation efforts. The reviewer saw no mention of poisoning resistance studies of these candidate materials.

A reviewer felt there was too much effort on materials growth, materials testing—no timeline or criteria for downselection shown.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that so far the team is not getting much at all for exhaust emission reduction.

Efficient Emissions Control for Multi-Mode Lean DI Engines: Jim Parks (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

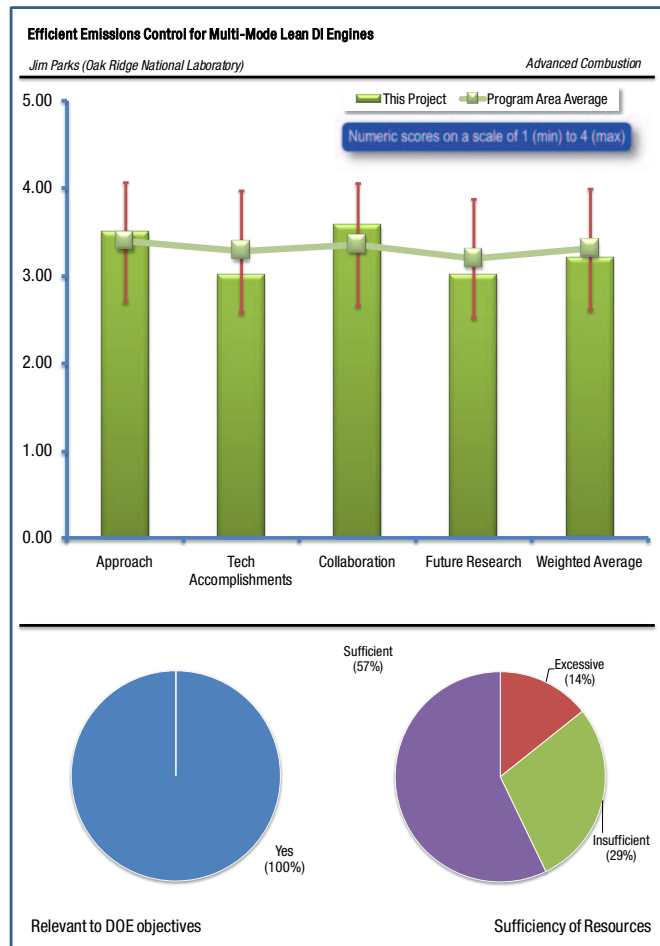
This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that lean burning engines provide efficiency improvements over stoichiometric engines that comprise the majority of the passenger vehicle fleet, so development of efficient emissions control strategies for lean burning engines will help to displace petroleum. Another reviewer said that lean-burn technologies have practical limitations in the U.S. that are being addressed here.

Another reviewer said the soot sensor and the dual fuel engine are both projects with high relevance to our plans moving forward. One reviewer commented that developing a good DPF loading sensor and the relation to low temperature combustion enables the low temperature combustion technology, which is designed to reduce over diesel emissions.

One reviewer said that the range of deliverables is all related to more efficient engine operation or more efficient emission control. A reviewer said that it is closer to the goal than other projects, highlighting tradeoffs of emissions and efficiency in DI engines.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that examination of multi mode engine operation to achieve low engine-out emissions and coupling (or lack of it) to aftertreatment systems is a very important system view in the project. Another commented that this approach is well focused on determining and regenerating loaded DPFs from HECC combustion systems.

One reviewer commented that characterizing emissions from advanced combustion operation and looking for synergies with aftertreatment strategies. The reviewer added that the approach leverages the skills and experience at ORNL.

One reviewer said that the exploration of dual fuel systems is an extension of the above work to verify the work at the University of Wisconsin and that RF sensing of particulate matter is a separate and interesting project. A reviewer said that it appears to focus on survey of methods and performance. The team needs to show a path to convert learning to improve engine performance.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said that developing and implementing the RF soot loading sensor technology is a solid accomplishment. A reviewer noted that the results for all to the aspects of the project were very satisfactory, but that the prospects for commercialization of RF particulate sensor were not discussed.

A reviewer commented that the program had been moved to a new 1.9L GM engine and the team began studying emissions control in concert with the dual fuel strategy of the University of Wisconsin. The reviewer noted that the project was also characterizing urea-SCR for HECC operation and had completed characterization of RF-based DPF diagnostic strategy.

A reviewer said that the RF sensor shows very interesting results, but needs to see long term impacts as ash and residual soot from partial regens build. A separate reviewer commented that there were some interesting observations. The reviewer continued that the project was missing linkage or plan on how observations will drive improvements in engine performance, but no short or long term targets communicated.

One reviewer stated that the work on the soot sensor was interesting, although a very clean answer relative to its accuracy in soot load measured (RF) vs. soot load weighed would have helped. The reviewer said that this would give a direct answer to the merit of this technology, especially if the “state of the soot” has an impact, as we all know that soot can certainly vary in its structure (solubles, particle size, agglomerate size, etc.)

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said the University of Wisconsin collaboration and the MECA collaboration satisfy both the technical needs and there was a good relationship with industry. A separate reviewer commented that the collaborators are well suited to project along with the skill sets at ORNL.

One reviewer commented on the excellent broad range of participants, technology transfer, direction, and communications. Another noted that the team was working with MECA and suppliers, with a link to CLEERS and other ORNL programs.

One reviewer said that the activity of partners and impact on reaching a defined goal not detailed in presentation.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that these are logical progressions from the work already accomplished. Another said that the project would continue dual fuel emissions and emissions control studies and HECC mode SCR NOx measurements.

A reviewer suggested that it would be good to have a means of connecting the various aspects of the project into a system for different operating conditions.

It will be important to distinguish the testing of urea-SCR catalyst usage for HECC from that of other studies of aging of urea-SCR catalysts. Another reviewer said that the engine needs to focus on delivering high efficiency. The reviewer recommended the team use EGR in the dual fueled engine to gain efficiencies and then look at emission control needs, focusing on most difficult and highest emission impact load point.

One reviewer said that the presentation was focused on observations and test development and asked how this will be leveraged for improved engine performance.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that this is very interesting work, linking aftertreatment and advanced combustion, adding that more resources should be moved into this program.

Another reviewer said that this is quite a valuable approach and in need of more resources or continuance. The reviewer continued that running at high efficiency delivers new challenges on emission control and the program needs to focus on critical aspects with the current limited funding, and that one approach is to deliver high-value results to justify further investment.

A reviewer said there were too many parallel efforts with no visible alignment to a goal related to engine performance, adding that it would be helpful to see the PI's vision and deliverables.

Cummins/ORNL-FEERC CRADA: NOx Control & Measurement Technology for Heavy-Duty Diesel Engines: William Partridge (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that reducing the burden of NOx control for lean burning heavy-duty diesel engines will lead directly to fuel savings and thereby to petroleum displacement. Another reviewer said that analyses in this project have made advances to meet DOE objectives for many years in an excellent collaborative effort.

Another reviewer said that it was a novel project incorporating new objectives (cylinder to cylinder variability, smart catalysts, new measurements like fuel in oil and H₂O) and that close collaboration with industry is important. One reviewer said that this work is an example of utilizing the unique instrumental capability of the national labs to develop instrumentation that advances engine and aftertreatment technology. By advancing engine and aftertreatment instrumentation this work enables more sophisticated and fuel efficient transportation technologies.

A reviewer felt that the project was very remote from DOE objectives. This is a test and measurement program. It is not obvious from the presentation how this work will improve engine (maybe this is proprietary to Cummins) but something that should be clearly communicated.

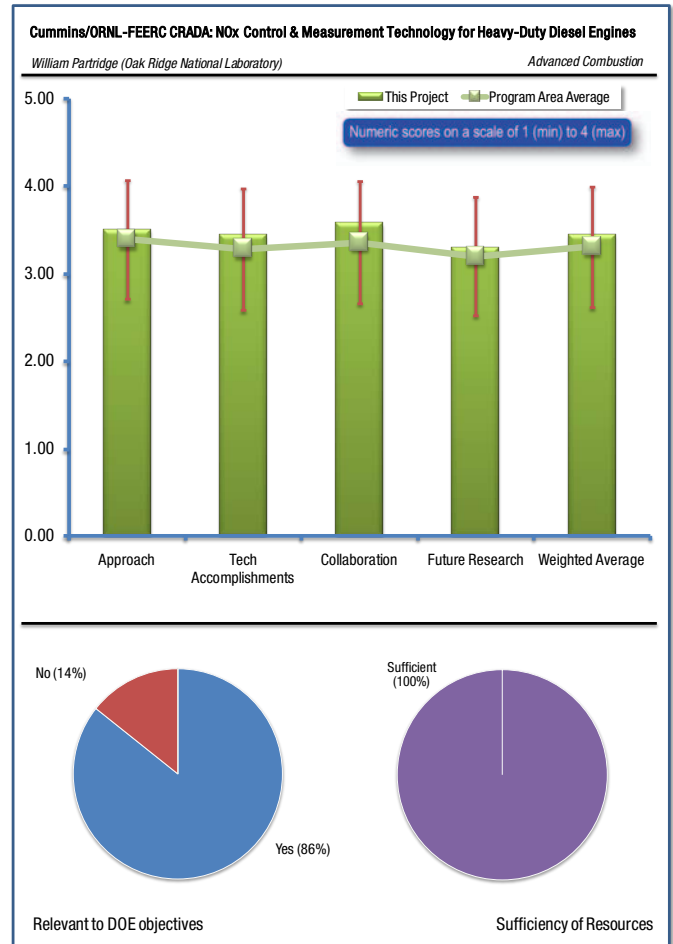
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that this work is effectively a set of smaller problems that can be solved with improved instrumentation and that each of the solutions presented here is a unique approach to the solution of that problem. The reviewer added that there is not actually a major global goal. A separate reviewer said that this was a winning approach and is a model for others and that the team should keep it up.

One reviewer stated that this was a long-term program seeking to overcome combustion, emissions, controls and durability challenges associated with developing cleaner and more efficient heavy-duty vehicles. The reviewer added that specific areas of study are combustion uniformity (spatially within cylinder, cylinder-to-cylinder) and controls/sensing to improve uniformity.

A reviewer said that the project had reported a good selection of tests in development that can help understand things that impact engine performance and are of interest to the audience. One reviewer said that the Cummins CRADA started in 1998 and continues with modifications and that it uses a wide range of methods along with specific ones that ORNL has developed.

One reviewer commented that the work has been performed in a few areas of direct interest and the results overall have been good. The reviewer added that the overall approach seems to be a bit scattered rather than having one clear cohesive objective, but that this seems okay in this instance.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer noted that on combustion uniformity, a fuel-in-oil diagnostic has been demonstrated and is now being implemented by Cummins. The reviewer noted that the device has been commercialized. The reviewer added that a fast exhaust measurement technique for H₂O was demonstrated and that the project was working toward “smart catalysts” using SpaciMS to understanding how catalysts can form beneficial intermediates. The reviewer saw these as significant practical outcomes.

Fuel in oil was described as a major accomplishment. The reviewer added that the fast exhaust water measurement is an interesting way to measure cycle to cycle variability, but they were not convinced it is an optimum solution. The reviewer added that time will tell if it shows long-term application. The reviewer added that the ammonia measurements are very interesting since this technology seems to be headed toward production application.

A reviewer said that the project met targets for combustion uniformity with water measurement and that the fuel-in-oil (FiO) diagnostic in ten minutes vs. days is a big improvement.

A reviewer said the project took a new approach to cylinder variability yielding new insights such as water and soot. The reviewer described the work as very good. The reviewer added that the intra-SCR distributed NH₃ storage project is also yielding new results that will be very important for ultra-high efficiency SCR deNO_x. The reviewer described these as very critical and useful results.

A reviewer saw good progress on short term test development goals, but added that the team did not report having seen impacts on engine improvement.

A reviewer said that although the H₂O measurement technique has been developed, the implementation on the engine combustion seems weak so far.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this group has been very effective in getting their instrumental solutions into the marketplace and this past year has been very successful for them. One reviewer commented that this was a very broad collaboration and in such collaborations communications and coordination become critical, with flexibility to adjust as new results come in. The reviewer added that this collaboration seems well functioning.

One reviewer said that this was largely an ORNL and Cummins team, but that is acceptable in this case. The reviewer understand that there were a lot more people mentioned relative to collaboration, but it seems the main program direction is set between only the two main partners. The reviewer continued that this is not necessarily a bad thing. The reviewer awarded the project bonus points for letting DaVinci commercialize some of the output from this project.

A reviewer saw a direct collaboration between Cummins and ORNL, with support from other industry partners and universities. Another reviewer noted that collaborative partner, Cummins, has a broad view of emissions control.

One reviewer said that it was not so obvious from the presentation how the synergies are coming from collaboration and impact on the engine improvement—too many parallel paths.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that proposed future work is good and the ammonia mapping is especially crucial. The reviewer was not fully convinced that the water measurements would be strongly utilized in the industry. These are new approaches to solving next-generation problems.

One reviewer said that ammonia SCR project is very critical. Industry will need 95+% SCR and this detailed understanding is needed. The reviewer suggested the project move forward with this in mind, focusing on how the results will improve performance. The reviewer suggested the academic groups might focus on fundamentals and interesting findings with the industry groups focusing on implementation.

A reviewer said that diagnostic tests were interesting and wondered which one will impact engine development and improvement sooner vs. later or at all, noting that this was not discussed.

A reviewer said the project was continuing many parallel efforts on in-situ intermediates measurements, fiber-based sensors, simulation and applying the diagnostic sensors.

One reviewer felt it was not clear on the type of LNT and SCR catalysts planned for testing. The reviewer encouraged the project to include both Fe/SCR and Cu/SCR catalysts. In addition, the reviewer wondered, is it possible to work on Spaci sampling of the SCR catalyst on the engine with urea injection?

A reviewer said it would be good to study a Cu catalyst that does not have the ammonia coverage dependence that Fe and vanadia catalysts have. The reviewer wondered if temperature sensing is included in project with Spaci-MS.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that the group has been very effective in utilizing their in-house resources along with their various industrial partners. One reviewer said that the program would benefit with a goal toward measurable improvement of engine performance factors via the testing methods developed. A reviewer commented that long term support for this CRADA has enabled many successes and an ability to dig deeply into problems and develop effective solutions. The reviewer also said that this is encouraging given how frequently the VTP is asked to shift directions in response to changes in public and government interests.

*Pre-Competitive Catalysis Research: Fundamental Sulfation/Desulfation Studies of Lean NOx Traps:
Todd Toops (Oak Ridge National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that LNT improvements will assist with DOE objectives. Another reviewer said that technologies that improve aftertreatment for lean systems enhance the implementation of lean engine technologies, adding that lean engine technologies will reduce our dependence on petroleum.

One reviewer said that LNT is a core technology for deNOx and high-efficiency lean burn engines and taking new incremental approaches can result in fast adaptation and improvements. One reviewer noted that as far as studies on LNT, particularly catalysts that while there is a known connection to efficiency improvements, not much discussed on how the deliverables of this work will be realized and the projected downstream impact.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

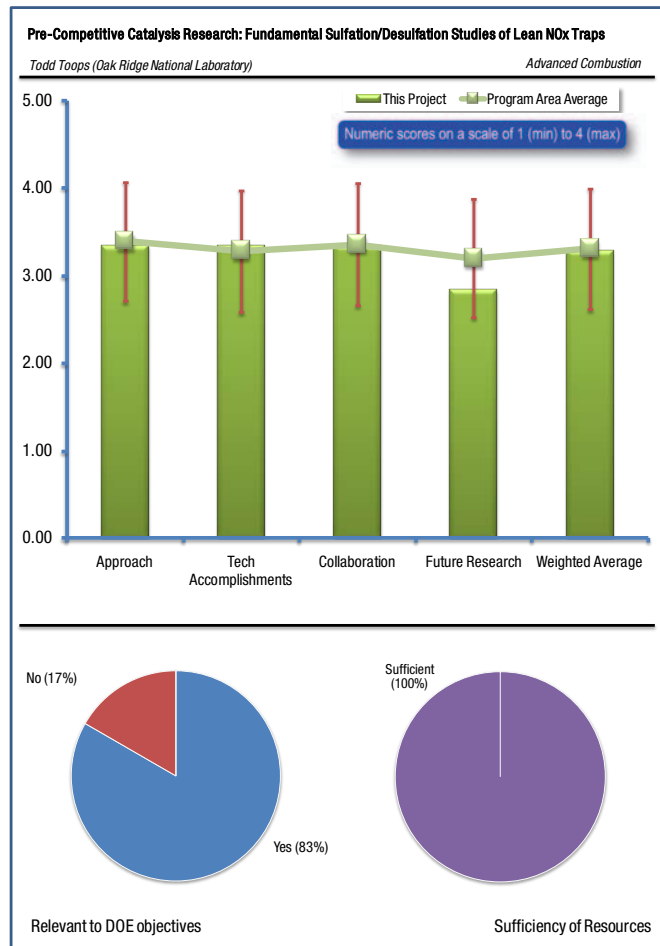
One reviewer said that the general approach to try new materials experimentally and with modeling is an excellent way to proceed. Another reviewer said that the items being examining with respect to LNTs and methods to further improve and understand them is of great interest and the plan is set to looking into areas of definite interest.

The reviewer saw a two-tiered approach of evaluating current catalysts and functionality of individual components, and exploring synthesized new materials. The reviewer said that the cross fertilization of these approaches is interesting.

A reviewer said that evaluation of dopants and supports is a logical way to approach the problem. The reviewer added that the negative is that the selection of dopants and different supports seems to be anecdotal. The reviewer suggested this study might benefit from a combinatorial approach since most of these materials have already been considered in the past.

One reviewer felt it was not clear on how SO₂ was measured during DeSOx tests. The reviewer asked how the deSOx was performed in Addison and what the gas conditions were during the DeSOx tests. The reviewer noted that depending on the deSOx conditions, a significant amount of H₂S is generated.

One reviewer said that this was a well-organized presentation, but absent of time-driven, measurable goals how is success defined here?



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that Ca-substituted LNT is yielding interesting findings on sulfate stability and NO_x interactions. The reviewer stated that the results are impressive and yielding promise. The reviewer added that the impact of high sulfur capacity and stability on NO_x functionality is correct bottom line analysis. The reviewer said that there were fascinating results on commercial catalysts and surprising and significant findings on Mg-Al₂O₃ impacts.

One reviewer said that very interesting results were obtained that lead to improved and lower temperature desulfation of LNTs. The reviewer added that using new catalyst materials that allow lower temperature desulfation with 5% Ca is an example.

A separate reviewer said that calcium dopant study is helpful and interesting and it seems as if the MgAl₂O₃ has been significantly evaluated by the suppliers. The reviewer added that the addition of Ceria-Zirconia is almost a given since most of the LNT systems rely on an oxygen storage material to enhance the NO_x reduction activity.

One reviewer said the impact of work on Ca role is presented well, but the team needs to tie this to a deliverable and a bigger picture.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said that this project has a strong group of collaborators. Another said that there is good opportunity for collaboration on this and it seems this information is being shared across a number of interactive groups, which is an excellent way to get the results out there. A reviewer noted good collaboration with Umicore and other centers at ORNL and CLEERS.

One reviewer said that the collaboration with Umicore is good but expressed concerns that there does not seem to be an OEM in the collaborative activity. The reviewer suggests that this study is perhaps best suited to a lean gasoline application and having an OEM as part of the work would be a significant benefit.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that lowering the deSO_x temperature under realistic deSO_x conditions is the most important metric. The reviewer asked if the project team can please describe this area in more detail next time. In addition, the reviewer requested the team please report all sulfur compounds during deSO_x (SO₂, H₂S, and COS).

One reviewer said that the plans are excellent, suggesting that it would be good to add microscopy to examine the materials with higher Ca content. The reviewer also said that in appropriate places, it would be good to add HC as a reductant to compare with H₂ in desulfation studies to be closer to a more realistic reductant.

A reviewer suggests that the project may wish to incorporate at least one additional level of PGM in the early screening studies on synthetic mixtures. The reviewer stated that PGM can significantly impact sulfation and NO_x functionality. The reviewer said there was a need for close collaboration with Umicore on logic of component additions and expected results.

One reviewer suggested that the project would benefit from discussion on the state of progress with respect to a deliverable or measureable impact on engine performance. A separate reviewer said that the future work is bits and pieces and does not bring any of the present studies into a focus.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer says that this seems like one of the better collaborations reviewed today.

*Advanced Engine/Aftertreatment System R&D
CRADA with Navistar, Inc.: Josh Pihl (Oak Ridge
National Laboratory)*

REVIEWER SAMPLE SIZE

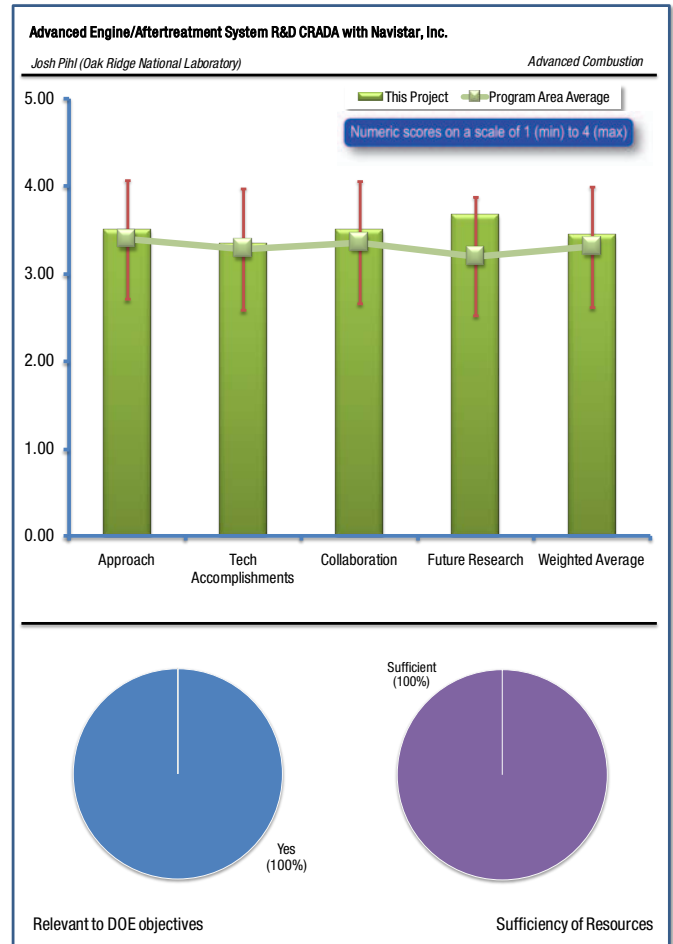
This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer says that the pursuit of improvements in NOx remediation and particulate removal is important and has been pursued well in this project. A separate reviewer commented that looking at the performance of SCR and DPFs is very relevant and of direct interest to a good many in industry.

One reviewer said that kinetic development for both DPF's and urea SCR systems is needed to be able to model the optimum configuration of the devices and this work provides information on those kinetics.

One reviewer noted that although long-term approach is towards high NOx, low PM operation for maximum engine efficiency, Navistar sees significant market segments that are resistant to this approach using SCR. The reviewer says that for these segments, DPF FC can become critical. Expenditure is modest and probably worth proceeding despite bucking of the long-term trend.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer stated that the approach of quantifying high level reactions on real life substrates for DPF and SCR is high value work on components of direct interest. The reviewer continued that folding these results into modeling is an excellent approach and should be pushed even harder, as modeling is the best method to exploit this knowledge.

A reviewer said that the range of tools was very appropriate for questions being pursued. Another reviewer said that there was a successful approach and results on SCR and that this was nice.

One reviewer said that this is two separate, relatively disjointed kinetics studies and that both kinetic studies are very worthwhile. The reviewer did add that the project does seem to lack a tight focus. The DPF OEM recommendation on materials, fundamental evaluation by ORNL, OBD and model incorporation with MTU were all aspects observed by the reviewer and stated to be very good.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The experimental evaluation of the kinetic response of the SCR catalyst is quite good. It remains to be seen if the CLEERS SCR protocol will provide sufficient information to develop accurate global kinetics.

One reviewer said there were many interesting results. The reviewer gave the example of how at low temperature, the system needs more like 1.2 NH₃/NO_x ratio to get good performance and the plot of activity vs. NH₃ adsorbed shows where the system should operate. The reviewer also said that for aging, the Pt deposition factor was interesting to prove in sectioned SCR catalysts. The

reviewer continued that for DPF work this year, aluminate, SiC and titanate all look similar in regen, but in back pressure variation is different, SiC falls more slowly.

Another reviewer made similar comments, noting that there were very interesting results on SCR. The reviewer said that this is critical to industry-wide approaches and the future need for 95+% deNOx systems. The reviewer also said that NH₃ adsorption and NO/NO₂ reduction characteristics might be explained by site of NH₃ adsorption vs. site for NOx reduction and NO oxidation (Yezerets, SAE 2010). The reviewer also said there were very interesting results on Pt migration and SCR aging and that preliminary DPF results show interesting trends on substrate impacts on regen and back pressure.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that the integration of the supplier, OEM, and an academic institution is very good and provides a wide range of background under which to develop and apply the kinetics. Another reviewer said that the collaborations with Navistar and Michigan Tech appear very strong. One reviewer said that you will need strong collaboration with Navistar on the DPF, as their situation is unique.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said that this long-term project has obtained many excellent results. The reviewer added that the effect of NH₃ coverage on SCR performance should also be done on a Cu catalyst for comparison with Fe. It supposedly has no large coverage dependence and that in an aging study it is also good to check the performance of front of second catalyst to see how it compares with back of first catalyst. There can be more aging at front of second catalyst.

A reviewer said that the focus for the future has ORNL focusing primarily on the soot oxidation kinetics and MTU developing the SCR kinetics. The reviewer suggests that it would have been better if MTU had been developing kinetics while the SCR experiments were ongoing in order to optimize the experimental-kinetic development interaction.

A reviewer suggested the project look at the Cummins SCR SAE 2010 paper on Fe- and Cu-zeolites and NH₃ adsorption vs. NOx reduction and that this might help explain the results better. The reviewer added that DPF direction is valid and will yield interesting findings.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were made.

Development of Chemical Kinetic Models for Lean NOx Traps: Richard Larson (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that model development is a critical part of making use of the data that is obtained on these emission control systems. A separate reviewer said that good kinetics and modeling are needed to advance field and that this is a key cornerstone.

One reviewer said that modeling of aftertreatment devices provides two benefits: one is to provide a global mechanism which can be used to simulate full aftertreatment architectures, and the second is to provide kinetic insight into the microkinetic behavior of the catalyst. The reviewer adds that this work provides microkinetic understanding of the LNT kinetics.

One reviewer said that this is a fundamental study and its impact is very remote to DOE goals.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that the modeling approach is very effective. Another reviewer described classic, well-proven approaches to building base as being taken by the project. A reviewer said that the development on kinetic models and comparison and refinement against experimental data is clearly the proper approach in this program and looking at LNT performance is critical work as we move forward.

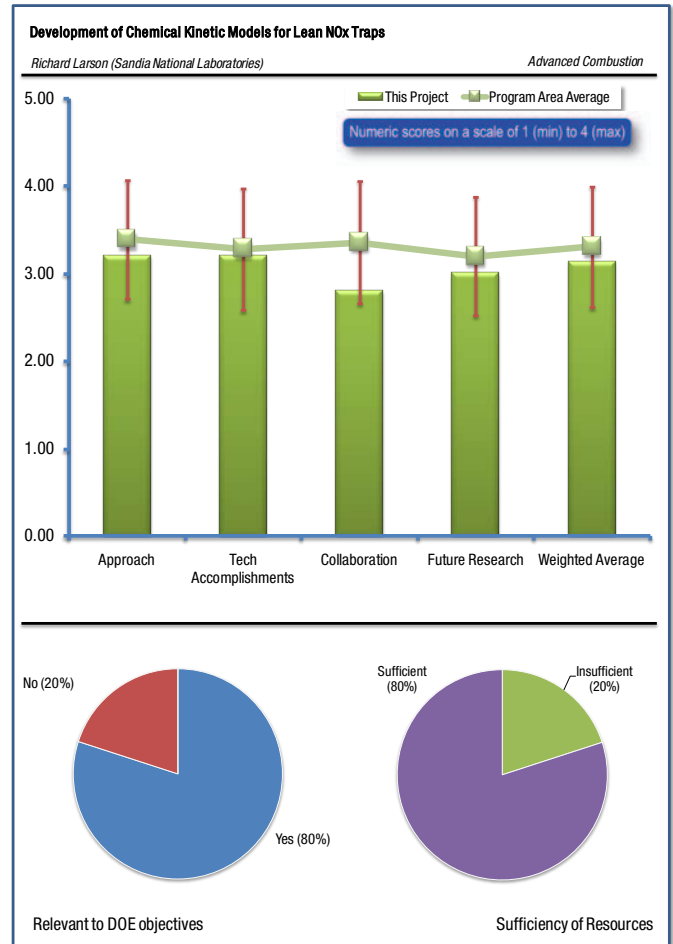
Another reviewer said that this project uses the well-developed chemical kinetic program package to study the kinetics of the LNT, noting that there are few attempts to do this at present. The reviewer adds that the major weakness in this approach is that the kinetic reactions are included and studied somewhat empirically and there is not an obvious, systematic approach to add or eliminate reactions needed for this mechanism.

One reviewer says that the project does not show how the fundamental learning obtained from the work will be specifically leveraged in engines and that it is hard to tell what is unique in this approach.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer says that in their view the major accomplishment is the development of a mechanism that appears to be effective, and that doing this is quite difficult. The reviewer adds that this mechanism includes NOx storage and release, oxygen storage and release and sulfur storage and release. The reviewer also says that as a micro-kinetic mechanism development, this is quite an accomplishment.

One reviewer said that excellent results have been obtained over the past several years. Recent work is on sulfur impact on NOx performance. The reviewer also noted that more short sulfations will be needed to get a good match for slide 7, which is a new result.



A reviewer said that there were outstanding modeling results on LNT NO_x speciation. The reviewer suggested that results showing sulfur adsorption on Pt during rich might explain NO_x spike on regen, and asked if the same thing is true on Rh. The same reviewer said that the desulfation simulation was also impressive. The reviewer suggested that the gap in sulfur aging needs to be explored and validated, and continued that they were interested in the desulfation results on Ce and Ba, and adsorption on Pt. The team should look at pulsing desulphation which is used to minimize H₂S.

A reviewer said that it is hard to tell if there is a lot of progress as it is not definitive on hard accomplishments or leveraging recent results for future tasks.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said there was excellent collaboration with ORNL researchers. Another reviewer said that there was collaboration with the right groups, and suggested the group make sure directions are adapted based on CLEERS and ORNL inputs. A reviewer observed the team is collaborating with Loboda. One reviewer said that the primary collaboration is with ORNL and it would enhance this project if an industrial partner was included in the work.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that it was excellent to be looking at reductants other than H₂ and CO in the reactions of interest to include more realistic feedstreams. Expanding the mechanism to include a hydrocarbon reductant needs to be considered. This reviewer believes that the CO and H₂ reductants will affect the oxygen storage components of the catalyst and those effects should be considered. Also the effect of NO as oxidant for the oxygen storage should be considered. Another reviewer said that this was a valid approach to fill gaps, and that migration into new reductants is key. The reviewer recommended developing base kinetics and modeling of sulfur adsorption on PGM during rich regeneration. The reviewer says that this is high potential and needs to be explored and that modeling is the beginning.

A reviewer did not see the path to impact. A separate reviewer stressed that they have a personal bias against LNTs: while they have some interesting characteristics and combining them with SCR's is very interesting approach, the real issue remains sulfur (think performance degradation vs. time). It just seems to the reviewer that sulfur is not a completely reversible poison, especially over thousands of hours. The reviewer knows this might well be outside the time scale of this work, but until someone steps up to long term sulfur effects on LNTs, they will remain SCR's "little brother." The reviewer added that EPA requires the useful life of emissions devices to be 435,000 miles and at 40-50 mph, the issue is LNTs do not work and that in real life the system must live much longer than 435k miles.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that it was hard to tell if there is a critical interaction for synergy or not and that the collaboration slide looked more mandatory than informative.

Development of High-Efficiency Clean Combustion Engines Designs for SI and CI Engines: Kenneth Patton (General Motors)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that for gasoline, diesel, and other advanced combustion approaches, improved valve actuation control is crucial to enabling these concepts and expanding more efficiency, clean operation. A separate reviewer said that advanced gasoline HCCI and diesel PCCI engines will provide significant fuel savings and thereby displace petroleum. A third reviewer stated that GM's involvement is critical to commercialization of LTC technology in LDV's. One reviewer mentioned FE enabling technologies.

A reviewer said that GM is developing relevant technology to improve gasoline and diesel engine fuel consumption and that a bold, high-risk objective of mass-producing camless engines is an appropriate use of DOE funds for this technology. The use of camless for diesel R&D is a good tool for evaluating more conventional VVA hardware and strategies.

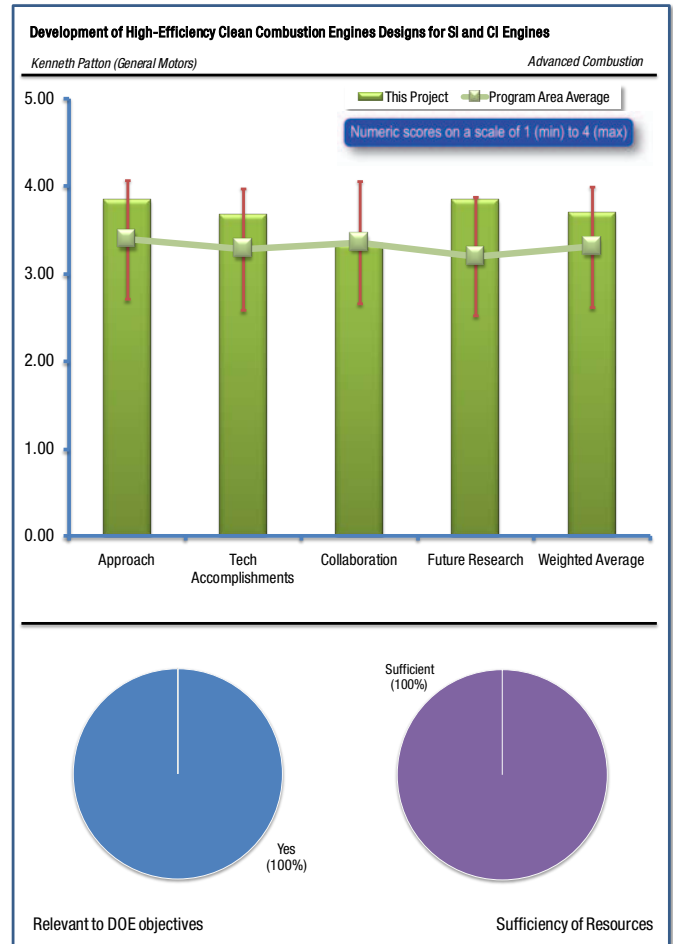
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that the focus on hardware development is appropriate at this stage, so that the barriers for commercialization can be addressed at this stage in the technology development. Another reviewer noted that there was sufficient effort invested to take significant new technologies from idea to hardware stage and demonstrate utility.

A reviewer said that combining analysis, production level practices and use/generation of hardware to produce production feasible system to achieve HCCI and that it was combining spin rig testing to evaluate valve motion control to prevent valve-piston interference. Also, the reviewer commented, the work was using a multicylinder engine with variable valve timing. The reviewer continued that for diesel, it was using VVA for PCCI to reduce/meet emissions and improve efficiency to develop a simpler VVA strategy. One reviewer said that the project is completed.

A reviewer said the project was well focused but was not sure why different VVA systems were chosen for different engines. The reviewer assumed there is a good reason which they had missed or misunderstood during presentation. The reviewer continued that long term, it seems a fully flexible Sturman-type approach would be cost prohibitive on a production engine.

A reviewer said that since the presenter did not provide supplemental reviewer slides, it was difficult to determine what, if any, program changes have been made based on previous reviews.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that it was nicely done with useful technical learning. Another reviewer noted that there was good progress toward overcoming barriers, but enough in the presentation to understand whether this will result in overcoming barriers. The reviewer added that it was good to see technologies out of this program will make it to production, but it was not clear which technologies did. The reviewer knows this is hard to do in limited slides.

A reviewer said the project had eliminated opportunity for valve-piston interference and was finding cycle-to-cycle variations that need further work to understand and suppress. The reviewer continued stating that there was improved thermal efficiency but noise levels were exceeded. The same reviewer stated that the project had completed engine modification for the project and an exhaust rebreathing strategy study, and explored late intake valve closing using a cam phasing approach. The reviewer noted that a patent application on diesel valve actuation to achieve internal EGR had been submitted.

A reviewer said there were VVLT system improvements on spin rig, which is an important step for eliminating confounding effects on results. The reviewer added that the development of the hardware and sensors needed for control of HCCI combustion in production engines is an important step in finally moving HCCI from lab to commercialization.

One reviewer noted that the project is done and it had enhanced internal GM experimental and analytical capabilities and enabled experimentation with “sandbox” VVA and other toys. The reviewer added that, hopefully, the project had increased the competency of the researchers and engineers who worked on the project.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said there was close collaboration with Sturman Industries on a production-feasible variable valve actuation technology for gasoline HCCI and a large team effort for diesel PCCI activity. A separate reviewer would like to see close collaboration continue toward commercialization, despite the end of the funding period. A reviewer said there was good collaboration with others and that Sturman is expert in the field and the most appropriate choice for collaborator. Another reviewer said that it seems to be good collaboration within the team with the rest of us are on the outside, but that is presumably unavoidable since people will not do such work fully in the public domain. One reviewer commented that it was internal to GM only, with suppliers as beneficiaries.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said they will take knowledge from this project and move closer to production level hardware, but more work is needed on cylinder pressure sensing and transient operation of VVA system. The reviewer added that the plans for future research are not clearly identified and wondered what will be done in the coming year to address shortcomings of this work.

A reviewer said that the project complete and that GM plans to use technology developed in this DOE program in future products. One reviewer said that the project is done and shouldn't be scored, another said that scoring was not applicable as the program is ending and the technology was likely to be included in future programs. One reviewer was unsure how to score since the project had ended.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that the project had achieved the objectives for the gasoline HCCI and made progress toward completion of diesel PCCI objectives. Another reviewer said the funding had been appropriate. One reviewer said the budget was higher than many other projects, but that the results seem commensurate with funding. One reviewer said this question was not applicable, another noted the project is done.

Advanced Boost System Development for Diesel HCCI/LTC Application: Harold Sun (Ford Motor Company)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

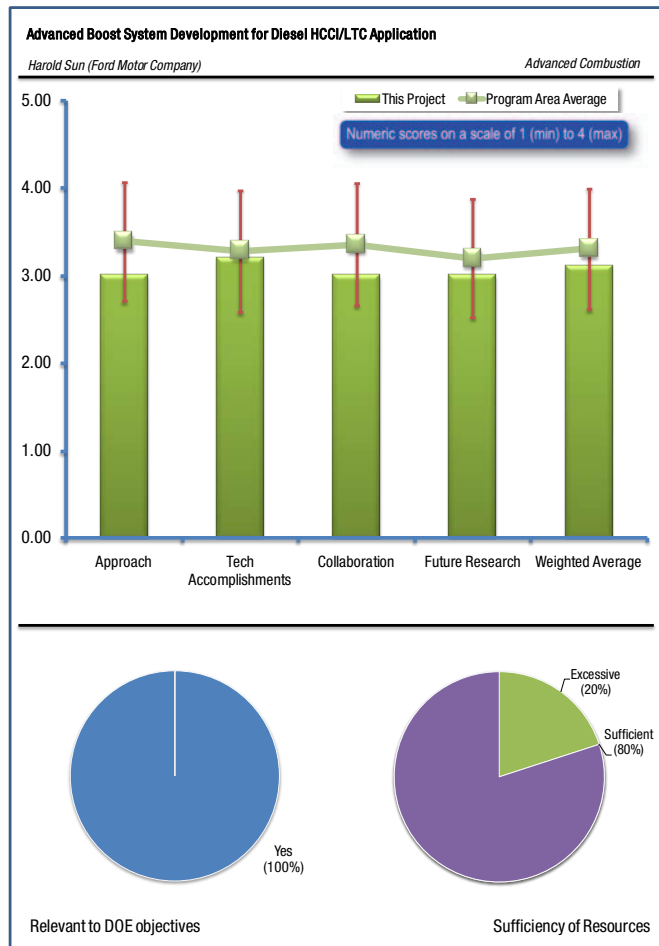
A reviewer said that this project addresses problem of surge of compressor with high EGR significant improvement in peak efficiency island and flow. Another reviewer said that diesel HCCI and LTC can lead to reduced burden and cost for clean diesel technology, and thereby can lead to deployment of higher efficiency passenger cars, which will lead to petroleum displacement. Another reviewer noted that the project was developing a technology to enable emissions and efficiency improvements. Another reviewer said that turbo-machinery is an important enabler for improved use of exhaust energy and that improvement in turbo-machinery is cited as necessary for enabling high efficiency concepts. The reviewer added that while that was not addressed in this study, the knowledge discovery from this project could still be relevant.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer stated that there was solid analysis, and good selection of partners. A reviewer said that this was a good project with good progress, adding that the speaker failed to follow DOE guidelines for presentations and did not provide supplemental reviewer slides. One reviewer said that the barrier is that heavy EGR to enable LTC puts the engine into a lower efficiency operating condition. The reviewer continued that both compressor and turbine in the turbocharger suffer efficiency losses with use of EGR, which confounds the effort to improve efficiency and therefore effort needs to be to improve “U/C” for engine efficiency improvement. The reviewer believed the project was trying to improve compressor and turbine efficiency over a wider range through CFD simulation, bench and engine tests.

A reviewer stated that technical barriers were well identified and addressed and that there were many challenges to new turbo-machinery designs. The reviewer commented that this project is doing a good, systematic job of addressing these barriers with innovative designs, but it was not clear if the approach changed from last year based on reviewer comments.

Another reviewer commented that this was literally reinventing the wheel, both the compressor and turbine wheels. The reviewer continued that the approach is a cookbook assignment for a turbo development task and has been done before a few times. The reviewer quoted from the presentation that “Challenging a relatively matured technology turns out to be much more difficult than we had anticipated,” and suggested it was time to “stop beating a dead horse.”



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said there were impressive improvements in turbo function. Another reviewer commented that there was significant improvement to the turbo for a light-duty drive cycle. A reviewer noted the project had completed four iterations of design. The reviewer noted that the team fabricated compressor wheels, performed flow bench and validation testing, and that there was improved turbo efficiency of 12-18% which translates to 2-3% fuel economy savings (is the cost of the modified turbo and compressor different than the production unit?). The reviewer continued that the project demonstrated improved U/C in desired operating range on the vehicle and noted that further improvement opportunities were identified but remains to be experimentally validated.

One reviewer said there had been good progress overall and nice accomplishments on path. The reviewer continued that the reported benefits from bench experiment will be checked on-engine in next phase. The same reviewer said the results are promising, but noted that the presentation had not included “extra” slides so the reviewer could understand how comments from last year were addressed. It was not clear to the reviewer what is new or what has changed by comparison. The reviewer found it hard to gauge some aspects of progress without that additional information. The reviewer was also curious that there was a request for an additional year.

One reviewer felt that this “technology development” program addresses issues that have been well-covered by diesel engine manufacturers in the USA (HD), and in Europe and Japan (LD). The reviewer continued that the findings so far are merely a confirmation of prior art by established turbocharger manufacturers R&D teams world-wide and the reviewer did not see new ground breaking results so far.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said there was a close working relationship with components suppliers on the iterations toward improved turbine and compressor. One reviewer thought that teaming with a turbocharger company is occurring (they think) and that this is very important. The reviewer noted there was not much discussion and no slide on role of collaborators. One reviewer said that there seems to be outstanding work within the group, but the rest of us are outside. The reviewer conceded that this probably can't be avoided due to proprietary issues. One reviewer believed that an established turbocharger supplier should be able to carry out all the suggested tasks, perhaps using Ford as the verifier. The reviewer questioned the use of the turbo supplier only for gas stand testing. The reviewer believed that Ford Europe/England must already have a few of this project's “new findings” and asked if the Ford NA engineers have reached out for their help.

QUESTION 5: HAS THE PROJECT 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?

A reviewer noted that the program was ending and this technology is very likely to be implemented in future products and research. Another reviewer said that it was important to get on-engine to see if predicted and bench-scale improvements translate well. A reviewer said that there is remaining work to be done on additional experimental validation of benefits, and to migrate the technology to a small turbo and small diesel engine application. The team expects an additional 6-9% improvement in compressor efficiency. One reviewer described this as an exercise that is really neither needed nor likely fruitful. The reviewer alluded to the presentation's summary comment: “The reviewer said that additional technologies have been identified and numerically validated to fill the gaps,” numerical validation is elusive.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that if in the end, if 2-3% (potentially more) fuel economy improvement in a vehicle can be achieved with low cost design changes (geometric design changes which should result in minimal cost change), then this project will yield a significant public benefit and represent a valuable technology investment by the VTP. One reviewer said there was appropriate funding, but another suggested further investment in this project be reduced.

Development of Enabling Technologies for High Efficiency, Low Emissions Homogeneous Charge Compression Ignition (HCCI) Engines: Scott Fiveland (Caterpillar)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that high efficiency clean combustion engines will lead to reduced emissions and reduced fuel consumption and thereby displace petroleum. Another reviewer described it as a good enabler for higher efficiency. One reviewer said that PCCI was demonstrated with low NO_x/PM and fuel economy improvement.

A separate reviewer suggested that HECC does not offer a substantial reduction in fuel consumption in heavy-duty applications relative to other technologies, but is significant for reducing aftertreatment complexity and pollutant emissions.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that there was a good approach for integrating technology building blocks. Another reviewer commented that the scope is broad enough, but spread across a significant cooperative network to achieve success. One reviewer said there was a clear identification of issues to be addressed and analysis of means to move forward.

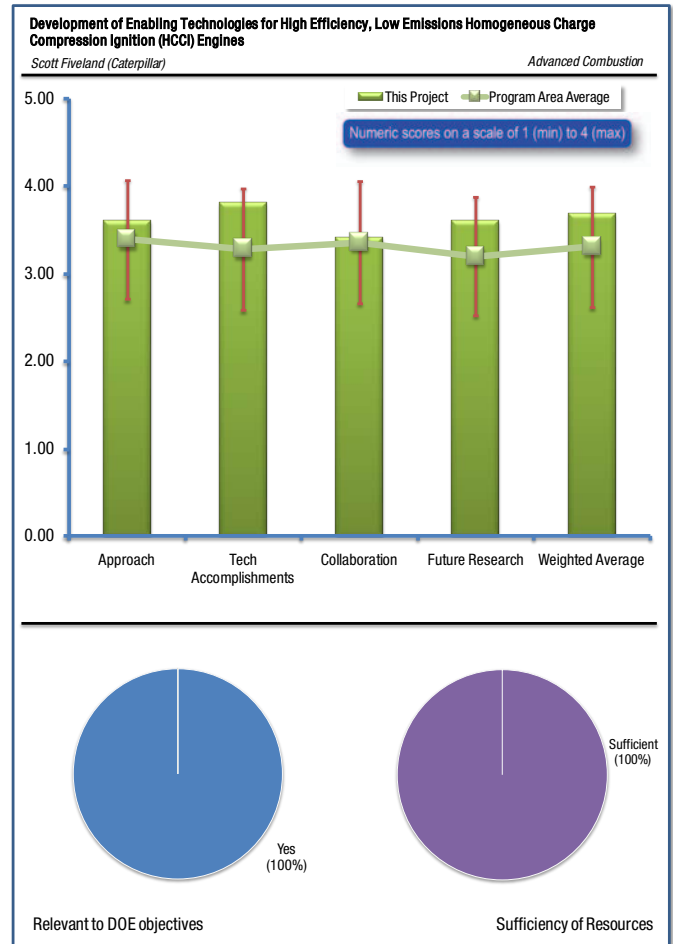
A reviewer felt that despite the perceived impracticality of gasoline/diesel blends, it is appropriate R&D. Another reviewer said that lately the project had been focused on fuel blending.

One reviewer commented that barriers to HECC involve mixture preparation, air utilization, heat rejection, load capability and combustion control. The reviewer noted that the project was using a systems approach to improving efficiency, and that this project focuses on combustion improvements by shortening combustion duration and engine out emissions. The reviewer continued that they were characterizing the HCCI combustion process to identify technology gaps, extend load range by optimizing spray injection and developing local premixing.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said there was solid research, implemented in hardware effectively. Another reviewer said that the accomplishments are significant over the course of the program, but it is not terribly satisfying to see how much remains yet undone.

One reviewer said that they had studied lifted flame combustion and plume to plume interactions in the SCORE facility to achieve smokeless combustion, the reviewer added that the project defined requirements to achieve smokeless combustion. The reviewer noted a greater number of orifices reduces the ability of the sprays to breathe in air, which shortens lift off length and that they were moving



lifted flame combustion into smaller bore engines. The reviewer continued that using fuel blending to push the load range of PCCI to higher levels shows promise and the team has experimental evidence to demonstrate the concept. There remains a challenge of dealing with pressure rise rate limit on maximum load capability.

A reviewer said that overall progress is very good and the latest report is OK. The reviewer asked why the project team was reporting on SNL work and why the last two slides were from 2009 AMR. The reviewer also questioned if there were no new reviewer comments from last year.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said the project involves collaboration with Sandia, ORNL and Exxon-Mobil and exploits the unique capabilities of the national labs. The reviewer added that the labs provided valuable input to help achieve the project objectives. Another reviewer said that the collaboration has been outstanding all around for a DOE-industry partnership. One reviewer said that they seem to have formed a very good team—OEM, suppliers, academia, labs. A reviewer asked if they were funding SNL for the work there.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that this line of research will lead into future contracts and product development and that this was a nice example of bringing far-out research closer to production. One reviewer said that the project was continuing work to develop solutions to the remaining limits on implementation of the PCCI strategy.

One reviewer thought that work in this area would continue, even though the project had ended. Another said the project was in wrap up stage. One reviewer said it would be more encouraging to see a concrete plan for addressing the remaining barriers in future work.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said the project has been successful in overcoming and identifying remaining barriers. Another reviewer said there were appropriate funding levels.

An Engine System Approach to Exhaust Waste Heat Recovery: Richard Kruiswyk (Caterpillar)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that waste heat recovery can directly reduce fuel requirements and thereby improve fuel economy and displace petroleum. Another reviewer said that an assessment of bottoming cycles is critical for heavy-duty applications. One reviewer described a direct means for efficiency improvement. A reviewer described the project as being focused on fuel economy improvements.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

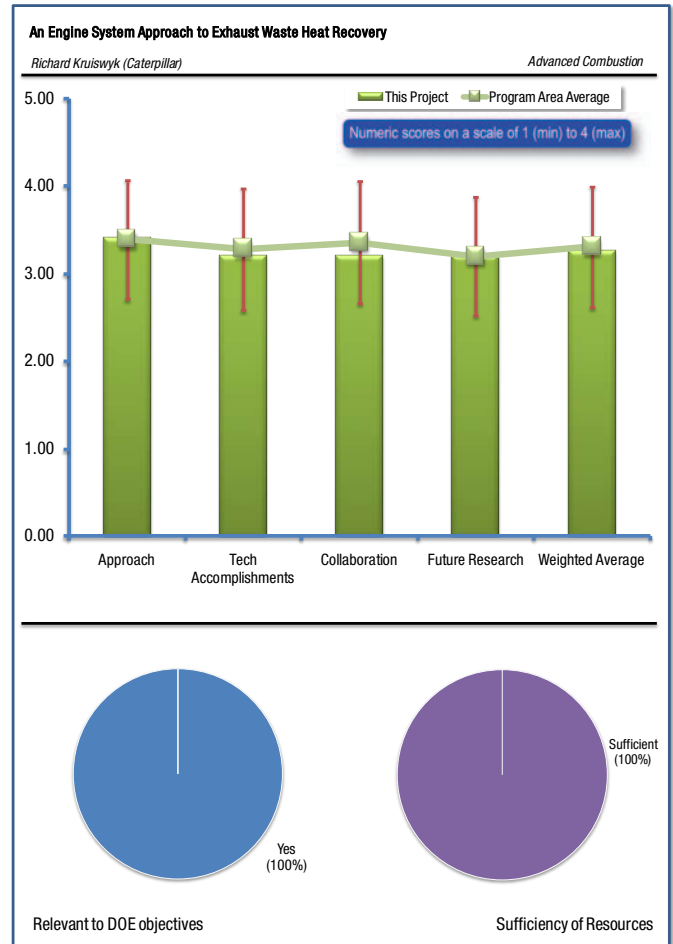
A reviewer said there were interesting ideas approached with appropriate computational and experimental tools, adding that the work has adapted appropriately, as system evolved through the project. A reviewer said that barriers include cost effectiveness, packaging and efficiencies of components for waste heat recovery. The reviewer continued that a systems approach to try to achieve 10% improvement in engine thermal efficiency, based on compound turbocharging with heat recovery via heat exchange between the intake air and the exhaust and a focus on production viable technologies to improve practicality. One reviewer said there was thorough consideration of the means to address the major losses, but it was unclear where turbocompounding will head at the conclusion of this effort. One reviewer agreed with reviewer comments made last year that the followed approach constitutes a revisit of previous technologies and an attempt to marginally improve them. The reviewer continued that the reported work is a routine developmental work that should be carried out by CAT without DOE support or involvement. The reviewer also wondered about where the total system integration effort was.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that the development of improved, “production-possible” HECC turbocharging hardware is significant. A separate reviewer commented that this was good work and saw solid opportunities for efficiency improvement.

One reviewer said that the project had demonstrated progress toward program goals, though the program is ending to make way for SuperTruck program. The same reviewer stated that the focus has been on procurement of components to test different concepts. The reviewer continued that for HP turbine the team had targeted 2% thermal efficiency increase just through improvement of turbine design, and achieved equivalent of 1.5% net thermal efficiency improvement and demonstrated 2-3% efficiency improvement at some speeds and loads in a test engine.

The reviewer continued that for LP turbine, they had targeted +1% engine thermal efficiency, and demonstrated about 2/3 of that target on a flow bench. The reviewer also noted that more modest gains had been targeted for compressors, and they had demonstrated about 60% of that target on a gas stand.



A reviewer said that turbo system design enhancements should be left to the specialists. The reviewer also felt that the overall results fall short of addressing the end objectives of the DOE program goals.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that component suppliers closely integrated in the project and the team had worked with a university and ORNL for test support. A separate reviewer commented that there was good collaboration with suppliers. One reviewer suggested that the project some collaboration with component suppliers, beyond what they doing now.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that the team had stated plans to continue the work internally as this project ends. Another reviewer said that the project was transitioning to SuperTruck and that some of the work will continue in the new program. The reviewer noted that they will test a Gen2 version of their turbogenerator design. One reviewer felt that the proposed future research had not fully been explained.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said that the project objectives had been completed within project timeframe. Another reviewer felt that to answer to this question they required some clear metrics that are not well-defined as far as this reviewer is concerned. One reviewer said there had been an appropriate level of funding.

Advanced Diesel Engine Technology Development for HECC: Donald Stanton (Cummins)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said there had been solid development of high efficiency technology. Another reviewer noted that high efficiency clean combustion could provide diesel efficiencies with reduced engine out emissions, thereby reducing the burden of aftertreatment from a cost and efficiency perspective. The reviewer added that HECC can lead to petroleum displacement. One reviewer said that fuel economy is in focus. Another reviewer said that the objectives are in line with DOE.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that efforts have included research on achieving 10% efficiency improvement, fuel interactions with the combustion process and enabling subsystems. The reviewer continued that extended PCCI operating range and incorporated lifted flame combustion and that ether was a two pronged approach to work in concert with SCR NOx control and to work to eliminate NOx aftertreatment. A reviewer noted that the project team had worked in both HD 15L engine and LD 6.7L engine.

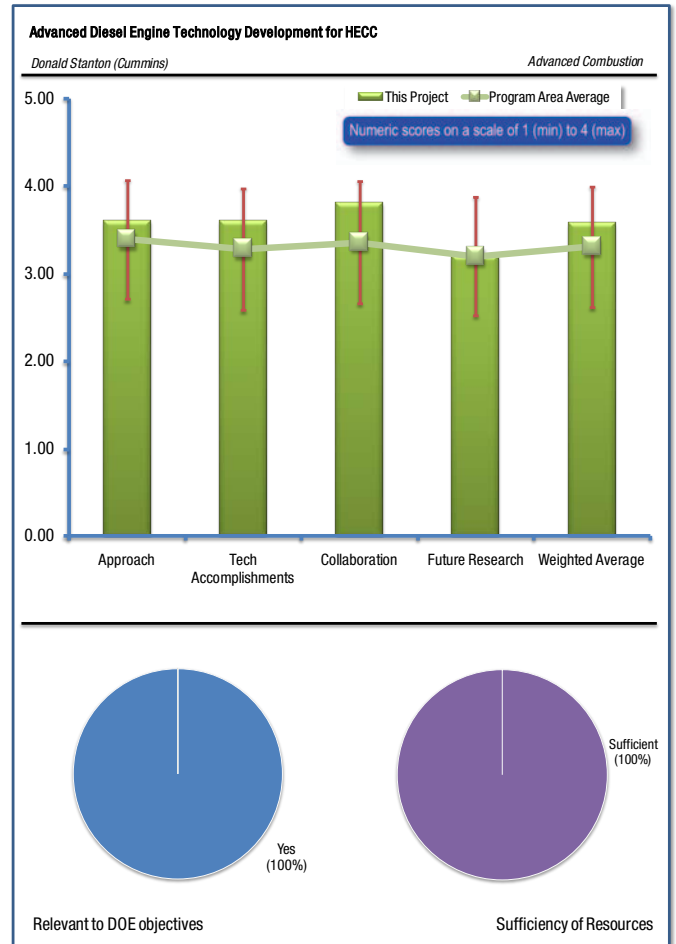
A reviewer said that the project was a nicely conceived program that included several key technologies. The reviewer added that there was a good combination of modeling, optical engine, and metal engine development. Another reviewer said that this was a good, comprehensive and well thought out approach.

A reviewer commented that for many programs including this, it will be useful to check the appropriate base, asking “what if their base engine is very poor (not that I think it is, but what if?).”

One reviewer felt that last year's presentation was focused on light-duty and wondered if Cummins has switched to MD/HD in mid-stream.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said there had been great progress; better results than they would have expected at the outset. One reviewer said the project had achieved both targets for NOx (external and internal), but robustness in the engine out PM remains an issue for in-cylinder NOx control strategy. The reviewer continued that the project team had achieved 10.2% thermal efficiency without NOx aftertreatment. The reviewer described other technical barriers that include cavitation damage to the injector orifice passages. The reviewer said that for HECC with high efficiency SCR, packaging, weight and DEF derived deposits remain challenges. The reviewer added that for the 6.7L engine, moving to HECC mode permitted removal of the NOx adsorber catalyst from aftertreatment system. The reviewer also said that for HECC and biodiesel compatibility achieved with sensing biofuel presence and active control.



One reviewer said that there were nice accomplishments but the presenter was only able to get through half of his slides. The reviewer continued that review of the remaining slides indicates progress is being made, but a response to last year's comments would have been useful to understand what guidance and action was taken. The reviewer believes that was a required slide.

A reviewer felt there were many recycled developmental tasks giving the examples of slides 13 and 14. The reviewer described this as not good. The reviewer described early PCCI combustion, early lifted flame combustion, reduced parasitic and increased CR piston as good. The reviewer described slides 15 and 16 as routine work for an engine company's R&D team.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said there was great collaboration drawing from industry, national laboratories, and universities. A separate reviewer noted extensive partnerships with ORNL, Purdue, BP and partners and that these partnerships led to significant contributions from the collaborations. One reviewer said there was a balanced team of national labs, academia and industry and that the project was well done. Another reviewer said there was nice teamwork with OEM, suppliers, labs, academia.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that one program is complete and another is on its way. The reviewer added that plans forward look good. A separate reviewer commented that the HECC program is closing out and targets were achieved. One reviewer said it seems that the work will continue in future programs. One reviewer said the LDECC program is continuing, but targets exceeded for thermal efficiency (15.5% demonstrated versus 10% target). Another reviewer said that nothing was revealed except a verbal statement that things will continue under the SuperTruck program. The reviewer suggested more focus on higher risk, higher payback research areas.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that the program appears to have been quite successful. Another reviewer said that there was a sizeable budget compared to many other projects, but results are commensurate with funds expended, adding that the project showed excellent work and results. One reviewer said that there was appropriate funding.

Exhaust Energy Recovery: Chris Nelson (Cummins)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that the organic Rankine cycle WHR system is a complex, high-risk, and difficult to package system, and is appropriate R&D area for DOE funds. The reviewer added that Cummins has done an outstanding job developing a system that will very likely be produced and deployed on new and possibly in-use engines for very real petroleum savings. A separate reviewer said that the project is well aligned with DOE objectives.

A reviewer said that the recovery of exhaust energy directly can lead to fuel savings and thereby petroleum displacement. Another reviewer said that waste heat utilization is focused on energy recovery and improving fuel economy. One reviewer observed high efficiency technology development.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said this was a nice approach and an interesting idea and that there was good use of simulation and analyses. The reviewer continued that the program has adjusted appropriately as situations change, partly due to its own earlier results.

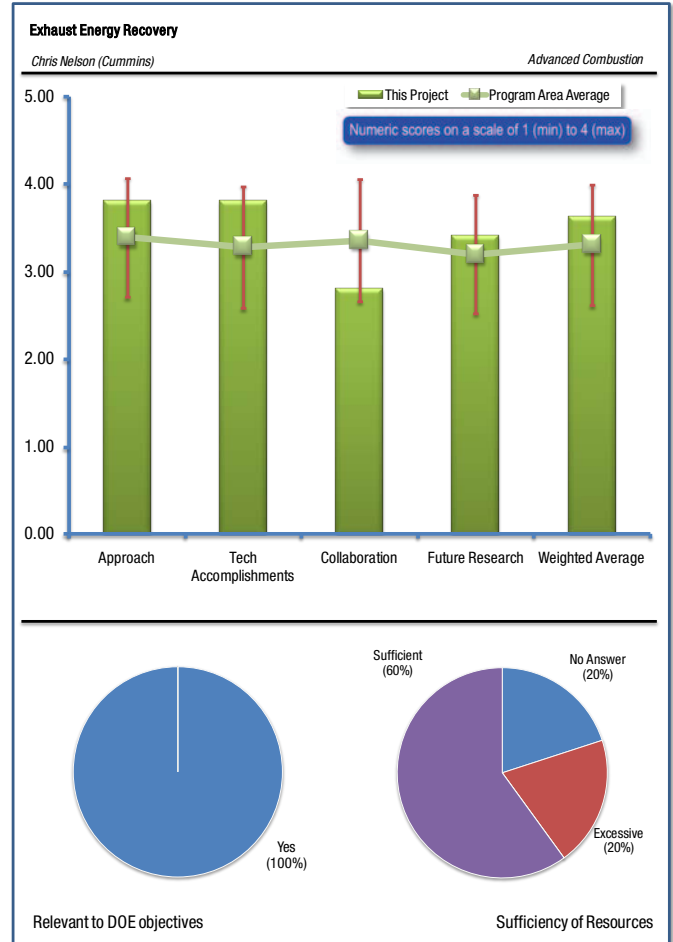
A reviewer said this was a solid approach and well thought out. The reviewer added that energy recovery is a viable approach, especially for HD vehicles. Engine system changes caused a re-evaluation. The team responded well.

A reviewer said that the program was targeting a 10% improvement onto top of the advanced engine being developed in the HECC and LDECC programs and that an organic Rankine cycle strategy was being pursued.

One reviewer suggests that WHU approaches have been investigated a few times during the last 40 years and that ORC R&D should be available from the DOE historical reports, from the “Big-3”, and U.S. HD diesel engine companies of old (CAT, Cummins, and DDC). The reviewer continued that this project provided an update on the state-of-the-art and that the practical implementation and the likelihood of production release must be undertaken as a priority, and updated continuously.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that the project had demonstrated incremental improvements including Rankine generator and more electric accessories, and achieved 9.4% efficiency improvement by last year. The reviewer added that further improvements gained another 1.4% efficiency improvement, for an overall >10% improvement and with the low NOx system with less/no EGR reduces system capability to 6.2% efficiency improvement.



One reviewer observed nice analysis and results. Another reviewer stated that the project met its goals even with a major change to the engine system. The reviewer was disappointed to not see some of the mandatory slides related to response to reviewer comments. The reviewer added that these slides help the reviewers to know what, if anything, was changed based on comments.

One reviewer commented that many technical barriers have been addressed and that more secondary work and peripheral activities have been undertaken. The reviewer continued that it was not clear if Cummins will seek partial or full release of the ORC WHU system even in limited production.

The same reviewer noted that the integration of the WHU system into the engine design was a very good effort. However, it seems that much “claptrap” is added to a very complex and ever-expanding engine sub-systems and components. The reviewer wondered what this will do to cost, reliability, and other important parameters. The reviewer added that they did not know if FMEA, both design and manufacturing, have been carried out or reported in prior years, stating that there was no reference to it here.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this has been primarily an internal program, but this is not seen as a problem. Another reviewer noted they were working with Cummins component divisions on system development. Another reviewer said that this was all internal collaboration and that while this is good, there may have been other opportunities missed.

One reviewer said that it is difficult to collaborate with others, especially during a wrap-up phase. The reviewer also suggested that DOE may want to change “Close, appropriate collaboration with other institutions; ...” to include collaboration with industry partners as well: this might have been included in prior AMR's a while back.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that the program is ending but carrying over into the SuperTruck program. A separate reviewer said that the work will carry on in the next program. Another reviewer said that the merits of continuing this work under the SuperTruck should be examined. The reviewer added that there can be higher priority items that would warrant funding preference. One reviewer stated that despite the project being complete, Cummins laid out plans for continuing this work and taking this technology to production. One reviewer noted the project was complete and they were not sure how to rate because of this.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that there was a large budget but results commensurate with funding, adding that this had been excellent work. One reviewer said there had been appropriate effort. One reviewer stated that the funding this past reporting period seemed to be on the high side for the reported progress during this shut-down task of the program.

High Efficiency Combustion and Controls: Kevin Sisken (Detroit Diesel)

REVIEWER SAMPLE SIZE

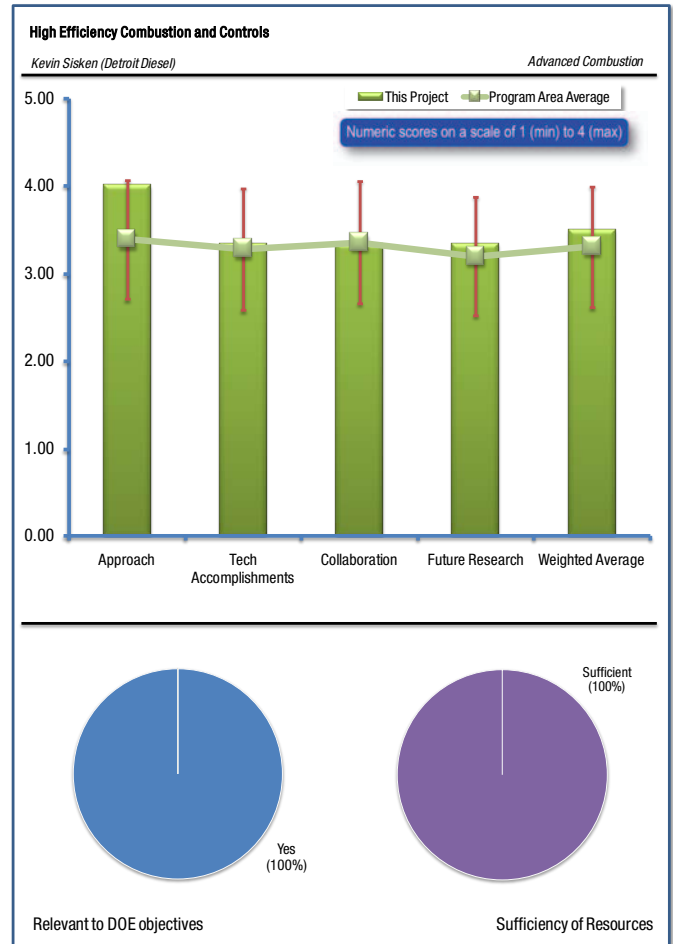
This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that high efficiency combustion and controls to achieve high efficiency combustion reduce fuel utilization and thereby lead to petroleum displacement. A separate reviewer said that the project was a demonstration of high efficiency technologies.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer commented that there was a good selection of technologies, nice use of simulation and experiment. A reviewer said that the target is to 10% fuel economy improvement through combination of refining a conventional combustion process, dual spray injection (low pressure and high pressure injection), transient controls and air system refinements. One reviewer said there were excellent project and results, although the reviewer felt that the speaker did not follow DOE presentation guidelines.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said there had been solid results with more to come. A separate reviewer commented that roughly 2% BSFC improvements were seen through conventional strategy. The reviewer added that control improvements target cycle to cycle variations reduction and cylinder balancing via ion or pressure sensing, but remains at the concept stage. The reviewer also said that the dual spray approach consists of one injector with two distinct spray modes, but durability of the injector is a problem and this approach is being dropped. The reviewer also said that predictive control shows more promise thus far by predicting current system behavior, and is being used for optimization which shows lower NOx and 3% FE improvement. The reviewer said that air system improvement showed 1% FE increase and is being migrated into production.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said there was a partnership with ORNL where experimental studies were performed, leveraging ORNL expertise in advanced combustion and controls. Another reviewer cited OEM, lab and suppliers.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that combustion system and controls work will continue in SuperTruck, the injector system will be dropped, and the air system is being put into production. The reviewer added that they will show the 10% improvement in demonstrator. A separate reviewer commented that they plan to continue in the next program.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said there was appropriate funding. Another reviewer was uncertain about the budget as the speaker did not follow DOE presentation guidelines. The reviewer added that the project had shown excellent results, so the budget is apparently adequate.

Low-Temperature Combustion Demonstrator for High-Efficiency Clean Combustion: William de Ojeda (Navistar International Corp.)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said the project was quite focused on fuel economy improvements. A separate reviewer commented that there was development of high efficiency technology. A separate reviewer noted that enabling the use of HECC approaches can reduce the emissions burden for diesel engines and thereby provide petroleum displacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that starting with Navistar's state-of-the-art production technology, the project focused on addressing technical barriers. The reviewer added that a systematic approach was used to tackle a difficult problem under stringent emissions complex. The reviewer continued well focused on in-cylinder combustion improvement and enhancements. The reviewer concluded that they covered the basis and this phase harvested a consistent multi-year approach.

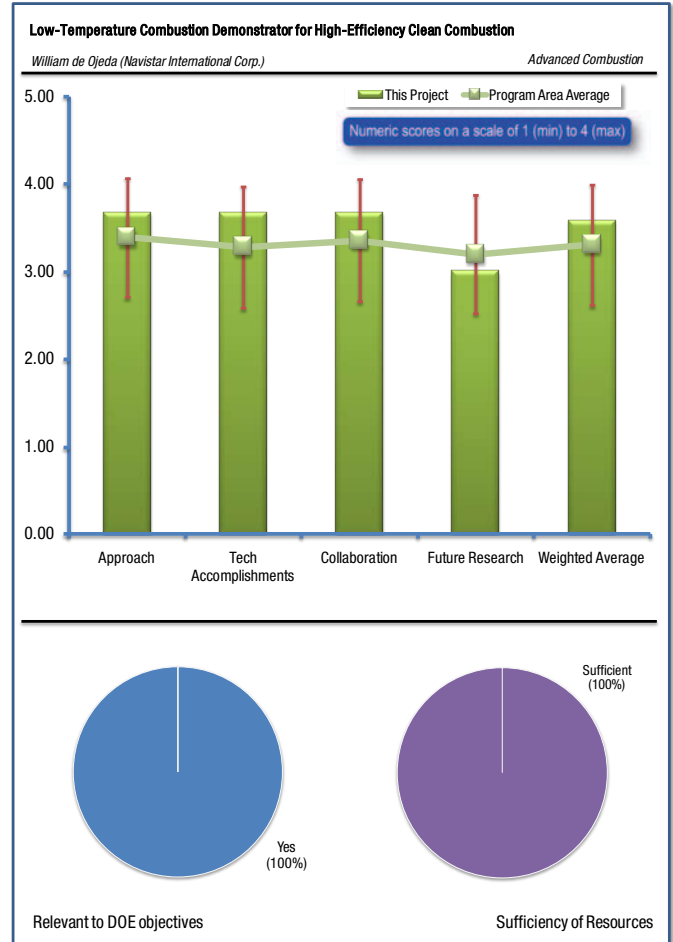
A reviewer said the project was attempting to meet 2010 emissions without NOx aftertreatment and improve efficiency by 5% using 2007 DPF strategy. The reviewer added that the platform is a 6.4L V8 engine and the work includes development of enabling component technologies. The same reviewer stated that they were considering the range of fuels, in particular the FACE fuels. The reviewer added that barriers include UHC, fuel economy, stability, load range, transients and fuel tolerance.

A reviewer said there was good use of simulation and experiments. The reviewer was not convinced that high efficiency can be obtained without any NOx aftertreatment, and attempting to do so may be limiting the concepts. The reviewer also said that for many programs including this, it will be useful to check the appropriate base. The reviewer asked “what if the base engine is very poor (not that I think it is, but what if?)”

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that progress is substantial, considering the challenge of improving the efficiency while maintaining the low NOx and PM combustion strategies such as high EGR rates. The reviewer added that Navistar’s pursuit of minimizing the engine-out NOx to avoid aftertreatment “backed them into a corner.” The reviewer continued that pragmatic adherence to production-viable approaches is a strength that deserves an honorable mention.

A reviewer noted that previous phases of project included engine improvements, such as VVA system. The reviewer added that reduced instability and extended operation range through VVA and feedback control was achieving >5% FE improvement with



additional reductions in emissions. The reviewer also said that using different injection strategies in different speed-load regimes and that they had showed that EIVC strategy allows 95% reduction in PM and 5% FE improvement at constant NOx.

A reviewer said that there had been good combustion results. The reviewer also said that assuming that fuel properties will be optimized to deliver nearly half the target efficiency improvement is risky and unlikely to happen.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said there had been extensive collaboration with component suppliers, fuel supplier, national labs and university. A separate reviewer noted that there was a great team, coordinating with multi-faceted partners and a national lab. One reviewer commented that LLNL's help with CFD and Chemkin is an astute move for Navistar to supplement what has been an anemic in-house competency. The reviewer added that the results reflect a well-coordinated collaboration effort. A reviewer said that the collaboration included an OEM with suppliers, academia, and labs.

QUESTION 5: HAS THE PROJECT 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?

One reviewer commented that the program is ending with no indication of future plans. The reviewer assumes this work will continue in future projects and suspects that much work is needed to come to a competitive efficiency given their apparent program assumptions. Another reviewer said that the presentation was not clear as to what/how the future work will be carried out, presumably under the SuperTruck program. The reviewer said that the presentation had only mentioned "fuel reactivity." The reviewer said it would be interesting to see how an industrial company will deal with this topic, obviously with the support of the national labs, and without double dipping in the DOE budget. A reviewer said that the program has ended.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said this was a good wrap up effort. A separate reviewer said there was appropriate funding

**Advanced Collaborative Emissions Study (ACES):
Dan Greenbaum (Health Effects Institute)**

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that avoiding adverse health effects is the reason for emission standards, and meeting emission standards is a prerequisite for efficient powertrains, so these studies are critical to the DOE VT mission. A separate reviewer said that to understand what level of pollutants may affect humans by looking at effects on mice and rats can help define the aspects of pollutants that may affect humans. One reviewer says that this work is to determine toxicology from heavy duty diesel exhaust using new generation combustion technologies.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

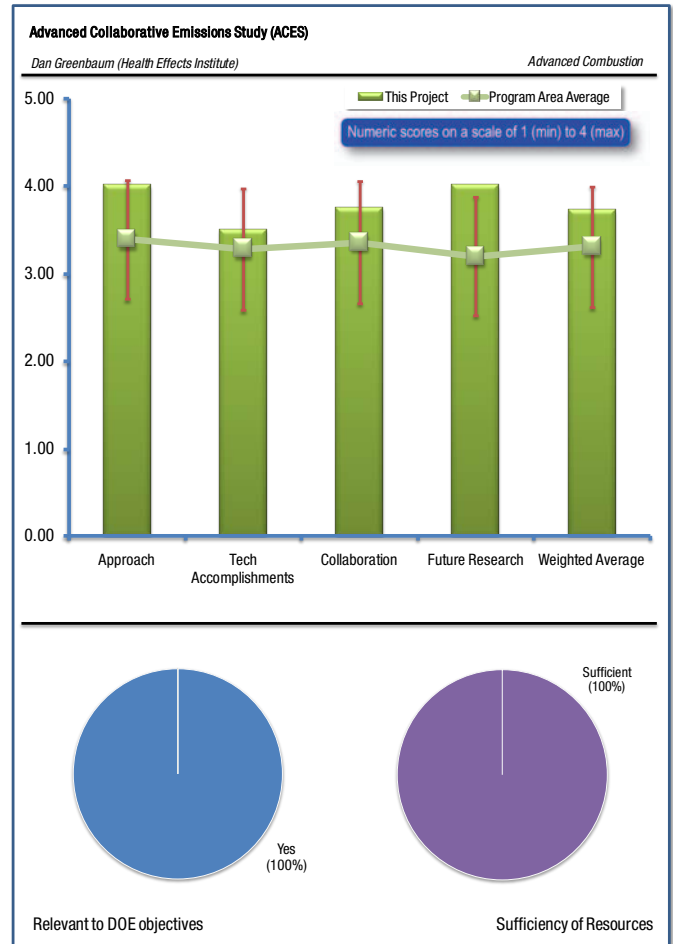
One reviewer says these are complex, difficult studies with their controls and they appear to be well-designed and getting useful data. A separate reviewer commented that while they are not a health effects expert, it is apparent that this group has top skills and has developed a most comprehensive and authoritative program. One reviewer says that this is consistent with the work done in the past. The reviewer adds that there is no reason that this study should not identify toxicological effects from the new generation of diesels. The reason that there could new effects occurs because the new combustion technologies could produce different exhaust gas emissions even at low concentrations.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer says that at this point the tests have been initiated and no results have been reported. A reviewer says the results of the study are eagerly awaited. A separate reviewer says that so far there are no final results, but there is little to distinguish the controls from the mice exposed to pollutants. The reviewer added that the PM created by the mice themselves would appear to complicate the study of PM effects.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this project has many appropriate partners, possibly more than any other ACE project. A separate reviewer said that all the necessary players are well represented and this is critical in order for the results of the project to be widely recognized as valid. One reviewer said that the advisory board for the Health Effects Institute is well staffed. The same reviewer was concerned that at least one of the people on the board is no longer with the listed institution and suggested it would be helpful if the staff listing was properly updated.



QUESTION 5: HAS THE PROJECT 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?

A reviewer said that the schedule for future work is excellent to follow through with current efforts for the coming year. One reviewer said that this project has the same focus as past tests and should be equivalently effective in identifying problems. A separate reviewer said that if the study shows no impact of pollutants on mouse and rat health, that will be a useful result. The reviewer added that this is not the goal of this project, but one can always hope that ultimately this family of research will find the “silver bullet” that leads to understanding of the characteristics of particles or what is adsorbed on them that may cause disease in humans exposed to large amounts of particulate matter. One reviewer said that the program continuation to completion is at hand. The reviewer hoped that consideration will be given to further testing of 2010 level systems, adding that it seems that Phase 3 is running 2007 level systems and they not heard a plan to do animal exposure of the later systems.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that the project seems to be well funded from a variety of sources.

Measurement and Characterization of Unregulated Emissions from Advanced Technologies: John Storey (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that this work is critical to the implementation of lean gasoline systems, both direct drive and hybrid. A separate reviewer said that it is important to know and understand unregulated emissions from fuels that may reduce our dependence on imported fuel. One reviewer said that this work is necessary to assure there are no unpleasant surprises in new technology. Emission controls are done to reduce health issues caused by older systems; we need to be sure we do not replace some problems with others.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

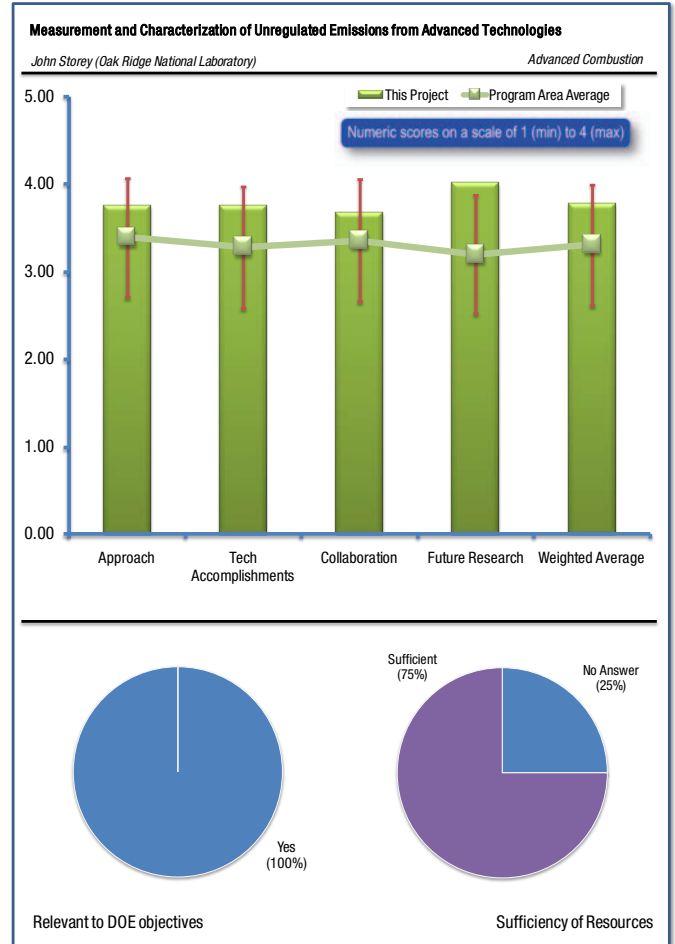
A reviewer said that the approach was well designed to determine the emission species from these alternatively fueled vehicles. A second reviewer said that characterization tools and means of operation to obtain samples are well-thought out and probably unique in their breadth. One reviewer said that this group is recognized for leadership in analyses of this kind and that there were good plans and facilities.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said that understanding the change in emissions as the ethanol component is increased in fuels is crucial. The reviewer continued that it is anticipated that the ethanol component will increase from today's 10%, and that often this increase is done for supply reasons. The reviewer added that it is necessary to understand the impacts of mandated increases in the ethanol component of gasoline fuels. A reviewer commented that there was excellent progress in a wide area of research, especially the E10, E20 blends which are of great interest. A second reviewer also noted the excellent results.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that a good range of collaborators is used. Another reviewer stated that the collaborations are cross cultural as they should be in this type of project adding that these collaborations seem to be well designed. The reviewer also said that from the presentation it is not clear how involved each of the partners is. A separate reviewer stated that the PI has good contacts at many industry locations and that in this work, more involvement from industry would help with experiment setup and implementation of the learning.



QUESTION 5: HAS THE PROJECT 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?

One reviewer is looking forward to seeing the results. A separate reviewer said the project is headed in the right direction and is achieving results that are not generally carried out elsewhere. A reviewer said that these are vehicle designed applications and this is as it should be for this type of project.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that this seems like an appropriate level of effort.

Collaborative Lubricating Oil Study on Emissions (CLOSE Project): Douglas Lawson (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that identifying possible toxic components in diesel soot is necessary to provide safety for incorporating high volumes of these vehicles on public roads. A second reviewer commented that the impact of emissions from lubricating oil vs. those from fuel-based species is an important piece of knowledge to improve overall emissions. One reviewer noted that understanding the sources of emissions is important to enable further reductions, and to understand the source apportionment for future regulatory actions.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

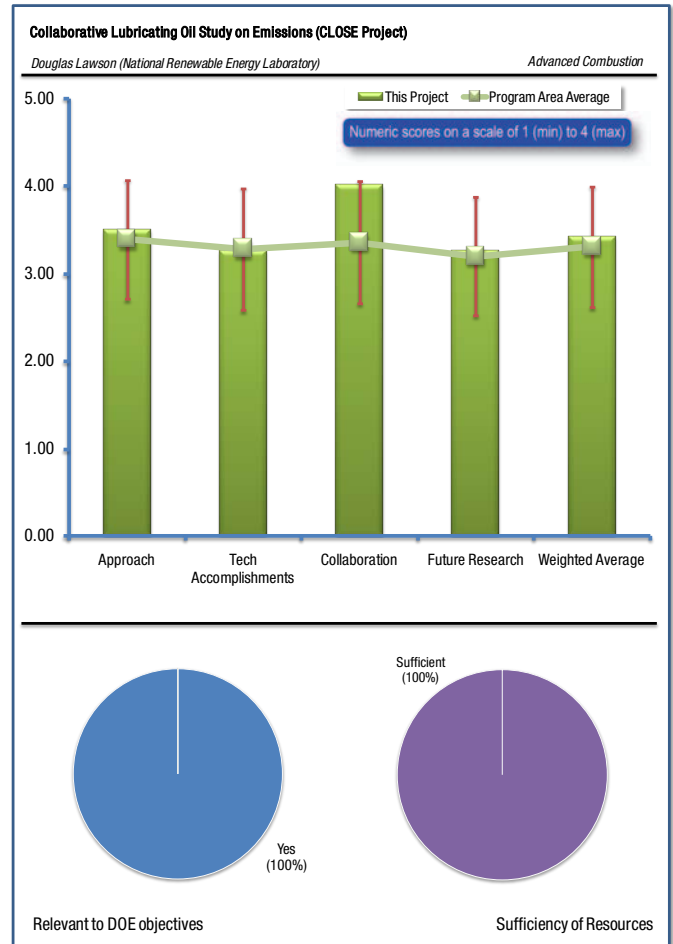
A reviewer said that the approach seems very appropriate for the measurements needed. A separate reviewer described carefully designed experiments with statistically valid analyses, supported by the important parties to the issue will result in quality results that are accepted widely. One reviewer said that there has been considerable discussion on the health effects of particulates emitted by gasoline vehicles; the reviewer added that it appears as if there is insufficient data to evaluate that effect. The reviewer continued that lean burn gasoline engines are available in Europe. There is discussion about the health effects of those particulates.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer commented that good progress has been made. A second reviewer felt that there was relatively little data presented here, and that the accomplishments seem to be to simply start taking data. The reviewer continued that the jury is out for accomplishments. Progress seems to be acceptable. One reviewer said that no real progress was reported, although much of the data has been taken. The same reviewer said that the results are still being reviewed by the partners in the work.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this work is well coordinated with the relevant air quality groups. Another reviewer said that the group of partners seem very appropriate, adding that it might be interesting to have more than one lubricant source/provider in the team, because of the importance of lubricant impact for the project. A separate reviewer said that all the necessary groups are actively involved in planning and executing this program.



QUESTION 5: HAS THE PROJECT 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?

