2. Electrochemical Energy Storage

The Vehicle Technologies Office (VTO) focuses on reducing the cost, volume, and weight of batteries, while simultaneously improving the vehicle batteries' performance (power, energy, and durability) and ability to tolerate abuse conditions. Reaching the Office's goals in these areas and commercializing advanced energy storage technologies will allow more people to purchase and use electric drive vehicles. It will also help the U.S. Department of Energy (DOE) meet the EV Everywhere Grand Challenge goal to enable plug-in electric vehicles (PEVs) that are as affordable and convenient for the American family as gasoline-powered vehicles by 2022.

VTO pursues three major areas of research in batteries:

- Exploratory Battery Materials Research: Addresses fundamental issues of materials and electrochemical interactions associated with lithium (Li) and beyond-Li batteries. This research attempts to develop new and promising materials, use advanced material models to predict the modes in which batteries fail, and employ scientific diagnostic tools and techniques to gain insight into why materials and systems fail. Building on these findings, it works to develop ways to mitigate those failures

- Applied Battery Research: Focuses on optimizing next generation, high-energy Li-ion electrochemistries that incorporate new battery materials. The activity emphasizes identifying, diagnosing, and mitigating issues that negatively impact the performance and life of cells using advanced materials.

- Advanced Battery Development, System Analysis, and Testing: Focuses on the development of robust battery cells and modules to significantly reduce battery cost, increase life, and improve performance. This research aims to ensure these systems meet specific goals for particular vehicle applications

This research builds upon decades of work that DOE has conducted in batteries and energy storage. Research supported by VTO led to today's modern nickel (Ni) metal hydride batteries, which nearly all first-generation hybrid electric vehicles (HEV) used. Similarly, the Office s research also helped develop the Li-ion battery (LIB) technology used in the Chevrolet Volt, the first commercially available plug-in hybrid electric vehicle (PHEV). This technology is now being used in a variety of HEVs and PEVs coming on the market now and in the next few years, including the Ford Focus electric vehicle (EV).

The batteries subprogram works extensively with a number of different organizations, including national laboratories and universities. Within the Department, the office collaborates with the Office of Science an Advanced Research Projects Agency-Energy (ARPA-e). Across the federal government, the subprogram collaborates with:

- The Interagency Advanced Power Group;
- The U.S. Environmental Protection Agency;
- The National Aeronautics and Space Administration;
- The National Science Foundation;
- The National Highway Traffic Safety Administration (U.S. Department of Transportation); and
- The U.S. Army Tank, Automotive Research and Development and Engineering Center (U.S. Department of Defense).

The subprogram collaborates on international research with:

- International Energy Agency's Implementing Agreement on Hybrid Electric Vehicles;
- The Clean Energy Ministerial's Electric Vehicle Initiative; and
- The Clean Energy Research Center bilateral agreement between the United States and China.

Much of the subprogram's research is conducted in sync with industry partners through:

- The U.S. DRIVE Partnership focusing on light-duty vehicles;
- The 21st Century Truck Partnership, focusing on heavy-duty vehicles; and
- The United States Advanced Battery Consortium (USABC), a partnership between DOE, Fiat Chrysler Au-

tomobiles, Ford, and General Motors to develop and demonstrate advanced battery technologies for hybrid and electric vehicles (EVs), as well as benchmark test emerging technologies.

As described in the EV Everywhere Blueprint, the major goals of the Batteries and Energy Storage subprogram are by 2022 to:

- Reduce the production cost of an EV battery to a quarter of its current cost;
- Halve the size of an EV battery; and
- Halve the weight of an EV battery.

Achieving these goals would result in:

- Lowering battery cost from $500/kwh to $125/kWh; and
- Increasing density from 100 Wh/kg to 250 Wh/kg, 200 Wh/l to 400 Wh/l, and 400 W/kg to 2,000 W/kg

Subprogram Feedback

The U.S. Department of Energy (DOE) received feedback on the overall technical subprogram areas presented during the 2016 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

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

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

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

Overview of the DOE Advanced Battery R&D Program: David Howell (U.S. Department of Energy) - es000

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
The reviewer replied yes, and stated that the program's background, prediction of battery cost, funding distribution, research roadmap, and strategy are adequately covered and easy to understand.

Reviewer 2:
The reviewer replied yes to this question.

Reviewer 3:
The reviewer replied yes to this question.

Reviewer 4:
The reviewer praised the presentation as having clearly outlined the different projects and focus areas of the program and provided an indication of how awards are decided. Nevertheless, the reviewer cautioned, it is not 100% clear why these areas are chosen and what requirements were used. Overall, though, the reviewer stated that from an original equipment manufacturer (OEM) perspective, a majority of the projects make sense and might ease the path for the implementation of electric vehicles.

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Reviewer 1:
The reviewer replied yes, the balance of the projects is good, remarking that the focus on silicon (Si)/intermetallic anodes and metallic Li covers very well the trend in industry and results can be implement quickly into already existing industry roadmaps. The reviewer added also the approach to develop diagnostic tools that support the material developments and decipher root causes of electrochemical energy storage degradation is useful as this can prove to be invaluable for the development of new materials. The reviewer concluded that the framework of funding agencies, this program covers a very important range of topics and besides the occasional overlap has his own footprint.

Reviewer 2:
The reviewer said yes, adding that there is an appropriate balance between near- and long-term research and development (R&D). The reviewer observed that the timeline chart clearly shows that Si anode coupled with a high capacity cathode which presents moderate risk pathway is one of the current emphasis, while Li-metal, Li-sulfur (Li-S), and Li-air would be the long-term research.

Reviewer 3:
The reviewer offered that there seems to have been at least some movement towards more near-term R&D and manufacturing issues as well as towards more advanced fundamental science, with reduced focus on mid-term R&D. This reviewer suggested this is favorable and should provide better value and benefit to U.S. industry in this technology area.

Reviewer 4:
The reviewer replied yes to this question.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer said yes, adding that most of the challenges are well known in the community and a majority of them are addressed in this program.

Reviewer 2:
The reviewer replied yes.

Reviewer 3:
The reviewer said.

Reviewer 4:
The reviewer said yes and expressed approval of the slide that shows the breakdown of the battery cost and the breakthroughs required at different process steps. The reviewer cautioned, however, that not all the research areas have challenges identified and present

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer replied yes.

Reviewer 2:
The reviewer said yes, generally.

Reviewer 3:
The reviewer praised the plan on the anode side as very clearly and outlined. However, the reviewer stated that in other areas, it is not as accurate for the case of a high-level overview but added that this could be caused by the time constraint for the projects.

Reviewer 4:
The reviewer remarked that most focus areas have plans laid out to address issues and challenges while some of them do not and noted as an example that advanced battery material has today's technology but a next generation target listed. The reviewer said that except for anode material, issues not addressed include how to reach the goal, what are the challenges, and what are any solutions.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
The reviewer replied yes.

Reviewer 2:
The reviewer said yes, stating that progress was clearly benchmarked against the previous year and the year of 2012, and that it seems that a continuous progress is being made to approach the 2022 target. The reviewer asked, however, about whether the $125/kWh for 2020 as listed on Slide two is the goal or a typo and it should be in 2022.

Reviewer 3:
The reviewer remarked that certain areas such as the licensing and commercialization of the components/ technologies from the Materials Engineering Research Facility (MERF) have clearly progressed since last year while other highlights were the conclusion of multi-year projects. The reviewer concluded that, in general, the progress was outlined well on a high level versus the general roadmap, which is adequate for the purpose of this presentation.

Reviewer 4:
The reviewer said yes in some areas and no in some areas. The reviewer elaborated that in some cases, it may be implied that progress which might have occurred independently within the global industry in this technology is explicitly due to DOE-funded activity. The reviewer observed an enormous amount of DOE-funded activity underway for which progress has been made in some areas that can be directly noted.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The reviewer said yes, adding that increasing the usage of renewable energy source and electrifying the vehicles is obviously one of the focus of VTO.

Reviewer 2:
The reviewer replied yes to this question.

Reviewer 3:
The reviewer said yes, in almost all cases.

Reviewer 4:
The reviewer replied that in general yes, but cautioned that sometimes the projects seem to be too specifically focused on a single problem and forget to address other barriers needed to be overcome in order to implement this technology in commercial products and/or use the software in industry.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:
The reviewer noted that program breaks down the battery research into many focus areas and that those research areas progress hand-by-hand to approach the advanced low-cost battery system. The reviewer concluded therefore, yes, the program is focused, well-managed and effective.

Reviewer 2:
The reviewer said yes, in general, remarking that in particular there seems to have been improved focus on some key topics which impact time-sensitive decisions for future direction in the last few years and that this indicates an improved focus on potential payoff versus continued effort. The reviewer assessed this as a positive trend.

Reviewer 3:
The reviewer replied yes to this question.

Reviewer 4:
The reviewer stated that the majority of the projects are well-managed and aligned with the VTO's needs and roadmaps, although the reviewer added that some of the projects seem a bit out of the scope and cover topics that should be addressed by the OEMs themselves if there is need for this particular technology. However, this is only true for a minority of the modelling and battery pack projects.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:
The reviewer stated that a key strength is the strong focus of the program towards materials and a focus on characterization and that one of the key solutions to improve Li-ion is to find new high-performance materials and coatings to protect and support existing materials. On the other hand, the reviewer noted, it is important to find the root causes of the degradation of energy storage systems and identify these interactions and mechanisms. A combination of these projects could be a powerful conclusion to enable better batteries.

A suggestion from the reviewer to further strengthen the program would be to widen the landscape of funding recipients, adding that although several new companies and institutes have received awards recently, the group could be extended to represent the changing structure of the battery research.

Reviewer 2:
The reviewer stated that Computer-Aided Engineering for Electric-Drive Vehicle Batteries (CAEBAT) should be very helpful for continuous battery R&D.

Reviewer 3:
The reviewer described as one of the key strengths that have developed more recently with some of the projects is the creation of large groups focused on key technical issues that must either must be resolved or which must be determined to be unresolvable, and upon which some reasonable time limit of effort has been placed. The reviewer noted another key strength is focused on battery manufacturing methods and related manufacturing innovation.

Efforts in this area may provide a pathway for the United States to show some leadership at some level in the general global battery industry.

The reviewer characterized as one of the weaknesses of some of the projects is in putting particular focus on scale-up, optimization of scale-up and optimization of processes for battery materials, particularly for ultra-specialty battery materials and chemicals. This does not seem to be an area in which the United States would be expected to be significant in the global battery industr , when other areas may still have potential (like battery manufacturing methods, etc.).

Reviewer 4:

The reviewer said the requirements and time line to meet requirements.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer replied yes.

Reviewer 2:

The reviewer said yes, generally.

Reviewer 3:

The reviewer stated that the majority of the projects are novel and innovative, which is also driven by the feedback loop in the award process with industry. However, the reviewer suggested that some of the projects however could use more input from the OEM's perspective, e.g., considering the volumetric capacity of novel Si compounds or the costs basis of manufacturing new materials.

Reviewer 4:

The reviewer indicated that the program does identify the critical research areas of battery technology and linked them together to meet the program target but pointed out that is difficult to comment whether each project adopts innovative ways to approach the barriers due to limited information shared at the meeting.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:

The reviewer answered yes to this question, noting it is possible to see that many universities, industrial members, and national laboratories are engaged in this program.

Reviewer 2:

The reviewer replied yes.

Reviewer 3:

The reviewer replied more or less, noting that the overall team includes the broad majority of key players in North America and is well-based to establish a supply-chain network for EVs in the United States. The reviewer suggested to increase the broadness of recipients towards start-ups and shorten the duration of the awards, remarking that this would increase the number of recipients and provide a faster reality check to new companies and provide early guidance.

Reviewer 4:

The reviewer stated that the program projects generally provide good collaboration with useful partners within the United States. However, the reviewer observed that almost completely, the program projects fail to involve any of the significant global battery manufacturers. While this is most generally due to limitations imposed by DOE and U.S. government, the reviewer warned that this limits the impact that the program can have on the industry in general and on the impact the program can have on U.S. industry specificall

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer said yes, commenting that once you are in the program the interaction with the partners and the funding agencies is good.

Reviewer 2:
The reviewer replied yes.

Reviewer 3:
This reviewer thinks and hopes so.

Reviewer 4:
The reviewer voiced that the program area is very effective in collaboration within the United States, but that it is perhaps by design generally ineffective in collaboration with global partners of importance.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer stated that there are no major gaps in the program portfolio.

Reviewer 2:
The reviewer said no.

Reviewer 3:
The reviewer indicated a desire to see some battery performance test data while making progress at different research sub-levels.

Reviewer 4:
The reviewer remarked that some limited but clear effort in technologies beyond Li would be useful within VTO, even if this is already covered at some level within DOE external to VTO.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
The reviewer replied yes.

Reviewer 2:
The reviewer remarked that as an overview of the program, it is difficult to cover every aspect of each topic but that, in general, the overview is very well organized and presented.

Reviewer 3:
The reviewer wondered if VTO is maybe too focused on the core topics and whether some projects should also address potential mid-term candidates which are not present in the current landscape. Additionally, the reviewer observed, the question of the viability of Li-metal-sulfur batteries for EV applications is not solved. To mitigate the risk here, the reviewer suggested that the program could fund specific projects that advance particular key technologies which could enable Li-metal-sulfur batteries later (e.g., a stronger focus on protecting Li-metal or strengthen the efforts in the development of solid-state electrolytes [SSEs]).

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:
The reviewer praised the program as very comprehensive and covering almost all critical aspects of the battery technology.

Reviewer 2:
The reviewer said no

Reviewer 3:

The reviewer commented that the requirements and challenges described by the VTO already cover most of the interesting areas but suggested potential additions could include fast charging and cold temperature performance or pack architectures enabling cold climate operation. The reviewer noted that most of the projects are strongly focused on the VTO roadmap and that perhaps a certain percentage of the projects should be awarded to potential competitors, i.e., to have a good overview in the project and to strengthen the completion between the technologies. The reviewer remarked that a stronger connection between cost calculation and materials project would also help to reach the program's goal.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:

The reviewer characterized the program as going well and making progress continuously and had no new ways to recommend.

Reviewer 2:

The reviewer replied no to this question.

Reviewer 3:

The reviewer praised the overall project landscape and approach as very good. The reviewer offered one way to improve on it would be to implement a very competitive sub-program with strict go/no-go decisions in which award recipients have only a short amount of time to prove their technology, but then receive a full project after a strict elimination process.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

The reviewer judged that overall, the VTO is in a good position and covers its topics very well. On the task to establish a supply-chain for EVs in the United States, the reviewer suggested that the program might have to find a way to work and strengthen their interaction with partners who are not headquartered in the United States, but have major activities in North America (i.e., cell manufactures and component suppliers).

Reviewer 2:

The reviewer recommended some level of direct engagement with the global battery industry.

Reviewer 3:

The reviewer claimed that only future needs of fast charging will be needed to make battery electric vehicles more acceptable.

Reviewer 4:

The reviewer suggested that for each project, listing the main contribution of each team member might help to improve the effectiveness of the program.

Project Feedback

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

Table 2-1 – Project Feedback

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Materials Benchmarking Activities For CAMP Facility	Lu, Wenquan (ANL)	2-19	3.20	3.40	3.60	3.30	3.36
Cell Analysis, Modeling, and Prototyping (CAMP) Facility Research Activities	Jansen, Andrew (ANL)	2-22	3.60	3.30	3.50	3.40	3.41
Overview and Progress of United States Advanced Battery Consortium (USABC) Activity	Elder, Ron (USABC)	2-25	3.33	3.17	3.42	3.08	3.23
Thick Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing	Li, Jianlin (ORNL)	2-29	3.25	3.13	3.75	3.25	3.25
Performance Effects of Electrode Coating Defects and IR Thermography NDE for High-Energy Lithium-Ion Batteries	Wood, David (ORNL)	2-31	3.17	3.00	3.33	3.17	3.10
Post-Test Analysis of Lithium-Ion Battery Materials at Argonne National Laboratory	Bloom, Ira (ANL)	2-33	3.00	3.13	3.38	3.25	3.14

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Process Development and Scale-Up of Advanced Active Battery Materials	Krumdick, Greg (ANL)	2-36	3.50	3.13	3.50	3.25	3.28
Process Development and Scale-Up of Critical Battery Materials	Krumdick, Greg (ANL)	2-38	3.50	3.50	3.63	3.25	3.48
Electrochemical Performance Testing†	Bloom, Ira (ANL)	2-40	3.50	3.33	3.83	3.17	3.42
INL Electrochemical Performance Testing†	Shirk, Matt (INL)	2-42	3.33	3.33	3.50	3.33	3.35
Battery Safety Testing†	Steele, Leigh Anna (SNL)	2-44	3.50	3.38	3.63	3.38	3.44
Battery Thermal Characterization†	Keyser, Matthew (NREL)	2-47	3.38	3.38	3.25	3.38	3.36
Towards Solventless Processing of Thick Electron-Beam (EB) Cured LIB Cathodes	Wood, David (ORNL)	2-50	3.38	3.38	3.25	3.25	3.34
New High-Energy Electrochemical Couple for Automotive Applications	Amine, Khalil (ANL)	2-52	3.50	3.20	3.30	2.83	3.24
High-Energy High-Power Battery Exceeding PHEV-40 Requirements	Rempel, Jane (TIAX)	2-55	2.88	2.75	2.75	2.50	2.75
Advanced High-Energy Lithium-Ion Cell for PHEV and EV Applications	Singh, Jagat (3M)	2-58	3.25	2.75	3.50	2.88	2.98

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
High-Energy Lithium Batteries for PHEV Applications	Venkatachala, Subramanian (Envia Systems)	2-61	3.30	2.90	3.40	2.33	2.99
High-Energy, Long Cycle Life Lithium-Ion Batteries for EV Applications	Wang, Donghai (Penn State)	2-64	3.50	3.25	3.25	3.08	3.29
High-Energy Density Lithium-Ion Cells for EVs Based on Novel, High Voltage Cathode Material Systems	Kepler, Keith (Farasis)	2-68	3.08	2.75	3.42	2.50	2.89
Fundamental Studies of Lithium-Sulfur Cell Chemistry †	Balsara, Nitash (LBNL)	2-71	3.33	3.33	3.17	3.00	3.27
BatPaC Model Development	Ahmed, Shabbir (ANL)	2-73	3.70	3.50	3.40	3.40	3.53
Design of Sulfur Cathodes for High-Energy Lithium-Sulfur Batteries †	Cui, Yi (Stanford University)	2-75	3.63	3.63	3.38	3.63	3.59
Efficient Rechargeable $Li-O_2$ Batteries Utilizing Stable Inorganic Molten Salt Electrolytes †	Giordani, Vincent (Liox)	2-78	3.13	3.25	3.13	3.13	3.19
Low-Cost, High-Energy Si/Graphene Anodes for Li-Ion Batteries†	Colwell, John (XG Sciences)	2-81	3.50	3.40	3.40	3.40	3.43
Low-Cost, High-Capacity Lithium-Ion Batteries through Modified Surface and Microstructure†	Zhang, Pu (Navitas Systems)	2-84	3.50	3.10	3.20	3.20	3.23

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Scale-Up of Low-Cost Encapsulation Technologies for High-Capacity and High-Voltage Electrode Powders†	King, David (Pneumaticoat Technologies)	2-86	3.80	3.50	3.20	3.00	3.48
High-Energy Anode Material Development for Li-Ion Batteries†	Hayner, Cary (Sinode Systems)	2-89	3.00	3.00	3.00	3.00	3.00
Advanced High-Performance Batteries for Electric Vehicle (EV) Applications†	Stefan, Ionel (Amprius)	2-92	3.25	3.38	2.38	2.50	3.11
A Disruptive Concept for a Whole Family of New Battery Systems	Roumi, Farshid (Parthian Energy)	2-95	2.20	2.30	2.60	2.40	2.33
Dramatically Improve the Safety Performance of Lithium-Ion Battery Separators and Reduce the Manufacturing Cost Using Ultraviolet Curing and High-Precision Coating Technologies	Arnold, John (Miltec UV International)	2-99	2.50	2.30	2.60	2.20	2.38
Low-Cost, High-Capacity Non-Intercalation Chemistry Automotive Cells	Jacobs, Alex (Sila Nano-Technologies)	2-103	3.08	3.33	3.25	3.08	3.23
Low-Cost, Structurally Advanced Novel Electrode and Cell Manufacturing	Woodford, Billy (24M Technologies)	2-107	2.70	2.80	2.20	2.60	2.68

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Advanced Drying Process for Lower Manufacturing Cost of Electrodes	Ahmad, Iftikhar (Lambda Technologies)	2-111	3.30	3.20	3.20	3.20	3.23
High-Energy Lithium Batteries for Electric Vehicles†	Lopez, Herman (Envia Systems)	2-115	3.20	3.30	3.40	2.50	3.19
A 12V Start-Stop Li Polymer Battery Pack†	Alamgir, Mohamed (LG Chem Power)	2-119	3.00	2.25	2.75	2.13	2.48
A Commercially Scalable Process for Silicon Anode Pre-lithiation	Stefan, Ionel (Amprius)	2-123	3.42	3.33	1.92	3.00	3.14
Development of Advanced High-Performance Batteries for 12V Start-Stop Vehicle Applications†	Kim, Jeff (Maxwell)	2-127	3.25	3.25	2.88	3.50	3.23
Enabling High-Energy, High-Voltage Li-Ion Cells for Transportation Applications: Modeling and Analysis	Dees, Dennis (ANL)	2-130	3.50	3.50	3.33	3.00	3.42
Enabling High-Energy, High-Voltage Li-Ion Cells for Transportation Applications: Project Overview	Dees, Dennis (ANL)	2-132	3.63	3.25	3.38	3.25	3.36
Enabling High-Energy, High-Voltage Li-Ion Cells for Transportation Applications: Materials Characterization	Dees, Dennis (ANL)	2-134	3.38	3.38	3.50	3.25	3.38
Next-Generation Anodes for Lithium-Ion Batteries: Overview	Dees, Dennis (ANL)	2-136	3.50	3.38	3.50	3.38	3.42

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Next-Generation Anodes for Li-Ion Batteries: Fundamental Studies of Si-C Model Systems	Kostecki, Robert (LBNL)	2-138	3.50	3.13	3.25	3.38	3.27
Electrodeposition for Low-Cost, Water-Based Electrode Manufacturing	Hellring, Stuart (PPG)	2-140	3.10	2.90	2.80	3.10	2.96
Li-Ion Battery Anodes from Electrospun Nanoparticle/ Conducting Polymer Nanofibers	Pintauro, Peter (Vanderbilt)	2-143	3.00	3.00	3.25	3.00	3.03
UV Curable Binder Technology to Reduce Manufacturing Cost and Improve Performance of LIB Electrodes	Arnold, John (Miltec UV International)	2-147	3.25	2.83	2.83	2.75	2.93
Co-Extrusion (CoEx) for Cost Reduction of Advanced High-Energy-and-Power Battery Electrode Manufacturing	Cobb, Corie (PARC)	2-151	2.70	3.00	3.10	3.10	2.95
Commercially Scalable Process to Fabricate Porous Silicon	Aurora, Peter (Navitas Systems)	2-155	3.29	3.14	3.29	3.21	3.21
Low-Cost Manufacturing of Advanced Silicon-Based Anode Materials	Feaver, Aaron (Group14)	2-160	2.64	2.79	2.93	2.86	2.78
An Integrated Flame Spray Process for Low-Cost Production of Battery Materials	Xing, Chad (University of Missouri)	2-165	2.42	2.75	2.75	2.92	2.69

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
New Advanced Stable Electrolytes for High-Voltage Electrochemical Energy Storage	Du, Peng (Silatronix)	2-169	3.20	3.20	3.20	3.20	3.20
Pre-Lithiation of Battery Electrodes†	Cui, Yi (Stanford University)	2-173	3.33	3.33	2.83	3.17	3.25
New Lamination and Doping Concepts for Enhanced Li-S Battery Performance†	Kumta, Prashant (U. of Pittsburgh)	2-175	3.50	3.38	3.13	3.38	3.38
Novel Chemistry: Lithium Selenium and Selenium Sulfur Couple†	Amine, Khalil (ANL)	2-178	3.38	3.13	3.38	3.13	3.22
Multi-Functional Cathode Additives for Li-S Battery Technology†	Gan, Hong (BNL)	2-180	3.17	3.00	3.33	3.50	3.15
Development of High-Energy Lithium-Sulfur Batteries†	Liu, Jun (PNNL)	2-183	3.50	3.38	3.63	3.38	3.44
Addressing Internal "Shuttle" Effect: Electrolyte Design and Cathode Morphology Evolution in Li-S Batteries†	Balbuena, Perla (Texas A&M)	2-186	3.38	3.25	2.88	3.00	3.20
Statically and Dynamically Stable Lithium-Sulfur Batteries†	Manthiram, Arumugam (U of Texas at Austin)	2-188	3.25	3.38	3.25	3.13	3.30
Mechanistic Investigation for the Rechargeable Li-Sulfur Batteries†	Qu, Deyang (U. of Wisconsin - Madison)	2-191	3.63	3.50	3.63	3.25	3.52

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Development of Novel Electrolytes and Catalysts for Lithium-Air Batteries†	Amine, Khalil (ANL)	2-193	3.38	3.50	3.00	3.00	3.34
Exploratory Studies of Novel Sodium-Ion Battery Systems†	Yang, Xiao-Qing (BNL)	2-195	3.33	3.33	3.33	3.00	3.29
Construction of High Energy Density Batteries†	Lang, Christopher (Physical Sciences Inc.)	2-197	2.80	2.80	3.10	2.90	2.85
Advanced Polyolefin Separators for Li-Ion Batteries Used in Vehicle Applications†	Wood, Weston (Entek)	2-200	3.33	3.00	3.00	3.17	3.10
Hybrid Electrolytes for PHEV Applications†	Moganty, Surya (NOHMs Technologies)	2-202	3.63	3.38	3.25	3.50	3.44
SAFT-USABC 12V Start-Stop Phase II†	O'Connor, Ian (Saft)	2-205	3.25	3.13	3.13	2.88	3.13
Development of Advanced High-Performance Electrolytes for Lithium-Ion Used in Vehicle Applications†	Meyers, Kristin (soulbrain)	2-209	2.40	2.50	3.20	2.60	2.58
A Closed Loop Process for the End-of-Life Electric Vehicle Li-Ion Batteries†	Wang, Yan (WPI)	2-212	3.63	3.38	3.25	3.25	3.41
Computer Aided Battery Engineering Consortium†	Pesaran, Ahmad (NREL)	2-215	3..67	4.00	3.33	3.33	3.75

† Denotes a poster presentation

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Consortium for Advanced Battery Simulation†	Turner, John (ORNL)	2-218	3.33	3.50	3.50	3.50	3.46
Development and Validation of a Simulation Tool to Predict the Combined Structural, Electrical, Electrochemical, and Thermal Responses of Automotive Batteries†	Marcicki, James (Ford)	2-221	3.67	3.50	3.33	3.17	3.48
Overall Average			3.27	3.17	3.20	3.07	3.19

† Denotes a poster presentation

Materials Benchmarking Activities for CAMP Facility: Wenquan Lu (Argonne National Laboratory) - es028

Presenter

Wenquan Lu, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

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

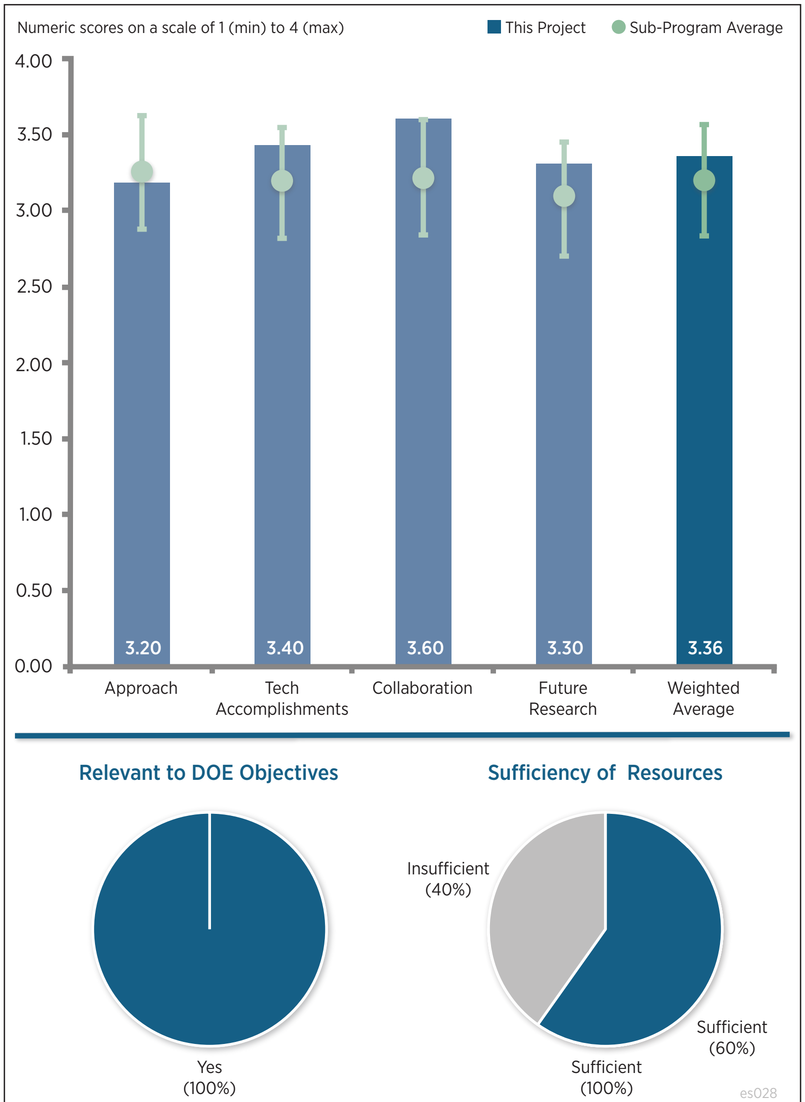

Figure 2-1 – Materials Benchmarking Activities For CAMP Facility: Wenquan Lu (Argonne National Laboratory) – Electrochemical Energy Storage

Reviewer 1:

The reviewer found that the Cell Analysis, Modeling, and Prototyping (CAMP) facility provides an excellent service to the community. The facility's organized information, consistent electrodes, and cycling protocols allow for others to enter the field with an expert s guidance.

Reviewer 2:

The reviewer said that the team's aim is to collaborate with material developers and leverage Argonne National Laboratory's (ANL) expertise in electrode design and cell testing to develop next-generation battery technology. The team has established standardized material testing protocols for evaluating samples from various developer for use in batteries for vehicles.

Reviewer 3:

The reviewer remarked that the presented work covered pre-lithiation, carbon additive, and nickel manganese cobalt oxide (NMC) material. All these are important issues in Li batteries. The reviewer suggested that the presentation next year further explain the relationship between this project and the general project on the CAMP facility. The project is apparently doing original battery work rather than benchmarking.

Reviewer 4:

The reviewer remarked that CAMP serves an important function in validating materials in a consistent protocol for fair evaluation and comparison. The evaluation of methods of pre-lithiation are good, we need this. However, the reviewer would not recommend putting a low-density Li source into a high-density cathode. The reviewer suggested putting it in the anode, which is already low density. If researchers are going to put it in the anode, the reviewer suggested considering the volume fraction of the Li source and its overall effect on volumetric energy density.

Reviewer 5:
The reviewer said CAMP could be a bit tighter focus, particularly given the modest budget and duration. According to the reviewer, it was not as clear as it could be whether CAMP is a service role or discovery program.

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

Reviewer 1:
The team worked on a broad area of interest such as reduction of initial capacity loss (ICL), effect of conductive additive on power and life, as well as studies on nickel-cobalt-manganese (NCM). Some of the data are preliminary and we need additional data to assess the true potential of these ideas. The reviewer said that among all the projects, the use of Li iron oxide (LFO) to reduce ICL is quite interesting and could be promising. The reviewer remarked that given the adverse effect of iron (Fe) in Li-ion batteries, it will be interesting to see full cell data especially at high temperature as well as storage data to examine its efficacy as a lithiation agent

Reviewer 2:
The reviewer remarked that many materials have been made available for the community that show excellent performance in cycling.

Reviewer 3:
The reviewer said that despite a concern about focus, this program has been very productive for the level of support. The reviewer found that the pre-lithiation technologies, though early, are very compelling. The reviewer would direct more resources there and hence indicated that resources on this program were not sufficient. The reviewer suggested defining go/no-go criteria for these approaches, or for pre-lithiation in general—this may fi with the stated benchmark mission.

Reviewer 4:
The reviewer commented that using hard carbon as a surrogate to study the issue of pre-lithiation through irreversible Li source in the cathode is interesting; it avoids the complications of using Si. The reviewer wondered that given that oxygen is generated during initial activation, what happens to the oxygen, does it oxidize the electrolyte. The reviewer also wondered about the microstructure of the cathode because the volume formerly occupied by the Li-rich oxides will now disappear. The reviewer suggested that the energy density of the cell made with hard carbon anode needs to be better described to include all cell components.

Reviewer 5:
The reviewer acknowledged having some difficulty judging this one. The reviewer knows that CAMP does a lot of work, but it is not well reflected in this set of slides. The reviewer noted that the focus was on a pre-lithiation source that has fundamental limitations, at the expense of all the other work the project team does. The reviewer acknowledged that the project included Cabot as a partner, but there are a lot of highly structured carbon blacks out there. The reviewer asked if the project team benchmark against other structured carbons, or just super P.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that the collaboration was extensive between the team and many internal and external labs.

Reviewer 2:
The reviewer said that the project has extensive interactions with both industrial and research institutions.

Reviewer 3:
The reviewer was glad to see that the project has an industrial collaborator. The reviewer asked if this collaborator does more than supply material.

Reviewer 4:
The reviewer was unclear how materials are selected for evaluation at CAMP. The reviewer inquired how decisions are made, are potential collaborators ever turned away, and if so, what percent and why. The reviewer inquired

that if not, does this mean that the facility needs more advertisement for those outside of the core energy storage community.

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

Reviewer 1:

The reviewer said that CAMP will continue to be a gateway to next-generation battery materials and the work proposed fully reflects that

Reviewer 2:

The reviewer commented that proposed work is a continuation of presented work and includes both benchmarking and original research on materials. The reviewer thinks that it would be help if the project mandate is better articulated in terms of the ratio between these two classes of activities.

Reviewer 3:

The reviewer suggested trying to be a bit clearer on the hypothesis (or hypotheses) and how opportunities are selected and prioritized.

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

Reviewer 1:

The reviewer commented that this project supports DOE's overall objective of petroleum displacement by aiding in the development of low-cost and durable materials for vehicle applications.

Reviewer 2:

The reviewer remarked that this facility contributes to practical evaluation of materials for researchers not otherwise able to do so and is important for validation of new materials.

Reviewer 3:

The reviewer said yes, the project is to help with the transition of laboratory materials discovery into higher levels of readiness for commercial deployment. The reviewer commented that thorough understanding of the state of the art is also important for projecting performance improvement and cost reduction.

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

Reviewer 1:

The reviewer suggested placing more resources into a program like this, but changing the focus to evaluate more materials coming from outside ANL. This would solve all those press releases where companies claim to have solved all battery problems. The reviewer also equated CAMP to mythbusters.

Reviewer 2:

The reviewer hoped to see the effort and focus pick up on pre-lithiation.

Cell Analysis, Modeling, and Prototyping (CAMP) Facility Research Activities: Andrew Jansen (Argonne National Laboratory) - es030

Presenter
Andrew Jansen, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

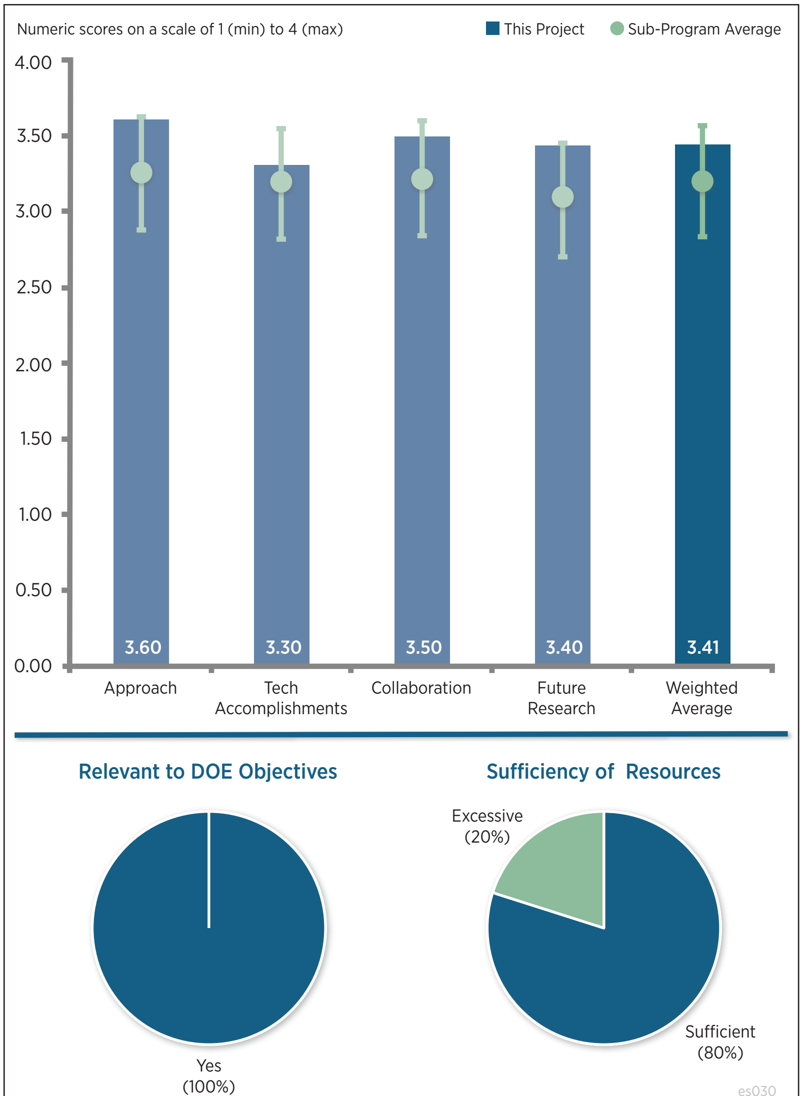

Figure 2-2 - Cell Analysis, Modeling, and Prototyping (CAMP) Facility Research Activities: Andrew Jansen (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer said that CAMP is certainly providing a platform to many material researchers who lack state-of-the-art electrode fabrication and testing facilities. The work is focused and well-planned, taking advantage of the ANL team's long experience in battery research.

Reviewer 2:
The reviewer commented that the project serves an important function for the research community to provide the early stage scale-up.

Reviewer 3:
The reviewer remarked that this facility is a great service to the energy storage community, including academic, industrial, and government institutions. The team is well qualified to run the facility.

Reviewer 4:
The reviewer thanked the project team because this was one of the few presentations the entire day where error bars were included on graphs. The reviewer appreciated the analysis of volumetric energy density fade, this is an interesting way to look at the results that the reviewer believes add value when thinking of a solution to the problem. The reviewer observed a careful, thoughtful approach to experimentation and data analysis. The comparison of pouch to coin cells is very important. The reviewer pointed out that researchers need to be able to use small format/easy to construct cells for early R&D and be confident it will translate

Reviewer 5:
The reviewer hoped that one or more pre-lithiation concepts graduates to CAMP and is not bogged down by intellectual property concerns.

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

Reviewer 1:

The reviewer commented that the fabrication of matched electrodes for distribution to other laboratories is enabling, both for materials being available and including protocols for cycling performance and analysis.

Reviewer 2:

The reviewer said that the team has carried out high quality work, from designing electrodes to studying Si anodes extensively for use in EVs as well as providing electrodes to various partnering organizations who themselves are trying to develop next generation cell technologies. The work on Si has been significant and thorough. The reviewer noted that of course there has not been any breakthrough result as yet, but this is a challenging task around the globe and studies carried out at CAMP will certainly help in better understanding the factors that will help us in developing a robust Si electrode.

Reviewer 3:

The reviewer commented clearly a lot of work by a very competent team, and guessed that each separate effort could have filled a presentation

Reviewer 4:

The reviewer noted that the facility has supplied materials and electrodes to many projects at ANL and beyond. The reviewer expressed concern that little was discussed with respect to quality control of the fabrication process. For these scale-up to be impactful, the performance of the tapes and cells have to be truly state of the art. This is very hard to do given the rapidly maturing manufacturing technologies. The reviewer asked how much benchmarking has the project done as compared to commercial products, and would like to know what the details of the quality control are.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that collaboration with other institutions is impressive. Many groups are involved and benefit from the work done at the CAMP facility.

Reviewer 2:

The reviewer said that the list of collaborating teams is quite extensive and impressive, spanning new and well-known material suppliers and coating companies, some of whom are entering the battery field for the first time The reviewer was reassured to learn that these companies have access to very standardized fabrication and test protocols.

Reviewer 3:

The reviewer remarked that the facility is well integrated with the research community in academia and national laboratories. The reviewer pointed out that the difficulty in working with industrial leaders is understandable, but the team needs to be creative to address the issue.

Reviewer 4:

The reviewer remarked pretty impressive, and would be interested on guidance based on successes and failures with regard to what problems/projects are likely to have impact and be well received under the open source constraints.

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

Reviewer 1:

The reviewer remarked that the list of proposed work is quite comprehensive, and the work on Si and other next-generation anode and high energy cathodes with the max impact will be most interesting to follow in the future.

Reviewer 2:

The reviewer wondered if this may be the right facility to look at formation process optimization and whether all the fuss over electrolyte additives and formation conditions is making a difference.

Reviewer 3:

The reviewer encouraged the team to come up with creative solutions to access technologies from industrial leaders. The reviewer said that it is very challenging but has to be done.

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

Reviewer 1:

The reviewer said that enabling intermediate-format testing of materials in non-flooded cell environments allows for a more realistic evaluation of new materials for many groups who would not otherwise have the resources to do so. This project, in this reviewer's opinion, is of the utmost importance for continued support.

Reviewer 2:

The reviewer said that the project supports DOE objectives of petroleum displacement. The CAMP offers a platform to many researchers for scaling up new battery materials and independently testing at the cell level.

Reviewer 3:

The reviewer said that the facility is an integral part of maturing technologies in the battery space.

Reviewer 4:

The reviewer commented that this program includes material development and techniques that could span many other efforts in the development of new materials for high-energy density batteries

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

Reviewer 1:

The reviewer said that the funds seems to on the high side considering the fact that CAMP had done a lot of work for outside partners who the reviewer is sure paid for their own work.

Overview and Progress of United States Advanced Battery Consortium (USABC) Activity: Ron Elder (United States Advanced Battery Consortium) - es097

Presenter
Ron Elder, United States Advanced Battery Consortium

Reviewer Sample Size
A total of six reviewers evaluated this project.

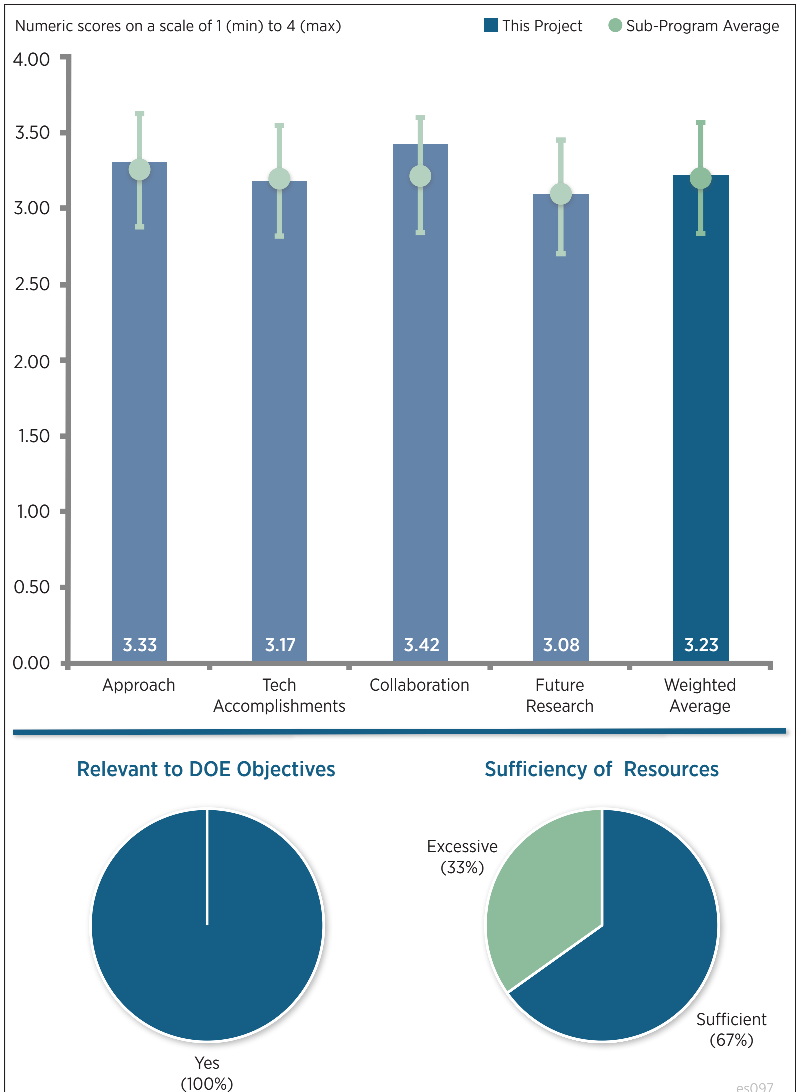

Figure 2-3 – Overview and Progress of United States Advanced Battery Consortium (USABC) Activity: Ron Elder (United States Advanced Battery Consortium) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer said that the United States Advanced Battery Consortium (USABC) with DOE's full support is undoubtedly taking the leading role in advancing the state-of-the-art in automotive battery technology.

Reviewer 2:
The reviewer commented that USABC has been very productive in fostering domestic battery technology development. The reviewer would like to know more about its plan on working differently with startups versus established businesses. Startups face significant financial and schedul challenges and could use every bit of help they can get from USABC.

Reviewer 3:
The reviewer said that USABC has provided a significant amount of funding for the industrial partners to develop new energy storage technologies for EVs. The funding mechanism has been proven critical for the development and introduction of the new vehicle technologies, which would otherwise take a long time.

Reviewer 4:
The reviewer appreciated the scope of projects for EVs, PHEVs, start-stop, etc. The reviewer said that we need these efforts to ensure development across applications. The reviewer expressed a concern about the high level of administrative/review to project work, which USABC seems to be addressing

Reviewer 5:
The reviewer noted that the objective is to develop advanced electrochemical energy technologies for EVs, PHEVs and 12 Volt (V) start-stop. The approach is to leverage U.S. Council for Automotive Research (USCAR) OEMs,

national laboratories, and industry to develop the components and materials. The reviewer noted that performance goals were summarized in tables. The reviewer said that the RFPI schedule, along with the RFPI task descriptions, were clear. Five years is reasonable to develop mitigations for cost, calendar life and cycle life barriers. The reviewer said that the RFPIs cover a wide scope, ranging from materials, testing and system components. This USABC program appeared to have a lot of overlap with the other DOE vehicle energy technology programs. The reviewer recommended that USABC should focus on accelerating the maturity of technologies at the system level while DOE programs focus on the basic and applied R&D level.

Reviewer 6:

The reviewer noted that the process for application and review is excessive. Decisions on funding should be made earlier in the process. The reviewer said that the use of DOE targets for short-term projects is unrealistic, and a realistic set of performance targets should be used.

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

Reviewer 1:

The reviewer said that USABC is selecting all highly pertinent topics from an automotive applications points of view. The reviewer commented that unlike before, it is good to see that USABC is funding projects on all types of energy sources and key components.

Reviewer 2:

The reviewer noted that USABC selectively funded a few industrial development programs. The programs covered the major area of vehicle applications. The reviewer suggested that as a DOE program, USABC should focus more on U.S.-owned and U.S.-based industries.

Reviewer 3:

The reviewer said that the metrics for evaluations of applications were provided, but more information is needed to allow for an appropriate review. The reviewer asked, out of the initial inquiries, what percent of applicants continued to the full application, and of applicants who finished the application, what percent were funded. The reviewer asked what the range of scores in evaluation was, and what the cutoff for funding was. The reviewer asked when companies did not meet requirements, where did they fail. Additionally, the reviewer noted that other qualitative descriptions were provided instead of numerical data. The reviewer inquired what accomplishments have truly been made by the funded researchers. The reviewer said that data should be provided for improvements, for example, if higher voltages have been accessed through improvements in electrolytes, how was this determined, and provided as an example cycle life with one electrolyte versus another in the same condition.

Reviewer 4:

The reviewer would like to hear about the project accomplishments, not just the fact that USABC kicked off a specific number of them. The reviewer said that it is difficult to judge the value of USABC funding without hearing about the specific progress made within the technical development projects.

Reviewer 5:

The reviewer said that USABC updated test manuals and funded companies to develop the materials needed to mitigate the aforementioned barriers. The reviewer pointed out that although the goals were presented, current status (two years into a five-year program) against those goals was not presented, thus it was difficult to gaug progress on the mitigation of barriers.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed good collaboration between car OEMs, DOE, national laboratories, and industry.

Reviewer 2:
The reviewer said that by its very nature, USABC requires collaboration, and that the team appears to engage well with a variety of collaborators.

Reviewer 3:
The reviewer said that USABC-sponsored programs are diversified, which involved the collaboration of government labs and industry.

Reviewer 4:
The reviewer said that while benchmarking and development efforts are well selected, it will be good to see more engagement from overseas suppliers such as the Japanese. However, the process needs to be made friendlier to attract more participation. The reviewer said that financial due diligence is a serious burden on many companies, as is the 50/50 cost-share.

Reviewer 5:
The reviewer remarked that a limited set of companies was included. The reviewer asked about the major players, like Tesla, and wondered if this application process is too onerous for them to participate. If not, the reviewer would like to know why Tesla is not included.

The reviewer pointed out that eliminating smaller companies as a result of the cost share requirement may reduce unique ideas. The reviewer would like to know what validation USABC has that cost share requirements lead to better projects, participation, and results.

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

Reviewer 1:
The reviewer said that there is a good list of topics.

Reviewer 2:
The reviewer said that it is a good idea to encourage collaboration teams to address cost, calendar life, and cycle life barriers. The reviewer remarked that it is also a good use of USABC resources to increase scale-up of promising technologies.

Reviewer 3:
The reviewer commented that the USABC proposal to update the manuals for test methods and cost models are very useful, and the development of cost reduction manufacture process is critical for American manufacture industry to remain competitive. The reviewer remarked that more detailed plans should be presented.

Reviewer 4:
The reviewer remarked that the plan for modifying the application process was unclear. The reviewer said that no numerical values or specific ta gets were provided, so it will be difficult to know if improvements were met. The reviewer commented that the goal of improving the process is too vague for this reviewer to have confidence in knowing that effective changes will be made.

Reviewer 5:
The reviewer acknowledged not seeing reference to what (from a project portfolio perspective) USABC would be looking for in the future. The reviewer knows that USABC has a roadmap, but according to the reviewer it was not emphasized in this presentation and there was not a link presented between projects being funded to this roadmap

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

Reviewer 1:
The reviewer remarked highly relevant for the DOE objective of petroleum displacement by developing advanced electrochemical energy technologies.

Reviewer 2:
The reviewer commented that by enabling funding of research at companies involved in battery research, it is likely that some improvements will be made in LIB performance.

Reviewer 3:
The reviewer said that projects were mainly focused on improvement in energy density or cost reduction of alternatives to petroleum

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

Reviewer 1:
The $125 million/5 years of effort was appropriate given the amount of work and teams involved.

Reviewer 2:
The reviewer thought that these funds would be better allocated by DOE directly, instead of through the USABC.

Reviewer 3:
The reviewer said that without knowing more details on the technical projects, this is difficult to assess. The reviewer said that it does seem like there are an excessive amount of resources directed to reviewing and re-reviewing proposals.

Thick Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing: Jianlin Li (Oak Ridge National Laboratory) - es164

Presenter

Jianlin Li, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

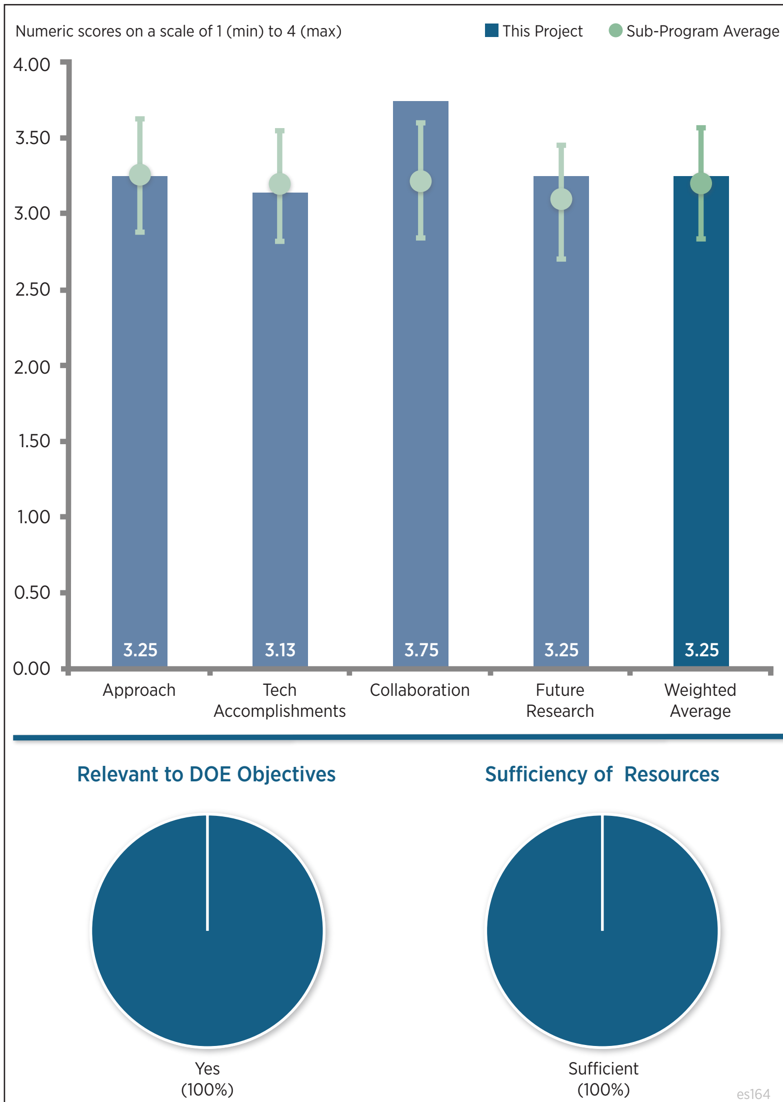

Figure 2-4 – Thick Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing: Jianlin Li (Oak Ridge National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer said that the program appears to cover all of the challenges associated with moving to an aqueous-based electrode coating process.

Reviewer 2:

The reviewer said that at this stage of the project, it will be helpful to incorporate statistical analyses tools and compare results for different cathode families. In addition to using internal baseline, it is important to do benchmarking. The reviewer said that it is strange to see the data on Slide 9 where the industrially processed electrode sheet is so inferior.

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

Reviewer 1:

The reviewer found that overall, progress is impressive. The benefit for the industry will be enhanced through the use of the experimental design tools where interactions between the parameters studied could be assessed and quantified. The reviewer said that this will also improve focus on the program objectives.

Reviewer 2:

The reviewer remarked that establishing the theoretical improvement of heat load for drying on N-Methylpyrrolidone (NMP) versus water calls into question the potential of the process improvement targets. There may be other benefits, including the environmental ease of handling water versus NM , however the cost savings may not be part of those benefits. The reviewer said that it does not appear that any lack of progress has contributed to the questionable target, but rather some initial errors in the initial evaluation of the potential improvement such a system could offer.

Reviewer 3:
The reviewer asked if the 15% cost reduction is really relevant and does it justify changes to the process.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer gave kudos for the great team assembled.

Reviewer 2:
The reviewer said that there appears to be a comprehensive list of appropriate collaborators across the spectrum of process, materials and end users.

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

Reviewer 1:
The reviewer said that proposed future research is well aligned with program objectives.

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

Reviewer 1:
The reviewer said that it is necessary to address and justify the significantly lower cost reduction expectations to move further.

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

No comments were received in response to this question.

Performance Effects of Electrode Coating Defects and IR Thermography NDE for High-Energy Lithium-Ion Batteries: David Wood (Oak Ridge National Laboratory) - es165

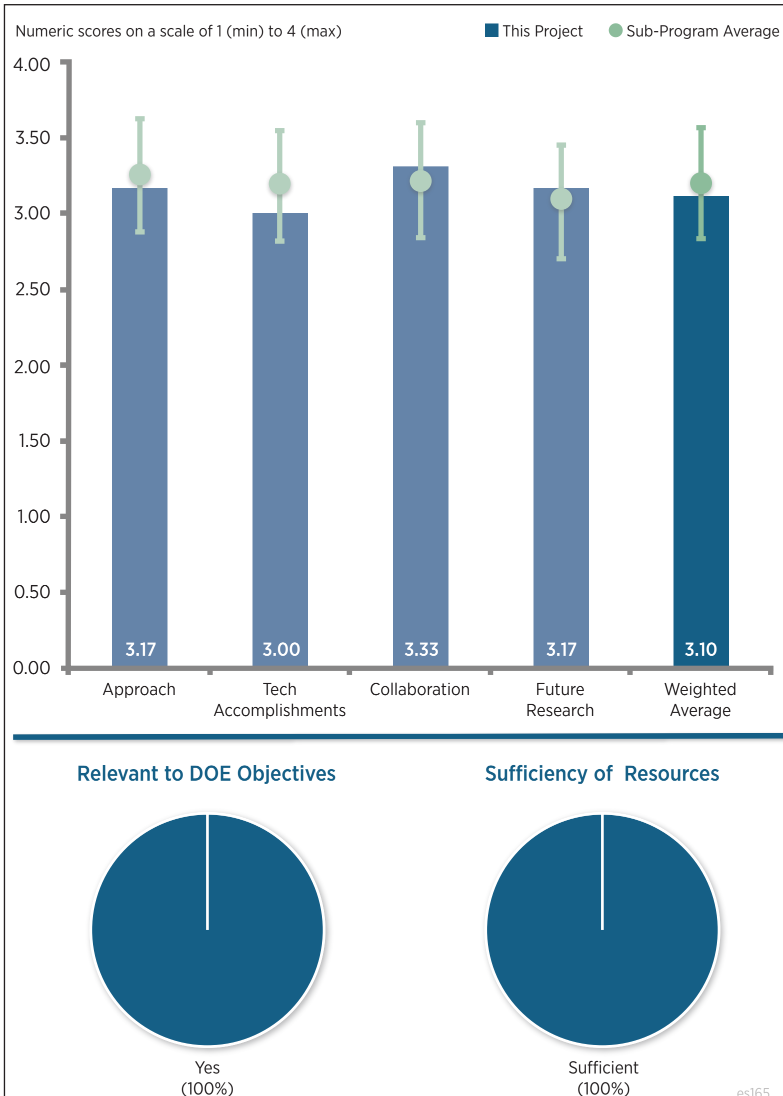

Figure 2-5 – Performance Effects of Electrode Coating Defects and IR Thermography NDE for High-Energy Lithium-Ion Batteries: David Wood (Oak Ridge National Laboratory) - Electrochemical Energy Storage

Presenter

David Wood, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

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

Reviewer 1:

The reviewer described that quantifying the types and effect of coating defects can have a large impact on the quality and cost of electrode manufacturing. The reviewer said that it seems critical in this program that the results are relevant and transferable to commercial manufactures as they are the location that will ultimately be able to translate the finding to real cost advantage.

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

Reviewer 1:

The reviewer stated that the target defects appear to be identifiable with the approaches developed. The reviewer assumed that these are the correct target defects.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer detailed that the fact there is real collaboration with commercial entities is good. It is critical for this program to make sure that it is working on a capability that does not currently exist in the industry as well as working within production parameters (line speed, coating process etc.) that are commercially relevant. The reviewer concluded that with that in mind, the list of commercial end users (those actually coating electrodes in commercial environments) could be stronger.

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

Reviewer 1:

The reviewer reiterated that it is critical to address areas that are not currently available in the commercial world, as well as to address areas on where the industry is going rather than where it has been.

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

No comments were received in response to this question.

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

No comments were received in response to this question.

Post-Test Analysis of Lithium-Ion Battery Materials at Argonne National Laboratory: Ira Bloom (Argonne National Laboratory) - es166

Presenter
Ira Bloom, Argonne National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

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

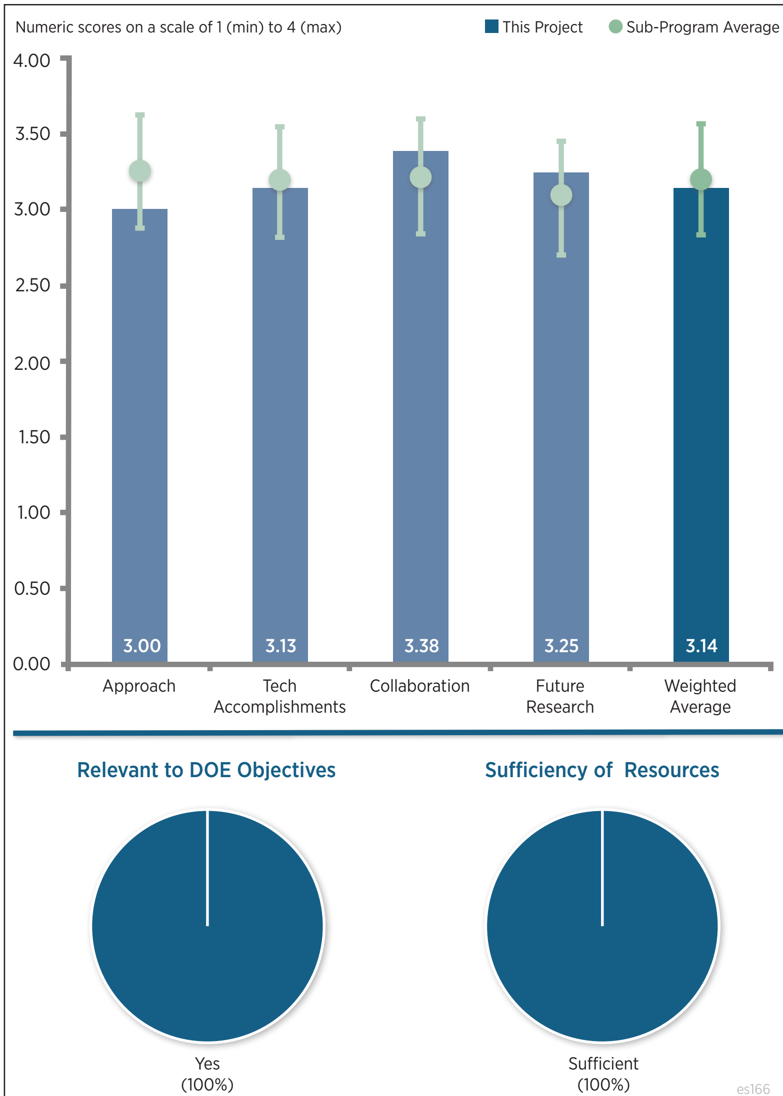

Figure 2-6 – Post-Test Analysis of Lithium-Ion Battery Materials at Argonne National Laboratory: Ira Bloom (Argonne National Laboratory) - Electrochemical Energy Storage

Reviewer 1:
The reviewer was very glad to see this being studied in detail, and commented that the project plays to ANL's strengths. The reviewer said that it would be better to use commercial electrodes, but the reviewer understands the challenges in doing that.

Reviewer 2:
The reviewer commented that the consortium is much needed to understand the effect of Li-ion materials after abusive conditions and to understand the impact of processing methods on cell performance. Three years is reasonable schedule for this effort.

The reviewer remarked that quantifiable milestones and go/no-go decision points were not provided. This program appears to have some overlap with Wood's effort at Oak Ridge National Laboratory (ORNL) to examine effect of processing conditions (e.g., electrode coating) on performance.

Reviewer 3:
The reviewer said that this program shades a bit toward a testing capability looking for a mission, and asked who the gatekeeper is for what to evaluate, and what criteria/decision process is used to initiate an evaluation. The reviewer suggested that the project team consider looking at formation and/or other places OEMs may be paying for quality or process control that we may not need, and cited robust engineering principles. The reviewer asked what the meaningful changes are in cell design or chemistry that should warrant requalification by customers, or by regulators. The reviewer asked what limitations there are on this front if restricted to open source bill of materials (BOM), processing, and fabrication equipment/tooling.

Reviewer 4:

The reviewer expressed uncertainty (at least from the presentation) how participants are planning to prepare samples for testing, and which processing parameters, beyond two types of chemistries and two types of solvent, will be evaluated. The reviewer asked if there is a detailed experimental plan in place.

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

Reviewer 1:

The reviewer said that the work done on the baseline cells looks good and in line with project objectives.

Reviewer 2:

The reviewer noted that the project is still early, so it is not fair to judge. The reviewer suggested that the project team not proceed until the team gets the electrode quality issues figured out. The reviewer said that the team should be able to make high quality anodes with NMP processing.

Reviewer 3:

The reviewer said that the team established effective experimental methods (e.g., Fourier transform infrared spectroscopy and impedance) for post-mortem analysis. The reviewer expressed uncertainty if some of the electrode issues (rippling, pin holes) were specific to ANL's coating process or were they caused by materials. The reviewer cited that ANL's study showed that aqueous process produced anodes had higher impedance than that of NMP. However, aqueous process has been used to produce good anode in commercial cells. Thus, according to the reviewer, it was not clear how applicable the insights learned from ANL's study were.

Reviewer 4:

The reviewer said that the project is still early, and was not clear on how copper (Cu) corrosion is tied to failure mode, whether through delamination, impedance gain, or electrochemical activity. The reviewer asked what the role of residual moisture and electrode drying operation is.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked excellent team with synergetic capabilities.

Reviewer 2:

The reviewer observed a great team with the perfect skill sets to tackle this project.

Reviewer 3:

The reviewer noted good collaboration between ANL, ORNL, and Sandia National Laboratories (SNL). The roles of each team member were clearly identified to justify their participation in the project

Reviewer 4:

The reviewer remarked that there seems to be good lab coordination, but these presentations tended to just post long lists of contributors and not defined roles or RASIC (Responsible, Approving, Supporting, Informed, and Consulted). The reviewer said that it starts to look like every national laboratory investigator throws in on every program to avoid being cut out. The reviewer remarked that it might help to have some internal competition/incentives and more defined roles. The reviewer also noted that the SNL abuse test role seemed downplayed.

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

Reviewer 1:

The reviewer commented that the proposed effort to understand the effect of aging and abusive conditions, e.g., overcharging, on Li-ion materials is much needed.

Reviewer 2:
The reviewer said that proposed future research has good focus and understanding, and that it is important to start including statistical tools like design of the experiments to understand the interaction between parameters studied.

Reviewer 3:
The reviewer said that the project reflects thoughtful experimentation to ensure final results will be meaningful e.g., getting good electrode quality. The reviewer noted that it is important to develop and validate all procedures. The reviewer asked if the project team could use commercial materials for the validation.

Reviewer 4:
The reviewer said that proposed future research could be better focused.

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

Reviewer 1:
The reviewer said that we need to address safety as we move towards higher energy materials and cells.

Reviewer 2:
The reviewer remarked that understanding the effect of aging and abusive conditions on Li-ion materials is very relevant to achieve reliable cell performance.

Reviewer 3:
The reviewer commented that this program is very important in aiding the fundamental understanding of the complex events in the cell causing its failure.

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

Reviewer 1:
The reviewer commented that it is great to see young scientists being trained by the best in this field

Reviewer 2:
The reviewer said that the $1.1 million/year for three years should be sufficient for this e fort.

Reviewer 3:
The reviewer said that once electrode issues are solved, this team has the skills to do the safety testing and analytical work required. The reviewer remarked that it looks like this project evaluates combinations of existing materials, and is not new material development.

Reviewer 4:
The reviewer would advocate for more emphasis on abuse testing and root cause failure, but acknowledged that this can be resource intensive if doing multiple large format cells and extended cycling on channels that can handle high capacity.

