4. Exploratory Battery Research

Introduction

Long-term research addresses the chemical instabilities that impede the development of advanced batteries. Researchers focus on synthesizing components into battery cells and determining failure modes, while maintaining strengths in materials synthesis and evaluation, advanced diagnostics, and improved electrochemical model development. Goals include developing a better understanding of why systems fail, creating models that predict system failure and permit system optimization, and investigating new and promising materials. The work concentrates on six research areas: advanced cell chemistry, non-carbonaceous anodes, new electrolytes, novel cathode materials, advanced diagnostics and analytical methods, and phenomenological modeling.

In this merit review activity, each reviewer was asked to respond to a series of six questions, involving multiple-choice responses, expository responses where text comments were requested, and one numeric score response. 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 pictorial form in eight graphs as the last page of each project, and the expository text responses will be summarized in paragraph form for each question. A table and graph presenting the average and standard deviation for each project relative to the overall average and standard deviation for this session is presented below.

Page	Project Title and Principal Investigator	Project Average Score	Project Score Standard Deviation
4-4	3-D Nanostructured Carbon-Tin Composite Anodes (R. Kostecki, Lawrence Berkeley National Laboratory)	3.09	0.70
4-8	Block Copolymer Electrolytes for High-Energy Density Lithium Batteries (N. Balsara, Lawrence Berkeley National Laboratory)	3.13	1.55
4-11	Characterization of New Cathode Materials using Synchrotron-Based X-Ray Techniques (X.Q. Yang, Brookhaven National Laboratory)	3.75	0.71
4-14	Design of PHEVs and Electrolyte Properties (J. Newman, University of California at Berkeley)	4.29	0.76
4-17	Electrode Construction and Testing (V. Battaglia, Lawrence Berkeley National Laboratory)	3.78	0.67
4-21	In Situ Observations of Lithium Dendrite Growth (A. West, Columbia University)	2.73	0.90
4-25	Interfacial Behavior of Electrolytes (J. Kerr, Lawrence Berkeley National Laboratory)	3.00	0.93
4-28	Intermetallic Anodes (M. Thackeray, Argonne National Laboratory)	3.73	1.01
4-32	Investigation of Metallic Lithium Anode and Graphite Current Collector for Advanced Batteries (N. Dudney, Oak Ridge National Laboratory)	2.78	1.09
4-36	Kinetics of Lithium Insertion into Silicon Anodes (V. Srinivasan, Lawrence Berkeley National Laboratory)	3.60	1.07
4-40	Low-Cost Graphite and Olivine-Based Materials for Li-Ion Batteries (K. Zaghib, Hydro-Quebec)	3.55	0.93

Page	Project Title and Principal Investigator	Project Average Score	Project Score Standard Deviation
4-44	Microscale Electrode Design Using Coupled Kinetic, Thermal, and Mechanical Modeling (A.M. Sastry, University of Michigan)	4.13	0.83
4-48	Molecular Dynamics Simulation Studies of Electrolytes and Electrolyte-Electrode Interfaces (G. Smith, University of Utah)	3.38	1.41
4-51	Nano-Structured Materials as Anodes (S. Whittingham, State University of New York-Binghamton)	3.22	1.30
4-54	Nano-Structured Metal Oxide Films (A. Dillon, National Renewable Energy Laboratory)	3.78	1.09
4-58	New Lithium-based Ionic Liquid Electrolytes that Resist Salt Concentration Polarization (D. DesMarteau, Clemson University)	3.00	1.07
4-62	Olivine and Layered Materials (Characterization, Rate Performance, and Stability) (G. Ceder, Massachusetts Institute of Technology)	4.50	0.71
4-66	Olivines and Substituted Layered Materials (M. Doeff, Lawrence Berkeley National Laboratory)	3.36	0.50
4-70	Origin of Surface Instability of Lithium Positive Electrode Materials upon Cycling (Y. Shao-Horn, Massachusetts Institute of Technology)	3.78	1.20
4-74	Overview: Batteries for Advanced Transportation Technologies (BATT) Program (V. Srinivasan, Lawrence Berkeley National Laboratory)	4.22	0.83
4-77	Performance Enhancement of Cathodes with Conductive Polymers (J. Goodenough, University of Texas at Austin)	3.91	0.70
4-81	Phase Behavior and Solid State Chemistry in Olivines (T. Richardson, Lawrence Berkeley National Laboratory)	3.50	0.71
4-85	Stabilization of Layered Metal Oxides (M. Thackeray, Argonne National Laboratory)	4.36	0.81
4-89	Stabilized Spinels and Nano Olivines (A. Manthiram, University of Texas at Austin)	3.91	1.04
4-93	Summary and Future Plans (V. Srinivasan, Lawrence Berkeley National Laboratory)	4.29	0.76
4-96	Synthesis and Characterization of Substituted Olivines and Layered Manganese Oxides (S. Whittingham, State University of New York-Binghamton)	4.09	0.83
4-100	The Impact of Electrode Structure on the Processes that Limit Cathode Performance (D. Wheeler, Brigham Young University)	2.60	1.07
	Overall Session Average and Standard Deviation	**3.60**	**1.04**


Exploratory Battery Research
Overall Average for Session
The Impact of Electrode Structure on the Processes that Limit Cathode Performance (Brigham Young University)
Synthesis and Characterization of Substituted Olivines and Layered Manganese Oxides (State University of New...
Summary and Future Plans (Lawrence Berkeley National Laboratory)
Stabilized Spinels and Nano Olivines (University of Texas at Austin)
Stabilization of Layered Metal Oxides (Argonne National Laboratory)
Phase Behavior and Solid State Chemistry in Olivines (Lawrence Berkeley National Laboratory)
Performance Enhancement of Cathodes with Conductive Polymers (University of Texas at Austin)
Overview: Batteries for Advanced Transportation Technologies (BATT) Program (Lawrence Berkeley National...
Origin of Surface Instability of Lithium Positive Electrode Materials upon Cycling (Massachusetts Institute of...
Olivines and Substituted Layered Materials (Lawrence Berkeley National Laboratory)
Olivine and Layered Materials (Characterization, Rate Performance, and Stability) (Massachusetts Institute of...
New Lithium-based Ionic Liquid Electrolytes that Resist Salt Concentration Polarization (Clemson University)
Nano-Structured Metal Oxide Films (National Renewable Energy Laboratory)
Nano-Structured Materials as Anodes (State University of New York-Binghamton)
Molecular Dynamics Simulation Studies of Electrolytes and Electrolyte-Electrode Interfaces (University of Utah)
Microscale Electrode Design Using Coupled Kinetic, Thermal, and Mechanical Modeling (University of Michigan)
Low-Cost Graphite and Olivine-Based Materials for Li-Ion Batteries (Hydro-Quebec)
Kinetics of Lithium Insertion into Silicon Anodes (Lawrence Berkeley National Laboratory)
Investigation of Metallic Lithium Anode and Graphite Current Collector for Advanced Batteries (Oak Ridge...
Intermetallic Anodes (Argonne National Laboratory)
Interfacial Behavior of Electrolytes (Lawrence Berkeley National Laboratory)
In Situ Observations of Lithium Dendrite Growth (Columbia University)
Electrode Construction and Testing (Lawrence Berkeley National Laboratory)
Design of PHEVs and Electrolyte Properties (University of California at Berkeley)
Characterization of New Cathode Materials using Synchrotron-Based X-Ray Techniques (Brookhaven National...
Block Copolymer Electrolytes for High-Energy Density Lithium Batteries (Lawrence Berkeley National Laboratory)
3-D Nanostructured Carbon-Tin Composite Anodes (Lawrence Berkeley National Laboratory)
0.00
1.00
2.00
3.00
4.00
5.00
6.00

3-D Nanostructured Carbon-Tin Composite Anodes (R. Kostecki, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size

This project had a total of 11 reviewers.

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

The work was felt to support DOE petroleum displacement objectives. Electrode studies are very relevant to the DOE battery objectives. Issues addressed are low energy, low power, poor cycle and calendar life, which are in line with the goals of the program. The work aims at increasing the capacity of anodes for Li-Ion batteries and hence is relevant. Kostecki's work will lead to a reduction in the use of oil because his work will lead to better, cheaper batteries for HEVs and PHEVs. A reviewer commented that metal anodes hold promise for high volumetric capacity PHEV batteries. Another felt this work could be an enabler for Sn or other anodes. A dissenter said that the current activity in this project supports the overall DOE objectives only in a very minor way and only with a very long term possible potential.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

To one commenter, this was a new project with potential. Another said that the original and creative approach has already been successful in previous years. The project goals are then feasible and well connected to the identified barriers. One said the experimental work so far is executed very well. Kostecki's approach of using chemical vapor deposition (CVD) to produce a new anode material for lithium ion cells may reduce the cost and improve the performance of these cells.

A reviewer noted that use of new methods to synthesize intermetallic compounds for anodes and characterization of the anodes using diagnostic techniques such as Raman spectroscopy is a part of the project plan. Deposition techniques to obtain thin films of C/Sn have also been explored in conjunction with obtaining better performing anodes for li-ion cells.

A reviewer said this was a high-risk project, but the approach of using a carbon matrix is a good one. The PI focuses on different degrees of carbonization/graphitization, which is good. Exploration of various organic precursors (Conoco knows all about this) and catalyst will vary the size of the graphene flakes formed. Pure graphite will be hard to obtain at temperatures selected. Emphasis on decreasing surface area will likely be necessary and should be an objective for study, which is challenge given the small particles, but the carbon might take care it.

A final reviewer specifically noted that irreversible capacity loss is high and may need graphite to fix that, but graphite needs too high of a ba temperature to work with the low melting point of tin.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

Several specific technology comments were provided here, along with more general comments. In general, a reviewer thought this could be a good first result but the authors should move away from this exotic methodology of making materials which have very few commercial applications. A significant result is the creation of composites that has some capacity. Kostecki's C/Sn anode, obtained by using CVD, shows promise as a material for lithium ion cells.

A reviewer stated the results are of a high level showing substantial progress towards goals. The loss of 40% of anode capacity in 500 cycles does not seem to be a very good result. The preparation process requires some cost evaluation and comparison with carbon costs. The behavior at low temperature should be investigated.

A reviewer highlighted the conclusion that C/Sn binderless thin-films can be manufactured in a fast, inexpensive, single-step process and the films C/Sn anodes display significantly improved electrochemical behavior. These films retained good electronic contact between the active material and the current collector. The significant improvement in cycleability is attributed to the high porosity and fine dispersion of Sn in 3-D carbon matrix.

A reviewer stated that a good method has been obtained to synthesize nano-composite anodes and binderless thin film on any substrate. Testing has shown that there are no detrimental dimension changes and the electronic conductivity has been maintained. The materials show high reversible capacities and the degradation mechanisms have been well understood and attributed mostly to the irreversible losses due to carbon. The program could benefit from some safety tests on completely assembled cells or half cells and by understanding the thermal properties of the new materials.

Another felt that the micro wave plasma technique looks promising and should be extended to silicon based materials (without forming SiC). The materials characterization results are convincing and the work should be supported further. The fact that they could cycle for 500 times is encouraging.

A reviewer said that although the project provides some positive findings for possible usage in the areas of li-ion consumer cells in the longer term, the likelihood of application in the area of HEV battery systems seems only to have some possible potential in the very long term. With the exception of the further CVD-related work, the other future work intended by this project would be of much greater value than the current project focus and the other future work should be supported.

A reviewer commented that there has been so much published literature on Sn embedded in carbon. This reviewer asked how this work is novel compared the work by Yoshio and others. 500 cycles to 60% fade (at what mAh/g?) has been reported by others before with similar materials. This reviewer saw nothing novel in this work with respect to what was reported by others in the past five years. The PI does not appear to have been keeping up on state of the art in the literature. Kostecki's diagnostic techniques are such a valuable tool within the BATT program: this reviewer hoped this task is not diverting his time away from his Raman and AFM work. It would be much more valuable for Kostecki to try to form ties to industry to use his diagnostic techniques for the benefit of industry - he could learn from Clare Grey and from Yoon and Yang at Brookhaven in that respect.

Finally, a reviewer praised the nice methods and good technical work. However, this reviewer still questioned scalability. Mass production methods using CVD and the like are definitely out there but are still cost prohibitive for many applications, especially when you have to lay down significant amounts of materials.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Comments on this prompt were mixed. One said that these materials might have a niche application. The improved material with low synthesis costs has a high chance of undergoing technology transfer and marketing. Another said that IPR results and publications show a clear attention to the technology transfer in various ways. A reviewer saw technology moving in a two-fold manner through publication, and by the Sn/C material being robust enough for technology transfer. A reviewer thought this was a high-risk project right now.

The processing methods involved with the current work might have application to some consumer or industrial battery systems in the long term, but it is unlikely that these would be suitable for application to HEV battery systems. Kostecki's approach may be adopted by cell manufacturers if they can become comfortable with the new to them processing methods associated with the CVD process.

A reviewer still questioned scalability. Mass production methods using CVD and the like are definitely out there but are still cost prohibitive for many applications, especially when you have to lay down significant amounts of materials. The method remains useful as a development tool for Whittingham and Thackeray's work.

It was suggested that Kostecki's diagnostic techniques are highly valuable. He should focus more on that and try to reach out more to industry to provide diagnostic support to battery companies and materials developers.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

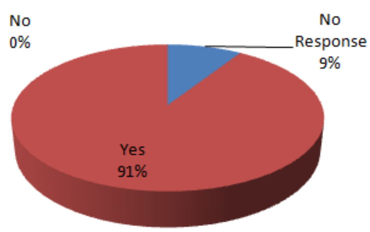
The resources seem adequate, and funding for this project is sufficient. A reviewer said that there had been good work for the funding obtained. Another could not comment on resource sufficiency. The final reviewer said that with the exception of the further CVD-related work, the other future work intended by this project would be of much greater value than the current project focus and the other future work should be supported by the available resources.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

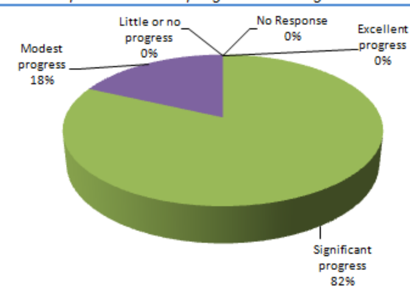
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: 3-D Nanostructured Carbon-Tin Composite Anodes

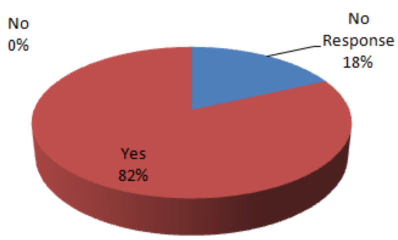
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



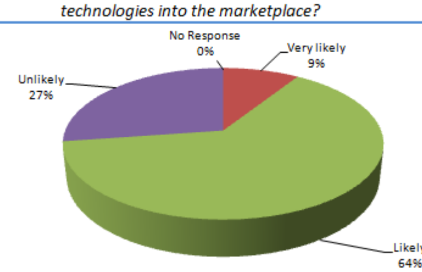
Question 3: Characterize the technical accomplishments and progress toward goals.



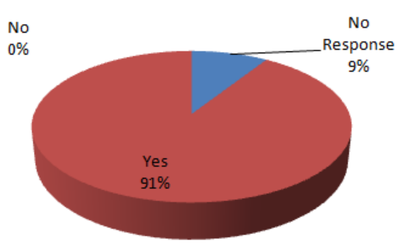
Question 2a: Are the goals of the project technically achievable?



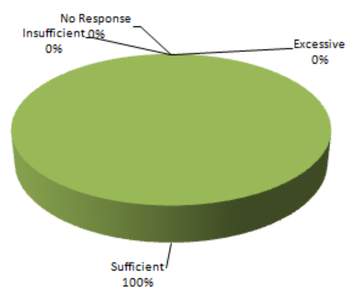
Question 4: How likely is the project team to move technologies into the marketplace?



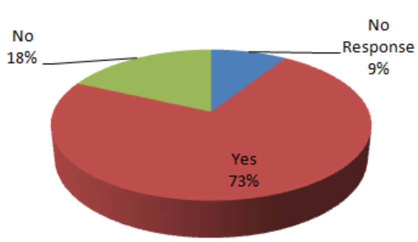
Question 2b: Have the technical barriers been identified and addressed?



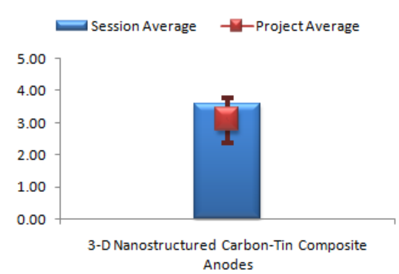
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Block Copolymer Electrolytes for High-Energy Density Lithium Batteries (N. Balsara, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size

This project had a total of 8 reviewers.

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

The work is related to the development of polymer electrolytes for high energy li-ion batteries. If the work can lead to the development of the desired polymers, they would be very useful in PHEV applications. The project is relevant to DOE objectives in looking at novel electrolyte for Li batteries, according to a commenter. To another, the work addresses high-energy for EV, long-range PHEV, as well as low flammability electrolytes. Balsara's work may lead to better batteries for HEVs and PHEVs which will result in less oil being consumed.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

Positively stated, a reviewer noted the project is on plan and progress is made. The approach focuses on one of the key issues of the Li metal batteries. The development of a better electrolyte coupled with the elimination of dendrite growth may revitalize high power and energy Li metal polymer systems. Balsara's work to develop a coating for the lithium metal anode may lead to higher energy density batteries.

The project needs to address concerns for high impedance over the range of vehicle operating temperatures. Low temperature seems to be a real challenge without a major change in polymer materials. Concept work is acceptable but this reviewer was not sure there is a path to a real product. While -30°C for a polymer electrolyte is probably never going to be realistic, this reviewer would have thought the material would have to at least run at ambient.

This should be a long-term project for the BATT program. We should look for immediate return on this type of electrolyte work.

One person commented that questions 2a and 2c are difficult to answer, and they are being optimistic that it will work out and we have a completely new type of electrolyte.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

Balsara's approaches are very novel and this reviewer was amazed by the improved conductivity values from a polymer electrolyte having such mechanical strength. Work on nanostructured electrolytes is encouraging and shows promise in the area of solid polymeric electrolytes. The polymer shows good mechanical modulus and conductivity and hence they could decouple the electronic and mechanical properties.

The results are very interesting but not yet complete. An analysis of the effective impact of the new electrolyte requires a comparison with a more conventional Li metal cell with specific performance considerations and above all impact in cycle life. A reviewer was not able to find any specific accomplishments, but the plans are all good.

A reviewer highlighted the good technical work and pictures that show good polymer structure of combining a soft but conductive medium inside a hard framework. Full cell work could benefit from using soft polymer only in cathode. Concept work is acceptable but the reviewer was not sure there is a path to a real product with a reasonable temperature performance, unless a design involving extensive heaters were acceptable. This reviewer believed having heaters to handle sub-zero temperatures may be reasonable but having to heat the cells all the time would seem to be expensive and far too wasteful of battery energy. Error bars on Li thickness/EO thickness are pretty large relative to difference in the means – the reviewer was not sure the explanation is correct for the conductivity.

Balsara's work has lead to an interesting coating, but the rate is much too low for use in batteries for HEVs or PHEVs. It is unlikely that he will be able to achieve high rates because of the low conductivity of his coating.

A reviewer asked that the team provide resistance measurements (AC impedance or HPPC at a ten second time scale) in terms of Ohm-cm^2 at different temperatures including 0°C, the high impedance of PEO and of Li metal at this temperature are of concern for PHEVs (which actually usually have operating requirements at -30°C) and a large barrier for use of Li metal-polymer batteries. John Kerr has done a good job of raising these concerns with Li metal - Balsara needs to address the problems identified by Kerr.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Among the positive aspects here are that they will have immediate application in low-rate devices, and that a start-up company and publications are already in place. Another noted that the PI has already formed a start-up company with an ambitious marketing plan. Similarly, a reviewer said that the PI has interest in a start-up company, and that the PI has done important fundamental work on electrolytes. The technology has been licensed to a small start-up, but the reviewer was not sure if this will actually make it to implementation for EV/HEV applications, but maybe more relevant to other applications where low temperature performance is not a requirement. Balsara's coating does not provide a rate that would be useful by battery developers. Finally, the activity of this project could have some impact on consumer batteries, but any impact on HEV/EV batteries would be considerably longer term and questionable.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

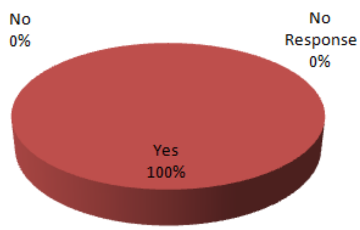
The resources are reasonable, said one reviewer. Another said that in general, Li-metal-related activity should be terminated. However, if any Li-metal-related projects are to be continued, this may be the most worthwhile current project. A reviewer recommended that the team only continue if they have an approach to get at ambient temperature performance. Otherwise this reviewer could not support funding this work any further under a vehicle program. The final comment was that the results from this project do not support continued funding for this project.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

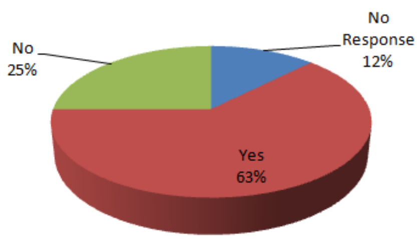
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Block Copolymer Electrolytes for High-Energy Density Lithium Batteries

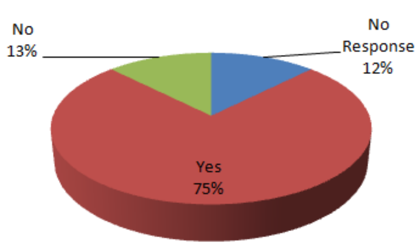
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



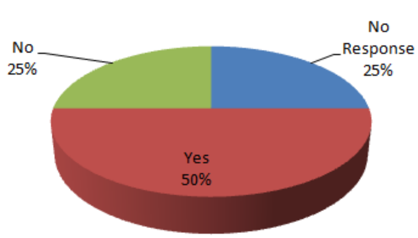
Question 2a: Are the goals of the project technically achievable?



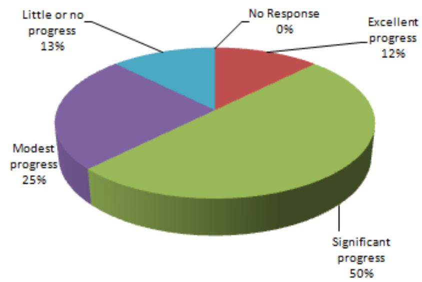
Question 2b: Have the technical barriers been identified and addressed?



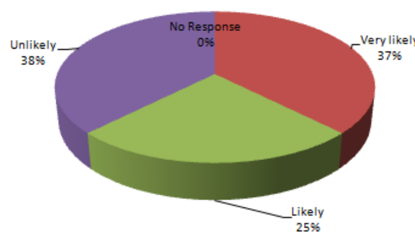
Question 2c: Is the proposed work likely to overcome technical barriers?



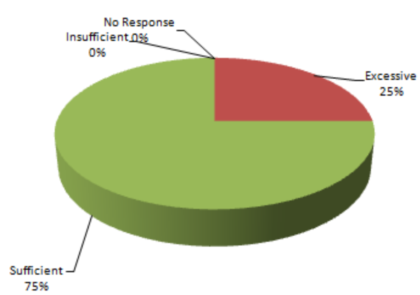
Question 3: Characterize the technical accomplishments and progress toward goals.



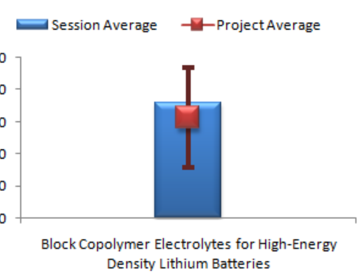
Question 4: How likely is the project team to move technologies into the marketplace?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 6: Overall Rating



Characterization of New Cathode Materials using Synchrotron-Based X-Ray Techniques (X.Q. Yang, of Brookhaven National Laboratory)

Reviewer Sample Size

This project had a total of 8 reviewers.

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

A reviewer stated this work was a key characterization tool for advancing battery technology. Another said that cathode characterization is functional to DOE program. Basic research is a continuous source of new ideas and stimulus for new solutions. Furthermore, efforts are being made to improve materials using coatings and using diagnostic tools such as synchrotron X-rays to characterize the materials to meet program goals. It correlates structural changes to performance improvements. A reviewer noted that this work relates to the in-situ synchrotron study of cathode materials and has relevance to Li-Ion batteries. Another felt this work addresses stability and reaction mechanisms. Finally, a reviewer said that Yang's work may lead to better understanding of the formation of the SEI layer, for example, using X-Ray techniques. His results may lead to better batteries for HEVs and PHEVs that will lead to reduction of oil use.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

To one reviewer, the approach is mostly related to a well-justified integration of measuring techniques to analyze structural changes and support development of new materials (cathodes and electrolytes). Another said that this unique integration of diagnostic tools must continue to be used by all the program participants to achieve continuous support in the research and development work. Good strategy with lots of different new materials studied, said another reviewer. A reviewer characterized the goal of their study as being clear and they have the techniques for studying the local electronic structure of cathode materials. Much of the work in this project involves critical support and knowledge provided to fundamental materials work being done in other projects. A reviewer highlighted the excellent use of multiple techniques and coordination with other PIs. Yang's experimental techniques yield dynamic data from in-situ studies, stated the final reviewer. His X-ray absorption work may lead to a better understanding of the phenomena that occur in cathodes due to the ability to follow the change in the oxidation state of Mn during discharge, for example.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

Brookhaven is doing excellent work in supporting the development of new energy materials, stated the first reviewer. The second said that the project is efficiently supporting the achievement of the key DOE goals with interesting experimental results able to improve various material developed by other participants. A third thought that good progress has been made in characterizing the new materials synthesized and suggested that the work continue. To another, these studies help deeper understandings of the electrode processes. A reviewer thought it would be interesting to extend the same approach to anode and complete cells analysis.

A reviewer stated that in situ X-ray diffraction and absorption studies on coated and uncoated $LiFe_{1-x}M_xPO_4$(M=Mn, Co, and Ni) type of olivine structured cathode materials showed the important effects of doping and surface coating on the structural changes and performance of the lithium-ion cells: XANES data supported by EXAFS showed that the oxidation state of Mn does not change with lithium content. On the other hand, Ni ions are oxidized by incorporating lithium ions in the transition metal layers. The oxidation state of Ni is close to that of NiO(Ni^{2+}) and $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$($Ni^{3+}$) for x=0 and 0.20, respectively. Similarly, another reviewer noted that using synchrotron XANES technique the authors have determined the local oxidation state of Ni. The result could shed light on the cycle life and stability of these kinds of cathode materials. A reviewer said the work provides good understanding of the chemistry using in situ experiments. This is key information to support modeling, fundamental understanding, and identifying problems with real electrodes.

Finally, Yang's work shows how the components in the cathodes change oxidation states with differing amounts of Li. His X-ray method shows clearly what actually happens during the cycling of cathodes.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The technology transfer is a continuous process underway, related to the strict collaboration in place in the project, noted the first reviewer. Second, the project team's results are very crucial for dissemination of the knowledge to industry and academia about the electronic stability and structure of these cathode materials. To another reviewer, this project has consistently provided key information to other materials development projects. The materials obtained in some of these projects will undoubtedly be transferred to or influence the marketplace in some way. Lastly, Yang's work shows how doping changes the mechanism for charge storage in doped olivines. His work shows that at what state of charge the components change oxidation state.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

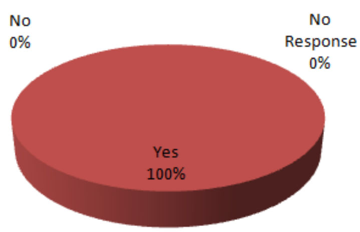
To several reviewers, the resources seem consistent with the work and funding is sufficient, with good work for the funding obtained. A reviewer stated that a possible extension to anode material and cells may require an increase of the resources. Resources devoted to electrolyte development work without well-defined and specific goals for this activity may be better re-directed towards X-ray related activities, stated a reviewer. In particular, re-direction of resources from electrolyte development work towards the planned in-situ XAS studies of thermal stability would be beneficial. The final reviewer could not comment on the resource level.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

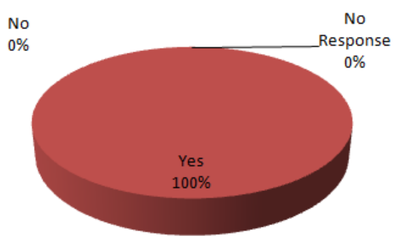
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Characterization of New Cathode Materials using Synchrotron-Based X-Ray Techniques

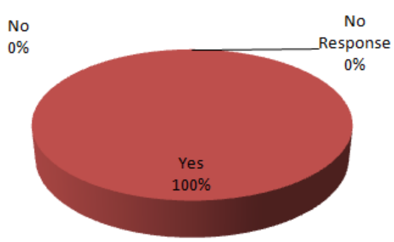
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



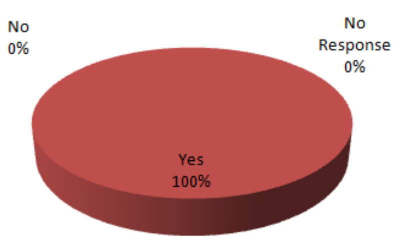
Question 2a: Are the goals of the project technically achievable?