A reviewer said that the project is scheduled to end this year and that it seems like some future work on related topics would be useful. The reviewer is not sure we don't know all about the issues involved. A reviewer said the project is 80% complete and will present results with suggestions for future work. A separate reviewer hoped the project is done on time in November.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said the project seems to be adequately funded from several sources.

Thermoelectric HVAC for Light-Duty Vehicle Applications: Clay Maranville (Ford Motor Company)

REVIEWER SAMPLE SIZE

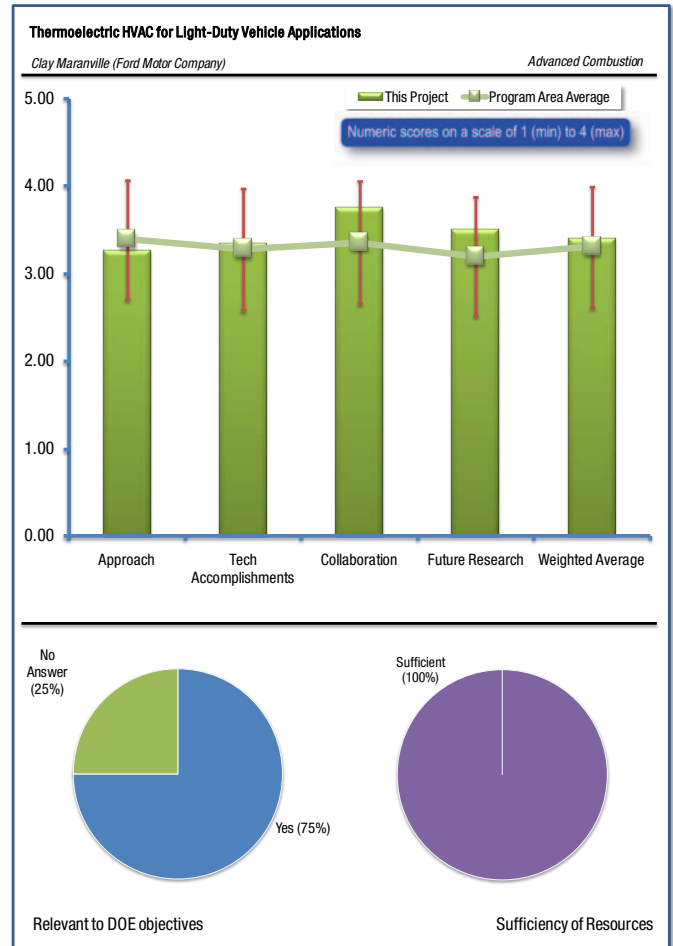
This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that this project does support DOE objectives of petroleum displacement. The reviewer added that the results of this research will make the vehicles become more fuel efficient and lighter in weight by not carrying many parts and components as with conventional HVAC systems. One reviewer said that the project concerned vehicle efficiency opportunities.

A reviewer said that this project concerns integrating thermoelectric coolers in HVAC systems in automotive systems. The reviewer continued that the project began in 2009 and is on track and that the essence of the work is to develop a way to package thermoelectrics in the HVAC system to address the accessory loads of which the HVAC systems are a part. The reviewer added that the technical and commercial approaches which are needed to bring TE to HVAC in automotive systems are the basic effort of this project and in the process the PI wants to eliminate (long term) redundant systems.

A reviewer commented that the approach that the project is taking appears to support the overall DOE objectives of displacing petroleum because of their development of advanced HVAC technologies and capabilities that enable hybrid and plug-in hybrid vehicles development and commercialization. However, the reviewer added, it is not clear at this very early stage of the program how well their choice of bismuth telluride thermoelectric materials will actually perform in achieving the program goals. The reviewer also said that bismuth telluride materials are generally not capable of achieving COP's > 1 in cooling applications, unless temperature differentials are closely controlled and minimized. The same reviewer said that there was no discussion on how they would accomplish this in this presentation. The reviewer also said that the fact that they have a parallel pathway / aspect of their program to develop advanced TE materials to incorporate at a later date is critical to the ultimate success of this system.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that this was a good team with good analytical methods. A separate reviewer said that the milestone time line is well developed with deliberate go/no-go targets and the project is a bit early and the range of results is understandably limited. The reviewer added that the project is intended to reflect "real world" operation in specific geographical locations. The reviewer also said that the tasks include to the following: develop test protocols, use a range of modeling approaches to enable high efficiency systems, and to design, integrate and ultimately validate performance in a demonstration vehicle. The reviewer continued by saying that collaborations with NREL and Visteon will take advantage of simulations tools they have developed to optimize such things as number of TEDs, location of vents, air temperature, flow rates, and so forth.

The same reviewer noted that the testing will leverage Ford's experience in designing climate control systems and that collaborations with BSST will further facilitate developing computer models to predict TE performance and design optimizations. The reviewer

ended by saying that some effort is also being directed toward improving ZT of commercial TE materials such as Bi_2Te_3 (especially for P-type materials and this effort is being pursued in collaboration with Ohio State.

They have a strong team that gives a high probability of success in addressing the goals and potential issues with bismuth telluride discussed above. It is not clear at this point how their team intends to create the compact, high-performance TE systems that will be required to enable this zonal-system concept. They are early in their design phase, so perhaps this will develop as the project matures. Their team progress in this regard will have to be monitored closely and their solutions to this issue must be evaluated closely. The project plans appear to be thoroughly developed at this stage. One reviewer said that the approach can be improved to be more effective.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that they have done as much as one would have expected given their early design stages. It was good to see that they have created a set of bounding design conditions and environments that will guide their design efforts. A separate reviewer stated that there were good initial results and that a solid plan is in place. A different reviewer said that the project is making progress toward the final objectives.

One reviewer said that the results presented were somewhat of a broader, nonspecific level. The reviewer believed it would have been better to focus on a specific result and discuss that in some detail. The reviewer continued, commenting that the effort has focused on a more real-world performance evaluation of a specific test platform (automobile model). The reviewer added that the Ford Fusion HEV was selected in the demonstration program around which integration of TE devices is being evaluated. The reviewer also noted that the Fusion is a flexible platform. The reviewer also said that a study of population density centers and driving patterns in a range of locations is being conducted to prove the efficacy of the concept and to minimize a test protocol.

The reviewer also said that Visteon is carrying out the baseline simulation and the results are being used to develop an understanding of thermal sensation (in a minikin). The reviewer continued by saying that BSST is developing a liquid look design to reduce the size of TE pellets. The reviewer also said that OSU efforts have centered on materials evaluation for TE.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that the project has a strong team that can address the challenges and issues that are associated with this project. The reviewer added that there appears to be very good collaboration with Visteon and NREL at this point, but it is not clear how much collaboration is on-going with BSST. A separate reviewer said that the collaborations are excellent, covering a full spectrum of issues as noted above. One reviewer stated that there was a good team assembled with complementary capabilities. One reviewer noted that this project has a good group of collaborators and good results can be expected via well coordinated work.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that the test plan for the way forward is well developed. One reviewer said that there was a solid plan with realistic stretch targets. A separate reviewer noted that the project's plans are logical and rationale, with a good emphasis on the barriers to overcome and mitigating the risks. Their demonstration vehicle selection is very good. One reviewer said that the proposed future work is reasonable and technically sound.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that the resources for this project are sufficient for the project to achieve the objectives in a timely fashion. A different reviewer said that the resources allocated are appropriate for the range of tasks being carried out. A separate reviewer stated that there was appropriate funding.

Improving Energy Efficiency by Developing Components for Distributed Cooling and Heating Based on Thermal Comfort Modeling: Gregory Meisner (General Motors)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

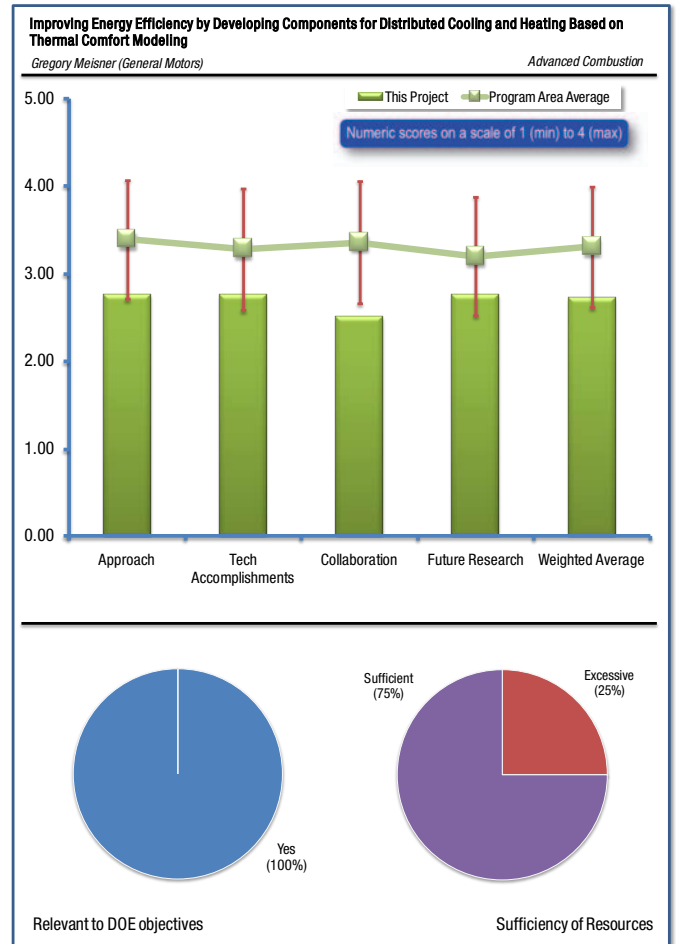
A reviewer said that this project does support DOE objectives of petroleum displacement by reducing the weight of the HVAC system by using thermoelectrics. One reviewer commented that this project does support the DOE objective of petroleum displacement, as it is a key enabler of hybrid and plug-in hybrid vehicle technologies. The reviewer continued by saying that the project appears in early stages of development however, so progress on achieving DOE objectives must be monitored closely as their project matures. A different reviewer said the relevance was vehicle efficiency improvement.

One reviewer said that this effort focuses on waste heat recovery for improving fuel economy and that as such it is relevant to DOE's interest. The target is to reduce HVAC consumption by 30%. The reviewer added that the partners include Berkeley, Delphi Thermal Systems and University of Nevada, and the overall objectives are to reduce HVAC components that employ TE materials to improve COP to a level greater than 2. The reviewer continued by saying that included is a component to understand the physiological response of passengers to heating and cooling cycles.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that the project had a good team with solid analytical approach and the correct skills mix to approach the problem. A reviewer said that the tasks include prioritizing a list of potential distributed heating and cooling components, complete selection of a suitable GM vehicle, and complete definition of a design approach. The reviewer continued by saying that these sorts of efforts, important as they are, probably do not deserve to be offered as major accomplishments (unless there are some special considerations that would give an appreciation for them). The reviewer added that Phase 1 concerns applying a “thermal comfort model” to determine how vehicles respond to heating and cooling, and the team will carry out wind tunnel testing in the Delphi wind tunnel. The reviewer also noted that Phase 2 will concern developing an initial prototype of HVAC components and evaluate performance on a demonstration vehicle. The reviewer also stated that additional phases were presented.

One reviewer said that in the presentation GM discusses the objective to “Develop new thermoelectric materials to improve the efficiency of thermoelectric generators for engine waste heat recovery.” The reviewer continued by saying that this project is not about improving thermoelectric (TE) generators for waste heat recovery, it is about improving the performance of TE cooling systems and their application to zonal cooling in automotive passenger cabin cooling. The reviewer suggested that GM should be focusing on TE materials for improving TE cooling system performance. The reviewer added that University of Nevada - Las Vegas is not well known for TE materials research, so it is not clear how well this aspect of their project will progress. The reviewer also commented that there is no discussion of thermal manikin evaluations, only discussion of human subject testing. The reviewer felt that this can be



quite subjective and may give ambiguous, vague results that will be difficult to interpret in guiding their design work. The reviewer also said that Phases 2, 3, 4 and 5 were only briefly described in the presentation, so it is difficult to assess the overall project plan except to say there are some uncertainties on how the phases fit together. The reviewer continued by saying that Phase 5 looks completely out of place in this project.

A reviewer felt that the thermal comfort model has not been clearly explained. The reviewer continued by saying that the presenter seemed to not having a good understanding of the concept and that the model has to be set up with appropriate boundary condition for validating a tri-zone system as said during presentation.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said that the program is just starting and there were good initial plans and results. A separate reviewer said that technical accomplishments and progress are not significant as presented and so therefore, it is still early to tell whether or not the project will be successfully carried out toward DOE goals.

A reviewer said that the tasks were presented in rather general terms, which made it a bit difficult to get a better sense of the accomplishments over the past year. The reviewer suggested that in the future, the PI should ask the collaborators to supply one slide that best illustrates the results of their effort over the year. The reviewer continued by saying that as it stands, the results presented were somewhat general and hard to judge, which perhaps may unfairly bias the perception of the progress made and the significance of the effort.

One reviewer said that the team members have started to develop their plans at this point, but they appear to be early in their project. The reviewer continued by saying that in 2010 the project plans to develop a mule vehicle for thermal comfort evaluations and those plans are good, but they must be integrated with results from UC-Berkeley's Thermal Comfort Model. The reviewer stated that this model must be updated quickly, but there was not discussion of what updates are necessary for this project. The reviewer also suggested that the project's work also needs to be integrated with the results from the mule vehicle thermal comfort evaluations, but GM did not discuss how this will be accomplished. The reviewer asked why UC-Berkeley is identifying the initial set of heating and cooling components for development and what Delphi's role was in this task effort.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that the collaborations are very good and the PI is leveraging their expertise to meet project goals. One reviewer said that the collaboration team is good; however, there are little results of the collaborative effort shown and explained during presentation. The reviewer added that a more aggressive collaborative effort needs to be demonstrated besides just mentioning what other collaborators have been developed for their own purposes.

A separate reviewer said that the project has a good team, but it is not clear whether it is as strong as the other team on this program. The reviewer continued by saying there is some collaboration occurring, but it is early in their project and this must be monitored going forward. The reviewer believed that there seems to be some collaboration on develop operating parameters and how these are related to the HVAC component design, but once again an incomplete list of specifics were given so it is difficult to judge what level of collaboration and what specific technical parameters are being discussed between the team members. One reviewer said that this was a good team with broad skills, but wondered if UNLV will contribute materials specifically for HVAC and if not, what their role is.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that it was a good plan that was just getting started. A separate reviewer noted that additional human testing will continue at Berkeley, and human testing will be performed at Delphi. One reviewer said that the plans may lead to improvements, but need better co-ordination and focus on the problems. A separate reviewer commented that Phase 5 looks to be completely out of place

and suggested that this project should focus on developing TE materials for enhancing TE cooling performance, not focus on developing TE materials for waste heat recovery.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said there was appropriate funding. A separate reviewer stated that the resources are adequate for the effort described, adding that it would help the PI's case to show more in the available time to justify the investment in this effort. Another reviewer noted that the resources seem to be more than what it needs to achieve the objectives and suggested that GM does better planning and become more aggressive in executing this very important project.

Thermoelectric Conversion of Waste Heat to Electricity in an IC Engine Powered Vehicle: Harold Schock (Michigan State University)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that this project is relevant to DOE's interest by its focus on exhaust waste heat recovery from automobiles and the associated gains in fuel economy that could potentially result. A separate reviewer noted that this project supports the overall DOE objectives of petroleum displacement by making the vehicles more fuel efficient and at the same time less pollutants. The reviewer added that using thermoelectrics as a way to harness the energy from waste heat is an excellent choice. The reviewer continued by saying that it will also reduce the weight and maintenance of vehicles by not having to carrying auxiliary power sources.

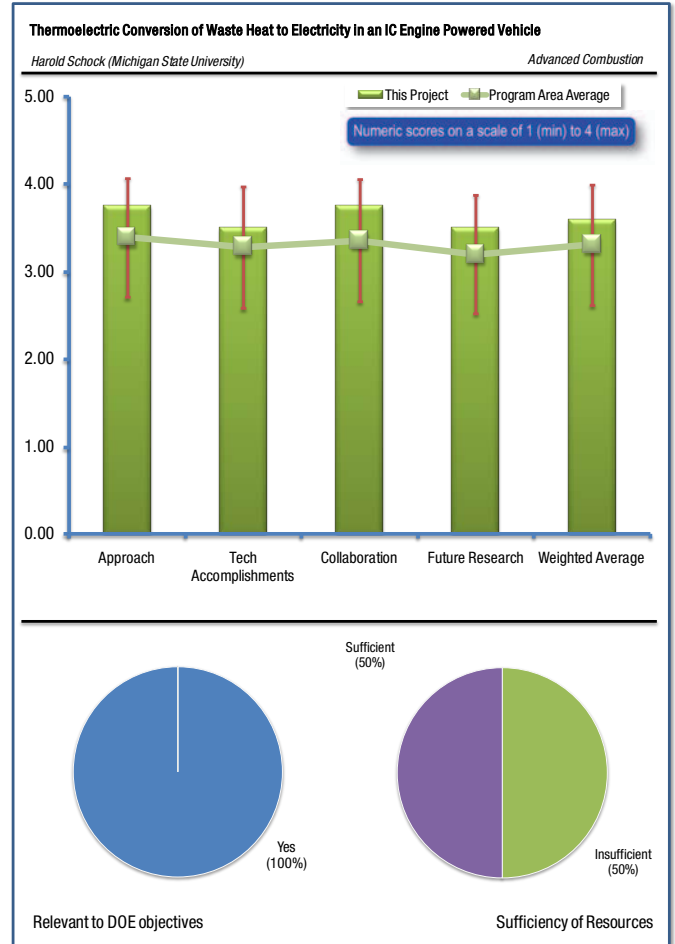
One reviewer said that this project on heavy vehicle waste energy recovery is particularly important because the amount of power that can be produced is much higher than in light-duty vehicles. The reviewer continued saying that the TEG system weight penalty on vehicle performance is also much less, if any at all, on a heavy vehicle than in a light-duty vehicle. The reviewer added that a 3-5% increase in BSFC is quite significant to the trucking industry and would have a significant impact on heavy vehicle fuel usage nationwide. One reviewer commented upon vehicle efficiency improvement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that the project had a good plan with appropriate team skills and systematic approach. The reviewer noted that the approach has been adjusted as the vehicle market moves. A separated reviewer stated that the presenter clearly demonstrated that the project's approach is working since they understand the technical difficulties and they have the solution to effectively solve the problems.

One reviewer noted that the approach is reasonable and covers a lot of elements. The reviewer added that the team assembled is wide-ranging and includes a range of expertise and capabilities. The reviewer believes that the problem has been addressed from a broad perspective, covering as it does materials development, modeling, metrology for performance, module design and integration. The reviewer continued by saying that the PI has also noted the importance of interfaces as an issue that needs to be addressed and they apparently have a solution (which was stated to be proprietary). The reviewer added that the project has targeted skutterudites as material with attractive properties for TEGs.

A reviewer said that they have taken a good approach to this project. The reviewer noted that the thermal cycling test that shows a 20% reduction in power output after 10 cycles is of concern, given that these systems must cycle 1500-2000 times per year in a typical vehicle application. The reviewer continued by saying that the project's work on advanced power electronics to integrate with this



system is very good and their systems approach incorporating thermal transport solutions, TE materials analysis, TE module assessments, power electronics and their vehicle-level analysis impacts is quite good.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer believes the project team has made excellent progress in achieving their goals. The reviewer added that they have addressed many of the technical challenges in thermal management, advanced TE materials, TE devices fabrication, system fabrication, and system analysis on limited funding throughout their project timeline. The reviewer continued by saying that the module and power scale-up studies are very good and shows the progression that has been made. The reviewer added that the work with advanced TE materials is also quite good and shows a pathway to higher power systems.

A separate reviewer said that there have been many good results, but component failures are a concern. The reviewer added that the vehicle application seems to have shifted to what the reviewer believes is a more attractive target.

One reviewer commented that it was an excellent presentation with many facts and figures. The reviewer continued by saying that the team is making lot of good progress toward the goals of the project and that this suggests that the barriers will be overcome. The reviewer recommends that this project be allowed to continue with funding since they have well demonstrated their effort in meeting DOE objectives.

A reviewer said that the project appeared to review several years of work and that it is evident that a large number of tasks have been included in the research over the year. The reviewer also commented that in the oral presentation of results, it was difficult to determine which results were for the most recent reporting year and which were part of earlier efforts, though the PowerPoint slides were clearer on this point. The reviewer suggested that in the future, the PI should attempt to stick with the most recent reporting year (since that is what is supposed to be evaluated) and to minimize background and past accomplishments. The reviewer suggested that the PI can be aided in this effort by simply requiring from his collaborators one slide that summarizes what they have done (in the past year) and perhaps one graph to show a representative quantitative result and an identifier of some sort on each of the supplied slides from a collaborator.

The reviewer also said the approach to materials taken by the PI is that skutterudites are attractive for TE modules and that his efforts have shown significant gains in thermoelectric efficiency ($ZT=1.6$ at around 800K).

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that they have a strong team that is well coordinated and quite knowledgeable in addressing this project's challenges and issues. The reviewer continued by saying that the project team's analytic and experimental integration of thermal system design, TE system design, advanced power electronics design, and advanced TE materials (i.e., skutterudites) is very good and their module and power scale-up studies are also very good and show the collaboration within their team. The reviewer also said that this project team has accomplished as much or more than any of the other contractors on this project with somewhat limited funds compared to the other contractors.

A separate reviewer stated there were solid relationships with a number of groups. A separate reviewer said that this project shows an excellent collaboration between these groups and their efforts are well coordinated. The reviewer strongly believes that collaboration is the key to successfully achieving the objectives.

One reviewer said that the collaborations are good and the team is extensive. The reviewer also said that what specific contributions could be attributed to specific partners was not always evident, and that perhaps in the future the PI could be more specific on this point.

QUESTION 5: HAS THE PROJECT 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?

One reviewer says that the team has a very good plan that is clearly based on their understanding of the barriers and the tasks. The reviewer strongly recommends that the MSU project continue to be funded so that they can successfully finish this very important task. One reviewer said that the way forward seems to focus on further material development with some work on interfaces. It was unclear to the reviewer what tasks would be continued given the apparent reduction of funding. A separate reviewer believed that the program is being scaled back and plans are uncertain. One reviewer said that the program's plans for building a 1 kW TEG prototype are very good and exactly the right step. The reviewer added that it builds and leverages nicely on their current progress and accomplishments.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said that this was an excellent presentation. The reviewer added that the presenter as well as the team has well demonstrated their efforts in successfully achieving the objectives. The reviewer believes that the resources seem to be insufficient for the MSU team to achieve the goals in a timely fashion. The reviewer strongly recommends to DOE that this project should continue to be funded at a higher level of funding until we have a final product that can be used on any IC engine powered vehicles. A reviewer said that the resources are adequate for the funding allocated to this project, adding that there has evidently been some scale-down in funding but still a lot of work is being pursued. A separate reviewer said that there was an appropriate level of funding.

Develop Thermoelectric Technology for Automotive Waste Heat Recovery: Gregory Meisner (General Motors)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

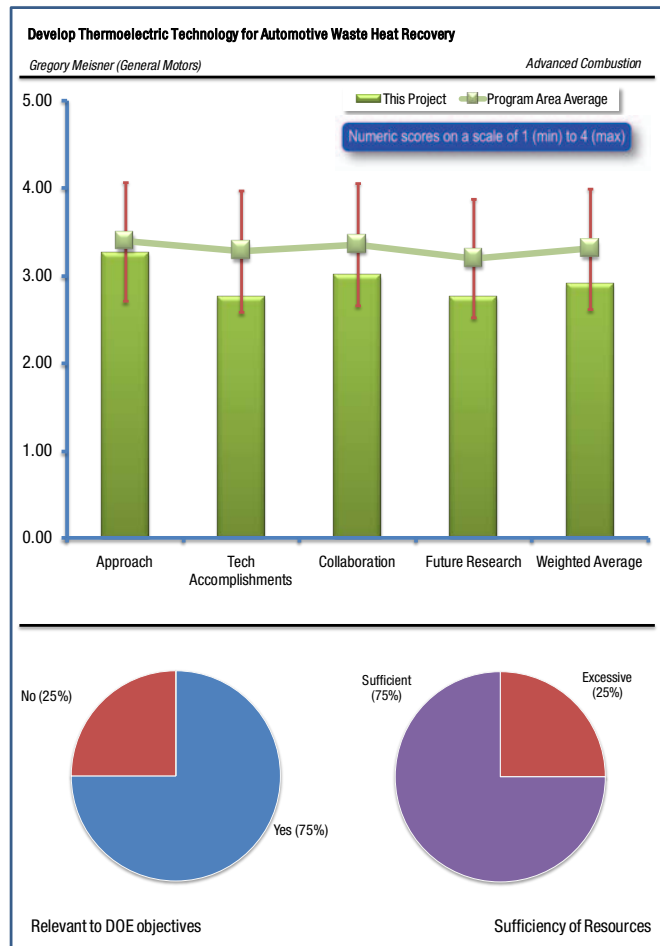
One reviewer suggested improved vehicle efficiency as an aspect of relevance. A reviewer stated that this project supports the overall DOE objectives of petroleum displacement by making the vehicles more fuel efficient and lower emission, adding that using thermoelectric as a way to harness the energy from waste heat will also cut down the weight of vehicles by not carrying auxiliary power sources. One reviewer commented that they are currently only using bismuth telluride in their thermoelectric generator (TEG) design to demonstrate their system design. The reviewer believes that this bismuth telluride system will not perform at high enough power levels to impact fuel economy and taking this approach will not bring this TEG system to a commercially viable product fast enough. The reviewer added that the team is generally making only small, evolutionary progress compared to other teams.

A separate reviewer stated that this project began in 2005 and thus far about \$13 million has been invested. The reviewer added that the overarching goal is integration of TE modules into automotive systems for waste heat recovery. The reviewer continued by stating that the specific objectives have included completing construction of a TEG, modifying a specific vehicle to accommodate a TEG, and fabricating TEG modules. The reviewer also noted that the effort also includes improving ZT and other thermo-mechanical properties of skutterudites (which appear to be the material targeted), though Bi_2Te_3 seems to be integrated in the TEG constructed.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said that the approach is reasonable and can be improved to overcome some barriers such as weight, size and volume. The reviewer believes these are very important in making the waste heat recovery TEG unit acceptable. A reviewer said that there was a good approach with initial modeling, material development, and now vehicle demonstration. A separate reviewer commented that the project began with developing a model to design TEG and to use the model to design, fabricate and assemble a prototype TE generator. The reviewer continued by saying that power electronics for power conditioning, algorithms for controlling thermal to electrical conversion and improved TE materials (skutterudites) constitute the main work of the effort. The reviewer added that in the module developed, Bi_2Te_3 was used.

A reviewer said that using a Chevy Suburban as a demonstration vehicle is a good approach and the team's thermoelectric (TE) system sectioning approach is a proper design approach. The reviewer continued by saying that the presentation gave no details on the energy flows in each section and the exhaust temperature profiles that justify why this approach was taken or what the benefit is from this approach in their application. The reviewer suggested that with a power output of only 350 W average, there is some question as to whether this sectioned design is truly optimized.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer stated that the project had shown solid accomplishments, but unfortunately, real world operation of LD vehicles has low exhaust energy availability and original program goals are not likely to be met. A separate reviewer said that a thermoelectric generator design was fabricated for an exhaust system using Bi_2Te_3 TE materials and that the details were shown of the design in a particular model car. The reviewer added that the TEG modules were fabricated by Marlow. The reviewer continued by saying the skutterudites with ZT of 1.6 at 800K were shown. The reviewer also said that the collaboration with UNLV examined how formation of nano precipitates could reduce thermal conductivity.

A reviewer said that GM needs to show some concern about the weight of the TEG even at the initial design level, since weight is a very important factor in determining the fuel efficiency as well as the applicability of the TEG. The reviewer added that a big and heavy TEG unit will defeat the purpose of improving fuel efficiency when it is used on vehicles.

One reviewer felt that the team has told little in this presentation and that it is difficult to assess their progress and accomplishments. The reviewer is quite concerned that they do not know the TEG weight and impacts of that weight on vehicle performance. The reviewer adds that if this system is too heavy, then any net fuel economy impacts will be small and possibly negligible. The reviewer felt that the project had relayed very little on their systems design, thermal design, TE design, and weight impacts on vehicle performance. The reviewer added that there is no energy diagram showing the details of temperatures and heat flows in the two sections, nor any discussion of the tradeoffs between energy flows, exhaust temperatures, and power in the two sections. Because of this the reviewer found it difficult to assess whether the average power of 350 W is the best that can be achieved with their system. The reviewer added that even after reviewer questions on the second section design, GM offered no further explanation on the design specifics. There was little or no discussion on how much fuel economy improvement was possible with a 350 W system and how weight impacts factored into that evaluation.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that the team of collaborators is extensive, with most concerned with the materials and fabrication concepts. A separate reviewer stated that it is a large, well-integrated team. A separate reviewer commented that they have a strong team with reasonable collaboration and coordination. However, given the strong team on paper, there seems to be (relatively-speaking) less progress on this project. The fact that they lost General Electric on their team has been a detriment to their project. One reviewer suggested that the coordination between partners could be improved to provide a means for a better design of TEG.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that future work will provide test results for an initial TEG, assembly of a second generation TEG with full electrical system components, perform dynamometer tests for a vehicle equipped with a TEG, and finally demonstrating fuel economy gain. For the latter, the reviewer said, even without any weight optimization of the TEG, the PI's results have shown a 5% improvement of fuel economy. The reviewer continued that the plan is to continue to examine skutterudites and suggested that the team should consider their availability to meet potential demand. The reviewer feels that future presentations should mention this issue.

A separate reviewer felt that plans for incorporating higher performance skutterudite materials are too slow. The reviewer added that their average power output is relatively small, and it is not clear that this power output will impact vehicle performance all that much or this team's approach will ultimately achieve close to the VTP project goals. The reviewer adds that the system design shows only a fair amount of innovation and the fact that they do not know their system weight at this point (or would not answer the question) is not a good indicator.

One reviewer recommended that GM should look at a more practical TEG design for their proposed future research. They need to pay attention to size, weight and volume for the TEG as well as the cost. The separate reviewer suggested that program be finished.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that the funding was appropriate. One reviewer felt that the investment of \$13 million is quite extensive over the past five years and that from the information it was unclear if there was sufficient return on this investment. The reviewer suggested that perhaps GM's overhead is very high which would account for the high costs. One reviewer felt that the resources provided for the project are excessive. The reviewer recommends that funding should be adjusted to reflect the progress has been made by the GM team.

Automotive Waste Heat Conversion to Power Program: John LaGrandeur (BSST LLC)

REVIEWER SAMPLE SIZE

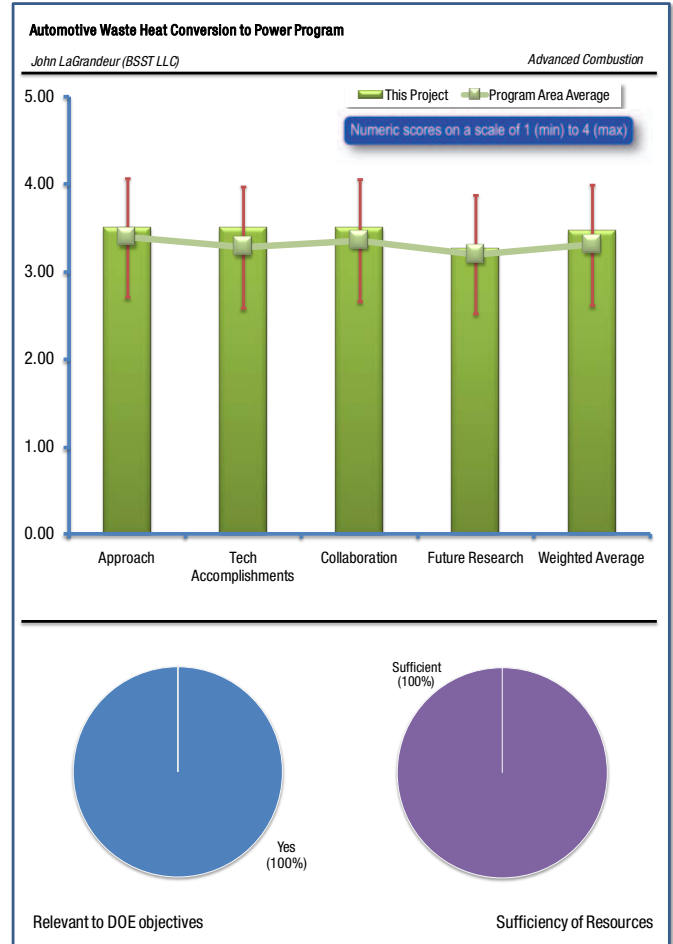
This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that the project supports the overall DOE objectives of petroleum displacement by making the vehicles more fuel efficient and less pollutants, adding that using thermoelectric as a way to harness the energy from waste heat and will also cut down the weight of vehicles by not requiring auxiliary power sources.

A reviewer said that this project began in 2004 and includes a range of collaborators (Ford, BMW, Visteon, JPL, Caltech, NREL, Virginia Tech, Faurecia). The reviewer added that the emphasis is on waste heat recovery, which is consistent with DOE's emphasis on improvement in fuel economy in automobiles.

A separate reviewer said that while the project does support DOE objectives, it is only a reserved “Yes” because their power level is only barely large enough to start impacting fuel economy. Their build and test of a 500 watt TEG system at NREL is quite significant in moving the technology forward. While their power output is starting to become large enough that they can impact the fuel economy in a light-duty vehicle, it is concerning that they are not planning to go above 500 watts. This represents a significant reduction / retrenchment (~33% reduction) from the 750 watt power level this team was proclaiming and committing to earlier in their project. There was little or no discussion in the presentation on why they had to degrade their power output. One reviewer noted improved vehicle efficiency.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer said there was a good approach with appropriate modeling, component level testing, and system plans and a useful improvement had been shown in each phase. A reviewer said the project objectives include developing a TEG architecture that improves manufacturability of TE engines and assemblies, evaluating and optimizing TE interfaces, and simplifying the TEG vehicle system including a reduction in the overall size and weight. The reviewer added that the project effort also includes testing interfaces (brazes, solders, liquid metals, etc). The reviewer continued by saying that this year a 500W TEG was build and tested (some experimental difficulties were noted that included leaks, which pushed back the milestone schedule for dynamometer testing), adding that the circular TE module was evaluated in a bench scale arrangement. The reviewer continued that the testing included evaluating interface materials and determining the temperature drops across the module. Cartridge heaters provided precise control of the heat input. The reviewer added that both individual TE elements testing and module testing of the hoop arrangement were carried out.

A reviewer said that the project team has a good understanding of the thermal and TE system problems and challenges of developing and fabricating the TEG system. The reviewer continued by saying that the validation of the robustness of thermal and electrical interfaces was very good and the team’s use and consideration of half-heusler materials and TE element segmentation is very good. The reviewer said this will ultimately help to increase their power output. The reviewer felt that the presentation lacked a system-level

discussion of how much a 500 watt TE power system could ultimately impact fuel economy. The reviewer noted that they had showed in 2009 that this impact could be 1.5 - 3.3% with ZT's ~ 1.25 and would only get to a 4.5 -5% level if ZT's ~ 2. The reviewer felt there was no plan apparent for achieving material ZT's ~ 2, so the only conclusion is that their impact on fuel economy with system is in the 1.5 - 3 % range, and this is low compared to the VTP goal.

A reviewer said that the approach can be improved not only by paying attention to the mechanical design of the heat exchanger but also on the TE materials development. The reviewer suggested that better TE materials that can be used at higher temperature are important in vehicle applications. The reviewer felt that the presenter did not sufficiently address the question of substrate material at high temperature. The reviewer continued by saying that the coefficient of thermal expansion, thermal conductivity as well as electrical conductivity all are important factors in selecting an appropriate substrate material for high temperature applications. The reviewer would like to have a rather clearer explanation from BSST on how they choose the substrate, especially on the high temperature side.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that there was good understanding of the importance of weight in the overall fuel economy requirement and the problem of back pressure had also been addressed. A separate reviewer commented that there had been good results so far.

A reviewer said the project's transition from a planar TEG design to a cylindrical system was particularly important, adding that the thermal cycling of their devices/assemblies at 100 to 1000 cycles is very good. The reviewer continued by saying that the TEG modeling and integrated TEG / vehicle modeling has been effective and quite helpful in enabling their team to move forward on their designs. The reviewer added that the fact that their TEG system weight is around 10 kg is quite good. The reviewer found it somewhat disappointing that the project team is only targeting about 500 watts in their final system. The reviewer stated that this represents a significant reduction / retrenchment from the 750 watt power level this team was proclaiming and committing to earlier in the project. The reviewer felt there was little or no discussion in the presentation on why the power output was degraded. The reviewer also said there was little or no discussion in the presentation concerning what impact a 500 watt system could have on fuel economy. The reviewer acknowledged that it was shown in their 2009 review. The reviewer believes the impact on fuel economy is small compared to VTP goals over an entire drive cycle. (Some of the results reported were from past years which was a bit distracting, though nonetheless interesting to see, to evaluating the work over the past year.)

One reviewer said that the Phase 3 planar form was redesigned into a cylindrical form to improve manufacturability and that this design is potentially significant. The reviewer added that a predictive model for TEG performance was developed and compared with measured I-V measurement and that design requirements and modeling of TEG temperature was also addressed. The reviewer continued by saying that exhaust system modeling was performed to achieve back pressure (an effort of Faurecia).

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this was a strong team and they have demonstrated very good collaboration and coordination in developing and testing their 500 watt and 125 watt systems, and developing and optimizing their engine and exhaust system interfaces. A separate reviewer said that this was an excellent team that combines two OEMs, suppliers, and academia. The reviewer added that it sounds like production will launch in a couple of years.

One reviewer stated that collaborations include teaming with Ohio State, Northwestern for materials characterization, adding that the PI has done a lot of work with the team he has assembled.

A reviewer said collaboration with a car company such as BMW and Ford is a good chance for this team to transition the technology directly to the consumers. The reviewer also noted that the cost analysis as well as TE materials availability and low cost manufacturing process were not discussed in the presentation.

QUESTION 5: HAS THE PROJECT 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?

A reviewer suggested that the team keep going adding that future production plans are encouraging. A separate reviewer suggested that future research should focus not only on the technology but also on low cost material and low cost manufacturing process. The reviewer felt that these should be included in the presentation along with the cost analysis. One reviewer said that their plans for vehicle performance testing at BMW, Ford, and NREL are logically thought out and their timing is good for commercializing this technology more quickly than other teams. The reviewer added that their retrenchment / reduction to a 500 watt system is cause for concern, especially with little discussion as to why the project incurred the power reduction and what might be done to re-claim the power reduction in the future. The reviewer felt it was not clear how the team plans to achieve a higher impact on fuel economy (closer to VTP goals) with their current system. One reviewer noted that the program ends this year and dynamometer testing still remains to be done. The reviewer added that this would constitute a phase 4 effort and a phase 5 objective would include TEG installation and evaluation in BMW and Ford Fusion Vehicles.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said that the project is indicated as being completed (this phase) in October 2010. A separate reviewer said that the resources are sufficient for the BSST team to carry out the project in a timely fashion. A different reviewer felt that current funding was appropriate.

5. FUELS & LUBRICANTS TECHNOLOGIES

The Fuels & Lubricants Technologies subprogram supports fuels and lubricants R&D to provide vehicle users with cost-competitive options that enable high fuel economy with low emissions, and contribute to petroleum displacement. Transportation fuels are anticipated to be produced from future refinery feedstocks that may increasingly be from non-conventional sources including, but not limited to, heavy crude, oil sands, shale oil, and coal, as well as renewable resources such as biomass, vegetable oils, and waste animal fats. The impact of changes in refinery feedstocks on finished fuels is an area of relatively new concern to engine manufacturers, regulators and users. Advanced engine technologies are more sensitive to variations in fuel composition than were earlier engines, in addition to facing tightening emissions standards. The goals are: (1) to enable post-2010 advanced combustion regime engines and emission control systems to be more efficient while meeting future emission standards; and, (2) to reduce reliance on petroleum-based fuels through direct fuel substitution by non-petroleum-based fuels. These activities are undertaken to determine the impacts of fuel and lubricant properties on the efficiency, performance, and emissions of current engines as well as to enable emerging advanced internal combustion engines. These advanced engines operate in low-temperature combustion regimes that are expected to become more prevalent in the marketplace because of their higher efficiency and continually improving emissions performance. These activities are coordinated with and supportive of EPA's fuels and emissions-related activities, as mentioned in their strategic plan.

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1 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 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
APBF Effects on Combustion	Bruce Bunting (Oak Ridge National Laboratory)	5-2	3.67	3.33	3.50	3.00	3.40
Fuels for Advanced Combustion Engines	Bradley Zigler (National Renewable Energy Laboratory)	5-4	3.33	3.50	3.80	3.00	3.43
Quality, Performance, and Emission Impacts of Biofuels and Biofuel Blends	Robert McCormick (National Renewable Energy Laboratory)	5-6	3.17	3.50	3.50	3.00	3.35
Fuel Effects on Advanced Combustion: Optical Heavy-Duty Engine Research	Charles Mueller (Sandia National Laboratories)	5-8	3.00	3.40	3.60	3.00	3.28
Mid-Level Ethanol Blends Test Program	Brian West (Oak Ridge National Laboratory)	5-10	2.83	3.33	3.33	2.83	3.15
Advanced Lean-Burn DI Spark Ignition Fuels Research	Magnus Sjoberg (Sandia National Laboratories)	5-12	3.20	3.00	3.00	3.00	3.05
Non-Petroleum-Based Fuels: Effects on Emissions Control Technologies	Scott Sluder (Oak Ridge National Laboratory)	5-14	3.17	3.33	3.33	2.83	3.23
Non-Petroleum-Based Fuel Effects on Advanced Combustion	James Szybist (Oak Ridge National Laboratory)	5-16	3.60	3.20	3.33	3.33	3.33
Advanced Petroleum-Based Fuels Research at NREL	Bradley Zigler (National Renewable Energy Laboratory)	5-18	3.00	3.17	3.50	3.00	3.15
Chemical Kinetic Modeling of Fuels	William Pitz (Lawrence Livermore National Laboratory)	5-20	3.33	3.40	3.50	3.00	3.35
OVERALL AVERAGE			3.23	3.32	3.44	3.00	3.27

APBF Effects on Combustion: Bruce Bunting (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer felt the project was relevant as it could potentially lead to introduction of new fuels or more efficient combustion. Another said the research to improve engine efficiency and alternative fuels research will result in petroleum displacement. A third reviewer said the project was focused on determining fuel characteristics that enable high efficiency, emission compliant engines, and that success would lead to lower consumption of petroleum based fuel. The final reviewer said that this project is investigating the fundamentals of combustion and engine operation. This has a direct bearing on efficient use of fuels, both petroleum and non-petroleum based.

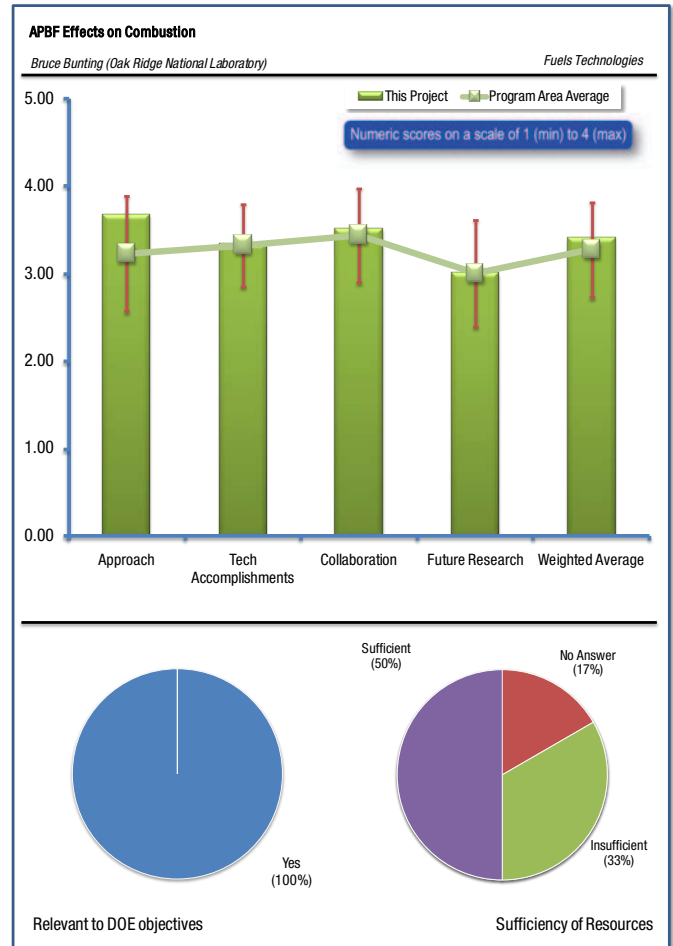
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reviewers felt there was a good combination of engine studies and modeling, and good investigations of the fundamentals of combustion technical barriers. A third review comment was that the project had an excellent approach of evaluating a range of fuel types and different engine platforms. This reviewer approved of the inclusion of petroleum based fuels, biofuels, and alternative fuels (oil sands & oil shale) to help establish fundamental understanding of relationship between fuel properties and compositions vs. performance. The final commenter noted that this project has used the FACE fuels from the CRC research and appears to be well designed.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer stated generally that there was good progress on many fronts on HCCI, PCCI and conventional combustion. Also stated was that the work on FACE fuels and HCCI exhaust chemistry has progressed well in the past year. The team has initiated a CRADA program on ionic liquids with GM, and determined that these lubricants have some benefits relative to conventional lubes (better thermal stability, better lubricity). A reviewer strongly supported addition of gasoline research engine due to potential for efficiency improvements and increasing supply of gasoline/ethanol in the U.S. pool: this reviewer also felt it was important to continue to improve the kinetic model. PCCI fuel effects were well studied, in this reviewer's opinion.

Reviewers noted several specific technical accomplishments of the project: the investigators have tested the CRC FACE diesel fuels in HCCI and PCCI advanced combustion modes, have identified the fuel properties/compositions preferred by each of these engines, and are also using these fuels as basis for a kinetic modeling mechanism reduction with the University of Wisconsin. Other accomplishments that were highlighted by reviewers included that the team has determined the detailed exhaust chemistry for the HCCI engine, and determined that 90% of HC emissions come from unburnt fuel. The team has also found that PM is from volatile condensation products, not traditional diesel soot. This reviewer pointed out that the team has built on experimental work by using CFD modeling.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Opinions on collaborations were generally positive. Among the comments were that the research team is working effectively with a wide range of groups, and that the collaboration with CRC, GM and others appears to be well directed. A reviewer said that the team has established collaborations with OEMs/engine manufacturers, several energy companies, and universities. The final reviewer said the collaboration was good, but that the team needs to mention details of the contributions of partners.

QUESTION 5: HAS THE PROJECT 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?

The first reviewer recommended the highest priority be placed on gasoline/ethanol work. Another suggested that cuts in budgets must be planned for, and the research team needs to rethink priorities to accommodate these potential cuts. A reviewer pointed out the FACE diesel work in the future research, and offered that ionic liquids represent a new class of lubricants. Plans of continuing experiments and statistical analyses and modeling to evaluate petroleum and biofuels in advanced combustion engine regimes are very good, according to another reviewer (although this reviewer had concerns about funding). This reviewer emphasized that more progress will be made on ionic lubes. The final reviewer stated that the PI didn't spend too much time on future work because he ran out of time.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer thought the project team made good use of resources. The other reviewers had some reservations about resources for this project: one was concerned that the reduction in APBF funding will have a great impact and will reduce the effectiveness of this program. This reviewer said it was important to continue to include petroleum based fuels as baseline and blend components. A third reviewer stated that the future of APBF research is unknown, as the budget is zeroed out for 2011. Some fuels are not available now, according to this reviewer, who suggested that the team emphasize renewable fuels instead of petroleum-based fuels.

Fuels for Advanced Combustion Engines: Bradley Zigler (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer stated that the FACE type programs are a necessary first step in making a wide-range of improvements in fuel economy and to use as baselines for the next generation of fuels. Another said this project improves understanding of fuel effects on efficiency and properties of new fuels. Further, this project is developing the most characterized fuels for fundamental R&D on both fuels and engines, which will lead to better understanding for alternative fuels use in engines. A reviewer said that the team is focused on enabling advanced combustion engines having improved fuel economy by understanding fundamental relationship between fuel properties and performance. The final commenter observed that the goals are to improve efficiency by 25% for gasoline and 40% for LD vehicles by 2015, to understand the fuel property impacts on advanced combustion processes, and to develop a characterization of advanced research fuels. This reviewer said the research team needs to include ethanol in the matrix because a large quantity of ethanol is entering the gasoline pool.

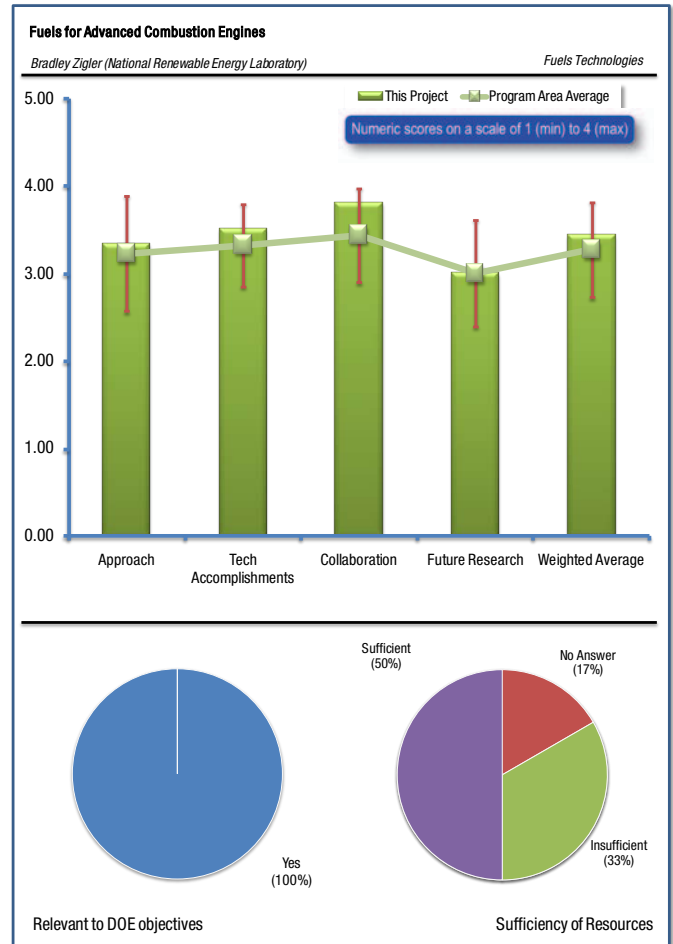
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO

PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer observed that the approach contains a number of important aspects: development of standard sets of diesel and gasoline fuels that are available to all researchers (enables comparison of results across different research labs and engine platforms; extensive characterization of the physical and chemical properties of the fuels to enable correlation of fuel properties to engine performance to an extent not done previously. Another said that characterization of diesel provides very useful information: this reviewer would like to see this work extended to some commercial diesel fuels for comparison. Since a lot of the tie-in to addressing the technical barriers is dependent upon how the FACE fuels are used, according to a third reviewer, this is largely a function of how/if researchers use these fuels. It seems like the fuels are being made readily available. A reviewer highlighted the great collaborative approach to developing a fundamental set of diesel and gasoline fuels as well as low temperature combustion regimes. The final commenter mentioned the project’s coalition of auto and oil companies, fuel blenders, and encouraged R&D activities.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Positive comments included that there were great accomplishments to date, and well characterized fuels. A reviewer thought that progress on characterization is excellent but could be faster. A reviewer said that progress on the gasoline fuel set has been slow (the only non-positive comment received). A third reviewer noted that the diesel fuels set has been developed and is available for purchase through a commercial fuels blender. This reviewer also stated that diesel fuels have been extensively characterized through the CRC FACE Working Group, and that development of the gasoline fuel set is in progress.



A reviewer noted several aspects of the research, including that the diesel fuel matrix is fully blended and characterization of diesel fuels is completed. The research team has also encouraged R&D activities to use the FACE matrix, and has conducted an in-depth analysis of fuels. The work has enabled the AVFL-18 project and a multi-component diesel surrogate with supporting kinetic model. This reviewer suggested that some of these characterization techniques should be applied to advanced and alternate fuels.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Collaboration was generally judged to be good: comments included that collaboration in FACE has been excellent and that there was good collaboration with many outside partners and recognition of same. A reviewer highlighted the collaboration with industrial partners, along with the DOE and Canadian National Lab participation. A reviewer said that working with CRC and academic institutions is crucial for this project to develop research fuels and this program does an excellent job of making the information available and hopefully people will use these fuels. The reviewer further noted that the team is working with industry to do a lot of the gasoline characterization. The final commenter said that this has been an excellent collaboration between the national labs and industry that has been facilitated through CRC - perhaps the best example of national lab-industry collaboration. This reviewer did note that the proposed reduction in APBF will potentially erode this collaboration.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that the future work looking at how engine-based data compares with FACE data is very interesting. It might also be interesting comparing to the work EPA is doing on the new complex model (at least with the gasoline FACE fuels). This reviewer said the researchers should put ethanol in the fuel because it is going to be a reality of the fuel system. Many refiners design their fuels based on ethanol being added to a blendstock (not necessarily blended into a finished fuel). Gasoline without ethanol is an endangered species, so it should be considered for inclusion in the gasoline matrix, according to this reviewer. Another reviewer had comments in a similar track, stating that ethanol should be integrated into gasoline fuels. This reviewer also said that a simpler gasoline matrix focusing on octane+ethanol would be more cost-effective. Future plans are to finalize and enable a fuel blender to manufacture and sell the FACE gasoline matrix, noted a commenter. A reviewer said that plans to obtain and characterize alternative and renewable fuels (similar to what was done with the FACE diesel fuels via CRC working group) are valuable: ultimately the scope and plans will depend on 2011 budget. Similarly, the last reviewer said that there had been good planning for future work but plans may be shifted with funding cuts.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Allocation of resources was judged to be good, but there were concerns about the uncertainty of future funding. A reviewer noted that the cutback in APBF funding has already led to some of the national lab participants to disengage from some of the collaborative programs with industry via CRC. Continued/further cutbacks will likely further erode this collaboration, which at least in the past was a key objective of the DOE programs.

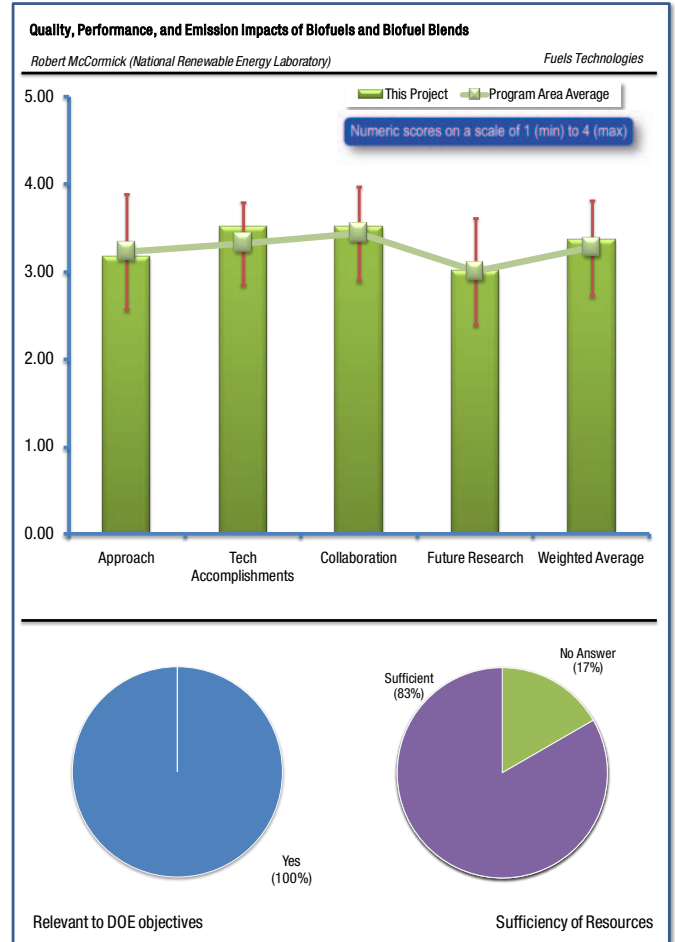
Quality, Performance, and Emission Impacts of Biofuels and Biofuel Blends: Robert McCormick (National Renewable Energy Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviews are generally favorable for this aspect of the research. A reviewer noted that Bob McCormick and colleagues have been the key source of making biodiesel a viable alternative fuel to the U.S. market: without the work of Bob and his partners, biodiesel would still never be used because the problems and shortcomings of the fuel would never be understood. Another comment was that the biodiesel emissions work is very important, especially as some entities push for higher concentrations of biodiesel blended into diesel. The biodiesel surveys are useful given the variability in biodiesel quality. Other comments were that the project focus is on biofuels and biofuels blends which would directly displace petroleum, and that renewables meet the overall DOE objectives of petroleum displacement (however, the quantities of biodiesel entering the pool are small). The final commenter said that it was important to understand the best use of biofuels and to remove barriers to use: this reviewer also noted that overall supply potential is limited.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer observed the excellent approach of focusing on aspects to understand and improve acceptability of biofuels such as: assessing quality of biofuels in the marketplace; development of new biofuels test methods; and biodiesel compatibility/impact on lube oil. Another comment stated that the team has made fundamental improvements to the viability of biodiesel fuel and resulted in improvements at ASTM for the blend and neat biodiesel fuel. A reviewer highlighted the performance testing, chemical analysis, engine and dynamometer testing: the key technical barrier is the biofuel quality.

On the other hand, a reviewer said that oil dilution conditions studied may not be relevant. A final commenter stated that this work is not tied together well to how it promotes the displacement of petroleum. The projects are well-designed and feasible, but need to focus more on the next generation of biofuels (renewable diesels and higher level alcohols).

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Positive comments included that there was good progress in understanding cold soak filtration, and that great technical accomplishments have been made today that led to better understanding of biodiesel. Progress was made in a number of different areas, according to another reviewer: conducted study evaluating biodiesel impacts on lube for passenger vehicles equipped with DPF/SCR and DPF/NAC systems; evaluated effects in DPF-equipped medium duty engines; looked at impact of alkali levels in biodiesel on DPF ash loading; examined biodiesel impact on Fe-zeolite SCR hydrocarbon storage; performed biodiesel exhaust HC emission speciation; developed new methods for analysis of biodiesel; conducted a survey of biodiesel blends being sold in marketplace; and identified causes of poor biodiesel performance at low temperatures. A final commenter had similar observations on

several aspects: biodiesel lube oil effect studies were completed; biodiesel emissions in DPF equipped engines were studied; DPF ash loading study and exhaust hydrocarbon emission characterization was completed, and a biodiesel blend survey was done.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Collaborations were generally felt to be good, with one reviewer observing that there had been good collaboration with OEMs and the National Biodiesel Board. Similar comments focused on the team's good work with engaging NBB, MECA, EMA, etc. and working directly with industry partners (Ford for the Fe-Zeolite SCR work), their good collaboration with co-researchers and acknowledgement of their input, and the way the team collaborates well with wide range of groups. The final comment noted that the Ford collaboration for Fe-zeolite study is good: the reviewer also pointed out the CRC collaborative study on low temperature operability validation for biodiesel blends.

QUESTION 5: HAS THE PROJECT 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?

A reviewer felt there were good plans for moving onto ethanol/alcohols and gasoline for SI engines, and that understanding emission impacts is important. A reviewer suggested looking at severe conditions for oil dilution impacts. A reviewer said that plans to continue biodiesel-lube studies and to do work on next generation biodiesel seem very appropriate and worthwhile. This reviewer observed that mixed alcohol work seems incompatible with regulations in some states that only permit the addition of ethanol to gasoline, not other alcohols. Another reviewer said that next generation biofuels are to be studied (convert biomass to syngas and convert that to higher molecular weight alcohol). This reviewer would also include vegetable oil methyl esters like jatropha. The final reviewer wasn't quite sure what upcoming work was being proposed to complete this upcoming year.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The only comments were that no indication that resources are not sufficient, and that the project is funded at \$1.8 million for 2010.

Fuel Effects on Advanced Combustion: Optical Heavy-Duty Engine Research: Charles Mueller (Sandia National Laboratories)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Among the comments received were that this program has fundamental work toward understanding combustion and behavior in current and future engines. There is a need to design new engines to use new fuels, and this work will help our understanding of combustion and the development of new technologies to utilize new fuels. A reviewer observed that the focus is on understanding how fuel properties and in-cylinder processes impact fuel efficiency and emissions: results from this work should help to improve fuel efficiency and reduce the amount of petroleum used. A reviewer noted that drop-in replacements need to have petroleum based fuels well characterized before we can understand how they work. Final comments involved noting that the project improves efficiency in HD engines, and that HECC engines using fuels improve U.S. energy security (this last reviewer would rank this a little lower in priority).

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

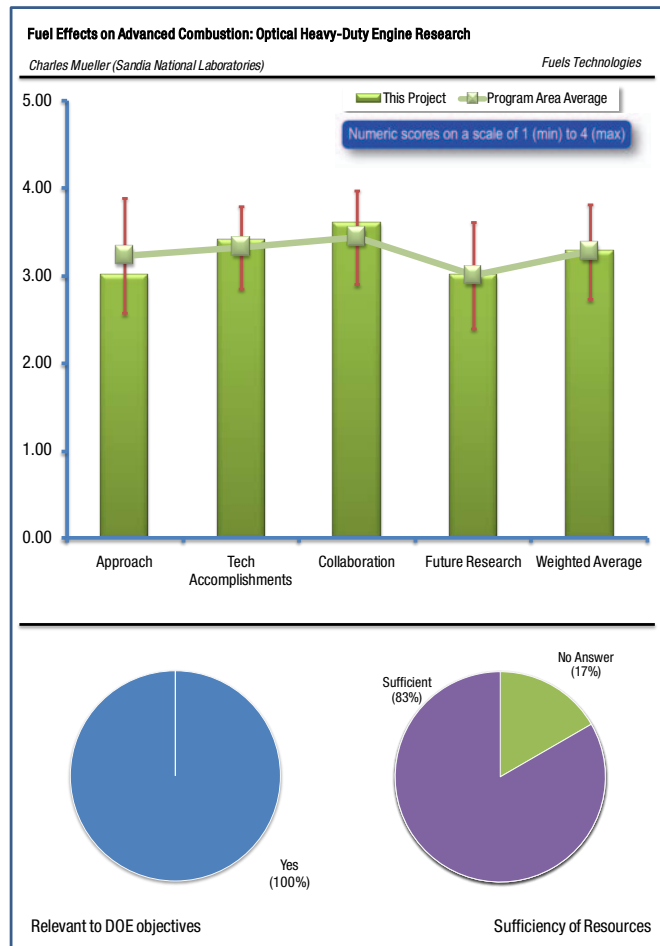
A reviewer said that there was a very good approach of doing fundamental studies in pressure bombs and optical engines as well as incorporating actual OEM equipment such as Cummins high pressure common rail injection system. A reviewer said that the optical engine provides a unique tool to evaluate combustion and validate models. A reviewer observed that the project is to implement and test in optical engine and acquire liquid lengths for biofuels: the reviewer asked how single component fuel properties and unsteadiness affect the liquid length. The final reviewer said that the approach is good with some insights on behavior of biodiesel types: this reviewer was somewhat uncertain as to the benefits described for surrogate diesels.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Observations on the work included that the team has measured liquid length under unsteady in-cylinder conditions. A reviewer said that there was great use of the optical single cylinder engine and the use of biodiesel in this program. The principal investigator has excellent command of the objectives and principles behind this project. The final commenter noted that the team has extended the liquid length study to unsteady conditions for model compounds, a ULSD certification fuel, and biodiesels. Interesting results were found with the biodiesels vs. the ULSD and the model compounds provide some insights in how to potentially improve performance when using biodiesels.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Collaborations were judged to be excellent, both in terms of the good use of resources and in the interaction with research partners and recognition of their contributions. Other highlights were the good work with OEMs, academia, government and CRC. A reviewer



especially noted the CRC and Caterpillar, MOU collaborations. A final comment focused on the good indication of collaboration with Cummins, with OEM's and energy companies via the AEC/MOU, and with CRC members via the surrogate diesel fuel project (AVFL-18). The collaboration with Cummins is probably the most frequent and direct (vs. the AEC/MOU collaboration and CRC collaboration).

QUESTION 5: HAS THE PROJECT 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?

The activities in continuing to look at impact of fuel properties/composition on liquid lengths and developing diesel fuel surrogates are valuable to advancing and achieving DOE goals. Similarly, a comment was received that liquid length is an important issue in advanced combustion, and higher volatility fuels should offer benefits. This reviewer felt that development of a surrogate is important for understanding fuel chemistry in complex fuels, and noted that it was difficult to add oxygen to diesel fuels. A reviewer pointed out that the work involves liquid length of multi-component hydrocarbon under unsteady in-cylinder conditions, and suggested a study of mixing HECC using a diesel. The final reviewer said there were good plans for future, but budget cuts may affect the outcome.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Comments for the resource question include that this program seems to be making fine progress and the current level of resources seems sufficient. A reviewer did point out that the work is funded at \$730 K for 2010: this reviewer considered this a lower priority project.

Mid-Level Ethanol Blends Test Program: Brian West (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The project was generally judged to be relevant to DOE objectives: using more ethanol would displace significant amounts of petroleum. Other comments include that the work is focused on higher amounts of ethanol in gasoline (which directly displaces petroleum), and that the work will enable informed decision making on E15 (this is a high priority project). A reviewer observed that ethanol is a main short+medium term biofuel and a main way to displace petroleum in the legacy fleet. The final comment was that this project and similar activities have national importance for fuels in our country.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

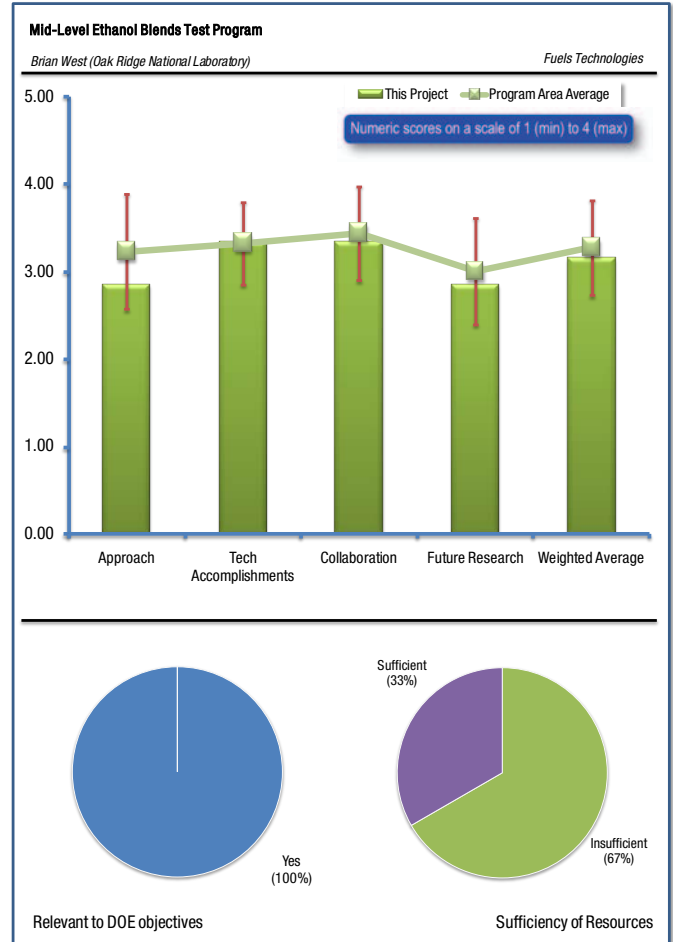
The comments were generally positive regarding the approach, but some suggestions were also made. A reviewer observed that this was a multiple parallel effort involving national labs and contractors. Another said that the project had a great approach toward understanding a myriad of effects on increased use of higher ethanol blends. A reviewer felt that this project had a good approach of testing effects of mid ethanol blends in vehicles and small engines. This reviewer questioned whether it is comprehensive enough (will enough data be collected and completely analyzed) for a correct decision to be made this summer on whether to allow a waiver for mid ethanol blends. This reviewer queried if there are enough replicates. A reviewer said that there was excellent coverage of emissions issues, but more work was needed in customer issues and in small engines. The project team should address potential customer impact issues of engine and fuel system durability. The final suggestion was that a larger focus on nonroad applications would greatly help inform decision makers about effect of blends of E10 and above on engines.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer observed that it looks like good progress was made in accomplishing the tasks developed for each of the individual programs. Another highlighted the excellent progress in catalyst durability and EPACT. A reviewer said that this is one of the largest research efforts to gauge the effect of a fuel on a wide range vehicles and engines. Despite the large policy implications of the results, this program has created very useful data to evaluate E15/E20 effects on newer vehicles and nonroad engines. A reviewer pointed out that the team has completed and published a legacy vehicle study and a detailed vehicle emissions study, along with an evaporative emissions study, a material compatibility study, and a full useful life vehicle emissions study. The final reviewer commented that there were great accomplishments limited by the funds available to execute the work.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Collaborations were judged to be very good overall, with one comment noting the great collaboration with a multiple list of institutions. Another said that there were good collaborations with OEM's and fuel producers via collaborative efforts with CRC.



Several reviewers highlighted specific organizations, including the good work with EPA, CRC, OEMs, and RIT; and the collaborations with CRC, EPA, UL, SwRI, TRC, ETC and Battelle. The final commenter noted the excellent collaboration by lab technical personnel: this reviewer would like to see expanded collaboration among stakeholders on overall program design and prioritization.

QUESTION 5: HAS THE PROJECT 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?

A reviewer observed that the plans seem to be to conclude programs by the end of 2010, and no specific plans were given for 2011. A reviewer suggested that the team complete the full useful life durability study, the evaporative study, and all other studies. Another suggestion was the need for additional work on engine and vehicle consumer-related issues. A reviewer thought that consumers of nonroad applications would greatly benefit from more research into marine engines and recreational vehicles. The final comment was that there is a continued need for more R&D on consumer impacts on vehicles and small engines, and cutting funds on this project would be disastrous for our country.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The general opinion of the group is that more funding is necessary: comments included that more resources are needed to address all of the potential vehicle and engine issues, and that more funding for this program has been and continues to be needed. A reviewer suggested that this program could use more funding to look at a more comprehensive look at marine, motorcycles, and snowmobiles. Additionally, there should be duplicate vehicles run as part of V4 in order to look at vehicle variability across the different ethanol blend levels. Another commenter observed that the programs appear to have been developed to fit available funding. Funding may not be sufficient to fully address issue of compatibility of mid level ethanol blends with existing infrastructure and vehicles (to get a good handle on type/percent of failures to expect). The final reviewer noted this is a \$40 million dollar program but good scientific data may come too late for the E15 waiver decision. This reviewer would encourage more funding to address the consumer impact studies, and suggested the team include current fleet representation of test vehicles.

**Advanced Lean-Burn DI Spark Ignition Fuels Research:
Magnus Sjoberg (Sandia National Laboratories)**

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Positive comments are that DISI engines have a good potential for high efficiency, and that improving gasoline/ethanol vehicle efficiency has a large impact on petroleum use. Another reviewer said that the project has a focus on lean burn DI for non-petroleum fuels which would directly displace petroleum if technically successful and widely deployed.

On the other hand, a reviewer felt that increasing the scientific understanding is generally good for the development of new technology, but believed the program could do a better job of bridging the gap in how this information will be applied. Another reviewer was still not convinced that this work is not competitive in nature, and perhaps should be done by OEMs at their expense, and not DOE's. DISI engines are being marketed today, so R&D by DOE on these engines perhaps should not be done.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

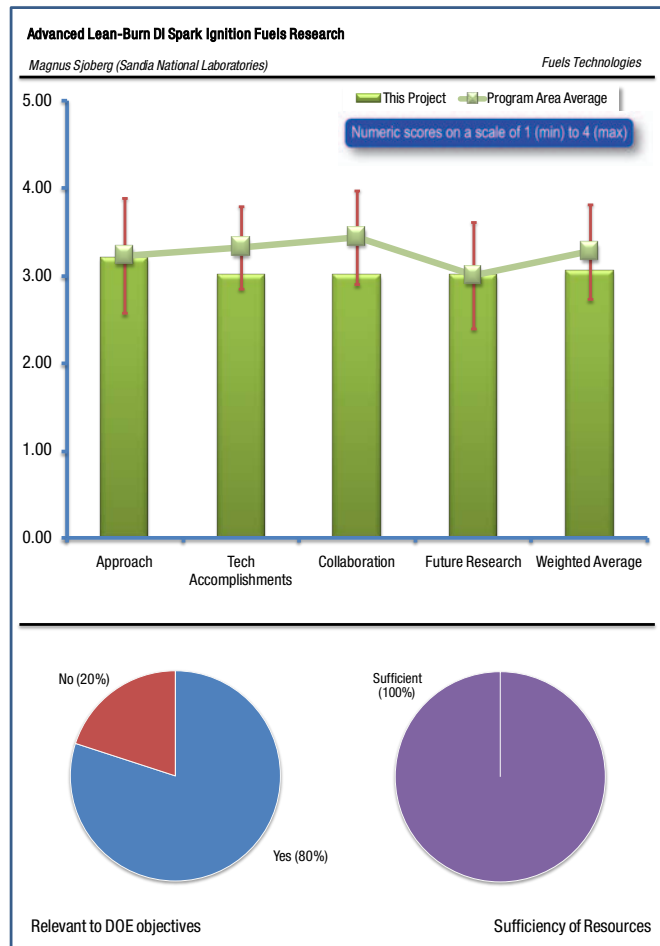
On the positive side, commenters felt that the approach of using metal engines, optical engines, and modeling is a good one; there was good imaging capability in the research engine platform; and that there was a good approach for the technology work planned to be performed (but relevance is the issue). A reviewer commented that occasional misfires/partial burn cycles are barriers. Engine knock must be avoided when operating with alternative fuels.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Review comments on the accomplishments were generally good. A reviewer said that the laboratory looks like it will be very helpful in generating good data and scientific understanding of objectives as things develop. Another felt the lab setup was good, and the equipment was very elegant. A reviewer noted that the engine has been installed, the new lab is ready, and engine tests will commence soon. A reviewer felt that development of the tool has been good, but this reviewer did not hear a strategy for its use to maximize benefits. The last reviewer said that most of the progress has been on setting up the DISI lab. No timeline was shown, so this reviewer did not know if engine setup is "on schedule" or not. Some work has been done in the HCCI lab on autoignition characteristics of gasoline and ethanol.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Collaborations were felt to be good with GM, the academy and others, in one reviewer's opinion. Another also highlighted the good collaboration with co-workers and GM and recognition of their contributions. A reviewer said that the primary industry collaborator seems to be GM. Collaborations with other OEMs and energy companies via the AEC/MOU were mentioned, but interaction via that mechanism is not likely as often, nor as direct as with GM. Collaborations with universities and other national labs were also



mentioned, according to this reviewer. A reviewer listed the collaborations he noted: SNL, LLNL, UW-M, UNSW and MOU. The final reviewer would like to see close collaboration with Oak Ridge activity.

QUESTION 5: HAS THE PROJECT 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?

The first of two comments on this aspect of the research was a recommendation to perform advanced high-speed optical diagnostics. The second commenter felt that the potential for improving efficiency of gasoline/ethanol engines is large. This reviewer would like to see a clearer connection to improved engine efficiency. According to this reviewer, this should be a good platform for investigating super/knock.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that there is no indication that resources are not sufficient. The second reviewer said that this project is interesting and academic and is lower priority.

Non-Petroleum-Based Fuels: Effects on Emissions Control Technologies: Scott Sluder (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer felt this work will help with engine optimization and emission control research for new fuels. Another thought the project was relevant, as it is reviewing the impacts of non-petroleum based fuels on the key emissions control systems. A reviewer offered that understanding of the impact of NPBF on emission system components is important for enabling the commercial use of these fuels. The last person stated that the project had inadequate data and predictive tools for fuel property effects. NPBF can be used more, resulting in petroleum displacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A commenter liked the real world samples before modeling. Another said the team brings together targeted engine-based and bench reactor studies. The final reviewer approved of the good approach toward getting real impacts from non-petroleum based fuels on emissions systems.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

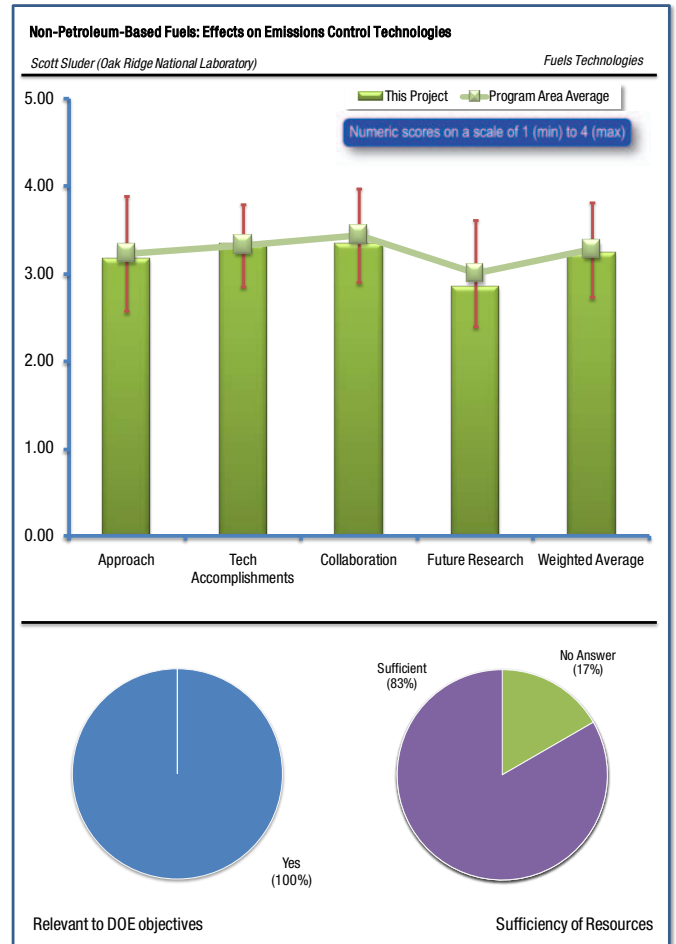
Positive comments included the good list of accomplishments (especially the understanding of effects of biodiesel on deposits). Another simply stated the project was proceeding well toward DOE goals. Work on the emissions using B20 was interesting and important to another reviewer, as there is a push for higher levels of biodiesel. A reviewer said there was good progress in a number of areas, including: causes of greater fouling of EGR coolers with biodiesel vs. ULSD due to greater surface condensation; improved understanding of biodiesel PM reactivity; and acceptable sodium levels. The final reviewer noted the PM trap work and said the team should analyze fuel+lube if possible.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Opinions on collaboration were all positive, including the reviewer who said there was good work with OEMs and academic partners. Another felt there was a good list of collaborators and recognition of their contributions. Two reviewers noted the collaborations with Cummins, Ford, and GM and some universities.

QUESTION 5: HAS THE PROJECT 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?

A reviewer thought the plans to continue and build on current program areas and results seem very appropriate. Another highlighted the good proposed future research. A reviewer was OK with the shift from diesel to biodiesel-related work. This reviewer thought that



use of diesel in light-duty vehicles could become detrimental from an energy balance standpoint due to projected changes in gasoline/ethanol and diesel supply balance. In this reviewer's opinion, effort on biodiesel should be balanced by noting that there is significant potential for vehicle use impacts, and that the overall impact of biodiesel on petroleum demand is limited by raw material supply. The final reviewer said the project needs some more focus on ethanol effects over biodiesel, since the impact of ethanol in the U.S. fleet is much bigger than biodiesel.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer felt that progress seems to be on track, so no indication that resources are not sufficient. The other reviewer simply noted that total resources were \$1.1 million.

Non-Petroleum-Based Fuel Effects on Advanced Combustion: James Szybist (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said that this work is necessary given the changes in typical fuel constitution, especially given the pressures on next generation biofuels from RFS2. Another felt that this research is fundamental in nature and provides potential improvements to engines to be used to optimize the use of biofuels. A reviewer noted that the focus is on non-petroleum based fuels, which if successful, would directly displace petroleum. Reviewers noted that the project will assess fuel property effects on advanced combustion, perform emissions and engine optimization, increase the thermal efficiency of E85 engines, improve engine efficiency, and better utilize gasoline/ethanol.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

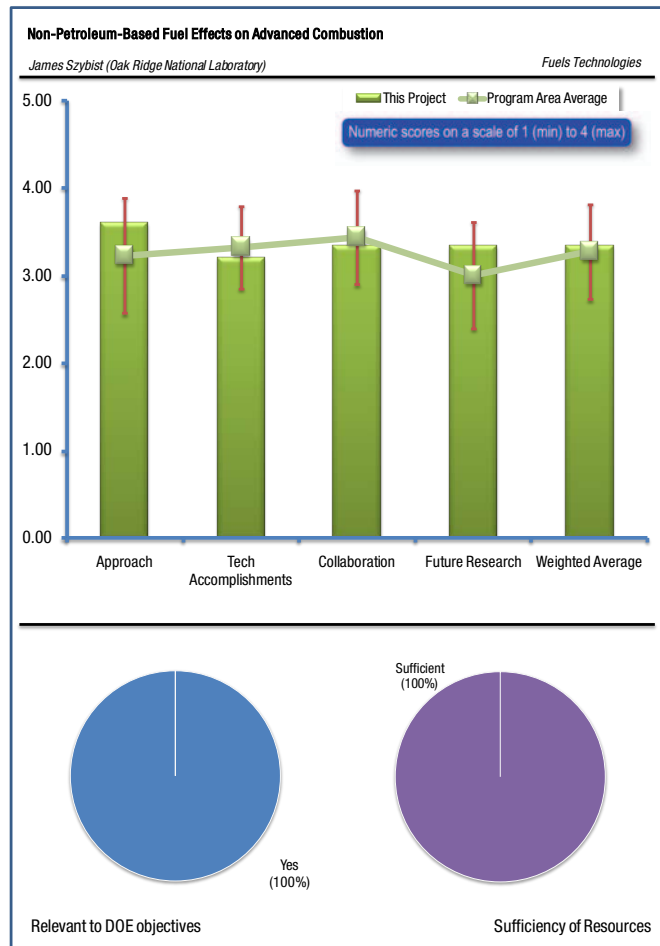
A reviewer said there was good use of statistical tools to make the most out of limited data, and a good job looking at ethanol-gasoline blends. Reducing the fuel economy gap between E85 and gasoline would be useful, according to this reviewer. Another commenter highlighted the excellent approach of combining testing of fuels in several different advanced combustion engine platforms and kinetics/modeling work. A reviewer supported the emphasis on gasoline/ethanol fuels using an advanced engine platform. Other comments included a note that there was a great approach on the technical program, and that the team was focusing on ethanol effects this year. A reviewer listed several aspects of the research as his comment: focus on a single cylinder approach; use of low and high octane gasolines and three ethanol blends; and use of a multi-cylinder diesel engine platform and single cylinder platform approach.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted that the project is progressing well toward the overall DOE goals. A second said there was good progress in improved understanding of gasoline/ethanol performance. A third thought this was a very interesting investigation into the reasons behind the E85 and gasoline energy efficiency difference. Finding out the deeper understanding will help improve engine design, according to this commenter. A fourth reviewer said this work involved a very interesting comparison of the reasons for performance differences between gasoline and ethanol blends in the single cylinder GDI engine with VVA. A reviewer suggested that the team also consider the effects of octane sensitivity on engine efficiency from work at MIT (Heywood) and others.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Collaborations with outside contributors were judged to be good by two reviewers. The third reviewer observed that the main industry partners appear to be Delphi and an unspecified energy company: there are also collaborations with University of Wisconsin and Reaction Design. The AEC/MOU consortia provides opportunity for feedback from OEMs and energy companies two times per year, but this is probably less directed input than from avenues such as Delphi.



QUESTION 5: HAS THE PROJECT 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?

A reviewer said there were good plans for the future, but that the team should include more emphasis on ethanol and other alcohols. A reviewer suggested that the team continue ethanol optimization on a multi-cylinder engine, the SA-HCCI strategy, the multi-cylinder HECC work, and the work planned in statistical analysis and kinetics research. The final reviewer endorsed the plans to study multi-cylinder engine. Dual/fuel work also has large potential to improve efficiency. This reviewer said the team should look at ethanol effect on knock-limits in modern DI boosted engines. This reviewer had heard anecdotally that benefits are better than predicted by standard octane tests.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said the resources seem sufficient. Another observed that total funding for 2010 was \$1470 K, and said that the single-cylinder approach may not relate to real world conditions.

*Advanced Petroleum-Based Fuels Research at NREL:
Bradley Zigler (National Renewable Energy Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer said this was very relevant research for non-petroleum based fuels optimization. A reviewer said that investigating how fuel chemistry affects advanced combustion will be invaluable in shaping how these combustion strategies develop and meet DOE objectives. A third reviewer observed that the work is focused on understanding combustion fundamentals which can lead to fuel efficiency improvements and use of alternative fuels. A reviewer pointed out the work on fuel impacts on advanced combustion and predictive tools for fuel effects. Improving fuel efficiency was noted by two reviewers as the relevance.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

To one reviewer, developing the FACE fuels will be important to move advanced combustion forward. Another said that there was a good combination of fundamental combustion measurements in IQT instrument and single cylinder engine testing. The third said that the work focused on fuel properties, ignition kinetics, combustion and emissions and had a good approach.