Process Development and Scale-Up of Advanced Active Battery Materials: Greg Krumdick (Argonne National Laboratory) - es167

Presenter
Youngho Shin, Argonne National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

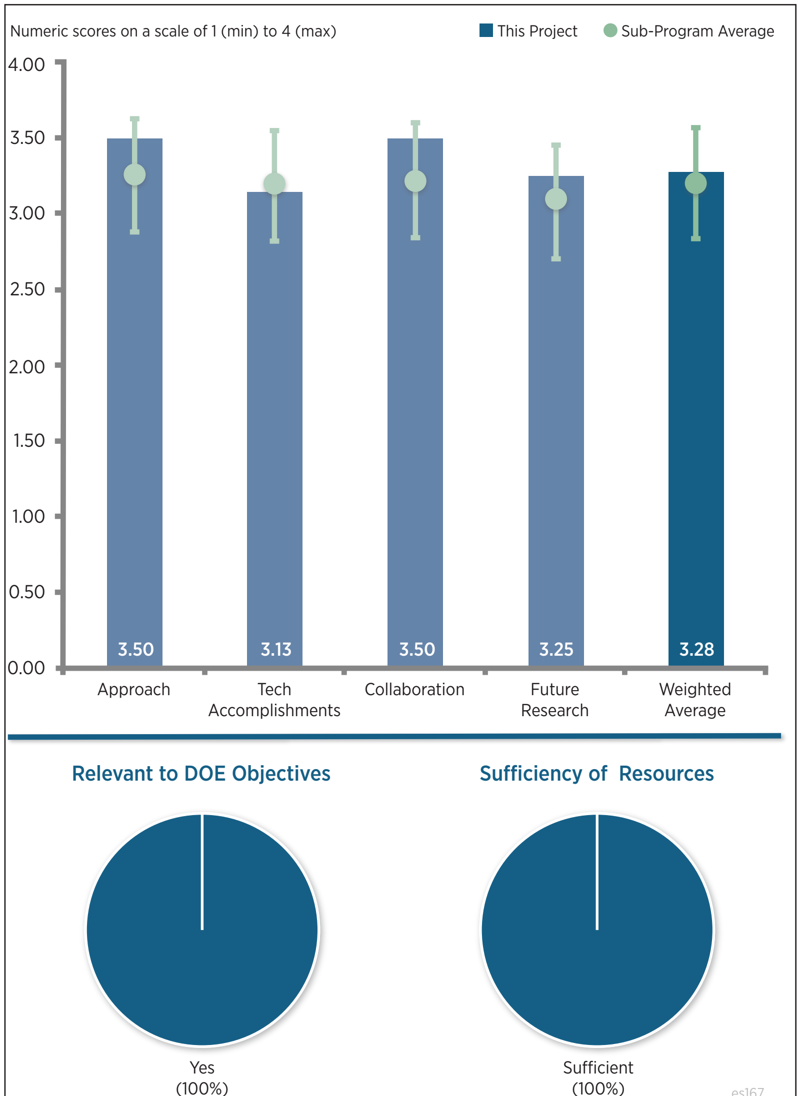

Figure 2-7 – Process Development and Scale-Up of Advanced Active Battery Materials: Greg Krumdick (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer remarked outstanding performance meeting the needs of the industry and research community while adding value to ANL's thorough licensing strategies.

Reviewer 2:
The reviewer said that providing consistent program scale volumes of advanced materials is a worthy goal to support ongoing development within the community. The reviewer said that it would be interesting to have more visibility into the process of how the target materials are determined in the first place. The development of any single material is an enormous commitment, so choosing the target materials seems as if it should be a highly critical step in the process.

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

Reviewer 1:
The reviewer remarked excellent use of the statistical tools for the optimization work. It is important to conduct comparison/benchmarking studies versus the industrially produced materials.

Reviewer 2:
The reviewer commented that the identified ta get materials appear to have been successfully developed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the list of the collaborators demonstrate the trust this group has earned, well done. It will be interesting to see the performance of the commercialized products.

Reviewer 2:
The reviewer commented that there appears to be reasonable collaboration with various process and equipment partners, and there could be better collaboration with the target material audience, particularly in the commercial arena.

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

Reviewer 1:
The reviewer said that proposed future research is well-balanced to meet the program objectives.

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

Reviewer 1:
The reviewer commented that this program plays a supporting role in supplying critical materials for advanced development activities.

Reviewer 2:
The reviewer said that the project addressed the gap between research, development, and commercialization.

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

Reviewer 1:
The reviewer said highly qualified, hard-working team

Process Development and Scale-Up of Critical Battery Materials: Greg Krumdick (Argonne National Laboratory) - es168

Presenter

Krzysztof Pupek, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

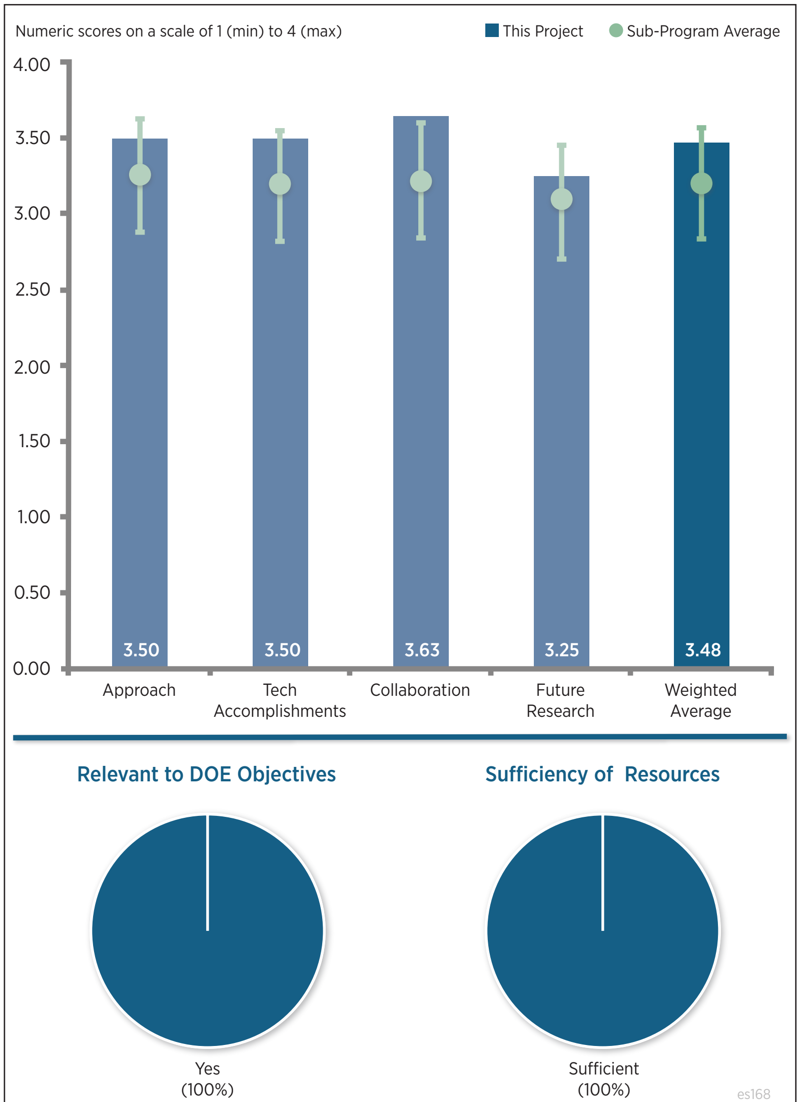

Figure 2-8 – Process Development and Scale-Up of Critical Battery Materials: Greg Krumdick (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer remarked impressive systematic engineering approach, sharp focus on the objectives.

Reviewer 2:

The reviewer pointed out that in order to provide critical advanced materials to the community, critical process developments must occur in areas where common material will be made. The focus on processes for fluorinated solvents and salts, and for advanced binders, appears to be a good choice as an area of development. The reviewer commented that as always in this type of program, the choice of target is critical as it is a long-term commitment to develop even pilot level processes, so the choice of areas must be relevant to the industry both today and tomorrow.

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

Reviewer 1:

The reviewer said that a number of unique materials were developed that can be applied to the advanced development efforts.

Reviewer 2:

The reviewer commented that the program meets DOE’s needs and fills in the gaps between R&D and commercial efforts.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that bringing on board a large-scale manufacturer will further increase the project value, and that establishing licensing revenue is impressive.

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

Reviewer 1:

The reviewer said that the pipeline is well balanced.

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

Reviewer 1:

The reviewer commented that the project is filling the gaps and reducing the risks.

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

No comments were received in response to this question.

Electrochemical Performance Testing: Ira Bloom (Argonne National Laboratory) - es201

Presenter

Ira Bloom, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

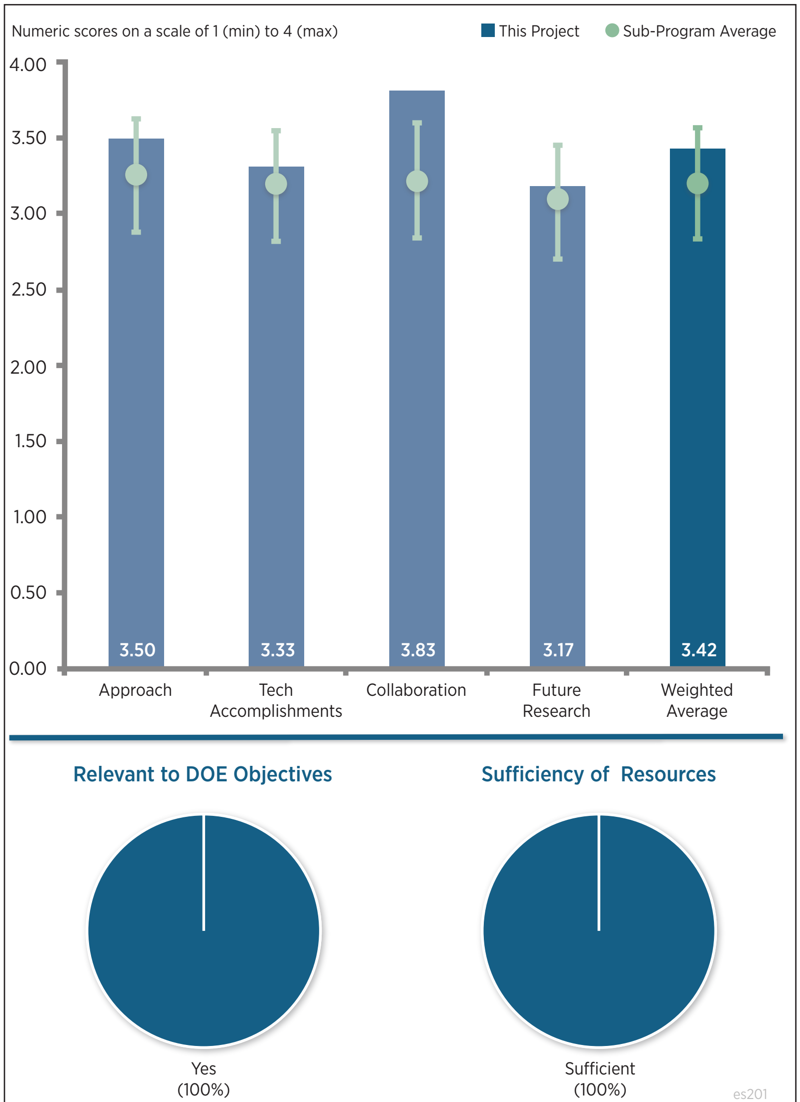

Figure 2-9 – Electrochemical Performance Testing: Ira Bloom (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer stated that the electrochemical cycle testing is the best way to verify that money spent on battery material and especially cell invention and development does in fact do what is claimed, and to authoritatively compare those results to commercial, state of the art performance and cell or material goals. The reviewer concluded that this work thus helps approach many of the barriers.

Reviewer 2:

The reviewer said that the study of the different international test standards is very interesting. It would be nice to see this this done on more standards beyond the United States and China. The reviewer said that for the fast charging test, the data should be plotted as a function of ampere hour (Ah) throughput. This may help make more sense of the idea that the fast-charge test profile seems to cause an increase in aging over the constant-current profile. Also, the use of another chemistry type such as NMC/carbon for the standard comparison study would be more relevant to the United States.

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

Reviewer 1:

The reviewer said that as mentioned above, it would be nice to see more a few more standards included in the study. Other than that, the reviewer characterized the benchmarking work was excellent. The testing done at the national laboratories is an important non-biased source of data for these technologies.

Reviewer 2:

The reviewer said that ANL is conducting ongoing and new testing on many cells. The comparison of U.S. and China protocols is interesting, but would be more useful if it were then used to harmonize regulation or methods. The reviewer commented that assistance in fast-charge protocol is important and of increasing importance in the future.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer pointed out that ANL has a wide range of partners with several partners in each of the areas.

Reviewer 2:

The reviewer said that this project collaborates with many different organizations including cell makers, vehicle makers, the USABC, and others. ANL creates an important independent source of data to compare technologies from many different developers.

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

Reviewer 1:

The reviewer said that continued electrochemical testing is appropriate and well planned.

China test work would benefit from a partner who can help use it to harmonize testing. The reviewer understands that is the goal, but ANL would benefit from the help of say the Society of Automotive Engineers (SAE) or some other organization that can help navigate the international harmonization waters.

Reviewer 2:

The reviewer remarked that the national laboratories will continue to be an important source of independent data for the industry. While the collaboration with the Chinese labs is interesting, the reviewer expressed uncertainty if more testing with lithium-iron phosphate (LFP) is very interesting for the U.S. market. That chemistry is not often used here.

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

Reviewer 1:

The reviewer said that this testing basically determines which chemistry is ready for marketing and thus participates in petroleum displacement.

Reviewer 2:

The reviewer stated yes and reiterated that the independent test data produced by the national laboratories is of a very high quality and an important source of information for the industry.

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

No comments were received in response to this question.

INL Electrochemical Performance Testing: Matt Shirk (Idaho National Laboratory) - es202

Presenter

Matt Shirk, Idaho National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

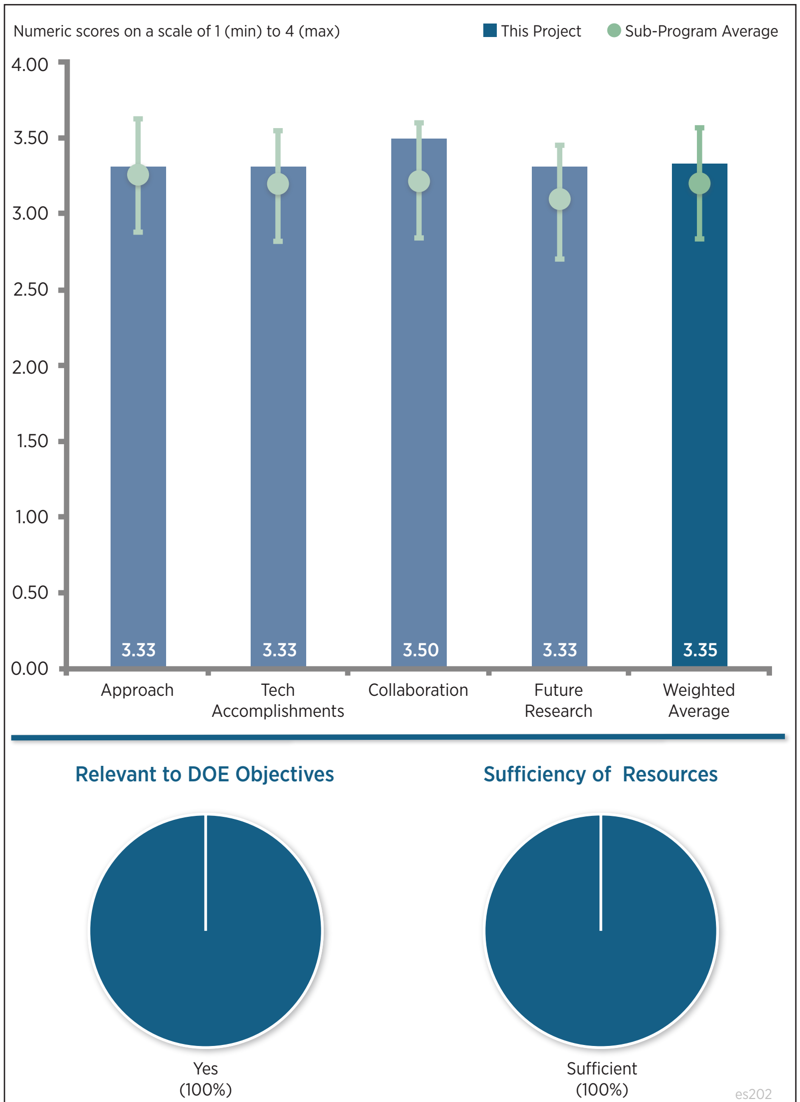

Figure 2-10 – INL Electrochemical Performance Testing: Matt Shirk (Idaho National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer said that electrochemical testing supports almost all the barrier-surmounting efforts by validating the results, so this supports all the cell and material work. The manuals the project team support help and guide research internationally and so effectively leverage other country's efforts toward DOE goals.

Reviewer 2:

The reviewer stated that the national laboratories are an important source of independent test data for the battery development programs conducted through the various DOE funding opportunities. To the extent that it is possible, due to restrictions on the data etc., the reviewer said that it would be nice to see comparison work done between the different cells tested. If the cells tested are all tested to the same test manuals, Idaho National Laboratory (INL) would be in the best position to understand what the state of the art is, and how each technology performs relative to that standard.

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

Reviewer 1:

The reviewer said that the project is probably the best (if by only a small margin) electrical test work at DOE, and the team has a large number of cells on the test, and are developing new tests such as vibration impacts on cells. At the same time, INL holds the lion's share of the test manuals, many of which were recently updated.

Reviewer 2:

The reviewer said that the slide/study on memoryless aging was very interesting. The reviewer would like to see a similar study with NMC only cathodes, as LMO has known calendar aging issues that may affect the results. The reviewer also expressed an interest to see a similar study with combinations of cycling and calendar aging. The reviewer also thinks that it is important to include the capacity fade information as well as the resistance rise, even though the memoryless aging is unlikely to exist when it comes to capacity fade.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that coordination with all the other research programs, laboratories, USABC, DOE, etc., is outstanding. As mentioned before, the independent testing at the national laboratories is a great contribution to the battery R&D community.

Reviewer 2:

The reviewer said that collaboration is great with government and industry, and decent with universities.

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

Reviewer 1:

The reviewer said that proposed future research is appropriate for their mission.

Reviewer 2:

The reviewer remarked that INL maintains a state-of-the-art test facility, and that it is a good idea to think ahead about what new equipment will be needed to test future technologies. The reviewer also pointed out methods for measuring the swelling of Si containing cells under cycling, high current channels for the next generation of 12V cell testing, and combination vibration and cycling testing, possibly in a temperature controlled environment.

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

Reviewer 1:

The reviewer remarked that by helping USABC bring improved batteries to market, INL is definitely helping displace petroleum.

Reviewer 2:

The reviewer commented yes, the data produced from this program is critical to the success of the DOE battery programs.

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

Reviewer 1:

The reviewer pointed out that INL is on the edge of needing more facilities and staff as the load of new materials and cells to test grows.

Battery Safety Testing: Leigh Anna Steele (Sandia National Laboratories) - es203

Presenter

Leigh Anna Steele, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

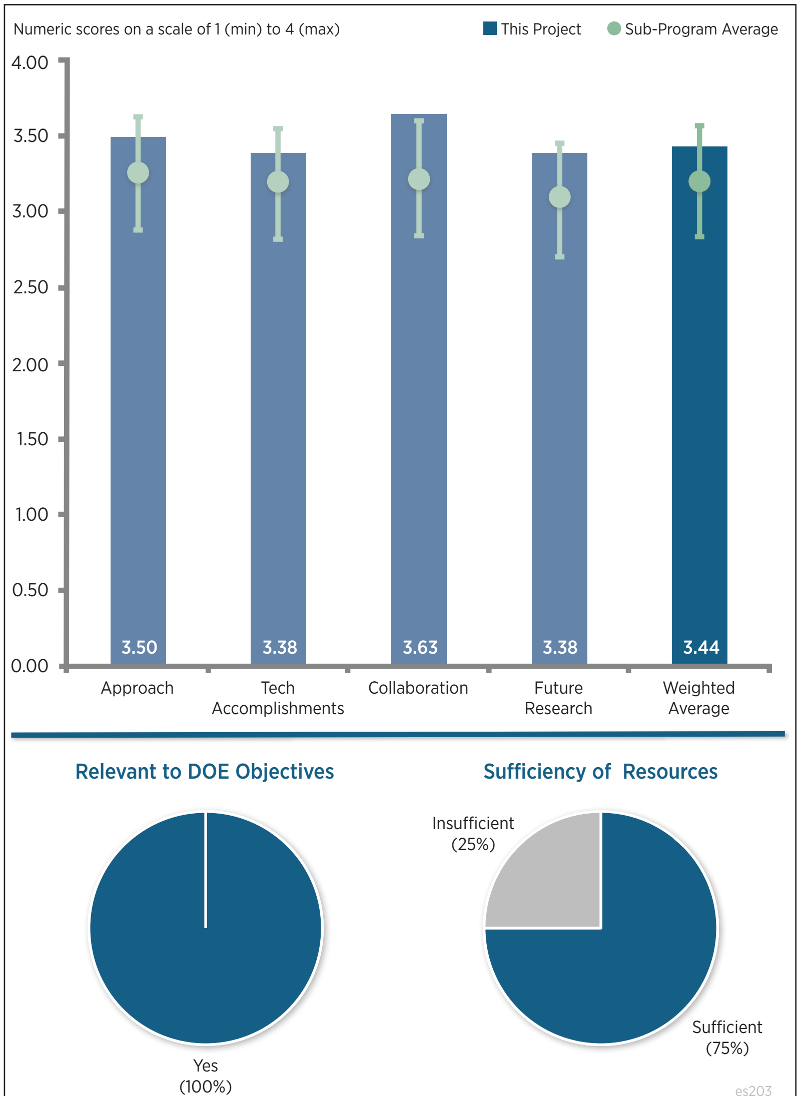

Figure 2-11 – Battery Safety Testing: Leigh Anna Steele (Sandia National Laboratories) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer affirmed that this group is the gold standard for safety and abuse testing. The project team plays a dramatically powerful role in getting batteries in vehicles and consumer times, without their data the risk would outweigh the possible benefits. The reviewer said that the team directly attacks the abuse response but also contribute to the durability evaluation and thus support the progress of all the other work done on new materials by ensuring they can focus on acceptable chemistry.

Reviewer 2:

The reviewer said that the approach seems solid. The reviewer expressed one concern related to the propagation experiments, specifically that the nail penetration (mechanical initiation) and the laser penetration methods are both very abrupt in the initiation. This provides an extremely fast temperature ramp-up that is rarely seen in real-life incidents. The reviewer noted that in particular, a common failure mode in real life is that a weak cell (low capacity) in an array can go into overcharge if a voltage monitoring failure occurs and that can precipitate a Li deposition-shorting mechanism and a slower temperature ramp-up as Li bridges are made and broken due to localized heating. The reviewer believed that this could be approached by a deliberate overcharging of a single cell in center or edge location and observe propagation.

Reviewer 3:

The reviewer commented that SNL continues to be the leader in the field of battery abuse testing. The work done there, specifically in developing and studying battery abuse test procedures, is extremely valuable to the field of battery R&D and commercialization. The reviewer said that it would be nice to see the work move beyond cell level testing and into larger module level testing in order to help the industry create best practices when dealing with larger test items.

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

Reviewer 1:
The reviewer observed very solid results.

Reviewer 2:
The reviewer commented that the progress in the testing of DOE-sponsored cells is well done, critical, and voluminous. The team also supported modeling work and are exploring an emerging problem of failure propagation as well. The reviewer remarked there is not much more that could be asked of the team available.

Reviewer 3:
The reviewer remarked that the short circuit/propagation work is very interesting. The reviewer would like to see more cell formats tested, particularly larger format pouch and prismatic can cells. The reviewer thought that the choice of cell cathodes is not optimal. NMC or nickel cobalt aluminum oxide (NCA) or blends containing NMC/NCA/LMO would be more relevant to the transportation industry.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer pointed out that in particular, the collaboration with the National Renewable Energy Laboratory (NREL) and the modeling program is very valuable. The reviewer asked if it would be possible to see some appraisals from customers of their satisfaction with test protocols and results.

Reviewer 2:
The reviewer commented that SNL does a great job of collaborating with other institutes, and the reviewer is looking forward to seeing the outcome of the continued collaboration between the experimental work at SNL and the modeling work at other national laboratories.

Reviewer 3:
The reviewer remarked that the team works with government, academic, and industry groups too numerous to mention in this box.

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

Reviewer 1:
The reviewer said that the proposed future research is not sexy but it is what the project team should be doing. The reviewer noted that staying in your swim lane and doing it well is important.

Reviewer 2:
The reviewer would like to see some studies on liquid coolant effects with regards to runaway propagation. The reviewer asked if the ten-pin array could be modified to include coolant in the air gap space.

Reviewer 3:
The reviewer reiterated comments that it would be nice to see larger cells and more automotive relevant chemistries included in the future work.

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

Reviewer 1:
The reviewer commented that this is one of the most important DOE programs to support the objectives as safety is paramount to achieving public acceptance of electric powered vehicles.

Reviewer 2:

The reviewer said that without question the project supports the goal. Without understanding the response to abuse conditions, much more engineering structure would be needed to ensure safety in vehicles and would probably raise the cost, mass and volume past a saleable point. The reviewer emphasized that this is key support.

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

Reviewer 1:

The reviewer would like to see the abuse program at SNL expanded. These data are very important to the development of battery technologies for transportation and the reviewer believed the funding level is low relative to the importance of the work to the industry.

Reviewer 2:

The reviewer qualified that the backlog the project team has points to the lab being on the edge of what is needed to provide appropriate investigation of enough batteries to hit project milestones, and more to the point to support the work that needs to be done outside the contract shown in this poster. The reviewer thought that added facilities and staff would be money well spent.

Battery Thermal Characterization: Matthew Keyser (National Renewable Energy Laboratory) - es204

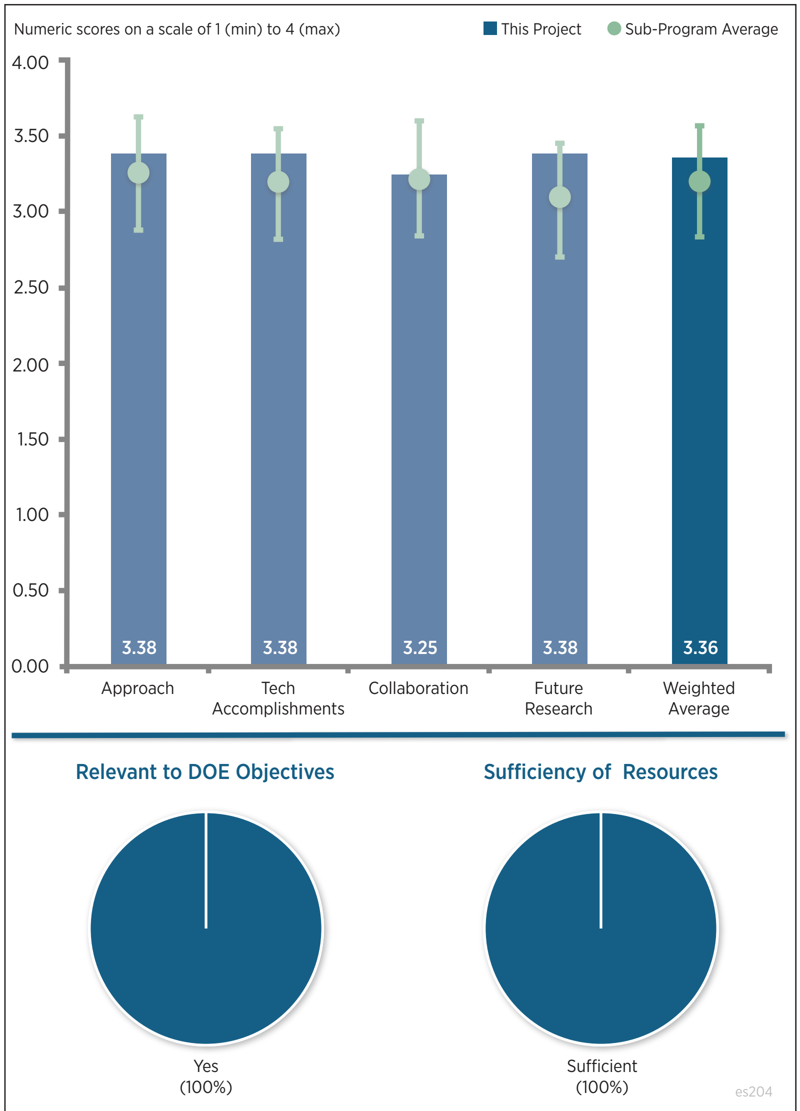

Figure 2-12 – Battery Thermal Characterization: Matthew Keyser (National Renewable Energy Laboratory) - Electrochemical Energy Storage

Presenter
Matthew Keyser, National Renewable Energy Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

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

Reviewer 1:
The reviewer described NREL as the world's best thermal characterization lab and group, most likely. The reviewer certainly trusts their work over all others. The project team is helping get batteries into commerce by overcoming all the barriers that internal and asymmetric heat generation cause.

Reviewer 2:
The reviewer said that the experimental approach is good based on the use of calorimetry as a key technique in evaluating battery function. The reviewer would like to see a comparison with other methods such as impedance analysis to separate the various components such as Joule heating and entropic effects to sort out the causes of efficiency loss and the growth in time and cycling on efficiency loss The emphasis is on only part of the story.

Reviewer 3:
The reviewer remarked that the thermal analysis data NREL provides is an important tool in the study of Li-ion batteries. The information on entropic heating is particularly interesting. The reviewer said that it would be nice to see more collaboration between the experimental data produced by NREL and the battery models produced by the other national laboratories. The reviewer pointed out that there were no slides showing the comparison between experimental and modeling results.

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

Reviewer 1:
The reviewer noted good progress on important questions. The project tested a nice variety of cells and in

discussion it was apparent the project team helped suppliers save money in their designs and improve function, helping advance the market toward use by consumers.

Reviewer 2:

The reviewer found that the technical accomplishments are good as far as the presentation is concerned. However, the reviewer would like to see more conclusions regarding the effects of active and passive cooling and the various approaches to this important aspect of battery design. The calorimetry studies should be able to shed considerable light on these aspects.

Reviewer 3:

The reviewer remarked that the term efficiency used on a few slides is a little vague. The reviewer expressed that it would be a good idea to include a definition about how that is calculated. The reviewer remarked that the plots of heat rate during discharge of various cell chemistries was interesting, but rather than using a constant C discharge rates, it would be nice to see the dynamic stress test (DST) cycle used with multipliers, for example, or possibly a comparison of charge versus discharge heating rates. The reviewer pointed out that it is not easy to size a thermal system based on constant current (CC) discharges alone.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that collaboration was very good with government and industry, less so with university, but this is okay.

Reviewer 2:

The reviewer said that there does not seem to be a close collaboration with battery/vehicle designers, at least from the presentation. There is no mention of other U.S. producers such as Tesla Motors, which is the largest producer of EVs in the United States. The reviewer noted that cost of battery systems and cell or module replacement issues interact strongly with degradation issues, and the reviewer would like to see some interaction with DOE and USABC partners to make some policy recommendations in this arena.

Reviewer 3:

The reviewer commented that the data on the multiple cell chemistries is interesting; however, there seems to be a lack of collaboration with the modeling groups within the national laboratories.

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

Reviewer 1:

The reviewer commented good plans, the modeling work will extend the capabilities. The reviewer found that the planned coordination is well chosen and helpful.

Reviewer 2:

The reviewer acknowledged being happy to see collaboration with the modeling teams listed under future work. This seems to be the big missing piece in an otherwise good body of work.

Reviewer 3:

The reviewer would like to see an emphasis on applications to specific systems in use today to o fer guidance to designers of active and passive cooling systems.

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

Reviewer 1:

The reviewer said that these studies are highly relevant to the U.S. EV industry in order to improve petroleum displacement measures. The effects of temperature are profound in both calendar life and cycle life limitations of batteries in present use and the interaction of cost measures.

Reviewer 2:

The reviewer pointed out that high and/or uneven heating can destroy cells due to the change in how it then charges or discharges making the cell exist at various states of charge (SOC) in different places so that it can easily over- or under-charge and thus destroy those areas. This work helps avoid that situation so batteries will last a long time and be acceptable to the public.

Reviewer 3:

The reviewer said yes, these thermal studies are an important source of data for the USABC and other battery research projects. The reviewer also said that the capabilities NREL has to do these studies is not easily found elsewhere.

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

Reviewer 1:

The reviewer said that the backlog is acceptable.

Towards Solventless Processing of Thick Electron-Beam (EB) Cured LIB Cathodes: David Wood (Oak Ridge National Laboratory) - es207

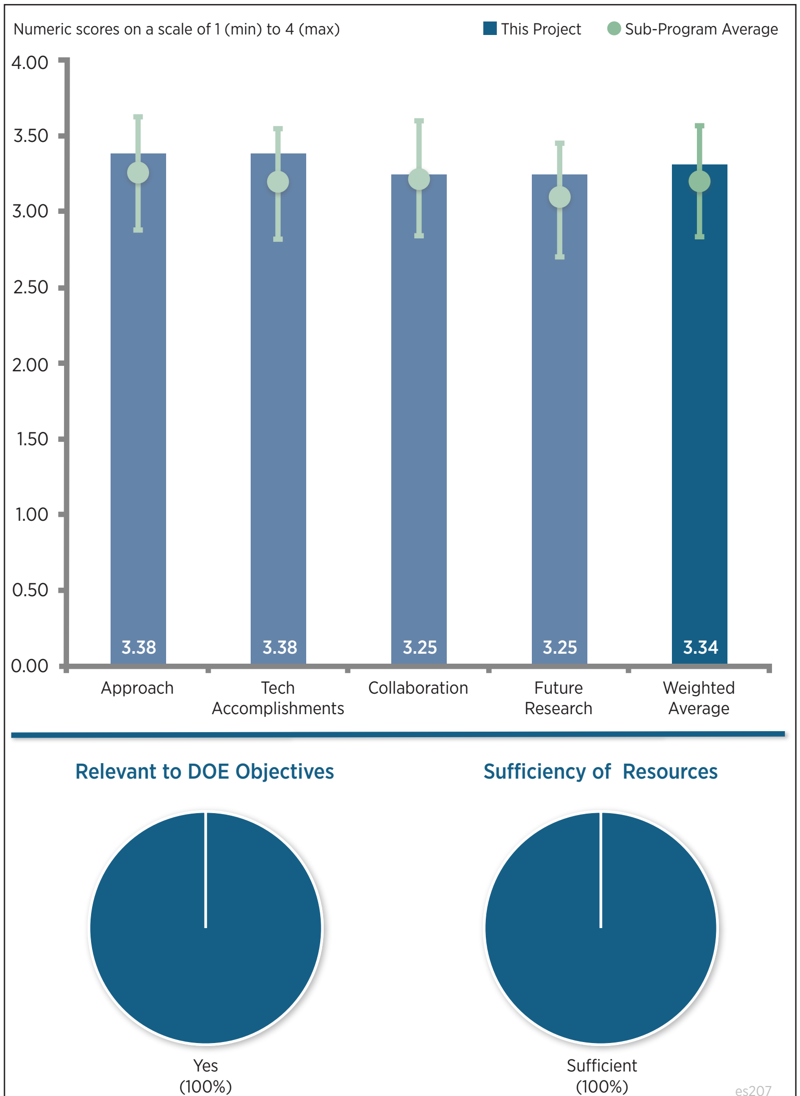

Figure 2-13 – Towards Solventless Processing of Thick Electron-Beam (EB) Cured LIB Cathodes: David Wood (Oak Ridge National Laboratory) - Electrochemical Energy Storage

Presenter

David Wood, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

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

Reviewer 1:

The reviewer said that this is a subtly complicated program. The development of a high-speed curing process begets challenges in the development of a high-speed coating process for the very viscous starting material. The reviewer commented that these are all interesting components; however, it can be a bit of a rabbit hole to develop one technique that demands the development of another in order to be effective.

Reviewer 2:

The reviewer said it is not very clear what the contribution is of the individual barriers identified to the cost savings. If established, it would be easier to prioritize and maintain focus.

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

Reviewer 1:

The reviewer commented that the initial results look very promising and need to be quantified (cost/benefi analyses).

Reviewer 2:

The reviewer found that the interaction of a high-speed curing line with a high-speed coating line using curable polymers appears to be a greater challenge than initially considered.

Reviewer 3:

The reviewer remarked that it would be useful to understand if choice of electrode formulation impacts the coating quality.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that as with all programs of this type, it is critical that this technology has relevance within the manufacturing direction of commercial entities for it to be relevant. The reviewer said that it would have been good to hear about specific comparisons to any other competing techniques that may or may not be in development.

Reviewer 2:

The reviewer said that guidance from or the independent project evaluation of a major high-volume global cell supplier would be a tremendous benefit to the project

Reviewer 3:

The reviewer remarked it will be helpful to identify the larger cell producer to validate the approach.

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

Reviewer 1:

The reviewer remarked that the project should include cost assessment/validation as more data are collected.

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

Reviewer 1:

The reviewer said that the program addressed the need for the battery cost reduction.

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

Reviewer 1:

The reviewer said that resources were sufficient for perhaps developing the drying/curing portion of the program, and perhaps under-resourced if expanded into high-speed deposition of high-viscosity coatings.

New High-Energy Electrochemical Couple for Automotive Applications: Khalil Amine (Argonne National Laboratory) - es208

Presenter

Khalil Amine, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

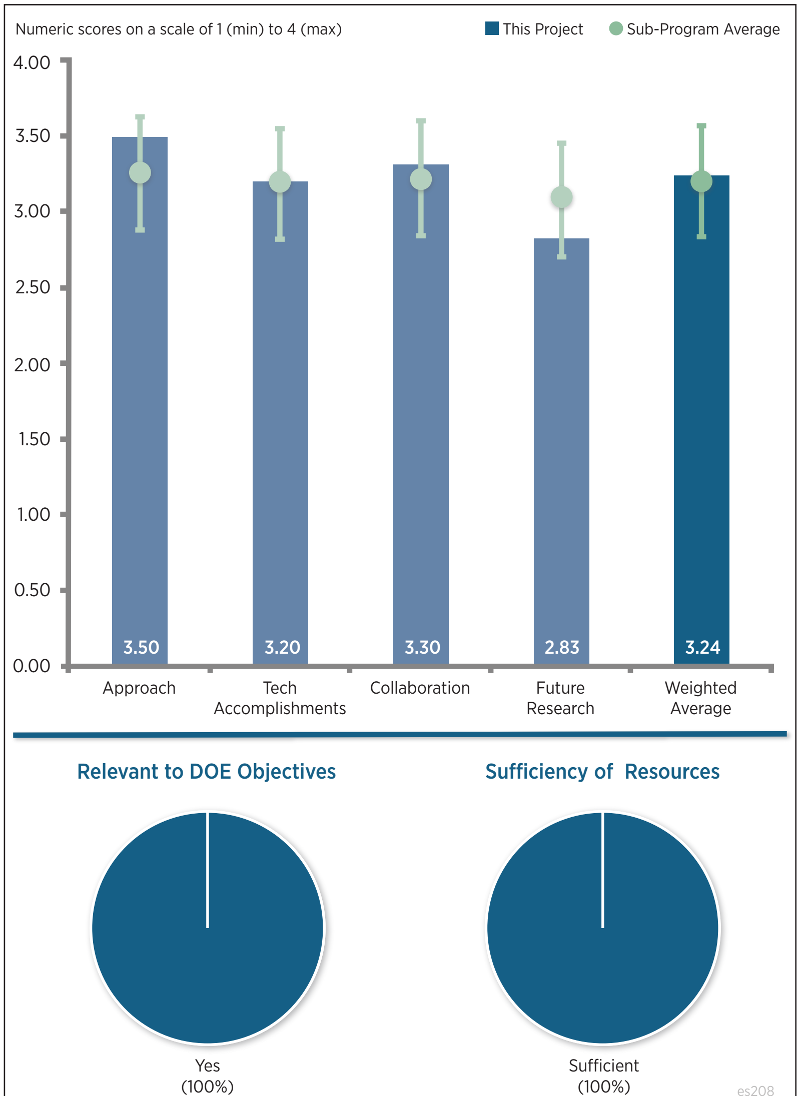

Figure 2-14 – New High-Energy Electrochemical Couple for Automotive Applications: Khalil Amine (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer said that the authors have focused on key barriers such as cathode and anode capacities to develop the next generation PHEV battery.

Reviewer 2:

The reviewer commented that the project is reducing the cost of the LIB through the energy density enhancement, and $/kWh reduction is one of the most relevant approaches for the automotive application.

Reviewer 3:

The reviewer detailed that the project's objective is to increase the specific energy to over 200 Wh/kg using Si-Sn anode and full gradient concentration cathode (FGC). The project team identified the first cycle irreversible los issue of the Si-Sn anode and mitigated it with a novel pre-lithiation technique that can be incorporated during the first cha ge. Milestones were clear and quantifiable. The reviewer found that the two-year schedule was reasonable to demonstrate specific ene gy improvement. The reviewer said that 200 Wh/kg should be achievable using graphite anode and FGC, and commented that the Si-Sn alloy anode seemed to introduce unnecessary risks.

Reviewer 4:

The reviewer remarked that this particular cathode/anode couple potentially improves energy density, while maintaining safety. The alloys do not take such a hit on electrode density, which is a good thing. The reviewer said that the pre-lithiation process is problematic due to the high first cha ge voltage required to access the Li, yet this was stated nowhere in the slides or the presentation in spite of repeated questions about downsides to the proposed approach.

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

indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said that pre-lithiation may represent a significant advance.

Reviewer 2:

The reviewer said that this is a highly focused, well-organized innovative research project that led to several key results, such as the FCG cathode, as well as the discovery of the lithia for pre-lithiation. The authors deserve credit for their work.

The reviewer remarked that while the analytical and cell data show strong potential for the FCG cathode to be a viable material for PHEV applications, comprehensive data for durability and cost guidance would have been useful. A Mn-rich outer layer naturally raises the question of Mn-dissolution at high temperatures and high-temperature durability of the cells. The reviewer noted that only room temperature data for full cells were presented, and the author referenced other data using a lithium salt additive, but the reviewer was unsure this salt is a panacea for Mn dissolution. Additionally, the reviewer said that guidance for cost (because FCG does involve separate processing steps) would be useful. The reviewer wondered how cost-efficient the manufacturing is and how difficult it is to control the morphology in a cstr synthesis. The use of lithia as a pre-lithiationn agent is definitely a neat idea that will enable researchers to circumvent other alternative and cumbersome techniques. The reviewer said it was not clear how tedious it will be to incorporate lithia during the electrode manufacturing steps. The reviewer asked if one would need to work in a moisture-controlled atmosphere. The reviewer identified this as a major and costly challenge.

Reviewer 3:

The reviewer said that researchers demonstrated the feasibility of the high-capacity Si-Sn composite anode and the FGC cathode with limited cycle life, and also demonstrated feasibility of the Si-Sn + MAG composite with limited cycle life. To mitigate the high first cycle irreversible loss of the Si-Sn anode, researchers demonstrated a novel in situ pre-lithiation technique activating lithium oxide (Li_2O) at high voltage at the cathode.

The reviewer said that the Si-Sn anode had high operating voltage versus Li and will require low discharge cut-off voltage (less than 2 V) in a full cell to achieve full utilization. The approximately 2.5V voltage swing at the cell level might pose a challenge for electronics at the battery pack level. The reviewer said that the researchers demonstrated the feasibility of cycle life and calendar life using the Si-Sn anode and FGC cathode. However, in order to claim that researchers mitigated the cycle life and calendar life barriers, the reviewer said that the team needed to have more than 50 cycles. According to the reviewer, the researchers projected specific ene gy greater than 200 Wh/kg, but have yet to demonstrate achieving much greater than 200 Wh/kg using the Si-Sn anode and the FGC cathode in a full cell. To achieve the high capacity using the FGC cathode at high voltages, such as greater than 4.3 V, the reviewer said that researchers need to address long-term stability of their electrolyte. The reviewer pointed out that Li_2O is extremely hygroscopic and tends to form lithium carbonate (Li_2CO_3) in air. Researchers need to provide some data on the processability of Li_2O in a manufacturing environment, such as dry room.

Reviewer 4:

The reviewer remarked excellent progress on the cathode development, and the reviewer asked what the barriers are preventing its large adoption. The reviewer was not clear what is new in using Li salts for the pre-lithiation, and referenced G. Amatucci's work on MeF. The reviewer asked how it is different from the Li-excess in the cathode, and how will the physical mixing effect the cathode structures on charge. The reviewer inquired if there are results on the cycleability. The reviewer asked, in general, how will adding Li_2O impact the slurry pH, and asked about slurry gelling. The reviewer inquired how the high voltage of the activation will affect the electrolyte stability, and where will the oxygen go.

Reviewer 5:

The reviewer said that the project is complete, yet there was no cycle life on cells containing the Si anode. The reviewer said that the gradient material scale-up to 1 kg is significant, and while the pre-lithiation was explored, researchers needed to show the downsides of the approach.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked excellent team for collaborative work.

Reviewer 2:
The reviewer commented excellent team of experts and institutional capabilities.

Reviewer 3:
The reviewer said that the team demonstrated good collaboration within ANL and with external ANL members. The roles of each team member was clearly identified to justify their participation in the project

Reviewer 4:
The reviewer suggested that collaboration with a cell partner might have been good as a check on the overall materials that the team ended up with; otherwise, team members appeared to have each contributed

Reviewer 5:
The reviewer remarked there was limited collaboration beyond ANL, and the team should have reached out to OEM coaters when the CAMP lab was struggling.

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

Reviewer 1:
The reviewer said that the project has ended.

Reviewer 2:
The reviewer said that the project is complete, so not relevant

Reviewer 3:
The reviewer remarked project completed.

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

Reviewer 1:
The reviewer said that the project definitely supports the DOE objectives of petroleum displacement

Reviewer 2:
The reviewer said that the project is highly relevant for DOE objective of petroleum displacement by increasing the specific ene gy of the battery.

Reviewer 3:
The reviewer pointed out that high energy density electrochemical couple are necessary for the e-mobility success.

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

Reviewer 1:
The reviewer noted that the project is complete.

Reviewer 2:
The reviewer commented that the $2.5 million over 2 years of funding was more than sufficient to achieve the greater than 200 Wh/kg goal. The reviewer commented that the funding should be sufficient to demonstrate greater than 200 Wh/kg using the Si-Sn and FGC cathode in a full cell, and to demonstrate cycle life and calendar life beyond feasibility using the high-capacity Si-Sn and FGC cathode.

High-Energy High-Power Battery Exceeding PHEV-40 Requirements: Jane Rempel (TIAX LLC) - es209

Presenter
Jane Rempel, TIAX LCC

Reviewer Sample Size
A total of four reviewers evaluated this project.

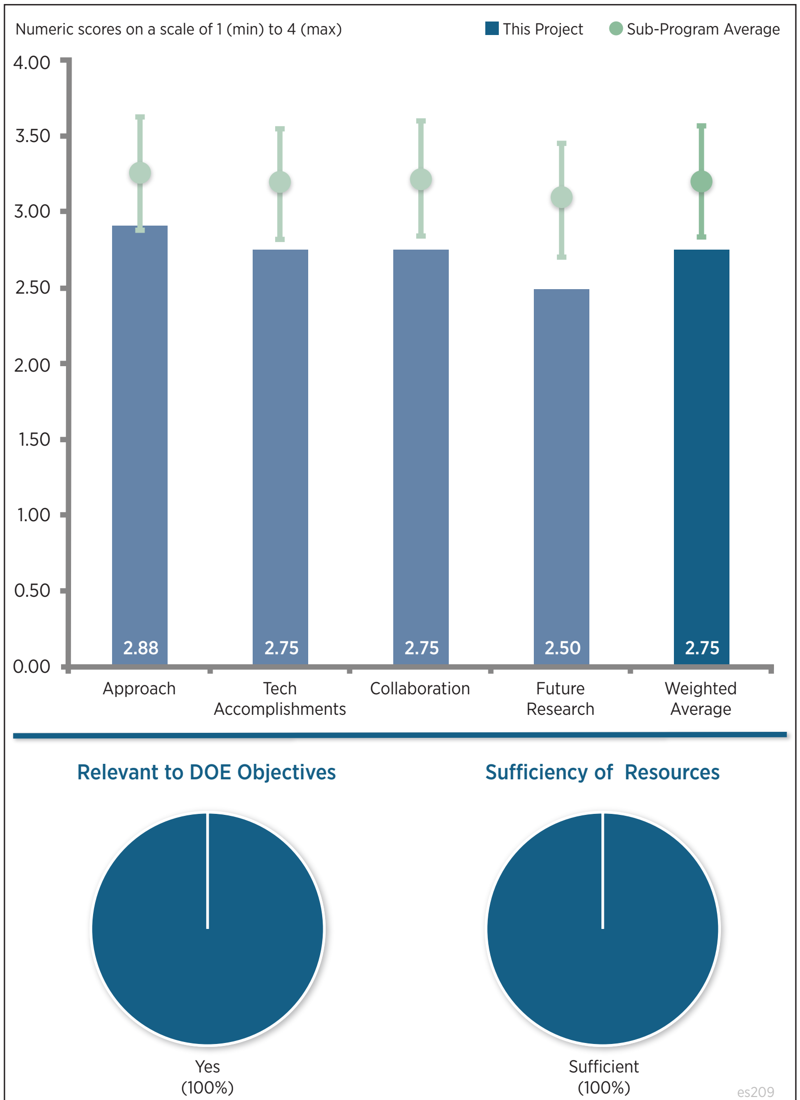

Figure 2-15 – High-Energy High-Power Battery Exceeding PHEV-40 Requirements: Jane Rempel (TIAX LLC) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer said that using the project team's in-house developed cathode in combination with Si-anode, the team had the objective of developing a PHEV-40 mile pack technology.

Reviewer 2:
The reviewer characterized the project as a try everything approach, which is unlikely to lead to large improvement, given all the work that has been done along these lines. Still, someone has to do this.

Reviewer 3:
The reviewer said the project seemed like an anode survey and applied development of an active material that was relatively optimized at the outset.

Reviewer 4:
The reviewer expressed uncertainty about what is novel here. CAM-7 has been around for a long time, and the reviewer said that rather standard Si anodes were used.

The reviewer would like to see more effects studied as other components were incorporated/varied (high-performance separators, binders, electrolytes, etc.). The reviewer asked if the team learned anything from the different combinations. The reviewer could not tell if there was development of the CAM-7 in this project, or if this is the same as in the past. If so, the reviewer would have liked to have seen the progression in performance.

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

Reviewer 1:
The reviewer said that the CAM-7 data look quite impressive from performance and durability points of view. While the full cell with graphite show attractive life data, that with the Si-anode appears to be limited by the Si-anode performance, which is still an emerging technology (only limited cycle-life data shown and only at room temperature). The reviewer said that data on calendar-life and abuse would have been welcome.

Reviewer 2:
The reviewer observed decent cycle life against graphite, and poor cycle life against Si. The reviewer also noted poor first cycle efficien , and moderate to poor coulombic efficiency (CE). The reviewer said that it would have been nice to see a comparison with other state of the art Si systems.

Reviewer 3:
The reviewer said that many can show high energy density using a high-energy cathode and a Si anode, as did this project, but researchers have to couple that with long cycle life, which this project did not show. Even if researchers have poor cycle life, it is better to show the data at the same voltage for which you calculate the energy density than to show cycle life at a lower voltage. The reviewer acknowledged appreciating the work on electrode design that is too often overlooked.

Reviewer 4:
The reviewer said that the concept of a silicon oxide (SiO_x) anode with high Ni cathode is already commercial, and the reviewer acknowledged missing what the accomplishment is here. The reviewer asked how this advanced the state of the art. The reviewer pointed out that abuse tolerance is a concern with this chemistry and needed to be addressed in a more relevant EV format than an 18650 lagging state of the art capacity and design.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that there were other partners, so that is good. However, the reviewer suggested using ANL's diagnostic capabilities more extensively to refine knowledge on failure mechanisms. Although Si material suppliers were acknowledged, it is not clear how much work was done with them or what their contribution was other than supply powder.

Reviewer 2:
The reviewer said that collaborations with teams who could carry out diagnostic work would have been a nice complement

Reviewer 3:
The reviewer said that the program was not collaborative.

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

Reviewer 1:
The reviewer said that the project has ended.

Reviewer 2:
The reviewer said that the program is complete.

Reviewer 3:
The reviewer said that the project is complete, so not a relevant question.

Reviewer 4:
The reviewer said that the project is completed.

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

Reviewer 1:

The reviewer said that the development of a durable, high-energy density cathode/battery supports the DOE objectives of petroleum displacement.

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

Reviewer 1:

The reviewer said that the project is complete, so not a relevant question.

Advanced High-Energy Li-Ion Cell for PHEV and EV Applications: Jagat Singh (3M) - es210

Presenter

Jagat Singh, 3M

Reviewer Sample Size

A total of six reviewers evaluated this project.

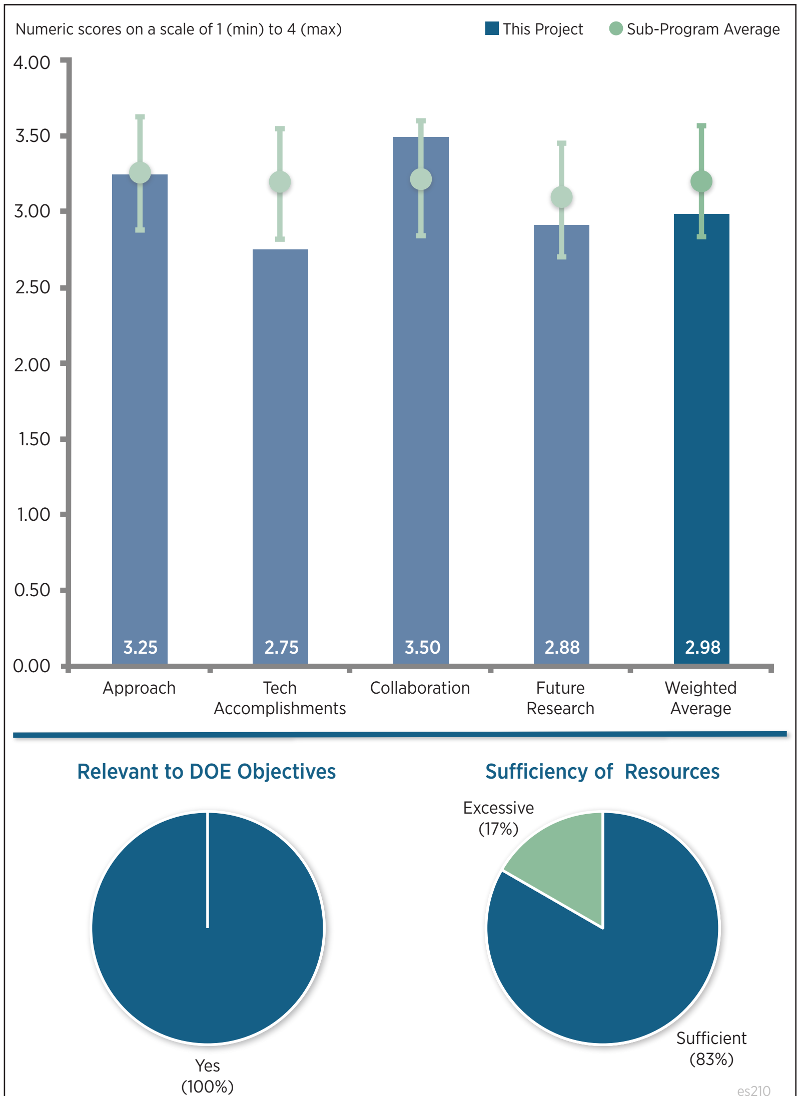

Figure 2-16 – Advanced High-Energy Li-Ion Cell for PHEV and EV Applications: Jagat Singh (3M) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer stated that this was a well-planned and well-coordinated effort to resolve key barriers to develop advanced battery technology.

Reviewer 2:

The reviewer stated that this is a good set of collaborators where each brings strength in specific cell components. The material set is very relevant and both the anode and cathode have significant challenges to be addressed

Reviewer 3:

The reviewer stated that the approach is conventional.

Reviewer 4:

The reviewer stated that it was a good approach to use 3M Si anode coupled with 3M high-V coated NMC to achieve the high specific ene gy. Excellent modeling projections of the specific ene gy and cycle life as a function of the charge cut-off voltages. The reviewer stated that two and a half years is a reasonable schedule for this project. The reviewer noted that milestones were not quantifiable and that descriptions in the milestone table were task descriptions, not milestones.

Reviewer 5:

The reviewer stated that in general it was a well-structured approach. A clearer definition of ta gets to be demonstrated would have helped in this project. It was not always clear as to how choices were made between the various cases studied.

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

Reviewer 1:

The reviewer stated that the team demonstrated over 250 Wh/kg at 1C rate and good cycle life over 100 cycles. Unlike other teams which only presented room temperature performance data, this team actually provided performance data at other temperatures. The reviewer stated that the project team needs a high charge cut-off voltage for the high specific ene gy achieved, long-term stability of the high-energy cells are unclear due to instability of electrolyte at high voltages. It was unclear if the Army Research Lab (ARL) high voltage electrolyte was used in their cell that demonstrated over 250 Wh/kg.

Reviewer 2:

The reviewer referenced the same issue as indicated above. Cycle life development was unconvincing, as data were lacking at this point in the project. The reviewer stated that low-temperature performance was unimpressive, for an EV-based goal. Also, that a lack of reporting on root cause analysis leads to questions, regarding some of the design selections made.

Reviewer 3:

The reviewer stated that the technical challenges here are very difficult, but considering the strength of the team, the progress is disappointing. This reviewer noted improvement in Si capacity and cycle efficienc , but pointed out that cycle life is only out to 100 cycles. There were no significant advancements in electrolytes

Reviewer 4:

The reviewer noted that energy density is not very high. Cycling life is only 100 cycles and power capability is also low. It should also be noted the project team did C-rate test using 100% SOC but cycling using 5-95% SOC (maybe to help extend cycle life), and use 35% capacity loss as threshold for cycling end of life (20% capacity loss is well-accepted for end-of-life).

The reviewer noted that state-of-the-art 18650 cells (Panasonic, LG, or Sony) can now reach around 3.4 to 3.5 Ah. Tesla has used 3.2 to 3.3 Ah 18650 cells for many years. Both Tesla 18650 cells and iPhone pouch cells can reach 260 Wh/kg at low rate and have better power than those in the slides; and they can be used for 1,000 cycles. The reviewer commented that current Tesla and iPhone cells are only charged to 4.2 V or 4.3 V. Increasing 4.2 V to 4.5 V or even 4.6 V, one can obtain 20% more energy density. The reviewer stated that the use of the word, “excellent,” on page six is pretty far out there and that Slide 7 is hardly something of which to be proud.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that this was an excellent team for collaboration encompassing key cell components with OEM, labs, a university, as well as developers.

Reviewer 2:

The reviewer thought that it was a well-picked team. Responsibilities were well-assigned and the project appeared to have been very well-managed.

Reviewer 3:

The reviewer stated that there was good collaboration between industry, national laboratories, and ARL. The roles and responsibilities for each team member were clearly specified, howeve , it was not clear the contribution of each team member in the demonstrated high energy cell.

Reviewer 4:

The reviewer noted that there was a good breadth of skills and technologies. This is the kind of team that really could make a breakthrough, which is why the reviewer was disappointed.

Reviewer 5:

The reviewer stated that it was not clear what ARL or Dr. Jow’s roles were.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points,

considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that this question was not scored, as project has ended. It was indicated that additional characterization testing will be performed by the national laboratories. This will be very important in evaluating the merits of the approaches taken within this program.

Reviewer 2:
The reviewer noted that the project is complete.

Reviewer 3:
The reviewer stated that the project is complete, so this question is not so relevant

Reviewer 4:
The reviewer stated that the future work is sharply focused on key aspects of the work (Si alloy anode, high energy NMC, and electrolyte additives). The reviewer recommended that for future presentations, include all test conditions on slides and any guidance on mechanisms/cost of new materials that improve the performance such as electrolyte additives.

Reviewer 5:
The reviewer stated that it is an unsuccessful project.

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

Reviewer 1:
The reviewer stated that if the goal is to lower EV battery costs and improve energy, then yes.

Reviewer 2:
The reviewer stated that this was highly relevant because high specific ene gy is critical to achieving petroleum displacement.

Reviewer 3:
The reviewer stated that the focus on higher voltage and reducing anode ICL are key targets to improve EV battery performance.

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

Reviewer 1:
The reviewer stated that the project ran slightly longer than planned, but found no apparent issues.

Reviewer 2:
The reviewer stated that there was sufficient resources for ene gy improvement over two and a half years.

Reviewer 3:
The reviewer stated that the scope seemed a bit broad.

Reviewer 4:
The reviewer reiterated that the project is complete, so this does not really matter

Reviewer 5:
The reviewer noted that Slide 2 says that the program end date is September 30, 2015, but is 15% complete. The reviewer questioned what happened.

Reviewer 6:
The reviewer stated that way too many resources were put into this project, considering that there were so many known problems with this material.

High-Energy Lithium Batteries for PHEV Applications: Subramanian Venkatachala (Envia Systems) - es211

Presenter

Subramanian Venkatachala, Envia Systems

Reviewer Sample Size

A total of five reviewers evaluated this project.

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

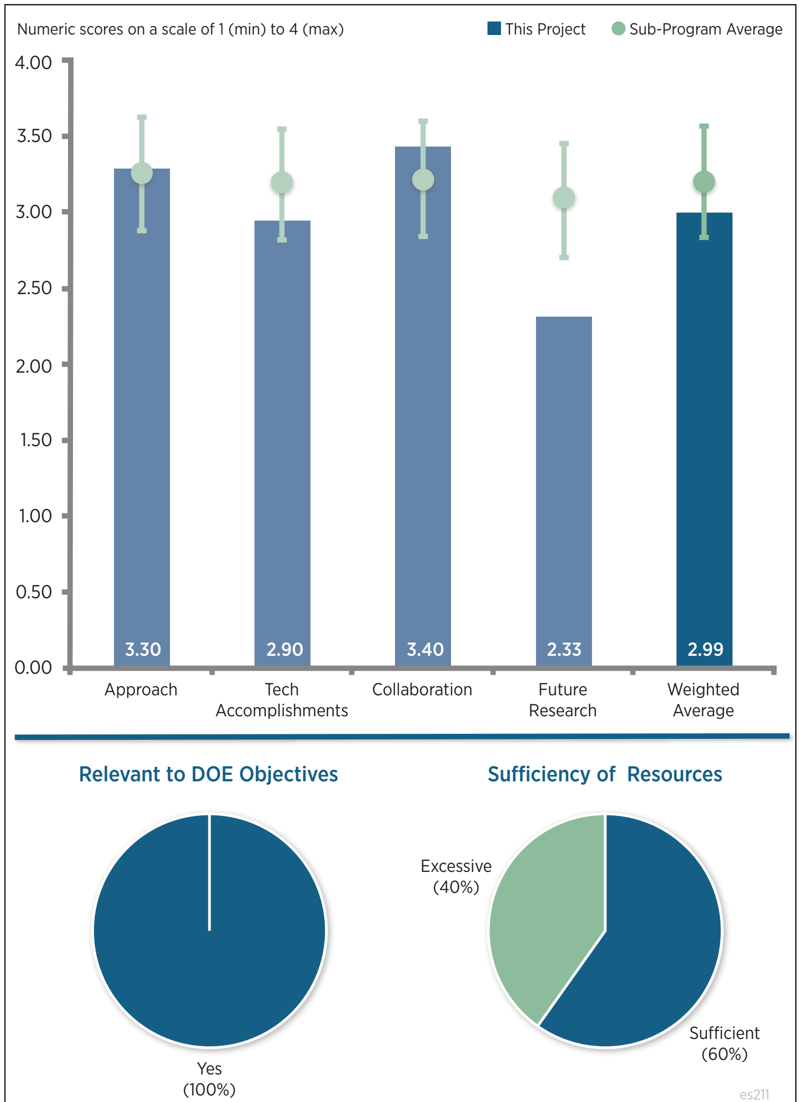

Figure 2-17 – High-Energy Lithium Batteries for PHEV Applications: Subramanian Venkatachala (Envia Systems) - Electrochemical Energy Storage

Reviewer 1:

The reviewer thought that the team has done outstanding work in trying to improve upon the properties of this high energy cathode material.

Reviewer 2:

The reviewer stated that the initial approach to use coatings to eliminate the DC resistance of Li-rich NMC at low SOC was a good one (unfortunately, it did not work). The reviewer appreciated the flexibility of the team to switch to an alternative cathode when the first approach did not work. There was good fundamental work by this team but marginal improvements demonstrated.

Reviewer 3:

The reviewer noted that the objective is to increase specific ene gy to over 200 Wh/kg using Si/C composite anode and high-capacity Mg-rich (HCMR) Li-rich cathode material. The project team identified and mitigated the power fade issue with the HCMR material at low SOC, and with cycling. The team showed the tasks, sub-tasks and timeline clearly in a table. The area specific impedance (ASI) milestones were clear and quantifiable The presentation described the coating and composition efforts succinctly to show the effectiveness of composition optimization in mitigating the power fade issue. Two and a half years was a reasonable schedule to demonstrate specific capacity improvement

The modeling data were not clear, it would have been more useful to model the ASI as a function of SOC. Si-based anode coupled with NMC should be sufficient to demonstrate over 200 Wh/kg.

Reviewer 4:

The reviewer stated that it seems like everything but the kitchen sink was thrown into this project, rather than focusing on a few areas that were most likely to have a payoff.

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

Reviewer 1:

The reviewer stated that while the issues of HCMR are well-known, the team has carried out highly focused and comprehensive studies to improve upon the vexing issues of voltage fade and durability. The results on materials manipulation, diagnostic and modeling are extensive and very useful even though the HCMR has turned out to be a hard nut to crack.

While the compositional changes brought about some significant improvement in the resistance of the materials, it is unfortunate that a lot of effort was aimed at surface modification, which turned out to be a futile attempt. However, the diagnostic studies were really well-planned and thorough. These results build the core of these studies and the authors have done an excellent job in analyzing the significant amount of especially spectroscopic and electrochemical data. Making the HCMR or a blend of HCMR and NMC to cycle to a charge voltage lower than that that does not give the expected energy boost might only have an appeal if there is a significant cost and safety advantages are there. It is not clear from the data that it is the case. The reviewer really loved the slides.

Reviewer 2:

The reviewer stated that the team clearly understood the issues of power fade and capacity fade with the HCMR cathode. The team demonstrated the effectiveness of composition modification in mitigating the power fade issue. The team demonstrated 200 Wh/kg at 1C, without using the high V cathodes that requires over 4.3 V. The team also demonstrated good cycle, greater than 300 cycles to 80% capacity retention. The high specific ene gy was not achieved by using very high cathode cut-off of over 4.3 V, thus should be less prone to stability issue. No data were presented regarding the voltage fade with cycling issue.

Reviewer 3:

The reviewer stated that there were marginal improvements (this was a difficult task), but more work should be have been done on the blends.

Reviewer 4:

The reviewer stated that there was limited anode work or progress. Payoff in cathode progress for amount invested seems somewhat incremental.

Reviewer 5:

The reviewer stated that 200 Wh/kg at 1C, plus 300-500 cycles should not have been the team’s initial target. Under such a power requirement, one can easily get cells with over 220 Wh/kg at 1C and over 1,500 cycles from any of the major suppliers. In fact, Envia has better cells (greater than 320 Wh/kg) with a different cathode and anode, which perhaps are not involved in the DOE/General Motors (GM) projects.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that this was an enormous multi-institution effort.

Reviewer 2:

The reviewer thought it was a good team that tried a lot of different things. The team gained fundamental understanding due to team members with different skill sets

Reviewer 3:

The reviewer stated there was excellent collaboration among teams that really complement each other’s expertise such as ORNL, Lawrence Berkeley National Laboratory (LBNL), etc.

Reviewer 4:

The reviewer thought that the team demonstrated good collaboration within Envia and with external Envia members. The roles of each team member was clearly identified to justify their participation in the project

Reviewer 5:
The reviewer stated that it seems to be a heavily Envia effort and no sign that decisions were driven by partner input despite apparent $1.6 million effort at partners. The surface stabilization efforts looked similar to work done elsewhere, notably ANL, and seems like there is potential overlap or need for more collaboration.

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

Reviewer 1:
The reviewer stated that the project has ended.

Reviewer 2:
The reviewer noted that the project is complete.

Reviewer 3:
The reviewer stated that the project is complete, so not relevant.

Reviewer 4:
The reviewer thought that this was a failed project.

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

Reviewer 1:
The reviewer stated definitel .