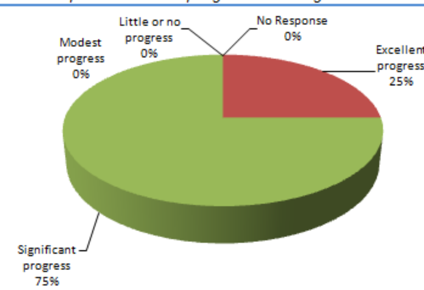
Question 2b: Have the technical barriers been identified and addressed?



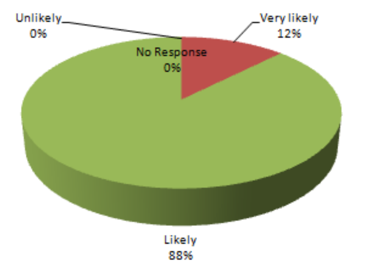
Question 2c: Is the proposed work likely to overcome technical barriers?



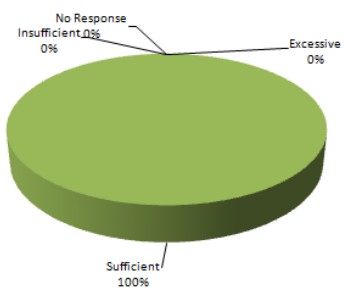
Question 3: Characterize the technical accomplishments and progress toward goals.



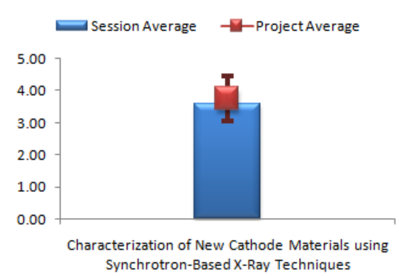
Question 4: How likely is the project team to move technologies into the marketplace?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 6: Overall Rating



Design of PHEVs and Electrolyte Properties (J. Newman, of University of California at Berkeley)

Reviewer Sample Size

This project had a total of 7 reviewers.

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

One reviewer indicated that the work is important for the development of PHEV and HEV vehicles, while another commented that Newman's contributions to improving batteries are well-known and will lead to improved cells for HEVs and PHEVs, thereby reducing oil consumption. One other person stated that modeling is a cross-cutting technology very relevant to achieving DOE objectives on battery development. One final reviewer wrote that understanding transport and thermodynamic properties may help improve electrolyte materials and help with the goals of the program.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

The first response indicated that the modeling information provides a benchmark for energy and power requirements for PHEVs and eventually EVs. One reviewer wrote that the group is developing improved experimental methods to study the transport and thermodynamic properties of the electrolytes, with the goal of achieving better electrolytes to meet program goals. Another respondent stated that the limited and well-focused goals were relevant to the DOE program. The approach is reasonable and able to achieve goals in a timely manner.

One final reviewer wrote that Newman's contribution in this project is useful to help battery producers focus on the limitations associated with current cells.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

Responses to this prompt were generally positive. One reviewer commented that the progress is good with a capacity to complete the work in a timely manner. Another person added that Newman has contributed useful results to battery developers. One respondent added that the work is very relevant for the current development of PHEV vehicles. It allows the OEM researchers and product development people to know the theoretical limit of the power-to-energy ratio for a given set of material parameters. Similarly, one individual remarked that the development of new methods for the determination of electrolyte properties provides useful alternatives for arriving at relevant information for other modeling or optimization purposes, and the development of new models for battery and vehicle design will be of current and significant value to vehicle OEMs and battery developers.

Another reviewer wrote that it was nice to see that Newman and his group developed a simplified model to provide insights on the design of HEVs and PHEVs. A combined battery and vehicle model has also been used to provide accurate and comprehensive prediction of behavior in HEVs and PHEVs, for design. Measurements of the transport and thermodynamic properties of $LiPF_6$ in several solvents support these models.

One final reviewer noted that transport and thermodynamic properties of the electrolyte has been studied. A simplified model to characterize the performance of HEVs and PHEVs has been developed. The model indicates that the state of discharge is an important factor in the power performance of the battery which is well-known. The separator thickness has been taken into consideration. That is only one factor. Another is the total internal resistance of the cell which translates to material properties, thickness of electrodes, conductivity of electrolyte and resistive losses are other factors that limit the power capability. It may help to use more or all of these factors in the design. The change of these properties with temperature is also an important aspect.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first reviewer wrote that these results have direct relevance to real-life applications. Another response commented that Newman has produced in this project relatively simple design rules that will help battery developers. One other reviewer stated that publications are adequate tools for transferring the project results, while one final person stated that the modeling concept is well known and well understood.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

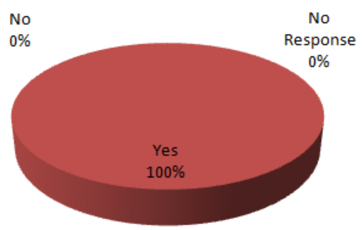
Two reviewers indicated that there are adequate resources for this project, while another felt that more work can be performed for the funding received. One other reviewer commented that, if the modeling of spurious lithium deposition is carried out as future work, efforts to produce and observe actual conditions resulting in lithium deposition in Li-ion systems should be included.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

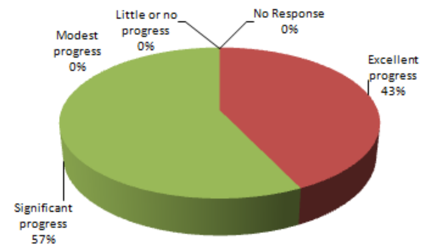
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Design of PHEVs and Electrolyte Properties

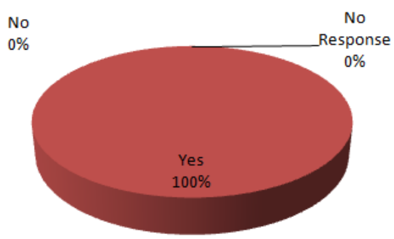
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



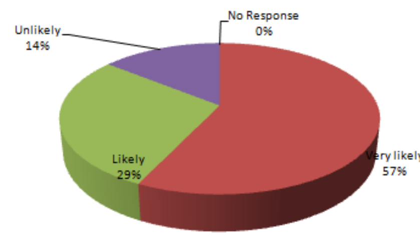
Question 3: Characterize the technical accomplishments and progress toward goals.



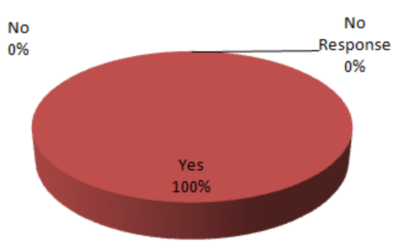
Question 2a: Are the goals of the project technically achievable?



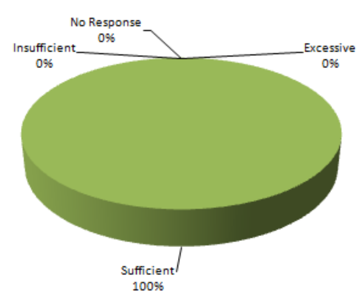
Question 4: How likely is the project team to move technologies into the marketplace?



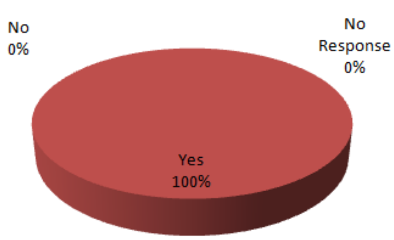
Question 2b: Have the technical barriers been identified and addressed?



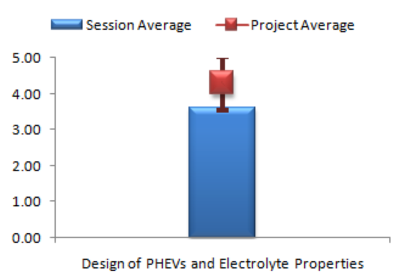
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Electrode Construction and Testing (V. Battaglia, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size

This project had a total of 9 reviewers.

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

This work addresses a very critical aspect of cell technology, stated the first reviewer. The second felt that technology optimization and experimental verification is relevant to confirm the achievement of the DOE objectives in battery development. The work is related to fabrication and design of electrode material for li-ion batteries. Electrode construction, analysis and understanding the limitations of this component of the cell support the program goal. Electrode design issues are critical to moving the project forward. Battaglia's work will probably lead to better batteries for HEVs and PHEVs thus reducing oil consumption.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

The first reviewer simply noted the very well-designed experiments. A reviewer said that the PI and team have addressed all the technical challenges extraordinarily well. The practical design of electrode and their optimization has been demonstrated very well. Study of electrode materials, characterization of the electrodes, collaboration with modelers, fabrication of half and full cells and testing are the project's strategy in meeting the program goals. To a reviewer, the focus on electrode design is very nice to see. The PI is also leveraging other program PI's and the work seems very well coordinated and focused.

A statement was made that the project has useful goals for the purposes of direct application within the BATT and ATD environment and maintains productive interaction within the BATT/ATD environment. Another similarly stated that the project is central to all BATT programs. The project has the key role to overcome the technical barriers of design, realization and testing of components and cells in order to get optimal performance. There is no focus on cost considerations in selecting materials and cell design, which may be a side result of the optimization work.

Battaglia's work is very useful to battery developers because his team can investigate possibilities that may be too expensive for developers to investigate. His work also yields explanations for his results that may help cell developers understand their results or help them decide not to investigate certain regions of possible recipes for electrodes. His work will help developers find optimum or near optimum recipes for electrodes for the desired operation (high-power or high-energy).

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

The results are very interesting, according to one reviewer, and are very important for coming up with electrodes especially for PHEV batteries. Battaglia's work is producing results that can be used immediately by cell developers. His work is also useful to academic investigators (Sastry, e.g.) who can use his experimental data to support their modeling work to help find optimum electrode fabrication procedures.

The progress is significant and really functional in accelerating the use of the BATT results. The extension to other materials is strongly recommended. An upgrading analysis from cell performances to equivalent battery system performances for various applications should be highly effective for progress evaluation.

A reviewer felt this was very good work that has the right mix of experiments guided by modeling; the control experiments for optimization and the correlation between structure-morphology of the electrode materials with cycling and rate capability has been demonstrated very well. The reviewer suggested that the researchers continue such work on newer materials that have passed Gen-3 chemistry and beyond so that we are on target for electrode optimization with PHEV application, although they believed that the researchers have already begun working on this.

Within the scope of the BATT and ATD environment, the project has made numerous useful findings which are of direct benefit towards BATT and ATD activities. However, the general activity of this program is already conducted on a much more rigorous and ongoing basis by all significant mass-producers of li-ion consumer cells in the global marketplace. The project would benefit greatly from interaction, collaboration, and formal cooperation with significant mass-producers of li-ion consumer cells in the global marketplace, and this would also be of great value to the rest of the BATT and ATD community.

The authors concluded that carbon/binder/active material interactions suggest different ratios for different applications and found that Mn-spinel evaluation indicated that BATT material is as good as, or better than, commercial material. The authors also stated that the optimized cathode design suggested cells of 500 Wh/l are possible. These studies were done in the lab with small electrodes and cells and by no means can be certain that these conclusions will hold for bigger cells. Also the conclusion that OMAC 15 from Osaka Gas may be a suitable replacement for MCMB-10 is not supported by names of any manufacturer who may use or is using it.

The critical ratio of carbon to binder when mixed with cathode active material was studied and found that the ratio affects the power performance of the material. Similar work was carried out with anode materials to determine a new graphite to replace the MCMB. Limitations of the new graphite have been well understood. If the method of pulsing is not adequate and the limitations of pulsing against a Lithium metal anode are well known, methods to improve this should be pursued. As this may lead to ambiguous results unless past experience has shown that a relative comparison would still be valid. The team will need to carry out some studies on materials used by battery manufacturers especially the carbons or graphites being used by them to replace the MCMB.

A reviewer appreciated that LBNL needs to improve its electrode- and cell-making capabilities, which are not yet state-of-the-art in terms of producing electrodes with low impedance. However, the formulation work is not a good use of national lab resources. The work is naive and well below the state-of-the-art in the industry - it is not telling industry anything not already known. Many of the results appear to be artifacts of poor mixing, coating, and calendaring procedures. Relative to finding a replacement for MCMB, the reviewer wondered why the PIs are not talking with Jansen at ANL, who has been screening commercially-available anode materials. This reviewer thought one part of this task was to make electrodes from the new materials being developed by others in the BATT program - why is there no mention of that?

A reviewer said the team showed good understanding and identifying the true “killer issues.” However, the path going forward seems less clear. This reviewer said the PI is doing really good work. Can/is this being fed into the Dees model? The reviewer thought there was just not enough time to present all this work.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Positive comments included that these findings are key knowledge and could be easily transferred to the developers. Key activities and tech transfer are likely (recognizing that transfer is to others in program and only indirectly to industry). Battaglia's screening work can be used immediately by cell developers and will reduce the time to market for cells for particular applications associated with batteries for HEVs and PHEVs. A reviewer said that the tech transfer is part of the approach with continuous contacts with developers and end users. A reviewer summarily said that the tech transfer would occur if significant work can be accomplished to find an anode that works.

The project's success and findings are directly transferable to the rest of the BATT and ATD activity as a whole. The project should be continued, but because the project's activity is redundant with and necessarily must be much less extensive than that of significant mass-producer's of li-ion consumer cells in the global marketplace, documentation of the project's general approach to electrode formulation optimization for the purposes of potential use by new battery developers who may enter the market in the future could be a valuable new goal for the project to consider and this might result in greater long-term technology transfer and market transformation promise for this project. With this focus, the project might also be able to dedicate more activity to interaction and learning with significant global li-ion manufacturers.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

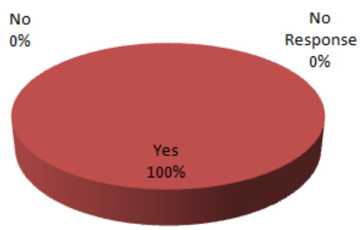
Funding for Battaglia's work is sufficient, according to one reviewer: to another, there was good work for the funding provided. A reviewer disagreed by saying that the resources should be increased. A reviewer added that the project would benefit from additional resources and from a tempered change in focus from internal optimization of BATT and ATD-related electrode optimization to more of a focus on interaction with and learning from significant global manufacturers of li-ion consumer cells, while at the same time documenting internal and external learning regarding the general process of electrode formulation optimization. Resources should also be increased to allow for the valuable planned activity involving quantification of carbon/binder and binder/active material interactions from DSC. The final commenter keyed on the good level of resources and the observation that they are leveraging and working with the other PI's extremely well.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

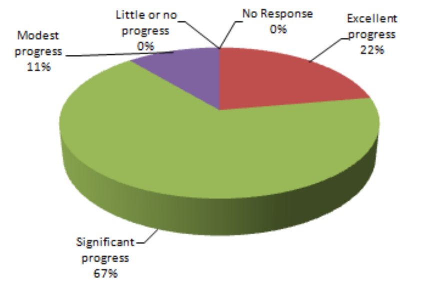
There were no expository comments for this question: refer to the graphic on the next page for this project’s summary score.

Project: Electrode Construction and Testing

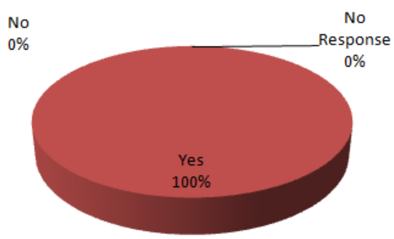
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



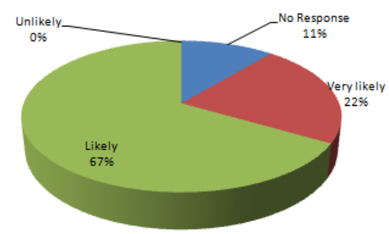
Question 3: Characterize the technical accomplishments and progress toward goals.



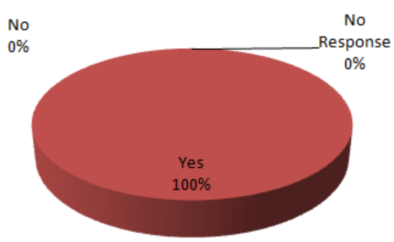
Question 2a: Are the goals of the project technically achievable?



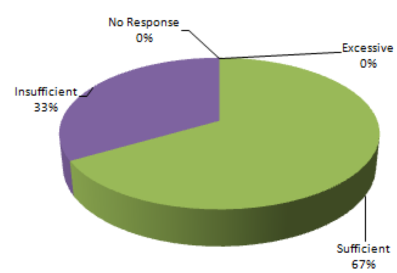
Question 4: How likely is the project team to move technologies into the marketplace?



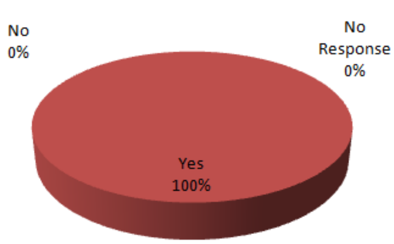
Question 2b: Have the technical barriers been identified and addressed?



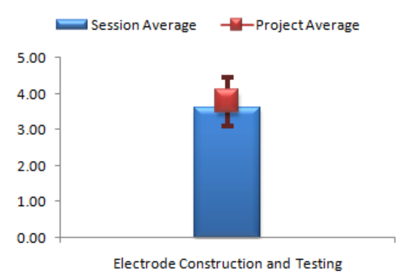
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



In Situ Observations of Lithium Dendrite Growth (A. West, of Columbia University)

Reviewer Sample Size

This project had a total of 11 reviewers.

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

Lithium does remain the holy-grail in anode technologies, according to one reviewer. It seems that only Li metal can address long-term EV demands, and these could be an enabler for lower cost cathodes for PHEV, but unlikely to be worth the risk in this reviewer's view. Another said that lithium metal electrodes would support DOE goals, but must be made safe. Their work addresses possible safety issues in developing Li-Metal electrodes. There are also some Li plating issues at low temperature on electrodes and their study could be relevant for li-ion battery research.

The analysis of Li dendrite formation is functional to basic knowledge of DOE program. West's work will lead to a better understanding of the formation of lithium dendrites which may lead to use of lithium metal in batteries for HEVs and PHEVs, which will lead to a reduction in oil use for cars. Limitations to long life and high cycle life are being studied by studying lithium dendrite formation and this in support of the PHEV and HEV goals and objectives.

The techniques developed for the measurements can be used for other systems that incorporate Li metal. That would be useful for optimizing electrolyte and additives, something that would be extremely useful for the program.

The final review comment was that although there is new work accomplished in this project, and the work is of high quality, the basic subject of this study does not warrant this type of activity and has already been extensively investigated over many past years.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

On the positive side, a reviewer said that if the objective is to watch dendrites, then the approach is very novel. Another said that the project is studying one of the major causes for reduced life in lithium-ion cells. This has been correlated to electrolyte properties which is a new approach. A reviewer also said that there is no deployment strategy in this kind of project, but their experimental plan and the tools to achieve them look feasible. The final comment was that West has developed an experimental technique that will provide useful data for the development of the so-called SEI layer on anodes in lithium ion cells. He has shown experimentally the effect of the VC additive.

On the other hand, reviewers said the team needs to do a better job of identifying electrolytes that can cycle lithium with a high figure of merit. Work on lithium metal will be rejected by most battery manufacturers, a reviewer stated, as it requires too much moisture control and risk of fires etc. in materials supply is high. This reviewer did not see how that would be successful. However, understanding the dendrite formation for other anodes than Li metal is a good idea. For another commenter, it appears that the project outcome could result in methods to impact dendrite growth or dendrite growth rate in a positive way. However, in terms of battery systems for HEVs or PHEVs, there is no clear route for deployment based on much past work over many years on li-metal systems. A reviewer said that the project mainly focuses on dendrite formation study and the technical barriers have been identified in the way to measure and analyze the dendrite growth. Li metal does not have great space in BATT. More analysis on the Li metal system may better clarify the situation and support decisions. The final comment was simply that the project had a low likelihood of success.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

Some of the specific goals of this project have been addressed, but these cannot be translated into progress towards DOE goals as related to HEV or PHEV battery systems, stated one reviewer. One person noted the good experimental set-up and the new technique for the study of dendrite formations. West's work shows that Li dendrites grow from the base electrode to a greater extent than from the tip of the dendrite. Consequently, he should be able to measure the rate of formation of dendrites. Several aspects of dendrite formation have been studied from nucleation to the velocity of growth to the effect of current density on this growth. The use of VS additive and its effect on the growth of dendrites has been studied well. The preferential nucleation of lithium dendrite on the base was not explained well. Is there a surface morphology difference between the base/ the tip and the sides of the copper rod? It may be beneficial to study the dendrite growth in systems that have a carbon anode for practical purposes. The study on copper is somewhat relevant as it could be extended to studies on cells that have undergone high cycle life where defragmentation of carbon has occurred exposing the surface of the copper. But it would still help if the anode were carbon.

The experimental analysis is outstanding in improving comprehension of the process but no answer is found yet for solving dendrite growth formation. The project seems quite slow. Experimentally the authors have clearly demonstrated the Li dendrite formation and their origin. The dependence of the role of solvent and additives in dendrite growth and formation is interesting.

The authors have shown that mass transport does not seem to play a role in dendrite initiation. Deposition quickly becomes mass transfer controlled after dendrite formation. High interfacial resistance inhibits dendrite formation, but it also hurts battery performance due to slowed Li transport through the SEI.

A reviewer said that the approach to view Li dendrite is novel but if they are trying to eliminate Li dendrites then these are not the approaches this reviewer would use. People have done these for many years without any permanent solution to the problems.

A reviewer stated the team was basically doing method development and just now starting to get data. This is good fundamental work in a difficult area. Interesting, looking at ether-based electrolytes will give better dendrite formation as another reviewer mentioned. One caveat is that these electrolytes will not withstand high voltage cathodes. Still, they are good for some V and Mn systems that do have good energy if paired with lithium, even with their low cathode potential.

The main problem with progress is in using electrolytes which do not cycle lithium metal very well. Thus, while the dendrites can easily be identified and studied, they are not characteristic of systems which can attain a high figure of merit which have minimal dendrite growth and which may have a different character, e.g. more mossy and less dendritic.

While this work is scientifically interesting, and this reviewer recognized that the project is still in its infancy, it is not clear how it has any relevance to practical issues with lithium batteries. Nearly 50 years of past work on Li metal have shown that it will not be practical to use lithium metal with liquid, gel, or even polymer electrolytes. Small increases in onset time are not practically significant - the onset time needs to be increased to years, not minutes, over the course of thousands of cycles in order to meet requirements for safety and life in automotive applications. Power would also be a problem with lithium metal, especially at low temperature, even for large batteries in PHEVs. The PI is talented but the choice of research focus is not the best. This reviewer asked that the team try to focus on issues of more relevance. The analysis is thorough and well done. But why is it a surprise that lower exchange-current density gives a lower rate of dendrite growth? That is basic to the theory of secondary current distributions.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

West's work may need to lead to a deeper understanding of the dendrite formation process based on the composition of the electrolyte. He has shown quantitatively how the time to produce Li dendrites depends on the PC concentration in the electrolyte. A reviewer said the development of a diagnostic tool will be a good focus. Excellent work performed that has great marketability was how one reviewer characterized the activity. Their work is important for understanding a fundamental process that could lead to new insights how lithium plates on surfaces. Success is likely if the work is refocused to non Li-metal electrodes.

On the less positive side, a reviewer did not see any revolutionary idea to resolve this mother of all problems (e.g. dendrite formation) within this scope of this program. Another said that it is too premature and limited information has been presented. This old problem does not yet have interesting answers. A suggestion was made that safety is a major problem with all lithium metal batteries to date, so the team will need to develop a strategy to deal with this.

Lastly, a reviewer said success was a very long shot, but may be worthy of funding on a small scale only. Frankly, the manufacturer's risk associated with coming out with a lithium metal cell would seem too prohibitive (witness the demise of Moli Canada and Avestor). No matter how much testing you do, it is going to be hard to be sure that lithium dendrite formation will not occur under real life conditions.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

The increase of the use of the in situ device may require more resources, depending on the recommended extension to other materials. Another said that there had been excellent work for the funding obtained. A reviewer stated that funding for this project is sufficient.

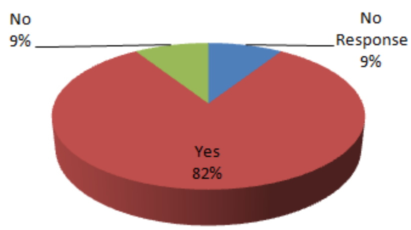
On the opposing viewpoint, funding for this activity should be terminated, stated a reviewer. Another said DOE should continue to fund, but at no more than the current level as this is a long shot, blue-sky program. DOE should give them another year to show whether this approach is useful or a dead end. They should have frequent oversight to ensure it still makes sense to continue.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

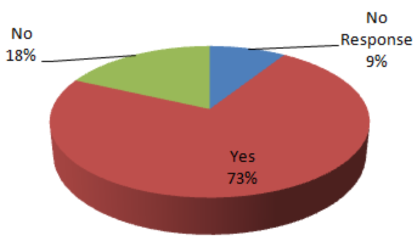
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: In Situ Observations of Lithium Dendrite Growth

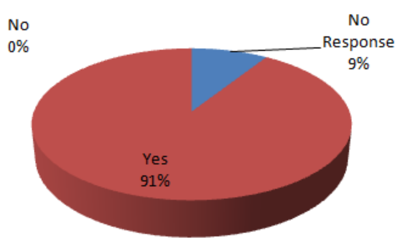
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



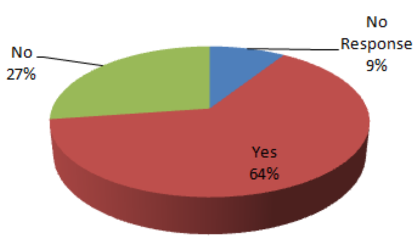
Question 2a: Are the goals of the project technically achievable?



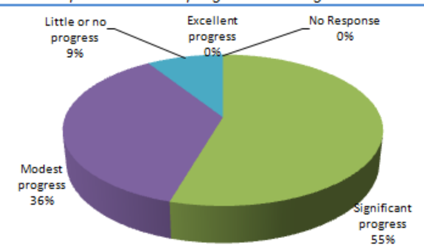
Question 2b: Have the technical barriers been identified and addressed?



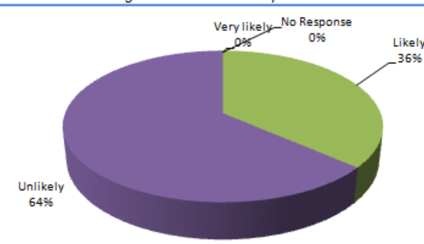
Question 2c: Is the proposed work likely to overcome technical barriers?



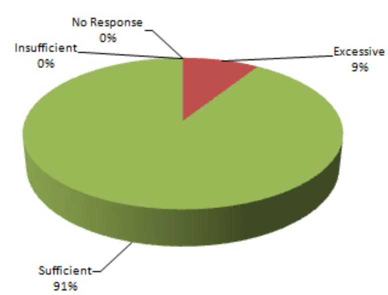
Question 3: Characterize the technical accomplishments and progress toward goals.



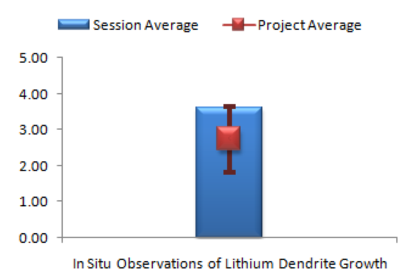
Question 4: How likely is the project team to move technologies into the marketplace?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 6: Overall Rating



Interfacial Behavior of Electrolytes (J. Kerr, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size
This project had a total of 8 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
Understanding of the interfaces is a key to improving battery characteristics, to one reviewer's mind. Another said that basic understanding of electrolyte behaviors is relevant in developing Li batteries for DOE program. A reviewer said that improved electrolytes provide better performance which leads to higher capacity and pulse power performance and longer life and they are all in line with the goals of the program. A reviewer noted that the work relates to electrolytes for li-ion batteries. The last comment was that Kerr's work on ionic liquids may lead to better batteries which would lead to more use of HEVs and PHEVs thereby reducing consumption of oil.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
One reviewer commented that the reviewer does very good work on analysis, but the reviewer saw a lot of issues being explored within his group and felt that it is rather confusing (NASA or ATD request etc.), so suggested that the program needs better focus. Another stated that the approach is adequate for an increased focus on novel electrolytes. The studied electrolytes (mainly ionic liquids) should be further analyzed to verify their compatibility with new electrodes. The author has a good plan and addressing the technical barriers, stated another reviewer. Among the notes made by a reviewer were that the Interfacial properties of ionic liquids with respect to different anodes have been studied and the carbonate based electrolytes and anode interfaces have also been studied. Finally, Kerr's work has not lead to useful results, which address the needs of battery developers.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
To one reviewer, the achievements are interesting and worth continuation and completion of the analysis according to the plan. Another offered that this is tedious work to pursue and this reviewer would understand the slow progress. Another comment was that the authors have studied effects of conductivity of ionic liquids with co-solvents and have made progress on the interfacial impedance study of graphite half cells with ionic liquid with co-solvents. The PIs need to carry out studies on completed cells. A reviewer looked forward to similar work on Gen-3 anodes as well (formation experiments with $LiPF_6$ electrolyte).

A reviewer felt there had been good analysis on the interfacial resistance study with ionic liquids. But the conclusion that they are not good for lithium-ion batteries may not be true. More studies should be carried out in this area as polymer li-ion cells will benefit from this type of electrolyte. With respect to the carbonates and the interfacial resistance, the use of LiTFSI additive in the electrolyte to improve performance at higher temperatures is good. Limitations of the materials have been understood but more work is required to make improvements.