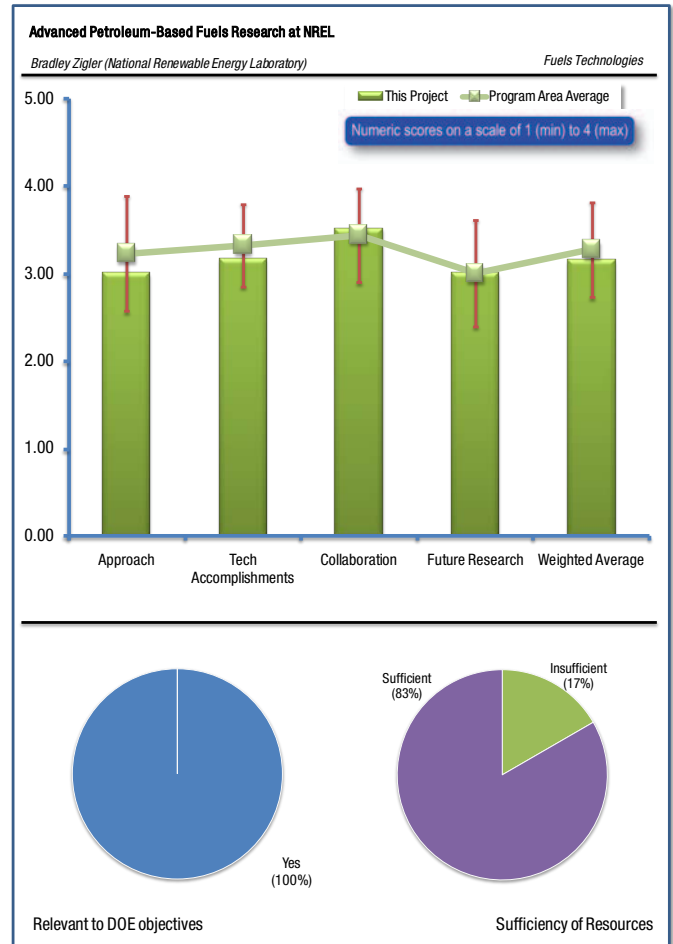
Two reviewers had some similar reservations about the ignition quality tester. One said that the IQT could be a good tool to validate kinetics, but the researchers would need to be cautious in extrapolating to engine. Another said that the work has a generally good approach, but one area of concern is emphasis on IQT as a surrogate for diesel engine. For cetane number measurement, IQT may be fine, but for fundamental diesel kinetics and modeling, IQT fidelity to a real diesel engine needs to be demonstrated.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers said there was good progress in understanding behavior of IQT and good technical accomplishments to date. Also noted was the good use of the FACE research cube to develop better engine models: the rapid characterization of fuel samples is very interesting. A reviewer thought the work was progressing well. It supports development of efficient computational strategies. It rapidly characterizes ignition properties of fuel samples. The final reviewer observed good progress in a number of areas: measurement of ignition delay times of a variety of diesel fuels (including FACE diesel fuels); characterized spray and developed KIVA CFD model; and compared IQT results for n-heptane with several kinetic models in the literature.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Collaborations were generally said to be good. One reviewer stated there were good collaborations with academics and applicable industry players. Another said the presenter provided a very good description of the type of collaboration with outside groups, and gave acknowledgement of their contribution. Collaborations with industry were done via CRC (AVFL and FACE committees) and with UC Berkeley and CSM. These three organizations were also noted by another reviewer, and a third said that the team is collaborating well with CRC and other groups.



QUESTION 5: HAS THE PROJECT 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?

The general plan builds on past progress and generally addresses overcoming the barriers. This reviewer suggested expanding IQT-based experimental and modeling research. Light-duty CNG optimization is exciting, commented one reviewer. Another said that the team should focus on ethanol blends over biodiesel, since the impact will be much greater.

A reviewer said that the reduction in NREL's ABPF 2010 budget (and presumably for 2011) has led to NREL having to disengage from some of the CRC programs (especially AVFL-16 and FACE). This is leading to a decrease in collaboration with industry.

A final reviewer said that the IQT work is correctly focused on supporting model development. This reviewer spotlighted a need to correlate the IQT to an engine to ensure relevance. This reviewer felt that work on future diesel fuel effects is a lower priority, since research has not indicated that advanced combustion is very sensitive to diesel fuel properties. New diesel fuel components will only gradually enter diesel pool. (This reviewer said this comment applies broadly to diesel-related fuels work, not only this activity).

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A commenter noted that a midyear cutback in NREL's 2010 APBF funding has led them to being unable to contribute the cost share that they had committed to for the CRC AVFL-16 program, which suggests that funding is insufficient for the plans/commitments that they have. The other review commenter noted that the project was funded at \$1.0 million for 2010: some funds may be redirected to other programs.

Chemical Kinetic Modeling of Fuels: William Pitz (Lawrence Livermore National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said that the models from this work will be useful to optimize fuels for use in advanced combustion to improve fuel efficiency. A similar comment from another reviewer stated that this was fundamental research to support DOE/industry fuel technology projects: models can be used to optimize fuels, thus improving efficiency. A reviewer said that the work was focused on developing fundamental kinetic and combustion data and models for petroleum and non petroleum based fuel components: this will lead to fuel efficiency improvements and potentially use of non petroleum based fuels. The final reviewer said that this project is looking at the fundamentals on combustion of fuels, both conventional and non-petroleum based. With this understanding, we can optimize biofuels in the U.S. fuels supply.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

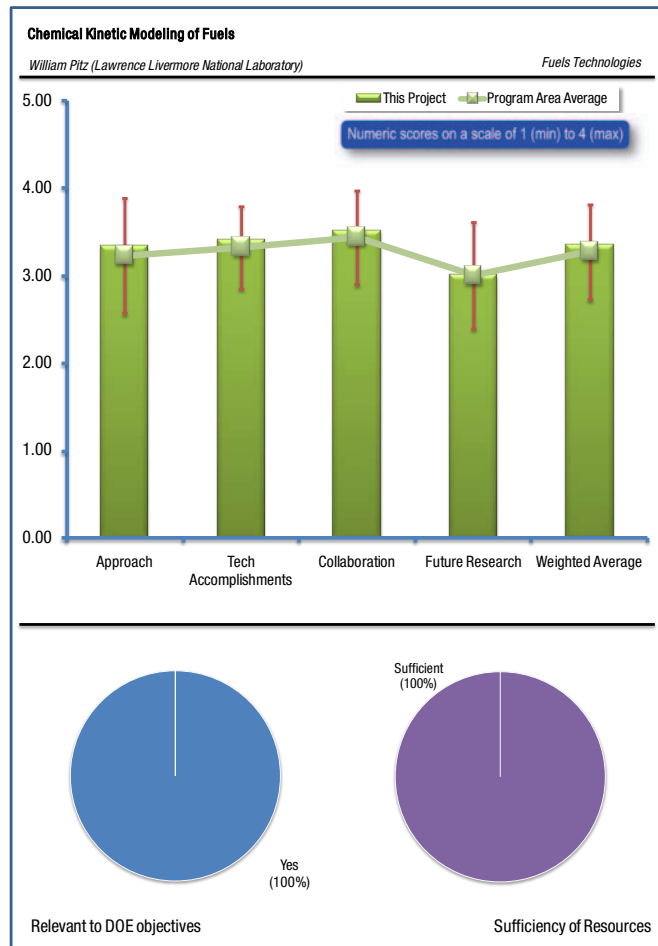
A reviewer said this work had a very good approach in developing the fundamental reaction mechanisms for various fuel components and comparing model results to data available in the literature. Another felt that the development and validation approaches were sound, and that models can play an important role in engine/fuel development. A reviewer highlighted the very good approach to deriving fundamental kinetics and reaction mechanisms for combustion. The final commenter stated that the team was developing chemical kinetics reaction models for each fuel component: models for methyl stearate, methyl decanoate, and methyl oleate were developed.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Among the positive comments were that there was nice development of validated mechanisms and a good list of accomplishments to date. A reviewer said that the accomplishments were good on the first two methyl esters: this reviewer can't wait until the team can model biodiesel next year. A reviewer offered that there was very good progress in a number of areas including: review of kinetic mechanisms in the literature; and development of reaction mechanisms for two of the five components in soy SME biodiesel. The final reviewer observed that the team had assembled a chemical kinetic model for two of the five main components of biodiesel.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Positive comments on the collaboration included a statement that all FT groups are collaborating well and that there was a great list of collaborators and recognition of their input. A reviewer said there had been good work with UConn and other university contacts: this was reflected in another's listing of the collaborators he saw (University of Toronto, National University of Ireland, and UConn as well as CRC ACE.) A reviewer saw mostly collaborations with other national labs and universities. Collaboration with industry has been mainly through some participation in CRC working groups (especially AVFL-18 diesel surrogate fuel development).



QUESTION 5: HAS THE PROJECT 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?

A reviewer thought that modeling actual biodiesel will be very useful, and that interesting work is being done on profiling butanols. Another thought there was a good plan for future work, and noted that the team is developing the capability to simulate the IQT which predicts cetane number. The reviewer also suggested developing a model for iso-pentanol. A reviewer offered that developing kinetic mechanisms for the remaining SME components will be very useful, and that the value of work on alcohols higher than ethanol will depend on whether they are ultimately viewed by the government and the public as being more like ethanol or like ethers (MTBE). A reviewer thought it may be more beneficial to address big gaps in understanding chemical kinetics of major constituents of diesel fuel. The final comment was that there were good plans for future work, but plans may be impacted by funding.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The two comments for resource sufficiency were that there is no indication that resources are not sufficient, and that this is good research work (albeit very academic).

6. MATERIALS TECHNOLOGIES

Advanced materials, including metals, polymers, and composites, can play an important role in improving the efficiency of transportation engines and vehicles. Weight reduction is one of the most effective ways to increase the fuel economy of vehicles while reducing exhaust emissions. The use of lightweight, high-performance materials will contribute to the development of vehicles that provide better fuel economy, yet are comparable in size, comfort, and safety to today's vehicles. The advanced materials research conducted under the direction of the U.S. Department of Energy's Vehicle Technologies Program will help ensure the nation's transportation energy and environmental future by making affordable full-function cars and trucks that use less oil and produce fewer harmful emissions.

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1 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 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
Technical Cost Modeling - Life Cycle Analysis Basis for Program Focus	Sujit Das (Oak Ridge National Laboratory)	6-3	3.33	3.33	3.33	3.00	3.29
Low Cost Carbon Fiber Overview	David Warren (Oak Ridge National Laboratory)	6-5	3.67	4.00	3.50	3.50	3.79
Carbon Fiber Pilot Plant and Research Facilities	David Warren (Oak Ridge National Laboratory)	6-7	3.67	3.00	3.33	3.33	3.25
Lower Cost Carbon Fiber Precursors	David Warren (Oak Ridge National Laboratory)	6-9	3.67	3.67	3.67	3.00	3.58
Low Cost Carbon Fiber from Renewable Resources	Frederick Baker (Oak Ridge National Laboratory)	6-11	4.00	4.00	3.50	4.00	3.94
Advanced Oxidation & Stabilization of PAN-Based Carbon Precursor Fibers	Felix Paulauskas (Oak Ridge National Laboratory)	6-12	3.67	3.33	3.33	3.67	3.46
Magnesium Front End Research and Development - Phase 1 (AMD 604)	Alan Luo (General Motors)	6-14	4.00	3.75	3.75	3.75	3.81
Multi-Materials Vehicle R&D Initiative	David Wagner (Ford Motor Company)	6-16	3.00	3.00	3.33	2.67	3.00
Development of High-Volume Warm Forming of Low-Cost Magnesium Sheet	Matt Zaluzec (Ford Motor Company)	6-18	3.50	4.00	3.25	2.33	3.57
Formability of Direct Cast Mg Sheet and Friction Stir and Ultrasonic Joining of Magnesium to Steel	Mark Smith (Pacific Northwest National Laboratory)	6-20	3.14	3.57	3.57	3.29	3.43
Integrated Computational Materials Engineering (ICME) for Mg: International Pilot Project (Part 1)	John Allison (Ford Motor Company)	6-23	3.00	3.50	3.00	3.50	3.31
Magnesium Projects	Paul Wang (Mississippi State University)	6-25	3.00	2.33	3.33	2.50	2.65
Pulse Pressure Forming of Lightweight Materials, Development of High Strength Superplastic Al Sheet, Friction Stir Spot Welding of Advanced High Strength Steels	Mark Smith (Pacific Northwest National Laboratory)	6-27	3.17	2.83	3.17	2.67	2.94
NSF Third Generation Advanced High Strength Steels	Ronald Krupitzer (Auto/Steel Partnership)	6-30	2.75	2.75	3.00	2.67	2.77

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Fundamental study of the relationship of austenite-ferrite transformation details to austenite retention in carbon steels	Michael Santella (Oak Ridge National Laboratory)	6-32	3.33	3.33	2.50	3.00	3.19
Advanced High Strength Steel Project	Paul Wang (Mississippi State University)	6-34	3.33	3.33	2.67	3.33	3.25
Auto/Steel Partnership: AHSS Stamping, Strain Rate Characterization, Sheet Steel Fatigue, AHSS Joining	Roger Heimbuch (Auto/Steel Partnership)	6-36	3.20	3.20	3.60	3.00	3.23
Coherent Research Plan for the Third Generation Advanced High Strength Steels for Automotive Applications	Xin Sun (Pacific Northwest National Laboratory)	6-39	3.00	3.25	3.00	3.00	3.13
Advanced Materials & Processing of Composites for High Volume Applications (ACC932)	Matt Zaluzec (Ford Motor Company)	6-41	3.00	3.00	3.50	2.50	3.00
Composite Underbody Attachment, Advanced Preforming and Related Processes for Manufacturing Low Cost Composites	Bob Norris (Oak Ridge National Laboratory)	6-43	3.33	3.33	4.00	3.33	3.42
Dynamic Characterization of Spot Welds for AHSS	Zhili Feng (Oak Ridge National Laboratory)	6-45	3.40	3.40	3.20	3.00	3.33
Online Weld Quality NDE & Control with IR Thermography	Zhili Feng (Oak Ridge National Laboratory)	6-47	3.00	3.00	2.20	2.40	2.83
Enhanced Resonance Inspection for Light Metal Castings	Xin Sun (Pacific Northwest National Laboratory)	6-49	3.75	3.50	3.25	3.25	3.50
<i>Evaluation and Characterization of Lightweight Materials: Success Stories from the High Temperature Materials Laboratory (HTML) User Program</i>	<i>Camden Hubbard (Oak Ridge National Laboratory)</i>	<i>6-51</i>	<i>2.50</i>	<i>3.00</i>	<i>3.00</i>	<i>2.50</i>	<i>2.81</i>
<i>High-Temperature Thermoelectric Materials Characterization for Automotive Waste Heat Recovery: Success Stories from the High Temperature Materials Laboratory (HTML) User Program</i>	<i>Hsin Wang (Oak Ridge National Laboratory)</i>	<i>6-53</i>	<i>3.00</i>	<i>3.50</i>	<i>3.00</i>	<i>3.00</i>	<i>3.25</i>
<i>Characterization of Catalysts for Aftertreatment and Biomass-derived Fuels: Success Stories from the High Temperature Materials Laboratory (HTML) User Program</i>	<i>Larry Allard (Oak Ridge National Laboratory)</i>	<i>6-54</i>	<i>2.50</i>	<i>2.00</i>	<i>2.50</i>	<i>2.00</i>	<i>2.19</i>
<i>Characterization of Materials for Li-ion Batteries: Success Stories from the High Temperature Materials Laboratory (HTML) User Program</i>	<i>Andrew Payzant (Oak Ridge National Laboratory)</i>	<i>6-56</i>	<i>3.00</i>	<i>3.00</i>	<i>3.00</i>	<i>2.00</i>	<i>2.88</i>
OVERALL AVERAGE			3.27	3.26	3.22	3.00	3.23

NOTE: Italics denote poster presentations.

Technical Cost Modeling - Life Cycle Analysis Basis for Program Focus: Sujit Das (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer felt that this work is necessary as a preliminary for every weight reduction endeavor. The other reviewer providing comment noted that technical cost modeling provides an objective relative measurement of lightweight and high-strength materials, promoting commercial use to reduce dependency on foreign sources and domestic petroleum for security and environmental benefit.

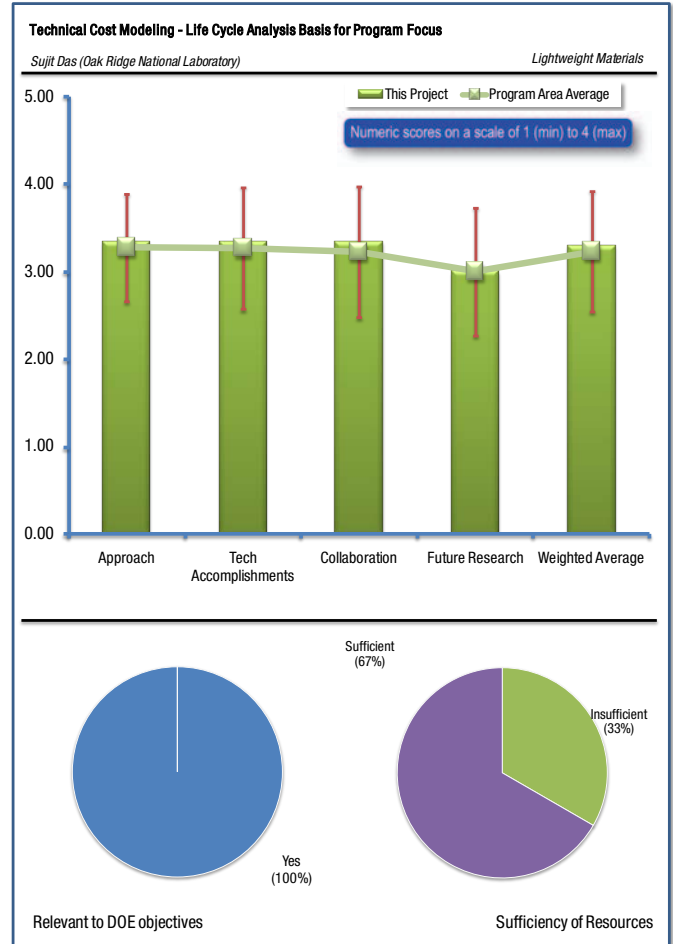
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer summarized that this effort is directed toward the estimation of the cost effectiveness on a life-cycle basis of the FY2010 50% vehicle body and chassis weight reduction goal compared to 2002 vehicles by developing and applying an Automotive System Cost Model. Another person commented that they believe the project intent was accomplished to sensitize the community as to the cost and GHG contribution of raw materials, manufacturing, assembly and use phase. Others had positive comments, and offered suggestions. For example, one evaluator remarked that the approach is good but recommended developing a user math model to provide an opportunity to modify material cost and GHG footprint segments (extraction, conversion, fabrication and use phase). The final reviewer observed that the weight reduction was obtained solely by materials swapping, weighted by cost for materials. They added that although this would be difficult to introduce in any model, attempts on weight saving by enhancing chemico-physical properties should be included, as well as gains through manufacturing.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer observed that in FY 2008 and 2009 the project analyzed cost effectiveness for the intermediate body and chassis weight reduction goals of 25% and 40% for either glass fiber-reinforced polymer composites or aluminum (25% weight reduction goal) or for carbon fiber-reinforced polymer composites and aluminum (40% weight reduction goal). Based on the milestones described, it seems that adequate technical progress has been achieved.

One reviewer expressed that this project represents very good work and acknowledged that the peer-reviewed technical content has received international recognition. Another agreed that this was a very good project, but would like to see weight reduction improvements based on physical properties enhancements.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Only two reviewers commented, with a difference of opinion. One felt that the researcher had shown a very good collaboration with international groups including Canada NRC. The other person knew that collaboration exists but added that the talk is far from explicit there.

QUESTION 5: HAS THE PROJECT 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?

Reactions to this question were mixed. One reviewer simply summarized that the proposed future effort will be to extend the Automotive System Cost Model to accomplish the following objectives: (1) the development of a baseline cost model for multi-material vehicle; (2) the development and validation of various weight reduction goals (25%, 40%, and 50%) of a multi-material vehicle; (3) the determination of the viability of lightweight materials in advanced powertrains such as hybrids and fuel cell vehicles; (4) the economic, energy, and environmental impact analyses from a life cycle perspective of lightweight material manufacturing technologies with an emphasis on magnesium and carbon-fiber polymer composites; (5) the cost reduction impact of recycling of lightweight materials from an economic, energy, and environmental life cycle perspective; and (6) the potential (system?) cost advantages of using lightweight material in heavy-duty vehicles. One commenter believed that it will be possible to build such a model, but it would seem that the critical task will be to verify the cost-projection assumptions on which the model is based. They added that it is not obvious from the slides alone that sufficient consideration has been given to this requirement. Moreover, in order to have any significant impact over time, ORNL or some other organization or team will have to maintain (i.e., update and revise) the proposed model as the cost elements change and especially as new materials come on line. This could involve a substantial investment of time and money, or would do so if it is the intent of DOE that this model be an ongoing resource for companies in the vehicle manufacturing and materials industrial sectors.

Other reviewers were more critical, with one person simply stating that the researchers need to more clearly define next steps rather than continue with a new target. The final reviewer pointed out that the investigator provided no mention of what physical properties enhancements can bring to weight reduction. They acknowledged that this is a very complicated integration problem; however, answers to questions related to physical properties show that this aspect needs to be deepened to be fully integrated into weight reduction schemes.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One commenter remarked that the effort appears to be adequately funded. Another person disagreed, stating that the research team should be given more resources in order to produce a more comprehensive and optimized study on weight reduction.

Low Cost Carbon Fiber Overview: David Warren (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Both reviewers to comment to this question had positive comments. One reviewer noted that this type of research in low-cost carbon fiber for automotive mass reduction is extremely relevant for GHG and fuel economy goals. The other reviewer explained that carbon fibers are necessary for lightweight vehicles. They added that such an enormous project can only be possible because the government is instigating in such a program. This is the right thing to do; however, it would have been better if the project was initiated about 20 years ago.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

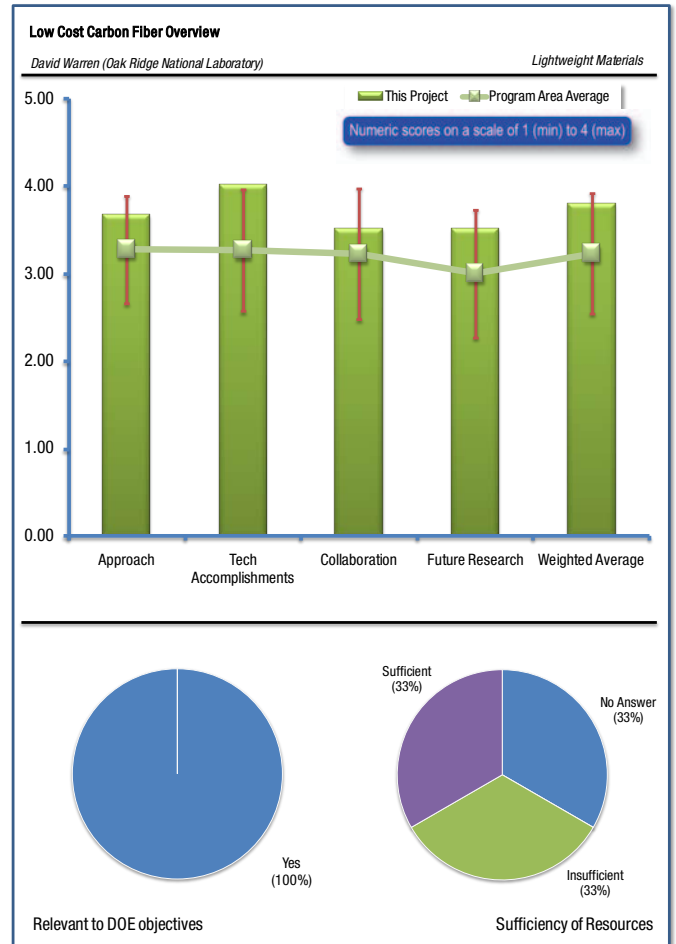
Comments were universally positive. One person simply noted that the program plans provide an excellent roadmap to show what is going on. Another person agrees, stating that the project is comprehensive and very well laid out. One commenter observed that the program overview covers a wide spectrum of projects; but suggested that LCA and recycling should be included in the program. The final commenter explained that the project goals and roadmap are very descriptive. They added that the researchers showed that a good process of concept feasibility of carbon fiber commercialization through technology up to market entry with specific deliverables was developed.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments to this question were all positive. One person stated that the presentation gave an overview and provided lots of information. Another evaluator noted that in view of the breadth of the program, the progress is amazingly strong. One reviewer remarked that the presentation gave a good overview of carbon fiber technology center to develop large scale material and processes for automotive uses. Another person pointed out that the researcher showed the common and unique issues between industries and addressed challenges for manufacturing in high volume automotive applications. Another reviewer had similar comments, adding that the presentation shows need for continued research into auto and other industries but requires “change” with this new major development. The final reviewer noted that the researcher provided an outstanding overview of costs including material, treatment, spooling, and packaging and showed that they have a full understanding of costs of carbon fiber including precursors. The reviewer also showed data for ramping up plant size to reduce cost by approximately 15%.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive. One person noted that numerous collaboration partners were involved and that funding sources by multiple agencies/partners were included, but also felt that more detail is required. The other reviewer stated that the researcher seems to be doing an outstanding job in promoting carbon fiber in the U.S.



QUESTION 5: HAS THE PROJECT 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?

One person noted that the project addressed the challenges for manufacturing in high volume automotive applications. Another person commented that the slide that describes the 67% mass reduction in the body-in-white using carbon fiber and discussion of crash protection/energy absorption requires more detail, such as including CAE capability of carbon fiber in crush zones and what MY vehicles are targeted. \$5-7 cost per pound for carbon fiber is the goal. They conclude by pointing out that the researchers need to understand and show how this translates into vehicle cost. Another commenter remarked that this presentation shows need for continued research into auto and other industries, but requires “change” with this new major development. They conclude by asking how this work translates into MY implementation. The final reviewer noted that the future work is more like completing all that is outstanding, and in their opinion, the funding resources are too little for the researchers to progress at the desired speed.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

It was stated by the first reviewer that clearly there is an urgency here. Another person simply noted that the researchers have sufficient resources to achieve milestones. The final reviewer disagreed, remarking that the only way, with the present team in place, to speed up the planned processes to fruition is to help the team with more funding and a larger crew.

Carbon Fiber Pilot Plant and Research Facilities: David Warren (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

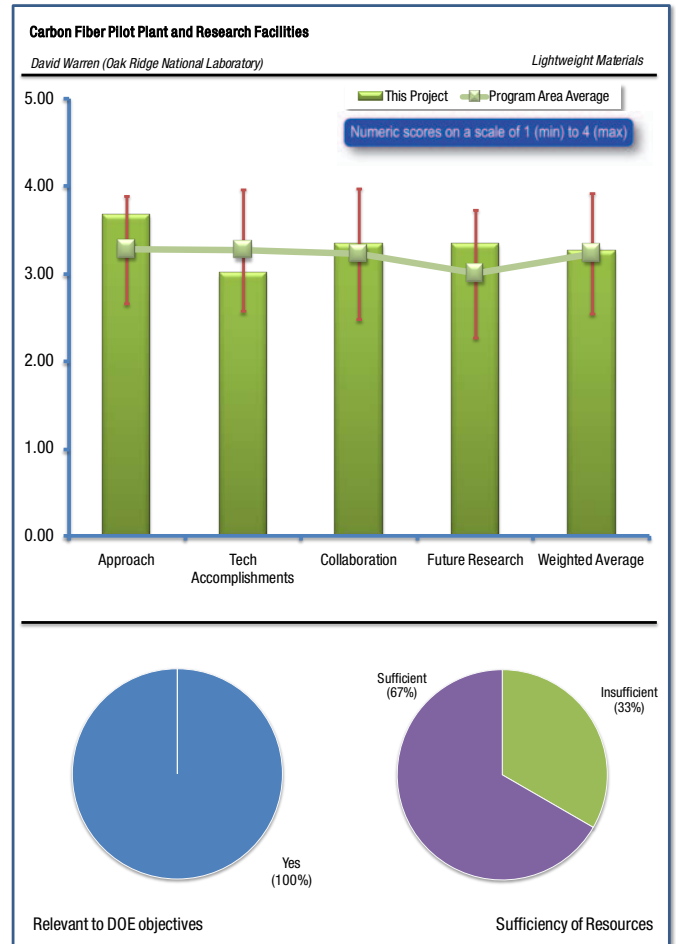
All reviewers had positive comments to this question. One person commented that this project supports the overall DOE objectives; utilization of carbon fiber in automotive components for significant mass reduction in order to improve fuel economy. Another person observed that this is a long-range technology development project; it is known that carbon fibers can contribute to the lightweighting of automobiles; this facility can remove some of the processing barriers for achieving low-cost fiber. The final reviewer remarked that the project absolutely supports DOE’s objectives; low-cost carbon fiber will provide a significant contribution the long-term lightweighting and petroleum displacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

All reviewer comments to this question were positive. One person expressed that this is a very good project where different approaches were taken to develop low-cost carbon fiber. They added that some of the technical and commercial barriers were not defined, so now the project should be focused on cost of production of carbon fiber to reach the original low-cost target (\$5-7/pound). The next evaluator stated that the researchers have shown an excellent plan; the technical barriers are identified; the idea of running parallel operating lines to compare conventional versus new technology is quite good. The final person also noted the very good approach, creating a pilot facility based on state of the art proven process and parallel processing stations.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person felt that the researchers have shown excellent progress associated with various materials and processes. They also acknowledged the dynamic adjustment of program goals based upon recent developments. Another person agreed that the progress is good, but felt that it can be accelerated. They noted that some barriers were overcome; however, the progress still lags the original goal of low-cost production. It should be evaluated at this stage for the final outcome. One evaluator remarked that currently the cost of the final product will not meet the cost target and that this project should be evaluated by outside experts for its final outcome. Another commenter observed that the manufacture of carbon fiber is very impressive, but criticized that the conversion into functional parts is not progressing at the same rate. Another reviewer noted that chopped fiber and SMC continues to be applied, but that the cycle time/price of thermoset materials is not in-line with automotive volume. The final reviewer had a different perspective on the project evaluation, since the project happens in the future; this is infrastructure development so the technical progress cannot be measured at this stage but has the potential to influence future generation fiber developments.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Several reviewers noted that the great collaboration in carbon fiber preparation with various parties involved has been excellent. Another person pointed out that the presentation indicated the interest from the U.S. industry base; not much information was provided on the list of interested companies/researchers; but it was still assumed that a broad range of partners is interested. The final reviewer suggested that the researchers need to reconsider internal ORNL part fabrication and ACC to introduce new thermoplastic processing, which imposes high volume/low-cost processing.

QUESTION 5: HAS THE PROJECT 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?

Comments were positive, but brought up suggestions in several areas. One person noted that the technical projects are not here as this is only infrastructure development. Another person mentioned that the research plan is very good; however they still have strong doubts about achieving the low-cost of the final product. The final evaluator noted that researcher's plans incorporate great next steps, but added that they need to predict the 10-year and 20-year plans.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Only one person commented, stating that it appears resource demand will increase for next year as well as the need for various types of engineers. Evolution requires new talents.

Lower Cost Carbon Fiber Precursors: David Warren (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

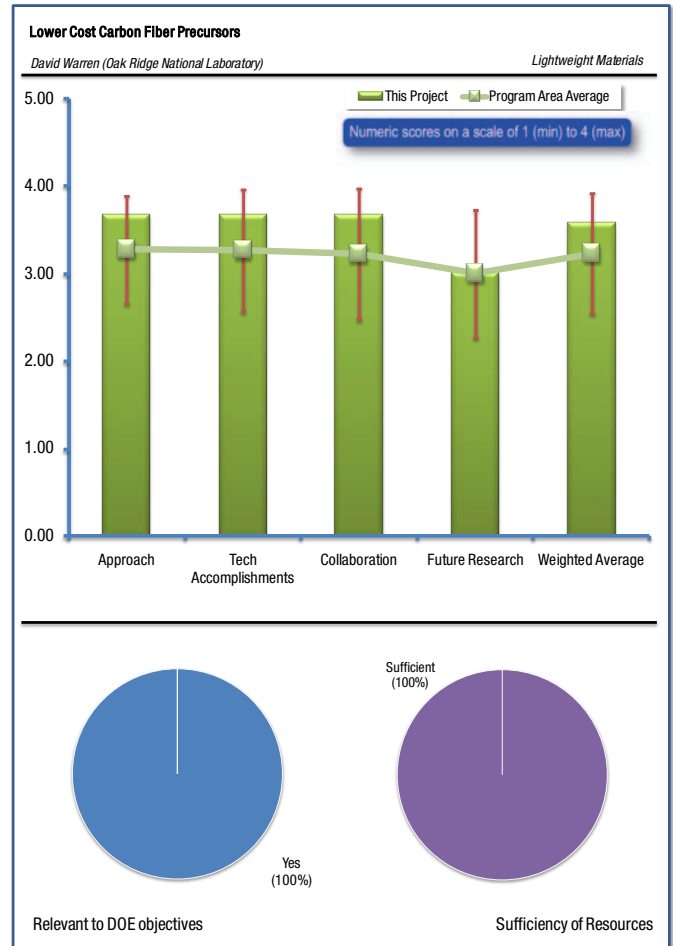
All reviewers generally agreed this work supports DOE objectives. One person commented that this topic is very relevant to obtain the goal of low-cost carbon fiber due the 51% cost of the precursor to the carbon fiber material. Another noted that all carbon fiber works are imperative for reducing the material weight for light vehicles. The final evaluator commented that the polyolefin work may very well produce game changing results.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One person simply stated that the project is comprehensive and exclaimed that the researchers have a good understanding of the subject matter and that the project shows good promise. Several people noted the effective data presentation methods. One person remarked about the good use of “simple” graphs/charts to explain the process, while having the detail included in additional slides. Another person agreed, noting the useful comparison of the current precursors and plan going forward with realistic expectations coded in red/yellow/green. They concluded by noting that the description of strength properties are at commercial levels with current precursor. Another commenter pointed out that the researcher fully explained the process–materials through process with concentration of precursors and differences between them. One person simply summarized that the work is attempting to optimize process control for consistent input material. Another noted that it is clear that the polyolefin work is still at the discovery stage. The final reviewer pointed out that the barrier is cost and efforts are being made to address this issue; however, the technology is still too new to tell the impact on cost.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person commented that the project fits very well with DOE’s goals and that the research team has shown good effort. Another evaluator noted that the researchers’ experience is paying off because progress is very good. One commenter mentioned that the laboratory scale technology development is progressing well; upgrade to larger scale is still some time away. Another evaluator remarked that the defined target of polyolefin precursors are promising to reduce carbon fiber overall cost to \$2-3 overall, adding that they felt that the textile precursor is currently the most viable. The final reviewer explained that new precursors are needed for carbon fiber manufacturing cost reduction. They felt that the researchers showed a good understanding and assessment that carbon fiber production, including relevant precursors, must be scaled for auto industry production for mass production usage as stated in the presentation.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One person commented that even though the project is restricted due to license exports, the collaboration is very comprehensive. Another person agreed, mentioning that due to trade restrictions the names of the partners are not revealed; however, the contributions are good. One evaluator noted the researchers' cooperative research program with U.S.- based precursor producers is under development, as well as a sister project with commonization between but there are differences. The final commenter noted that the project is fully integrated with suppliers in the U.S. and Canada and technology transfer procedures in place for key suppliers outside this group.

QUESTION 5: HAS THE PROJECT 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?

One evaluator suggested that the years of feasibility, technology readiness and MY introduction should be targeted for specific precursors and overall cost target. Another person noted that the researchers provided a good description and future plans to research kidney shape (not round) fiber decreases strength and plan in place to develop capability for "round" fibers. They acknowledged that a timeline in place to address but lacking detail. One person pointed out the good question from peer panel of "which horse" is winning the race considering precursors and manufacturing processes. They concluded by asking if there are other precursor materials that appear promising. The final reviewer commented that the objectives for three different material developments were explained. One reviewer stated that the rating would have been a "4" rating if the project were not in its last year.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One person simply stated that the project has sufficient resources to achieve milestones. Another person cautioned that before closing the program, DOE and ORNL need to carefully analyze the results to find out whether there would be more to gain by extending the work. The final person remarked that, according to his recollection, Dr. Warren had three talks. This was also the case last year, and maybe the year before. The reviewer suggested that ORNL should have different people present the project status and results to bring fresh perspectives to maintain the interest on such important projects.

*Low Cost Carbon Fiber from Renewable Resources:
Frederick Baker (Oak Ridge National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One evaluator expressed that any progress toward the use of renewable resources is good for DOE. The other reviewer commented that production of low-cost carbon fiber is essential for widespread utilization in automobiles in order to improve fuel economy. They agreed that this project supports the overall DOE objectives.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One person simply stated that the project is very comprehensive. The other commenter agreed that this is a very good project, but added that their main concern is to minimize the variation of properties of carbon fiber with lignin process.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person simply observed that this is a very good project. The other reviewer pointed out that excellent progress has been made; however, the production process has to be refined, and also the variation in lignin properties has to be minimized.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

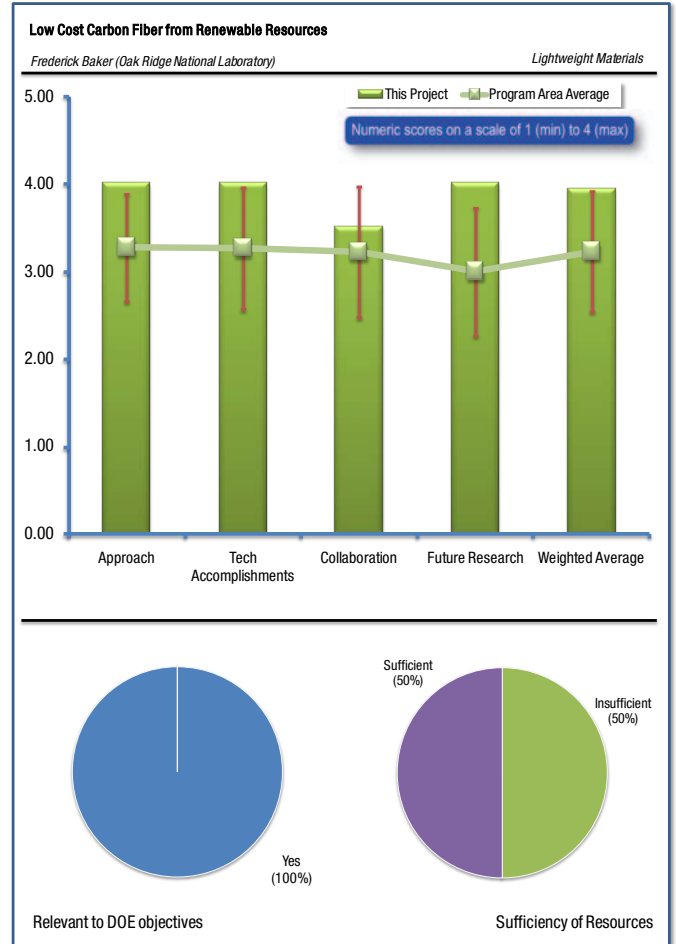
Responses were generally positive. One person remarked that the collaboration with different countries and various partners has been excellent. Another evaluator pointed out that partners are fully engaged. The final reviewer commented that there is evidence of a good effort but the collaboration should be broadened, especially more diverse than what was alluded to in the talk.

QUESTION 5: HAS THE PROJECT 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?

One person commented that the future work is well defined and focused on overcoming the barriers. The other reviewer simply exclaimed “go for it!”

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Only one person commented, stating that the financial resources should clearly be expanded.



Advanced Oxidation & Stabilization of PAN-Based Carbon Precursor Fibers: Felix Paulauskas (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer noted that the project effort is geared toward reducing the cost of carbon fiber. Another person also noted that development of low-cost carbon fiber for the automotive industry is critical to mass reduction, resulting in improved fuel economy; this project supports the overall DOE objectives in this regard. One commenter noted that this work is improving the process time for a particular feed material which can reduce the weight. The last comment was that the researchers are focused on fast stabilization to increase throughput, in spite of the risk of the process.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

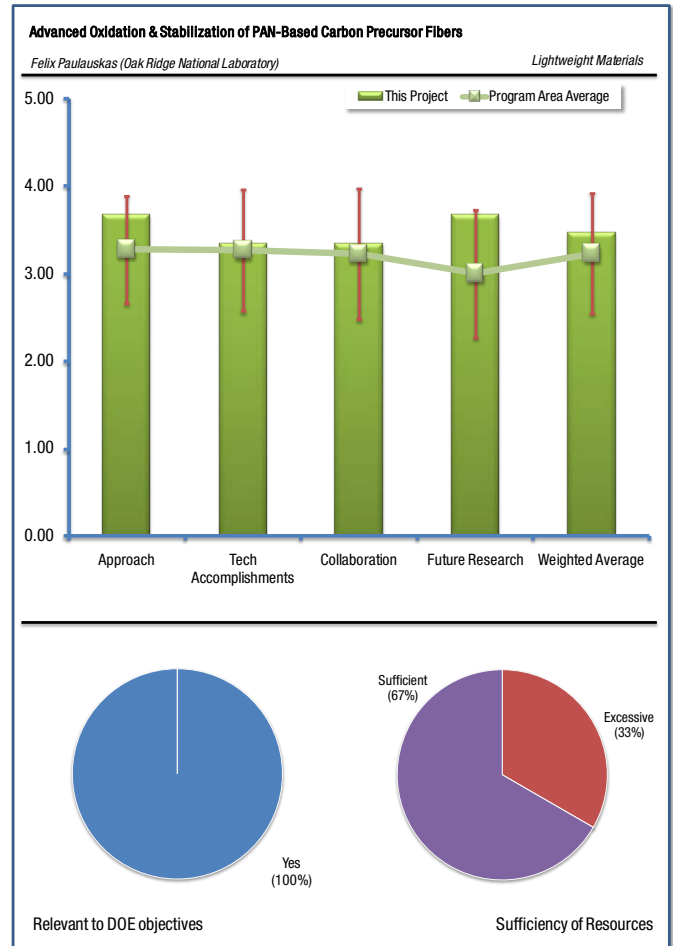
Both comments were very positive. One person remarked that this is a very good project with a very detailed and focused approach. The other commenter pointed out that the project is very comprehensive and shows that ORNL has had a long experience with working on carbon fibers.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments to this question were all positive. Two reviewers stated that this was a very good project. One continued, stating that more efforts to improve the properties of fiber, specially the modulus, should be directed. One person acknowledged that there is a good understanding of the process and defined deliverables and that excellent progress has been made within the timeframe. They concluded by stating that here is a good understanding of the shortcoming and what is achievable. The final reviewer observed that the lab-scale of the process is developed; the progress towards commercial use is being planned.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reactions to this question were equally mixed. One person noted that collaboration with various parties has been excellent. Another person agreed that one company is identified; however, their role is not clearly defined. One evaluator explained that collaboration is a delicate point on which ORNL and DOE should spend more time discussing which information can be released and which cannot. The final reviewer criticized that if the goal is to disseminate part of the intellectual property knowledge, then they can do better. However, if ORNL is required to also protect the intellectual property of the industrial partners, then this reviewer wondered if they are not going too far in the amount of disclosures they produce.



QUESTION 5: HAS THE PROJECT 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?

The future project plan is very clear and focused based on the results so far to overcoming major barriers. Another person added that the project is a good lead, and they expect that future work will be very well conducted. Others were positive, but had questions or reservations. One person commented that the presentation indicates that the Phase I was completed and Phase II is to begin October 2010; however the achievements of Phase I are not highlighted. The reviewer concluded by asking what is the decision gate to move to Phase II. Another evaluator observed that Phase II goals are defined, but looks like it is continuation of status quo from Phase I. The final reviewer acknowledged the comprehensive approach and planned scale up, the milestone list, and the ideas are good, but asked where the metrics are.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One person simply commented “maybe not.” Another reviewer suggested that maybe it is time to consider bringing new people with other perspectives to maintain interest on this important topics. The final evaluator observed that as the cost for Phase I is not available it is hard to estimate the request; they could not validate why \$1 million is requested from the work information provided because no work breakdown was presented.

Magnesium Front End Research and Development - Phase 1 (AMD 604): Alan Luo (General Motors)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

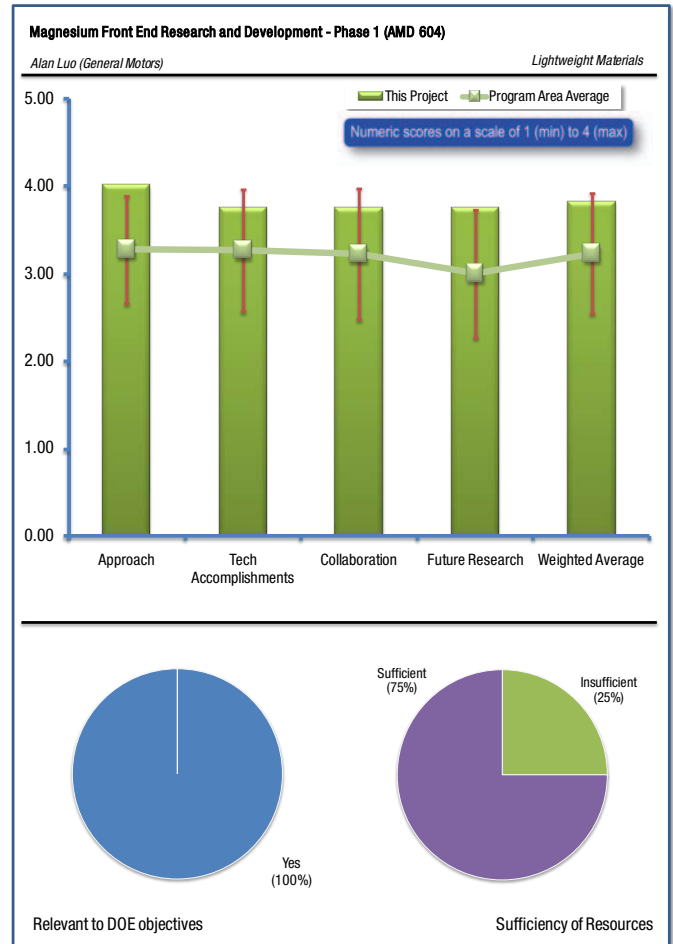
All comments for this question were positive. One person remarked that this topic is very relevant to obtain the goal of vehicle mass reduction via component material replacement to magnesium and redesign. Another noted that lightweighting using magnesium directly relates to displacement of petroleum. One reviewer simply commented that this project is clearly an effort to reduce weight of any vehicle. The final person remarked “finally a talk where practical applications are exemplified,” adding that the project should clearly be promoted and extended.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments to this question were all positive. One person noted that good targets and baseline vehicle (HSS) were provided as comparison, but pointed out that the researchers need to identify future model year implementation and cost with specific model years and feasibility. One commenter acknowledged that the investigator provided a good discussion of low-cost sheet and forming—builds on other projects for data. Another person added that the project used a great approach, assessment and recommendation towards commercialization. One evaluator noted that the project is very good and geared toward industrial applications. One person observed that the approach is highly detailed with a discussion focusing on the eight key tasks. They added that the presentation provided a good discussion of corrosion and surface finishing—acknowledged issues with body materials. The final reviewer had very detailed comments, stating that the technical target of the USAMP effort, which has several presentations in this project, is to organize and deploy an international research and development project aimed at the advancement of magnesium technology by a dedicated collective of researchers toward the goal of having sufficient engineering and manufacturing capabilities to exploit the full weight-reduction potential of magnesium alloys as engineering materials for entire automotive sub-structures, thereby leading to concomitant fuel economy realizations at affordable cost, excellent vehicle performance and with due consideration for the environment. (This is taken from the presentation materials). The targets are (1) mass reduction up to 60% less than steel comparator; 35% less than aluminum comparator structure, (2) neutral or slight cost penalty compared to steel baseline; and (4) vehicle performance attributes comparable to baseline structures. The specific approach is to focus on vehicle front end assembly components.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person noted that the researcher showed very good progress, accomplishments according to objectives, and schedule compliance. Another commenter agreed that the progress was extremely good in view of handling difficulties exhibited by magnesium. One person observed that crashworthiness (fracture) was discussed with issues of buckling deformation, but asked what the next steps are to be addressed. One evaluator noted that the presentation showed that welding and joining of magnesium was being done with friction stir welding, but asked whether this is feasible, and under what circumstances, on this material. The reviewer added that the presentation



discussed other types of welding (good), but also needs to include cost/feasibility of additional tooling for accurate comparison of costs. One person noted that the investigator acknowledged that magnesium does not address airborne noise and a sound package must be included for an NVH comparison; however the additional mass and cost were not accounted for in this study. One reviewer felt the researcher gave a good discussion of fatigue/durability and that they understand limitations and work to be done with CAE models. They added that adhesive systems must be addressed for body panels but further work must be done on this.

The final reviewer had very detailed comments, explaining that the FY2009 accomplishments for Tasks 1.1 to 1.8 are presented in the materials. They note with interest the comment in the discussion of Task 1.1 (Crashworthiness) that magnesium alloys showed pervasive fracture in crash loading. In general, the discussion presented indicates that this large project is working in a careful and thorough manner through what seems to this reviewer to be a very large material property option space. Task 1.5 (Low-Cost Extrusion and Forming) is clearly of great commercial importance, especially the effort to improve the mechanical properties of the listed alloys. In addition to the wide corporate and academic representation in this project from the U.S., the U.S.-Canada-China collaboration is an important and very positive feature.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were all positive. One person observed that numerous collaboration partners are involved with multiple funding sources by multiple agencies/partners, but more detail is required on the extent of each. Another reviewer commented that the researcher showed significant domestic and international participants including industry, university and government labs worldwide. The final evaluator simply commented on the good team, synergy, and complementarity.

QUESTION 5: HAS THE PROJECT 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?

One person noted future research plans include low-cost extrusion and forming, also asking whether this process available today and at what additional cost. Another evaluator expressed that Phase II is interesting, but asked if this uses optimized design from other materials. They concluded by stating that “highly efficient design” requires better definition. Another commenter agreed with the excellent recommendation towards Phase II including multi-material construction of a cast, extruded and sheet (magnesium, steel and aluminum). One evaluator felt that the future is very promising, but also asked what applications of magnesium are unique and where can it be used. They noted that the presenter indicated that intricate shapes are best due to the casting. Body-in-white structures are limited to shock towers and non-corrosion placements (interior), so the reviewer asked how this applies to high volume vehicles. One reviewer had detailed comments, stating that the project’s future efforts for the magnesium alloy front end included the following: (1) the design and build of a demo structure which embodies attributes of a major body structure; (2) to work through tasks in corrosion, fatigue and joining centered around a demo structure; (3) to continue extrusion, sheet and casting tasks to make parts for the demo structure and fully integrate with the integrated computational materials engineering (ICME) task and to potentially evaluate additional alloys, especially age-hardening alloys and reduced anisotropy; and (4) to redefine the crashworthiness and noise, vibration and harshness (NVH) tasks. The final reviewer also had detailed comments, describing that while the search for better magnesium alloys (i.e., improved crashworthiness, better corrosion resistance, more uniformly controlled formability) is undoubtedly an appropriate undertaking, and one which will enhanced our understanding of this class of alloys, it should also be noted that solutions which pair up magnesium alloys with other light-weight material classes in multi-material assemblies might also be worthwhile to consider. The discussion of the critical assumptions and issues in the presentation material was very helpful and well done. It seems that the problems and issues pointed out here are the beginnings of a roadmap for future investigations. (A question for DOE: how widely beyond the project participants will the detailed technical results of this family of projects be made available? And what arrangements have been made concerning the ownership of the Intellectual Property?)

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One person commented that is the kind of projects DOE should promote; there will be many applications in the pipeline. Two other reviewers stated that the project has sufficient resources for Phase II to achieve milestones.

Multi-Materials Vehicle R&D Initiative: David Wagner (Ford Motor Company)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

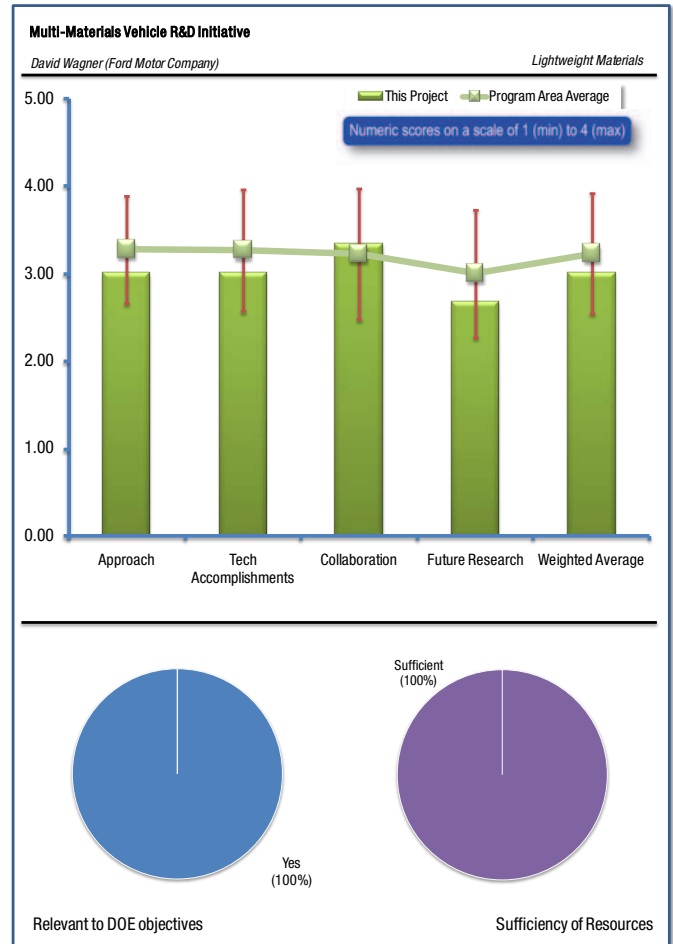
One reviewer commented that this project is very important in order to reduce the mass of vehicle resulting in improving fuel economy in a most cost-effective manner. They added that this project fully supports the overall DOE goal. Another person commented that this type of holistic vehicle project will fully integrate other specific areas of research into understanding the feasible percentage, cost and fuel efficiency gains of overall mass reduction.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer had detailed comments that summarized the project, stating that the objective of the USAMP Multi-Material Vehicle project is to develop lightweight materials technologies for cost-effective, large-scale implementation in vehicles that meet consumers’ needs while providing increased fuel efficiency. The approach is to begin with identification of benchmark current production powertrains to use for simulation purposes to identify required weight reduction targets. Simulations have been ongoing since that time to ascertain appropriate weight reduction targets. Several evaluators explained that this project is closing out and wrapping up, and that the researchers need to integrate “lessons learned” from this project into the next MMV project. One person added that the presenter stated the need for a clean sheet for the next design—similar to Lotus type methodology based on recently released report, which they fully agree with. One person noted that the 2009 objectives for the “L7” minivan 7-passenger project were to achieve 31 mpg, but asked at what time frame. The final evaluator criticized that this project was ill-conceived; it should have started with a clean sheet of paper. Stitching several existing projects to a new project was a bad idea. It is very difficult to achieve the goal by eliminating the existing barriers.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer commented that they agree with presenter that the project needs a detailed report instead of a 30,000 foot view. One commenter observed that this MMV project was able to achieve 16% mass reduction; half of this was achieved by marrying with other projects. There is a need for an overall “new” project: three years at \$1 million per year. Another evaluator criticized that very little progress was made towards the original goal and very few barriers have been overcome; the reviewer concluded by stating that this project should be closed. One reviewer pointed out that the researcher acknowledged the limitations of separate studies and noted that a further “holistic” vehicle approach is required. Another evaluator described that this type of holistic vehicle project will fully integrate other specific areas of research into understanding the feasible percentage, cost and fuel efficiency gains of overall mass reduction. One reviewer observed that this MMV project helped system/component optimization for cost/feasibility but further work is required in the next MMV project. The last evaluator commented that the MMV accomplishments for FY2009 are the following: (1) helped project teams complete the donor vehicle systems-level manufacturing and assembly baseline cost modeling project; (2)



continued to guarantee alignment between all three projects on engineering performance metrics (3) initiated MMV903 Lightweight 7+ Passenger Vehicle Study (L7) with the goals of developing a generic lightweight 7+ passenger vehicle concept to demonstrate application of mixed material technologies and mass compounding towards the creation of a lightweight, cost-effective vehicle to achieve at least a 40% increase in EPA combined fuel economy with no sacrifice in safety, comfort, features, utility, or performance.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Both commenters agreed that collaboration was present, but had criticisms. One person explained that coordination among various partners was good; however, the project plan was not well conceived, which resulted in poor end results. The other noted that numerous collaboration partners were involved. Funding sources were provided by multiple agencies/partners but more detail is required on the extent of each.

QUESTION 5: HAS THE PROJECT 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?

One reviewer had detailed comments that summarized the project, stating that in FY2010, the MMV R&D initiative will continue to help close out the three USAMP MMV “Seed” projects, and remain opportunistic in attracting new project ideas from USAMP in areas such as multi-material joining technologies. MMV will complete Phase 1 of the L7 project (MMV 903) in the second quarter of CY 2010, the powertrain and weight matching for fuel economy and performance, present the results to the USAMP Steering Committee and determine with the Committee whether further work in this area is warranted. Future efforts would be conducted under the auspices of other U.S.AMP groups, i.e., AMD, ACC, A/SP or NDE. MMV will complete all efforts and reports by mid September 2010 so that the project can be closed in FY2010. One reviewer simply noted that the MMV Phase 1 will be done in the second quarter of CY2010. Another person suggested that the powertrain could possibly be developed by EPA if agency coordination is required. One evaluator felt that the project is well-defined and the team seems to be working through the milestones in an efficient manner. Another person disagreed, stating that the project was ill-conceived, and thus has little relevance toward eliminating barriers. One evaluator suggested that the MMV project needs to be more of a near-term project targeting a specific MY and technology feasibility readiness CY. The final reviewer asked who is doing crashworthiness study.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Only one person commented, stating that they withhold their rating until the next study is started, but noted that this project had sufficient resources to achieve milestones.

Development of High-Volume Warm Forming of Low-Cost Magnesium Sheet: Matt Zaluzec (Ford Motor Company)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

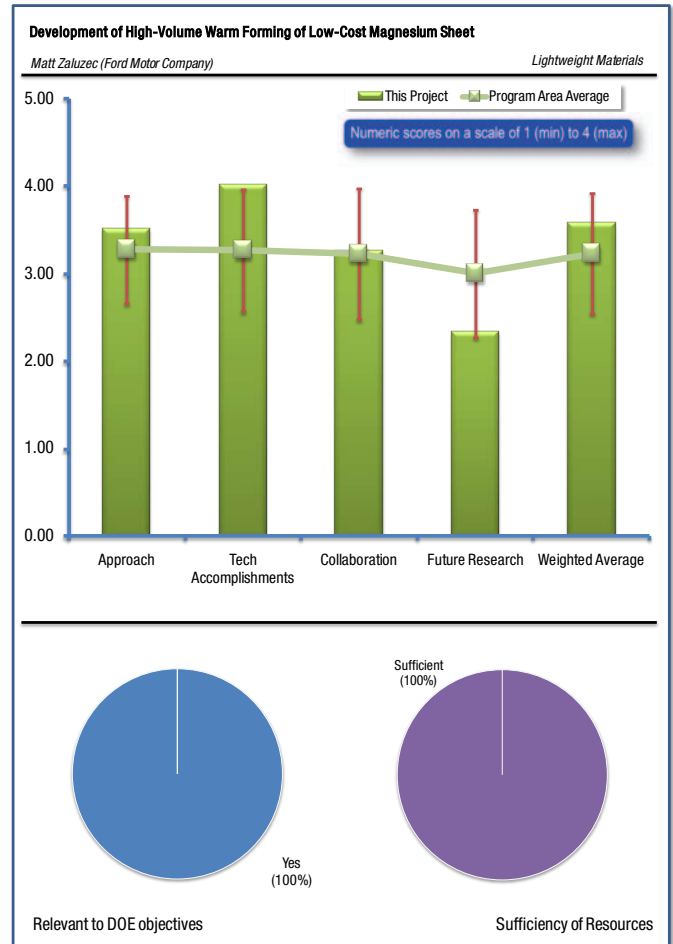
Most comments to this question were positive. One person explained that magnesium has the potential to reduce the weight of vehicle which is known to improve fuel efficiency; this project is demonstrating an enabling technology to improve productivity of magnesium. Another person agreed that magnesium sheet is integral to the lightweighting initiative to reduce petroleum. Another evaluator also agreed that the project will reduce the dependence for foreign sources of petroleum. The final reviewer commented that the project was closed about a year ago, so it should not be in the session.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer provided a detailed project summary, stating that the objective of this project was to develop the technology and material supply base for cost-effective lightweight body panels fabricated from sheet magnesium. Specific deliverables include the following: (1) design and build a warm forming die and demonstrate a deep draw capability on conventional direct chill (DC) material; (2) evaluate materials and compare the formability of continuous cast (CC) and direct chill (DC) materials; and (3) demonstrate high volume cycle times with CC material on an integrated forming cell. Continuous casting (CC) is a key technology for enabling the development of low-cost magnesium sheet. The project will receive material from major global magnesium suppliers and be characterized via lab-scale investigation at the University of Virginia and CANMET and through stamping trials at Troy Tooling Technologies. Novel die systems will be designed and constructed that enable the use of warm forming in conventional single-action presses. The die will be used to determine critical forming parameters for magnesium sheet including preheat temperature, die temperature, and forming speed. Full automation including loading of pre-heated sheet and part extraction will be developed to achieve acceptable cycle times. Another evaluator expressed that the project is focused, with all the aspects relevant to manufacturing of a component being considered, and that most of the work was carried out by independent participants who were coordinated by end users (auto OEM). One person commented that the effect of die temperature variability on formability was identified and the team developed technology for die temperature control. One commenter noted the solid approach toward development and material supplier comparison. The final reviewer had somewhat critical comments stating that the approach appeared to be good, but “what can be said for water that passed under the bridge quite a while ago... that hindsight is always 20/20.”

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer provided a detailed project summary, stating that the FY2009 accomplishments are as follows: (1) established forming maps for all five materials and correlated those maps to the lab-scale characterization work. Both DC and CC material displayed large forming windows at 300°C; (2) designed, developed a new pre-heating system based on a retrofitted conveyor furnace capable of



supporting a production rate of 5 to 10 parts per minute; (3) integrated pre-heater, press and newly acquired robot (loaned from Ford) to automatically load pre-heated sheets into the press, and connected PLCs from the press and robot with various limit switches to enable a fully-automated forming cycle; and (4) demonstrated run-at-rate capability of warm forming panels from both DC and lower-cost CC magnesium sheet. One reviewer commented that the project had identified the technical issues and solved many of them; it was shown that for magnesium, forming is achievable at high temperature; however, the component is a simple form and no actual component was manufactured. The final person simply stated that the progress was very good accomplishment according to plan.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Responses to this question were mixed. One person mentioned that multiple, international partners are involved with the work being well distributed. One person simply observed that international material suppliers were involved. One evaluator remarked that universities, other than ICME, were not involved. The final person commented that the researcher did provide many details on the collaboration.

QUESTION 5: HAS THE PROJECT 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 comments in general showed uncertainty about the future plans. Two people commented that according to the presented materials, all of the tasks and milestones for this project were completed at the end of FY2009, and there is no indication that this project will continue into FY2010. Another person asked “What next? We spent the money and what do we have?” One evaluator observed that not much of a follow-up was presented but they were convinced there is still plenty to do for this to be fully transferred to industry. One reviewer commented that the question of why one sheet behaved differently than another still needs to be defined. The last reviewer pointed out that the critical assumptions and issues are very clearly described in the presentation material. The availability of magnesium sheet is clearly an important part of the DOE project. The emphasis on supplier development is an especially significant observation. If the supplier is properly qualified in advanced, then it would be reasonably anticipated that they would be tasked to address the issue of lubrication, thermal stability, and so on.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reactions to this question were mixed, with a bit of confusion about why the project was evaluated. One person simply stated that the additional resources seem fine. Another evaluator expressed that this work should be continued. One evaluator criticized that this project should not have been in the session since it has passed. The last person asked whether a new project should start where the present one ends. They answered their own question, by saying “no”, but a new effort should be promoted and encouraged.

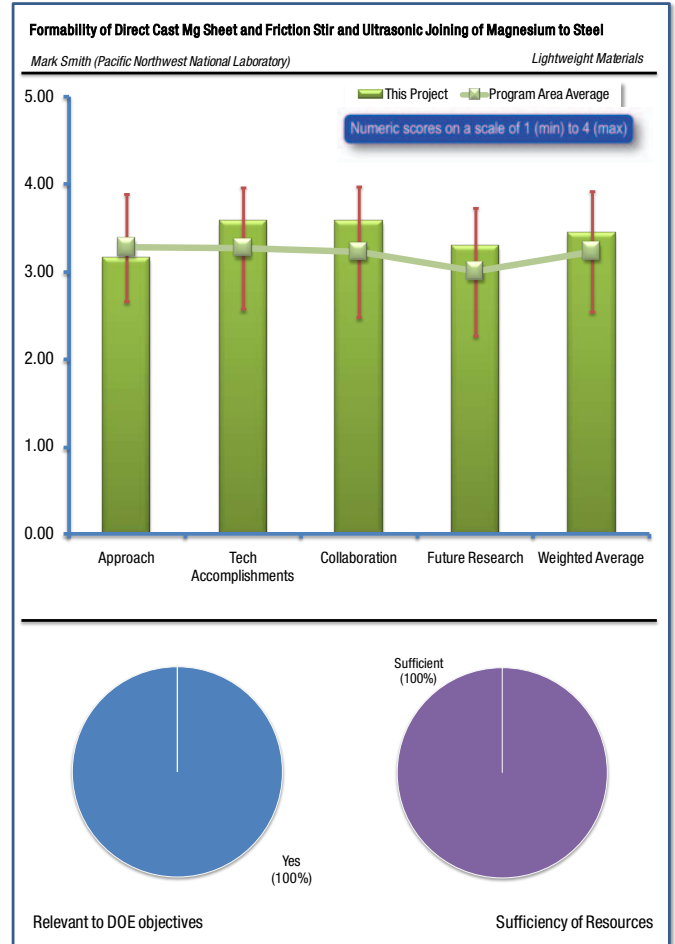
Formability of Direct Cast Mg Sheet and Friction Stir and Ultrasonic Joining of Magnesium to Steel: Mark Smith (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Comments to this question were all positive. One person noted that this work is a very important subject for DOE and also for potential users. Another person acknowledged that the project is directly related to weight reduction objectives as well as cost reduction and performance improvement and design optimization. One person expressed that the use of magnesium sheet facilitates the use of magnesium in automobiles to improve fuel economy and displacement of petroleum. One evaluator remarked that cost reduction in warm forming is an enabler for the use of magnesium in vehicles; magnesium can be used to reduce the weight of the vehicle and this project is an enabler. One evaluator added that this work supports the use of magnesium as a suitable material for material replacement and mass reduction of vehicles. Others commented that warm forming and joining are fundamental techniques for such materials. One reviewer stated that bonding of this material is critical for advanced development of solid state methods (welding-friction stir and ultrasonic)—both deemed to be “non-melting” instead of adhesives. Another reviewer pointed out that multi-material joining is also important for the use of optimum material combination. The final reviewer explained that joining magnesium to steel is important and probably high risk, especially when considering long-term durability.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer provided a detailed project summary and comments, stating that there are two targets of this project: (1) the formability of continuous cast magnesium sheet, and (2) friction stir and ultrasonic state joining of magnesium to steel. The objective of the first target is to reduce processing cost for automotive sheet products by replacing conventional wrought processed magnesium sheet with continuous-cast sheet. The objective of the second target is the development of solid-state technologies for bonding magnesium to steel which may enable broader application of magnesium alloys in automotive structures requiring integration with steel components. The technical approach for the first target is essentially to work through the following issues: the tribology of magnesium warm-forming (surface roughness, coefficient of friction with selected lubricants), then post-formed property characterization (tensile test, microstructural characterization), and elevated temperature formability testing. The technical approach for the second target is to work through the following issues: to evaluate friction stir and ultrasonic welding (the interaction of process parameters, develop tooling), and then characterize structural strength of the join (correlate process parameters to mechanical properties), and then investigate inter-layer corrosion (investigate coating effects). Another person simply noted that the approach in welding strength is sound. Another agreed that the researchers have used a well-defined and targeted approach. They also suggested that the researcher should also include corrosion assessment for FSW of magnesium to steel; for the resources expended corrosion of magnesium-steel joints should be evaluated). One evaluator felt the researcher gave good feedback of formability relative to surface roughness, lubricant alternatives. Another person commented that the approach includes milestone and go/no-go decision charts are helpful to explain choices. They

added that the presentation outlined the report with deliverables developed but there is a need to concentrate on suitability for OEM usage. Others had comments related to the content and level of detail and analysis included in the presentation. One person mentioned that too many issues were evaluated; the findings are useful but the question of why needs to be answered more clearly; for example the presentation did not address why surface roughness affects the formability. Another evaluator commented that they would have given a higher rating, but the reviewer explained the presentation was too fast to be good. The last reviewer commented that the project really needs to focus on the zinc coatings, their composition and overall effects on mechanical properties. They added that it is highly unlikely that there is a metallurgical or even a solid-state joint without the zinc layer due to the differences in Mp.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person provided a detailed summary, outlined below:

Project “A”

1. Reducing processing costs for conventional wrought processed Mg sheet with continuous cast sheet. Reviewing tooling lubricants. Good description of tasks are developed 1 through 4 with technical accomplishments of these lubricants shown by surface roughness measured. Mentioned that vender-to-vendor variation. (approximately 10 times). Interesting high roughness had better formability.

2. Post formed mechanical characterization by vendors. Green checks show acceptable parts.

Review microstructure of the Mg "texture" on post formed material.

Accomplishments included 5 suggestions for feedback to vendors and identified.

3. Proposed future work.

Non-isothermal warm forming of Al and Mg (shown on slide 15).

Project “B”

Friction stir welding with U.S.CAR (GM, Ford, and Chrysler)

Noted few options exist for joining Mg components to steel parts.

Plan to evaluate corrosion and possible coatings.

Technical accomplishments shown (20% increase in joint strength)

Summary and upcoming work is slightly vague on deliverables.

Several reviewers had brief comments noting project elements that were described such as 1) the effect of surface roughness on the formability, 2) the alternate lubricant analysis, and 3) the joining efficiency for magnesium-steel joint. One person noted that the FSW and USW work well because zinc seems to facilitate the welding. One evaluator observed that the project made great progress on high-temperature forming lubricants, influence of surface roughness on forming and reasonable progress on post-formed properties. Another person agreed, stating that the progress to date on both project targets has been excellent. Another reviewer also agreed about the good progress as well as the thoughts for potential for commercialization. One reviewer questioned what caused the dip in the friction stir welding graph. They also noted that the researchers stated that the graph is “correct” with little explanation. One evaluator explained that this is all fundamental work and relevant to sheet forming and joining magnesium structures, but they added that they would like to see the spot friction welding work expanded to include mixed magnesium products, i.e. sheet, extrusions and die castings that are joined to coated steel. The last reviewer suggested that the work be expanded to include spot friction weld bonding where an adhesive is incorporated.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Responses were generally positive, but some reviewers felt improvement was necessary. One person criticized that better clarity is necessary here. Another evaluator acknowledged that the project included many partners both industrial and within laboratories, but not much was said. It appears that PNNL is going alone and it is hoped that this is not the case. Another person, however, felt that the project is an extremely well coordinated collaboration with the USAMP program on warm-forming and that the project plays a key role and delivered. One evaluator noted that numerous collaboration partners involved and that funding is provided by multiple agencies/partners, but also felt that more detail is required on the extent of each. One reviewer remarked that this project entails U.S. DOE lab participation in a larger USAMP project with many partners and suppliers that is integrated with a larger project. The final commenter noted that Mark has always been an excellent collaborator with the USAMP/USCAR organization and encourages this to continue as it is positive and beneficial.

QUESTION 5: HAS THE PROJECT 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?

One reviewer provided a detailed project summary and comments. For the remainder of FY2010, the proposed future work on the first target will be (1) to relate microstructure, post-formed strength and formability properties, and also (2) to investigate forming limits under bi-axial forming. For the longer term, the issues to be investigated will include (3) non-isothermal warm-forming of aluminum and magnesium, concentrating on tribology under non-isothermal conditions, the development of models of thermal and strain distribution in sheet, and investigating ways to enhance durability of forming-dies for high-volume manufacturing. The upcoming work for the magnesium to steel joining target includes: (4) the joint interface characterization, especially the effects of coatings, adhesives, and paint on the surfaces, and (5) future efforts to address the fundamentals and manufacturing of each process, e.g., clamping forces, weld offsets, and corrosion protection. One reviewer expressed that the future work plans seems beneficial, specifically relative to corrosion. Another person remarked that this work clearly needs to be pursued and encouraged; it is the key to the multi-material vehicle.

The effort should be refocused. One evaluator noted that one project is complete this FY; plan for the second project (joining) is too broad but exploratory. Another person commented that the zinc coatings on the steel appear to help joining as the zinc melts possible; this could be future research. One reviewer asked whether the tip sticks when ultrasonic welding magnesium, since this occurs with aluminum. The reviewer suggested that this might be a good area to review to determine feasibility; this research would be critical to understand manufacturing and joining issues with magnesium. One evaluator noted that a reviewer asked a good question about variability between weld-to-weld and within the weld. They suggested that this could be a future research area conducted under realistic OEM conditions. A reviewer asked whether there are production targets for these types of methods. They also asked what the agreement of the OEMs and established tooling costs is. The final reviewer suggested that the researchers consider more computational modeling with others, or redirected on existing resources available at PNNL.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One person commented that this project had sufficient resources to achieve milestones. Another person agreed, stating that the funding resources seem to be adequate for scope, but suggested that further work in this area is needed. The final reviewer expressed that the project may not have adequate resources, pointing out that adding samples is important to assess the variability of the results.

Integrated Computational Materials Engineering (ICME) for Mg: International Pilot Project (Part 1): John Allison (Ford Motor Company)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One person commented that this project is important to the overall goal of the DOE objectives because of the weight reduction potential with magnesium to improve fuel economy. The only other reviewer to comment observed that this is the first project where ICME is being used to enable optimization of manufacturing processes and design to reduce cost of magnesium components. This project combines the theoretical aspects of material science and magnesium alloy developments. This project is very valuable to develop materials where cost-effective new materials can be used in order to reduce the cost of vehicle.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

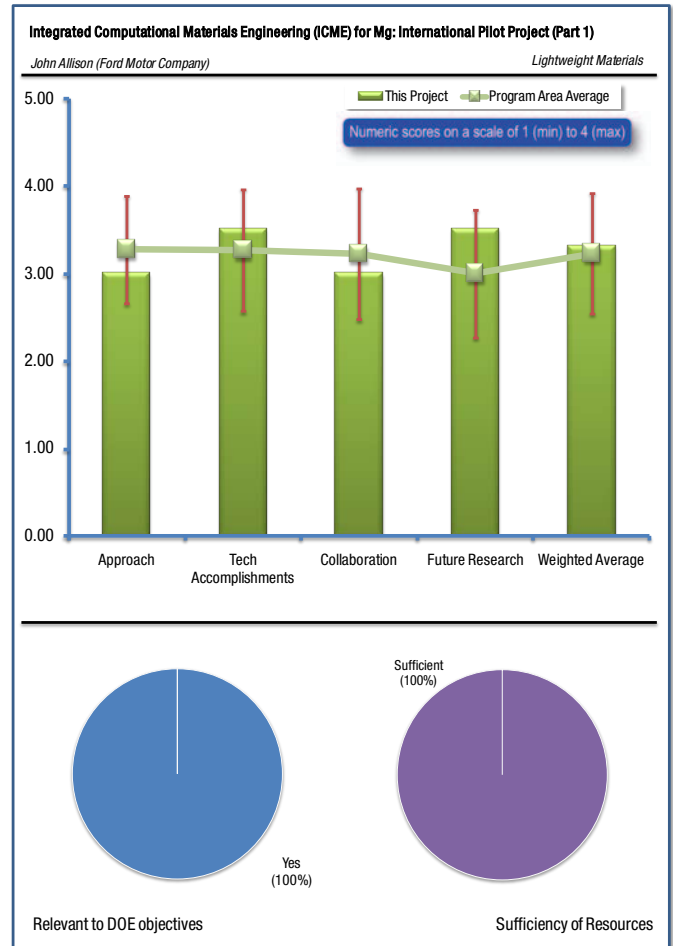
One evaluator noted that some of the technical challenges have been addressed; however, coordination with so many parties involved is a significant challenge. They suggested that the program should be focused to achieve a particular goal within the time frame and validate with experimental data. Another evaluator noted that the main objective of this project is to establish, demonstrate and utilize an Integrated Computational Materials Engineering (ICME) knowledge infrastructure for magnesium in body applications for microstructural engineering, process and product optimization, and future alloy development. The reviewer predicted that two consequences will follow: (1) this effort will create a “collaboration space” for high quality data and models, and (2) it will also help to identify and fill technical gaps in the fundamental knowledge base.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person commented that this project has just started and has made excellent technical progress in FY2009. The only other reviewer to comment added that some critical progress has been made towards the objectives, but it should be better coordinated among various parties involved.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

This project involves so many partners such as different countries, various research institutions and many manufacturing companies, it must be better coordinated.



QUESTION 5: HAS THE PROJECT 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?

One reviewer provided a detailed summary and comments, stating that the future work being proposed is described on slides 21 and 22. These efforts are associated with five technical teams: (1) Phase Equilibria and DFT Task Team (e.g., complete first-principles calculations of precipitate or meta-stable phases other than AZ9; link with casting precipitation hardening model); (2) Sheet Task Team (implement dynamic recrystallization model into crystal plasticity; develop constitutive model formulation including adiabatic heating, damage, anisotropy, and kinematic hardening); (3) Casting Task Team (calibrate the solution treatment kinetics model; complete strength model); (4) Cyberinfrastructure Task Team (assess informatics needs and enhance repository of experimental data and model calibration tools); (5) Extrusion Task Team (complete static / dynamic recrystallization experiments; complete weld seam studies and develop weld seam models; model twinning and precipitation hardening). Another evaluator commented that the project is a very challenging project with material science and process development. Another person noted that the future project plan is very ambitious. It addresses some of the challenges in overcoming the barriers. The final reviewer also had detailed comments stating that the project objective is to build an ICME infrastructure for magnesium alloys is very important. The collaborative agreement which has been pulled together, both national and international, is a strong and encouraging indication of success. They remarked with respect to the earlier USAMP project, that one of their areas of concern is the future financial support which will be required to maintain, and grow, the ICME database when the current DOE project funding is over in FY2012. They concluded by expressing that they believe that this point is really only the tip of a large collection of questions which are becoming increasingly hard to avoid.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Only one person commented, stating that at this time the resources are sufficient, and can be adjusted in future depending upon the results.

Magnesium Projects: Paul Wang (Mississippi State University)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Both reviewer comments were positive. One evaluator remarked that magnesium has a significant potential contribution in future years resulting in petroleum displacement. The other person described that the multi-scale model, as presented, is a good introduction to any experimental lightweight endeavor, but that the work needs to go further.

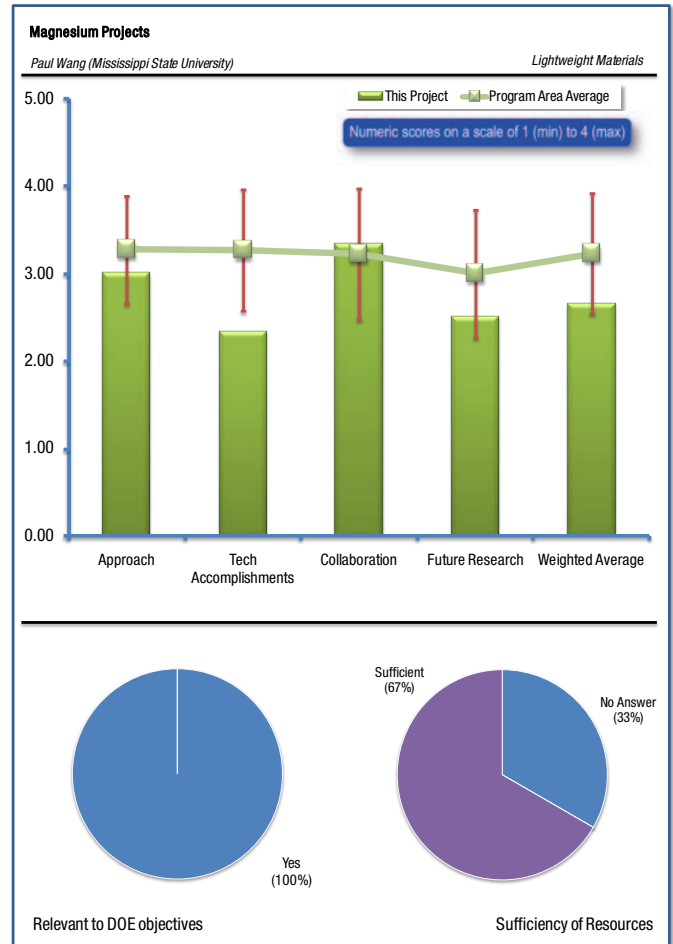
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer provided a detailed project summary and comments that the objective is to develop multiscale physics-based material models which are experimentally validated to be used for design optimization of components, systems, and lightweight materials; and to provide a robust design methodology including uncertainty to create innovative solutions for the automotive and materials industries. Theory development, experimental characterization, large-scale computing, new material development, and math-based tools are sought for use in designing next-generation vehicles under various crash and high-speed impact environments. The development of the cyberinfrastructure will leverage tools, technologies, and software developed by other large-scale scientific cyberinfrastructure projects and will be augmented by original research in computer science and software engineering towards the creation of large, distributed, autonomic and cooperative software systems supporting virtual organizations. Another evaluator felt the approach was comprehensive, but in such complicated multi-dimensional systems, the strategy becomes key to any real progress. Others were more critical of the approach. One person stated that the approach seems fragmented and more aligned with sustainability for the next 20 years. The vision is outstanding but the approach is a bit selfish. The final commenter criticized that the explanation about the strategy should be reviewed and clarified.

Another evaluator felt the approach was comprehensive, but in such complicated multi-dimensional systems, the strategy becomes key to any real progress. Others were more critical of the approach. One person stated that the approach seems fragmented and more aligned with sustainability for the next 20 years. The vision is outstanding but the approach is a bit selfish. The final commenter criticized that the explanation about the strategy should be reviewed and clarified.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person felt that the progress is good, although the spread of properties has to be significantly narrowed to have any real industrial applications in a not too distant future. Others, however, were not able to ascertain the level of progress. One person explained that the ICME results are very long-term, and the accomplishments are more of a vision and not yet measurable. The last reviewer remarked that it is difficult to determine what this team has accomplished in FY2009 based on the presentation alone. They acknowledged that some of the effort has gone into a literature search on magnesium, which is of course useful. They concluded by stating that for example, the presentation material shows the FY2009 work which was done on modeling and doing experimental work on corrosion.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers were all complimentary on this subject. One person simply noted that the researchers had shown collaboration with industry. Another evaluator felt that the collaborations were extensive, which is a strong point of this effort. The last commenter remarked that it appears to include many industrial and university partners.

QUESTION 5: HAS THE PROJECT 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?

One evaluator observed that the integrated model is outstanding, but felt that it is difficult to see too much how this will apply to real cases for now. They added that they understand why the researchers want to keep the effort as broad as possible, but suggested that it is in their best interest to illustrate the strength of their approach by giving one “practical” example. The other reviewer commented that it seems that the plans are to acquire data via experimentation on magnesium alloys and then to code up the results in a database. The reviewer added that they do not understand the relevance of the K-12 education effort in Task 12, even though this is a potentially useful effort in its own right.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers had a difficult time evaluating this question. One person mentioned that it was hard to judge whether the level of funding is adequate or not. The other reviewer commented that the effort clearly has to be continued but would like to see advantages through “practical” examples.

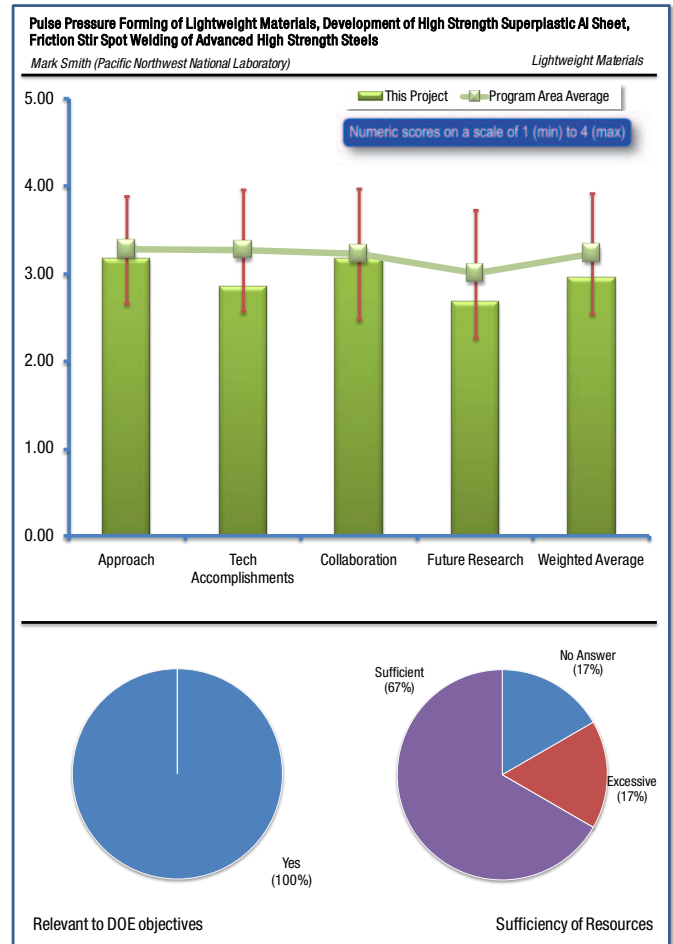
Pulse Pressure Forming of Lightweight Materials, Development of High Strength Superplastic Al Sheet, Friction Stir Spot Welding of Advanced High Strength Steels: Mark Smith (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 6 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reviewers were all positive, with some providing suggestions for keeping the work on track. One person commented that this is relevant to most of the VT goals, especially, performance optimization and somewhat to lightweight. Another person agreed, simply noting that pulse pressure forming (PPF) is adequate for DOE lightweight vehicles. One evaluator observed that this type of work supports the use of alternative suitable material and methods for material replacement and mass reduction of vehicles. Another commenter explained that this will enable the use of magnesium and aluminum which reduces weight and improves fuel economy, thus reducing petroleum use within the U.S. Another evaluator agreed, adding that commercialization of a magnesium sheet, aluminum and dual phase AHSS lead to lightweighting and subsequent fuel reduction. The final reviewer cautioned that since considerable PPF forming underway at the OEMs, it is critical to make sure the PNNL work is more stretch than what the OEMs are working on already.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Comments were generally positive, but reviewers provided several suggestions for improving. One reviewer provided a detailed project summary that stated that the project objective is resolved into three main targets: (1) pulse pressure forming (PPF) of lightweight materials, (2) development of high-strength superplastic aluminum sheet for automotive applications; and (3) friction stir spot welding of advanced high-strength steel (AHSS). The reviewer concluded by noting that each technical target is paired with a clear gap analysis. Another reviewer noted that the researcher captured the cost and cycle time limitations of SPF and has a target to improve to 250 MPa, so “good direction and good luck, this will be difficult.” One evaluator remarked that barriers of individual projects are identified along with potential mass reduction feasibility in all three topics. Another person simply mentioned that superplastic forming of aluminum sheet can produce high elongation, while another mentioned that PPF was well prepared and executed. One evaluator observed that pulse-forming and FSW of steels are good approach, however they are concerned about the need for work on high-strength alloys for superplastic forming—the real issue is forming speed. One reviewer mentioned that technology gaps were identified and a basic approach/strategy was shown; however, the reviewer felt that the researcher needs to use technologies presented in both forming and joining to feasible high volume production implementation timeline. They concluded by asking when these technologies will be used and on which parts specifically. Another commenter pointed out that while the project is still in the research phase for fundamentals, tooling capital costs and manufacturing times at OEM speed should be considered as future research. One person criticized that the goals other than high strain rate forming characteristics are not clearly defined, and seem to be made-up as the program proceeds. They noted that the project involves fundamental research, but near-term commercial

applications were not apparent. The final reviewer remarked that the project is ending without opportunity for pulse pressure application.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer provided a detailed project summary and comments, stating that the FY2009 accomplishments for each of the targets area are precisely described in the presentation materials. About target 1 (PPF): the reviewer found the diagram of the PPF very useful and the series of slides describing both the experimental apparatus and the experimental results convincing. One issue they identified was the non-uniform distribution of the pressure on the bottom of the sheet and the odd shape of the pressure profile vs. time curve (they also noted that the time scale appears to be mislabeled as seconds instead of the actual units of microseconds) To what extent is the shape of this curve dependent on the geometry of the chamber? Can more complicated part geometries than the dome using the PPF approach? Would preheating the material enhance its formability? What is the intrinsic (shot-to-shot) variability of the PPF process? About Target 2 (high-strength superplastic aluminum sheet): The process was to preheat the aluminum sheet to SPF temperature (about 450°C). Five alloys were prepared and investigated. This reviewer's take on this target area in light of the discussion in the supplemental slides is that there are significant issues remaining. About target 3 (friction stir spot welding of AHSS): The project has done material selection and also done work on the definition of the process parameters. Work on coating materials is ongoing.