Reviewer 2:
The reviewer stated that this was highly relevant for the DOE objective of petroleum displacement by increasing the specific ene gy of the battery.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones

Reviewer 1:
The reviewer commented that the $3.8 million effort was appropriate given the amount of work and the demonstrated results.

Reviewer 2:
The reviewer was not sure why project was continued absent progress on high-V stability.

Reviewer 3:
The reviewer thought that way too many resources were put into this project, considering that there were so many known problems with this material.

High-Energy, Long Cycle Life Lithium-Ion Batteries for EV Applications: Donghai Wang (Pennsylvania State University) - es212

Presenter

Donghai Wang, Pennsylvania State University

Reviewer Sample Size

A total of six reviewers evaluated this project.

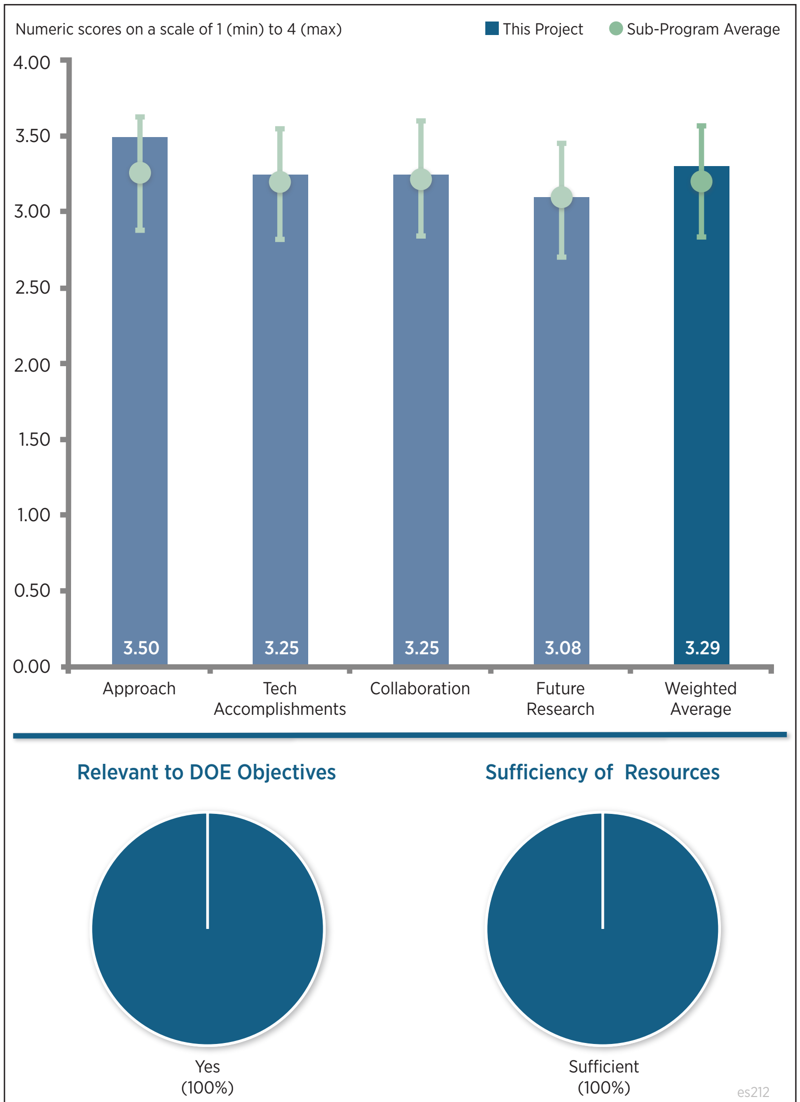

Figure 2-18 – High Energy, Long Cycle Life Lithium-Ion Batteries for EV Applications: Donghai Wang (Pennsylvania State University) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer found that the project is focused, well-organized, and addresses all key barriers using proven approaches and powerful diagnostic tools.

Reviewer 2:

The reviewer commented that this was a well-organized, carefully thought out set of coordinated experiments.

Reviewer 3:

The reviewer thought that it was a good approach to use Ni-rich layered oxide coupled with Si-alloy/C anode to achieve greater than 330 Wh/kg. To achieve greater than 500 cycles, their approach was also reasonable, to use functional conductive binder, fluorinated electrolytes and additives, and pre-lithiation. Quantifiable milestones wer provided, but a schedule was not provided. The period of performance was three years, which might be sufficient to demonstrate technologies feasible of achieving the specific ene gy and cycle life.

Reviewer 4:

The reviewer appreciated the attention to electrode loading and abuse tolerance.

Reviewer 5:

The reviewer stated that the approaches basically addressed most of the critical issues associated with high energy density electrode materials and are well laid-out.

Reviewer 6:

The reviewer stated that it was an excellent choice to include scale up of the material in this project. Good fundamental work with the secondary ion mass spectrometry (SIMS) analysis and good performance of the cathode material in graphite cells. However, disappointing results on the anode (this project was not alone in that regard).

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

Reviewer 1:

The reviewer stated that the team has made significant progress on di ferent components. The integrity of the optimized electrodes, electrolyte, and binder, including the pre-lithiation, is well done.

Reviewer 2:

The reviewer stated that there was good progress on the cathode, especially synthesis. However, less good progress on anode. Results on analytical are very interesting and can form the basis of new projects

Reviewer 3:

The reviewer stated that the authors have investigated several well-established techniques to enhance the durability of Ni-rich cathodes which initially deliver a capacity of about 200 millampere-hour (mAh)/g but unfortunately show considerable fade. The approaches show somewhat similar improvement in their durability at room temperature, but the full cell performance needs to be improved, as the authors recognize. The diagnostic data, especially those derived using time of flight (OF), are highly insightful. The Si-anode results show promise but considerable work remains to be done.

Reviewer 4:

The reviewer stated that high quality cathodes were developed. Si anodes have poor cycle life, as demonstrated in Slides 12 and 13. There was also good electrolyte development. The reviewer commended the authors for the CE graph on Slide 15, with efficiency going from 90% to 100%, instead of hiding the results going from 0% to 100%. Finally the reviewer stated that first cycle efficiency needs to improv

Reviewer 5:

The reviewer stated that the team leveraged TOF-SIMS to quantify the decomposition products, which resulted from Al-doped FGC cathode, on anode and cathode. The project team demonstrated pre-lithiation using stable Li-metal powder to improve coulombic efficiency from 80% to close to 99%. Fluorinated electrolyte seemed to improve cycle life over 50 limited cycles.

The reviewer said that surface coating seemed to improve the cycle life of the Ni-rich layered oxide, but it was not clear if the team mitigated the cycle life voltage sag issue with surface modification. Even though the approach was to use the Ni-rich layered oxide to achieve the high specific ene gy, electrolyte optimization, electrode optimization, and pre-lithiation in a pouch-type full cell was based on NMC523, not the Ni-rich layered oxide. Because NMC71515 is less stable than NMC523, the team would have to requalify the NMC71515 with the fluorinated electrolyte, the pre-lithiation, and the electrode optimization. The project team demonstrated limited cycle life using the functional conductive binder at a Si-graphite loading of 4.9 mAh/cm^2 in a half cell, but no full cell data based on this binder. The team has yet to demonstrate a full cell using the Ni-rich layered oxide coupled with the Si-graphite anode, as was described in their approaches.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that there was good collaboration among the teams.

Reviewer 2:

The reviewer thought that the co-presentation showed good collaborative participation from two participants. There are a variety of efforts here, ranging from cathode to anode to scale-up to analytical. It showed a good comprehensive team and skill sets.

Reviewer 3:

The reviewer stated that there was good team composition with the roles and responsibilities of each team member clearly specified

Reviewer 4:
The reviewer stated that the team and the collaborators are well known experts in the field from di ferent aspects.

Reviewer 5:
The reviewer stated that the project may have benefited from a manufacturing partner on the team

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

Reviewer 1:
The reviewer stated that there were promising results on many fronts. This work should be encouraged.

Reviewer 2:
The reviewer stated that the future work addressed the remaining challenges. The plans are realistic and achievable in the remaining project period.

Reviewer 3:
The reviewer stated that there are about three months left before the project completion in September 2016. The team's main focus should be to integrate the improved components (Ni-rich layered cathode, Si-graphite anode, functional conductive binder, fluorinated electrolyte, and pre-lithiation) in a full cell and demonstrate specifi energy and cycle life.

Reviewer 4:
The reviewer stated that the team is well qualified to advance understanding and suggest solutions on thermal runaway mitigation. The reviewer would like to see remaining resources continue to address that.

Reviewer 5:
The reviewer noted that while the team has focused more on cathode material (bulk/surface) properties, it is possible that the use of suitable electrolytes might improve further the performance, especially at high temperatures. Thus the reviewer recommended expanding the work on electrolyte. As is well-known, additives are known to considerably improve the durability of high Ni content cathode performance.

Reviewer 6:
The reviewer suggested the team focus more on improving the cycle life of the Si at current capacity, rather than improving capacity. Pre-lithiation is being worked on by others, let them do it; get your cycle life improved without pre-lithiation (that is just a band aid). The reviewer believed that this is the right team to address these challenges

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

Reviewer 1:
The reviewer stated definitel .

Reviewer 2:
The reviewer stated that the project was highly relevant because high cycle life at high specific ene gy are critical to achieving petroleum displacement.

Reviewer 3:
The reviewer stated that the project addressed the barriers for the high energy battery well. If successful, it can meet the DOE objectives.

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

Reviewer 1:
The reviewer stated that it was a good team with lots of results. With focus, this team can make progress on remaining challenges

Reviewer 2:
The reviewer stated that there were sufficient resources for ene gy improvement over three years.

Reviewer 3:
The reviewer commented that the resources are sufficient. The team members and collaborators have all the necessary expertise and sources to address the barriers.

High-Energy Density Li-ion Cells for EVs Based on Novel, High Voltage Cathode Material Systems: Keith Kepler (Farasis) - es213

Presenter
Michael Slater, Farasis

Reviewer Sample Size
A total of six reviewers evaluated this project.

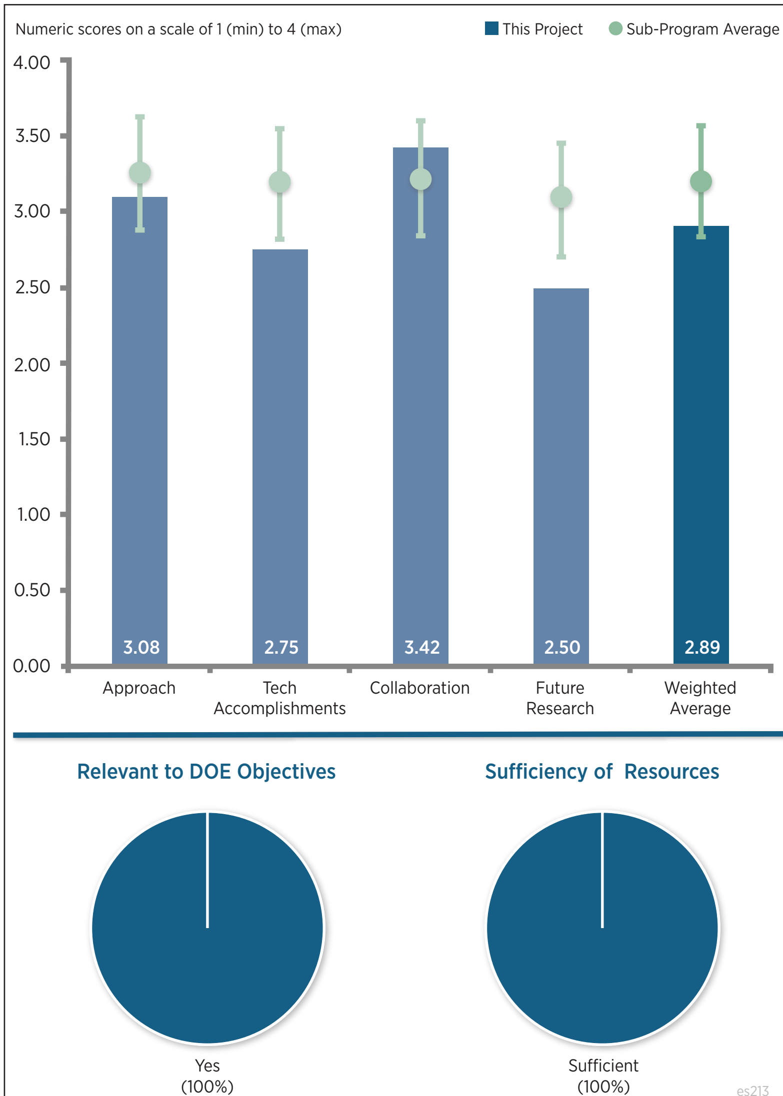

Figure 2-19 – High-Energy Density Li-ion Cells for EVs Based on Novel, High Voltage Cathode Material Systems: Keith Kepler (Farasis) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer stated that the multi-faceted cathode approach was very good. Sufficient work on the anode was demonstrated.

Reviewer 2:
The reviewer noted that the research team’s claim that nanowires, with less surface area than spheres, should have better first cycle efficien . This is reasonable, but has been tried before without much success. Also, the reviewer did not see where the project team reported their values. Finally, the ion exchange synthesis has some potential.

Reviewer 3:
The reviewer was glad to see someone looking further into Chris Johnson’s excellent work on the ion exchange approach. It was also good to see the project team working on nanowires, a different approach from most of the other projects. Same for the titanium-modified (i) NMC (even though it did not work out). The reviewer would like to see more projects like this that explore different approaches.

Reviewer 4:
The reviewer stated that the approach was to leverage high capacity layered-layered metal oxide coupled with Si-based anode to achieve the specific ene gy goal. Two and a half years is reasonable to demonstrate the feasibility of achieving the specific ene gy goal. However, the milestones were not quantified, and the team should provide some modeling data on how they plan to achieve greater than 350 Wh/kg using their Si anode that only had two times higher specific capacity than that of graphite

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

Reviewer 1:
The reviewer stated that the progress seemed moderate on anode and electrolyte.

Reviewer 2:
The reviewer stated that the program would have benefited from compiling results in a gap chart. It was not clear as to how great the remaining gaps were.

Reviewer 3:
The reviewer stated that the results were okay for the novelty of the approach. The reviewer appreciated the team's point on the voltage window of 4.4-3 V, however the good cycle life cannot really be compared to others cycling over a wider voltage range. It would have been good to show the cycle life over a wider voltage range for the NMC/graphite. Also there was not much progress on the Si anode. Furthermore, the presenter said that there was extensive electrolyte screening, but the reviewer saw no evidence of that and questioned the number of different electrolytes. The reviewer also asked the team if it could learn anything based on what worked and what did not work.

Reviewer 4:
The reviewer noted that the team demonstrated several methods to mitigate the voltage stability and impedance issues of the high-capacity layered NMC materials. The team also demonstrated the potential cycle life benefit of fluorinated solvents while highlighting the gassing issue due to fluorinated solvents. Specific capacity Generation 2 cells was not provided, only cycle life compared to capacity retention was presented. The team modified lithium manganese rich-NCM (LMR) via ion-x to improve the rate capability and showed decrease in impedance, but there was no data at the full cell level. The reviewer pointed out that there was also no data demonstrating the mitigation of the voltage sag issue.

Reviewer 5:
The reviewer thought that overall, the project team's Si results are poor. The statement in Slide 11 that their material is cost-effective is not supported. Finally, Ti substitution does not improve things very much, according to Slide 15, up to only 25 cycles.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer found that there was a good set of partners and balance of contribution and capabilities, which set the standard for this group of awards.

Reviewer 2:
The reviewer thought that the collaboration appeared to be comprehensive and effective.

Reviewer 3:
The reviewer stated that there was a good team and a diverse set of materials. Materials developers (e.g., OneD, DuPont) can have trouble in optimizing a single component as they do not have the whole system. This project is a good example of how they can be integrated into a larger effort with other component developers.

Reviewer 4:
The reviewer noted that there was good team composition with the roles and responsibilities of each team member clearly specified

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

Reviewer 1:
The reviewer stated that the project has ended.

Reviewer 2:
The reviewer stated that the program is complete, so this question was left blank. It will be essential to review the final test results from the labs once testing is complete, in order to verify that this technical approach was successful.

Reviewer 3:
The reviewer stated that the project is complete, so this question is not relevant.

Reviewer 4:
The reviewer stated that the project is completed.

Reviewer 5:
The reviewer stated that the project should be ended.

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

Reviewer 1:
The reviewer stated that the specific goals to improve ene gy density, and lower overall energy storage costs, appear to have been kept central to the program.

Reviewer 2:
The reviewer stated that the project was highly relevant because high specific ene gy is critical to achieving petro displacement.

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

Reviewer 1:
The reviewer noted that Farasis did respond to the concern on the anode research. The no-cost extension applied made sense, given the scope of the project.

Reviewer 2:
The reviewer stated that the project is complete, so not relevant.

Reviewer 3:
The reviewer stated that $3.5 million over two and a half years should be sufficient to demonstrate the specifi energy goals.

Reviewer 4:
The reviewer commented that funds were possibly excessive, but funding splits were not provided.

Fundamental Studies of Lithium-Sulfur Cell Chemistry: Nitash Balsara (Lawrence Berkeley National Laboratory) - es224

Presenter

Nitash Balsara, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

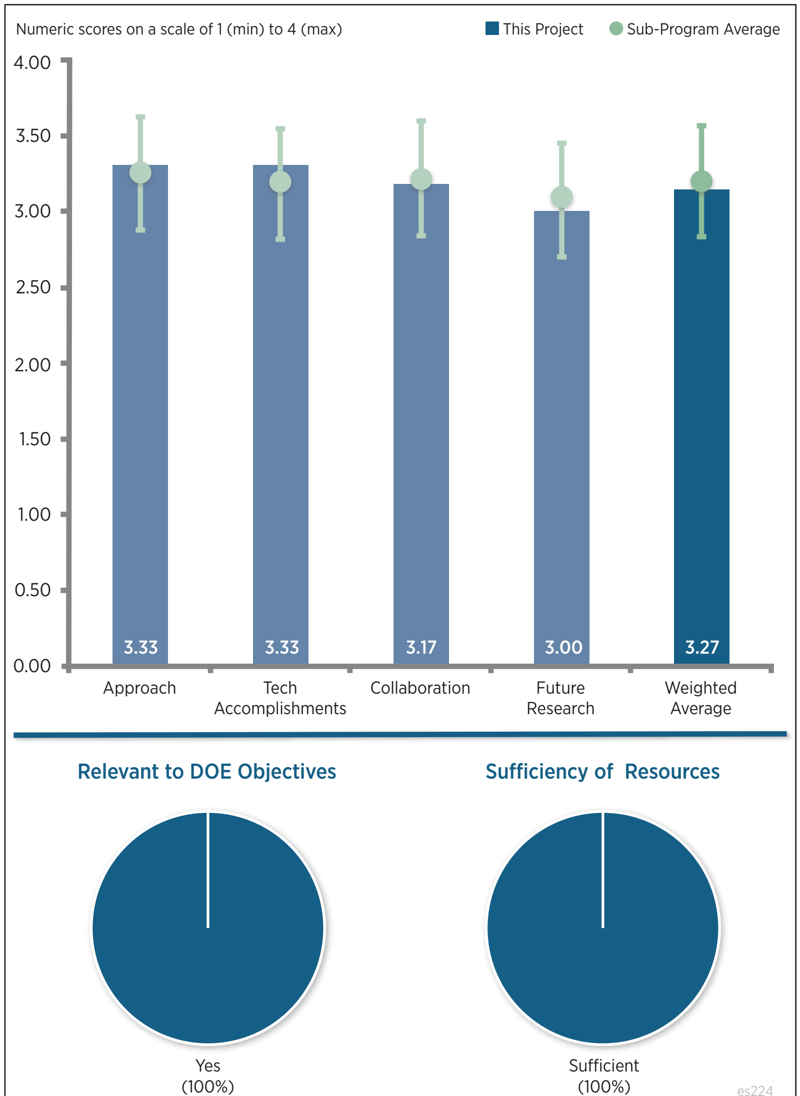

Figure 2-20 – Fundamental Studies of Lithium-Sulfur Cell Chemistry: Nitash Balsara (Lawrence Berkeley National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer thought that the project team's approach is relatively unique and should add light to what remains a challenging problem and technology.

Reviewer 2:

The reviewer stated that the project combines multiple tools to probe the speciation of the polysulfide solutions in different solvents. The project also designed in situ cells for X-ray based techniques. The study promises to improve our understanding of the solution chemistry in order to improve Li-S battery performance.

Reviewer 3:

The reviewer noted that the approach is to use calculations and in situ diagnostics to understand the reaction products in Li/S cells during cycling. The approach seems good, although the reviewer wondered about the use of symmetric polystyrene-block-poly (ethylene oxide) (SEO)-based electrolytes for some of these studies as those are not used in actual cells.

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

Reviewer 1:

The reviewer stated that there was good progress and all milestones planned to be met, have been met, or are on track. Team has succeeded in building cells to permit in situ X-ray absorption spectroscopy (XAS) studies through the anode and cathode side of the cell.

Reviewer 2:

The reviewer stated that the work on free radical detection is comprehensive. Computational work on sulfur species also shows promise.

Reviewer 3:

The reviewer stated that the project team made good progress on understanding the speciation of the polysulfides. The reviewer did not understand why the team is not focusing on polyethylene oxide (PEO) electrolytes if that is the team's plan for the future.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the collaboration was good and reasonable.

Reviewer 2:

The reviewer stated that the project team has a number of collaborators, most of them are from University of California at Berkeley.

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

Reviewer 1:

The reviewer stated that further in situ studies promises to provide insight on limiting issues in Li-S; initial indication seems to be related to Li anode.

Reviewer 2:

The reviewer stated that the project team is continuing their work. The reviewer expects them to make significant progress on understanding the polysulfides, but it is not clear the team has a plan for improvement of the present state of the technology.

Reviewer 3:

The reviewer stated that given that many of the basic goals of the project have been met, and encouraged the PI to solicit input from companies working on Li-S battery technology to determine the best next steps.

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

Reviewer 1:

The reviewer stated that yes, Li-S is a low-cost couple that needs fundamental studies, although the reviewer wondered what the differences are when using the solid polymer electrolyte compared to the typical liquid ones.

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

No comments were received in response to this question.

BatPaC Model Development: Shabbir Ahmed (Argonne National Laboratory) - es228

Presenter

Shabbir Ahmed, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

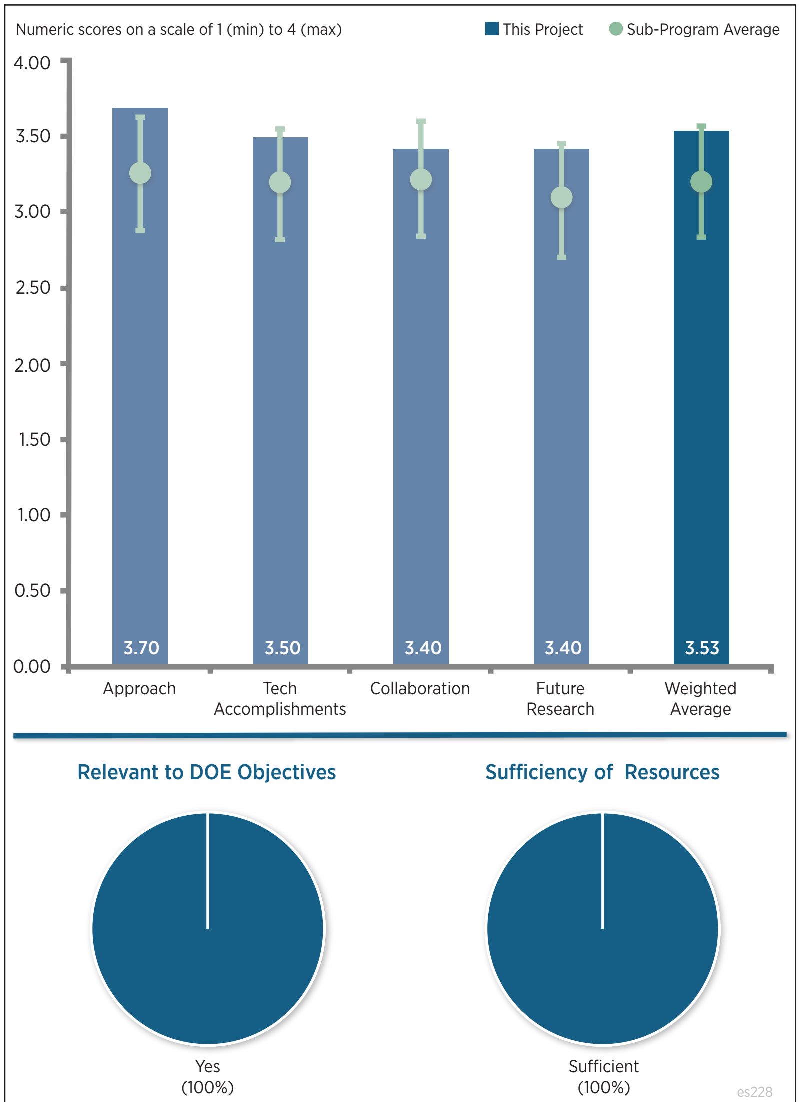

Figure 2-21 – BatPaC Model Development: Shabbir Ahmed (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer stated that the effort is well focused to improve upon and expand the capability of the BatPac model.

Reviewer 2:

The reviewer stated that the BatPac has continued to evolve and serve as a resource for the battery community.

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

Reviewer 1:

The reviewer thought the authors have done a great job in establishing important parameters such as optimal electrode loading (current density for Li plating) and the impact of key processes such as NMC production and cathode drying, dry room operation, and formation steps on the cost of battery pack model. These are key steps that contribute to the cost of the battery manufacturing.

Reviewer 2:

The reviewer stated that the fidelity of the model continues to improve by incorporating increased level of details, particularly on the processing aspects. The challenge appears to be model validation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that there was excellent collaboration with many key material suppliers, equipment manufacturers, and researchers.

Reviewer 2:

The reviewer commented that the team has served the research community well and the model appears to be popular. There is concern that the model is not as well communicated to industry. The team is encouraged to think creatively about how to do model validation: it is difficult to get direct input from industry so it is necessary to develop various metadata sets so that concerns of propriety can be alleviated.

Reviewer 3:

The reviewer stated that the presenter was not able to justify how collaborators' contributions affected the model. The efforts in reaching out to industrial partners is weak, especially in light of the criticisms last year.

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

Reviewer 1:

The reviewer thought that the project has identified valuable additions (mainly manufacturing) to conside . However, increasing validation from leading industrial players is the key.

Reviewer 2:

The reviewer thought that the proposed research areas look good, and made three additional suggestions. First, the reviewer questioned if there is any work done on processing cost for anodes, such natural or artificial graphite, Si-based materials, as well as titanate anode. Even though their cost impact is less significant than that of cathodes, it will be good to complement the database already generated. Second, the study on the impact of plant automations on cost looks interesting. It will be instructive to compare this to the announced cost reduction by Tesla in their gigafactory. Of course NCA becomes then a part of the study. Third, the reviewer noted that 24M has predicted $50/kWh battery cost, but asked if the model can validate that.

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

Reviewer 1:

The reviewer stated that a reliable battery pack model is essential and useful for tracking the goal and progress of battery pack technology development.

Reviewer 2:

The reviewer commented that this model is useful for industries to make well-informed decisions on materials and battery designs.

Reviewer 3:

The reviewer stated that the model calculates the expected cost of the batteries, which helps the battery customers and suppliers to make decisions on business strategies and provides the batteries for electric vehicle applications.

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

Reviewer 1:

The reviewer stated that additional resources could be beneficial to support greater marketing/public relations of BatPac in general and specifically internationall .

Design of Sulfur Cathodes for High-Energy Lithium-Sulfur Batteries: Yi Cui (Stanford University) - es230

Presenter
Yi Cui, Stanford University

Reviewer Sample Size
A total of four reviewers evaluated this project

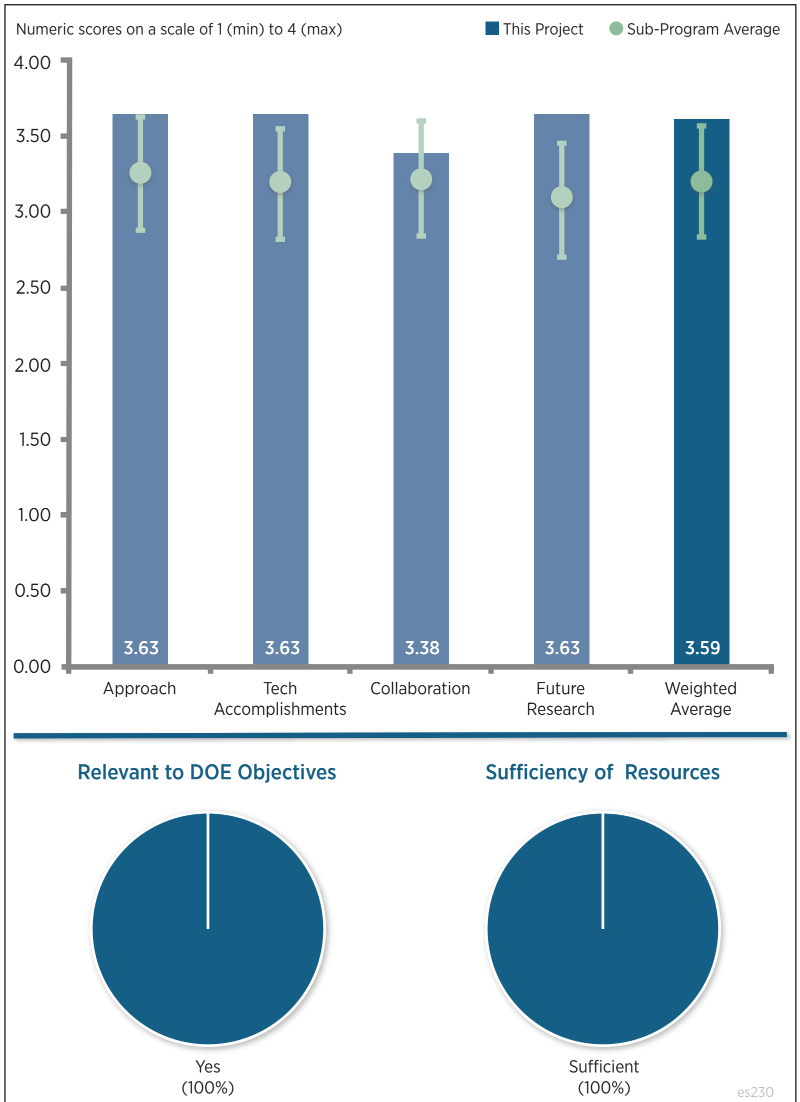

Figure 2-22 – Design of Sulfur Cathodes for High-Energy Lithium-Sulfur Batteries: Yi Cui (Stanford University) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer found that the approach the PI is taking is excellent. Novel sulfur nanostructures and multifunctional coatings are being designed and fabricated to overcome the issues related to volume expansion, polysulfide dissolution, and insulating nature of sulfur. This is complimented by structure and property characterization and electrochemical testing.

Reviewer 2:
The reviewer stated that the use of nanostructured cathode materials to confine polysulfides, or shield the from electrolyte interaction, could be the key to Li-S cell cycling. Very good use of multiple approaches to managing this issue.

Reviewer 3:
The reviewer thought that a better fundamental understanding of polysulfide adsorption on metal oxides and other approaches in the scope of this project are important contributions to achieving effective Li-S electrode designs that are goal of the projects. The systematic screening is excellent, valuable work.

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

Reviewer 1:
The reviewer noted that the project will be completed at the end of July. Outstanding progress was achieved this past year. Milestones were met in a timely manner. The project team identified the interaction mechanism between sulfur species and different types of sulfides/oxides/metals, and is on a path to find the optimal material t

improve the capacity and cycling of S cathode. There were numerous peer-reviewed journals describing the novel approaches that were undertaken.

Reviewer 2:

The reviewer noted that apparently a very nice cycling stability has been achieved, with 300 0.2C cycles shown, with a cathode capacity of 1,000 mAh/g, using conductive polymer coated hollow S cathodes. Another approach was to use TiS_2 coated S, those showed 400 very stable cycles near 600 mAh/g. Finally, the project team evaluated polysulfide capture on the surface of metal oxides

Reviewer 3:

The reviewer stated that the results demonstrate good progress and are convincing in technical accomplishment; however, cost and energy density are main goals and the presentation should quantify such parameters, even if the goal is not in reach due to the difficulty of the challenges. To convey the result, it is not ideal to scale coulombic efficiency plots from 0% to 100%

Reviewer 4:

The reviewer thought that the reliance of using lithium sulfide (L_2S) as the initial electrode materials could pose a financial burden to the adoption of this technolog . The reviewer asked if the researchers of this project can come up with a synthesis route that can lower the cost of Li_2S.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The PI had a number of highly effective collaborations (Ab initio simulations: Prof. Qianfan Zhang, and Amprius).

Reviewer 2:

The reviewer stated that it makes sense to have simulation work and other tasks that can be completed with little interaction at partners in China and in situ X-ray work right in the area.

Reviewer 3:

The reviewer thought that it looks okay, but would appreciate more collaborations with domestic institutions, including other S focused battery companies as this project is sharply focused on solutions to enable Li-S cells as opposed to a more fundamental study.

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

Reviewer 1:

The reviewer noted that the project will be completed this year.

Reviewer 2:

The reviewer stated that future research is reasonable, but wondered if the electrolyte volume issue is under control yet. Traditionally, Li-S cells have operated with an effective S catholyte, meaning the cell Wh/kg and Wh/l is severely restrained by the amount of electrolyte in the cell.

Reviewer 3:

The reviewer noted that the researcher pointed out that the dendritic growth of Li on the anode could be a problem in Li-S battery. This is a point that has been omitted/evaded by the Li-S research field due to the view that the crossover of polysulfides can reduce this catastrophic e fect. It would be interesting to know more about this fundamental process specifically in the Li-S system

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

Reviewer 1:
The reviewer stated that the project is highly relevant. Efforts like this will aid in the development of Li-S batteries. This technology is expected to decrease the high cost of batteries.

Reviewer 2:
The reviewer stated yes, Li-S is a low-cost couple and the S cathode needs novel approaches to manage the polysulfides

Reviewer 3:
The reviewer thought that the findings can lead to commercial solutions for high ene gy density, low-cost batteries.

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

Reviewer 1:
The reviewer thought that there was excellent value for the investment.

Efficient Rechargeable $Li\text{-}O_2$ Batteries Utilizing Stable Inorganic Molten Salt Electrolytes: Vincent Giordani (Liox) - es233

Presenter

Vincent Giordani, Liox

Reviewer Sample Size

A total of four reviewers evaluated this project

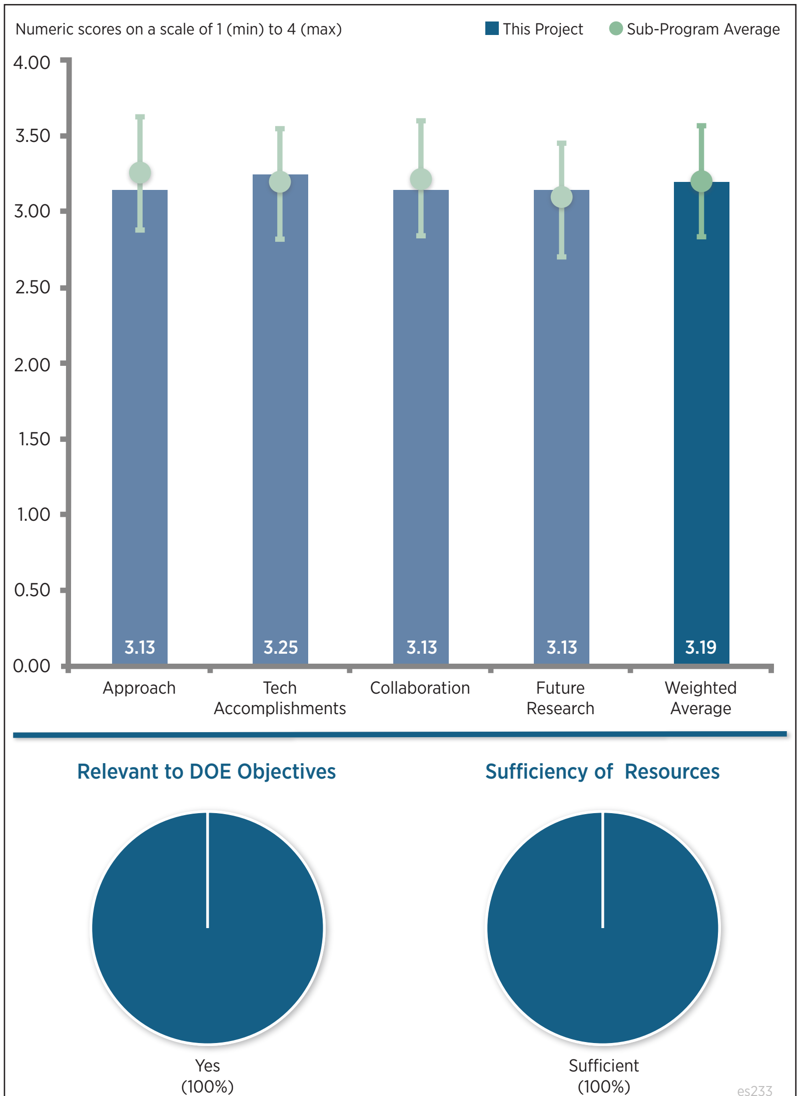

Figure 2-23 – Efficient Rechargeable $Li\text{-}O_2$ Batteries Utilizing Stable Inorganic Molten Salt Electrolytes: Vincent Giordani (Liox) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer stated that there are many commercial and/or lower cost methods of making micro, meso, and nano porous Ni. It is unclear why the three-dimensional (3D) Ni truss nanolattice structure was chosen for investigation and whether this structure is superior to existing and commercially available porous Ni.

Reviewer 2:

The reviewer stated that it was a generally good approach to overcome some issues. The materials and electrodes used are very fundamental. The PIs need to address the motive behind choosing the catalysts and electrode structures. Aspects about operating at high temperature need to be also addressed (from a system perspective). Rate capability tests need to be performed, as well as operation at low temperatures and system start-up. The reviewer also thought that safety needs to be discussed.

Reviewer 3:

The reviewer stated that the approach to find a tolerant Li/oxygen electrolyte at elevated temperature seems good. It seems incredibly hopeful that this electrolyte, if found, will also solve the issues of V hysteresis, low rate, and ability to cycle only low mAh/cm^2. It also seems very aggressive to hope that it will permit the cell to operate in air compared to pure oxygen.

Reviewer 4:

The reviewer had a comment regarding the topic Ni catalyzes the formation of Li_2O discharge product. It is unclear to what the real catalyst is here and if it is NiO. The investigators showed Ni_3+ in the post mortem study of the Ni catalysts. It would be interesting to know if these $Ni+_3$ are relevant to the catalytic process and what crystal form they are in.

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

Reviewer 1:

The reviewer thought that up to now results have shown use materials and electrodes that are challenging to be scaled up and used. Iridium oxide (IrO_2) that has been identified as the most promising catalyst but the cost and availability need to be addressed.

Reviewer 2:

IrO_2 was identified as promising non-carbonaceous electrode candidate for oxygen reduction reaction (ORR) electrochemistry. However, Ir is expensive and may not be economically viable.

Reviewer 3:

The reviewer stated that it was good finding that cells made with Ni- and Li-doped NiO permits high coulombic and round trip efficiencies. Howeve , cathode materials screened, from carbon through to TiC showed relatively poor oxygen evolution reaction ORR ratios

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that materials and electrodes used from the California Institute of Technology need to be designed for the project. LBNL work contributed well to the project.

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

Reviewer 1:

The reviewer stated that because Ir is expensive, the PI should consider low-cost alternatives.

Reviewer 2:

The reviewer stated that there is a long way to go, lots of challenges remaining. The major issue here of course is that even if this cell can be made to cycle reversibly, it is not clear that automotive customers would be willing to commercialize a 100-150° Celsius (C) battery. Nevertheless, this is a good study for proof in principal.

Reviewer 3:

The reviewer stated that future research points mentioned need to be expanded and more topics need to be added. The technology has potential but needs to be aligned with DOE timeline and targets. Even if the problems mentioned are addressed and/or solved there are still open points that need to be overcome.

Reviewer 4:

The reviewer stated that it is unclear to how the researchers would address the goal to provide a cell and system that can operate robustly in ambient air without O_2 purification. The researchers of this project have not even tangentially studied any effects of water vapor and carbon dioxide (CO_2)

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

Reviewer 1:

The reviewer stated that this molten salt battery could potentially scale up for stationary applications.

Reviewer 2:

The reviewer thought it was reasonable, not a home run however due to the temperature range of the cell.

Reviewer 3:

The reviewer stated yes, but Li-air technology is in general challenging to address the targets of DOE.

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

No comments were received in response to this question.

Low-Cost, High-Energy Si/Graphene Anodes for Li-Ion Batteries: John Colwell (XG Sciences) - es237

Presenter

Robert Privette, XG Sciences

Reviewer Sample Size

A total of five reviewers evaluated this project.

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

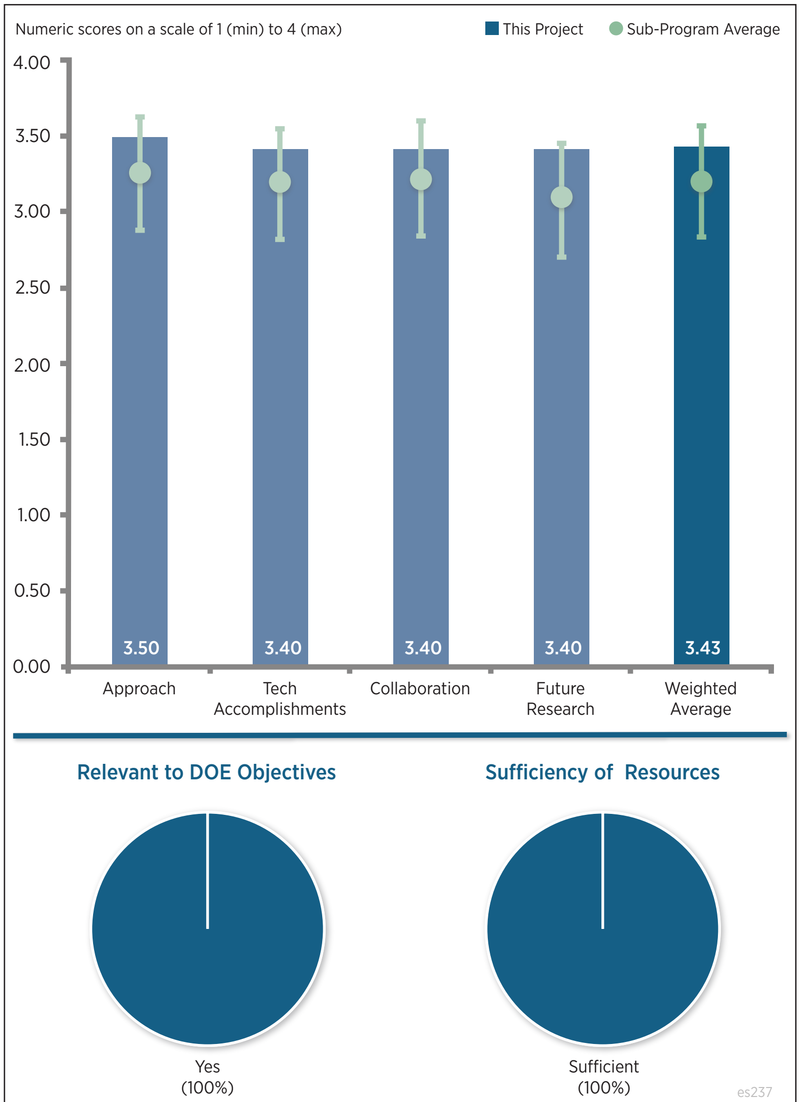

Figure 2-24 – Low-Cost, High-Energy Si/Graphene Anodes for Li-Ion Batteries: John Colwell (XG Sciences) - Electrochemical Energy Storage

Reviewer 1:

The reviewer stated that XG Sciences is developing SiG^{TM} anode with improved performance, and thus addressing the three barriers: specific energy, life, and cost.

Reviewer 2:

The reviewer noted that this was material-centric, and the developer did a good job of defining the key program metrics, then seeking to meet them.

Reviewer 3:

The reviewer stated that this is possible way to stabilize Si negative electrodes. Seem to be hitting the goal of 600 Ah/kg for the anode. However, it would be nice to have independent verification, and know what this enables in full cells at the consumer or large format cell level. The reviewer thought that the project team needs to understand better if the Si is truly sealed inside or if the graphene is loosely wrapped around the particle.

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

Reviewer 1:

The reviewer stated that the SiG^{TM} anode materials shows good consistency in first cycle capac ty (FCC), first cycle efficiency (FCE) and capacity retention. The best 2 Ah full cell built by XG with SiGTM anode has a cycle life of 1,176 at 86.9% retention, which is better than other anode projects. However, the good performance is limited in the voltage window of 4.2–3.25.

Reviewer 2:

The reviewer stated that it seems appropriate for the level of funding. Seems on track vis-a-vis the plan. The initial durability goal was hit. The reviewer would have liked to see more energy and indeed reporting of energy as well as Ah capacity.

Reviewer 3:
The reviewer stated that more information on cost model approach would have been beneficial. A target of 600 mAh/g was set for the anode, but the modelling had shown that 800 mAh/g was really required, in order to achieve 350 Wh/kg. Some additional modeling, predicting an EV-sized cell (with their collaborators) would have been beneficial

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that XG Sciences collaborates with several national laboratories and industrial partners.

Reviewer 2:
The reviewer said it appeared that there had been good collaboration, but the exact roles of each institution could have been made more clear.

Reviewer 3:
The reviewer stated that the addition of more collaborators and nature of additional collaborators is excellent; however, achieving the involvement of global high-volume cell producer(s) would have been one remaining area for improvement.

Reviewer 4:
The reviewer noted that many of the partners are more like suppliers, but still sufficient to get outside ideas to help the project team do good work.

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

Reviewer 1:
The reviewer stated that the project is nearly over, but there are good plans for future.

Reviewer 2:
The reviewer noted that the program is closing out, but the developer is making good use of the data generated during the program. It will be important to evaluate the final articles against the program goals, to verify that this project approach was effective.

Reviewer 3:
The reviewer stated that XG clearly indicated the next step task: to improve voltage window performance with higher energy specific ene gy (850 mAh/g). The reviewer added that XG needs data to support the claim that XG SiG™ achieves competitive price as compared to graphite, and how far it is to the EV Everywhere target $125/kWh for full battery.

Reviewer 4:
The reviewer stated that given funding and progress the future plans seem right. Again, it would be nice if the project team could give some sort of idea how this would enable improvements in commercial cells. The reviewer would like to see more emphasis on durability, and suitable or compatible positive electrodes and electrolytes.

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

Reviewer 1:
The reviewer stated yes, the work is in right direction.

Reviewer 2:

The reviewer stated that this moderate cost (hopefully) method to make higher energy cells, which will help with penetration of electrified vehicles

Reviewer 3:

The reviewer stated that this low-cost high-energy Si anode will promote the use of batteries and EVs, which will help with the petroleum displacement.

Reviewer 4:

The reviewer noted local advanced material supply, allowing for an appreciable energy density increase.

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

Reviewer 1:

The reviewer stated that the current achievements demonstrate that XG Sciences has sufficient resources to achieve the milestones.

Reviewer 2:

The reviewer stated that there were no issues observed.

Low-Cost, High-Capacity Lithium Ion Batteries through Modified Surface and Microstructure: Pu Zhang (Navitas Systems) - es238

Presenter
Pu Zhang, Navitas Systems

Reviewer Sample Size
A total of five reviewers evaluated this project.

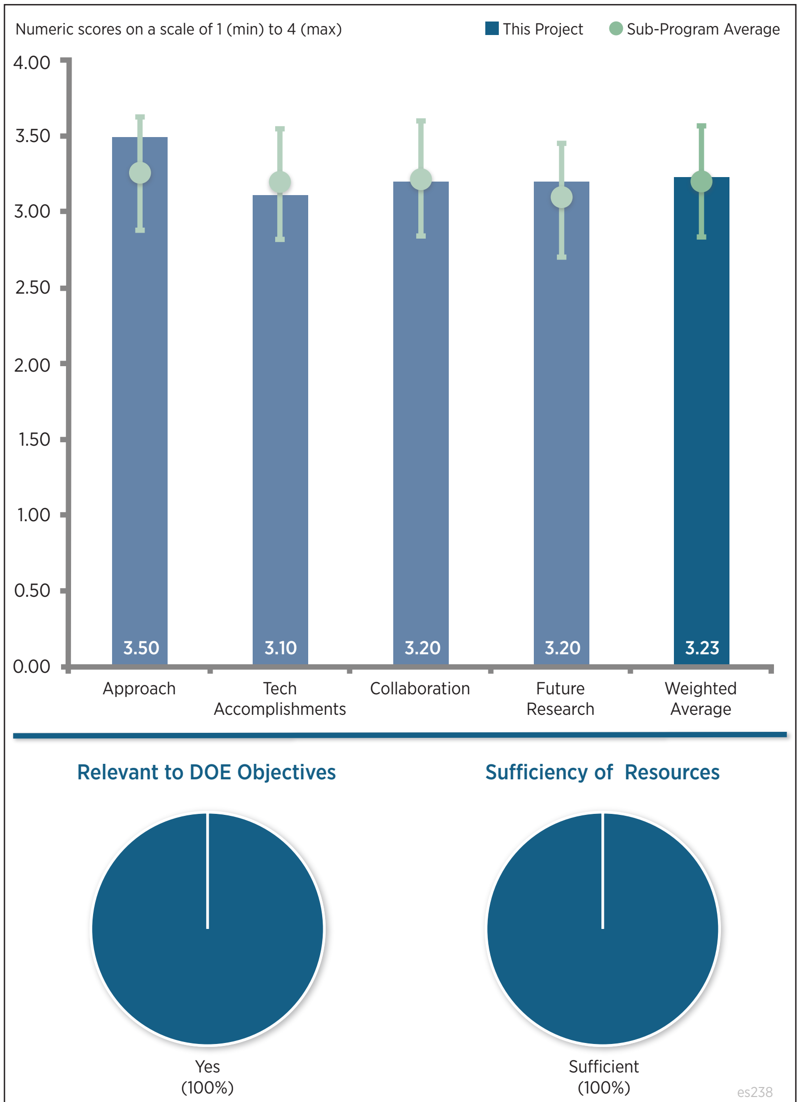

Figure 2-25 – Low-Cost, High-Capacity Lithium Ion Batteries through Modified Surface and Microstructure: Pu Zhang (Navitas Systems) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer stated that 2016 works concentrated on improving tap density scale up process.

Reviewer 2:
The reviewer noted that as shown, the approach is clearly focused on addressing specific and relevant material metrics.

Reviewer 3:
The reviewer stated that the low-cost and standard manufacturing method to make stable Si electrodes attacks major barriers and seems well planned.

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

Reviewer 1:
The reviewer stated that progress has been good. Cycle life improvement requires an explanation as to why pouch cells have performed better than coin cells. The reviewer encouraged the developer to track progress via a gap chart, as a summary.

Reviewer 2:
The reviewer stated that the project team seems to have made good progress with the scale-up complete. Not clear that the team will reach cycling goals that are relevant to customer use.

Reviewer 3:
The reviewer noted that the pilot scale products match or exceed the capacity retention of lab scale product, but

both are about only 200 cycles with less than 80% retention. The half cell (anode) test shows only 450 cycles at a capacity of 550 mAh/g. Object was greater than 800 mAh/g and greater than 1000 cycle at 80% depth of discharge (DOD). 2 Ah full cell delivered but cycle life test shows less than 200 cycles at 90% retention.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that ANL and A123 Systems, LLC joined the project in 2016.

Reviewer 2:
The reviewer did not find a la ge variety of collaborators, but enough.

Reviewer 3:
The reviewer thought that more clarification of partners roles throughout the presentation would help.

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

Reviewer 1:
The reviewer found the future work well defined

Reviewer 2:
The reviewer thought it seems appropriate and matches the plan that the team showed as the DOE agreement.

Reviewer 3:
The reviewer was concerned that a path to 1,000 cycles is not clear.

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

Reviewer 1:
The reviewer stated that the works are in the right direction.

Reviewer 2:
The reviewer said this could lower cost of cells and thereby get them in commerce.

Reviewer 3:
The reviewer stated that this project enhances the energy density and improves cost of the batteries, which will help EVs to displace petroleum.

Reviewer 4:
The reviewer commented yes, insofar as this is a domestic material, which at a competitive cost could enhance the manufacture and supply of energy storage devices.

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

Reviewer 1:
The reviewer stated that Navitas, in collaboration with ANL and A123 Systems, LLC, has the potential to do the job (low-cost long cycle Si anodes).

Reviewer 2:
The reviewer stated that this is a good partnership, although the exact contributions of each throughout the project could be made clearer.

Scale-Up of Low-Cost Encapsulation Technologies for High Capacity and High Voltage Electrode Powders: David King (Pneumaticoat Technologies) - es239

Presenter

David King, Pneumaticoat Technologies

Reviewer Sample Size

A total of five reviewers evaluated this project.

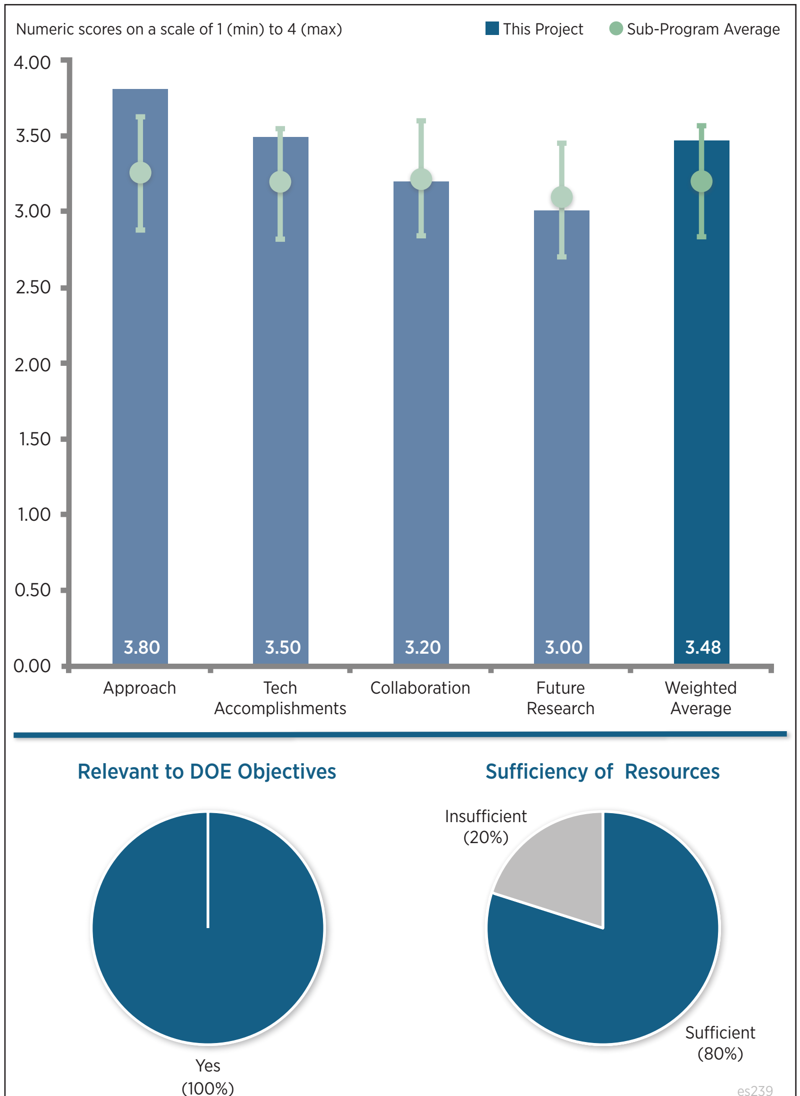

Figure 2-26 – Scale-Up of Low-Cost Encapsulation Technologies for High Capacity and High Voltage Electrode Powders: David King (Pneumaticoat Technologies) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer stated that the PneumatiCoat Small Business Innovation Research (SBIR) project is a successful project that helps improving cycling life of a variety of cathode and anode materials with economic viability. The presentation is clear and convincing.

Reviewer 2:

The reviewer stated that there was an excellent structure of the program.

Reviewer 3:

The reviewer commented that the coating will improve the stability of the active material and scale up will reduce the cost of coating.

Reviewer 4:

The reviewer though that the approach is excellent based on SBIR limitations of effort. It might have been nice to see more comparisons of other coating methods, there was at least a good effort to compare the chemical precipitation method in detailed performance studies. The decision to go with atomic layer deposition (ALD) on powders rather than electrodes led to an excellent implementation of scale-up to pilot plant operation of an ALD methodology.

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

Reviewer 1:

The reviewer thought that the results were very impressive. The one area of concern for the developer should be understanding the limitations of aluminum oxide-based ALD coatings for some high voltage systems. The reviewer encouraged the investigations in the phosphates.

Reviewer 2:

The reviewer stated that the ALD particle semi-continuous coating process has the advantages of low-cost and high-throughput, and is effective in improving electrode performance.

Reviewer 3:

The presence of pilot plant equipment sets the stage for in detail heavy implementation in particular systems. The reviewer would like to see such implementation extended to other more promising systems such as low cobalt NMC positive and Si or Si/C negative electrode materials.

Reviewer 4:

The reviewer noted that although progress previously reported at the last AMR was excellent, the nature of actual accomplishments, progress, or new outcomes since then either is not as clearly reported or simply has been of less significance

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer enthused that PneumatiCoat can actually collaborate will all players in the battery field by providing their coating technologies.

Reviewer 2:

The reviewer stated that the team is well structured, and all contributions from partners were shown.

Reviewer 3:

The reviewer found that the collaboration is limited so far and no information is given about industrial partners. Material suppliers should definitely be included although the reviewer understands the need for protection of proprietary issues. This could be a breakthrough technology, and needs to be fast tracked to get best results.

Reviewer 4:

The reviewer noted that while collaboration and coordination with main partners appears to have been productive, the nature or possible utility of collaboration with unidentified corporate partnerships is completely opaque.

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

Reviewer 1:

The reviewer stated that it seems PneumatiCoat has done everything and is ready for phase III.

Reviewer 2:

The reviewer thought that future work is correctly directed. The reviewer also referenced prior comments regarding balancing of focus of work. Anode-based coating studies may be an area of future work as well.

Reviewer 3:

The reviewer stated that while the project is nearly done, no future work or plans are noted.

Reviewer 4:

The reviewer commented that future research is really not documented in report.

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

Reviewer 1:
The reviewer stated that the good results reported need to be fully validated and put on fast track because of the high relevance of the techniques. The improved cycle life should also result in improved calendar life of the batteries to increase the level of relevance to DOE programs.

Reviewer 2:
The reviewer stated that yes, the work is on right track

Reviewer 3:
The reviewer thought that the low-cost coating technology will provide long lasting batteries to encourage petroleum displacement in automotive applications.

Reviewer 4:
The reviewer stated yes, insofar that this process may enable significant improvement in cathode material durability. The big question on advanced anode durability improvement remains.

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

Reviewer 1:
The reviewer thought that the pilot plant can produce a lot of material, but it is not clear that cell building and testing resources are adequate for fast track evaluations.

Reviewer 2:
The reviewer stated that the initial progress earlier in project seemed to be excellent in light of budget size and apparent resources.

Reviewer 3:
The reviewer stated that the current achievements demonstrate that PneumatiCoat has sufficient resource to achieve the milestones.

Reviewer 4:
The reviewer commented that the project appeared to be well-balanced.

High-Energy Anode Material Development for Li-Ion Batteries: Cary Hayner (Sinode Systems) - es240

Presenter

Cary Hayner, Sinode Systems

Reviewer Sample Size

A total of four reviewers evaluated this project.

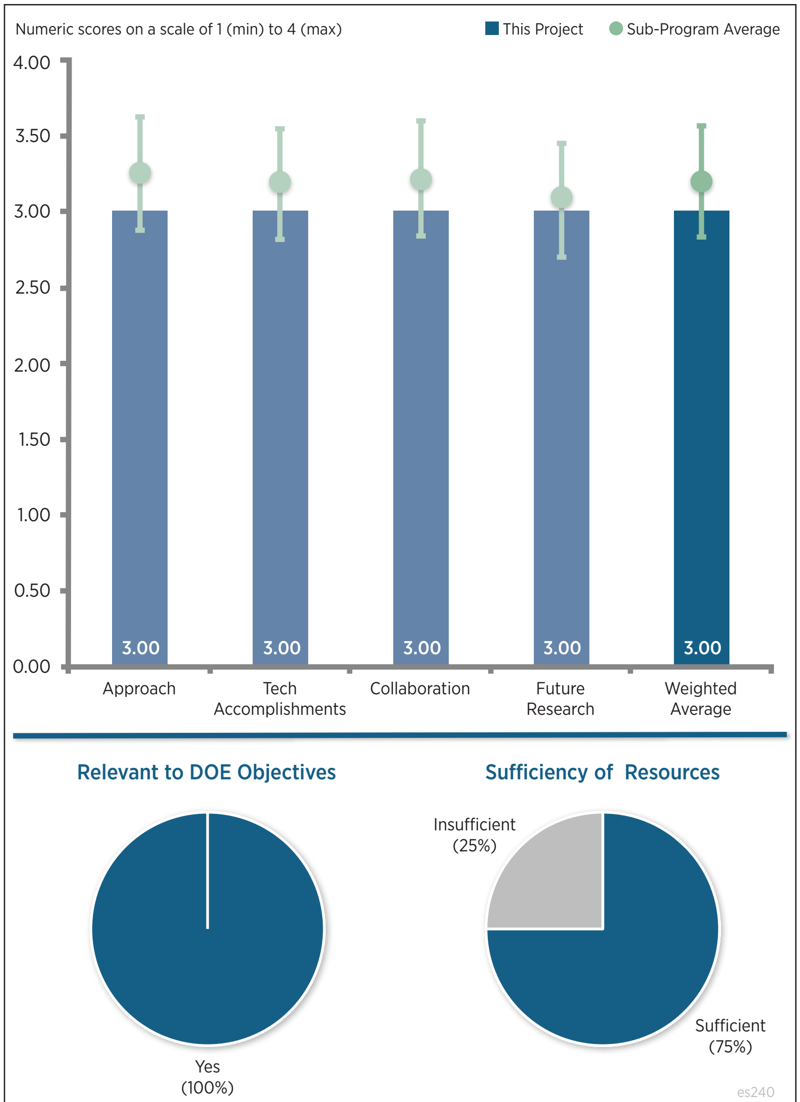

Figure 2-27 – High-Energy Anode Material Development for Li-Ion Batteries: Cary Hayner (Sinode Systems) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer commented that the efforts of development and commercialization of silicon-carbon (Si-C)-based anode by SiNode Systems are in line with DOE's targets on battery materials: performance, life and cost.

Reviewer 2:

The reviewer thought that the approach of using a graphene-Si anode has definite advantages in making a high energy anode with good cycling properties and low cost. These properties can be optimized with a good selection of materials with an emphasis on low-cost and high-performance. The approach of using a staged marketing approach runs the risk of floundering on an early marketing stage without ever reaching the desired EV market, however.

Reviewer 3:

The reviewer commented that the main issue is calling out USABC battery system cost target, without clearly identifying the anode material properties necessary to achieve that and the performance goals. A more comprehensive set of material targets (e.g., include tap density, sheet conductivity, etc.) should be considered.

Reviewer 4:

The reviewer stated that the objectives do not target the final cost DOE battery ta gets of $125/kWh with the detail of cost of producing cells. Also the business case is not well defined on being the anode material supplier to the battery industry. The cost versus production rate is not included.

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

Reviewer 1:
The reviewer stated that the 1,000 times scale-up was achieved with comparable performance. However, cycle life data are only up to 140, far from the end performance targets: 750-1,500 mAh/g anode, 1,000 cycles.

Reviewer 2:
The reviewer commented that the progress to date is promising, but still far from acceptable in terms of cycle life. The use of additives and surface treatments are hard to evaluate because the types of additives and surface treatments are not discussed at all. At least some generic explanations would be helpful in attempting evaluations of these crucial steps.

Reviewer 3:
The reviewer commented that this is a very interesting approach, and encouraging improvement in cycle life. More discussion of key material parameters influencing cycle life, and associated identified failure modes woul be worthwhile. The reviewer suggested that the team continue with the binder investigations, as this could have a considerable impact on this work.

Reviewer 4:
The reviewer stated that the status of the cost of the material and improvement from last year is missing in the accomplishments.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that there were well-defined partnerships, and good evidence of the e fective collaboration.

Reviewer 2:
The reviewer stated that the collaboration with the state-of-the-art cell supplier will help to validate the cost benefit of the advanced anode material.

Reviewer 3:
The reviewer stated that SiNode Systems should seek collaboration with national laboratories for advanced characterization techniques.

Reviewer 4:
The reviewer stated that collaborations to date have only involved pragmatic evaluation and material supply questions. The group needs to develop more forward looking collaborations if they are to move in the direction of intermediate product development and ultimately EV products. In particular, the group needs to develop collaborators to make cathodes, to coat their anode materials to a high standard, and to manufacture finished cells. The team also needs collaboration to enter the above business areas.

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

Reviewer 1:
The reviewer stated that the remaining challenges and barriers are clearly recognized in the presentation.

Reviewer 2:
The reviewer noted that this project is nearly finished, so a strong finish is necessary to obtain funding for the nex step of development.

Reviewer 3:
The reviewer stated that the future research should include the cost analysis to show the gap between DOE cost goals and SiNode Systems business strategy.

Reviewer 4:
The reviewer commented that without identifying the failure modes, it is difficult to see how the cycling goals shall be met. This is the open work however, so the developer should focus on this. The reviewer also suggested considering calendar life in the evaluation.

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

Reviewer 1:
The reviewer thought that the work is in right direction.

Reviewer 2:
The reviewer stated yes, insofar the development of a low-cost Si-containing anode material (and supplier) furthers industrialization of large format and durable energy storage systems.

Reviewer 3:
The reviewer stated that the R&D provides low-cost, high-energy density solutions to encourage petroleum displacement.

Reviewer 4:
The reviewer commented that the relevance is somewhat downgraded because of the staged marketing approach, which may take many years before the desired DOE objectives can be addressed.

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

Reviewer 1:
The reviewer stated that there were no issues.

Reviewer 2:
The reviewer stated that at present levels of resources, the chance of entering even the first stage of cell manufacture and market entry is unlikely. The project team needs a strong partner in these areas.

Advanced High-Performance Batteries for Electric Vehicle (EV) Applications: Ionel Stefan (Amprius) - es241

Presenter

Ionel Stefan, Amprius

Reviewer Sample Size

A total of four reviewers evaluated this project.

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

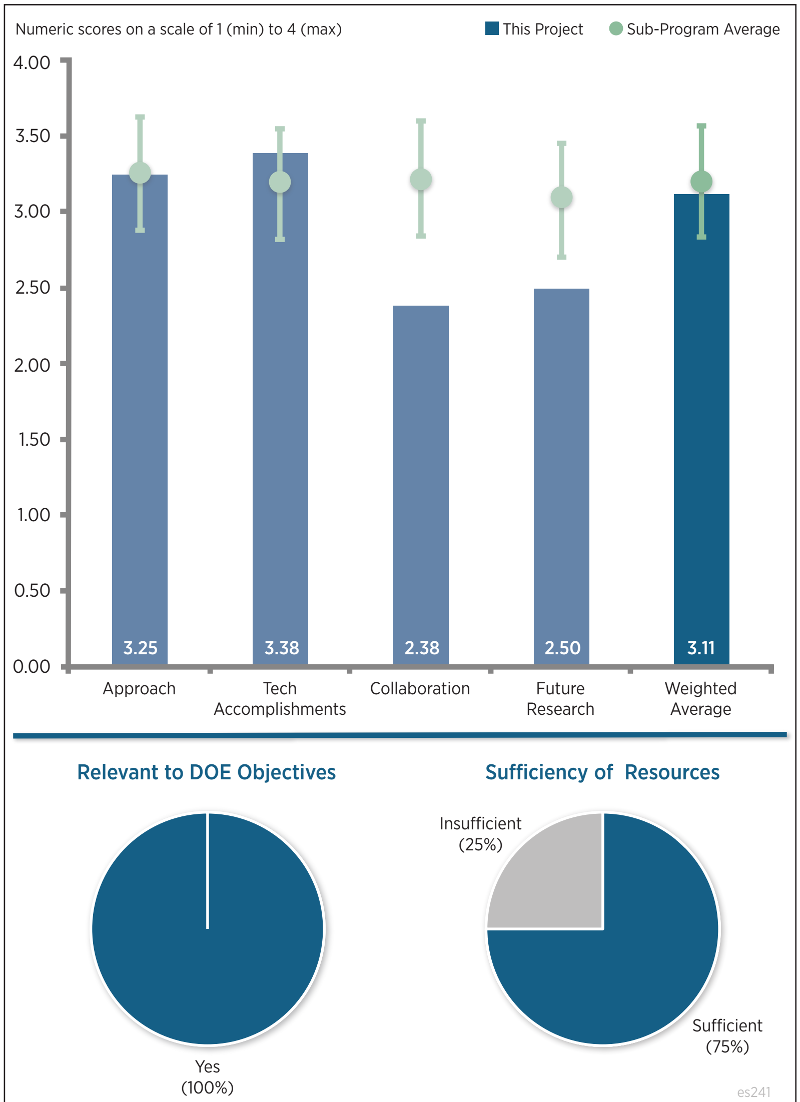

Figure 2-28 – Advanced High-Performance Batteries for Electric Vehicle (EV) Applications: Ionel Stefan (Amprius) - Electrochemical Energy Storage

Reviewer 1:

The reviewer stated that Amprius is starting with well-performing Si anodes and is trying to improve them.