The findings of this work which indicate that ionic liquids may not be suitable for higher rate applications such as hybrid vehicles are of value. It may make sense to generally end work with ionic liquids on this project, after providing slightly more support and documentation for this general conclusion, which should be more formalized. The portion of work focused on exploring formation phenomena, electrolyte degradation, and electrolyte kinetics with $LiPF_6$ versus LiTFSI, etc. should be continued and expanded.

A reviewer was very glad to see the measurements of interfacial impedance expressed in Ohm-cm^2. These measurements raise a red flag for other projects in the BATT and ATD programs that are looking at Li metal. Relative to the AC impedance of unformed cells, the hypotheses presented are somewhat “wild” to this reviewer: there are a lot of other factors that could be contributing to the high impedance of the unformed cell - and it is not clear that this line of work will be of any use. This reviewer thought pursuing the impedance of unformed cells is a distraction from the main issue, which is the impedance of the formed cell. The work presented is unfocused and it is not clear what was learned. The plans for next year look more focused. The reviewer supports the proposed work to look at the effects of impurities and additives on degradation reactions in the electrolyte. The PI is a talented organic chemist and his skills in elucidating reaction mechanisms in the organic electrolytes would be very valuable. In general, the BATT program is far too focused on polymer electrolytes. Batteries for PHEVs need to be low impedance and polymers will never meet that requirement. All battery companies focused on automotive applications are interested in liquid (or perhaps gel) electrolytes because of their power benefits, yet there is no component of the BATT program on liquid electrolytes.

Finally, Kerr's work has shown that ionic liquids are unlikely to help overcome the barriers to producing better batteries for HEVs and PHEVs.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

On a negative note, a reviewer said that Kerr's work is unlikely to lead to improved batteries. Other comments were more positive: a reviewer said that the technology transfer is well in place with well defined collaborations. Another said that the work is relevant for BATT activity, but the reviewer suggested including more fundamental work on ionic liquid electrolytes. The studies involving activity other than with ionic liquids provide directly transferable information of use to the marketplace. A reviewer stated that a lot of good work is being carried out by battery manufacturers in this area. It may be difficult to market if significant improvements are not made. Lastly, a reviewer offered that the PI needs to renew his contacts with industry to get re-calibrated on issues of interest to the battery industry.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

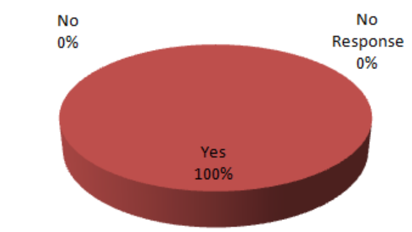
Comments varied on this aspect of the research, ranging from the view that the resources are adequate to the view that the PI does not appear to have sufficient resources to deliver focused results. Work is insufficient compared to the funding obtained, and according to this reviewer the investigators need to have better optimism and options for improvement. Resource focus should generally be re-directed from ionic liquids to the other activities of this project. The funding for this work is excessive relative to the useful results obtained, was the last comment offered.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

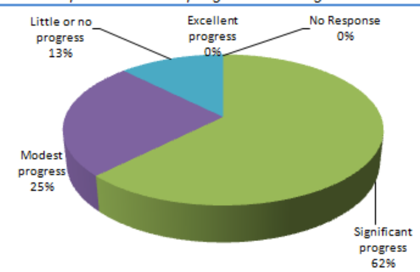
There were no expository comments for this question: refer to the graphic on the next page for this project’s summary score.

Project: Interfacial Behavior of Electrolytes

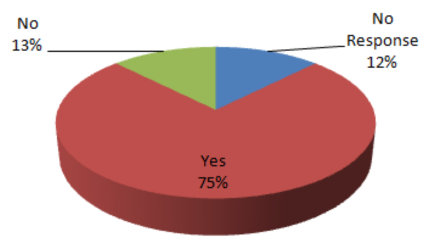
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



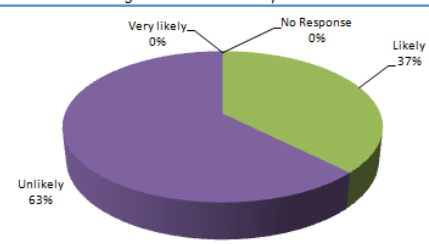
Question 3: Characterize the technical accomplishments and progress toward goals.



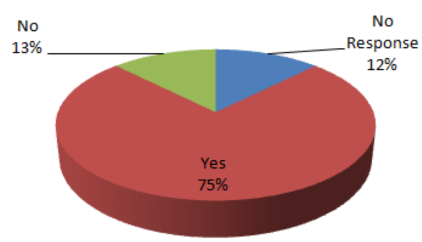
Question 2a: Are the goals of the project technically achievable?



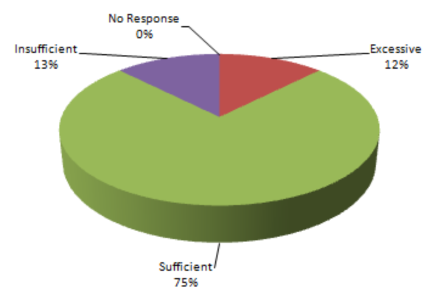
Question 4: How likely is the project team to move technologies into the marketplace?



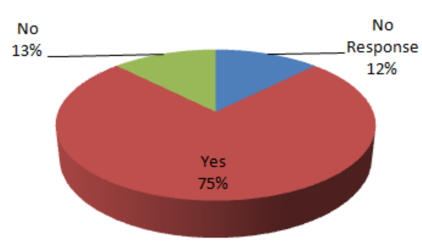
Question 2b: Have the technical barriers been identified and addressed?



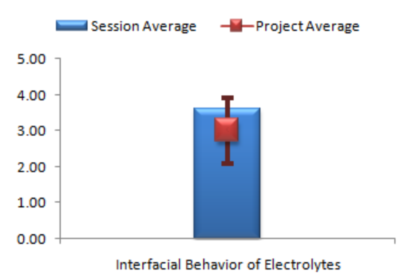
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Intermetallic Anodes (M. Thackeray, of Argonne National Laboratory)

Reviewer Sample Size

This project had a total of 11 reviewers.

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

A reviewer said that the novel high-capacity anode investigation is very relevant to DOE program. This project looks at new intermetallic anodes with improved performance. Another stated that the study of new anode materials is part of the goal for this program to obtain higher capacity cells for the PHEV program. Similarly, a reviewer commented on the development of intermetallic anodes for Li-Ion batteries. To another, intermetallics could replace anode as a high capacity (high volumetric capacity) anode material. A reviewer agreed with the focus on powders and Sn for cost and practicality. To another, this project supports overall DOE objectives, but only with a very long term focus. The final comment was that Thackeray's work on producing new Mn cathodes will probably reduce the cost of batteries for HEVs and PHEVs which would reduce oil consumption.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

Overall comments included that the defined goals are clear with well defined barriers to be overcome. The approach is original and technically reasonable in addressing solutions with new materials. The goals are challenging, but the approach seems reasonable. There is still too much focus on low specific energy materials, stated a reviewer. A reviewer characterized this as a challenging project, but it can be done. This reviewer thought it was a good change to move away from Sb. Study of new anode materials is the focus of this work to obtain a stable anode for future li-ion cells.

More specific comments included the note by a reviewer that $CoCu_5Sn_5$ shows highest capacity (400 mAh/g) and best stability (2-0 V) and was selected as the composition for further study. Further comments were that the authors are in the process of moving from present Cu-Sn system to Cu-M-Sn and finally Co-Sn system. This reviewer agreed that the ball-milling method is a good method for screening but moving to other methods like hydrothermal or thermal reduction could be used in a case-by-case basis. A reviewer noted that there are companies that can produce molten spherical metal particles - maybe this can help in the synthesis? This was clearly what was used in the "commercial sample". The improved first cycle efficiency shows that this can be beneficial.

Thackeray has shown that his intermetallic anode work to replace carbon will provide anode materials that will be safer than carbon in lithium ion cells. His work on Sn based anode materials indicate that it may be possible to generate a better anode that will be safer than carbon in lithium ion cells.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

A broad range of comments were received. A reviewer said that the results are outstanding. Other comments are that the target of 400 mAh/g has been achieved. Process evaluation and scale up related aspects need some focus. $LaSn_3$ is interesting but a preliminary cost evaluation related to the use of La is suggested. The PI has covered a lot of ground starting from Cu-Sn to LaSn3. More characterization work of materials is needed to put this material in proper ground. Full scale cells with promising or established cathodes should also be tested. The task is doing a good job of trying to creatively invent new anode materials. A reviewer asked if Stan's data shows that the Sony Nexelion anode is already at 400 mAh/g and therefore haven't they already met your goal?

Another said that this is a long-term project. This reviewer liked the focus of 400 mAh/g alternative anode with an eye toward 1000 mAh/g or higher capacity anodes at a low cost. However, the PI continues to focus on materials which are rather expensive and also low capacity. That would not lead to the leapfrog being sought with respect to either cost or capacity. He should work on high payoff materials such as Si, though it might be rather challenging.

Further comments are that addition of surplus graphite and carbon to the electrode significantly improves cycling stability through improved electronic connectivity, cf. Si electrodes, but capitalizes on the capacity of the graphite component. A good study of different anodes has been carried out. Several anode materials available in the market including those similar to one used by Sony have been studied. The $LaSn_3$ is a good anode for study, but the presence of tin whiskers is a concern. With time these can grow and creep and there may be a loss of active anode material leading to not only loss of performance but also shorting.

A reviewer suggested the project team needs to carry out extended cycle life studies on the lanthanum type anodes to determine their limitations. The nature of electrolyte was not mentioned. What work has been performed on optimization of electrolyte for this type of anode?

Another suggestion involved the reviewer noting that the team has been working on similar systems for quite some time (except $LaSn_3$). They should move on to a more interesting anode system that has more energy capacity (volumetric and gravimetric). A further suggestion was that the team should include measurements of impedance - are these materials appropriate for high power applications? A reviewer offered that the PI needs to work with the BATT program to get materials into full cells for cycle-life testing: 20 cycles at low rate is not enough to see what is happening. What happens at rates of interest to automotive applications (PHEV and HEV)?

The increased cycling efficiency in the first cycle for the "commercial sample" is an important proof point for one deficiency seen in precipitated samples. If spherical particles can be made, also better electrodes can be made, which will help with mechanical degradation. The mixed materials are interesting as a first step towards commercialization and a good mitigator that still allows higher performance. Some electrolyte development will be needed for this, but that can come later.

A reviewer noted the great partner - the SEMs look really encouraging. This reviewer said that it was a good approach to be focusing on tin and a novel concept in the $LaSn_3$ material. Ensuring adequate cycle life will be very hard - need thousands, not tens of cycles for the DOE goals.

Thackeray has made progress on several possible new materials based on Sn for intermetallic anodes to replace carbon. His industrial material partner may be producing this material for evaluation by battery manufacturers.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

On the plus side, most of the results have a commercial market and the technology transfer is guaranteed by the high quality publications. There are good chances for technology transfer if the barriers are overcome. Thackeray's results are encouraging and will probably be used in the marketplace as anode material for lithium ion cells. A reviewer said that the project is high risk right now, but worth pursuing.

Suggestions included that in regards to $LaSn_3$ – “go for it!” Future plans are good. This reviewer suggested adding synthesis through spray melt, which could improve properties and possibly be used as a fast synthetic technique once proven out. A reviewer offered that addition of surplus graphite and carbon does not resolve the safety problem. The new anode materials would be tested electrochemically by industry for final capacity and optimization, stated another.

While the project may achieve advances sufficient for transfer to the marketplace, this would most likely be in the area of battery systems for consumer electronics (given the basic properties and present costs of intermetallic compounds), in the shorter term, rather than in the area of battery systems for automotive applications. Similarly, a reviewer noted that patents were filed and already getting some "bites". This may be something that the consumer electronics people will pick up first and implement (like Sony's Nexelion). However, goals are so challenging that the likelihood of success is inevitably only modest in nature.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

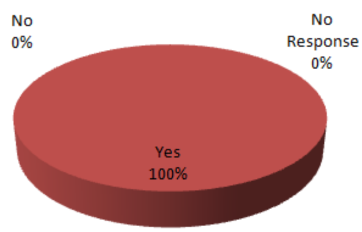
Resources were felt to be adequate, and funding sufficient, to some of the reviewers. A reviewer did state that more work can be performed for the funding received. A reviewer said that the right people are involved and they have found an excellent external partner to help them along: this reviewer recommended funding at current level - longer term program. The final reviewer could not comment on resources.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

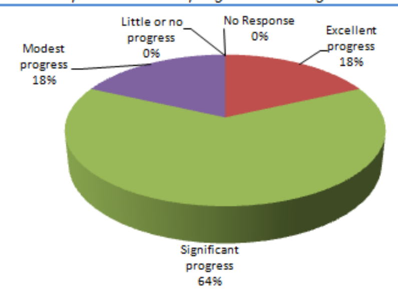
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Intermetallic Anodes

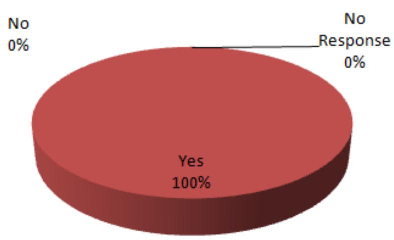
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



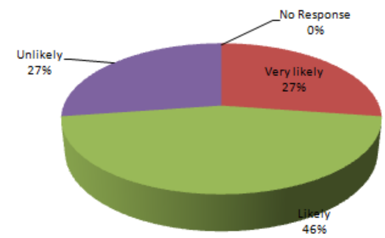
Question 3: Characterize the technical accomplishments and progress toward goals.



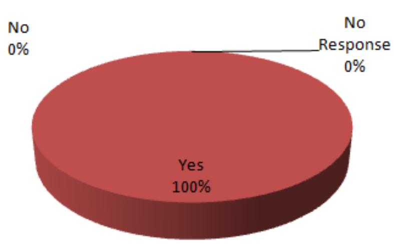
Question 2a: Are the goals of the project technically achievable?



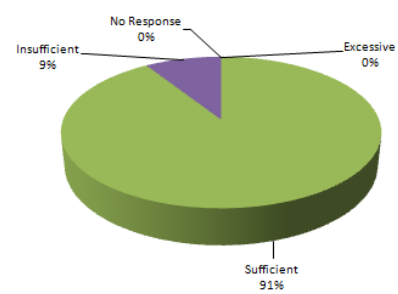
Question 4: How likely is the project team to move technologies into the marketplace?



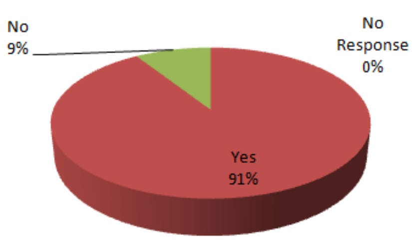
Question 2b: Have the technical barriers been identified and addressed?



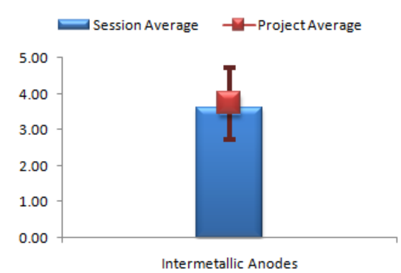
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Investigation of Metallic Lithium Anode and Graphite Current Collector for Advanced Batteries (N. Dudney, of Oak Ridge National Laboratory)

Reviewer Sample Size

This project had a total of 9 reviewers.

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

Comments included that studies on non active components together with anode are highly functional to achieve DOE objectives. Another said that the study of new current collectors for improved safety and cycle life is within the goals of the PHEV program. The statement was made that the work is related to development of cathode and anode current collectors for Li-Ion batteries. A reviewer said that Li is needed for EV and maybe high range PHEV. Dudney's work would lead to reduced oil use if her work can be used to improve the performance or life of lithium ion cells for HEVs and PHEVs. A suggestion was made that the portion of this project devoted to metallic lithium anodes does not support the overall DOE objectives and should be terminated.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

On the positive side of the ledger, the strategy is reasonable and well structured to overcome identified barriers. Different forms of carbon have been looked at for improved current collectors that are more stable and safe over long life. This is in line with the program goals. The team is making good progress on their plan. Finally, Dudney's work on carbon current collectors for cathodes may result in better cells. Her work on lithium metal anodes may lead to useful since Oak Ridge National Laboratory has a history of success with a thin film lithium metal cell using a separator known as LiPON. It may be that Dudney's work will yield similar results for metal anode high rate lithium ion cells; however, her work to date has not produced a protective film for the Li metal in a lithium ion cell.

On the other hand, Li cycling is very hard to address and robustness of C foam is an issue. A reviewer said that there is nothing new in the approaches. This reviewer thought DuPont had worked on the graphite paper for quite some time. The work on Li anode is nothing new.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

Dudney's work represents a reasonable start, but her results have not revealed anything new, stated the first reviewer. Although the work is quite relevant, a reviewer did not think it will lead to any significant achievement using the current concepts. A reviewer said that the limited results already achieved by this new project are stimulating. Foam collectors should be circulated in BATT for larger evaluation. The change to SEI study on Li metal anode is very appropriate.

The use of graphite foam or fiber is certainly an interesting idea to one reviewer. For coating the electrodes, slurry concentration increased sevenfold, still remaining very fluid possibly leading to higher energy density with single coat. $LiFePO_4$ particle size was also reduced to 0.3-0.8μm by Spex milling with 0.3mm media. Carbon precursors yielding graphitic carbon performed better than those giving glassy carbon.

After selection of the different forms of graphite, tests have been carried out with complete cells and studied for cycle life. In-situ diagnostic studies have been carried out to study the sintered bonding between the current collector and cathodes. Finally thermal conductivity analysis has also been carried out. Comparisons have been performed with the existing 18650 type cells. With respect to the anode, interface instabilities at the li metal anode in a liquid or polymer electrolyte have been studied. Passivating layers using carbonate films and Lipon have been used and the li dendrite formation studied. Work on both electrodes is very promising for this reviewer.

Both anode (carbon foam) and cathode film optimization is relevant, stated another reviewer. The heat transfer properties are a novel aspect of their work. This reviewer suggested the team should be bit more specific on what they need to accomplish on their Li anode work. Is it removing the technical barrier for Li metal as anode or understanding the mechanism of dendrite formation?

The portion of this project focused on graphite current collectors involves promising electrode configuration alternatives. The project scope should be expanded to examine active materials other than $LiFePO_4$. Although there is new work accomplished in this project related to metallic lithium anodes, and although the work is of high quality, the basic subject of metallic lithium anodes does not warrant this type of activity and the basic subject has already been extensively investigated over many past years. Activity involved with metallic lithium anodes should be terminated, according to this reviewer.

A reviewer queried, is the carbon current collector compatible with the mechanical requirements for wound or prismatic cells? This reviewer requested the team show data and make pouch cells, not swage-type cells. Why are there three projects with the program (Vaughey, West, and Dudney) all looking at Li metal? Li metal has high impedance especially at low temperature. Is there any hope of overcoming that problem? Is there any hope of Li metal lasting 10 years under PHEV cycling conditions? This reviewer did not see anything new in this work over what has already been studied with Li metal over the past 50 years.

These are early days in Li work, according to another's view. The team still seems to have a fair amount of background knowledge to catch up on. Also, this reviewer suggested the PI try and tap into expertise at PolyPlus and/or Ohara on protective coatings for lithium metal. The carbon foam work looks interesting, but the reviewer would caution that the volume as well as weight impact has to be considered, since increasing the cell volume comes with an associated increase in weight and cost from the cell inerts.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Comments on tech transfer included that the technology has a good chance for technology transfer if it is made practical. Also, the information obtained from anode and cathode electrode films should have interest to industry. The portion of the work devoted to graphite current collectors may result in useful transferable technology. Current collector materials are for the moment a result of commercial and scientific interest.

A reviewer commented on a specific technical point in this section. It was shown that, on the Li anode, 'breakdown' of the resistive SEI barrier occurs instantly when higher current applied and after 'breakdown' resistive SEI recovers rapidly. No suggestions were given with respect to improving the safety when one uses highly reactive Li metal as the anode.

A reviewer said that Li cycling is very hard to address and robustness of C foam is an issue but the plan seems very good. Dudney's results to date have not generated information that will be adopted by cell developers.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Resources seem adequate and good work was done for funding obtained. Levels of effort are OK for this difficult, long range work. There were not enough results yet at this early stage for this reviewer to give a higher summary rating - not a reflection on PI or funding.

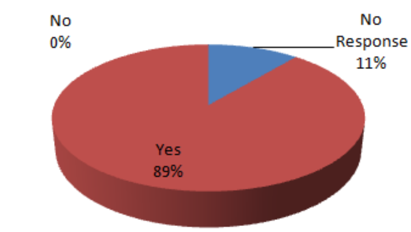
On the other hand, a reviewer said the funding for this project is excessive for the results obtained. Any resources in this project devoted to metallic lithium anode activity should be terminated immediately (in another's opinion) and redirected toward the graphite current collector study and development. The last reviewer cannot comment on this.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

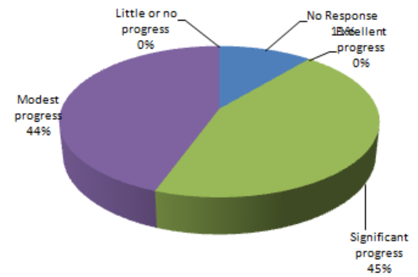
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Investigation of Metallic Lithium Anode and Graphite Current Collector for Advanced Batteries

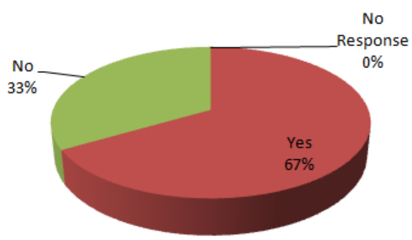
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



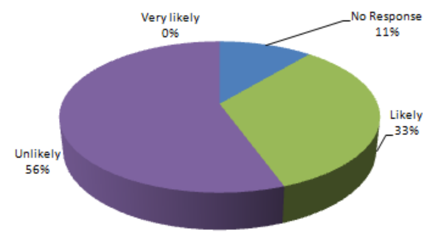
Question 3: Characterize the technical accomplishments and progress toward goals.



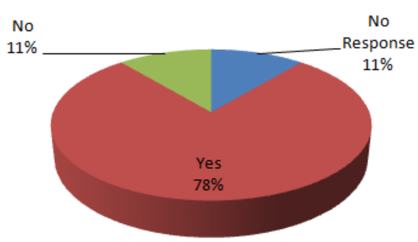
Question 2a: Are the goals of the project technically achievable?



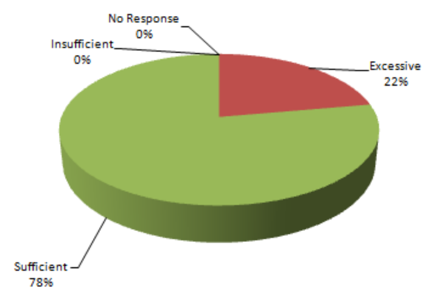
Question 4: How likely is the project team to move technologies into the marketplace?



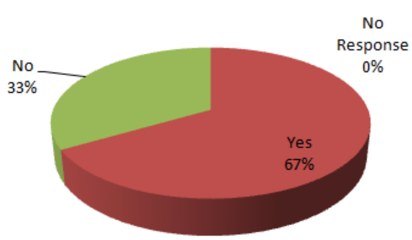
Question 2b: Have the technical barriers been identified and addressed?



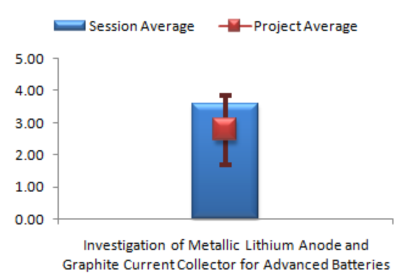
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Kinetics of Lithium Insertion into Silicon Anodes (V. Srinivasan, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size
This project had a total of 10 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
A reviewer stated this work was very relevant, and another said that the modeling is relevant to support key technological targets in DOE OVT program objectives. A reviewer highlighted the modeling of Li-ion batteries: another said the work was addressing high energy anodes. A reviewer said that the work is focused on understanding the limitations of using alloy anodes for PHEV applications and is in line with the program goals. Srinivasan's work on Si anodes may lead to the reduction of oil consumption by providing better anode material for lithium ion cells for HEVs and PHEVs. The final reviewer noted that the basic modeling intentions of this work are useful, but the significant focus of this work on silicon and/or other alloy anodes is premature and should be re-directed.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
A commenter said that this kind of support is needed to better understand silicon lithium alloys. A reviewer stated that the work plan is well laid out. Energy/Pulse power design curves look to be very useful for overall program direction.

To a reviewer, the modeling work in this project has very clear goals and a reasonable approach to adapt and validate model according to the change of the VT program. The estimation of PHEV battery performances starting from material performances is a very valuable work (a comparison with BYU modeling with Nelson to analyze).

For each new material synthesized and studied, a model is developed to perform thermodynamic and rate experiments. Comparisons are made between the model and data, extended to half and full cells and finally to battery systems. The project plan is an excellent way to complete studies on new materials.

The final reviewer said that Srinivasan's work on developing mathematical models of systems of interest by predicting the required characteristics of electrodes and separators in cells will lead to faster development of new material and its use in cells.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
Overall comments were that this was very nice work in a new program. A reviewer said that the results are interesting in simulating the behavior of some new materials. A reviewer asked if the work could be extended to porous electrodes- that is where the reviewer believed ultimate interests lie. Srinivasan's methodology has produced useful results that can be used to focus the work of others who are developing materials for cells.

To one reviewer, the goal of this work was to compare the performance of various lithium-ion cathodes when used in HEV and PHEV applications using mathematical modeling. The model predicts that high energy efficiency can be obtained by 5 orders of magnitude I/aLi. However, double-layer can sustain currents during short periods allowing lower resistance than predicted by the offset voltage. Models also provides guidance to material developers about how small a particle needs to be to achieve HEV power, and to cell developers about how thick should the electrode be for a PHEV battery application.

Extensive comments from another reviewer included that the offset potential between the lithiation and delithiation processes have been modeled and studied very well. This is similar to what is observed in real systems. The OCV at the different states of charge are very different from the OCV at the different depths of discharge. Improvements and further work on modeling will help understand the phenomenon better. An understanding of the side reactions occurring during the charge versus the discharge process may help understand the offset in potential. In-situ studies and characterization of surfaces may provide some insight into the two areas where there is a difference between the experimental data and modeling. This is an important aspect that can be extended to understand some safety characteristics of the li-ion cells. It has been observed that if li-ion cells are only 50% charged, their safety characteristics are very different from those at 100% SOC. Although this may not reflect the differences in the lithiation/delithiation process, it still looks like it may provide some insight into the better safety at lower states of charge.

The author presented modeling results on Si film anodes and explained the reason for hysteresis in terms of lithiation and delithiation voltages in silicon. Suggestions included that the modeling is based on thin films. But I understand this can be extended to real electrodes also.

While the basic modeling intentions of this work are useful, according to another reviewer, the significant focus of this work on silicon and/or other alloy anodes is premature and should be significantly re-directed toward carbon or graphite anode systems.

A reviewer pointed out a high rate of side reactions - is that an indication of poor purity in the cell fabrication? Could that be a reason for the high impedance? This reviewer said that fitting a model simply to charge-discharge curves is bad modeling. The team should make use of more available information - ac impedance, GITT, etc. The model does not seem to be matching the experimental data very well, and the proposed mechanism seems improbable.

A further commenter stated this was good work although obviously one has to be careful about using thin films for anything but fundamental work, as stated by the PI. This work seems to have shed new light on potential problems with Si not previously known (or at least not publicly appreciated). Energy/Pulse power design curves look to be very useful for overall program direction, assuming they are reliable and people actually use them. It was hard to form a judgment about this from the talk, which mostly was on the Si work.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Comments included that the publications and BATT meetings are a good means to transfer the results to potential users and that the Energy/Pulse power design curves look to be very useful for overall program direction (this reviewer was not so sure about the applicability of the Si work).

The use of modeling to understand experimental data is a good method for understanding basic thermodynamic as well as kinetic properties. If a good model can be developed, it can have good marketing prospects.

The basic modeling capability which may be involved with this project may be useful to the wide community. The specific attempts to understand and model differences between lithiation and de-litiation processes has the potential to provide directly useful information but the scope of this particular focus seems to be too small compared to the total scope of the current project.

A reviewer stated that the PI needs to reach out to others within the BATT program to model their materials and help in identifying limiting factors. The PI needs to get a better feel for what "good" practical systems look like, and what are realistic magnitudes of the various components of impedance in well-made systems - that way, he would better be able to identify impedances that are artifacts of poor cell construction. This reviewer suggested that perhaps he could try modeling a commercial Asian-produced power-tool battery e.g. Panasonic's - such work would also benefit US battery companies.