Another reviewer also provided a detailed account of the project progress.

Project 3: Pulse pressure forming overview and deliverables achieved. Good chart on project overview with funding and partners. Addresses all types of materials (Al, Mg, HSS). Acknowledgement of single sided tooling is preferred due to cost. Technology gaps identified and approach/strategy shown (although basic). Technical accomplishments; EMF (electromagnetic forming) is key enabler going forward. High speed cameras employed for micro sampling of material strain during forming. Using OEM and supplier input for material selection. Bounded material selection to available products instead of exotic materials (good).

Project 4: Super plastic AL sheet for auto applications. SPF relevance to technology gaps. Need to identify comparison to "steel" part. Which type? HSS, UHSS? Good point of identifying auto manufacturing process constrains for high volume SPF aluminum sheet.

Project 5: Friction stir spot welding. Did not have time to present.

One reviewer commented that the work is too summarized to have a real opinion on it. Another person agreed that the project showed good results on all fronts and specifically that the aluminum superplastic forming is interesting work but not really relevant to auto needs. One evaluator mentioned that there has been little if any accomplishment for commercialization. Another person expressed that regarding the SPF alloys, the focus on the 6xxx alloys should focus on two things, reducing the processing costs that are required to get the grain refinement. The last reviewer described that what most do not know is that the SPF sheet aluminum results in surface striations. They suggested that the researcher ask GM how much money it costs to hand finish the SPF panels they introduced on their products; it eventually led to them pulling the process due to cost.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were all positive. One person simply stated the researcher has shown a good use of OEMs. Another evaluator observed that only GM, Ford and Chrysler were collaborators; no university or other DOE labs. They added that both OEMs and material suppliers are engaged, as well as the good partnership with U.S. Steel and Alcoa along with OEMs (Chrysler, Ford and GM). Another reviewer agreed that there has been good OEM and USAMP collaboration, and reinforced that the researchers should continue this. The final commenter noted that efforts should be made to broaden collaboration: new members should be included in the team.

QUESTION 5: HAS THE PROJECT 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?

One reviewer provided a detailed summary and comments. Future plans for Target 1: This is clearly indicated in the presentation materials. The multi-pulse PPF process and the deeper study of the constitutive relations are critically important. The reviewer supposed that one would also like to investigate the controllability of the electric discharge and the effects of its positioning in the chamber with respect to the bottom surface of the part being formed. Future plans for Target 2: The primary deliverable from the project will be an alloy system and microstructure that produces the desired properties. This system will then be transferred to an aluminum mill for production. The project notes that material supplier involvement has been difficult. Future plans for Target 3: Final process parameter validation and injection molding die design are underway. Another person also provided detailed comments, observing that this is an interesting project with a range of difficult issues which will need to be faced. The participation of some aluminum companies, including one or more of those listed in the presentation (Kaiser, Alcoa, and Corus), is absolutely essential for Target Area 2 to have any chance at all of having practically useful consequences. It also seems that the AHSS welding effort in Target Area 3 is frankly one to which the team is not strongly committed and which is inadequately funded. The bright light in this show is the PPF approach in Target Area 1. The reviewer concluded the comments by observing that this technique is a variant of an old forming process called “explosive” forming and that controllability issues for process technologies of this sort are not easy. Another evaluator commented that all these have to be pursued and amplified to have any use for the industry. One evaluator suggested that the researchers continue to focus on cost reduction for both the SPF 5xxx and 6xxx alloys. Another person suggested that the researcher’s attention should be turned to SPF of steels which is very challenging. Another person observed that further understanding of room temperature forming is required regarding pulse pressure forming. One reviewer acknowledged that technology gaps identified and basic approach/strategy were shown, but that the researchers need to use technologies presented in both forming and joining to feasible high volume production implementation timeline. They concluded by asking when these technologies will be used, and on which parts specifically. The next person remarked that although they are still in research phase for fundamentals, tooling capital costs and manufacturing times at OEM speed should be considered as future research. Another asked what the consistency and repetition of the various processes is; this was not shown. They added that they were unsure about the differences between symmetrical and non-symmetrical dies. The final reviewer suggested that the program be closed without future research or commercialization.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reactions to this question were mixed. One person thought that this project had sufficient resources to achieve milestones. Another person suggested that maybe not, especially since a lot more experiments have to be done. Another person observed that \$3 million seems like an enormous amount of funds for this effort, especially since there are efforts on pulse forming within OEMs and SPF of aluminum is questionable. The final reviewer has non-funding resource related comments that Dr. Smith had several talks and this year as well as in years past. The reviewer was not fully convinced that this is necessary, and felt that DOE and PNNL should bring new faces with fresh perspectives to rekindle the interest on such projects.

*NSF Third Generation Advanced High Strength Steels:
Ronald Krupitzer (Auto/Steel Partnership)*

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

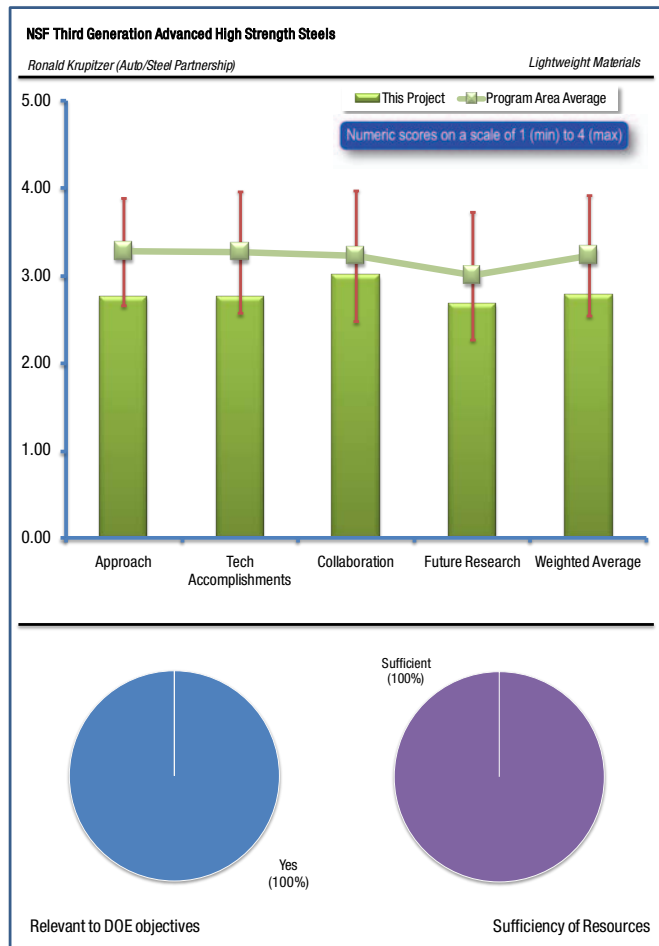
Reactions to this question were all positive. One person commented that utilization of advanced high strength steels helps to reduce vehicle mass resulting in improved fuel economy; so this project supports the overall DOE objectives. Another person agreed, stating that any work on AHSS is necessary to lightweighting vehicles. The final person commented that the suite of projects involving development of new steels or modeling efforts; will improve the use of third generation steels and achieving increased weight reduction.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer provided a detailed project summary and comments that the objective of this Auto/Steel Partnership (A/SP) project is to enhance the capability of AHSS from 25% mass savings to over 35% as an affordable materials approach to improving fuel economy and reducing vehicle emissions. More specifically, this team intends to (1) develop the metallurgy for a 3rd Generation AHSS with NSF, DOE and A/SP funded university research, (2) improve AHSS mechanical properties defined by the “Third Generation AHSS” field on the following total elongation-tensile strength diagram, and to improve modeling methods for fundamental steel mechanical property development. (The presentation materials contained a useful depiction of the AHSS “opportunity” in the elongation vs. tensile strength graph.). One reviewer pointed out that the project plan is very well defined, but addresses only some of the barriers. They suggested that a more focused definition and realistic goal should be articulated. Another person noted that the project includes nine tasks each involving its own work plan; each is trying to solve a fundamental problem and the approach for each one is quite well drawn and progressing well. The final reviewer commented that the approach appears to be thoughtful but the effort is too disparate to give any indication that this will lead to some real applications in a not too distant future. The project appears to be too much a collection of NSF projects. The need for consolidation is there.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One evaluator noted that the FY2009 accomplishments are listed by participant. Another mentioned that significant progress by researchers in universities was made so far: however, even small scale production of these steels needs to be demonstrated from the models. The next person commented regarding higher austenite contents; at least two projects are creating structure containing more than 13% retained austenite. One person simply pointed out that the researchers were able to show good microstructure control. Another reviewer observed that models to predict properties/forming are being developed. The final reviewer did not see how this can be put together to have any near-term use.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One person noted that the project is jointly funded from DOE and NSF. Another person acknowledged the collaboration between universities, AS/P and funding agencies. One evaluator remarked that there is excellent technology transfer potential due to industry participation in each step of the project. Another commenter explained that good project collaboration exists, but it can be improved; there are some duplications because of undisclosed information among various researchers. The last reviewer had similar comments that the project includes a significant pool of co-workers and/or institutions, but they do not appear to be collaborating on a unique goal.

QUESTION 5: HAS THE PROJECT 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?

One person had detailed comments, stating that as noted in the presentation, FY 2010 is the final year for many of the projects. The researchers apparently used the 2010 workshop of investigators to announce the potential for future work in these project areas. They added that depending on the individual projects, some third year work on several projects will be completed in the next fiscal year because of variations in the scheduling and funding for these projects. They concluded by pointing out that the project plans to do technology transfer by means of workshops and technical publications. Another person commented that future research programs have been identified, but that some of the barriers need to be defined. One evaluator noted that this will be the last year for most of the tasks. The final reviewer commented that, as structured, they are not convinced whether such interagency effort should be pursued.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One person remarked that if the effort was to create a database of 3rd generation AHSS then the funding is sufficient. The other reviewer to comment was not convinced the effort should be continued.

Fundamental study of the relationship of austenite-ferrite transformation details to austenite retention in carbon steels: Michael Santella (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

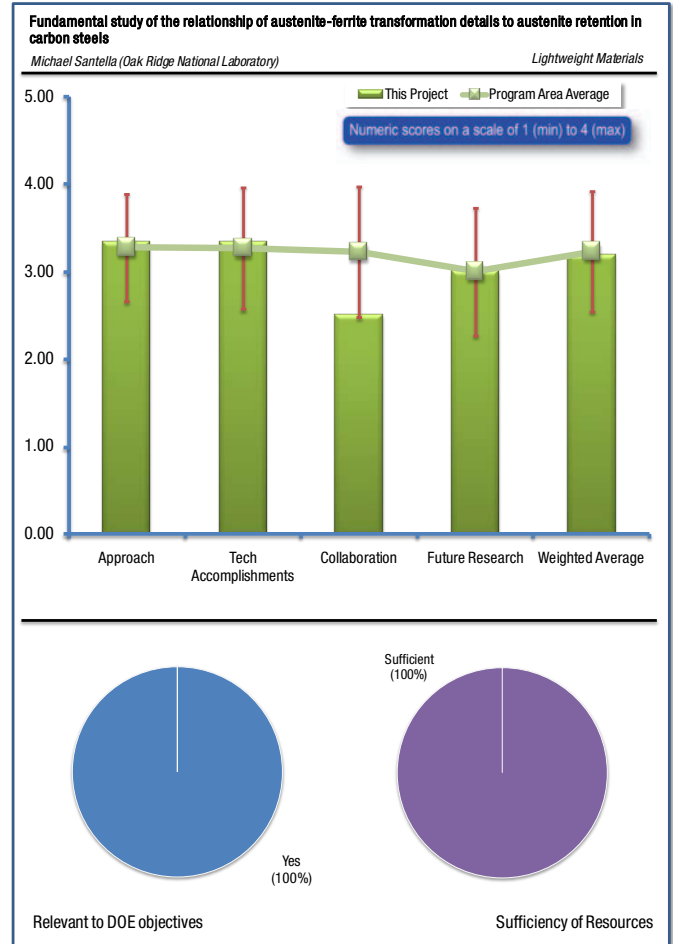
One reviewer commented that more utilization of advanced high-strength steels in automotive applications would result in mass reduction, which would in turn help to improve the fuel economy, which supports the overall goal of DOE objective. The second, and final, evaluator stated that retaining more austenite will increase the ductility; will improve the performance and reduce the weight; however, this will be effective only in a longer time line as the enabling technologies need to be created.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One person provided a detailed project summary and comments, noting that the project objective is real-time characterization of austenite-ferrite transformation behavior during temperature/time conditions representative of the processing conditions of AHSS. The effort is to determine conditions that promote retained austenite. This will contribute to building the scientific foundation needed for development of “3rd Generation” (Gen III) AHSS. The deliverables include (1) the quantitative description of austenite-ferrite transformation behavior during simulated finishing operations, including the effects of carbon, manganese, and silicon; (2) a quantitative description of alloying element partitioning between austenite and ferrite; and (3) an assessment of how retained austenite can be maximized within constraints of normal sheet processing infrastructure. Another reviewer expressed that the project is well defined and noted that some barriers were identified. The researchers added that some of the barriers were well simplified, but felt that the project needs to be focused only few barriers. One commenter simply suggested that the researchers concentrate on microstructure modification. The final reviewer asked what happens to the structure during subsequent processing (welding, annealing etc). They added that these steels exhibit good properties due to the special microstructures, so they asked what the use of the initial phase distribution is if these steels are modified due to secondary processing.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer provided a detailed project summary describing that the project demonstrated in FY2009 that it could successfully track α - γ transformations during rapid heating/cooling. The researchers also established that measurements of lattice parameters are possible. Some challenges were noted: (1) continuous proposal writing for Advanced Photon Source (APS) beam time, and (2) experimentation and data analysis is not “canned” and is in fact being perfected in parallel with experiments. The experiment begins with resistive heating of the sample in a vacuum and then continues with the exposure of the same to the APS synchrotron flux. Another person remarked that the researcher achieved good progress in understanding the transformation kinetics and microstructure development. The last person noted that some progress has been made, that the researcher has demonstrated basic feasibility, and that some barriers were overcome, but concluded by noting that the researcher needs to focus on specific deliverables.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One person noted that this is a national lab project and that project partners are being sought. The other reviewer to comment observed that with limited partnership, the coordination is very good.

QUESTION 5: HAS THE PROJECT 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?

One person noted that the future work for FY2010 includes the following tasks: (1) experimental alloys are being defined to promote austenite through alloying, and (2) a novel processing scheme to produce ferrite + austenite is under consideration. They added that the project notes that industry/university collaborations are being sought. Another person thought that the future plan is well defined. It addresses some of the barriers, but should be focused on deliverables. The final reviewer suggested that the researchers include more characterization and have less emphasis on tech transfer.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

There were no responses to this question.

*Advanced High Strength Steel Project: Paul Wang
(Mississippi State University)*

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

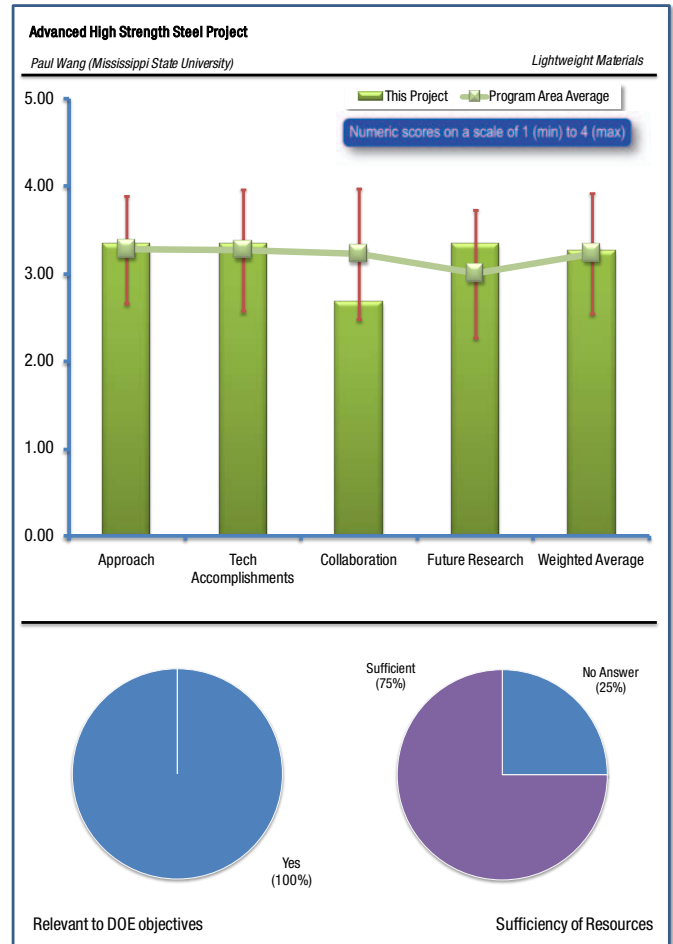
All reviewers had positive comments for this question. One person stated that the project fits very well with DOE's petroleum displacement objective. Another commenter felt that this type of work supports the use of alternative suitable materials and methods for material replacement for mass reduction of vehicles. One commenter stated that AHSS provides lightweighting opportunity which translates into displacement of petroleum. The final evaluator expressed that AHSS is very important for lightweighting vehicles and so is creating new alloys with improved physical properties.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One person provided a detailed project overview and comments, describing that the project objective is to use a hierarchical multi-scale methodology to investigate the effect of precipitates and additives to the overall strength and ductility in steel alloy design for automotive applications. Critical issues being addressed include the selection of key micro-alloying elements, interaction of precipitate and matrix phases, and ultimately composition-structure-property relationship. The approach is to perform simulations on quantum mechanical first-principles based on Density Functional Theory (DFT). Accurate atomistic simulations will be performed using Modified Embedded Atom Method (MEAM) and force-matching-embedded-atom-method (FMEAM) potentials. Finally, large-scale atomistic simulations will be conducted to study the effect that size, shape, and volume fraction of different inclusion particles have on the material properties of steel alloys. The correlation with atomistic simulations is made explicitly in the presentation materials. Another reviewer observed that the researchers presented a very comprehensive correlation with atomistic research, while another noted the good definition of approach and subtasks. Another person simply noted that project included topics from microstructures to DFT computations. One evaluator thought that the program is solid, but very broad, and suggested that a more focused project would be better. One reviewer mentioned that the project investigated advanced HSS project microstructure states to determine fundamental mechanisms to determine overall strength and ductility of steel alloys. The final person noted that the flowchart is clear but asked if there is a defined detailed timeline.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person provided a detailed project overview and comments, stating that as the FY2009 accomplishments demonstrate, this project has done a very good job of working through its tasks. The results are clearly presented in the materials provided. The accomplishments include the following: (1) performed the full spin-polarized density functional theory (DFT) calculations on Fe ferrite phase to correctly account for the ferromagnetism in Fe atoms; (2) developed a new multi-objective optimization methodology as a robust procedure to construct reliable and transferable interatomic potentials for steel alloy systems; (3) applied the multi-objective optimization procedure to construct reliable interatomic potentials for Fe, C, and Fe-C using the force-matching-embedded-



atom-method (FMEAM); (4) obtained FMEAM interatomic potentials for Fe-V alloys; (5) established a basic framework for the accelerated development of reliable and efficient interatomic potentials for other combination of alloy systems; (6) performed DFT calculations of cementite Fe-C alloy phase and optimized the structure, of the diffusion of V in ferrite phase, and of the diffusion of V in cementite phase; and (7) conducted fundamental materials/mechanical properties characterization and microstructure characterization on advanced high-strength steel (AHSS) alloy samples obtained from POSCO, performed thermomechanical treatment and investigated the effect of bake-hardening. Another person noted that the researcher provided a good summary of the project. The final evaluator commented that the results “appear to be quite good ... remain quite theoretical ... strong on modeling, including grain boundaries effects ... too academic to be readily applied.”

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers were suggested work could be done to improve in this area. It was unclear to one reviewer if industry, suppliers, or OEMs actively engaged. The other person to comment observed that the work appears to come uniquely from Mississippi State. It would be desirable to see collaboration and work integration.

QUESTION 5: HAS THE PROJECT 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?

One person summarized that the FY2010 deliverables for this project are (1) the development and validation of MEAM potentials to model lightweight alloys, specifically, Fe-C; (2) atomistic simulations of micro-alloying effect, specifically, V diffusion and V segregation at grain boundaries; and (3) the effect of altered microstructure on the strength-ductility combination of DP steels. Another person summarized that the use of computational chemistry simulations, especially the DFT simulations for (quasi-) ab initio computations of the properties of engineering materials is critically important. The reviewer strongly concurred with the project's remarks that “this investigation should facilitate the design of new generation of advanced high-strength steels by providing fundamental understanding of several critical issues that include the selection of key combination of micro-alloying elements, interaction of precipitate and matrix phases, and ultimately composition-structure-property relationship.” One evaluator asked how this relates to feasibility of using this material in production or future vehicles. They added that this advanced type of research has been completed on a single composition but asked how this translates into future OEM usage of 3rd generation steels and wondered if the steel industry uses this information or directs use to the OEMs and suppliers. The final person noted that the project is going from magnesium alloys, aluminum alloys, and then to steel alloys for next years.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reactions to this question were mixed. One person thought that this project had sufficient resources to achieve milestones. The other reviewer to comment suggested that the project may not have sufficient funds; the project is so broad that it can “consume” more funds.

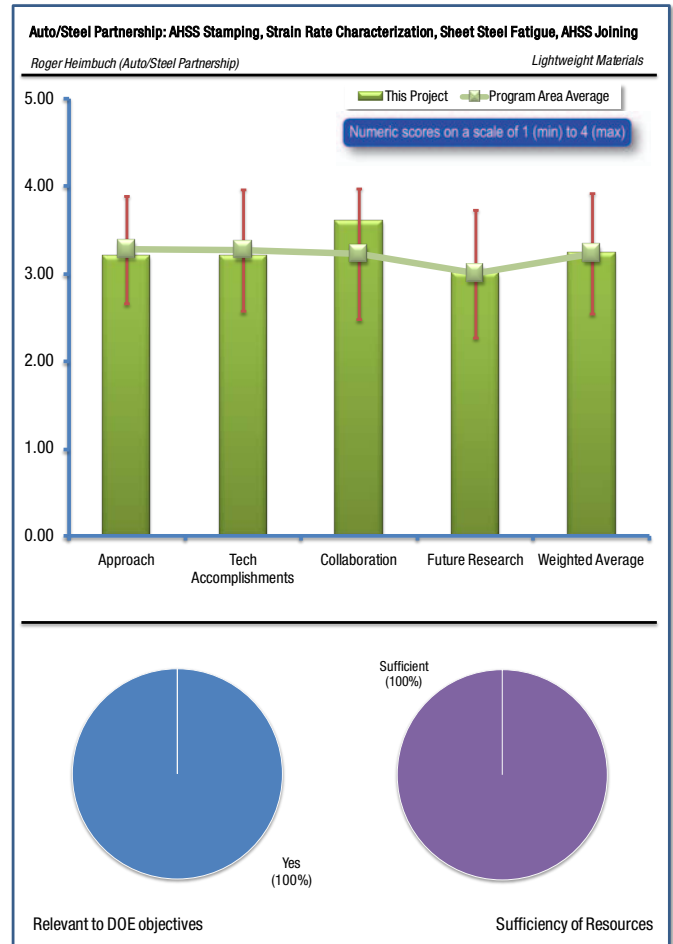
Auto/Steel Partnership: AHSS Stamping, Strain Rate Characterization, Sheet Steel Fatigue, AHSS Joining; Roger Heimbuch (Auto/Steel Partnership)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Reactions to this question were all positive. One person commented that the utilization of AHSS sheet steel in automotive components helps to reduce mass of the vehicle, resulting in improvements in fuel economy in a most cost-effective manner. They added that this project strongly supports the overall DOE objectives in replacing petroleum. Another evaluator commented that this type of work supports the use of alternative suitable materials and methods for material replacement and mass reduction of vehicles. Third generation AHSS, along with previous generations, are enablers. The reviewer added that the future proposal will consist of manufacturing challenges for OEMs using reduced gage material, implementing tooling and OEM constraints resulting in usable information for OEM use. One commenter simply stated “especially for vehicle manufacturing”. One evaluator pointed out that high-strength steels can contribute to improved performance and save fuel; many projects explained in this presentation contribute to the increased use of AHSS in vehicle structures. The final person observed that AHSS stamping is now the state-of-the-art, maybe not for reaching 50% weight reduction, but for everything in vehicles.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One person provided a detailed project overview and comments, stating that the objective of this project is the investigation of the engineering properties of Advanced High Strength Steels (AHSS). This project resolves into four technical target areas: (1) AHSS stamping, (2) fatigue of AHSS, (3) strain rate characterization, and (4) AHSS joining. Each of these target areas has a specific line of approach: (1) AHSS stamping investigates springback prediction, reduction, and the characterization of fracture during AHSS stamping; (2) fatigue of AHSS will develop guidance and data for base-material, spot-weld, and MIG/laser weld fatigue to support the weight reduction initiative, and also use the results to evaluate predictive methods; (3) strain rate characterization will develop new experimental setups for characterization of the strain rate sensitivity of AHSS, a new robust spot weld finite element formulation for modeling the spot weld, and a characterization of the bake hardening effect of DP steels at high strain rates; and finally (4) AHSS joining will provide welding and joining expertise to support A/SP project teams in developing lightweight automotive body structures, supplement the existing welding and joining technical knowledge to facilitate an increased use of AHSS, and utilize A/SP research data to prepare industry weldability and weld quality acceptance standards. Another reviewer commented that the overall project goals were well defined, but that some of the barriers could have been better defined and that the project should be better focused on end results. One commenter noted that the researcher provided a good overall presentation and past work with goals, deliverables and future direction clearly defined. They concluded by noting that the technology transfer plan is always in sight. One reviewer simply mentioned that the project included a predictive tool and good development of the model, while another person observed that springback was explicitly dealt with. Another person commented that further work needs to be completed as crash

models show mass is left on the table, which should incorporate non-linear strain curves. Several people commented on the long project timeframe and loss of focus. One person noted that 3rd generation AHSS forming trials are on the horizon, but also suggested that the project needs a more concrete time frame for MY implementation on high volume vehicles. Another evaluator remarked that it has been a very long timeline since start (10 years), which can lead to the loss of focus. The final person acknowledged that many aspects were studied, but that this will reduce the focus as well.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person provided a detailed project overview and comments, stating that the progress to date for the technical target areas is described as follows: (1) In the AHSS stamping area the progress to date is described on slides 11 through 18. The reviewer noted with interest the work done on the well known problem of edge fracture and cracking and also concurs with the observation that this is dependent upon the specific geometry of the edge as well as the local stress/strain rates. (2) In study of fatigue of AHSS, the empirical approach to weld fatigue measurements seems to be moving in a plausible direction. (3) The goals of the strain rate characterization target were apparently reached in early FY2009. (4) The AHSS joining target area will be concluded in September 2010. The description of the results obtained is provided in the presentation materials. Another reviewer mentioned that the researchers provided a good description of achieved results for tensile strains and tensile strength. Another highlighted the good data generation and the creation of a substantial database. One evaluator pointed out that significant progress has been made and that some of the barriers were identified. The reviewer also suggested that this project should be focused and must be completed by 2011. Others had similar comments about project timing and value. One person commented that the project findings are relevant to the industry, but in some cases it is incremental. Another person commented that long running projects will add small value after few years. Another evaluator acknowledged that realistic designs were achieved with two published manuals for industry. The reviewer read the application guidelines in January 2010 for advanced high-strength steel. The final person commented that the technology transfer plan shows they are engaged with supply industry and this is technically relevant work.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reactions to this question were mixed. One person felt that the whole supply chain (manufacturers, parts supplier and OEM) are involved. Another evaluator agreed, stating that the technology transfer plan shows they are engaged with supply industry. Another reviewer acknowledged that partnering with U of M and others is good and that the project is aligned with FreedomCar and A/SP goals. The reviewer also mentioned that other partners for fatigue and other items were included and that the researcher has shown good technology transfer in published papers and with results being used in crash model events. Others simply stated that there was good dissemination of results, teams, and complementarily. Another commenter noted that the collaboration with universities is good, but suggested that some component manufacturers should also be included. They added that technology transfer should be directed to OEM and component manufacturers, cautioning that this suggestion should be taken seriously. One person noted that the researchers finished FEA-predicted results with experimental work, but that the results were vague and that the tool is completed even though the current supplier dropped out. They noted that project work is continuing without a supplier project partner, but were unsure whether the team was working to identify a new supplier project partner. The final person commented that it appears there are issues with collaboration with some universities. They noted that all groups are engaged, but asked about other issues.

QUESTION 5: HAS THE PROJECT 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?

One person provided a detailed project overview and comments, stating that the future plans for each technical target area is described as follows: (1) In AHSS stamping, the edge fracture work will be continuing into 2011, and the 3rd Generation Advanced High-Strength Steel forming trials are on the horizon. (2) The work proposed toward a variability study of fatigue of AHSS is important and will doubtlessly be a useful addition to the work which has already been done. It seems to the reviewer that the identification of “key geometric parameters” is a reasonable step, but they would not be surprised to hear that the root cause analysis of weld variability for the AHSS class of materials will require a more extensive set of process parameters. (3) Since the goals of the strain rate characterization technical task have been completed, the tasks remaining seem to be technology transfer. Finally, (4) since the AHSS

joining target area will be completed in September 2010, A/SP does note that they are preparing a future project under the ASP310 Joining Strategy Steering Committee. Another person felt that this team has done a very thorough and careful job. One reviewer noted that edge fracture, fatigue, strain rate modeling, welding and forming, and joint efficiency for cost models are all very important, but were glossed over. Another person commented that previous work concentrated on chassis and body-in-white, and that lightweight fuel tanks are the next target. They remarked that the future works plan should be sure to include high-volume production vehicles. One evaluator asked about the availability of these HSS for the “world” market; they note that this is challenging, pointed out but no plan is discussed. Another reviewer mentioned that the future proposal will consist of manufacturing challenges for OEMs using reduced gage material. Several people had comments relating to the future project scheduling. One person observed that various tasks are completed, or will be completed, this FY. Another noted that these four projects should be completed within the completion date as specified in the report. One evaluator explained that the reviewer discussed having the joining project complete by 9/2010, but that no current plans were developed. The final person noted the future work developed under the ASP310 joining strategy steering committee. The reviewer was unsure of future goals, but hopefully would be complete by end of summer.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One person commented that overall, the project should be somewhat more focused. Another reviewer felt that the project had sufficient resources to achieve milestones. The final person commented that although resources are quite substantial, such a project can “consume” even more.

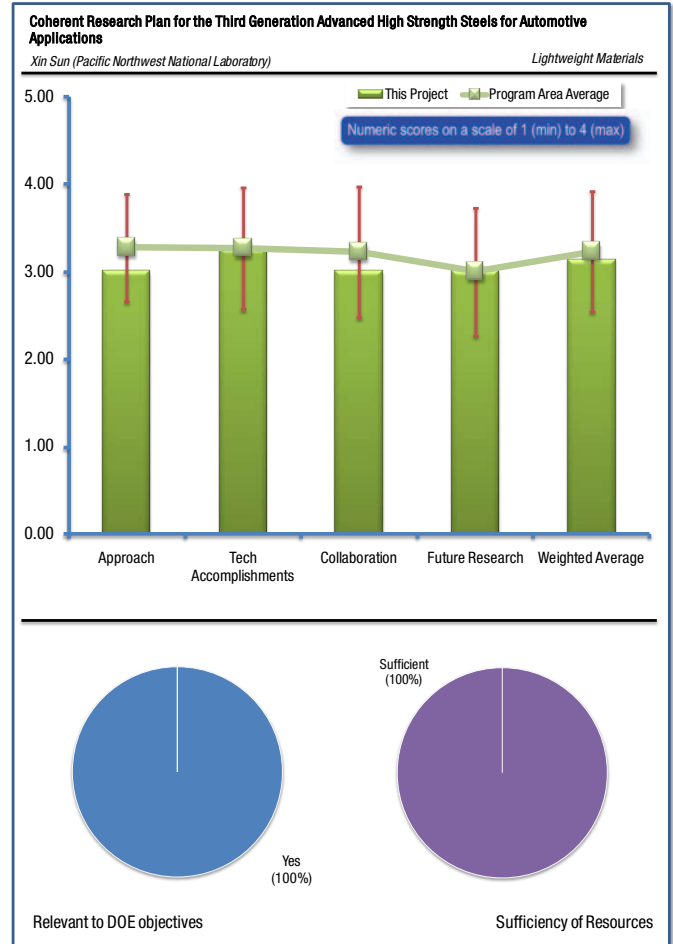
Coherent Research Plan for the Third Generation Advanced High Strength Steels for Automotive Applications: Xin Sun (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer suggested that next generation AHSS will lead to weight reductions in high volume vehicles; however in their view, it is highly unlikely that these steels will meet the goal of 50% weight reduction. They added that with the exception of the 50% goal, “The Plan” addresses all of the other major objectives of the DOE lightweight vehicles technology program and they will contribute to overall weight reductions in multi-material vehicles. Another evaluator stated that more utilization of AHSS would result in mass reduction, thus improving fuel economy; so for this reason the project supports the overall DOE objectives. One commenter remarked that high formability AHSS provides significant lightweighting, crashworthiness (safety) and fuel economy, and displacing petroleum. The last reviewer to comment explained that steels will continue to drive weight out of the body structures, especially in the cast of cars. They concluded by stating that the design of the ultra-lightweight safety cage out of steel is a focal point for the domestic OEMs.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer mentioned that the stated goal was to develop a “coherent plan” for Gen 3 AHSS, but that the approach to arriving at a coherent plan was not well described. The reviewer felt that there seemed to be three material concepts that were explored using interesting techniques, but this did not result in a coherent plan. The detailed models (dislocation dynamics and FEA-based microstructure-stress-strain response) were state-of-the-art and provided interesting insights - they could have been much more valuable if placed in a coherent plan to provide real direction. The approach also did not deal with manufacturing issues such as joining, forming, surface finish, which limits its impact. Another person commented that the project is well defined, but could be more focused on deliverables. They added that the researcher also needs to identify some specific barriers. One evaluator acknowledged the good approach, but added that it is reliant on the university to define a series of individual projects. They also noted that the project lacks overall technical leadership and the resulting projects lack a common vision for subsequent commercialization. One commenter pointed out that the original goal of this project has been changed to include 3rd generation of AHSS. They criticized that the original project should have been completed, and a new project should have been started specifically geared to 3rd generation of AHSS. The final reviewer commented that the fundamental strengthening mechanisms were referred to as “new”, but stressed that these have been the fundamental strengthening mechanisms for years, whether it is steel, aluminum or nickel-base super alloys.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person criticized that the original project deliverables have been changed, and that the rate of progress has been slow. Another person criticized that they did not see the “coherent” plan. They acknowledged that the detailed modeling results were helpful and interesting, but they did not seem to result in a clear plan or vision of where to go. One reviewer noted that some progress has been made so far for 3rd generation of AHSS. One person remarked that the researcher has shown excellent work in understanding the effects of particle size on the strengthening mechanisms of steel products. There appears to be a good fundamental knowledge of nano- and sub-micron particles sizes on substitutional and GB n. Another evaluator also noted the good progress, and that many small projects were included, but the work was lacking in defined goals and milestones to evaluate performance. The reviewer added that the results reported are quite impressive but not coordinated.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Responses to this question were all positive. One person pointed out the good collaboration with A/SP, auto industry and steel companies. Another evaluator mentioned the good collaboration with North American and European steel suppliers. Another person agreed that the collaboration with partners is good, but felt that it should have been extended to steel producers. The final commenter stated that the collaboration was limited to annual meetings. They suggested that the beneficial results could be amplified if multiple university resources were working together on a common theme.

QUESTION 5: HAS THE PROJECT 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?

Reactions to this question were mixed, with several reviewer providing comments to improve this area. One person simply stated that the researchers should definitely continue this work. One reviewer commented that as individual alloy design ideas, the future plans were very good, but as a coherent plan, they missed the future work that would lead to a plan. They suggested that a coherent plan would deal with many different aspects, formability, cost, welding, surface finish, etc. This reviewer was expecting an industry roadmap and did not see it. Another person pointed out that the future research program is too broad, and needs to focus on deliverables. The final commenter explained that there are many ongoing small projects that are all ending in 2010. They added that the researchers will look at new projects after the projects are completed, but suggested that they should consider commencing projects each year to avoid the transition period of starting research.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Both reviewer comments were positive. One person commented that the resources are sufficient for what was accomplished. The other person stated that the projects seem to be directly related to funding.

Advanced Materials & Processing of Composites for High Volume Applications (ACC932): Matt Zaluzec (Ford Motor Company)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Both reviewers had positive comments. One person remarked that the introduction of composite materials in automotive components is essential for mass reduction for improved fuel economy; this project supports the overall DOE objectives. The other reviewer commented this type of research in low-cost carbon fiber for automotive mass reduction is extremely relevant for GHG and fuel economy goals for near-term usage.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer provided a detailed summary of the presentation that covered several separate work projects.

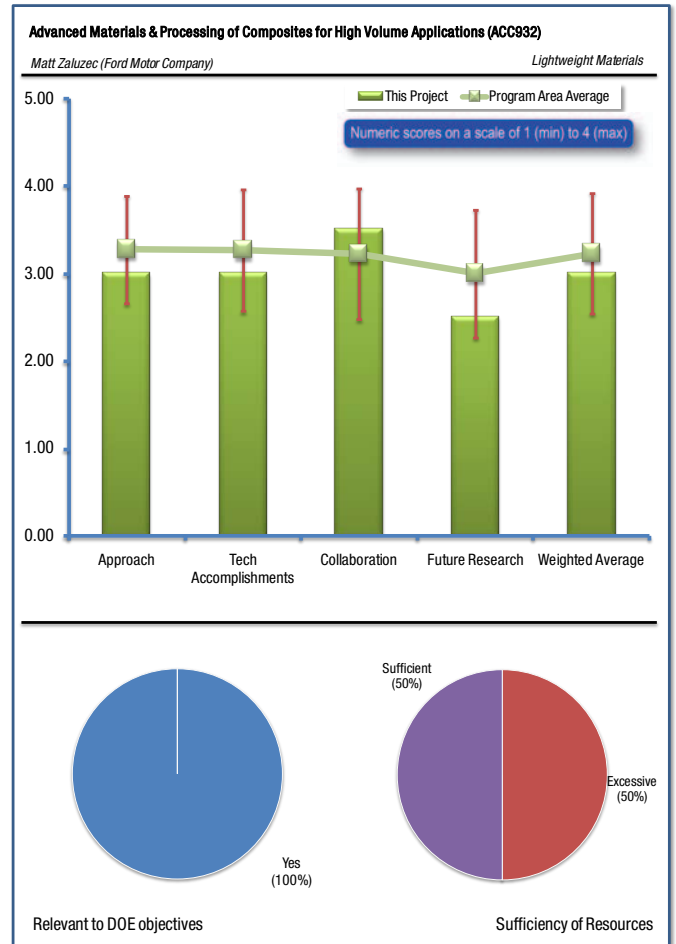
#1 Carbon fiber SMC - Carbon Fiber Sheet Molding Compound Material: Good timeline complete with barriers addressed and partners determined. 2012 usage for possible MY 2016 vehicles (?). Still need better link to overall mass reduction, ultimate OEM cost and MY usage.

#2 Thermoplastic Composites (D-LFT): Good steps to investigate challenges with suppliers. Direct compounding process limits shipping/logistic costs. Raw material made on site to finished material. Glass fiber compatible with e-coat process.

#3 Crash Energy Management: Must understand failure modes of critical components. Complex physics of crush. Working with four independent universities. Truly predictive tools are required—per the slide. It appears that this project is driving standardization. This is similar to steel where dual phase is used and during crash-strain hardening is occurring. This becomes complex as new carbon fiber precursors are developed and used. Consistently changing environment but U.S. AMP understands and is following the issues. Some challenges include resin, precursor, process, static vs dynamic crush and weave angle.....even work being done with “random” weave which would be less expensive to produce.

#4 (ACC007): 2014 completion of cost-effective mass reduction of the passenger vehicle with safety included. Note this is done at high volume with acceptable cost. Good usage of milestones with underbody and composite seat including design, fabrication and testing. Note cycle time is estimated at 2-1/2 minutes but standard steel stamping is much less (seconds). Prototypes are available but still need to address impact resistance of this versus steel.

One reviewer commented that the 23% mass reduction appears feasible on the seat but at what MY implementation and from what baseline? The last person noted that these projects have significant weaknesses, not addressing the most of the barriers. These projects are not well defined and also not deliverables. The projects are too optimistic on deliverables.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person thought that the progress to date is lagging, and that not many barriers have been addressed by the researcher. Another reviewer remarked that the researcher is very concerned on the outcome (deliverables). One evaluator noted that the identified bending stiffness is most important—have established primary causes of BLRT (Note phase 2 slide). One person noted that the researcher understands the challenges of density and control for consistent properties. The final person commented that the researcher understands the challenges ahead still exist due to manufacturing/process variability for low-cost carbon fiber. They also noted that challenges still exist with steel industry as well.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One person noted that there is good collaboration among partners, although the progress is slow. Another reviewer pointed out that the collaboration with suppliers for carbon fiber along with OEMs to define production limitations. One evaluator observed that U of M is doing significant research on defects (intentional and unintentional) based on size of part. The final reviewer commented that, with respect to Project #3, crash energy management, that the researchers must understand the failure modes of critical components. They also noted that the project includes the complex physics of crush and that the researchers are working with four independent universities.

QUESTION 5: HAS THE PROJECT 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?

One person simply noted that the additional work is being done with chopped fiber and injection molded parts. Another reviewer commented that the milestones developed for BLRH and peer reviewed journal papers estimated to be delivered in October 2010. They also mentioned that Bond Line Read Through (BLRT) is an issue for Class A surfaces and that OEMs have Class A challenges to use carbon fiber for surface appearance. The last person to comment stated that the final deliverables are too optimistic and that they doubt very much in meeting timing and deliverables. They concluded by noting that the project timeline is too long, and should be tied to deliverables.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reactions to this question were mixed. One reviewer commented that this project has sufficient resources to achieve milestones. The other person commented that the funding is very excessive for the deliverables.

Composite Underbody Attachment, Advanced Preforming and Related Processes for Manufacturing Low Cost Composites: Bob Norris (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

All reviewers had positive comments. One person stated that the good integration between ORNL and ACC ensures that the fabrication of carbon fiber for the automotive industry is becoming practical, so the project definitely fits DOE’s objective. Another reviewer commented that the development of manufacturing technologies for composite parts will increase their use in vehicles; composites can contribute to more than 25% weight reduction. The last evaluator felt that the project absolutely met DOE’s goals; the post-2020 era will be dominated by carbon fiber to displace petroleum.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

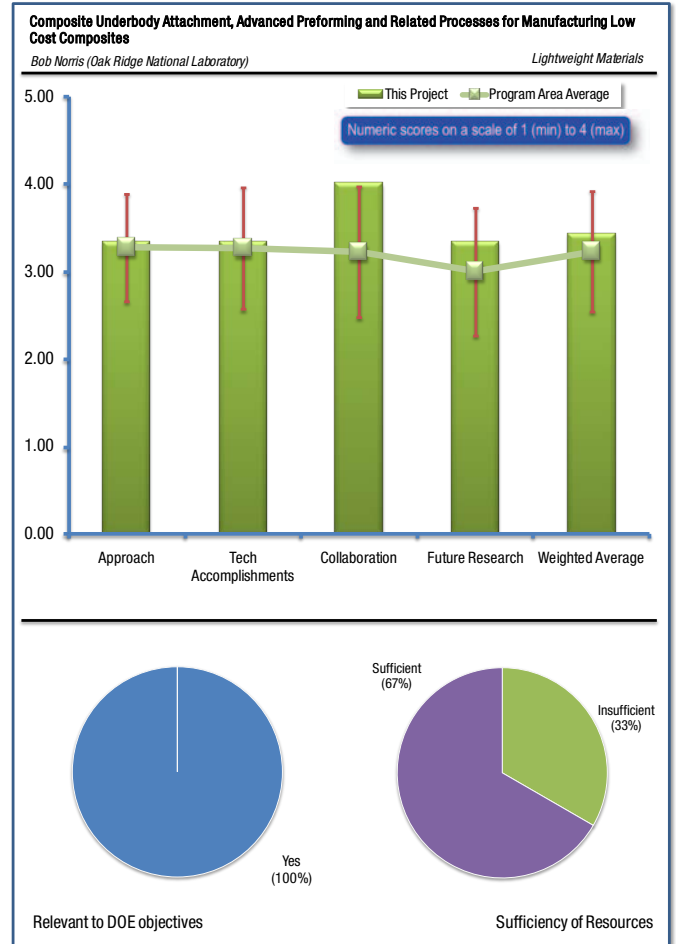
One person simply noted that the approach is good and relatively easy to follow. Another person agreed, remarking that the researcher presented an excellent approach towards commercialization by creating a state of the art pilot facility and parallel advanced modules adjacent to baseline processes. The final reviewer pointed out that the process development for part manufacturing; this is enabling technology for wider acceptance of the product.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person noted that automated fiber laying is an improvement over hand laying or laminate routes. Another reviewer simply stated that excellent progress was made with a published schedule. One evaluator expressed that the progress is good and that the advantage for thermoplastics to get thinner cross-sections is well presented. The last person suggested that equipment development may not be the best task to be supported (chopper gun).

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer explained that this is a U.S. DOE lab project in collaboration with ACC, and is well integrated with good participation from various levels of supplier, producer and end user. Another person simply noted that the project is a two-party collaboration, with very good collaboration. The last person noted that many partners, domestic and international, including large experienced industrial partners are involved.



QUESTION 5: HAS THE PROJECT 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?

One commenter mentioned that barriers are identified, and that many have been overcome (e.g. organosolv). The other reviewer to comment described that the effort is substantial and the future work is even more important because it will lead directly to real applications.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One commenter suggested that to realize the potential, resources are most probably off by an order of magnitude. The other reviewer commented that as presented, the funding appears sufficient; however, they would like to see it increased for faster integration with the car industry.

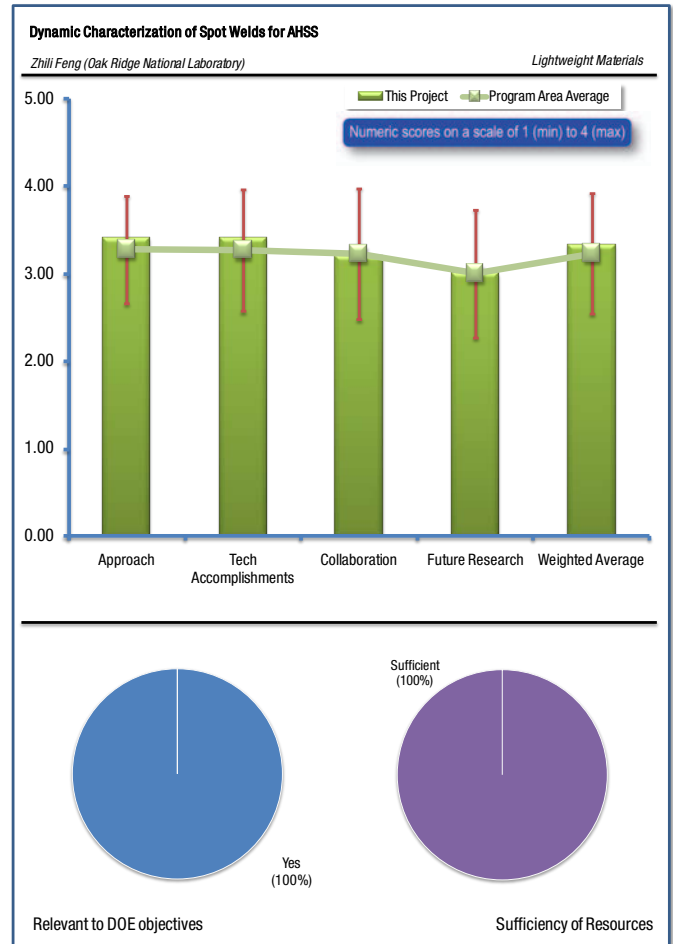
Dynamic Characterization of Spot Welds for AHSS: Zhili Feng (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

All people had positive comments to this question. One person stated that the project relates to VT objectives related to improved performance optimization. Another reviewer commented that joining of new materials is an essential part of widespread use of lightweight materials in order to achieve mass reduction resulting in improved fuel economy; this project supports the overall DOE objectives. One evaluator expressed that this type of work supports the use of alternative suitable materials and methods for material replacement and mass reduction of vehicles. Third generation AHSS, along with previous generations, are enablers. OEMs have challenges with new material usage and require practical tools for crash modelers to use this joining method. Another reviewer observed that this is an enabling technology development; development of modeling capability to predict weld performance. The last commenter said that AHSS are integral to the OEMs drive toward higher fuel efficiency. AHSS and the associated joining technology are critical for both all-steel and mixed-metal vehicle body-in-white architectures.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH

TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One person simply stated that the researcher presented a good plan with valid assumptions, while another noted that the approach is very good. Another reviewer agreed, stating that this is a comprehensive and very well targeted program. They added that all of the key requirements have been included in the program plan, from detailed weld nugget strength predictions to solid element for FEA and mapping programs. Another evaluator also agreed, expressing that this is a very good project because most of the joining failures occur in dynamic conditions, so understanding of joining for AHSS in dynamic characterization is essential in widespread utilization of AHSS. One person summarized the project phases. Phase 1: Accomplishments resulted in correlation in various failure modes. The initial version of SWE has been developed and is capable of addressing weld geometry. Phase 2: will include additional materials and R&D with OEM modelers along with component level demonstration and validation for technology transfer. The last person to comment noted that this work attempts to go beyond existing models developed for SW failure analysis. If successful, this will nicely mesh with crash models like Rdioss and LS-dyna.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person felt that the researcher has shown excellent progress in a relatively short time. Another person agreed that the progress is good considering the material availability of various grades of AHSS. They also noted that some of the barriers have been addressed. One evaluator described that the project covers a wide range of AHSS grades FY2010 to 2013 and the results were used to collaborate with OEM modelers to integrate into commercial tools for CAE. Another person remarked that this model can be tied into major OEM crash simulation code as special user element. The code has been tested by a major U.S. OEM with simulation results reasonably

capturing the observed failure modes. They concluded by asking whether the code is accurate enough for OEMs in general for production vehicles. Several reviewers raised questions about the work. One person asked whether welds of dissimilar metals are included. Another evaluator stressed that the researcher must consider the heat affected zone on the material and model the center and sides of welds appropriately. One person acknowledged that the modeling predicts the failure mode, but felt that it over- or under-predicts the actual test results. Another reviewer explained that the use of hardness measurements to estimate strength need to be validated. The final reviewer commented that the success of Phase I could lead to more efforts in fatigue testing of complex 2Tm 3T and 4T weldments. Once Phase II is completed, consider a Phase II focused on fatigue testing yet another element of ensuring safe and reliable AHSS vehicles.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The collaboration was recognized by all but one commenter. One person noted that the collaboration with various partners has been good. Another person pointed out that the project includes collaboration with the Auto Steel Partnership; while another described that the project is a joint effort between USAMP and DOE. OEMs were used to validate models. One reviewer suggested that the researcher continue with the current level of collaboration, it is strong and duly noted. The final person commented that the collaboration is generally excellent, but suggested that to maximize the project value it would be good to include commercial code vendors such as LS-DYNA and ESA - and SORPAS (for welds).

QUESTION 5: HAS THE PROJECT 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?

One person commented that the future plan of this project is good, and that some barriers to be overcome have been defined. Another reviewer observed that the future plans are generally well defined and appropriate, but proposed that it would be good to include more activity to interface with commercial code vendors. They added that another aspect which would be good to explore is moving to a quantitative structure-property model for HAZ rather than a correlation. One person pointed out that the presenter identified the issues to be studied; however no mention of validation with actual tests and improving the predictability. Another evaluator noted that the framework is being developed in this project so this can be applied to other materials (e.g. aluminum). They recommended that the researcher explore this area further for use in additional materials. One commenter pointed out that, as stated in technical assessment, the code has been tested by a major U.S. OEM with simulation results reasonably capturing the observed failure modes, but they asked whether this is this accurate enough for OEMs in general for production vehicles. Another evaluator asked if gaps or other potential flaws in manufacturing process are being considered or reviewed. They also asked how the tolerance of weld is included in the simulation code, but questioned whether this is outside the scope of this project. The last person simply advised that the researcher should consider fatigue testing as part of a Phase III proposal.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Both comments to this question were positive. One person felt that the money is very well targeted and will provide excellent value to the automotive industry. The second person expressed that this project has sufficient resources to achieve milestones.

Online Weld Quality NDE & Control with IR Thermography: Zhili Feng (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

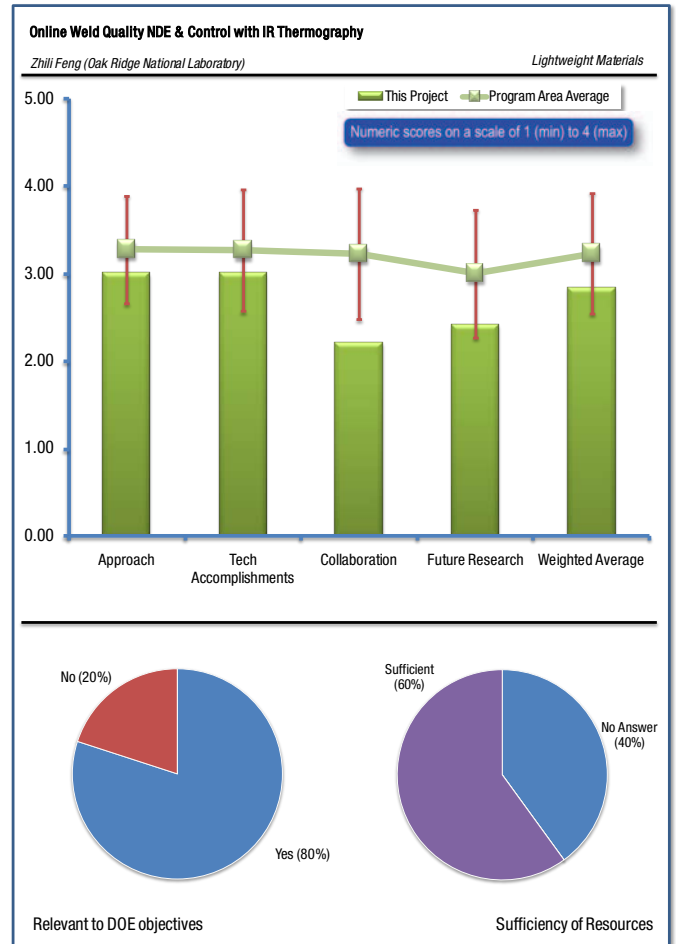
This project had a total of 5 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer commented that the project is very relevant for manufacturing cost reduction and performance optimization of welded structures. Another person agreed, remarking that in order to utilize any new material for the automotive industry, joining capability and its quality of joining is an essential part of the applications; so this project fits the overall DOE objective in order to improve fuel economy. One reviewer agreed this work is important, but suggested that it is a stretch to consider spot weld modeling as a lightweighting petroleum displacement. Another reviewer commented that although this is strictly an NDE study, it is an enabler for qualifying the integrity of RSW's of steel and aluminum weldments. The last person acknowledged that NDE is a fundamental cost saving tool and fits well the DOE objective; however, they doubt that this project will be of any use because its application is too impractical.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Reactions to this question were mixed, with most reviewers having critical comments. One person simply stated that the project is exceptionally well targeted and well thought out approach. Another felt that the approach is interesting but most likely will not be useful without years of research and a comprehensive plan intern milestones which lead to completion. One evaluator explained that several online weld quality inspections have been developed during the last several years, but that none of them are perfect, but direction of new developments has been positive. They added that although the barriers have been identified, the actual practice in a real assembly plant would be very difficult and that the application and interpretation of IR method are very difficult in a production line. Another reviewer commented that the methodology appears to be a low-budget approach which used textbook assumptions, and did not include baseline measurements. One reviewer recommended re-scoping the project to achieve the long-term goal of commercial usefulness including multiple materials, coatings, HAZ. Another person had similar recommendations to re-scope the team to include CAE code manufacturer(s), increase scope to include benchmarking, multiple materials, multiple weld conditions (2T, 3T, etc.). One reviewer stated that the goal of licensing code inhibits the commercialization and use. One evaluator criticized that the team includes the "same old guys who get the same old result." They admonished that the technical community is not the material suppliers and OEMs, so they recommended including the Edison Weld Institute and Weld Suppliers (e.g. CenterLine). One reviewer pointed out that NDE's of AHSS spot welds could be very important. Since the technique would be applied on the fly, once the spot weld is done and the frame is moving from one point to another, it does not matter whether the weld is good or bad. In case the weld is bad, the frame cannot be moved back for a repeat, so at this point, this reviewer was not sure whether the manufacturer wants to know if a particular weld is bad. Several reviewers had camera technology related comments. One person said that IR thermography could be a very good tool for identifying whether a weld is good or bad, but thermodynamics may not be helping. Another person noted that 1-second is needed for good IR system resolution, but since frames are continuously moving, the residence time of the instrumentation



could become a severe limitation. The last reviewer strongly cautioned that a large body of this work was done in the mid 1990's by Thermal Wave Imaging to use pulse thermography to inspect spot welds; the limitation then was the speed of image capture and the cost of a 600Hz IR camera.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person observed that excellent results have been shown in a short time. This reviewer was especially impressed with unique devices for heating and cooling, but was not sure how well this will translate into an OEM body shop until they are able to determine more about cost and speed of implementation. Others had similar scale-up questions. One person commented that some laboratory processes have been made, but noted that how they will be used in a production line is a big question because the method has to be significantly modified in order to be used in a production line. Another person agreed that good progress has been shown, but stressed that a robust system is needed for plant applications. One evaluator thought that preliminary findings "appear" to be interesting and match, but the images need to be characterized visually. Another person commented that the model for predicting microstructure of spot welds is progressing well and promises to be an important tool for the car industry. The final commenter expressed that the model correlating microhardness to weld temperature is intriguing, but not clear. They suggested that the researcher needs to develop some calibrations and, maybe, some standards. More work would improve that aspect. They concluded by stating that since microhardness is relatively easy to apply, such use could become an enabler for other technologies than welding.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One person simply noted that the target is a turnkey system that would cost no more than \$25K; typically a minimum of four systems would be needed per plant. One reviewer noted that the team appears to be good. One person observed that there appears to be an extended group of industries interested in the project, but the PI did not explain well the different roles of these companies. Another person suggested that there might be lots of conflicting aspects in the group presented on the slides. One person commended the researchers on the very good use of A/SP to set out targets and priorities. Another evaluator, however, felt that more OEMs and Tier One suppliers should be involved in the program. Another person agreed, recommending to expanding the group beyond the A/SP. They also asked why the researcher would isolate based upon paid membership. The last person suggested that the researchers really need to do more homework and cite a large body of work done in the past.

QUESTION 5: HAS THE PROJECT 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?

One person felt that the preliminary results deserve reconsideration to re-scope long-term project. Another evaluator suggested that more input is needed from OEMs in overcoming barriers. Another reviewer recommended that the project should move quickly to low-cost devices and aluminum. One person suggested that the researcher continue to develop a "make-like-production" system and a detailed database to look up and characterize weld quality. The final reviewer is not convinced that this work should be continued: for safety reasons, companies are still going to have a lot of extra welds. The testing will have to be done in situ with possibility of repeating the weld operation (if necessary) before the redundant welds will be eliminated.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Only one person commented, stating that as presented, the project should be stopped.

*Enhanced Resonance Inspection for Light Metal Castings:
Xin Sun (Pacific Northwest National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

All reviewers had positive comments for this question. One reviewer pointed out that this is an enabling technology for improved use of light metal alloy components. One person observed that development of inspection methods for quality control is essential for widespread use of lightweight materials in order to improve fuel economy, so this project clearly supports the overall DOE objectives. Another evaluator described that light metal castings and validation will significantly contribute to improved fuel economy and displacement of petroleum. The last commenter remarked that any NDE technique fits very well DOE's goal on reducing weight for vehicles because it enables the constructor to better the capacity of the material by limiting "the safety margin."

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

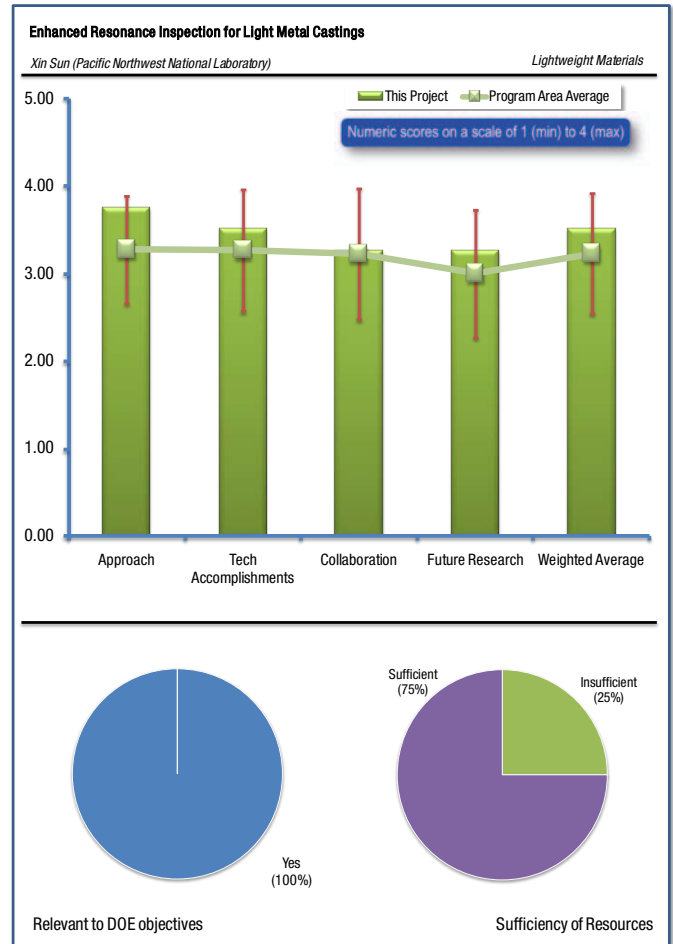
Reactions to this question were all positive. One person felt that the approach is very good and that new developments in controlling the quality of castings would be very beneficial for widespread use of lightweight materials. Others stated that the basic mechanism was well elaborated, that the need and the advantages are well explained, and that the gap on the decision making process was identified. One reviewer thought the researcher provided a great summary and leadership developing nondestructive tests with quantitative measurement. The last person commented that extracting useful information from such a simple excitation mechanism requires cleverness and brightness. They added that this is a very difficult problem and the author made a good demonstration.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person simply stated that this was a good demonstration of technology. Another felt that the progress is very good considering so many parties are involved in the work. It is a good project in developing new technology in determining the quality of casting, especially for lightweight castings. One person highlighted that the model can predict the location of the defect and the size; however, validation from actual parts is to be completed. The last reviewer mentioned that this project is on the way in solving a major problem of detecting flaws within a material, and their locations as well.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One person characterized the industry collaboration as satisfactory, while another called it good. The final person described that there is a large pool of companies interested in the project but the effort appears to be solely that of PNNL. It would be desirable that companies start on dealing with this technique to vet it as soon as possible.



QUESTION 5: HAS THE PROJECT 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?

Reactions to this question were mixed. One person stated that the project is completed, and that no additional funding is requested. Others however stated that the future research program seems to be very good, but the process has to be user friendly and also reliable. One person however, stated that this work is continuing in another project. Another evaluator continued, stating that preliminary work has resulted in significant findings and most importantly a new project. The last person commented that the idea of using more than one excitation source may greatly help in the identification and the location of flaws. They advocated that this should be pursued provided that the instrumentation of the excitation remains simple to apply.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer commented that the funding appears to be sufficient, but this project should be significantly extended because, in the end, the industry will always try to accelerate and simplify its work. The other reviewer to comment stated that it appears that more human resources will be needed to address the computational requirements and multiple applications.

Evaluation and Characterization of Lightweight Materials: Success Stories from the High Temperature Materials Laboratory (HTML) User Program: Camden Hubbard (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One person commented that the measurement of stress in various components after manufacturing processes is an important factor determining the final performance; since the residual stress affects corrosion, fatigue life and other functions understanding this is important before using advanced material for lightweighting. The other reviewer commented that HTML can always present results that would fit any topics, but it is not because techniques are applied to light materials that it fits DOE’s goal for light vehicles.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One person summarized that this presentation covers four different characterization projects carried out at HTML lab; and added that the approach for each task is well planned and executed and that the work is contributing to the overall progress of a larger project. Another reviewer remarked that any measurement can be applied to light materials, but this project needs to much more focused to “get my vote.” The last reviewer commented that not much input is necessary for such characterization tasks.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

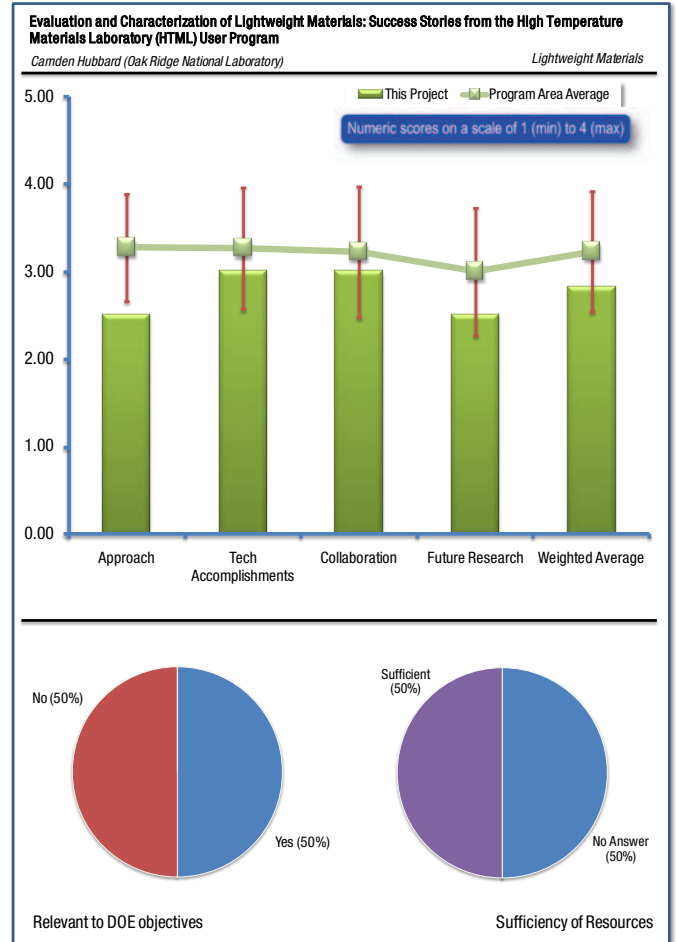
One person felt that the tasks clearly identified the final outcome and explained how it affects the overall program. The other reviewer to comment felt that the results are OK, but stated that the presentation is tailored to what can be done with light materials rather than applied to light materials to fit a broader goal.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One person simply stated that collaboration is a strong point of this organization. Another person agreed, remarking that as a user facility, HTML has many partners.

QUESTION 5: HAS THE PROJECT 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?

One reviewer described that two of the projects are being completed in 2010, while three more are planned to go up to 2011; however, no change in direction is planned. The last person commented that the HTML represents a good set of facilities and they will always produce results, but criticized that if “the final goal is not well defined, so what...”



QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The only reviewer to comment criticized that the funding should be stopped for this kind of open-ended research; this kind of work is NSF's focus.

High-Temperature Thermoelectric Materials Characterization for Automotive Waste Heat Recovery: Success Stories from the High Temperature Materials Laboratory (HTML) User Program: Hsin Wang (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer felt that the work is important, but is not directly related to light materials. The first applications may well be for heavy vehicles where the amount of energy to harvested is far greater than for light vehicles. The other evaluator commented that material development for automotive applications needs clear understanding of behavior of materials under various loadings and environments; this presentation elaborates the efforts of one company, GM, trying to develop new thermoelectric materials.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer pointed out that characterization of new materials for their thermoelectric behavior is carried out using the HTML. The other person to comment stated that the researcher used a very good approach for a difficult (high-risk) program that may well lead to high rewards.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One person observed that a clear understanding of the behavior of new materials, calthrates, was obtained after the testing. The other reviewer commented that the project has reached a stage where hope appears to be feasible for real applications; excellent.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

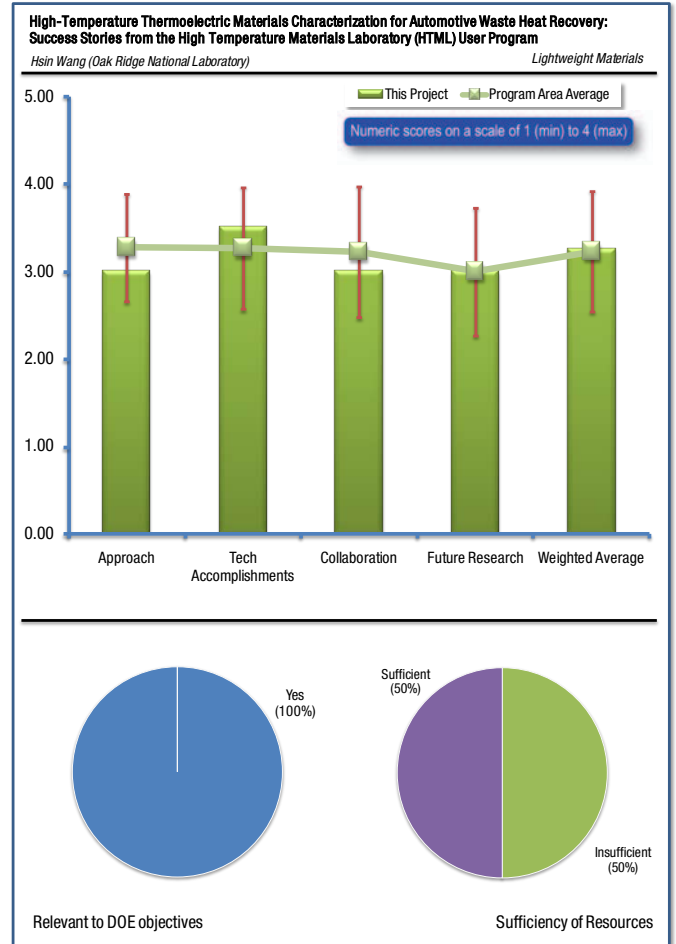
One person pointed out that as a user facility it is necessary for a partner to carry out work at HTML. Others commented on the good team, complementary capabilities, and good synergy.

QUESTION 5: HAS THE PROJECT 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?

The only person to comment said “go for it!”

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One person stressed that the funding should clearly be extended. The other person to comment noted that a new program may be initiated to promote such energy saving technology.



Characterization of Catalysts for Aftertreatment and Biomass-derived Fuels: Success Stories from the High Temperature Materials Laboratory (HTML) User Program: Larry Allard (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One person commented that biofuels can contribute to petroleum displacement; the characterization of catalytic behavior is important in improving the efficiency of the biofuel production. Another person cautioned that any project can be associated with improving efficiency and to reduce petroleum dependency; however, quantification will remain difficult. This performance measure may not be relevant to all projects. The last person expressed that any catalysis program can fit the DOE goal for light vehicles; however, the material as presented is more in NSF’s court than in any other.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One person noted that these are characterization experiments and the methodology is quite clear. The other reviewer to comment stated that the approach is typically that for a NSF proposal but not for DOE; open-ended research has no place here. They added that to fit DOE's goal, the approach should be changed and fit an applied goal within a rather short timeframe.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

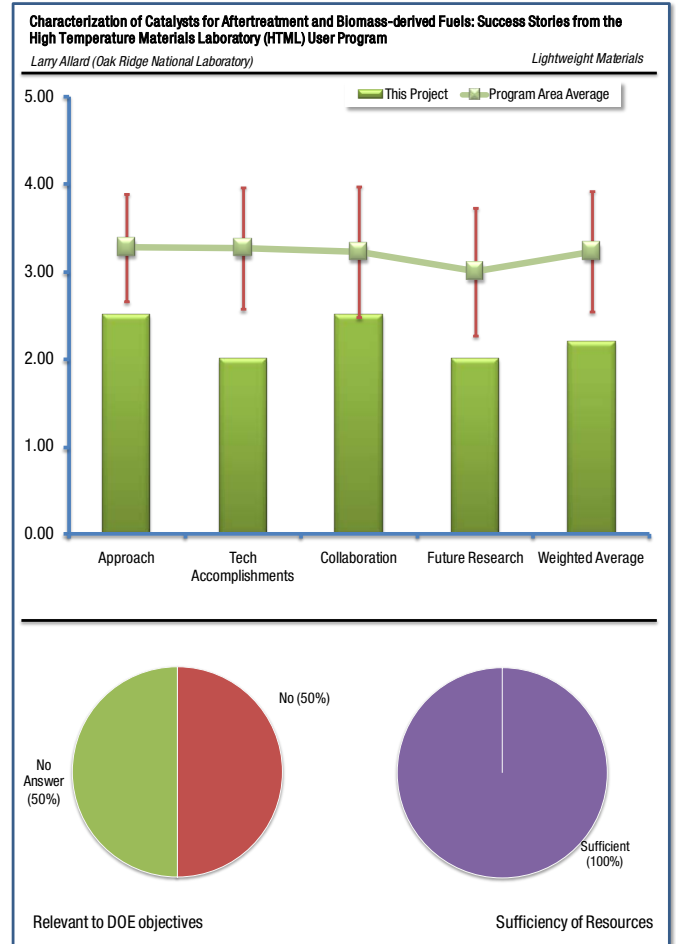
One evaluator mentioned that the facilities are excellent and state-of-the art; and that the characterization methodology is good. The last reviewer commented that the project seems to show that they can do measurements on catalysts, but the reviewer stressed that they need to see real catalysis improvement over the present state-of-the art to get their vote.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One commenter remarked that since HTML is a user facility, collaboration with other researchers is essential; and that the collaboration mentioned in the presentation is fair. The other reviewer to comment pointed out that the University of Michigan team is well known for catalysis and the HTML is a good match for high temperature characterization of catalysts.

QUESTION 5: HAS THE PROJECT 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?

One reviewer described that the four projects reported are all characterization of materials; the plan is based on the material development carried out in partner organization, but not much detail is presented here. The last person to comment felt that this program should be continued, but the final goal should be much more focused with significant improvement over the present state-of-



the art toward drastic energy savings of, for instance, doubling the mileage per gallon with respect to the present average to about 80 miles/gallon for light vehicles.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The only reviewer to comment stated that the project can be structured to better match DOE's energy savings goals.

Characterization of Materials for Li-ion Batteries: Success Stories from the High Temperature Materials Laboratory (HTML) User Program: Andrew Payzant (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One person commented that electric vehicles need to improve their performance and the information generated in this project can provide inputs for the development of new compositions for Li-ion batteries. Another reviewer simply stated that it is not a straight yes. The last evaluator pointed out that this project is an open-ended research project, so this reviewer would like to see a more focused application.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One person felt the presented approach is comprehensive. The other reviewer to comment explained that the projects are characterization in nature and the work plan is good.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

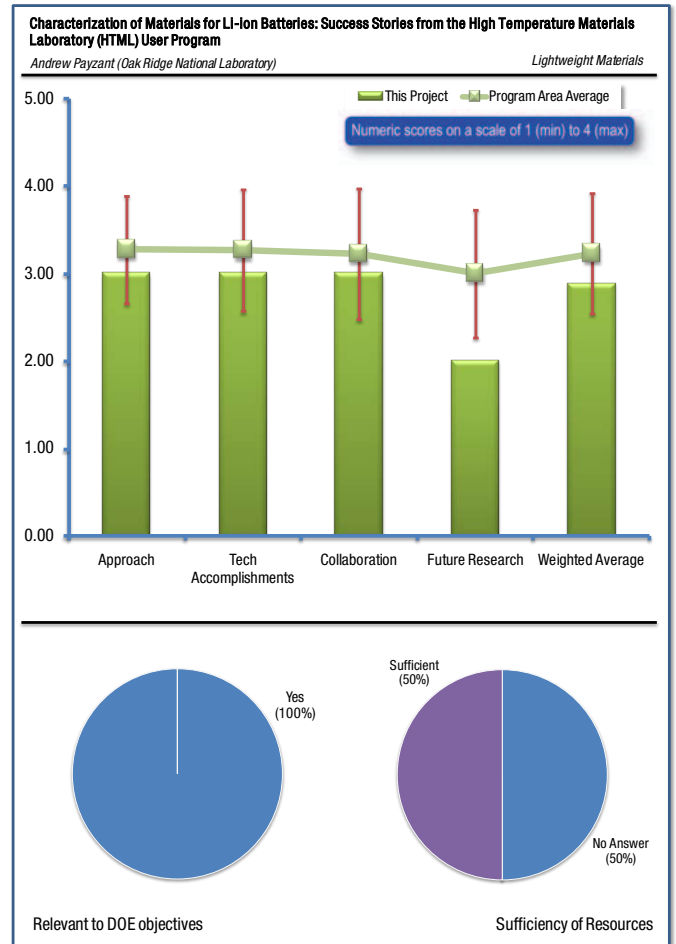
One reviewer stated that the technical accomplishments were OK, but without a direct application to an existing battery, it is difficult to estimate accomplishments. They added that there is no state-of-the art, no metrics, no difference between the state-of-the art and the final goal; stating that measurements for the sake of measuring something. The other reviewer expressed that significant understanding of material behavior had been achieved in the projects; various aspects such as effects of service temperature, repeated charging and fatigue on the performance of battery materials were evaluated; this leads to development of newer materials with better capabilities.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One evaluator described that the presentation is on the collaboration between HTML and various other organizations; each project has one partner; as HTML is a service provider in nature it is fair that they have at least one partner in each project. The other reviewer to comment felt that the collaboration was a strong point of the project and that the researchers had assembled a good complementary team.

QUESTION 5: HAS THE PROJECT 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?

One person highlighted that the presentation covers four individual projects on characterization; three of them are expected to be completed in 2010 and one will end in 2011; so there is no need to evaluate the future research plan. The other reviewer to comment



thought that the project should be tailored to a given battery to improve its characteristics by an overall factor of 2 or more, which would be equivalent to creating an entirely new battery.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer commented that DOE should continue to fund such research, but has to keep the “feet of the team to the fire” toward a definite goal. The last person commented that allowing the HTML to continue on presented open-ended research results do very little to promote substantial energy savings. On the other hand, if HTML wants to continue along the lines described in the presentation, then its funding should be transferred to NSF.

7. MATERIALS TECHNOLOGIES: PROPULSION MATERIALS

Advanced materials, including metals, polymers, composites, and intermetallic compounds, can play an important role in improving the efficiency of transportation engines and vehicles. Weight reduction is one of the most effective ways to increase the fuel economy of vehicles while reducing exhaust emissions. The development of propulsion materials and enabling technologies will help reduce costs while improving the durability, efficiency, and performance of advanced internal combustion, diesel, hybrid, and fuel-cell-powered vehicles. The advanced materials research conducted under the direction of the U.S. Department of Energy and the Vehicle Technologies Program will help ensure the nation's transportation energy and environmental future by making affordable full-function cars and trucks that use less oil and produce fewer harmful emissions.

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1 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 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
Design Optimization of Piezoceramic Multilayer Actuators for Heavy Duty Diesel Engine Fuel Injectors	Huay-Tay Lin (Oak Ridge National Laboratory)	7-3	2.33	3.00	3.00	2.67	2.79
Fatigue Enhancements by Shock Peening	Curt Lavender (Pacific Northwest National Laboratory)	7-5	3.33	3.33	3.33	3.67	3.38
Fuel Injector Holes (Fabrication of Micro-Orifices for Fuel Injectors)	George Fenske (Argonne National Laboratory)	7-7	4.00	4.00	3.67	3.33	3.88
Tailored Materials for Advanced CIDI Engines	Glenn Grant (Pacific Northwest National Laboratory)	7-9	3.00	3.67	3.00	3.67	3.42
NOx Sensor Development	Robert Glass (Lawrence Livermore National Laboratory)	7-11	3.33	3.00	3.33	3.67	3.21
Low Cost Titanium – Propulsion Applications	Curt Lavender (Pacific Northwest National Laboratory)	7-13	3.00	3.00	3.67	3.00	3.08
Friction and Wear Enhancement of Titanium Alloy Engine Components	Peter Blau (Oak Ridge National Laboratory)	7-15	3.67	3.67	3.33	3.00	3.54
Erosion of Radiator Materials by Nanofluids	Jules Routbort (Argonne National Laboratory)	7-17	3.67	3.33	3.67	3.00	3.42
Materials Issues Associated with EGR Systems	Michael Lance (Oak Ridge National Laboratory)	7-19	4.00	4.00	4.00	4.00	4.00
Durability of Diesel Engine Particulate Filters	Thomas Watkins (Oak Ridge National Laboratory)	7-20	3.00	3.50	3.00	3.00	3.25
Catalysts via First Principles	Chaitanya K. Narula (Oak Ridge National Laboratory)	7-22	3.67	3.33	2.67	3.33	3.33
Thermoelectric Mechanical Reliability	Andrew Wereszczak (Oak Ridge National Laboratory)	7-24	3.00	3.00	3.00	3.00	3.00
Thermoelectrics Theory and Structure	David J. Singh (Oak Ridge National Laboratory)	7-26	3.33	3.33	3.33	3.33	3.33
Proactive Strategies for Designing Thermoelectric Materials for Power Generation	Terry Hendricks (Pacific Northwest National Laboratory)	7-28	3.00	3.33	3.00	3.33	3.21

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
<i>Solder Joints of Power Electronics</i>	<i>Govindarajan Muralidharan (Oak Ridge National Laboratory)</i>	7-30	3.50	3.00	3.50	3.50	3.25
<i>Materials Compatibility of Power Electronics</i>	<i>Beth Armstrong (Oak Ridge National Laboratory)</i>	7-32	2.67	3.00	2.00	2.67	2.75
<i>Environmental Effects on Power Electronic Devices</i>	<i>Andrew Wereszczak (Oak Ridge National Laboratory)</i>	7-34	3.33	3.33	2.67	3.00	3.21
<i>Materials for HCCI Engines</i>	<i>Govindarajan Muralidharan (Oak Ridge National Laboratory)</i>	7-36	3.50	3.50	2.50	3.50	3.38
<i>Hydrogen Materials Compatibility for the H-ICE</i>	<i>Stan Pitman (Pacific Northwest National Laboratory)</i>	7-38	3.33	3.33	3.33	3.33	3.33
<i>Materials-Enabled High-Efficiency Diesel Engines</i>	<i>Michael Kass (Oak Ridge National Laboratory)</i>	7-40	2.67	2.67	3.33	3.00	2.79
<i>Materials for High Pressure Fuel Injection Systems</i>	<i>Peter Blau (Oak Ridge National Laboratory)</i>	7-42	3.50	3.50	3.50	3.50	3.50
<i>Materials for Advanced Engine Valve Train</i>	<i>Phil Maziasz (Oak Ridge National Laboratory)</i>	7-44	3.67	4.00	3.67	3.33	3.79
<i>Compact Potentiometric NOx Sensor</i>	<i>Dileep Singh (Argonne National Laboratory)</i>	7-46	3.33	3.67	3.33	3.00	3.46
<i>NDE Development for ACERT Engine Components</i>	<i>Jiangang Sun (Oak Ridge National Laboratory)</i>	7-48	3.50	3.00	3.50	3.50	3.25
<i>Surface Texturing for Friction Control</i>	<i>George Fenske (Argonne National Laboratory)</i>	7-50	3.33	3.67	3.00	3.33	3.46
<i>Friction Modeling for Lubricated Engine and Drivetrain Components</i>	<i>George Fenske (Argonne National Laboratory)</i>	7-52	3.50	2.50	3.00	3.00	2.88
<i>Ultra-Fast Chemical Conversion Surfaces</i>	<i>George Fenske (Argonne National Laboratory)</i>	7-54	3.50	3.50	3.50	3.50	3.50
<i>Catalyst Characterization</i>	<i>Thomas Watkins (Oak Ridge National Laboratory)</i>	7-56	3.00	3.50	3.50	3.50	3.38
<i>Ultra-High Resolution Electron Microscopy for Catalyst Characterization</i>	<i>Larry Allard (Oak Ridge National Laboratory)</i>	7-58	3.33	3.00	3.33	2.67	3.08
<i>Low-Friction Hard Coatings</i>	<i>Ali Erdemir (Argonne National Laboratory)</i>	7-60	3.50	4.00	3.50	3.50	3.75
<i>Residual Stress Measurements in Thin Coatings</i>	<i>Dileep Singh (Argonne National Laboratory)</i>	7-62	3.33	3.33	2.33	3.00	3.17
<i>Diamond Based TE Materials</i>	<i>Dieter Gruen (Argonne National Laboratory)</i>	7-64	4.00	4.00	4.00	3.00	3.88
<i>Durability of ACERT Engine Components</i>	<i>Hua-Tay Lin (Oak Ridge National Laboratory)</i>	7-66	3.00	3.67	3.33	3.00	3.38
<i>Life Cycle Modeling of Propulsion Materials</i>	<i>Sujit Das (Oak Ridge National Laboratory)</i>	7-68	3.33	3.33	2.00	2.33	3.04
OVERALL AVERAGE			3.30	3.36	3.16	3.18	3.30

NOTE: Italics denote poster presentations.

Design Optimization of Piezoceramic Multilayer Actuators for Heavy Duty Diesel Engine Fuel Injectors: Huay-Tay Lin (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A reviewer observed that the project was initiated in FY09 with an annual budget of \$300K, and project goals are consistent with the program. The PI has done a good job in articulating them (in a sort of boilerplate list that could be applicable to any of the other programs being supported). The second was unsure, saying the presentation didn't directly or indirectly indicate the project would lead to any consumer application. The third reviewer noted that the intent is to increase energy efficiency of heavy duty vehicles. One comment is that there should be clarity of the stage of research and development these projects are (see OMB circular A-11). This is basic research.