Reviewer 2:

The reviewer noted that the objective is to develop high specific ene gy Li-ion cells utilizing Amprius Si nanorod anodes for EV batteries. There were two specific objectives. First, to design and fabricate Si nanowire anodes matching with advanced (high-capacity and high-energy density) cathodes and state-of-the-art cell components. Second, to design, fabricate, test, and deliver 2 Ah, 10 Ah, and 40 Ah Li-ion cells with Si nanowire anodes that meet the USABC 2020 goals: 350 Wh/kg and 750Wh/l at end-of-life (EOL), a 12:1 power:energy ratio, and 1,000 DST cycle life. There are two technical barriers that will be addressed: to reduce the mass and volume of the anode for higher energy density, specific ene gy, and lower costs, and to improve the cycle life by optimizing the nanowire structure.

The reviewer thought that the approach looks good and is consistent with the project/DOE goals. The use of Si anode can result in moderate gains in specific ene gy and energy density, especially after proper pre-lithiation. However, with the Si anode, there is a huge penalty in the cycle life even with the nanorods here and it is not clear to what extent further optimization can mitigate this. Yet, this is one of the viable approaches. The specific approach involves matching Si nanowire anodes with advanced (high capacity and high ene gy density) cathodes and state-of-the-art cell components, and the development of an anode and other cell components in a 2 Ah cell form factor and later scale it up to an intermediate 10 Ah cell and alter to 40 Ah cells for performance demonstration. Overall, the project is well designed, and integrated with other efforts.

Reviewer 3:

The reviewer thought that the approach to anode development rates much higher than the cathode development or the full cell approach. The emphasis on cobalt (especially that charged to high voltage) presents a severe safety hazard and should be discontinued. Other cathode materials should be considered that can meet the requirements for full cell energy and power.

Reviewer 4:

The reviewer thought that the PI is putting too much emphasis on cobalt-based cathode materials. This is definitely wrong for transportation applications, on which the project is focused. High-nickel NMCs are able to attain similar capacities at high voltages and more in line with the transportation sector. Indeed, cost is the overriding issue for this project. It is hard to see how the anode fabrication method could ever meet USABC and DOE cost targets.

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

Reviewer 1:

The reviewer thought that the accomplishments for the negative electrode development are excellent. However, the use of cobalt oxide is not acceptable for EV usage and no acceptable alternatives are presented. The limiting electrode for cycle life seems to be the negative electrode and the results to date do not meet the goals of DOE, but the progress is encouraging, especially when compared with other Si attempts by other contractors.

Reviewer 2:

The reviewer noted that there has been good progress made on the cell fabrication and scale up. Specificall , Si nanowire cells were developed with capacities of 2.6 to 3.1 Ah depending on the cathode, which met USABC requirements expect the cycle life. Also, 30 of the Si nanowire-NMC 2.0 Ah cells were delivered to INL and SNL for performance and safety evaluation.

Furthermore, the reviewer stated that the design and tooling has been completed for 10 Ah cells and the testing of first 10 Ah prototype cell. These cells performed well in the short-terms tests and met the energy and power goals. However, the performance relative the cycle life and calendar life is less than desired. It is not obvious or stated clearly what the strategies would be for improving the life characteristics, such as modifying the electrolyte or reducing the Si content. Nevertheless, the overall progress is good and is consistent with the scheduled milestones and DOE goals.

Reviewer 3:

The reviewer stated that it is near the beginning of the program. Gap analysis shows substantial progress, with decent energy density and life, although not yet at the USABC goals, especially to meet EOL goals. A discussion of pre-lithiation ended with an admission (during questions) that pre-lithiation is not really viable.

Reviewer 4:

The reviewer stated that in general for a Si anode Li-ion cell, these are pretty good results. Unfortunately, they have a long way to go for transportation applications.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that there are no formal partners, but most potential partners are way behind what Amprius has already accomplished. Amprius does collaborate on an ad hoc basis

Reviewer 2:

The reviewer stated that there are no collaborators listed and this is a deficiency of the project. The workers should be spending their full time on anode development, but could benefit by collaborating with cathode and full cell experts to enhance the anode work.

Reviewer 3:

The reviewer commented that there are no collaborations on this project, but will be established (with the DOE laboratories) for testing after the cells are delivered.

Reviewer 4:
The reviewer reiterated that the researchers stated that there is no team in the team overview.

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

Reviewer 1:
The reviewer stated that there are three goals going forward. First, to continue studies to increase the cycle life by optimizing the electrolyte formulation, anode structure, cathode materials and coating, and separator type. Second, to verify and/or demonstrate that the EOL energy density and specific ene gy will exceed the USABC requirements. Finally, to continue studies to source the appropriate cathode material with high capacity and cycle life. It is imperative that a systematic failure mode analysis (DPA) will be performed to identify the failure modes and develop strategies to mitigate them. This is indeed a challenge for the Si-anode based Li-ion cells. Another intricate characteristic is the abuse tolerance, which is reportedly worse compared to the conventional Li-ion batteries. The future work planned is logical with appropriate decision points in the materials selection and cell fabrication processes.

Reviewer 2:
The reviewer stated that it is too early to make much of a judgment on whether their ideas will lead to big improvements.

Reviewer 3:
The reviewer found that the proposed future work is ambitious, but the path to advancing the state of cell development is not well delineated. The cathode and electrolyte developments are only stated as goals, but no details regarding the approach are given.

Reviewer 4:
The reviewer pointed out that there is little to no detail concerning how the team is going to attack the cycle/calendar life issue, which should be its highest priority.

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

Reviewer 1:
The reviewer stated that the energy requirements are close, but the cycling life work needs improvement to meet the DOE goals.

Reviewer 2:
The reviewer commented that the low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles. High capacity anode materials are required to improve the specific energy of Li-ion cells. Si anode has the potential to offer twice the capacity of graphitic anodes, and Amprius has developed a fairly robust Si anode based on Si nanorods. There are early results on small laboratory cells and it would be timely to demonstrate the performance benefits (higher specific en gy and energy density) in large format cells against the USABC requirements, which is the objective in this project.

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

Reviewer 1:
The reviewer stated that the group needs to collaborate with others, as discussed above, to have a chance to meet the goals. This would require additional resources.

Reviewer 2:
The reviewer commented that the resources seem to be excessive, but make sense based on the cost share from the sub-contractor.

A Disruptive Concept for a Whole Family of New Battery Systems: Farshid Roumi (Parthian Energy) - es242

Presenter
Farshid Roumi, Parthian Energy

Reviewer Sample Size
A total of five reviewers evaluated this project.

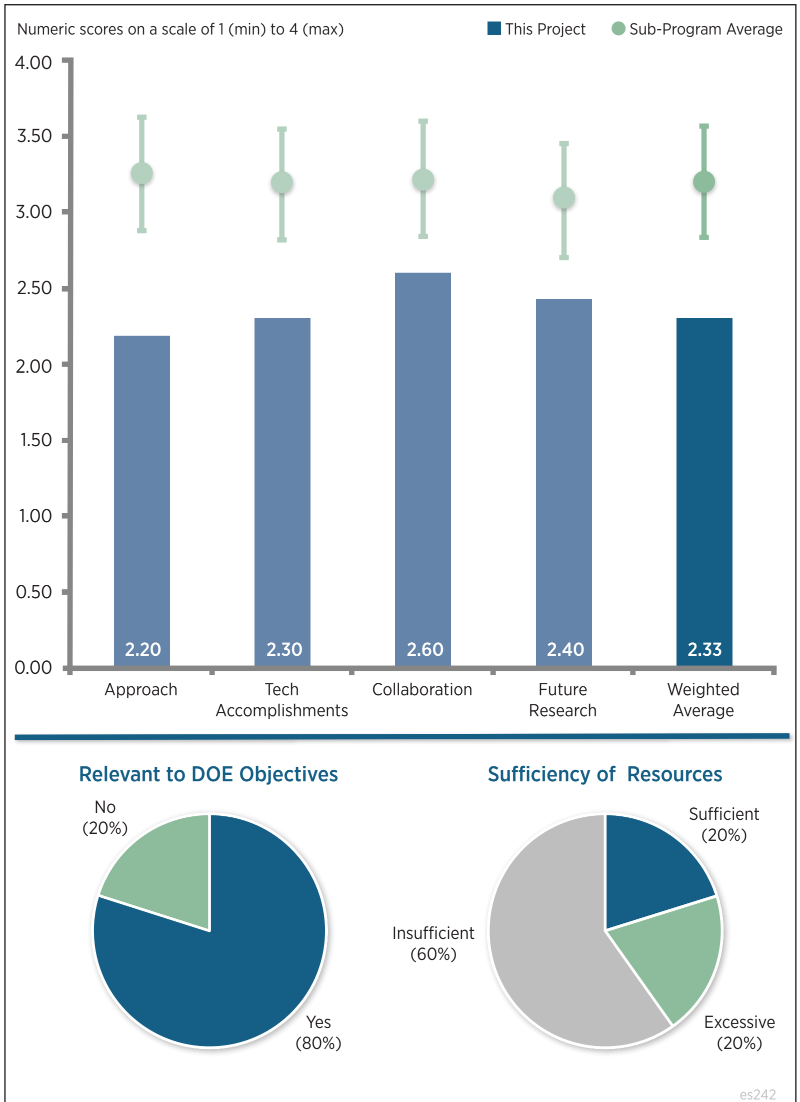

Figure 2-29 – A Disruptive Concept for a Whole Family of New Battery Systems: Farshid Roumi (Parthian Energy) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer observed a nontraditional cell design that appears to be at the very early stages of development, and also described the project as quite novel. The objectives were clearly stated, but the discussion of the approach was incomplete and focused more on the results that approach. Slide five is incomplete in the discussion of the battery architecture and Slide 6 is confusing in terms of an approach. From discussions with the presenter, a better approach is believed to exist than was presented.

Reviewer 2:
The reviewer stated that this project approach is very unconventional and ambitious relative to most other battery designs. Due to this novel approach, the performers should present technical results showing the progress of their technology since their start in February of 2015. The performer did not present any new experimental data regarding their novel cell design concept, and the only data presented on Slide 5 were identical to what was presented last year. Based on this lack of technical concept presentation, the validation of this unusually approach is not supported by any technical data.

Reviewer 3:
The reviewer pointed that this is alternative cell architecture, which is chemistry agnostic, to achieve high energy density. This is much needed and will complement advanced materials to achieving high energy density. This approach was based on a multi-layer, Supper Cell (Scell^{TM}) 3D architecture to achieve high energy density and high rate goals. Two and a half years is sufficient to demonstrate feasibility of this technolog .

The reviewer commented that the project team needs to provide assumptions for modeling in order to assess modeling validity. Milestones were not quantifiable, and they were task descriptions, not milestones. Given the small size of the components, the team needs to provide a schematic on how they plan to integrate the components in the ScellTM.

Reviewer 4:
The reviewer stated that the ScellTM design was not innovative, and as a matter of fact, similar designs can be found in the U.S. patents in the 1990's for alkaline batteries. The ideal was to increase the interfacial surface area, but the interfacial area in the ScellTM would not be larger than the traditional cell. Many problems were encountered in the engineering of a primary alkaline battery. The likelihood for the design to work in rechargeable batteries is low.

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

Reviewer 1:
The reviewer noted that good technical progress was shown, but the discussion on methods for low-cost fabrication of the various battery elements were overstated in that there was no clear path to low-cost production at scale. At best, an approach to producing battery elements to allow prototype cells was demonstrated. The reviewer added that, to be fair, it is clearly very early in the development process.

Reviewer 2:
The reviewer stated that the team presented very limited technical accomplishments during the performance period. The majority of the new experimental data shared were based on coin cells and spacer height variation, data which used conventional materials and delivered no performance improvement over what is commonly achievable with Li-ion technology.

Reviewer 3:
The reviewer acknowledged that the PI has demonstrated the feasibility of the design and tested prototypes, but exclaimed that the PI needed to show some real electrode capacity data from a prototype, especially with this type of project. The work presented focused on how the key parameters were determined. However, the team is still at the beginning of the development phase and a long way from deciding on optimizing process steps.

Reviewer 4:
The reviewer stated that the project team demonstrated the concept of an in situ, conformal separator via electrophoretic deposition (EPD). If successful, this conformal separator technique can be an enabler for 3D cells. The project team also measured the effect of ionic diffusion distance on capacity utilization. Even though the 3D design should be capable of achieving full capacity at high rates, all the experimental results so far showed that full capacity was only achieved at low rates. Thus, even though full capacity was achieved at low rate, the team has not demonstrated the high rate feasibility enabled by the 3D architecture at the component level.

Reviewer 5:
The reviewer did not understand why the half coin cells were made and tested. The faults of the design were not identified: both anode and cathode were thick, unsure if the cell can sustain practical rate of cha ge and discharge, and unsure if the Li-ion become uniformly distributed in the cathode. The reviewer found that the conclusion was totally unsupported.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that the PI has a slide listing contributions from partners. This is good and clear.

Reviewer 2:
The reviewer stated that this is a good collaboration with national laboratories, academia, and industry. The roles of each team member was clearly identified to justify their participation in the project

Reviewer 3:
The reviewer noted that the developer identifies many partner o ganizations with significant battery skills. The

collaborators' contribution should extend to guiding the performance of basic electrochemical tests to provide the cycle life, specific ene gy, energy density, power, etc. of this technology.

Reviewer 4:

The reviewer opined that collaborations with a potential manufacturer are lacking. While it is obvious that a partnership with a cell manufacturer is probably not viable, HydroQuebec does not appear to be the commercialization partner that will be required. It was not obvious until Slide 20 who was doing what.

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

Reviewer 1:

The reviewer thought that the discussion of the future work does not appear to support the identified challenges and barriers.

Reviewer 2:

The reviewer stated that the project team needs to characterize the performance of the in situ conformal separator via EPD. The team should also demonstrate full integration using the in situ conformal separator.

Reviewer 3:

The reviewer stated that efforts to study high risk/reward anode systems, like Si, seem inappropriate given the extremely limited technical data presented with more conventional materials like graphite. This approach uses novel cell geometries and it is highly probable that the high volume change of Si will compound the challenge in proving the technical viability of this performer's base approach. Future work should center on experimentally proving the advantages of the performer's proposed cell geometry system using conventional materials.

Reviewer 4:

The reviewer warned that no solid future research plan was proposed to address the major design problem. The half-cell work has nothing different as those reported in the literature.

Reviewer 5:

The reviewer noted that the PI realizes the daunting task ahead and has already developed alternative approaches for moving ahead. The PI will have to make significant progress with working prototypes and results. The reviewer expressed concerns regarding whether expansion of Si anode rods will deteriorate causing increased impedance with cycling.

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

Reviewer 1:

The reviewer stated that this is highly relevant, because high energy density is critical to achieving petro displacement.

Reviewer 2:

The reviewer stated that while it is high risk, the concept is quite novel and worthy of funding.

Reviewer 3:

The reviewer noted that DOE objectives would be supported if the Scell™ design works.

Reviewer 4:

The reviewer warned that currently this project does not support the mission of DOE for petroleum replacement. No new technical performance level has been demonstrated and the proposed cell geometry is very high risk with an unclear promise of reward.

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

Reviewer 1:
The reviewer stated that $750,000 for two and a half years might not be sufficient to demonstrate feasibility of the Scell™ concept.

Reviewer 2:
The reviewer stated that the PI will probably need additional funding to achieve milestones. However, the project team should demonstrate proof of concept sufficiently to get additional funding

Reviewer 3:
The reviewer noted that this project is in a very early stage and has many challenges. The level of funding requested to complete the proof of concept is a minimum of three times what is available.

Reviewer 4:
The reviewer stated that project resources are appropriate.

Dramatically Improve the Safety Performance of Li-Ion Battery Separators and Reduce the Manufacturing Cost Using Ultraviolet Curing and High-Precision Coating Technologies: John Arnold (Miltec UV International) - es243

Presenter

John Arnold, Miltec UV International

Reviewer Sample Size

A total of five reviewers evaluated this project.

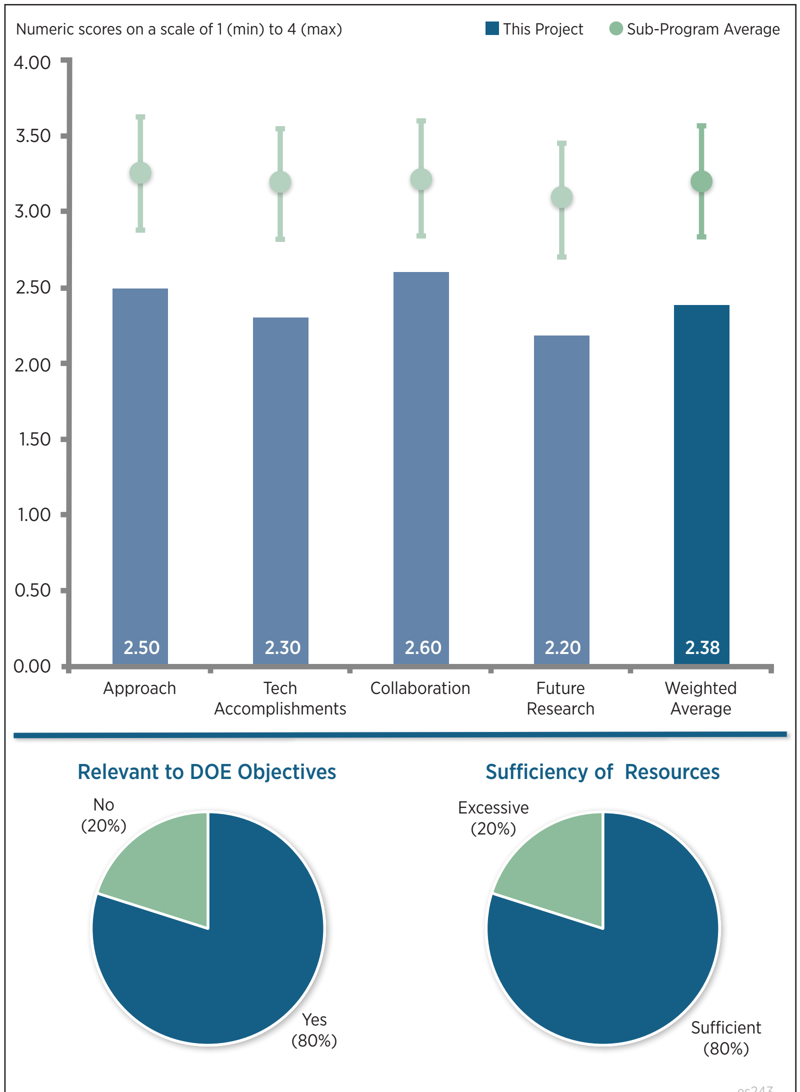

Figure 2-30 – Dramatically Improve the Safety Performance of Li-Ion Battery Separators and Reduce the Manufacturing Cost Using Ultraviolet Curing and High-Precision Coating Technologies: John Arnold (Miltec UV International) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer said that the work's objective is very relevant-to improve separator performance at elevated temperatures; however, there are not enough technical details discussed.

Reviewer 2:

The reviewer said that the objective here is to improve the safety of LIBs by improving the shutdown characteristics of Li-ion cells and reduce the risk of thermal runaway and fire, without impacting the conductivity of the separators and the high rate discharge rates. Another specific objective is to reduce the manufacturing costs for the ceramic coated separators by 50%. The reviewer stated that ceramic-coated separators reduce the risk from Li dendrites, minimize the separator shrinkage during thermal runaway, and also improve the interfacial stability at the electrodes. The approach here involves ultraviolet (UV)-cured binders to coat the separators with ceramic materials. Methods will be developed at the bench-top level to identify suitable binder chemistry with good adhesion and to prove its viability to coat separator rolls and to validate these separators before commercialization. The reviewer said that the studies address the technical barriers of safety and cost Li-ion batteries, though it is not clear if the proposed coating method will result in significant cost benefits over the conventional ceramic coating The project is well designed, and integrated with other efforts, but according to the reviewer the relevance and justification of this project are to be substantiated with a proper cost assessment

Reviewer 3:

The reviewer said that the technical advantages of UV processing compared to conventional ceramic separators are not clear. Through the addition of a new step, the promise of a cost reduction is not supported by the data shown and the technical performance improvements are either the same as the incumbent (mechanical/temperature stability) or unproven (voltage stability).

Reviewer 4:
The reviewer remarked that the project involves utilizing UV curing to create ceramic-coated separators. The emphasis is on making the materials and comparing to uncoated versions. The reviewer said that this area of research is worthwhile for investigation, but this team is too inexperienced to know what tests need to be performed to analyze its materials for LIB applications. The reviewer remarked that no cost analysis was presented, and questions about commercial viability due to cost increases in fabrication were inadequately answered.

Reviewer 5:
The reviewer said that it would be great to see cost economic analysis and technical target specifications based on costs. The reviewer said that the work plan also needs to include full cell testing using carbon anodes; characterize permeability; uniformity; loss in pore volume; and chemical stability in electrolyte

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

Reviewer 1:
The reviewer said that the project team made good progress towards meeting the proposed objectives with UV curing and coatings.

Reviewer 2:
The reviewer remarked that good progress has been made on the UV-cured polymer-bonded ceramic coatings on the separators and their assessment in a Li-ion cell. Specificall , the team developed UV-curing coatings for various separators coatings for polyethylene (PE), polypropylene (PP), and trilayer separators that show low high-temperature shrinkage and good functionality in a 5 V Li-ion chemistry. Additionally, patterned coatings have been developed on these separators, though the effect of these patterns is yet to be determined. The reviewer commented that the assessment, however is incompatible at the material level. The effects of the coating on the porosity, conductivity and electrochemical compatibility have not been quantitatively determined. The reviewer said that it is essential to establish the chemical/electrochemical compatibility of the UV-curable pre-cursors with the electrode materials (before and after curing). The assessment in the cell in also in complete without proper comparison with baseline, discharge rate. Above all, according to the reviewer, proper cost assessment is to be made to provide a convincing argument that this UV-cure method is beneficial. Overall, progress is good and is consistent with DOE s goals.

Reviewer 3:
The reviewer said that some of the test data look promising, but there really should be more technical details released to allow a proper evaluation. Without those, it is hard to judge whether uniformity, cost, etc. would be commercially competitive.

Reviewer 4:
According to the reviewer, the performer stated that the mechanical/thermal performance shown on Slide nine is comparable to a conventional ceramic separator. Additionally, the performer has very limited data to show electrochemical stability. The reviewer cited that Slide 11 shows limited cycling without disclosing voltage window, current rates, temperature or many other relevant technical details. The stated reason for using a lithium manganese, nickel oxide (LMNO) versus a lithium titanium oxide (LTO) system was to achieve high voltage on the cathode and safety on the anode. In a 1.5 mAh cell, the rational of safety for using LTO instead of carbon is not well supported, this would also raise questions of reductive stability of the material.

The reviewer said that a basic cyclic voltammetry experiment should be performed to determine the stability of this new material. The project team mentioned that they are not electrochemists, but some of their collaborators are and should assist them. Barring that help, the reviewer said that a possible, experimental setup for the team to perform is a coin cell-based stainless steel (SUS) blocking cell setup with cyclic voltammetry at 1 to 10 mV/second scan rate sweeping 0 to 5 V versus Li using 5 uA/cm^2 as the threshold for stability.

Reviewer 5:

The reviewer pointed out that demonstrating a coating is possible was already performed (see 2015 slides). The reviewer asked what has really been accomplished to address whether these materials are practical for LIB operation and if they are commercially competitive. The reviewer said that this study lacks any wetting investigation, analysis of performance of separators in environments that would create Li dendrites that lead to cell failure, and cycling with more reducing anodes. The PI did not understand high-voltage battery operations with the current cathode and LTO anode versus using a graphitic anode; the reviewer said that it is worrisome that the PI is not aware and that the PI's collaborator has not given enough guidance to understand. Moreover, the comparisons are unfair; comparisons should not be made to uncoated materials but instead to competitive coated separators.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that there are good collaborations with a national laboratory (ANL) for the product validation and with the separator manufacturer (Celgard) for subsequent scale up and commercialization.

Reviewer 2:

The reviewer suggested that the collaborators should more strongly support the prime performer in electrochemical testing.

Reviewer 3:

The reviewer remarked that at ANL, Amine and coworkers performed charge/discharge experiments. This collaboration is minimal and has not resulted in the PI understanding the necessary performance metrics needed to evaluate the material. The reviewer said that simple charge/discharge tests are inadequate to evaluate the material; Amine should have facilitated further testing.

Reviewer 4:

The reviewer said that it is not clear how the collaboration worked, and gave as an example how there are no target specifications resulting from the collaborative activities

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

Reviewer 1:

The reviewer detailed that the proposed future research is to demonstrate the benefits of printed coating, develop coatings with additional shut-down temperatures, and design customized commercial prototype press and verify the ability for high-speed coating with superior coating uniformity, tension, and consistency. The reviewer pointed out that it is important to augment these efforts with a proper cost assessment. The future work planned is logical and consistent with project objectives.

Reviewer 2:

The reviewer remarked that the first bullet on Slide 16, "Confirm advantages of printed coating," should b performed before any other work is done. Exploring additional shutdown temperatures, scale-up and coating speed improvements are not relevant if the performer's base chemistry is not electrochemically stable or provides a clear technical advantage over conventional ceramic separators.

Reviewer 3:

The reviewer said that future research directions for the project team should include testing membranes in real cells in their partners' laboratories. The details do not include the challenges associated with such testing (on what conditions with respect to accelerated testing, etc.). The reviewer was unclear how one can measure success with this project, i.e., in terms of applicability of their coated membranes for LIB cells.

Reviewer 4:
The reviewer stated that the PI's focus has been on creating separators, and that the PI's plans to validate materials are lacking.

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

Reviewer 1:
The reviewer said that in addition to improving performance characteristics, such as specific ene gy, energy density and specific power of the E batteries, it is also important to improve their safety characteristics to enable their widespread adoption. Large-capacity Li-ion cells and batteries can release substantial amounts of energy during thermal runaway, which can propagate to adjacent cells in a multi-cell module. Advanced separators with less thermal shrinkage, e.g., a ceramic-coated separator, are currently being used, which partly prevent such a runaway, but the ceramic-coating add to process costs for the separators. The reviewer detailed that this project is aimed at developing new low-cost methods for ceramic-coated separators.

Reviewer 2:
The reviewer commented that the project helps in developing safer LIB technology and energy storage industry.

Reviewer 3:
The reviewer said that if this project could demonstrate some improvements over the incumbent ceramic coated separator technology, this could aid DOE's mission of petroleum reduction.

Reviewer 4:
The reviewer remarked that this project's accomplishments and plans are not sufficient to determine if this material is competitive with others on the market. Fabrication is not enough. The reviewer said that a thorough series of tests is needed, and the project team seems unaware of these tests in many cases.

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

Reviewer 1:
The reviewer said sufficient resource

Reviewer 2:
The reviewer said that the resources seem to be adequate for the scope of the project.

Reviewer 3:
The reviewer remarked that the resources are sufficient, but they are not being used. The reviewer said that with the experts at ANL, this company should be able to do much more for product validation.

Reviewer 4:
The reviewer commented that the project resources are large compared to the relatively small amount of technical data performed and presented.

Low-Cost, High-Capacity Non-Intercalation Chemistry Automotive Cells: Alex Jacobs (Sila Nanotechnologies) - es244

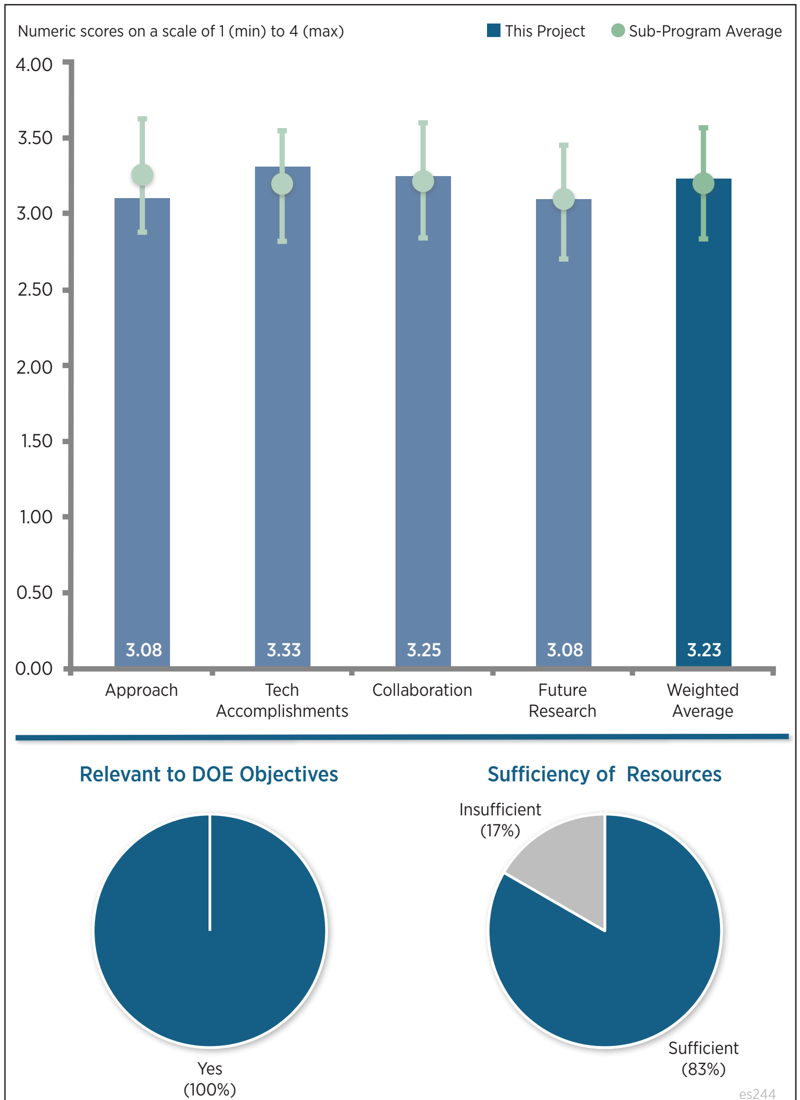

Figure 2-31 – Low-Cost, High-Capacity Non-Intercalation Chemistry Automotive Cells: Alex Jacobs (Sila Nanotechnologies) - Electrochemical Energy Storage

Presenter

Gleb Yushin, Georgia Tech

Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer said that the anode portion of this project seems to be an excellent approach. The decision to couple this with iron(III) fluoride (FeF_3) also offers a fresh approach to dealing with the shortcoming of these materials. The reviewer said that whether this will be low-cost needs to be addressed.

Reviewer 2:

The reviewer said that the objective here is to develop next-generation battery chemistries that can provide a two-fold improvement in performance. The approach involves the development of electrochemically stable ultra-high specific capacity metal fluoride (MFx)-based cathodes based on novel core-shell MFx nanocomposite powders. Such core-shell designs are expected to help mitigate the challenges, including dissolution, low electrical conductivity, volume changes, etc., that otherwise lead to large voltage hysteresis and rapid capacity fading. The reviewer remarked that later, the synthetic methods will be scaled up, which could be a drop-in-replacement to the conventional material synthesis. These metal fluoride cathodes will be combined with the Si anodes with a similar core-shell design being developed by Sila Nanotechnologies Inc. The reviewer remarked that the project is well designed, and integrated with other efforts.

Reviewer 3:

The reviewer observed that good progress was made on the iron(II) fluoride Fe $_2$ system, particularly relative to previous attempts. The reviewer indicated that questions remain regarding the temperature sensitivity of the 4.6M Lithium bis(fluorosulfonyl)imide (LiFSI)/dimethoxyethane (DME) electrolyte, the performer should report performance figures at a span of relevant temperatures (i.e. -40° to 60°C). Additionally, the reviewer pointed out that no information was presented towards the original target of a low-cost solution.

Reviewer 4:
The reviewer noted that the objectives state cost reduction and battery lifetime increase. The reviewer commented that while the Sila Si anode was shown to increase lifetime, the discussion of an approach to cost reduction was incomplete and merely based on the increased energy density.

Reviewer 5:
The reviewer said that the project aims to develop a conversion-based cathode material in couple with a Si anode with a shell. The approach of confining the MFx in the porous carbon material has been reported elsewhere, but the PI reported decent cycle life.

However, conversion materials have tested very extensively. The reviewer said that the distinction between this work and those reported elsewhere was not clear.

Reviewer 6:
The reviewer said that this project is extremely challenging, and recommended that the developer first define th cell design the project team intends to target, and from there derive the respective anode and cathode material properties to be addressed. These properties can then become the target of the research, through prioritization. The reviewer agreed that reversibility of FeF_2 and copper(II) fluoride (Cu $_2$) would remain highest priority.

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

Reviewer 1:
The reviewer said that the PI demonstrated that the conversion cathode (FeF_2) was synthesized and good cycle life can be achieved. The solubility of Fe was eliminated, and the technical milestones were met.

Reviewer 2:
The reviewer said that good progress has been made on the Si anode and to a lesser extent on the metal fluoride cathodes, using core-shell design. For the Si anode, the core consists of porous nano-structured Si, covered by a solvent impermeable and mechanically robust shell with fast Li transport. The anode shows a high capacity of ~800-100 mAh/g with a low-volume change of less than 12% and as a result good cycle life in half-cells and laboratory full cells with NCM and lithium iron phosphate (LFP) cathodes. However, according to the reviewer, the anode loading is noticeably small with 2-5 mAh/cm^2, which is not much better than graphite anodes. For the metal fluoride cathode, the MFx is confined in carbon nanopores, and is also coated with a protective outer shell The electrolyte is a highly concentrated solution of LiFSI in DME, which shows good cycle life for Li but might be too viscous for high rate discharges and is also not cost-effective. The reviewer said that even though the cycle life demonstrated here is fairly good, the cathode loading is not mentioned here (thin electrode generally cycle well) and the hysteresis is still noticeable. The reviewer identified as another shortcoming how the Si-MFx cell would need some pre-lithiation, which is a difficult proposition. The data shown here are only in half cells. The reviewer concluded that the overall progress is good and is consistent with the DOE goals.

Reviewer 3:
The reviewer remarked that the PI has progressed well and has demonstrated capacity and cycle life of the anode. The project team has gone on to make a working system from FeFx producing the longest cycle life cell to date. The reviewer said that the PI has collaborated well with partners.

Reviewer 4:
The reviewer said that the developer was not clear on the cycle rate applied to achieve current cycle life. Anode progress appears to be excellent, but progress on the cathode has not been as much. The reviewer recommended that the PI continue to build a foundational structure around the cathode active material cycling mechanistics, and resultant failure modes.

Reviewer 5:
The reviewer said that the hysteresis seen in the FeF_2 system is perhaps less than other approaches with this chemistry, but far larger than conventional cathodes. If the long-term goal is to pair this cathode with a Si anode,

the already large problem of SOC determination with Si systems owing to hysteresis maybe exacerbated. The reviewer said that the PI should present a strategy/approach to deal with this potential implementation barrier.

Reviewer 6:

The reviewer said that the PI was evasive when asked about how Li was introduced into the cell.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said there are a small number of collaborators, but the collaboration is great.

Reviewer 2:

The reviewer said that the PI has collaborated well with the ARL. Together the team resolved the solid electrode interface (SEI) component identification, leading to the use of electrolyte formulation that reduced Fe dissolution, making the FeFx system workable. Without this collaboration, the project would be dead.

Reviewer 3:

The reviewer commented that there is an on-going collaboration with the ARL in the development of suitable electrolytes for Li-FeF_2 cells and with the university partner for the anode/cathode development.

Reviewer 4:

The reviewer found that the level of collaboration seems appropriate.

Reviewer 5:

The reviewer said that the PI only has limited collaborators.

Reviewer 6:

The reviewer said that additional collaborations would help.

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

Reviewer 1:

The reviewer said that the proposed future research is reasonable.

Reviewer 2:

The reviewer said that the proposed future research is aimed at developing Li-ion permeable (solvent impermeable) shells on CuF_2-C composite powders prior to forming them into electrodes, exploring doping of MFx in order to enhance rate performance and stability, developing high-capacity loading cathodes for matching with Si anodes, and finally optimizing electrode construction and electrolyte composition to achieve high rate performance in full cells. The reviewer said that these studies are well aligned with the project objectives and DOE’s program goals.

Reviewer 3:

The reviewer remarked that the progress towards a CuF_2 systems seems promising; however, the previously raised questions of cost, hysteresis and temperature sensitivity should also be addressed for that system.

Reviewer 4:

The reviewer requested that the project team please focus on a single material class, and understand the key failure modes, before pursuing another class of material. While the desire to move to CuF_2 is understood, it may be premature.

Reviewer 5:

The reviewer was unsure that it is wise to attempt to perfect the CuFx system at this point. More resources should be focused on improving the FeFx system and then getting a handle on developing a low-cost process. The reviewer commented that more information is needed to compare expected cost reduction. The project team will need to develop a process for pre-lithiating either the Si or the FeFx for the cell to work.

Reviewer 6:

The reviewer said that the future work appears incomplete when compared to the remaining challenges and barriers.

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

Reviewer 1:

The reviewer said that this is a highly innovative, and potentially disruptive development. It is worth further investigation.

Reviewer 2:

The reviewer remarked that this project is relevant to the DOE mission of improved batteries to decrease petroleum consumption.

Reviewer 3:

The reviewer said that the cathode materials being considered have direct relevance to DOE's objectives.

Reviewer 4:

The reviewer pointed out that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles. The conventional cathodes based on intercalation of Li, typically less than one Li per metal, and have low specific capacities and thus limit the specific en gy and energy density of the Li-ion cells. It is imperative that new cathodes that involve multi-lithiums are to be developed to address this technical barrier. The reviewer commented that conversion cathodes have the ability to involve multiple lithiums and metal fluorides (e.g., Fe_3) involve two-three reversible lithiums and thus have high specific capacity and can lead to improved specific ene gy and energy densities but require further developments to overcome the challenges of poor conductivity poor reversibility and large hysteresis during cycling.

Reviewer 5:

The reviewer remarked that if this project is successful, it will exceed many of DOE's targets making EVs a commercialization a reality.

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

Reviewer 1:

The reviewer found that the resources seem to be adequate for the scope of the project.

Reviewer 2:

The reviewer commented that the budget appears commensurate to the work plan.

Reviewer 3:

The reviewer said that the project funding seems appropriate for scope.

Reviewer 4:

The reviewer expressed concern that, if some promise is shown with the cathode work, this project may be too small to address the complexities associated with this class of cathode active material (CAM). The developer should watch their resource needs closely.

Reviewer 5:

The reviewer believed that the financial resources are sufficient at this stage of the R&

Low-Cost, Structurally Advanced Novel Electrode and Cell Manufacturing: Billy Woodford (24M Technologies) - es245

Presenter

Billy Woodford, 24M Technologies

Reviewer Sample Size

A total of five reviewers evaluated this project.

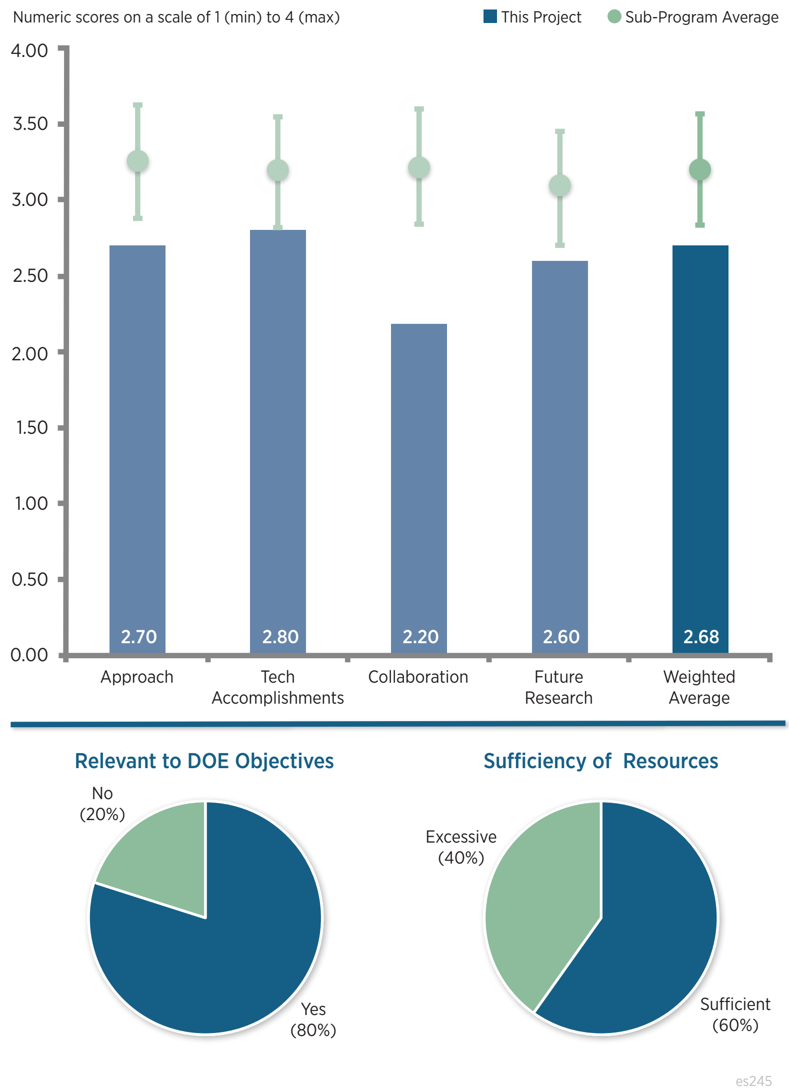

Figure 2-32 – Low-Cost, Structurally Advanced Novel Electrode and Cell Manufacturing: Billy Woodford (24M Technologies) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer commented that the idea is unique and methods of evaluation are sufficient

Reviewer 2:

The reviewer summarized that the objective here is to modify the electrode design that allow better utilization of thick electrodes, which results in a reduction of inactive materials (separators and current collectors) that translates to higher specific ene gy and energy density. To enable proper utilization of the active material in these dense electrodes, the porosity/tortuosity need to be sufficiently high, as is being done here using magnetic methods. With fewer unit operations for the electrode fabrication and low capital equipment costs compared to the conventional Li-ion cells, this modified design is expected to be easier to scale up. The reviewer commented that this architecture is anticipated to be amenable for high volume manufacturing, especially for stationary applications. The reviewer said that it is not clear, however, how this modified design of electrodes will enable an abuse tolerant battery system. The reviewer wondered if this is possibly by the mechanical flexibility of the cells. The project is well designed, and integrated with other efforts.

Reviewer 3:

The reviewer said that this is a potentially disruptive idea for battery technology in general. However, not enough information was provided to assess the impact on EVs.

Reviewer 4:

The reviewer commented that the performer is targeting the barriers of cost, performance, and abuse, but did not provide technical data to support progress despite being 75% complete with their project’s timeline. The reviewer said that the project disclosed very little technical detail regarding the technical details of the semisolid electrodes at the center of this project.

Reviewer 5:

The reviewer said that there are many concerns with the approach. The proposed work has several barriers, including manufacturing cost, energy density, and reliability. In terms of manufacturing cost, this is something that is being partially addressed. Even though a number of manufacturing steps are reduced, it is not clear on the costs of specialty materials used for making gels/slurries for enhanced conductivity. The reviewer said that it would be good to see the cost analysis and comparison of costs associated with new electrode chemistries. In terms of energy density, the reviewer said that these calculations need to be more transparent at both cell level and pack level. In terms of reliability, the company is delivering cells to DOE labs for testing.

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

Reviewer 1:

The reviewer said that technical and investment accomplishments so far are fairly good.

Reviewer 2:

The reviewer said that good progress has been made in demonstrating the scaling-up capability of this technology, and in fabricating 4-6 Ah cells with these thick electrodes to demonstrate good cycle life and calendar life characteristics. However, there were a few issues that were not quite clear. The reviewer cited analysis showing that high areal capacity can be realized at high current densities in these electrodes, but the actual current densities in these (thick) electrodes may be higher than in the conventional designs. It was not clear how well these cells behave at high rates (data not provided), but the round trip efficiency of 90% is lower than normal (95%). Furthe , the reviewer commented that no information was provided on the specific ene gy and energy density of the 6 Ah cells, nor on the cost benefits associated with this design. As may be expected, the volumetric energy density is considerably low; the reviewer believed 200 Wh/l was mentioned. The reviewer said that it is not clear how the electrode design can be optimized to improve cycle life. The reviewer was encouraged to see that the 6 Ah cells have passed all the United Nations (UN), UL and USABC safety tests. Overall, the progress is good and consistent with DOE's goals.

Reviewer 1:

The reviewer said that there was really not enough technical information presented to provide a meaningful assessment, e.g., mixing rate, formation cycle, etc.

Reviewer 2:

The reviewer commented that regarding cost, only broad statements of process simplification were stated without any technical detail to assess the feasibility of this performer's approach. Regarding performance, the performer did not answer basic questions regarding cells, such as specific ene gy and energy density, despite receiving these specific questions in the 2015 review feedback, and during the 2016 presentation. Regarding abuse, the reviewer said that Slide 12 has blanket statements of pass of a mixture of test procedures (UN, UL and USABC) without any technical detail (European Council for Automotive R&D [EUCAR] score, temperature, voltage, current, time, etc.) shared. Additionally, during the review the question of temperature came up and the performer stated that low-temperature (40°C) survivability was possible, but did not comment on performance. The reviewer commented that given the high viscosity nature of this performer's semisolid electrodes, a range of temperatures (-40° to 60°C) should be studied and the technology's energy, power and cycle life reported.

Reviewer 3:

The reviewer said that it is difficult to evaluate the progress because of missing (needed) information in the presentation slides and in response to reviewer questions. The reviewer remarked that it was amazing was how difficult it was to extract mAh/kg and mAh/ values for any of the cells presented. The reviewer said that it was unclear why testing at low temperatures has never been attempted given the simplicity and low-cost of acquiring a cooling chamber. Low-temperature operation is important for stationary storage; if batteries are not cold tolerant, then insulation should be considered in cost analysis.

The reviewer said that values for conductivity should be reported for representative suspensions. If conductivities can be tuned, the range of accessible conductivities should be provided. The effect of SEI formation on individual particles was unclear, as was the consequence on ionic and electronic conductivity. The reviewer remarked that numerical values for conductivity should have been provided for the reviewers, and were not given in response to reviewer questions.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that there were no external partners mentioned, but the cells (4 Ah) were sent to ANL for an independent assessment.

Reviewer 2:
The reviewer remarked that some mention of cells being cycled at ANL was given during the presentation, but no results were shared. The reviewer would like to know what has been done for cell validation.

Reviewer 3:
The reviewer commented that no collaborations were described.

Reviewer 4:
The reviewer said there were no data on collaborations.

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

Reviewer 1:
The reviewer remarked that despite the lack of information provided for review, it appears that plans to meet UL requirements will be completed.

Reviewer 2:
The reviewer said that the proposed future research is aimed at demonstrating the final cathode and anode volume loading, electrode quality metrics at 260+ cm^2 footprint and target electrode yield, target cell manufacturing yield, and delivering final program deliverables: cells with 260+ c ^{2} footprint exceeding target yield. The reviewer said that these studies are well aligned with the project objectives and DOE's program goals. However, it would be helpful if there are numbers associated with the demonstration of enhanced performance or reduced cost, which are the technical barriers for the DOE VTO program.

Reviewer 3:
The reviewer said that the plan is to deliver on the project milestones. One issue the reviewer identified is that very few things are quantitative in the presented milestones, so it is very difficult to gauge how much remains to be done.

Reviewer 4:
The reviewer said that the appropriate future direction is not possible to determine given the lack of technical content presented by the performer.

Reviewer 5:
The reviewer commented that the company claims to have raised a lot of venture capital. The reviewer said that it is simply puzzling to see the company relying on DOE and Advanced Research Projects Agency – Energy (ARPA-E) grants. The reviewer said that it is not clear what is being accomplished with the DOE support. The future goals include meeting target anode and cathode loadings. In the progress, the project team already showed delivery of cells and packs of cells. So, according to the reviewer, it is not clear why the company has delivered

the cells without meeting the target loadings for anode and cathode. The reviewer commented that the actual challenges with increasing loadings are also not detailed enough to see whether the team has the proper plan to overcome them.

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

Reviewer 1:
The reviewer said that these cells may lead to lower-cost, longer-lasting cells that could be used in electrified vehicles and in stationary storage.

Reviewer 2:
The reviewer commented improved energy storage technology with low manufacturing cost.

Reviewer 3:
The reviewer noted that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles. Fabrication of conventional Li-ion cells involves complex, wet/dry/wet operations with an expensive infrastructure and with a high proposition of inactive materials resulting in lower specific ene gy/energy density and higher costs. The reviewer said that new methods of electrode fabrication are desired that would lead to improved energy densities, reduced cost and increased ease of scale up, which are being addressed by the project.

Reviewer 4:
The reviewer said that given the lack of technical content shared, it is not possible to determine if this project will contribute to the DOE mission of petroleum reduction.

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

Reviewer 1:
The reviewer said that the resources seem to be slightly excessive for a two-year project with this scope.

Reviewer 2:
The reviewer remarked that the project resources are large relative to the small amounts of technical content presented.

Reviewer 3:
The reviewer commented that the company raised a large amount of venture capital monies and it is unclear why the project team needs support from DOE and ARPA-E to make technical progress. The reviewer said this does not seem right [DOE Program Clarification: 24M has support for a particular high risk/high reward activit , namely a detailed quantitative analysis of its unique battery architecture/manufacturing to vehicle electrification needs. DOE's view is that this is not an activity that venture capital funding entities would support at this time in 24M's life cycle.].

Advanced Drying Process for Lower Manufacturing Cost of Electrodes: Iftikhar Ahmad (Lambda Technologies) - es246

Presenter
Iftihkar Ahmad, Lambda Technologies

Reviewer Sample Size
A total of five reviewers evaluated this project.

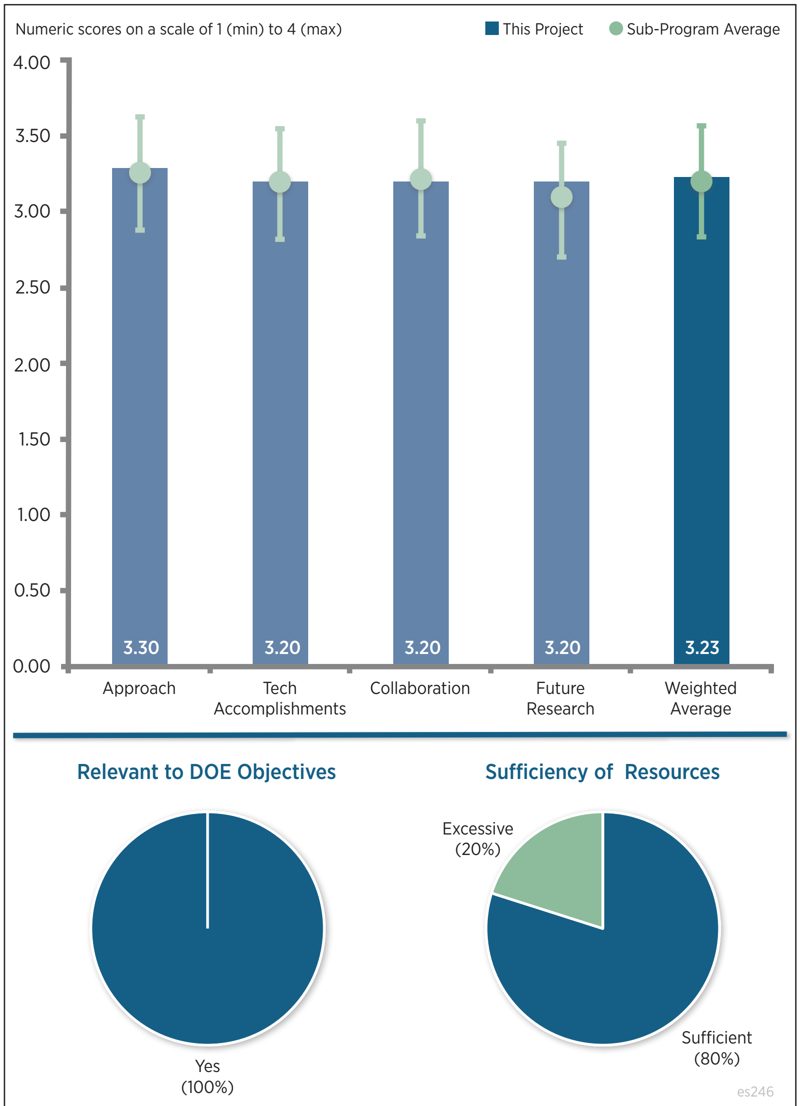

Figure 2-33 – Advanced Drying Process for Lower Manufacturing Cost of Electrodes: Iftikhar Ahmad (Lambda Technologies) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer remarked that the objective here is to develop an alternate electrode fabrication process that consists of an advanced rapid drying process that will allow increased electrode loading for high energy density batteries and also reduced fabrication costs. The conventional method of electrode drying is a slow and high-cost operation needing a large footprint. In contrast, the advanced drying process (ADP) with variable frequency microwaves (VFM) is shorter (1/5 in length) and quicker, with microwaves penetrating the electrode slurry and rapidly driving the solvent molecules out of thick coatings. The reviewer commented that the VFM provides more uniform heating than fixed frequency microwaves processes and also allows processing on metal foil without any damage. It is possible this process will result in a reduction in the electrode manufacturing cost by 30%, but the cost benefit at the battery level will be much less. The reviewer noted that the approach involves developing an ADP/VFM processing chamber that is designed to fit in the pilot coating line at Navitas. Prototype cells will be built to demonstrate the efficacy of the ADP/VFM over the conventional (infrared) heating. The milestones look reasonable to verify and validate this new drying process. The reviewer concluded that overall, the project is well designed, and integrated with other efforts.

Reviewer 2:
The reviewer remarked that the approach seems interesting, i.e., using microwave to dry the electrodes.

Reviewer 3:
The reviewer said that the approach of a new drying method for electrode manufacturing appears sound and to have been achieved. The true impact of manufacturing cost and any unintended performance degradations still

need to be studied. The reviewer commented that the advantage of this approach is often described in terms of equipment dimensions (Slide 10 and 14), which is not a priority, unlike the project goals of cost or energy density improvement.

Reviewer 4:

The reviewer remarked that using a VFM to dry the electrode web will accelerate the production speed, which would reduce production cost. The rapid variable frequency will ensure the uniformity of microwave distribution and the metal exposure. The reviewer said that the PI should provide a detailed cost analysis to forecast the potential impact on the cost.

Reviewer 5:

The reviewer said this approach provides a unique way—at least for the battery community—to more effectively dry coatings.

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

Reviewer 1:

The reviewer remarked that the project team seemed to make great progress in demonstrating a workable microwave apparatus for drying a continuous roll-roll process. The progress in preventing microwave power leak for a metal foil going through the oven is interesting.

Reviewer 2:

The reviewer said that good progress has been made in the first year towards designing the ADP/VFM processing chamber that will be integrated with the pilot plant cell fabrication at Navitas. This chamber will allow 170 mm foil (without much microwave leakage) and has a sub-chamber to contain hot-air for surface drying and solvent removal, in addition to internal heating with microwaves. The reviewer detailed that after fabricating this device, roll-to-roll dried electrodes have been fabricated and are being tested for cycle life. Full cell testing shows no difference in rate performance between standard and ADP dried electrodes. The reviewer said that even though this process looks simpler, faster and supposedly cheaper, there are a couple of issues, including the following: First, rapid drying can lead to non-uniform drying (especially with thick electrodes) and cracks in the electrode surface. No data were presented (e.g., scanning electrode microscopes [SEMs] showing the uniformity of the dried electrodes. Second, it is not clear how much optimizing (frequency range) is needed, if there is a change in the slurry composition (e.g., organic solvent or water). Third, it is helpful to have a preliminary cost model, with the savings in the process time, footprint etc. and project the overall cost savings at the battery level. Overall, according to the reviewer, the progress is good and consistent with the project objectives and DOE's goals.

Reviewer 3:

The reviewer said that the oven development and electrode/cell build work by Navitas shows good technical progress. The reviewer noted that open questions remain, including if the increased drying speed distorts the creation of pore volumes of active material and/or impacts the current collector (i.e., in the case of aluminum by changing the exfoilating paths whereby $LiPF_6$-based electrolytes create AlF_3 and passivate the layer). The reviewer said that this should be investigated by power/resistance studies with Navitas-made electrodes (electrochemical impedance spectroscopy [EIS], hybrid pulse-power capability, current/voltage [i-V] pulse, etc.).

Reviewer 4:

The reviewer stated that the project progressed well. The prototype VFM dryer was built and tested as planned. The traditional drying and VFM drying were compared and the advantages were demonstrated. The reviewer suggested that the PI should focus more on the impact on the electrode physical properties, e.g., density, conductivity, etc.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that there is an on-going collaboration with a cell manufacturer (Navitas).

Reviewer 2:
The reviewer said that collaborations seemed appropriate.

Reviewer 3:
The reviewer said that collaboration seems fine

Reviewer 4:
The reviewer encouraged the PI to collaborate with both material and cell manufactures.

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

Reviewer 1:
The reviewer said that the proposed work in the remaining few months of the project is directed at demonstrating the viability of ADP for electrode fabrication in prototype Li-ion cells. Specific relevant activities being planned are cell fabrication (at Navitas) and continuing the cycle life testing on the ADP-processed electrodes, verifying the process with electrodes containing higher active material loadings, and completing energy related cost analysis for the ADP drying processes and assess the overall cost benefits

Reviewer 2:
The reviewer commented that future work should focus on initial project targets of cost reduction (supported by technical data now that the project team has a working system) and prospect for increasing electrode energy density. Additionally, the reviewer recommended that any impact on electrode/power from the different drying method should also be studied.

Reviewer 3:
The reviewer stated that the proposed future research covers the method development. Both cost and impacts on electrode properties should be included.

Reviewer 4:
The reviewer recommended that analysis of recovered NMP through 1H and 13C nuclear magnetic resonance (NMR) spectroscopy should be performed in comparison to analysis of NMP recovered using more common heating methods for NMP removal to determine if (partial) decomposition is occurring, and if so, are the byproducts the same. The reviewer said that amides are thermally sensitive, and even with average temperatures of 120°C, or possibly higher in localized areas, decomposition is a concern as far as the impact on the recyclability of NMP. The reviewer pointed out that determining if Cu corrosion occurs and its effect on cell cycling is an important area to explore.

Reviewer 5:
The reviewer suggested that the project needs more attention on the electrode characterization in terms of porosity, mechanism of drying, effect of drying with thickness, etc. In addition, the reviewer recommended that a task should be added for monitoring the microwave leakage and ensuring personnel safety. For example, under what conditions could the microwaves leak from this system and how will this be detected.

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

Reviewer 1:
The reviewer detailed that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles. The high costs are partly attributed to the complex time-intensive fabrication processes for the electrodes with the conventional coaters/dryer. New methods of coating the active materials are desired with the aim of increasing electrode loading and/or reducing the cost of electrode fabrication, which are being addressed here.

Reviewer 2:
The reviewer commented that this process may lead to lowered costs of electrode fabrication through faster processing.

Reviewer 3:
The reviewer stated improved manufacturing practice and potentially low-cost for electrode manufacturing for Li-ion batteries. The reviewer said that the project potentially applies to other applications as well.

Reviewer 4:
The reviewer said that if the benefits of this novel drying method can be quantified (such as cost reduction an energy density improvement), this could serve DOE's mission to reduce petroleum reduction.

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

Reviewer 1:
The reviewer pointed out that the PI's background is ideal for addressing the challenges of this project, and the pairing with Navitas appears to be quite effective in the production and testing of materials.

Reviewer 2:
The reviewer said that the resources are adequate for the scope of the project.

Reviewer 3:
The reviewer commented that resources seem appropriate.

High-Energy Lithium Batteries for Electric Vehicles: Herman Lopez (Envia Systems) - es247

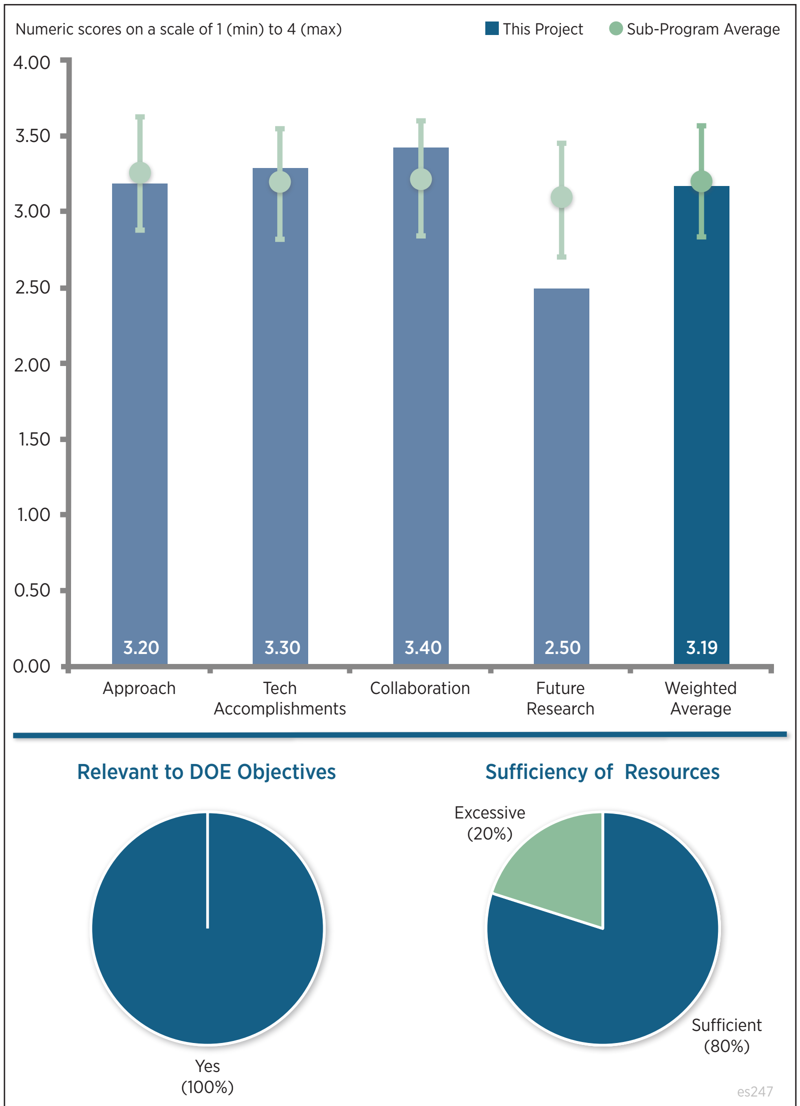

Figure 2-34 – High-Energy Lithium Batteries for Electric Vehicles: Herman Lopez (Envia Systems) - Electrochemical Energy Storage

Presenter

Herman Lopez, Envia Systems

Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer said that the approach used in this effort is very effective at addressing the technical barriers identified for this project. For this reviewer, areas of concern for this effort would be at this point not much work has been done in the area of power capability, and at this point there is limited testing at high/low temperatures. The reviewer said these data would significantly strengthen this effort.

Reviewer 2:

The reviewer opined that the flow diagram is not very informative, but that one can get a flavor of the project team's approach from the rest of the presentation.

Reviewer 3:

The reviewer commented that the approach to cell development is good and seems to be achieving the specific energy goals, but the testing protocol as reported is quite incomplete. No pulse testing during cycling is reported, and the reviewer is concerned that the optimization based solely on specific ene gy and energy density will result in severe problems with pulse capability later in life. This can cause a back to the drawing board effect on the cell development protocols. The reviewer suggested that if there are data on pulsing, these should be reported so that a valid assessment of status can be done.

Reviewer 4:

The reviewer said that not a lot of testing on the power capability of cell for cathode/anode with different surface area/porosity and electrolytes have been conducted. It was unclear to this reviewer what the target is of cell resistance for the contractor to meet the power target for a 12V battery. Furthermore, it was unclear to this reviewer if the contractor can meet the cost target without other factors being considered, such as the materials cost and manufacturing cost reduction.

Reviewer 5:

The reviewer detailed that the objective here is to develop high capacity cathode and anode materials, screen commercial electrolytes and separators, optimize pre-lithiation processes and integrate them into high-capacity pouch cells that meet the USABC EV battery goals. The previous efforts were with Li-rich Mn-rich layered-layered cathode materials, which have not shown the desired performance (poor cycle life and voltage fade). The current approach is to develop cathodes based on Mn-rich and Ni-rich cathodes that seem to have good cycle life characteristics, but with slightly lower specific capacities. The reviewer said that the anode development is however more intricate and is based on n-type Si and polymer composite with pre-lithiation affected electrochemically. Additionally, the electrolyte and separator are also being optimized, especially to stabilize the SEI on the Si anode. The reviewer pointed out that these strategies are similar to those being evaluated in various laboratories, with the difference being the electrochemical-pre-lithiation of Si. The reviewer said that the issues in handling prelithiated Si during fabrication have not been listed, nor have the benefits of such pre-lithiation been demonstrated. The reviewer remarked that these studies address the technical barriers for high-energy Li-ion batteries, though the targeted specific ene gy and energy densities are already realized in commercial cells with graphitic anodes and the state of art cathodes. The reviewer said that the project is well designed, and integrated with other efforts, but the feasibility of Si anode with the projected performance enhancements will be a challenge for this project.

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

Reviewer 1:

The reviewer noted that there was a wide range of technical accomplishments on several fronts.

Reviewer 2:

The reviewer pointed out that having demonstrated over 500 cycles in a full 21 Ahr pouch cell with specific ene gy of approximately 260Whr/kg, this effort is demonstrating outstanding progress. Furthermore, demonstrating this performance using greater than 50% Si show significant promise for this material

Reviewer 3:

The reviewer said that the results to date are promising for the 21 Ah cells using the C/3 test regime. There seems to be an effort to include some statistical evaluations as well, which the reviewer feels is mandatory in this kind of development project. The lack of pulse data are a concern because of the possibility of making decisions based only on CC cycling and having a severe deficiency in pulse characteristics. Thus, the decisions to go on to larger cells have been taken without DST cycling data to determine DST cycle life and without periodic 30s pulse tests to determine power density. The previous cells were quite deficient with respect to both of these quantities. The reviewer is also concerned about the downward curvature of the cycle life data as to the impact on other types of cycling, e.g., DST or other current rates, and C/1.

Reviewer 4:

The reviewer said that good progress had been made with various cell components and cell designs. A cycle life of 500 cycles was realized in 21 Ah, (approximately 260 Wh/kg) pouch cells with NMC cathode, Si anode (greater than 50%) and with selected electrolyte and surface modification. At the component-level, the cathode performance looks good, but the reviewer was not sure what the loading is, if it is comparable to that in the full cell. In contrast, the Si anode could be a problem to meet the requirements of cycle life (of 1,000 cycles) and specific ene gy. The reviewer said that anode development is still ongoing with respect to composition, coatings and electrode morphology. Surprisingly, the cell specific ene gy is not high even with 50% of Si, possibly due to the irreversible capacity loss. The reviewer found that roll to roll pre-lithition development is encouraging, but no data were presented on the pre-lithiated anodes. It would be interesting to see if the irreversible capability loss is totally compensated by this pre-lithiation. The reviewer said that proper cost analysis needs to be made to assess from the pre-lithiation and the associated electrode handling needs versus its benefits. There is substantial anode delamination even in the baseline cells; the reviewer speculated it was with a graphite anode. The reviewer said that the prototype cells (21 Ah) showed decent performance, but the specific ene gy and cycle life are well short of the goals, and need to be improved in in the third year to meet the project (or USABC) targets. The reviewer concluded that overall, progress is good and is consistent with DOE’s goals.