The final comment was that Srinivasan's methodology enables battery developers to determine what approaches may be useful to overcome technical barriers such as low round trip energy efficiency of cells at various rates. His methodology can be used to understand better experimental results that are not easy to interpret.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

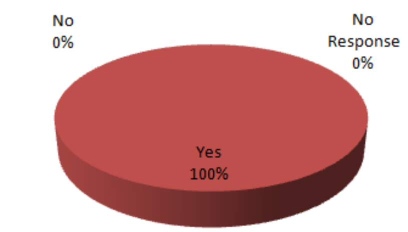
Please continue the good work, stated one reviewer. Another felt that the results and the work done justify the resources dedicated. A third said there was good work for funding obtained. Funding for this project is sufficient in another's view. A dissenting comment was that resources should be re-directed to focus totally or almost totally on graphitic or carbon based system modeling at this time. The last reviewer could not comment on resource sufficiency.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

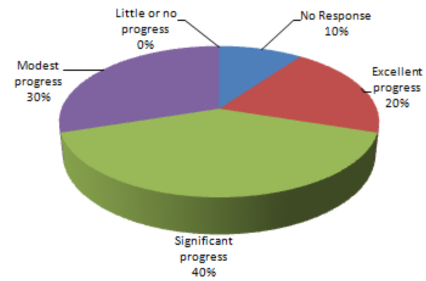
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Kinetics of Lithium Insertion into Silicon Anodes

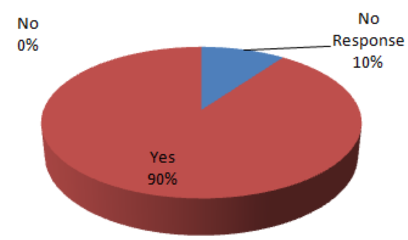
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



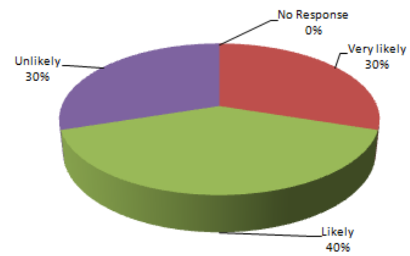
Question 3: Characterize the technical accomplishments and progress toward goals.



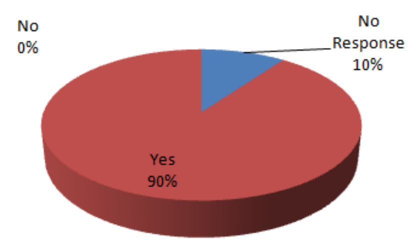
Question 2a: Are the goals of the project technically achievable?



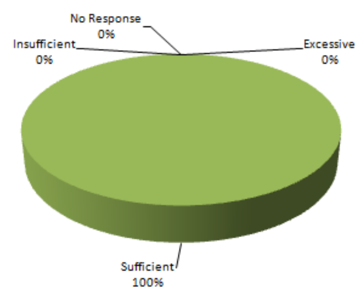
Question 4: How likely is the project team to move technologies into the marketplace?



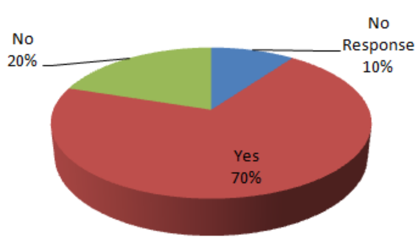
Question 2b: Have the technical barriers been identified and addressed?



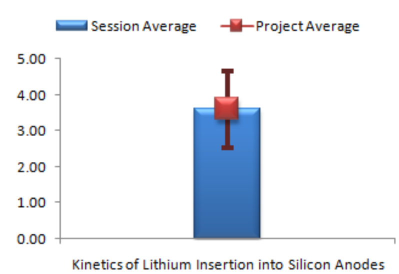
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Low-Cost Graphite and Olivine-Based Materials for Li-Ion Batteries (K. Zaghib, of Hydro-Quebec)

Reviewer Sample Size
This project had a total of 11 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
Comments here were generally positive. Low-cost materials are a key factors leading to less expensive batteries. Low cost high power materials are obviously key to HEV requirements but PHEV applicability is not so obvious. Anode work by the only industry involved in BATT gives more relevance to the activity. Identification and use of suitable graphite materials for anode to reduce cost and improve performance is in correlation to the goals of the program. The work is related to development of materials for Li-Ion batteries. Information in the presentation is very useful for electrode manufacturing of $LiFePo_4$, which is a promising low cost material for HEV and PHEV batteries. Finally, Zaghib's work will lead to better batteries for HEVs and PHEVs, which will reduce our use of foreign oil.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
On a positive note, a reviewer said it was important to continue to evaluate negative electrode materials. To another, the project has valuable goals with an adequate strategy to achieve them. The PI has put forward a good team with National Labs to supply materials as per their needs for SEI study and characterization of carbon anodes. Good strategy and excellent implementation was how another characterized this very well-thought-out study. A reviewer said that if the PI finds something, he is obviously well-positioned to implement it as far as $LiFePO_4$ is concerned. A reviewer did think the goals were unclear, however.

A reviewer commented that new graphites are required due to the stoppage in production of MCMB by Osaka Gas Company, and the project has tested new synthetic graphites. Similarly Zaghib's development of a water soluble binder (WSB) to replace the more expensive PVDF may result in a lower cost cell with comparable performance. His work on an alternative anode carbon material to replace MCMB may lead to additional cost savings.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
Reviewers offered many detailed comments here. A reviewer said that Karim's work is world class and his studies on moisture uptake by olivines are very useful. Very good results in various complementary areas, stated another reviewer. A reviewer said that several new materials were identified and under study. A reviewer queried whether the team could focus on cheap natural graphites as anode materials with some modifications. To another, the work shows how the phosphate needs to be handled and also some long term stability: all important parameters for a battery manufacturer to obtain long life for batteries having the iron phosphate material.

Accomplishments were noted by several commenters. A reviewer said that it was shown that OMAC-15 and SNG12 are suitable as alternatives to graphites. Comparable first cycle current efficiency was obtained with graphite fabricated with WSB or PVDF indicating WSB is a suitable substitute for PVDF in Li-ion cells with SNG12 anode and $LiFePO_4$ cathode showed higher rate capability than comparable cells with MCMB and OMAC. High rate performance was obtained with SNG12 anode and $LiFePO_4$ cathode materials. Significant water absorption by olivine compounds is observed, but is reduced by appropriate drying and storage. Water content is concluded to be a determinant factor on the performance of olivines. Another said that comprehensive work was carried out to understand the performance of new graphites and the effect of water on the cyclability and performance of the cells with the new graphites. Different binders have also been studied. Zaghib has completed work that shows that it may be possible to use WSB and a new carbon material for the anode in lithium ion cells to reduce the cost of cells.

Several suggestions were offered. The project may benefit if completed cells are constructed and the thermal properties studied using calorimeter methods in collaboration with Sandia. The abuse tolerance of the cells with the new graphites should also be studied. The processing of graphite anodes with water soluble binder work and their comparison with PVDF should continue. More electrochemical characterization of water soluble binder binders should be done. Studying the mechanism of SEI formation on new anode materials should be encouraged.

A reviewer commented that the project is useful in terms of investigation of factors which affect electrode manufacture and in manufacturing electrodes to supply to other BATT researchers. Investigation and validation of WSB's is useful. However, it seems unnecessary or excessive to devote nearly an entire BATT project to these two topics. A project which would involve more focused and exploratory activity might be more appropriate. For example, investigation of the differences at the fundamental level between electrodes using PVDF vs WSB binders and investigation of the fundamental mechanisms for these differences might be more appropriate topics. As a BATT project, the project should not investigate materials cost (in this case, of graphite) as a significant factor.

Another stated that this task seems very unfocused - lots of incremental work on a variety of projects. What is the overall goal of this task? It is not clear, and it is not clear how this task contributes to the battery community as a whole. To this reviewer, the topics do not match BATT's goals of long-term high-risk research. The work is well done and the analysis is sound, it just isn't clear why this is part of the BATT program as opposed to ATD or the USABC developer program.

A final reviewer said that HQ has been an important and reliable contributor to many other groups in the program, and the water-based cathode work seems successful. This reviewer was unsure on the benefit of going down this road vs. addressing all the other problems the program is facing.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The move to the marketplace was encouraging to some. These are key materials for usage in advanced batteries, stated one. Another felt that this was good work that shows promise for identifying new anode materials, and will lend itself easily for technology transfer as well as marketing. A reviewer noted that the company has products already in market place or in the process of commercialization. Similarly, a reviewer commented the technology was already in batteries that are high performing. A reviewer said that the project will help other BATT researchers in their activities. Presentations and collaborations are reasonable ways to transfer knowledge and technology. Zaghib's work is probably being adopted by battery producers based on the success he has had in this project. A final reviewer stated that other companies are already using water-based coating technologies for various systems. This reviewer did not see that HQ's will necessarily add to the state of the art nor be the one that is implemented.

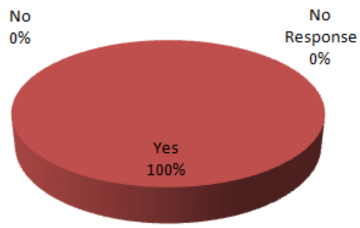
Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?
Funding was sufficient to one reviewer: to another, the question was hard to analyze, but resources seem adequate. A third said that there was good work for the funding obtained. A fourth reviewer could not comment.

A reviewer was glad to see that they are building a dry room to make real cells for the program. This should address a key failing in previous years where contracting the work out basically failed in that the cells had poor quality, were expensive and not well-defined or understood. In particular, those cells actually wasted PI time by generating data on poor cells that were very misleading and diverted attention from the real issue - making good cells to test. This reviewer was glad to see the DOE program is going to fix this problem rather than trying to live with it. Expect rating to increase next year to reflect this work.

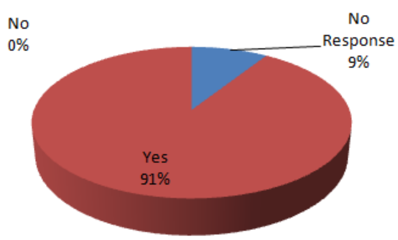
Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Low-Cost Graphite and Olivine-Based Materials for Li-Ion Batteries

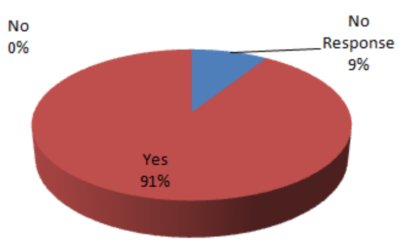
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



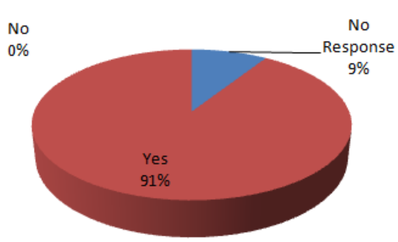
Question 2a: Are the goals of the project technically achievable?



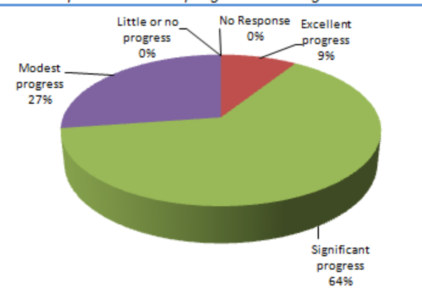
Question 2b: Have the technical barriers been identified and addressed?



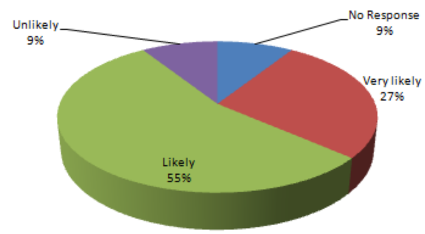
Question 2c: Is the proposed work likely to overcome technical barriers?



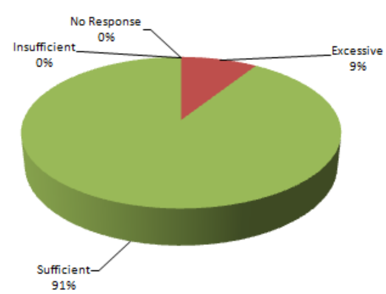
Question 3: Characterize the technical accomplishments and progress toward goals.



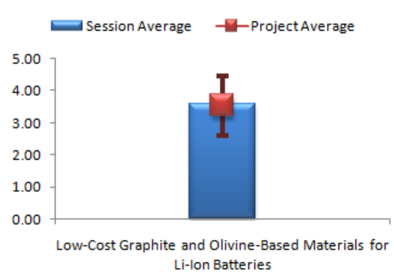
Question 4: How likely is the project team to move technologies into the marketplace?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 6: Overall Rating



Microscale Electrode Design Using Coupled Kinetic, Thermal, and Mechanical Modeling (A.M. Sastry, of University of Michigan)

Reviewer Sample Size

This project had a total of 8 reviewers.

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

Responses to this prompt were generally positive. One reviewer felt it is very relevant to the understanding and development of cell technologies, while another person stated that modeling is a cross-cutting technology very relevant to achieve DOE objectives on battery development. One other respondent stated that using simulations to determine optimum electrode compositions is in line with the goal of the program. Another wrote that the work is related to modeling and optimization of electrodes for Li-ion batteries. One reviewer commented that this work has great insight in understanding electrode design, which is needed for any HEV battery. One final reviewer added that Sastry's work will probably lead to better batteries for HEVs and PHEVs, which will result in lower oil consumption.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

Responses were again generally positive. The first respondent wrote that the project has a productive strategy with clear vision and actions. The previous year work has already demonstrated the capacity of the research team to identify technical barriers and solve them. Another reviewer commented that Sastry uses highly sophisticated tools to model and analyze the electrode characteristics, while one other reviewer indicated that there is a very good team in place to address the technical barriers encountered in electrode material optimization. One reviewer noted that understanding the electrode compositions, morphology, etc. with modeling is the basis of the strategy. It is an important piece of work that needs to be done to provide a place to start. Experimental results can then be used to refine the models and continue with providing guidance to electrode manufacturing. These studies will provide insight into limitations for short life and can help improve life by improving materials and compositions. Another individual remarked that the group is looking at real problems that have applications to many cell designs, both in and outside EV/HEV program. One reviewer stated Sastry's work on modeling mechanical aspects of materials for cells is useful to companies in their quest to overcome barriers to produce better batteries for HEVs and PHEVs.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

One reviewer indicated that the project is producing valuable and effective results of importance for material developers and battery manufacturers. The approach must be continued to be systematically applied to all the materials and key barriers affecting battery performances, including battery production processes. Similarly, one person wrote that Sastry's work is really helping us in theoretically understanding the complex relationships that govern the properties of an electrode. These are great results and this reviewer would love her to continue this work with an eye towards PHEV systems. One other respondent commented that Sastry's group has produced results that are relevant to battery manufacturers. Sastry's results indicate that coating active particles instead of using carbon conducting filler material may be worthy particularly of consideration by cell developers. One reviewer suggested that the group should continue working with an experimentalist to redefine theoretical parameters like intercalation stress, morphology versus cycle life, etc. The authors have addressed very challenging modeling work which includes packing or tapping density, particle morphology, and intercalation stress. These effects are often interrelated and the authors have done a very good job in decoupling these and studying the effects. One reviewer concluded by commenting that the researchers presented very good progress and the results could help the OEMs achieve better cell performance.

One response noted that Dr. Sastry showed that conductive coatings result in low contact resistance, which is obvious, but using carbon black/PVDF composite coatings was shown to be more advantageous than the addition of conductors (e.g. graphite) to composite cathodes in improving conductivity for all baseline materials investigated. Another reviewer remarked that it was hard to follow as there was so much presented, but this PI does world class modeling and offers excellent insight into electrode design – bridging the fundamental and applied parts of the program.

One reviewer asked why the PI cannot work on a concrete system such as L333 material or olivine? That would be a platform for testing the models. Another reviewer pointed to the effect of aspect ratio on stress - please consider the orientation of the long axis with respect to the crystallographic axes. Most materials of interest have an anisotropic volume change with the degree of intercalation. One final reviewer wrote that modeling, electrode designing, experimental testing (by collaboration) and then analysis and then remodeling at the 3D level are the focus. The composition and electrode manufacturing methods have been found to be very important. Determining the effect of packing on conductivity is a good approach. Ionic as well as electronic conductivity have been studied. In the stress study, there is a disagreement between theoretical and experimental data. Consideration of activation energy and polarization effects may help with getting better results for the intercalation process understanding. There needs to be more 3D modeling to better understand real systems.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first response commented that these results can be easily transferred to developers, while another reviewer indicated that there are many technology transfers in place via publications and direct contacts. One person felt that the results are relevant for industry in the fabrication and optimization of electrodes for Li-ion batteries. Another reviewer stated that the group is looking at real problems that have applications to many cell designs, both inside and outside the EV/HEV program. One other response commented that Sastry has produced useful modeling results concerning the design characteristics of cells for better batteries.

One person stated that, if the modeling method were more flexible, it may have better marketability. This is an excellent starting point for students and researchers, but there is a long way to go before this model can be used for comparison to real systems, as there are a lot more factors involved in a real system than just a one-dimensional model. One final reviewer commented that many of the results seem somewhat disconnected from what is seen in the industry experimentally.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

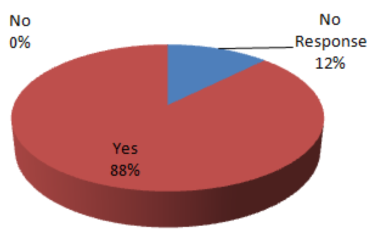
One reviewer recommended that the funding be increased. Others felt the funding was sufficient as is. One person commented that the resources are adequate to the work done, while another wrote that there has been good work for the funding received. One individual suggested keeping funding at the current level; the PI is doing value-added work with what she has and the amount of work done is actually very impressive. One response stated funding for this project is sufficient.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

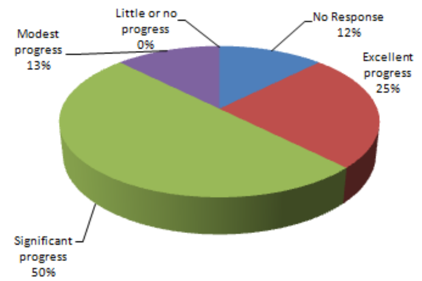
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Microscale Electrode Design Using Coupled Kinetic, Thermal, and Mechanical Modeling

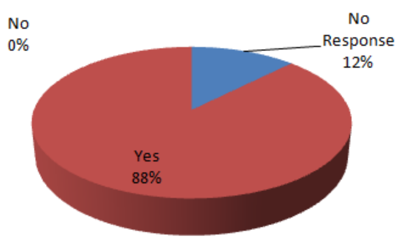
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



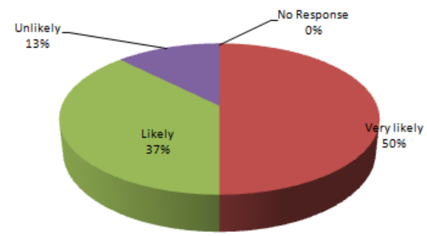
Question 3: Characterize the technical accomplishments and progress toward goals.



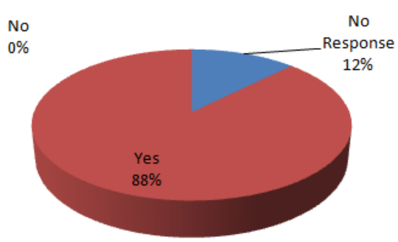
Question 2a: Are the goals of the project technically achievable?



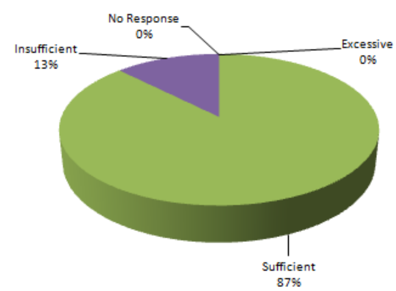
Question 4: How likely is the project team to move technologies into the marketplace?



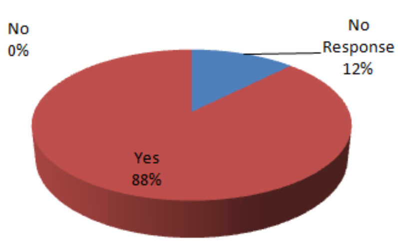
Question 2b: Have the technical barriers been identified and addressed?



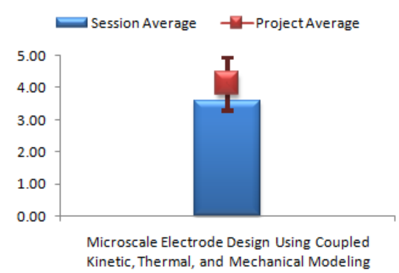
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Molecular Dynamics Simulation Studies of Electrolytes and Electrolyte-Electrode Interfaces (G. Smith, of University of Utah)

Reviewer Sample Size

This project had a total of 8 reviewers.

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

The work is related to modeling of electrolyte system for lithium-ion batteries. Modeling and simulation is essential in understanding and developing new electrolytes. Similarly, modeling of Li components is functional to the development of optimized Li batteries, and is relevant to the DOE program. Modeling is used to study lithium-ion transport and provide models and suggestions to improve transport properties at low temperature which is in conjunction with the program goals. The dissenting review opinion was that Smith's work is unlikely to produce better batteries for HEVs and PHEVs. Consequently his work is unlikely to result in reduced consumption of oil.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

The authors are using sophisticated methodologies to come up with tools to understand the interfaces. The PI is addressing the modeling challenges for understanding the interfacial behavior at the surface of the electrodes and electrolytes with respect to Li-ion diffusion. After the revision two years ago, the project has defined clearer and more reasonable targets and an acceptable strategy to perform simulation in strict collaboration with the experimental groups, better supporting the material and component R&D. A reviewer noted the use of quantum chemistry calculations to understand basic transport properties, and that the team will provide models to users and collaborate with experimentalists to compare data and then predict new materials for future use. A reviewer expressed the viewpoint that Smith's approach is unlikely to yield useful results for battery developers.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

Reviewers had positive comments for this prompt: a reviewer felt there had been excellent progress, and believed their current and future work are well thought out. The reviewer was optimistic that these will lead to a better understanding. The project is starting to give interesting results, even if the progress is quite slow in supporting material and components, stated another reviewer. However, the established collaborations are being effective in improving the effective use of this modeling activity. Alternatively, Smith's work has not produced much useful information for battery developers, according to another reviewer.

In more detailed commentary, a reviewer wrote that the authors state that they have established a first-generation atomistic model for $LiFePO_4$ based and a quantum chemistry-based atomistic model for poly(vinylenecarbonate). It was not clear how these findings can lead to improved performance of these materials.

The team has developed simulations for carbonate-based solvents with different salts and salt concentrations. Interfacial properties have been shown to be dependent on the choice of electrolyte and salt. Lithium transport properties have also been modeled for different electrolytes such as ionic liquids, liquid electrolytes and polymeric electrolytes. Other work includes models for cathode materials and additives as well as to simulate chemical reactions. The model is insufficient as it does not take into consideration all the components of an electrode. The growth in modeling methods with the use of cathode active material and an additive shows that it is positive. But all the components in the electrodes (active material, carbon, binder, additives, etc.) and then a completed cell need to be considered to get a practical picture and to make predictions for practical use. Several modeling techniques and programs exist in the market. Sandia, in collaboration with Dr. White (USC), has done some very good work on modeling li-ion batteries. Some collaboration or consultation with them may help.

Modeling of temperature dependence of Li ion conductivity in ionic structures is an important step to the understanding the transport property. The reviewer suggested that the authors should continue this work as they are in collaboration with experimental groups like Clemson University.

The scope of the project may be too great. Narrowing focus to concentrate on non-ionic liquid electrolyte conductivity modeling, phenomena involving non- ionic liquid electrolytes, SEI formation phenomena in non- ionic liquid electrolyte systems, and the future planned work with modification of the anode with polymers and transport in SEI components may be more productive.

A reviewer was glad to see the new work on liquid electrolytes. However, the particular electrolytes selected for study are not of interest to industry for a variety of reasons. The PI should talk more with industry or with people in the ATD program (e.g. Jansen at ANL, Smart at JPL, and Jow and Xu at ARL) to learn what electrolytes are of more relevance to the battery industry. This reviewer was very glad to see that future work will focus on issues at low temperature - this is very important. The PI should collaborate with Xu, Jow, Jansen, or Smart on that project - they are much more in tune with state of the art than the PI presently is.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

On the positive side, technology transfer is now acceptable to one reviewer. To another, much of the work in this project provides information which is directly transferable to the marketplace.

A reviewer was of the opinion that the work was not advanced enough for technology transfer or marketing. But the reviewer thought this work is very important from fundamental science view and is a very good match for BATT program.

A reviewer suggested that the PI needs to learn the state-of-the-art so that he does not continue to focus on irrelevant electrolytes. A final comment was that Smith's work is not yielding useful results for battery developers.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

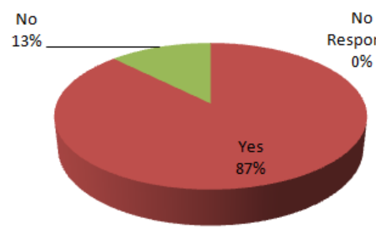
The resources are adequate to one, and excessive to another relative to the useful results. A reviewer did say that although the modeling work is behind with respect to technology level, the volume of work done is sufficient for the funding obtained. In general, resources in this project which are devoted to the study of ionic liquids should be re-directed toward the other current and planned areas of activity for this project.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

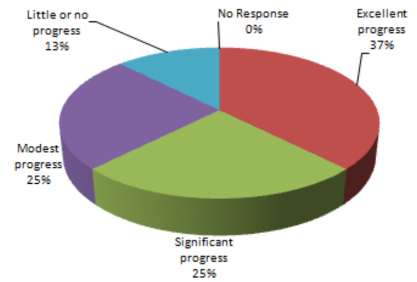
There were no expository comments for this question: refer to the graphic on the next page for this project’s summary score.

Project: Molecular Dynamics Simulation Studies of Electrolytes and Electrolyte-Electrode Interfaces

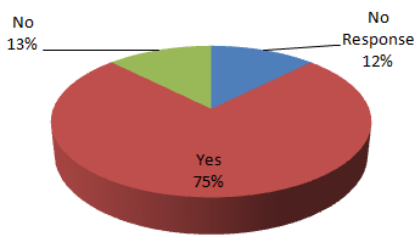
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



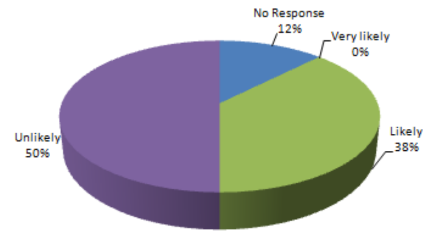
Question 3: Characterize the technical accomplishments and progress toward goals.



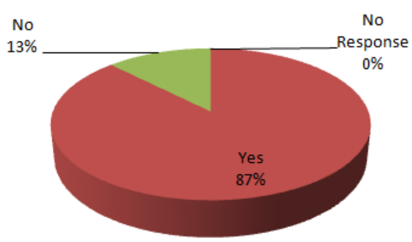
Question 2a: Are the goals of the project technically achievable?



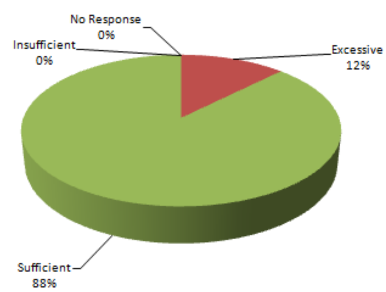
Question 4: How likely is the project team to move technologies into the marketplace?



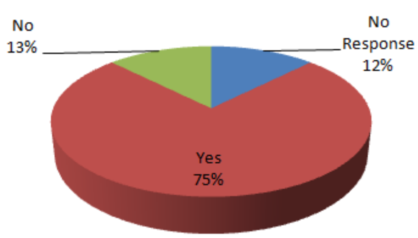
Question 2b: Have the technical barriers been identified and addressed?



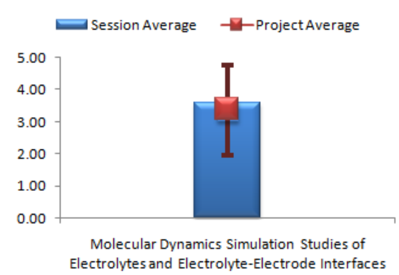
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Nano-Structured Materials as Anodes (S. Whittingham, of State University of New York-Binghamton)

Reviewer Sample Size

This project had a total of 9 reviewers.

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

A reviewer said that work on safer and less costly anodes is very relevant to the DOE program. Similarly, a reviewer felt that the project is looking for new anodes to replace the carbons to have anodes compatible with the improved anodes, which is in support of the program goals. A reviewer said that metallic anodes can lower the volumes of batteries and provide higher volumetric capacities. They could also be potentially safer compared to carbon anodes, all of which is the goal of PHEVs and HEVs. A reviewer said these anodes are needed for long range PHEVs and EVs. One reviewer simply highlighted development of anodes for Li-Ion batteries. A reviewer stated that Whittingham's work will probably lead to development of better anodes for use in lithium batteries for HEVs and PHEVs which will lead to less oil being used for transportation. A final reviewer said that this project supports overall DOE objectives, but only with a very long term focus.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

Statements regarding the goals and barriers included that the program still does not have a strong focus, and that the project focuses on a few and well defined targets with a clear approaching strategy. The scientific and technological choices and activities should be integrated by economical evaluation. A reviewer said that the study of alternate cathodes for safety, low cost and high volumetric energy density is in sync with the program's strategy of achieving high energy density and power density li-ion cells for PHEV. A reviewer felt that the author has a comprehensible plan with industry and National lab for studying their anodes. One characterized this as a high risk project, but very worthwhile pursuing. A final comment was that Whittingham's work on producing new anode material will help battery producers break through technical barriers associated with the anode material in lithium ion cells.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

Technical comments on this question were received in several areas. A reviewer stated that the increased capacity has been achieved for various materials. Another noted that stability is improving: this should be the main focus of next year. Behavior at low temperature should be analyzed. Cost analysis should support the material selection. A reviewer said that given the challenging task, this program has made great progress. The Si-Co-C looks very promising. Further, Whittingham's work on MnOx as an anode material has produced results that may be used by lithium ion cell producers.

More specifically, a reviewer offered comments that a wide range of new anode materials have been studied. New materials are being explored that will be compatible with low cost manganese based cathode materials especially those that will help prevent gas accumulation in pouch cells. Improvements in volumetric energy densities in comparison to the existing carbon have been studied by going to these new materials. The testing using suitable electrolytes provides a more comprehensive understanding of the workability of the new anodes. The safety of the new materials needs to be studied at the cell level.