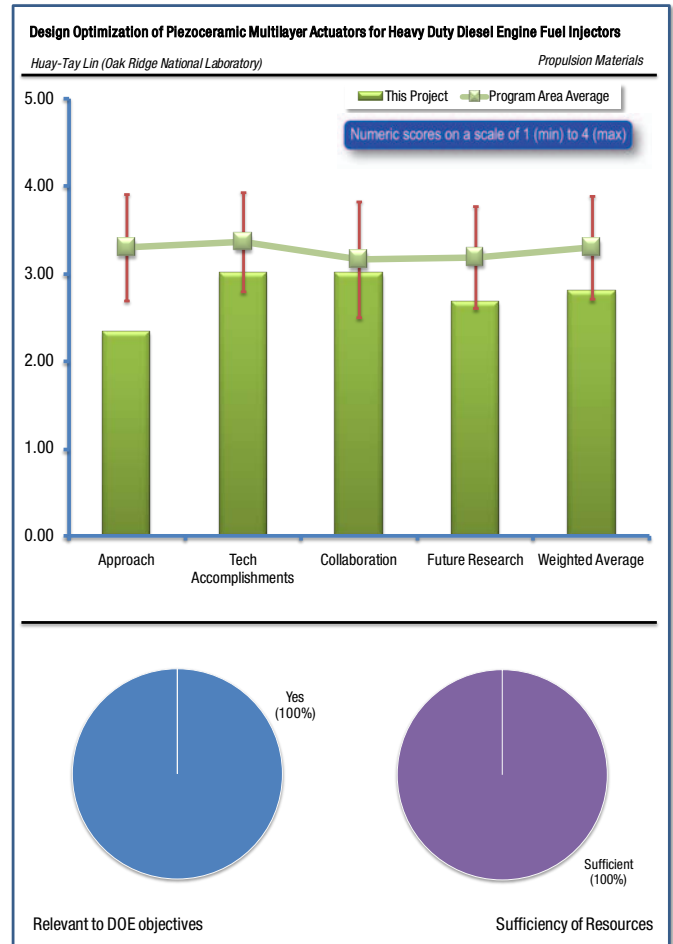
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer noted that this project aims to attack the problem of efficiency by development of a piezoelectric fuel injector for heavy-duty diesel engines. It was not clear how the link between the injector and engine performance was made. The design was simply presented along with its technical aspects, but precisely what needed to be designed to achieve performance enhancements was not evident. The PI should endeavor to make a stronger link between injector parameters and engine performance metrics. The presentation suffered somewhat from inadequately setting the stage for the approach (experiments done, conditions imposed, etc.) A reviewer said that there was some disconnect between the research presented and the goal of increasing efficiency. Individual experiments and testing were not roadmapped into a cohesive story of how these elements fit into the overall goal. The final reviewer expressed the belief that the project research schedule could potentially be compressed, terming the milestone schedule very generous.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Review comments were mixed for this aspect of the research. A reviewer observed that the PI seems to have done a lot of work to outline performance (e.g., electric field effects). The methodology he has brought to bear on his experiments is impressive. The PI needs to set the stage better for the various tasks, rather than jumping into a presentation of the technical results. (The reviewer pointed out that on one of the PI's often used figures, the x-axis had the symbol "m" that was not defined until questions were asked about it.) It was often very difficult to follow the thread of discussions of the various figures that were presented. The reviewer rated the research progress as "good" because the PI has done a lot of work, but would rate the clarity of presentation, relevance and rationale as "poor." The essential question of "why" an approach was taken was not answered.

Given this rating scheme it appears this program will reach the stated goals and objectives. However, the relevancy to improved fuel efficiency and economy were not evident. The reviewer's overall impression is a scientific project that is increasing the science



knowledge base but is lacking direct industrial application. The reader definitely needed a broad background in this field to understand any direct consumer relevancy. However, there is no indication of any follow-on research using alternative fuels. At best this appears to support continuation of diesel engine technology. At worst, this appears to be a scientific investigation program resulting in a technical report and nothing further. There is no indication of any producibility or reliability data or direct or in-direct (supporting) manufacturing base.

Some questions were raised on the state of the ultimate design for fuel injector actuators for which Cummins is responsible. Individual experiments and data did not lead to an understanding of the overall objective of this effort. This reviewer also had comments about the presentation, noting that acronyms and abbreviations should be clear, and some of the charts were not clear.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer praised project collaboration with industrial partners – Cummins, Inc. and materials suppliers. A second, conversely, felt there seemed to be little collaboration with industry, and noted that the PI is awaiting a final design from Cummins and that interaction between the PI and the team should be more descriptive. A reviewer restated the list of partners (Cummins, Kinetic Ceramics, EPCOS, and ORNL) and noted there appeared to be no other co-developers: the reviewer also observed there is an existing industrial base and a readily-available consumer market.

QUESTION 5: HAS THE PROJECT 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?

One reviewer felt the proposed follow-on work was reasonable, but called for a stronger connection to be made between injection pressure and fuel spray characteristics, noting that elements such as droplet size, velocity, and number density really are the crucial parameters that will influence performance. This reviewer expressed the hope that the major industrial partner could work with the PI to forge a stronger link between injector piezoactuation and engine performance. The second reviewer felt the post-presentation Q&A more effectively explained the thrust of this project than the presentation itself. In particular, he questioned whether the project can be concluded and results transitioned to mass production and, if they could, whether service personnel could, with current training and instrumentation, service and maintain the mass-produced equipment (or is this too specialized for the current average diesel mechanic). If the objective is to improve fuel economy, the potential drawback is a requirement for additional training with associated advanced diagnostic equipment for the servicing mechanic. It is furthermore questionable whether this technology will be cost effective for the purchasing truck company/driver and whether this project will make an overall impact on a trucking industry potentially moving from petroleum based fuels to other fuels. To the final reviewer, the narrative fails to fully describe the proposed work and its implementation. This reviewer suggested a roadmap be developed to show how the individual elements progress towards the ultimate goal.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers commented on this question. One felt the resources were adequate for the tasks performed. The other suggested accelerating the project to curtail the final research year, increasing final project year funding to cover production of a final report and terminate the project.

Fatigue Enhancements by Shock Peening: Curt Lavender (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said this research may result in improved engine efficiencies by increasing injection pressures and the overall durability of reciprocating parts. Another had positive comments on the relevance, stating the work is directly related to turbo-charged engine technology in turbine body and component failure analysis resulting in better producibility and component reliability.

The final reviewer observed that this project began in 2007 on the problem of “shock peening” (i.e., water peening). The PI is approaching the end of this project (2010) at a level of \$300K per year. The project is focused on increasing the operating stresses of materials through enhancement of fatigue life. Three methods examined are laser shock peening, water jet peening, and friction stir processing. Only LJP results were presented. The goal has been to demonstrate fatigue enhancements and to prototype a component enhanced by surface modification for full scale evaluation (this latter is an effort with Cummins).

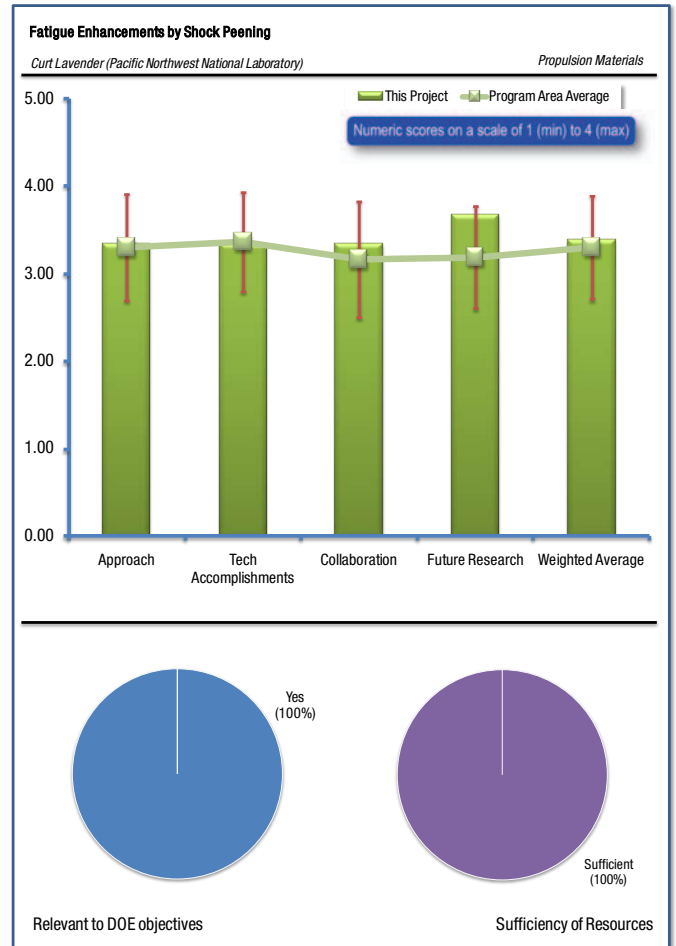
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer stated that the approach investigated fatigue enhancements and technology deployment: the latter perhaps is still in a state of development (e.g., adoption of LJP for materials processing in industry). A reviewer observed the team is pursuing multiple avenues of investigation (laser shock peening and waterjet) along with friction stir: this enhances opportunities for success. The final reviewer said that LSP or WSP both have potential for a new method of shock and reliability testing. These are potentially cheaper in application with more consistent results, thus improving the overall safety of the material. This suggests the need for a comprehensive test standard if this technology is accepted as the industry standard, and addresses the question of quality assurance during manufacturing. For DOD, such a test may be required during quality assurance or acceptance testing. The team used commercially available components for testing.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer felt progress was shown in developing residual stresses with the waterjet and laser peening processes. Technology transfer of the laser process is proceeding along with prototype development. Progress was shown in developing and enhancing the friction stir process. Further comments highlighted that the briefing suggests industry applicability, and there is a readily-available manufacturing base. There is potential for a follow-on project, but any follow-on project should be carefully evaluated for direct improvements to industrial applications versus increasing the knowledge database.

The final reviewer said that this past year, the effort concerned LSP and WJP tests. The PI did a nice job of presenting the physics of the peening processes investigated. The peening process seems somewhat complicated, and it is quite interesting that an element of



control exists. The residual stress enhancement with LSP is impressive. The WJP process was stated to produce longer fatigue life, but results for WJP were not shown.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer deemed interaction among project collaborators to be effective and the collaborators as good. The others observed that collaboration included several participating companies and the South Dakota School of Mines, and that collaboration includes Cummins as well.

QUESTION 5: HAS THE PROJECT 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?

One reviewer expressed the view that the project appears to be completed. He found the results interesting and was hopeful that industry would adopt these processing techniques. The second reviewer noted that the project will terminate in FY 2010 and a final report is expected. The reviewer did not suggest any future work and, based on the presentation, believed the techniques would then transition into industrial application(s). This reviewer suggested the team consider a test standard discussion with DOT, DOC, NTSB, and non-government organizations like ASTM. According to the final reviewer, testing is proposed for real components enhanced by the laser process, and rolling bearing tests with waterjet peened components are also to be conducted. Work will continue to further development of the friction stir processing technology.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Of the two reviewers offering relevant comments on this question, one termed the cost-sharing arrangement excellent. The other believed the resources to have been adequate for the work performed. The third merely noted the project's probable termination in FY 2010.

Fuel Injector Holes (Fabrication of Micro-Orifices for Fuel Injectors): George Fenske (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

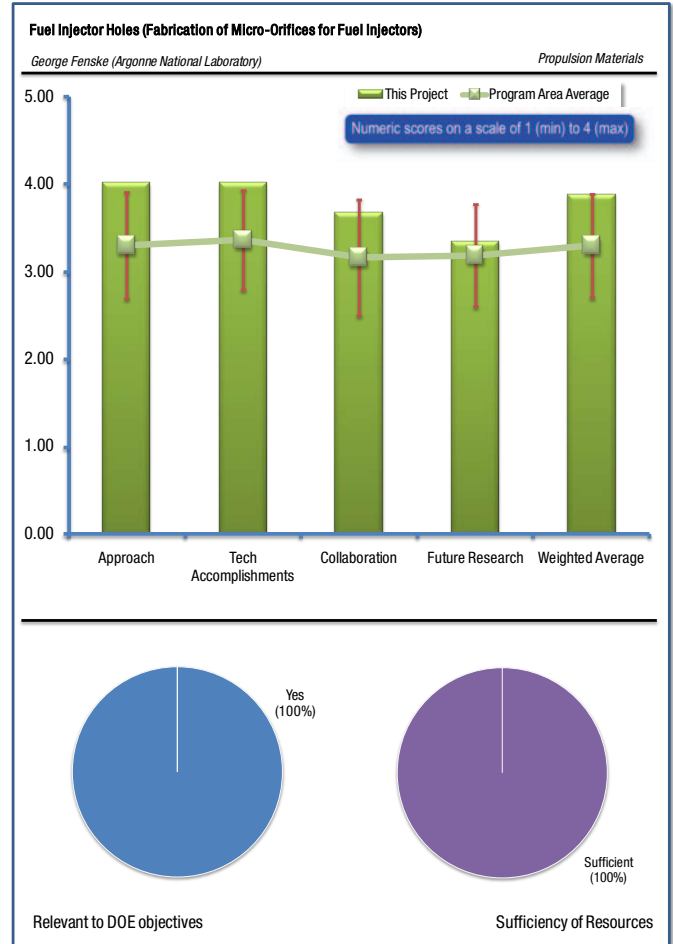
All three reviewers commenting agreed that this project is relevant to DOE’s goal of reducing petroleum consumption and cited specific mechanisms by which improved fuel injector design would contribute to meeting this goal. The first reviewer said the project is to develop fuel injector manufacturing technology to reduce diesel emissions by reducing in cylinder production of particulates: this project also improves fuel efficiency. Another noted that the basic philosophy of this topic is fuel injector design to reduce engine-out PM. Reducing PM reduces regeneration frequency, which is especially important for medium to light duty vehicles. These vehicles will require an active PM regeneration, which is a high fuel consuming cycle. By better control of emissions, the engine manufacturers have more flexibility in calibrating their engine, leading to improved fuel efficiency.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The three reviewers concurred in their positive evaluation of the project approach. The focus was sharply tailored to evaluating the plating techniques uniformity and robustness. Uniformity is critical to meet required injector to injector variation metrics used by the engine OEMs. Evaluating the plating robustness is also a critical aspect of meeting full operating life of this component. At the beginning of the project, a great number of alternative technologies have been evaluated. This gives good confidence that the chosen process is near optimum. There was good translation of the requirements in the final application to the upfront material testing. The final reviewer noted several specific aspects of the work: use of an electroless nickel process that is mature and can be used in mass productions; treat prototype component for technology transfer to industrial platers; spray visualization study by EPA; use of NDE technique to assist evaluation; and incorporation of engine testing in plan.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer called progress excellent and said it was highly likely the plating process would be amenable to mass production. The second reviewer considered the objectives of this project to be excellent. It is well understood in the combustion community that fuel vaporization is critical to meet low engine-out particulates: however, the barrier is lower engine-out emissions. The only weakness the reviewer identified in this project is the absence of any emission data to validate that this particular approach is going to meet the desired objective of lower PM. The reviewer did think the team was on the right track. The final reviewer listed a series of accomplishments: addressed coating adhesion issue; transferred concept to industrial platers; demonstrated feasibility of 3-D X-Ray imaging technique to examine the uniformity of coating; made excellent use of NDA tools; and evaluated application of high frequency vibrator to simulate cavitation erosion.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

All three reviewers praised the collaboration evident in this project. One noted “great collaboration with many cross-functional entities,” citing four project partners and their contributions (imaging technique with EPA, EDM supplier, Extrude Honing company, Electroless Plating Company, and a fuel injector OEM). Another pointed out the collaborators’ “solid interest.” The third cited the participation of the EPA as having improved the project and noted the beginning of cooperation with industry.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said the planned future component testing “look[ed] good.” He suggested moving the scheduled engine testing forward, expressing the view that injector design was far enough along to warrant engine and emissions testing. A second reviewer felt that future plans were based on progress made to date and urged close attention to cavitation erosion test results, feeling they could lead to increase manufacturer interest if positive, but could constitute “show stoppers” if results were poor. The third reviewer noted four items of proposed future work: flow visualization study by EPA; prepare second generation multi-sized orifice nozzle for OEM; conduct cavitation erosion study; and develop 3-D X-ray imaging.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer considered the project’s rate of expenditure and its results to be in balance. The other comment was that progress on injector design looks good, and the only missing data is engine emission results.

Tailored Materials for Advanced CIDI Engines: Glenn Grant (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

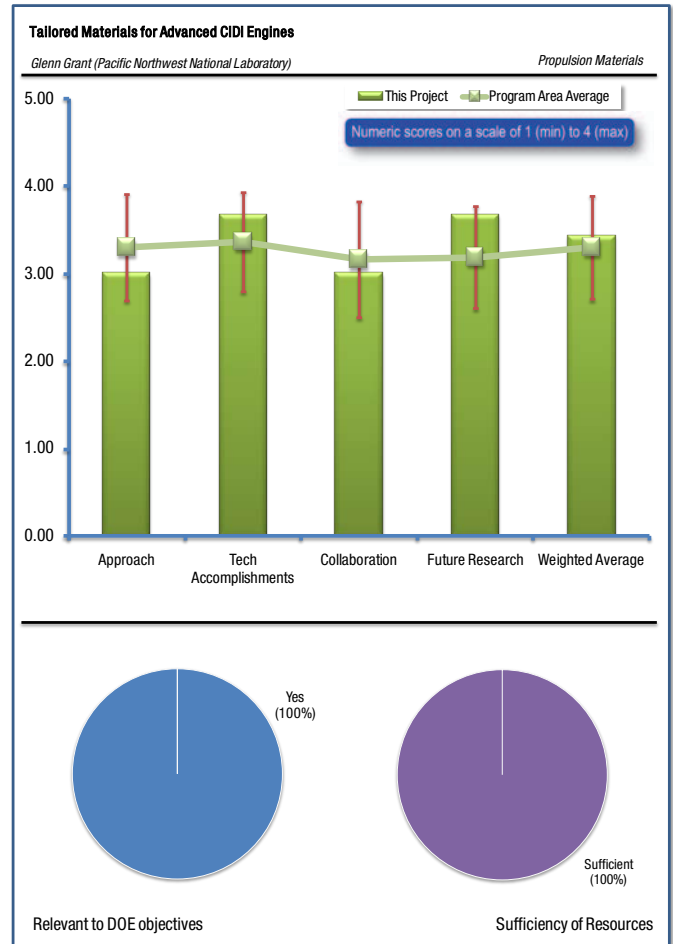
Reviewers generally agreed that this project supports DOE’s goal of displacing petroleum. This project displaces petroleum by making the required fuel efficient technology at a lower cost. This is done by processing low cost materials to improve in-cylinder peak pressures. This piston processing technique enables technology that allows the engine to operate more efficiently. Other higher cost materials accomplish the same goal, but by lowering the overall cost the technology is easier to implement in the marketplace. Allowing for higher pressures when using aluminum pistons will lead to reduction of fuel consumption, according to the second reviewer. The final reviewer listed several aspects of the work that are relevant: improve fuel efficiency; increase peak brake thermal efficiency and durability; and reduce powertrain cost.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer observed the project is focused on improving the strength of the materials in the piston bowl. Friction stirring is promising for this application as well as for adding mixing materials for improved strength. The fundamental target is improved strength with a lower cost material. However, this project is ending this year, and there is no engine validation in the plan. The key objective should be demonstrating fuel efficiency. A solid approach is chosen, according to the second reviewer, who said that certain material properties should have been under investigation somewhat earlier in the project to allow for corrective action (as an example thermal conductivity of friction stirred nanotubes in the aluminum.) The final reviewer listed several activities: develop surface modification; investigate FSP; and maintain primary focus on aluminum piston coupons.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Two reviewers felt technical progress in this project was good to excellent. The first urged that the project report compare the modified aluminum piston being investigated to the current steel piston for high cylinder pressures. He pointed out that a wider operating window for the former would result in a reduction of overall fuel consumption. The second reviewer deemed that theoretically, the initial goals seem to be met. This program shows good technical work to meet a desired goal. To this reviewer, the program is missing the key objective of evaluating the technique in an engine: sufficient progress towards meeting this objective has been produced, and it is time to evaluate this technique on an engine. The third reviewer cited three technical accomplishments of the project: stirred in carbon nanotube and nanofiber to reduce CTE; studies of FSP mixing process; development of prototype piston blank.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer observed that collaboration with the partners in the project is good: an involvement of a piston manufacturer would improve the consortium. The second comment was that the interaction with other partners looks very good. Since this project is concluding soon, demonstrating the DOE objective should be the highest priority. Engine results that demonstrate the effectiveness of the techniques should be highest priority at this time. The third reviewer said the team had worked closely with Missouri S&T, Cat, and BYU, and is in the process of working with piston suppliers.

QUESTION 5: HAS THE PROJECT 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?

One reviewer termed the proposed work in line with the previous findings, and noted it is in its final stage. The second said future work continues the theme of improving overall material strength using other mixing materials. The third reviewer cited three items of future work (thermal and mechanical tests are planned; FSP trials for thermal property control, maybe using MMCs; and complete trial in steel) and urged that consideration be given to constrained thermal fatigue tests of FSP samples and eventually producing pistons with FSP bowl rims for rig and engine testing.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer deemed the project budget in balance with the mentioned activities. The other comments were that the material work is generally meeting objectives, and a suggestion that the team consider doing constrained thermal fatigue test of FSP samples and then component testing and engine testing.

NOx Sensor Development: Robert Glass (Lawrence Livermore National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

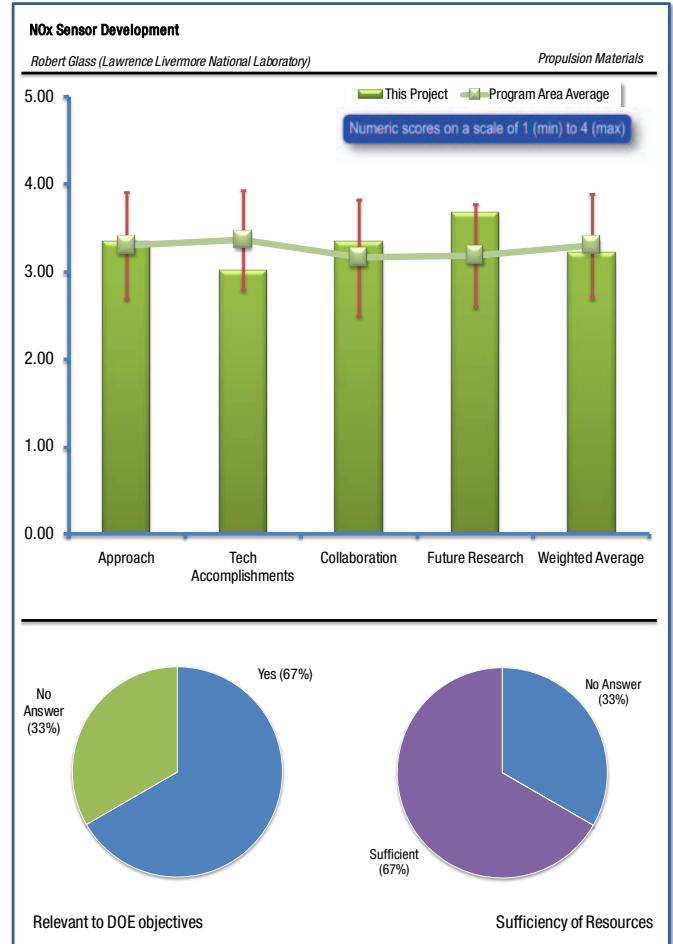
All reviewers agreed that this project supports DOE’s overall fuel consumption reduction goal, directly and indirectly. Reliable, accurate, responsive and economical NOx sensors could greatly facilitate the wider adoption of diesel engines in the light-duty vehicle sector by simplifying the task of bringing them into compliance with the more stringent tier of emissions regulations. The wider adoption of diesels would reduce LDV fuel consumption both directly, through per-vehicle fuel consumption reduction and indirectly, through less severe fuel processing at the refinery. Increasing the efficiency of engines can facilitate the reduction in fuel consumption; NOx control is paramount in designing efficient engines, according to the second reviewer. This project indirectly supports DOE petroleum displacement objectives by enabling low temperature combustion, PCCI, and other type of near-homogeneous type combustion strategies that theoretically could improve the part load efficient of advanced compression ignition engines.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Two reviewers commented favorably on the project approach. Using well-established and proven oxygen sensor technology as a point of departure in the design of less expensive NOx sensors is a key advantage of the project approach. To the second reviewer, the overall approach is logical and very good. The only suggestion is that the PI considers more cyclic testing to assess long term drift on the LSM sensor; presentation material suggests that LSM sensor may not predict NOx accurately enough given the 100% error once the NH₃ concentration began to increase. The third reviewer praised the clear explanation of the approach and challenges given in the presentation but felt the project duration to be excessive; over five years or more, he felt, focus may be lost and progress become incremental.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

This project has made much progress in addressing certain sensing issues, including oxygen concentration and temperature sensitivities; the group should be commended for their efforts. Nevertheless, this reviewer observed there is still much work in front of the PI in producing an end product that precisely measures NOx while correcting for oxygen and NH₃ concentrations and temperature, and can withstand the long term duty cycle of a light-duty engine warming up and cooling down. The second reviewer stated that the evolution of the technology was described and the importance of various parameters was explained. However, more explanation would have provided clarity on the following issues: What had happened over the past seven years? Did the research only concentrate on the same material during this time period? What is being used in Europe?



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

All three reviewers felt this project exhibited good to very good collaboration and coordination. One observed that working with a major LD engine/vehicle producer is appropriate and commendable, and called the choice of Ford as the LDV builder partner particularly apt, citing Ford's patent on the sole currently available electrochemical NO_x sensor. The second agreed, noting there was very good collaboration between LLNL and Ford Motor Company; it is critical that the vehicle OEM will be assisting in testing these sensors under real world conditions. Also, the PI has taken the initiative to seek a commercialization partner. The third reviewer mentioned that an automotive OEM is involved, but participation from a Tier 1 supplier is yet to be identified; as the technology has been developed over more than a decade, it is necessary to have some manufacturer involved.

QUESTION 5: HAS THE PROJECT 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?

Two reviewers commented. One said simply "none" in response to future work, and the other said that while the pathway for the next two years was outlined, no commercialization plan was proposed.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

None of the reviewers commented on this question.

Low Cost Titanium – Propulsion Applications: Curt Lavender (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

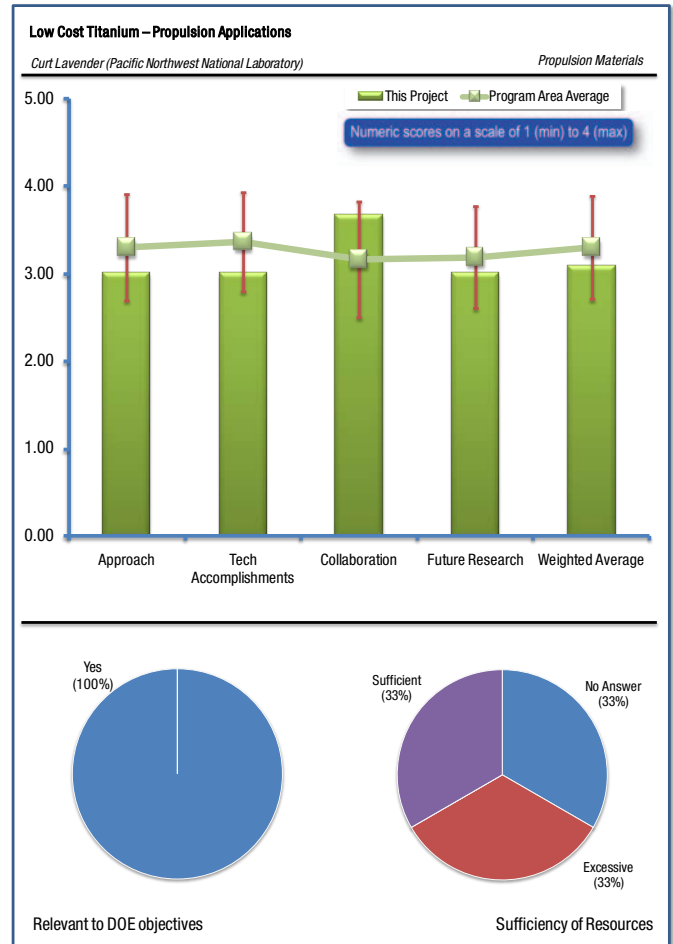
Two reviewers felt this project to be potentially relevant to DOE’s principal goal, but agreed such relevance had not been expressly claimed or explained. One said that while the magnitude of potential engine efficiency improvements (if any) due to use of high strength-to-weight-ratio titanium alloys in piston engines has not been assessed yet in this project, it is generally accepted that reducing the mass of reciprocating assemblies is beneficial to engine mechanical efficiency. This could reduce fuel consumption, at least indirectly, perhaps by permitting reduction of engine displacement for a given power output. The other agreed that there is some potential relevance for this project to meet DOE fuel petroleum displacement, but the PI didn’t seem to understand how this would occur from an engine thermodynamic view point. The third reviewer’s comment centered on reduced weight, increased durability, and improved manufacturing and producibility of Ti-containing parts.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The two reviewers voicing concern at the absence of an explicit justification for the project in terms of fuel conservation potential reiterated those concerns in responding to this question. A reviewer has some concern regarding the extent of alloy identification, characterization and processing work to date, in view of the fact that no explicit assessment has yet been made of the potential benefits of incorporating titanium alloy reciprocating parts in engines. Another comment was that the project approach is good in the sense of looking at material properties, cost, and fatigue of the low cost titanium, but it is poor from the perspective of understanding how using this material will improve engine thermal efficiency. The latter question should be answered prior to the former material property assessment assuming that fuel efficiency is driving this project. The last reviewer observed this is a new start effort: modify current end items (turbine fan) by using Ti replacement total assembly or Ti parts, and determine feasibility of using Ti in lieu of current materials. There are potential cost savings in improved durability, manufacturing, durability, and maintainability.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Good progress seems to have been made in the materials processing areas noted in the approach, but this work, promising as its results have been, may be premature, given that the potential benefits of this technology to engine performance have not yet been quantified. A second reviewer observed that this is a new project, but the PI has shown some initial material property measurements and so initially progress is good. Nevertheless, it would be helpful to look at improving fuel efficiency as the first step in this project versus as a later step based on its justification for existence. The final comment was that this is a new start effort that leverages the DOE GIPP effort. It does not appear to involve any significant technology issues in producing or testing Ti containing components.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

All three reviewers considered this project to be exhibiting good collaboration and coordination among the participants. One called the international collaboration commendable, one deemed the partnership among the principal investigator, an engine OEM and a material producer to be very good, and the third noted the involvement of private industry, academia and potential international partners, including Cummins (who has the manufacturing base to produce these titanium items).

QUESTION 5: HAS THE PROJECT 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?

One reviewer termed planned future research as good overall, but suggested that engine efficiency effects receive priority attention. A second reviewer concurred, saying “Modeling of efficiency effects of titanium engine parts can’t happen too soon.” While the trend has been strongest in Europe to date, it can be expected that U.S. vehicle manufacturers, too, will come under increasing pressure to assume “cradle-to-grave” responsibility for their products. This will include disposal and recycling of vehicles at the end of their lives. It might therefore be prudent to assess the implications of introducing a wholly new family of alloys into engine construction. Titanium is neither iron/steel nor aluminum, which account for the great majority of current engine construction materials. How will Ti parts be separated and recycled? The third reviewer said there is no indication of weight reduction if titanium is substituted for steel and the tradeoff is durability vs. weight and cost. The reviewer did believe the work addresses current industry requirements, and is married to near-term industry requirements. Future work is to pick existing steel engine system, substitute Ti components, and test, determining feasibility of substituting Ti for steel. The limiting factor is the availability of Ti ores. If Ti ore is available in the continental U.S., this may be feasible. However, if Ti is subject to interdiction, supply shortfalls, or is just unavailable, then this is a questionable project.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Only one reviewer commented: “In view of possible ‘cart-before-the-horse’ weakness identified above [i.e., much material processing work; no quantification of fuel economy improvement potential], expenditures on Ti alloy processing may prove to have been excessive.”

Friction and Wear Enhancement of Titanium Alloy Engine Components: Peter Blau (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

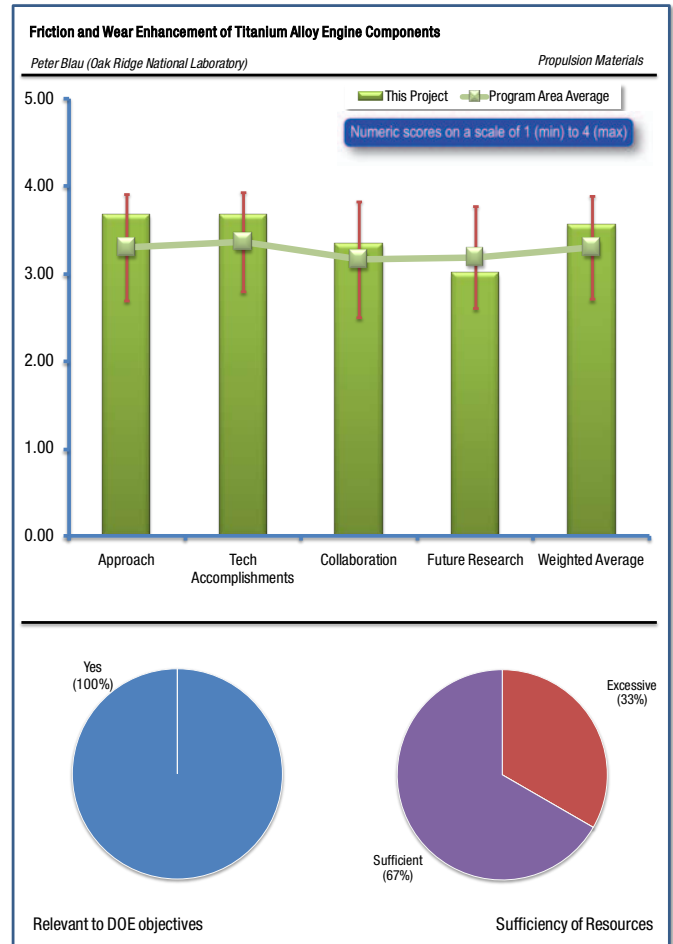
Two reviewers felt this project relevant to DOE’s principal goal. One said so explicitly and both mentioned the potential advantages of lightweight materials for engine part construction. A reviewer further added that the overall strategy is to develop lighter materials using titanium alloys for engine components such as connecting rods, valves, bushings, pistons, etc. A reviewer observed that the goal is to reduce weight, but lightweight alloys have friction and wear issues. Engine efficiency would increase if standard alloys could be replaced with Ti alloys. The final commenter simply noted that one can reduce overall weight of materials using Ti versus steel.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The focus on titanium is relevant to the first reviewer. Generally, titanium components in engines will drive up cost because of the expense of the material. However, this issue seems to have been addressed by a companion project, so cost may in fact not be an issue. The specific objective includes a focus on the connecting rod and the requirements for engineering bearing surfaces. Additional tasks include bench scale testing, construction of a loading test rig, and selection of candidate surface treatments and coatings. The methodology to be used seems to be somewhat standard (e.g., ASTM testing) and, in that regard, the forthcoming data should be less subject to uncertainties (i.e., no new diagnostics are developed and known and proven instrumentation is used). The second reviewer noted that work this year is on the system definition to select connecting rods, and the work seeks to expand aerospace pallatives to reduce fretting and look at other tribologic issues. Approach is a logical progression of tasks building upon the results of preceding tasks, and the phases are well defined to depict the yearly funding cycles. The final reviewer felt that essentially this work is integration of existing technologies with Ti material, which uses aerospace technology for vehicle applications. This is one of those projects that could be accelerated with additional funding. Using existing technologies also suggests the prototyping milestone could be accomplished faster, depending upon the availability of Ti component, manufacturing capability, and component part testing. DOE should consider some additional funding with acceleration of this project.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Two reviewers acknowledged the accomplishments in early stages of this new project. The project is relatively new, according to the first reviewer. What was presented concerned mainly results from literature studies to advocate titanium, some of the issues involved with it, and results from an effort to measure the friction coefficient. Some results on tomographic imaging measurements were also presented that document wear on bare materials. Overall, the PI has done a lot in a relatively short time. The issue here is what has been learned and/or how he will process the information he has obtained to allow more generalizations of the results. A second reviewer thought there was good progress made with literature review, testing protocols determined, baseline tests and planning for other alloys and surfaces to be investigated. Results of initial wear tests well depicted and explained.



The third reviewer expressed the work objective as substituting Ti components in an existing steel-based test engine. Essentially, how fast could candidate test items be demonstrated? This appears to be a traditional project timeline—literature review, initial lab testing, down-select candidates, etc. Could this project be run in parallel—multiple similar design items with different coatings and surface treatment samples and test. There appears to be an unstated modeling and simulation component inherent to this project. If so, that needs to be explained. If not, then what are the most likely surface treatment/coatings and could a test of candidate items be accelerated?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

All three reviewers recognized the participation in this project of academic and industrial partners as well as that of NASA. The PI has endeavored to create a dynamic team, in the view of the first reviewer, who said the main concern is an apparent lack of commitment (e.g., CRADA or equivalent) for the collaborators. The PI indicated this as an advantage, but the virtue of formal commitments is that the collaborators will then have a vested interest in the results obtained here and not simply be casual observers with no real intent to use the results that would be obtained. The second review comment was that the team is partnering with private industry and academia, as well as NASA. They are reacting to current industry requirements. The work supports existing industry manufacturing capability. The final reviewer said that collaboration involves 100% DOE funding, informal collaboration with Cummins, Greenleaf and NASA. The presentation charts were dated, as the team now has Virginia Commonwealth University. This reviewer also noted the claims of the PI about how informal non-CRADA agreements make progress easier. There is a good mix of industry/ academia and other government agencies.

QUESTION 5: HAS THE PROJECT 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?

One reviewer referred to his comments under Question 3 (above) in which he speculated that project efforts could be “run in parallel” and the testing of candidate surface treatments thereby accelerated. The second reviewer’s viewpoint was that the project just started in October 2009, and limited progress has been made to date. More work on bench-scale friction and wear tests and design, build, and testing a spectrum loading wear test system remains for FY10. FY11 will build upon this basis and flow into full concept validation in the last year. The test rig fabrication will greatly aid future progress on this and other efforts.

The detailed comments from the third reviewer discussed the continuing work that will include bench scale testing and confirm plans for scale-up and validation phase. The PI believes that if friction wear can be improved, new applications will be opened. The piston rod is a sort of paradigm for this. Some mechanism should be investigated to get the PNNL team of the Low Cost Titanium – Propulsion Applications project folded into this effort, or vice versa. For all of the testing and measurement that has been done and which is apparently to be done in the coming year, the PI should endeavor to look more closely at his future data to attempt to understand mechanisms for the effects his team finds. Modeling work will help here. To be most effective, the experiments should provide specific data that can be modeled, and where there are disagreements the model should be improved or the experimental hardware refined. There appears to be little of such an approach here. It is not clear that results will be forthcoming that might be generalized. The PI should guard against merely obtaining data without scrutinizing them to attempt to extract basic mechanisms for the effects involved.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer deemed the resources to be adequate. A second commented “New project.” The third reviewer felt the project funding was reasonable at \$300-400,000. However, he noted the similarity of this project (and its rationale) to the PNNL Low Cost Titanium project and questioned whether, in view of the \$700,000 funding of the latter, the investment in titanium may be excessive. (The PI here thanked Curt Lavender of PNNL in his introduction, the reviewer noted.) He recommended consideration be given to combining them or, if it’s deemed advisable to continue both, that the two at least be coordinated.

Erosion of Radiator Materials by Nanofluids: Jules Routbort (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

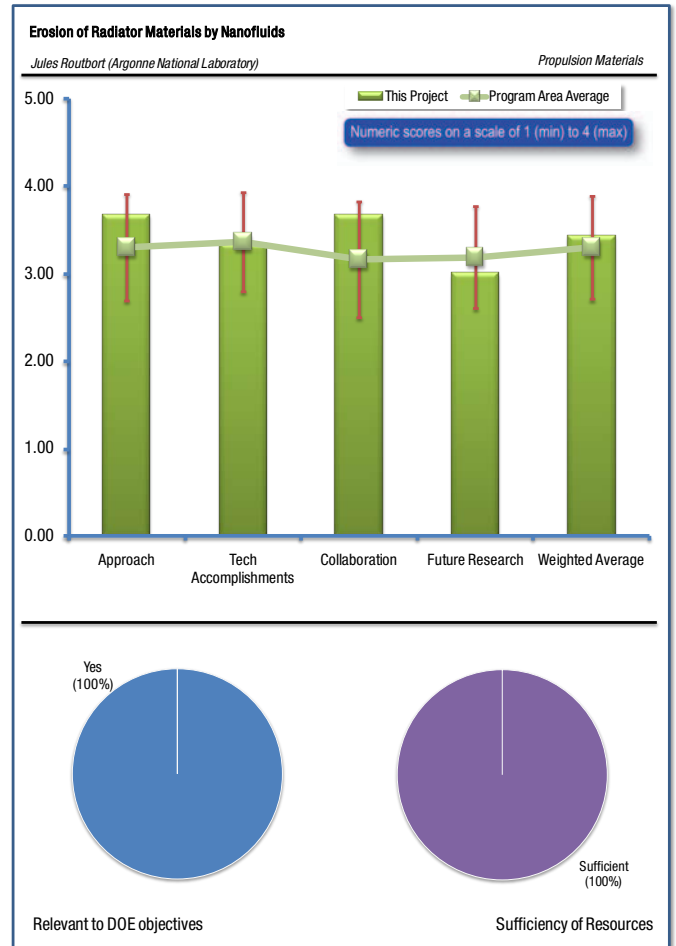
QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

All three reviewers agreed that the project is relevant to DOE petroleum conservation goals. Two cited the possibility of the work leading to smaller radiators, reduced vehicle frontal area and attendant aero drag reduction. One mentioned reduced pumping energy requirements. One reviewer, however, noted that nanoparticles in heat transfer fluids might *increase* viscosity (and pumping energy requirement) and could possibly clog liquid lines, although they have been shown to enhance heat transfer with higher thermal conductivity (according to the PI). This reviewer also suggested that a more quantitative link should be established between research in nanofluids and petroleum displacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Three reviewers all expressed some reservations regarding the approach to accomplishing the work. The premise that nanofluids exhibit enhanced thermal conductivity was questioned by one reviewer. The reviewer observed that the presentation states “Nanofluids have enhanced thermal properties...” The enhancement is most likely not anomalously high, which has been a big selling point in past nanofluids research. A lot has been made of the ability of nanofluids to enhance conductivity beyond Maxwell's expression. One must be skeptical of such results. The reviewer continued by stating that the PI cites some data that show enhancements in thermal conductivity (e.g., the alumina composites, etc.). At the same time, a large round robin study (i.e., J. Phys D, Appl. Phys, 43,165501 (2010)) concluded that, in fact, “...no anomalous enhancement of thermal conductivity was observed in the limited set of nanofluids tested in this exercise.” The fluids in that study are not the same as here, but the point is that a balanced and guarded approach should be taken. The data that show enhanced heat transfer coefficients are interesting but it was unclear how they were obtained.

A second reviewer questioned whether the subject nanofluids could withstand lengthy periods of quiescence in a vehicle cooling system, be usable on demand, and still perform as specified, and if such fluids could withstand environmental temperature extremes (-40° to 135°F). The reviewer noted this is for a military-related vehicle application. This reviewer also wondered if the project could be accelerated, given that the nanofluids were provided by industry and that no erosion had been detected. He also inquired about the extent of the industrial base for nanofluid production. The third reviewer noted this was part of a larger program to develop nanofluids for heat transfer applications, and spoke of a straightforward approach analyzing pumping power (due to increased viscosity) and erosion.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said progress has been good, with ongoing planning for full scale/ real environment testing using automotive components. An innovative test apparatus was developed to investigate alternative nanofluids. The second reviewer noted that the technology involves no critical or strategic ores or materials: the source of nanofluid components appears readily available. The briefing did not specify the availability of nanofluid components, discussion revealed a very available industrial base with readily available nanofluid component supplies. The third reviewer observed that a range of data was reported. This reviewer thought the erosion measurements are important, as they show no effect over prolonged impingement onto a rotating impeller, which is quite interesting. However, there seemed to have been little effort to identify the mechanisms for this quite interesting result. One would have thought that prolonged impingement would have had an effect, but it seems not to be the case here. Pumping power versus flow rate shows significant increase over fluids without nanoparticles. The data appear to be well correlated.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

All three reviewers praised the collaboration of multiple research partners. The collaboration with other institutions and agencies appears to be substantial regarding financial investment. It is good that Valvoline is supplying the nanofluids. A reviewer highlighted the multiple private industry, academia, and government participants. The last reviewer noted these aspects: good teaming, multiple work for others, and in kind and multiple material suppliers with the Tank Automotive Command, Michelin, Saint Gobain, Nanoscale, other DOE laboratories and Valvoline.

QUESTION 5: HAS THE PROJECT 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?

Reviewers discussed several suggestions and observations regarding future work. The first reviewer wondered if this work could be accelerated with availability of additional nanofluid candidates. When could this be commercially available? Will this new fluid be cost effective to the consumer while being environmentally safe and easily disposed? The second reviewer commented about the team making a logical progression to a full scale engine and automotive pumps. Work will include measurement of erosion rates, power consumption, efficiencies and long term performance. This reviewer is unsure if resources are to be available for tests in a full scale radiator facility. The final reviewer stated that the PI will continue the erosion tests, imposing a range of flow rates and a modified erosion apparatus using a higher volume percent of nanofluids, as well as graphitic nanofluids. CFD modeling is also proposed, but the description of it is vague. Property measurements of a fluid before and after a fluid has been used will also be performed. This reviewer also observed that the PI intends to test results in a full-scale radiator configuration. In future presentations, it would help to say a few words about the methodology and uncertainty of the data to be reported. Furthermore, nanofluids will only be industrially viable if they can be produced in large quantities: it is not evident to this reviewer that is the case. Finally, there should be a strong effort to understand the data, not merely to show enhancements or degradations, etc.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer thought the team has made good progress with smaller than usual levels of funding, and it also seems to get major in-kind investments. The team may want to determine what resources would be needed for full scale radiator testing. There appears to be a significant contribution from other agencies and industrial partners (e.g., TARDEC, Michelin, etc.) who appear to be contributing significant costs and fluids, observed the second reviewer. The final reviewer noted only that the work is funded through FY 10.

Materials Issues Associated with EGR Systems: Michael Lance (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 1 reviewer.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

A single reviewer commented on this project. He observed that improved EGR cooling assists in producing lower engine-out NOx. Typically when engine-out NOx emissions are high, the catalyst efficiencies must be raised to meet the regulated standards. Typically NOx efficiencies are improved with higher SCR temperatures. Therefore, de-tuning the engine will increase exhaust temperatures so that the NOx emissions are met. However this inefficiency sacrifices fuel economy.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The reviewer described the project as having been set up to integrate all the issues associated with EGR fouling and to truly understand the EGR fouling problem. All the diesel engine suppliers are contributing EGR coolers and an advisory board was created to evaluate the work.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The reviewer said “The objectives of the program are on target.” This approach is initially concentrated on characterizing the PM morphology that creates the cooler inefficiencies. The next phase targets solutions to the problem. An important aspect of the program is that it includes bio fuels.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

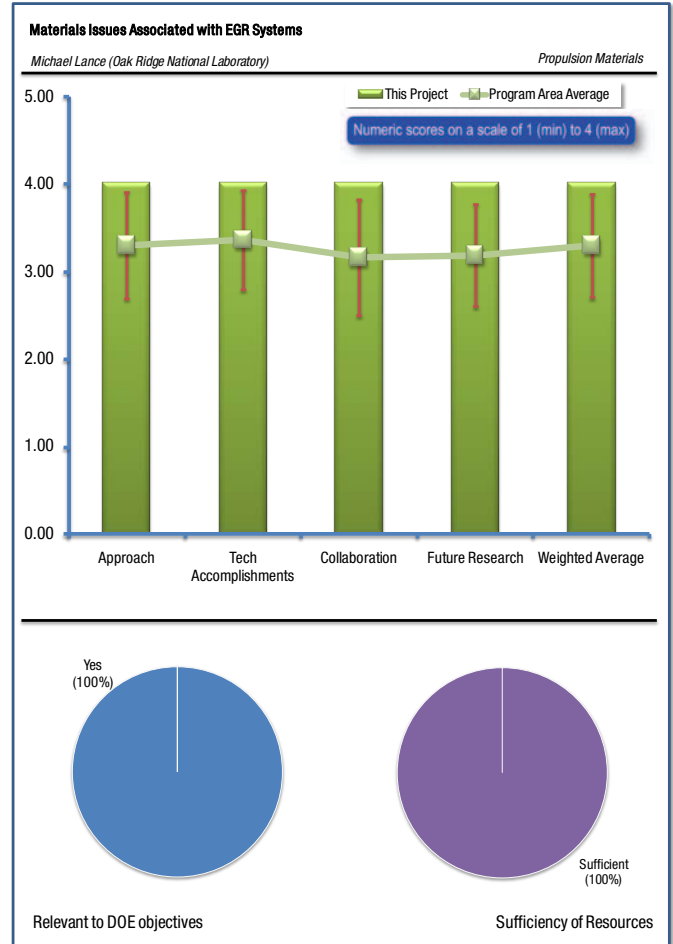
The reviewer noted the involvement of virtually all U.S. heavy-duty diesel engine builders in this project, and noted that it is industry-focused.

QUESTION 5: HAS THE PROJECT 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?

The reviewer noted that the objective is to use the EGR PM morphology to generate potential mitigation solutions.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The reviewer said only that the project seems to be staffed properly and designed to leverage outside OEMs as well as biofuel work from another program.



Durability of Diesel Engine Particulate Filters: Thomas Watkins (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Two reviewers commented on this project. They agreed it is relevant to DOE’s petroleum conservation goal, but one called the relation indirect: this is clearly a supportive project. The other said DPF durability is still a concern within the automotive industry. The program may improve the regeneration strategy that will theoretically reduce fuel consumption.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer observed that DPF regeneration is a process that requires significant improvement throughout the industry. Therefore the data generated may be very important in improving the overall fuel consumption. However, there is no evidence that the data is producing those results. Some concrete measures of fuel efficiency gains must be included in future reviews. The second reviewer thought that looking at the porosity strength relation is a good approach. Durability is also determined by the number of regenerations, which in themselves have a relation with the pore sizes. When the last relationship was also taken into consideration, a better definition for the optimum could have come out of this project.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

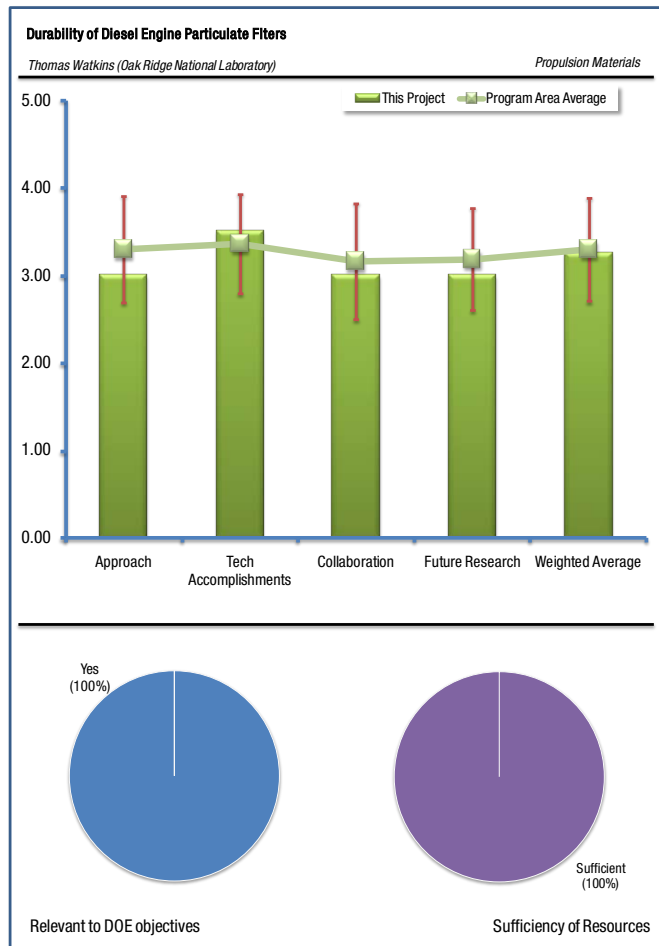
Progress is in accordance with plans, one reviewer said. The other reviewer said that the objective is to characterize the physical and mechanical properties of DPFs, and the fundamental results are targeted to that objective. However, the objective further states the team is developing tools to assess their reliability and durability: this area is weak, as there are no data showing how results improved DPF durability. Better coordination with the model or vehicle results would help this project.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer called collaboration good, but recommended strengthened sharing of DPF durability results. The other wanted better collaboration with project partner Corning and said combinations with the activities going on in DOE’s catalyst programs could enrich the outcome of the project.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said, “Future plans look good.” He also called for correlation of material data with DPF durability. The other reviewer said only, “Project is nearly finished.”



QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Good data generation on the different DPF materials, stated the only review comment.

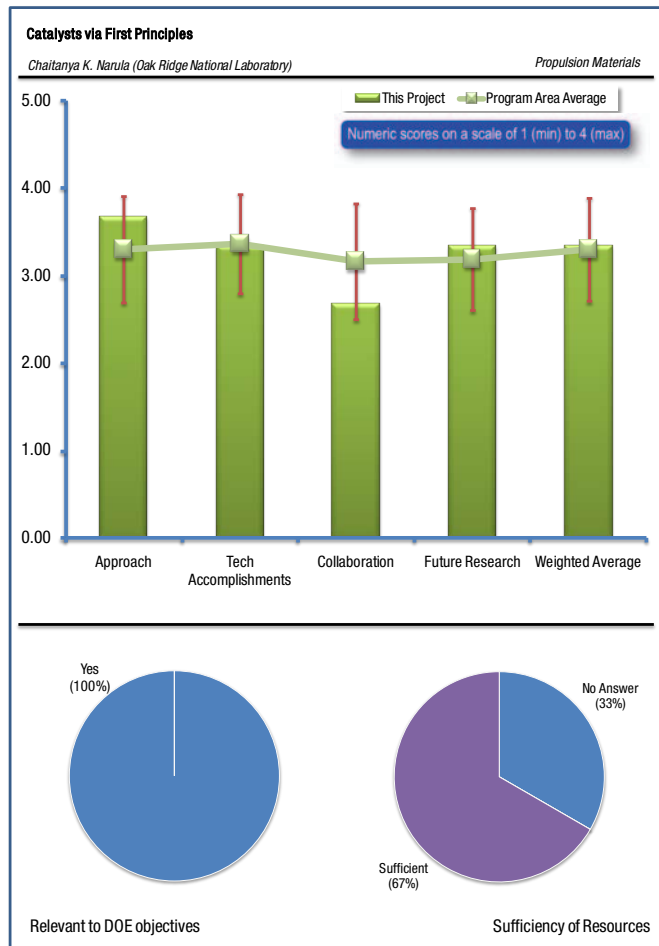
Catalysts via First Principles: Chaitanya K. Narula (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

All three reviewers agreed this project is relevant to DOE’s petroleum conservation goal, although one said its relevance was very indirect, in that it could enable development of NO_x aftertreatment devices that in turn could enable advanced combustion approaches offering higher engine thermal efficiencies. Another characterized this as a very basic study of characterization and understanding of mechanisms involved in catalytic action of materials; improving the performance will enhance the efficiency of catalytic action. This reviewer observed that all projects which try to understand the mechanisms can be shown to contribute to the fuel conservation; however, more fundamental studies like this will have impact in long term but cannot be measured directly. The final reviewer commented that exhaust aftertreatment catalysts are universally employed to permit both SI and CI engines to meet current emissions standards, a trend that began in the mid-1970s and that can be expected to continue indefinitely. The importance of catalyst performance to vehicle fuel efficiency can hardly be overstated. Catalyst design, however, has depended heavily on trial-and-error evaluation. The ability to identify potential catalyst formulations and predict their performance based on first principles of catalysis would clearly represent a significant step forward.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Two reviewers commented. The first characterized this as a project involving characterization of material and developing theory on operation; the approach is well defined. The second stated that this is a very good, financially low cost, fundamental materials discovery R&D effort that has great potential to add engine OEMs in developing future NO_x aftertreatment devices.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

“Significant understanding has been achieved and explained well,” one reviewer said. The other felt the project is leading to very fundamental understanding on how to locate platinum on a catalytic surface with improved reactivity. This reviewer thought it would be interesting eventually to develop a design of a bench-scale catalyst and compare its performance to the performance of a current state-of-the-art item.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer simply noted that this is basic characterization work and no industrial partners are involved. The other credited the Principal Investigator with gaining the support of John Deere, noting the project has been the victim of the downturn in the automobile business. This reviewer thought it would be beneficial if the PI could find other partners such as GM or DDC.

QUESTION 5: HAS THE PROJECT 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?

There were no comments on this question from any of the three reviewers.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

There were no comments on this question from any of the three reviewers.

Thermoelectric Mechanical Reliability: Andrew Wereszczak (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Thermoelectric materials are enablers in improving the thermal efficiency of vehicles, according to the first reviewer. The second felt that this project is indirectly tied to DOE petroleum displacement goals by addressing real world engineering reliability and durability issues with thermoelectric materials that could enable the use of waste energy recovery devices which can improve vehicle level fuel consumption. The third said that thermoelectric materials could enable the use of energy rejected to the atmosphere as heat by internal combustion engines. Electrical energy produced by practical (i.e., economic, reliable and effective) TE devices could result in reduction of engine accessory loads (alternator, PS pump, A/C, etc.) and contribute to improving fuel efficiency.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

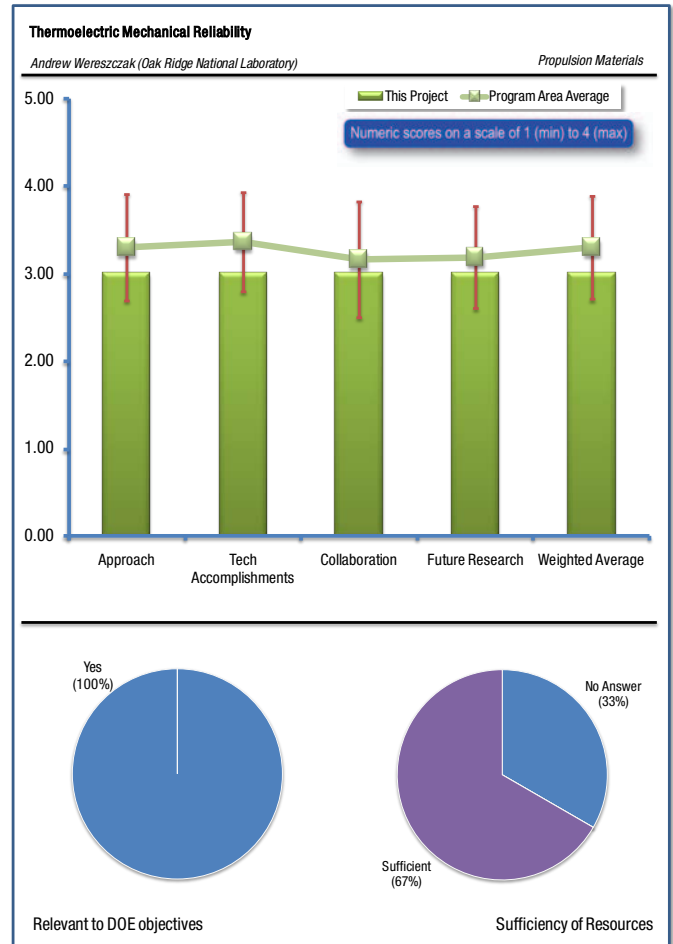
A reviewer noted that the approach shows clear appreciation of current TE material limits and a logical approach to extending them. Other comments were that the lack of test procedures is a barrier for the development of materials. Using regular characterization methods, the project is developing newer test procedures; data base generation is critical for future material development. The final reviewer said that the approach is targeted at addressing the obvious key thermomechanical properties of the candidate thermoelectric material. It is apparent that a major property is missing from their targeted list. Does the PI believe that the 3 point tensile test is the best approach for simulating tensile stress seen in the real TEM application? Does a historical two point tensile test make sense? Also, based on the various measured thermophysical properties, what type of efficiency improvement does the PI expect for a waste energy recovery system?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

According to the first reviewer, this project has generated some interesting and useful data on certain potential material candidates that is valuable in assessing the potential for improving overall waste energy conversion system efficiency. It would be useful if the PI could extrapolate these findings toward the impact of the performance of a waste energy recovery system. The second comment was that a significant amount of data had been generated; this includes the development of new test process; standard test development is an easy way of disseminating and benchmark the progress.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Review comments were generally positive, including a note that one supplier of material and one user is involved. A reviewer termed the collaboration with a high-volume vehicle manufacturer as commendable, but the presentation did not make it clear what General Motors' role/contribution has been, or what GM will contribute in future work. The final comment was that it appears a material



supplier is supporting this project and also GM in some capacity; it is not clear what level of participation GM has invested in this effort.

QUESTION 5: HAS THE PROJECT 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?

Overall, there is a good approach for measuring various candidate material thermophysical properties; it would be helpful if the PI could extrapolate any such measurements toward waste recovery system performance improvement. A second reviewer reiterated the question of what role GM will play in this project. The third reviewer listed these activities: test process development is expected to be completed; characterization of the material; and interaction with industry for production.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were provided for the resource sufficiency.

Thermoelectrics Theory and Structure: David J. Singh (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

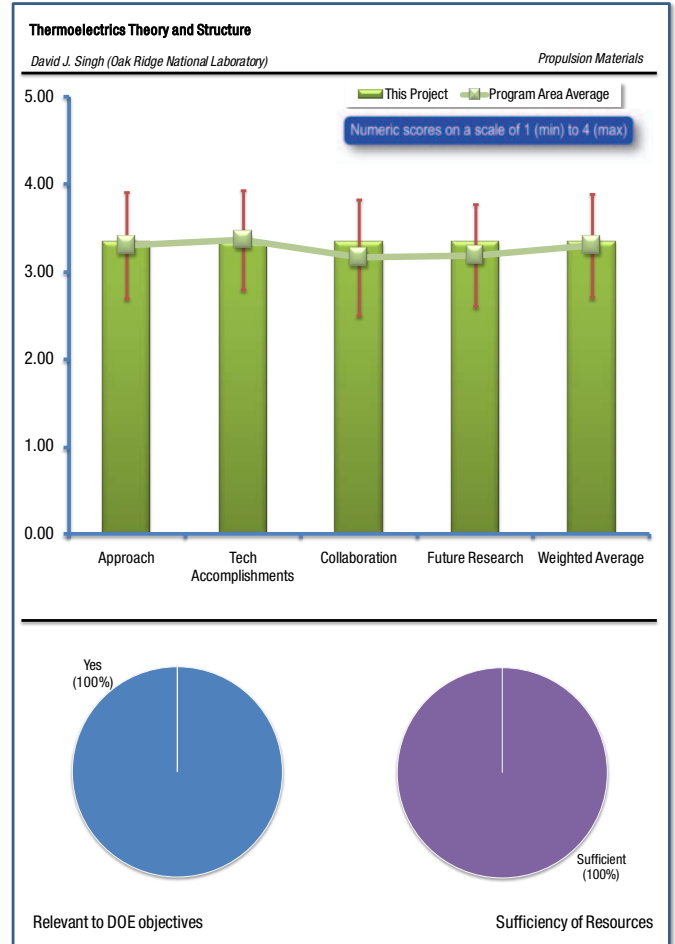
All three reviewers agreed this project is relevant to DOE’s petroleum conservation goal. To the first reviewer, this project is broadly relevant to DOE’s interest for enhanced efficiency. In this project, this objective is being addressed by the perceived need for high ZT materials for various waste heat recovery applications. The targeted goal of \$1/W down to \$0.20/W is relevant (though it is not clear that it will actually be achievable). The motivation articulates the standard points of relevance for thermoelectrics. The second reviewer also agreed with the relevance and said that the goal is to recover waste heat from exhaust gases to recover energy. This would increase automotive efficiency and reduce use of petroleum. The final reviewer said the project was relevant, based on supply problems of rare earth availability. The effort seeks substitutes to rare earths. However, the title is misleading suggesting no relevancy: this reviewer recommended the title be changed to indicate some specific end use.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The three reviewers appear to agree that the approach is basically sound. One reviewer said the project uses standard, established technologies. Another said the project is good basic research leading to selection of materials, noting that the focus is on transport theory, looking at materials and design tools. Use of go/no go gates is useful (if indeed they are making impartial decisions along the way). The third reviewer noted that the project emphasizes a theoretical approach to materials development to achieve high ZT. The emphasis is almost exclusively on materials development (theoretically) with a view to finding new materials and design rules using first principles calculations to identify favorable compositions for thermoelectric materials. The PI shows fine insight to recognize the supply issue for TE and other materials. The approach emphasizes skutterudite materials.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted that the PI carried out first-principles computations on a variety of crystal structures (of calcium and strontium plus others). Very favorable results for thermoelectrics were observed at a level of existing skutterudites, but at lower cost. The PI also carried out “transport” calculations (though he did not elaborate on what he meant by “transport”). The reviewer further noted that when compared to more standard materials like Bi₂Te₃ and other widely considered TE materials, Ca and Sr compounds were found to be cheaper, safer and with performance equal if not superior. The second reviewer approved of conducting a project that addresses material supply availability and cost. The final reviewer observed that heavy band / light band mixture studies for high ZT were completed, thermal conductivity of filled skutterudites was investigated, and virtual crystal calculations were conducted for new materials.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Two reviewers commented positively on collaboration, one terming the collaborations with Caltech and others “very good,” and noting that the PI is doing computations to complement the experiments done there. This work is similar to other universities that the PI is collaborating with, including an Energy Frontier Research Center. Another observed good collaboration with academia, industry and other government agencies, including General Motors, Naval Research Laboratory, Massachusetts Institute of Technology, Oregon State, Corning and California Institute of Technology. The third noted the absence of a CRADA, but nevertheless noted “extensive private industry, academia and Federal Government agency participants.”

QUESTION 5: HAS THE PROJECT 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?

Initial comments about the future work include its high potential for waste heat recovery, and its focus on completion of theoretical work to optimize selection of good performing thermoelectric compounds. The latter reviewer also stated the goal is to develop high performance/ low cost components.

To the third reviewer, the future work includes virtually no discussion of precisely how the materials would be used nor of the packages that would house them. The PI should know that unless efficient packages can be developed to house the materials he will develop, the potential benefits of high ZT materials will not be realized in practice. While this is a materials development effort, the larger picture must be kept in mind, since after all, DOE is an applications program. In future work the PI should give the audience an appreciation for some of the theory involved (e.g., equations, computational power brought to bear, etc.)

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Resources were characterized as being adequate for what is being pursued, and sufficient to continue work. The final comment was that the project ends in FY11, and more research is required for the new material. Applications of this technology await better materials. Also, this technology is applicable to only high temperature environments. It is probably not suitable for battery operated vehicles, but has applications potential for gas/diesel and H type vehicles.

Proactive Strategies for Designing Thermoelectric Materials for Power Generation: Terry Hendricks (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

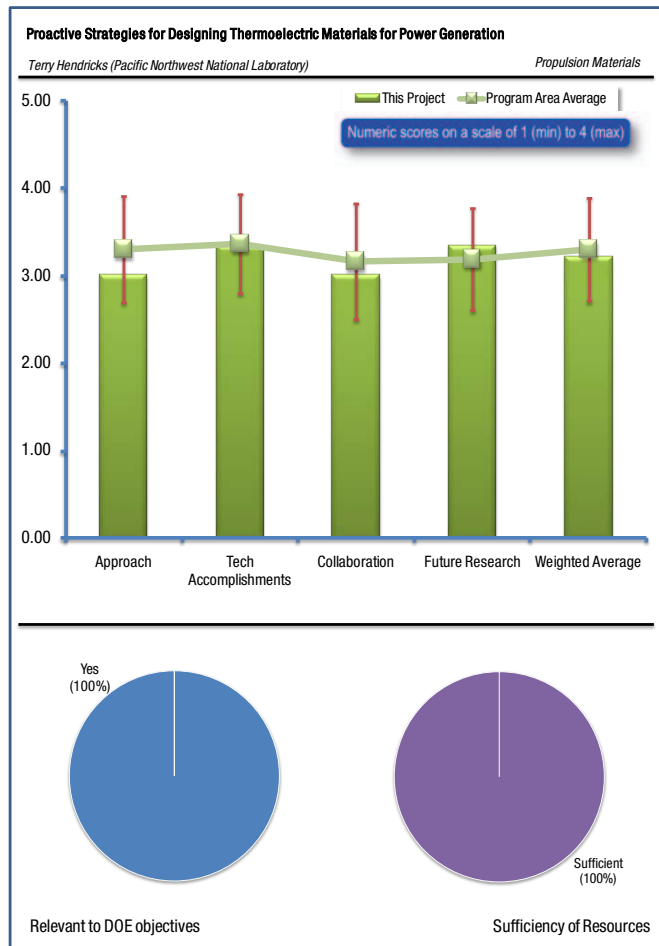
Reviewers were generally positive about the support of DOE objectives, with one reviewer stating that the objective is to improve commercial and heavy truck efficiency by recovering exhaust heat, directly supporting DOE goals. The second reviewer termed this as being “standard DOE vehicle objectives.” The third reviewer commented more extensively, stating that this work concerns materials relevant to waste heat recovery. The project also deals with skutterudites and their design for power generation. The stated motivation appears to be somewhat boilerplate for the VTP program (hybrids, significant waste from exhaust, passenger climate control, reduced load on engine, etc.). The commenter observed that the PI is developing new n and p type thermoelectric materials that can withstand temperatures of 800 and 900 K. A targeted goal is a ZT of 1.6 or higher, achieved in a relevant temperature range.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

All reviewers approved of the technical approach employed in this project. A reviewer termed the project a good basic investigation with third-party validation, noting that the team is also investigating structural properties as any compound selected would be operating in a harsh environment. Another comment was that the work uses In and Co (both higher cost minerals) and other rare earth minerals: available supply may not meet demand if this technology progresses. The technical approach appears sound to meet project objectives. However, the skutterudite materials derived from this research may make any product too expensive to incorporate into a vehicle. The final comment was that the organization of the project is very good and proceeds in a logical fashion. A combination of thermoelectric development and materials characterization is being pursued. The approach to material enhancement is to fill the voids in skutterudites to reduce the black body phonon radiation that passes through the crystal structure, thereby lowering the thermal conductivity and enhancing ZT. A rather wide range of indium and serium based materials are being examined in a systematic approach that seeks to include measurements of Seebeck coefficient, electrical and thermal conductivity.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Two reviewers mentioned several accomplishments with apparent approval, observing extensive testing and characterization of over a dozen materials and seeing no indications of any technical barriers. Other accomplishments noted included the measurement of structural properties and elastic moduli, and development of innovative test equipment (high temperature measurement system) for n and p type thermoelectric compounds. The third and final commenter was more descriptive in his comments: the PI noted that module packaging is as important as materials development, which is very good. Measurements that have been made include CTE, Seebeck coefficient and electrical resistivity. A resonant ultrasound system is used to measure Young's modulus and Poisson's ratio. A high



temperature chamber was developed to make these measurements. Impressive as this effort is, it was not immediately clear what the relevance of these measurements was to using thermoelectrics for waste heat recovery. Data on Seebeck coefficient and electrical resistivity were reported. The results showed a ZT between 1.5 and 1.6 at about 470K, which is impressive.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers also generally lauded this aspect of the project. One noted the development of an effective working relationship with Oregon State University, who apparently does thermal property measurements: more details of the OSU experimental capabilities would enhance the work performed. A second reviewer cited an adequate team of academia, industry and other government agencies (Oregon State University, Oak Ridge National Laboratory, Tellurex Corporation, BSST LLC, ZT Plus) and coordination with another waste heat recovery and utilization project. The third reviewer simply noted that there are eight agencies involved in this project.

QUESTION 5: HAS THE PROJECT 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?

A reviewer said that future work would optimize synthesis procedures, fabricate compounds and include third party testing to validate performance. Structural properties would continue to be a key parameter to investigate. Another said the future work characterizes the new materials, focusing on the n-type In, Cs, At materials. The final comment was that future work includes similar measurements as reported this year (e.g., Young's modulus, Poisson's ratio, CTE, etc.), introducing "rattlers" in a range of rare Earth materials, and characterizing TE properties with ORNL. It would help to have some cross-referencing of the data to be obtained with other groups.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers called the project resources adequate for the work to be done and sufficient through FY 10, with program completion in FY 10. One noted the similarity of this project's goals with those of PM013 and asked if the two could be combined. The third praised excellent use of resources but was not sure of any cost sharing.

Solder Joints of Power Electronics: Govindarajan Muralidharan (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer said the project indirectly supports high-efficiency energy and electronics by providing for higher-temperature solder joints that are more reliable. The other reviewers' comments appeared to reflect some misgivings, however. One said the project is relevant in computer controls for advanced vehicle power systems, etc. The third reviewer was openly skeptical, conceding that the integrity of solder joints is certainly important for long-term reliability of electronic packages, which are pervasive in many vehicle control systems, but stating that the thread of connection of enhancements and improvements in this area with "petroleum displacement" is tenuous and a stretch at best. The work plan sets the stage for this problem in the context of electronic reliability; a stronger connection with petroleum displacement needs to be made.

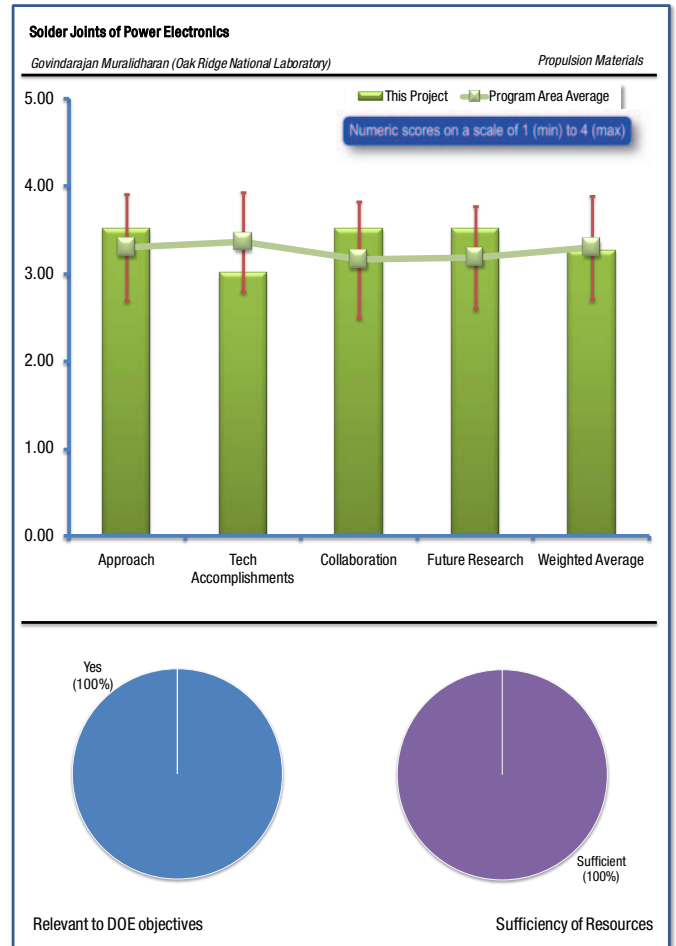
QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer observed that the project reaches completion in FY10. The reviewer offered several comments on the presentation, noting that he had to read the entire briefing to discover this was related to future electric vehicles. If this reviewer had been a congressional staffer he would be asking some tough questions about the applicability of this project. Given staffers do not have considerable time to completely review each project, as written this project would have been a candidate for termination. This reviewer suggested either changing the title for more relevancy or moving the application closer to the front of the presentation.

Another reviewer said the structures analyzed in the project experiments appear to be somewhat standard, consisting of layered materials with solder joints. The approach to measure the time dependence of joint strength may be important in general, but it is unclear why this information is important for the targeted application unless the packages analyzed are expected to experience cycling in application. No discussion of this point was included. The third reviewer said this was a straightforward approach for the project objective: joints are to be studied with regarding the effect of steady-state exposure to of high temperature on microstructure and the strength of the joint over time investigated. Thermal cycling of solder candidates will be tracked to develop knowledge on degradation.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The PI has done a good job developing a range of experimental data, has fabricated a number of gold/tin joints, and collaborated with Powerex, according to one reviewer, but despite the fact that the thermal cycling data reported appears to have been carefully done, it was unclear what the significance of the 30 minutes of uninterrupted operation and what it was intended to simulate. This reviewer noted that some of the observations were qualitative in nature, making generalizations difficult: for example, the damage accumulation over repeated thermal cycling. He said the modeling effort was interesting. Thermal diffusivity data were reported, and interesting as



they may be, it was unclear what these data were used for and how they contributed to the objectives of the project. The second reviewer was unable to comment on project accomplishments since there is just no individual slide marked “accomplishments”: what was accomplished? The third commended investigation of lead-free solder joints, but wondered if nickel would become an issue under domestic or international environmental regulations. He also approved the use of finite element modeling to investigate failure modes.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said collaboration with Powerex is good but was left unsure of the precise nature of the Ford and NREL interactions and what they were providing to the project. Another called the collaboration with industry (Ford, Powerex) adequate, noted the discussions with NREL, and speculated that collaboration might have been constrained by project funding levels which are lower than other projects. The third reviewer simply noted the participation of one major motor company and one apparent supplier.

QUESTION 5: HAS THE PROJECT 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?

One reviewer termed the proposed future work a logical extension of current work efforts, further noting that work will continue on thermal diffusivity and degradation of joints over time and that multiple thermal cycles are planned on three candidates. The second appeared to agree, noting a sequential progress in testing the solder joints. The third reviewer, however, called for a stronger case to be made for the thermal diffusivity data which the PI is proposing for follow-on work. He also desired better justification for the 3000 thermal cycles that are to be imposed. He considered shear measurements to be important, but as with the other data, precisely how it all fits together and where the PI is going with the information he has obtained and proposes to develop for the future needs to be clearer.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The project resources appear to be adequate for the research carried out, according to one reviewer. A second called them smaller than for a typical project, but seems to be making excellent use of funding. The third reviewer noted that the project completes in FY10 and needs a written report. Also, when will the results from this project transition to industry?

This reviewer noted here (perhaps misplaced) that he totally disagreed with the previous year evaluation comment. The temperature in northern North Dakota can plunge to -70F, the high in Arizona is over 110F, and the salt contamination in New England is almost as bad as Hawaii. As we design vehicles as one vehicle is suitable for all climatic and environmental extremes the thermal cycling range should include the extremes. This reviewer suggests -40C to 115C as the range. If this is accepted, then what in your opinion will be the effect on your solder joints?

Materials Compatibility of Power Electronics: Beth Armstrong (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer noted that better packaging of power electronics into hybrid vehicles makes them more viable. More hybrids correlates with better fleet fuel efficiency. This reviewer also stated that since his perspective is from the vehicle side, packaging and increasing electrical power enables the opportunity to increase fuel efficiency. PHEV vehicles benefit from this type of research. Another considered this to be an enabling project to have more efficient power electronic systems. The third reviewer’s comment stated the project objective to overcome the barriers on cost of high temperature integrated power electronic (HTIPE) systems and abuse tolerance and ruggedness of HTIPE systems.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

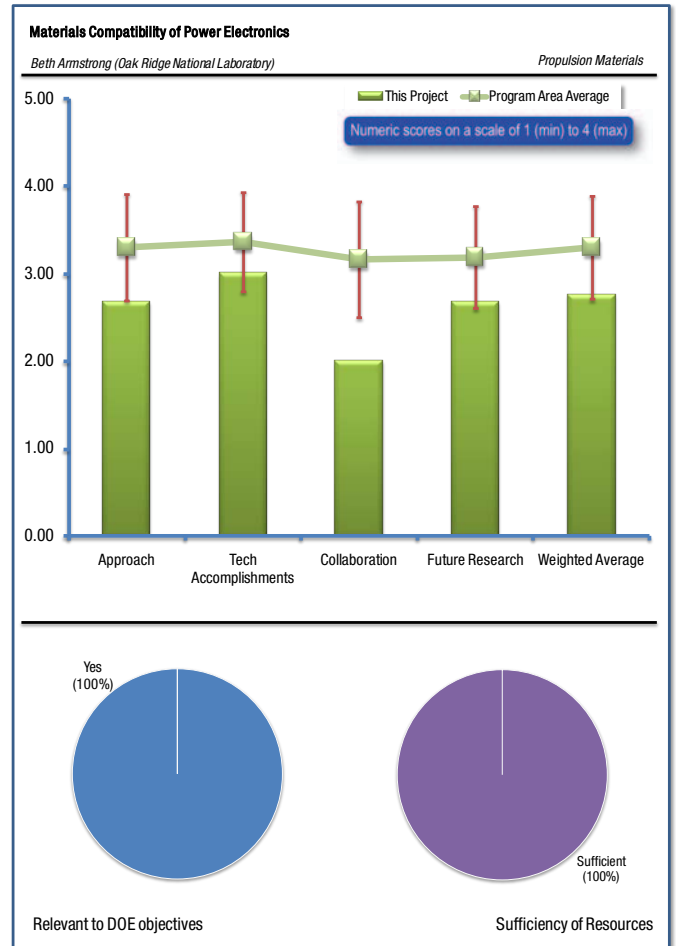
The project test plan is sound, according to one reviewer, but the unknown effect of the final coolant material is a setback to overall project. The project continues to evaluate potential cooling requirements. A second reviewer felt the approach is focusing more on characterizing the aluminum conductors and less on the actual cooling optimization. The third reviewer’s comments offered no evaluation of the technical approach, restating the activity of developing and validating a laboratory methodology to evaluate the degradation of power electronics materials/components by evaporative cooling liquids.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer enumerated three project accomplishments directly from the presentation: developed methodology to evaluate the interaction of the power electronic components with the fluids used in the evaporative cooling systems and initiate testing of methodology; validated the proposed methodology for examining the interaction of the electrical components with evaporative coolant; and initiated mapping of materials compatibility space of power electronics with appropriate evaporative coolant. The second reviewer also cited one of these accomplishments, noting that the result so far is a methodology for testing electric conductors in a coolant. Since it is highly likely that the coolant chosen in this project will be replaced it is important that an insight is given in the robustness of the methodology in case of an alternative coolant. The final reviewer said that the project focuses on the fundamental objectives of material durability with external cooling.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Two reviewers said no collaboration had been mentioned in the presentation; the third desired to see more interest from industry, noting that few final users are involved in this project.



QUESTION 5: HAS THE PROJECT 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?

Noting that the project is winding down, one reviewer urged that effort be devoted to defining test methods so as to make them usable with alternative coolants. Another simply reiterated the proposed research from the presentation: use more prototypic boards; and develop minimum test data that allows for a meaningful dialogue with system designers. The third reviewer said the project finishes by developing test plans that would be used by an end user.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The only comment on this question was “Tasks meeting time requirements.”

*Environmental Effects on Power Electronic Devices:
Andrew Wereszczak (Oak Ridge National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Two reviewers noted that power electronic devices (PEDs) are a key enabling technology for hybrid-electric vehicles, which offer significant petroleum displacement potential. One stated that power electronics are key to practical, mass-producible electric and hybrid-electric vehicles which offer significant petroleum displacement potential. Another said that this project supports the use of power electronics in HEVs which are one vehicle propulsion technology that could improve specific vehicle application fuel consumption over a given duty cycle. The final reviewer observed the presentation did not elaborate on barriers and significance, but developing cooling methods can contribute to improved performance of PEDs.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Two reviewers addressed comments to this question. One said the problem is well defined, but wanted a clearer explanation of where these devices are used and how it contributes to the vehicle. The other said the approach is addressing the key shortcomings of PEDs – thermal management and reliability issues.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

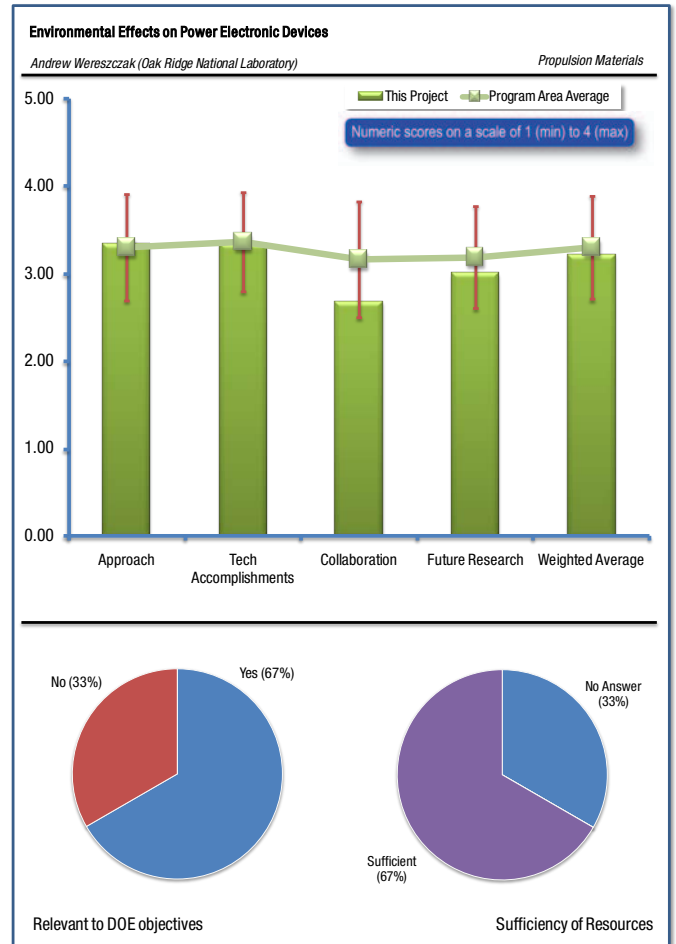
One reviewer cited a patent application that arose from the project work. A second reviewer, noting that the mechanical analysis and thermophysical portions of the project yielded data for the poster, was left wondering what the end state was for the maximum allowable coolant inlet temperature and how it compared to the DOE target of 105°C. The third reviewer noted that effective cooling is crucial to the practicality of power electronic devices. The ability to reject heat without complex ancillary cooling systems is important to the economics of high-power electronic components and their ability to withstand the temperatures and mechanical stresses of the automotive environment will determine their operating lifetimes.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Two reviewers did not comment; one said the project appears to be a single-investigator effort and it isn't clear if the PI has been collaborating with industry or non-DOE government agencies.

QUESTION 5: HAS THE PROJECT 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?

All three reviewers either noted that the project is slated to end in FY 2010, that no future research was proposed in the presentation or that there had been no request for further funding.



QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

There were no comments on this question.