Reviewer 5:

The reviewer remarked that it was unclear if the resistance data provided consists of polarization resistance, and on-cell power performance data were provided to show cells' power capability. With limited time remaining for this project to be finished, the reviewer expressed concern if the project can meet the on time. The battery management system (BMS) progress was not detailed, and a detailed testing of the BMS design by the end of 2016 is a concern.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer enthused that this program is a great example of the value of a strong collaborative partnership to significantly accelerate the advancement of an R&D e fort.

Reviewer 2

The reviewer commented that there are excellent collaborations with several researchers from different organizations, specialized in different components and manufacturing processes.

Reviewer 3:

The reviewer remarked that there seems to be a good level of collaboration on the materials and cell making sides. There does not seem to be oversight on the cell testing aspects, as noted above.

Reviewer 4:

The reviewer said that the project team is reaching out to partners in many different areas.

Reviewer 5:

The reviewer suggested that the contractor leverage efforts by academia such as ANL and/or LBNL or facility to see if the project team can reduce the time in testing and trying with different size and porosity cathodes/anodes, etc.

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

Reviewer 1:

The reviewer remarked that proposed future research is to continue to develop the Si anode with pre-lithiation, Mn/Ni rich cathodes, and electrolytes and incorporate the down-selected materials into large capacity cells. Further, the studies will focus on understanding and mitigating the cells through destructive physical analysis (DPA) studies. The reviewer found that the future work planned is logical with appropriate decision points in the materials selection and cell fabrication processes.

Reviewer 2:

The reviewer believed that there should be a lot more test data before launching into a new cell vehicle (41 Ah cells). This could be a real problem depending on pulse and DST results.

Reviewer 3:

The reviewer said that there is little to no detail concerning how the project team is going to attack the cycle/calendar life issue, which should be their highest priority.

Reviewer 4:

The reviewer said that it appears extremely risky to accomplish the cell and 12V pack design, while finishing the testing of the 12V pack to demonstrate the design meeting goals (life and low-temperature performance) may be extremely challenging.

Reviewer 5:

The reviewer said that the PI provided very limited information on the future work for this effort. In part this is due to the excellent results that the team has been able to achieve to date; however, much work remains as the team is not tracking to meet all of the EV targets.

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

Reviewer 1:
The reviewer commented that this effort is a highly relevant as it addresses key challenges to reaching the aggressive EV energy storage targets. This is one of the efforts that shows the most promise of pushing toward the specific ene gy goals without completely sacrificing cycle life. The reviewer said that having demonstrated 500 cycles with a very high Si content anode is encouraging.

Reviewer 2:
The reviewer remarked that this is highly relevant as the specific ene gy gains are substantial compared to present production cells.

Reviewer 3:
The reviewer said that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles. High-capacity cathode and anode materials are required to improve the specific energy of Li-ion cells. Blends of Ni/Mn rich cathodes and Si composite anodes are promising both from energy and cost perspectives, and are being addressed in this project.

Reviewer 4:
The reviewer remarked that the work conducted to fulfill USABC s 12V battery pack requirement support DOE's goals in pushing for vehicle electrification

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

Reviewer 1:
The reviewer remarked that the contractor appears to need some help or collaboration from academia or industry.

Reviewer 2:
The reviewer commented that if the lack of pulse test data are due to lack of resources, the researchers should seek ways to improve the test positions.

Reviewer 3:
The reviewer said that it appears that the PI has sufficient resources to complete this e fort.

Reviewer 4:
The reviewer said that resources seem to be slightly high for the scope of the project, but may be reasonable based on the large number of team members.

A 12V Start-Stop Li Polymer Battery Pack: Mohamed Alamgir (LG Chem Power) - es249

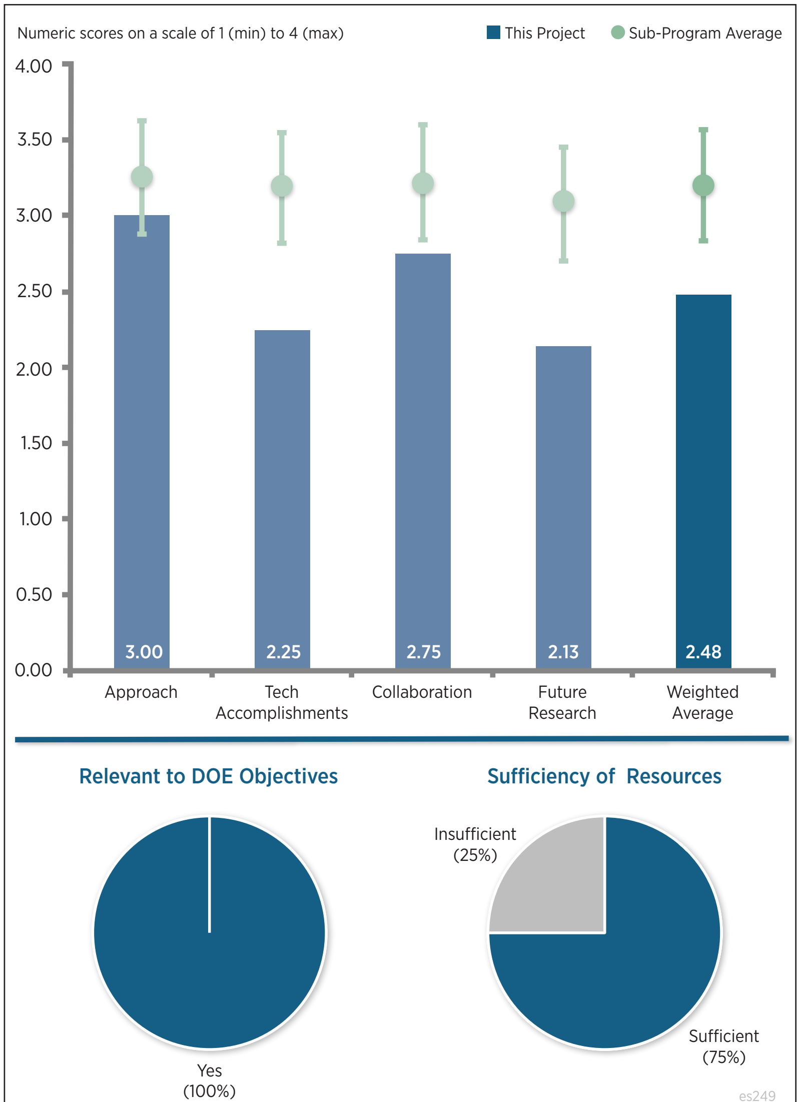

Figure 2-35 – A 12V Start-Stop Li Polymer Battery Pack: Mohamed Alamgir (LG Chem Power) - Electrochemical Energy Storage

Presenter

Mohamed Alamgir, LG Chem Power

Reviewer Sample Size

A total of four reviewers evaluated this project.

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

Reviewer 1:

The reviewer remarked that the objective here is to develop a high-power Li-ion cell suitable for use in the 12V start-stop battery by optimizing the cell chemistry for cold-cranking requirements, design a low-cost, simplified BMS and finall battery with a cost target of less than $220. The approach involves optimizing various cell components, including cathode and anode and their structure, electrolyte and separator for enhanced power, especially at low temperatures. The reviewer noted that the approach also includes the development of low-cost battery pack designs (mechanical, thermal and electrical) to meet USABC targets. The reviewer said that the approach addresses the technical barriers, and the project is well-designed, feasible and integrated with other Vehicle Technologies projects.

Reviewer 2:

The reviewer said that battery life and power performance are still a challenge, and there is no clear path provided to overcome the technical barriers.

Reviewer 3:

The reviewer commented that in general, the approach is effective and contributes to overcoming some of the identified barriers. One area of concern is that there has been limited progress in addressing one of the key challenges, which is cold crank at lower states of charge. The reviewer remarked that there is very little info on the approach to address this deficienc .

Reviewer 4:

The reviewer said that this project was very difficult to analyze for approach because the cell specifics were no presented. Furthermore, there were inconsistencies, such as the porosity study in 2015 in which the cell resistance at 10 s after charge and discharge decreased as the porosity decreased through three trials. The reviewer would expect this variable to reverse as the porosity continued to decrease and the electrolyte available volume decreases, and as a result, the ion flux in the electrolyte will now introduce substantial resistance. The reviewer pointed out that on other studies such as cathode material surface area in 2016, the resistance was lowered as the surface area increased, but again the reviewer would expect a reversal when the particles get sufficiently small and the surface area increases. Also, if was not clear if the porosity was held constant through this study.

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

Reviewer 1:

The reviewer remarked that the project studied various cathodes and anodes with different compositions and morphologies and different electrolyte formulations to enhance cold-cranking power and high-temperature durability. Also, the effect of dopant, surface area and porosities were studied for the cathode material. There was a progressive development in the ASI and EIS impedance and in the high-temperature resilience at 60°C, with the recent cathode, anode and electrolyte materials. In addition, the team designed a battery pack fabricated and delivered with a low-cost BMS and thermal system. Even though it is convincing that good progress has been made relative to the material development and cell/pack design towards the project goals, not enough data have been presented to assess the compliance of this progresses with the requirement (e.g., cell and battery discharge curves at low temperatures and after storage and pack design details to the extent permitted by intellectual property). The reviewer said that only relative data on the ASI, EIS and high temperatures was shown, and it is not clear as to how the battery temperature could be pegged to 52°C even after four hours of exposure to 75°C; the reviewer wondered what happens after four hours or, say, 12 hours.

Reviewer 2:

The reviewer said that limited progress have been achieved to meet project and DOE goals in terms of life, specific energy and power density, etc. The reviewer suggested adding more electrolyte screening work in to help realize the goals.

Reviewer 3:

The reviewer remarked that this project is near completion (November 2016), yet is only 50% complete with multiple challenges remaining, in particular in the area of cold crank. Furthermore, the program was only able to achieve 25% progress during the year. The reviewer said that this effort will not meet the stated goals.

Reviewer 4:

The reviewer commented that because an insufficient range of variables was studied (particularly in porosity and surface area), a true optimization was not found. Therefore, the cold cranking was unsatisfactory, according to discussion with the authors. Furthermore, the use of arbitrary units for the resistance at 10 s, it was not possible to assess the sensitivity of the resistance to the different variables. The reviewer would like to see a valid statistical analysis including absolute values in order to evaluate progress in the program.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that there is formal collaboration and partnership with the DOE laboratories for testing the cells and batteries from this project (deliverables).

Reviewer 2:

The reviewer said that the only collaborations are with national laboratories and that seems to be mainly based on submitting battery packs for evaluation at the end of the program. Thus, according to this reviewer there does not seem to be any real collaboration or even discussion of the work in progress.

Reviewer 3:

The reviewer suggested that the contractor include an academic partner in helping to attack key barriers to DOE goals.

Reviewer 4:

The reviewer said that there exists some collaboration within the LG team to develop the technology. However, the reviewer would like to have seen the PI explore additional collaboration to address some of the key technical barriers that will not likely be addressed with this effort.

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

Reviewer 1:

The reviewer commented that the proposed future research is to continue the development of cell components to improve the cold-cranking power, by evaluating various electrolyte compositions and separators. Also, there will be further optimization of the pack and the BMS designs to reduce the overall cost of the 12V battery. The reviewer said that these activities are well aligned with the project goals; however, details are not provided on the decision points and risk mitigation strategies.

Reviewer 2:

The reviewer said that because pack and BMS design remain to be optimized and the program ends in November 2016, there does not seem to be enough time to improve the cell basis for the project, although it is stated that further optimization will be done on cells.

Reviewer 3:

The reviewer said that there insufficient information provided to prove that the proposed future research can achieve the battery life, specific ene gy goals, etc. for EV batteries.

Reviewer 4:

The reviewer commented that this program is reaching completion and in all likelihood will fail to overcome the remaining technical barriers. It is unlikely that the proposed future work will successfully enable the cold crank requirements to be met.

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

Reviewer 1:

The reviewer pointed out that the project is important in improving stop/start systems to improve auto fuel efficienc .

Reviewer 2:

The reviewer remarked that this effort is relevant and addresses a key enabling energy storage solution needed to facilitate 12V start/stop vehicle platforms.

Reviewer 3:

The reviewer detailed that the replacement for standard 12V lead-acid batteries with Li-ion batteries will result in lower battery mass and volume of over 60%, enhanced cycle and service life and reduced maintenance due to lower self-discharge. In addition to these benefits, Li-ion batteries reduce the load on the alternator as they retain more power and are able to handle the charge faster than lead-acid batteries. The reviewer said that this results in reduced fuel consumption and thus reduced CO_2 emissions. Current active materials have low specific power to support cranking, especially at low temperatures. The reviewer also said that new active materials and cell components and/or designs are required to meet the demands for high power density, and also pack costs, which are being addressed here.

Reviewer 4:
The reviewer commented that EV battery development may help the vehicle electrification e forts promoted by DOE.

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

Reviewer 1:
The reviewer commented that the resources are adequate for the project scope.

Reviewer 2:
The reviewer said that the contractor appears to have sufficient funds to conduct the work, but collaboration with academia such as a national laboratory is recommended to help speed the process.

Reviewer 3:
The reviewer remarked that this effort will run out of time before addressing the stated milestones.

A Commercially Scalable Process for Silicon Anode Pre-Lithiation: Ionel Stefan (Amprius) - es250

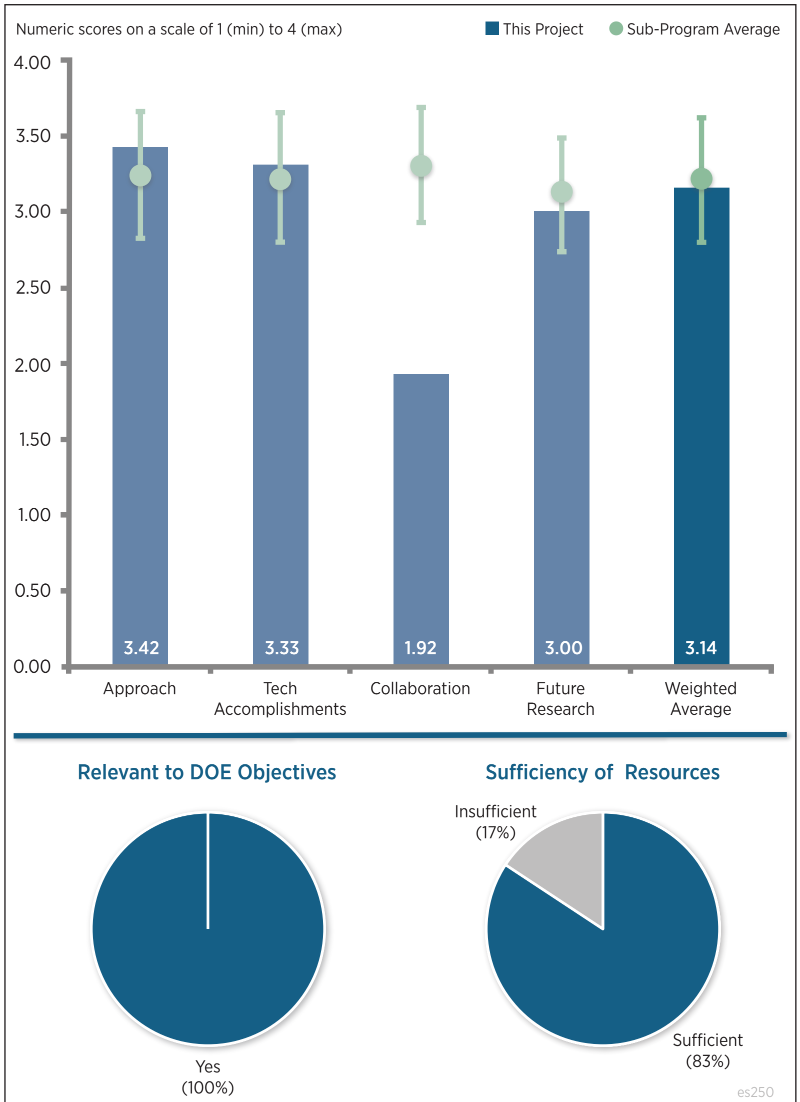

Figure 2-36 – A Commercially Scalable Process for Silicon Anode Pre-Lithiation: Ionel Stefan (Amprius) - Electrochemical Energy Storage

Presenter

Ionel Stefan, Ampirus

Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer remarked that the team performed an outstanding work to exhaustively explore different ways of prelithiating Si anodes and increasing its energy density. The project team systematically down-selected a series of chemical, physical and electrochemical approaches and summarized their feasibility. The reviewer remarked that the knowledge gained would be of value for the Si-based chemistry.

Reviewer 2:

The reviewer said that pre-lithiation is an effective way to compensate the capacity loss due to SEI formation. The PI pretty much covered all the possible ways for pre-lithiation.

The reviewer suggested that the cost estimate should include the potential compromise of the manufacture throughput.

Reviewer 3:

The reviewer remarked that the prelithation approach outlined seems reasonable. The overall cost target is described as $0.10/Ah based on a comparison to the equivalent cost of adding $0.18/Ah of lithium cobalt oxide ($LiCoO_2$). The reviewer suggested that the cost impact of each preliathion method should be explicitly quantified to assess the progress of the overall approach.

Reviewer 4:

The reviewer found that the approaches are feasible. The reviewer suggested that the team should also compare the additional cost from the prelithation process and the saving from reducing the loading of cathode materials.

Reviewer 5:

The reviewer remarked that the approach was well thought out and indeed it seemed that a lot of the pre-lithiation selection methodology was done as a paper exercise. The reviewer would have liked to have seen some additional trails. This project is near completion and it seems that the PI has already concluded that pre-lithiation is not going to have much of an effect on their system and any commercial pre-lithiation station will be expensive and perhaps uneconomical (for their system).

Reviewer 6:

The reviewer remarked that the objective is to develop and demonstrate a commercially scalable process for Si anode pre-lithiation that will add no more than 10% to the cost of producing Si nanowires, facilitating production of Si anodes that cost significantly less than today s premium graphite anodes. The eventual goals are to demonstrate the pre-lithiation strategy at pilot level pre-lithiation capacity (greater than 100 cells/day) with a cost of less than $0.1/Ah and providing a cathode utilization of greater than 5%. This would address the barriers of poor utilization of the cathode and lower capacity/energy of Li-ion cell with the Si anode. The reviewer said that the project team investigated various pre-lithiation schemes, including electrochemical (in situ and ex situ), chemical and physical methods, in terms of effectiveness and feasibility, i.e., in terms of improving the coulombic efficienc , cell capacity and cycle life of the (full) Li-ion cells. The reviewer detailed that after down-selecting two pre-lithiation methods, plans are to set up pilot tool/set up to deliver prelithiated Si nanorod anodes and deliver 10 2-Ah-cells for demonstrating the benefits of this pre-lithiation. The reviewer found that this project is well designed, and integrated with other efforts, but the feasibility of the Si anode with the projected performance enhancements will be a challenge.

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

Reviewer 1:

The reviewer remarked that the team evaluated different possible approaches systematically, and identified the best one based on cost and technical feasibility.

Reviewer 2:

The reviewer found that good progress had been made on the assessment of various pre-lithiation strategies and down-selecting a couple of approaches for the pilot scale production and demonstration. After identifying the optimum pre-lithiation charge level required, four methods (two electrochemical, one physical and one chemical) have been selected for further evaluation of technical feasibility. Guidelines were established for the cost and process implications, including pre-lithiation in cell assembly. Among the methods evaluated, the electrochemical method with a sacrificial Li salt seems to be adaptable and tested further in proof-of concept cells to show the improvement in the cell capacity and cycle life. However, the improvement in the cell capacity is marginal only 5-7%, which leads to the question if the pre-lithiation is worth the additional cost/effort. The reviewer commented that the improvement in cycle life, though less significant, implies that the pre-lithiation does not entirely eliminate the irreversible capacity loss continuing to happen in the first few cycles. It would be useful to show some more data on the benefits of pre-lithiation, for example, cell coulombic efficiency during cycling and the initial formatio of the cells with and without pre-lithiation. The reviewer asked is the solvent for pre-lithiation different from that in the battery electrolyte, and if so, how is its stability versus Si and cathode. The reviewer queried what happens if there is residual sacrificial salt after pre-lithiation.

The reviewer noted that, finall , the cycle life is not substantially better with the Si nanorods compared with the other Si anodes reported in the literature, suggesting that further developments are warranted for their use in EVs. The reviewer said that a proper cost analysis needs to be made to assess the benefits from the pre-lithiation and the associated electrode handling needs versus its benefits. The reviewer commented that overall progress is good and is consistent with the scheduled milestones and DOE goals.

Reviewer 3:

The reviewer applauded the systematic way to approach the pre-lithiation issues (e.g., determination of the impacts of the loading capacity on cycleability and discharge capacity). Using Student's t-test is a big plus.

Reviewer 4:

The reviewer pointed out that during the technical review, two of the project objectives (greater than 100 cells/day and greater than 95% cathode utilization) were not addressed. The technical progress towards these two other objectives (in addition to the $0.10/Ah goal) should also be described. The ideal process condition is described as gas formation during pre-lithiation. The reviewer asked does this new step add to the formation related cost of manufacturer. Slide 16 describes a pre-lithiation protocol and cell response, but without further technical detail the statements made of “anode voltage and pre-lithiation charge reached target values” is not possible to assess independently. The reviewer said that Slide 17 quantifies the impact of pre-lithiation on cell capacity as 5-7%, Si fade/volume expansion is often tied to the utilization of Si active material (i.e., 800 versus 1,500 mAh/g will lead to very different crystal structures of the LiSi alloy and as a result life). The reviewer asked if the decreased cycle life shown on Slide 18 is a result of such a move. The reviewer asked if the performer has tested the new system using half-cell and/or three-cell electrode setups to explicitly quantify the enhancement of anode capacity.

Reviewer 5:

The reviewer said that progress continues to be made on this project and the PI has demonstrated that pre-lithiation is possible. However, more progress might have been made if collaboration had been sorted rather than going at it alone.

Reviewer 6:

The reviewer said that the final results using sacrificial Li salt approach showed 5-7% increase in overall en gy density. This outcome is less than what is expected from a project of such size.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that there are no collaborations on this project, but these will be established (with the DOE laboratories) for testing after the cells are delivered.

Reviewer 2:

The reviewer said that no collaborators are identified, but it does not seem obvious that the work remaining would benefit from the addition of new partners at this late stage of the project

Reviewer 3:

The reviewer remarked no collaborators.

Reviewer 4:

The reviewer stated that Ampirus conducted most if not all of the work themselves.

Reviewer 5:

The reviewer said that it looks as though the project does not involve any collaborations from national laboratories or universities. The reviewer suggested that the PI should reach out and get more expertise from institutions in order to accelerate the utilization of this process into practical applications.

Reviewer 6:

The reviewer observed no collaboration as Amprius is the only performer in this project. Because there is no “N/A” category, the reviewer selected “Unsatisfactory,” which it is unfair to the project [DOE Program Clarification: DOE will take this into consideration for future Annual Merit Reviews].

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

Reviewer 1:

The reviewer detailed that plans are to continue optimizing the process conditions; design, test and optimize a pilot set up and equipment compatible with the current cell assembly process; and produce and deliver cells with a prelithiated Si anode. There are corresponding challenges, however, in sourcing the materials for pre-lithiation, scaling up to the pilot production and long-term feasibility and process reproducibility. The reviewer said that the future work planned is logical with appropriate decision points in the materials selection and cell fabrication processes.

Reviewer 2:
The reviewer commented that the proposed research for the remaining three-four months is solid, but it is hard to be accomplished within the timeframe.

Reviewer 3:
The reviewer remarked that future efforts should focus on the cost evaluation and feasibility of the chosen method before scale-up is planned.

Reviewer 4:
The reviewer suggested that perhaps the PI should focus more on just further reducing the irreversible capacity loss to the system.

Reviewer 5:
The reviewer remarked that the future plan looks ambitious considering the project will end in September.

Reviewer 6:
The reviewer said that the project is ending in September 2016. The reviewer was unclear if the PI would continue the pilot effort if there is no continuous funding from DOE.

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

Reviewer 1:
The reviewer said that incorporating Si anodes into Li-ion batteries will support DOE’s goal

Reviewer 2:
The reviewer commented that if successfully commercialized, the development of this prelithation work would contribute to DOE’s mission to reduce petroleum consumption.

Reviewer 3:
The reviewer remarked that pre-lithiation is critical for the high energy batteries, particularly when nanostructured active materials are used. Improving the first cycle efficiency and reducing the cathode loading is the right way t achieve the high energy density of next generation of Li-ion batteries.

Reviewer 4:
The reviewer said that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles. High capacity anode materials are required to improve the specific ene gy of Li-ion cells. Si anode has the potential to offer twice the capacity of graphitic anodes, and Amprius has developed a fairly robust SI anode based on Si nanorods. The reviewer said that despite the high specific capacit , these anodes pose the problem of high irreversible capacity, which consumes the reversible Li in the cells and lowers the cell capacity/energy. New strategies of prelithiating Si would be useful to mitigate this problem, which is being addressed in this project.

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

Reviewer 1:
The reviewer said that the resources seem to be adequate for the scope of the project, but the initial schedule of one year is not sufficient. It has now been extended to another yea .

Reviewer 2:
The reviewer commented that project resources seem appropriate.

Reviewer 3:
The reviewer said yes.

Reviewer 4:
The reviewer emphasized that the team should collaborate with national laboratories and universities.

Development of Advanced High-Performance Batteries for 12V Start-Stop Vehicle Applications: Jeff Kim (Maxwell) - es251

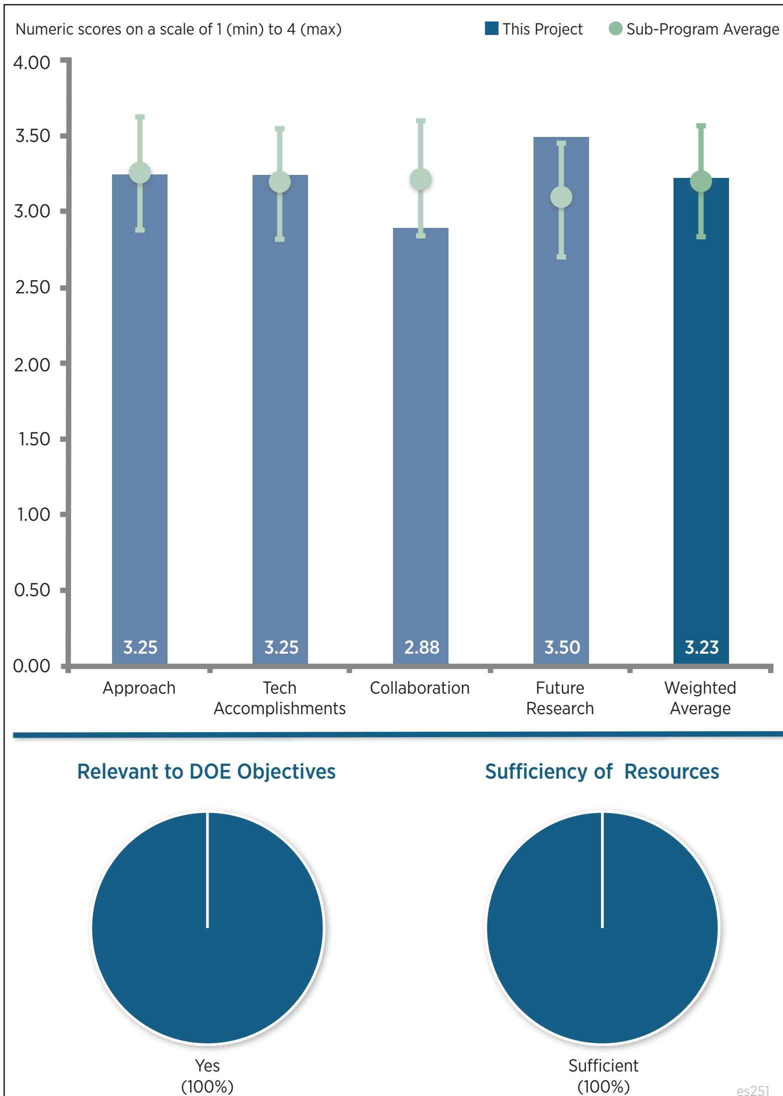

Figure 2-37 – Development of Advanced High-Performance Batteries for 12V Start-Stop Vehicle Applications: Jeff Kim (Maxwell) - Electrochemical Energy Storage

Presenter
Jeff Kim, Maxwell

Reviewer Sample Size
A total of four reviewers evaluated this project.

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

Reviewer 1:
The reviewer said that the general approach is good, but details are significantly lacking. The reviewer was unable to assess key aspects of the approach because of the lack of details, e.g. the type of electrolyte, the types of additives to reduce gassing, etc.

Reviewer 2:
The reviewer described that the objectives here are to develop a robust low-cost ultra-capacitor pouch cell that can operate over a wide temperature range; hybrid power system comprising the ultracap pouch cells and commercial Li-iron phosphate ($LiFePO_4$)-based Li-ion cells for the 12V start stop system, and demonstrate the technical and economic feasibility; battery/capacitor management system (BCMS); CAD model of the 12V module; and a system cost model. Specific challenges addressed in the development of ultra-capacitors are the electrolytes with suitable additives, separators and low-cost robust cell designs for the pouch cells that would enable low-temperature performance and yet minimize gassing at warm temperatures. The reviewer commented that the approach addresses the technical barriers of the 12V start-stop battery system. The project is well-designed towards the program objectives, feasible and integrated with other Vehicle Technologies projects.

Reviewer 3:
The reviewer said that the approach used in this effort is very effective at addressing the technical barriers identified for this project. One area of concern for this e fort would be the potential toxicity of the final electrolyte solvent for the capacitor; this is something that has not been addressed in the approach. The reviewer would also like to see quantitative metrics that demonstrate that the approach of a hybridized ultracapacitor/LIB solution is better that high-power Li-ion batteries alone.

Reviewer 4:

The reviewer said that the developed system appears to have sufficient ene gy at -30°C, but can only provide power to limited cranking numbers. The reviewer inquired if there were any efforts conducted to study how to increase battery utilization if there is energy that has not been used.

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

Reviewer 1:

The reviewer detailed that in an effort to identify cell components that minimizes high-temperature gas generation while having no negative impact on other key cell operating characteristics, several electrolyte combinations including acetonitrile, carbonate and ionic liquids and gas-suppression additives and separators were evaluated and suitable components were selected for the ultracapacitor pouch cell. The pouch cells were designed, fabricated and demonstrated to performance requirements. These ultracapacitor pouch cells are being tested by the national laboratories. The reviewer remarked that a proof-of concept system was built with a battery/capacitor management system, which was demonstrated to meet USABC energy and cold crank requirements. The cost model is being developed, which projects a cost closer to the targeted $180. The reviewer found that these accomplishments are in agreement with the plans, and the progress is consistent with the project objectives and DOE’s goals.

Reviewer 2:

The reviewer said that a tremendous amount of progress has been achieved so far, but it remains a challenge to meet the goal for the module lifecycle.

Reviewer 3:

The reviewer said that the technical accomplishments and progress towards the DOE goals were highly effective. However, the PI did not provide any supporting data to substantiate the progress that was made—supporting data and information would strengthen this criteria.

Reviewer 4:

The reviewer commented that technical accomplishments were evaluated on the final results in a gap analysis; however, the path to the results was not clear because of a lack of details. The problem with the report is that only the DOE requirements are evaluated and no results are shown beyond these parameters. Therefore, according to the reviewer it is not possible to even guess what the long-term value and usage of a capacitor-battery hybrid system for 12V stop/start system may be.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that the collaborating partners that will be leveraged for this program are primarily in the area of verification testing. There appears to be effective, well-coordinated collaboration.

Reviewer 2:

The reviewer commented that the only collaborations are the confidential testing done at national laboratories, so no access to collaboration status can be seen.

Reviewer 3:

The reviewer said that there is an on-going collaboration with the DOE laboratories, specifically with ANL in the testing of the ultracapacitors, with NREL for understanding the thermal aspects of the hybrid system, and with SNL for abuse tolerance.

Reviewer 4:

The reviewer commented none noted.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points,

considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

This project has demonstrated the benefits of utilizing a hybrid power system combining Li-ion cells and ultra capacitors, which may be useful for other applications as well. The remaining challenges are to finalize the ultracap pouch cell configuration, build the hybrid power system based on the CAD model and a digital version of the power management system, test the system against the USABC specifications and demonstrate its viability for the start-stop application. It is not clear, however, if the problem of gas generation has been completely solved and the ultracap provides adequate survivability at warm temperatures.

Reviewer 2:

The reviewer stated that this effort ends in June 2016 with a two-month extension. The next steps include conducting verification testing to evaluate the performance and abuse data

Reviewer 3:

The reviewer commented that a lack of detail on specifics makes assessment difficul

Reviewer 4:

The reviewer remarked none noted.

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

Reviewer 1:

The reviewer said that it appears that most DOE criteria are met, which gives a good state of relevance to the project.

Reviewer 2:

The reviewer commented that replacing the conventional 12V lead-acid batteries with Li-ion batteries for start-up applications will reduce the lower battery mass, volume (by 60%), improve the service life and reduce the maintenance. Their rapid recharge reduces the load on the alternator as they retain more power and are able to handle the charge faster than lead-acid batteries. All these characteristics will result in reduced fuel consumption and thus reduced CO_2 emissions. The reviewer stated that the technical challenges for the Li-ion batteries for this application are high power densities at low temperature for cold cranking, long cycle life and a wide range of operating temperatures. A hybrid system comprising commercial high-power Li-ion cells and low-temperature ultracapacitors may be an interesting combination to meet these performance and cost challenges. The reviewer stated that this project is aimed at developing such a power system.

Reviewer 3:

The reviewer remarked development of a hybrid energy storage may help the vehicle start and stop strategy to increase fuel economy.

Reviewer 4:

The reviewer said that this effort is relevant and addresses a key enabling energy storage solution needed to facilitate 12V start/stop vehicle platforms.

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

Reviewer 1:

The reviewer commented that the resources are adequate for the scope of the project to achieve the stated milestones per the schedule.

Reviewer 2:

The reviewer pointed out that this program is near completion; final deliverables are being made for verificatio testing.

Enabling High-Energy, High-Voltage Li-Ion Cells for Transportation Applications: Modeling and Analysis: Dennis Dees (Argonne National Laboratory) - es252

Presenter

Daniel Abraham, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

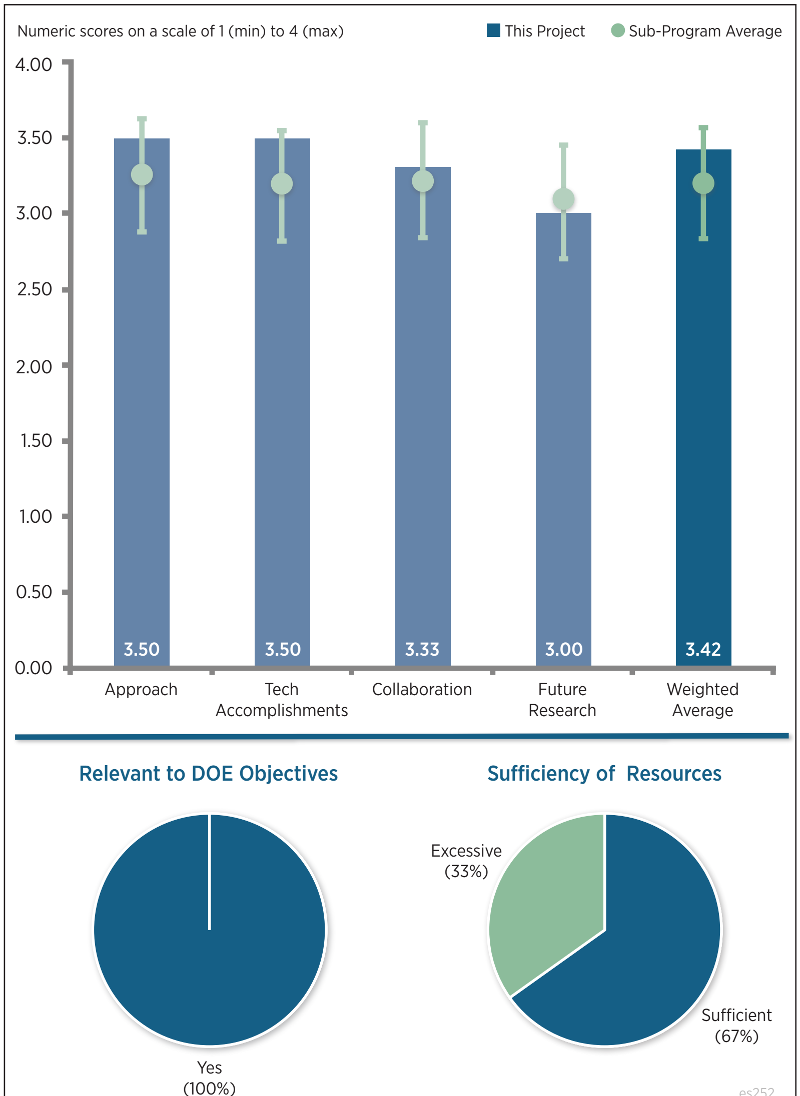

Figure 2-38 – Enabling High-Energy, High-Voltage Li-Ion Cells for Transportation Applications: Modeling and Analysis: Dennis Dees (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer commented that this is part of the broader program, in this case focusing on the fundamental and performance analysis of the system. Overall, the program approach is ambitious and well laid out.

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

Reviewer 1:

The reviewer stated that it is rather early in the program to make a significant comment on progress. If the material standardization and the protocol standardization have been completed and are operable, that would be a good start. The reviewer said that laying out the known challenges of the system in this format was also a good start.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer reiterated that this is an ambitious program that is dependent on effective coordination and collaboration. The project appears to be successfully accomplished in terms of the internal group collaboration. There was no mention of external industry collaborations. The reviewer was unclear if this was sought or considered so the reviewer is not clear if it is a negative or not.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points,

considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that while this is a coordinated deep dive effort, this is an area where considerable work has occurred in the past. Hopefully, there will be a critical focus on key identified mechanism issues rather than a re hash of work to date.

Reviewer 2:

The reviewer commented that it would be useful to understand if Li-trapping on the anode side is a continuous process throughout the cycle life of the battery.

Reviewer 3:

The reviewer suggested slightly less focus on the modeling-only portion of future work, and more focus on the additional electrolyte study portion.

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

No comments were received in response to this question.

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

No comments were received in response to this question.

Enabling High-Energy, High-Voltage Li-Ion Cells for Transportation Applications: Project Overview: Dennis Dees (Argonne National Laboratory) - es253

Presenter

Jason Croy, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

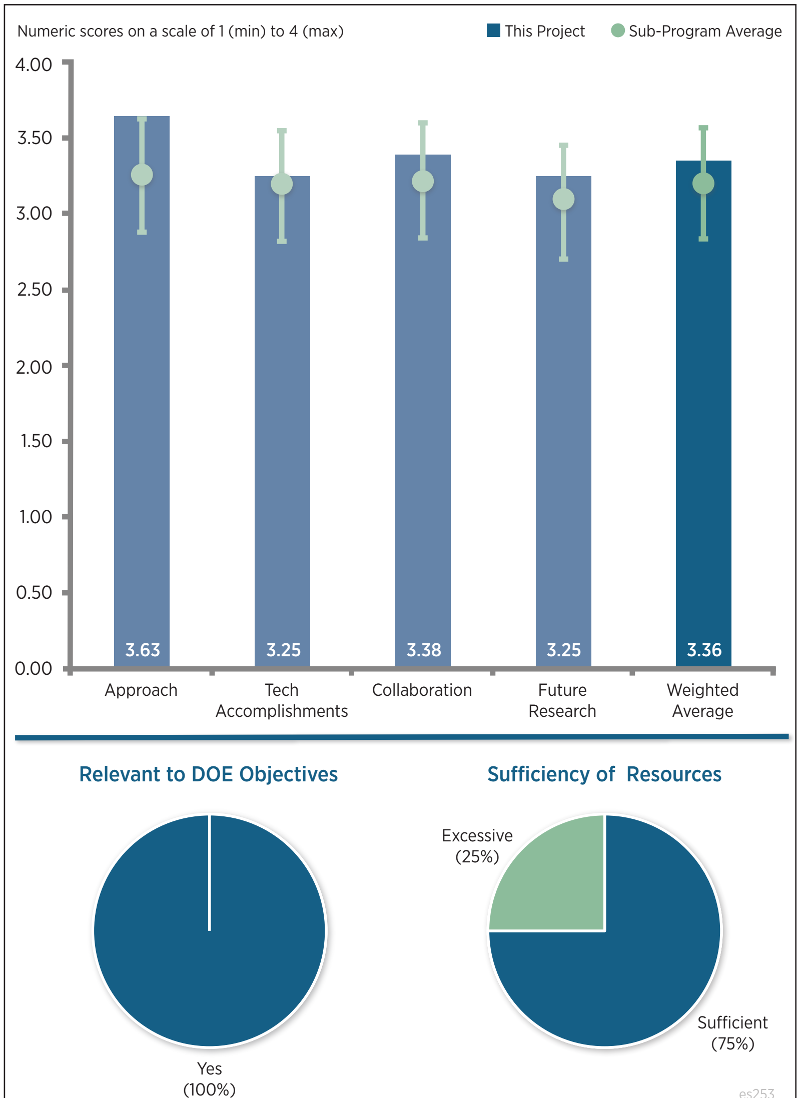

Figure 2-39 – Enabling High-Energy, High-Voltage Li-Ion Cells for Transportation Applications: Project Overview: Dennis Dees (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer remarked excellent progress on demonstrating a systematic approach to problem solving and utilizing talent across the DOE community.

Reviewer 2:

The reviewer said it is a worthy goal to provide standardized material sets and analysis protocols across a large multi-group program.

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

Reviewer 1:

The reviewer remarked a lot of good and trusted data due to the use of the statistical tools.

Reviewer 2:

The reviewer commented he specific technical progress of this program will be evaluated in the technical sections of the presentation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented well-coordinated effort.

Reviewer 2:

The reviewer remarked that in particular, this portion of the multiple presentations is focused on the collaboration and coordinating aspects of the program. It appears to be going quite well and will hopefully be a model for programs going forward. It was not clear to this reviewer if commercial collaboration is anticipated or sought.

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

Reviewer 1:

The reviewer commented very high expectation for this program in the research and commercial community.

Reviewer 2:

The reviewer said that future research was not discussed specifically in this presentation; howeve , we can assume that the standardization of materials and protocols will aid future work.

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

Reviewer 1:

The reviewer commented one of the promising approaches to higher energy density cells.

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

No comments were received in response to this question.

Enabling High-Energy, High-Voltage Li-Ion Cells for Transportation Applications: Materials Characterization: Dennis Dees (Argonne National Laboratory) - es254

Presenter

John Vaughey, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

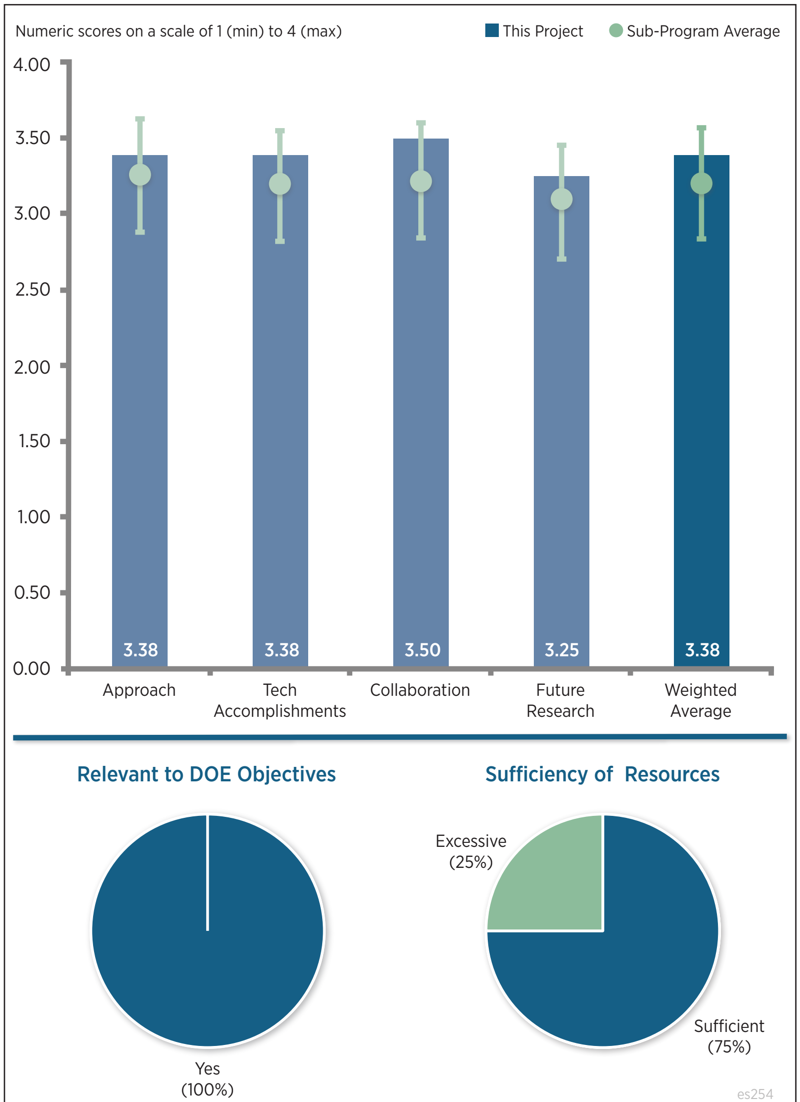

Figure 2-40 – Enabling High-Energy, High-Voltage Li-Ion Cells for Transportation Applications: Materials Characterization: Dennis Dees (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer said that this portion of the program is aimed at evaluating the role of surface coatings for improvement of cycle life behavior of Ni-rich cathode materials. The reviewer said the approach appears to be well laid out with baseline system analysis, model system development, and analytical tool development.

Reviewer 2:

The reviewer remarked that based on the question and answer session, it is apparent that surface stability is a function of the Ni-content and affinity to certain coating techniques is a function of the Mn content in the studied cathode compositions. Thus, the reviewer suggested that it might be helpful to re-think the approach and to better design experiments for easier results interpretation.

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

Reviewer 1:

The reviewer commented some good understanding of some of the basic characteristics of coated cathode materials has been developed.

Reviewer 2:

The reviewer believed that results indicating that alumina coating negatively impacts the performance warrant deeper analysis. Industry is currently using this approach so it would be nice to understand which benefits industry sees.

Reviewer 3:

The reviewer remarked a lot of good work and a lot of data, but it was difficult to draw conclusions; a more systematic experimental approach will be helpful.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented seasoned team of professionals.

Reviewer 2:

The reviewer said that the large team appears to be functioning well. It was unclear to this reviewer what level of commercial collaboration is anticipated or needed.

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

Reviewer 1:

The reviewer commented that future research continues to focus on cathode coating development. It is not clear if any other approaches have been considered.

Reviewer 2:

The reviewer remarked that it would be interesting to see the comparison of the coating versus bulk doping as a function of the Ni/Mn content. This might lead to the different strategies for different families of materials. In addition, high Ni content materials are made using Li hydroxide, not Li_2CO_3 at lower sintering temperatures. The reviewer asked what effect on surface stability that might have.

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

Reviewer 1:

The reviewer said that the project addresses energy density/safety needs.

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

No comments were received in response to this question.

Next-Generation Anodes for Lithium-Ion Batteries: Overview: Dennis Dees (Argonne National Laboratory) - es261

Presenter

Dennis Dees, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

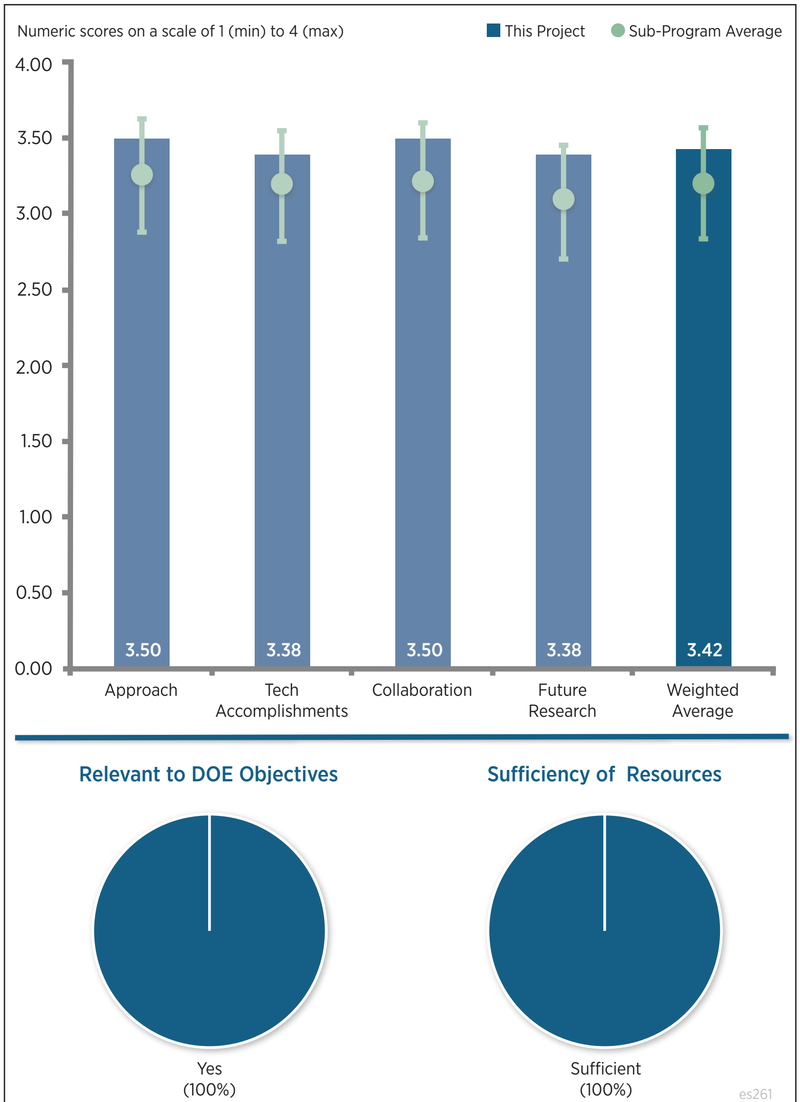

Figure 2-41 – Next-Generation Anodes for Lithium-Ion Batteries: Overview: Dennis Dees (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer remarked outstanding effort to systematically assess advanced anode systems.

Reviewer 2:

The reviewer said that the project uses the same program structure as the High Voltage cell development program, which in theory has promise. This is a potentially large scope technical challenge that has been studied intensely for many years. The reviewer said that finding new approaches and developing useful new knowledges will be a challenge. The reviewer said that it is too early to tell how the program shape will roll out so the reviewer believed it is a little early to review quantitatively.

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

Reviewer 1:

The reviewer said excellent use of the characterization tools/capabilities of the collaborating entities, and good effort on addressing Li inventory in the cell.

Reviewer 2:

The reviewer commented that preliminary work on program structure, material standards and protocol standards appears to be moving along well.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that the assembled team is excellent.

Reviewer 2:

The reviewer observed a good use of resources/synergies of the national laboratories.

Reviewer 3:

The reviewer said that collaboration is currently with internal contributors, and the reviewer was unclear if industrial partners are sought after or anticipated.

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

Reviewer 1:

The reviewer believed the direction of the proposed work should provide many insights into the issues associated with Si anode development.

Reviewer 2:

The reviewer commented a good plan for continued work on a reasonable set of key focus areas of importance.

Reviewer 3:

The reviewer said that the need for adding Li inventory was established decades ago. It is important to utilize national laboratory modeling capabilities to identify the most effective pre-lithiation route. The LFO concept was developed by ANL at least five years ago and it is important to understand its utility versus just being used as a research tool. Questions to consider include, for example, how LFO hygroscopicity will effect slurry quality, slurry pH and possible gelling. The reviewer asked what the effect is of the dead weight of the LFO on the gravimetric/volumetric energy density. Another approach the reviewer detailed could be fundamental understanding of the irreversible capacity in the Si anode and mitigating it through the new material architectures design

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

Reviewer 1:

The reviewer said that it is important to validate the hopes for the commercial use of the advanced high-capacity anodes.

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

Reviewer 1:

The reviewer said that the resource structure may have to change over time with new understanding.

Next-Generation Anodes for Li-Ion Batteries: Fundamental Studies of Si-C Model Systems: Robert Kostecki (Lawrence Berkeley National Laboratory) - es262

Presenter

Robert Kostecki, Lawrence Berkeley National Laborator

Reviewer Sample Size

A total of four reviewers evaluated this project.

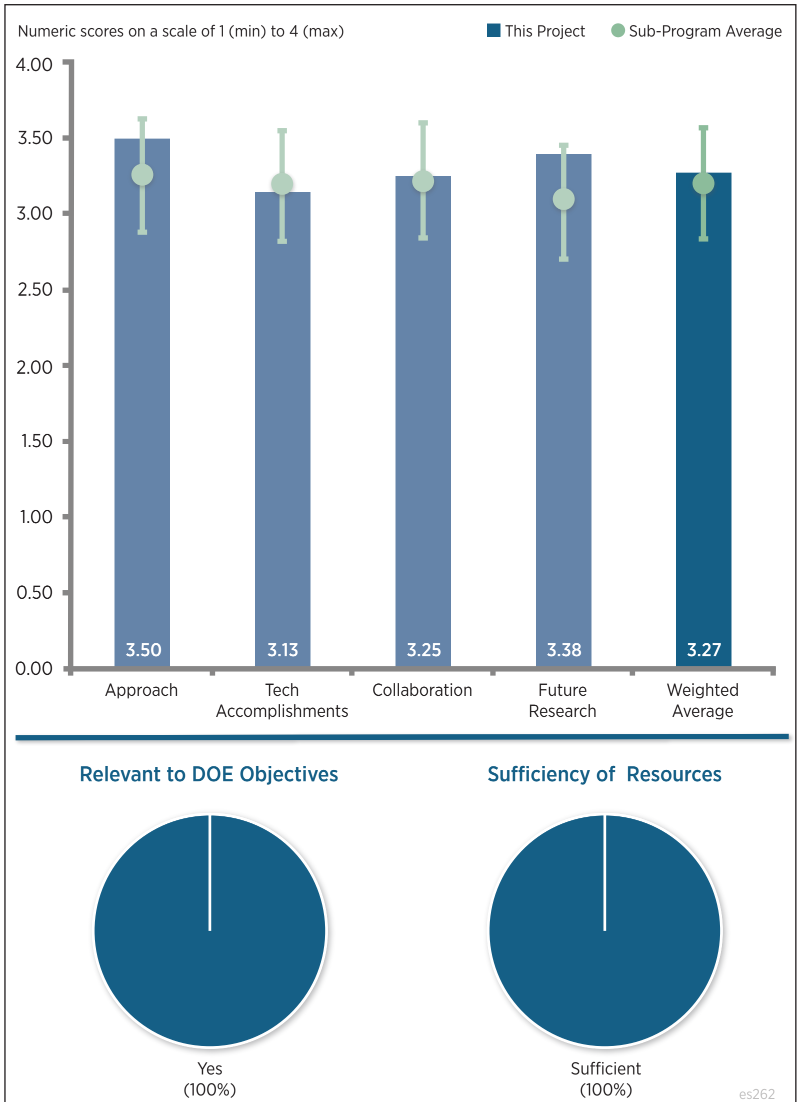

Figure 2-42 – Next-Generation Anodes for Li-Ion Batteries: Fundamental Studies of Si-C Model Systems: Robert Kostecki (Lawrence Berkeley National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer acknowledged that the PI is an intelligent, critical thinker and he lays out the challenges in Si development in a very compelling manner. The PI laid out the history that there has been 40 years of development on the Si system and progress still is not where it needs to be. So this program will be challenged to bring new insight to the table, but the energy storage community can hope that researchers like Kostecki are up to the task.

Reviewer 2:

The reviewer said that it was a good approach to have an integrated electrochemical and diagnostic study to study the two key issues with Si-based anodes, namely the large irreversible loss and the large volume change. The reviewer noted that a schedule and quantifiable milestones were not provided.

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

Reviewer 1:

The reviewer said that the program is too new to provide any significant technical progress beyond laying out the challenges and approach.

Reviewer 2:

The reviewer noted that the project was just kicked off in January 2016. The PI formed the project team and established the experimental procedures for diagnosis. In addition to the polypyrrole (PPy) binder, the reviewer suggested that the project team should also examine the validity of the self-healing binder for use in Si-based anode to mitigate the volume expansion issue.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that this is another deep dive program where the internal collaboration appears to be quite extensive and well supported, and external collaboration has not been developed yet, if indeed it is going to be.

Reviewer 2:

The reviewer commented good team composition but the project needs to specify the roles and responsibilities of each team member.

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

Reviewer 1:

The reviewer said that the areas laid out for study appear to be the correct areas to provide insight into Si anode performance.

Reviewer 2:

The reviewer suggested that future research should focus on the role of additives. For example, fluorinated ethylene carbonate (EC) additive were shown to improve the cycle life of Si-based anode. The reviewer remarked that understanding the role of the additives in the SEI should provide guidance in search of even better additives for Si-based anode.

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

Reviewer 1:

The reviewer said that the project is highly relevant because Si-based anodes are an enabler to achieve DOE-specific ene gy goals, but we still lack fundamental understanding that correlates performance with Si-based materials.

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

Reviewer 1:

The reviewer remarked that the issues brought here could significantly change the landscape of critical research for Si anode development. The ability to respond to new information with new research directions and perhaps new funded programs will be a challenge for DOE to respond to.

Reviewer 2:

The reviewer commented sufficient resources for this diagnostic e fort over 2.5 years.

Electrodeposition for Low-Cost, Water-Based Electrode Manufacturing: Stuart Hellring (PPG Industries) - es263

Presenter

Stuart Hellring, PPG Industries

Reviewer Sample Size

A total of five reviewers evaluated this project.

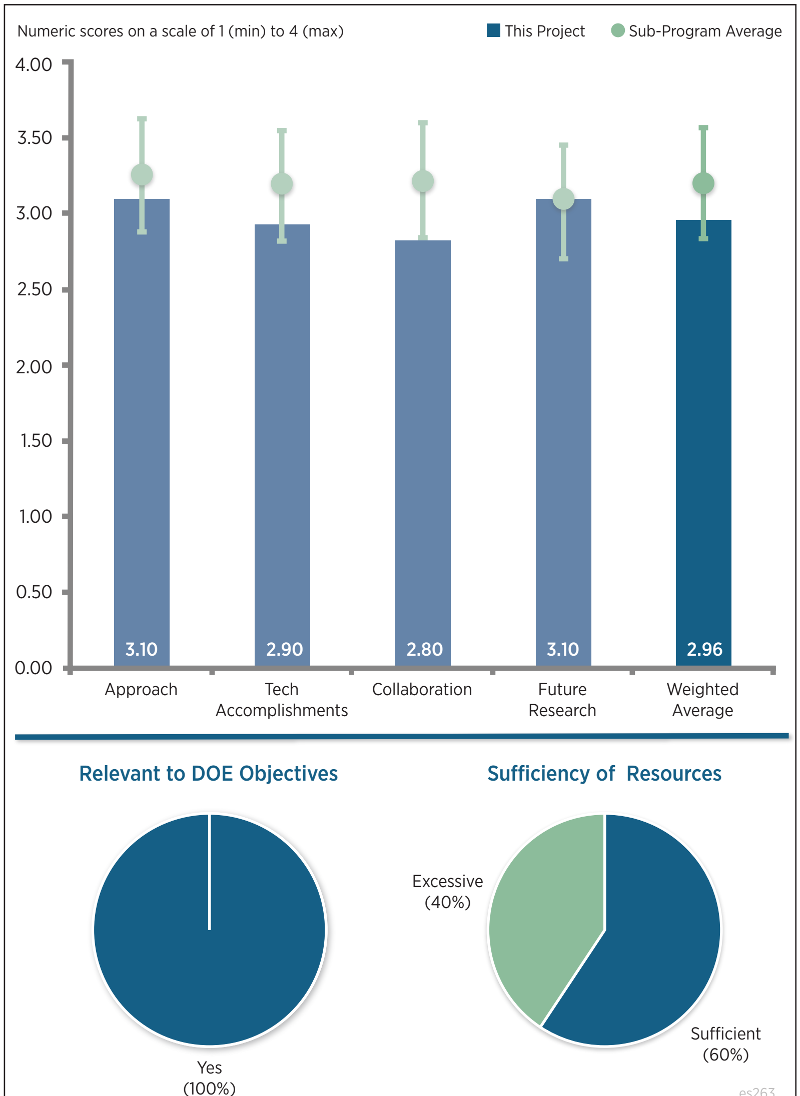

Figure 2-43 – Electrodeposition for Low-Cost, Water-Based Electrode Manufacturing: Stuart Hellring (PPG Industries) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer said that the technical approach seems novel and is premised on viewing the electrode coating as a more common automotive e-coat system. The battery electrode is significantly more technically complex than a typical e-coat system, so this approach appears to be very high risk if also high reward.

Reviewer 2:

The reviewer said that the objective here is to develop a new low-cost water-based electrodeposition method to manufacture battery electrodes for Li-ion cells. In contrast to the conventional NMP-based slot-die coating method, the proposed electrodeposition method has the advantages of being low-cost, easier to scale up with high throughput and has low emissions. Dense and uniform coatings are possible in a shorter time, with both the sides coated simultaneously and thus reducing the overall cost. The reviewer described that the approach involves identifying suitable resins with charged groups and developing cathode materials of a suitable particle size to facilitate rapid mobility and deposition of the cathode material using electrophoretic method. The reviewer said that this project is well designed, and integrated with other efforts.

Reviewer 3:

The reviewer commented that the aqueous electro deposition to replace slot dye coating seems promising, especially for the two-side simultaneous coating. As any electrochemical process, diffusion limitation will come to play, which will limit the deposition rate.

Reviewer 4:

The reviewer expressed concern about the deposition of multiple materials to create working electrodes ever working well. However, the reviewer thinks the idea should be explored and that the team is appropriate for this study.

Reviewer 5:

The reviewer was not entirely clear on the motivation for this approach, using an electrophoretic method to deposit powders to make electrodes. The reviewer was unclear how well the project team competes with speed of other manufacturing processes.

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

Reviewer 1:

The reviewer said that the project is at its onset, but the initial data on materials properties seems reasonable.

Reviewer 2:

The reviewer remarked that within the short period of the project, substantial results were obtained.

Reviewer 3:

The reviewer said that being a new project, reasonably good progress has been made in the first quarter with the electrodeposition process for the cathodes. A cathode material (NMC-523) of desired particle size has been synthesized and its Li dissolution characteristics during water soak have been determined. The reviewer remarked that several binders (eight) have been synthesized. This progress is consistent with the schedule. However, the reviewer said that it is important to assess the chemical/electrochemical stability of the resins (binders) in the battery electrolytes; the electrochemical stability of the substrate (the reviewer wondered if this is Al) at these high deposition potentials (and in aqueous medium); the effects of gas evolution during deposition; the effects of residual water, if any; and demonstrate the feasibility of coating both sides simultaneously. The reviewer also commented that a preliminary cost estimate needs to be made to make the argument that this is indeed economical and will lead to a noticeable reduction in battery cost, which is one of DOE's goals.

Reviewer 4:

The reviewer said that it is hard to evaluate at this stage. It is difficult to give a higher rating than that assigned, but based on further accomplishments, this value could raise.

Reviewer 5:

The reviewer commented that the project just started.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer pointed out that there are useful collaborations with DOE's laboratories (ANL and ORNL) to provide suitable cathode materials and develop aqueous deposition methods, respectively. Also, there will be a collaboration with the cell manufacturer, Navitas, to assist in the manufacturing and commercialization efforts.

Reviewer 2:

The reviewer remarked that the PI has established adequate collaborations.

Reviewer 3:

The reviewer commented that the performer cited many collaborators with strong battery groups. The reviewer suggested that partners should support the prime strongly in establishing an early proof of concept for the novel approach so that the prime does not invest time and resources in developing an e-coat system that they by themselves cannot determine is functional.

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

Reviewer 1:
The reviewer said that the future work described in Slide 16 seems appropriate. The performer should work strongly with the collaborators to the confirm battery performance of resulting coatings early in their development process.

Reviewer 2:
The reviewer remarked that the future research plan is adequate. The PI should put more attention to the feasibility evaluation, e.g., can the uniform coating be achieved at a practically adequate rate.

Reviewer 3:
The reviewer pointed out that the project just started, and remarked that the proposed research strategy seems fine even though the overall motivation for this approach is not clear.

Reviewer 4:
The reviewer remarked that the proposed future research is to address the remaining challenges of synthesizing the active materials in the desired particle (small) size; optimizing the formulation of the electrodeposition bath, verifying its stability towards electrodes, and identifying the electrodeposition parameters; assessing the performance of the cathode films; and estimating the performance characteristics in Li-ion batteries (with these cathodes). It is also important to have a preliminary cost model to support the claims of reduced costs. In short, according to this reviewer a lot has to be done to prove the viability of this concept.

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

Reviewer 1:
The reviewer pointed out that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles. The high costs are partly attributed to the complex fabrication processes for cathodes and anodes. The reviewer commented that new methods of coating the active materials are desired that would lead to a reduction of overall costs for the cell fabrication and for the batteries, which is being addressed here.

Reviewer 2:
The reviewer remarked that lowered costs of electrode fabrication and eliminating NMP from the deposition method are both helpful toward creating electrodes for EVs at more competitive costs.

Reviewer 3:
The reviewer commented that this project is high risk and high reward with the potential to support DOE's mission to reduce petroleum consumption.

Reviewer 4:
The reviewer said that the project will potentially lead to improved battery electrodes and the process for making them.

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

Reviewer 1:
The reviewer said that this group is ideal for performing the study.

Reviewer 2:
The reviewer said that project resources seem appropriate for the scope.

Reviewer 3:
The reviewer said that resources seem to be slightly excessive for the scope of the project, possibly due to the participation of multiple organizations (including national laboratories).

Li-Ion Battery Anodes from Electrospun Nanoparticle/ Conducting Polymer Nanofibers: Peter Pintauro (Vanderbilt University) - es264

Presenter

Peter Pintauro, Vanderbilt University

Reviewer Sample Size

A total of six reviewers evaluated this project.

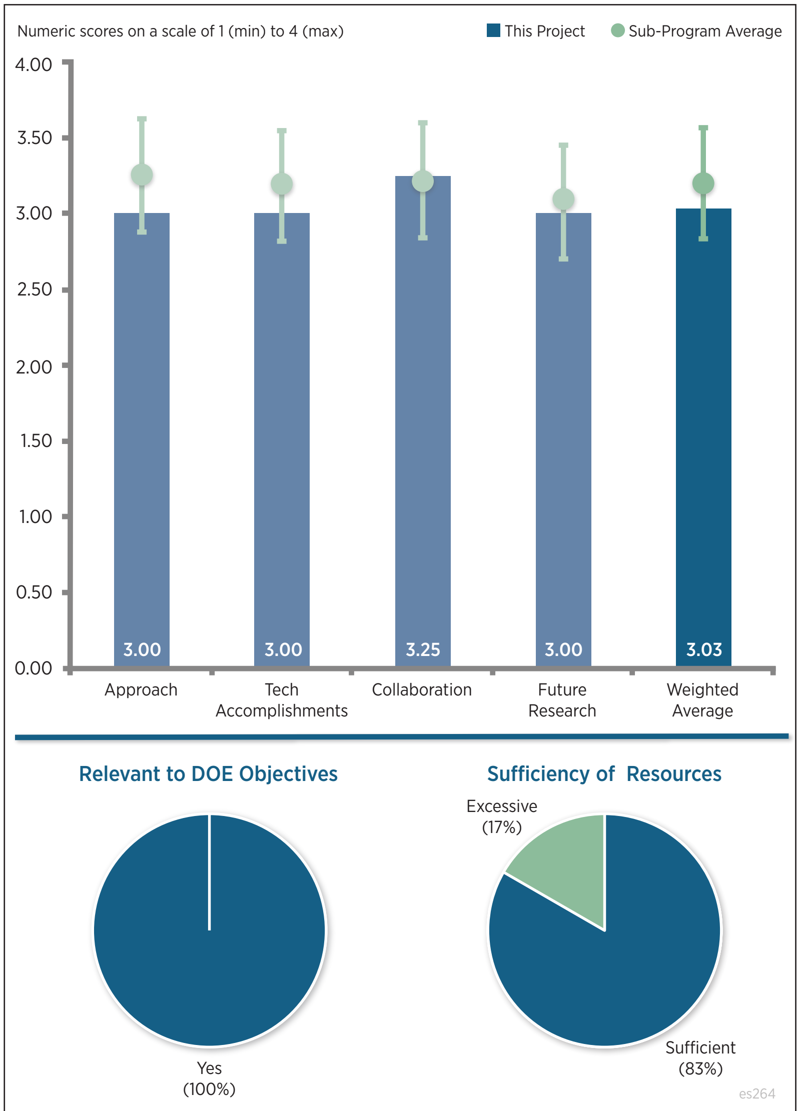

Figure 2-44 – Li-Ion Battery Anodes from Electrospun Nanoparticle/Conducting Polymer Nanofibers: Peter Pintauro (Vanderbilt University) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer remarked that the approach of using electrospinning to make fibers containing active materials for making thick electrodes is interesting.

Reviewer 2:

The reviewer said that the objective here is to develop high specific and volumetric capacity of nanofiber anode mats with Si nanoparticles and an electronically conductive binder for Li-ion batteries. The targeted performance is greater than 750 mAh/g and 800 Ah/cc after 50 cycles and with a high anode loading corresponding to an areal capacity of 3 mAh/cm^2. The reviewer said that the technical barriers being addressed here are the rapid capacity fade of Si anode material and achieving high areal capacity that will result in high energy densities for Li-ion cells. The approach is to synthesize electro-spun Si-C nanofiber (with at least 50% of Si nanoparticles) with a conductive binder (initially the binder developed at LBNL earlier and later another binder), and fabricate and test Si-based nanofiber anodes in Li-ion half cells. The reviewer said that the approach looks feasible with proper milestones to demonstrate the feasibility. The reviewer identified that one problem, however, has to do with the evaluation of Si nanoanodes in half-cells, which is not as complete and even misleading. The performance in a full cell is more challenging, with considerably reduced cycle life and the irreversibility and SEI build on Si determine the overall gains in specific ene gy and energy density at the cell level. The reviewer said that the project is well designed, and integrated with other efforts.

Reviewer 3:

The reviewer said that this approach appears to have volumetric energy density issues, with the target performance value (Slide three) of 1.07 and what was achieved (Slide 6) of 0.56. Moreover, the referenced conventional cast C/poly(vinylidene fluoride) (PVDF) value of 25 mAh/c ^{3} shown on Slide 9 is extremely low and unrealistic (example calculations of 1g/cm^3 in a finished electrode assuming 2.27 g/c ^{3} starting density and losses for binder and 50% porosity lead to an effective density of 1g/cm^3 which leads to 25 mAh/g which at 2C for any graphite electrode is highly suspect) as a comparison basis. The reviewer said that care should be taken in the future to cite more relevant comparison values for the incumbent technology and to clarify the volumetric issues of this approach.

Reviewer 4:

The reviewer liked the novelty of the approach, but was concerned about cost. The reviewer wondered if a cost evaluation can be done early in the project (like now).

The reviewer suggested that the project team be very clear in calculations on areal and volumetric energy densities. The PI spoke a lot about porosity, between fibers and within fibers This caused the reviewer to think about low energy density as the project fills up the electrodes with ai .

Reviewer 5:

The reviewer pointed out that large volume expansion caused mechanical fracture, unstabilized SEI, and poor electrode integrity are the main challenges for applying Si based materials in Li-ion batteries. The project does not address how to solve that problem sufficientl . The reviewer said that electrospun Si nanoparticles in a fiber shape has been investigated by other researchers for many years. Although the conductive polymer binder has been introduced into this project, however, the thickness of the electrode is still a challenge.

Reviewer 6:

The reviewer said that the PI pursues an integrated Si-based electrode using electrospinning technique. It will create a unique electrode mat with porosity structure and well-connected matrix. However, this approach will have to use high polymer contact in order to achieve spun-fibe . The reviewer said that this will inevitably impact the energy density by volume. The reviewer said that an electrospinning technique is also unfit for la ge scale production considering its inefficienc .

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

Reviewer 1:

The reviewer said that the team made significant progress in making Si containing electrospun fibers for makin thick anode.

Reviewer 2:

The reviewer said that good progress has been made in the last few months of the project on the electro-spun Si-C fibrous mats with a conducting polyme . Specificall , using an electronically conductive polymer binder synthesized at LBNL, Si-C fibers were electrospun with 20-50 weight percentage Si nanoparticles. Thick electrodes of approximately 62 µm have been fabricated using Si-C fibers, and polyacrylic acid (AA) binder and tested in half-cells. The reviewer said that high gravimetric (1,000 mAh/g), areal (3.5 mAh/cm^2), and volumetric (560 mAh/cm^3) capacities were achieved with the Si-C/PAA mat anodes, especially after compaction. The reviewer detailed that fiber mat strength appears to be important for achieving high initial capacity and to minimize capacity fade with cycling. Even though these results look promising, the reviewer pointed out a couple of issues. Details are not provided on the irreversible capacity (or Coulombic efficiency), which is an important design paramete . Also, cyclic performance in a half-cell gives little indication of how well the electrode cycles in a full cell. The reviewer concluded that overall, the progress is good and is consistent with DOE's goals.

Reviewer 3:

The reviewer said that the slurry cast values shown on Slide 10 fade approximately 1%/cycle through 25 cycles and although the Vanderbilt results may be comparable to the LBNL results, the absolute performance is not excellent as stated. Slide 15 mentions welding electrodes but does not give a clear description of process used. The reviewer suggested that the conditions of testing (voltage swept, current, temperature, electrode thickness, etc.) should be added to Slides 9, 10, 16 and 17 for a better understanding of work performed.

Reviewer 4:

The reviewer said that the project is rather early to judge; however, the reviewer cited good progress on getting the electrospinning process working with the PFM/Si.

Reviewer 5:

The reviewer remarked that the project just started last year, and the team has made some progresses to optimize the process and control the electrode structure. These are all necessary initial steps towards addressing the barriers listed at the beginning.

Reviewer 6:

The reviewer said that in the short period since the project was awarded, the PI tested various polymers as fibe - making agent, including the electronically-conductive binder and PAA. The preliminary results demonstrated that this approach is viable for making Si-composite electrodes, but it will take more time to prove that the electrode materials are indeed superior to state-of-the-art Si electrode materials processed via bulk production, and the process is indeed viable to scale-up for Kg-scale production.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that this is a good multi-intuitional project involving a university (Vanderbilt University), two DOE laboratories (LBNL and ORNL), and an industrial partner (e-Spin Technologies).

Reviewer 2:

The reviewer said that collaborators seem appropriate.

Reviewer 3:

The reviewer said that the collaborators in this project have sufficient expertise in this field, which can address th barriers effectively.

Reviewer 4:

The reviewer commented that partners have all the skill sets technically, but asked who the commercialization partner is, and who can provide feedback on manufacturability, cost, etc.

Reviewer 5:

The reviewer commented that there is apparent close collaboration between the PI and the team members.

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

Reviewer 1:

The reviewer remarked that future work seems appropriate.

Reviewer 2:

The reviewer said that the proposed future efforts seem to be fine with the milestones and goals

Reviewer 3:

The reviewer detailed that the proposed future research is to continue electrospinning studies for Si/PFM/PEO fibers of less than 1 µm diameter and demonstrate stable capacities of greater than 500 mAh/g at 0.1C; and develop dual fiber electrospun nanofiber mats (40-100 µm with an areal capacity of 3 mAh/ ^{2}) containing separate Si/PFM/PEO fibers (for Li storage) and C/PVDF fibers (for electrical conduction) These targets are reasonable provided the irreversible capacity is low (less than 10%), Coulombic efficiency is high (greater than 99%) and capacity fade is low (less than 0.4%) during cycling in a full cell. The reviewer said that future work planned is logical with appropriate decision points in the materials selection and demonstration.

Reviewer 4:

The reviewer said that the addition of carbon fibers to improve conductivity after pressing is a good idea. The reviewer asked what the surface area is of the polymer fibers, and are these Si or carbon fibers. It seemed to th reviewer as though there could be a lot of parasitic reactions/SEI formation that would result in poor CE. The reviewer asked if the project team makes an SEI on the polymer. If it is electronically conducting enough, the electrolyte will be exposed to a reducing potential

Reviewer 5:

The reviewer expressed a concern. As this process needs Si in the form of nanoparticles, the cost of this process will certainly depend upon the cost of Si nanoparticles. The reviewer said that it would be interesting to try to make a composite electrode using a Si containing precursor.

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

Reviewer 1:

The reviewer said that Si-based materials are the desirable candidate for achieve the DOE objectives.

Reviewer 2:

The reviewer said that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles. High capacity cathode and anode materials are required to improve the specific energy of Li-ion cells. Si anodes are promising to provide high specific capacity (mAh/g) and volumetric capacity (mAh/cc) compared to graphitic anodes, which will result in high gravimetric and volumetric energy densities for Li-ion cells. However, there is an inherent issue of volume expansion with the Si anode that affects its cyclic stability. The reviewer said that in order to mitigate this issue, new anode nanostructure architectures are being explored worldwide, which is also the aim for this project.

Reviewer 3:

The reviewer said that if successful, this project could help contribute to DOE's mission to reduce petroleum consumption.

Reviewer 4:

The reviewer commented an improved electrode manufacturing process and potentially a high energy density Si anode.

Reviewer 5:

The reviewer affirmed that the project is relevant to DOE objectives

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

Reviewer 1:

The reviewer said that resources seem to be quite appropriate for the scope of the project.

Reviewer 2:

The reviewer commented that project resources seem appropriate.

Reviewer 3:

The reviewer said that resources are sufficient

UV Curable Binder Technology to Reduce Manufacturing Cost and Improve Performance of LIB Electrodes: John Arnold (Miltec UV International) - es265

Presenter

John Arnold, Miltec UV International

Reviewer Sample Size

A total of six reviewers evaluated this project.

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

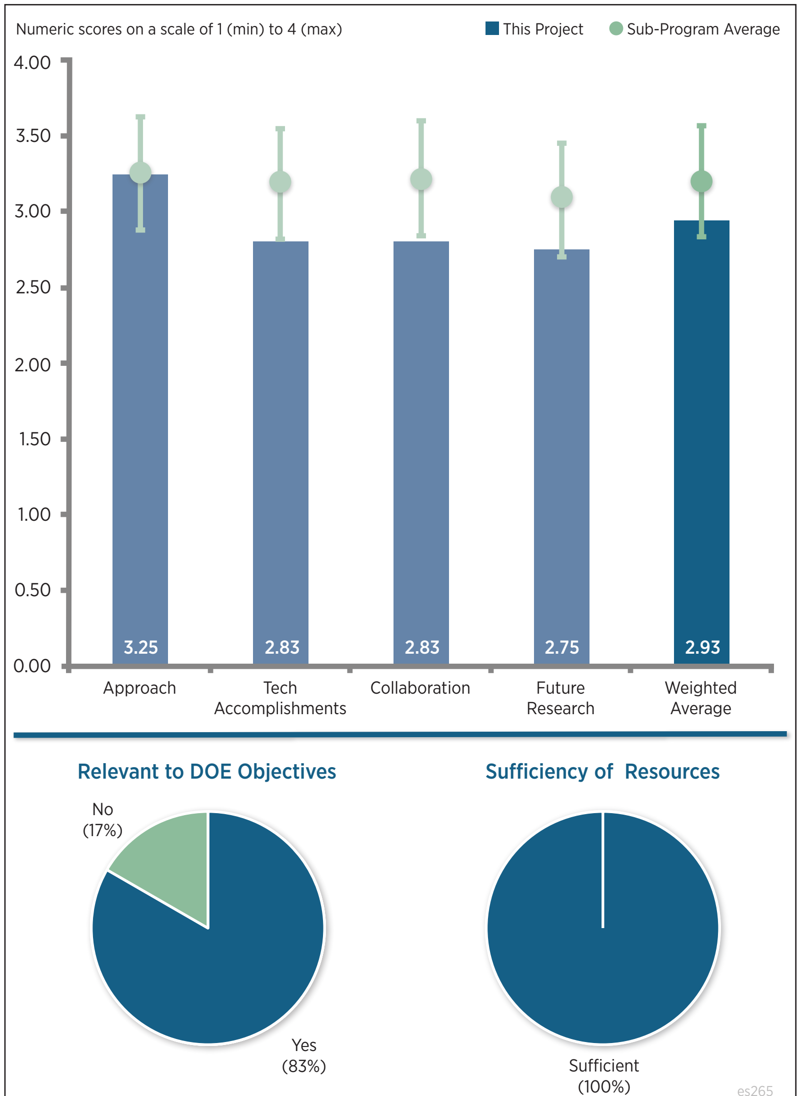

Figure 2-45 – UV Curable Binder Technology to Reduce Manufacturing Cost and Improve Performance of LIB Electrodes: John Arnold (Miltec UV International) - Electrochemical Energy Storage

Reviewer 1:

The reviewer stated that the objective is to develop UV curable binders for LIB electrodes to reduce manufacturing cost and also to improve performance of Li-ion batteries. The reviewer noted that in contrast to the conventional electrode fabrication with polyvinylidene difluoride (PVDF) and NM solvent, this UV-cured method provides faster curing and rapid drying, possibly with simultaneous two-sided coating, resulting in considerable reduction in capital costs (80%) and some savings in the operational costs for Li-ion cells. The reviewer added that it will also allow a reduction in the binder content, improved binder stability during cycling. The reviewer explained that UV light instantly polymerizes photo-reactive mixture into a solid plastic, and the coating is fully cured and ready to use or test immediately after light exposure. After identifying suitable binders, the reviewer added, high-speed coating and curing with slot die and printing technology will be explored. Such UV-cured polymers were used to form polymer electrolytes successfully. The reviewer remarked that the project is well designed and integrated with other efforts, especially with a similar project from this organization on using UV-cured resin for coating ceramic layers on separators.

Reviewer 2:

The reviewer stated that using UV-curable technique to process the electrode binder is an innovative approach as it will rid of many heavy equipment for drying and solvent-recovery, as well as saving time and energy.

Reviewer 3:

The reviewer pointed out that UV-cured coating has substantial advantages (e.g., high speed, two-side simultaneous curing, no solvent, etc.).

Reviewer 4:
The reviewer remarked that the approach is generally effective in terms of saving the cost. The reviewer added that the trade-off on performance needs to be further studied. The large particle of active materials might block UV and, as a result, the reviewer explained, curing might not be uniform.

Reviewer 5:
The reviewer commented that manufacturing cost reductions of 80-95% are claimed for this approach, but are not substantiated by any technical data provided.

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

Reviewer 1:
The reviewer stated that good progress has been made in the first quarter on the U -cured binders for fabricating electrodes for Li-ion cells. Specificall , suitable binders have been identified and electrodes have been fabricated using UV-curing. These electrodes demonstrated performance comparable to the standard electrodes with PVDF binder (different amounts), even showing lower impedance growth and better capacity retention during cycling both at high and low temperatures. However, the reviewer questioned that it has not been mentioned what the electrode loadings are in these studies. Further, the process has been demonstrated to be faster (100 m/min). Finally, the reviewer added, modeling studies have been performed which show that the manufacturing costs will be reduced by 80-90%, and 24% of the cost reduction included materials for Li-ion cells. There will also be additional benefits in the capital and operational costs. The reviewer remarked that even though the initial results are encouraging, it is not clear how good the electrode uniformity will be with higher electrode loadings. The reviewer concluded that overall progress has been good and consistent with DOE goals.

Reviewer 2:
The reviewer remarked that, given the short period since the project was awarded, the PI was able to show that the new electrode processed by their UV approach can indeed rival the semiconductor optical amplifier (SOA) electrode.

Reviewer 3:
The reviewer stated that electrodes were made using a UV-curing method in comparison with traditional PVDF coating, and that cells were made from the electrode and tested electrochemically. The reviewer noted that preliminary data show the parity performance, and that more cycle data should be included.

Reviewer 4:
The reviewer noted that the accomplishment meets the planned milestone. However, the reviewer added, PI claimed that the major challenges of capacity, impedance, and long-term cycling have been overcome, but no convincing data were shown in the presentation.

Reviewer 5:
The reviewer noted that very few technical details were provided on Slide 8 regarding impedance, such as the alternating current (AC) impedance test pattern (e.g., frequency swept, amplitude). The reviewer questioned why only the -10°C data were shown, and whether impedance means the real axis intercept, or the radius of curve 1, 2, or other feature. Similarly, the reviewer commented that very few technical experimental details were provided, such as details of cycles run (e.g., voltage, current, temperature, etc.). The reviewer questioned whether the data plotted belonged to one cell or the average of many. The reviewer pointed out that Slide 9 shows 200 cycles of 2C/2C testing, which would take approximately 10 days to reach depending on further details of the test pattern not shared (such as voltage swept, rest periods, cell type/construction, electrode details, etc.). The reviewer remarked that further testing with a variety of temperatures, cycle voltages, rates, etc. should be shown if similar performance relative to the PVDF system is to be believed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer praised the collaborations with DOE laboratories (ANL ORNL) for technical guidance and product validation. ANL is assisting in the testing and analysis of UV-cured cathodes in pouch cells and comparing performance to PVDF baseline, while ORNL is assisting in the coating and testing of a multilayered UV cathode with goals of higher energy density and higher voltage cells.

Reviewer 2:
The reviewer remarked that the collaborators are the experts in the battery field, and that the collaboration is expected to be effective.

Reviewer 3:
The reviewer commented that there is close collaboration between the PI and the team members.

Reviewer 4:
The reviewer noted that collaborations seem appropriate, but should contribute more strongly to help the prime perform basic electrochemical characterization to determine if this material change is workable in a battery system.

Reviewer 5:
The reviewer indicated that the PI should find more collaborators

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

Reviewer 1:
The reviewer stated that the proposed future research is adequate.

Reviewer 2:
The reviewer stated that the proposed future efforts are reasonable.

Reviewer 3:
The reviewer noted that the proposed future research focuses on the installation and operation of high-speed coating with slot die and printer technology to demonstrate high-speed coating and curing, both single- and double-sided. The reviewer expressed that it needs to be confirmed if this method is applicable to high-ene gy density multi-layered cathode coatings. The reviewer added that planned future work is logical and the milestones are reasonable and consistent with project objectives.

Reviewer 4:
The reviewer indicated that future efforts should focus on supporting the very large cost-reduction potential claimed by the performer. The reviewer observed that the first bullet of Slide 1 states that challenges of capacity, impedance, and cycling have been overcome, but that little technical data to support these conclusions have been shown. The reviewer said that the performer needs to provide much more electrochemical testing data at the electrode proof-of-concept stage before focusing on any equipment and speed scale ups.

Reviewer 5:
The reviewer pointed out that chemistry and electrode structures still need further optimization, which are not included in the future plan.

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

Reviewer 1:
The reviewer remarked that in addition to improving the specific ene gy, energy density, and specific power of Li-ion batteries, it is also important to reduce their costs for a widespread adoption in the EV market. The conventional electrodes, or at least cathodes, are fabricated using fluorinated binders dissolved in NM , which requires elaborate drying to remove the solvent. Newer binders and with simpler drying (i.e., curing) processes are

required to reduce the cost of electrode fabrication and thus the cost of Li-ion batteries. The reviewer stated that the project is aimed at developing new such binders cured by low-cost methods, i.e., UV irradiation.

Reviewer 2:

The reviewer agreed that reducing manufacturing costs is an effective way to reduce the overall cost of a battery pack.

Reviewer 3:

The reviewer stated that the project is relevant to DOE goals.

Reviewer 4:

The reviewer commented that, based on the low amounts of technical data shown, it is not possible to determine if this work would be able to serve the DOE mission to reduce petroleum usage.

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

Reviewer 1:

The reviewer said the resources seem to be adequate for the scope of the project and the number of participants.

Reviewer 2:

The reviewer stated that, based on the low amounts of technical data shown, the resources seem large.

Co-Extrusion (CoEx) for Cost Reduction of Advanced High-Energy-and-Power Battery Electrode Manufacturing: Corie Cobb (Palo Alto Research Center) - es266

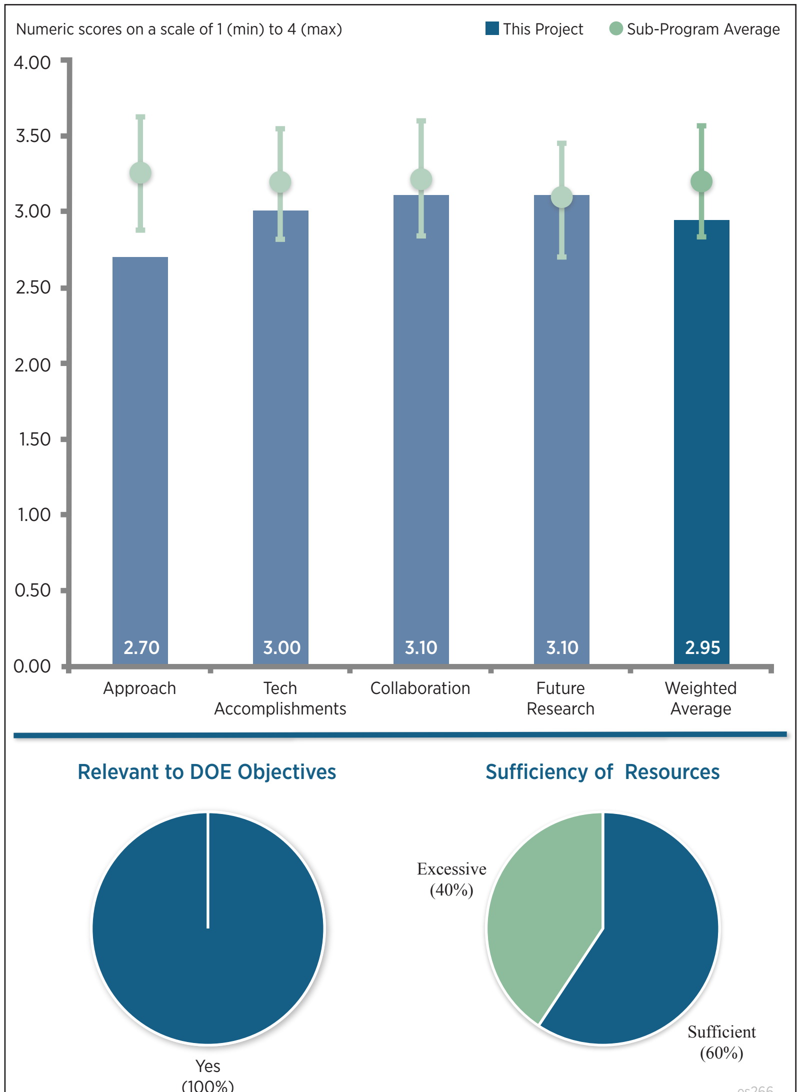

Figure 2-46 – Co-Extrusion (CoEx) for Cost Reduction of Advanced High-Energy-and-Power Battery Electrode Manufacturing: Corie Cobb (Palo Alto Research Center) - Electrochemical Energy Storage

Presenter

Corie Cobb, Palo Alto Research Center

Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer observed that the objective of the project is to develop pilot-scale fabrication of high-capacity pouch cells through co-extrusion. The use of thick-structured cathodes and matching-thick anode is expected to result in improved performance (20% gain in Wh/kg) and reduced cost (greater than 30%). The reviewer indicated that near-term objectives include: demonstrating the CoEx cathodes in coin cell with over 20% gain in Wh/kg over a baseline cell (the reviewer questioned how such a quantitative comparison can be made in a coin cell where the ratio of active material to cell casing is not favorable); optimizing the thick CoEx cathode design; developing matching-thick graphite anode; and performing an assessment of its scale up and commercialization. The reviewer added that even though the CoEx concept looks appealing, especially with the structured electrodes, such structural pattern may not be retained after calendering. Without calendaring and compaction, the performance will be poor for a thick electrode due to low electronic conductivity, and result in low volumetric energy density. The reviewer expressed that the milestones look reasonable, except that for the demonstration of the cathode, its thickness is not specified. The reviewer noted that the design of print head and the slurry consistency are critical for the co-extrusion of the cathode. The anode will be slot-die coated, i.e., in the conventional manner, but with different conductive diluent and binder for thicker electrodes (125-200 µm). Overall, the reviewer concluded, the project is well designed and integrated with other efforts.

Reviewer 2:

The reviewer noted that the approach addressed the barriers effectively, and that the cost should dramatically be reduced by increasing the loading of active materials in the batteries.

Reviewer 3:
The reviewer stated that the advantages of the proposed approach as opposed to making mesoporous composite electrodes are not clear. In fact, the reviewer elaborated, the proposed approach will be limited in the volume fraction for active material loading due to the lateral gap limitation between gaps. The reviewer expressed that the mechanical integrity of the cathode layer near hollow groves is also questionable. Similarly, the reviewer added, the chemical stability through dissolution will also be enhanced in the hollow groves filled with electrolytes

Reviewer 4:
The reviewer observed that the PI proposed to use a printing technique to create a structure electrode matrix so that requirements for both energy density and power density can be satisfied. The reviewer commented that it seems unnecessary to use a printing technique, at least for the single-material processing, and that a mechanical patterning will probably create the same effect at a much lower cost.

Reviewer 5:
The reviewer expressed difficulty in evaluating this question with the information given in the presentation. The reviewer acknowledged that the program has just started, but indicated a lack of technical detail in the slides. The reviewer commented that goals for the cells need to be disclosed, and that it is impossible to determine the merit of the technology without an idea of the power density targets. The reviewer pointed out that USABC publishes its targets, and claimed that DOE funding should not be used to fund projects without clear targets for the cell performance [DOE Program Clarification: This is an exploratory Advanced Processing R&D project; it is significantly early in the project to build a reasonable cost model. Cost models will be deliverables in the final year of the project.]. The reviewer warned that cost claims are dubious, and added that more specific cost modeling needs to be shown to give merit to cost claims. The reviewer did not see how a 30% decrease of cost is possible on a kWh basis. The reviewer pointed out that, as far as the reviewer understands, the program is not decreasing the amount of active material, only the number of layers in a cell. Because the current collectors and separator do not add up to 30% of the cell cost, the reviewer added, even removing them completely will not result in a 30% reduction in cost. Similarly, manufacturing accounts for only around 30% of the cost in the worst case, thus the same issues exist. The reviewer expressed that energy density claims are similarly dubious, and that electrochemical modeling data should be shown to support the claims.

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

Reviewer 1:
Although the project started late, the reviewer commented, the team has made significant progress

Reviewer 2:
The reviewer noted that progress seems okay in demonstrating the fabrication of striped electrodes.

Reviewer 3:
The reviewer commented that good progress has been made in the first quarter towards the CoEx and thick structured cathodes in Li-ion cells for improved specific ene gy and reduced cost. The reviewer pointed out that work is in progress to design the cell targets for the NMC cathode graphite materials; to perform modeling for the optimal geometries of the CoEx cathode for a 10-30% energy improvement; to demonstrate single-layer CoEx cathode films with over 142 mAh/g at C/2 discha ge rate; and to verify that baseline anode matches well with CoEX thick cathode with suitable binder and conductive diluent. The reviewer questioned what the thickness of the single-layer CoEx cathode films was. The reviewer also noted that preliminary experiments were completed to demonstrate initial print feasibility for CoEx cathode structures. The reviewer said that, even though the process looks simpler, there are a couple of issues: First, the post-extrusion calendering will damage the structural aspects (with gradient porosities) of the cathode. Second, it is not clear if thick anode will function as well, without any additional channels for electrolyte; even though cathode is limiting at room temperature, at low temperatures anode is known to be limiting. Third, with only 10-30% gain at the cathode level, the gains at the cell and battery level will be less attractive. Finally, because cost is one of the presumptive benefits here, it requires substantiation with a preliminary cost model. Overall, the reviewer concluded, the progress is good and consistent with the DOE goals.

Reviewer 4:
The reviewer stated that even though it is early in the program, at this point the reviewer would expect to see more detailed cost modeling and electrochemical modeling to give merit to the cost reduction and energy density improvement claims.

Reviewer 5:
The reviewer observed that results shown are preliminary and not convincing that the electrodes created are superior to the state of the art. The reviewer added that more time is needed to make that judgment.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer pointed out that there are useful collaborations with external partners that include DOE laboratories (ANL and ORNL) and industry (Navitas).

Reviewer 2:
The reviewer expressed that future collaboration with ORNL is good, but strongly suggested collaboration with the national laboratories to work on cost modeling. The cell performance targets for the program need to be disclosed.

Reviewer 3:
The reviewer stated that the team is strong, involving national laboratories and the automotive industry, and that it would be better to also involve battery manufactures at some point in the future.

Reviewer 4:
The reviewer commented that collaboration is close.

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

Reviewer 1:
The reviewer observed that the proposed future research is aimed at the following tasks: develop CoEx cathode films with high utilization; develop suitable matching thick graphite anode; perform a scale up analysis; and modify the print heads for 1 Ampere-hour (Ah) pouch cells. In addition, alternate drying methods will be established to avoid electrode cracks, multiple CoEx structures will be explored to achieve the desired structural properties, and multiple graphite anodes will be assessed for the matching thick anode. The reviewer suggested a preliminary cost versus performance model based on the material properties and coin cell data to support the claims of benefits over the devices with conventional electrodes. The reviewer concluded that the future work is logical and addresses the risks in the proposed electrode architecture.

Reviewer 2:
The reviewer stated that the future plan is trying to address all the barriers and was laid out in detail.

Reviewer 3:
The reviewer commented that the proposed research strategy is okay with respect to the funded project objectives.

Reviewer 4:
The reviewer noted the proposed future efforts are reasonable.

Reviewer 5:
The reviewer said that notes from first section apply to this as well

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

Reviewer 1:
The reviewer stated that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles, and that reducing the inactive materials (current collectors and separators) by utilizing thick electrodes will have benefits in both performance (higher ene gy density) and cost. However, the reviewer added, the current electrode designs yield poor results if used in thick configuration. New electrode designs and fabrication methods are desired that would allow the use of thicker electrodes and improve both performance and cost of Li-ion batteries, which are being addressed by the project.

Reviewer 2:
The reviewer agreed that the idea of reducing cost and improving energy density support DOE objectives.

Reviewer 3:
The reviewer indicated improved manufacturing processes for LIB electrodes.

Reviewer 4:
The reviewer observed that improving the loading of the active materials is an effective way to reduce the cost of the high energy batteries in terms of dollars-per-kWh.

Reviewer 5:
The reviewer stated that the project is relevant to DOE goals.

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

Reviewer 1:
The reviewer indicated that resources seem a little excessive for the scope of the project, even with multiple partners.

Reviewer 2:
The reviewer stated that the amount of funding seems high given that no new electrochemistry or equipment will be developed during the program. The project is using existing chemistries and coating technologies for the anode and existing printing technologies for the cathode.

Commercially Scalable Process to Fabricate Porous Silicon: Peter Aurora (Navitas Systems) - es267

Presenter

Peter Aurora, Navitas Systems

Reviewer Sample Size

A total of seven reviewers evaluated this project.

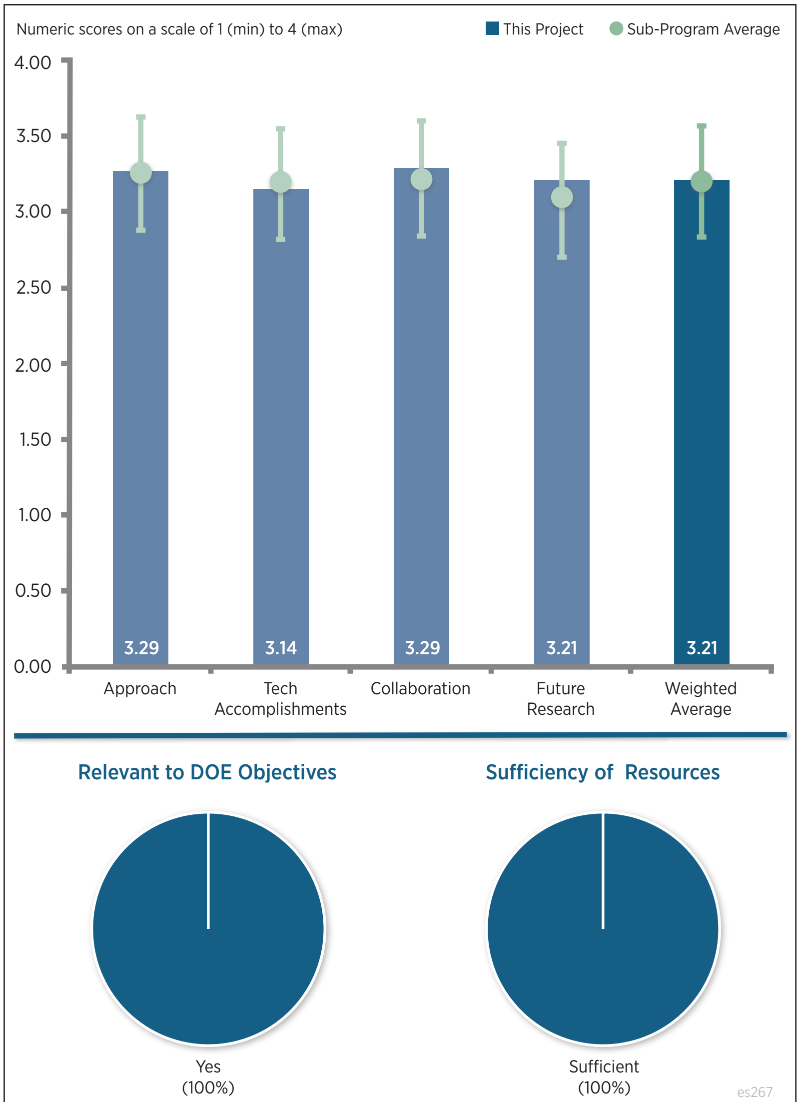

Figure 2-47 – Commercially Scalable Process to Fabricate Porous Silicon: Peter Aurora (Navitas Systems) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer observed that the objective is to develop a novel, commercially-scalable approach to produce microporous Si with a targeted specific capacity of 800 mAh/g, in the desired powder morphology, and at low process cost. In contrast to the conventional methods that uses hazardous materials, such as silane and hydrofluoric acid, this method has three steps: solid-state milling, reduction and thermal treatment, followed by etching. The estimated cost of the microporous Si thus produced is about $10/kg, as opposed to $24/kg for the conventional process. The reviewer noted that specific objectives include a bench-scale optimization of the three processes, demonstrating the performance of the materials in baseline prototype cells, establishing a pilot-scale production plant (over 10kg per batch), and assessing its economic feasibility. Suitable tasks with appropriate milestones and performance targets have been identified. The reviewer concluded that the project is well designed and integrated with other efforts.

Reviewer 2:

The reviewer noted that the development of a production method to make Si anode material in which the hydrofluoric acid (HF) etching is eliminated is a step toward a feasible industrial process

Reviewer 3:

The reviewer remarked that the approach proposed by the PI to make microporous Si through green etching without using HF is novel.

Reviewer 4:

The reviewer observed that the project is still in its early stages, but that the approach seems technically sound. The reviewer commented that it is not clear from the slides where the cost savings come from. The reviewer added that Navitas Systems' approach to making the microporous Si seems more involved than the standard process, and that next year it is important to show more details from the in progress cost modeling step. The reviewer recommended avoiding the use of the term green etching being that it is overly vague for a scientific presentation

Reviewer 5:

The reviewer commented that the strategy and approach were fine. Commercial use of HF for etching can be expensive; additional safety precautions are required, and waste disposal also leads to added cost. The reviewer added that additional information on cost benefits should be broken down to the various process steps, and that a second way to express cost reduction, such as dollars-per-kWh savings, may be helpful.

Reviewer 6:

The reviewer stated that although the team proposed a new approach to scale up the process to make porous Si electrodes, it has not been demonstrated that porous Si would meet the requirement of the anode materials on cycle life, volumetric energy density, and cost. The reviewer added that a lot of potential issues associated with porous Si have not yet been solved, including low cycle efficiency and tap densit .

Reviewer 7:

The reviewer commented that the approach to change microporous Si processing steps for cost reduction seems appropriate. However, an inherent assumption is made that conventional microporous Si is desirable as an anode, and that if only the price was cheaper it would be commercialized. The reviewer expressed that this case is not made convincingly by this project and is at the center of its motivation. More technical comparisons against the conventional materials should be made in this approach to help clearly differentiate the impact of this project's approach.

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

Reviewer 1:

The reviewer praised that good progress has been made in the last few months of the project on developing a low-cost process for manufacturing microporous Si powder for Li-ion cells. Laboratory-scale process optimization has been initiated that includes three steps: mechanical milling, thermal reduction to achieve desirable particle structure and composition, and etching to fully remove metal oxide. Mechanical milling allows the reduction temperature to be lowered by 200°C. The microporous Si produced here compares well with the commercial microporous material in physical characteristics as well as electrochemical performance. However, the reviewer observed, the electrochemical performance seems to be quite preliminary with a rapid capacity fade even in half-cell, though the microporous material is slightly superior to the commercial baseline. The reviewer added that apart from the technical performance, the critical step here is to perform an economic assessment of the process to verify its economic advantages over current battery material manufacturing processes. Overall, the reviewer concluded, the progress is good and is consistent with the DOE goals.

Reviewer 2:

The reviewer noted that the team has made a lot of progress. For the half cell data, the reviewer suggested the team also show the ratio between porous Si and graphite in the Si/graphite blend anode.

Reviewer 3:

The reviewer expressed that while the program is in the very early stages, the initial data show the approach has promise. The reviewer would have liked to see more information to support the cost claims.

Reviewer 4:

The reviewer stated that a Si anode with high porosity was synthesized, characterized, and tested in electrochemical cells, and decent cycle life was obtained against benchmark material.

Reviewer 5:

The reviewer commented that the technical targets on Slide 5 seem reasonable, but that all the cycling data shown on Slides 13 and 14 are based on percentage of capacity retention and thus it is not possible to determine progress towards goals. Slide 11 highlights that impurities in the new material are less 3%; however, the reviewer suggested that the existing value in the commercial microporous Si be reported for comparison. On Slide 13, the reviewer observed that the microporous approach appears to have no impact on cycling. The reviewer suggested that these data be shown in absolute terms, and that cell details (e.g., size, construction type) be shared and commented on.

Reviewer 6:

The reviewer observed that given the short period since the project was awarded, the preliminary results are far from being convincing that the current approach will produce superior Si materials.

Reviewer 7:

The reviewer strongly suggested that the PI find the best commercial reference source for all the baseline studies. The reviewer recommended that the PI report CE and cycle life next year. The reviewer expressed that the PI has a good handle on the process parameters to investigate in Tasks 1 and 2 with the metals removal step. The reviewer also suggested the PI investigate the degree of final purity needed by carrying out performance tests at di ferent etching efficiencies

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed that there are good ongoing collaborations with several partners: Nexceris, LLC for scale-up; ANL for material characterization and cost modeling; Navitas Systems for assessment in prototype Li-ion cells; XG Sciences for anode evaluation; and the University of Utah for scaling up the powder milling process.

Reviewer 2:

The reviewer stated that the collaborations seem appropriate.

Reviewer 3:

The reviewer expressed that the list of partners in the project looks well thought-out and likely to contribute to the project's success.

Reviewer 4:

The reviewer noted that collaborators are quite strong and the expertise are complementary to one another.

Reviewer 5:

The reviewer commented that the PI seems to have arranged for sufficient collaboration and external expertise on project.

Reviewer 6:

The reviewer suggested that cell manufacturers be included.

Reviewer 7:

The reviewer said that collaboration is close between PI and team members.

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

Reviewer 1:

The reviewer stated that reasonable future efforts were proposed.

Reviewer 2:

The reviewer pointed out that the proposed future research is to demonstrate the benefits of the microporous Si being developed, optimize the synthesis further, and scale it up. Specific activities include completing the lab scale process optimization (mechanical milling, thermal treatment, and oxide removal; identifying alternative etching chemistries to reduce cost with reduced environmental footprint; validating electrochemical properties;

and identifying opportunities for cost reduction associated with scaling up the processes. The reviewer noted it is crucial to demonstrate that this process has technical and economic advantages over a conventional method, which is a go/no-go milestone. The reviewer concluded that the future work planned is logical, with appropriate decision points in the process development.

Reviewer 3:
The reviewer expressed the plan was reasonable.

Reviewer 4:
The reviewer appreciated the inclusion of the go/no-go date based on process cost.

Reviewer 5:
The reviewer observed that monitoring coulombic efficiency and cycle life against a good reference will be important measurement tools in progress.

Reviewer 6:
The reviewer suggested that future work prioritize the focus on cost estimation to reduce the cost of microporous Si, as that is stated as the main purpose of this project.

Reviewer 7:
The reviewer recommends the team consider both improving the performance and reducing the cost.

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

Reviewer 1:
The reviewer said that, if successful, this project may support the DOE objective of petroleum displacement.

Reviewer 2:
The reviewer observed that the use of microporous Si in anodes shows promise, and having a cost effective source of the material will contribute to the DOE goals of petroleum displacement.

Reviewer 3:
The reviewer noted that the project supports DOE's overall objective.

Reviewer 4:
The reviewer commented that reducing the cost and improving the energy density/cycle life are closely related with DOE objectives.

Reviewer 5:
The reviewer stated that the project is relevant to DOE goals.

Reviewer 6:
The reviewer pointed out that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles. High capacity cathode and anode materials are required to improve the specific ene gy of Li-ion cells. Si anodes are promising to provide high specific capacity (mAh/g) and volumetric capacity (mAh/cc) compared to graphitic anodes, which will result in high gravimetric and volumetric energy densities for Li-ion cells. However, the reviewer expressed that there is an inherent issue of volume expansion with the Si anode that affect its cyclic stability. In order to be resilient to the volume expansion and the resulting cracking, microporous Si material is used, which this project is aiming to develop.

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

Reviewer 1:
The reviewer expressed that the resources seem appropriate for the scope of the project.

Reviewer 2:
The reviewer noted that resources seem appropriate.

Reviewer 3:
The reviewer stated that resources are sufficient for no   .

Low-Cost Manufacturing of Advanced Silicon-Based Anode Materials: Aaron Feaver (Group14) - es268

Presenter
Aaron Feaver, Group14

Reviewer Sample Size
A total of seven reviewers evaluated this project.

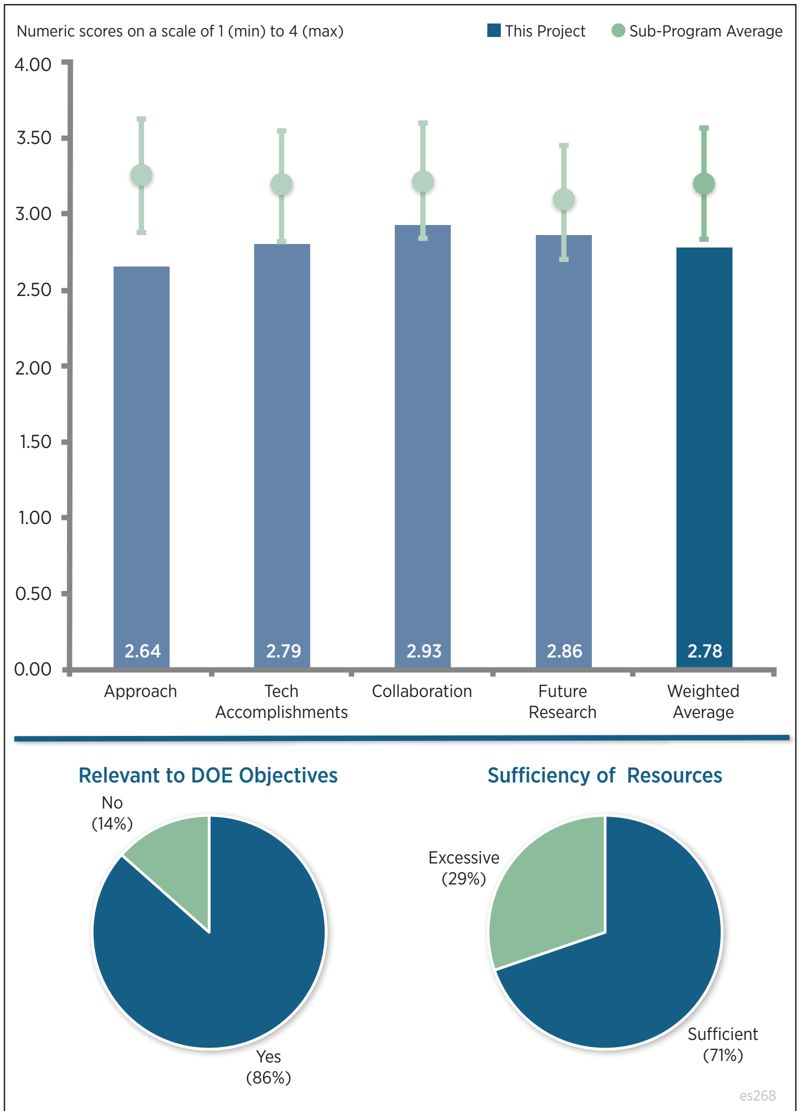

Figure 2-48 – Low-Cost Manufacturing of Advanced Silicon-Based Anode Materials: Aaron Feaver (Group14) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer stated that the objective is to develop a high-capacity, low-cost and long-life silicon-carbon (Si-C) composite anode material for Li-ion batteries, based on EnerG2's carbon technology works. Specific ta gets are a specific capacity of 1,000 mAh/g (or 1,000 cycles) and with lower cost than the current graphite based on dollars-per-Ah. However, there is no quantification on the cost. The reviewer suggested that a better cost target be based on dollars-per-Wh rather than dollars-per-Ah (because Si lowers the cell voltage) that also takes into account initial irreversible capacity. The reviewer pointed out that the strategy is based on the EnerG2 expertise in carbon materials manufacturing to create an ideal Si-support matrix material, using feedstock materials from suitable suppliers. Upon a successful demonstration in full cells, the subsequent efforts will focus on manufacturing a pilot scale plant for the Si-C material production. The reviewer concluded that the task plan and milestone look reasonable, with a cost target of $0.034/Ah for the anode alone, and that, overall, the project is well designed and integrated with other efforts.

Reviewer 2:
The reviewer said that, although not disclosed, the approach taken by the PI to make Si-C composite seems to be innovative. The trade-off correlation between capacity and volume expansion follows a much less sloppy trend.

Reviewer 3:
The reviewer commented that little information regarding the approach taken in this project was shared, except to cite using a carbon developed by the EnerG2 parent company. The reviewer added that more technical information regarding the approach is needed to judge its chance of reaching the ambitious cost and energy barriers targeted.

Reviewer 4:

The reviewer expressed that there is not enough baseline data on the material to judge if investing in a scale-up process is a good use of DOE funds. Cycle data out to 300-500 cycles would be more consistent with other published Si anode technologies, and would give more confidence in the scale-up process. The reviewer pointed out that Slide nine, Cycle Life Comparison, is not very meaningful, and that it is an apples-to-oranges comparison. The reviewer noted that because the two materials are cycled at different capacities, it is hard to say that one is better than the other. For example, at least for the first graph, the pure Si is cycling at a higher capacity than the Si-C material at the end of cycling. The reviewer said that, if the goal was 30 cycles, the reviewer would take the pure Si material. Likewise, if pure Si was cycled to the same capacity as the Si-C material, it may show better cycle life and it would then be the preferred material again. Regarding Slide 10, the reviewer suggested that the figure be plotted as a function of volumetric rather than gravimetric energy density. The reviewer explained that it would be easy to achieve a result like this by just leaving a significant amount of open space in the material, but that, unless there is also an improvement in gravimetric energy density, the strategy is meaningless.

Reviewer 5:

The reviewer pointed out that the detailed approach is unclear and not fully revealed. Based on the information provided, it seems that carbon is being mixed with Si, which is not unique.

Reviewer 6:

The reviewer observed that Si-C composite electrodes have apparently been explored extensively. The reviewer expressed that the approach does not show any novelty and how to address the critical issues related with Si, such as mechanical fracture and low cycle efficienc .

Reviewer 7:

The reviewer recommended Slide 4 be modified from “3-4x increase in ene gy density” to “30-40% increase.” The reviewer commented that utilization of EnerG2 expertise in carbon materials manufacturing to create an ideal Si support matrix material has good basis.

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

Reviewer 1:

The reviewer praised that good progress has been made in the first quarter towards developing the Si-C composite material based on EnerG2’s carbon expertise. Suppliers have been identified for feedstock for Si-C composites, matching the targeted anode costs (less than $0.034/Ah), and preliminary studies have been carried out on the Si-C composite materials synthesized in-house. The reviewer observed that the materials show good cycle life in half cells, with high coulombic efficiencies. Howeve , the irreversible capacity in the first cycle is missing, which has a bearing on the overall cell energy densities. The reviewer pointed out that there is no information on the anode loading, and that it is more challenging to achieve good cycle life in a thick electrode and in full cells, where the Li loss from the irreversible capacity and continued solid electrolyte interface (SEI) build up is crucial. The reviewer added that mechanistic studies have been also made, which suggest reduced volume expansion with the Si-C materials. The reviewer commented that it would be useful to have a preliminary cost/performance model for the Si-C materials that takes into account the irreversible capacity and loss of reversible Li, lower operating voltage versus graphite, etc. in order to revise the project targets. Overall, the reviewer concluded, progress is good and consistent with the project objectives and DOE goals.

Reviewer 2:

The reviewer expressed that, given the short period, encouraging results are shown.

Reviewer 3:

The reviewer said that the initial work looks very promising. The reviewer pointed out that low-expansion composites are a definite plus, and added that the PI understands the relationship between this and high coulombic efficiency/cycle life

Reviewer 4:
The reviewer commented that, because the program is just in its beginning stages, there is not much data to judge the merit of the approach. However, the reviewer would have liked to see more preliminary cycle data, adding that other Si-C anode makers are showing data out to 500-800 cycles with similar capacities. The reviewer pointed out that the 2.0 V cutoff shown in Slide 13 is a very low voltage cutoff, and questioned what the reason was for choosing such a harsh condition.

Reviewer 5:
The reviewer observed that the two achievements claimed were low expansion rate and stable SEI layer. However, the presentation of percentage expansion did not fully reveal the actual expansion in comparison with benchmarks. The reviewer added that there is no evidence showing the SEI layer is stable.

Reviewer 6:
The reviewer stated that the technical comparison against pure Si in Slide nine is not relevant; pure material is known to behave extremely poorly, regardless of supplier source, and developed material is only shown for up to 80 cycles, which is a very short period. Slides 11 and 12, the reviewer continued, cite improvements made to coulombic efficiency without any description of what was changed or the test conditions used to demonstrate this improvement. Improved coulombic efficiency is typically cited as evidence of improved capacity stabilit . However, the reviewer explained, this trend is not clearly shown in the dataset provided, and would only be applicable where the mechanism was dominated by irreversible capacity loss.

Reviewer 7:
The reviewer noted that the presentation included some preliminary electrochemical performance. However, the reviewer said, baseline performance is poor.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed that there is an ongoing collaboration with a university partner, University of Washington, and a DOE laboratory, Pacific Northwest National Laboratory (PNNL)

Reviewer 2:
The reviewer expressed that collaboration partners seem to have the necessary tools to help on the project.

Reviewer 3:
The reviewer stated that there is a collaboration with University of Washington and PNNL.

Reviewer 4:
The reviewer described the team as strong, and pointed out that the collaboration might start in the near future because the project just began this year.

Reviewer 5:
The reviewer recommended getting a cell manufacturer to collaborate and verify full cell results.

Reviewer 6:
The reviewer commented that the existing collaborations seem appropriate, and that the project should consider adding a partner with extensive electrode/cell making/testing experience. If the prime or the partners already have this skill, the reviewer suggested more technical data be provided at future reviews.

Reviewer 7:
The reviewer noted that collaboration is close.

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

Reviewer 1:
The reviewer stated that the proposed work is directed at demonstrating the benefits (cost and performance) of Si-C composite anode with EnerG2's carbon. Specific relevant activities being planned are: developing Si-C commensurate with the technical and cost targets and demonstrating in full cells; optimizing the manufacturing process; and setting up a pilot manufacturing plant for the material. The reviewer expressed that these studies are well-aligned with targeted objectives and milestones.

Reviewer 2:
The reviewer noted that future work seems appropriate.

Reviewer 3:
The reviewer commented that the proposed future research looks reasonable at this stage.

Reviewer 4:
The reviewer said that the future plan is realistically reasonable.

Reviewer 5:
The reviewer stated that the proposed future research seems to be feasible.

Reviewer 6:
The reviewer expressed that the goals seem to be more about materials scale-up than improving the cycle life performance of the material, and that there is no information given on the approach to improving performance. The reviewer pointed out a big jump between 500 cycles in Year 1 and 1,000 cycles in Year 2 with no details on how this will be accomplished. The reviewer added that cell level goals are also missing, and without those investing in process scale-up is not reasonable.

Reviewer 7:
The reviewer observed that the proposed future research was very brief and hard to evaluate.

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

Reviewer 1:
The reviewer commented that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles, and that high specific-capacity materials, especially with low-cost synthesis, are desired to improve the specific ene gy and energy density of Li-ion batteries to make the EV batteries more acceptable. The reviewer stated that Si-based anode materials are promising to provide three times the improvement in specific capacity compared to graphitic materials, but are hampered by poor cycle life due to considerable volume expansion. One approach to mitigate this, the reviewer pointed out, is to form composite materials with carbons, which is being pursued here.

Reviewer 1:
The reviewer agreed that increasing the energy density and reducing the cost of anode materials supports the DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer said that the project supports the overall DOE objectives given that Si-C composites are a potential candidate to improving the energy density of next-generation Li-ion batteries.

Reviewer 3:
The reviewer called the project relevant.

Reviewer 4:
The reviewer expressed that the specific approach of this project is not clearly delineated from the broad class of Si anode work, and therefore it is difficult to judge their probability of contributing to the mission of DOE to reduce petroleum consumption.

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

Reviewer 1:
The reviewer commented that the resources seem appropriate.

Reviewer 2:
The reviewer said that the funding is sufficient, but that more emphasis should be placed on improving the electrochemical characteristics (cycle life) of the material before scale-up.

Reviewer 3:
The reviewer noted that the resources are sufficient for no .

Reviewer 4:
The reviewer expected a lot more progress with the funding level.

Reviewer 5:
The reviewer stated that the resources seem to be slightly excessive for the scope and novelty of the project.

An Integrated Flame Spray Process for Low-Cost Production of Battery Materials: Chad Xing (University of Missouri) - es269

Presenter

Chad Xing, University of Missouri

Reviewer Sample Size

A total of six reviewers evaluated this project.

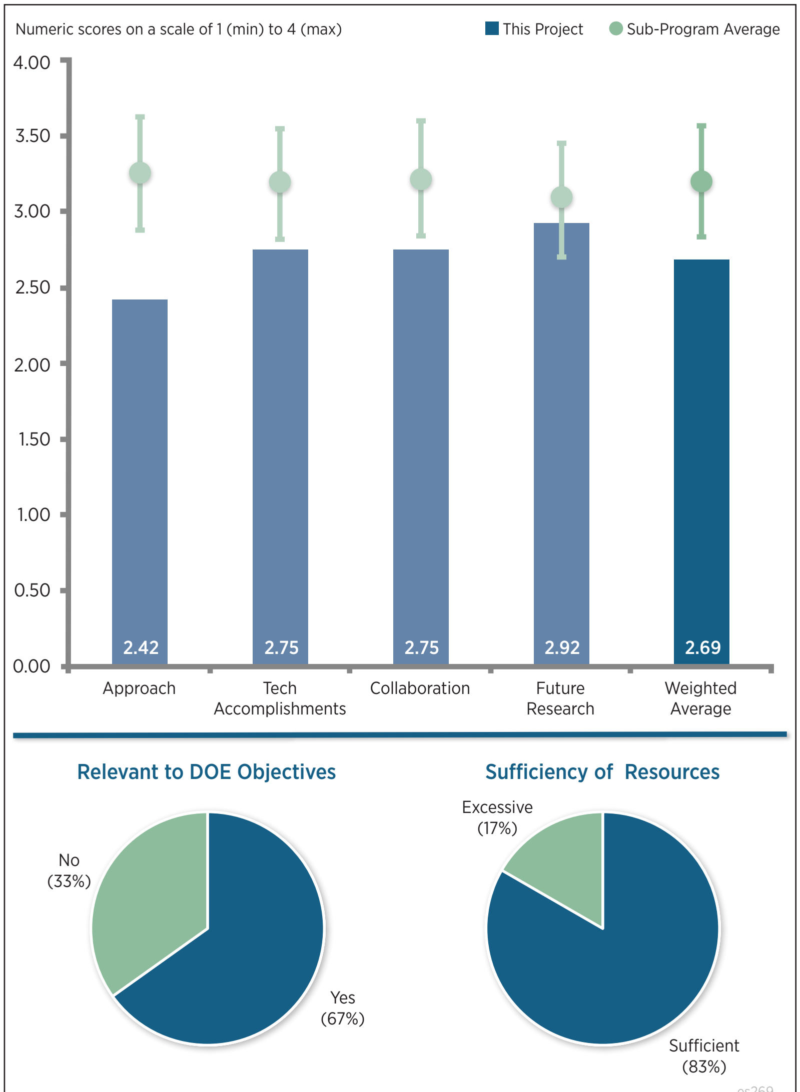

Figure 2-49 – An Integrated Flame Spray Process for Low-Cost Production of Battery Materials: Chad Xing (University of Missouri) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer pointed out that the objective here is to develop an integrated manufacturing technology for producing battery materials, based on a water-based flame spray process. Cathode precursors (metal acetates) are dissolved in deep eutectic solvents (e.g., glycerol) and the metal oxides are deposited by a flame spray process and converted into battery material powders in a single process. Both cathode and anode materials will be produced in this manner and tested in laboratory cells similar to the standard materials. Upon verifying the performance of these materials, a pilot plant production line will be developed. This process is expected to result in a 25% reduction in the cost of the material, which needs to be substantiated with a cost model. However, the reviewer explained, the overall benefit in the battery costs will be lower and needs to be properly estimated. The reviewer concluded that the project is well designed and integrated with other efforts.

Reviewer 2:

The reviewer noted that the goal of reducing the cost of cathode material production is very relevant, adding that a process that removes the intensive calcining step in traditional material production would be good for the industry. The reviewer suggested avoiding using the term green manufacturing process in a scientific presentation because the term is vague and largely without meaning. The reviewer recommended elaborating on what is meant by green. The reviewer expressed lack of clarity on the coating and processing steps of the process shown in Slide 5. The reviewer questioned if those steps are included in the project; if that is not the case, the reviewer recommended they be left off the process flo .

Reviewer 3:

The reviewer stated that the green manufacturing objective is clear based on the approach described. However, the reviewer pointed out that other objectives of 25% cost reduction and a 250 Wh/kg target are less clearly related. The reviewer recommended a quantitative cost comparison be shared early on in this project. Additionally, the 250 Wh/kg target at the cell level is not so relevant. The reviewer added that given the unclear background in cell making of the prime and the technical details shared, targets in terms of cathode material performance would make more sense.

Reviewer 4:

The reviewer indicated that although the reviewer is in favor of additional studies into cathode production via flame pyrolysis, the reviewer is not a great fan of this project. The reviewer expressed that the PI seems to have wound the project around the use of green deep eutectic solvents (DESs) perhaps in order to get funded. The reviewer's concern is that the PI has no intention at present to compare their future findings to what could be produced using water with the same raw materials. The reviewer added that it may well be that this approach produces a better final material, but we will never know. The reviewer also expressed concerns about the fact that the PI intends to use this material in cells directly from the reactor.

Reviewer 5:

The reviewer said that while the team claims the process can significantly reduce the cost, there is no cost analysis to show how much the cost reduction might be.

Reviewer 6:

The reviewer commented that the proposed approach of flame spray does not seem to support the objective of low cost and green process. The reviewer added that, considering the large volume of precursors and the low efficiency of production as compared with solid state or other solution techniques, the energy consumption versus conversion efficiency reflect a high production cost Additionally, the production parameters have to be explored in order for the materials produced to be well-controlled in terms of both morphology and performances. The reviewer expressed that this project should not be in the Applied Battery Research (ABR) program, and that perhaps moving to Battery Materials Research (BMR) is a better option.

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

Reviewer 1:

The reviewer said that, being a new project, fairly good progress has been made in the first quarter with identification of DESs and precursor formulations. The initial design as well as preliminary testing of the flame spray process has been completed, and NMC cathode powders were produced. The distribution of the transition metals (Co, Ni, and Mn) is uniform within these powders. The reviewer pointed out that even though this process seems to simplify the synthesis of lithiated metal oxides, some details are missing. For example, it is not clear how well Li is distributed in the cathode powders. The reviewer questioned what the tap density of these powders would be, whether it will be high enough as conventional solid-state methods, especially with the acetate precursors. The reviewer also asked how this method is adopted for graphitic anode materials. The reviewer added that, now that the preliminary process has been developed, it is important to verify if the cost benefits will be at the expected level, i.e., 2% reduction. Overall, the reviewer concluded, the progress is good and consistent with the DOE goals.

Reviewer 2:

The reviewer noted that much progress has been made within three months, and that the process apparently needs further optimization.

Reviewer 3:

The reviewer commented that given the short period since the project was awarded, the PI already delivers a lot of results. However, it is still too early to tell whether the materials produced is indeed superior to those produced via state-of-the-art approaches.

Reviewer 4:

The reviewer pointed out that Slide 12 lists some particle diameters of NMC materials, but that more material properties (e.g., D10, D50, D99, tap density, BET, impurities, X-ray diffraction, etc.) should be shown to determine the quality of cathode material made.

Reviewer 5:

The reviewer observed that the presence of Ni, Mn, and Co does not necessarily indicate that the material is a viable cathode material, and that the presence of Li is still unknown, as is the structure of the material. The reviewer added that because powders have been produced by the process, there should be some coin half-cell data to show they are actually capable of functioning as cathode materials, and the tap density should have been determined.

Reviewer 6:

The reviewer noted that this is just the first quarter and not a lot has actually been accomplished. The reviewer claimed that the PI mentioned the tap density of the product was ~1g/cc, and that this is very low given that NMC is typically 2-2.8 g/cc, adding that this is a challenge regarding energy density. The reviewer suggested that before doing too much work with half or full cells, the team should do a few post-calcine treatments and report how the EC performance changes or does not change. The reviewer said that the PI is already seeing a variety of morphology in its early days, but should closely monitor for continuous improvement.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that a strong contribution from EaglePicher Technologies as a battery maker/user seems very important to this project, and it is hoped that their contribution is shown as the project progresses.

Reviewer 2:

The reviewer observed that there will be a formal collaboration with EaglePicher Technologies and also possibly with ANL to assess these electrode powders in comparison with conventional materials.

Reviewer 3:

The reviewer said that collaboration with EaglePicher Technologies is a good step.

Reviewer 4:

The reviewer commented that it seems the collaboration has not started yet because the project has just begun. The reviewer suggested the PI talk to the experts on cathode materials so the barriers can be addressed appropriately.

Reviewer 5:

The reviewer expressed that there is very little evidence of collaboration with partners. The reviewer suggested finding a partner with experience producing and testing coin cells, and added that a partner with knowledge of using the process in an industrial setting is important.

Reviewer 6:

The reviewer stated that collaboration is unclear at the current stage.

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

Reviewer 1:

The reviewer observed that the proposed future research is to continue the optimization of the DESs precursors for making stoichiometric compositions of the NMC powders, to improve the nozzle design and operational conditions for spraying the DES, to optimize the flame reactor design, to understand the factors a fecting the powder morphologies, and to begin the assessment of these powders in Li-ion test cells in comparison with the baseline materials. The reviewer said these studies are well aligned with the project objectives and with the DOE program goals of lowering battery costs.

Reviewer 2:
The reviewer stated that future work seems appropriate and should also be compared against an existing commercially-available material for reference.

Reviewer 3:
The reviewer noted that proposed future efforts are reasonable.

Reviewer 4:
The reviewer was happy to see cell testing included in the future work, but that cost modeling is missing and should absolutely be included as part of the future work.

Reviewer 5:
The reviewer suggested the PI compare to products from aqueous system.

Reviewer 6:
The reviewer pointed out that the team did not emphasize the chemistry.

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

Reviewer 1:
The reviewer commented that low specific ene gies and high costs of Li-ion batteries are serious impediments to their widespread adoption in vehicles. The high costs are partly attributed to the complex and multi-step synthesis of cathode materials. The reviewer stated that new low-cost and simpler methods are desired that would lead to reduced costs for the batteries, which is being addressed here.

Reviewer 2:
The reviewer noted that high cost of the cathode materials is a large barrier for the applications in electrical vehicles. The PI is targeting to significantly reduce the cost by developing a novel and green approach. The reviewer expressed that the project fits overall DOE objectives quite well

Reviewer 3:
The reviewer commented that if it turns out there is a viable cathode material produced by the process, then yes, the project does support DOE goals.

Reviewer 4:
The reviewer indicated that it is unclear how this manufacturing approach improves specific ene gy or reduces cost, and thus its contribution to the DOE mission to reduce petroleum consumption is difficult to determine

Reviewer 5:
The reviewer stated that it is not yet a proven technology.

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

Reviewer 1:
The reviewer stated that project resources seem appropriate.

Reviewer 2:
The reviewer noted that project resources are sufficient for no .

Reviewer 3:
The reviewer indicated that the resources seem to be slightly excessive for a project with this scope, especially for an academic institution.

New Advanced Stable Electrolytes for High-Voltage Electrochemical Energy Storage: Peng Du (Silatronix) - es271

Presenter
Peng Du, Silatronix

Reviewer Sample Size
A total of five reviewers evaluated this project.

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

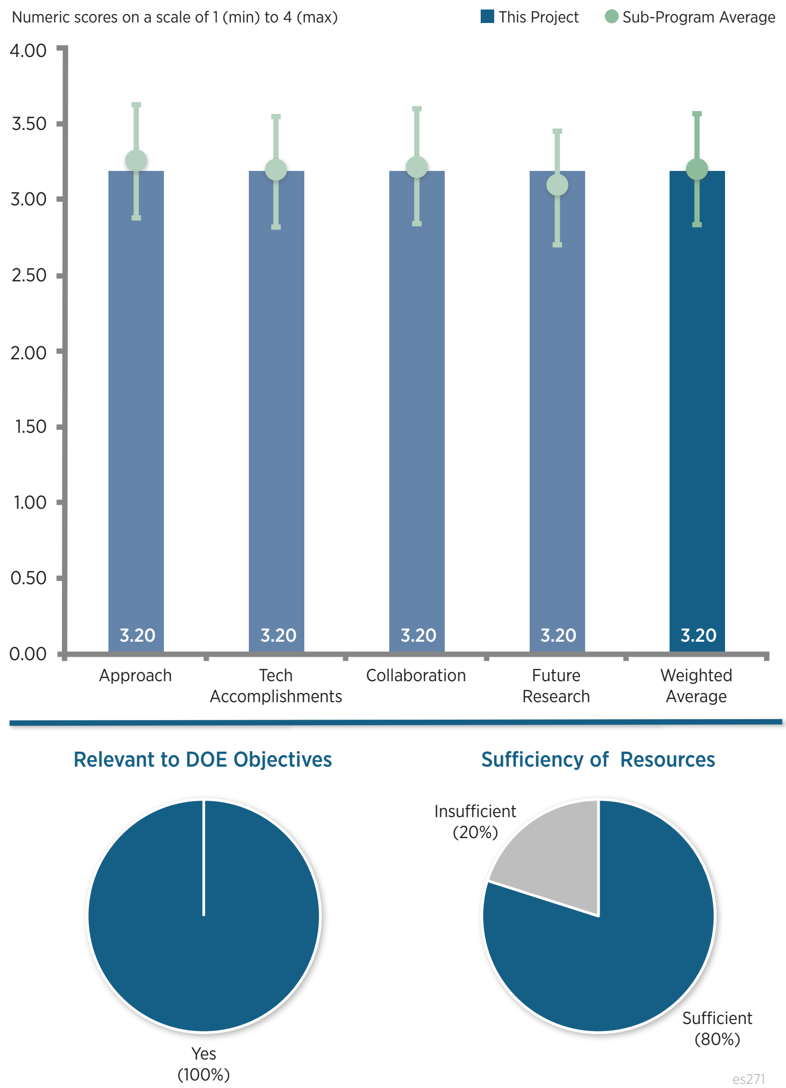

Figure 2-50 – New Advanced Stable Electrolytes for High-Voltage Electrochemical Energy Storage: Peng Du (Silatronix) - Electrochemical Energy Storage

Reviewer 1:
The reviewer stated that the objective of this project is to develop an electrolyte system stable at high voltage (greater than 5 V) to enable the development of high energy density Li-ion batteries required by the automotive industry. Such electrolytes will allow the use of recently-emerging high specific energy cathode materials. Specific targets for these electrolytes are good oxidative stability up to 6 V with very low oxidative rates (less than 0.02 mA/cm^2). These electrolytes will be evaluated against the 5 V lithium nickel manganese oxide (LNMO) cathode anticipating an improved performance versus the carbonate-based electrolytes, with a cycle life greater than 300 at 50°C and a capacity retention greater than 80%. These new electrolytes are based on organosilicon (OS) solvents with selective functional and bulky groups for achieving the desired electrochemical stability. Similar OS solvents systems were studied earlier in the literature with some marginal success. Also, these solvents, when added in small proportions, provide improved thermal stability for $LiPF_6$ salt. The reviewer concluded that the approach looks logical, addressing the key technical barriers of electrolyte stability, and the project is well integrated with the other cathode developmental efforts.

Reviewer 2:
The reviewer noted that the PI has developed a series of fluorinated OS compounds that are stable at high voltages. This provides an opportunity to investigate whether they are suitable for Li-ion electrolytes for high voltage cathodes.

Reviewer 3:
The reviewer commented that targeting the polysiloxane-based chemistry to yield a high voltage stability material

is appropriate, but that very little is described regarding the specific technical approach (e.g., polymer engineering for high voltage).

Reviewer 4:

The reviewer pointed out that OS-based electrolytes have proven to be safe for elevated temperatures. Making these electrolytes sustain high voltages is a good approach for developing high energy Li-ion electrolytes. The reviewer added that more attention should be paid to low-temperature performance.

Reviewer 5:

The reviewer expressed that the approach addressed the issue related with the decomposition of $LiPF_6$ at high voltages. However, it does not cover the oxidation of electrolyte solvent.

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

Reviewer 1:

The reviewer praised the team for making impressive progress in such a short period after the project started last October.

Reviewer 2:

The reviewer stated that reasonably good progress has been made in the last six months in developing the new 5 V electrolytes. Four OS solvents have been successfully synthesized and characterized, and some of them show less oxidative floating current at high voltage of 5-6 V, even at high temperatures, compared to the baseline electrolytes. In parallel, several new additives with bifunctional groups have been identified for protecting the anode/cathode surface at these high (and low corresponding to graphite) voltages. Another 5 V cathode, lithium cobalt phosphate (LCP), has been shown to perform well with improved discharge profile and cycling stability in the baseline electrolyte containing one of these additives. Also, against the 5 V LMNO cathode, some OS-rich formulations show lower oxidative current and expectedly better cycle life. The reviewer commented that these studies look encouraging. However, it should be noted that the additive impacts both anode and cathode in different ways. Some of the additives (e.g., lithium bis(oxalate)borate [LiBOB]) seem to be protecting the cathode, but add to the SEI build up the in anode. The reviewer added that it is therefore important to select and optimize the solvents/additives in full cells rather than half cells. The reviewer concluded that, overall, progress is consistent with the objectives of the project and DOE goals.

Reviewer 3:

The reviewer stated that the technical metric of 20 $\mu A/cm^2$ for electrochemical stability introduced in Slide three is too high and should be more like 5 or 10 $\mu A/cm^2$ to align better with requirements and published literature. The reviewer also pointed out that the volume growth over time plot shown in Slide six is not so informative without knowing the test details (e.g., original volume size, pressure of constraint). Additionally, four different OS variants are introduced in Slide nine without any explanation of their structure, design goals/purpose, or information describing why they were made or tested. On Slides 10 and 11, the reviewer explained, OS3 and OS3a decompose before the reference, and OS3b/c show comparable current flow in the 5.0-5.7 V range. The reviewer asked whether there are purity issues with these materials or if they are inherently unstable. The reviewer stated that the rate of cyclic voltammetry (CV) in millivolts-per-second for these and all experiments should be shared, and asked if this behavior is sensitive to the scan rate. The reviewer pointed out that Slide 18 shows LCP with a low CE, and asked if this is a result of electrolyte decomposition or if the material unstable. The reviewer also asked what the voltage of cycling is. The reviewer said that Slides 19-23 should describe the cell used (e.g., type, dimensions, electrode features, design capacities), and the voltage stand plots on Slides 19 and 22-23 should be normalized for surface area ($\mu A/cm^2$) instead of current (mA). Description of the design of experiments for 21-23 and the future ARL species is necessary as the addition of additives is introduced in a haphazard, non-rigorous way. The reviewer also pointed out that the carbonate reference is superior to OS3 at 20% in the voltage stand tests on Slides 19 and 21, and questioned if this result is reproducible and whether any of the other OS3 variants (i.e., a, b, c) were tested in a similar way.

Reviewer 4:
The reviewer commented that multiple solvents were synthesized and tested, and that decent performance was demonstrated against benchmark electrolyte.

Reviewer 5:
The reviewer observed good technical results in half cells, and added that work needs to be done in full cells as well. The reviewer suggested trying to improve conductivity.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer praised good and useful collaborations with ARL and ANL.

Reviewer 2:
The reviewer stated that the collaborators identified seem appropriate. The reviewer added that coordination between the parties should ensure that the effort is not divided between too many cathodes (LCP versus LNMO) and sources of additives (prime, ARL and ANL), and that complexity is managed.

Reviewer 3:
The reviewer said collaboration is good.

Reviewer 4:
The reviewer noted that the team is very strong in the field of electrolytes

Reviewer 5:
The reviewer suggested the PI seek more collaborators in both chemical and battery companies.

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

Reviewer 1:
The reviewer observed that the proposed future research is to continue developing new OS solvents/additives based on modeling and experiments in cells with the 5 V cathodes. Successful electrolytes will be tested in full cells at different temperatures, which will be augmented by post-cycling analysis, with the eventual goal of demonstrating the performance in 300 mAh pouch cell with the 5 V LNMO cathode. With the multiple options on solvents and additives, the reviewer said that the risk is adequately mitigated. The reviewer stated that these studies are well aligned with project goals, with appropriate decision points.

Reviewer 2:
The reviewer noted that future work seems appropriate.

Reviewer 3:
The reviewer commented that the proposed future research is solid, and that more attention should be paid to low-temperature performance.

Reviewer 4:
The reviewer said that the planned future research is well defined. The reviewer recommended testing more in full cells and adding -30°C rate testing.

Reviewer 5:
The reviewer suggested the future plan include how to stabilize the electrolyte solvent at high voltage as well.

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

Reviewer 1:
The reviewer stated that low specific ene gies and energy densities and high costs are serious impediments for Li-ion batteries to be widely adopted in vehicles. New materials, such as high specific ene gy cathode and anode materials, are required to improve the gravimetric and volumetric energy densities of Li-ion cells. The cathode specific ene gy can be improved by increasing its specific capacity and/or increasing its operating voltage. New cathode materials have emerged recently that can function at higher voltages 4.3-5.0 V. However, their applicability is being limited by the absence of suitable electrolytes that are stable at these high voltages. The reviewer concluded that new types of electrolytes stable at 5 V are, therefore, desired, which is being addressed by this project.

Reviewer 2:
The reviewer commented that, if successful, this project could contribute to DOE's mission of reducing petroleum consumption.

Reviewer 3:
The reviewer expressed that if these materials can deliver on high voltage expectations, the project will help to provide high energy density cells.

Reviewer 4:
The reviewer noted that the project closely supports the overall DOE objectives, adding that it is a straightforward approach to increasing the energy density by expanding the cell voltage.

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

Reviewer 1:
The reviewer observed that if deliverables are met, the PI may need additional support to lower production costs.

Reviewer 2:
The reviewer commented that the resources seem to be appropriate for the scope of the project.

Reviewer 3:
The reviewer stated that project resources seem appropriate. However, the reviewer pointed out inconsistencies in the funding values shown on Side 2 (i.e., Total: $1.665 million, DOE: $897,000, Contractor $333,000).

Pre-Lithiation of Battery Electrodes: Yi Cui (Stanford University) - es272

Presenter

Yi Cui, Stanford University

Reviewer Sample Size

A total of three reviewers evaluated this project

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

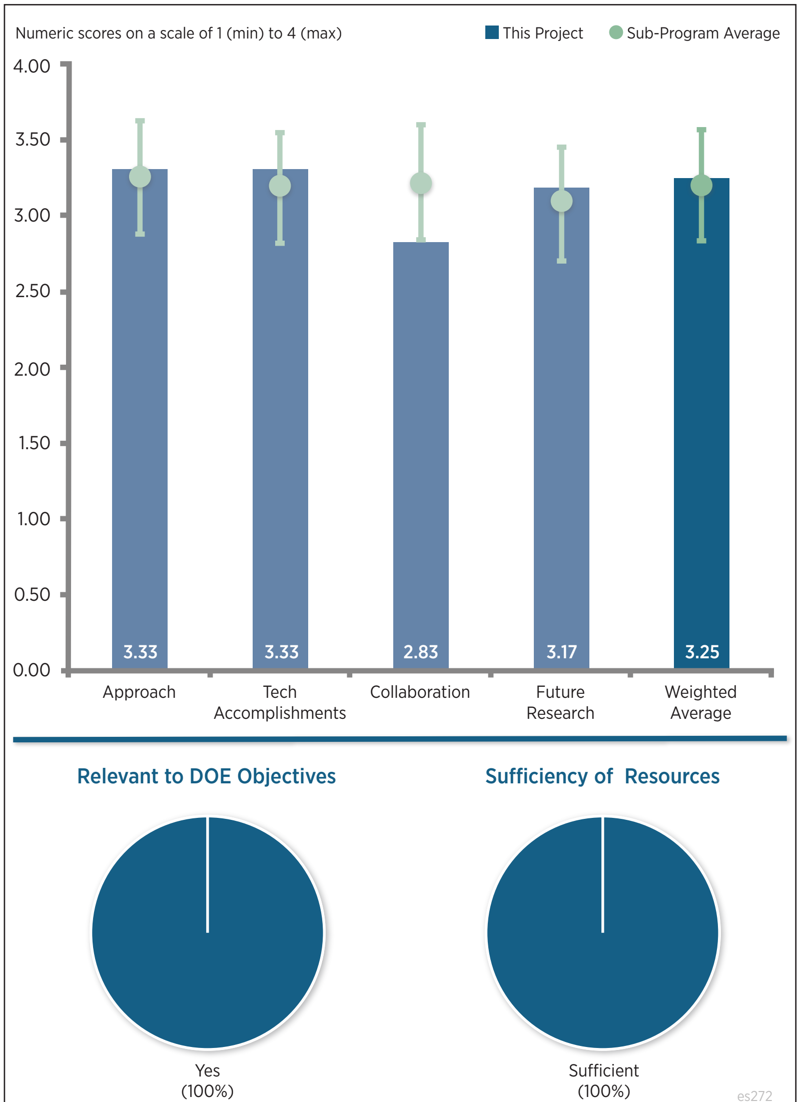

Figure 2-51 – Pre-Lithiation of Battery Electrodes: Yi Cui (Stanford University) - Electrochemical Energy Storage

Reviewer 1:

The reviewer observed that multiple approaches attempted to achieve pre-lithiationpre-lithiation, and that all provided Li to the anode material to compensate for the ICL. Given the huge number of people developing pre-lithiationpre-lithiation technologies, the reviewer encouraged this team to tackle both the technical aspects and the economic ones. The reviewer added that there is no point in developing a pre-lithiation technique if it costs more than, say, just adding an extra cathode to the cell.

Reviewer 2:

The reviewer noted that the work utilized a systematic approach to the issue from many possible angles.

Reviewer 3:

The reviewer stated that this effort employs a sound approach to prelithiate Si. The PI pursues two main directions: increasing first-cycle coulombic efficiency via anode pre-lithiationpre-lithiation, and increasing first-cyc coulombic efficiency via cathode pre-lithiation

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

Reviewer 1:

The reviewer observed good progress in the first yea .

Reviewer 2:

The reviewer stated that good progress was made this last year, but that challenges still remain for the team. The reviewer pointed out that the results have been published in top peer-reviewed scientific journals and provided the following citation: Nature Energy 1, 15008(2016) JACS, 137, 8372(2015), Nano Letters16, 1497(2016).

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
Given that Amprius, Inc. already has a funded project from DOE to develop pre-lithiation technology, the reviewer would like to see other developers and research institutions here as partners.

Reviewer 2:
The reviewer noted that the PI has established collaborations with SLAC and Amprius, Inc., and that it does not appear that the team reached out to other investigators outside their immediate circle.

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

Reviewer 1:
The reviewer noted that the proposed future research is good, but that the cost of these various approaches should be evaluated.

Reviewer 2:
The reviewer expressed for the team's consideration that exploring other materials with high pre-lithiation capacity may not be the best use of resources late in the project.

Reviewer 3:
The reviewer stated that future activities are appropriate. The team will improve the stability of pre-lithiation reagents in the slurry process by developing new solvent-binder combination, and plans to improve the stability of pre-lithiation reagents in the dry and ambient air condition by exploring different kinds of coatings and nanostructures.

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

Reviewer 1:
The reviewer commented that the project is extremely relevant to many advanced anode and cathode cell designs, but pointed out that there are many people trying techniques like this.

Reviewer 2:
The reviewer noted that pre-lithiation of high capacity electrode materials such as Si is an important means to enabling those materials in high-energy batteries.

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

Reviewer 1:
The reviewer commented that there is good amount of work and progress for the money.

New Lamination and Doping Concepts for Enhanced Li-S Battery Performance: Prashant Kumta (University of Pittsburgh) - es279

Presenter
Prashant Kumta, University of Pittsburgh

Reviewer Sample Size
A total of four reviewers evaluated this project.

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

Reviewer 1:
The reviewer said that the approach to solving the issues of polysulfide dissolution and poor conductivity in Li-S cells in intriguing. The team is attempting to coat the nano sulfur particles with Li conducting material, to dope the S to improve its conductivity, and using LiC/S nanoparticles to prevent polysulfide dissolution.

Reviewer 2:
The reviewer commented systematic development of potential solutions to address the known hurdles that keep Li-S from achieving specific ta gets.

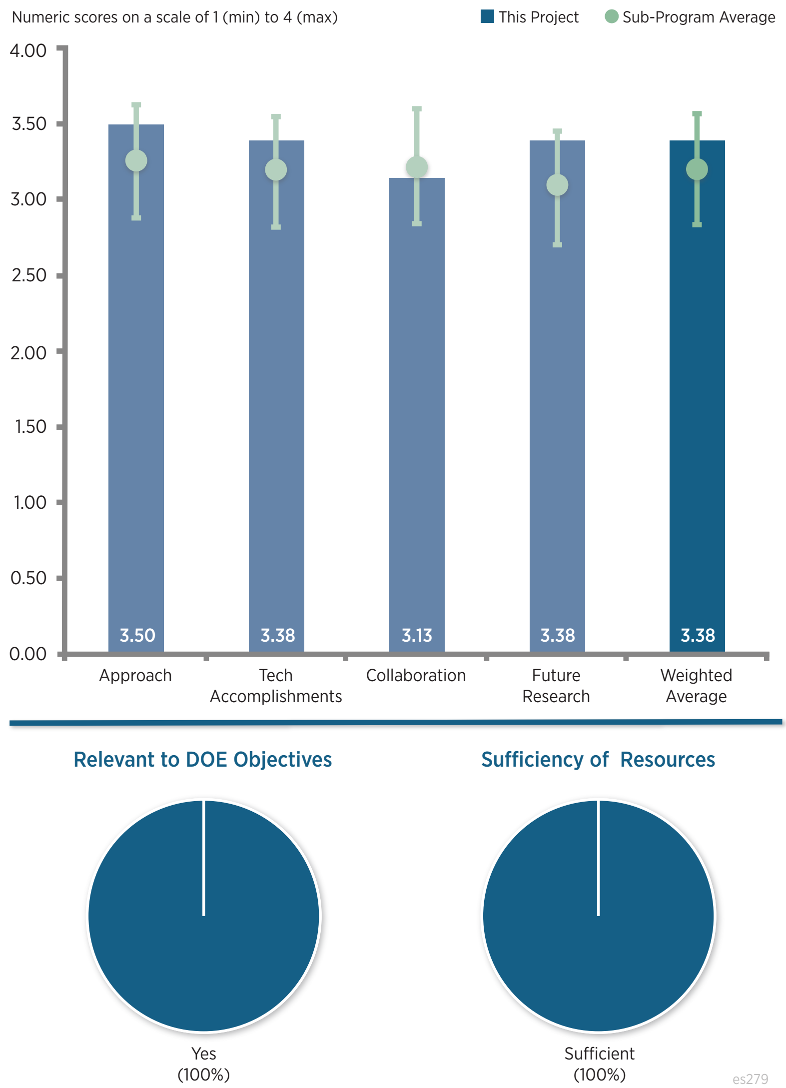

Figure 2-52 – New Lamination and Doping Concepts for Enhanced Li-S Battery Performance: Prashant Kumta (University of Pittsburgh) - Electrochemical Energy Storage

Reviewer 3:
The reviewer said that the investigation is logical and is expected to move the science of Li-S battery technology forward. The team recognizes the difficulty and are using several approaches to increase their chances of success. For example, the team will synthesis and characterize Li-ion conductor (LIC) coating materials to prevent polysulfide dissolution. The reviewer pointed out that the team will develop LIC coated sulfur nanoparticles and doping strategies to improve the electronic conductivity of sulfur and use framework materials to ensure polysulfide retention

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

Reviewer 1:
The reviewer said that excellent progress has been achieved this past year. The team successfully identified an effective LIC membrane and demonstrated its ability to shield polysulfide from dissolving into the electrolyte. The reviewer pointed out that the PI had numerous publications and presentations.

Reviewer 2:

The reviewer said excellent, all milestones to date have been met. However, cycling results using nano sulfur coated with LIC are modest at best, with approximately 25% fade in only 60 cycles. The reviewer found it laudable, however, that the team is making sulfur electrodes with loadings of 3-6 mAh/cm^2, which is needed for EV cells. Flexible sulfur wires appear to do better, with minimal capacity lose but again over only 60 cycles.

Reviewer 3:

The reviewer commented that as to be expected, some promising solutions toward achieving the final goal have been demonstrated.

Reviewer 4:

The reviewer commented that the multilayer composite cathode certainly is a viable concept. It would be worth knowing how possible it is to scale this up.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer pointed out that collaborations exist with Drs. Maiti and Achary at the University of Pittsburgh and with Dr. Manivannan at the National Energy Technology Laboratory.

Reviewer 2:

The reviewer remarked good partners for a relatively small university effort. However, as this project is specifically focused on solving practical issues with sulfur cathodes (as opposed to a more fundamental study), involving companies trying to commercialize Li-S technology might be valuable.

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

Reviewer 1:

The reviewer commented that the doping of sulfur is particularly interesting.

Reviewer 2:

The reviewer said that the proposed efforts are excellent and are focused on the remaining technical challenges, such as high electronic conductivity, reduce weight and increase energy density.

Reviewer 3:

The reviewer observed some excellent ideas, e.g., first-principle alteration of sulfur to improve electronic conductivity and reaction kinetics; the reviewer also noted some ideas that might not be as innovative. The reviewer remarked good thoughts have been put into the continuation, maybe some more prioritization for the future work would increase the chance for achieving the best result.

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

Reviewer 1:

The reviewer commented that the project could enable alternative lightweight low-cost batteries.

Reviewer 2:

The reviewer said that the project is highly relevant. The team seeks to identify new sulfur cathode materials displaying higher gravimetric and volumetric energy densities than present materials in conventional Li-ion batteries. The reviewer commented that if successful, it will result in a new battery that is capable of delivering better energy and power densities and will be more lightweight than current Li-ion battery packs.

Reviewer 3:

The reviewer said extremely relevant, high-loading sulfur cathodes are an excellent way to achieve the DOE EV Everywhere energy and cost goals.

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

No comments were received in response to this question.

Novel Chemistry: Lithium Selenium and Selenium Sulfur Couple: Khalil Amine (Argonne National Laboratory) - es280

Presenter

Khalil Amine, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

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

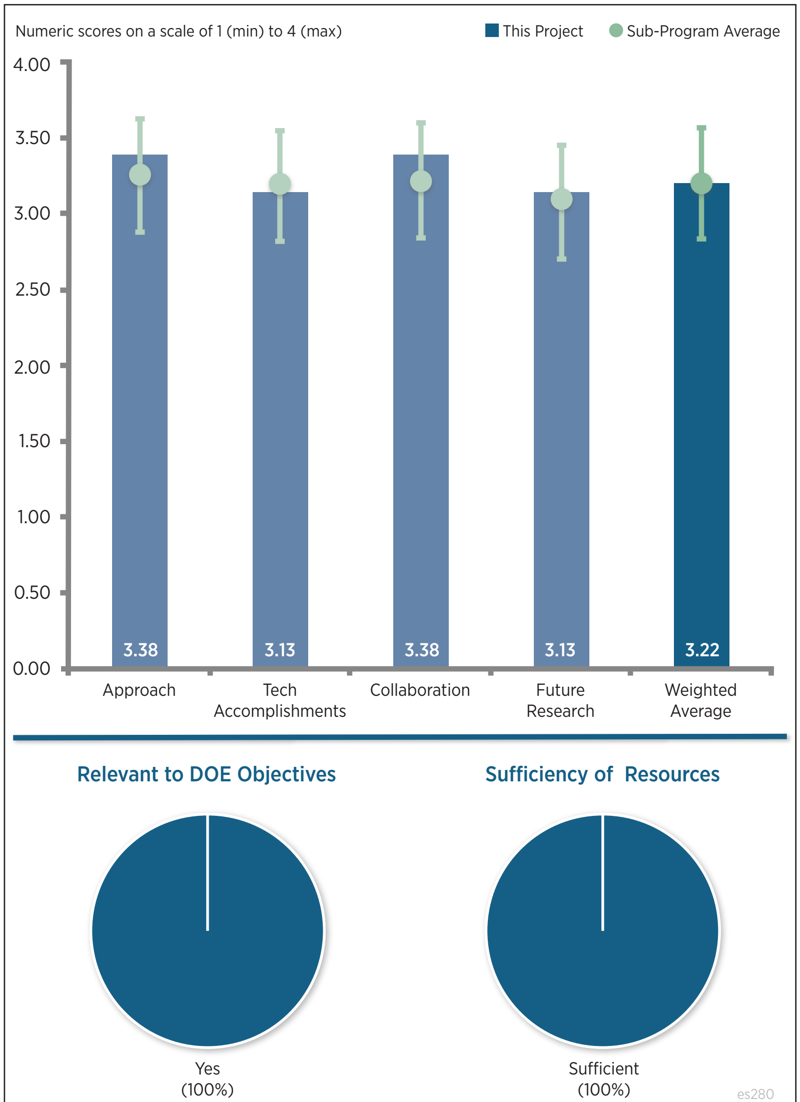

Figure 2-53 – Novel Chemistry: Lithium Selenium and Selenium Sulfur Couple: Khalil Amine (Argonne National Laboratory) - Electrochemical Energy Storage

Reviewer 1:

The reviewer praised a good approach to add selenium (Se) to S to improve conductivity, which is similar to what other groups are doing but with the added benefit that Se is electroactive. The reviewer questioned whether there is a clear path to manage polysulfide dissolution and migration to the Li-metal anode.

Reviewer 2:

The reviewer noted that the work is a methodical investigation of the applicability of the Se-based chemistry with helpful parallels to the somewhat similar Li-S system. The reviewer added that the approach to addressing the barriers is excellent.

Reviewer 3:

The reviewer stated that the approach is unique. The team plans to solve the problems associated with the redox shuttle effect of dissolved Li polysulfides and higher loading of active material by nano-confining the SxSey in nanoporous conductive matrix, and partially replacing S with Se.

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

Reviewer 1:

The reviewer observed that a goal of 500 cycles was set, but only 50 were shown. The reviewer suggested that battery cycling plots be shown until failure is observed. The reviewer added that, given the number of years devoted to the project and only having 50 cycles reported, reaching 500 cycles seems unrealistic.

Reviewer 2:

The reviewer noted that good progress was achieved this past year. The electrical conductivity of S cathode was significantly improved by adding Se, and better compatibility between the Se cathode and the carbonate-based electrolyte was validated with no dissolution of polyselenide phases. The reviewer pointed out that an article describing the project's results was accepted in Nano Letters.

Reviewer 3:

The reviewer commented that nearly all of the results to date are on Li/Se couples, which is not the focus of this project, adding that work on S-Se alloys is just beginning. The reviewer pointed out that the project overview mentions cycling of S5Se2, but that results are not shown. The reviewer also mentioned that the one set of cycling data show about 300 mAh/g, but at only 2.5 V, meaning the energy is barely better than today's Li-ion cathodes. The reviewer concluded that the barriers to S utilization are well known, and that this approach seems to only address the S conductivity issue, which is not a deal breaker right now.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that good collaborations exist with Prof. Chunsheng Wang of University of Maryland, Dr. X. Chen and Dr. L Curtis of the Materials Science Division at ANL, and Dr. Yang Ren and Dr. Chengjun Sun of the Advanced Photon Source Office at ANL.

Reviewer 2:

The reviewer stated that it is unclear how the computational co-PIs have contributed to the work reported in this presentation.

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

Reviewer 1:

The reviewer said that the proposed future research is perfect and very strategic.

Reviewer 2:

The reviewer stated that the proposed work is good and should allow the team to advance the technology.

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

Reviewer 1:

The reviewer commented that the project is relevant. The objective is to develop a novel SxSey cathode material for rechargeable Li batteries with high energy density and long life as well as low-cost and high safety. The reviewer stated that improved battery chemistries will enable the DOE to reach the PHEV and EV target goals.

Reviewer 2:

The reviewer pointed out that Li-S cells are clearly relevant as they offer the possibility of a much lower cost cell. It is not clear to this reviewer if this approach will address the multiple issues with Li-S.

Reviewer 3:

The reviewer noted that high capacity Li-Se/S batteries could be used in energy storage applications if performance is improved.

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

Reviewer 1:

The reviewer stated that $500,000 per year is a good amount of money for relatively few new results.

Multi-Functional Cathode Additives for Li-S Battery Technology: Hong Gan (Brookhaven National Laboratory) - es281

Presenter

Hong Gan, Brookhaven National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

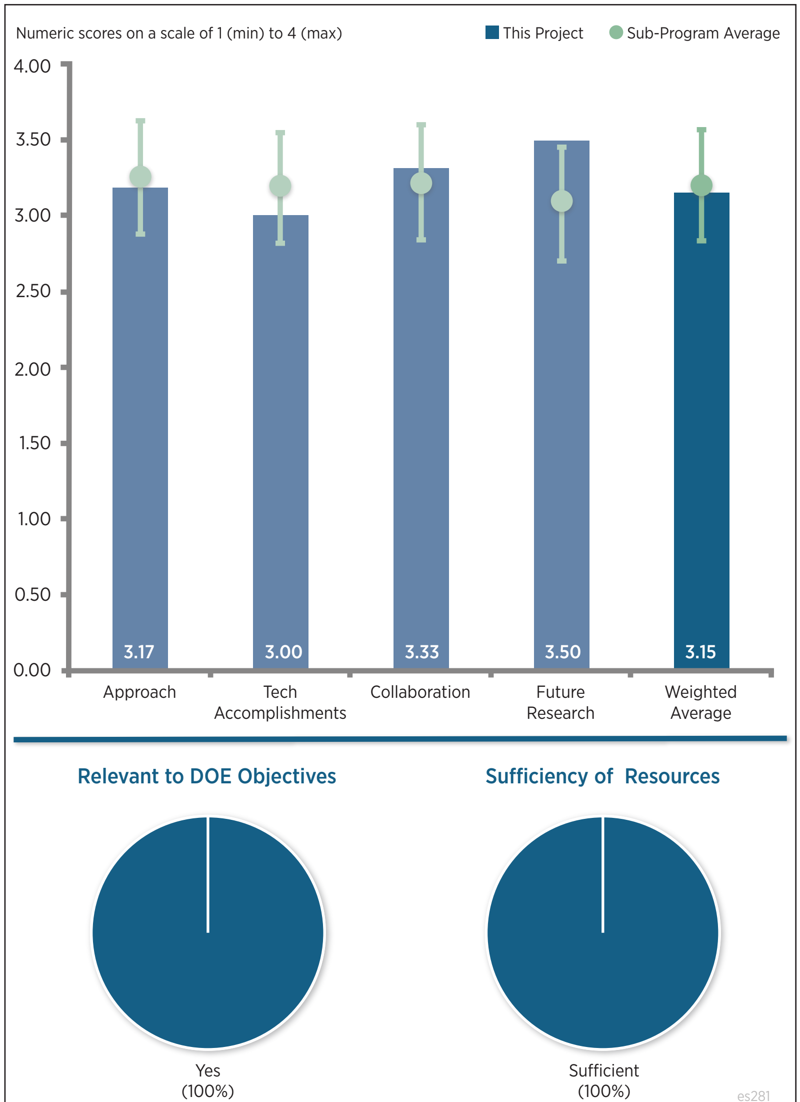

Figure 2-54 – Multi-Functional Cathode Additives for Li-S Battery Technology: Hong Gan (Brookhaven National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer commented that, in general, the approach is systematic and the topic important for addressing Li-S barriers. The reviewer observed that the baseline system may not be ideal because it comes with a number of problems unrelated to the area the project is addressing.

Reviewer 2:

The reviewer said that the approach is well thought out, and is contributing to overcoming the technology barriers. The team will focus on improving the cathode energy density, power capability, and cycling stability of a Li-S battery by introducing multifunctional cathode additives (MFCA). The team will investigate transition metal sulfides due to their high electronic conductivity and chemical compatibility to the sulfur cell system. The reviewer added that this approach is sound.

Reviewer 3:

The reviewer stated that the approach to improve S utilization through improved conductivity using additives is reasonable. The reviewer added that there are several issues that this approach will likely not address, like polysulfide dissolution and reaction at the Li-metal anode, and the need for la ge volumes of electrolytes that reduce Wh/kg values.

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

Reviewer 1:

The reviewer praised that excellent progress has been made and that several MFCAs were investigated. Transition metal sulfides (e.g., CuS, titanium disulfide iS$_2$], FeS_2, and CoS_2) in S:MFCA hybrid cathodes were found to promote initial sulfur cell discharge power capability at 1C rate. The reviewer added that the team filed patents and published the project findings in the Journal of the Electrochemical Societ .

Reviewer 2:

The reviewer noted that a good amount of work was reported, but that most of the results are not of interest due to the low energies reported. For example, 300-500 mAh/g at 2 V is barely better than NMC, which cycles thousands of times.

Reviewer 3:

The reviewer stated that the project contributes to the understanding of benefits of transition metal sulfide additives, but could not identify a sulfide that adds significant valu

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that collaboration is very effective.

Reviewer 2:

The reviewer indicated that excellent collaborations exist. They include investigators from Brookhaven National Laboratory (BNL), Stony Brook University, and Columbia University.

Reviewer 3:

The reviewer observed that there is a relatively small amount of collaboration, which may be appropriate at this stage.

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

Reviewer 1:

The reviewer noted that the team is concentrating on the most promising additive, TiS_2, adding that it will be interesting to see if there are any new approaches to mitigating/reducing polysulfide dissolution

Reviewer 2:

The reviewer pointed out that required system-level attention was recognized to efficiently investigate the beneficial sulfur/ iS$_2$ interaction.

Reviewer 3:

The reviewer commented that future activities are focused on overcoming technical barriers, noting that the investigators understand the many challenges facing the development of a Li-S battery. The team will focus on the leading MFCA candidate (S/TiS_2) and advance the fundamental understanding of the system. This will be followed by hybrid electrode processing where the team will optimize the energy density. After obtaining a high-performance electrode, cells will be built and undergo electrochemical performance testing. The reviewer agreed that the plan is an effective method to advance and then to assess the technology.

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

Reviewer 1:

The reviewer agreed that Li-S cells hold promise for very low costs.

Reviewer 2:

The reviewer described the investigation as highly relevant. The Li-S battery system has gained significant interest due to its low material cost potential and its attractive volumetric and gravimetric energy density, which is theoretically higher than conventional Li-ion batteries.

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

No comments were received in response to this question.

Development of High-Energy Lithium-Sulfur Batteries: Jun Liu (Pacific Northwest National Laboratory) - es282

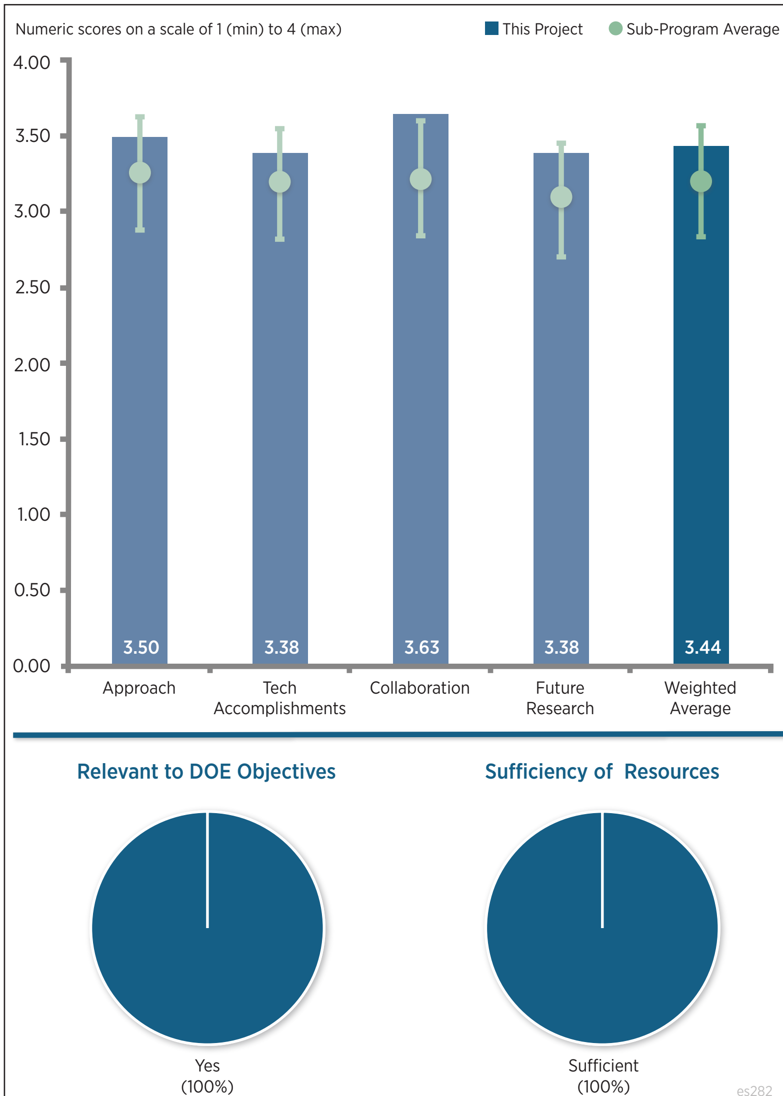

Figure 2-55 – Development of High-Energy Lithium-Sulfur Batteries: Jun Liu (Pacific Northwest National Laboratory) - Electrochemical Energy Storage

Presenter

Jun Liu, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

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

Reviewer 1:

The reviewer declared that the focus on thick sulfur cathodes is excellent, and that separating the Li-metal and its issues from the sulfur cathode is a very nice idea. The reviewer expressed that good progress on making 2-8 mg/cm^2 sulfur cathodes has been made. The reviewer also liked that the team plans to directly address the electrolyte amount by reducing the pore volume.

Reviewer 2:

The reviewer called the approach a very well prepared strategy that enables the focused investigation of multiple issues in Li-S batteries.

Reviewer 3:

The reviewer indicated that this work has more thorough characterization than many other Li-S projects, which is needed to understand mechanisms.

Reviewer 4:

The reviewer commented that the approach is sound. Previous studies indicated that the corrosion of Li anode is one of the key degradation mechanisms for Li-S batteries, and it is thus difficult to critically evaluate the performance of the cathode. The team is therefore decoupling the influences from the Li anode side by using a lithiated graphite anode in the Li bis(trifluoromethanesulfonyl)imide dioxolane (LiTFSI-DOL) electrolyte. The reviewer stated that this should allow the team to successfully investigate the intrinsic properties of cathode.

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

Reviewer 1:
The reviewer indicated that very good progress has been made in building and cycling a graphite/sulfur (Gr/S) cell. The reviewer pointed out that the fade rate was still high at about 25% over 100 cycles, but that it is a very good first step. The reviewer added that it will be interesting to see if the team can identify causes of fade.

Reviewer 2:
The reviewer stated that the work lays a good foundation for further investigations. The reviewer added that findings confirming established knowledge are good but could go furth . The reviewer also commented that thick electrode fabrication provides helpful data.

Reviewer 3:
The reviewer declared that good progress was made this year. High reversibility and rate capability were achieved on graphite electrodes with the LiTFSI/DOL electrolyte. The team also showed Gr/S cells displaying high capacity retention and coulombic efficiency with sulfur loadings greater than 2 mg/c $^{2.}$

Reviewer 4:
The reviewer expressed that it does not appear that the group has met the performance metric for March 2016. A goal of 80% capacity retention over 100 cycles was stated, and it can be seen from the plot of Capacity versus Cycle Number that more than 20% of the capacity was lost.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said the team of national laboratories, industry, and universities is excellent.

Reviewer 2:
The reviewer indicated that many institutions are listed as collaborators, and their scope of work is described.

Reviewer 3:
The reviewer observed that the team is collaborating with ANL, BNL, General Motors, and University of Western Ontario, and that their roles were clearly defined

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

Reviewer 1:
The reviewer expressed that the future work is well defined and consistent with the results to date and the project objectives.

Reviewer 2:
The reviewer stated that it is unclear how barriers that have led to capacity fade will be addressed. For example, the reviewer called the comment that reads "Address electrolyte amount and penetration issues in high loading sulfur electrode" unspecific, and therefore not possible to evaluate

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

Reviewer 1:
The reviewer particularly liked the concentration of thick S cathodes of 3-4 mAh/cm^2, which will be needed for high energy automotive cells.

Reviewer 2:
The reviewer said the Li-S system is a potential system for low-cost and high-capacity batteries. The reviewer indicated that this project increases the understanding of strategies toward high loading cathodes, and electrolyte

and cathode reactions. The reviewer noted that this knowledge is critically important for the successful implementation of Li-S batteries.

Reviewer 3:

The reviewer stated that this effort supports DOE objectives. The theoretical specific ene gy of Li-S batteries is approximately three times higher than Li-ion batteries. However, the reviewer commented that the major challenge for Li-S batteries is polysulfide shuttle reactions, and that this e fort seeks to stop those reactions and to enable its transition into the market place.

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

Reviewer 1:

The reviewer called the resources adequate, and noted that there has been good progress for the investment to date.

Reviewer 2:

The reviewer pointed out that the total amount of funding for this work was not provided on Slide 2.

Addressing Internal "Shuttle" Effect: Electrolyte Design and Cathode Morphology Evolution in Li-S Batteries: Perla Balbuena (Texas A&M University) - es283

Presenter

Perla Balbuena, Texas A&M University

Reviewer Sample Size

A total of four reviewers evaluated this project

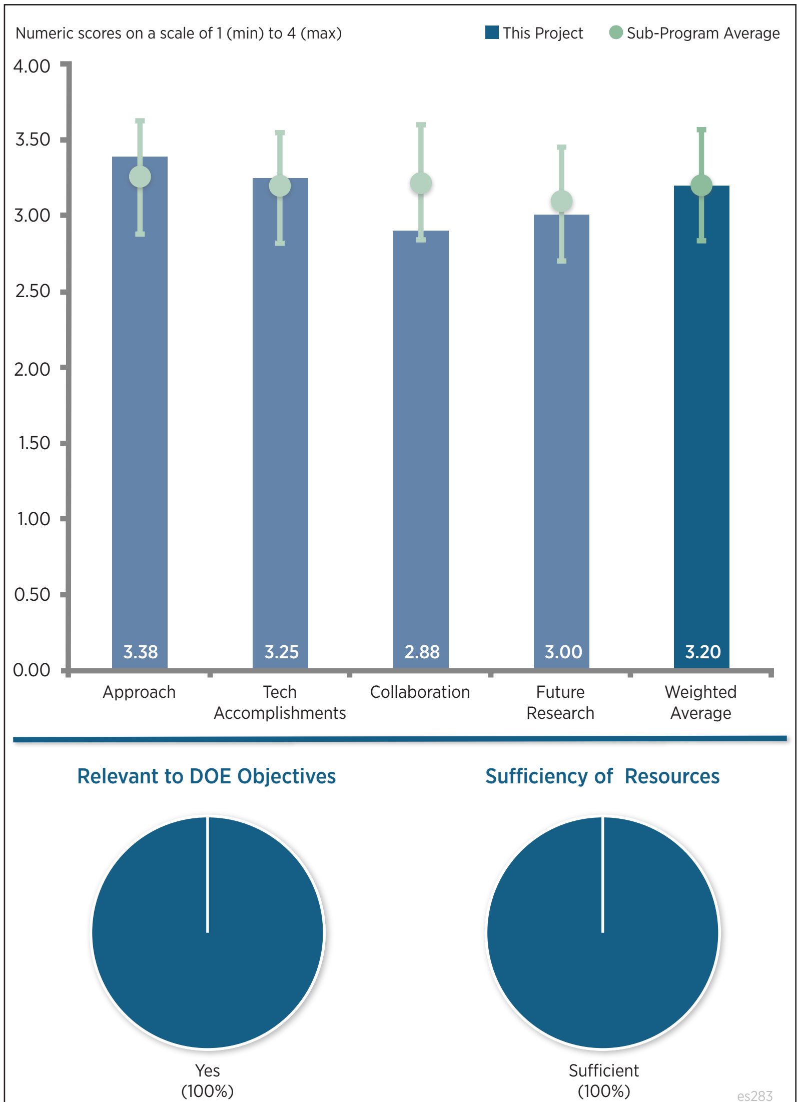

Figure 2-56 – Addressing Internal "Shuttle" Effect: Electrolyte Design and Cathode Morphology Evolution in Li-S Batteries: Perla Balbuena (Texas A&M University) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer noted that the project combines theoretical simulation with cathode synthesis and electrochemical testing to tackle the major problems with developing Li-S batteries.

Reviewer 2:

This reviewer observed a mostly fundamental model approach to understanding potential effects of complex structures on polysulfide cathode structures in Li-S systems. As with all complex molecular level models, explained the reviewer, the concern will be whether it represents to real-world systems in a meaningful way. Despite this concern, the reviewer acknowledged that the approach adds to the field

Reviewer 3:

The reviewer opined that the project team probably promises a bit too much, but has an aggressive plan to meet its expectations.

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

Reviewer 1:

This reviewer particularly liked the project team's examination of interactions between the polysulfides and cathode matrix, which could certainly lead to long term improvements of the technology.

Reviewer 2:

The reviewer noted that work has progressed as planned and further observed a modest amount of commendable, experimental work. This reviewer added that it is difficult to judge the relative merits of the results because there does not appear to be any control variations.

Reviewer 3:

This reviewer asserted that the project team made some significant progresses in simulation, and suggested the need for more efforts in improving electrochemical performance of the carbon sulfur composites (CCs/S). Further, the reviewer observed that not much synergy between the simulation and synthesis/testing works so far.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer indicated that collaboration appears appropriate for the work.

Reviewer 2:

The reviewer noted that the project team started collaboration with PNNL and ANL, and recommended that the project team adopt the advanced characterization methods available in national laboratories to link the simulation with the materials structure and morphology.

Reviewer 3:

The reviewer asserted that the project team has limited collaborations.

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

Reviewer 1:

The reviewer identified a need for more specific plans regarding future work, such as how to identify reasons fo failures and successes of specific electrolyte compositions

Reviewer 2:

The reviewer pointed out that here is not a lot of detail here.

Reviewer 3:

This reviewer commented that the future research list appears very ambitious, and it was not clear whether the focus will be on modeling or experimental approaches.

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

Reviewer 1:

This reviewer recognized that Li-S batteries have great potential and any progress in this direction will help support DOE objectives.

Reviewer 2:

The reviewer opined that the Li-S system is a system of interest that has very complex issues associated with its potential improvement.

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

Reviewer 1:

This reviewer noted that the project team has both theoretical and experimental expertise, and started collaborating with national laboratories.

Reviewer 2:

The reviewer stated pending clarification of future work

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Statically and Dynamically Stable Lithium-Sulfur Batteries: Arumugam Manthiram (University of Texas at Austin) - es284

Presenter

Arumugam Manthiram, University of Texas at Austin

Reviewer Sample Size

A total of four reviewers evaluated this project.

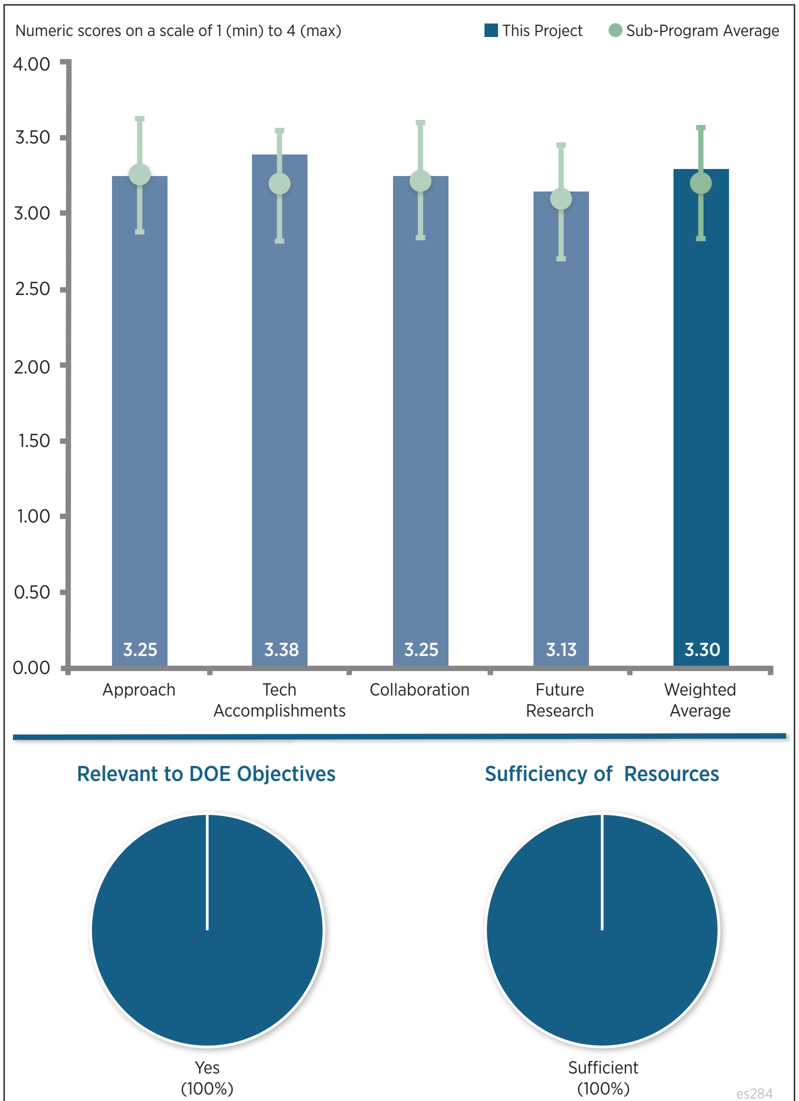

Figure 2 57- Statically and Dynamically Stable Lithium-Sulfur Batteries: Arumugam Manthiram (University of Texas at Austin) - Electrochemical Energy Storage

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

Reviewer 1:

This reviewer asserted that the project is sound and focused. The investigators will develop statically and dynamically stable Li-S batteries by developing polysulfide (PS) filte -coated separators that will protect the Li-metal anode. This will be accomplished by establishing a materials chemistry database for coating materials and for PS-filtered coated separators. The reviewer further noted that investigators from other facilities may be able to benefit from the database, too.

Reviewer 2:

The reviewer observed a good approach to filtering polysulfides which keeps them from reaching the Li-metal anode, and increases S loading to commercially relevant values. However, explained this reviewer, at some point the huge volume of electrolyte needed to enable S cathodes to work has to be addressed. This reduces Wh/kg by quite a bit.

Reviewer 3:

Trapping polysulfides closer to their place of origin is better than filtering at the separat , opined this reviewer. Nevertheless, the reviewer acknowledged that experience gained and knowledge about PS-filter separators will contribute to solving the PS issue.

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

Reviewer 1:

This reviewer commented that good progress has been achieved thus far: the databases were established; various coating materials with different morphologies and microstructures were analyzed and categorized; and four different carbon materials for PS-filter coatings are unde going a thorough investigation.

Reviewer 2:

For cells that have not failed after 200 cycles, the reviewer recommended continued cycling to determine how long they will last.

Reviewer 3:

This reviewer reported that a very large number of possible filtering materials (applied to the cell separator) have been screened. However, the reviewer opined that results to date are not particularly promising. The reviewer commented that cells with spherical C materials suffer 25% capacity fade in 75 cycles, while those with CNF suffer about the same fade in 200 cycles. Although the reviewer observed good improvement, there is still a long way to go and work on thick electrodes is just starting.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted good collaboration with ORNL.

Reviewer 2:

This reviewer described collaborations with Veith group on thin films as appropriate for this stud .

Reviewer 3:

The reviewer reported that there is collaboration with Dr. Gabriel Veith, ORNL.

Reviewer 4:

This reviewer observed that collaboration is used for a specific task only and suggested that it might be useful to have other perspectives contribute to the project on a regular basis.

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

Reviewer 1:

The reviewer described this thorough project with extensive characterization as an excellent approach to understanding Li-S batteries.

Reviewer 2:

This reviewer asserted that the proposed work is well thought out and includes clear go/no-go decision points.

Reviewer 3:

The reviewer observed an ambitious goal to test metal sulfides and address high-loading cathodes in F 2017. Less may be more, suggested this reviewer.

Reviewer 4:

It was unclear to this reviewer whether the team understands the cause of the observed capacity fade: loss of S through reactions of polysulfides at the Li-metal interface; loss of access to S due to electrical isolation; or buildup of Li-metal SEI.

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

Reviewer 1:

This reviewer opined that Li/S research is very relevant due to the potential low-cost of the technology.

Reviewer 2:
The reviewer affirmed that the project is relevant to DOE. A basic science understanding gained during this effort will be used to develop the Li-S technology as the next-generation power source for electric vehicles.

Reviewer 3:
The reviewer commented that realizing commercial Li-S cells would allow for increased reliance on renewable energy sources in connection to the electrical grid.

Reviewer 4:
This reviewer stated that the results contribute to the goal of low-cost, high-capacity Li-S batteries.

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

Reviewer 1:
The reviewer observed excellent value for the investment.

Mechanistic Investigation for the Rechargeable Li-Sulfur Batteries: Deyang Qu (University of Wisconsin, Milwaukee) - es285

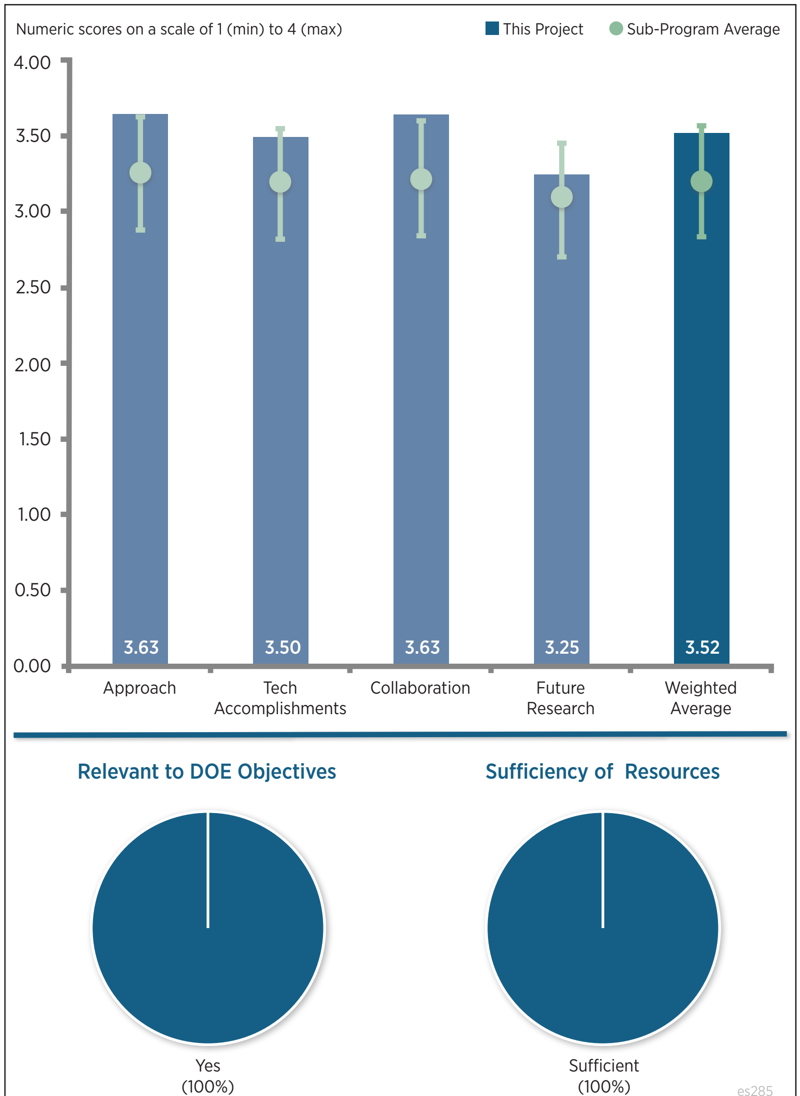

Figure 2-58 – Mechanistic Investigation for the Rechargeable Li-Sulfur Batteries: Deyang Qu (University of Wisconsin, Milwaukee) - Electrochemical Energy Storage

Presenter

Deyang Qu, University of Wisconsin

Reviewer Sample Size

A total of four reviewers evaluated this project.

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

Reviewer 1:

The reviewer observed an excellent approach and explained that the investigators will develop an analytical method for the quantitative and qualitative assessment of dissolved elemental sulfur and polysulfide ions in non-aqueous electrolytes. These kinds of studies are essential in order to investigate the kinetics of the sulfur redox reaction.

Reviewer 2:

The reviewer emphasized that setup of an in situ electrochemical HPLC-MS cell is an outstanding approach.

Reviewer 3:

This reviewer indicated that it is definitely interesting to try and understand the specific polysulfides formed during S lithiation Although this is a worthwhile study, it is not immediately clear to the reviewer how this will lead to solutions to the polysulfide anode reaction issues or the need for so much excess electrolyte.

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

Reviewer 1:

The reviewer stated that the polysulfide dissolution details achieved in this project are unprecedented and make important corrections to the existing view in the field

Reviewer 2:

This reviewer observed very good progress in less than one work year.

Reviewer 3:
This reviewer commented that good progress was achieved and reported that several polysulfides were separated and qualitatively analyzed for the first time. Furthe , the reviewer explained that there were numerous publications and presentations.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed an excellent use of industry, national laboratory, and university resources.

Reviewer 2:
The reviewer indicated that there are excellent collaborations with other institutions and industry. The reviewer added that the PI has close collaborations with Johnson Controls' scientists and engineers, and that this collaboration may be beneficial to the project as it would allow the validation of fundamental research findings i pilot-scale cells.

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

Reviewer 1:
The reviewer opined that in situ confocal microscopy setup would deliver very promising results.

Reviewer 2:
Future plans were outlined and look appropriate according to this reviewer.

Reviewer 3:
This reviewer expressed confusion, and specified that there is a la ge amount of future work listed, which is odd because the project is scheduled to end September 2016. The reviewer believed the project concluded that polysulfide concentrations can only be measured during the first electron transfer due to subsequent reactions i the electrolyte that form multiple polysulfide species. This issue has been known in the literature for some time, explained the reviewer.

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

Reviewer 1:
According to the reviewer, this work presents a major contribution to understanding mechanisms in Li-S batteries, which are a candidate for low-cost, high-energy batteries.

Reviewer 2:
The reviewer asserted that the project is relevant to the DOE. Li-S batteries could enable a competitive market entry of electric vehicles by reducing the cost and extending the driving distance per charge.

Reviewer 3:
A Li-S battery is probably the only practical route for breaking the 300 Wh/kg barrier for VT applications, opined this reviewer. The reviewer further explained that fundamental understanding of the failure modality of the electrode is critical for improving the cycle life of the Li-S battery.

Reviewer 4:
This reviewer stated that the project is relevant because Li-S offers a clear path to low-cost cells.

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

Reviewer 1:
Although this project seems to have reached a natural ending point, the reviewer observed good value for the investment.

Development of Novel Electrolytes and Catalysts for Li-Air Batteries: Khalil Amine (Argonne National Laboratory) - es286

Presenter

Khalil Amine, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

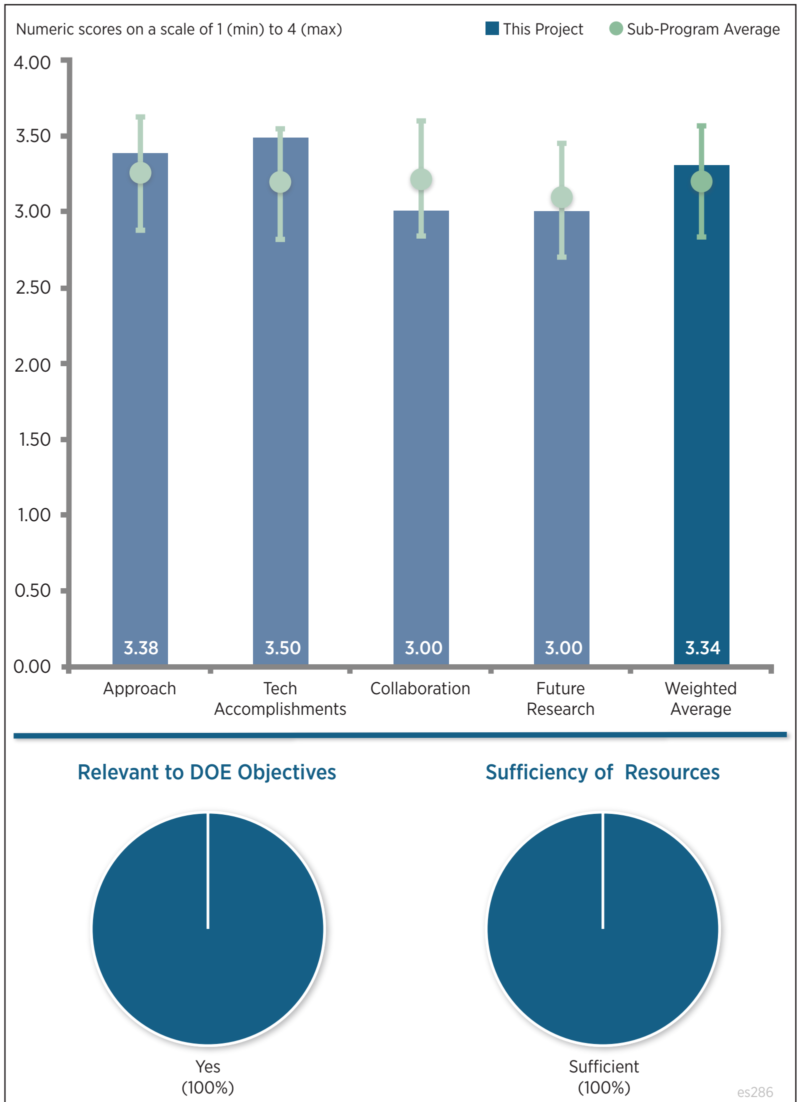

Figure 2-59 – Development of Novel Electrolytes and Catalysts for Li-Air Batteries: Khalil Amine (Argonne National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer stated that this is very much a science project and the team's combined modeling and experimental approaches are very adequate. The focus on catalyst development has proven productive, according to this reviewer, who also explained that electrolyte work has been largely on the modeling side.

Reviewer 2:

This reviewer described the challenges to a practical lithium-air (Li-O_2) system as enormous. While this is one piece of this complex system, the study of new options for cathode catalyst systems is of some interest to the reviewer.

Reviewer 3:

The reviewer was unclear what experiments are planned for "Electrolyte Development," in particular, "Test new Li-air battery electrolytes."

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

Reviewer 1:

This reviewer opined that the project has made tremendous progress in identifying the formation of peroxide versus superoxide under different conditions and how that affects overpotential.

Reviewer 2:

This reviewer commented that the work resulted in materials producing noticeably different electrochemical performance of unique catalyst structures, adding to the knowledge base against the system. While this is not placed in context with all of the overall challenges faced by the system, the reviewer asserted that it is a contribution to the field

Reviewer 3:
This reviewer highlighted that there is no experimental work on "Electrolyte Development," particularly with regard to experiments on "Test new Li-air battery electrolytes."

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that collaboration appears appropriate for the project.

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

Reviewer 1:
The reviewer recommended a strong experimental component to test modeling predictions under the topic of "Electrolyte Development," and specificall , "Test new Li-air battery electrolytes."

Reviewer 2:
The proposed list of work is rather expansive and generic, according to this reviewer, who also pointed out that the potential work plan needs more detail.

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

Reviewer 1:
This reviewer commented that further developing this system is important in the context of diversifying choices of battery chemistries for EV. It would be helpful, suggested the reviewer, if the project can provide an analysis on the system performance (i.e., if a closed system is designed) and its expected energy density.

Reviewer 2:
The reviewer opined that the ultimate practicality of Li-O_2 is highly debatable, though some fundamental work in the field can help establish just how practical it may or may not be

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

No comments were received in response to this question.

Exploratory Studies of Novel Sodium-Ion Battery Systems: Xiao-Qing Yang (Brookhaven National Laboratory) - es287

Presenter
Xiao-Qing Yang, Brookhaven National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

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

Reviewer 1:
This reviewer observed some really good work that not only gives insight into the sodium (Na)-ion cathode system, but all intercalation systems. Quite complete and well grounded, continued the reviewer, who also said good job.

Reviewer 2:
The reviewer described the work on new materials for Na-ion batteries as very good, carefully planned, and well documented. More focus is needed on the cell level though, and the reviewer further suggested that linking the choice of active materials to the capacities at the cell level be beneficial

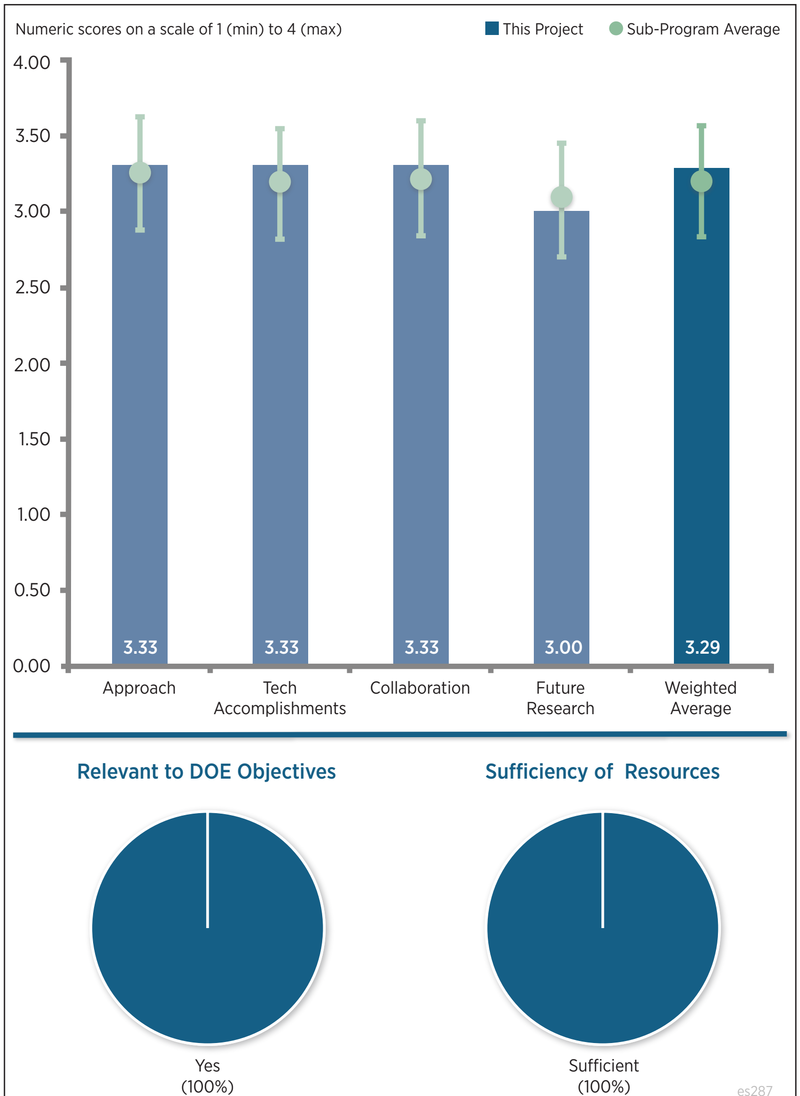

Figure 2-60 – Exploratory Studies of Novel Sodium-Ion Battery Systems: Xiao-Qing Yang (Brookhaven National Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:
The reviewer remarked that mechanisms of Na-ion batteries are identified with well-planned and documented experiments. This reviewer also observed very useful insights on Na-ion battery technology.

Reviewer 2:
This reviewer discerned a very nice set of experimental results that allow good insight into intercalation dynamics. The techniques appear sound and the results are reasonable. The reviewer described the work as really good, and suggested that there could be a little more focus on summarizing the relevance of results.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that collaboration appears appropriate for this work. This reviewer further reported a lot of development, then application of advanced techniques, and appropriate expertise in them.

Reviewer 2:
The reviewer stated that even though the external partner network is large, the contribution is well organized and all partners seem to participate in the work.

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

Reviewer 1:
The reviewer reported that focus is largely on mechanisms and fundamental work, and that this is well explained given the maturity of technology.

Reviewer 2:
This reviewer indicated that the focus of future work appears to be on expanded technique development. Hopefully, added the reviewer, this will applied across a number of system studies.

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

Reviewer 1:
The reviewer opined that this is the type of fundamental work that can be used to develop new insight into important chemical processes.

Reviewer 2:
The reviewer stated yes, and explained that the work is aimed towards an understanding of sodium-ion batteries, which is needed to further develop these systems.

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

Reviewer 1:
This reviewer reported that there seems to be a good level of collaboration and ability to apply a number of advanced techniques to the study.

Construction of High Energy Density Batteries: Christopher Lang (Physical Sciences, Inc.) - es288

Presenter

Christopher Lang, Physical Sciences Inc.

Reviewer Sample Size

A total of five reviewers evaluated this project.

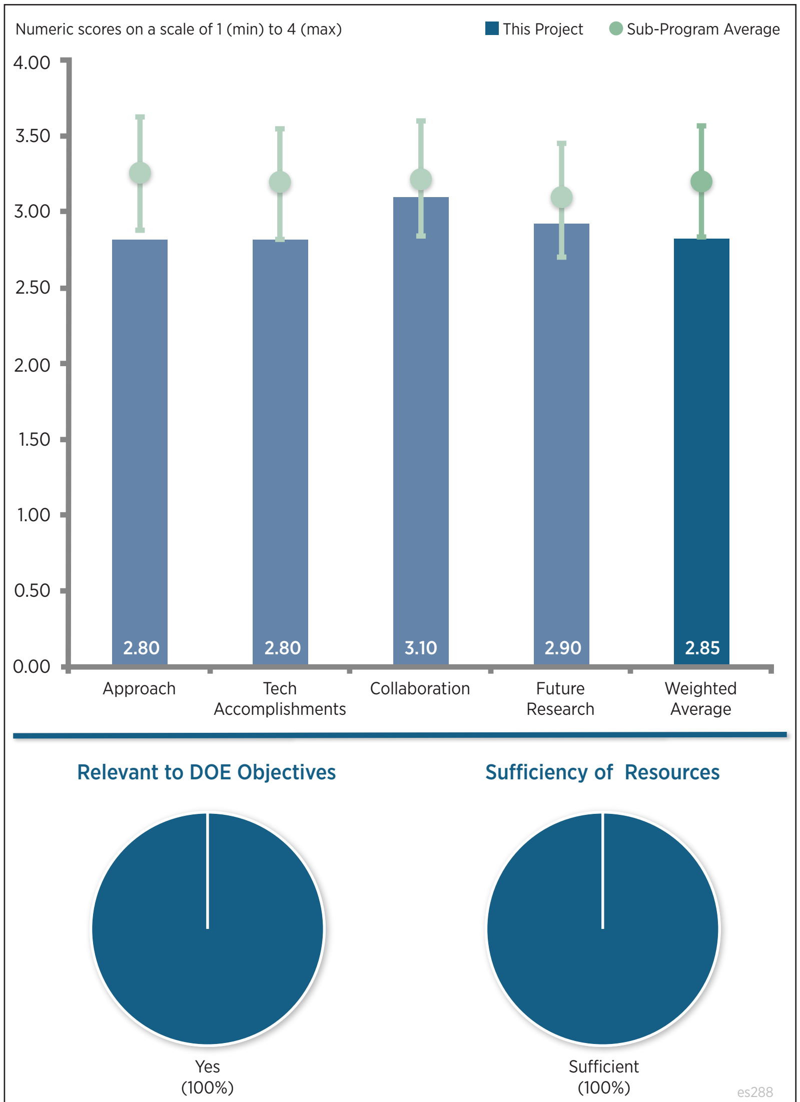

Figure 2-61 – Construction of High Energy Density Batteries: Christopher Lang (Physical Sciences, Inc.) - Electrochemical Energy Storage

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

Reviewer 1:

PSI's efforts, as reported by this reviewer, are concentrated in increasing energy density of batteries by reducing inactive mass. The target is 25% increase in cell energy density.

Reviewer 2:

The reviewer commented that this is an incremental improvement in electrode design, higher active loading content, and improved volumetric efficienc . More evidence as to how the 25% energy density improvement is to be achieved should be provided. The reviewer further recommended that the developer would benefit from o ganizing the deliverable goals and performance objectives into a gap chart.

Reviewer 3:

This reviewer stated that the approach to make lower weight electrodes with equivalent performance to conventional electrodes is an interesting one. The composite material is not defined, but it apparently has a lower weight than Cu or aluminum conventionally used as negative or positive electrode substrate. The reviewer added that no idea of the energy density (Wh/L) can be assessed because nothing was said about the thickness or density of the test substrate. The reviewer explained that what the project team calls energy density is actually the specific energy (Wh/kg), and the possible improvement in this property may be accompanied by a decrease in energy density if the composite density is too low. This reviewer also highlighted two other aspects that are not considered: conductance of the materials may be insufficient for many higher rate discha ge tests (cells seem to be tested only at C/3 rate); and the specification of the coating (which contains less carbon and binder than conventional coatings) may also lead to poorer performance under higher rate continuous or pulse testing. The reviewer suggested that these tests be conducted as part of the approach to fully evaluate the project.

Reviewer 4:

Although the objectives are with respect to the state of the art technologies, this reviewer noted that the state of the art is not well defined. Furthermore, the reviewer reported that cost justification of the innovative process is no provided.

Reviewer 5:

The reviewer found it difficult to evaluate the technology or approach due to a lack of any useful details regarding basic benefit mechanisms or technology content

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

Reviewer 1:

The reviewer described progress to date as good, and suggested that the developer needs to provide more information on the composite current collector so that its benefits and potential failure modes can be better understood. It was also recommended by this reviewer that anode-side work be discussed within the program, such that partner development may better support the cell designs for deliverables, and take advantage of potential anode innovations.

Reviewer 2:

This reviewer commented that progress to date is interesting because apparently better stability at high voltage is achieved than with conventional cells. The reviewer reiterated that there is a lack of rate date presented; so, the down side of this approach cannot be assessed. The reviewer further noted that using a test with only partial discharge has little meaning if comparative tests are not performed, as is the case here.

Reviewer 3:

The reviewer highlighted that the progress reported (i.e., lower mass of composite current collector, 50% less solvent, and 98.5% active materials in electrode) does not convert to a benchmark showing the progress in increasing the overall energy density. This reviewer inquired about current achievement to the targeted 25% energy density increase. The reviewer explained that rate performance of high active (HA) NCM-622 in 3+ Ah cells is basically the same as the baseline NCM-622, but the key information about the energy density improvement of HA cell is missing. The reviewer further recommended that the cycling test of the HA cells charged to different voltages should include results of a baseline cell.

Reviewer 4:

The reviewer acknowledged that understanding 80-100% SOC cycling performance can be useful. However, avoiding something closer to full DOD cycling seemed troubling to this reviewer, even if notably less cycling can be accomplished.

Reviewer 5:

This reviewer remarked that cost reduction due to high active material loading, energy density improvement due to higher voltage, and effect on cycle life are not addressed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed a good team, and added that it will be interesting to see the progress once more advanced active materials are incorporated.

Reviewer 2:

According to this reviewer, the collaboration with the state of the art cell developers is necessary to evaluate success of the innovative coating technology.

Reviewer 3:

This reviewer reported that PSI collaborates with both national laboratory and industry partners.

Reviewer 4:
The reviewer opined that it is valuable to have a scale-up partner because the background of the PI is not strong in this area.

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

Reviewer 1:
This reviewer reported that remaining challenges and future works are identified

Reviewer 2:
The reviewer commented that the investigator seems to recognize the need for rate evaluation in future work, and suggested that the project team also investigate the true energy density in this work (Wh/L).

Reviewer 3:
This reviewer recommended that the developer include a contrast of cell design with an advanced anode.

Reviewer 4:
The reviewer recommended that cycle life using the automotive cycling profile and calendar life to last 15 years should be planned for the future research.

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

Reviewer 1:
The reviewer explained that the need for higher specific ene gy is an important DOE goal.

Reviewer 2:
This reviewer asserted that the work is in the right direction.

Reviewer 3:
The reviewer remarked that the research, if successful, should improve the domestic cell assembly cost and will meet or beat DOE targets.

Reviewer 4:
While incremental, this reviewer indicated that the technical approach could benefit industry quickl .

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

Reviewer 1:
The reviewer observed no issues at this time.

Reviewer 2:
This reviewer opined that Physical Sciences Inc. is capable of providing the resources to optimize the coating technologies.

Advanced Polyolefin Separators for Li-Ion Batteries Used in Vehicle Applications: Weston Wood (Entek) - es289

Presenter

Weston Wood, Entek

Reviewer Sample Size

A total of three reviewers evaluated this project.

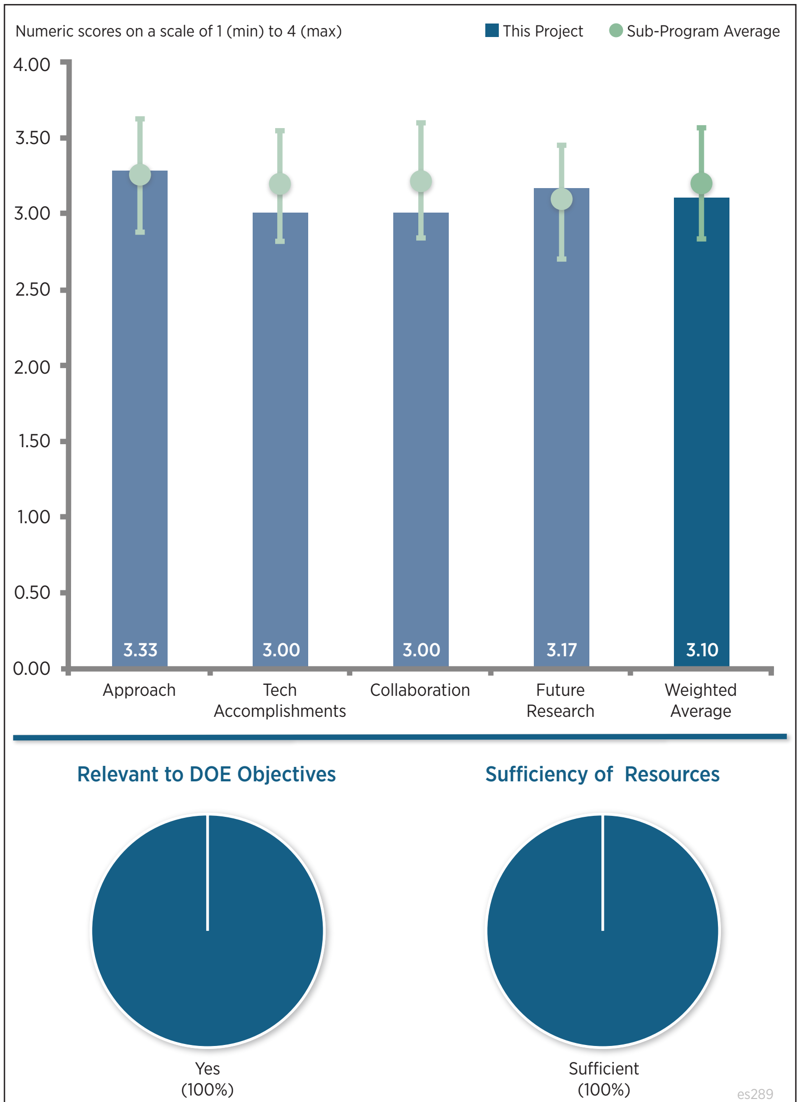

Figure 2-62 – Advanced Polyolefin Separators for Li-Ion Batteries Used in Vehicle Applications: Weston Wood (Entek) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer commented that the technical approach is up-to-date and detail led in order to reach the USABC final deliverables. This reviewer further reported that all standard test and metrics were followed for separator testing. If successful, opined the reviewer, the manufacturing approach will reduce cost and improve performance as described in the target.

Reviewer 2:

This reviewer noted that the project addresses some of the points and identified the following gaps: there is no work on high voltage stability; cost is only addressed by linking it to the fill time; there are no details on process for the coating of the multilayer separator; and there are no cell measurements.

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

Reviewer 1:

The reviewer remarked that the project team made good technical progress towards the silica and alumina filled separator. Optimization of the conductivity and wetting was also noted by this reviewer. The reviewer further acknowledged good improvement over the baseline separator.

Reviewer 2:

This reviewer reported the lack of electrochemical tests, compatibility of coated separators to cathode materials, and high voltage stability.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer observed good teaming with Farasis on cell testing and development and Portland State University for characterization.

Reviewer 2:

The reviewer commented that Farasis' role was not active at the moment, and the role of the other partner except from SEM imaging is unclear.

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

Reviewer 1:

The reviewer praised that improvement in energy density is a plus, especially designing separators for 5 V stability.

Reviewer 2:

According to the reviewer, this project has the potential to improve over the current status, if next year's work is completed. However, continued the reviewer, a link of production methods cost needs to be discussed and the cost cannot be addressed by only linking it to cell fill time

Reviewer 3:

This reviewer explained that the proposed future work addresses what is to be done, but not how it will be done. The reviewer provided the following examples: "Drying methods and ceramic coating formulation optimization will be evaluated," was stated without specifying what drying methods will be attempted; and "Evaluate the feasibility of continuously coating separator using immersion, spray coating, and powder coating systems" was stated without specifying coating methods. The reviewer also recommended that coating adhesion strength should be measured and quantified

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

Reviewer 1:

The reviewer summarized that this project aims at developing advanced Li-ion batteries with improved safety and energy density. It also aims at improving the manufacturing process for separators that could potentially reduce cost and energy consumption.

Reviewer 2:

This reviewer asserted that enabling better batteries is a clear DOE target.

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

Reviewer 1:

This reviewer described resources as adequate.

Hybrid Electrolytes for PHEV Applications: Surya Moganty (NOHMs Technologies) - es290

Presenter

Surya Moganty, NOHMs Technologies

Reviewer Sample Size

A total of four reviewers evaluated this project.

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

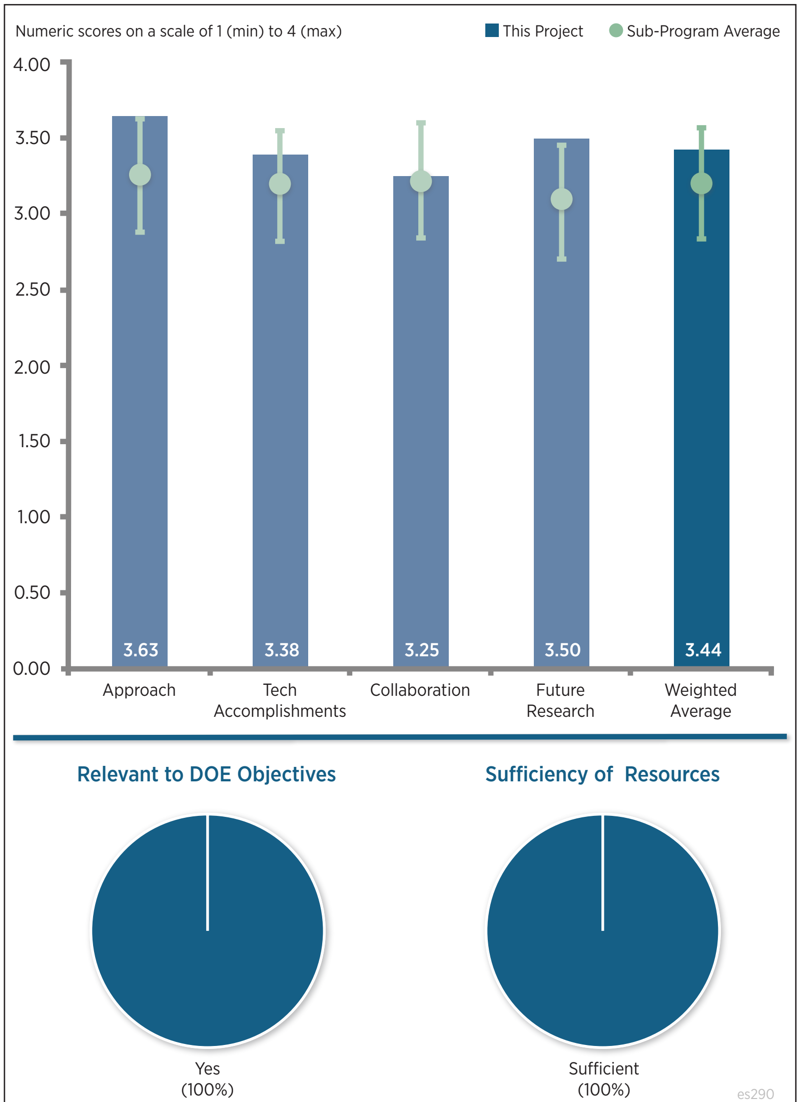

Figure 2-63 – Hybrid Electrolytes for PHEV Applications: Surya Moganty (NOHMs Technologies) - Electrochemical Energy Storage

Reviewer 1:

This reviewer commented that the project is very well designed with quantifiable milestones

Reviewer 2:

This reviewer stated that the PI proposed to synthesize and formulate ionic liquid based electrolyte for high voltage electrolytes. Considering the intrinsic problem with carbonate-based solvents, which release CO_2 at high voltage and high-temperature, it is necessary to explore non-carbonate-based solvents. The reviewer opined that this project started a meaningful direction.

Reviewer 3:

The reviewer indicated that targets and the project pathway are very well defined and o ganized. However, the reviewer noted that the project does not include safety tests, even though this is critical for electrolytes.

Reviewer 4:

The reviewer highlighted several strong points: good baseline comparison with EC-DMC/EMC electrolyte with NOHMS ionic liquids (IL) and additives; the team has adequate tools and characterization methods to test the performance of ILs for high voltage applications; and first testing on 2 Ah cell is a good idea even before on a small single layer pouch cell is preferable as listed in the project team’s milestones. This reviewer identified one major issue and emphasized that, as the team knows, even if 5 V electrolytes are designed, the cathodes and cathode surfaces may not be stable above 4.4 V or so. This calls for surface modifications and other treatments to stabilize, advised the reviewer. The capacity loss at higher voltage could be due to multiple reasons as the cathodes like NMC may not be stable as well.

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

Reviewer 1:

The reviewer listed impressive technical accomplishments: higher temperature stability than EC; correlation between ring-size and temperature stability; improved low-temperature conductivity; lower vapor pressure at elevated temperatures than conventional electrolytes; improved stability against the graphite, NMC, and nickel manganese oxide (NMO) electrodes; and improved capacity retention.

Reviewer 2:

Given the short period since the project award, the reviewer asserted that the PI has already made significant progress in synthesis and characterization.

Reviewer 3:

This reviewer described the technical accomplishments and progress as good, but stated that there is no information about the electrode loading in the presentation. Further, the reviewer inquired whether there is a plan to get higher loading cathodes.

Reviewer 4:

The reviewer observed that the cycling data are presented between 4.95 V-3.5 V for NMO-graphite, and asked what the justification was for the lower voltage cut-o f. The reviewer stated that should be clear, and wondered if it is reactivity with the negative electrode. Further, this reviewer expected that all of the cathodes used for comparison have similar loading and test metrics for a meaningful comparison. The reviewer further asked what the typical electrode loading was for graphite and NMC/NMO, and stated that this should have been listed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer observed close collaboration between the PI and team members.

Reviewer 2:

CoorsTek's contribution in the project was not fully clear to this reviewer.

Reviewer 3:

Referencing Slide 17 ("New Partner TBD"), the reviewer commented that it was unclear why a new partner is needed.

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

Reviewer 1:

The reviewer noted that proposed efforts are innovative and highly meaningful.

Reviewer 2:

Proposed future work is well defined and clearly stated, as stated by this reviewe .

Reviewer 3:

The reviewer observed a pretty ambitious goal as illustrated in the challenges and barriers section. Partnering with A123 Venture and CoorsTek is a positive. This reviewer looked forward to constructive feedback about the cost and scale up, and added that it is a good idea to provide some fundamental or mechanistic picture about why ILs are stable at higher oxidative voltage. Details are often hidden in literature, but this reviewer indicated that a clear picture needs to be provided for the cell and engineering community.

Reviewer 4:

This reviewer asserted that several issues have to be addressed to finish the project in a good way: mass production of the ionic liquids and electrolyte; safety tests have to be performed; electrolyte formulation recommendations for specific cathodes (i.e., NMC and NCA) have to be published

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

Reviewer 1:

This reviewer asserted that advances and mass penetration of EVs are one of the approaches to displace fossil fuels.

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

Reviewer 1:

The reviewer described resources as adequate. Overall, opined this reviewer, USABC milestones are very ambitious given the very nature and status of IL R&D, but the team has the right approach and tools to push the envelope.

Reviewer 2:

This reviewer recommended use of a proof-reader because there are many typos in the es290_moganty_2016_p presentation.

SAFT-USABC 12V Start-Stop Phase II: Ian O'Connor (Saft) - es291

Presenter

Ian O'Connor, Saft

Reviewer Sample Size

A total of four reviewers evaluated this project.

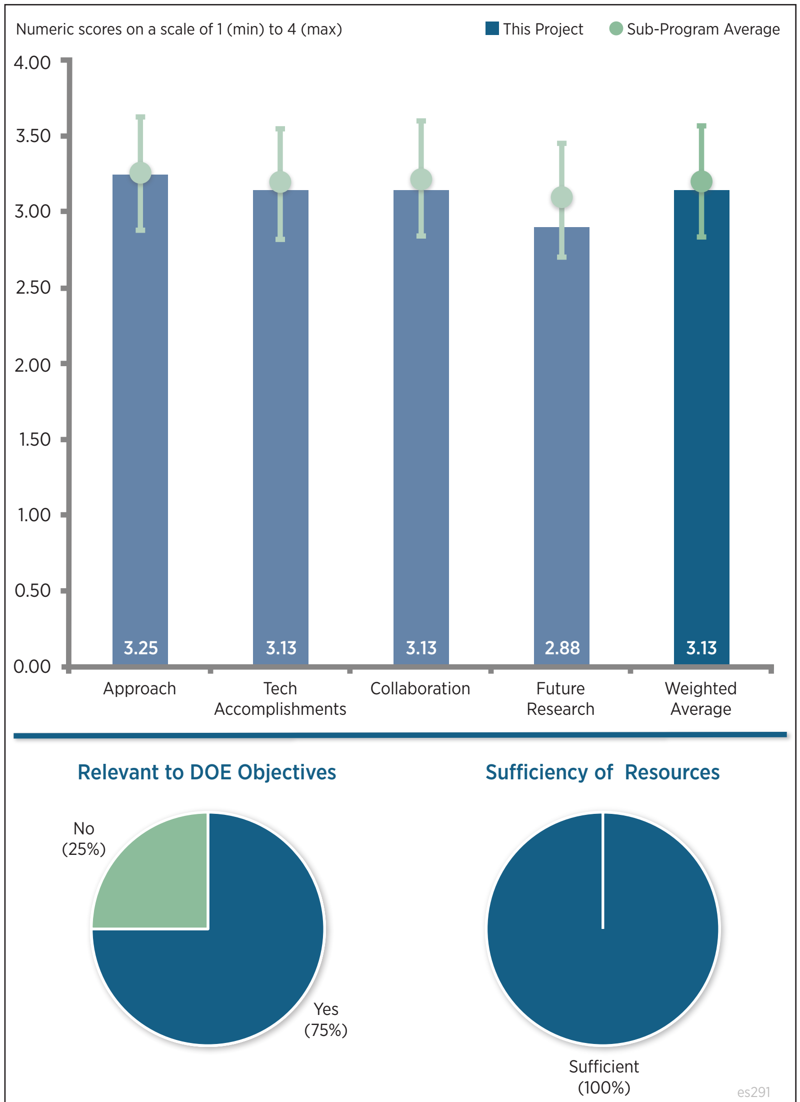

Figure 2-64 – SAFT-USABC 12V Start-Stop Phase II: Ian O'Connor (Saft) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer reported that the objective is to develop an advanced, high-performance battery module for 12V start-stop (SS) vehicle applications, in compliance with the USABC performance requirements, based on SAFT's proprietary all-aluminum LTO LIB technology. The goal is to deliver to USABC 12V SS module assemblies with cells in a prismatic format placed in thermoplastic module along with battery management electronics, for a cost of less than $220. This reviewer further explained that the approach involves the use of a LTO anode, which has the advantages of high power capability, long life, and free Li plating and lithium manganese oxide (LMO) cathode. Different electrolyte blends (i.e., binary and ternary) are being examined for improved low-temperature conductivity and high-temperature stability (i.e., gassing). In parallel, continued this reviewer, a simple battery pack design is being developed with SAFT's BMS to meet the USABC targets. The reviewer concluded that the approach addresses the technical barriers, and added the project is well-designed, feasible, and integrated with other VTO projects.

Reviewer 2:

This reviewer commented that the roadmap of the work is good and covers most of the critical targets. The reviewer suggested that the only aspect missing is lifetime testing of LIB for start-stop applications, and inquired whether this is supposed to be the same as for the sealed lead acid battery of three years. This reviewer further expressed interest in whether the use of LMO as the cathode with the Mn dissolution would effect this lifetime.

Reviewer 3:

The reviewer explained that the presentation was only available to this reviewer in a poster format rather than the traditional AMR format. Thus, the reviewer could not rank this as some of the mandatory slides were missing. The reviewer checked with the project team during the poster session to determine if there was a formal template to read and evaluate.

The reviewer observed a technically sound and mature project that should be ready as a deliverable baring some issues. LTO/LMO full cell should work for this kind of start-stop application. The only issue identified by the reviewer, and also pointed out by the project team, is the electrolyte performance at -30°C. This could affect the cold cranking. This reviewer would have liked to have seen more data and/or results about the project team's electrolyte test results and other relevant data.

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

Reviewer 1:

Because the key requirement for the USABC program is the cold cranking, the reviewer indicated that much of the recent effort was focused on identifying electrolytes with good low-temperature conductivity and also high-temperature stability. Some formulations with binary solvents show improved conductivity and also low-temperature cranking, but the high-temperature gassing continued to be an issue. This reviewer stated that the addition of some additives reduced gassing, but affected the low-temperature performance. Undoubtedly, according to the reviewer, it is a challenge to find suitable electrolyte systems or low-temperature power and high-temperature stability. The reviewer asserted that SAFT's approach of electrolyte optimization is appropriate. In addition, a battery pack was designed with five prismatic cells and also contains a system control in the battery to ensure optimum performance, as well as longevity. The final module is intended to be a drop in replacement for lead acid batteries to eliminate the need for a dual battery in a start-stop system. The reviewer concluded that these accomplishments are encouraging and progress is consistent with the project objectives and DOE goals.

Reviewer 2:

This reviewer stated that measurable progress has been made towards high-power and low-temperature (e.g., -30°C) operations of LTO LIB cells.

Reviewer 3:

Although progress is good, the reviewer noted that the project timeline in terms of years is not mentioned. Therefore, the reviewer could not provide an evaluation in terms of progress towards the ultimate goals.

Reviewer 4:

This reviewer reported that the team has identified or down selected a few electrolyte compositions that are in the range of approximately 10 mS/cm at -30°C. That should augur well. The reviewer expressed interest in seeing some cell-level performance using those electrolytes, especially at low temperatures. Additionally, the reviewer pointed out that no technical information was provided for the project team's choice of binary and ternary solvent systems for its electrolytes.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer indicated that no external collaboration was specified. The reviewer added that the project seemed self-contained and did not need collaboration and coordination with other institutions.

Reviewer 2:

The reviewer reported that there were no other project partners listed.

Reviewer 3:

This reviewer assumed collaboration and coordination with other institutions were satisfactory and indicated that an evaluation could not be made because of a lack of information presented in this regard.

Reviewer 4:

The reviewer commented that there is no collaboration explicitly mentioned, but that it is possible that the project deliverables will be tested by the DOE laboratories.

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

Reviewer 1:

This reviewer summarized that proposed future research includes determining the root cause for gas generation in an LMO/LTO cell at high temperatures, especially in electrolytes that provide good low-temperature performance. The goal of the future studies is to prevent and/or diminish gas generation in the LMO/LTO cell design while concurrently identifying an alternative electrolyte that achieves the cold cranking requirements. The reviewer added that the eventual goal is to develop and manufacture more than 20 fully operational batteries with an integrated electronic system contained in a novel architecture, and identify a path to full commercialization.

Reviewer 2:

The reviewer commented that future research is well defined, and listed the following statements: "Moving forward, SAFT's goal is to prevent and/or diminish gas generation in the LMO/LTO cell design whilst concurrently identifying an alternative electrolyte that achieves the cold cranking requirements;" and "... develop and manufacture over 20 fully operational batteries with an integrated electronic system contained in a novel architecture, and identify a path to full commercialization."

Reviewer 3:

This reviewer noted that there was no project timeline on the poster.

Reviewer 4:

This reviewer was unable to evaluate the future work proposed because no information was presented. An assumption was made by this reviewer that proposed future work is satisfactory.

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

Reviewer 1:

The reviewer explained that replacing conventional 12V lead-acid batteries with LIBs for start-up applications will reduce battery mass and volume (by 60%), improve service life, and reduce maintenance. The rapid recharge reduces load on the alternator because more power is retained and the charge is handled faster than lead-acid batteries. The reviewer asserted that all of these characteristics will result in reduced fuel consumption and, thus, reduced CO_2 emissions. Current active materials have low specific power to support cranking, especially at low temperatures. New active materials, in conjunction with advanced electrolytes, are needed to provide low-temperature cranking and high-temperature resilience. Also, continued this reviewer, simpler pack designs and battery management systems are essential to make the LIB a viable replacement. The reviewer stated that this project is aimed at addressing these aforementioned challenges.

Reviewer 2:

This reviewer offered that start-stop application can increase fuel efficiency by turning o f the engine operation during traffic stops and/or signals

Reviewer 3:

The reviewer indicated that displacement of sealed lead acid (SLA) batteries for start-stop applications would have minimal impacts on the use of internal combustion engines for propulsion. Additionally, this reviewer has not seen a carbon lifecycle analysis that has shown that LIBs use less carbon to produce than SLA batteries. This would be good to include, suggested the reviewer, and would allow for a project partner.

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

Reviewer 1:

This reviewer described resources as adequate.

Reviewer 2:

The reviewer commented that resources are adequate for the scope of the project to meet the stated milestones in the scheduled time.

Reviewer 3:

Although funding amount was not mentioned, the reviewer explained that Saft is a large company and has multiple efforts on increasing the durability and performance of LIBs that can be leveraged for this work.

Development of Advanced High-Performance Electrolytes for Lithium-Ion Used in Vehicle Applications: Kristin Meyers (soulbrain) - es292

Presenter
Kristin Meyers, soulbrain

Reviewer Sample Size
A total of five reviewers evaluated this project.

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

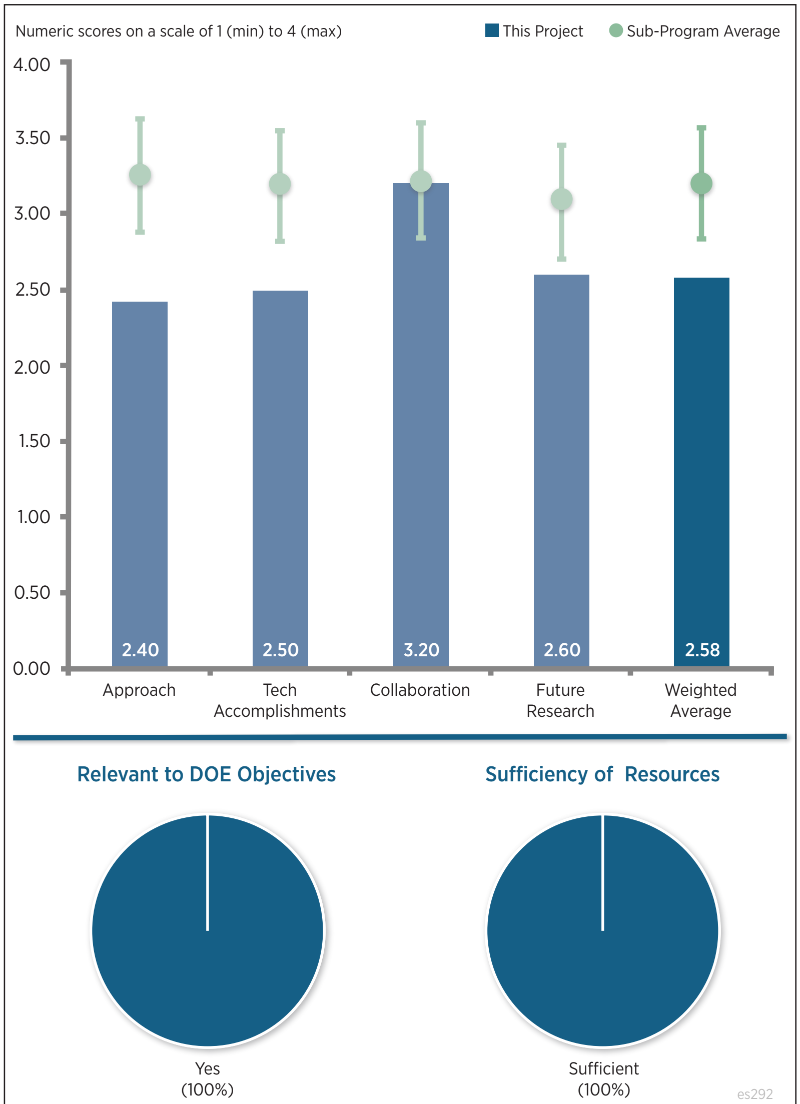

Figure 2-65 – Development of Advanced High-Performance Electrolytes for Lithium-Ion Used in Vehicle Applications: Kristin Meyers (soulbrain) - Electrochemical Energy Storage

Reviewer 1:
The reviewer acknowledged that this is a new project and commented that there is insufficient information provided in terms of the PI's precise approach to develop high voltage electrolytes.

Reviewer 2:
Referencing the introduction, this reviewer reported that the barriers to technology adoption mention abuse tolerance, but the planned scope of work only includes overcharge testing. The reviewer noted that the pathway towards cost reduction is not addressed, though this may be addressed later in this new project.

Reviewer 3:
The reviewer noted that the current cost of LIB packs is listed as $800-$1,000/ kWh in the "Barriers" section of Slide 2. The reviewer strongly expressed certainty that the price has reduced by at least a factor of 2.5 in 2016, and recommended that this be reevaluated. It was difficult for this reviewer to appreciate the approach due to the lack of technical information. The reviewer further reported that the project team is working on various high voltage electrolyte formulation and cathodes form suppliers.

Reviewer 4:
The eventual success of the project depends on too many parameters, according to this reviewer. While the title of the project is "Development of Advanced High-Performance Electrolytes..," the reviewer observed that much of the effort is on testing NMC (from three vendors) and $LiNi0_{0.5}Mn_{1.5}O_4$ (from two vendors) in several electrolytes. The reviewer offered the following recommendations: the project should use one or two readily available and well-characterized high voltage cathodes and focus on developing electrolytes; the PI should disclose the scientific principle, if not the chemical composition, underlying the electrolyte development; conduct experiments on

the effect of single wall carbon nanotube (SWCNT) conductive additives after developing a better electrolyte formulation; and the PI should justify the cost reduction chart on Slide 5 by providing the relevant data.

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

Reviewer 1:

Understanding that the project started less than a year ago, this reviewer indicated that the only technical progress presented was optimizing the electrode performance using conductive additives, Super P® versus SWCNT. All others were observed by this reviewer to be in progress with no data yet.

Reviewer 2:

The reviewer acknowledged that the project started this year and the technical accomplishments to date would be small. Additionally, the reviewer offered that soulbrain mentioned that the reduction of conductive additive surface would reduce electrolyte oxidation, but did not show a pathway to measure the conductive additive surface area.

Reviewer 3:

This reviewer reiterated that the results provided are inadequate to judge.

Reviewer 4:

The project only started in January, and this reviewer commented that scarce data and information were given to evaluate project progress.

Reviewer 5:

Based on the scant data presented, the reviewer found that the various formulations with additives designated as “A” to “E” do not change the density and conductivity very much. Therefore, it seemed to this reviewer that an improved electrolyte has not been found. This reviewer advised that the PI should provide convincing data on improved performance before moving the project to the “Optimization of the electrolyte…” stage under “Remaining Challenges and Barriers.”

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer opined that the following partnership is good and should conclude in successful conclusion of this project: USABC for project management expertise; soulbrain for electrolyte expertise; and Iontensity for cell building and testing expertise.

Reviewer 2:

The reviewer observed that the collaboration seems to be close.

Reviewer 3:

This reviewer highlighted that no slide was presented. Therefore, this reviewer could not provide a ranking, and an assumption was made that collaboration and coordination with other institutions is satisfactory.

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

Reviewer 1:

This reviewer looked forward to seeing the progress in the project team’s high voltage electrolyte testing using various surface-modified cathodes from various suppliers

Reviewer 2:

The reviewer described identification of the high-voltage capable cathodes as good. The project team identified the need to reduce the surface area of the conductive binder, but have not identified a way to test this. This reviewer suggested that a dynamic gas generation test (cell swelling, etc.) should be identified, because di ferential scanning calorimetry (DSC) testing is done simply on a component level, and overcharging and gassing will react on a cell level. The reviewer further suggested that a level of acceptable amount of swelling (due to gassing) should be identified

Reviewer 3:

This reviewer commented that it was unclear what future efforts would be made, and opined that more time is needed because there is not much information to judge in the poster and slides provided.

Reviewer 4:

The reviewer strongly advised that experiments on the effect of SWCNT conductive additives should come after developing a better electrolyte formulation. It was further suggested by this reviewer that the project should use one or two readily available and well-characterized high voltage cathodes and focus on developing electrolytes.

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

Reviewer 1:

The reviewer stated that this research topic is targeted towards electric drive train vehicles that will reduce dependence on fossil fuels.

Reviewer 2:

This reviewer explained that increasing the abuse tolerance of Li-ion batteries will help with the technology adoption, especially in vehicle technologies, which will help displace petroleum based technologies.

Reviewer 3:

The cost and performance of electrolyte is an essential part of the LIB industry, asserted this reviewer.

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

Reviewer 1:

Resources are adequate as observed by this reviewer.

Reviewer 2:

The reviewer commented that there should be enough technical resources from soulbrain and Iontensity to complete the project.

A Closed Loop Process for the End-of-Life Electric Vehicle Li-Ion Batteries: Yan Wang (Worcester Polytechnic Institute) - es293

Presenter

Yan Wang, Worcester Polytechnic Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

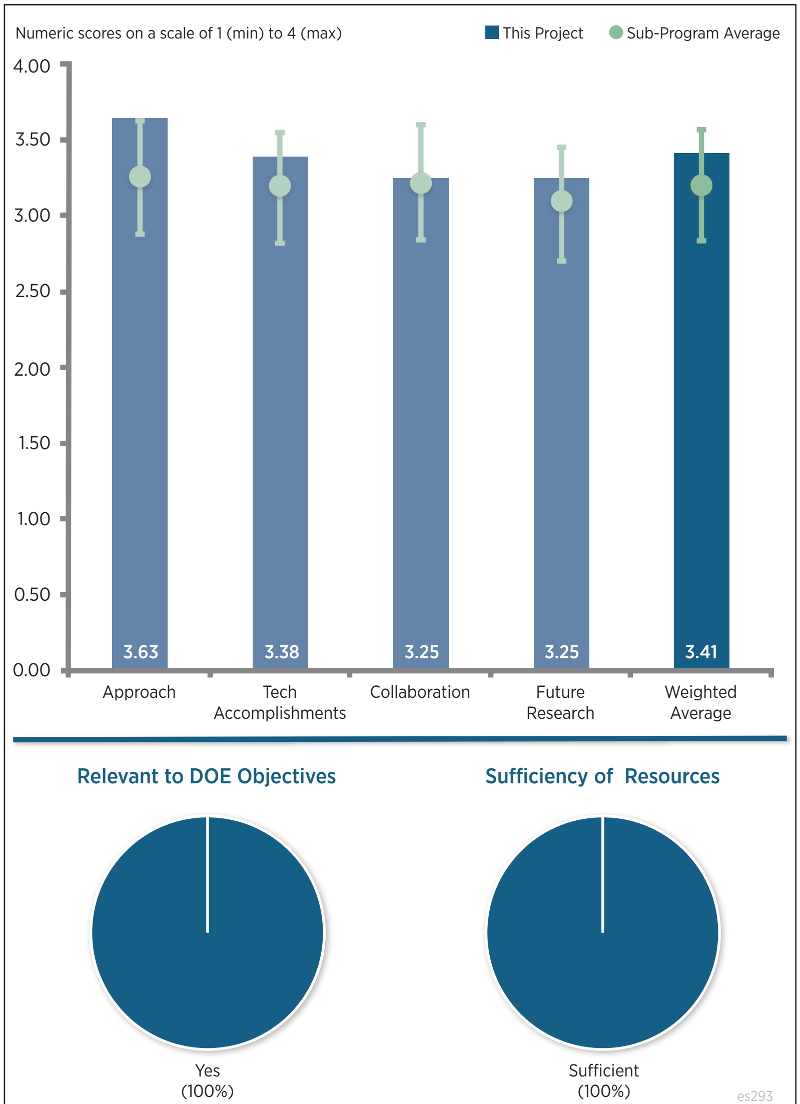

Figure 2-66 – A Closed Loop Process for the End-of-Life Electric Vehicle Li-Ion Batteries: Yan Wang (Worcester Polytechnic Institute) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer observed a unique, innovative, technical approach that appears to be promising for battery recycle.

Reviewer 2:

This reviewer asserted that this is a very cost effective approach for recycling LIBs.

Reviewer 3:

The reviewer commented that the approach used in this effort is very effective at addressing the technical barriers identified for this project. One area of concern for this effort will be the quality of the materials that are generated as part of this recycling process. The reviewer advised that this is an area that needs to be more thoroughly addressed as the program proceeds.

Reviewer 4:

The approach mentioned the need for recovery of Cu and aluminum, but the reviewer noted that there did not seem to be any specific work to accomplish this activit . The reviewer added that the approach to NCM recovery seemed valid.

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

Reviewer 1:

The reviewer stated that this effort just started and that it is somewhat premature to comment on the project team's progress. However, even at this early stage, the project team has effectively demonstrated feasibility of this approach at generating a highly flexible process for converting recycled batteries into usable NMC cathode material. Clearly, noted this reviewer, the next steps of improving the quality of the cathode materials generated from this process will be key.

Reviewer 2:

This reviewer indicated that, although the recovery efficienc   of NCM is less than the target (greater than 80%), the actual value was not given. Subsequently, it was not possible to evaluate progress. The reviewer further commented that the extracted product seems to be of good, but not excellent, quality.

Reviewer 3:

The reviewer reported that some preliminary progress has been achieved in less than five months and expressed interest in seeing more progress at the next AMR meeting.

Reviewer 4:

This reviewer shared that the recovery efficiency is currently 50%, which has room for improvement. Additionally, the reviewer inquired about the recovery efficiency from the shredded pack to recovered powders, as well as how to improve the sieving process.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

Excellent collaborations to provide cells and packs were observed by this reviewer.

Reviewer 2:

The reviewer indicated that good collaboration has been identified and partners are well coordinated

Reviewer 3:

It was unclear to this reviewer whether the group has the expertise for synthesizing state-of-the-art NMC.

Reviewer 4:

The reviewer opined that collaboration and coordination with other institutions is one of the only weaknesses in this effort. The reviewer recommended that the program would significantly benefit from a broader collaborativ team to include battery manufacturers that have a NMC or mixed metal oxide cathode as part of their base offering. This would provide the team with valuable input regarding the quality of the recycled materials that are being generated from their process and be key at identifying potential issues early in the development process.

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

Reviewer 1:

The reviewer praised the effective future work plan and highlighted that the PI has properly identified the key challenges and areas of concern for this effort.

Reviewer 2:

This reviewer reported that the proposed future research focused on key barriers.

Reviewer 3:

The reviewer advised that actual recovery results should be plotted in future research, and pointed out that no details are given as to how the recovery process will be optimized, nor how the metals may be recovered.

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

Reviewer 1:

This reviewer commented that development and demonstration of LIB recycling technique is the key to fulfill DOE goals on vehicle electrification

Reviewer 2:

This reviewer observed a highly relevant effort that addresses one of the next major issues associated with the electrification of vehicles (i.e., how one can recycle materials from spent LIBs)

Reviewer 3:

Recycling will be crucial for EV acceptance and economics, opined this reviewer.

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

Reviewer 1:

It seemed to this reviewer that the budget may be tight to fulfill the proposed research goals and recommended more funds in the future, if required.

Reviewer 2:

The reviewer that this effort appears to have sufficient resources, and suggested it would be strengthened with additional collaborative partners.

Computer Aided Battery Engineering Consortium: Ahmad Pesaran (National Renewable Energy Laboratory) - es294

Presenter

Ahmad Pesaran, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

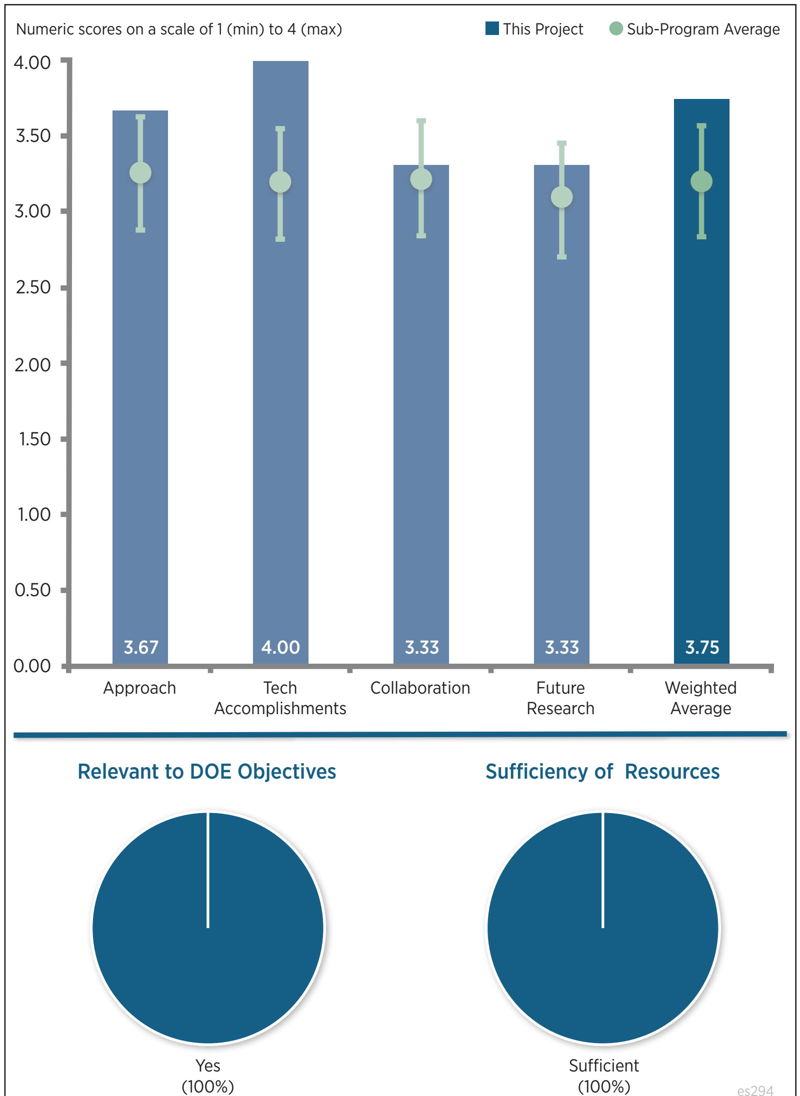

Figure 2-67 – Computer Aided Battery Engineering Consortium: Ahmad Pesaran (National Renewable Energy Laboratory) - Electrochemical Energy Storage

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

Reviewer 1:

The reviewer commented that the PI has developed an outstanding approach to address the technical barriers to this program. The project is building on years of demonstrated success and is leveraging/well integrated with other efforts. This reviewer concluded that it would be very difficult to improve on the project team's plan.

Reviewer 2:

This reviewer explained that the approach to increase computational efficiency is based upon the multi-scale multi-domain (GH-MSMD) developed in CAEBAT II, which seems effective.

Reviewer 3:

The reviewer noted the approach involves building a front-end onto commercial solvers (e.g., Fluent) to allow for battery pack analysis. This will be very useful for automotive and battery companies, opined this reviewer, who also added that earlier versions were already incorporated into ANSYS. The reviewer asked whether it will be useful to academic researchers without access to these large commercial codes.

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

Reviewer 1:

Although very early, this reviewer observed considerable accomplishments and referenced Slide 12 and Slide 13. The reviewer added that the project team is in touch with major solver companies to incorporate their work.

Reviewer 2:
This reviewer pointed out that the team has already demonstrated very good progress for each of the three tasks during the relative short duration of the program. Based on this work, it appeared very likely to the reviewer that the team will be able to achieve the stated goals for this effort.

Reviewer 3:
It appeared to this reviewer that the research has been conducted smoothly and progress has been achieved as planned so far.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer strongly praised the PI for having assembled an outstanding collaborative partnership with world leading institutions, which serves as a template for how to assemble a team. This reviewer particularly commended how the PI breaks out roles and responsibilities for each of the supporting organizations.

Reviewer 2:
This reviewer observed good research collaboration between the contract and the academia/industry partners. The reviewer added that the contractor has collaborated with the GM/ANSYS team on CAEBAT III, co-funded by DOE and the Army to increase the pack level combined mechanical/electrochemical/thermal modeling computational efficienc . This reviewer asked whether this CAEBAT III project can leverage that GM project.

Reviewer 3:
This person expressed concern about overlap among three groups who are doing more or less the same thing, led by ORNL, NREL, and Ford. The reviewer understood that DOE may feel it wants a competition in order to get the best results. The reviewer warned of a danger that the three groups will produce three different program sets that will be very difficult to compare, in case they do not happen to compute the same quantities. In that case, the reviewer cautioned that the community may start making incompatible predictions, which could lead to confusion and slow progress.

Of the three groups, ORNL seemed best positioned to this reviewer because ORNL is collaborating with both Ford and NREL. Ford, which wants to create a proprietary system, seemed least connected according to this reviewer. Without some overall coordination, this reviewer expressed concern that the result will be messy.

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

Reviewer 1:
The proposed research was sound and reasonable to this reviewer.

Reviewer 2:
The reviewer conveyed that each of the tasks has a very robust and detailed future work plan. This person further suggested that an assessment of risks and corresponding mitigation strategies would be helpful to determine the viability of the approach.

Reviewer 3:
It was unclear to this reviewer that the tomographic work has been carefully planned. Referencing Slide 15, the reviewer pointed out that the problem with measuring diffusivity is unresolved. This reviewer also noted that the problem of identifying the minimum representative volume element size has not been addressed. The reviewer added that mechanical failure is a statistical, not deterministic, process in which the presence and intensity of local flaws and/or inhomogeneities may control failure rate. Texas A&M University, with its stochastic reconstruction

and meso-scale physics may address this issue, but the reviewer stated that there is no detail. The reviewer agreed that crush, rather than nail-tests, are considered important.

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

Reviewer 1:

The reviewer affirmed that this project provides a critically needed capability for the auto industr .

Reviewer 2:

The reviewer asserted that this effort is highly relevant to DOE objectives. This person added that advanced modeling and simulation (M&S) tools will accelerate the development of cost effective, advanced energy storage solutions with improved safety and performance characteristics.

Reviewer 3:

If successful, this reviewer commented that the developed tolls may help reduce battery cell development time to speed vehicle electrification

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

Reviewer 1:

The reviewer indicated that sufficient funding has been provided and/or budgeted to support the success of this project.

Reviewer 2:

This effort has sufficient resources to achieve the stated milestones, asserted the reviewe .

Consortium for Advanced Battery Simulation: John Turner (Oak Ridge National Laboratory) - es295

Presenter
John Turner, Oak Ridge National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

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

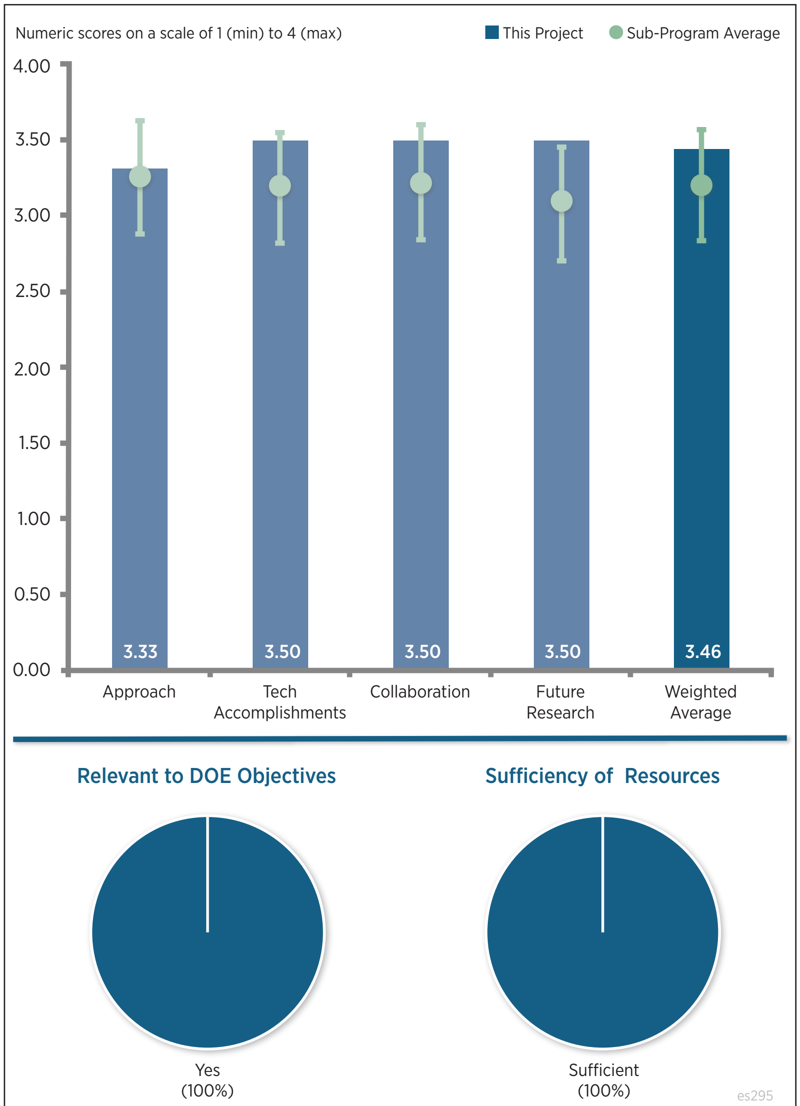

Figure 2-68 – Consortium for Advanced Battery Simulation: John Turner (Oak Ridge National Laboratory) - Electrochemical Energy Storage

Reviewer 1:
The approach seemed reasonable to this reviewer, who also inquired whether there is any possibility for this project to leverage other, on-going CAEBAT III.

Reviewer 2:
The reviewer observed an approach that involves building a front-end onto commercial solvers (e.g., Fluent) that allows for battery pack analysis. This will be very useful for auto and battery companies. The reviewer reported greater than 150 downloads via the website, http://batterysim.org/. The following inquiries were also made by this reviewer: whether it will be useful to academic researchers without access to these large commercial codes; the level of necessary detail to reproduce results in baseline performance modeling; and whether the project team really needs to go to DualFoil, or whether a lumped model would work, because both have adjustable parameters.

Reviewer 3:
The reviewer declared that the approach used in this effort is very effective at addressing the technical barriers identified for this project. One particular advantage to this e fort is that it is building on the Open Architecture Software (OAS) and components of the Virtual Integrated Battery Environment (VIBE), developed as part of CAEBAT 1. This reviewer offered that one area of concern is the project team needs to have a more robust methodology to validate the completed models.

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

Reviewer 1:
This reviewer commented that the team appears to be making excellent progress addressing the technical barriers to this program.

Reviewer 2:
So far, this reviewer found that the research progress achieved in this project is as planned.

Reviewer 3:
The reviewer reported that the program has just begun, and opined that it is not enough to mention the modulus under "Effective properties with binder." This person inquired as to where the project team was going to get binder failure data, and whether this failure is ductile, brittle, or fatigue, for example.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer noted good collaboration with partners has been conducted as planned.

Reviewer 2:
The reviewer commended the PI for having done a very nice job developing collaborative relationships to meet this effort's goals. This person stated that there is a significant amount of work being conducted at Naval Surface Warfare Center (NSWC) Carderock that will be particularly helpful to validate abuse simulations.

Reviewer 3:
This person expressed concern about overlap among three groups who are doing more or less the same thing, led by ORNL, NREL, and Ford. The reviewer understood that DOE may feel it wants a competition in order to get the best results. The reviewer warned of a danger that the three groups will produce three different program sets that will be very difficult to compare, in case they do not happen to compute the same quantities. In that case, the reviewer cautioned that the community may start making incompatible predictions, which could lead to confusion and slow progress.

Of the three groups, ORNL seemed best positioned to this reviewer because ORNL is collaborating with both Ford and NREL. Without some overall coordination, this reviewer expressed concern that the result will be messy.

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

Reviewer 1:
This reviewer indicated that future research outlined by the contractor is effective and it targets on the key barriers identified in the project team s proposal.

Reviewer 2:
The reviewer commented that a lot of work remains, particularly with this being a new start program. The reviewer added that the PI has laid out a very comprehensive plan complete with risks and mitigation strategies to address the remaining technical barriers.

Reviewer 3:
It was unclear to the reviewer that the tomographic work has been carefully planned, and noted that the problem of identifying minimum representative volume element size has not been addressed. The reviewer pointed out that mechanical failure is a statistical, not deterministic, process in which the presence and intensity of local flaws inhomogeneities may control failure rate. This person inquired about how this will be addressed. The reviewer opined that NMR is probably not a good way to measure diffusivity for a system where the diffusion coefficient depends strongly on concentration, which is the case with Li^+. The reviewer further explained that this is because

the concentration of species (e.g., contact ion pairs) depends strongly on concentration, and these objects diffuse at much different rates than solvent-separated ion pairs. See work by Oleg Borodin, suggested the reviewer, who added that this issue is recognized in FY 2017 Q2, but no solution is presented.

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

Reviewer 1:

The reviewer opined that this supports DOE's EV Everywhere goals by enabling increases in energy density, specific ene gy, and power while maintaining safety.

Reviewer 2:

The reviewer offered that this effort is highly relevant to DOE objectives, and that advanced M&S tools will accelerate the development of cost effective advanced energy storage solutions with improved safety and performance characteristics.

Reviewer 3:

The reviewer asserted that this project provides a critically needed capability for the auto industry.

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

Reviewer 1:

It appeared to this reviewer that there are sufficient resources to address the technical barriers for this program

Reviewer 2:

None were noted by this reviewer.

Development and Validation of a Simulation Tool to Predict the Combined Structural, Electrical, Electrochemical, and Thermal Responses of Automotive Batteries: James Marcicki (Ford Motor Company) - es296

Presenter

James Marcicki, Ford Motor Company

Reviewer Sample Size

A total of three reviewers evaluated this project.

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

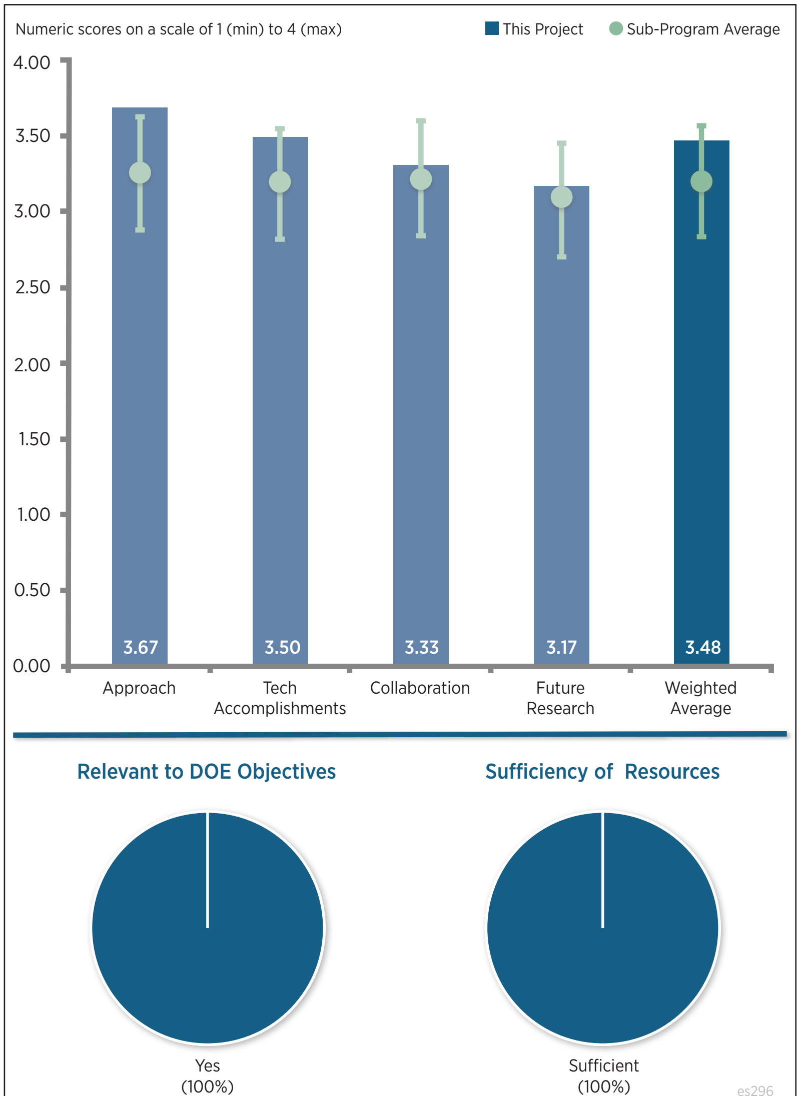

Figure 2-69 – Development and Validation of a Simulation Tool to Predict the Combined Structural, Electrical, Electrochemical, and Thermal Responses of Automotive Batteries: James Marcicki (Ford Motor Company) - Electrochemical Energy Storage

Reviewer 1:

This reviewer commended the approach used in this effort as very effective at addressing the technical barriers identified for this project. The reviewer further highlighted that one area of particular strength for this approach is the robust validation plan that has been put together.

Reviewer 2:

The reviewer reported that the approach involves building a front-end onto LS-DYNA that allows for battery pack analysis, and added that this is a very useful thing to do.

Reviewer 3:

This reviewer stated that the approach addressed the key barriers to understanding battery tolerance under mechanical abuse.

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

Reviewer 1:

This reviewer observed impressive technical achievement given that this project was started about four months ago.

Reviewer 2:

The reviewer pointed out that this is a new start program that began January 2016, and the team is already making very good progress developing and validating the initial models needed to complete this effort.

Reviewer 3:

This reviewer noted that the project is new, and few solid accomplishments are described compared to those in the NREL and ORNL projects.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that good collaboration appeared to be occurring and asked whether the modes to be developed in this project can fit into OAS

Reviewer 2:

This reviewer commented that the PI has assembled an effective collaborative team addressing the challenges associated with this effort. The reviewer suggested that collaboration with NSWC Carderock may be useful because it collects a significant amount of abuse data

Reviewer 3:

This person expressed concern about overlap among three groups who are doing more or less the same thing, led by ORNL, NREL, and Ford. The reviewer understood that DOE may feel it wants a competition in order to get the best results. The reviewer warned of a danger that the three groups will produce three different program sets that will be very difficult to compare, in case they do not happen to compute the same quantities. In that case, the reviewer cautioned that the community may start making incompatible predictions, which could lead to confusion and slow progress.

Of the three groups, ORNL seemed best positioned to this reviewer because ORNL is collaborating with both Ford and NREL. Without some overall coordination, this reviewer expressed concern that the result will be messy.

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

Reviewer 1:

The reviewer commented that a lot of work remains given that this is a new start program. This person further observed that the PI has laid out a very comprehensive plan to complete the work, with a particular strength being in the validation plan. The reviewer suggested that providing more info on the risks and approaches to mitigate the risks would be one area that may strengthen future work. This person found the critical issues and risks discussion to be very useful, and also recommended that additional discussion/consideration about how abuse testing is very dependent on the cell chemistry and cell design, as well as on the test condition, would be very useful.

Reviewer 2:

This reviewer suggested having battery validation in several different temperatures (such as one at low temperature) to represent vehicle environment.

Reviewer 3:

The reviewer noted that the problem of identifying minimum representative volume element size has not been addressed. The reviewer explained that mechanical failure is a statistical, not deterministic, process in which the presence and intensity of local flaws/inhomogeneities may control failure rate, and inquired about how this will be addressed.

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

Reviewer 1:

This reviewer found this effort to be highly relevant to DOE objectives. Advanced M&S tools, especially tools to increase abuse tolerance during crash systems will accelerate the development of cost effective advanced energy storage solutions for electrified vehicle platforms

Reviewer 2:

The goals of this project support the overall DOE objective for vehicle electrification, observed this reviewe .

Reviewer 3:

The reviewer asserted that this project provides a critically needed capability for the auto industry.

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

Reviewer 1:

It appeared to this reviewer that there are sufficient resources allocated to this project in order to achieve its goals

Reviewer 2:

The reviewer perceived that the team has sufficient resources to achieve the stated milestones

Acronyms and Abbreviations

3D	Three Dimensional
ABR	Advanced Battery Research
AC	Alternating current
ADP	Advanced drying process
Ah	Ampere-hour
ALD	Atomic Layer Deposition
AlF_3	Aluminum fluorid
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ARK	Abuse Reaction Kinetics
ARL	Army Research Lab
ARPA-E	Advanced Research Projects Agency - Energy
ASI	Area Specific Impedanc
ATR	Attenuated Total Reflectanc
BATT	Batteries for Advanced Transportation Technologies
BCMS	Battery/Capacitor Management System
BES	Office of Basic Ene gy Sciences
BMR	Battery Materials Research
BMS	Battery Management System
BNL	Brookhaven National Laboratory
BOM	Bill of Materials
C	Carbon
CAD	Computer-aided design
CAEBAT	Computer-aided engineering of batteries
CAM	Cathode Active Material
CAM-7	Proprietary cathode material for Li-ion batteries
CAMP	Cell Analysis, Modeling, and Prototyping
CC	Constant Current
CC/S	Carbon Sulfur Composite
CE	Coulombic Efficienc
Co	Cobalt
CO_2	Carbon Dioxide
CoS_2	A Cobalt-Sulfide Cattierit
Cu	Copper
CuF_2	Copper (II) Fluoride
CV	Cyclic Voltammetry
DME	Dimethoxyethane
DoD	Depth of Discharge
DOE	U.S. Department of Energy
DPP	Dynamic particle-packing
DSC	Differential Scanning Calorimetry
DST	Dynamic Stress Test

EC	Ethylene Carbonate
EIS	Electrochemical Impedance Spectroscopy
EOL	End-of-Life
EPD	Electrophoretic Deposition
EUCAR	European Council for Automotive R&D
EV	Electric Vehicle
FCC	First Cycle Capacity
FCE	First Cycle Efficienc
Fe	Iron
FeF_3	Iron Fluoride
FeS_2	Iron Sulfid
FGC	Full Gradient Cathode
FY	Fiscal Year
GM	General Motors
Gr/S	Graphite/Sulfur
HA	High-Active
HCMR	High Capacity Manganese Rich
HEV	Hybrid Electric Vehicle
ICL	Initial capacity loss
IL	Ionic Liquid
INL	Idaho National Laboratory
IR	Infrared
IrO_2	Iridium Oxide
kg	Kilogram
LBNL	Lawrence Berkeley National Laboratory
LCP	Lithium Cobalt Phosphate
LFO	Lithium Iron Oxide
LFP	Lithium Iron Phosphate
LFP	Iron Phosphate
Li	Lithium
Li_2CO_3	Lithium Carbonate
Li_2O	Lithium Oxide
Li_2S	Lithium Sulfid
LIB	Lithium Ion Battery
LiBOB	Lithium bis(oxalate)borate
LIC	Lithium-ion Conductor
$LiCoO_2$	Lithium Cobalt Oxide
$LiFePO_4$	Lithium-Iron Phosphate
LiFSI	Lithium Bis(flurosulfonyl)mid
Li-ion	Lithium Ion
LiO_2	Lithium Oxygen
$LiPF_6$	Effective electrolyte salt for lithium-ion battery
Li-S	Lithium-Sulfur

LiTFSI	Lithium Bis(Trifluoromethanesulfonyl)Imid
LMNO	Lithium-Manganese Nickel Oxide
LMO	Lithium Manganese Oxide
LMR	Lithium Manganese Rich
LNMO	Lithium Nickel Manganese Oxide
LS-DYNA	Non-linear finite element analysis software progra
LTO	Lithium Titanium Oxide
M&S	Modeling and Simulation
MERF	Materials Engineering Research Facility
MFCA	Multifunctional Cathode Additives
MFx	Metal Fluoride
Mg	Magnesium
Mn	Manganese
MSMD	Multi-Scale Multi-Domain
Na	Sodium
NaOH	Sodium hydroxide
NCA	Battery cathode material (nickel cobalt aluminum oxide)
NCA	Nickel Cobalt Aluminum
NCM	Nickel Cobalt Manganese
ND	Neutron diffraction
NDE	Non-Destructive Evaluation
Ni	Nickel
NMC	Nickel Manganese Cobalt oxide
NMO	Nickel Manganese Oxide
NMP	N-Methylpyrrolidone
NMR	Nuclear Magnetic Resonance
NREL	National Renewable Energy Laboratory
NSWC	Naval Surface Warfare Center
O_2	Oxygen
OAS	Open Architecture Software
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
ORR	Oxygen Reduction Reaction
OS	Organosilicon
PAA	Polyacrylic Acid
PE	Polyethylene
PEO	Polyethylene oxide
PEV	Plug-in Electric Vehicle
PFM	Poly(9,9-dioctylfuorene-co-9-fluorenone-co-methybenzoic este
PHEV	Plug-In Hybrid Electric Vehicle
PI	Principal Investigator
PNNL	Pacific Northwest National Laborator
PP	Polypropylene

PPy	Polypyrrole
PS	Polysulfid
PVDF	Polyvinylidene Difluorid
RASIC	Responsible, Approving, Supporting, Informed, and Consulted
R&D	Research and Development
S	Sulfur
SAE	Society of Automotive Engineers
SBIR	Small Business Innovation Research
SE	Selenium
SEI	Solid Electrolyte Interface
SEI	Solid Electrolyte Interface
SEM	Scanning Electron Microscope
SEO	Symmetric Polystyrene-block-poly (ethylene oxide)
Si	Silicon
Si-C	Silicon Carbon
SIMS	Secondary ion mass spectrometry
SLA	Sealed Lead Acid
SNL	Sandia National Laboratories
SOA	Semiconductor Optical Amplifier
SOC	State of Charge
SS	Start/Stop
SSEs	Solid State Electrolytes
SUS	Stainless Steel
SWCNT	Single Wall Carbon Nanotube
Ti	Titanium
TiS_2	Titanium Disulfide
TOF	Time of fligh
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Ene gy sustainability
UN	United Nations
USABC	U.S. Advanced Battery Consortium
USCAR	U.S. Council for Automotive Research
UV	Ultraviolet
V	Vanadium
V	Volt
VFM	Variable Frequency Microwaves
VIBE	Virtual Integrated Battery Environment
VTO	Vehicle Technologies Offic
Wh	Watt hour
XAS	X-ray Absorption Spectroscopy