Another reviewer's detailed comments stated that Sn-C0 and MnO_2 anodes look promising but how does the capacity retention look at 50 cycles or above? How much is the volume expansion at full lithiation? This reviewer said that it looks like the team has been working on similar stuff (like MnO) for quite a bit of time. It is time to move on to other high capacity anode systems.

A further set of comments began with the observation that the voltage profiles for the Mn oxide anode show very high resistance - why for a nano material? Is this material appropriate for high power applications? What C rate is used for cycling? This reviewer wanted this included on the graphs. For future work on Sn the team should include C rate as well as DOD as a variable in the cycling study. The PI claims to be focused on safety, yet no safety data is shown. How do we know that nano materials are safer than micron-sized carbon? Please collaborate with ANL or SNL to compare safety to carbon.

A final commenter said that Si cells seem to be nosediving. Hopefully with the new cycling and more time, cycle life testing can be extended out further. Sn looks better to this reviewer.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

A reviewer stated that the topic is very sensitive to industry interests. The collaboration with various national labs is an effective way to favor technology transfer. Another said that technology transfer has been carried out and the product has great prospects for commercialization based on the extensive collaboration with battery manufacturers. A reviewer said that if successful, every battery company would like to have this type of material. A reviewer observed that technology transfer is occurring through peer reviewed publications and work with industry. The collaboration with Primet is good. While the project may achieve advances sufficient for transfer to the marketplace, this would most likely be in the area of battery systems for consumer electronics (given the basic properties and present costs of intermetallic compounds) in the shorter term, rather than in the area of battery systems for automotive applications. This is a long-term low likelihood-of-success goal, stated another commenter. But the fact they are working with an outside company to make the materials and also teaching them to make and test cells is encouraging. Finally, Whittingham's results on MnOx are useful and will probably be adopted by lithium ion cell developers.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

One felt that the effort planned for the coming year seems to require more resources. Another similarly stated that more funding could be provided for the good work performed. One said that funding for this project is sufficient. One could not comment on the resources.

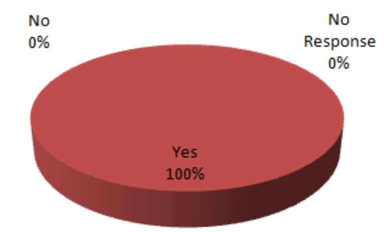
More detailed comments included that the future work is good but that some emphasis should be focused on electrode making, so that optimum cycling can be obtained, which is a challenge with probably a very hard to formulate material. Another said it was a bit early in this work to judge, but this reviewer remained optimistic. The program needs to be coordinated with ANL's - they seem in part to have very different beliefs regarding Si. The differing beliefs may be OK, but the labs should still be working together.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

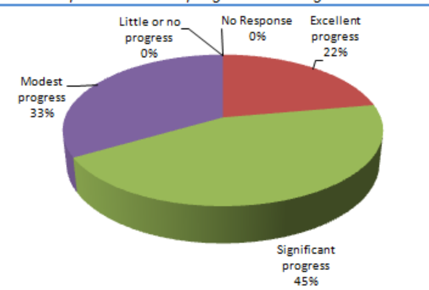
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Nano-Structured Materials as Anodes

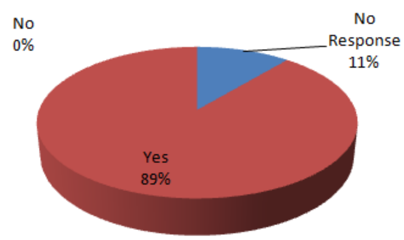
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



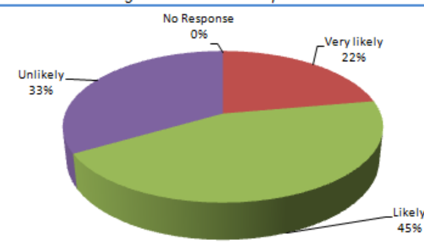
Question 3: Characterize the technical accomplishments and progress toward goals.



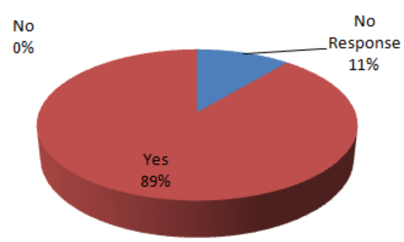
Question 2a: Are the goals of the project technically achievable?



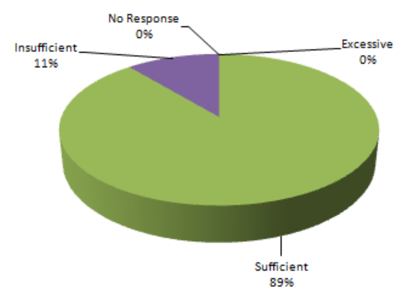
Question 4: How likely is the project team to move technologies into the marketplace?



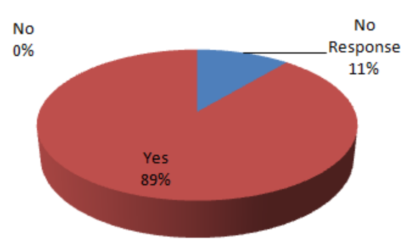
Question 2b: Have the technical barriers been identified and addressed?



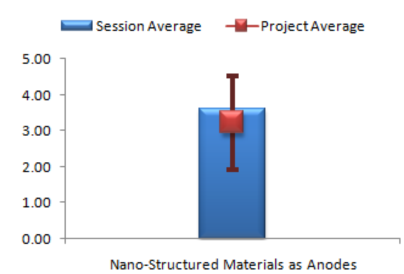
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Nano-Structured Metal Oxide Films (A. Dillon, of National Renewable Energy Laboratory)

Reviewer Sample Size

This project had a total of 9 reviewers.

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

The first reviewer saw the project as very relevant. Another comment was that novel anode materials are necessary to meet better DOE objectives of lower cost and higher performances. Similarly, the use of a less expensive anode material with the goal of less cost, durability and performance are in line with the goals of the PHEV program. The work involves synthesis of high capacity anode materials for Li-Ion batteries. Dillon's work may lead to better anodes for lithium ion cells which will lower oil consumption through HEVs and PHEVs.

A more detailed comment was that the project provides some new useful information regarding MoO_3 as a potential future anode material which may be of interest in the long term. However, it is unclear that the process used to produce the nanoparticles could ever be developed into a practical or feasible high-volume process. In a related statement, a reviewer felt that with its high potential (1.5V vs. Li), MoO_3 cannot be used (in this reviewer's opinion) for PHEV despite its high capacity. For HEV this reviewer did not believe there would be an advantage anyway - do we even need a new anode? MoO_2 may be worthwhile.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

The approach is well described and reasonable (to one reviewer) with activities of fundamental (characterization) and practical/technological (low-cost production process) nature. The technical barriers are appraised and well-addressed with an organized planning. The choice of MoO_3 deserves interest for the intrinsic technical features (high specific capacity).

Another reviewer noted that electrodeposition methods have been used to make porous MoO_3 materials for anodes. The project strategy is in conjunction with the goals of the program. Another said that good work was done on MoO_3 but this does not seem to be a promising material: future work with MoO_2 may be worthwhile.

Dillon's work may lead to low cost MoO_3 anodes for lithium ion cells. This anode material has demonstrated value in the form of nanoparticles. Dillon's work may provide help to cell developers produce practical electrodes from the two micron particles. Her hot-wire chemical vapor deposition process may be capable of producing useful MoO_3 particles which can be harvested and used as an anode in a lithium ion cell.

Other comments were that the project team has already made good progress in the project, but that the determination that the related process could be scalable or viable is unclear.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

To one reviewer, good progress has been made in obtaining a good method to obtain the materials for the new anode. Testing has shown that at least 150 cycles have been obtained with negligible loss of performance. This was a good synthesis effort to a reviewer's eye and the electrochemical performance is robust till 150 cycles. The scale-up effort looks promising. The reviewer suggested the team must pursue an effort towards enhancing the rate capability.

To another, these are excellent results: this reviewer had one suggestion for experimentation. Have the authors looked at tuning the voltage (lower) by using dopants? A reviewer stated the determination that the related process could be scalable or viable is unclear.

This is good technical work on MoO_3 - combination of synthesis, characterization and modeling. But this reviewer did not see how the voltage penalty of 1.5V vs. Li with MoO_3 could be overcome. Dillon's material has a high capacity, but also a high potential. However, her material may be suitable for use in high potential cathode cells.

The accomplishments are very interesting and complete, stated another. The technical performances are impressive (in excess of 500 mAh/g). The cost aspect of the inexpensive process is another important achievement of the project. Samples of the anode should be circulated in BATT for parallel evaluation with various cathodes and electrolytes.

Detailed comments from another noted that MoO_3 nanoparticle electrodes fabricated with electrophoresis are shown to have a reversible capacity of 630 mAh/g, delivering around 500 mAh/g at 2C rate (2 μm thick). The nanoparticles are made with an inexpensive HWCVD technique that has been scaled-up such that properties in thicker electrodes may be optimized. Coin cell testing, employed for 100 μm thick films with 70% MoO_3 nanoparticle active material in collaboration with the University of Colorado, revealed the same high reversible capacity as the thin film electrodes with only slightly diminished rate capability. By modifying the HWCVD synthesis conditions it may be possible to produce MoO_2 nanoparticles.

This task has covered a lot of ground in little time and is doing a great job of getting up to speed in the lithium-ion world. The PI is showing creativity in developing new materials and in combining diagnostic techniques with modeling to understand the materials.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Dillon's material shows promise for further development by cell manufacturers. The technology will move forward (in one reviewer's opinion), as evidenced by the license agreement they are working on. This new material already has interest from industry and adequately transferred, stated another. A reviewer saw that technology transfer seems to be in work already. A reviewer felt there was good progress in technology transfer, both industry and technical publication. A reviewer did reiterate the voltage penalty of MoO_3, however.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

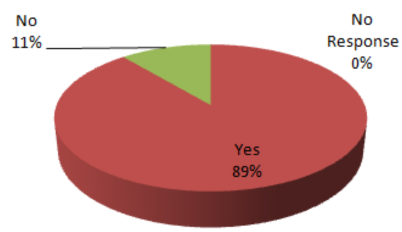
Funding for this project is sufficient, stated one reviewer. Likewise, the resources are adequate to the planned efforts for another reviewer. Similarly, a reviewer noted there was good work for the funding provided. A reviewer expressed the view that for future work, the intent or scope of activity related to pre-lithiation is unclear. A reviewer recommended discontinuing MoO_2 work, but DOE should continue to fund MoO_3 if it is believed high capacity at <1V vs. Li can be achieved. The final reviewer could not comment on the resource sufficiency.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

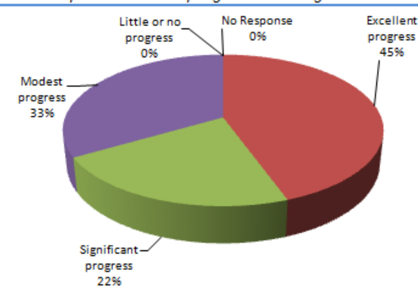
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Nano-Structured Metal Oxide Films

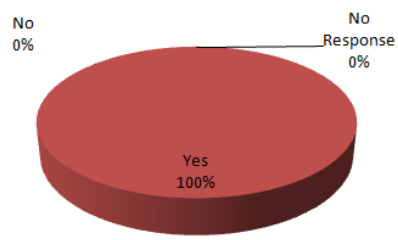
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



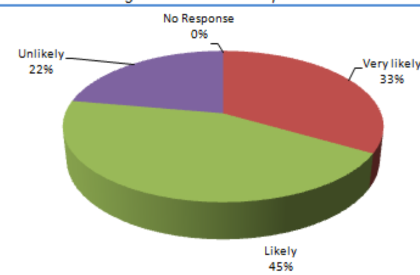
Question 3: Characterize the technical accomplishments and progress toward goals.



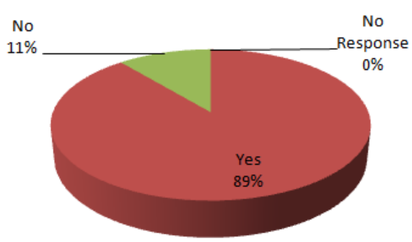
Question 2a: Are the goals of the project technically achievable?



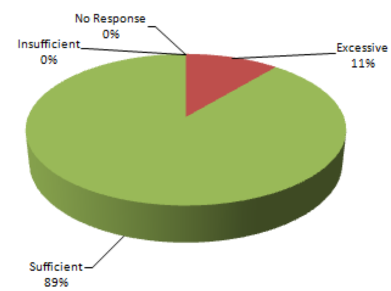
Question 4: How likely is the project team to move technologies into the marketplace?



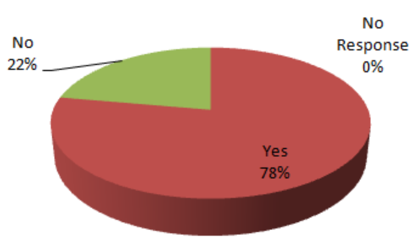
Question 2b: Have the technical barriers been identified and addressed?



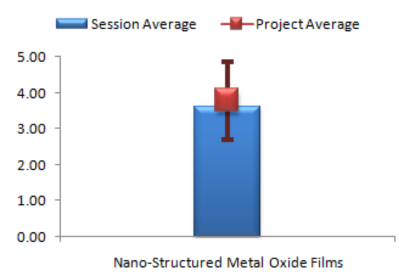
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



New Lithium-based Ionic Liquid Electrolytes that Resist Salt Concentration Polarization (D. DesMarteau, of Clemson University)

Reviewer Sample Size
This project had a total of 9 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
Lithium salts are key to cells with improved performance and safety, stated one reviewer, who also felt the U.S. has fallen behind in this field. New electrolytes are important for meeting DOE goals, said another. Development of new electrolytes for li-ion batteries was highlighted by a third reviewer. Improvements in electrolytes will be used to meet the goals of the program by improving ionic transport leading to increased capacity and increased power capability and in the end longer life. Finally, DesMarteau's work will probably not lead to better batteries for HEVs and PHEVs.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The PI has addressed all the above points and looks like the project is well on plan, said a reviewer. A reviewer also stated that the team has done good technical work, and the focus on binders seems appropriate as long as stability to high voltage is acceptable for these materials. The reviewer noted that the selections in the multiple-choice questions refer to the low likelihood of success for the past work on using a salt as an electrolyte.

A reviewer said that ionic melts were used to improve ionic conductivity, and new flouropolymers were also synthesized for use as binders for cathodes. The approach is interesting because it aims at solving key problems of current electrolytes by studying novel electrolytes.

On the other hand, a reviewer would recommend that the authors pay attention to the cost of these exquisite electrolytes. Even if they come out with a solution but it is expensive no developer will have any interest. Also, this reviewer would shy away from using plasticizers. The final comment was that DesMarteau's work is unlikely to yield material that will be useful for batteries.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
Good technical work, said one reviewer. The PI did what he set out to do in making these new materials and characterized them properly. There was nice collaboration/learning from Kerr at Berkeley to address the cathode manufacturing issue. In view of the synthetic work involved, they have accomplished a lot in the time. Furthermore, results on both the ionic liquid-based electrolytes and the new additive for cathodes are promising. More experimental work is required to confirm them: (1) At low temperature, and (2) in higher voltage cathodes and cells.

The authors have designed new electrolyte which addresses existing problems in Li salt electrolytes like low transference number, conductivity, etc. The effect of these new electrolytes on cell capacity and cyclability was examined. The second part of the work involved new ionomer as cathode binders. The reviewer suggested that work should be directed towards understanding the SEI formation on anodes for these ionic liquids. This work should be continued, but greater focus should be put on the lithiated fluoropolymer activity, and more specifically on demonstration of improvements in any areas of performance via implementation of the fluoropolymer as a binder in the cathode.

In this presentation, it was stated that the lithiated electrolytes comprised of low-lattice-energy anions on a fluoropolymer backbone have been synthesized and are available for use in formulating high-voltage cathodes. Although the authors stated that improved performance is expected in terms of high-rate charge/discharge, capacity utilization, and capacity fade, no results are there yet to support the claims. It was also stated that (1) the use of $Li_4Ti_5O_{12}$ electrode provided zero-strain intercalation / deintercalation of Li+ and does not form SEI, (2) Adding PEGDME to the electroltye increased transport by decreasing viscosity and decreased Li+ transference number, and (3) adding di-lithium salt of fluorosulfonimide Fluorolink E electrolyte to the cathode formulation increased transport properties within the bulk of the cathode. These are good accomplishments, but need to be independently verified.

The ionic conductivity was characterized and the ionic melts were tested with typical cathodes and anodes in a complete (swage-type) cell and changes made to make it work. Good work was done on completed cells. Good work has been done with the electrolytes for cathode binders. It will be good to carry out tests on completed cells as planned. Use of additives or other changes in the structure may improve its room temperature performance. Its compatibility with the rest of the cell components should also be determined if used as binder in cathodes.

For the ionic melt polymer electrolyte, the reported conductivity is 100 times lower than the liquid electrolytes in use in batteries today. This poor conductivity is reflected in the dismal cell performance - major rate limitations even at C/5. This reviewer was glad to see that the PI has realized these limitations and is stopping work on this project. The reviewer thought that the ionomer binder was an interesting idea. The main performance criterion for binders is how much binder (weight percentage of electrode) is required to achieve adhesion to the current collector. The reviewer asked that the PI show adhesion measurements. It may be useful to work together with Gao Liu at LBNL on this work. The reviewer also asked that the PI show measurements of cell impedance indicating whether the new binder actually gives any benefit to cell impedance.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Technology transfer is underway by publications and confirmation of the results may open the way to commercial implications. Important ionic liquid electrolyte work was another positive statement on this work.

The PIs have acknowledged the issue with low temperatures and are redirecting the work appropriately to binders. Also, the materials being considered are PEO-free and should overcome the instability of PEO to high voltages. Going forward this reviewer would still like to see them clearly identify what benefits their proposal to work on binders would give over conventional binders – this reviewer “must have missed that.”

According to a less-positive comment, the current electrolytes are not novel enough (they need plasticizers) to be of commercial interest. DesMarteau's work has not produced material that is on interest to battery developers, stated another.

There are a lot of different electrolytes already available in the market for polymer li-ion cells. But if really outstanding results are obtained there is a good chance for the technology transfer and marketing. At this point the results are not significant.

Other statements included that continued work with ionic liquids may result in transferable technology, but the activity with fluorinated polymers as binders may offer a greater opportunity for more significant transferable technology. It was suggested that the PI might wish to talk with companies like Arkema and Solvay that make PVDF.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

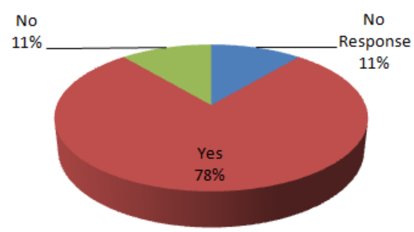
Several comments were received here: first, the resource and efforts seem reasonable even if some acceleration would be desirable in verifying performances. The second commenter said there was reasonable work for funding obtained. A reviewer suggested that the resources should be split more evenly between the work with lithiated fluoropolymer binders and the work with ionic liquids, with more focus on lithiated fluoropolymer binders. A reviewer recommended continuing this work at the current level. This reviewer’s overall rating reflects the fact that the past work has not really led to practical materials, but the future work on binders is promising. The reviewer liked their approach and they have learned a lot in the last 18 months. The final commenter dissented, saying funding for this project should stop because no useful material has been produced even though this project has been funded for many years.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

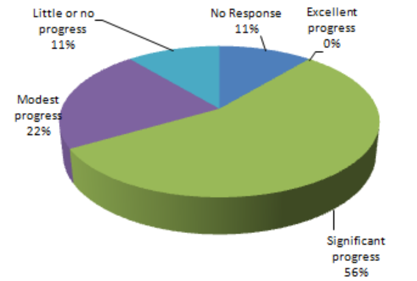
There were no expository comments for this question: refer to the graphic on the next page for this project’s summary score.

Project: New Lithium-based Ionic Liquid Electrolytes that Resist Salt Concentration Polarization

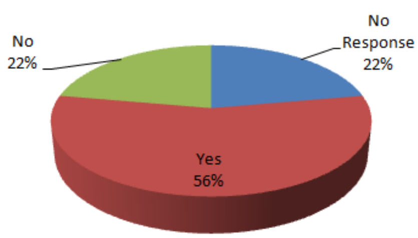
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



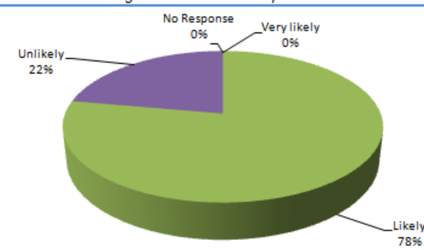
Question 3: Characterize the technical accomplishments and progress toward goals.



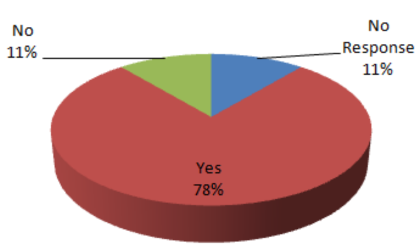
Question 2a: Are the goals of the project technically achievable?



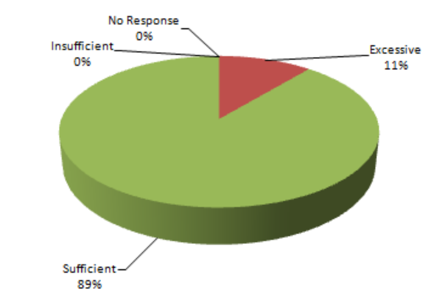
Question 4: How likely is the project team to move technologies into the marketplace?



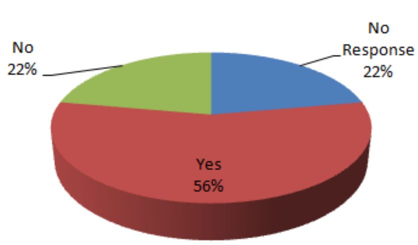
Question 2b: Have the technical barriers been identified and addressed?



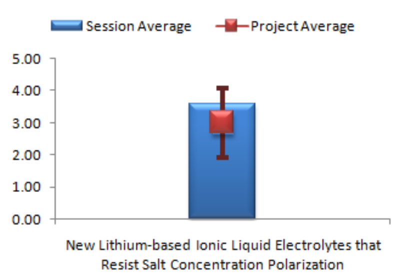
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Olivine and Layered Materials (Characterization, Rate Performance, and Stability) (G. Ceder, of Massachusetts Institute of Technology)

Reviewer Sample Size

This project had a total of 10 reviewers.

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

A reviewer stated that the work was very relevant and the principal investigators do great science. Another said that basic research on cathodes is relevant to DOE program. A reviewer stated the two major types of materials, layered oxides and olivines, are important for DOE and industry battery programs. The work relates to computation and experimental study of advanced cathode materials for li-ion material. Understanding the limitations of electrode materials using material characterization techniques and modeling meet the goals of studying better materials to improve stability and performance of new materials that will provide higher energy density. Ceder's work will lead to better batteries for HEVs and PHEVs, which will reduce oil consumption. Finally, a reviewer said the team is working on critical problems, although the reviewer was still not sure that materials with Co are ever going to be low enough in cost to meet this program's needs.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

Positive comments include that the authors have a sound and cutting-edge plan to push the state-of-the-art and that the team has the right experimental and theoretical expertise to make rapid development in design of high rate and capacity cathode materials. A reviewer said that the strategies involve first principle calculations combined with experimental evaluations: this has proved to be a powerful combination. The computational and experimental mix is a well-combined approach in analyzing material behavior and optimizing synthesis, stated a reviewer. The program is trying to identify novel and unique materials to improve the rate capability of li-ion technology. Ceder's work on predicting the stability of cathode materials will help cell developers' quest to reduce the cost of materials and improve performance. Finally, a reviewer noted that some of the barriers may be "laws of physics type of things." But this work is critical to understanding the problems.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

Positive comments were found here as well, including that these are outstanding studies and results (this reviewer was highly impressed.) Another said that results have set the standard for material understanding both for equilibrium consideration and also dynamic processes. This has been direction-setting work. Another commented that the results on olivine and layered cathodes are interesting but the focus on new materials should be increased. The project addresses key technical barriers in terms of both first-principles modeling and actual active materials properties. The activity involved in this project should be expanded. A reviewer would suggest the authors focus more on novel materials for the future than on understanding behavior of currently available commercial materials. (Developing new techniques however is highly appreciated, like the PI has done).

The reviewer noted the computationally investigated quaternary phase diagram of Li-Fe-O-P to understand synthesis and thermal stability and also noted the team was planning to investigate the effects of surface and particle size on electrochemical properties of $LiFePO_4$ and $LiMnPO_4$. These findings will be quite useful. More capacity at higher rate of discharge for $LiMnPO_4$ is unusual and interesting. Also noted was that a systematic study of the surface morphology has been undertaken. Surface modifications have also been studied to understand if there are improvements in the cyclability. The in-situ MAS NMR is a very good diagnostic tool. This is an excellent new method to study a practical environment as in a complete cell. It may be useful to study the cells with a carbon anode.

From excellent computational modeling combined with experimental efforts, the PI team has designed and demonstrated a very high power cathode material that looks very promising. Modeling li-ion extraction potential at different sites (like surface and bulk) is a good estimate for designing the right cathode electrode. The other interesting aspect of their work is improving the rate of these cathode and correlate with particle morphology. The NMR technique for applying to such cathode is unique and should be encouraged as it a very local probe to study lithium.

For the mechanism of Li diffusion a reviewer suggested the team work with Richardson and Chen to try to come up with a consistent story. With respect to $LiMnPO_4$ and the effect of capacity on rate capability (e.g. 1C versus 2C), does this depend at all on the charge conditions or other previous history that precede the discharge? The computational searching for materials is very exciting. In-situ NMR is quite an accomplishment. The reviewer looks forward to seeing how this can improve understanding of materials.

A reviewer said there was excellent collaboration between Ceder/Gray/ANL/Berkeley and focus on critical problems that are hindering implementation of high-rate/low-cost materials. This is a great approach to almost designing a material and is critical work to understand materials and identify the main issues. Very nice work, stated this reviewer. This provides an invaluable service to the BATT/ATD groups.

Ceder et al.'s work helps clarify where the opportunities are for reducing the cost of cathode material through, for example, a deep understanding of the rate dependence on the morphology of cathode particles.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Cutting-edge and novel materials will result from this work, according to one reviewer. Ceder's claim of greater than 100C rate with high potential material based on surface layer modification is exciting and may lead to better material for cathodes. The main technology transfer is in direction setting for material types, stated another reviewer. Another viewed the results and the actions (publications and patent) as showing a clear attitude to technology transfer. A reviewer said the work was focused on key materials. Even negative conclusions are very useful as they can stop work on dead ends.

Good work, stated a reviewer, who continued by observing that the capability for in situ NMR especially in a complete cell is a very novel and highly useful technique that many cell manufacturers would also like to adopt to get quick data on material improvements they make. Another said that the new cathode materials show very low capacity loss even at 40C rate. The new material and the processing parameters for cathode fabrication hold the key for achieving this.

The development of a $LiFePO_4$ material of extremely high rate capability is a very significant accomplishment with direct transfer potential. The in-situ NMR methodology should be of direct value to other researchers and should help to provide greater fundamental understanding of many cell chemistries.

Grey does an excellent job of collaborating with other members of the BATT program and with industry to improve understanding of many of the materials being developed; she should continue to reach out to other members in the BATT program. Ceder should reach out more to other members of the BATT program to work with them to experimentally validate his quantum mechanical calculations.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

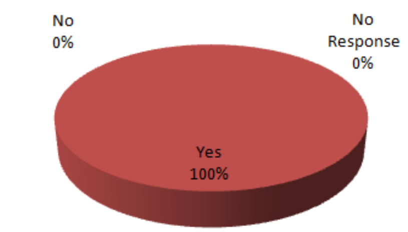
The first reviewer would not mind increasing the funding considering the volume of results they have produced. The second said there was excellent work for the funding obtained. The third opinion was that funding for this work is sufficient. Another said that resources for this project should be increased. The large budget and the amount of work done gave confidence on the right balance of resources to another reviewer. Very good collaboration and utilization of resources was the view of a reviewer, who just questioned the work on Co-containing materials (acceptable for the method development of course). The final comment here was that this task is really two PI's, why are they lumped into one task? There really is insufficient time to review all the work done.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

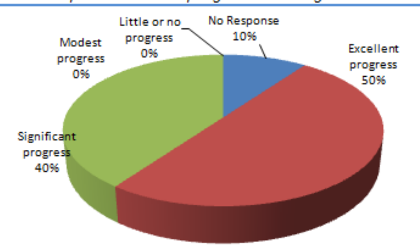
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Olivine and Layered Materials (Characterization, Rate Performance, and Stability)

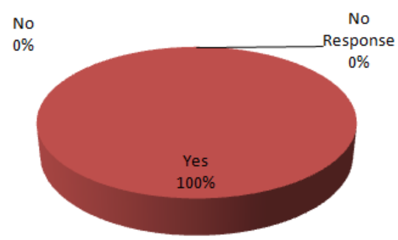
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



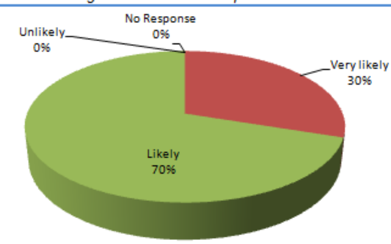
Question 3: Characterize the technical accomplishments and progress toward goals.