*Materials for HCCI Engines: Govindarajan Muralidharan
(Oak Ridge National Laboratory)*

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Two reviewers responded to this question with germane comments. One said the project had “*de facto*” relevance to DOE’s goals, as with any project to reduce material weight and derive benefits of fuel economy. However, he continued, the targeted goal of 25 to 40% improvement of fuel efficiency is very aggressive. The second reviewer observed investigation on improved engine valve materials that operate at higher temperatures for advanced, high-efficiency engine concepts. The third comment simply noted the improved exhaust valve material.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

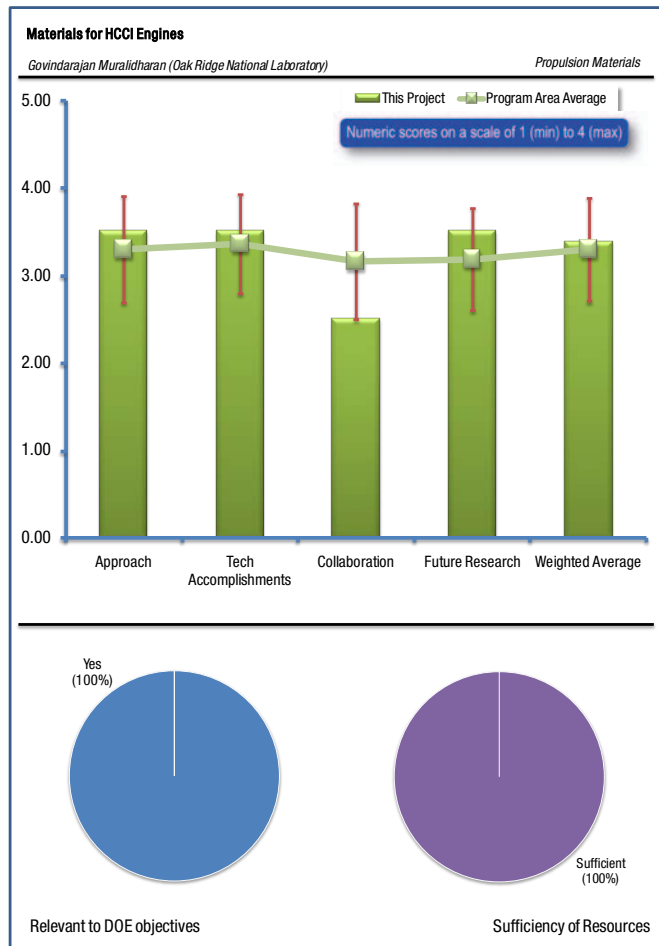
Two reviewers praised the use of computational approaches in this project, one saying the integration of computational approaches to materials development is useful, and the other citing good use of thermodynamic/kinetic computational models to predict performance before testing. The first of these reviewers, however, commented that little was presented to more fully understand this component of the project. The PI noted the potential for “...rapid identification of new alloys with desired microstructure...” through modeling. However, the discussion of this point was sparse as it was presented only in block diagram form. More details need to be described. He also said the efficacy of the approach for achieving project goals is uncertain given a lack of a direct, quantifiable link between right material having been found or developed and improvement in fuel economy. Future presentations, this reviewer continued, should include a discussion of fuel economy and materials, not just “statements (rather like hand waving)”. The third reviewer merely noted that the project appears to be on schedule for completion.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer, citing nice progression from modeling to practice, noted that the modeling had led to selection of an alloy with desired microstructure and properties and that small quantities have been made and larger heats subjected to fatigue testing. A second noted accomplishment of “a lot,” and mentioned hardness testing, stress measurements, identification of structural features, etc. However, he was left wondering where this testing and measurement leads. Finally, the third reviewer posed a question: “There is no indication of any combination of Ni and Co at concentrations lower than about 50%. Was there some analysis that suggested this concentration, or could the mixture percentage be lowered further?”

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Project collaborations were deemed reasonable by one reviewer, but considered to be a bit vague, including as they do ‘discussions’ and ‘guidance’ as with Eaton and Carpenter Industries. He called for better quantification to determine what these ‘discussions’ and ‘guidance’ have led to. Feeling it unclear that there was a commitment to work together, this reviewer urged collaborations be



solidified through agreements, cost share, personnel exchanges, equipment donations, etc. and that the benefit of these interactions be made explicit. The PI notes that they are having extensive discussions with Eaton on an “on-going” basis. What does this mean? Similarly, the interaction with Carpenter (“discussions”) is vague. These collaborations should be more substantive, or if they are then evidence to that effect should be provided.

This reviewer also noted that Eaton and Carpenter were the only project participants identified, that there was no indication of any manufacturing potential after project completion and no indication of commercial interest. The other reviewer noted that collaboration had been primarily with industry and speculated that smaller resources may have limited a broader participation by academia and other government agencies.

QUESTION 5: HAS THE PROJECT 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?

Two reviewers simply noted the project’s planned completion in FY 2010, one noting the expectation of one or more patent applications and observing the project will investigate long term exposure, rotating beam fatigue and other characterizations. The third urged that the PIs should scrutinize their results more closely to develop a rationale for the future: the way forward seems to be more of the same from the past. Their itemized list of “future work” provides little in the way of a roadmap to their ultimate end state. In developing a roadmap, it would help to draw the reader through the rationale so that it can be better understood how the proposed tasks for the future would fit into the ultimate goals.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers said, respectively, that project funding seems reasonable for the tasks carried out, and that the funding profile was typical with no cost sharing evident. The third asked if any follow-on work was planned.

Hydrogen Materials Compatibility for the H-ICE: Stan Pitman (Pacific Northwest National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

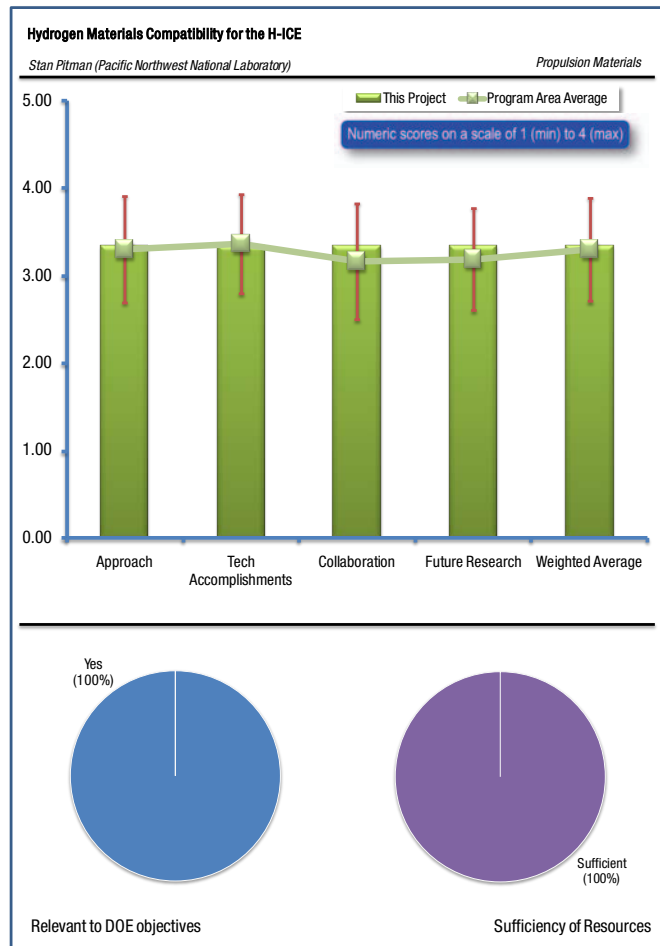
One reviewer implicitly characterized this project as relevant to DOE’s petroleum conservation goal by noting that hydrogen is not petroleum dependent. The second reviewer’s comment was similar: he said the project is focused on a technology that will enable the introduction of hydrogen as fuel for vehicles. The third reviewer was reiterating project objectives: this project tries to improve the durability and performance of fuel injectors for use in direct-injection hydrogen internal combustion engines by evaluating failure modes of piezoelectric materials, coatings, and connectors in high-pressure hydrogen gas; characterize actuator performance in hydrogen and developing new experimental methods for evaluating performance; and measure the friction and wear characteristics of injector materials and coatings in hydrogen gas in order to develop better injector designs.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer noted that the program is targeted at the technical barrier of a robust hydrogen injector: the two topics are the effects of hydrogen poisoning on the piezoelectric material, and increased injector wear due to hydrogen's lack of lubricity. The program targets injector designs issues related to hydrogen fuel. Another stated that the chosen approach for the development of hard coatings to avoid wear in a hydrogen rich environment is a good combination of coating design and experimental validation: this reviewer felt that the approach on characterizing of the adsorption of hydrogen is good, but how to create a barrier coating is still not well described. The final reviewer reiterated several aspects of the approach: evaluate kinetics and mechanism for deterioration of piezoelectric materials by hydrogen and examine potential remedies; and develop and evaluate novel coating methods for improved actuator reliability.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer, noting that the project is nearing completion, said a lot of work still has to be done. This reviewer wondered whether a project extension had been requested, since a presentation slide suggested proposed future work would take place in FY2011 as well as in FY2010, when the project is slated to end. He nonetheless considered that understanding of hydrogen ingress in piezo materials shows good progress. If the multi-layers approach is successfully validated, this reviewer said, this would also be a significant improvement. The second reviewer concurred, saying the nanolaminates look promising for reduction in injector wear caused by hydrogen, and felt tools like ion scattering and quasi-elastic neutron scattering should improve basic understanding of hydrogen poisoning as well as new solutions to stop it. The final reviewer listed technical accomplishments: H₂ charged samples show surface blistering except BaTiO₃; PZT/Pd H₂ charged surface shows Pd/Pb mixing (confirmed with RBS); fits of ERDA spectra give hydrogen depth profiling and compared with control (uncharged sample) for residual hydrogen; neutron scattering was used to study



H₂ in piezoelectrics; two tribometers are being used to evaluate lubricity and wear characteristics of Cr/N and B/N nanolaminates; and nanolaminates had superior tribological properties relative to the individual monolayers.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer called project collaboration with industrial partners and national labs good; the other two cited the project collaborators by name (Westport International, Ford Motor Company, National Laboratories).

QUESTION 5: HAS THE PROJECT 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?

Two reviewers commented. One said the future plan is a logical progression, and involves trying to better understand and model the hydrogen deposition within the injector. The other said that plans are in line with outcomes of the project to date but that it would be a challenge to finish within timeframe of 2010. A third reviewer did offer inputs, but only by listing future work: complete evaluation of hydrogen damage in PZT, and recommend potential remediation methods; and complete statistically-designed experiments of Cr/N and B/N coatings in argon and in hydrogen.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Of the two reviewers offering comments, one said the project had sufficient support for the described task and the other said that with only 10% left to accomplish, the resources should be sufficient.

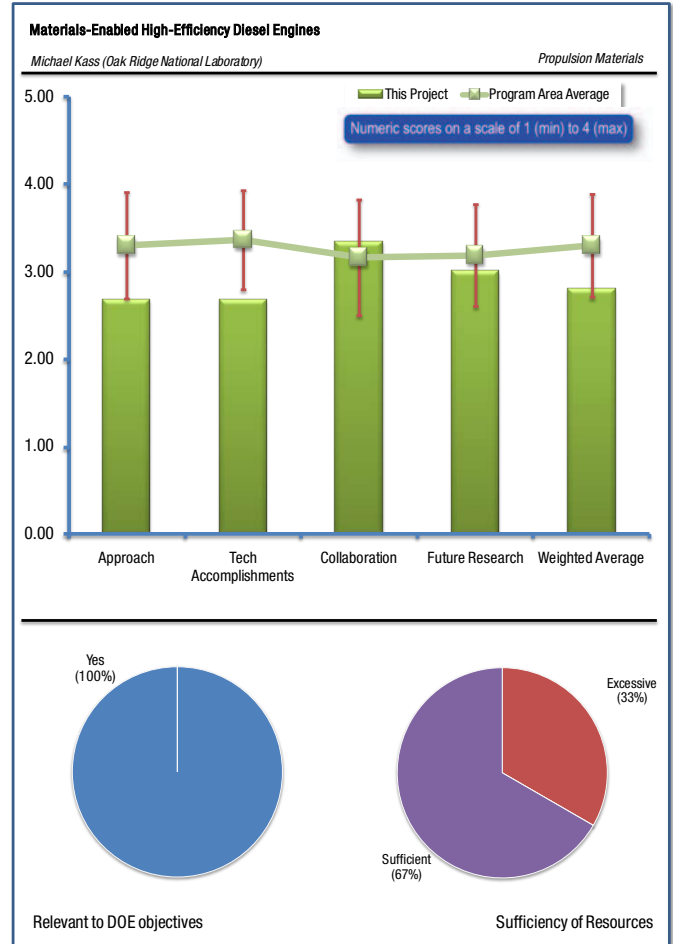
Materials-Enabled High-Efficiency Diesel Engines: Michael Kass (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Two reviewers deemed this project relevant to DOE’s petroleum displacement goal. One said understanding the performance of materials used in diesel engines will help to improve efficiency and reduce fuel consumption. The other agreed that material improvements in these areas are directionally better for fuel economy and emissions, but also noted that industry partners limit the amount of information presented. This reviewer said that the project seems to target better lightweight materials for turbochargers and other powertrain components. The third reviewer observed that the presentation associated with this project (which is recognized to be in its early stages) provides little detail on a) precisely what advanced materials will be examined and b) how this project differs from/overlaps with Project PM033. However, use of biofuels would appear to be relevant to petroleum displacement and high-performance materials (other than the TBCs that are the subject of PM033) are also presumptively relevant to improved HDD engine performance.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

A reviewer cited the paucity of specifically relevant information in the presentation in explaining the rating he gave the project in this category. A second reviewer called fundamental power train material improvements a good goal, but very broad. He suggested that more focused experiments would help analyze the overall result. The third reviewer mentioned the commissioning of a full-scale test cell with engine and looked forward to subsequent progress, noting that once this setup is available it will be possible to evaluate various technologies and materials and bench mark the process.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said basic research into the Second Law analysis is a good starting point but that sparse data limits the amount of feedback. The second reviewer observed that so far only the infrastructure has been set up; in the future, testing can benchmark various products including fuel mixes, new materials and exhaust control systems. The last reviewer, acknowledging the project’s early stages, said it is unrealistic to expect ‘significant’ or ‘excellent’ progress to be evident.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

“Collaboration with industry is very strong,” one reviewer said. The second agreed, calling Caterpillar an excellent choice for an industrial partner. The third also noted this collaboration, terming the partnership with Caterpillar well-coordinated. But this reviewer said the ways in which other material suppliers are involved in the project is not explained. In this reviewer’s view, a key question is “Who will be keeper of knowledge?” If the complete process chain is involved, he continued, then the knowledge is well

disseminated. That isn't apt to be the case, in this reviewer's opinion, if Caterpillar is the sole industrial repository of knowledge gained from this project.

QUESTION 5: HAS THE PROJECT 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?

Reviewers seemed implicitly to recognize that proposed future research was most significant in this relatively new project. Only two commented. One called future work "most critical" and anticipated that efficiency and material durability information would emerge from it. The second simply observed that the plan for testing is in progress.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

"Resources are very strong," in the words of one of the two reviewers who commented. The second said funding for this project appears excessive relative to its likely payoff over and above that of the (apparently) closely related Project PM033, the small contribution that diesel-type biofuels are likely to make to petroleum displacement in the foreseeable future, and the project's brief duration.

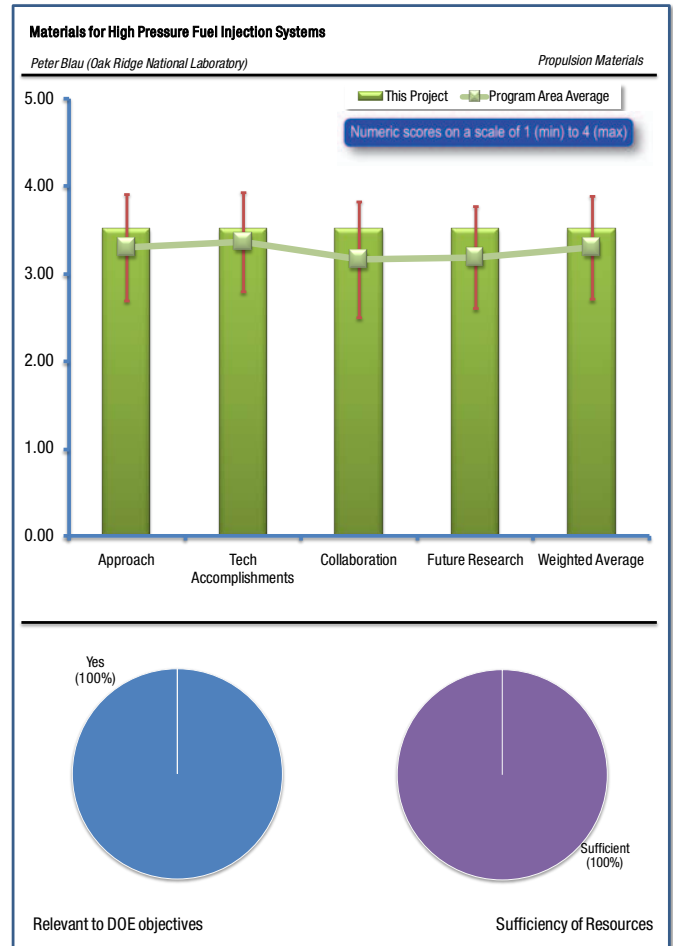
Materials for High Pressure Fuel Injection Systems: Peter Blau (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Two reviewers acknowledged the connection between advanced diesel fuel injection systems and high-efficiency engines and, by extension, this project’s relevance to DOE’s petroleum conservation goal. One of these reviewers mentioned the need for new materials for increased fuel injection design pressures in high-efficiency engines. The other reviewer noted that the premise here seems to be that materials surrounding nozzle spray holes have to resist high pressure fatigue. And if materials are developed such that nozzles will not fail by fatigue (or clogging, shape changes, etc.), then fuel efficiency will be improved by 20%. The connection is tenuous (especially the 20% figure).¹ Certainly, if nozzles don't fail engines can continue to operate. If dimensional tolerances on holes are maintained, fuel can continue to be injected and engines continue to operate. However, the PIs need to do a better job to connect the lack of maintaining nozzle performance characteristics (which evidently is the key here) with petroleum displacement. The relevance they cite is all true (nozzles must resist changes in shape.) The issue here is the connection with petroleum displacement. This reviewer continued by saying that to give the PI the benefit of the doubt, certainly novel materials that would maintain injector parameters represents an enabling technology. So in that sense the project is relevant. Nonetheless, the PIs should make a stronger link to “petroleum displacement.” The third reviewer’s comment was simply that this is a continuing effort scheduled for completion in FY11.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer characterized the approach as analytical, looking at looking at microstructures, residual stress, and fatigue studies for materials for fuel injector nozzles, and results were compared to current alloys. This reviewer deemed that a logical progression of research was depicted. Another stated that the approach taken is one of characterizing dimensional tolerances and microstructure of alloys, determining residual stresses, and carrying out fatigue studies. Again, the relevance of these activities to petroleum displacement should be better made. The indirect connection is understood but it should be the responsibility of the PI to make that connection. What was perhaps curious is that for all of the effort on materials testing and characterization of structural features, no effort is included to study the quality of the spray that is produced, and in particular how it might degrade by mechanisms that influence failure modes of the material. In the end it is the droplet parameters that control performance and this should be included in this study as well. It is hard to envision how a study of nozzles and associated materials issues can be separated from performance of sprays. The final comment was that the project appears to be on schedule and there are no apparent research barriers.

¹ DOE Note: This appears to be a misunderstanding on the reviewer’s part. The 20% engine efficiency improvement goal is an overall goal of the Advanced Combustion Engine program; no single project is expected to achieve it. PM021 is one of several projects that support the goal of raising heavy-duty diesel engine efficiency from 42 to 50%.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer observed steady progress being shown on the work plan and noted the development by the project team of novel tools for sample preparation and testing approaches. Another said the quality of the work performed is good and the characterization of microstructural features is nicely done. What's lacking is how it all fits together, according to this reviewer. The PI was intent on showing all of the nice things that were done. In the end, one may still wonder "so what?" The connection to performance improvements should be strengthened, in particular showing how the fatigue testing will lead to petroleum reductions. The final review comment was that from the information provided in the briefing the project appears to be on schedule with no expected barriers to completion.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

"The collaboration with Caterpillar is very good," one reviewer said, and the emerging collaboration with CARTECH is also good. This reviewer recommended that collaboration be initiated with a manufacturer of atomizers (e.g., Parker-Hannefin, DeLaval, etc.). A second reviewer described a suitable team of government agencies, a large equipment manufacturer (Caterpillar) and a materials developer (Carpenter Technology Corporation). The last reviewer listed Caterpillar and ORNL as collaborators.

QUESTION 5: HAS THE PROJECT 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?

A reviewer termed the planned future work (extend the fatigue testing and include studies of crack nucleation) a logical expansion of the present work, also noting that some work remains in FY10 (fracture toughness and fatigue tests). A second suggested a path involving these items: "Continue through FY11, get the report, transition the research to CAT, and terminate the project." The future work may be summed up in the following way by the third reviewer: more of the same. It would be good for the PI to tell us why he thinks the proposed path of more fatigue testing and fracture measurements should be continued. Also, it would be appropriate to inform the reader what end point he is shooting for and how the proposed path of more testing will get him there.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Resources were deemed sufficient with excellent in-kind contributions by one reviewer. A second called resources adequate.

Materials for Advanced Engine Valve Train: Phil Maziasz (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

All three reviewers seemed to agree on the relevance of this project to DOE’s petroleum conservation goal. One said materials allowing higher combustion chamber temperatures will lead to reduced fuel consumption. Another noted that high-efficiency combustion creates challenges for existing valve materials, and the third observed that the project supports 2015 commercial engine goal (improve efficiency by 20% over 2009 baseline engine) in an apparent reference to the ACE program.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

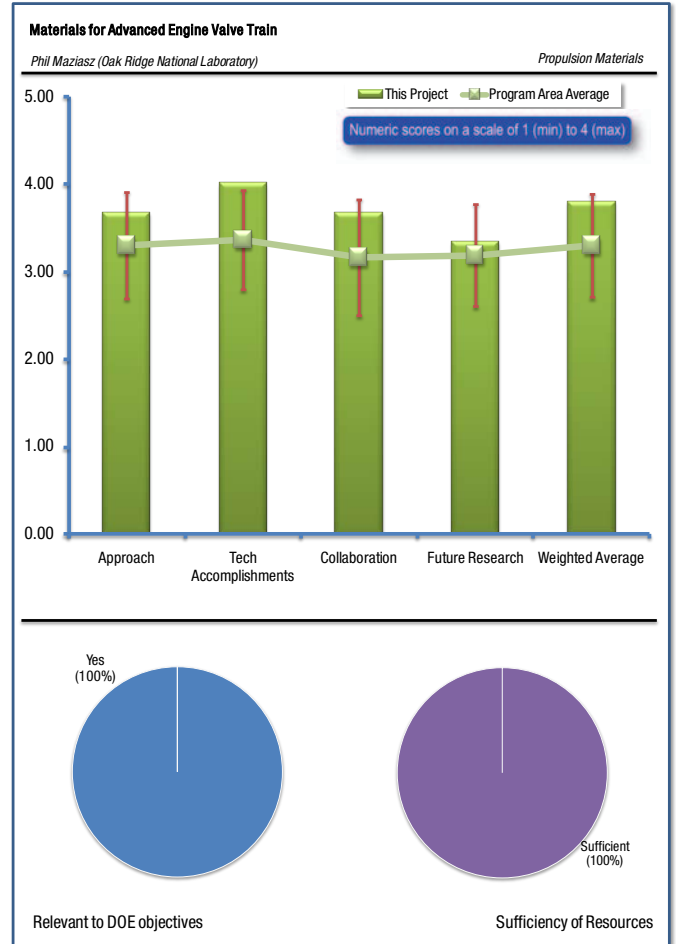
Two of the three reviewers expressed opinions on the technical approach employed in this research. One said the approach is solid and the chosen direction is quite logical. He added that one factor not touched on in the presentation was the matter of valve material thermal conductivity. “Poor heat conductivity,” he noted, “can in itself lead to higher temperatures. This can [counter any] gain in thermal resistance.” The second reviewer said the program has implemented a sound technical approach to understanding the root cause of valve wear. This reviewer also noted that the approach should entail first identifying the cause of the failure and working with component suppliers, then formulating solutions to the problem. The third reviewer listed several aspects of the approach: characterized the root-causes of high temperature wear on engine and wear-rig tested standard valves and seats; worked with seat-insert supplier to modify and test seats with more wear resistance; identified Ni-based superalloys with more temperature capability than standard 31V alloy used for exhaust valves; and worked with valve supplier to obtain prototype valves and test specimens made from new superalloys with better high-temperature capability

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said, “The program has identified the root cause of valve failure. They implemented a corrective action and validated their work on a test stand.” He called the project well managed and noted it is working very closely with its industry partner. Another said results so far indicate that the goal will be met. Implementation on the market has a high probability. The third reviewer listed a series of accomplishments: addressed critical high-temperature wear issue between seat inserts and exhaust valves for diesel engines; identified root-cause microscopic nature of wear attack for both seat-inserts and exhaust valves; used pre-oxidation to mitigate wear on seat-inserts, and solution is ready for commercialization; and used critical knowledge to select and test Ni-based superalloys with more performance at higher temperatures to further mitigate wear

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

“The whole value chain is involved,” said one reviewer. However, he went on, “there is not much evidence of interaction provided. Suppliers are involved as suppliers and not so much as partners.” A second reviewer cited strong collaborations with the team’s



industry partner. The third reviewer said the project lead is working closely with Caterpillar, their valve seat supplier, and valve suppliers throughout the project.

QUESTION 5: HAS THE PROJECT 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?

“This program seems to be set for a handoff to the industry partners,” according to one reviewer, who noted that more materials are to be analyzed. Another noted its sharp focus in its final phase, and the likelihood that it would most likely finish successfully. The third reviewer reiterated the proposed future work from the presentation: Caterpillar will continue to rig-test new prototype valves, while ORNL will continue creep-test specimens of new Ni-based superalloys; tested prototype valves and creep specimens will then be characterized and analyzed at ORNL; and engine-tests of the durability of modified seat-inserts and upgraded exhaust valves will then lead to commercial production.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Comments included that the budget and results are in balance, and all deliverables met.

Compact Potentiometric NO_x Sensor: Dileep Singh (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

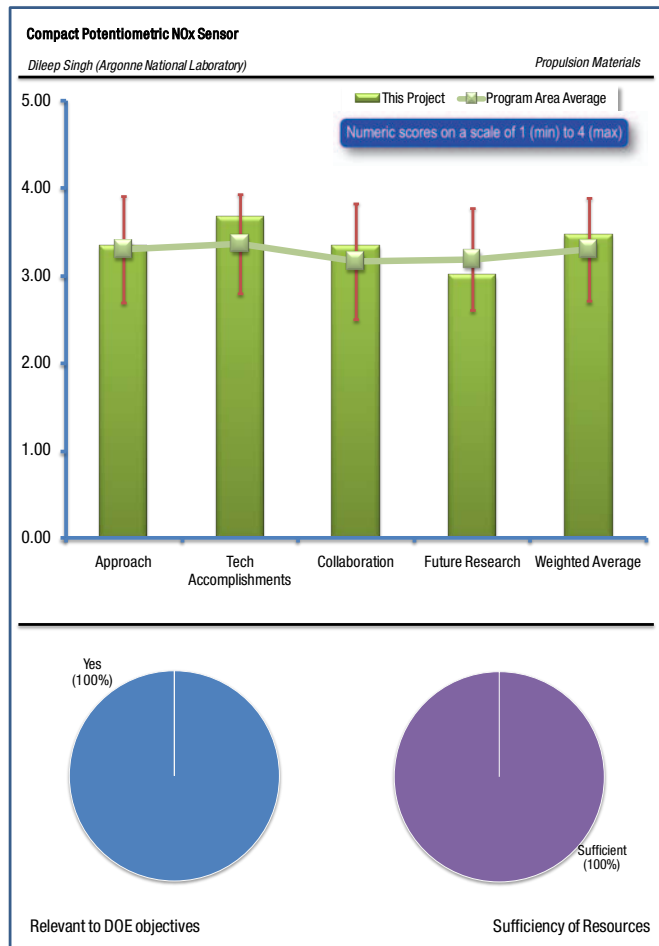
All three reviewers agreed on the relevance of this project to DOE’s petroleum conservation goal. One called NO_x sensors “critical in emission control in diesel engines; without the sensors the energy efficient benefits of the diesel engines cannot be realized fully.” A second, describing the goal of the project as development of a compact, reliable, inexpensive NO_x sensor that is amenable to mass production, said this will enable efficient combustion. The reviewer also said that the final goal is to optimize operation of vehicle combustion system that will increase fuel efficiency and reduce emissions. The third, using very similar words, said accurate, durable and economic exhaust gas composition sensors can enable close control of combustion, which can improve both engine fuel efficiency and environmental compliance. NO_x sensors, he went on, would be especially valuable in this regard, as NO_x is a key indicator of combustion behavior, a criteria pollutant and a key contributor to photochemical smog.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said basing the NO_x sensor on an oxygen sensor has an enhanced payoff. In this case, O₂ sensing is key to control of three-way catalyst emission control systems and NO_x sensing is also broadly applicable. Another reviewer was interested in technology(ies) in use for this purpose in Europe for NO_x sensing and would have liked to have seen this topic addressed: this reviewer noted that the work is modifying the current sensor to measure NO_x. The third reviewer quoted the approach description from the presentation: first develop a high-temperature oxygen sensor and subsequently modify it to sense NO_x concurrently; sensor design is based on relatively simple and well-known electrochemical principles; develop high temperature plastic joining technology to join the YSZ sensor components to produce a leak-proof package; using appropriate filter(s) and sensing materials, modify the oxygen sensor such that NO_x concentrations are measured; and conduct extensive tests to validate the performance of the sensor.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer listed the technical accomplishments as demonstrating the feasibility of the sensor technology and testing the sensor for performance. The other also listed accomplishments, highlighting these: based on YSZ ceramic, a basic sensor package design developed; using the sensor package design, an oxygen sensor with an internal reference developed and demonstrated; modifications made to the basic oxygen sensor design to sense NO_x; modified oxygen sensor design has been demonstrated to sense NO_x; and performance of NO_x sensing has shown excellent sensitivity, resolution and long-term performance



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

“Various participants in the supply chain are involved,” said one reviewer. A second reviewer cited “excellent collaborations” with three industry partners (Marathon Sensors, McDaniel Ceramics, and Integrated Fuel Technology).

QUESTION 5: HAS THE PROJECT 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?

“Follow-on work on sensor development for other exhaust gas species is ambitious and potentially very valuable. Multi-species sensors could have specific applicability to unconventional combustion systems, particularly low-temperature combustion regimes,” according to one reviewer. Another asked, “How long will it take to develop a new, electrically conducting ceramic? What is available in the market now?” The third reviewer listed future work: develop electrically conducting ceramics electrode and evaluate its electrical properties and joining characteristics with zirconia; include the ceramic electrode in the sensor package design and fabricate sensor; develop strategies to include CO and CO₂ sensing on the current sensor platform; initiate discussions with OEMs for technology demonstration and eventual transfer of technology; and need to study long-term durability of the sensor under field or engine operation conditions.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No reviewer offered a comment on this question.

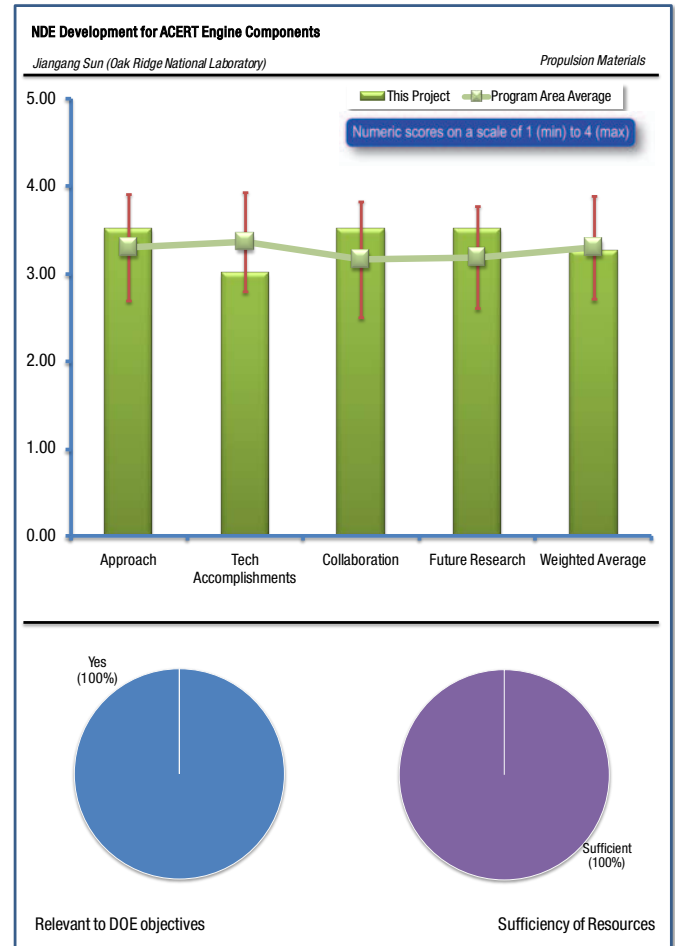
**NDE Development for ACERT Engine Components:
Jiangang Sun (Oak Ridge National Laboratory)**

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Two reviewers agreed that this project was at least indirectly relevant to the fuel conservation goal established by DOE. One said the work indirectly supports objective via development of rapid, nondestructive evaluations of surface properties of engine components. The other felt that the relevance here is one of being more of an enabling technology than a direct link to a process that can materially improve engine efficiency. NDE methods will always be valuable, provided they are accurate and easy to use. The focus here on developing NDE methods applicable to thermal management components, structural components, etc. is well placed. But the PIs should establish a greater link with petroleum displacement, and how much of a displacement, in their future work. The third reviewer pronounced himself unsure of the project’s relevance. The reviewer read the entire briefing twice, coming to two different opinions on what the presenter intended to convey: 1) the project thrust is NDE development for Thermal Barrier Coatings or, the reviewer believes, paint for vehicle exhaust systems; or 2) the NDE is for a TBC internal to the exhaust system. The presentation needs to clearly indicate what a TBC is and what NDE is being considered to test that TBC.



QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer stated that the team investigated current methods of nondestructive evaluations focusing on thermal barrier coatings. Efforts covered as-processed, thermally-cycled and engine-tested components. A variety of substrates and test methods were investigated. The second reviewer noted that they cannot argue the technical approach. Their confusion is probably in the definition of TBC. Technically, what TBC? Or will the NDE be so generic that it could be used to test any TBC? The final reviewer said that the PI includes this statement in his presentation: “By 2015, develop supporting materials technologies to improve heavy-duty engine efficiency to 50% while meeting emission standards (Goals from Multi-Year Program Plan).” However, this seems to be just a boilerplate statement lifted from another source. Precisely how the present study ties into this statement is not clearly developed in the proposal. In future presentations, the PIs should endeavor to draw connections with broader goals in a more logical way, showing how what they propose fit intimately with these broader goals. The approach based on thermal imaging and optical scanning methods is appropriate. The list of methods under development is impressive (applications for TBC damage evaluation, thermal property measurement, inspection). The methods include a laser backscattering system, optical coherence tomography, and thermal imaging. This is a lot. To assist evaluation, it would be preferable to focus on one in the presentation and provide details. As it stands, there is a lot of testing but where it leads is not clear. The rationale for the methodology is lost in the range of approaches being pursued simultaneously. The PI gives us a snapshot but the rationale is lost, and the reviewer is left with the thought of “what have we learned and how can the results be generalized?”

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer noted the development of test stands and fixtures, the thermal cycling of thermal barrier coatings and the optical and thermal imaging. The second stated he was able to offer no input, from the briefing. The third observed that a lot of testing is reported. However, interpretation of results was somewhat lacking. The PIs should step back and evaluate their own work. They should endeavor to extract cross-cutting principles from their observations. In the absence of doing this, what results from the approach is a collection of data that leads to uncertain conclusions, or no conclusions at all. Since 2007 when this project began, we have to evaluate what has been learned. The answer is elusive. Yet, the PIs have done some good work (e.g., a patent was issued in 2009 so there is substance to their work). They should also be encouraged to publish their work in journals as contrasted to conference proceedings where the latter is often of a lower standard and will not require as much thought in preparation. This effort will force them to scrutinize and critique their own work in greater detail.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said that the collaboration among ORNL, Cat and ANL is good, bringing together a range of relevant expertise. Collaborations with SUNY, Harvard and NASA, however, he felt are not described in detail: the PI mentions efforts in these collaborations to “evaluate and validate thermal imaging technologies for TBC characterizations and NDE,” but where this would be done among those listed, who would do it and how the work would be paid for are not discussed. The substance is lacking. A second reviewer noted Caterpillar and ORNL as collaborators, as the technology is appropriate for only diesel engines at this time. They suggested another diesel engine builder (Cummins) as a possible collaborator, although he recognized that, as one of Caterpillar’s competitors, it might not be an appropriate choice of industry collaborator. The reviewer asked if this is a test, could it be used industry-wide? And, should it be considered as a standard NDE test method by ASTM, etc.? The third reviewer deemed there to be a suitable team of partners and technology transfer collaborations. Partners include Caterpillar (industry) and Oak Ridge National Laboratory. Technology transfer is being assisted by Stony Brook, Harvard, and NASA to assist in evaluation of thermal imaging technologies for the barrier coatings.

QUESTION 5: HAS THE PROJECT 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?

The project plan, said one reviewer, suggests successful completion in FY2011. The second reviewer spoke about work that will continue with the thermal imaging methods and plans that are to develop X-ray and ultrasonic techniques to complement the thermal imaging. The third reviewer summed up the future work as “more of the same” (i.e., “Continue development of thermal imaging methods...”). The plan for the future is not well developed in terms of what it is going to lead to. The reviewer did not get a sense that much thought has been put into the future plan. For example, the PIs state they will “Investigate NDE methods for thermal recovery materials”: are not they doing that already? If they want to “Develop x-ray and ultrasonic imaging methods for inspection of joint components,” it seems that is what they have been doing for the past three years.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers essentially agreed that “the budget of \$200,000 seems reasonable,” as one put it, although he would have liked to see a financial contribution from the industry partners. The other reviewer regarded the funding as sufficient, and he, too, noted a lack of indicated cost sharing.

Surface Texturing for Friction Control: George Fenske (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

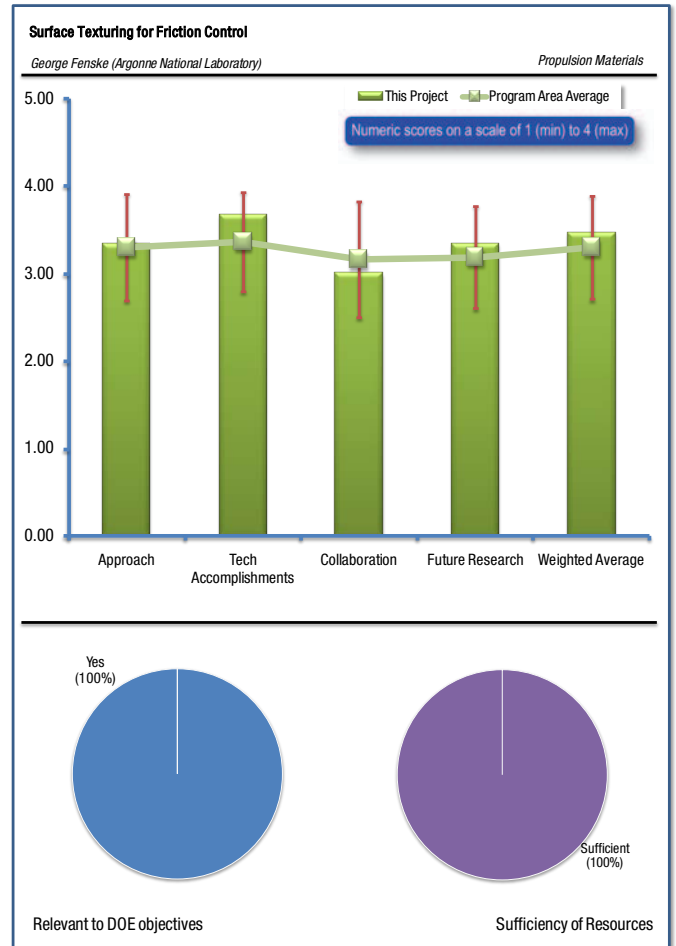
All three reviewers stated their belief that the project is relevant to petroleum conservation, succinctly and in very similar language. One said: “Basic friction reduction improves vehicle and power train efficiencies.” The second said that basic friction reduction improves vehicle and powertrain efficiencies. The third observed that friction reduction will improve efficiency and translate to fuel savings and emission reduction.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

The first reviewer observed that the set up offers a fundamental understanding of lubrication: the approach is logical for fundamental friction analysis. The second observed that the chosen approach is based on evaluating various surface texturing methods for given application. Since surface texturing is already in use, a more elaborate literature study should be integrated in the project to be able to build on already achieved results. It would also be an opportunity to take oil viscosity as a variable in this project. If a low viscosity oil provides sufficient lubrication, this in itself would lead to improved fuel efficiency without a reduction in frictional forces. The third reviewer listed several aspects of the approach: mechanistic study of the impact of surface texture will be studied by measuring lubricant fluid film thickness and friction under different lubrication regimes; application specific evaluation will be evaluated initially with appropriate bench top test rig. Eventually, component testing will be conducted on optimized textured surfaces; and the impact of surface texturing on basic tribological failure mechanisms will be evaluated using appropriate testing, surface and subsurface analysis and characterization.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer felt it was difficult to assess accomplishments and progress as the project is in its early stages. The second reviewer observed that the initial accomplishments are understanding where and why this surface preparation will reduce friction. The tests being conducted will help define the appropriate use of this surface preparation. The third reviewer listed a number of technical accomplishments: lubricant fluid film thickness measurement with optical interferometry; comparison of fluid film thickness for dimpled and undimpled surfaces; application specific journal bearing benchtop testing to assess application for engine main bearing; used a conformal block-on-ring contact configuration to measure friction for dimpled and undimpled steel ring sliding against conformal steel block; and surface texture (dimples) did showed reduced friction in conformal journal bearing contact configuration test.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Two reviewers each said the only collaboration was with Northwestern University (one noting specifically that the work is on vibro-mechanical method of surface texturing with dimple) and both urged wider collaboration be sought, one suggesting industries for potential real-world applications. The third reviewer said that this program is fundamental science and the collaborators are mostly universities.

QUESTION 5: HAS THE PROJECT 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?

One reviewer said proposed future work would be outstanding when a clear picture of the state of the art was given. The second said the future work will identify technology optimization and its limitations. The third listed aspects of the future work: continue application specific tribological performance testing of textured surfaces; evaluate the impact of surface texturing on the various tribological failure mechanisms (scuffing, wear, contact fatigue, etc); evaluate the impact of surface texturing on the actions of lubricant additives in formation of tribochemical boundary films; and explore various methods and forms of surface texturing for tribological performance enhancement. This reviewer suggested that the team needs to explore potential applications in industries.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Two reviewers said the budget, respectively, was appropriate and, given that it was a new project, the initial funding of \$200,000 should be adequate. The other reviewer's comment was that most goals were met.

Friction Modeling for Lubricated Engine and Drivetrain Components: George Fenske (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The reviewers generally agreed on the support of this work to DOE objectives. Engine and drivetrain friction is a major (and poorly understood) contributor to energy losses and hence a potentially lucrative area for mechanical efficiency improvement. This would have direct benefits in fuel consumption reduction. Heretofore, driveline friction reduction has depended on straightforward manipulation of hydrodynamic lubrication conditions (e.g., reduced-viscosity engine oils). Understanding of boundary and mixed-film lubrication has lagged behind. The second reviewer said that friction is one of the major contributors to the reduced efficiency (others being drag and low temperature operation); understanding the friction will benefit by providing pathways to overcome this problem.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer called the project goal ambitious, but said the approach was excellent. The other said the significance of the project goal is well explained. He went on, however, to inquire about the current state of knowledge. Friction has been studied for a long time and many theories and models exist; what is the significance of this particular approach?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

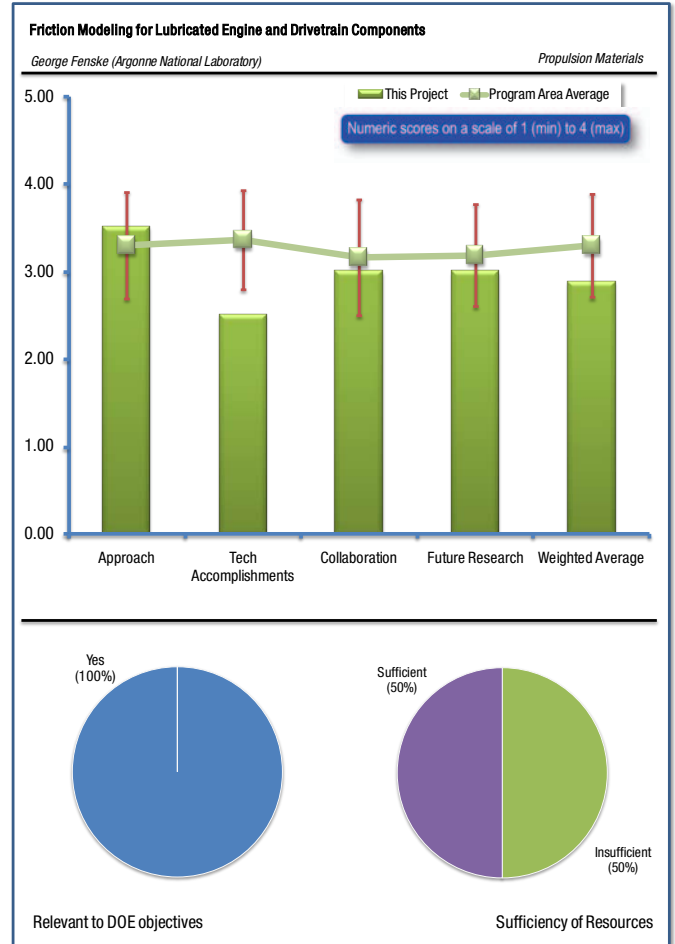
One reviewer felt it would be unrealistic to expect significant technical accomplishments, given that the project was in its early stages at the time the presentation was made. The other reviewer, acknowledging the difficulty of modeling a mixed mode since data is not available to validate predictions, felt it would be beneficial if efforts are made to confirm the model.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer could not find fault with the choice of Castrol as an industrial partner in this project. However, driveline tribology has received significant attention in the past decade or two. There must be firms with the specialized background experience and analytical capability to assist this project. Have any been sought out and their interest in collaborating solicited? The second reviewer noted that a material supplier and university are involved.

QUESTION 5: HAS THE PROJECT 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?

Only one reviewer offered an opinion on this question, saying development of test protocols is a good idea.



QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

In this review category, too, a single reviewer commented, to the effect that “This appears to be a rather modestly funded project in view of its potential payoff.”

Ultra-Fast Chemical Conversion Surfaces: George Fenske (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

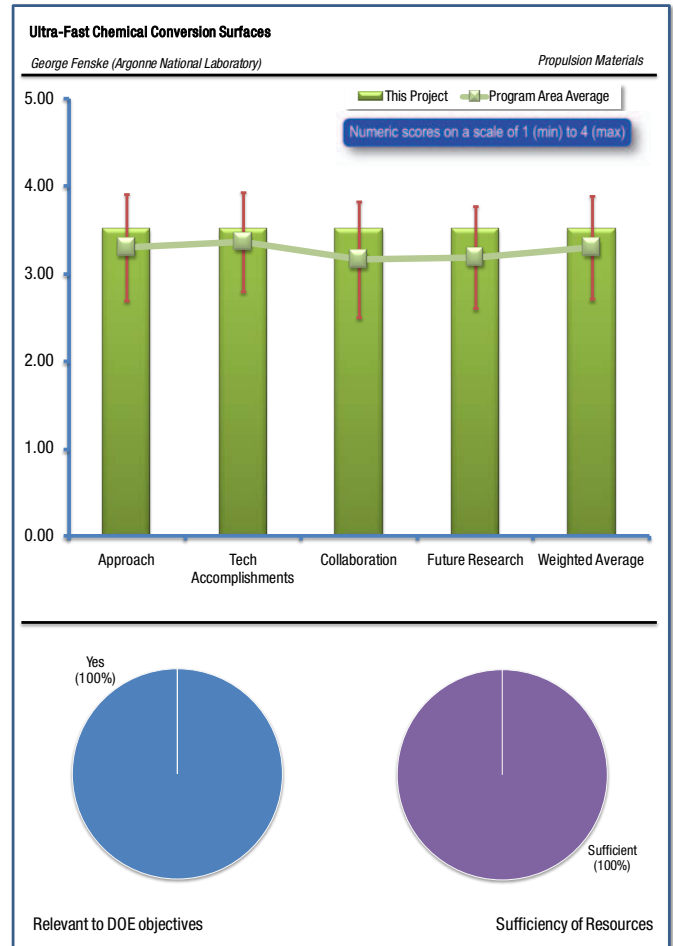
This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

Only one of this project’s two reviewers commented, saying the project indirectly supports objective by developing higher-durability and lubricity components that can operate under severe operating conditions.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

“The approach includes go/no go decision points, which is an excellent idea,” according to one reviewer. He added, “Approach is a step-wise progression of process optimization/lab studies.” The other reviewer said that if the work is successful, this may have direct applicability to an end item and the consumer market. From purely a business viewpoint, any increase in durability results in a corresponding increase in the item service life and an indirect increase in overall cost of the end item. The recommendation is to focus on one or several specific items that could benefit from such a process. The concept is to improve specific item durability while holding costs.



QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer noted that the researchers were able to boride complex geometry parts with coatings twice as hard as carburized/nitride surfaces. Excellent wear test results were achieved versus uncoated specimens. This is good precursor work. The second reviewer wondered if the boriding process could be scaled up for mass item production, noting that no information was included in the presentation on this subject. The reviewer also noted that the collaboration slide indicates boriding examples for engine parts. Could the boriding process be used for other vehicle applications; i.e., brake pistons, brake shoes, or brake drums? The question is intended to increase brake service life.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The project partners were characterized by one reviewer as a “quality team that includes Bodycote North America, Burgess-Norton, Mahle and NASA.” The other reviewer mentioned several private industry organizations and NASA participating in this effort.

QUESTION 5: HAS THE PROJECT 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?

The project demonstrated very thick and hard borided layers on test engine parts, according to the first reviewer. The project is currently on a five year timeline. Due to early boriding successes, there is potential for project acceleration. This commenter suggests

a project review with the intent of accelerating this effort. The second reviewer anticipates initiating boring of actual engine components – a good next step. Also, the focus on developing quality control will aid in deployment of the technology.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer felt the project funding appears sufficient for the project milestones. If the project is accelerated, there could be a project savings in the last research year. The other reviewer noted the 25% contractor cost share and said the project looks on target.

Catalyst Characterization: Thomas Watkins (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The two reviewers commenting on this aspect of the project seemed to believe it relevant, at least indirectly, and with some qualifications. One said that more efficient catalysts can lead to improved efficiency. At the beginning of this project in 2002, this was certainly true. After eight years this may not be so clear anymore. A reflection on this is needed. This reviewer also said, however, that the project focus was on ammonia slip and that efficient ammonia decomposition would allow for a higher urea dosing level, making the SCR more efficient. The reviewer noted that for the operator, urea is also a part of the cost of ownership; this should also be considered. The second reviewer observed that lean burn engines generally will require the use of an SCR and perhaps a DPF. Some control processes such as DPF regeneration may cause the stored ammonia on the SCR to prematurely release. At this time ammonia is not regulated, but ammonia release would certainly be regulated if widespread slip was encountered.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

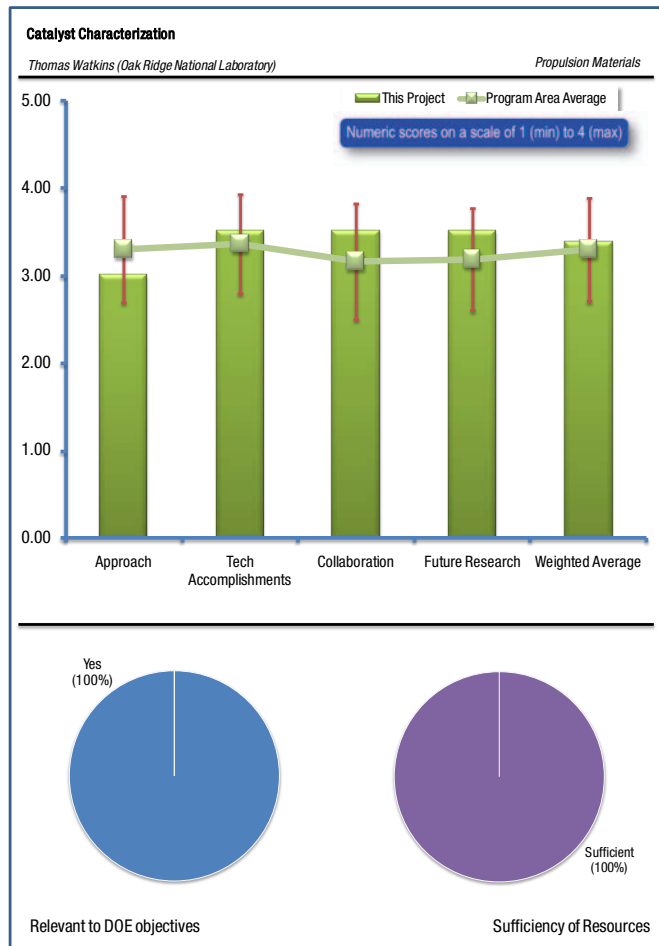
In the first commenter’s view, this program is set up to provide the material understanding associated with ammonia slip catalysts: this basic knowledge will be critical in designing these catalysts in the future. The second reviewer said that the study of the AMOX material in various stages of degeneration is a good approach to define a life prediction model, but how to come to an improvement is not well described.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer, acknowledging the delay in materials deliveries through 2009 (due to the 2010 heavy-duty engine product launch), said “progress this year is good.” The other said that X-ray photoelectron spectroscopy seems to be a good tool to analyze the ammonia slip catalysts. Analyzing the catalyst coatings will help identify changes associated with aging. Ultimately this should lead to a better understanding of the catalyst formulations.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

“Collaboration with partners seems strong,” said one reviewer. The other agreed, saying there is a close cooperation with industry.



QUESTION 5: HAS THE PROJECT 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?

One reviewer said, “The focus looks appropriate,” and called future work toward understanding catalyst aging mechanisms “critical.” Proposed future research builds on past work, the other said, but a clearer statement on the way toward improved performance of the materials is lacking.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer stated the project is meeting goals: the second offered that the mentioned budget must be sufficient for the mentioned deliverables in 2010.

Ultra-High Resolution Electron Microscopy for Catalyst Characterization: Larry Allard (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The first reviewer said that catalysis is helpful in reducing the harmful emissions in diesel engines; understanding the reaction will help in developing new materials for catalytic converters. The second noted that catalysts are in universal use for engine exhaust aftertreatment and their advent is critical to permitting engine calibrations that optimize fuel consumption. Catalysts are also crucial to the practicality of fuel cells and to fuel processing and refinement. All these attributes contribute strongly to making catalysts crucial to petroleum displacement. The third offered a tentative yes to supporting of objectives, but PI should be clear on the applicability of this research to the stated goal. Assume new high efficiency engines operate in a regime harsher than current catalysts.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

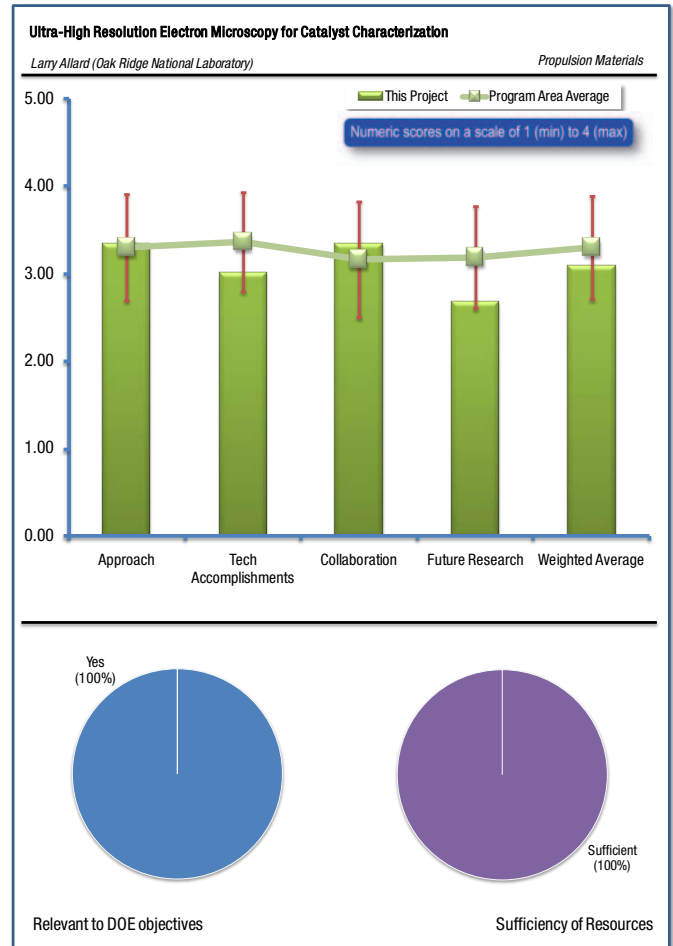
The approach was termed outstanding by one reviewer, referring to the use of electron microscopy to elucidate catalytic processes that take place at the atomic level. The second reviewer said, “This is a characterization project and the approach is good.” This reviewer also highlighted the fact that new test methods and infrastructure are being developed to study catalytic reaction in-situ. The third reviewer, noting the equipment acquisitions of the lead organization, said the approach struck him as “a solution set looking for a problem via analysis of catalysts. The PI should be clearer in his methodology and rationale.”

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Two reviewers commented. One cited the building and commissioning of instruments to study the reactions and various additions to the microscope and their readiness for use. The other reviewer said the team has made progress in holder and other apparatus developments.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Slate of academic, institutional and industrial collaborators is extensive, according to the first reviewer, suggesting that collaboration and coordination are good to outstanding. Presentation, however, provides insufficient information on breakdown of project responsibilities among collaborators to permit an “outstanding” rating. The second comment was that there was a wide stable of academic, industry and other government agencies in the collaborations. The final review comment was that basic researchers from universities, federal labs as well as applied personal from industries are involved in the project.



QUESTION 5: HAS THE PROJECT 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?

Only one reviewer commented on this question. The program will continue with its development of in situ gas reaction and double-tilt heating capabilities for catalyst reaction studies. The team will initiate work with some more industry partners, which is advisable.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The sole comment was that there was some cost sharing, but the reviewer did not know if the equipment budget is sufficiently large on this effort to displace scientific and technical lab personnel.

Low-Friction Hard Coatings: Ali Erdemir (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

The two reviewers agreed the project is relevant to DOE goals, but one termed it “a continuing project with direct industry and DOE relevance” and the other felt it “indirectly supports objective by increasing durability and performance of high-efficiency engines.” The latter commenter said that the PI should be clearer in stating how this project supports the goal.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Concerning the approach, only one reviewer offered a comment, commending the “good use of go/no go gates” and a “logical progression of feasibility tests leading up to field studies/durability analyses and full-scale production investigation.”

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

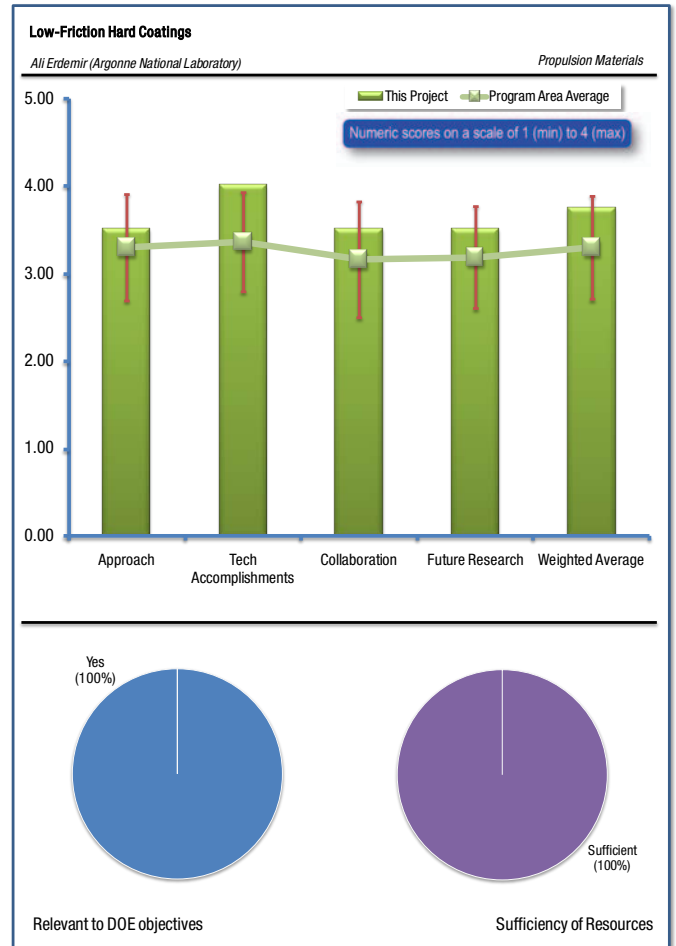
One reviewer noted that private industry is pursuing licensing agreements for commercial scale-up and production, observing the work has direct industry applications. The other stated, “Excellent accomplishments so far; won R&D award and work is underway to commercialize the technology.”

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

“Well-balanced team of government, industry and original equipment manufacturers and parts suppliers,” was one reviewer’s assessment of collaboration and coordination with other institutions. The other noted that “Two private industry companies are interested in licensing from Argonne.”

QUESTION 5: HAS THE PROJECT 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?

One reviewer considered that future work builds upon initial success and will continue development with performance evaluation in fired engines. He also cited plans to reduce production costs by reducing coating thickness. The second reviewer notes that the briefing suggests the validation of optimized coating durability and performance under fired conditions and piston ring product specific bench top and field studies in a fired engine could be combined or accelerated. Is this possible?



QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A single reviewer commented on this question, saying the effort has shown good progress with a smaller amount of funding than usual for these projects. He was unsure of cost sharing, noting indications in the presentation that the team is getting some in-kind equipment from a manufacturer.

Residual Stress Measurements in Thin Coatings: Dileep Singh (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

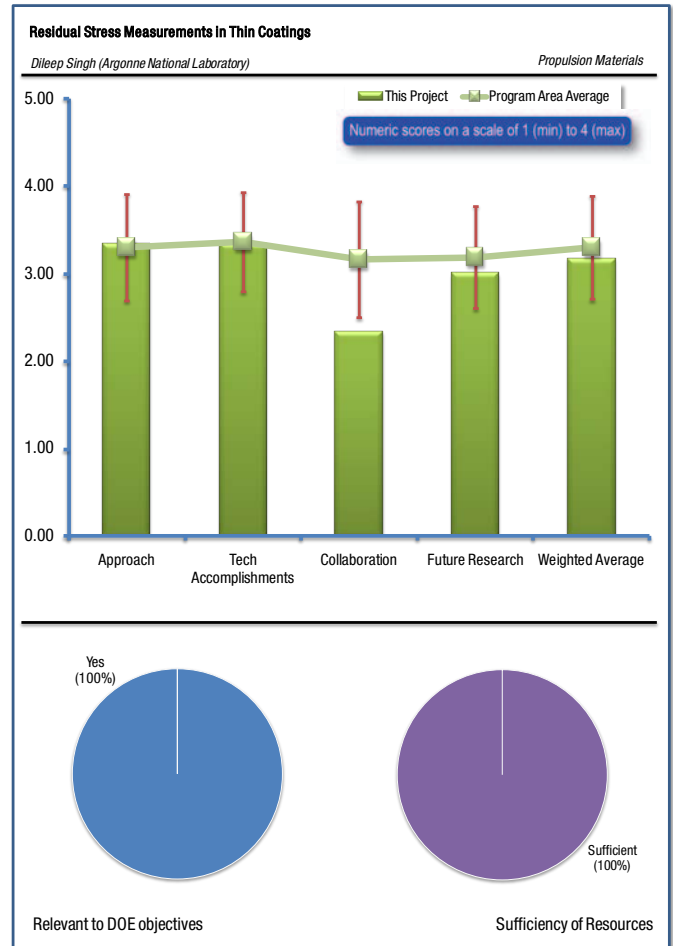
All reviewers agreed that this project supports and is relevant to DOE’s petroleum conservation goal. A reviewer stated that this topic reduces petroleum use by reducing friction. Another observed that internal friction within the drive train of a vehicle contributes significantly to the fuel consumption. So the development of low frictions coatings is beneficial for fuel consumption. For the automotive industry reliability is important so control of quality is important; this project will contribute to this. The final reviewer said that the purpose of this project is to develop and measure depth-resolved residual stress in thin coatings to extend component life and reduce life-cycle costs. The final goal is to minimize friction and wear in vehicle drive trains and engine components that can significantly reduce parasitic energy losses, and consequently, will result in petroleum displacement.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

“High-energy X-ray looks like a good tool to evaluate super-hard coatings,” one reviewer said, adding that “process of evaluating and testing these coatings will give the techniques value with [the] vehicle industry.” A second reviewer termed the approach straightforward; however, it looks that new technology has entered the project as progress is missing on the FIB experiments. The third reviewer enumerated several aspects of the approach: develop/refine high energy x-rays for profiling residual strains in thin coatings by measuring the change in the lattice parameter of the coating constituents; deposit low friction high wear resistance coatings and profile residual stresses; develop scratch-based techniques to measure hardness, fracture toughness, and adhesion energy of thin coatings; and relate residual stresses, mechanical & tribological properties, and processing to coating durability. Develop scratch-based techniques to measure hardness, fracture toughness, and adhesion energy of thin coatings.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer acknowledged the milestones listed in the presentation: X-ray based techniques developed and applied for residual stress measurements; stresses correlated to processing conditions (deposition rates, power and time) for MoCuN, TiC, and ZrN coatings; adhesion energy for MoCuN coated samples measured; and nano-indentation technique has been demonstrated for characterization of coating. Another cited building the evaluation techniques to examine material coatings as being able to generate positive feedback from industry. Understanding adhesion energies will truly assist in the development of low friction coatings. One of the most important issues is a good correlation between de measured residual stresses and the tribological performance, according to the last reviewer. Once a good correlation is created it is clear that the barriers are overcome.



QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

There doesn't seem to be strong collaboration with the coating community yet, in the first reviewer's opinion. However, the basic science is good which should produce more external interest. The second reviewer listed working with Borg Warner, Galleon International, and Hauzer Techno Coatings, Inc. as his response. The third reviewer said discussions have to start with industrial partners to collaborate, as is mentioned in the presentation. This was also mentioned in the 2009 presentation, so little progress is made.

QUESTION 5: HAS THE PROJECT 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?

The future work plan is good, one reviewer said, but more industry input is needed to direct developed techniques to the most promising low-friction coatings. A second reviewer agreed in part, citing a clear, defined path forward building on past achievements. The third reviewer listed several points regarding the future work: complete adhesion energy evaluations for TiC and ZrN; complete mechanical properties of TiC and ZrN coated samples for varying processing conditions; measure tribological performance for MoCuN, TiC, and ZrN coated samples; correlate the measured residual stresses in MoCuN, ZrN, TiC coatings to tribological properties and processing; and initiate discussions with coating manufacturers for collaboration. This reviewer said the team needs to explore industrial applications of the NDE method and coating system developed

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Only one reviewer spoke specifically to this question, saying "\$200,000 seems adequate for the development work." Another found "no specific information was provided." The third said the project plan is on track.

Diamond Based TE Materials: Dieter Gruen (Argonne National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 2 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One reviewer noted that thermoelectrics can be used for recovery of waste heat and result in increased efficiency. However, the other reviewer, who viewed the presentation slides without hearing the presentation or the following discussion, felt that other than a general statement of supporting DOE goals, the briefing does not indicate any direct applicability to an end item or consumer requirement. As written, this briefing suggests a continuing basic research program potentially increasing the knowledge base. The briefing needs a clear goal of support to the consumer. The accomplishments all tend to support a very basic, in-house research program investigating the fundamentals of this technology.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer felt there was insufficient detail in the presentation to permit an evaluation of the project work approach. He suspected this was due to the confidentiality requirements of a CRADA and suggested a direct conversation with the researcher. The second reviewer, on the other hand, praised a robust program that includes environmentally benign materials, in-house fabrications and research complemented by theoretical calculations.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

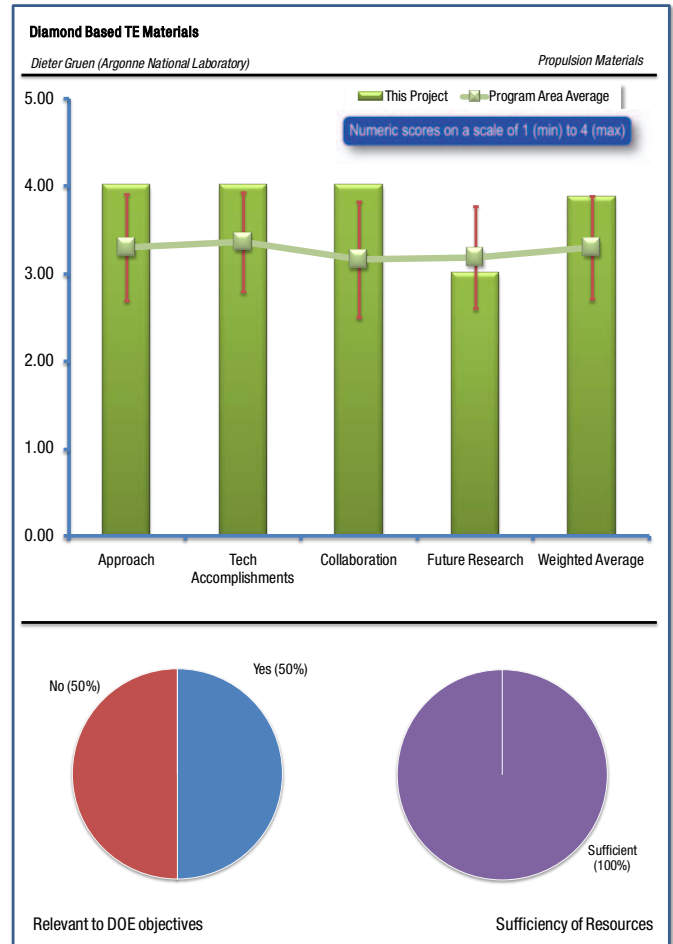
One reviewer acknowledged impressive increases in thermoelectric performance and development of in-house fabrication and test methods. The second reviewer said the accomplishments all appear to be in-house without direct consumer application.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

In response to this question, one of the two reviewers noted the wide spectrum among team participants of government agencies, international, academic and industry. The other reviewer was under the impression the project elicited only academic interest with no private industry participation.

QUESTION 5: HAS THE PROJECT 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?

One reviewer felt there was insufficient information for comment, but observed that the presentation materials suggest this project is either exploring areas not previously researched or is exploring a related or variation of an existing subject. If the former, this reviewer will agree on the need for a firm scientific foundation before proceeding to prototyping, manufacturing, etc. If the latter, better focus



on the consumer is needed. The other noted that the work is almost completed, but the team will continue to seek to increase the Seebeck coefficient by exploiting compositional changes and new fabrication techniques.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer deemed the project resources sufficient, while calling for the project to be focused and a project plan to be developed with definite deliverables and termination date. The other reviewer said the project was almost complete.

Durability of ACERT Engine Components: Hua-Tay Lin (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

All three reviewers deemed this project relevant to the DOE petroleum conservation goal. The first noted that reducing high-temperature heat losses from heavy-duty diesel engines is a straightforward means of improving their fuel efficiency (provided the energy thus saved can be effectively used). The so-called “adiabatic engine” is a long-regarded goal. The second said that allowing for higher temperatures in general leads to higher fuel efficiency. In case of the exhaust, higher temperature gases provide more energy to the turbo, making it more efficient. Testing and characterizing materials for diesel engine components will provide valuable information for improving the energy efficiency, said the third reviewer.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

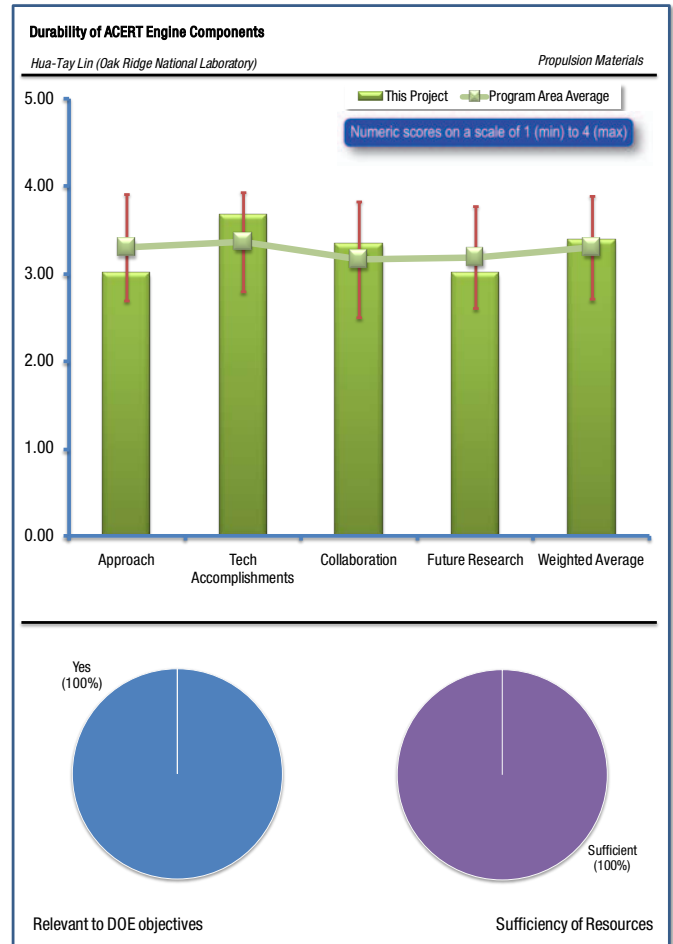
The approach employed in this work is good to very good, in the first commenter’s view. It is practical and logical and, given time, seems likely to result in a clear understanding of how durable and effective thermal barrier coatings can be applied, qualified and evaluated. To the second reviewer, the benchmarking of various valves and materials is good and will provide data for future development. The third comment was that the work had a solid approach. The strong point is the validation in the engine. Coatings can fail due to residual stresses as a result of the manufacturing process. Based on the provided information, no investigations are done in this direction. This information can be important to assess the robustness of the process.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer cited the excellent progress made in application of the coating in the exhaust manifold. Good progress is reported in the field of TiAl. The findings may prove essential for defining next steps. The other reviewer commenting echoed this prediction: “The information generated will provide the database for future material and component development. Various aspects such as material, design and process can be evaluated in the test bed.”

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

“The choice of Caterpillar as industry partner is commendable,” said one reviewer, “Cat has lengthy experience in this area (engine heat loss control). The ACERT engine, with its series turbochargers, should be responsive to reduced exhaust heat losses.” Based on researchers’ responses to questions posed at last year’s Annual Merit Review, a second reviewer said “there is evidence for involvement of a great number of parties active in the field.” The third reviewer’s comments noted mention of the fact that products from various Tier 1 and Tier 2 suppliers are being tested, however the mechanism of disseminating the knowledge to them is not mentioned. If all the information will stay with Caterpillar, it may confer an undue advantage.



QUESTION 5: HAS THE PROJECT 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?

One reviewer said the description of future work could be more specific, but nonetheless the proposed activities build on the progress mentioned in the presentation.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Funding is probably sufficient, one reviewer said, but contract duration may be insufficient to achieve maximum results. The second reviewer offering a comment on this question felt the project resources were sufficient for the materials investigation, but field testing will be challenging for the budget mentioned.

Life Cycle Modeling of Propulsion Materials: Sujit Das (Oak Ridge National Laboratory)

REVIEWER SAMPLE SIZE

This project had a total of 3 reviewers.

QUESTION 1: DOES THIS PROJECT SUPPORT THE OVERALL DOE OBJECTIVE OF PETROLEUM DISPLACEMENT? WHY OR WHY NOT?

One comment was that lightweight materials are an important component in reducing mass and petroleum consumption. Improving material cost also assists industry to sell new technologies. The second was increased heat resistance allows for higher exhaust temperatures. This opens the potential for further improvements of fuel efficiency. This potential is not mentioned; only weight savings are mentioned. However, it is a marginal contribution. The final reviewer stated that the work was to estimate the cost-effectiveness of the CF8C+ cast austenitic stainless steel in automotive applications.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

One reviewer said, “Completely analyzing the cost effectiveness of CF8C+ through the entire useful life is an excellent example of truly understanding the total cost of this new material.” He went on:

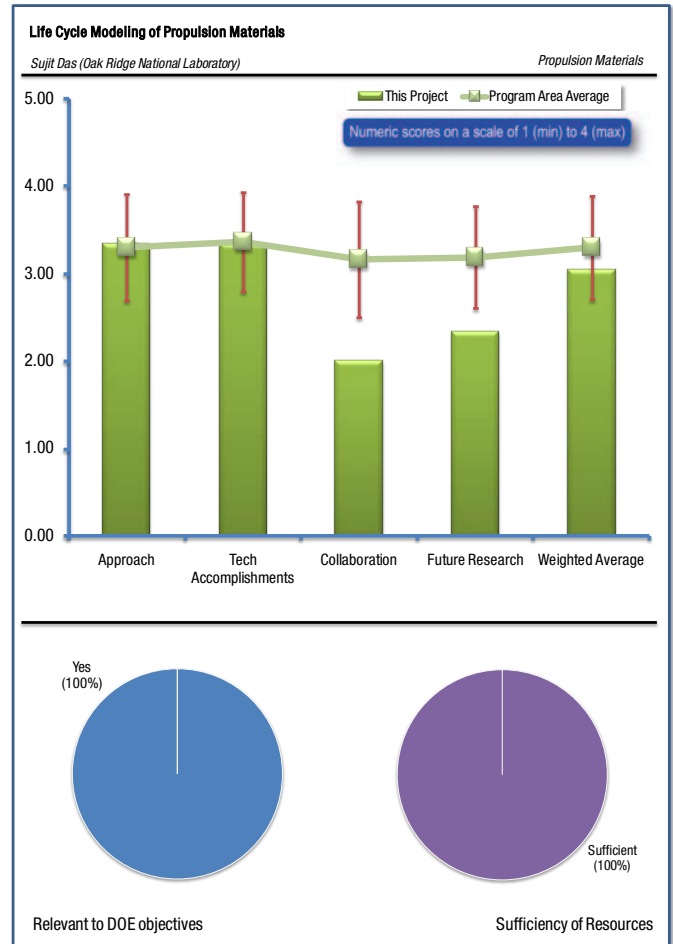
“Evaluating this material against its alternatives shows the effectiveness of this product. Correlating the material costs to fuel savings brings the overall point home.” The second reviewer said the approach “in itself is straightforward. The amount of information provided to assess the cost efficiency is limited. It should be mentioned what the expected fuel savings are.” The final reviewer listed several aspects of the approach: cost-effectiveness estimation based on a range of competing, corrosion-resistant stainless steel and nickel-base superalloys currently used in applications where CF8C+ might be used; and analysis level considered both material (per pound replacement basis) and specific component application (addressing manufacturing differences)

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Review comments included that evaluating this material against its alternatives shows the effectiveness of this product. Correlating the material costs to fuel savings brings the overall point home. Also stated was that the weight savings are limited. The total potential of the material must be stated to get a better insight in the potential gains. Also temperature limitations for mentioned alternative materials must be made clearer in the presentations. The final reviewer listed accomplishments: life cycle modeling of advanced propulsion materials was undertaken with an initial first-year effort determining cost-effectiveness of CF8C+ cast austenitic stainless steel; CF8C+ has been demonstrated successful in several high-temperature applications and so a life cycle assessment in terms of energy, economic, and environmental is consequential; and several analysis levels were considered, starting with raw material cost and ending with component cost with due consideration of fuel savings due to lightweighting.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Two reviewers said no collaboration was identified and that not much collaborating with industry was evident, respectively. The third mentioned having seen Caterpillar mentioned in earlier reviews.



QUESTION 5: HAS THE PROJECT 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?

One reviewer said the proposed future work mentions other materials as potential weight-saving materials, but these materials are not foreseen for the applications mentioned for the material CF8FC+. This could lead to a loss of focus. The other reviewer offering an opinion said “Close-out plan is set up to provide industry with the results they would need to continue the development of this material.” The third reviewer listed future work: energy savings analysis of CF8C+ cast austenitic stainless steel—ongoing; life cycle analysis of engine lightweighting in terms of downsizing vs. lightweight materials use—ongoing; liability of advanced propulsion materials in advanced powertrains such as hybrids and fuel cell vehicles; economic, energy, and environmental impact analyses from a life cycle perspective of advanced propulsion materials manufacturing technologies with an emphasis on aluminum, magnesium, titanium, and ceramics; and advanced propulsion materials’ potential in heavy-duty vehicles.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

“Resources should be sufficient for finalizing the study objective” was the sole relevant comment. Another comment offered was that the program plans look to be on target.

8. TECHNOLOGY INTEGRATION

The Technology Integration subprogram accelerates the adoption and use of alternative fuel and advanced technology vehicles to help meet national energy and environmental goals and accelerate dissemination of advanced vehicle technologies through demonstrations and education. This subprogram’s efforts logically follow successful research by industry and government and help to accelerate the commercialization and/or widespread adoption of technologies that are developed in other VT program areas. Deployment activities linked to R&D also provide early market feedback to emerging R&D.

Subprogram functions include both regulatory and voluntary components. The regulatory elements include legislative, rulemaking, and compliance activities associated with alternative fuel requirements identified within the Energy Policy Acts of 1992 and 2005 (EPACT 1992 and EPACT 2005). Voluntary efforts include demonstration of advanced technology vehicles to verify market readiness and public information, education, outreach and technical assistance efforts. VTP works with public/private partnerships between DOE and local coalitions of key stakeholders across the country (such as Clean Cities) to implement strategies and projects that displace petroleum. In addition, the annual DOE/EPA Fuel Economy Guide publication and related data dissemination efforts (required by law) are produced, along with the website www.fueleconomy.gov.

Education aids in overcoming institutional barriers to widespread use of advanced vehicle technologies and alternative fuels. Activities such as the Advanced Vehicle Competitions (EcoCAR) and GATE encourage the interest of university student engineers and engage their participation in advanced technology development.

In August 2009, the Department announced the selection of eighteen projects totaling \$400 million to purchase thousands of plug-in hybrid and all-electric vehicles for test demonstrations in several dozen locations; to deploy them and evaluate their performance; to install electric charging infrastructure; and to provide education and workforce training to support the transition to advanced electric transportation systems. ARRA-funded Advanced Electric Drive Vehicle Education activity supports educational programs to substantially reduce petroleum consumption. Activities under this program include engineering degree and certificate programs, emergency responder and safety training, consumer and K-12 educational outreach, developing and providing teaching materials, and training service personnel, vehicle mechanics, and supporting infrastructure. For this merit review, these projects were the only ones reviewed: the remainder of the Technology Integration activity was not reviewed in 2010.

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

Presentation Title	Principal Investigator and Organization	Page Number	Relevance to Jobs and Economic Development	Relevance to Technology Development	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Advanced Electric Drive Vehicle Education Program	Al Ebron (West Virginia University)	8-3	2.50	3.00	3.00	3.50	2.75	3.09
Indiana Advanced Electric Vehicle Training and Education Consortium (I-AEVtec)	James Caruthers (Purdue University)	8-6	2.80	3.40	3.40	3.60	3.00	3.34
Advanced Electric Drive Vehicle Education Program: CSU Ventures	Gary Caille (Colorado State University)	8-9	3.50	3.00	3.00	3.67	3.25	3.38
Advanced Electric Drive Vehicles – A Comprehensive Education, Training, and Outreach Program	Mehdi Ferdowsi (Missouri University of Science and Technology)	8-12	2.50	2.80	2.40	3.00	3.00	2.69

Presentation Title	Principal Investigator and Organization	Page Number	Relevance to Jobs and Economic Development	Relevance to Technology Development	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Development and Implementation of Degree Programs in Electric Drive Vehicle Technology	Ka Yuen Simon Ng (Wayne State University)	8-15	3.25	3.25	3.75	3.25	3.25	3.43
U.S. Emergency Responder Safety Training for Advanced Electric Drive Vehicles	Andrew Klock (National Fire Protection Association)	8-18	2.43	3.29	3.14	3.43	2.83	3.10
Recovery Act – An Interdisciplinary Program for Education and Outreach in Transportation Electrification	Carl Anderson (Michigan Technological University)	8-22	3.25	3.50	3.50	3.25	3.25	3.34
Recovery Act—Transportation Electrification Education Partnership for Green Jobs and Sustainable Mobility	Huei Peng (University of Michigan)	8-25	3.00	3.00	3.40	3.20	3.00	3.22
Advanced Electric Drive Vehicles	Lawrence Schwendeman (J. Sargeant Reynolds Community College)	8-28	3.00	3.50	3.25	1.50	3.50	2.51
Electric Vehicle Service Personnel Training Program	Gerald Bernstein (City College of San Francisco)	8-31	2.80	3.20	3.20	2.80	2.60	2.93
OVERALL AVERAGE			2.87	3.20	3.19	3.13	3.02	3.09

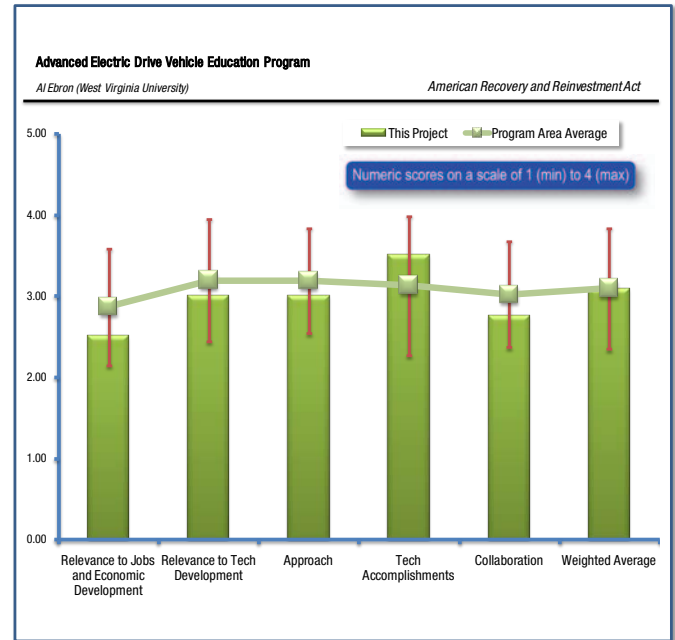
Advanced Electric Drive Vehicle Education Program: Al Ebron, West Virginia University

REVIEWER SAMPLE SIZE

This project had a total of 4 reviewers.

QUESTION 1A. RELEVANCE: IS THE PROJECT EFFORT RELEVANT TO THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA) OF 2009 GOALS: CREATE NEW JOBS AS WELL AS SAVE EXISTING ONES; SPUR ECONOMIC ACTIVITY AND INVEST IN LONG-TERM ECONOMIC GROWTH.

The first reviewer stated this project envisions a development of 17 new FTE jobs while retaining 20.5 FTE positions. With the total budget described as \$8.6 million for three years, this level of funding appears high in order to support 37.5 positions. The reviewer can't see how this project will invest in long-term economic growth. A second reviewer commented that job creation was not discussed in detail, but the numbers were provided in the slides. Education and training programs are an essential part of workforce development, but must be judged as an indirect rather than a direct contribution to recovery goals. The economic growth was anticipated to come from consumer education. Another reviewer said this project will develop in-classroom training and online information which is geared at educating first responders on the various electric drive technologies, which hopefully should help to retain jobs and also educate people about becoming trainers. The project will also educate the public about advanced transportation technologies, which will hopefully lead to larger market penetration of the technologies into the marketplace.



The final reviewer said that while the development of secondary education materials may make students “more marketable,” the fact that all students can find jobs upon graduation tends to indicate that the addition of EV and HEV technology content by itself will not increase the amount of jobs that are created. Where jobs could be created is if the tasks with EV and HEV's are considered as higher status jobs—then more students might enroll and thus fill these empty mechanic jobs. In regards to first responder training, the reviewer sees no additional jobs being created by the creation/addition of EV and HEV specific content to the first responder training curriculum. This reviewer also states in addition to the marketing of EV and HEV technologies and career opportunities, they expect such public outreach can create interest in students to pursue EV and HEV related jobs in which there could be some modest job growth potential for this activity.

QUESTION 1B. RELEVANCE: DOES THE PROJECT’S TECHNOLOGY DEVELOPMENT PLAN AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOALS OF ACCELERATE THE DEVELOPMENT OF U.S. MANUFACTURING CAPACITY FOR BATTERIES AND ELECTRIC DRIVE COMPONENTS AS WELL AS THE DEPLOYMENT OF ELECTRIC DRIVE AND ALTERNATIVE FUEL VEHICLES AND INFRASTRUCTURE? DOES THE PROJECT’S DEVELOPMENT AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOAL TO ESTABLISH EDUCATION PROJECTS THAT ACCELERATE THE MASS MARKET INTRODUCTION AND PENETRATION OF ADVANCED ELECTRIC DRIVE VEHICLES, WHICH INCLUDES LIGHT, MEDIUM, AND HEAVY DUTY ADVANCED ELECTRIC VEHICLES (EV), PLUG-IN HYBRID ELECTRIC VEHICLES (PHEV), AND FUEL CELL ELECTRIC VEHICLES (FCV)?

The first reviewer commented that they were unable to determine this as the principal investigator (PI) provided very little real detail as to the project's fundamental underpinnings. The PI spoke in the most general of terms, more about talking to people and different organizations about the effort and almost nothing about the details of the different educational endeavors. This reviewer questioned several numbers that were provided. The PI spoke of the plans to hold 98 one day or half day (depending) seminars over the three-year period with attendance estimated to be about 15 per class, training a total of 1,470 first responders. When asked if police were part of

the population, the PI said they would be invited, even though more often than not police will respond first to a highway incident before fire is ever called, yet the target population for the training is fire fighters. Moreover, when asked about the reach of the program, the PI said 200 million people will be exposed to the information through the use of Odyssey and online programs. There is a lot of space between 1470 folks being trained and 200 million people, so this reviewer needs a lot more detail.

Another reviewer stated that addressing the consumer and emergency responder barriers to widespread acceptance of AEDs should address the VT ARRA project goals of accelerating the development of U.S. manufacturing capacity. Improving automotive technician training will certainly help accelerate the mass market introduction and penetration of AEDs. One other reviewer said this project has a large consumer education/outreach component, including conducting 98 workshops, creating teaching materials, conducting the National AFV Odyssey day two times over the course of the three-year project, trainings to reach multiple audiences, etc. NAFTC has 50 national training centers, tech schools, universities and private schools that do “train the trainer” systems...as the only national group that does this, they can disseminate the training tools to get this new material out across the country. The final reviewer thought that while this project will do little to stimulate/accelerate the development of U.S. manufacturing capacity for batteries and electric drive components, it does lay down the educational underpinnings to stimulate interest in EV/HEV technology, development of the necessary repair technician infrastructure, and assist with the safety of first responders through appropriate education.

QUESTION 2. DEVELOPMENT/DEPLOYMENT APPROACH: ARE THE PROJECT’S TECHNICAL AND DEPLOYMENT MILESTONES AND SCHEDULE CLEARLY IDENTIFIED, APPROPRIATE, AND FEASIBLE, AND ARE TECHNICAL AND COMMERCIAL BARRIERS AND RISKS ADEQUATELY ADDRESSED?

The first reviewer said there was so little real detail to the presentation that this is very hard to determine. There appeared to be a number of risks such as the involvement of computer simulations by SABRE but no description of what or how this integration is envisioned was provided. There also wasn’t a picture of a proposed simulation concept or strategy. A second reviewer stated the multiple audiences that the team is targeting indicate that the project has outstanding outreach capabilities. The potential of reaching 200 million people in any sort of meaningful way seems a bit dubious, but the team has clearly thought about creating multiple pathways to reach many different audiences. This reviewer is aware that the online simulations haven’t yet been started, but careful thought must go into deploying them into schools. Firewalls, administrative hassles and hardware limitations can really cause issues. The bottom line is that it’s no simple task, but as the PI indicated, they hadn’t yet begun development on that stage. Another reviewer commented that the technical and deployment milestones and schedule are clearly identified, appropriate and feasible, especially given that some of these milestones (conducting the AFV Odyssey Day) have been done in prior years. There wasn’t much discussion about technical or commercial barriers and risks, but they are not sure how appropriate that is to this project. The final reviewer said the project seems to have a good handle on how to execute the various elements of the project to meet its specified goals within the specified budget. However, the first responder program seems to be a duplication of efforts with the NFPA project. This reviewer recommends that DOE find a way for them to work together on this project.

QUESTION 3. TECHNICAL ACCOMPLISHMENTS AND PROGRESS: WHAT IS THE OVERALL PROGRESS TOWARDS PROJECT’S OBJECTIVES AND MILESTONES? IS PROGRESS ADEQUATELY REPORTED AND QUANTIFIED (E.G., NUMBER OF JOBS, INSTALLATIONS, ETC.) AS REQUIRED BY ARRA?

The first reviewer said they were unable to determine the rate of progress of overcoming barriers. Two other reviewers stated the project seems to be making good progress at implementation and seemed right on target. The last reviewer commented that given this is a three year project, they have already done a good job getting certain aspects completed: the development of the advisory committee (this group has already had meetings) and are well on their way in developing curriculum and training tools. The slide presentation spoke to being 9% complete in meeting the project objectives, and it seems likely that they will be able to accomplish their overall goals during the three-year period.

QUESTION 4. COLLABORATIONS/PARTNERSHIPS: DOES THE PROJECT TEAM EFFECTIVELY USE COLLABORATIONS/PARTNERSHIPS WITH REGIONAL, STATE, LOCAL GOVERNMENTS, INDUSTRIAL, COMMERCIAL, UNIVERSITY, RESEARCH ORGANIZATIONS, AND SIMILAR ORGANIZATIONS TO ACHIEVE ITS OBJECTIVES?

The first reviewer stated that the PI cited a number of collaborative partners, all of whom are intimately familiar with the automotive industry, and many have experience with the electric vehicle/battery power industry. Another reviewer thought the collaborations and partnerships are where this project really was the strongest. This is a stupendous list of collaborators being incorporated into the project appropriately. One reviewer commented there are a number of partners involved in this project which will help to ensure its success. The final reviewer said the project seems to be well leveraged with significant cost share and a good cross section of partners that have the ability to significantly add value to this project.

PROJECT STRENGTHS

The first reviewer said that presently the concentration on first responder training is good, but the details of how they really intend to do this remain clouded. Another reviewer stated there was an abundance of partners. There was also a good approach of developing a full package of everything from emergency responder training to consumer education to technician training. One reviewer commented that the PI did a good job of outlining the goals and objectives of the project. It appears that they will be able to meet their goal of reaching over 200 million people through all of the activities in this project, including education and outreach activities, safety training and recruiting sites for the National AFV Odyssey. Collaborating with numerous project partners is also a project strength. Nearly 100 training and workshops will be completed through this session. The final reviewer said the project seems to be well organized, leveraged, and supported by a good portfolio of partners.

PROJECT WEAKNESSES

The first reviewer said “talk about smoke and mirrors, this project has a lot of it.” The reviewer was troubled by the fact that Sabre is going to develop a simulation, but fails to give details as to what that really means. When asked about how much “hands-on” would be part of the one day or half day training, the PI said about 10%. First responders are hands-on people – they prefer to learn by doing and not sitting through a college type lecture. Hands-on should be no less than 50% of the course, and it can be done with a little thought or imagination. Another reviewer stated there is possible overlap with other projects if the PIs don't talk soon. The reviewer is just not sure the team knows what's involved with online simulations. One reviewer commented their only concern about this project is the degree to which it is creating *new* information, as opposed to simply updating the training curriculum that has been developed over the years by the National Alternative Fuels Training Consortium. Assuming vehicle technologies are continually evolving, then the need to review/update existing training materials is very relevant. The final reviewer said the first responder element of this project is redundant to the efforts being conducted by the NFPA.

SPECIFIC RECOMMENDATIONS

The first reviewer said that a good deal of attention needs to be paid to this program. The details of how and what they intend to do, even from a conceptual perspective, should be demanded by DOE. Their numbers, in terms of expenditures and return on investment and outreach, have no seeming cohesion. The reviewer recommended asking them to provide the details of how they intend to proceed within 90 days, and the answers are not satisfactory this reviewer suggested terminating funding. Two reviewers commented that this is one of several projects addressing emergency responder training. The project needs to coordinate its first responder EV/HEV curriculum development efforts with those being conducted in the NFPA project. In addition, EERE is developing open source technology that may offer a cost savings as this project begins to develop its online simulations.

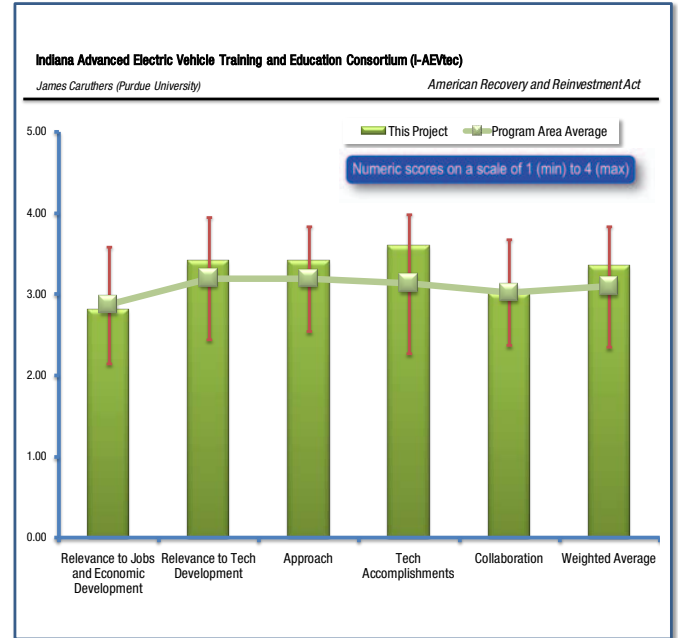
Indiana Advanced Electric Vehicle Training and Education Consortium (I-AEVtec): James Caruthers, Purdue University

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1A. RELEVANCE: IS THE PROJECT EFFORT RELEVANT TO THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA) OF 2009 GOALS: CREATE NEW JOBS AS WELL AS SAVE EXISTING ONES; SPUR ECONOMIC ACTIVITY AND INVEST IN LONG-TERM ECONOMIC GROWTH.

The first reviewer said the project directly supports the ARRA 2009 goals to create new jobs and save existing ones in advanced transportation electrification. The project provides 28 new courses for EV education and training and designs and creates new EV certificate programs. Collaborations with industry will provide strong pipelines for students to local and national jobs in the future. Three reviewers stated that no measurable information provided that directly supports job growth. One of those reviewers said that educational efforts clearly support a growing industry and mention of training at Delphi suggests potential for job retention. However, this tie should be strengthened, at least in the presentation. Another reviewer also noted that the PI’s response to a question indicated that the project work could result in adding a few positions. While there are important benefits, e.g., improved economic competitiveness, associated with better educated engineers and well-trained technicians, it is difficult to establish a direct link between a project like this and specific job-creation benefits. The last of the reviewers to comment said that no information was provided for job growth, and also said please develop a plan to track students that graduate from the program and go into industry. The final reviewer stated that by educating students in electric vehicle technology, the field of engineering in electric vehicle technology expands and creates a greater opportunity for new ideas and inventions to spur more jobs.



QUESTION 1B. RELEVANCE: DOES THE PROJECT’S TECHNOLOGY DEVELOPMENT PLAN AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOALS OF ACCELERATE THE DEVELOPMENT OF U.S. MANUFACTURING CAPACITY FOR BATTERIES AND ELECTRIC DRIVE COMPONENTS AS WELL AS THE DEPLOYMENT OF ELECTRIC DRIVE AND ALTERNATIVE FUEL VEHICLES AND INFRASTRUCTURE? DOES THE PROJECT’S DEVELOPMENT AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOAL TO ESTABLISH EDUCATION PROJECTS THAT ACCELERATE THE MASS MARKET INTRODUCTION AND PENETRATION OF ADVANCED ELECTRIC DRIVE VEHICLES, WHICH INCLUDES LIGHT, MEDIUM, AND HEAVY DUTY ADVANCED ELECTRIC VEHICLES (EV), PLUG-IN HYBRID ELECTRIC VEHICLES (PHEV), AND FUEL CELL ELECTRIC VEHICLES (FCV)?

All five reviewers agreed that the project does an excellent job at developing and creating an EV/VT ARRA education and training project that will directly support the ARRA goal to establish education projects that accelerate mass market production of EV, PHEV and FCV vehicles. One of the reviewers also said that while the deployment to mass market may not be direct, the impact on the market space is indirect. Another reviewer also stated the relevance to impacting medium and heavy duty EVs was not adequately addressed. One reviewer also commented that the involvement of multiple institutions in the project is also important to increasing the numbers of students, as well as consumers generally, whose knowledge will accelerate the introduction and acceptance of competitive vehicles. Another reviewer said this project does not seem to directly address manufacturing capacity and deployment. The final reviewer stated that by educating students and using the go-cart program, the activity will excite the nation into using electric drive vehicles.

QUESTION 2. DEVELOPMENT/DEPLOYMENT APPROACH: ARE THE PROJECT'S TECHNICAL AND DEPLOYMENT MILESTONES AND SCHEDULE CLEARLY IDENTIFIED, APPROPRIATE, AND FEASIBLE, AND ARE TECHNICAL AND COMMERCIAL BARRIERS AND RISKS ADEQUATELY ADDRESSED?

The first reviewer said the project team is doing an excellent job at implementation and deployment of their schedule and milestones. Courses are designed and deployed across the university/college systems. A K-12 system is developed, and one EV go-cart race is demonstrated. Multiple hubs are already developed based on the existing nanoHub. The project does an excellent job of leveraging existing resources to accelerate their milestones. The project is extending to other networks like 4-H, which is a creative effect approach. Another reviewer observed that the presenter said that project deliverables were on schedule but the milestones weren't very detailed. Technical and commercial barriers were not really addressed. One reviewer commented that presenter materials suggested that a detailed project plan has been developed. The timeline for each task has been established and activities are well described in both the slides and the oral project presentation. Tasks are clearly identified. Major milestones for each task could be overlaid on the time line, and barriers were not specifically identified or mentioned. A minor point this reviewer had was that it is assumed that the arrows should indicate that Task 6.0 and Task 8.0 activities will occur throughout the three years of the project. Another reviewer said the team addressed coordination/duplication of courses among the many partners, while the last reviewer said this is a very energetic and well rounded program. This project is trying to excite the public into using electric drive vehicles by educating students and using the go-cart program.

QUESTION 3. TECHNICAL ACCOMPLISHMENTS AND PROGRESS: WHAT IS THE OVERALL PROGRESS TOWARDS PROJECT'S OBJECTIVES AND MILESTONES? IS PROGRESS ADEQUATELY REPORTED AND QUANTIFIED (E.G., NUMBER OF JOBS, INSTALLATIONS, ETC.) AS REQUIRED BY ARRA?

The first reviewer stated the project at present stage is making excellent progress toward achieving the project milestones. The number of jobs was not presented, but the fact that 2,000 students attended the first EV go-cart race is impressive and will indirectly impact job creation. Twenty-eight new courses were designed with sixty students. The Indiana Advanced Electric Vehicle Training is also now offering certificates as well as associate degrees for training vehicle technicians, and BS and MS degree programs for design and manufacturing engineers in the electric vehicle industry. They will also offer a certificate program in electric vehicle safety for emergency responders. All of the above demonstrates progress toward the required ARRA goals. Another reviewer said the project was on schedule. All subcontracts with the universities are in place, some just recently. Engagement with industry appears weak at this stage, however. One other reviewer also mentioned the project has gotten off to a great start and all sub-contracts are in place. Courses were developed and delivered in the spring 2010 semester. Both Spring Fest 2010 and the inaugural EV Grand Prix event in April were early accomplishments which are creating awareness of and excitement about the potential for electric drive transportation. Another reviewer commented that this project is just starting; please plan to track students going to industry. The last reviewer said that many classes and labs have already been created. A hands-on approach to education is one of the only ways to have students love the work they do.

QUESTION 4. COLLABORATIONS/PARTNERSHIPS: DOES THE PROJECT TEAM EFFECTIVELY USE COLLABORATIONS/PARTNERSHIPS WITH REGIONAL, STATE, LOCAL GOVERNMENTS, INDUSTRIAL, COMMERCIAL, UNIVERSITY, RESEARCH ORGANIZATIONS, AND SIMILAR ORGANIZATIONS TO ACHIEVE ITS OBJECTIVES?

The first reviewer stated the project includes strong industry collaborators such as EnerDel and multiple regional academic centers including Ivy Tech, Notre Dame, IUPUI Purdue-Calumet and IU. The list of industry collaborators is extensive and in fact appears like a consortium. Two MS programs jointly with Delphi and Crane will be highlighted. The project might take under consideration the concept of using staff from industry to lead some of the new courses, for example in advanced battery technology where the speaker indicated that the university does not demonstrate strength. Another reviewer said they would like to see more emphasis with industry and perhaps national laboratories. The presenter indicated there was good integration with multiple Indiana Universities including community colleges. It is unclear how much impact this activity will have outside Indiana. There was also an indicated tie into DoD, which is good but the details need to be explained. A greater role of state and local government other than universities would seem to be an opportunity they could approach. One other reviewer mentioned that the reviewer materials included an impressive list of Indiana academic, industry and other organizations associated with the project. The PI indicated there will be an

initial meeting in July with all members of the consortium. An excellent case was made for the benefits of the emerging partnership with 4-H as a means to engage young people. In response to a question, there was an indication that there will be collaboration with the Indiana Clean Cities coalitions; however, they are not included on the reviewer slides. The last two reviewers agreed there were a very good set of partners, with one of the reviewers also adding to please be sure to coordinate among all of them.

PROJECT STRENGTHS

The first reviewer said the project strengths include a very strong university collaboration and coordinated leadership efforts. The collaborating industry “consortium” is impressive and leveraged well. The program has a strong deployment plan for the Midwest and includes a diversity plan. Performance data and management plans are implemented well. The EV go-cart series is a large draw for exciting the masses and students. The progress on courses is new and certificate programs are very strong. One reviewer stated there were an impressive number of new courses under development. There appears to be significant leveraging with NSF Hub, SmartGrid Award, Clean Cities, etc. Another reviewer stated that the PI has a lot of enthusiasm and excitement. This results in a highly motivated project team, and students who have also become enthused and motivated. There is a comprehensive package of education, training and information initiatives. The project has gotten out of the blocks quickly. Early and successful creation of initial courses bode well for future success. Linkage of this I-AEVtec project with Purdue/Ivy Tech's SmartGrid grant should have benefits for the stakeholders of both projects. One reviewer also said that partnerships are one of the project strengths, leveraging broad capabilities of all the partners. Three of the reviewers also said the EV Grand Prix is an excellent idea and a good strength of the project which will create a lot of outreach opportunity.

PROJECT WEAKNESSES

The first reviewer said that the details of courses are lacking. There is a concern about quality of the courses, since many are new without significant new faculty or industry involvement. Another reviewer commented that the large set of partners and capabilities will be very challenging to manage effectively. One other reviewer stated that partnering universities need to become more active in the project. Hopefully by next year with the subcontracts in place, the universities will be active in the project. Two other reviewers mentioned that overall the project is strong and performing at this point very well. One of those reviewers said one thing that may be strengthened is outreach to jobs and training specifically of technicians.

SPECIFIC RECOMMENDATIONS

The first reviewer said to consider using EnerDel as a teacher for a battery class. Another reviewer stated this is a good project to continue. Four other reviewers all mentioned the project should get more engagement from the industry, like collaborating with Indiana's Clean Cities coalitions, universities, and vehicle manufacturers as well as exchanging information, etc. with other recipients of ARRA Vehicle Technologies education grants working on other similar efforts to leverage and develop best practices.

Advanced Electric Drive Vehicle Education Program: CSU Ventures: Gary Caille, Colorado State University

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1A. RELEVANCE: IS THE PROJECT EFFORT RELEVANT TO THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA) OF 2009 GOALS: CREATE NEW JOBS AS WELL AS SAVE EXISTING ONES; SPUR ECONOMIC ACTIVITY AND INVEST IN LONG-TERM ECONOMIC GROWTH.

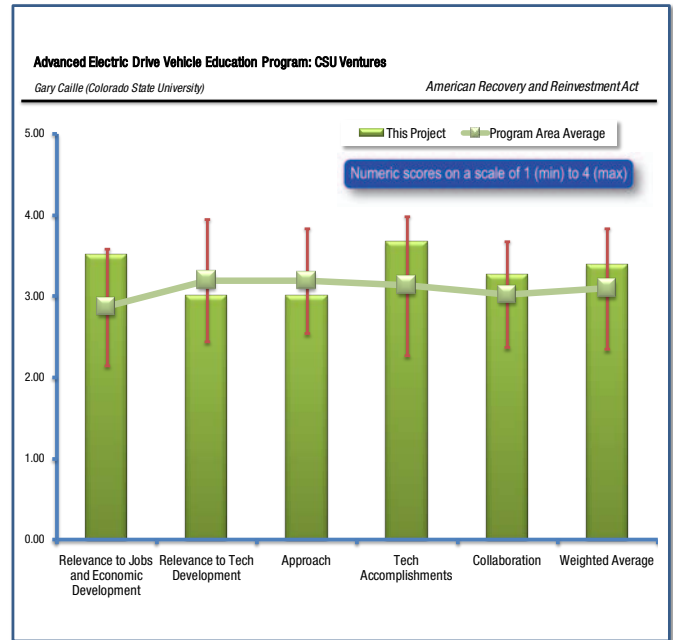
The first reviewer said one of the more attractive parts of this project is the specific and stated goal of attracting veterans to the training program; this is admirable and correctly done. Another reviewer stated the team has identified several key workforce challenges such as the need for training and addressing the barriers that prevent potential workers from entering jobs (awareness of opportunities, training, financial assistance). They have provided opportunities to address these issues. Their ongoing and proposed activities will increase the effectiveness of training and seem to be on track to create new jobs. It is very exciting to see a project that addresses the issue of how training links to the pipeline of employment—at least for the community college piece. One reviewer commented there is good information about the relationship between potential jobs, the ability for women to be good technicians, the need for returning vets to get jobs, and the well-paying aspect of these jobs. Targeting audiences from middle school all the way through professional educators and conducting related outreach is a strength. Two of the reviewers also noted in their remarks that there is a shortage of 60,000 qualified automotive technicians, with the added complication of those skilled in new propulsion activities.

Their ongoing and proposed activities will increase the effectiveness of training and seem to be on track to create new jobs. It is very exciting to see a project that addresses the issue of how training links to the pipeline of employment—at least for the community college piece. One reviewer commented there is good information about the relationship between potential jobs, the ability for women to be good technicians, the need for returning vets to get jobs, and the well-paying aspect of these jobs. Targeting audiences from middle school all the way through professional educators and conducting related outreach is a strength. Two of the reviewers also noted in their remarks that there is a shortage of 60,000 qualified automotive technicians, with the added complication of those skilled in new propulsion activities.

The last reviewer said the development of secondary education materials may make students “more marketable”, but the fact that all students can find jobs upon graduation tends to indicate that the addition of EV and HEV technology content by itself will not increase the amount of jobs that are created. Jobs could be created if the jobs on EV and HEV's are considered to be higher status – then more student enrollment might result and thus fill the empty mechanics jobs that are currently out there. In the first responder training there are no additional jobs being created by the creation/addition of EV and HEV specific content to the first responder training curriculum. For the university engineering degree programs, given the fact that OEM's and system suppliers are in a crash course to develop and market EV and HEV's, there is a need for engineers with appropriate EV/HEV skills. Thus, many current engineers whose skills are not currently in demand may be able to use this training to position themselves to be able to re-enter the job market with skills that are in demand.

QUESTION 1B. RELEVANCE: DOES THE PROJECT’S TECHNOLOGY DEVELOPMENT PLAN AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOALS OF ACCELERATE THE DEVELOPMENT OF U.S. MANUFACTURING CAPACITY FOR BATTERIES AND ELECTRIC DRIVE COMPONENTS AS WELL AS THE DEPLOYMENT OF ELECTRIC DRIVE AND ALTERNATIVE FUEL VEHICLES AND INFRASTRUCTURE? DOES THE PROJECT’S DEVELOPMENT AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOAL TO ESTABLISH EDUCATION PROJECTS THAT ACCELERATE THE MASS MARKET INTRODUCTION AND PENETRATION OF ADVANCED ELECTRIC DRIVE VEHICLES, WHICH INCLUDES LIGHT, MEDIUM, AND HEAVY DUTY ADVANCED ELECTRIC VEHICLES (EV), PLUG-IN HYBRID ELECTRIC VEHICLES (PHEV), AND FUEL CELL ELECTRIC VEHICLES (FCV)?

The first reviewer said the project is starting early, as they are working with all levels of education for ULEV technicians starting in middle school to the college level and beyond. This project, as well as the process of educating the interested individuals, will take time and a number of years to complete. Another reviewer commented there is a great approach with curriculum development, hands-



on test equipment and inclusion of virtual reality based training. The program will help to create an educated and skilled group who can service vehicles and fill jobs helping with the deployment of alternative fuel vehicles. By working on modifying course curriculum, this project is helping with institutional change. One other reviewer mentioned that contracts are in place for all subcontractors, there was a kick off meeting held in February, they have started to hire grad students, courses have been started, and a professional course in hybrid technology is being developed. They are also working on a maintenance course to tie in with EV courses as well as looking to leverage course development from various outlets (Georgia Tech and Colorado State). The last reviewer stated that while the first responder and secondary/mechanic training aspects of this project will do little to stimulate/accelerate the development of U.S. manufacturing capacity for batteries and electric drive components, they do lay down the educational underpinnings to stimulate interest in EV/HEV technology, develop the necessary repair technician infrastructure, and assist the safety of first responders through appropriate education. However the university engineering degree program will help generate the U.S. based engineering talent necessary to stimulate/accelerate/sustain the development of U.S. manufacturing capacity for batteries and electric drive components as well as OEM integration of these systems.

QUESTION 2. DEVELOPMENT/DEPLOYMENT APPROACH: ARE THE PROJECT'S TECHNICAL AND DEPLOYMENT MILESTONES AND SCHEDULE CLEARLY IDENTIFIED, APPROPRIATE, AND FEASIBLE, AND ARE TECHNICAL AND COMMERCIAL BARRIERS AND RISKS ADEQUATELY ADDRESSED?

The first reviewer said yes, they are faced with similar issues associated with the slow acceptance of change in educational curricula at the state level. Trying to institute institutional change is difficult and the reviewer would recommend that DOE support these endeavors nationwide with appropriate visits by senior DOE managers with their grantees to the state educational decision making bodies to express to them the need to "fast track" approval of the curricula certifications. Another reviewer mentioned it seems hard to improve on the approach. The PI is well aware of the challenges of overcoming the institutional inertia of four-year universities, but the team is working hard on making progress and keeping to schedule. This reviewer is very impressed by the proposed plan that focuses on special needs populations, women and veterans. One reviewer commented that the first responder course mod is 75% complete at Arapahoe Community College; modifications to the automotive tech training course are in progress, the team has procured all of their test equipment, and they have initiated virtual reality training options. The project also initiated a design study to develop a management engine to take inquiries to appropriate web locations. It will be very interesting to know if this project is successful with the returning veterans. The final reviewer stated the project seems to have a good handle on how to execute the various elements of the project to meet its specified goals within the specified budget. However, the first responder program seems to be a duplication of efforts with the NFPA project. This reviewer would recommend that the DOE find a way for them to work together on this project.

QUESTION 3. TECHNICAL ACCOMPLISHMENTS AND PROGRESS: WHAT IS THE OVERALL PROGRESS TOWARDS PROJECT'S OBJECTIVES AND MILESTONES? IS PROGRESS ADEQUATELY REPORTED AND QUANTIFIED (E.G., NUMBER OF JOBS, INSTALLATIONS, ETC.) AS REQUIRED BY ARRA?

The first reviewer said that CSU has procured the equipment necessary to conduct the labs and hands-on training associated with the project. This is considered a major milestone accomplished so far. They appear ready to proceed with the training but were frustrated with the process of gaining certification from the state agencies. Another reviewer stated the progress was well documented and well reported. It seemed like a lot of work had been started but was just in initial phases. The presentation did indicate progress was being made but that more significant progress would be made over the summer. One reviewer mentioned that it was noted that job creation will reach approximately 80-85 new full time employees. When asked how the veterans are responding to the program, it was noted that it is still too early to tell, given the state of the project. The last reviewer commented the project seems to be making good progress at implementation and goal fulfillment.

QUESTION 4. COLLABORATIONS/PARTNERSHIPS: DOES THE PROJECT TEAM EFFECTIVELY USE COLLABORATIONS/PARTNERSHIPS WITH REGIONAL, STATE, LOCAL GOVERNMENTS, INDUSTRIAL, COMMERCIAL, UNIVERSITY, RESEARCH ORGANIZATIONS, AND SIMILAR ORGANIZATIONS TO ACHIEVE ITS OBJECTIVES?

The first reviewer said the types and levels of collaboration and partnership associated with this project are outstanding; it appears they are including the right stakeholders into the process from the beginning. Another reviewer stated the collaborations and project

goals that targeted special populations like women and returning vets is laudable. One reviewer commented there is a nice job of mixing various partners in this project (Arapaho, Raytheon, MRI, etc). Attempting to leverage these groups, including veteran organizations, to get financial assistance (and not just from the Veterans Administration but other sources). The project team is also working with the CSU School of Occupancy Therapy as well, and the U.S. Army and Marine Corps. The final reviewer mentioned the project seems to be well leveraged with significant cost share and a good cross section of partners that have the ability to significantly add value to this project. However, it seems that there are a number of parallel efforts to develop service tech curriculum. Perhaps, there could be an effort to coordinate these programs so “best practices” can be developed that leverage the great ideas from each of the individual programs.

PROJECT STRENGTHS

The first reviewer said it is a great project that has aims and partners, but as reviewers we were able to see the project in action and it really showed its strength. During the presentation, the PI recognized that there was overlap with emergency responder training for electric vehicles and he was willing to take steps to address this. This really shows that the VT program has funded a flexible project that wants to do good things and is able to respond quickly to a changing landscape. Another reviewer commented the project seems to be well organized, leveraged, and supported by a good portfolio of partners. The use of "virtual reality" concepts to facilitate effective “long distance learning” opportunities is intriguing. For next year's presentation, it would be great if they could demonstrate how it works (i.e., the scope/look/feel of the system). Two reviewers agreed that attracting veterans is a right course of action and should be commended. One of the reviewers also said it will be interesting to see if it succeeds in getting more women in to the field of training on advanced transportation technologies. The presenter did a good job at outlining future activities (graduate certification in electric transportation, etc).

PROJECT WEAKNESSES

The first reviewer stated that the PI's presentation needs a bit more focus, especially when delineating the program's accomplishments. The reviewer had to ask what they have done so far to learn about the equipment purchase, a major item to report. For the next review, the PI should concentrate on “this is what we were asked to do; this is what we did or have done so far.” Another reviewer said the weakness is really minor and probably because of the time allotted for the presentation and the early stage of the project: it was unclear to them how the Virtual Reality (VR) part of the project is integrated. Right now it seems to be a separate part of the effort and it is non-trivial to take high-end simulations and push them out to typical classrooms. The project will need to have a tight integration of trainers, professors, students and VR designers. One reviewer mentioned the first responder element of this project is redundant to the efforts being conducted by the NFPA. The last reviewer did not see any project weaknesses, other than they hope that veterans actually take advantage of the program since it is a great concept.

SPECIFIC RECOMMENDATIONS

The first reviewer said that if at all possible, DOE should support presentations to state educational bodies to fast track approval of new curricula. Another reviewer stated they would recommend working with an expert on how best to integrate distance learning. It makes sense given the geographical spread of the partners, but there is an art to it—you can't just decide to use online learning and hope to get the most out of it. The last reviewer commented the project needs to coordinate its first responder EV/HEV curriculum development efforts with those being conducted in the NFPA project. Also, the same type of coordination between parallel programs would also make sense with respect to the development and validation of the service tech curriculum. Perhaps, there could be an effort to coordinate these programs so “best practices” can be developed that leverage the great ideas from each of the individual programs.

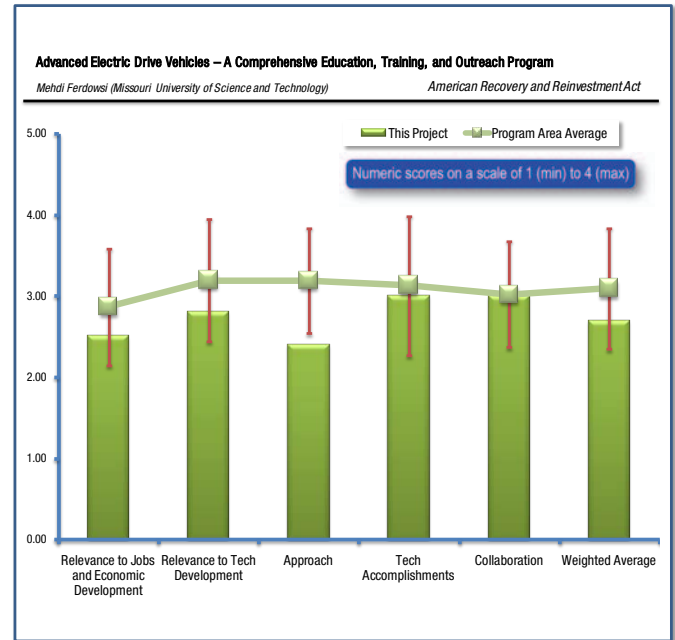
Advanced Electric Drive Vehicles – A Comprehensive Education, Training, and Outreach Program: Mehdi Ferdowsi, Missouri University of Science and Technology

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1A. RELEVANCE: IS THE PROJECT EFFORT RELEVANT TO THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA) OF 2009 GOALS: CREATE NEW JOBS AS WELL AS SAVE EXISTING ONES; SPUR ECONOMIC ACTIVITY AND INVEST IN LONG-TERM ECONOMIC GROWTH.

The first reviewer said the project to advance electric drive vehicles using a comprehensive education, training, and outreach program is very relevant to ARRA goals. The project will create new jobs, save existing jobs, and spur economic activity and invest in long-term economic growth by creating a creative outreach and training program for pre-college and high school students in order to develop a pipeline of well-qualified individuals to pursue careers in the field of advanced automotive energy systems. The work includes an innovative technology transfer model to foster research and educational collaborations between the electric drive vehicle industries and academic institutions and presents a means to disseminate the educational research. Three reviewers all said the presentation did not address specific job or economic activity benefits associated with the project. One of those three reviewers also said that refining coursework into a cohesive EV focus thrust will clearly help support the growing need for technologists for a growing EV market. Another one of those reviewers commented that the presented materials have a general statement of the ARRA goals, but no indication of the project's expected contribution to achieving them. No additional information was provided in the oral briefing. While there are important benefits, e.g., improved economic competitiveness, associated with better educated engineers and well-trained technicians, it is difficult to establish a direct link between a project like this and specific job-creation benefits. The last of those three reviewers also said the project is in early stages, and requested that the team develop a plan to track students that graduate from the program and go into industry. The final reviewer observed that by educating students in electric vehicle technology, the field of engineering in electric vehicle technology expands and creates a greater opportunity for new ideas and inventions to spur more jobs.



QUESTION 1B. RELEVANCE: DOES THE PROJECT’S TECHNOLOGY DEVELOPMENT PLAN AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOALS OF ACCELERATE THE DEVELOPMENT OF U.S. MANUFACTURING CAPACITY FOR BATTERIES AND ELECTRIC DRIVE COMPONENTS AS WELL AS THE DEPLOYMENT OF ELECTRIC DRIVE AND ALTERNATIVE FUEL VEHICLES AND INFRASTRUCTURE? DOES THE PROJECT’S DEVELOPMENT AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOAL TO ESTABLISH EDUCATION PROJECTS THAT ACCELERATE THE MASS MARKET INTRODUCTION AND PENETRATION OF ADVANCED ELECTRIC DRIVE VEHICLES, WHICH INCLUDES LIGHT, MEDIUM, AND HEAVY DUTY ADVANCED ELECTRIC VEHICLES (EV), PLUG-IN HYBRID ELECTRIC VEHICLES (PHEV), AND FUEL CELL ELECTRIC VEHICLES (FCV)?

The first reviewer stated the projects is relevant to ARRA goals and as presented will make a substantial contribution to VT ARRA 2009 objectives. Critically important to outstanding success for ARRA is a focus on metrics of success and useful deployment of new materials. The breadth and method for deployment of training tools and education programs is innovative and analytical, and will support the acceleration of development of U.S. manufacturing and an EV infrastructure. Another reviewer said there was no substantive discussion directly addressing manufacturing. Despite identifying two battery companies as half of the industry partners, the educational emphasis on energy storage appears weak with the focus being more on power electronics and electric machinery. One reviewer mentioned the initiatives included within the project have the potential to make a significant contribution to a more well-educated and capable electric drive transportation workforce, and to consumers who are better informed. However, the lack of details

and specific plans in the information communicated during the merit review raises concerns about whether the project will achieve its potential.

Another reviewer said this project does not seem to directly address manufacturing capacity and deployment. It does directly establish an education program, and indirectly impacts the mass market introduction of advanced vehicles. Two reviewers commented this project helps prepare automotive engineers, technicians, and personnel for the new field of transportation electrification as well as creates public awareness about electric drive vehicles. One of those reviewers also added the project creates outreach programs.

QUESTION 2. DEVELOPMENT/DEPLOYMENT APPROACH: ARE THE PROJECT’S TECHNICAL AND DEPLOYMENT MILESTONES AND SCHEDULE CLEARLY IDENTIFIED, APPROPRIATE, AND FEASIBLE, AND ARE TECHNICAL AND COMMERCIAL BARRIERS AND RISKS ADEQUATELY ADDRESSED?

The first reviewer said while the project is just starting, the approach presented is outstanding. The assessment and deployment plans are far reaching and if implemented correctly, they will have a significant impact on ARRA goals. The milestones are clear and focused. The project will create outreach programs and provide education for pre-college and high school students in order to develop a pipeline of well-qualified individuals to pursue careers in the field of advanced automotive energy systems; create a technology transfer model to foster research and educational collaborations between the electric drive vehicle industries and academic institutions; and conduct and disseminate educational research, which explores factors that mediate learning outcomes. To achieve their project deliverables, the project team is developing an Electric Drive Vehicle Technology Graduate Certificate Program and an Associate of Applied Science degree option. The team is developing hands-on educational tools and interactive exhibits for science centers and museums and has organized summer camps for high school and pre-college students. The managing team presents a strong project controls effort to achieve results with EVMS and go/no-go decision making processes. The leadership has taken care to initiate strategic partnership with the automotive industry and uniquely conduct a systematic-iterative evaluation of learning and educational activities. This type of iterative, dynamic evaluation is outstanding. Another reviewer stated that the details of number of courses to be developed, the subjects, and the timeline were not given in the presentations. Of the five courses mentioned in the presentation, only one was a new course, while the others were modifications. It was also noted that there was a hiring freeze preventing the hiring of a secretary. The project also did not seem to be considering adjunct faculty to provide additional resources/expertise.

A commenter mentioned that the general information presented does not include specific milestones or schedule details. Overall, the merit review slides and briefing do not inspire confidence that the project is being tightly managed and will achieve the results expected for an expenditure of this magnitude. In the presentation slides, there is no indication of which partner organizations will be contributing to which initiatives. The oral briefing provided some information, e.g., that the St. Louis Science Center will be engaged in promoting public awareness. Reference was made to regional dissemination of results in year two, but no information was provided on the approach or particular plans for that activity. No milestones, even general ones, were identified for year three. The statements concerning year one milestones are not very useful or informative, and are repeated word for word in the presented material on future work (lack of attention to detail). Another reviewer asked how the courses will be coordinated among the partner schools. Will there be duplication of effort? The last reviewer said the project will develop degree programs, hands-on educational tools and summer camps for high school students. The project will also initiate partnerships as well as the evaluation of educational materials.

QUESTION 3. TECHNICAL ACCOMPLISHMENTS AND PROGRESS: WHAT IS THE OVERALL PROGRESS TOWARDS PROJECT’S OBJECTIVES AND MILESTONES? IS PROGRESS ADEQUATELY REPORTED AND QUANTIFIED (E.G., NUMBER OF JOBS, INSTALLATIONS, ETC.) AS REQUIRED BY ARRA?

The first reviewer said the project is only 8% complete at time of presentation. Five classes have been taught in support of the project and all contracts/subcontracts finalized. Finalizing the university-industry MOA is also accomplished and includes: University of Central Missouri, Linn State Technical College, St. Louis Science Center, Smith EV, Dow Kokam, Chrysler and A123. Another reviewer stated the progress has been primarily towards equipment procurement. A hiring freeze may create a resource issue. Four reviewers said the sub-contracts have been finalized and three of those reviewers also mentioned that one course has been designed as well. Another reviewer commented there is no indication of specific progress on other initiatives. Problems leading to delays in achieving some actions were noted. Overall, the discussion of issues and concerns seemed at times to be a more important part of the

message than the discussion of accomplishments and progress. The last reviewer said this project is just starting; please plan to track students going to industry.

QUESTION 4. COLLABORATIONS/PARTNERSHIPS: DOES THE PROJECT TEAM EFFECTIVELY USE COLLABORATIONS/PARTNERSHIPS WITH REGIONAL, STATE, LOCAL GOVERNMENTS, INDUSTRIAL, COMMERCIAL, UNIVERSITY, RESEARCH ORGANIZATIONS, AND SIMILAR ORGANIZATIONS TO ACHIEVE ITS OBJECTIVES?

The first reviewer said the balance of university- industry strategic partnering is impressive. Collaborations are strong and the industry players will certainly support an effective dissemination of the results. The alignments with industry may also serve as a purposeful pipeline for students to jobs. Industrial partners include Smith EV, Dow Kokam, Chrysler and A123. Another reviewer commented the project appears to have forged a good mix of strategic partners representing battery companies as well as vehicle OEMs, although it is unclear how extensive this interaction will be. It is unclear whether this effort will extend beyond the state. One reviewer mentioned the strategic partners listed in the presented materials are excellent. However, a project of this magnitude should be more aggressive in seeking additional partners in the state of Missouri. For example, government organizations, consumer groups, Clean Cities coalitions, advocacy groups, utilities, etc. Another reviewer also stated there is a good set of partners; please be sure to coordinate among all of them. The last reviewer said the project is collaborating with three colleges and four strategic partners. There is a battery model from Dow Kokam and they have a 20hp electric powertrain for labs with a DC motor.

PROJECT STRENGTHS

The first reviewer said the main strengths of the project are the breadth of education and outreach, extension and evaluation of learning tools into the public mainstream science centers, and a dynamic iterative process for metrics and success. The industry partners that include A123 are commendable. Two reviewers agreed there are good strategic partners from industry. The last reviewer mentioned these project strengths: battery technology due to partnerships, battery models, and hardware.

PROJECT WEAKNESSES

The first reviewer said there are no weaknesses obvious at present until project progresses. Another reviewer stated that strong curriculum development and faculty recruitment was not apparent. One reviewer commented that the project management seems to be struggling in dealing with the challenges of moving out smartly on some of the project's initiatives. The slides presented do not portray an active, high energy, well-focused project. The oral briefing helped a bit, but not enough. Another reviewer added that planning for coordination among all of the partners was a weakness. The final reviewer said there was no use of engine/energy storage device with the powertrain, students see and deal with only one part of the system (battery) and there was only one mechanical engineering course.

SPECIFIC RECOMMENDATIONS

The first reviewer said the project should consider adding a training course that includes commercialization and/or deployment aspects of the EV field. Another reviewer stated this project should be provided with additional guidance regarding coursework development and augmentation of faculty, including adjunct faculty from industry perhaps through web-based instruction. One reviewer added that specific milestones, with accomplishment dates, should be established for each initiative/activity/task. Then a management structure, which identifies responsibility and accountability for each milestone, should be clearly defined. The project team should be more aggressive in establishing partnerships and collaborations with other Missouri organizations. Communication about the project should convey more enthusiasm about what is being done, the results achieved, and how the challenges are being met, and less about what the problems and potential problems are. (This does not mean ignoring the problems, or glossing them over, but having a positive attitude and plan for dealing with them.) Another reviewer asked that coordination be undertaken for all of the proposed courses, first responder training, and large number of partnerships among all of the other projects in this area. The final reviewer said to expand the implementation into the mechanical engineering program. While the students learn to highly optimize the electrical powertrain, they might not learn how to optimize the whole system together, such as what can be done with the engine/energy device to help electrical powertrain or batteries instead of only the other way around.

Development and Implementation of Degree Programs in Electric Drive Vehicle Technology: Ka Yuen Simon Ng, Wayne State University

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

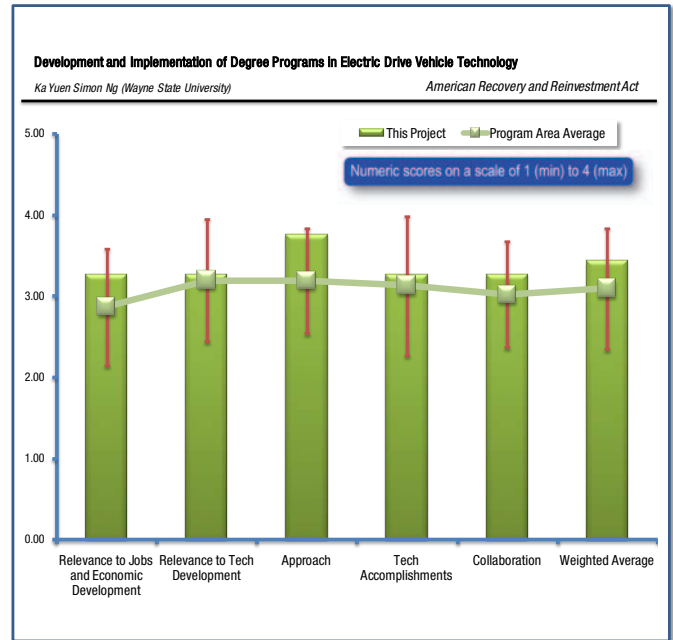
QUESTION 1A. RELEVANCE: IS THE PROJECT EFFORT RELEVANT TO THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA) OF 2009 GOALS: CREATE NEW JOBS AS WELL AS SAVE EXISTING ONES; SPUR ECONOMIC ACTIVITY AND INVEST IN LONG-TERM ECONOMIC GROWTH.

The first reviewer said this project has great relevance to the goals of ARRA 2009. It aims at a higher segment of the education market for electric vehicles. The efforts of Wayne State University are commendable: while other programs are concentrating on automotive technicians, the question is who will work on the large scale efforts to develop better electric vehicles in the future. The PI outlined a very comprehensive approach. Another reviewer mentioned job creation was not specifically discussed but the PI has worked hard to incorporate industry input. This should lead to the creation of a highly desirable workforce. One reviewer commented they think they are the only university in the nation to develop a master’s degree program in electric transportation and, therefore, they will be model curriculum for other universities around the U.S. Two reviewers said this program works to implement a master's degree, bachelor’s degree, and associates degree, as well as an undergraduate concentration and graduate certificate program in electric drive vehicle and electric transportation technology programs. One of those reviewers added this is important to ensure that there is a workforce knowledgeable about E3 activities.

The last reviewer said that while the development of community college-based service technician-focused Associate Degree program may make students “more marketable”, the fact that all students can find jobs upon graduation tends to indicate that the addition of EV and HEV technology content by itself will not increase the amount of jobs that are created. Where jobs could be created is if the jobs in the EV and HEV fields are considered to be higher status, then you might see more student enrollment and thus fill the empty mechanics jobs that are currently out there. Given the fact that OEM's and system suppliers are in a crash course to develop and market EV and HEV's in university engineering degree programs, the reviewer believes that there is a need for engineers with appropriate EV/HEV skills. Thus, many current engineers whose skills are not currently in demand may be able to use this training to position themselves to be able to re-enter the job market with skills that are in demand. Also given the location of this program (in the Detroit metropolitan area) it will have a greater positive effect on the local industry and economy in this particularly hard hit area.

QUESTION 1B. RELEVANCE: DOES THE PROJECT’S TECHNOLOGY DEVELOPMENT PLAN AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOALS OF ACCELERATE THE DEVELOPMENT OF U.S. MANUFACTURING CAPACITY FOR BATTERIES AND ELECTRIC DRIVE COMPONENTS AS WELL AS THE DEPLOYMENT OF ELECTRIC DRIVE AND ALTERNATIVE FUEL VEHICLES AND INFRASTRUCTURE? DOES THE PROJECT’S DEVELOPMENT AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOAL TO ESTABLISH EDUCATION PROJECTS THAT ACCELERATE THE MASS MARKET INTRODUCTION AND PENETRATION OF ADVANCED ELECTRIC DRIVE VEHICLES, WHICH INCLUDES LIGHT, MEDIUM, AND HEAVY DUTY ADVANCED ELECTRIC VEHICLES (EV), PLUG-IN HYBRID ELECTRIC VEHICLES (PHEV), AND FUEL CELL ELECTRIC VEHICLES (FCV)?

The first reviewer said it was the only program that they reviewed that addressed ARRA goals in terms of the development of new technologies and electric drive components. Housed in the Engineering School, Wayne State is working to deliver highly educated engineers to the future of the electric car development industry. The program is laboratory hands-on intensive with the development of an electric drive vehicle engineering laboratory in process. Another reviewer stated the program is noteworthy for incorporating



storage systems and power electronics. The lab component seems new, but the rest of the curriculum seems to have been recycled. The reviewer asked if DOE paid for curriculum development. If DOE did then this explains the rapid progress. One reviewer commented the purpose of this project is to test real life systems in the energy storage lab, electric propulsion lab and control and integration labs which will assist students in getting jobs in the industry upon graduation. Most of these labs have been ordered with the hope that they will be available by the end of 2010. The goal of this project is to create a comprehensive curriculum. They already have 30 students signed up for the graduate student classes with a target of 50 students. The last reviewer said that while the community college-based service technician-focused associate degree program aspects of this project will do little to stimulate/accelerate the development of U.S. manufacturing capacity for batteries and electric drive components, it does lay down the educational underpinnings to stimulate interest in EV/HEV technology and development of the necessary repair technician infrastructure. However the university engineering degree program (master's and bachelor's) will help generate the U.S. based engineering talent necessary to stimulate/accelerate/sustain the development of U.S. manufacturing capacity for batteries and electric drive components as well as OEM integration of these systems.

QUESTION 2. DEVELOPMENT/DEPLOYMENT APPROACH: ARE THE PROJECT'S TECHNICAL AND DEPLOYMENT MILESTONES AND SCHEDULE CLEARLY IDENTIFIED, APPROPRIATE, AND FEASIBLE, AND ARE TECHNICAL AND COMMERCIAL BARRIERS AND RISKS ADEQUATELY ADDRESSED?

The first reviewer said the barriers to the development of the program and course work have been overcome. Another reviewer mentioned that this project is producing a multi-tiered educational experience for students (master's, bachelors, associates level certificate, even K-12 teacher workshop). One other reviewer commented that the project's technical and deployment milestones are well defined. They received a lot of industrial input based on an industry workshop which was used to help develop the curriculum. Being in Detroit has given them highly experienced adjunct faculty to teach some of these courses. Two of the reviewers said the project has already gotten its curriculum approved at the master's, bachelor's and associates level, and classes will be offered in September 2010. The final reviewer mentioned the project seems to have a good handle on how to execute the various elements of the project to meet its specified goals within the specified budget. The management team and advisory board seems to have the depth and diversity necessary to cover the key areas of program development and execution.

QUESTION 3. TECHNICAL ACCOMPLISHMENTS AND PROGRESS: WHAT IS THE OVERALL PROGRESS TOWARDS PROJECT'S OBJECTIVES AND MILESTONES? IS PROGRESS ADEQUATELY REPORTED AND QUANTIFIED (E.G., NUMBER OF JOBS, INSTALLATIONS, ETC.) AS REQUIRED BY ARRA?

The first reviewer said that progress was adequately reported, as the program is said to start with a full class about 15-25 students with over 50 students voicing interest in the program so far. The reviewer's impression is that WSU has the enthusiasm to advance more interests in these degree programs in the future. Another reviewer commented the progress is outstanding, but the reviewer would question how much of this was already "in the can." With so few partners, the goals are far more achievable as well. One reviewer mentioned that the project team has completed all of their year-one activities, while the last reviewer said the project seems to be making good progress at implementation and goal fulfillment.

QUESTION 4. COLLABORATIONS/PARTNERSHIPS: DOES THE PROJECT TEAM EFFECTIVELY USE COLLABORATIONS/PARTNERSHIPS WITH REGIONAL, STATE, LOCAL GOVERNMENTS, INDUSTRIAL, COMMERCIAL, UNIVERSITY, RESEARCH ORGANIZATIONS, AND SIMILAR ORGANIZATIONS TO ACHIEVE ITS OBJECTIVES?

The first reviewer said their relationship management process is very good and they have had industry days to garner support and input for the program. They have enlisted Macomb Community College as their partner in this venture. Another reviewer mentioned that NextEnergy and the Industrial Advisory Board are serving as collaborators on this project. The Industrial Advisory Board is a diverse group of labs, battery manufacturers, government, universities, utilities, automobile manufacturers, etc. One other reviewer commented the project seems to be well leveraged with significant cost share. While not explicitly listed, in the course of the presentation it became apparent that it has a good cross section of partners/supporters (including Ford and other local suppliers) that will help make this program a success. The final reviewer said the project has very few partners which might reduce the impact of the program.

PROJECT STRENGTHS

The first reviewer said the project is a laboratory-intensive, learning-based program using three laboratories including: Energy Storage Laboratory, Electric Propulsion Laboratory, and the Control and Integration Laboratory. All the programs are in different phases of development. Another reviewer stated that this is a comprehensive engineering education program and is the first master's degree program in the area. The program integrates production, which is an innovation, and it strives to be the national model. It already had approval from university and state for the program and the degree and certificate program will be ready for implementation. The PI is gathering industry input and working to incorporate a process of continuous improvement. One reviewer commented that this project recognizes the huge need for courses to support the successful introduction of advanced transportation technologies. The last reviewer mentioned the program seems to be well-targeted to meet the needs of both the local industry and engineers who need to gain (or re-tool) skills in this rapidly growing area. The program is also coordinating its curriculum development with the Michigan Tech Program. Perhaps this coordination can be expanded to other DOE sponsored programs that are developing the same type of programs and curriculum.

PROJECT WEAKNESSES

The first reviewer said the project seems to lack scalability. There could be more partnerships with community colleges (in addition to Macomb) and there needs to be some connection with industry on the workforce development side. The reviewer also said it seems like the project reaches very few students (but they acknowledged they might have missed something). Another reviewer mentioned there is a question as to whether this is really a new curriculum or not, as it isn't 100% clear from the presentation. The last two reviewers commented they could not identify any significant program weaknesses.

SPECIFIC RECOMMENDATIONS

The first reviewer asked that if this is to be a national model, is there a plan for dissemination? There appears to be a need for systems integration research and coursework. Would the PI be willing to make the curriculum available online? Another reviewer said the project should expand coordination of curriculum development and validation beyond Michigan Tech to include other similar DOE funded programs. The last reviewer commented that additional funding should be provided to Wayne State for year three and beyond.

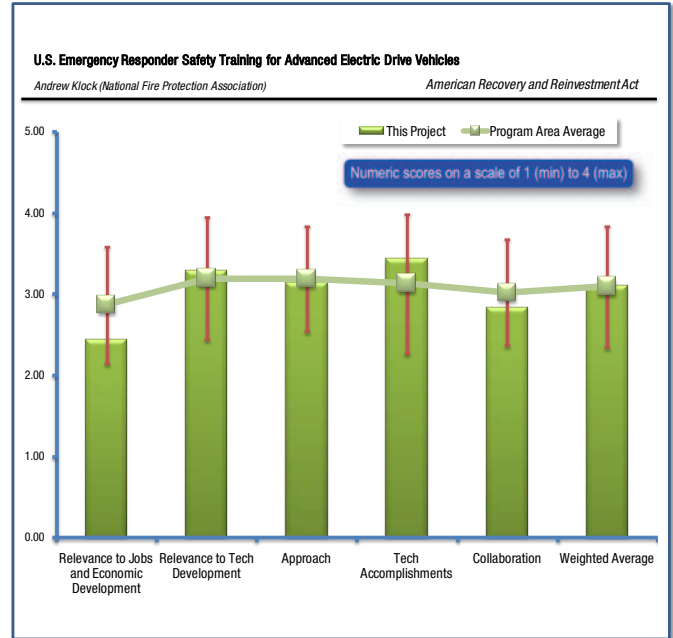
U.S. Emergency Responder Safety Training for Advanced Electric Drive Vehicles: Andrew Klock, National Fire Protection Association

REVIEWER SAMPLE SIZE

This project had a total of 7 reviewers.

QUESTION 1A. RELEVANCE: IS THE PROJECT EFFORT RELEVANT TO THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA) OF 2009 GOALS: CREATE NEW JOBS AS WELL AS SAVE EXISTING ONES; SPUR ECONOMIC ACTIVITY AND INVEST IN LONG-TERM ECONOMIC GROWTH.

The first reviewer said the project is relevant and will make important and substantial contributions to the ARRA 2009 goals. The project brings together a comprehensive team of first responders and emergency response associations to create a training objective that will provide very important results in support of national accelerated deployment of EVs. The training of emergency responders will reduce property damage, injury, and loss of life, and help achieve public acceptance of high volume advanced EV production in the U.S. Another reviewer commented that job creation and retention were not directly addressed. It is clear that appropriate first responder, EMS, and law enforcement protocols are necessary for full-scale deployment. One reviewer thought the project has a lot of relevance but was unsure about the process and steps used to develop an overall approach. This reviewer kept thinking about what has been done already in the area of electric vehicle emergency operations in cities that still use electric power to drive much of their mass transit systems. Two reviewers stated that this is an important project; however, the presentation did not address specific job or economic activity benefits. One of the two reviewers added that there should be some incremental positions associated with managing and implementing the project activities, but it is difficult to establish a direct link between a project like this and permanent job-creation and economic benefits. Another reviewer said the project is in the early stages, while the last reviewer added the project is expanding fire safety by providing knowledge to fire response teams with experts in EVs.



QUESTION 1B. RELEVANCE: DOES THE PROJECT’S TECHNOLOGY DEVELOPMENT PLAN AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOALS OF ACCELERATE THE DEVELOPMENT OF U.S. MANUFACTURING CAPACITY FOR BATTERIES AND ELECTRIC DRIVE COMPONENTS AS WELL AS THE DEPLOYMENT OF ELECTRIC DRIVE AND ALTERNATIVE FUEL VEHICLES AND INFRASTRUCTURE? DOES THE PROJECT’S DEVELOPMENT AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOAL TO ESTABLISH EDUCATION PROJECTS THAT ACCELERATE THE MASS MARKET INTRODUCTION AND PENETRATION OF ADVANCED ELECTRIC DRIVE VEHICLES, WHICH INCLUDES LIGHT, MEDIUM, AND HEAVY DUTY ADVANCED ELECTRIC VEHICLES (EV), PLUG-IN HYBRID ELECTRIC VEHICLES (PHEV), AND FUEL CELL ELECTRIC VEHICLES (FCV)?

The first reviewer said the bottom-line importance to a successful EV deployment plan and penetration of the U.S. market space is safety. This project directly supports the mission of the ARRA goals by supporting the safety of the deployment of electric drive and alternative fuel vehicles and infrastructure. Another reviewer mentioned that whereas educational efforts are not directly addressing the manufacturability of batteries and EVs, this project fills a critical role to enable public acceptance and safety. One reviewer commented there is first responder training considered here and they are not relevant to the goals as stated in 1b. Another reviewer stated the project does look likely to contribute to ARRA project goals to establish education projects that accelerate mass market introduction of advanced electric drive vehicles. One other reviewer added that focused, extensive training of first responders is a vital initiative which needs to be accomplished in conjunction with the commercial introduction of electric drive vehicles. This project should contribute significantly to accomplishing that training. Another reviewer said this project does not seem to directly address manufacturing capacity and deployment. However, it does directly establish a training program, and indirectly impacts the mass

market introduction of advanced vehicles. The last reviewer mentioned that by providing fire safety response, the community becomes more knowledgeable and accepting of electric vehicle technology.

QUESTION 2. DEVELOPMENT/DEPLOYMENT APPROACH: ARE THE PROJECT'S TECHNICAL AND DEPLOYMENT MILESTONES AND SCHEDULE CLEARLY IDENTIFIED, APPROPRIATE, AND FEASIBLE, AND ARE TECHNICAL AND COMMERCIAL BARRIERS AND RISKS ADEQUATELY ADDRESSED?

The first reviewer said the approach to the project is outstanding and the comprehensive collaborations are impressive. The project is just beginning but already demonstrates strong project controls and EVMS skills. The team presents a carefully thought-out PEP and implementation and distribution strategy. The coordination with NFPA will lead efforts in a high-value, standards-based training programs to U.S. emergency responders (fire service, EMS, and law enforcement). The team has considered problems in the community where EV safety is not taken seriously or understood and is addressing the problem. Another reviewer added the project has a very well-organized approach with partners across the stakeholder community. The team needs to find additional resources for training. Expanding the scope to include buses and charging station appears appropriate. One reviewer commented that the approach calls for the hiring of a computer simulation company for training development, but no details were given about what that company is envisioned to do or how will computer simulations be used to support the training goals and objectives. Not much detail was given about the training development program.

Another reviewer stated this project seems very passive. To this reviewer, there did not seem to be a clear plan for dissemination or ensuring this training is used. This reviewer thinks NFPA has a real opportunity to leverage their position and not just function like another grantee. One reviewer mentioned that the materials presented were complemented by the PI's briefing and provided a succinct, understandable and credible statement of barriers. The presentation of milestones, activities and plans, by calendar quarter, provides confidence that the project is well-planned and focused on achieving its objectives. The presented graphics, and the PI's discussion of the training distribution plan, also contribute to this feeling of confidence.

Linking the first responder training to development and adoption of relevant NFPA codes and standards, as stated in the project objectives, should be a significant benefit resulting from this project. The presented materials identify roles of NFPA divisions. Another reviewer said there are a large number of partners to coordinate, and suggested that the team plan to interact with all of the other projects in this area. The last reviewer added that this is a very aggressive project for emergency responder safety training. The project involves many parties and it will be interesting to see if the tasks will be completed on time from all these parties.

QUESTION 3. TECHNICAL ACCOMPLISHMENTS AND PROGRESS: WHAT IS THE OVERALL PROGRESS TOWARDS PROJECT'S OBJECTIVES AND MILESTONES? IS PROGRESS ADEQUATELY REPORTED AND QUANTIFIED (E.G., NUMBER OF JOBS, INSTALLATIONS, ETC.) AS REQUIRED BY ARRA?

The first reviewer said that to date, the team has already accomplished a significant amount of reconnaissance and data collection in the field. The project leadership team has formed technical committees, attended an EV workshop in Detroit, and gathered fire service needs. Already, they have developed the conceptual direction for an emergency response advanced EV training program, and established a communications plan. SMEs are being hired to create a blended learning program to reach as many emergency responders as possible. Another reviewer commented it appears that this project is progressing nicely towards its objective and there is indication that the project is front loaded. One reviewer stated the presentation spoke to training nearly 1.1 million first responders, but the reviewer was left with a sense of not knowing a lot about the details of the development process. Another reviewer added the project is about where it should be for the start time. There is little to quantify at this point, so it is hard to comment on accomplishments early on, but the project looks to be on track. One reviewer said the project is getting out of the blocks quickly. The presentation effectively conveys information on specific results accomplished to date. A plus is that the format created for the milestones/plans is also used to communicate progress. Project partners have been engaged, a fire service technical panel has been established, and feedback from the technical committee has been obtained during two meetings. Another reviewer mentioned to please add a plan to quantify the impact of this project, while the last reviewer said the project clearly is implementing a detailed plan and developing or already developed teams for fire safety review.

QUESTION 4. COLLABORATIONS/PARTNERSHIPS: DOES THE PROJECT TEAM EFFECTIVELY USE COLLABORATIONS/PARTNERSHIPS WITH REGIONAL, STATE, LOCAL GOVERNMENTS, INDUSTRIAL, COMMERCIAL, UNIVERSITY, RESEARCH ORGANIZATIONS, AND SIMILAR ORGANIZATIONS TO ACHIEVE ITS OBJECTIVES?

Five reviewers agreed that the project team effectively uses relevant collaborators and associations extremely well and the list includes most stakeholders from firefighting, automotive OEMs, standards organizations (e.g., SAE and UL, as well as NFPA itself). One of those reviewers added it appears that engaging law enforcement stakeholders could be strengthened. Another reviewer said the project might want to consider adding FEMA and EMS national organizations, since FEMA can add mandated training and EMS is more organized with refreshers and mandated training. Another reviewer mentioned that contracts are set for communications support and web development and additional on-going collaborations should be established. One reviewer commented that the project team should coordinate with other projects in this area that are also working on first responder training regionally. Another reviewer added they are clearly interested in providing the best dynamic training for electric vehicle fire response.

The last reviewer said one of the primary collaborations and partnerships that should be developed is one with Homeland Security, in particular those in charge of the Homeland Security Exercise and Evaluation Program (HSEEP). In the opening of the presentation, the PI spoke to the inability of the fire service to financially sustain the training model. One of the ways in which this might be overcome is for a partnership to emerge with Homeland Security. Consider for a moment, a man pack bomb incident aboard an electric bus or trolley. First responders would have to understand the implications of this scenario outside of the normal mass transit transportation. This reviewer would be very surprised if this has not already been considered in cities where electric power is still used for mass transit. More than that, Homeland Security Exercise Funds could be used to support first responder training and evaluation. Moreover, if this is first responder training it must somehow connect with police since more times than not they are first on the scene of an emergency.

PROJECT STRENGTHS

The first reviewer said the project scope and proposed training program is essential for the nation and success of a national EV deployment program. The project is led by a strong team with a comprehensive and dedicated collaborative team. Future work will continue to develop standards based training content and curriculum, verification with SME review teams, instructor material and field reference guides for all U.S. Emergency Responders. Another reviewer added the project has a very focused effort on a critical need. One reviewer mentioned there is outstanding project approach and planning. The presentation of activities and milestones is complete, covers the entire duration of the project, and is easily understood. NFPA's credibility with the various fire service organizations is yet another strength. Three reviewers agreed there are many organizations involved to provide the right material, feedback on the material, and ensure the material reaches the people that need it, etc. One of those reviewers said they are very knowledgeable on the subject matter and the requirement of dealing with many organizations.

PROJECT WEAKNESSES

Two reviewers said no weaknesses are observed at present. A reviewer offered that the project may benefit from outreach to local school communities. A reviewer stated the project may consider engaging law enforcement more. Another reviewer mentioned they must admit that the PI surprised them when asked about the National Fire Protection Association's plan to "lash this training" to NIMS in some way. He didn't seem to be familiar with the acronym for the National Incident Management System, primarily a development of fire organizations out of the work in the 1970's called Firescope. One reviewer commented that a weakness is outsourcing or hiring outside firms for all development. The project will be "taken to the cleaners" and these firms will produce proprietary software that will have costs associated for updating. Within a couple of years, the materials will be out of date because the electric vehicle technology will have advanced. Two reviewers added the project does not include an initiative on collaboration with other organizations which are developing and providing electric drive vehicle training for first responders. In particular, these organizations include recipients of Department of Energy grants for projects which include first responder training. The last reviewer said it seems like a low funding amount for all the tasks and parties involved.

SPECIFIC RECOMMENDATIONS

Three reviewers said to coordinate with the other projects in this area that are also working on first responder training. One of those reviewers also requested that the impact of this project on jobs should be quantified. Another reviewer noted that the PI indicated that coordination with other projects can now be done, since NFPA has met for the second time with the project's technical committee. Another reviewer stated that connecting first responder training in ULEV vehicles to incidents within the purview of Homeland Security seems natural to this reviewer. Moreover establishing the connection to the National Incident Management System (NIMS) would create a "pull" strategy for first responders. Simply put, this means that first responders would have to be versed in responding to this ULEV vehicle incident. This would remove a number of barriers to fire participation, since an incident on an electric bus or within the confines of an electric car, for example, would become part of the HSEEP scenarios.

The last reviewer stated to change directions. This reviewer said the team should provide honest-to-goodness firefighter input on developing emergency responder materials to the other projects that are developing modules and put all the project efforts into using the astounding list of partners to work on dissemination to local jurisdictions and academies. The team should help develop recommendations on protocols for response for jurisdictions around the nation to adopt; this is what the NFPA should be doing. The team should work on creating scenarios for drills at local academies and stations. Possibly add FEMA to the project list of partners and work on making some training mandatory through FEMA's capabilities. Alternatively, work with EMS state directors to include material in the refresher course. EMS is more organized and regulated than fire, and the project will have a chance of hitting most of the EMTs during their refreshers over the next three years.

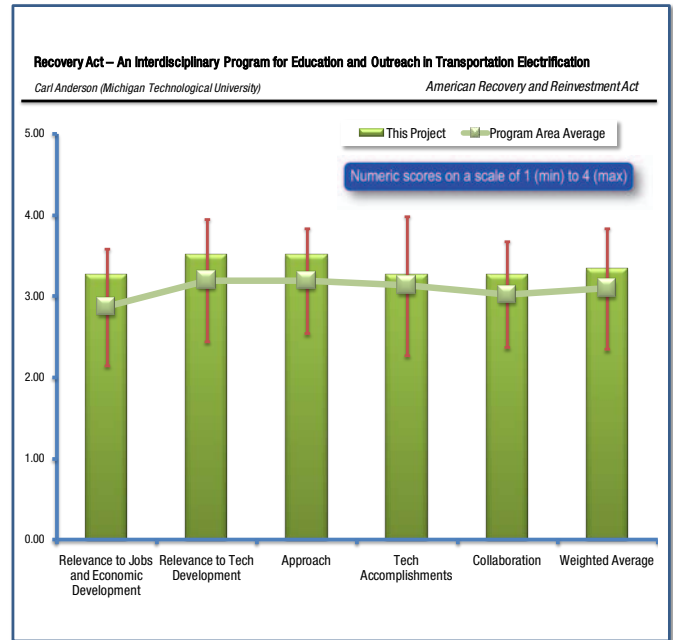
Recovery Act – An Interdisciplinary Program for Education and Outreach in Transportation Electrification: Carl Anderson, Michigan Technological University

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1A. RELEVANCE: IS THE PROJECT EFFORT RELEVANT TO THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA) OF 2009 GOALS: CREATE NEW JOBS AS WELL AS SAVE EXISTING ONES; SPUR ECONOMIC ACTIVITY AND INVEST IN LONG-TERM ECONOMIC GROWTH.

The first reviewer said their enrollment goals of 120 graduate students with an expected 50% split of on-campus and distance education students is also worthy of note, and is an achievable number considering the potential of the mobile laboratory to pre-sell the instruction. Another reviewer stated the project will create interdisciplinary undergraduate curriculum and graduate courses leading to a professional science master’s degree. Job creation through training and education was mentioned, but few activities seem to tie in with industry directly. The presentation covers this topic in more depth, but was not covered by the speaker. One reviewer added this project is designed to provide undergraduate and graduate curriculum, and to incorporate distance learning. Two reviewers also mentioned the project is going to create a mobile laboratory for both distance learning and additional education/outreach. The last reviewer commented on the university engineering degree programs, and said given the fact that OEMs and system suppliers are in a crash course to develop and market EV and HEV’s, there is a need for engineers with appropriate EV/HEV skills. Thus, many current engineers whose skills are not currently in demand may be able to use this training to position themselves to be able to re-enter the job market with skills that are in demand. Also given the program’s Michigan location (and extended reach into the Detroit metropolitan area), it will have a significant positive effect on the local industry and economy in this particularly hard hit area.



QUESTION 1B. RELEVANCE: DOES THE PROJECT’S TECHNOLOGY DEVELOPMENT PLAN AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOALS OF ACCELERATE THE DEVELOPMENT OF U.S. MANUFACTURING CAPACITY FOR BATTERIES AND ELECTRIC DRIVE COMPONENTS AS WELL AS THE DEPLOYMENT OF ELECTRIC DRIVE AND ALTERNATIVE FUEL VEHICLES AND INFRASTRUCTURE? DOES THE PROJECT’S DEVELOPMENT AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOAL TO ESTABLISH EDUCATION PROJECTS THAT ACCELERATE THE MASS MARKET INTRODUCTION AND PENETRATION OF ADVANCED ELECTRIC DRIVE VEHICLES, WHICH INCLUDES LIGHT, MEDIUM, AND HEAVY DUTY ADVANCED ELECTRIC VEHICLES (EV), PLUG-IN HYBRID ELECTRIC VEHICLES (PHEV), AND FUEL CELL ELECTRIC VEHICLES (FCV)?

The first reviewer thought this program has the potential of making a big difference in the understanding of and increased penetration of electric vehicles in the market place. Their secret weapon is the mobile laboratory that can serve a number of purposes from education and hands-on experiential learning to public relations in a number of venues. From recruiting new students, to familiarization of new technologies, to technology demonstrations, the mobile lab has the potential of arresting any fear or doubt about the soundness of electric vehicle technology. Another reviewer sensed that this project represented a modification of curriculum, not the creation of new material. This reviewer also asked if DOE paid for curriculum development out of this grant. It will help advance industry by introducing electrification coursework. One reviewer commented that this is an education/outreach activity comprised of curriculum, a mobile laboratory, and distance learning designed to increase knowledge about electric drive technologies. The last reviewer stated the graduate and undergraduate university certificate programs will help generate the U.S. based engineering talent necessary to stimulate/accelerate/sustain the development of U.S. manufacturing capacity for batteries and electric drive components as well as OEM integration of these systems.

QUESTION 2. DEVELOPMENT/DEPLOYMENT APPROACH: ARE THE PROJECT'S TECHNICAL AND DEPLOYMENT MILESTONES AND SCHEDULE CLEARLY IDENTIFIED, APPROPRIATE, AND FEASIBLE, AND ARE TECHNICAL AND COMMERCIAL BARRIERS AND RISKS ADEQUATELY ADDRESSED?

The first reviewer said the program takes an aggressive yet controlled education development approach to developing graduate and undergraduate interdisciplinary engineering instruction. The three-year objective of developing a master of engineering degree targets the higher end of the market, a noteworthy goal. Another reviewer added that feasible goals have been set, and the program is using well-established mechanisms for delivery of courses. The only real risk is the mobile lab, and it will be interesting to see if the mobile lab becomes sustainable after this grant. One reviewer stated the curriculum for this project is already completed; the mobile laboratory is to be completed by December 2010 and is intended to be used by the end of 2011. The last reviewer mentioned the project seems to have a good handle on how to execute the various elements of the project to meet its specified goals within the specified budget. An interdisciplinary team of faculty and staff appear to have the depth and diversity necessary to cover the key areas of program development and execution.

QUESTION 3. TECHNICAL ACCOMPLISHMENTS AND PROGRESS: WHAT IS THE OVERALL PROGRESS TOWARDS PROJECT'S OBJECTIVES AND MILESTONES? IS PROGRESS ADEQUATELY REPORTED AND QUANTIFIED (E.G., NUMBER OF JOBS, INSTALLATIONS, ETC.) AS REQUIRED BY ARRA?

The first reviewer said the design, development and fabrication of the mobile laboratory for instruction and outreach is worthy of note and is a great idea and effort: what better way to introduce new and potential entrants to the industry of electric vehicles than by bringing a full-on laboratory to their doorstep. This mobile laboratory could very well be modeled by other educational institutions around the country and used to penetrate rural areas where potential electric vehicle students could be found. From an educational perspective, it provides for a full hands-on experience. Another reviewer mentioned the project has made great progress in overcoming institutional inertia. The PI attributes this to close connections with dean. One reviewer commented that the number of jobs reported or quantified was not discussed during the presentation, though there is a slide that addresses this point. In terms of meeting the goal of developing curriculum, that has been accomplished. The mobile lab is being developed (though is not complete as of now); students are already starting to take advantage of the developed curriculum. The last reviewer stated the project seems to be making good progress at implementation and goal fulfillment. This is more impressive given the complexity involved in the design and fabrication of the mobile laboratory (key element of this program).

QUESTION 4. COLLABORATIONS/PARTNERSHIPS: DOES THE PROJECT TEAM EFFECTIVELY USE COLLABORATIONS/PARTNERSHIPS WITH REGIONAL, STATE, LOCAL GOVERNMENTS, INDUSTRIAL, COMMERCIAL, UNIVERSITY, RESEARCH ORGANIZATIONS, AND SIMILAR ORGANIZATIONS TO ACHIEVE ITS OBJECTIVES?

The first reviewer said the partnerships and collaboration for this project is exemplary. MTU as the lead has included GM, Michigan Green Jobs and the Argonne National Laboratory as some of its partners. There is great industry collaboration. Another reviewer added there are good and diverse partners that range from academia to industry to marketing. One reviewer stated that while there are a number of partners in this project based on the slides, the presenter didn't go into their role(s) so it wasn't clear what value they are adding to this project. The last reviewer mentioned the project seems to be well-leveraged with significant cost share and an impressive array of industry partners and supporters.

PROJECT STRENGTHS

All four reviewers all agreed the mobile laboratory will be a key element (and strength) that will greatly enhance the programs distance learning and outreach activities. Another reviewer added the program seems to be well targeted to meet the needs of both the local industry and engineers who need to gain (or re-tool) skills in this rapidly growing area. The program is also coordinating its curriculum development with the Wayne State program. Perhaps this coordination can be expanded to other DOE sponsored programs that are developing the same type of programs and curriculum.

PROJECT WEAKNESSES

Two of the reviewers both said they could not identify any significant program weakness. Another reviewer added a weakness could be the scalability/sustainability of mobile lab and the small number of participants in the program. The last reviewer observed that the presenter indicated the curriculum for this project was basically already completed prior to issuing of this award. One question the reviewer had is whether federal funding was provided to the funder with the assumption that the monies would be used to develop the curriculum.

SPECIFIC RECOMMENDATIONS

The first reviewer recommended that once the first mobile lab is built and successfully piloted, build six more mobile labs and distribute them to other universities across the U.S. Give full credit to MTU for the original idea. Use the mobile labs as hands-on learning laboratories as well as a comprehensive outreach program to bring otherwise forgotten folks into the electric vehicle and power systems industry. Another reviewer stated it would be great if the simulation-based training developed for the lab could be viewed online too (hosted on the university's website and made open source) so that the training material could be used by more than just the few that fit in the bus. In addition, some of the training simulations may be useful for remediation or review before tests. The last reviewer suggested expanding the coordination of curriculum development and validation beyond Wayne State to include other similar DOE funded programs.

Recovery Act—Transportation Electrification Education Partnership for Green Jobs and Sustainable Mobility: Hwei Peng, University of Michigan

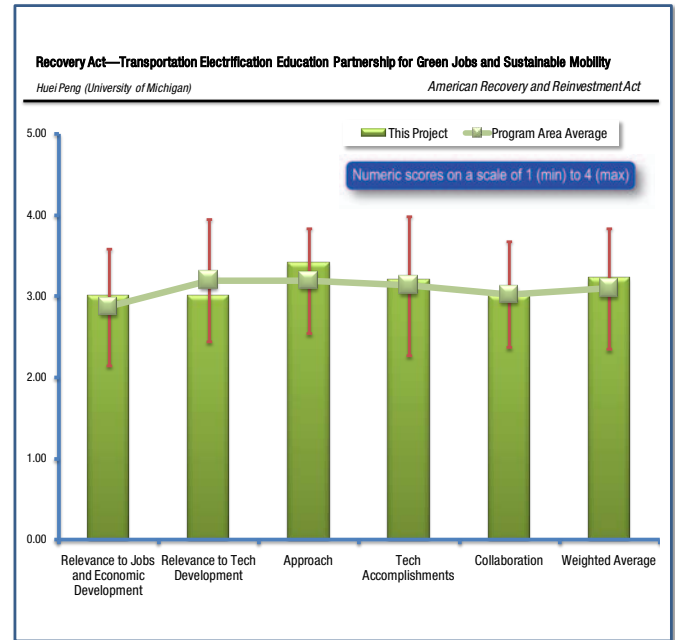
REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1A. RELEVANCE: IS THE PROJECT EFFORT RELEVANT TO THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA) OF 2009 GOALS: CREATE NEW JOBS AS WELL AS SAVE EXISTING ONES; SPUR ECONOMIC ACTIVITY AND INVEST IN LONG-TERM ECONOMIC GROWTH.

The first reviewer said this project is directly supporting the ARRA 2009 goals and sustaining, maintaining and creating (also regaining) jobs in ET/Automotive and ES. The project demonstrates strong overlap and collaboration with OEMs, and good use of leveraging resources and available funding. The university has observed

students move from 65% to 25 % of the automotive engineering program from traditional programs in the past five years. They are finally now seeing re-entry to the program and developing 10 courses under this project. Uniquely, one course combines Energy Systems and Automotive Engineering, and has up to 400 students by combination, and a new course on modeling and simulation is established. This reviewer went on to say that overall the project will directly support job creation through training and education to support deployment and acceptance of EV and spur economic growth. The project will be supporting 10 credit courses that are expected to impact 300-500 students annually. The short courses will impact 100-200 professional engineers annually, and K-12 and other consumer education and outreach activities should impact more than 1,000 annually. The final goal is job creation through training and education. The team is also developing professional web-based training with GM and has two batches of students already. The web-based impact will be far reaching. One reviewer stated while there are important benefits, e.g., improved economic competitiveness, associated with better educated engineers and well-trained technicians, it is difficult to establish a direct link between a project like this and specific job-creation benefits. Three reviewers agreed that job creation was not specifically addressed in the review presentation. One of those reviewers added that job creation and retention were not directly addressed, but proximity to major automotive companies and professional courses would suggest an opportunity for job retention. The last reviewer stated the project provides job creation through training and education.



QUESTION 1B. RELEVANCE: DOES THE PROJECT’S TECHNOLOGY DEVELOPMENT PLAN AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOALS OF ACCELERATE THE DEVELOPMENT OF U.S. MANUFACTURING CAPACITY FOR BATTERIES AND ELECTRIC DRIVE COMPONENTS AS WELL AS THE DEPLOYMENT OF ELECTRIC DRIVE AND ALTERNATIVE FUEL VEHICLES AND INFRASTRUCTURE? DOES THE PROJECT’S DEVELOPMENT AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOAL TO ESTABLISH EDUCATION PROJECTS THAT ACCELERATE THE MASS MARKET INTRODUCTION AND PENETRATION OF ADVANCED ELECTRIC DRIVE VEHICLES, WHICH INCLUDES LIGHT, MEDIUM, AND HEAVY DUTY ADVANCED ELECTRIC VEHICLES (EV), PLUG-IN HYBRID ELECTRIC VEHICLES (PHEV), AND FUEL CELL ELECTRIC VEHICLES (FCV)?

The first reviewer said overall the project will directly support job creation through training and education to support deployment and acceptance of EV and spur economic growth. The project will be supporting 10 credit courses that will directly impact VT ARRA project goals of accelerate the development of U.S. manufacturing capacity for batteries and electric drive component. The new courses will cover advanced aspects of VT, AED, batteries and VSS. The course will support the deployment of electric drive and alternative fuel vehicles and their infrastructure by training the future workforce. The courses are crosscutting by nature and designed to accelerate workforce and training in the EV field. Support from the funding will also be used to improve laboratory training facilities. This reviewer went on to say there is impressive progress, as the project started October 2009 and four of the ten courses

have already started. Another reviewer added that funding for this project is relatively modest relative to others. Accordingly, the project seems to be appropriately split between augmentations of an already strong curriculum with investments in laboratory capabilities. One reviewer mentioned this project includes multiple education and training initiatives which, in total, will result in significant numbers of highly qualified professionals whose expertise will benefit the electric drive transportation industry. The inclusion of three universities in the project is also important to increasing the numbers of students, as well as consumers generally; whose knowledge will accelerate the introduction and acceptance of competitive electric drive vehicles. The presented material provides a succinct, easily understood project objective statement and overview of the initiatives within the project. Another reviewer stated this project does not seem to directly address manufacturing capacity and deployment, but it does directly establish an education program, and indirectly impacts the mass market introduction of advanced vehicles. The last reviewer commented that by providing educated students in electric vehicles and electric vehicle technologies, companies have students to hire to accelerate the use of electric vehicles.

QUESTION 2. DEVELOPMENT/DEPLOYMENT APPROACH: ARE THE PROJECT'S TECHNICAL AND DEPLOYMENT MILESTONES AND SCHEDULE CLEARLY IDENTIFIED, APPROPRIATE, AND FEASIBLE, AND ARE TECHNICAL AND COMMERCIAL BARRIERS AND RISKS ADEQUATELY ADDRESSED?

The first reviewer said the course designs appear sound and the approach to development appropriate. One particular course, "modeling and control of batteries," is somewhat unique. This project direction is needed as well as innovative. All four courses are taught by two faculty members. This appears to be breaking new ground for the university, and "forcing" collaboration. Other courses are still being approved by distance learning, and new course approval takes time. Student enrollment is impressive, even if the distance learning number is still small. Three labs are being renovated, simulating many different HEVs. Another reviewer mentioned there is good coordination between three universities and also strong industry interaction, including in course development and instruction. There is good leverage of existing strengths in automotive engineering and engineering systems. One reviewer added that overall, the tables and graphics in the presentation do a nice job of communicating the approach to, and content of, the project. They instill confidence that the project has been well planned and address the barriers in a logical manner. However, no indication is provided in the first portion of the presentation about the activities and specific timing associated with laboratory development, which evidently accounts for a significant portion of the project's resources. Information is provided near the end, however. In his oral presentation, the PI discussed the laboratory improvements as an important complement to the course development activity. Another reviewer asked how the courses and labs will be coordinated among the partner schools, and is there a duplication of effort? The last reviewer stated this is a very good plan. The speaker was adamant on leveraging other educational electric vehicle programs to better implement the K-12 education plan.

QUESTION 3. TECHNICAL ACCOMPLISHMENTS AND PROGRESS: WHAT IS THE OVERALL PROGRESS TOWARDS PROJECT'S OBJECTIVES AND MILESTONES? IS PROGRESS ADEQUATELY REPORTED AND QUANTIFIED (E.G., NUMBER OF JOBS, INSTALLATIONS, ETC.) AS REQUIRED BY ARRA?

The first reviewer said five innovative training courses have been created and five more are being offered in fall, including Plug-in Vehicle Infrastructure (Fall 10, UMAA), Automotive Power Electronics Laboratory (Fall 10, UMAA), Vehicular Power Systems and Loads (Fall 10, UMD), Green Mobility Laboratory and associated courses (Fall 10, Kettering), Green Energy Manufacturing (Winter 11, UMAA), Integrated Hybrid Electric System Laboratory (Fall 11, UMAA), Development of an Education Kit for Electric Automobiles (Fall 12), Saturday morning seminar series on Green Mobility and Website Development (Fall 12). The laboratory specs are being developed and under evaluation. Another reviewer mentioned the project has gotten off to an excellent start. Four courses were developed and delivered in the first semester of 2010. The PI also discussed progress on other initiatives, such as education of high school students and laboratory development work. One reviewer added this project is just starting, but please plan to track students going to industry. The last reviewer commented the project is showing progress towards courses, summer camp, education kit, and laboratory development.

QUESTION 4. COLLABORATIONS/PARTNERSHIPS: DOES THE PROJECT TEAM EFFECTIVELY USE COLLABORATIONS/PARTNERSHIPS WITH REGIONAL, STATE, LOCAL GOVERNMENTS, INDUSTRIAL, COMMERCIAL, UNIVERSITY, RESEARCH ORGANIZATIONS, AND SIMILAR ORGANIZATIONS TO ACHIEVE ITS OBJECTIVES?

The first reviewer said this project involves three partner schools: University of Michigan Ann Arbor, University of Michigan Dearborn, and Kettering University. Industrial collaborators are involved in course and lab development and include GM, Ford, DTE, AVL, A&D, and A123. The industrial partners serve the roles of equipment providers, invited lecturers, course material provider, and support our K-12 outreach activities. Another reviewer added that the "SimCity-Like" video education tool is intriguing. One reviewer noted the industrial collaborators listed on the presentation slides, and the roles identified for them in project implementation, are outstanding. However, a project of this magnitude should be more aggressive in seeking additional collaborators, particularly in the state of Michigan. For example, government organizations, consumer groups, Clean Cities coalitions, advocacy groups, utilities, etc. should be engaged and informed. The last two reviewers agreed there is a very good set of partners; while one of the reviewers also said to please be sure to coordinate among all of them.

PROJECT STRENGTHS

Four of the reviewers agreed there is a strong collaboration with the industry. One of those reviewers also added the project strengths included innovative cross disciplinary course development. The K-12 outreach program and summer camps will be effective. Courses involve exciting hands on training opportunities to empower and engage students. Another reviewer added that another project strength is M&S effort for the battery system. One reviewer said the PI makes an outstanding impression. He is articulate and thoughtful, and his presentation contributes to a perspective that the project is logical and well-managed. Another reviewer mentioned there is a very comprehensive set of courses and labs. The last reviewer noted that some of the project strengths were simulations, a hands-on approach with the automotive education kit, multiple faculty members on the same course to implement the best course since the course content is new, summer camp and education kit (K-12), and undergraduate courses and graduate courses.

PROJECT WEAKNESSES

The first reviewer said it is not completely clear what is meant by "green" manufacturing. Deployment outside Michigan may be addressed better. Another reviewer mentioned that planning for coordination among all of the partners is a weakness. The last two reviewers agreed that there are no project weaknesses, with one of the reviewers adding the project is doing a very good job for the funding level.

SPECIFIC RECOMMENDATIONS

The first reviewer said the project needs to clarify exactly what "green manufacturing" means. Another reviewer requested development of a table with specific milestones associated with each project initiative, with accomplishment dates, for inclusion in presentation materials. The project team should be aggressive in developing partnerships and collaborations with other Michigan organizations, and with the leaders of other electric drive transportation education and training projects. Information on new course offerings, outlines and content should be routinely shared with other universities and community colleges, particularly those in Michigan and those developing courses with Department of Energy funds. The last reviewer added to please coordinate all of the proposed courses, labs, first responder training, and large number of partnerships among all of the other projects in this area.

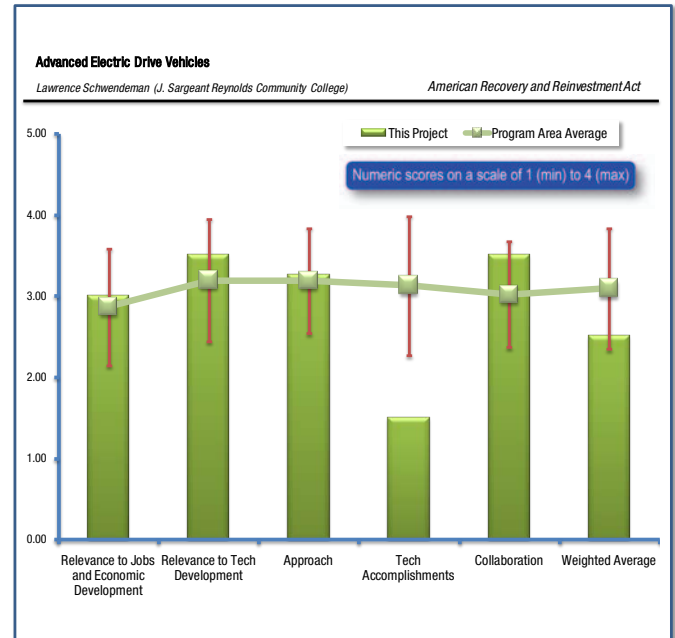
Advanced Electric Drive Vehicles: Lawrence Schwendeman, J. Sargeant Reynolds Community College

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1A. RELEVANCE: IS THE PROJECT EFFORT RELEVANT TO THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA) OF 2009 GOALS: CREATE NEW JOBS AS WELL AS SAVE EXISTING ONES; SPUR ECONOMIC ACTIVITY AND INVEST IN LONG-TERM ECONOMIC GROWTH.

The first reviewer said the folks at J. Sargeant Reynolds Community College have taken a practical, “feet on the ground,” well researched and implementable approach to developing education for the future of electric vehicle automotive technicians. They have an intimate understanding of the issues and challenges associated with producing technicians for an ever-increasing complex field of automotive repair. One of the major issues they face can be described as “work ethic:” finding employees that want to work hard and earn their way every day in a tough and demanding business can be difficult to achieve. However, their presentation demonstrated to this reviewer they are the right team for the job. Another reviewer added that this project is likely to have a direct and long term impact on creating new jobs and saving existing ones. The automotive tech course will spur economic activity and enable independent facilities to stay in business as advanced electric vehicles become more prevalent and need servicing. One reviewer mentioned this project targets the training of automotive technicians. The program involves developing a career certificate for advanced EVs and to develop five advanced EV courses in the study certificate. The plan calls for developing the courses, including a lab component, piloting the course, and then refining the course and offering it. The first course is being offered this summer on HEVs with 5 students. EVs and plug-in hybrid courses will take place in 2011, FCEVs in 2012. They have a marketing plan but have not released it yet. The project will do a distance education program when the other courses are finalized. Two reviewers agreed that, in terms of creating new jobs, everyone that signs up for the training and completes the training can be gainfully employed, so the success rate is 100%. The last reviewer commented that the Development of Automotive Technology Education Materials may make students “more marketable,” but the fact that all students can find jobs upon graduation tends to indicate that the addition of EV and HEV technology content by itself will not increase the amount of jobs that are created. Where jobs could be created is if the jobs for EV and HEV's are considered to be higher status – then you might see more student enrollment and thus fill the empty mechanics jobs that are currently out there.



QUESTION 1B. RELEVANCE: DOES THE PROJECT’S TECHNOLOGY DEVELOPMENT PLAN AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOALS OF ACCELERATE THE DEVELOPMENT OF U.S. MANUFACTURING CAPACITY FOR BATTERIES AND ELECTRIC DRIVE COMPONENTS AS WELL AS THE DEPLOYMENT OF ELECTRIC DRIVE AND ALTERNATIVE FUEL VEHICLES AND INFRASTRUCTURE? DOES THE PROJECT’S DEVELOPMENT AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOAL TO ESTABLISH EDUCATION PROJECTS THAT ACCELERATE THE MASS MARKET INTRODUCTION AND PENETRATION OF ADVANCED ELECTRIC DRIVE VEHICLES, WHICH INCLUDES LIGHT, MEDIUM, AND HEAVY DUTY ADVANCED ELECTRIC VEHICLES (EV), PLUG-IN HYBRID ELECTRIC VEHICLES (PHEV), AND FUEL CELL ELECTRIC VEHICLES (FCV)?

The first reviewer said they have taken a practical and implementable approach to developing a career studies program of 22 credits targeted towards developing an ever increasing gap in automotive repair for electric vehicles. That gap lies between the manufacturer’s automotive repair department, which they in fact supply with trained technicians, and the non-manufacturer repair shop which has no electric car technician supply chain. JSRCC’s program is designed to fill that gap. Another reviewer mentioned that by providing an educational facility for technician training, this project will help accelerate mass market introduction and penetration

of EV's by enabling them to be treated as the norm and not a specialty that must be taken to a manufacturer-specific shop for a pricey repair. One reviewer added by educating this segment of the population, they will be getting jobs in a growing market segment. The last reviewer stated that while the service technician training aspects of this project will do little to stimulate/accelerate the development of U.S. manufacturing capacity for batteries and electric drive components, it does lay down the educational underpinnings to stimulate interest in EV/HEV technology and the development of the necessary repair technician infrastructure.

QUESTION 2. DEVELOPMENT/DEPLOYMENT APPROACH: ARE THE PROJECT'S TECHNICAL AND DEPLOYMENT MILESTONES AND SCHEDULE CLEARLY IDENTIFIED, APPROPRIATE, AND FEASIBLE, AND ARE TECHNICAL AND COMMERCIAL BARRIERS AND RISKS ADEQUATELY ADDRESSED?

The first reviewer said they described a simple and straightforward development and implementation plan, with reachable milestones and a good system of checks and balances to assure the programs are in fact piloted before going to distribution. The reviewer was concerned that the final iteration of the courses would not provide the students with enough hands-on work, since the plan for implementation called for using distance education. They have filled this gap with planned labs so that courses will have a real hands-on element, most essential for a program such as this. Another reviewer added the project is well-focused and on track. Institutional inertia in creating a degree pathway or certificate was not an issue. One reviewer stated the milestones are clearly defined and the team has already gotten a course up and running on hybrids. The EV and FCEV courses will come in the next year or so. The last reviewer mentioned the program seems to be focused on the creation of courses. Lack of partners and reliance on vehicle "donations" limits the students' ability to work directly on vehicles using different types of EV/HEV technologies. No plan to address this, other than to convert a conventional vehicle to an electric vehicle, was given. While such a conversion would be interesting, the technology levels of typical "conversions" significantly lags that of vehicles currently entering the market and thus would likely have limited educational value.

QUESTION 3. TECHNICAL ACCOMPLISHMENTS AND PROGRESS: WHAT IS THE OVERALL PROGRESS TOWARDS PROJECT'S OBJECTIVES AND MILESTONES? IS PROGRESS ADEQUATELY REPORTED AND QUANTIFIED (E.G., NUMBER OF JOBS, INSTALLATIONS, ETC.) AS REQUIRED BY ARRA?

The first reviewer said they will teach their first course in the summer of 2010, having initiated the program in December of 2009 and there has been excellent progress so far. Another reviewer stated the progress was reported adequately and quantified in terms of coursework created, under development and equipment to be purchased. One reviewer mentioned the project has five students in the HEV program currently, and the team indicated they can place everyone who graduates from the program because the need is great. The PI will be getting a free gas-powered automobile and converting it to an EV as the lab exercise for the EV course. The last reviewer added that progress on the course work is adequate but there are little to no results on the development of appropriate labs and lab materials (i.e., EV or HEV vehicles of differing technologies).

QUESTION 4. COLLABORATIONS/PARTNERSHIPS: DOES THE PROJECT TEAM EFFECTIVELY USE COLLABORATIONS/PARTNERSHIPS WITH REGIONAL, STATE, LOCAL GOVERNMENTS, INDUSTRIAL, COMMERCIAL, UNIVERSITY, RESEARCH ORGANIZATIONS, AND SIMILAR ORGANIZATIONS TO ACHIEVE ITS OBJECTIVES?

Three of the reviewers all said there were no partnerships listed on presentation materials. One of those reviewers added the presenter did indicate they would like to partner: this seems like a terrific opportunity, since they have identified a real workforce need. Another reviewer also stated Firestone service facilities were mentioned as providing lab/instructional facilities. The last reviewer commented there are collaborations with GM, Ford and Bridgestone for hands-on collaboration.

PROJECT STRENGTHS

The first reviewer said one of the project strengths is that there is a simple, straightforward, "feet on the ground," implementable approach to developing a career studies program to fill the gap left by manufacturer training programs for electric automotive technicians. Another reviewer added the PIs have identified an outstanding workforce development project that will meet a real need. Project implementation seems right on track and we need to make them a national model. One of the reviewers stated the project is educating an important segment of the population. The last reviewer mentioned they can't really point to any specific strength as this project only has a range from poor to adequate.

PROJECT WEAKNESSES

Three of the reviewers agreed that collaborations and partnerships is a weakness of the project. One of those reviewers said this is a great program, and this reviewer was sure the team can be linked up with more community colleges to help meet the need of independent shops that need higher trained mechanics. Another reviewer added that low student enrollment/throughput and poor lab facilities are weaknesses. The last reviewer stated they couldn't think of any project weaknesses.

SPECIFIC RECOMMENDATIONS

The first reviewer said to keep the project going, while another reviewer suggested perhaps attending a relevant conference, contacting AACC, or linking up with some of the other DOE-funded AEV projects would increase the impact of this program. The last reviewer added the project needs to aggressively seek industry partners that can provide assistance in areas of weakness, and also coordinate curriculum development with other parallel DOE funded projects.

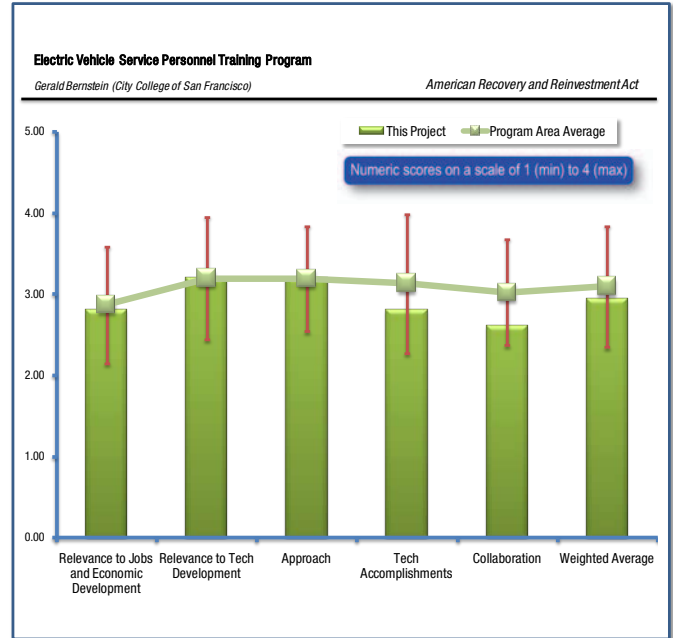
*Electric Vehicle Service Personnel Training Program:
Gerald Bernstein, City College of San Francisco*

REVIEWER SAMPLE SIZE

This project had a total of 5 reviewers.

QUESTION 1A. RELEVANCE: IS THE PROJECT EFFORT RELEVANT TO THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA) OF 2009 GOALS: CREATE NEW JOBS AS WELL AS SAVE EXISTING ONES; SPUR ECONOMIC ACTIVITY AND INVEST IN LONG-TERM ECONOMIC GROWTH.

The first reviewer said the project directly supports the VT 2009 ARRA goals by making an investment in training technicians and creating new jobs for repair and maintenance positions for EV. This will help accelerate electric vehicles into the market space by supporting consumer behavior and alleviating worry about maintenance problems. Another reviewer added the project is addressing a key barrier for customer acceptance by training the technicians for independent repair shops and municipal fleets. The project is located in an area with one of the highest concentrations of HEV in the nation, thus serving critical training needs for the deployment of EVs. One reviewer mentioned the presentation did not identify specific job or economic activity impacts associated with the project. While there are important benefits, e.g., improved economic competitiveness, associated with better educated engineers and well-trained technicians, it is difficult to establish a direct link between this type of project and specific job-creation benefits. Another reviewer stated the project is in the early stages and job creation was not specifically addressed in the review presentation. This reviewer asked that the team develop a plan to track graduates from the program that go into industry. The last reviewer commented this project helps educate the new generation of auto technicians to become familiar with electric vehicles, which creates an expertise in electric vehicles.



QUESTION 1B. RELEVANCE: DOES THE PROJECT’S TECHNOLOGY DEVELOPMENT PLAN AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOALS OF ACCELERATE THE DEVELOPMENT OF U.S. MANUFACTURING CAPACITY FOR BATTERIES AND ELECTRIC DRIVE COMPONENTS AS WELL AS THE DEPLOYMENT OF ELECTRIC DRIVE AND ALTERNATIVE FUEL VEHICLES AND INFRASTRUCTURE? DOES THE PROJECT’S DEVELOPMENT AND/OR DEPLOYMENT PLAN ADDRESS THE VT ARRA PROJECT GOAL TO ESTABLISH EDUCATION PROJECTS THAT ACCELERATE THE MASS MARKET INTRODUCTION AND PENETRATION OF ADVANCED ELECTRIC DRIVE VEHICLES, WHICH INCLUDES LIGHT, MEDIUM, AND HEAVY DUTY ADVANCED ELECTRIC VEHICLES (EV), PLUG-IN HYBRID ELECTRIC VEHICLES (PHEV), AND FUEL CELL ELECTRIC VEHICLES (FCV)?

The first reviewer said the training of service and repair technicians will only support the ARRA goal of accelerating the development of U.S. manufacturing capacity for batteries and electric drive components as well as the deployment of electric drive and alternative fuel vehicles and infrastructure. Having more service technicians who are trained in the new technologies, systems and components will be critical for sustainability and consumer confidence. Another reviewer added this project includes technician training initiatives that will result in increased numbers of qualified vehicle maintenance personnel whose expertise will benefit the electric drive transportation industry. The inclusion of small businesses which have developed a knowledge base and practical skills in working on electric drive systems, together with a large fleet customer requiring hybrid vehicle maintenance, is a plus. This project is the smallest of the ARRA-funded vehicle technologies education projects. It is expected that this will limit the reach of the project and the number of individuals trained with project funds compared to other projects. Two of the reviewers agreed this project does not seem to directly address manufacturing capacity and deployment. However, one of the reviewers said it does directly establish a training program, and indirectly impacts the mass market introduction of advanced vehicles. The other reviewer also said it clearly addresses long-term

maintenance needs. The last reviewer stated with more technicians that are familiar with electric vehicles, consumers become more likely to purchase EVs because they will talk to and know people personally who can fix these vehicles.

QUESTION 2. DEVELOPMENT/DEPLOYMENT APPROACH: ARE THE PROJECT'S TECHNICAL AND DEPLOYMENT MILESTONES AND SCHEDULE CLEARLY IDENTIFIED, APPROPRIATE, AND FEASIBLE, AND ARE TECHNICAL AND COMMERCIAL BARRIERS AND RISKS ADEQUATELY ADDRESSED?

The first reviewer said the project approach appears sound. The team will develop a curriculum for hybrid, PHEV, EV and FCV technologies and identify training aids for automotive technician programs, independent technicians, and municipal fleet operators. They will disseminate curriculum locally to test portability, and sample colleges and employers in Southern California and neighboring states to identify training support and infrastructure needs. Deployment efforts are strong. The team plans to adapt newly created curriculum for high school/ vocational schools. Another reviewer mentioned that despite a relatively modest budget, it is a well thought out plan that addresses all technician needs (outside of the OEMs) as well as for expanding training efforts from San Francisco to the Bay Area, to California, to neighboring states. Also, the team could use a strategy to HEV as initial stages for future expansion of training program for EVs and FCVs. One reviewer added the milestones for 2010, and the approach to accomplishing them, are clearly stated, straightforward and reasonable. From the PI's oral presentation, it can be concluded that the project team has a good grasp of the work required to develop and deliver the electric drive technical training curriculum, and the capability to accomplish it. What is not so clear is how the expansion of the training outside the San Francisco Bay area will be accomplished with available project resources. Neither the approaches to expansion, nor the organizations with which CCSF expects to collaborate, were spelled out. In response to a question, the PI stated that training programs in Oregon are targeted, but that no one there has been approached yet. Another reviewer asked how will the training courses be coordinated among the partner schools and others? Is there a duplication of effort? The last reviewer commented the approach is to develop and pilot a series of related training courses, and then improve course content, equipment requirements and instructor skills.

QUESTION 3. TECHNICAL ACCOMPLISHMENTS AND PROGRESS: WHAT IS THE OVERALL PROGRESS TOWARDS PROJECT'S OBJECTIVES AND MILESTONES? IS PROGRESS ADEQUATELY REPORTED AND QUANTIFIED (E.G., NUMBER OF JOBS, INSTALLATIONS, ETC.) AS REQUIRED BY ARRA?

The first reviewer said the team is making strong progress on goals and milestones. Prior to the project the team launched a first Hybrid Maintenance and Repair course piloted at CCSF during fall 2009 using a donated Prius. The team also held a Saturday class for thirty students in automotive electrical that is a pre-requisite. In February 2010, the team held its first study kick-off meeting. The project also has two of the three partner contracts in place; the third is in process. The first curriculum-design meetings conducted with San Francisco shops (site for municipal and private fleet maintenance training) and the first curriculum-design meeting conducted with Chabot College faculty for both their student program and independent technician program curriculum. The team has made an initial equipment list for first round of training (diagnostic software, in addition to a donated hybrid car). Another reviewer stated that the presentation materials support a conclusion that there has been excellent progress in meeting the objectives, and achieving the milestones, associated with the project's first year. The project got out of the blocks quickly, with a new course piloted during the fall of 2009. The municipal fleet partner (which is also a customer for trained technicians) has been engaged in curriculum design. A reviewer added this project is just starting; please plan to track graduates of this program going to the industry. A final reviewer said the project is making good progress under very modest funding.

QUESTION 4. COLLABORATIONS/PARTNERSHIPS: DOES THE PROJECT TEAM EFFECTIVELY USE COLLABORATIONS/PARTNERSHIPS WITH REGIONAL, STATE, LOCAL GOVERNMENTS, INDUSTRIAL, COMMERCIAL, UNIVERSITY, RESEARCH ORGANIZATIONS, AND SIMILAR ORGANIZATIONS TO ACHIEVE ITS OBJECTIVES?

The first reviewer said the project lead is College of San Francisco and collaborators include Chabot College, Pat's Garage, Perfect Sky, and San Francisco Municipal Shops. The beauty of the collaborations in this project is the model may be adapted, repeated and deployed. Another reviewer added that the project has built a team with good experience from early EV vehicles as well as Hymotion conversions and SAE training courses. One reviewer mentioned there seem to be excellent working relationships among the community colleges leading the project, the small businesses specializing in maintenance of electric drive vehicles, and

representatives of fleets which require maintenance personnel with electric drive vehicle expertise. Those organizations involved in the project to date are all in or near San Francisco (which is reasonable for year one).

If the objectives and milestones for years 2 and 3 are to be successfully achieved, then collaborators/partners must be identified and working relationships developed. The concept of expanding the project is sound, but partners are needed. Another reviewer stated there are a good set of partners and to please be sure to coordinate among all of them while the last reviewer said the project has maintenance shops, especially the shop that specializes in EVs.

PROJECT STRENGTHS

The first reviewer said a project strength is the planned deployment into other cities. San Francisco is an EV training ground for technicians and consumers. Another reviewer stated it is a well-organized and cost effective program with a great strategy to expand training activities to surrounding areas. One reviewer added the project leaders and participants have practical, “hands-on” experience with both vehicle maintenance and imparting their expertise to students.

Project participants recognize the growing need for electric drive vehicle technicians to be employed by organizations other than those directly connected with vehicle manufacturers. The project is responsive to this increasingly important market. Another reviewer mentioned another strength is the partnerships with others schools and some industry. The last reviewer commented the strengths are the collaborations with garages specializing in electric vehicles, training technicians and fleet operators, and free short courses for marketing to technicians.

PROJECT WEAKNESSES

The first reviewer said a project weakness is the geographic confinement at present, while another reviewer added coordination of training courses among other schools as another weakness. One reviewer mentioned there are no specific plans which seem to have been developed for meeting the objective to expand the training beyond the San Francisco area. The last reviewer stated the project could use some collaboration directly from OEMs. The reviewer then says that is easier said than done for a small school, but this would help with the availability of equipment and support.

SPECIFIC RECOMMENDATIONS

The first reviewer said the project should share the model with other regions as the concentration of vehicles grows. Another reviewer commented an action should be taken soon on assembling the plan for expansion and sharing of the training curricula developed, and approach used, in the Bay area during the initial project year. This should include near-term engagement of other leaders among community colleges and technical schools in California.

The PI should present his work, and its results to date, to leaders of DOE Clean Cities coalitions in California and Oregon. Linking to Clean Cities initiatives, and using their contacts, could assist in achieving the benefits of the expansion planned for the CCSF project. The last reviewer requested that the team please coordinate the proposed training courses, first responder training, and large number of partnerships among all of the other projects in this area.

9. ACRONYMS

Acronym	Definition
A/SP	Auto/Steel Partnership
ACC	American Chemistry Council
ACE	Applied Cost Engineering team
ACES	Advanced Collaborative Emissions Study
AEC	Advanced Engine Combustion
AED	Advanced Electric Drive
AES	Auger Electron Spectroscopy
AFV	Alternative Fuel Vehicle
AHSS	Advanced High Strength Steel
ALD	Atomic Layer Deposition
ANL	Argonne National Laboratory
APBF	Advanced Petroleum-Based Fuels
APEEM	Advanced Power Electronics and Electric Machines Program
APRF	Advanced Powertrain Research Facility
APS	Advanced Photon Source
ARC	Accelerated Rate Calorimetry
ARL	Army Research Laboratory
ARRA	American Recovery and Reinvestment Act
ASIC	Application-Specific Integrated Circuit
ASTM	American Society for Testing and Materials
AVFL	Advanced vehicle/fuel/lubricant committee
AVTA	Advanced Vehicle Testing Activity
BATT	Batteries for Advanced Transportation Technologies
BCD	Bipolar-CMOS-DMOS
BES	DOE Basic Energy Sciences
BEV	Battery Electric Vehicle
BLRT	Bond Line Read Through
BMEP	Brake mean effective pressure
BMS	Battery management system
BSFC	Brake specific fuel consumption
BTE	Brake thermal efficiency
CAE	Computer Aided Engineering
CAFÉ	Corporate Average Fuel Economy
CANMET	Canada Center for Mineral and Energy Technology
CARB	California Air Resources Board
CF	Carbon Fiber
CFD	Computational fluid dynamics
CH4	Methane
CI	Compression Ignition

Acronym	Definition
CLEERS	Cross-Cut Lean Exhaust Emission Reduction Simulation
CLOSE	Collaborative Lubricating Oil Study on Emissions
CMOS	Complimentary Metal-Oxide-Semiconductor
CNF	Carbon Nano-Fibers
CNG	Compressed Natural Gas
CNT	Carbon Nanotubes
CO	Carbon Monoxide
CO2	Carbon Dioxide
COP	Coefficient of Performance
CPI	Compact Power Inc.
CR	Compression ratio
CRADA	Cooperative Research and Development Agreement
CRC	Coordinating Research Council
CSI	Current Source Inverter
CSU	Colorado State University
CTE	Coefficient of thermal expansion
CVD	Chemical Vapor Deposition
DBC	Direct bonded copper
DEM	Digital Elevation Model
DeSOx	Flue Gas Desulfurization
DFMEA	Design Failure Mode Effects Analysis
DFT	Density Functional Theory
DI	Direct Injection
DISI	Direct injection spark ignited
DOC	Diesel oxidation catalyst
DOD	Department of Defense
DoD	Depth of Discharge
DOE	Department of Energy
DOT	Department of Transportation
DPF	Diesel particulate filter
DRIFTS	Diffuse Reflectance Infrared Fourier Transform Spectroscopy
DSC	Differential Scanning Calorimetry Analysis
DST	Dynamic Stress Test
DT	Diagnostics Testing
E85	85 percent ethanol blend with gasoline
EC	Ethylene Carbonate
ECI	Enterprise Content Integration
EDLC	Electric Double-Layer Capacitor
EERE	Energy Efficiency and Renewable Energy
EETT	Enhancing Education Through Technology
EGR	Exhaust Gas Recirculation

Acronym	Definition
EIL	Engineers in the Loop
EMC	Ethyl methyl carbonate
EMF	Electromagnetic Forming
EMI	Electromagnetic Interference
EMS	Emergency Medical Services
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ERC	Engine Research Center at University of Wisconsin
ERDA	Elastic Recoil Detection Analysis
ETC	Environmental Technology Council
EUCAR	European Council for Automotive R&D
EV	Electric Vehicle
FACE	Fuels for Advanced Combustion Engines
FCEV	Fuel cell electric vehicles
FCV	Fuel cell electric vehicles
FE	Fuel Efficiency
FEA	Finite Element Analysis
FEERC	Fuels, Engines, and Emissions Research Center
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIB	Focused Ion Beam
FMCSA	Federal Motor Carrier Safety Administration
FMEA	Failure Mode and Effects Analysis
FMEAM	Force-Matching-Embedded-Atom-Method
FMEP	Friction Mean Effective Pressure
FPE	Free-Piston Engine
FSP	Friction Stir Processing
FSW	Friction Stir Welding
FUDS	Federal Urban Drive Schedule
FY	Fiscal Year
GATE	Graduate Automotive Technology Education
GDE	Gas diffuse electrode
GDI	Gasoline Direct Injection
GHG	Greenhouse gases
GIXS	Grazing-Incidence X-ray Scattering
GM	General Motors Corporation
GPS	Global Positioning System
GPU	Graphics Processing Unit
GTI	Gas Technology Institute
H2	Hydrogen
HAZ	Heat Affected Zone

Acronym	Definition
HC	Hydrocarbon
HCCI	Homogeneous Charge Compression Ignition
HD	Heavy-duty
HDD	Heavy-duty diesel
HECC	High Efficiency Clean Combustion
HEV	Hybrid Electric Vehicle
HICEV	Hydrogen internal combustion electric vehicle
HIL	Hardware in the Loop
HNEI	Hawaii Natural Energy Institute
HPLB	High-Pressure, Lean Burn
HSEEP	Homeland Security Exercise and Evaluation Program
HSS	High Strength Steel
HTGB	High Temperature Gate Bias
HTIPE	High temperature integrated power electronics
HTML	High Temperature Materials Laboratory
HTOL	High Temperature Operating Life
HTRB	High Temperature Reverse Bias
HVAC	Heating Ventilating and Air Conditioning
IC	Internal Combustion
ICE	Internal Combustion Engine
ICME	Integrated Computational Material Engineering
IGBT	Insulated-gate bipolar transistor
IMEP	Indicated Mean Effective Pressure
IMMD	Integrated Modular Motor Drive
INL	Idaho National Laboratory
IP	Intellectual Property
IQT	Ignition Quality Tester
ISFC	Indicated Specific Fuel Consumption
ISO	International Organization for Standardization
JARI	Japan Automobile Research Institute
JFET	Junction Gate Field-Effective Transistor
JPL	Jet Propulsion Laboratory
KIVA	Internal combustion engine simulation code (Los Alamos)
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LCA	Lifecycle cost analysis
LD	Light-duty
LDECC	Light Duty Efficient Clean Combustion
LDV	Light Duty Vehicle
LES	Large Eddy Simulation
LFP	Lithium iron phosphate

Acronym	Definition
LIC	Lithium Capacitors
LJP	Laser Jet Peening
LLNL	Lawrence Livermore National Laboratory
LMP	Lithium Metal Polymer
LNMO	Lithium Nickel Manganese Oxide
LNT	Lean NOx Trap
LSDC	Low Speed Duty Cycle
LSM	Lambda (oxygen) Sensor
LSMO	Lanthanum Strontium Manganite
LSP	Laser shock peening
LTC	Low Temperature Combustion
LTO	Low Temperature Oxide (form of silicon dioxide)
MCMB	Mesocarbon Microbeads
MDIUF	Multi-Day Individual Utility Factor
MEAM	Modified Embedded Atom Method
MEDC	Michigan Economic Development Corporation
MIG	Metal Inert Gas (welding)
MIT	Massachusetts Institute of Technology
MMV	Multi-Material Vehicle
MOSFET	Metal-Oxide-Semiconductor Field-Effective Transistor
MOU	Memorandum of Understanding
MSU	Michigan State University
MTBE	Methyl Tertiary Butyl Ether
MTDC	Medium-Truck Duty Cycle
MTU	Michigan Technology University
NAFTC	National Alternative Fuels Training Consortium
NASA	National Aeronautics and Space Administration
NCA	Battery cathode material (nickel cobalt aluminum oxide)
NDA	Non-Destructive Analysis
NDE	Non-Destructive Evaluation
NEDC	New European Driving Cycle
NEV	Neighborhood Electric Vehicle
NFPA	National Fire Protection Association
NG	Natural Gas
NGP	Nano Graphine Platelets
NIMS	National Incident Management System
NIST	National Institute of Standards and Technology
NMC	Lithiated nickel-manganese-cobalt oxide
NMR	Nuclear Magnetic Resonance
Nox	Nitrogen Oxide
NPV	Net Present Value

Acronym	Definition
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
NSR	NOx Storage/Reduction
NVH	Noise/vibration/harshness
NVO	Negative valve overlap
OBD	Onboard Diagnostics
OEM	Original Equipment Manufacturer
OH	Hydroxide
OMB	Office of Management and Budget
ORC	Organic Rankine cycle
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
PCCI	Premixed Charge Compression Ignition
PED	Power Electric Device
PEEM	Power Electronics and Electric Machines
PEP	Program Execution Plan
PFR	Plug Flow Reactor
PGM	Precious-group metals
PHEV	Plug-In Hybrid Electric Vehicle
PI	Principal Investigator
PM	Particulate Matter
PMEP	Pumping Mean Effective Pressure
PNNL	Pacific Northwest National Laboratory
PPF	Pulse Pressure Forming
PSAT	Powertrain Systems Analysis Toolkit
PSD	Particle Size Distribution
PVDF	Polyvinylidene Fluoride
PZT	Lead zirconate titanate film
R&D	Research and Development
RAPTR	Regenerative Air Preheating and Thermochemical Recuperation
RPM	Revolutions Per Minute
SAE	Society of Automotive Engineers
SAED	Selected Area Electron Diffraction
SBIR	Small Business Innovation Research
SCORE	Sandia/Caterpillar Optical Research Engine
SCR	Selective Catalytic Reduction
SEI	Solid electrolyte interface
SEM	Scanning Electron Microscope
SI	Spark Ignition

Acronym	Definition
SLMP	Stabilized Lithium Metal Powder
SMC	Sheet Molding Compound
SmCo	Samarium-Cobalt
SME	Soy Methyl Ester
SNL	Sandia National Laboratory
SOA	State of the art
SOC	State of Charge
SOI	Silicon on insulator
SOI	Start of Injection
SRS	Safety Response Separator
SUNY	State University of New York
SUV	Sport Utility Vehicle
SWNT	Single wall nanotube
TARDEC	Tank Automotive Research, Development, and Engineering Center
TBC	Thermal Barrier Coating
TBD	To Be Decided
TCR	Thermochemical Recuperation
TDC	Top Dead Center
TE	Thermoelectrics
TEG	Thermoelectric Generator
TEM	Transmission Electron Microscope
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek
TS	Thermal Stratification
UC	University of California
UHC	Unburned Hydrocarbons
UL	Underwriters Laboratories
ULSD	Ultra-low sulfur diesel
UMTRI	University of Michigan Transportation Research Institute
UNLV	University of Nevada Las Vegas
USABC	US Advanced Battery Consortium
USCAR	United States Council for Automotive Research
UT	University of Tennessee
UV	Ultra Violet
UW	University of Wisconsin
UWM	University of Wisconsin at Madison
VGC	Vehicle-Grid Connection
VR	Virtual Reality
VSI	Voltage source inverter
VSS	Vehicle Systems and Simulation activity
VT	Vehicle Technologies
VTP	Vehicle Technologies Program

Acronym	Definition
VVA	Variable Valve Actuation
VVLT	Variable Valve Lift and Timing
W	Watt
WHR	Waste Heat Recovery
WSP	Wet Shot Peening
XAS	X-ray Absorbtion Spectroscopy
XPS	X-ray Photoelectron Spectroscopy
XRD	X-ray Diffraction (Crystallography)
YSZ	Yttria-stabilized zirconia
ZT	Thermoelectrics figure of merit (measure of efficiency)

10. CROSS-REFERENCE OF PROJECT INVESTIGATORS, PROJECTS, AND ORGANIZATIONS

Cross-Reference, Sorted by Project Investigator

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8-3	Al Ebron (West Virginia University) -- Advanced Electric Drive Vehicle Education Program <<Technology Integration>>
6-14	Alan Luo (General Motors) -- Magnesium Front End Research and Development - Phase 1 (AMD 604) <<Materials Technologies>>
7-60	Ali Erdemir (Argonne National Laboratory) -- Low-Friction Hard Coatings <<Propulsion Materials>>
3-56	Allen Hefner (NIST) -- Electro-thermal-mechanical Simulation and Reliability for Plug-in Vehicle Converters and Inverters <<Power Electronics & Electrical Machines Technologies>>
2-76	Andrew Jansen (Argonne National Laboratory) -- Fabricate PHEV Type Cells for Testing & Diagnostics <<Energy Storage Technologies>>
2-57	Andrew Jansen (Argonne National Laboratory) -- Improved Methods for Making Intermetallic Anodes <<Energy Storage Technologies>>
8-18	Andrew Klock (National Fire Protection Association) -- U.S. Emergency Responder Safety Training for Advanced Electric Drive Vehicles <<Technology Integration>>
6-56	Andrew Payzant (Oak Ridge National Laboratory) -- Characterization of Materials for Li-ion Batteries: Success Stories from the High Temperature Materials Laboratory (HTML) User Program <<Materials Technologies>>
7-34	Andrew Wereszczak (Oak Ridge National Laboratory) -- Environmental Effects on Power Electronic Devices <<Propulsion Materials>>
7-24	Andrew Wereszczak (Oak Ridge National Laboratory) -- Thermoelectric Mechanical Reliability <<Propulsion Materials>>
2-151	Ann Marie Sastry (University of Michigan) -- Microscale Electrode Design Using Coupled Kinetic, Thermal and Mechanical Modeling <<Energy Storage Technologies>>
2-135	Anne Dillon (National Renewable Energy Laboratory) -- Nanostructured Metal Oxide Anodes <<Energy Storage Technologies>>
2-33	Anthony Thurston (BASF) -- Process for Low Cost Domestic Production of LIB Cathode Materials <<Energy Storage Technologies>>
2-109	Arumugam Manthiram (University of Texas at Austin) -- Stabilized Spinels and Polyanion Cathodes <<Energy Storage Technologies>>
3-31	Ayman El-Refaie (General Electric Global) -- Scalable, Low-Cost, High Performance IPM Motor for Hybrid Vehicles <<Power Electronics & Electrical Machines Technologies>>
1-22	Aymeric Rousseau (Argonne National Laboratory) -- Autonomie Plug & Play Software Architecture <<Hybrid and Vehicle Systems Technologies >>
1-47	Aymeric Rousseau (Argonne National Laboratory) -- Heavy Duty Vehicle Modeling and Simulation <<Hybrid and Vehicle Systems Technologies >>
1-28	Aymeric Rousseau (Argonne National Laboratory) -- Impact of Driving Behavior on PHEV Fuel Consumption for Different Powertrain, Component Sizes and Control <<Hybrid and Vehicle Systems Technologies >>

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7-32	Beth Armstrong (Oak Ridge National Laboratory) -- Materials Compatibility of Power Electronics <<Propulsion Materials>>
6-43	Bob Norris (Oak Ridge National Laboratory) -- Composite Underbody Attachment, Advanced Preforming and Related Processes for Manufacturing Low Cost Composites <<Materials Technologies>>
2-21	Bor Jang (Angstrom Materials) -- Hybrid Nano Carbon Fiber/Graphene Platelet-Based High-Capacity Anodes for Lithium Ion Batteries <<Energy Storage Technologies>>
5-18	Bradley Zigler (National Renewable Energy Laboratory) -- Advanced Petroleum-Based Fuels Research at NREL <<Fuels & Lubricants Technologies>>
5-4	Bradley Zigler (National Renewable Energy Laboratory) -- Fuels for Advanced Combustion Engine Technologies Engines <<Fuels & Lubricants Technologies>>
2-141	Brett Lucht (University of Rhode Island) -- Development of Electrolytes for Lithium-ion Batteries <<Energy Storage Technologies>>
2-5	Brian Barnett (TIAX LLC) -- PHEV Battery Cost Assessment <<Energy Storage Technologies>>
5-10	Brian West (Oak Ridge National Laboratory) -- Mil-Level Ethanol Blends Test Program <<Fuels & Lubricants Technologies>>
5-2	Bruce Bunting (Oak Ridge National Laboratory) -- APBF Effects on Combustion <<Fuels & Lubricants Technologies>>
6-51	Camden Hubbard (Oak Ridge National Laboratory) -- Evaluation and Characterization of Materials Technologies: Success Stories from the High Temperature Materials Laboratory (HTML) User Program <<Materials Technologies>>
8-22	Carl Anderson (Michigan Technological University) -- Recovery Act – An Interdisciplinary Program for Education and Outreach in Transportation Electrification <<Technology Integration>>
7-22	Chaitanya K. Narula (Oak Ridge National Laboratory) -- Catalysts via First Principles <<Propulsion Materials>>
5-8	Charles Mueller (Sandia National Laboratories) -- Fuel Effects on Advanced Combustion Engine Technologies: Optical Heavy-Duty Engine Research <<Fuels & Lubricants Technologies>>
4-111	Chris Nelson (Cummins) -- Exhaust Energy Recovery <<Advanced Combustion Engine Technologies>>
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2-45	Christopher Johnson (Argonne National Laboratory) -- Design and Evaluation of Novel High Capacity Cathode Materials <<Energy Storage Technologies>>
4-30	Christopher Powell (Argonne National Laboratory) -- Fuel Spray Research on Light-Duty Injection Systems <<Advanced Combustion Engine Technologies>>
4-79	Chuck Peden (Pacific Northwest National Laboratory) -- Degradation Mechanisms of Urea Selective Catalytic Reduction Technology <<Advanced Combustion Engine Technologies>>
4-76	Chuck Peden (Pacific Northwest National Laboratory) -- Enhanced High Temperature Performance of NOx Storage/Reduction (NSR) Materials <<Advanced Combustion Engine Technologies>>
2-117	Clare Grey (SUNY-Stony Brook) -- First Principles Calculations and NMR Spectroscopy of Electrode Materials: NMR <<Energy Storage Technologies>>

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2-100	Claus Daniel (Oak Ridge National Laboratory) -- In Situ Characterization of Fatigue Behavior of Electrodes <<Energy Storage Technologies>>
4-123	Clay Maranville (Ford Motor Company) -- Thermoelectric HVAC for Light-Duty Vehicle Applications <<Advanced Combustion Engine Technologies>>
7-5	Curt Lavender (Pacific Northwest National Laboratory) -- Fatigue Enhancements by Shock Peening <<Propulsion Materials>>
7-13	Curt Lavender (Pacific Northwest National Laboratory) -- Low Cost Titanium – Propulsion Applications <<Propulsion Materials>>
2-11	Cyrus Ashtiani (Enerdel) -- USABC PHEV Battery Development Project <<Energy Storage Technologies>>
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2-59	Dan Abraham (Argonne National Laboratory) -- Novel Electrolytes and Additives <<Energy Storage Technologies>>
4-117	Dan Greenbaum (Health Effects Institute) -- Advanced Collaborative Emissions Study (ACES) <<Advanced Combustion Engine Technologies>>
2-143	Daniel Scherson (Case Western Reserve University) -- Bifunctional Electrolytes for Lithium-ion Batteries <<Energy Storage Technologies>>
4-67	Darrell Herling (Pacific Northwest National Laboratory) -- CLEERS: Aftertreatment Modeling and Analysis <<Advanced Combustion Engine Technologies>>
4-39	David Carrington (Los Alamos National Laboratory) -- KIV4-4 Development <<Advanced Combustion Engine Technologies>>
7-26	David J. Singh (Oak Ridge National Laboratory) -- Thermoelectrics Theory and Structure <<Propulsion Materials>>
6-16	David Wagner (Ford Motor Company) -- Multi-Materials Vehicle R&D Initiative <<Materials Technologies>>
6-7	David Warren (Oak Ridge National Laboratory) -- Carbon Fiber Pilot Plant and Research Facilities <<Materials Technologies>>
6-5	David Warren (Oak Ridge National Laboratory) -- Low Cost Carbon Fiber Overview <<Materials Technologies>>
6-9	David Warren (Oak Ridge National Laboratory) -- Lower Cost Carbon Fiber Precursors <<Materials Technologies>>
4-54	Dennis Assanis (University of Michigan) -- A University Consortium on Efficient and Clean High-Pressure, Lean Burn (HPLB) Engines <<Advanced Combustion Engine Technologies>>
2-79	Dennis Dees (Argonne National Laboratory) -- Electrochemistry Cell Model <<Energy Storage Technologies>>
7-64	Dieter Gruen (Argonne National Laboratory) -- Diamond Based TE Materials <<Propulsion Materials>>
7-46	Dileep Singh (Argonne National Laboratory) -- Compact Potentiometric NOx Sensor <<Propulsion Materials>>
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3-52	Fei Wang (Oak Ridge National Laboratory) -- High Power Density Integrated Traction Machine Drive <<Power Electronics & Electrical Machines Technologies>>
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2-83	Frank McLarnon (Lawrence Berkeley National Laboratory) -- Electrochemistry Diagnostics at LBNL <<Energy Storage Technologies>>
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8-9	Gary Caille (Colorado State University) -- Advanced Electric Drive Vehicle Education Program: CSU Ventures <<Technology Integration>>
2-36	Gary Henriksen (Argonne National Laboratory) -- Overview of Applied Battery Research <<Energy Storage Technologies>>
1-10	George Fenske (Argonne National Laboratory) -- Boundary Layer Lubrication Mechanisms <<Hybrid and Vehicle Systems Technologies >>
1-12	George Fenske (Argonne National Laboratory) -- DOE/DOD Parasitic Energy Loss Collaboration <<Hybrid and Vehicle Systems Technologies >>
7-52	George Fenske (Argonne National Laboratory) -- Friction Modeling for Lubricated Engine and Drivetrain Components <<Propulsion Materials>>
7-7	George Fenske (Argonne National Laboratory) -- Fuel Injector Holes (Fabrication of Micro-Orifices for Fuel Injectors) <<Propulsion Materials>>
7-50	George Fenske (Argonne National Laboratory) -- Surface Texturing for Friction Control <<Propulsion Materials>>
7-54	George Fenske (Argonne National Laboratory) -- Ultra-Fast Chemical Conversion Surfaces <<Propulsion Materials>>
8-31	Gerald Bernstein (City College of San Francisco) -- Electric Vehicle Service Personnel Training Program <<Technology Integration>>
2-115	Gerbrand Ceder (Massachusetts Institute of Technology) -- First Principles Calculations of Electrode Materials <<Energy Storage Technologies>>
3-41	Gilbert Moreno (National Renewable Energy Laboratory) -- Characterization and Development of Advanced Heat Transfer Technologies <<Power Electronics & Electrical Machines Technologies>>

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1-68	Glenn Keller (Argonne National Laboratory) -- Advanced Powertrain Research Facility Vehicle Test Cell Thermal Upgrade <<Hybrid and Vehicle Systems Technologies >>
4-61	Gouming Zhu (Michigan State University) -- Flex Fuel Optimized SI and HCCI Engine <<Advanced Combustion Engine Technologies>>
7-36	Govindarajan Muralidharan (Oak Ridge National Laboratory) -- Materials for HCCI Engines <<Propulsion Materials>>
7-30	Govindarajan Muralidharan (Oak Ridge National Laboratory) -- Solder Joints of Power Electronics <<Propulsion Materials>>
2-123	Grant Smith (University of Utah) -- Molecular Dynamics Simulation Studies of Electrolytes and Electrolyte/Electrode Interfaces <<Energy Storage Technologies>>
1-43	Greg Cesiel (General Motors) -- Plug-in Hybrid (PHEV) Vehicle Technology Advancement and Demonstration Activity <<Hybrid and Vehicle Systems Technologies >>
1-45	Greg Fenette (Ford Motor Company) -- Ford Plug-In Project: Bringing PHEVs to Market <<Hybrid and Vehicle Systems Technologies >>
3-33	Greg Smith (General Motors) -- Advanced Integrated Electric Traction System <<Power Electronics & Electrical Machines Technologies>>
4-131	Gregory Meisner (General Motors) -- Develop Thermoelectric Technology for Automotive Waste Heat Recovery <<Advanced Combustion Engine Technologies>>
4-125	Gregory Meisner (General Motors) -- Improving Energy Efficiency by Developing Components for Distributed Cooling and Heating Based on Thermal Comfort Modeling <<Advanced Combustion Engine Technologies>>
3-11	Gui-Jia Su (Oak Ridge National Laboratory) -- A Segmented Drive Inverter Topology with a Small DC Bus Capacitor <<Power Electronics & Electrical Machines Technologies>>
3-7	Gui-Jia Su (Oak Ridge National Laboratory) -- Inverter Using Current Source Topology <<Power Electronics & Electrical Machines Technologies>>
2-145	Guoying Chen (Lawrence Berkeley National Laboratory) -- Performance and Safety of Olivines and Layered Oxides <<Energy Storage Technologies>>
4-128	Harold Schock (Michigan State University) -- Thermoelectric Conversion of Waste Heat to Electricity in an IC Engine Powered Vehicle <<Advanced Combustion Engine Technologies>>
4-103	Harold Sun (Ford Motor Company) -- Advanced Boost System Development for Diesel HCCI/LTC Application <<Advanced Combustion Engine Technologies>>
1-6	Helmut E. Knee (Oak Ridge National Laboratory) -- Truck Duty Cycle and Performance Data Collection and Analysis Program <<Hybrid and Vehicle Systems Technologies >>
1-38	Henning Lohse-Busch (Argonne National Laboratory) -- Advanced Technology Vehicle Benchmark and Assessment <<Hybrid and Vehicle Systems Technologies >>
6-53	Hsin Wang (Oak Ridge National Laboratory) -- High-Temperature Thermoelectric Materials Characterization for Automotive Waste Heat Recovery: Success Stories from the High Temperature Materials Laboratory (HTML) User Program <<Materials Technologies>>
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8-25	Huei Peng (University of Michigan) -- Recovery Act—Transportation Electrification Education Partnership for Green Jobs and Sustainable Mobility <<Technology Integration>>
2-48	Ilias Belharouak (Argonne National Laboratory) -- Search for High Energy Density Cathode Materials <<Energy Storage Technologies>>
3-35	Iver Anderson (Ames) -- Permanent Magnet Development for Automotive Traction Motors <<Power Electronics & Electrical Machines Technologies>>
2-55	Jack Vaughey (Argonne National Laboratory) -- Lithium Metal Anodes <<Energy Storage Technologies>>
8-6	James Caruthers (Purdue University) -- Indiana Advanced Electric Vehicle Training and Education Consortium (I-AEVtec) <<Technology Integration>>
1-36	James Francfort (Idaho National Laboratory) -- AVTA – PHEV Demonstrations and Testing <<Hybrid and Vehicle Systems Technologies >>
1-49	James Francfort (Idaho National Laboratory) -- AVTA HEV, NEV, BEV and HICEV Demonstrations and Testing <<Hybrid and Vehicle Systems Technologies >>
5-16	James Szybist (Oak Ridge National Laboratory) -- Non-Petroleum-Based Fuel Effects on Advanced Combustion Engine Technologies <<Fuels & Lubricants Technologies>>
2-15	Jamie Gardner (3M) -- Advanced Cathode Material Development for PHEV Lithium Ion Batteries <<Energy Storage Technologies>>
1-54	Jan Friesner (Navistar International Corp.) -- Plug IN Hybrid Vehicle Bus <<Hybrid and Vehicle Systems Technologies >>
3-27	Jason Lai (Virginia Tech) -- Advanced Soft Switching Inverter for Reducing Switching and Power Losses <<Power Electronics & Electrical Machines Technologies>>
3-42	Jason Lustbader (National Renewable Energy Laboratory) -- Air Cooling Technology for Power Electronic Thermal Control <<Power Electronics & Electrical Machines Technologies>>
2-137	Jason Zhang (Pacific Northwest National Laboratory) -- Development of High Capacity Anode for Li-ion Batteries <<Energy Storage Technologies>>
2-119	Jason Zhang (Pacific Northwest National Laboratory) -- Development of High Energy Cathode for Li-ion Batteries <<Energy Storage Technologies>>
1-18	Jeffrey Gonder (National Renewable Energy Laboratory) -- Emissions and Fuel Consumption Test Results from a Plug-In Hybrid Electric School Bus <<Hybrid and Vehicle Systems Technologies >>
7-48	Jiangang Sun (Oak Ridge National Laboratory) -- NDE Development for ACERT Engine Components <<Propulsion Materials>>
4-90	Jim Parks (Oak Ridge National Laboratory) -- Efficient Emissions Control for Multi-Mode Lean DI Engines <<Advanced Combustion Engine Technologies>>
4-52	Jim Parks (Oak Ridge National Laboratory) -- Emissions Control for Lean Gasoline Engines <<Advanced Combustion Engine Technologies>>
3-66	Jinfang Liu (Electron Energy Corporation) -- High Performance Permanent Magnets for Advanced Motors <<Power Electronics & Electrical Machines Technologies>>

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2-165	John Kerr (Lawrence Berkeley National Laboratory) -- Interfacial Behavior of Electrolytes <<Energy Storage Technologies>>
4-134	John LaGrandeur (BSST LLC) -- Automotive Waste Heat Conversion to Power Program <<Advanced Combustion Engine Technologies>>
2-153	John Newman (University of California at Berkeley) -- Analysis and Simulation of Electrochemical Energy Systems <<Energy Storage Technologies>>
1-51	John Rugh (National Renewable Energy Laboratory) -- CoolCab Thermal Load Reduction Project: CoolCalc HVAC Tool Development <<Hybrid and Vehicle Systems Technologies >>
4-119	John Storey (Oak Ridge National Laboratory) -- Measurement and Characterization of Unregulated Emissions from Advanced Technologies <<Advanced Combustion Engine Technologies>>
2-147	Jordi Cabana (Lawrence Berkeley National Laboratory) -- Positive and Negative Electrodes: Novel and Optimized Materials <<Energy Storage Technologies>>
4-97	Josh Pihl (Oak Ridge National Laboratory) -- Advanced Engine/Aftertreatment System R&D CRADA with Navistar, Inc. <<Advanced Combustion Engine Technologies>>
7-17	Jules Routbort (Argonne National Laboratory) -- Erosion of Radiator Materials by Nanofluids <<Propulsion Materials>>
8-15	Ka Yuen Simon Ng (Wayne State University) -- Development and Implementation of Degree Programs in Electric Drive Vehicle Technology <<Technology Integration>>
1-15	Kambiz Salari (Lawrence Livermore National Laboratory) -- DOE's Effort to Reduce Truck Aerodynamic Drag through Joint Experiments and Computations <<Hybrid and Vehicle Systems Technologies >>
2-102	Karim Zaghib (Hydro-Quebec) -- Low Cost SiO _x -Graphite and Olivine Materials <<Energy Storage Technologies>>
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3-63	Kevin Bennion (National Renewable Energy Laboratory) -- Thermal Management of PHEV / EV Charging Systems <<Power Electronics & Electrical Machines Technologies>>
2-177	Kevin Gering (Idaho National Laboratory) -- Diagnostic Testing and Analysis Toward Understanding Aging Mechanisms and Related Path Dependence <<Energy Storage Technologies>>
2-67	Kevin Gering (Idaho National Laboratory) -- Novel Compounds for Enhancing Electrolyte Stability and Safety of Lithium-ion Cells <<Energy Storage Technologies>>
4-113	Kevin Sisken (Detroit Diesel) -- High Efficiency Combustion and Controls <<Advanced Combustion Engine Technologies>>
1-3	Kevin Walkowicz (National Renewable Energy Laboratory) -- Medium and Heavy-Duty Vehicle Field Evaluations <<Hybrid and Vehicle Systems Technologies >>
2-89	Khalil Amine (Argonne National Laboratory) -- Develop and Evaluate Materials and Additives that Enhance Thermal and Overcharge Abuse <<Energy Storage Technologies>>
2-53	Khalil Amine (Argonne National Laboratory) -- Developing High Capacity, Long Life, and High Power Anodes <<Energy Storage Technologies>>
2-139	Khalil Amine (Argonne National Laboratory) -- Electrolytes - Advanced Electrolyte and Electrolyte Additives <<Energy Storage Technologies>>
2-39	Khalil Amine (Argonne National Laboratory) -- Engineering of High Energy Cathode Material <<Energy Storage Technologies>>
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2-169	Kristin Persson (Lawrence Berkeley National Laboratory) -- Atomistic Modeling of Electrode Materials <<Energy Storage Technologies>>
4-70	Kyeong Lee (Argonne National Laboratory) -- Development of Advanced Diesel Particulate Filtration (DPF) Systems <<Advanced Combustion Engine Technologies>>
6-54	Larry Allard (Oak Ridge National Laboratory) -- Characterization of Catalysts for Aftertreatment and Biomass-derived Fuels: Success Stories from the High Temperature Materials Laboratory (HTML) User Program <<Materials Technologies>>
7-58	Larry Allard (Oak Ridge National Laboratory) -- Ultr4-High Resolution Electron Microscopy for Catalyst Characterization <<Propulsion Materials>>
8-28	Lawrence Schwendeman (J. Sargeant Reynolds Community College) -- Advanced Electric Drive Vehicles <<Technology Integration>>
3-9	Leon Tolbert (Oak Ridge National Laboratory) -- High-Temperature, High-Voltage Fully Integrated Gate Driver Circuit <<Power Electronics & Electrical Machines Technologies>>
3-48	Leon Tolbert (Oak Ridge National Laboratory) -- Novel Packaging to Reduce Stray Inductance in Power Electronics <<Power Electronics & Electrical Machines Technologies>>
4-16	Lyle Pickett (Sandia National Laboratories) -- Low-Temperature Diesel Combustion Cross-Cut Research <<Advanced Combustion Engine Technologies>>

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5-12	Magnus Sjoberg (Sandia National Laboratories) -- Advanced Lean-Burn DI Spark Ignition Fuels Research <<Fuels & Lubricants Technologies>>
3-54	Mahdu Chinthavali (Oak Ridge National Laboratory) -- High-Temperature Air-Cooled Traction Drive Inverter Packaging <<Power Electronics & Electrical Machines Technologies>>
3-18	Mahdu Chinthavali (Oak Ridge National Laboratory) -- Wide Bandgap Materials <<Power Electronics & Electrical Machines Technologies>>
2-111	Marca Doeff (Lawrence Berkeley National Laboratory) -- Olivines and Substituted Layered Materials <<Energy Storage Technologies>>
2-27	Marina Yakovleva (FMC) -- Stabilized Lithium Metal Powder, Enabling Material and Revolutionary Technology for High Energy Li-ion Batteries <<Energy Storage Technologies>>
4-4	Mark Musculus (Sandia National Laboratories) -- Heavy-Duty Low-Temperature and Diesel Combustion & Heavy-Duty Combustion Modeling <<Advanced Combustion Engine Technologies>>
6-20	Mark Smith (Pacific Northwest National Laboratory) -- Formability of Direct Cast Mg Sheet and Friction Stir and Ultrasonic Joining of Magnesium to Steel <<Materials Technologies>>
6-27	Mark Smith (Pacific Northwest National Laboratory) -- Pulse Pressure Forming of Materials Technologies, Development of High Strength Superplastic Al Sheet, Friction Stir Spot Welding of Advanced High Strength Steels <<Materials Technologies>>
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- 4-82 Michigan Technological University (John Johnson) -- Experimental Studies for DPF and SCR Model, Control System, and OBD Development for Engines Using Diesel and Biodiesel Fuels <<Advanced Combustion Engine Technologies>>
- 6-34 Mississippi State University (Paul Wang) -- Advanced High Strength Steel Project <<Materials Technologies>>
- 6-25 Mississippi State University (Paul Wang) -- Magnesium Projects <<Materials Technologies>>
- 8-12 Missouri University of Science and Technology (Mehdi Ferdowsi) -- Advanced Electric Drive Vehicles – A Comprehensive Education, Training, and Outreach Program <<Technology Integration>>
- 3-58 NASA (Philip Neudeck) -- Development of SiC Large Tapered Crystal Growth <<Power Electronics & Electrical Machines Technologies>>
- 8-18 National Fire Protection Association (Andrew Klock) -- U.S. Emergency Responder Safety Training for Advanced Electric Drive Vehicles <<Technology Integration>>

- 2-135 National Renewable Energy Laboratory (Anne Dillon) -- Nanostructured Metal Oxide Anodes <<Energy Storage Technologies>>
- 5-18 National Renewable Energy Laboratory (Bradley Zigler) -- Advanced Petroleum-Based Fuels Research at NREL <<Fuels & Lubricants Technologies>>
- 5-4 National Renewable Energy Laboratory (Bradley Zigler) -- Fuels for Advanced Combustion Engine Technologies Engines <<Fuels & Lubricants Technologies>>
- 4-121 National Renewable Energy Laboratory (Douglas Lawson) -- Collaborative Lubricating Oil Study on Emissions (CLOSE Project) <<Advanced Combustion Engine Technologies>>
- 3-41 National Renewable Energy Laboratory (Gilbert Moreno) -- Characterization and Development of Advanced Heat Transfer Technologies <<Power Electronics & Electrical Machines Technologies>>
- 3-42 National Renewable Energy Laboratory (Jason Lustbader) -- Air Cooling Technology for Power Electronic Thermal Control <<Power Electronics & Electrical Machines Technologies>>
- 1-18 National Renewable Energy Laboratory (Jeffrey Gonder) -- Emissions and Fuel Consumption Test Results from a Plug-In Hybrid Electric School Bus <<Hybrid and Vehicle Systems Technologies >>
- 1-51 National Renewable Energy Laboratory (John Rugh) -- CoolCab Thermal Load Reduction Project: CoolCalc HVAC Tool Development <<Hybrid and Vehicle Systems Technologies >>
- 3-64 National Renewable Energy Laboratory (Kevin Bennion) -- Motor Thermal Management <<Power Electronics & Electrical Machines Technologies>>
- 3-37 National Renewable Energy Laboratory (Kevin Bennion) -- Power Electronic Thermal System Performance and Integration <<Power Electronics & Electrical Machines Technologies>>
- 3-63 National Renewable Energy Laboratory (Kevin Bennion) -- Thermal Management of PHEV / EV Charging Systems <<Power Electronics & Electrical Machines Technologies>>
- 1-3 National Renewable Energy Laboratory (Kevin Walkowicz) -- Medium and Heavy-Duty Vehicle Field Evaluations <<Hybrid and Vehicle Systems Technologies >>
- 1-64 National Renewable Energy Laboratory (Matthew Thornton) -- Integrated Vehicle Thermal Management <<Hybrid and Vehicle Systems Technologies >>
- 3-39 National Renewable Energy Laboratory (Michael O Keefe) -- Thermal Stress and Reliability for Power Electronics & Electrical Machines Technologies and Electric Machines <<Power Electronics & Electrical Machines Technologies>>
- 5-6 National Renewable Energy Laboratory (Robert McCormick) -- Quality, Performance, and Emission Impacts of Biofuels and Biofuel Blends <<Fuels & Lubricants Technologies>>
- 3-61 National Renewable Energy Laboratory (Sreekanth Narumanchi) -- Thermal Performance and Reliability of Bonded Interfaces <<Power Electronics & Electrical Machines Technologies>>
- 2-98 Naval Surface Warfare Center (Patricia Smith) -- High Energy Density Ultracapacitors <<Energy Storage Technologies>>
- 1-54 Navistar International Corp. (Jan Friesner) -- Plug IN Hybrid Vehicle Bus <<Hybrid and Vehicle Systems Technologies >>
- 4-115 Navistar International Corp. (William de Ojeda) -- Low-Temperature Combustion Demonstrator for High-Efficiency Clean Combustion <<Advanced Combustion Engine Technologies>>
- 2-24 NC State/NLE (Xiangwu Zhang) -- New High-Energy Nanofiber Anode Materials <<Energy Storage Technologies>>
- 3-56 NIST (Allen Hefner) -- Electro-thermal-mechanical Simulation and Reliability for Plug-in Vehicle Converters and Inverters <<Power Electronics & Electrical Machines Technologies>>

- 2-121 North Carolina State University (Wesley Henderson) -- Inexpensive, Nonfluorinated Anions for Lithium Salts and Ionic Liquids for Lithium Battery Electrolytes <<Energy Storage Technologies>>
- 6-56 Oak Ridge National Laboratory (Andrew Payzant) -- Characterization of Materials for Li-ion Batteries: Success Stories from the High Temperature Materials Laboratory (HTML) User Program <<Materials Technologies>>
- 7-34 Oak Ridge National Laboratory (Andrew Wereszczak) -- Environmental Effects on Power Electronic Devices <<Propulsion Materials>>
- 7-24 Oak Ridge National Laboratory (Andrew Wereszczak) -- Thermoelectric Mechanical Reliability <<Propulsion Materials>>
- 7-32 Oak Ridge National Laboratory (Beth Armstrong) -- Materials Compatibility of Power Electronics <<Propulsion Materials>>
- 6-43 Oak Ridge National Laboratory (Bob Norris) -- Composite Underbody Attachment, Advanced Preforming and Related Processes for Manufacturing Low Cost Composites <<Materials Technologies>>
- 5-10 Oak Ridge National Laboratory (Brian West) -- Mi1-Level Ethanol Blends Test Program <<Fuels & Lubricants Technologies>>
- 5-2 Oak Ridge National Laboratory (Bruce Bunting) -- APBF Effects on Combustion <<Fuels & Lubricants Technologies>>
- 6-51 Oak Ridge National Laboratory (Camden Hubbard) -- Evaluation and Characterization of Materials Technologies: Success Stories from the High Temperature Materials Laboratory (HTML) User Program <<Materials Technologies>>
- 7-22 Oak Ridge National Laboratory (Chaitanya K. Narula) -- Catalysts via First Principles <<Propulsion Materials>>
- 2-173 Oak Ridge National Laboratory (Christopher Janke) -- Long-Living Polymer Electrolytes <<Energy Storage Technologies>>
- 2-171 Oak Ridge National Laboratory (Claus Daniel) -- Coupled Kinetic, Thermal, and Mechanical Modeling of FIB Micro-machined Electrodes <<Energy Storage Technologies>>
- 2-100 Oak Ridge National Laboratory (Claus Daniel) -- In Situ Characterization of Fatigue Behavior of Electrodes <<Energy Storage Technologies>>
- 7-26 Oak Ridge National Laboratory (David J. Singh) -- Thermoelectrics Theory and Structure <<Propulsion Materials>>
- 6-7 Oak Ridge National Laboratory (David Warren) -- Carbon Fiber Pilot Plant and Research Facilities <<Materials Technologies>>
- 6-5 Oak Ridge National Laboratory (David Warren) -- Low Cost Carbon Fiber Overview <<Materials Technologies>>
- 6-9 Oak Ridge National Laboratory (David Warren) -- Lower Cost Carbon Fiber Precursors <<Materials Technologies>>
- 3-52 Oak Ridge National Laboratory (Fei Wang) -- High Power Density Integrated Traction Machine Drive <<Power Electronics & Electrical Machines Technologies>>
- 3-50 Oak Ridge National Laboratory (Fei Wang) -- Power Device Packaging <<Power Electronics & Electrical Machines Technologies>>
- 6-12 Oak Ridge National Laboratory (Felix Paulauskas) -- Advanced Oxidation & Stabilization of PAN-Based Carbon Precursor Fibers <<Materials Technologies>>
- 6-11 Oak Ridge National Laboratory (Frederick Baker) -- Low Cost Carbon Fiber from Renewable Resources <<Materials Technologies>>

- 7-36 Oak Ridge National Laboratory (Govindarajan Muralidharan) -- Materials for HCCI Engines <<Propulsion Materials>>
- 7-30 Oak Ridge National Laboratory (Govindarajan Muralidharan) -- Solder Joints of Power Electronics <<Propulsion Materials>>
- 3-11 Oak Ridge National Laboratory (Gui-Jia Su) -- A Segmented Drive Inverter Topology with a Small DC Bus Capacitor <<Power Electronics & Electrical Machines Technologies>>
- 3-7 Oak Ridge National Laboratory (Gui-Jia Su) -- Inverter Using Current Source Topology <<Power Electronics & Electrical Machines Technologies>>
- 1-6 Oak Ridge National Laboratory (Helmut E. Knee) -- Truck Duty Cycle and Performance Data Collection and Analysis Program <<Hybrid and Vehicle Systems Technologies >>
- 6-53 Oak Ridge National Laboratory (Hsin Wang) -- High-Temperature Thermoelectric Materials Characterization for Automotive Waste Heat Recovery: Success Stories from the High Temperature Materials Laboratory (HTML) User Program <<Materials Technologies>>
- 7-66 Oak Ridge National Laboratory (Hu4-Tay Lin) -- Durability of ACERT Engine Components <<Propulsion Materials>>
- 7-3 Oak Ridge National Laboratory (Huay-Tay Lin) -- Design Optimization of Piezoceramic Multilayer Actuators for Heavy Duty Diesel Engine Fuel Injectors <<Propulsion Materials>>
- 5-16 Oak Ridge National Laboratory (James Szybist) -- Non-Petroleum-Based Fuel Effects on Advanced Combustion Engine Technologies <<Fuels & Lubricants Technologies>>
- 7-48 Oak Ridge National Laboratory (Jiangang Sun) -- NDE Development for ACERT Engine Components <<Propulsion Materials>>
- 4-90 Oak Ridge National Laboratory (Jim Parks) -- Efficient Emissions Control for Multi-Mode Lean DI Engines <<Advanced Combustion Engine Technologies>>
- 4-52 Oak Ridge National Laboratory (Jim Parks) -- Emissions Control for Lean Gasoline Engines <<Advanced Combustion Engine Technologies>>
- 3-13 Oak Ridge National Laboratory (John Hsu) -- Novel Flux Coupling Machine without Permanent Magnets <<Power Electronics & Electrical Machines Technologies>>
- 4-119 Oak Ridge National Laboratory (John Storey) -- Measurement and Characterization of Unregulated Emissions from Advanced Technologies <<Advanced Combustion Engine Technologies>>
- 4-97 Oak Ridge National Laboratory (Josh Pihl) -- Advanced Engine/Aftertreatment System R&D CRADA with Navistar, Inc. <<Advanced Combustion Engine Technologies>>
- 2-175 Oak Ridge National Laboratory (Karren More) -- In-Situ Electron Microscopy of Electrical Energy Storage Technologies Materials <<Energy Storage Technologies>>
- 6-54 Oak Ridge National Laboratory (Larry Allard) -- Characterization of Catalysts for Aftertreatment and Biomass-derived Fuels: Success Stories from the High Temperature Materials Laboratory (HTML) User Program <<Materials Technologies>>
- 7-58 Oak Ridge National Laboratory (Larry Allard) -- Ultr4-High Resolution Electron Microscopy for Catalyst Characterization <<Propulsion Materials>>
- 3-9 Oak Ridge National Laboratory (Leon Tolbert) -- High-Temperature, High-Voltage Fully Integrated Gate Driver Circuit <<Power Electronics & Electrical Machines Technologies>>
- 3-48 Oak Ridge National Laboratory (Leon Tolbert) -- Novel Packaging to Reduce Stray Inductance in Power Electronics <<Power Electronics & Electrical Machines Technologies>>

- 3-54 Oak Ridge National Laboratory (Mahdu Chinthavali) -- High-Temperature Air-Cooled Traction Drive Inverter Packaging <<Power Electronics & Electrical Machines Technologies>>
- 3-18 Oak Ridge National Laboratory (Mahdu Chinthavali) -- Wide Bandgap Materials <<Power Electronics & Electrical Machines Technologies>>
- 7-40 Oak Ridge National Laboratory (Michael Kass) -- Materials-Enabled High-Efficiency Diesel Engines <<Propulsion Materials>>
- 7-19 Oak Ridge National Laboratory (Michael Lance) -- Materials Issues Associated with EGR Systems <<Propulsion Materials>>
- 6-32 Oak Ridge National Laboratory (Michael Santella) -- Fundamental study of the relationship of austenite-ferrite transformation details to austenite retention in carbon steels <<Materials Technologies>>
- 2-161 Oak Ridge National Laboratory (Nancy Dudney) -- Investigations of Cathode Architecture using Graphite Fibers <<Energy Storage Technologies>>
- 1-32 Oak Ridge National Laboratory (Paul Chambon) -- PHEV Engine Control and Energy Management Strategy <<Hybrid and Vehicle Systems Technologies >>
- 7-15 Oak Ridge National Laboratory (Peter Blau) -- Friction and Wear Enhancement of Titanium Alloy Engine Components <<Propulsion Materials>>
- 7-42 Oak Ridge National Laboratory (Peter Blau) -- Materials for High Pressure Fuel Injection Systems <<Propulsion Materials>>
- 7-44 Oak Ridge National Laboratory (Phil Maziasz) -- Materials for Advanced Engine Valve Train <<Propulsion Materials>>
- 3-4 Oak Ridge National Laboratory (Randy Wiles) -- Direct Water-Cooled Power Electronics Substrate Packaging <<Power Electronics & Electrical Machines Technologies>>
- 4-49 Oak Ridge National Laboratory (Robert Wagner) -- Achieving and Demonstrating Vehicle Technologies Engine Fuel Efficiency Milestones <<Advanced Combustion Engine Technologies>>
- 4-46 Oak Ridge National Laboratory (Robert Wagner) -- High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Diesel Engines <<Advanced Combustion Engine Technologies>>
- 1-41 Oak Ridge National Laboratory (Robert Wagner) -- Light-Duty Lean GDI Vehicle Technology Benchmark <<Hybrid and Vehicle Systems Technologies >>
- 5-14 Oak Ridge National Laboratory (Scott Sluder) -- Non-Petroleum-Based Fuels: Effects on Emissions Control Technologies <<Fuels & Lubricants Technologies>>
- 4-64 Oak Ridge National Laboratory (Stuart Daw) -- CLEERS Coordination & Joint Development of Benchmark Kinetics for LNT & SCR <<Advanced Combustion Engine Technologies>>
- 1-20 Oak Ridge National Laboratory (Stuart Daw) -- PHEV Engine and Aftertreatment Model Development <<Hybrid and Vehicle Systems Technologies >>
- 4-43 Oak Ridge National Laboratory (Stuart Daw) -- Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes <<Advanced Combustion Engine Technologies>>
- 7-68 Oak Ridge National Laboratory (Sujit Das) -- Life Cycle Modeling of Propulsion Materials <<Propulsion Materials>>
- 6-3 Oak Ridge National Laboratory (Sujit Das) -- Technical Cost Modeling - Life Cycle Analysis Basis for Program Focus <<Materials Technologies>>
- 7-56 Oak Ridge National Laboratory (Thomas Watkins) -- Catalyst Characterization <<Propulsion Materials>>

- 7-20 Oak Ridge National Laboratory (Thomas Watkins) -- Durability of Diesel Engine Particulate Filters <<Propulsion Materials>>
- 3-44 Oak Ridge National Laboratory (Tim Burress) -- A New Class of Switched Reluctance Motors without Permanent Magnets <<Power Electronics & Electrical Machines Technologies>>
- 3-16 Oak Ridge National Laboratory (Tim Burress) -- Benchmarking of Competitive Technologies <<Power Electronics & Electrical Machines Technologies>>
- 4-95 Oak Ridge National Laboratory (Todd Toops) -- Pre-Competitive Catalysis Research: Fundamental Sulfation/Desulfation Studies of Lean NOx Traps <<Advanced Combustion Engine Technologies>>
- 4-92 Oak Ridge National Laboratory (William Partridge) -- Cummins/ORNL-FEERC CRADA: NOx Control & Measurement Technology for Heavy-Duty Diesel Engines <<Advanced Combustion Engine Technologies>>
- 6-45 Oak Ridge National Laboratory (Zhili Feng) -- Dynamic Characterization of Spot Welds for AHSS <<Materials Technologies>>
- 6-47 Oak Ridge National Laboratory (Zhili Feng) -- Online Weld Quality NDE & Control with IR Thermography <<Materials Technologies>>
- 4-79 Pacific Northwest National Laboratory (Chuck Peden) -- Degradation Mechanisms of Urea Selective Catalytic Reduction Technology <<Advanced Combustion Engine Technologies>>
- 4-76 Pacific Northwest National Laboratory (Chuck Peden) -- Enhanced High Temperature Performance of NOx Storage/Reduction (NSR) Materials <<Advanced Combustion Engine Technologies>>
- 7-5 Pacific Northwest National Laboratory (Curt Lavender) -- Fatigue Enhancements by Shock Peening <<Propulsion Materials>>
- 7-13 Pacific Northwest National Laboratory (Curt Lavender) -- Low Cost Titanium – Propulsion Applications <<Propulsion Materials>>
- 4-67 Pacific Northwest National Laboratory (Darrell Herling) -- CLEERS: Aftertreatment Modeling and Analysis <<Advanced Combustion Engine Technologies>>
- 7-9 Pacific Northwest National Laboratory (Glenn Grant) -- Tailored Materials for Advanced CIDI Engines <<Propulsion Materials>>
- 2-137 Pacific Northwest National Laboratory (Jason Zhang) -- Development of High Capacity Anode for Li-ion Batteries <<Energy Storage Technologies>>
- 2-119 Pacific Northwest National Laboratory (Jason Zhang) -- Development of High Energy Cathode for Li-ion Batteries <<Energy Storage Technologies>>
- 4-73 Pacific Northwest National Laboratory (Kenneth Rappe) -- Combination and Integration of DPF-SCR Aftertreatment Technologies <<Advanced Combustion Engine Technologies>>
- 6-20 Pacific Northwest National Laboratory (Mark Smith) -- Formability of Direct Cast Mg Sheet and Friction Stir and Ultrasonic Joining of Magnesium to Steel <<Materials Technologies>>
- 6-27 Pacific Northwest National Laboratory (Mark Smith) -- Pulse Pressure Forming of Materials Technologies, Development of High Strength Superplastic Al Sheet, Friction Stir Spot Welding of Advanced High Strength Steels <<Materials Technologies>>
- 1-56 Pacific Northwest National Laboratory (Michael Kinter-Meyer) -- Standards for PHEV/EV Communications Protocol <<Hybrid and Vehicle Systems Technologies >>
- 7-38 Pacific Northwest National Laboratory (Stan Pitman) -- Hydrogen Materials Compatibility for the H-ICE <<Propulsion Materials>>
- 7-28 Pacific Northwest National Laboratory (Terry Hendricks) -- Proactive Strategies for Designing Thermoelectric Materials for Power Generation <<Propulsion Materials>>

- 6-39 Pacific Northwest National Laboratory (Xin Sun) -- Coherent Research Plan for the Third Generation Advanced High Strength Steels for Automotive Applications <<Materials Technologies>>
- 6-49 Pacific Northwest National Laboratory (Xin Sun) -- Enhanced Resonance Inspection for Light Metal Castings <<Materials Technologies>>
- 3-25 Pennsylvania State University (Michael Lanagan) -- Glass Dielectrics for DC Bus Capacitors <<Power Electronics & Electrical Machines Technologies>>
- 8-6 Purdue University (James Caruthers) -- Indiana Advanced Electric Vehicle Training and Education Consortium (I-AEVtec) <<Technology Integration>>
- 1-69 Ricardo (Scott Ellsworth) -- AVTA Vehicle Component Cost Model <<Hybrid and Vehicle Systems Technologies >>
- 5-8 Sandia National Laboratories (Charles Mueller) -- Fuel Effects on Advanced Combustion Engine Technologies: Optical Heavy-Duty Engine Research <<Fuels & Lubricants Technologies>>
- 4-21 Sandia National Laboratories (Joe Oefelein) -- Large Eddy Simulation (LES) Applied to LTC/Diesel/Hydrogen Engine Combustion Research <<Advanced Combustion Engine Technologies>>
- 4-13 Sandia National Laboratories (John Dec) -- HCCI and Stratified-Charge CI Engine Combustion Research <<Advanced Combustion Engine Technologies>>
- 4-16 Sandia National Laboratories (Lyle Pickett) -- Low-Temperature Diesel Combustion Cross-Cut Research <<Advanced Combustion Engine Technologies>>
- 5-12 Sandia National Laboratories (Magnus Sjoberg) -- Advanced Lean-Burn DI Spark Ignition Fuels Research <<Fuels & Lubricants Technologies>>
- 4-4 Sandia National Laboratories (Mark Musculus) -- Heavy-Duty Low-Temperature and Diesel Combustion & Heavy-Duty Combustion Modeling <<Advanced Combustion Engine Technologies>>
- 4-7 Sandia National Laboratories (Paul Miles) -- Low-Temperature Automotive Diesel Combustion <<Advanced Combustion Engine Technologies>>
- 2-92 Sandia National Laboratories (Peter Roth) -- Abuse Tolerance Improvement <<Energy Storage Technologies>>
- 4-24 Sandia National Laboratories (Peter Van Blarigan) -- Free-Piston Engine <<Advanced Combustion Engine Technologies>>
- 4-99 Sandia National Laboratories (Richard Larson) -- Development of Chemical Kinetic Models for Lean NOx Traps <<Advanced Combustion Engine Technologies>>
- 4-19 Sandia National Laboratories (Richard Steeper) -- Automotive HCCI Engine Research <<Advanced Combustion Engine Technologies>>
- 4-10 Sandia National Laboratories (Sebastian Kaiser) -- Sandia Optical Hydrogen-fueled Engine <<Advanced Combustion Engine Technologies>>
- 3-23 Sandia National Laboratories (Shawn Dirk) -- High Temperature Polymer Capacitor Dielectric Films <<Power Electronics & Electrical Machines Technologies>>
- 3-68 SB Electronics (Ed Sawyer) -- Low Cost, High Temperature, High Ripple Current DC Bus Capacitors <<Power Electronics & Electrical Machines Technologies>>
- 2-30 Sion Power (Yuriy Mikhaylik) -- Protection of Li Anodes Using Dual Phase Electrolytes <<Energy Storage Technologies>>
- 2-133 SUNY-Binghamton (M. Stanley Whittingham) -- Nanostructured Materials as Anodes <<Energy Storage Technologies>>

- 2-107 SUNY-Binghamton (M. Stanley Whittingham) -- The Synthesis and Characterization of Substituted Olivines and Layered Manganese Oxides <<Energy Storage Technologies>>
- 2-117 SUNY-Stony Brook (Clare Grey) -- First Principles Calculations and NMR Spectroscopy of Electrode Materials: NMR <<Energy Storage Technologies>>
- 2-5 TIAX LLC (Brian Barnett) -- PHEV Battery Cost Assessment <<Energy Storage Technologies>>
- 3-46 U.S. Hybrid (Abas Goodarzi) -- Bi-directional d2-dc Converter <<Power Electronics & Electrical Machines Technologies>>
- 2-153 University of California at Berkeley (John Newman) -- Analysis and Simulation of Electrochemical Energy Systems <<Energy Storage Technologies>>
- 4-87 University of Connecticut (Pu-Xian Gao) -- Three-Dimensional Composite Nanostructures for Lean NOx Emission Control <<Advanced Combustion Engine Technologies>>
- 4-84 University of Houston (Michael Harold) -- Development of Optimal Catalyst Designs and Operating Strategies for Lean NOx Reduction in Coupled LNT-SCR Systems <<Advanced Combustion Engine Technologies>>
- 2-151 University of Michigan (Ann Marie Sastry) -- Microscale Electrode Design Using Coupled Kinetic, Thermal and Mechanical Modeling <<Energy Storage Technologies>>
- 4-54 University of Michigan (Dennis Assanis) -- A University Consortium on Efficient and Clean High-Pressure, Lean Burn (HPLB) Engines <<Advanced Combustion Engine Technologies>>
- 8-25 University of Michigan (Huei Peng) -- Recovery Act—Transportation Electrification Education Partnership for Green Jobs and Sustainable Mobility <<Technology Integration>>
- 2-129 University of Pittsburgh (Prashant Kumta) -- Nano-scale Composite Hetero-structures: Novel High Capacity Reversible Anodes for Lithium-ion Batteries <<Energy Storage Technologies>>
- 2-141 University of Rhode Island (Brett Lucht) -- Development of Electrolytes for Lithium-ion Batteries <<Energy Storage Technologies>>
- 2-109 University of Texas at Austin (Arumugam Manthiram) -- Stabilized Spinel and Polyanion Cathodes <<Energy Storage Technologies>>
- 2-127 University of Texas at Austin (John Goodenough) -- Solid Electrolyte Batteries <<Energy Storage Technologies>>
- 2-123 University of Utah (Grant Smith) -- Molecular Dynamics Simulation Studies of Electrolytes and Electrolyte/Electrode Interfaces <<Energy Storage Technologies>>
- 4-57 University of Wisconsin (Rolf Reitz) -- Optimization of Advanced Diesel Engine Combustion Strategies <<Advanced Combustion Engine Technologies>>
- 3-27 Virginia Tech (Jason Lai) -- Advanced Soft Switching Inverter for Reducing Switching and Power Losses <<Power Electronics & Electrical Machines Technologies>>
- 8-15 Wayne State University (Ka Yuen Simon Ng) -- Development and Implementation of Degree Programs in Electric Drive Vehicle Technology <<Technology Integration>>
- 8-3 West Virginia University (Al Ebron) -- Advanced Electric Drive Vehicle Education Program <<Technology Integration>>