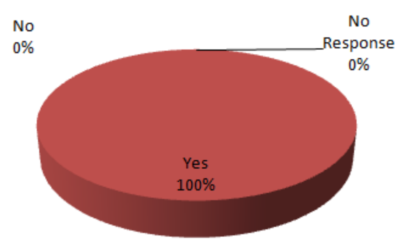
Question 2a: Are the goals of the project technically achievable?



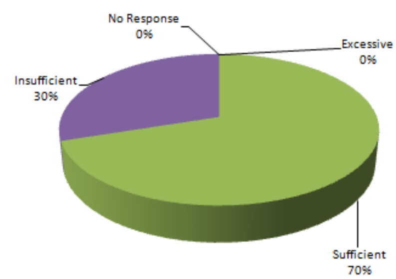
Question 4: How likely is the project team to move technologies into the marketplace?



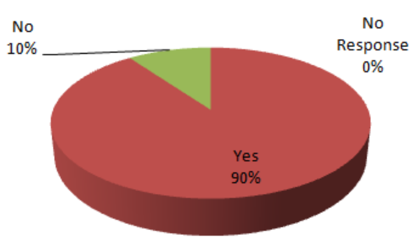
Question 2b: Have the technical barriers been identified and addressed?



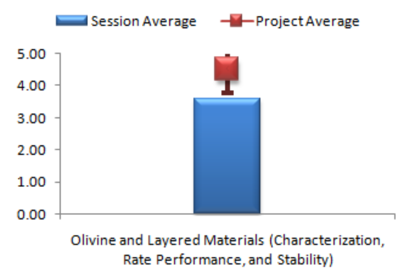
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Olivines and Substituted Layered Materials (M. Doeff, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size

This project had a total of 11 reviewers.

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

A reviewer said the work was very relevant, with a focus on low-cost, benign materials. Another stated that the novel cathodes development is relevant to the DOE program. A reviewer further noted that all materials studied are important for PHEV and HEV development. To another, the low cobalt layered oxides are well placed for petroleum displacement with batteries. The use of low-cost high energy materials with stable performance is in line with the goals of the PHEV program. Additionally, the work is related to synthesis of low-cost cathode materials for li-ion batteries and optimizing the cathode properties. Another opinion was that improved power capability in relevant cathode materials (as demonstrated in this program) is directly relevant to overall DOE objectives. A reviewer stated that the carbon coating seems to have advantages for many materials (anodes and cathodes) and so the studies have a general applicability. The reviewer is still concerned about the use of Co for this program, even at only the 10% level. The team will have to look at what Co price is likely to be if this technology were to be implemented. It may increase a lot depending on how large the HEV business would be in relation to other industrial uses. Finally, Doeff's work to reduce the amount of Co in cathode materials and her $LiFePO_4$ carbon coating work may lead to cheaper batteries which help expedite the use of HEVs and PHEVs thereby lowering the use of oil for transportation.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

A reviewer stated that the project has well-defined targets (may be too many but consistent with the large budget) in improving various cathode materials. Olivine and metal oxides are very interesting cathodes and they require an in-depth study. Another pointed out the PI worked on quite a few systems, but this reviewer was not sure that she can then focus on the different systems. To another, the program is too spread out between the different materials. It appears that the work done on mixed metal oxides is taken care of in other programs within DOE. Also the high voltage efforts are hindered until a good electrolyte has been demonstrated - appears to not be fruitful. However, the work on Mn-based olivines is an interesting area, and would be worth pursuing going forward. A reviewer thought that Co levels still seem to be a real killer from a cost performance for PHEV and maybe even for HEV applications. A reviewer highlighted the selection and study of low-cost benign cathode materials. Methods used include optimization of carbon coatings, reduction of Co content in mixed oxides by substitution, and investigation of the compatibility of electrolyte with ionic liquids for stability above 5V. The strategies focused on are good for obtaining the goals of the program. Lastly, Doeff's carbon coating process may lead to better performing cathode materials, which may be used by industry.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

General comments included that the progress has been very good with some original results. Also, only the work on Mn based olivines represents new matter. A reviewer stated that the aluminum substitution for cobalt could be a significant finding. Low cobalt has a very beneficial economic effect on materials. Maintaining the rate capability in low cobalt materials will be the key to the benefit.

A reviewer commented that the goals of the project are generally good, but the focus of future work and goals should be narrower. The work investigating Al substitution is valuable and should be expanded further. Any future activity involving cost or high voltage electrolytes or specific to high voltage cathodes should be accomplished in a program(s) separate from this one.

A reviewer noted the interesting and innovative approach to "wiring up" a cathode with carbon wires that could have very wide applicability. This reviewer questioned if the PI understands the reason for the Al/Co doping differences. For example, the measurements of electronic conductivity versus temperature to get at activation energies was useful from a fundamental level, but the PI should check this at a state of charge at ambient just to see if the electronic conductivity changes during charge and discharge (unless they have reasons for expecting this not to be a factor). They seem to have assigned the lower performance to diffusion really by default and this reviewer is not sure that they have done enough to rule out electronic conductivity effects.

A reviewer said the analysis shows a quite low storage capacity with no proposal for improvements. The work to find substitutes to Co must be increased in the cost reduction direction. The choice to stop work on ionic liquid cells is not justified: there are new ionic liquids with improved performances able to favor the use of high voltage cathodes.

Extensive comments were offered by one, who said that elaborate studies have been performed with the nano-manganese phosphates, Al substituted mixed oxide and the room temperature ionic liquids. A good understanding has been obtained regarding the limitations of each aspect studied. Several other groups have also used carbon coatings for the manganese phosphates, so it might be good to bring out how this work is different from that of the others. The aluminum substitution was explained well but the highlight was on the improved performance. However, at ratios above y=5%, the capacity and performance at higher rates drops. This was not explained well. There seems to be an optimum Al ratio which needs to be further pursued. The work with the room temperature ionic liquids was not comprehensive enough and did not address if the combination of Ti coating and the ionic liquids were a benefit. Program could benefit from some safety tests.

The correlation between composite conductivity and capacity retention is an important step towards standardizing and optimizing the cell performance. Room temperature ionic solvents for 5V are a good research effort and the direction we should be taking for future li-ion cell for high power. The other interesting research effort of this team has been substituting Cobalt and replacing with other cheap and safe elements like Al.

The reported rate capability of the $LiFePO_4$ synthesized is not state-of-the-art compared to what other groups have reported. Is the issue the electrodes, cells, or materials?

The Al-Ni-Mn-Co work offers a nice look at new compositions, and good use of collaborations and complementary techniques to understand fundamental mechanisms of dopants. Ionic liquids suffer from low transfer numbers so they have low power at times greater than one-second - what was the point of this work?

Doeff's work is similar to the work of others in the BATT program. It may be possible to reduce the overlap of effort by having quarterly meetings of the PIs in the program who are doing similar material development work.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The work is all relevant to developers, according to one reviewer. In particular, aspects of this work related to Al substitution are directly relevant and transferable. Another observed that there are already agreements underway. If high-capacity materials stable at higher voltages are obtained, this technology could be transferable for marketing. To another reviewer, the project team has optimized the materials which can make commercial inroads. They seem to have already some effort in that direction. It is good to see that the PI is making more of an effort to transfer technology and work with industry; this reviewer hopes that trend continues. Doeff's work on Al substitution for Co in mixed oxide cathodes may lead to cheaper material that performs as well or better than currently used, more expensive material.

Carbon coating seems to have advantages for many materials (anodes and cathodes) and so the studies have a general applicability, maybe even beyond the particular materials being coated in this work. The low-Co design work might be a good fit for power tool and consumer electronics, but this reviewer thought it is still too costly for the DOE programs.

A reviewer dissented with the others on this point, stating that at this point in time the work is very exploratory and is not likely to transfer in the near future.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

The funding was characterized as substantial by one reviewer and sufficient by another. A reviewer said that there does not seem to be anything very innovative for the funding obtained. The quantity of work is reasonable for the time period but does not reflect reasonably the funding provided.

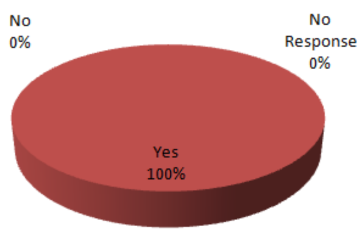
A reviewer recommended scaling back to Mn-based olivines and funnel the mixed metal oxide funding to other efforts. The licensing of olivines to a small Bay Area company appears to be a distracting activity. It was not clear to the reviewer that this technology is ready and that would reduce the chance of success as the new company would fail in their attempts to commercialize. The project team perhaps should have waited with commercialization until the technology was ready, which would have a higher impact in industry. The last suggestion was that any resources on high voltage electrolytes or specific to high voltage cathodes in the future should be redirected towards the other goals of this project.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

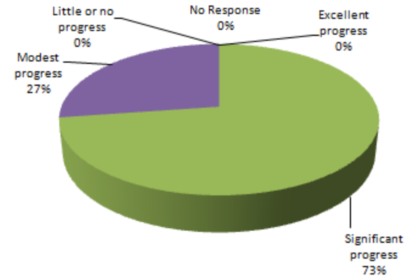
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Olivines and Substituted Layered Materials

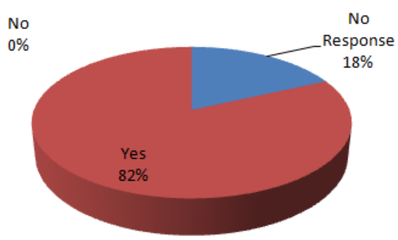
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



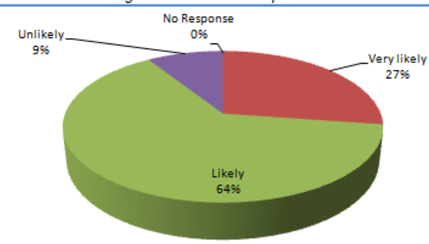
Question 3: Characterize the technical accomplishments and progress toward goals.



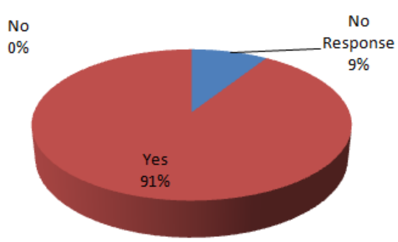
Question 2a: Are the goals of the project technically achievable?



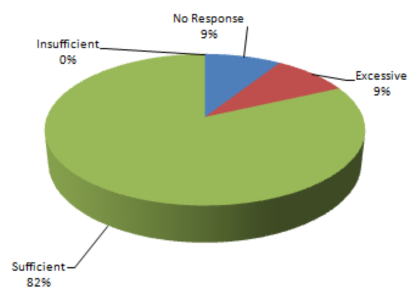
Question 4: How likely is the project team to move technologies into the marketplace?



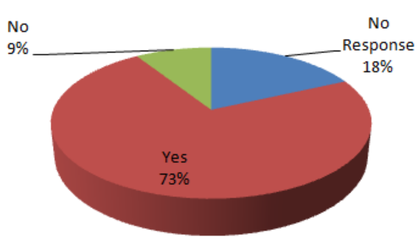
Question 2b: Have the technical barriers been identified and addressed?



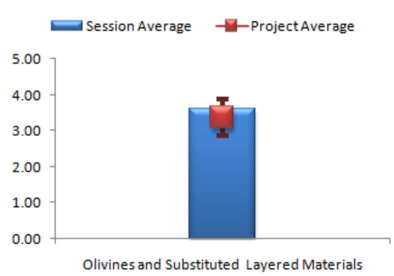
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Origin of Surface Instability of Lithium Positive Electrode Materials upon Cycling (Y. Shao-Horn, of Massachusetts Institute of Technology)

Reviewer Sample Size

This project had a total of 9 reviewers.

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

One person commented that the program is very relevant. Another person commented that the program focuses on fundamental studies to improve the life of the lithium battery: a key target of the DOE Program. Another person noted that the program is directed to understanding methods of stabilizing high voltage cycling which is essential in obtaining high capacity in many materials. One person pointed out that the program is aimed at next generation li-ion battery: hence it is a petroleum displacement technology.

One reviewer indicated that an improved surface of a material can enhance the performance characteristics. Another person agreed that the project supports DOE's objectives if the fundamental understanding can be applied in the future to materials of more interest for vehicles, e.g. Ni and Mn-based. The last person remarked that Shao-Horn's work may lead to longer cycle life of batteries for HEVs and PHEVs which would lead to less oil consumption.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

One reviewer commented that the PI's work on coated materials may lead to a better understanding of the role of the coatings on $LiFePO_4$, e.g., which may lead to longer-life cathodes in lithium ion cells. Another person commented that the methods chosen for the analysis of surfaces are very well deployed both in the investigator's laboratory as well as with collaborations. Another person noted that the study aims at analyzing fundamental aspects of the interface behavior of the coated cathodes. They also commented that the chemical and structural analyses drive the interpretation of the working mechanisms. One person thought that the use of surface coating with the aluminum phosphate is a good approach, adding that this is hypothesized to provide protection to the electrodes and provide higher cycle-life and lower impedance growth. Another reviewer mentioned that the correlation between the interfacial phenomenon and capacity degradation is important to understand stability and the mechanism of capacity loss and durability. The last person commented that the PI needs to work on techniques of making good electrodes. Cycling data is relatively poor for the materials and no baseline is established, from which the formulation can be verified. If the focus is on cycle life, then a baseline needs to be established that allows verification of the improvements, which will quantify the improvement. The reviewer suggested that a small adjustment here would go a long way. They point out that the PI is obviously skilled in the art of synthesis and characterization of these materials. The choice of operating at 4.7V as highest oxidation potential will affect most electrolytes, which yields effects of less interest to the reviewer. They felt that the potential is too high to be interesting for the battery developers. They concluded by commenting that the methodologies for the safety (abuse tolerance) measurements are on the other hand good.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

One person commented that the progress is very good with results and hypotheses answering to the goals planned. Another reviewer acknowledged that the characterization of the interface for coated cathodes is very important for understanding the lithium ion transport in these materials. They added that the XPS and STEM work of coated cathodes is important and timely. Another person also mentioned that the PI is using modern tools such as TEM to develop a better understanding of the structure of coatings on cathode particles as well as using XPS to determine the composition of these coatings. The reviewer indicated that the results may help battery developers produce better coatings. One person commented that this is a relatively new program and the methods are difficult to implement; however, significant results that have changed the understanding of coatings have already been obtained. Another reviewer mentioned the researcher presented good data with analytical tools to show that the coated electrodes provide better cycle life and lower impedance. The methodology that describes the capturing of HF by the aluminate is good. The use of cobaltate cathode is also a good choice since this is an established material with very high energy density. The reviewer concluded by asking whether any study been carried out to see if the coating prevents the loss of oxygen or if the oxygen lost combines with other side products to reduce the hazards brought about by the release of oxygen. Another reviewer commented that this task has done a very good job of combining complementary diagnostic techniques to answer a fundamental question of high interest to the battery community. They add that charge transfer impedance is not usually associated with frequencies below 0.1 Hz; the source of the impedance difference below 0.1 Hz would more likely be diffusion - complementary experiments like GITT, including looking at the relaxation during rest, would resolve that question, which is key to verifying the proposed mechanism. The reviewer concluded by suggesting that the PI use thin electrodes with a good formulation (conductive additive) to focus on the question of charge transfer vs. diffusion resistance. One person noted the good initial progress for this complex issue, however they have several reservations about coatings, including (1) If they are porous, they will not survive in the long run because of continuous attack by the electrolyte, (2) It is not going to change the thermal properties significantly, and (3) How about the resistance due to coatings? Another person noted that the presentation provided evidence for surface CoFxOy and AlFxOy on the cycled electrodes, but it was not clear how exactly these compounds affect the cycling characteristics. The last person commented that some cycling results are in question, which erodes the impact of the work.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The work focus is on basic chemistry, so it is unlikely that the fundamental results will be commercialized. Another reviewer had similar comments, stating that the project involves more fundamental characterization but results are important for basic research. One person remarked that there is no clear evidence of possible technology transfer even if the accomplishments may support the development of new coating materials and processes. One person applauded the project's good work and indicated that the results obtained so far look very good. They point out that the use of the coating, if proven to be safer with respect to oxygen release, may help in the technology transfer and marketing. The last person commented that while Co is more of interest for batteries for portable electronics, this work may be applicable to materials of more interest to vehicles, such as Mn and Ni. The researcher hoped that this task plans to address these other materials in the near future.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

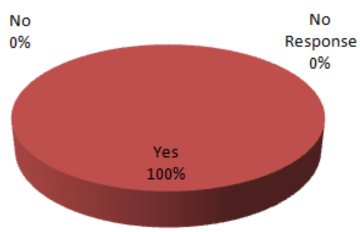
One reviewer simply observed that the PI and the team have the right technique and know how to keep in track. One person commented that the resources seem adequate even if there is a lack of information in the presentation. Another reviewer noted that the PI has done good work with less funding than other projects and suggested that more funding may accelerate the work being performed. Another felt that the resources appear sufficient for the amount of work done, but noted that the results are not that promising. The last person argued that the funding is excessive for this project based on the results obtained to date.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

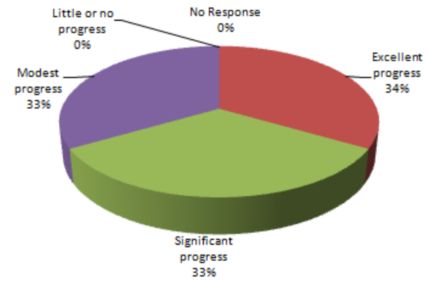
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Origin of Surface Instability of Lithium Positive Electrode Materials upon Cycling

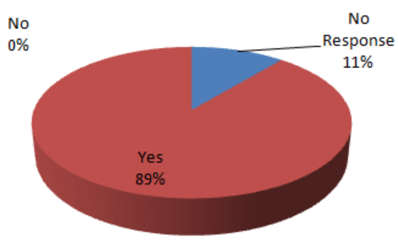
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



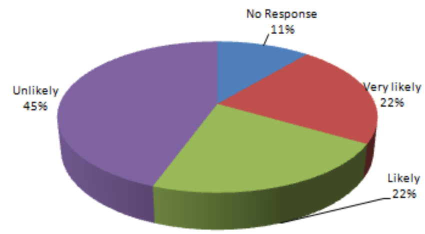
Question 3: Characterize the technical accomplishments and progress toward goals.



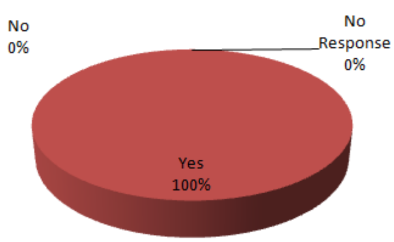
Question 2a: Are the goals of the project technically achievable?



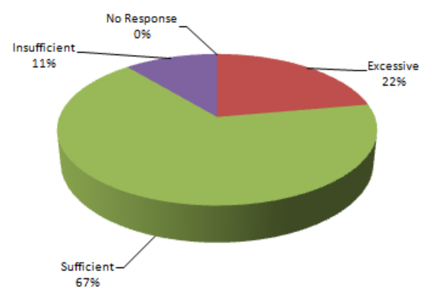
Question 4: How likely is the project team to move technologies into the marketplace?



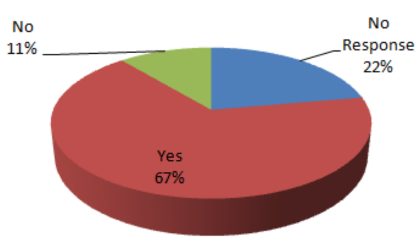
Question 2b: Have the technical barriers been identified and addressed?



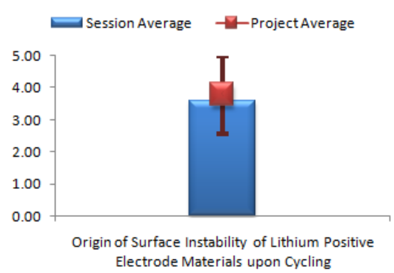
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Overview: Batteries for Advanced Transportation Technologies (BATT) Program (V. Srinivasan, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size

This project had a total of 9 reviewers.

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

One person felt that this project is absolutely necessary for the above long-term objective, while another added that it is important understanding and search for new materials. One person commented that the project involves basic research is addressing key objectives of DOE OVT program on batteries. Another reviewer indicated that a roadmap to reach the DOE goals was presented. Another person remarked that the BATT program will lead to a reduction in oil consumption because the work in this program will lead to batteries for HEVs and PHEVs. One person commented that we need a strong focus on materials research aimed for next generation energy storage materials, and that such exploratory research could potentially bring some revolutionary breakthrough as small evolutionary changes would not be sufficient to make electric vehicles a reality in terms of technical capability and cost. The last person commented that improved materials produced through means of surface modifications are promising for forming materials that can have long life. They added that approaching modeling and synthesis hand-in-hand is very useful for accomplishing this. Also, they mentioned that the electrode fabrication needs to support that type of development, so the program is well rounded to support the goal.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

One person pointed out that since these are long-term projects, questions 2a and 2c are not easy to answer. Another person indicated that the project's strategy is directed toward fundamental research. Another felt that the scientific and technological barriers are very challenging but the approach and the research strategy show appraisal of the risks and adequate commitments on key aspects. One commented noted that each area of study has several groups working on it to study the necessary modifications; the reviewer thought this strategy is a great approach. Another reviewer liked the idea of teaming up in the BATT program and thought this would make the effort more coherent so that Battery ATD folks can get the benefit, something like a pyramid model which is a good start. One person mentioned that the project employed a good approach and balance of the right people. They cautioned that low costs for PHEVs are essential, so looking at inherently costly systems is not going to help much. (Costing was not really mentioned much after the introduction.) One of the reviewers highlighted that BATT has issued an RFP in the area of "Synthesis and Characterization of Novel Electrolytes and Additives for Use in High-Energy Lithium-ion Batteries", which they thought was a good strategy to attract innovative ideas. The last reviewer commented that the materials synthesis combined with electrode fabrication and measurements along with modeling is a good approach for understanding the system, which leads to a deep understanding of limiting mechanisms in the various systems. It is a good idea to study what happens above 4.3V, as that area can be accessed frequently during fast charge pulse. Study of the mechanisms to limit imbalance in the cells, localized deposition of lithium, and other local degradation mechanism and their dependence on formulation and materials can identify system that lends themselves to be "safely" overcharged temporarily, which the allows higher charge currents and hence smaller batteries, which in turn leads to decreased cost and smaller systems.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

One reviewer remarked that Venkat and Professor Newman are doing a great job in managing this program, adding that Venkat is an excellent pick to lead this program. One person stated that the program is going on well and progress is made in the area of exploratory scientific research on batteries. Another person noted that the BATT program has produced information about materials of interest to the battery community. One commenter noted that the good coordination among various projects and principal investigators is quite impressive and very essential for the success of the BATT program. One person observed the collaboration between basic research and applied research is good. They added that using modeling techniques to compare and confirm the data is a good way to go. The reviewer concluded by mentioned that the PI presented a very good map of work allocations. One person stated that the presentation provided an overview of the BATT program and the rationale behind the choices, but the technical accomplishments will be better evaluated during single project presentations. They noted that the key activity line and good ideas have been not illustrated. They concluded by observing that the proposed changes from the previous Review are not evident in the program description. The last person thought that it was hard to say from an overview, so they really need to wait for individual reports to make a determination.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

One person commented that the BATT program may have many results able to be transferred. Another person noted that the improved systems will help with cost and performance optimization. The last person commented that this program is focused on basic work which will ultimately reach the marketplace.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

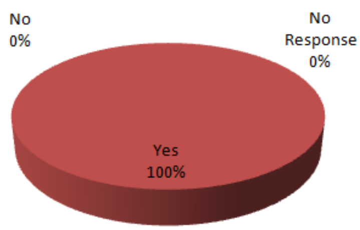
One person stated that the question is not applicable for the time of question, but the presentation was excellent and was very well delivered. Another person observed that no indication is given in relation to the resources that seem adequate in terms of high expertise. One person commented that the funding is sufficient for this program, and that the program would benefit from co-funding from industry to form industry/academic teams to address urgent needs of industrial researchers. One reviewer suggested that BATT activities should be expanded in terms of resources so that more number of university PI's get funded to carry out exploratory research in the area of energy storage. Several European and Asian nations are spending a lot more in this area. The last person however felt that research activity on lithium metal systems should be significantly, or totally, re-directed towards li-ion systems. They concluded by also noting that some significant level of resources devoted to ATD program should be re-directed to BATT program.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

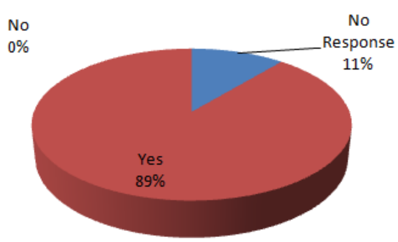
There were no expository comments for this question: refer to the graphic on the next page for this project’s summary score.

Project: Overview: Batteries for Advanced Transportation Technologies (BATT) Program

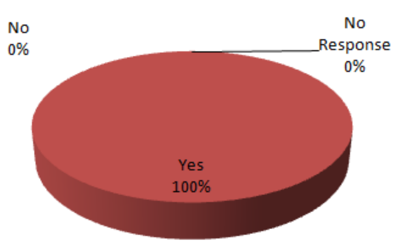
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



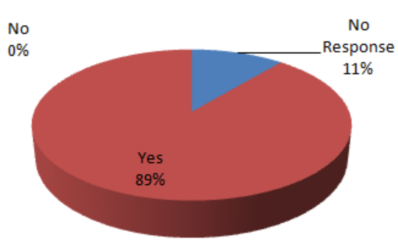
Question 2a: Are the goals of the project technically achievable?



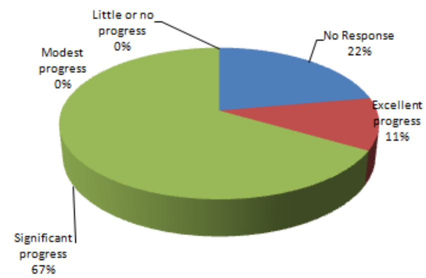
Question 2b: Have the technical barriers been identified and addressed?



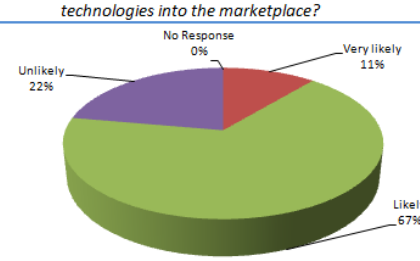
Question 2c: Is the proposed work likely to overcome technical barriers?



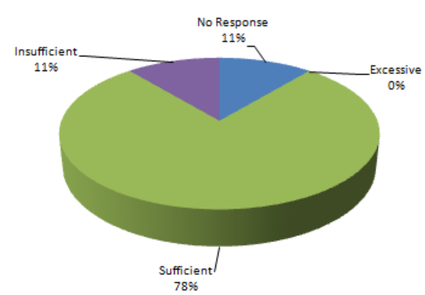
Question 3: Characterize the technical accomplishments and progress toward goals.



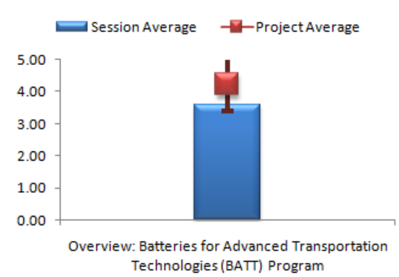
Question 4: How likely is the project team to move technologies into the marketplace?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 6: Overall Rating



Performance Enhancement of Cathodes with Conductive Polymers (J. Goodenough, of University of Texas at Austin)

Reviewer Sample Size

This project had a total of 11 reviewers.

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

Reviewers were in favor of this project's contribution to DOE objectives, stating that the new material focus is very supportive of DOE goals, that low-cost cathodes are important, and that cathode development remains extremely relevant to DOE objectives. Further, the goals and objectives of cost, safety and environmental compatibility are in sync with the program goals. Also, the work is related to synthesis of stable cathodes for Li-Ion batteries. To one reviewer, the purpose of this work was to improve capacity and rate capability of composite $LiFePO_4$/C/PTFE cathodes by replacing inactive C + PTFE with an electrochemically active, conductive polymer, such as polypyrrole (PPy), polyaniline (PANI), and thus, supports the DOE objective. A reviewer said that the polymer work addresses improving the most promising cathode material for HEVs, which is important for braking regneration and possibly for fast charge during long trips. Lastly, a reviewer said that Goodenough will produce material to build better batteries to reduce oil consumption. He has demonstrated his remarkable skills many times.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

Reviewer comments included that this was a novel idea in advancing the cathode technology, that the strategy is well developed and proven to be successful in the past, and that the project proposes innovative materials with a clear vision of the challenging barriers and with interesting scientific and technical approach to overcome them. A reviewer said that selection of a conductive polymer workable in the required voltage range and that has less resistance between it and the current collector and one that has a convenient synthetic route has been the project plan. A reviewer added that the authors have demonstrated stable $LiFePO_4$ stabilized by polymers and solved a few technical and scientific challenges. A reviewer noted that Goodenough's work on conductive polymers will provide a basis for cell manufactures to consider in their development work. A reviewer dissented moderately with the rest of the group, stating that the study shows that the method could be used and improvements are available, but it was unclear if the best polymer has been chosen: other work can follow, so there is a bit of success there.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

Positive comments about the technical accomplishments included that the high rate capability of a novel polymer doped cathode has been demonstrated with experimental evidence, and that the authors have synthesized new cathodes with higher stability and rate capability using a polymeric method. They also are developing novel anode materials which can put more lithium per redox center. The work is an extremely important step towards development of novel anodes and should be encouraged. Furthermore, the authors developed synthetic routes for PPy and PANI electrodeposition of PPy on C-$LiFePO_4$ shown to be superior to chemical deposition of PPy and PANI. They showed that the capacity and rate capability of the chemically synthesized $LiFePO_4$/PPy composite cathode is comparable with the electrodeposited film and higher than the parent $LiFePO_4$. The composite $LiFePO_4$ material presents a useful development for theoretical consideration.

Other positive comments included that there was a good description of work performed and data shows good correlation between synthetic and deposition techniques to the cycle life and rate capability of the materials. Also, the PI has laid out a clear, logical, and ambitious strategy for trying to invent new materials. Goodenough's work has produced useful information about conducting polymers, stated another. To a commenter, the past year's work has successfully obtained cycling of carbon coated lithium iron phosphate in the presence of conductive polymers at high rates. The search for new materials in next year's program is higher risk, but the potential payout is greater. Finally, the polymer work showed some progress but only with low voltage cathodes - fortunately it is with a very important low voltage cathode.

A reviewer was concerned about the stability of such materials in automotive environment for 15 years. This reviewer suggested that stability should be a key task in these studies. A further suggestion was that behavior at low temperature should be verified in cells. The planned work on novel cathodes and new anode materials should be accelerated and reinforced. Finally, a reviewer suggested that the cathode work was not so new but the anode work should continue.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Comments received here include that this is a unique idea: any positive result can easily be transferred to the marketplace. Goodenough's work has produced products and will probably do so again. Two reviewers noted that technology transfer is already in place with patent licensee (Phostech) who is marketing the technology. The achievements of polymer work were notable and useful to a reviewer, but the longer term approach is obviously a high risk fishing expedition, but with a very experienced and successful angler. The likelihood of success still seems low, but "we won't catch anything unless we start fishing somewhere."

A reviewer said that the conductive polymer approach does not easily yield to manufacturing methods, but the new material search has a better chance of moving to the marketplace. Similarly, the method of producing the composite $LiFePO_4$ material may not be practical to another reviewer's belief from an economic viewpoint.

Finally, the goal is to improve the rate capability and capacity of cathodes. New synthetic routes were developed which has higher rate capability. New results would be disseminated by external publications.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

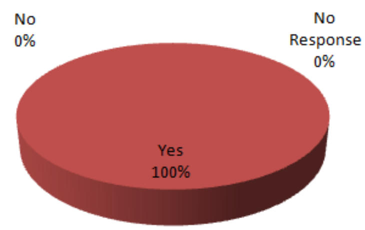
Commenters felt the project was sufficiently funded or in need of some additional funds. Resources should be increased to take into account the extension to new materials development, stated one reviewer. To another, this was good quality work that could benefit from more funding. A third reviewer said the future plan looks interesting and is worth pursuing. This reviewer thought that if someone can come up with new materials it would be Goodenough, so DOE is cautioned to make sure he has the appropriate funding for this. A reviewer said that this was a well-chosen recipient of seed money for new materials. This reviewer recommended that DOE keep this at relatively modest funding level, but be patient and not expect too much for a year or two. The final reviewer could not comment on resources.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

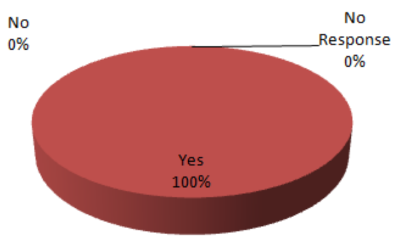
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Performance Enhancement of Cathodes with Conductive Polymers

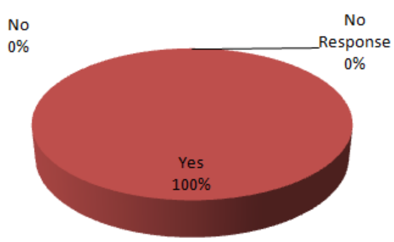
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



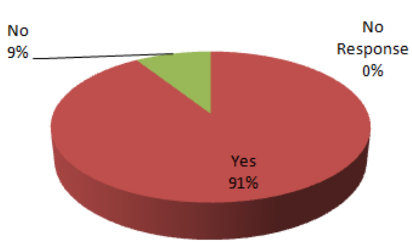
Question 2a: Are the goals of the project technically achievable?



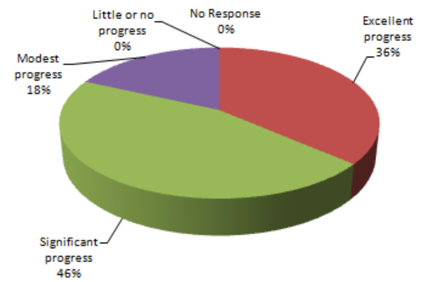
Question 2b: Have the technical barriers been identified and addressed?



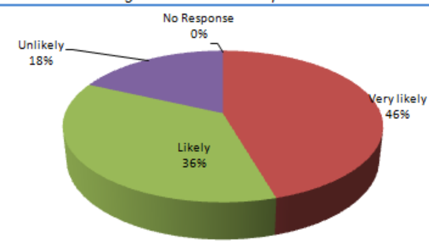
Question 2c: Is the proposed work likely to overcome technical barriers?



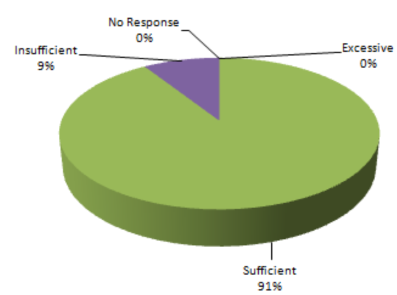
Question 3: Characterize the technical accomplishments and progress toward goals.



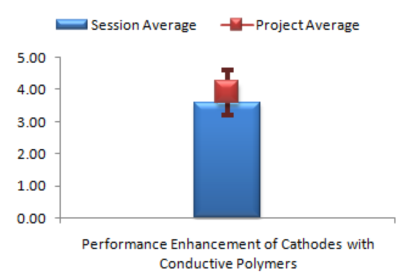
Question 4: How likely is the project team to move technologies into the marketplace?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 6: Overall Rating



Phase Behavior and Solid State Chemistry in Olivines (T. Richardson, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size

This project had a total of 10 reviewers.

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

Cathodes dictate the capacity of cells, stated one reviewer. Another observed that cathode development is very relevant to DOE EV and PHEV program. Richardson's work will lead to better cathode material for batteries for HEVs and PHEVs, which will reduce use of oil for cars. A reviewer felt the goals of the PHEV and EV program have been taken into consideration. Similarly, another stated that the work is very well suited towards PHEV and HEV goals. A reviewer noted that the high density (tap density) is important for PHEVs, so the PI has selected a good area that (if successful) will help commercialization of PHEVs. The final reviewer said that the team is trying to get a practical $LiMnO_2$ chemistry.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

The goal and technical details has been extremely well thought out, according to one reviewer. Another said that the basic fundamental research has been clearly structured to screen and select novel olivine compositions. The strategy can support the development of higher performance electrodes for EVs and PHEVs. A reviewer stated that synthesis of novel materials has been pursued with several material characterization techniques to understand the nature and structure of the materials and crystals synthesized. Richardson's work shows that it may be possible to produce higher potential material by using Mg instead of Fe in olivine material.

The choice to focus on high tap density is good, said another reviewer. This will help create good electrodes and true effects on cyclability can be studied instead of just studying chemical and electrochemical effects, which is the case in most programs. Here also good mechanical stability will be achieved, which is critical to success.

The project provides valuable fundamental materials information, in another's view. However, it does not yet appear to address or explore rate capability issues of the studied materials, although this is intended for future work. Rate capability and/or conductivity observations would be critical for consideration of deployment.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

A reviewer highlighted the results on impact of cathode particle size and shape. Another spoke of the team having identified $MnPO_4$ decrepitation as a contributing factor in the poor performance of $LiMnPO_4$ cathodes. The severe limitations of the manganese phosphates and the decrepitation are well understood. But the future work and how this could be overcome was not well explained. There was no optimistic tone at the conclusion of the talk. It may not be advisable to pursue the manganese phosphate work in the future based on the lack of direction or options to improve the work. The option for other materials to be studied is a good future goal. Another said it was very good work into fundamental mechanisms of $LiFePO_4$; the team should keep working to wrap this up into a complete story of the mechanism of phase-boundary movement. Does the decrepitation actually affect cycle life with $LiMnPO_4$? It is not clear how the observations from chemical delithiation correspond to behavior in a cell. Why was the PI not given time to present his anode work?

Another felt that the team members are addressing a key problem where they could probe lithium ion diffusion in planes of $LiFePO_4$. To this effect they have synthesized $LiFePO_4$ plates having the right crystallographic orientation and shapes. Subsequently using micro-Raman they have shown Li ion distribution in the right crystallographic plane (AC plane). The experiments validated their model in terms of li-ion diffusion in olivines. The PI has also made progress in addressing the mobility of li-ion in various crystalline directions. The reviewer concluded by stating that this work must be supported.

The directional aspects of the olivines are important and well worth pursuing, according to a reviewer. Synthetic methods to stimulate the optimized morphology for this will lead to improved performance, and possibly improved energy density, which is next year's target.

The project appears to have achieved some useful and valuable accomplishments. However, one of the accomplishments is identified as addressing safety, and there is no apparent evidence to this reviewer's view describing this activity or the specific development.

Finally, Richardson's work is very useful because he is showing through careful experimentation with modern tools such as TEM why olivine materials function as they do. He has presented work that indicates the Mn olivines may be very difficult to produce; however, Mg stabilized material may be possible.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Richardson's work will be useful to battery component developers and cell producers. The PI seems to see a low success likelihood, but he has shown good science in his approach. No optimism was shown, according to another reviewer, in improving the stability of the materials for future technology transfer or marketing. Another stated that while the rating here was "unlikely" the reviewer would still rate their work very best interims of understanding quantitatively the phase boundary behavior of $LiFePO_4$. Their particle engineering effort is important for the success of $LiFePO_4$. Their current research on studying the degradation mechanism of $LiMnPO_4$ is also very relevant for validating these kinds of high-energy cathodes for PHEV and next generation cells.

Too early to tell, but certainly the synthetic methods and morphology created will be interesting for companies synthesizing olivines. The correlation to performance is important in conjunction with this and will help companies optimize their processes.

The achieved results justify the actions of the project team to publish some results and patent others, stated a reviewer. The PI needs to make more of an effort to reach out to industry and support the U.S. battery industry.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

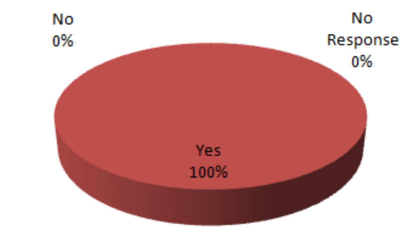
Adequate to one reviewer, to another funding for this work is insufficient based on the results obtained. Richardson's group should be funded at a higher level. In contrast, another reviewer said the work performed is inadequate for the funding obtained. A positive attitude of how to improve the material properties may have helped.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

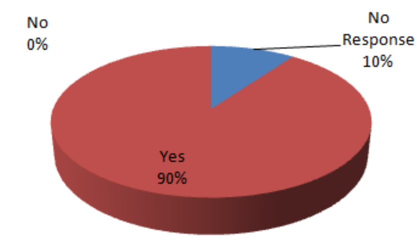
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Phase Behavior and Solid State Chemistry in Olivines

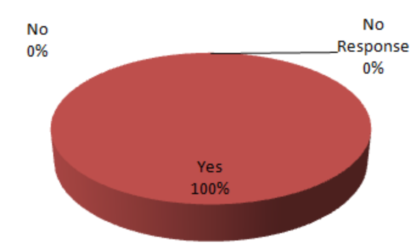
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



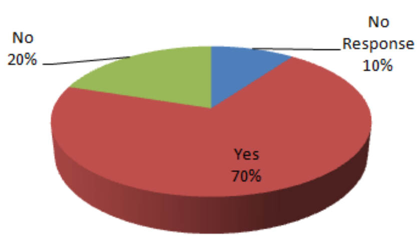
Question 2a: Are the goals of the project technically achievable?



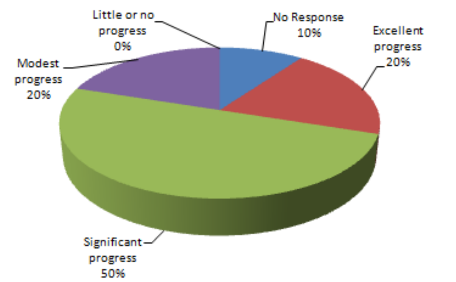
Question 2b: Have the technical barriers been identified and addressed?



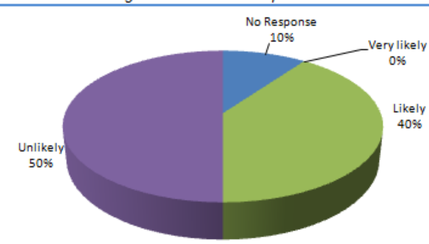
Question 2c: Is the proposed work likely to overcome technical barriers?



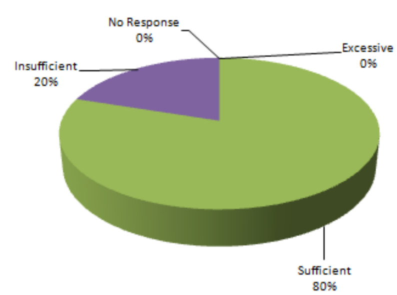
Question 3: Characterize the technical accomplishments and progress toward goals.



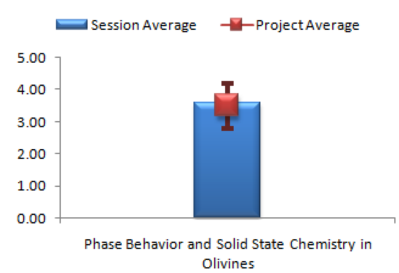
Question 4: How likely is the project team to move technologies into the marketplace?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 6: Overall Rating



Stabilization of Layered Metal Oxides (M. Thackeray, of Argonne National Laboratory)

Reviewer Sample Size

This project had a total of 11 reviewers.

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

One person remarked that absolutely, only through this kind of work can we make breakthroughs to reach the DOE goals. Another person agreed, stating that the project targets the key objectives of the DOE program: energy content, cost and stability. One person simply noted that this is a high level new material program. One reviewer mentioned that the program supports the development of materials for next generation energy/power batteries. Another person acknowledged that the project's goal is to obtain high energy materials at low-cost providing high cycle life and good abuse tolerance is a stated goal for the PHEV project and this program does that by looking at the new high power manganese based cathodes. One person noted that low-cost and high-capacity needed for PHEV. Another person commented that this project will lead to electrodes that will last longer which will enable suitable batteries for HEVs and PHEVs thereby reducing oil use. Another person had similar comments, stating that the material researched by the PI is very promising for a low-cost, high-performance positive electrode material for HEV and PHEV systems. The last person suggested that this work is valuable and should be continued and expanded.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

One person felt that the work is excellent, noting that the researchers are already working very extensively with external partners. Another person indicated that the researchers are addressing the right materials problems that need to be overcome like stability of materials, their surfaces and capacity. One person thought that a good understanding is being established on the limitations, adding that the use of fluorination is a good way to go. One person commented that the strategy highlights the need for high-capacity cathode materials and possible means to obtain them, which is essential for PHEV program which must have higher energy cathode materials. Another person indicated that the goals are well defined with reasonable and convincing steps to achieve them. They added that the project must be significantly supported and possibly passed to more industrial phases: ATD and battery development for verifying cost and scale up. One person pointed out that the strategy or purpose of this work is to design and fabricate intermetallic anodes to replace graphite which this reviewer thought was a good approach to explore new and innovative ideas. A reviewer thought that the idea about stabilizing structural units, instead of working on dopants, is a nice strategy that obviously works. They added that the fluroniation of surfaces is also a sound approach (that has been proven in other systems) for improving performance further. They concluded by acknowledging that the researchers have developed a good deployment strategy. One person commented that the PI has demonstrated that his process leads to stabilization of layer oxides and that thus process may be used by battery developers to improve the life time of their cells. One reviewer commented that the project should characterize conductivity of the basic studied material(s), and should provide some observations of power capability in a typical electrode formulation configuration. The reviewer added that modeling of dissolution should be progressed as possible on from the initial studies of $LiCoO_2$ as a validation of the method towards more relevant materials which would hopefully include spinel/layered compound blends. The last reviewer would like the program to understand the excess capacity more; the uncertainty makes them a bit nervous. They asked whether the extra capacity is available at low-rate even after long open circuit stand in the charged state, or does this "bleed off" during standing by side reaction with the electrolyte.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

One person simply stated that the project involves outstanding industry leading work. Another person commented that the results show a very promising high-performance material that is also embraced by community. Another person acknowledged the project involves very good scientific work, both in trying to develop new understanding and in being honest about what is not yet fully understood. Another person noted that the PI's results seem promising and may lead to a new material for cathodes in lithium ion cells. One reviewer noted that new results towards development of intermetallic anodes were shown; some of these materials could have good potential. Another person noted that numerous Sn substitute materials have been studied, but none has replaced graphite and made to any useable batteries as yet. Another reviewer mentioned that the investigators have added fluoride etching on the material surface to improve the previously developed materials, with improved cycle-life as a result. One person highlighted that the results show an excellent progress with breakthrough achievements, but that the specific energy requires to be better presented. They concluded by suggesting that scale up problems and cost implications should be analyzed. One person highlighted that the work has made excellent progress in advancing the specific energy of the cathode material. They noted that it is a very novel idea for stabilizing a structure, but asked whether this material will survive overcharge or thermal stability. The reviewer was not sure there are electrolytes which can survive such high voltages over the greater than ten-year timeframe we are looking for. They concluded by asking how to alleviate the first cycle in efficiency. The last reviewer commented that methods to improve the stabilization of the cathodes need to be pursued as it is well understood that there is an irreversible first cycle loss. The reviewer felt that fluorination is a good way to go, but it still does not seem to remove the first cycle loss, although it improves the cyclability of the cells after that first loss. Another issue they noticed is going to high voltages, such as 4.6V to 4.8 V. These voltages are never practically recommended for li-ion batteries; when one goes to higher charge voltages, one can obviously get higher capacities, but this will compromise the safety. The reviewer recommended some microcalorimeter work on the materials in small coin cells to understand the heat generation at these high voltages. The last person cautioned that they remain a little concerned about high irreversible capacity loss as this is far more than can be compensated for by the irreversible loss at most carbon anodes. They asked if these materials can be "formed" externally and then placed in a cell. If this is feasible, a program to do this could be useful, patentable, profitable, and a good fit for the synthetic skills of the PI and ANL. They note that industry might be a better developer of high-voltage electrolytes than ANL, suggesting that their partnering royalty agreements could potentially cover a cooperative agreement for technology exchange.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

One person simply noted that the next-generation materials are of great interest. Another mentioned that the material made by the PI may be useful for commercial cells. One person commented that if the initial loss is overcome and if the capacities can be improved with the lower end of charge voltages (4.0V to 4.2V), it is good technology for transfer and marketing. Another person simply stated that this is already underway, which says it all. Another person indicated that patents are already licensed. Another reviewer noted that the licensees are already in place and results can be only improved. Another person also acknowledged that this is already happening (they are receiving royalty income), so the team seems to have winner. One reviewer highlighted that this task has done an excellent job of publishing good scientific papers as well as working to commercializing the materials. Another reviewer commented that the project is developing materials which are of significant interest to the marketplace, and the modeling of dissolution, if applied to relevant materials, would be of great interest and value to activities already underway in the marketplace. One person cautioned that, with the recent activities by 3M, there is risk that the patent portfolio is hindering commercialization if a clear path is not available to companies; this may have to be addressed and studied. The final reviewer cautioned that it is likely but more chemistry has to be studied like interaction with electrolytes, cathode pair. They highlighted that this is non-trivial as each set of these redox pairs has to be studied in detail.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

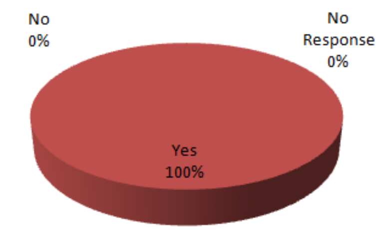
Reactions to this question were mixed. One person commented that they could not really comment on this question, but guessed the funding is sufficient to achieve their goals. They concluded by stating that the plan seems reasonable. One person thought that funding for this project is sufficient. Another person indicated that the resources should be increased, if anything, to further this work. Another person commented that actually, the project should be given whatever the PI's think they need. The reviewer could not tell if they have enough or not. They concluded by pointing out that the royalty path they are following may effectively move this forward to implementation without DOE support, so maybe what they have is actually sufficient. Another person commented that some more resources would be dedicated to abuse tolerance analysis and scale up work. One person pointed out that the project is approaching commercialization, but still some optimization is needed and for that funding should remain for at least another couple of years. They congratulated the great work in general and money well spent by DOE. The last person, however, felt that more work can be done for the funding received; a lot of this work is also being carried out as part of the applied research program. The reviewer acknowledged that some leverage exists, which either should help do more work or reduce the cost of the current work.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

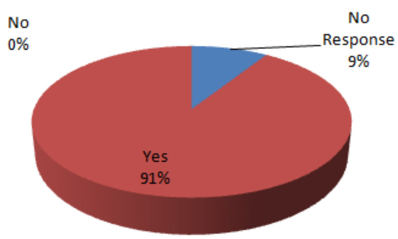
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Stabilization of Layered Metal Oxides

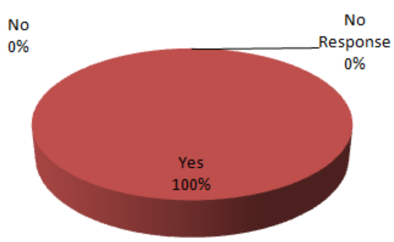
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



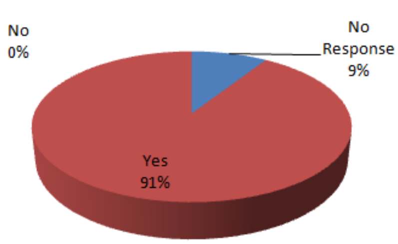
Question 2a: Are the goals of the project technically achievable?



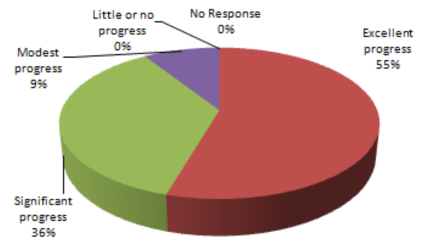
Question 2b: Have the technical barriers been identified and addressed?



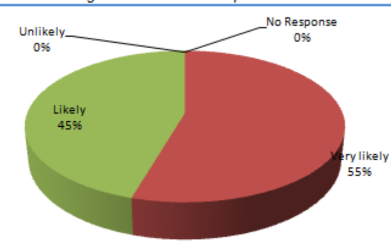
Question 2c: Is the proposed work likely to overcome technical barriers?



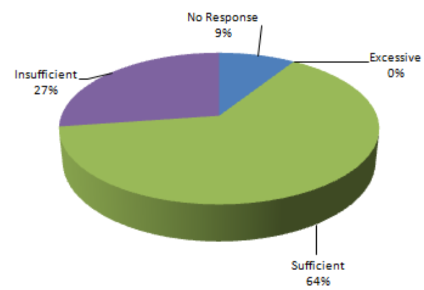
Question 3: Characterize the technical accomplishments and progress toward goals.



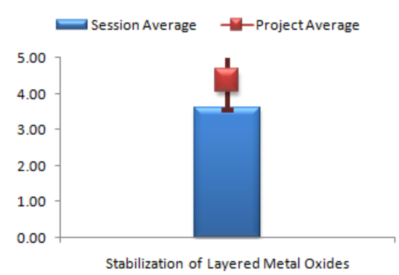
Question 4: How likely is the project team to move technologies into the marketplace?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 6: Overall Rating



Stabilized Spinels and Nano Olivines (A. Manthiram, of University of Texas at Austin)

Reviewer Sample Size
This project had a total of 11 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
Responses were generally positive in this section. One reviewer stated that improved spinel materials are very promising low-cost materials for HEV and PHEV positive electrodes, while another added that high-power stabilized spinels and new forms of olivine are important for HEV goals. One other reviewer indicated that the work is very relevant, and a high performance cathode is the heart of a next-generation cell. One respondent noted that the group is working with low-cost materials, while another person commented that cathode cost and improved performances are key objectives relevant to DOE program. Similarly, one reviewer wrote that Manthiram's work may lead to higher energy density cathodes and consequently more rapid development of batteries for HEVs and PHEVs, which would lead to less oil consumption. Another person remarked that the goals of cost, cycle life, safety, rate capability, and energy density are in sync with the goals of the PHEV program. One final reviewer simply noted the work is aimed at synthesis and optimization of cathodes for Li-ion batteries.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first reviewer commented that there are a lot of creative ideas to resolve the problems, while another respondent added that the approach is well justified, starting from the comprehension of the way various cathodes work and then proposing modifications to overcome barriers. One reviewer indicated that the use of stabilized high power spinels is a good approach, adding that the oxygen substitution limitations are well understood and the use of fluorine substitution is a good approach. Another respondent noted the team has a goal of pairing their spinel cathodes with novel anodes to achieve high power and capacity. They have also demonstrated mixed cathodes, which could be the way to go. Excellent progress has been made towards synthesis of nano-olivines. One other reviewer commented on the solids approach with doping and study, adding that there are good cyclability studies that differentiate. This reviewer adds that this is well done, and it appears that the investigators have control of how to make good cells for this purpose, which is unusual.

One reviewer felt that Manthiram's materials do not appear to have the required rate capability for batteries for HEVs and PHEVs.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One respondent indicated the group has shown a promising synthesis approach and performance, while another reviewer stated they have done a good job at inventing new materials. One reviewer commented that the demonstration of a significant reduction in first-cycle loss in spinel-type cathodes is of value, and the demonstration of alternative first-cycle charging methods which improve cycle life are of value as well, and these aspects of this work should be expanded in future work. The polymer coating of $LiFePO_4$ appears promising and this work should be expanded. Another reviewer noted that this is excellent work carried out on the quick method of synthesis of the nano-iron phosphates. The mixed cathodes substituted oxides are also a good study, and the factors affecting the performance have also been well studied. Some work on safety can be pursued in cells made with the new cathode material- carbon electrode. The project may benefit from providing materials to labs such as Sandia to make larger cells and study the safety. One other person remarked that the proton insertion technique

for determining the lithium content in layered oxides is novel. As per the cyclability of their cathodes, their study of Mn dissolution is crucial for long cycle life and capacity loss. The authors have lot of valuable and pertinent data to conclude their results and it looks like their synthesis strategies are working. The reviewer suggested that the basic materials synthesis efforts must continue, especially synthesis and optimization of nano-olivines with directed shape and morphology.

One response stated that the results are very good with significant progress, even if the cathode capacity remains low (about 130 mAh/g) at high voltage. The analysis at 60°C seems questionable with spinel: more operating temperature should be analyzed including low temperature tests. The choice of materials in the new cathodes must follow some well defined criteria (cost, availability), as for Co, for example. Another person wrote that there are quite a few interesting and novel results. This work shows good promise for further fundamentally new results. This reviewer advised against Co-based olivine, adding that he or she thought we are trying to move away from this metal.

One reviewer noted that $LiFePO_4$ nanorods coated with a mixed ionically and electronically conducting polymer exhibit excellent rate capability in the lab but in the real world in scaled up situations the implication is not clear. Good rate capabilities are already shown by some manufacturers of the cells with $LiFePO_4$ cathodes. So what is the advantage of this study? Lots of good work, but how these findings can be used was not clear. Another reviewer commented that the stabilized spinel work for 4V materials seems to be at a point of diminishing returns – needs new ideas if work is to continue. 5V spinel work is very high risk in view of electrolyte instability over long use situations. Olivine nanorods look like a good possibility for implementation if economically viable methods of preparation can be devised. One other respondent indicated that Manthiram's work has produced material that may be useful because of the higher potential of his cathode material. Unfortunately, this reviewer noted that the rate capability of his material is low.

One final reviewer indicated that he or she thought that the Koreans had already shown that F-doping, oxide coating, and mixing with other cathodes were all effective ways to stabilize spinel many years ago. This reviewer is not sure how original this work is. Thus, this work seems to follow rather than lead. That said, this reviewer adds that the PI appears to be able to provide an important understanding to some of these effects. The level of control demonstrated in the synthesis work on $LiFePO_4$ is interesting.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first response indicated that the group's low-cost synthesis of olivine is of direct interest to developers. One reviewer commented that technology transfer to a start-up has been already realized. One respondent stated that the group is doing excellent work and detailed studies on the materials. This has a high likelihood for technology transfer and marketing. Another person stated that the high quality of this work will led to near-term commercialization. One reviewer wrote that success will be useful for both battery companies and materials manufacturers. Technology can easily be transferred, due to the richness of results from the PI and the clear information on synthetic conditions, crystal structure, and its correlation to performance.

One response stated that, in particular, the polymer coating process for $LiFePO_4$ appears to be directly transferable to the marketplace. Another person added this task has done a good job of inventing new materials, adding that the PI needs to partner with others (perhaps his new startup) to start exploring the practical issues involved with making and operating batteries from these materials, e.g., cost constraints of coating phosphates with expensive mixed conducting polymers; achievable electrode densities with nanorod materials, and overcharge protection in the context of 5V cathode materials.

Other reviewer were less positive, with one commented that many of the ideas on the spinel have been developed by others in Asia. So, while implementation of this is likely, this reviewer is not sure that this work is the driver for that. Olivine work will have to compete with other methods – not sure it is any better than other materials. He or she did not see any comparison with other nano-materials. One final reviewer stated that Manthiram's material is unlikely to meet the needs of industry because of its low rate capability.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Responses to this prompt were generally positive. One reviewer stated that the resources seem adequate, while another wrote that the quantity of work performed is of high volume compared to the funding obtained. Several different aspects have been pursued with excellent results obtained, and the funding should be increased based on the quantity and quality of the work. The additional funding provided can be used for synthesizing more materials and providing them for larger cell manufacturing and testing. One other person commented that next year's focus for spinels is good. One reviewer indicated that he or she could not comment on this, but added that the PI and team are extremely capable and technically qualified in their area. One other respondent suggested that continued work to further examine rapid processing methods for $LiFePO_4$ may warrant additional resources, or more ideally a separate project.

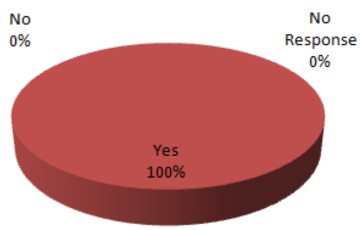
In contrast, one final reviewer felt that the funding for this project is excessive relative to the results obtained.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

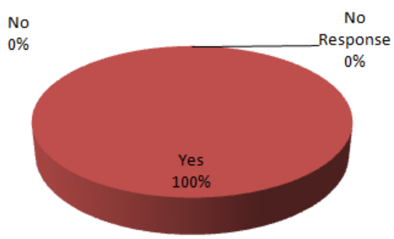
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Stabilized Spinels and Nano Olivines

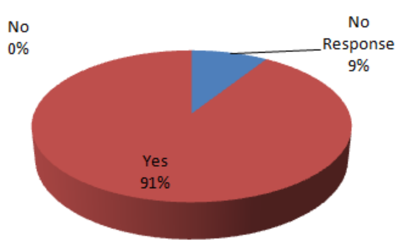
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



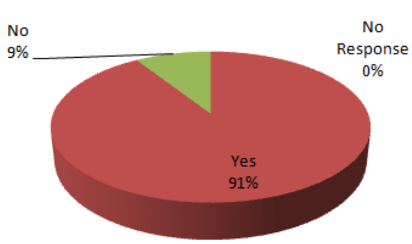
Question 2a: Are the goals of the project technically achievable?



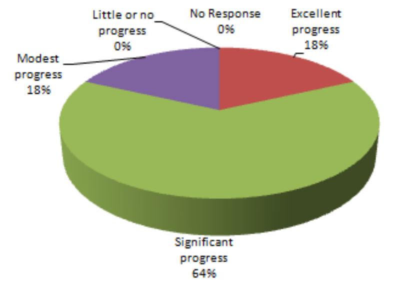
Question 2b: Have the technical barriers been identified and addressed?



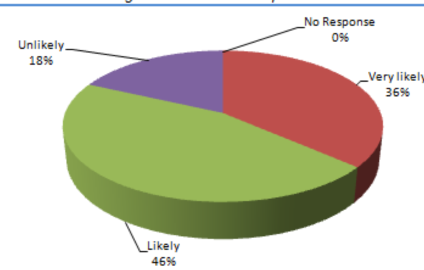
Question 2c: Is the proposed work likely to overcome technical barriers?



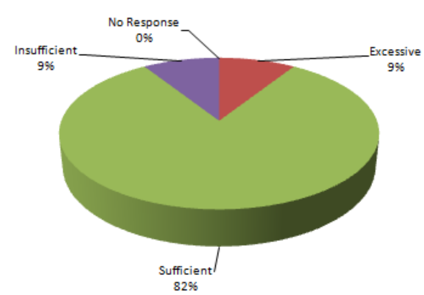
Question 3: Characterize the technical accomplishments and progress toward goals.



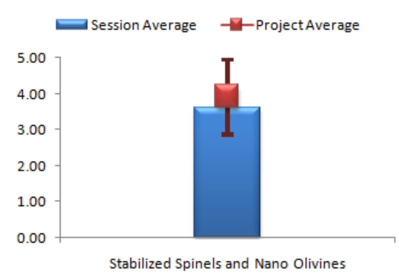
Question 4: How likely is the project team to move technologies into the marketplace?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 6: Overall Rating



Summary and Future Plans (V. Srinivasan, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size
This project had a total of 7 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer commented that BATT is very relevant to meet DOE goals, while another added that the BATT program is ideal for developing the next generation of energy storage technology. One reviewer stated, yes, adding that the flowchart shows that all the good collaboration will help meet the goals of the program. Another reviewer stated that the group working on the key things and seems to be the only way to get at long-range PHEV and EV. One final reviewer wrote that the BATT program has led to useful results that may lead to better batteries for HEVs and PHEVs, which will lead to less oil consumption.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first reviewer commented that BATT has challenging targets with very good strategy based on cutting-edge fundamental research. Another respondent added that the BATT program addresses long-term research in most aspects of the Li-ion battery technology. This reviewer feels efforts should be extended beyond lithium-based systems. One other person stated there is good strategy with all the collaborations and interactions to meet the program goals. Another response noted the excellent balance and wide range of abilities in the program. The PI is generally of a very high quality and almost all of the staff is comprised of Tier 1 people. The management seems focused and holistic. One person noted the BATT program has helped develop a complete understanding of the barriers to better batteries and has funded projects that have contributed to overcoming these barriers.

One final reviewer suggested that some optimization with ATD and Battery Development programs should be looked at on modeling, final battery evaluation, and material development and testing. Some joint economical evaluations should be started to better estimate the potential cost reduction in material and component development.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer commented that the results have surely progressed in a timely fashion with some outstanding results on new materials, new electrodes, new electrolytes, and, in general, in a better comprehension of fundamental mechanisms. Some efforts should be dedicated to the extrapolation of basic results to final batteries. Another respondent noted that BATT has issued a RFP in the area of “Synthesis and Characterization of Novel Electrolytes and Additives for Use in High-energy Lithium-ion Batteries” and is always looking for new ideas that advance the mission of DOE/BATT. There is good coordination and good work.

One response indicated that it was nice to have an overview at the end for ranking purposes and also at the beginning for background/information purposes. Another stated that if the different groups can also keep up with some of the work performed by battery manufacturers and other researchers, it may accelerate the process of reaching the goals.

One reviewer commented that if they continue the momentum like last year this would make a lot of progress. One final reviewer noted that the BATT program has made significant contributions to the development of better batteries. However, this reviewer adds that some of the projects that have been funded for several years have not borne fruit, such as the DesMarteau project. These projects should not continue to receive funding.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.
The first reviewer commented that the BATT program has produced useful results that have been used in the battery industry. One other reviewer added that there are a large number of examples of different types of transfers.

One person indicated there is good collaboration and understanding of team strengths, but added that the group needs more acceleration in tasks to meet goals and have technology transfer. One final reviewer felt that while in general the group is working on the right things, some of the blue sky stuff (Li anodes) is frankly unlikely to make it to market, but it is important to have those coming along as well as long as the funding levels do not get too high and the projects are watched closely to make sure they still make sense (this does not mean we should not have patience with them – progress in these areas will take a lot of time). This reviewer understands that things like this are needed to address the energy needs of the longer-range PHEVs. It is always important to consider material costs associated with major efforts, as expensive materials are unlikely to ever make it to market unless the cost is associated with the production methods. This reviewer is skeptical whenever he or she sees Co mentioned.

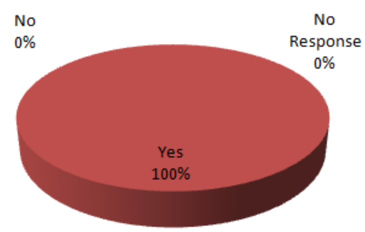
Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?
One reviewer commented that the resources must be adequate to support program changes, while another reviewer noted that the university programs seem to have much less than the National Labs, which is understandable. The resources available at universities should be better utilized by providing more funding, as a lot of basic research can be and has been performed by those groups. Another respondent encourages more support to the BATT program to include more university researchers. Similarly, one reviewer thinks the BATT program should be funded at a higher level if the poor projects are pruned.

Specifically, one respondent thinks that activity involving Li-metal should be eliminated or significantly reduced. One final reviewer noted that there are a lot of expensive people in the group, but the tasks are daunting enough to match the expense. Looking forward, this reviewer expects this work to continue to advance the science and encourage implementation without doing the detailed development/optimization work that battery companies are better placed to do.

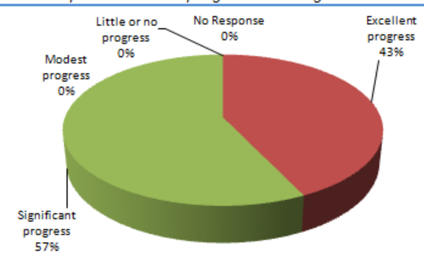
Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Summary and Future Plans

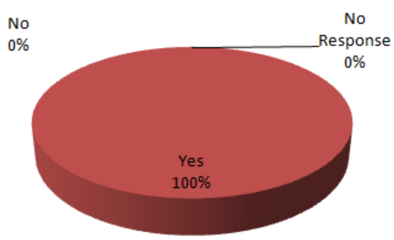
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



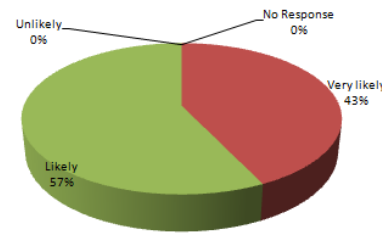
Question 3: Characterize the technical accomplishments and progress toward goals.



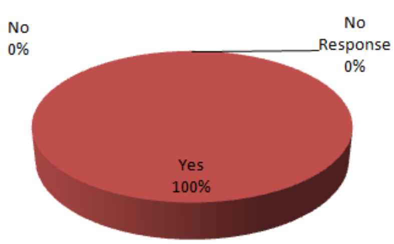
Question 2a: Are the goals of the project technically achievable?



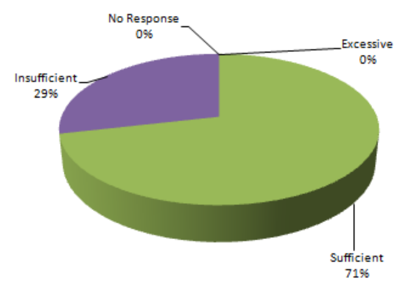
Question 4: How likely is the project team to move technologies into the marketplace?



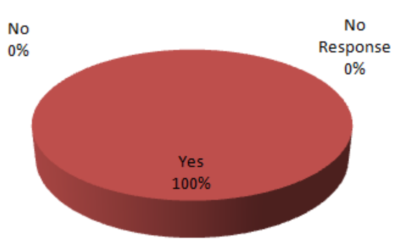
Question 2b: Have the technical barriers been identified and addressed?



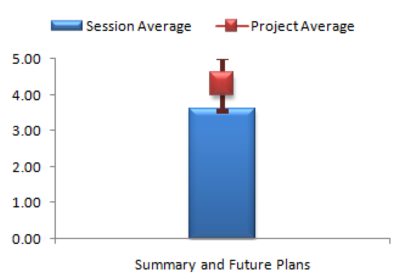
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Synthesis and Characterization of Substituted Olivines and Layered Manganese Oxides (S. Whittingham, of State University of New York-Binghamton)

Reviewer Sample Size
This project had a total of 11 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One person simply stated the project supports DOE very much so, as a better cathode will lead to a better cell. Another reviewer agreed, stating that cathode development is a key enabling technology relevant to DOE program. One reviewer indicated that the work is related to the development of high capacity cathodes for li-ion batteries. Another added that the goals include lower cost high capacity and high-rate batteries. One person observed that Whittingham's work may lead to better batteries for HEVs and PHEVs, which would lead to a reduction of oil consumption. Another mentioned that the materials under study have the possibility of increasing the energy of lithium ion batteries to help meet the PHEV goals. One person noted that the focus is on low-cost and environmentally friendly materials, which is in line with the PHEV goals. The use of high power materials with manganese and iron phosphates is also meeting the goals of the program. The last person commented that materials with high Mn content can prove to be cost effective high performance materials. These are yet not synthesized in a satisfactory way, which is in part what this program can do.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
One person noted that the barriers are clearly identified and the approach is clearly addressing actions to overcome them. Another commented that the authors are competent and the plan is feasible and have put up a good team to study the basics of electrode materials. Another person commented that the low-cost materials and processes are bound to attract industrial interest and should have a big pull from such companies. The reviewer also liked the practical approach of the PI in always looking at the production costs and scalability. They acknowledged the nice work with the $LiFePO_4$, but were glad to see them planning to move on to higher capacity phosphate materials. Another person stated that Whittingham's approach may lead to better cathodes that will last longer and be cheaper than currently used materials. One person commented that the studies on the different phosphates and the layered transition metal oxides does meet the goals identified by the PHEV program and will help overcome the technical barriers. Another person mentioned that hydrothermal methods are generally useful in exploring a broad range of new phosphate materials. They concluded by observing that the impact of reduced cobalt in layer material will have a beneficial economic effect. One reviewer commented that the study of where Ni resides, Li layer or not in Li layer, can help produce synthesis paths that leads to compounds with high Mn content and less Ni in the Li layer. This will likely help increase cycling stability of such a materials, as Ni^{2+} would be disruptive to the materials ability to perform. The last person mentioned the synthesis pathways for olivines with mixed metals are useful for optimizing higher performing compounds.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer commented that progress has been made in upgrading of voltage on phosphate materials while increasing the conductivity and maintaining capacity. Methods of making low cobalt layered oxides are underway. Another reviewer stated that the authors have synthesized $LiFeO_4$ and optimized their synthetic parameters. They have extensively used detailed characterization technique

like X-ray, TEM, SEM, etc. They have also used magnetization studies to see the hysteresis effect in Ni-based cathodes to monitor Ni valency. One person indicated that the discovery of some new synthetic methods and how that affects the crystal structure of materials are all very important for the correlation to electronic and ionic behavior. One other respondent noted the increase in understanding of key synthesis conditions and the questioning of accepted theories, adding that this is good work on the right kinds of materials. One person added that Whittingham is working on reducing the expensive Co component of cathodes, and he is trying to reduce the amount of Ni in the cathode material. He is also trying to find the optimum conditions for the production of $LiFePO_4$.

Some reviewers offered suggestions. One response stated that the progress has been very good with interesting results in terms of increased capacity and preparation process development (hydrothermal for $LiFePO_4$). Some economical studies will be valuable to specify better cost aspects. Another reviewer wrote that the substitutions in the layered oxides and the cycle data showed are good. The studies on the different metal phosphates and the hydrothermal synthesis studies also provide excellent data. More work to study the safety and abuse characteristics of the materials can be carried out in the future to confirm the safe use of these materials.

One other respondent remarked that there has been very good progress in synthesizing new materials and understanding the structures, then asked: why use Ni and Co at all for making low-cost materials (unless you do for understanding purposes)? Another reviewer noted that some olivines and layered manganese oxides have made it into commercial batteries – the present study may confirm their usefulness, but does not add any added advantage of these compounds.

One reviewer commented that, regarding the Ni-Mn-Co work, there has been a lot of work done on these compositions by other groups around the world; what is the original contribution of this work? Regarding the $Ni_{0.5}Mn_{0.5}$ work, it is not clear what the goal of this work is and what work is being done in this task. PO_4 work: this project is showing creativity lacking in the above work. This is nice work thinking of novel phosphate compositions to investigate. One final reviewer noted the focus on: (1) determining optimum Ni/Mn/Co composition is valuable and should be continued and (2) capacity and conductivity of $LiFePO_4$ is valuable and should be continued. Work involving cost-related aspects of $LiFePO_4$ and related processing should be very limited and should only be at a very high level, if at all. Study involving determination of processing methods for $LiFePO_4$ and cost-related aspects of $LiFePO_4$ should basically be discontinued in this project. Greater focus to increase the conductivity or power capability of $LiFePO_4$ would be significantly more valuable than working to increase the storage capacity of Fe and Mn containing phosphates, and these should not be a focus of future work for this project.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first reviewer stated that various actions have been in place for assuring technology transfer, while another commented that commercialization of some of these materials has already been done and is expected to continue in the future. One other reviewer felt that the cost drivers and practicality of synthetic methods are very attractive for commercialization. One respondent noted that Whittingham is producing several (perhaps cheaper) olivines, adding that his work may lead to a material that performs better and has a longer cycle life. His work on producing Mg olivines may be used by battery developers. Another response indicated that the researchers have already licensed their technology to Phostech, while one other reviewer remarked that hydrothermal methods are already transferred to lithium iron phosphate materials. One reviewer felt that, in particular, determination of an optimum Ni/Mn/Co ratio should be directly transferable or of value to the marketplace. Another respondent added that materials companies can bring out the compounds in an effective way with this information. The information on control of morphology is particular important for companies trying to commercialize the materials. The hydrothermal process can be a very cost effective way of synthesize these compounds, which may lead to low-cost material for HEV and PHEV use.

One person wrote that the optimized $LiFePO_4$ or Nickelates have a commercialization path, but added that there are already several competitors in this area. So they need to come up with something different in terms of new attributes which distinguishes them from others. One final reviewer indicated that Ni-Mn-Co materials are already in commercial production in Asia; is the PI talking with any companies to license IP?

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Two reviewers indicated that the resources for this project seem adequate, while another reviewer felt that the group is doing good work for the funding obtained. One reviewer commented that the ability to tailor morphology is important and the PI can obviously do this. This may enhance conductive pathways and hence performance, all of which are desired for improved electrode materials. There is a good choice of activities for the next year, and optimizing the Mn content is particularly desired for cost reasons.

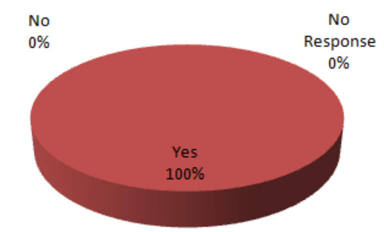
Another respondent stated that resources intended to be focused on detailed aspects of processing methods or cost aspects on this project should be re-directed towards the other goals of this project. One final reviewer commented that the researcher seems to have a lot on his plate, but added that he or she would like to see more support and even more collaborations.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

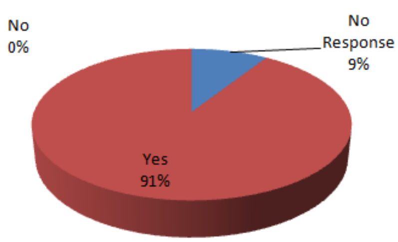
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Synthesis and Characterization of Substituted Olivines and Layered Manganese Oxides

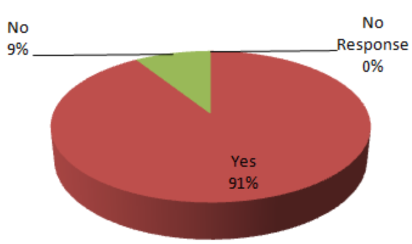
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



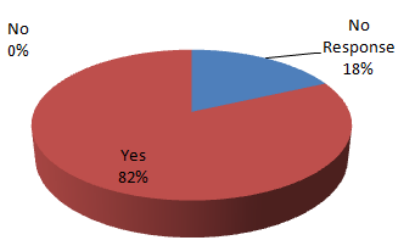
Question 2a: Are the goals of the project technically achievable?



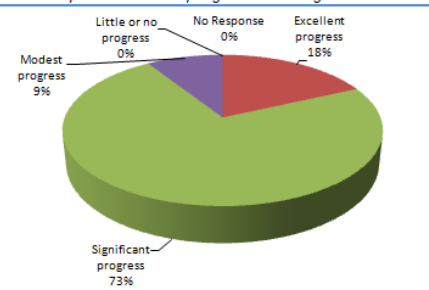
Question 2b: Have the technical barriers been identified and addressed?



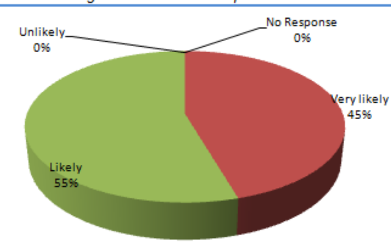
Question 2c: Is the proposed work likely to overcome technical barriers?



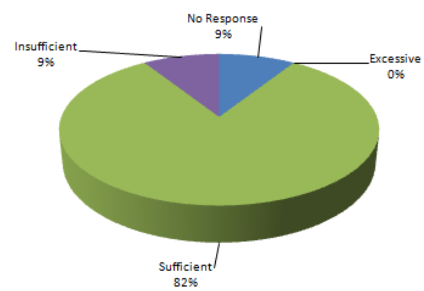
Question 3: Characterize the technical accomplishments and progress toward goals.



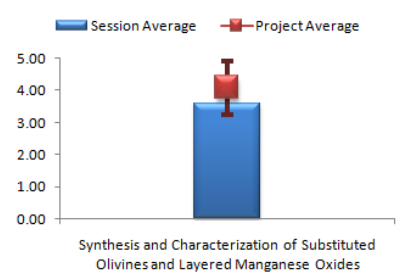
Question 4: How likely is the project team to move technologies into the marketplace?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 6: Overall Rating



The Impact of Electrode Structure on the Processes that Limit Cathode Performance (D. Wheeler, of Brigham Young University)

Reviewer Sample Size

This project had a total of 10 reviewers.

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

Positive comments included that this was a basic study to improve comprehension of working mechanisms and is relevant to DOE objectives, and that it is gaining understanding of cathode material properties to improve materials that would meet the program goals for PHEV. Also noted were that the goal of this work is to optimize already existing anode and cathode materials for Li-Ion batteries. Furthermore, electrode design is important for keeping cell impedance down and maybe even in maintaining good cycle life and that Wheeler's work may lead to improved electrodes which may produce better batteries for HEVs and PHEVs which would lead to a reduction in oil use. The final reviewer said that in general, optimized electrodes are needed to fully evaluate new materials and study formulation dependencies. This program was not so successful in doing so.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

A reviewer reflected positively on the work, stating that the strategy is clear and consistent with the scope to improve the fundamental knowledge and support material development. The work plan was also felt to be feasible, and Wheeler's work may lead to design rules to help optimize the design of electrodes by changing the composition and structure of the electrodes. Trades between the use of materials of lower impedance versus using more inert materials which in turn translates to increasing electronic transport properties have been carried out.

On the other hand, a reviewer said the work is important but was not sure the approach is novel enough. A reviewer said similarly that the project seems too superficial to be successful. The interaction with other participants was not clear to a reviewer, nor was the work on first principle modeling. A reviewer suggested that the PI needs to spend time looking at commercial electrodes and establish baseline. The results and any interpretations are suffering from lack of fundamental understanding of what constitutes a good electrode.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

A number of comments were received on the technical aspects of the work. One statement was that a reviewer did not see any substantial results coming out of the program as yet. Another shared that the team needs to show clearly the changes needed in physical parameters to improve electrode operation. Furthermore, a reviewer felt the team had a lack of understanding in electrode fabrication. Formulation work (effect of conductive additives) was stated by one reviewer to be really not at all useful for a university to do - the approach is naive relative to what is done in industry. This reviewer said that we already have Srinivasan at LBNL and Dees at ANL doing similar work on optimizing loading and density; what new contribution does this work make to the program aside from training students? Finally, this reviewer said that much of the electrode design work is pretty obvious and it doesn't really explain fundamentally what's going on. The model seems to be a fitting system, not based on what's actually happening in the battery. Frankly, the Dees model seems to be a much better bet to this reviewer. The thickness impact on power and energy are very well known as are the importance of calendaring the materials to attain good interparticle contact - basic electrode design work.

On the other hand, a reviewer stated that the results are good and in line with the project objectives. Additionally, the electrode analysis work is very important for the extrapolation of the results from material- or lab-cell results to equivalent vehicle battery system: the method should be extended to all the BATT similar results on cell materials. Further, the extension to other cell components and the study at low temperature should be of value. It was noted that the project may deliver alternative methods to achieve useful modeling of electrodes for the purposes of cell design and performance. This may be useful for other researches in other projects. Finally, effective transport properties in the porous electrode were felt to be useful - it would be good to have a more fundamental understanding of how tortuosity depends on electrode morphology and porosity. This reviewer encouraged the PI to do more work in this area. New models are a good start - the work should be done in collaboration with others in the BATT program to help them understand their materials.

A reviewer commented that studies on cell level performance with changes made to loading, porosity, etc. of the electrode materials, especially the olivine cathode have been carried out to determine the energy and power densities. The correlation between peak performance and loading was explained well. Bulk electrode properties were shown to have impact on cell high rate performance. The development of a battery model helps extend intrinsic properties like electronic conductivity to the performance of a complete cell. The simulation for the thin cell has good correlation with experimental data only at the highest and lowest rate. Same is seen for the thick cell simulation too. No explanations were provided for that. That area of discrepancy may have to be focused on to determine what the limiting factors at those intermediate rates are.

A reviewer noted that the team has optimized the electrode fabrication performance for both energy and power. The parameters like thickness and porosity, carbon weight percent were varied and the corresponding capacity and rate was compared. Subsequently these parameters were modeled. This reviewer suggested that the team carry out these optimizing parameters for a few important cathode and anode materials that have potential for PHEV (energy) cell and tie up with industry if the results are promising. Argonne has already done work in this area and author should choose materials that are rather complementary/not done.

Wheeler's work shows clearly that the thickness and other design parameters of the electrodes must be optimized based on the desired performance. For example, the electrodes for a PHEV10 battery must be different from those for a PHEV40 battery.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

On the positive side, the technology transfer is related to the collaborations and publications and the use of the electrode analysis work may improve the transfer. The project is working on the tech transfer and has a good likelihood for tech transfer as it is being extended to completed cells. Additionally, the electrode optimization and design knowledge gained is important for industry. Finally, Wheeler's work will help battery manufacturers optimize their cell designs to meet the criteria for the HEV or PHEV application.

On the negative side, a reviewer characterized these as poor results. Another said that much of the work presented is naive and not state-of-the-art; we hope that the PI will stay in close contact with others in the BATT program to increase the relevance of his work. A third did not see how the work really pushes the program forward. Lastly a reviewer offered that it is possible that the model might influence cell or electrode design elsewhere in the future.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

To one, the resources seem adequate to the work done: to another, funding was sufficient. A reviewer offered more comments, stating this was very good work for the funding received. The project could benefit from increased funding. Universities are a good resource for both scientific work and high-tech equipment. The cost of labor is also less. Hence more funds can be provided to fund more basic research at the Universities, especially for groups like this that do quality work. Another comment was that training should take place for electrode manufacturing, so better experimental data can be available for the coated electrodes. This will make the PI more effective and then he can apply his core skillset in modeling in a successful way.

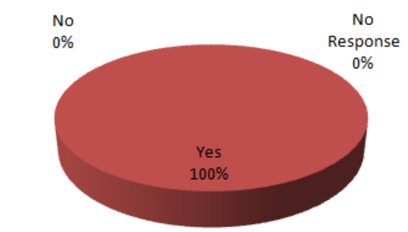
One reviewer could not comment on the funding level. The final reviewer recommended cutting funding for this program, stating that others in the program do better electrode design work (ANL) and far better and more relevant modeling work (Dees/Sastry).

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

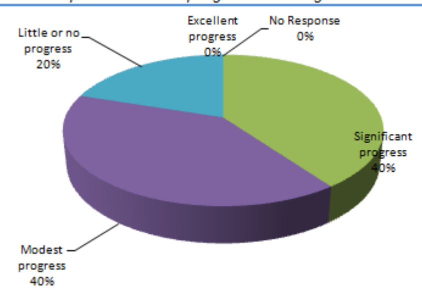
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: The Impact of Electrode Structure on the Processes that Limit Cathode Performance

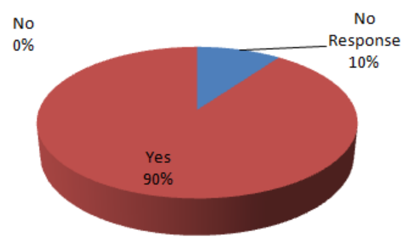
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



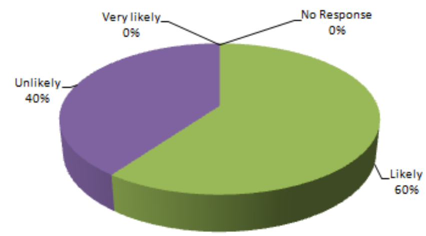
Question 3: Characterize the technical accomplishments and progress toward goals.



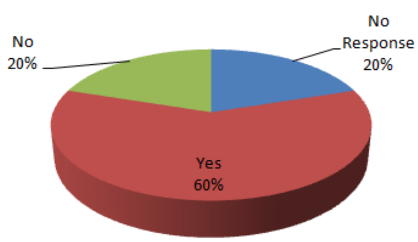
Question 2a: Are the goals of the project technically achievable?



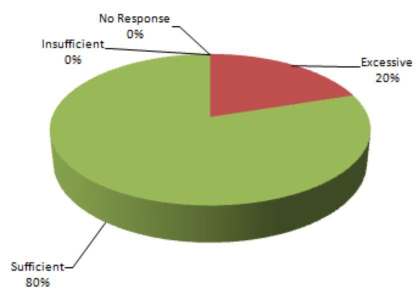
Question 4: How likely is the project team to move technologies into the marketplace?



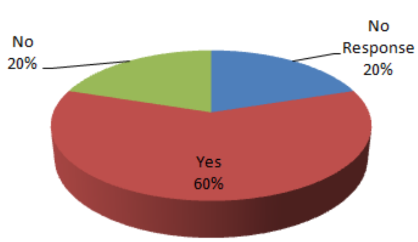
Question 2b: Have the technical barriers been identified and addressed?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating