1. Battery R&D

The Vehicle Technologies Office (VTO) supports research, development, demonstration, and deployment (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well innovations in connected infrastructure for significant systems-level energy efficiency improvement); innovative powertrains to reduce greenhouse gas (GHG) and criteria emissions from hard to decarbonize off-road, maritime, rail, and aviation sectors; and technology integration that helps demonstrate and deploy new technology at the community level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), VTO advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The Batteries subprogram supports the decarbonization of transportation across all modes, serves to increase American advancement/manufacturing of battery technology, and creates good paying jobs with the free and fair chance to join a union and bargain collectively. The subprogram supports research with partners in academia, national laboratories, and industry covered under the Energy Storage Grand Challenge key priority and four distinct crosscuts including: Critical Materials, Grid Modernization, Advanced Manufacturing, and Energy Sector Cybersecurity.

The subprogram supports early-stage R&D of high-energy and high-power battery materials, cells, and battery development that can enable industry to significantly reduce the cost, weight, volume, and charge time of plug-in electric vehicle (PEV) batteries. This activity is organized into three sub-activities: advanced battery materials research, advanced battery cell R&D, and battery recycling R&D. Advanced battery materials research is coordinated with the Critical Minerals Initiative and includes: early-stage research of new lithium-ion (Li-ion) cathode, anode, and electrolyte materials (currently accounting for 50% to 70% of PEV battery cost) and the development of "beyond Li-ion" technologies, such as lithium (Li) metal anodes, solid-state electrolytes (SSE), and sulfur-based cathodes, that have the potential to significantly reduce weight, volume, and cost reduction of over 80% 2008 baseline, with a target of $60/kWh.

Advanced battery cell R&D includes early-stage R&D of new battery cell technology that contains new materials and electrodes that can reduce the overall battery cost, weight, and volume while improving energy, life, safety, and fast charging. Battery recycling R&D includes the development of innovative battery materials recycling and reuse technologies, and the Lithium-Ion Battery Recycling Prize, both of which aim to assure sustainability and domestic supplies of key battery materials and minerals.

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 are summarized: the multiple choice and numeric score questions are presented in graph form for each project, and the expository text responses is summarized in paragraph form for each question. A table of the average numeric score for each question for each project is presented below.

Table 1-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
BAT028	Materials Benchmarking Activities for Cell Analysis, Modeling, and Prototyping (CAMP) Facility†	Wenquan Lu (Argonne National Laboratory)	1-8	3.60	3.30	3.70	3.40	3.44
BAT164	Advanced Processing Science for Novel Battery Electrode Architectures	Jianlin Li (Oak Ridge National Laboratory)	1-12	3.50	3.50	3.25	3.33	3.45
BAT167	Process Development and Scale-Up of Advanced Active Battery Materials	Ozge Kahvecioglu (Argonne National Laboratory)	1-17	3.50	3.50	3.88	3.50	3.55
BAT168	Process Development and Scale-Up of Critical Battery Materials - Continuous Flow-Produced Materials	Krzysztof Pupek (Argonne National Laboratory)	1-21	3.42	3.33	3.75	3.42	3.42
BAT226	Probing Interfacial Processes Controlled Electrode Stability in Rechargeable Batteries†	Chongmin Wang (Pacific Northwest National Laboratory)	1-26	3.50	3.25	3.75	3.38	3.39
BAT230	Nanostructured Design of Sulfur Cathode for High-Energy Lithium-Sulfur Batteries†	Yi Cui (Stanford University / SLAC National Accelerator Laboratory)	1-30	3.50	3.63	3.50	3.50	3.56
BAT232	High Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions	Vincent Battaglia (Lawrence Berkeley National Laboratory)	1-34	3.25	3.33	3.25	3.08	3.27
BAT280	Novel Chemistry: Lithium-Selenium and Selenium-Sulfur Couple†	Khalil Amine (Argonne National Laboratory)	1-39	3.50	3.38	3.13	3.38	3.38

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
BAT285	Investigation of Sulfur Reaction Mechanisms†	Deyang Qu (University of Wisconsin at Milwaukee)	1-44	3.50	3.50	3.30	3.40	3.46
BAT315	Process R&D for Droplet-Produced Powdered Materials	Joe Libera (Argonne National Laboratory)	1-50	3.10	3.00	3.00	3.00	3.03
BAT360	Scale-up, Optimization and Characterization of High-nickel Cathodes†	Arumugam Manthiram (University of Texas at Austin)	1-55	3.38	3.25	2.75	3.00	3.19
BAT362	High-Capacity S Cathode Materials†	Prashant Kumta (University of Pittsburgh)	1-59	3.50	3.30	3.50	3.20	3.36
BAT367	Multiscale Characterization Studies of Li Metal Batteries†	Peter Khalifah (Brookhaven National Laboratory)	1-63	3.50	3.50	3.70	3.30	3.50
BAT368	Full Cell Diagnostics and Validation to Achieving High Cycle Life†	Eric Dufek (Idaho National Laboratory)	1-68	3.14	3.00	3.29	2.64	3.03
BAT377	ReCell–Overview and Update	Jeffrey Spangenberger (Argonne National Laboratory)	1-74	3.00	3.00	3.38	3.13	3.06
BAT386	eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Overview and Progress Update	Venkat Srinivasan (Argonne National Laboratory)	1-79	3.50	3.83	3.83	3.67	3.73
BAT423	Development of New Electrolytes for Lithium-Sulfur Batteries†	Gao Liu (Lawrence Berkeley National Laboratory)	1-82	3.50	3.40	3.50	3.40	3.44
BAT427	In Situ and Operando Thermal Diagnostics of Buried Interfaces in Beyond Lithium-Ion Cells†	Sumajeet Kaur (Lawrence Berkeley National Laboratory)	1-87	3.00	3.00	2.00	2.83	2.85
BAT429	Electrolytes and Interfaces for Stable High Energy Sodium-Ion Batteries†	Jason Zhang (Pacific Northwest National Laboratory)	1-90	3.38	3.38	3.25	3.38	3.36

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
BAT456	eXtreme Fast Charge Electrode and Cell Design Thrust	Andrew Jansen (Argonne National Laboratory)	1-94	3.50	3.33	3.83	3.33	3.44
BAT463	eXtreme Fast Charge Electrochemical and Thermal Performance Thrust	Eric Dufek (Idaho National Laboratory)	1-97	3.67	3.50	3.50	3.50	3.54
BAT470	Process R&D Using Supercritical Fluid Reactors	Youngho Shin (Argonne National Laboratory)	1-100	3.33	3.42	3.42	3.33	3.39
BAT475	Towards Solventless Processing of Thick Electron-Beam (EB) Cured Lithium-Ion Battery Cathodes	Zhijia Du (Oak Ridge National Laboratory)	1-106	3.50	3.50	3.42	3.25	3.46
BAT524	Advanced Electrolytes for Li Metal Batteries†	Chunsheng Wang (University of Maryland)	1-112	3.63	3.50	3.50	3.50	3.53
BAT528	Structurally and Electrochemically Stabilized Silicon-rich Anodes for Electric Vehicle Applications†	John Thorne (Enovix)	1-116	3.17	3.17	3.17	3.17	3.17
BAT529	Rationally Designed Lithium-Ion Batteries Towards Displacing Internal Combustion Engines†	Rick Costantino (Group 14 Technologies)	1-119	3.67	3.33	3.50	2.83	3.38
BAT531	Solid State Lithium-ion Batteries Using Silicon Composite Anodes†	Pu Zhang (Solid Power Battery)	1-122	3.17	3.00	2.67	3.00	3.00
BAT532	Electrolytes with Lithium-ion Batteries with Micro-sized Silicon Anodes†	Chunsheng Wang (University of Maryland)	1-125	3.13	2.88	3.38	2.75	2.98
BAT533	Fluorinated Local High Concentration Electrolytes Enabling High Energy Density Silicon Anodes†	Amy Marschilok (Stony Brook University)	1-129	3.00	3.17	3.17	2.83	3.08
BAT534	Devising mechanically compliant and chemically stable synthetic solid-electrolyte interphases on silicon†	Pierre Yao (University of Delaware)	1-132	3.17	2.83	3.17	2.83	2.96

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
BAT544	Machine Learning for Accelerated Life Prediction and Cell Design	Eric Dufek (Idaho National Laboratory)	1-135	3.63	3.50	3.63	3.50	3.55
BAT546	Scaling-Up and Roll-to-Roll Processing of Highly Conductive Sulfide Solid-State Electrolytes	Dongping Lu (Pacific Northwest National Laboratory)	1-139	3.10	3.30	3.30	2.70	3.18
BAT547	Continuous high yield production of defect-free, ultrathin sulfide glass electrolytes for next generation solid state lithium metal batteries	Tim Fister (Argonne National Laboratory)	1-143	3.40	3.30	3.30	3.30	3.33
BAT548	Scale-Up of Novel Li-Conducting Halide Solid State Battery Electrolyte	Mike Tucker (Lawrence Berkeley National Laboratory)	1-147	3.50	3.40	3.30	3.10	3.38
BAT571	ReCell Center-Direct Recycling of Materials	Jessica Durham Macholz (Argonne National Laboratory)	1-152	3.25	3.13	2.88	2.75	3.08
BAT572	ReCell Center-Advanced Resource Recovery	Yaocai Bai (ORNL)	1-156	2.88	3.00	2.75	2.88	2.92
BAT573	ReCell Center-Design for Sustainability	Andrew Colclasure (NREL)	1-160	2.75	2.75	2.50	2.75	2.72
BAT574	ReCell Center-Modeling and Analysis	Allison Bennett Irion (Argonne National Laboratory)	1-164	3.38	3.38	3.75	3.25	3.41
BAT575	eXtreme Fast Charge Electrolyte Development Thrust	Bryan McCloskey (Lawrence Berkeley National Laboratory)	1-168	3.67	3.67	3.67	3.50	3.65
BAT576	Solid State Batteries with Long Cycle Life and High Energy Density	Haegyum Kim (Lawrence Berkeley National Laboratory)	1-171	3.38	3.25	3.38	3.38	3.31
BAT577	Low-Pressure All-Solid State Cells	Tony Burrell (National Renewable Energy Laboratory)	1-175	3.50	3.17	3.67	3.33	3.33

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
BAT578	Stable Solid-State Electrolyte and Interface for High-Energy Density Lithium-Sulfur Battery	Dongping Lu (Pacific Northwest National Laboratory)	1-178	3.60	3.70	3.50	3.40	3.61
BAT579	Multifunctional Gradient Coatings for Scalable High-Energy Density Sulfide-Based Solid-State Batteries	Justin Connell (Argonne National Laboratory)	1-183	3.25	3.38	3.50	2.75	3.28
BAT580	Thick Selenium-Sulfur Cathode Supported Ultra-thin Sulfide Electrolytes for High-Energy All-Solid-State Batteries	Guiliang Xu (Argonne National Laboratory)	1-187	2.80	2.90	2.80	3.00	2.88
BAT581	Precision Control of the Lithium Surface for Solid-State Batteries	Andrew Westover (Oak Ridge National Laboratory)	1-192	3.20	3.00	3.00	3.20	3.08
BAT582	Inorganic-Polymer Composite Electrolytes with Architecture Design for Lithium Metal Solid-State Batteries	Enyuan Hu (Brookhaven National Laboratory)	1-196	3.00	2.75	2.88	2.88	2.84
BAT583	Development of All-Solid-State Battery Using Anti-Perovskite Electrolyte	Zonghai Chen (Argonne National Laboratory)	1-201	3.30	3.30	2.90	3.20	3.24
BAT584	Integrated Atomic-, Meso-, and Micro-Scale Diagnostics of Solid-State Batteries†	William Chueh (Stanford University/ SLAC National Accelerator Laboratory)	1-206	3.50	3.30	3.00	3.50	3.34
BAT585	Anode-Free Lithium Batteries†	Jason Zhang (Pacific Northwest National Laboratory)	1-211	3.00	2.88	3.00	3.25	2.97
BAT586	Earth-abundant Cathode Active Materials for Li-Ion Batteries: Cathode Design and Synthesis†	Jason Croy (Argonne National Laboratory)	1-216	3.20	3.10	3.20	3.00	3.13
BAT588	Earth-abundant Cathode Active Materials for Li-Ion Batteries: System Analysis†	Daniel Abraham (Argonne National Laboratory)	1-221	3.25	3.38	3.38	3.13	3.31
BAT589	Cation-disordered Cathode Materials (DRX+) - Synthesis, Scale-up and Cell Testing†	Guoying Chen (Lawrence Berkeley National Laboratory)	1-225	3.67	3.58	3.33	3.50	3.56

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
BAT592	Advanced Anode Manufacturing Through Ultra-Thin Li Deposition	Subramanya Herle (Applied Materials, Inc.)	1-230	3.50	3.38	3.88	3.38	3.47
BAT593	Strategies to Enable Lean Electrolytes for High Loading and Stable Lithium-Sulfur Pouch†	Shirley Meng (University of California at San Diego)	1-234	3.50	3.13	3.50	3.25	3.28
BAT594	New Engineering Concepts to High Energy Density Li-S Batteries†	Prashant Kumta (University of Pittsburgh)	1-238	3.00	2.88	2.38	2.88	2.84
BAT595	Development of Li-S Battery Cells with High Energy Density and Long Cycling Life†	Donghai Wang (Penn State University)	1-242	3.50	3.50	3.10	3.30	3.43
BAT596	Development of a High-Rate Li-Air Battery using a Gaseous CO_2 Reactant†	Amin Salehi-Khojin (University of Illinois at Chicago)	1-246	3.50	3.50	3.33	3.00	3.42
Overall Average				**3.34**	**3.27**	**3.29**	**3.18**	**3.28**

† Denotes a poster presentation.

Presentation Number: BAT028
Presentation Title: Materials Benchmarking Activities for Cell Analysis, Modeling, and Prototyping (CAMP) Facility
Principal Investigator: Wenquan Lu (Argonne National Laboratory)

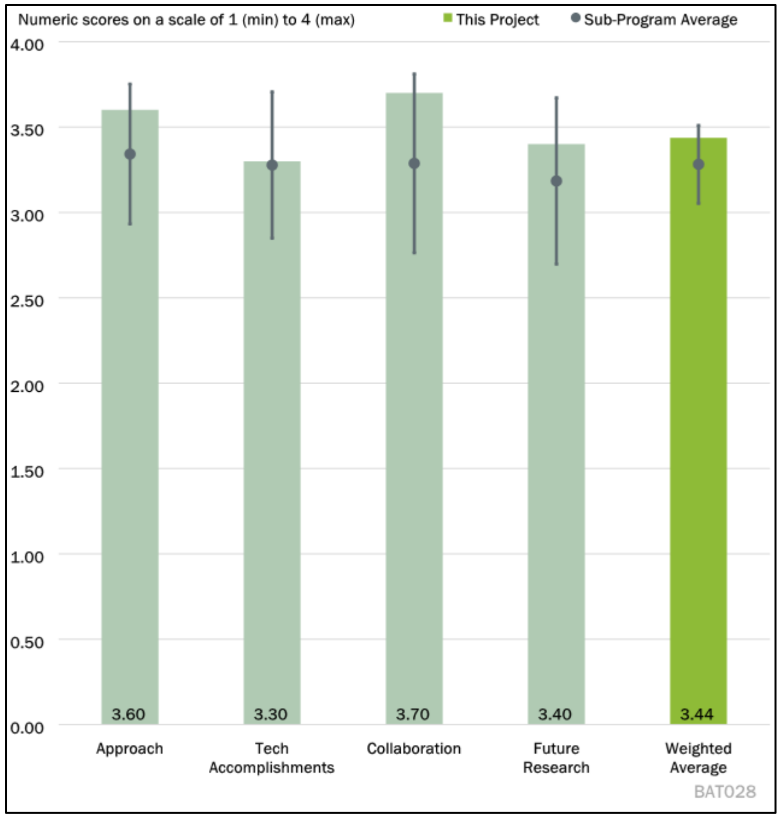

Figure 1-1 - Presentation Number: BAT028 Presentation Title: Materials Benchmarking Activities for Cell Analysis, Modeling, and Prototyping (CAMP) Facility Principal Investigator: Wenquan Lu (Argonne National Laboratory)

Presenter

Wenquan Lu, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted that the project addressed one of the two technical barriers, specifically focusing on high-energy active materials' identification and evaluation in coin cells. These materials included SSE, modified NMC523, SiO, and carbon nanotube (CNT) conductive agent. The project failed to elucidate how these efforts would address the barrier of creating sustainable electric vehicle (EV) batteries that meet or exceed the DOE/U.S. Advanced Battery Consortium (USABC) goals. However, from email correspondence with the principal investigator (PI), it was evident that they understood and had plans to test in full pouch cells, projecting performance for larger EV batteries.

Reviewer 2:

The reviewer observed that the project's aim was to provide benchmarking services for battery material developers using a standard protocol with 2032 coin cells. Although this facility is vital for battery R&D programs, it presents no significant technical challenges. Electrochemical tests on battery cells are a common practice in the battery community. The team appeared to have undertaken activities beyond just benchmarking, as evidenced by the delayed milestone mentioning the coating of a thin layer of ceramic. The reviewer noted the absence of a defined timeline beyond March 2023.

Reviewer 3:

The reviewer acknowledged that the 2022 timeline was met, but delays were observed for the thin-film milestone set for early 2023. The SSEs polyethylene glycol diacrylate (PEGDA) and lithium lanthanum zirconate (LLZO), were relevant due to their elasticity against volume changes and high stability, respectively. Various electrolytes were studied, but performance testing in full EV cells was not conducted. The reviewer emphasized the need for high-capacity cathodes made from abundant crustal materials to reduce costs. NCM523, presented as an option to reduce Ni and Co usage, was highlighted. The reviewer also commended the PI's efforts to enhance cyclability, concluding that the technical barriers were addressed in a well-structured project with a feasible schedule.

Reviewer 4:

The reviewer found the technical barriers clearly defined and addressed. However, they wished the third task on the milestones slide (Slide 4) had an estimated completion time instead of merely being labeled as "Delayed."

Reviewer 5:

The research concentrated on active and additive materials, including additives for solid polymer electrolyte (SPE), nickel manganese cobalt (NMC) coating with Al_2O_3, SiO annealing, and carbon additives in the cathode mix. The reviewer pointed out these activities were geared toward meeting the cost and performance goals set by the DOE/USBAC.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated the annual milestone experienced delays due to supply chain interruptions caused by COVID-19.

Reviewer 2:

The project's objective was to identify and evaluate cell chemistries, and the technical accomplishments centered around SPE, NCM523 surface modification, SiO anode heat treatment, and electrode conductivity improvement using CNT. The reviewer confirmed these activities were aligned with the project's objectives, covering recent developments in cathodes, anodes, and electrolytes.

Reviewer 3:

Two out of three milestones were met, with one being delayed, according to the reviewer.

Reviewer 4:

The reviewer praised the work, noting that various materials were synthesized, characterized, and tested at the CAMP facility. They recommended mentioning if all five studied materials were initially provided by material developers and strongly advised testing using a single-layer pouch cell, skipping coin cell tests.

Reviewer 5:

The reviewer found the research progress consistent with the project plan, with notable achievements. Despite a delay caused by supply chain disruptions, the balance between research and validation was tipped more towards the former. The reviewer suggested a more balanced approach for future endeavors.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer deemed collaboration within the project as outstanding. While extensive collaborations existed both internally at Argonne National Laboratory (ANL) and externally with various industrial companies and universities, the reviewer felt that the individual contributions of the institutes remained unspecified.

Reviewer 2:

The reviewer recommended naming collaborators in the technical accomplishments section.

Reviewer 3:

The reviewer saw that while the project had numerous partners from national laboratories, universities, and industries, specific contributions from these entities were not clearly delineated.

Reviewer 4:

The reviewer remarked that it is great to see that collaboration has been extended not only to multiple national laboratories but also to many universities and most importantly to many industrial material, equipment, and cell developers.

Reviewer 5:

The reviewer commented that the research work was well coordinated; however, the roles and contributions from different collaborators are not well specified.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer noted that the project clearly defined a purpose for its future work and deemed the plan achievable.

Reviewer 2:

The reviewer stated that one persistent challenge was the identification of high-energy active materials. The primary obstacle was identified as accessing these advanced active materials. As the project’s main focus was on benchmarking rather than R&D, this hurdle was not viewed as a technical challenge but rather as a public relations or outreach mission. The reviewer also highlighted that since future activities largely relied on inputs from research institutes and industry developers, it was not practical for the project team to define future endeavors internally.

Reviewer 3:

The reviewer acknowledged that while the areas for continued research were clearly identified, a more in-depth definition of the active materials, specifically the cathode and anode, was necessary. They also pointed out that the rationale for persisting with the research on the selected topic was not explicitly mentioned.

Reviewer 4:

In terms of the proposed future work, the reviewer found it to be very well articulated in alignment with the project’s objective. They offered a suggestion: to study the higher nickel cathode, specifically NCM 811, and expressed curiosity about the selection of NCM532 for the project.

Reviewer 5:

The reviewer confirmed that the project had a distinct direction for future work, detailing each task. They believed that the upcoming research was poised to successfully meet its goals.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer observed that the project persistently emphasized screening and evaluating new battery materials. This effort aimed to augment the CAMP electrode library and bolster the CAMP facility's prototyping capabilities, aligning with the broader goals of the VTO subprogram.

Reviewer 2:

The reviewer found the project's objectives to be in sync with the VTO program's expectations.

Reviewer 3:

The reviewer noted that the project extended its support to various domains, including analysis, batteries, energy-efficient mobility systems, and materials. Emphasis was placed on the evaluation of electrolytes in full cells and enhancing cathode structures to optimize battery cycle life.

Reviewer 4:

The reviewer identified the project as supportive of the VTO Batteries subprogram within the VTO's objectives.

Reviewer 5:

The reviewer underscored the project's dedication to benchmarking and fostering a deeper comprehension of the active and additive materials. The reviewer emphasized that such endeavors undoubtedly fortify the CAMP facility's role in prototyping cells and nurturing the development of its electrode library, which serves the overarching VTO subprogram objectives.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer believed that the project had adequate resources to achieve the designated milestones punctually. They suggested a possible reorientation: if the project could direct more efforts towards screening and evaluating battery materials in larger cells, specifically 1–2 Ah cells, instead of relying solely on coin cells, it might offer more pertinent outcomes. These results, the reviewer felt, would better align with the VTO's objectives for EV battery development. While coin cells offer a rapid means for material screening, it is beneficial to validate performance in larger pouch cells.

Reviewer 2:

The reviewer noted that while resources were deemed sufficient for the task at hand, the report did not provide clarity on future milestones.

Reviewer 3:

Regarding the CAMP facility, the reviewer highlighted that its collaboration with various partners augmented its capability to contribute to and bolster the final, scalable products across industries.

Reviewer 4:

The reviewer stated that the project's resources were aptly allocated and were sufficient.

Reviewer 5:

While resources were generally seen as ample to meet the outlined milestones, the reviewer pointed out the potential for delays, stemming from supply chain disruptions.

Presentation Number: BAT164
Presentation Title: Advanced Processing Science for Novel Battery Electrode Architectures
Principal Investigator: Jianlin Li (Oak Ridge National Laboratory)

Presenter

Jianlin Li, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

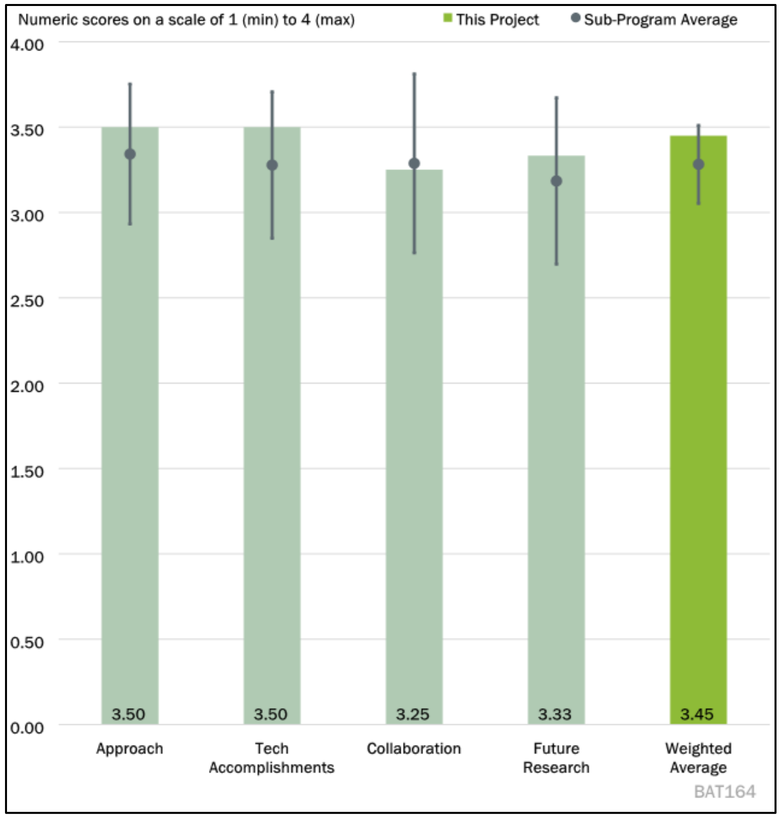

Figure 1-2 - Presentation Number: BAT164 Presentation Title: Advanced Processing Science for Novel Battery Electrode Architectures Principal Investigator: Jianlin Li (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted that the project primarily proposed two significant tasks: demonstrating a two-layer thick cathode and demonstrating a working solid-state battery (SSB). The task to fabricate a two-layer thick cathode aimed to improve energy and power density, and it was both justified and well-designed.

Reviewer 2:

The reviewer observed that the project aimed to increase electrode loading by creating a thick electrode. The primary technical barrier addressed was the compromise between energy density and power density. The two-layer electrode design, which included an energy layer and a power layer, was compelling. The freeze casting technique, which was anticipated to enhance Li diffusion rates, was of particular interest. The PI was advised to examine the porosity, specifically the pore distribution, of both layers to further refine the electrode creation process.

Reviewer 3:

The reviewer found the project to be highly challenging. During the review period, the team appeared to have more successfully tackled issues related to understanding cathode processing than they had with optimizing and addressing cost issues.

Reviewer 4:

The reviewer believed that the approach presented was logical. The objectives for future work into 2024 were clear. However, the target completion date of Sept. 30, 2024 (as mentioned on Slide 2) seemed ambitious, and the project might require additional time and effort.

Reviewer 5:

The reviewer noted that the work directly addressed the problems highlighted, such as the cracking of thick coatings with a water solvent and the long cycle-life of SSBs.

Reviewer 6:

The reviewer commented that the research work was conducted closely aligned with the stated barriers. From their observation, the study appeared to be well-planned and was progressing smoothly.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer observed that the two-layer cathode had effectively showcased improved rate performance. This task was completed punctually. The challenge associated with making the lower layer denser was aptly identified. Additionally, the conundrum of achieving both high porosity and high electrical conductivity was also accurately identified and communicated. While a working SSB was presented with several challenges highlighted, the reason for the bottom layer still being fabricated through a conventional process—instead of the freeze casting method—remained ambiguous. Was this a result of the interface between the two layers or because the bottom layer made by the freeze casting method could not be as dense as the conventionally produced ones? A study delving into this would benefit the understanding or enhancement of the two-layer manufacturing process.

Reviewer 2:

The reviewer mentioned that the electrode's performance was tested in different systems, including a solid-state one. An impressive performance from a high loading electrode was displayed. The PI was advised to systematically probe the impact of various process parameters on electrode performance.

Reviewer 3:

The reviewer noted that the experiments were well-conceived to address vital questions, yet there remained numerous unresolved issues. The concept of the two-layer porosity electrode intrigued the reviewer, but the specifics, like how Li transport would function, especially in cases of lower porosity, were vague. Further examination of this problem was deemed essential. While rate performance and cycle life improvements were commendable, the experiment testing ionic conductance lacked clarity. Analyses concerning different salts (lithium bis(fluorosulfonyl)imide [LiFSI] vs. lithium bis(trifluoromethanesulfonyl)imide [LiTFSI]) appeared to be of limited value. Given the multitude of variables, it was challenging to pinpoint the most pivotal ones. Mentions of nanoscale domains and solid-electrolyte-interphase (SEI) composition were present, but their connection to cell performance or processing specifics was not established.

Reviewer 4:

The reviewer found the findings concerning cluster domain formation with LiFSI vs. LiTFSI to be engaging. More extensive details on freeze casting process parameters would have been beneficial. Beyond solids content, were there other variables influencing pore structure, such as freezing rate, particle size, or solvent composition? Even if altering these parameters was not feasible, and presentation time was restricted, sharing more insights about the freeze casting process would have provided a more comprehensive grasp.

Reviewer 5:

The reviewer acknowledged the team's clear progress in slurry coatings using the freeze tape casting process and their significant headway regarding cell cycle life with the LiTFSI solid-state polymer electrolyte. However, the cathode-specific capacity was on the lower side (100 mAh/g as opposed to the approximately 170 mAh/g of traditional NMC622). Moreover, evident challenges persisted, especially concerning the SSE, like the high current density Li stripping issue.

Reviewer 6:

The reviewer commented that all preliminary results appeared encouraging. This included the aqueous-based ink and coating, the electrode architecture design and preparation, and its performance in solid-state cells. Concerns potentially impacting future industrialization were also assessed and addressed.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the collaboration concentrated on material aspects, particularly on the electrolyte, cathode synthesis, and binder selection. The findings were disseminated to battery manufacturers for the potential integration of this technology.

Reviewer 2:

The reviewer highlighted that the PI collaborated with a diverse group, including those from material manufacturing, equipment manufacturing, universities, and national laboratories. The PI was encouraged to showcase the results of these collaborations and their subsequent impact.

Reviewer 3:

The reviewer mentioned that a range of collaborations had been initiated with both academia and industry.

Reviewer 4:

From the reviewer's observation, there seemed to be a multitude of partnerships: collaborations with other laboratories and universities for analytical endeavors, with commercial material suppliers for diverse materials, and with equipment suppliers, among others. The transition of these processes to a more scalable and continuous operation was of interest, especially given the current assumption that many processes were executed in batches.

Reviewer 5:

While the reviewer recognized the existing collaborations associated with certain tasks, they expressed a desire for a more detailed explanation of the interactions and dynamics between the partners.

Reviewer 6:

The reviewer commended the well-orchestrated research efforts across universities, national laboratories, and material suppliers. Although some findings awaited further validation from battery manufacturers and extended evaluations in end products, the PI's proactive approach in sharing the results with leading battery manufacturers was lauded.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer recognized the absence of an established fabrication method for SSBs, signaling a distinct avenue for upcoming research. However, there was ambiguity regarding the chosen fabrication technique for future studies and how this research would address the identified fabrication challenges.

Reviewer 2:

The reviewer observed that the planned future research aligned with the project's objectives, aiming to surmount barriers. Specifically, the assessment of the electrode/SSE interface could enhance comprehension of SSE batteries. The PI was urged to undertake more comprehensive cell testing.

Reviewer 3:

The reviewer deemed the future plans to be logical and in harmony with the outlined research.

Reviewer 4:

The reviewer conveyed enthusiasm for the work in progress, noting that the steps for the remainder of 2023 were well-defined. However, there was a concern about the projected end date of Sept. 30, 2024, as presented on Slide 2. The objectives detailed on Slide 17 for Fiscal Year (FY) 2024 seemed ambitious, hinting at significant forthcoming work that might necessitate considerable effort.

Reviewer 5:

The reviewer acknowledged that the team had pinpointed several tasks addressing the program's deficiencies and had identified the primary technical hurdles that remained to the program's success.

Reviewer 6:

The reviewer commended the project for its lucid definition of both near-term and mid-term research priorities and objectives. The alignment of these with the highlighted barriers was appreciated. The PI's emphasis on future commercialization activities was notably lauded.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that the project aimed to fabricate thick electrodes with distinct architectures. This direction aligned with the VTO objectives of achieving high-performing EV batteries and cells. By addressing the project's goal, there was potential to enhance the charge rate performance, while adhering to specific energy density requirements and taking into consideration fabrication method constraints. A key observation was that augmenting the thickness, or areal capacity, of the electrodes could boost a battery cell's energy. This enhancement came from amplifying the quantity of active material and concurrently reducing the proportional cost of other inactive components.

Reviewer 2:

The reviewer remarked that the project bolstered the overarching VTO objectives. This was achieved by exploring ways to augment the energy density of SSBs, particularly by utilizing a high loading electrode.

Reviewer 3:

For the reviewer, the project's relevance was evident in its commitment to forging low-cost, thick cathodes that deliver commendable battery performance. Such an endeavor was deemed crucial for the VTO's mission.

Reviewer 4:

The reviewer recognized the project's clear orientation towards propelling battery technology forward. This advancement spanned both innovative architectures, like controlled cathode pore structure and electrolyte morphology, and novel manufacturing methodologies such as freeze tape casting. The project's endeavors were viewed as invigorating.

Reviewer 5:

The reviewer acknowledged the program's pertinence in advancing battery research. The focus was on crafting high-energy density/medium power NMC battery systems and furthering exploration into SSBs, which represented a future trajectory for Li-ion batteries (LIBs).

Reviewer 6:

The reviewer emphasized that the project supported the VTO subprogram's goals. These encompassed reducing battery-related expenses while simultaneously enhancing cell energy and power density.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed that the team was equipped with a pilot-scale coater, a dry room, and pouch cell evaluation facilities at Oak Ridge National Laboratory (ORNL) to realize the stipulated objectives.

Reviewer 2:

The PI and their collaborators, according to the reviewer, possessed adequate resources to carry out the proposed research.

Reviewer 3:

The reviewer stated that the resources were satisfactory.

Reviewer 4:

Looking ahead, the reviewer noted that if the project exhibited potential in 2024, there might be a need for additional resources to upscale the technology.

Reviewer 5:

The reviewer acknowledged the adequacy of the program's resources and collaborations. The team seemed well-positioned to attain their objectives. The achievement of key milestones, especially pertaining to the solid-state segment, would depend on the team's technical prowess and cooperative endeavors.

Reviewer 6:

The reviewer emphasized that the researchers had ample resources at their disposal to meet the project's set milestones.

Presentation Number: BAT167
Presentation Title: Process Development and Scale-Up of Advanced Active Battery Materials
Principal Investigator: Ozge Kahvecioglu (Argonne National Laboratory)

Presenter

Ozge Kahvecioglu, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

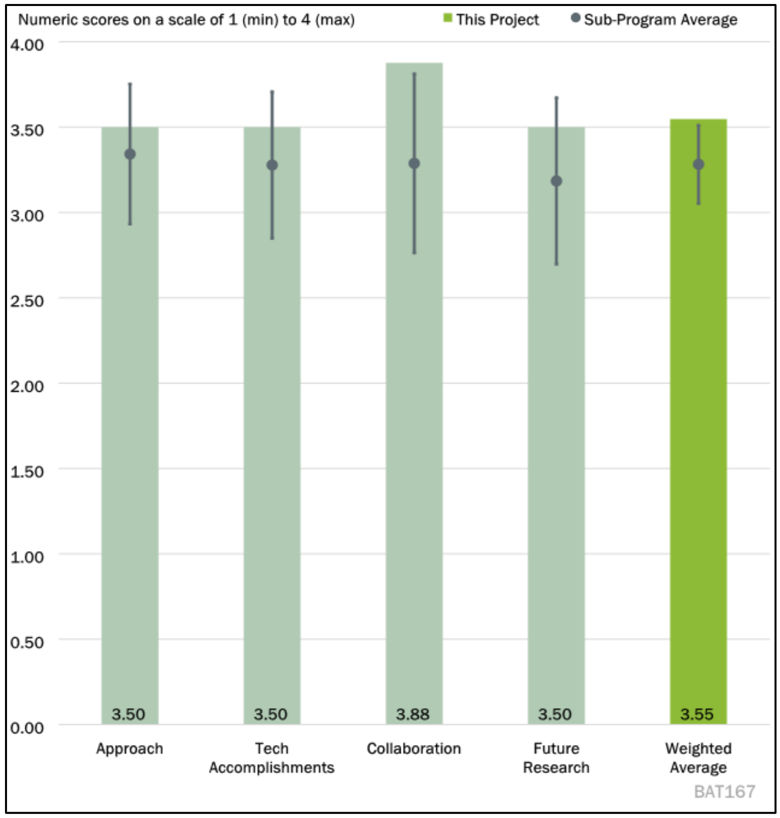

Figure 1-3 - Presentation Number: BAT167 Presentation Title: Process Development and Scale-Up of Advanced Active Battery Materials Principal Investigator: Ozge Kahvecioglu (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer highlighted that the project had dual objectives: first, to supply the upstream with high-quality precursor cathode active materials (pre-CAMs) for the US battery research communities, aiding in the development of new CAM synthesis and innovative synthesis methodologies; and second, to devise manufacturing processes for pre-CAM and CAM that are both scalable to industry standards and cost-effective. The reviewer praised the program, noting its considerable successes and numerous technical achievements.

Reviewer 2:

The PI was acknowledged by the reviewer for directing a commendable array of research and development projects centered on CAM and pre-CAM evolution. The PI’s adept use of continuous stirred-tank reactor (CSTR) and thermal vapor recompression (TVR) instruments within the Materials Engineering Research Facility (MERF) was noted. The reviewer expressed admiration for the extensive work undertaken by the PI, particularly emphasizing the significant progress in creating nickel manganese (NiMn) lithium-rich CAMs for earth-abundant cathode material (EaCAM).

Reviewer 3:

The reviewer emphasized that the project was thoughtfully designed, encompassing clear objectives that addressed both technical and financial aspects. The assembled team, as per the reviewer, was strategically chosen to facilitate rapid and reliable feedback.

Reviewer 4:

The reviewer remarked on the project's successful alignment with its defined objectives and the prevailing challenges in this sector. The organized and effective approach towards achieving specific targets was commended.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer highlighted the project team's significant role in supporting multiple VTO Batteries subprogram (BAT) projects in their research and development, notably BAT569, BAT183, and BAT402, along with numerous other battery programs. The team's commitment to catering to the specific needs of these projects by providing tailored high-quality pre-CAMs is noteworthy. They have shown agility in their research approach by continually refining and improving the synthesis procedures based on the requirements of the broader battery research community and scaling needs of battery manufacturers.

Reviewer 2:

The reviewer commented that the team, in its recent breakthroughs, has shifted towards the production of carbonate precursors. This move has curtailed the need for ammonia in the co-precipitation process when compared to the hydroxide route. Such innovations demonstrate a conscious effort towards making battery material production more environmentally friendly while also cutting down production costs.

Reviewer 3:

The reviewer noted that the PI's work is commendable. There has been a clear demonstration of progress and tangible outcomes across all the research projects under his/her leadership. One of the significant highlights being that the discharge capacity of most of the CAMs developed by the PI is on par, if not superior to, the current state of the art.

Reviewer 4:

The reviewer stated that BAT167A's study is thorough and astutely addresses both the technical and economic facets of cathode materials for LIBs. The reviewer posed certain critical questions to the PI and the team, especially concerning their presentation on Slide 6. The queries revolve around the lithium manganese rich-nickel manganese cobalt material (LMR-NMC) synthesis, its time efficiency, particle integrity in the fast vs. slow carbonate routes, and potential discrepancies in the cathode calendering process for the two routes. Further, there is curiosity about the significance of the TVR method in commercial cathode manufacturing. A suggestion was also provided, emphasizing the potential benefits of researching the impact of Li salt particle size on cathode material synthesis and performance. Lastly, the reviewer praised the project's holistic approach, especially the utilization of real-time particle tracking and multi-scale modeling. It's evident that the project is fulfilling its objective of supplying materials to other laboratories and projects, which aligns with its overarching mission. However, the reviewer also pointed out areas that could benefit from further elaboration, such as understanding the behavior of particle aggregates and connecting them to specific processing steps.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commended the collaborative nature of the project, showcasing a synergistic relationship between the project and the broader battery research communities. The collaborations span a multitude of research directions, highlighted by partnerships with entities such as the DRX+ consortium and those focusing on EaCAM.

Reviewer 2:

The reviewer noted that the Materials Engineering Research Facility (MERF) inherently demands the synthesis and development of preCAMs and cathode active materials (CAMs). The PI's ability to excel in this domain is evidenced by the high quantity and quality of the preCAMs and CAMs that have been developed. These achievements underscore the PI's cooperative and collaborative spirit. Her commitment to supporting various projects, ensuring their success, stands out prominently.

Reviewer 3:

The reviewer stated that the project's collaboration is all-encompassing, reaching beyond just the ANL. Noteworthy partnerships with institutions like the Brookhaven National Laboratory (BNL) and Virginia Tech have been instrumental in bringing pivotal insights that have furthered the project's objectives.

Reviewer 4:

The reviewer underlined the widespread collaborations with esteemed academic institutions and national laboratories in the project's comprehensive approach.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer highlighted the team's clear understanding of the remaining challenges. They've outlined a future research plan that addresses the US battery community's needs regarding active cathode materials. A significant milestone would be the team's development of procedures that eliminate the use of ammonia in pre-CAM production.

Reviewer 2:

The reviewer appreciated the thoughtfulness of the plan, particularly emphasizing the strategies laid out for the EaCAM consortium.

Reviewer 3:

The reviewer underscored the importance in future work of understanding the stability of Mn in a hydroxide precursor. The idea of replacing other metal ions for Co was also flagged as noteworthy, with a call to delve into the implications of introducing different non-transition metal ions on both structural and electrochemical performance.

Reviewer 4:

The reviewer noted that the proposed research is well-aligned with the identified challenges.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized that the synthesis of CAMs is pivotal to the development of Li-ion batteries. The efforts of the project play a vital role in propelling vehicle electrification forward, aligning with the primary objective of VTO.

Reviewer 2:

The reviewer noted the importance of the PI’s work in relation to VTO objectives. Given that the CAM accounts for about one-third of the cost of Li-ion cells for EVs, the development of innovative preCAMs, CAMs, and their fabrication methods becomes incredibly pertinent to VTO goals.

Reviewer 3:

For the reviewer, the role of the cathode in determining the electrochemical performance of a LIB is indispensable. Thus, the need for a synthesis method that’s both scalable and cost-effective becomes paramount.

Reviewer 4:

The reviewer pointed out that one of VTO’s key goals is the development of cost-efficient, optimized processes for electrode fabrication.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer highlighted the proficiency of the project team in materials processing. Coupled with extensive collaboration with national laboratories, universities, and industry, the team is well-equipped with the necessary resources and capabilities to meet their milestones in a timely manner.

Reviewer 2:

The reviewer appreciated the increment in funding for FY 2023, noting its importance especially in light of inflation.

Reviewer 3:

The reviewer reiterated that the formation of the team aligns well with the project’s objectives.

Reviewer 4:

The reviewer observed that the resources available to the team match the proposed objectives.

Presentation Number: BAT168
Presentation Title: Process Development and Scale-Up of Critical Battery Materials - Continuous Flow-Produced Materials
Principal Investigator: Krzysztof Pupek (Argonne National Laboratory)

Presenter

Krzysztof Pupek, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

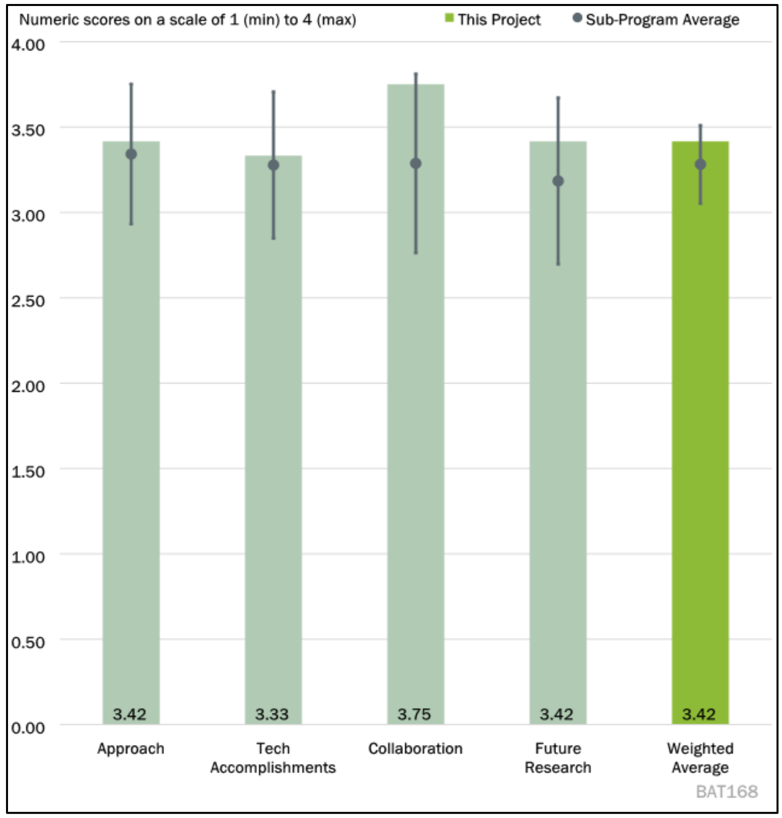

Figure 1-4 - Presentation Number: BAT168 Presentation Title: Process Development and Scale-Up of Critical Battery Materials - Continuous Flow-Produced Materials Principal Investigator: Krzysztof Pupek (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted the project’s promising approach to scaling up emerging Li salts and solvents for the development and evaluation of new electrolytes. They commended the well-designed structure of the project, especially its focus on cost-effective continuous processes. However, the reviewer provided specific feedback on certain aspects. Firstly, they suggested a literature review for optimizing F-DCI and referenced a relevant paper. Secondly, they emphasized the need to improve the selectivity and yield of FMMB. Lastly, they recommended deeper engagement with organic synthetic chemists to better understand reaction mechanisms.

Reviewer 2:

The reviewer acknowledged the advantages of continuous flow chemical synthesis over traditional batch production and highlighted its benefits, including high throughput and better quality control. The reviewer also suggested the PI offer more details on the separation technology, emphasizing potential challenges with traditional preparation quality control systems.

Reviewer 3:

The reviewer found that the project articulates technical barriers well and viewed the project scope and timeline as generally reasonable.

Reviewer 4:

The reviewer remarked on how effectively the project addresses technical barriers in electrolyte development. They praised the project's aim of developing a continuous flow process, emphasizing its crucial importance and potential for bridging bench-top chemistry and large-scale manufacturing. They also highlighted the project's synergy with other DOE programs.

Reviewer 5:

The reviewer observed the team's effective addressing of the technical barrier. They expressed confidence in the group's use of continuous flow chemistry and the involvement of the MERF, deeming the timeline both reasonable and feasible.

Reviewer 6:

The reviewer appreciated the team's approach, especially the identification of materials developed by other groups critical for scale-up research and commercialization. They also emphasized the potential of the team's continuous flow process for large-scale production, once validated.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the technical progress aligns well with the project plan for FY 2023. They emphasized the completion of lithium tricyanoimidazole (Li-TCI) via diazotiation chemistry and the development of a continuous flow process for certain compounds. Additionally, they mentioned the ongoing processes for scaling up various compounds, concluding that the milestones for FY 2023 have been met.

Reviewer 2:

Another reviewer noted the use of the continuous flow technique for synthesizing several additive compounds and conducting basic corrosion tests. They encouraged the PI to offer more specifics on product yield and stability. They also stressed the need to investigate the interaction of additives with various components of the battery.

Reviewer 3:

The reviewer lauded the project, noting the team's expertise in liquid electrolyte characterization and research techniques.

Reviewer 4:

The reviewer recognized the team's extensive progress in line with the project plan for FY 2023, emphasizing the synthesis and molecular characterization efforts. The reviewer also mentioned the team's future plans for electrochemical tests.

Reviewer 5:

The reviewer applauded the team's synthesis of Li-TCI, Li-F-DCI, and their initiative to scale up LiBHFip. They acknowledged the synthesis of various fluorinated compounds and highlighted the high selectivity achieved for FMMB. The reviewer found the imidazole-based salts and fluorinated solvent integral to battery research.

Reviewer 6:

The reviewer praised the team's progress, emphasizing their synthesis of lithium borate ester salts and fluorinated butanediol ethers. They regarded these ethers as promising solvents for Li metal batteries. The reviewer also mentioned the team's investigation into the corrosion behavior of different electrolytes using specific tests, deeming these findings essential for future research.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer acknowledged this project's extensive collaboration and coordination efforts with ANL, academic institutions, other national laboratories, and industry right from the beginning. They emphasized how these collaborations have been fundamental to ensuring planned progress and upholding the project's integrity.

Reviewer 2:

The reviewer highlighted the vast array of collaborators, spanning national laboratories, universities, and industries. However, they called on the PI to provide tangible evidence showcasing the advantages of such an extensive collaborative network.

Reviewer 3:

The reviewer commented positively on the team's effective management of partnerships with synergistic collaborators.

Reviewer 4:

The reviewer lauded the MERF project as a shining example of successful collaboration among industry, academia, and national laboratories. They noted the team's provision of a list of electrolyte molecules for the wider battery community and did not express any concerns regarding additional collaborations.

Reviewer 5:

The reviewer highlighted the MERF's extensive collaborations with both academia and industry. They pointed out the benefits of distributing large quantities of new materials to the battery community. This process accelerates the investigation and evaluation of new materials and simultaneously supports the broader battery research community.

Reviewer 6:

The reviewer celebrated the team's outstanding collaborative efforts with various research groups and industries. Through these collaborations, they gain insights into the most promising materials for scaling up and identify critical barriers to overcome. For instance, the reviewer mentioned the FDMB solvent as a prime example of a material that, once scaled up, could propel advancements in Li metal battery development.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer recognized the project's well-defined purpose for its future endeavors. Emphasizing the plan to optimize continuous flow chemistry for scaling up the production of new Li salts and fluorinated solvents, they see it as a significant step towards speeding up the development of new electrolytes for Li-based batteries.

Reviewer 2:

This reviewer touched upon the project's future focus areas, including battery testing, green processes, further flow process optimization, and quality assurance. They suggested the PI to particularly concentrate on refining separation technology to ensure quick and efficient harvesting of the pure product.

Reviewer 3:

The reviewer commended the project's clear and reasonable future plans. However, they mentioned the potential challenges with coin cells, suggesting that the team might want to validate the selected electrolytes using pouch cells when approaching the project's conclusion.

Reviewer 4:

The reviewer reiterated the project's well-structured future purpose and plan for the upcoming fiscal year. They cautioned the team against extensive proposed work, urging them to remain focused on essential tasks. They also hinted at the potential advantages of integrating tasks related to techno-economic analysis (TEA).

Reviewer 5:

The reviewer pointed out that the future research seems like a natural progression of the current research, with clear purposes. Given the PI's collaborations and detailed timelines, they believe that the plans will be executed on schedule.

Reviewer 6:

The reviewer highlighted the excellent future work research plan, advising the team to stay updated with the latest advancements in the field. They mentioned the potential outdatedness of some materials before their scale-up, referring to a next-generation fluorinated butanediol ether developed by the Stanford group. They suggested considering this new material for future scaling up efforts, potentially even replacing the project's current target.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer acknowledged the project's alignment with the VTO subprogram objectives. They emphasized its crucial role in bridging the gap between the invention of advanced battery materials and their high-volume manufacturing. This project, in their opinion, ensured a swift and effective assessment of emerging materials, enhancing outcomes of the VTO projects.

Reviewer 2:

The reviewer highlighted the project's relevance to the VTO objectives, noting its potential to contribute to cost-effective, high-volume production of essential chemicals for Li batteries.

Reviewer 3:

The reviewer pointed out the project's high relevance to various VTO subprograms, particularly those focusing on Li-ion and possibly Li-S technologies.

Reviewer 4:

The reviewer underscored the project's pivotal importance in supporting the overarching VTO subprogram objectives. They noted that while the project was in a fundamental phase, its future implications could be significant.

Reviewer 5:

The reviewer brought attention to the project's achievements, such as the development of imidazole-based salts and new fluorinated solvents. With the synthesis of numerous samples aiding battery research groups, they affirmed the project's alignment with VTO objectives.

Reviewer 6:

The reviewer commended the project's strong association with the development of novel materials in the domain. They reiterated its valuable contribution to achieving the broader VTO subprogram objectives.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources had been sufficient for the project to reach its stated milestones promptly. They highlighted the comprehensive resource list that included the MERF at ANL, electrochemical testing and characterization facilities, both at ANL and with project partners, and technical assistance from academic institutions for flow chemistry optimization.

Reviewer 2:

The reviewer emphasized that, given the resources at ANL and collaborators, the team had more than adequate resources for the project they had proposed.

Reviewer 3:

The reviewer mentioned that the resources had been sufficient.

Reviewer 4:

The reviewer noted that the project had been well-resourced to complete its tasks. They mentioned the state-of-the-art facility and believed the funding level had been apt for supporting the project. The reviewer also expressed a wish for the wider community to offer swift feedback on electrolyte performance and recognized the potential need for dedicated efforts in analyzing battery data as it amassed towards the project's conclusion.

Reviewer 5:

The reviewer pointed out that there had been ample resources to complete the project, including certain aspects like materials synthesis and scale-up, characterization, electrochemical testing, and valuable feedback from collaborations.

Reviewer 6:

The reviewer observed that the project's resources had been adequate. They suggested the potential of channeling these resources into the development of fewer materials to expedite their progress.

Presentation Number: BAT226
Presentation Title: Probing Interfacial Processes Controlled Electrode Stability in Rechargeable Batteries
Principal Investigator: Chongmin Wang (Pacific Northwest National Laboratory)

Presenter

Chongmin Wang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

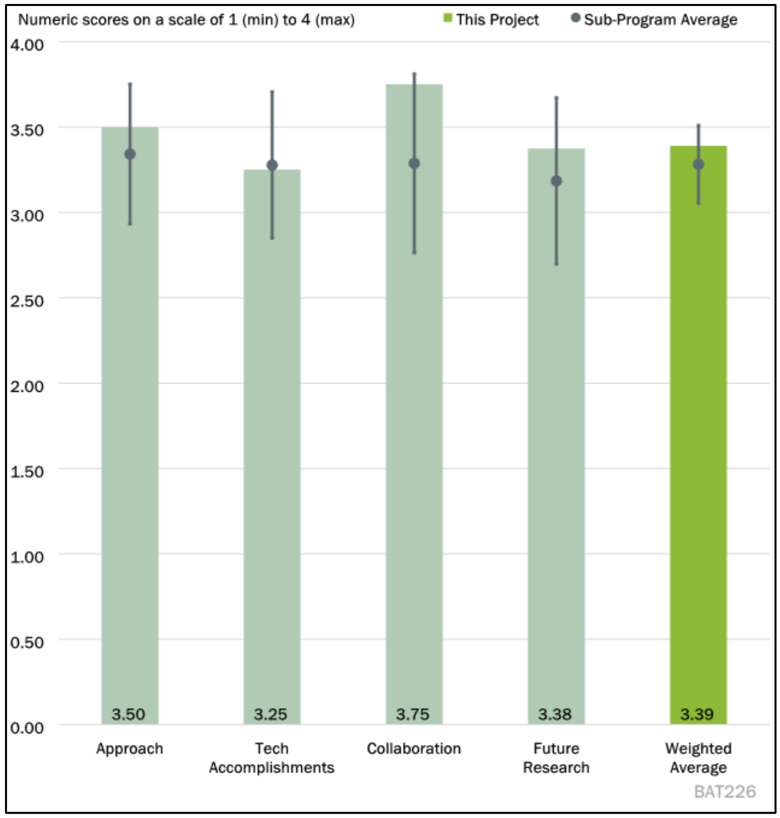

Figure 1-5 - Presentation Number: BAT226 Presentation Title: Probing Interfacial Processes Controlled Electrode Stability in Rechargeable Batteries Principal Investigator: Chongmin Wang (Pacific Northwest National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer mentioned that the PI had employed a highly logical approach to explore the electrical attributes of the SEI. They emphasized the project's significance in identifying and characterizing the SEI structure and properties based on the electrolyte chemistry. The reviewer appreciated the project's well-thought-out design and its contribution to overcoming the known challenges.

Reviewer 2:

The reviewer commented that the authors had utilized an impressive range of techniques that targeted crucial questions related to the SEI.

Reviewer 3:

The reviewer acknowledged the project's structured design, feasible timeline, and the appropriate selection of characterization tools. They commended the approach that distinctly assessed the influence of various components in the electrolyte on the SEI's properties formed with Li metal. The integration of experimental findings with simulations to discern the reasons for observed behaviors during characterization was also well-regarded by the reviewer.

Reviewer 4:

The reviewer asserted that the project had been well-crafted with a fitting timeline. They highlighted the exceptional spatial resolution of transmission electron microscopy (TEM) tips and inquired if any variance in electronic properties had been observed across different SEI layer locations.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer acknowledged the exceptional technical progress of the project. They commended the PI and collaborators for addressing the identified issues using an array of high-grade tools and instruments, and through effective collaboration with specialists in relevant domains. The reviewer then suggested some points for further exploration: (1) Regarding the phenomenon of Ni dissolution and its migration to the anode side, the PI's reference to a catalytic effect needed more clarity; and (2) The reviewer sought details about how the parameters for the Li growth phase field model were determined.

Reviewer 2:

The reviewer remarked that the project was in its early stages. They noted that the authors had identified several intriguing correlations, and they would need to discern the causative factors from the resultant effects.

Reviewer 3:

The reviewer highlighted the substantial technical advancements made relative to the project's blueprint. They emphasized the project's achievements in decoding the effects of varied electrolyte constituents, including dissolved Ni and both inorganic and organic components, on the SEI's electronic conductivity. A deeper explanation about how these components amalgamate into the SEI and cause the observed changes in electronic properties would provide a profound comprehension of the SEI's dynamics. The project's insights into the SEI's microstructure and its implications on Li growth, as portrayed via phase field simulations, were appreciated. The reviewer felt that elaborating on the significance of specific microstructures, like the denser presence of Li_2O nanoparticles in the whiskers, would be beneficial.

Reviewer 4:

The reviewer praised the innovative use of the TEM probe (W) to measure the SEI layer's electron leakage. They sought clarity on how the distance between the W-tip and the electrode surface was maintained to ensure that the captured current was both scientifically meaningful and replicable.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commended the PIs for their outstanding collaborative strategy, noting that it significantly bolstered the experimental results.

Reviewer 2:

The reviewer praised the team's collaborations, terming them as "excellent."

Reviewer 3:

The reviewer acknowledged the robust collaboration evident within the project team. They emphasized the seamless integration of cathode materials from various national laboratories, solid-state components and modeling contributions from university affiliates, and the support in forging new characterization capabilities received from external partners. The reviewer appreciated the clarity with which each partner's contributions were delineated.

Reviewer 4:

The reviewer affirmed the high quality of collaboration within the team.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer highlighted that the proposed work fits seamlessly with the ongoing approach, and there's a clear trajectory towards delving deeper into interfacial phenomena.

Reviewer 2:

The reviewer labeled the project's directions as "promising."

Reviewer 3:

The reviewer recognized the targeted focus of the future endeavors on understanding the interactions between cathodes and SSEs in Li-ion solid-state and Li-S solid-state systems. They commended the project for its potential in addressing the challenges surrounding interfacial stability in SSBs. However, the reviewer also expressed a desire for clearer confirmations of the adaptability of the techniques to situations where both interfacing materials are solid.

Reviewer 4:

The reviewer positively commented on the clarity of the project's future research intentions.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that the project's focus aligns with the VTO subprogram's goals, especially in gaining a deeper understanding of the SEI formation and its relation to various electrolyte chemistries.

Reviewer 2:

The reviewer acknowledged the significance of SEI in battery research. While noting that the SEI issue in liquid systems has largely been addressed by battery industries through empirical methods, the reviewer emphasized that advancements in resistance against dendrite formation remain invaluable.

Reviewer 3:

The reviewer stressed the project's relevance and emphasized the importance of understanding SEI for the progression and adoption of Li metal anodes, which supports the VTO's objectives.

Reviewer 4:

The reviewer posed critical questions related to the study's methodology and its applicability in practical scenarios. Specifically, they queried how the insights derived from using a low vapor pressure lean high-capacity electrolyte (LHCE), due to the unique requirements of TEM, would be applicable to systems that utilize carbonate-based electrolytes. The reviewer sought clarity on whether the project's findings would hold true for alternative electrolyte systems.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources appear sufficient to achieve the stated milestones.

Reviewer 2:

The reviewer commented that the resources are sufficient.

Reviewer 3:

The reviewer said that the resources are sufficient for the project to achieve the stated milestones.

Presentation Number: BAT230
Presentation Title: Nanostructured Design of Sulfur Cathode for High-Energy Lithium-Sulfur Batteries
Principal Investigator: Yi Cui (Stanford University/SLAC National Accelerator Laboratory)

Presenter

Yi Cui, Stanford University/SLAC National Accelerator Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

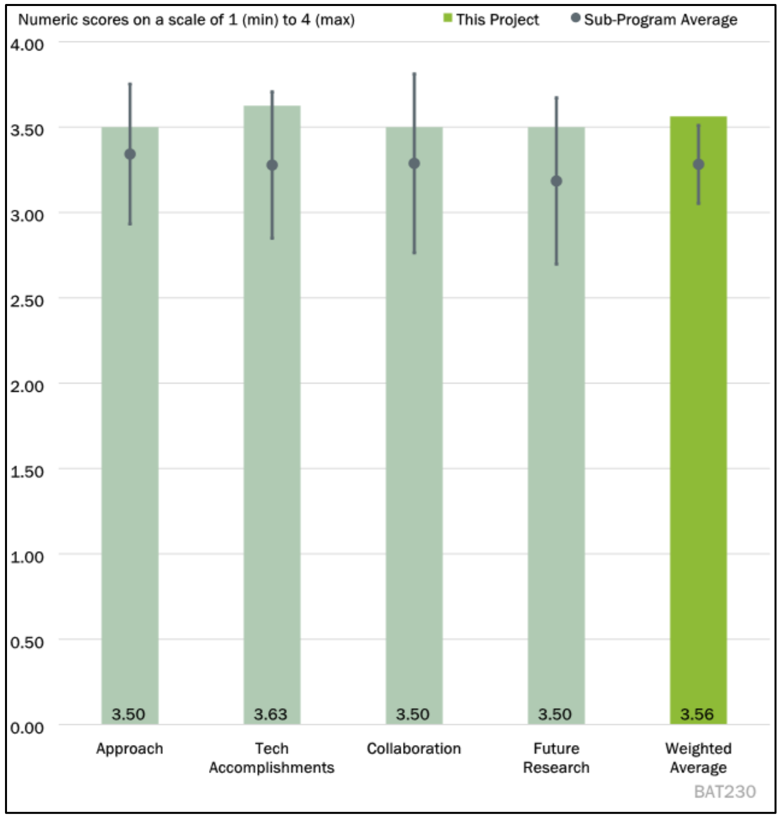

Figure 1-6 - Presentation Number: BAT230 Presentation Title: Nanostructured Design of Sulfur Cathode for High-Energy Lithium-Sulfur Batteries Principal Investigator: Yi Cui (Stanford University/SLAC National Accelerator Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commented that while the project has clear objectives, there was difficulty in understanding how these objectives were achieved due to insufficient explanations. The reviewer highlighted specific areas, such as the concept of nanoscale encapsulation, the nature of functional coatings used, and the choice of redox mediators, that were inadequately explained.

Reviewer 2:

The reviewer noted that the project integrated knowledge in nanostructured S cathode design with the use of mediators to address challenges faced by all-solid-state lithium-sulfur (Li-S) batteries. They appreciated the use of advanced characterization to gain insights into the failure mechanisms of the cells and the degradation of electrode materials during their operation. The overall project design and timeline were deemed satisfactory by the reviewer.

Reviewer 3:

The reviewer recognized the project's intentions to enhance the life cycle of sulfur cathodes by introducing novel encapsulation methods at nanoscale and developing new sulfur nanostructures with multifunctional coatings. The present focus on developing redox additives to enhance sulfur kinetics was acknowledged, especially in the context of solid electrolyte systems. However, the reviewer pointed out certain potential drawbacks: the need for scalability of the developed methods, concerns regarding the choice of Co for the redox additive due to supply issues, and doubts about the uniqueness of the material in light of similar studies.

Reviewer 4:

The reviewer summarized the project's aim to develop cost-effective and high energy density Li-S batteries suitable for EVs. They detailed the project's approach, which includes designing innovative sulfur cathodes with multifunctional coatings to tackle various challenges, and the development of redox mediators to support the high energy density requirements of all-solid-state Li-S batteries.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer mentioned that while the introduction of redox mediators and single-atom catalysts showed potential in improving the charge, it would be beneficial for more details to be included in the poster presentation, especially if the work has been previously published. The reviewer acknowledged the complexity of the project and emphasized that even minor advancements are valuable given the challenging nature of the project.

Reviewer 2:

The reviewer highlighted two significant accomplishments of the team: (1) the design of a new redox mediator that enhanced sulfur utilization in all-solid-state Li-S batteries, achieving an impressive cell energy density; and (2) the development of a Co single atom catalyst that optimized both sulfur utilization and reduced overpotential. The reviewer further appreciated that these advancements were published in reputable journals.

Reviewer 3:

The reviewer noted that progress had been made in creating a single atom catalyst to facilitate Li-S conversion, resulting in improved battery performance in terms of capacity and reduced overpotential. These achievements were documented in peer-reviewed articles. However, the reviewer raised concerns regarding sulfur utilization, sulfur loading, and the impact these factors have on battery performance. They also pointed out an unaddressed task related to testing cathodes with high capacity and high-rate ability, emphasizing its importance.

Reviewer 4:

The reviewer summarized the advancements made in the project, underscoring the development of all-solid-state Li-S batteries augmented by redox mediators and the impressive energy density achieved. Additionally, the incorporation of Co single atoms facilitated a rapid Li-S conversion in the batteries, with promising capacity and overpotential results.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer emphasized the significance of collaborations, noting that they serve to enhance and bolster the project.

Reviewer 2:

The reviewer stated the project has integrated expertise from notable institutions like SLAC/Stanford University, and PNNL, bringing together professionals specialized in material synthesis, advanced characterization, and pouch cell testing. The diversified skills of the team mesh well together, creating a complementary ensemble.

Reviewer 3:

The reviewer identified several collaborations, mentioning relationships with respected faculty members from Stanford and researchers from other prominent institutions. However, the reviewer expressed concerns regarding the lack of clarity surrounding certain collaborations, specifically those with the Battery500 (B500) team outside of Stanford, as well as PNNL or INL. They highlighted the necessity of suitable collaborations, possibly involving a battery company or a national laboratory, for tangible cell-level demonstrations. Without these partnerships, the reviewer feared that such technologies might remain restricted to the material level, impeding their progression to higher technology readiness levels (TRL).

Reviewer 4:

The reviewer praised the project's association with esteemed professors from Stanford University, recognizing the importance of their expertise in redox mediator synthesis and optical characterization. Additionally, collaborations with SLAC and PNNL were also highlighted as valuable.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that there are several pivotal aspects of the project that the team needs to further delve into. One such pivotal point is the underlying mechanism of the single-atom catalyst, which has not been fully elucidated in the current report.

Reviewer 2:

The reviewer remarked that from the plans shared, it appears that the team is gearing up for an in-depth advanced characterization and simulation to gain insights into the operational principles of both the redox mediator and the single atom catalyst. Achieving this deeper understanding could be instrumental in realizing further advancements, particularly in the realms of areal sulfur (S) loading and rate capabilities in all-solid-state Li-S batteries.

Reviewer 3:

The reviewer commented that given the project is to conclude in 2023, there are reservations on how much the team can accomplish, especially in terms of tangible hardware demonstrations, in the available timeframe. While there's an expressed intent to uncover the working mechanism of the single-atom catalyst in solid-state Li-S cells via both experimental and theoretical approaches, the scope of demonstrations of high capacity and enhanced rate capability all-solid-state lithium-sulfur batteries (ASSLSBs) within the project's current span is not clearly established.

Reviewer 4:

The reviewer observed that the team has clearly outlined the challenges ahead, such as achieving and maintaining high capacities and stability in Li-S batteries, and the nuances associated with increasing the mass loading of active sulfur in the cathode. Addressing concerns like enhancing the rate capability in the context of SSEs and handling the diffusion of sulfur species are crucial. The roadmap includes *operando* X-ray absorption spectroscopy measurements, high areal mass loading tests for sulfur cathodes, and an exploration of the mechanism of the single-atom catalyst in ASSLSBs. The reviewer is keen to see the navigation through these challenges and the resulting advancements in ASSLSBs, especially on marrying high capacity with high-rate capability.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the project's alignment with the VTO subprogram's focus on advancing Li/S batteries is evident and commendable. This establishes the relevance of the project's goals in the broader context of the subprogram's objectives.

Reviewer 2:

The reviewer commented on the project's emphasis on the development of high-energy, low-cost all-solid-state Li-S batteries. Such advancements can potentially address the limitations of current LIBs, especially in energy density, cost, safety, and supply chain challenges. This focus aligns with the VTO's aspirations to pave the way for cutting-edge batteries suitable for automotive applications.

Reviewer 3:

The reviewer affirmed that the project's efforts resonate with DOE's broader objectives. By pioneering the development of Li-S solid-state cells boasting enhanced safety, improved cycle life, lower costs, and higher specific energy, the project underscores its commitment to meeting these objectives. The experience and knowledge accumulated from prior B500 team research on liquid electrolyte systems have indeed highlighted significant challenges. These include issues related to polysulfide shuttling and anode stability. Recognizing this, the project's shift towards solid electrolyte systems, especially with its focus on innovative solutions like nanoscale coatings and single-atom catalysts, is both strategic and timely. The reviewer expressed that this direction reaffirms the project's alignment with the objectives and goals of the DoE VTO's battery program.

Reviewer 4:

The reviewer articulated that the project's content directly addresses the primary barriers plaguing battery storage solutions. By targeting challenges such as high costs, limited energy density, reduced battery lifespan, and safety concerns, the project manifests its commitment to revolutionizing the battery storage domain.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources available to the project are sufficient.

Reviewer 2:

The reviewer commented that the collaborative nature of the project, involving scientists from various institutions possessing complementary skills and capabilities, ensures that there are ample resources to effectively undertake and complete the proposed work.

Reviewer 3:

The reviewer observed that, in the context of the overall B500 project, the resources seem to align well with the project's scope. They even suggested that the resources might be slightly on the generous side, especially considering the nature of university research and development endeavors.

Reviewer 4:

The reviewer affirmed that the allocated funds are proportional to the scope of work. The evident progress and significant findings further validate this assertion.

Presentation Number: BAT232
Presentation Title: High Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions
Principal Investigator: Vincent Battaglia (Lawrence Berkeley National Laboratory)

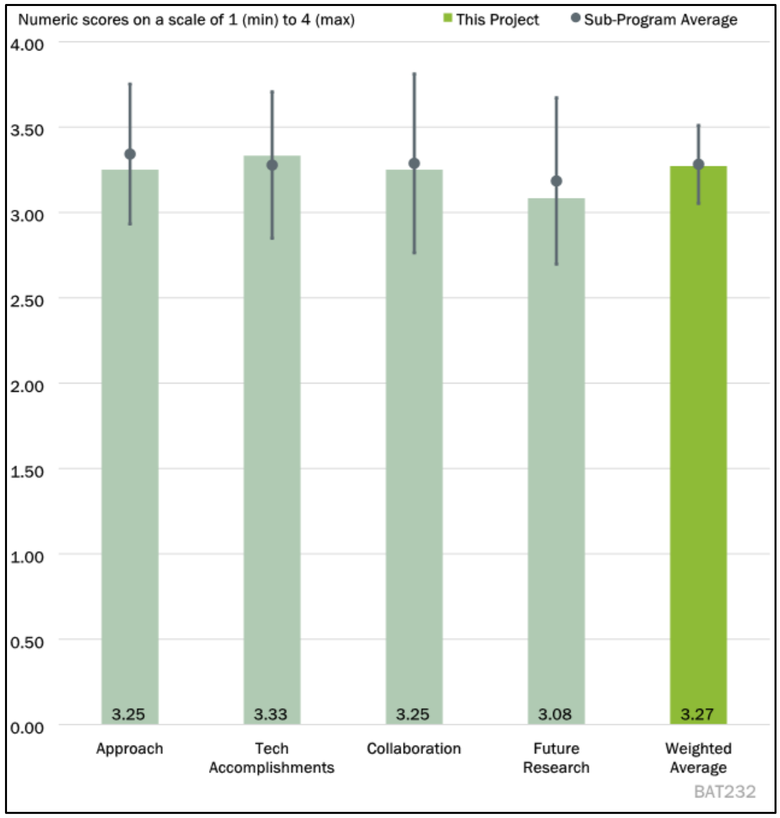

Figure 1-7 - Presentation Number: BAT232 Presentation Title: High Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions Principal Investigator: Vincent Battaglia (Lawrence Berkeley National Laboratory)

Presenter

Vincent Battaglia, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked that the project’s approach emphasized understanding the interplay between electrode ingredients and coating properties. Specifically, they commended the team’s initiatives to minimize inactive fractions, enhancing overall capacity. The exploration of carbon additives and the sequence of mixing are also highlighted. Nonetheless, the reviewer provided constructive feedback: (1) proposing the integration of a statistical Design-of-Experiment methodology to better grasp the interplay and primary factors; (2) emphasizing the importance of comprehending the density and porosity of the coating; and (3) focusing on the optimal use of active material at elevated rates.

Reviewer 2:

The reviewer observed a certain lack of meticulousness in the presentation. They noted errors like misspellings in the project title on the initial slide and overlooked comments left in the margins. While the attempt to use a green highlight for clarity was appreciated, the presentation’s organization needed improvement. Despite these oversights, the reviewer acknowledged that the project’s approach, especially regarding the study of mixture components on the synthesized cathode, was detailed and well thought out. However, they also felt that the project’s progression seemed a bit slow, considering the outlined objectives.

Reviewer 3:

The reviewer articulated that the project's ambitions and challenges were evident. They emphasized the significance of understanding processing conditions and their effects on electrode performance. The current approach might require revisiting, especially considering dispersion challenges with certain materials. The reviewer provided specific suggestions like verifying the mix's homogeneity with a Hegman gauge and focusing on the coating's durability during subsequent electrode processing steps. They also shared insights from personal experience on the potential issues of coatings with low binder content.

Reviewer 4:

The reviewer stated that while the project's approach was comprehensive and catered to immediate needs in cell production, it missed out on addressing some fundamental research linked to the technical barriers. There was a clear emphasis on understanding the slurry process and real-time particle size analysis, but it was essential to consider the broader technical objectives.

Reviewer 5:

The reviewer praised the project's design, emphasizing its precision and targeted scope. They commented that the project's tight focus ensured the realization of the set objectives. Yet, they also cautioned against any unwarranted expansion in scope, which might compromise the timeline.

Reviewer 6:

The reviewer affirmed that the report did a commendable job in concentrating on carbon additives and binders. The approach showed promise in addressing the technical barrier about cycle life and provided insights that could be vital for surmounting challenges related to high specific power and energy.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer observed that the technical progress is closely following the project plan. The reviewer commented that a baseline process has been established on NMC/Denka black/polyvinylidene fluoride (PVDF) mix, which makes the study on new additives and new active materials more systematic. The reviewer commented that a new focus on lithium iron phosphate (LFP) cathode is a good example that the knowledge cumulated from the systematic study can be applied to the new chemistries.

Reviewer 2:

The reviewer commented that it was difficult to find significant improvements on the technical progress.

Reviewer 3:

The reviewer stated that given the smaller particle size of LFP compared to NMC, one should expect a need for more solvent to achieve target coating viscosity. In addition to yield stress measurement, it may be helpful to look at time-dependent behavior like thixotropy or structure-recovery, if these have an impact on the coating quality.

Reviewer 4:

The reviewer commented that different carbon materials, different CAM, binder etc. were investigated. The conductivity and slurry viscosity were measured. Scanning electron microscopy (SEM) was used to investigate the surface morphology. The PI was recommended to test the coated electrode in either a half cell or full cell.

Reviewer 5:

The reviewer commented that the progress is slow. The reviewer observed that carbon and solvent appear like one variable to be tuned simultaneously to ensure the optimum conditions for adherence to the electrode without loss of the active material. The current analysis is useful to show the degree of entanglement of the several components, but the reviewer stated that further work is needed for a better understanding of the impact of the various processes (mixing, drying, etc.). The reviewer had the following additional questions/observations: (1) The chemistry and specially the interfacial properties of the carbon/cathode material (for example NMC vs LFP) may be important but were not discussed here; (2) Slurry formulations: what does it mean: "Amount of solvent modified based on 'feel' of coating expert?"; and (3) Viscosities: it is not clear what can be learned from the graph on Slide 34.

Reviewer 6:

The reviewer commented that a wide array of data has been shown on slurry formulations, the effect of changing carbons, and how changing slurry components influences the electrode conductivity, adhesion, and morphology. The technical achievements and progress support the program milestones well. As was stated for the approach though, only 3 slides (Slides 7, 13, and 21) address the technical barriers and no slides mentioned how the research applies to cell energy density and/or power.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer stated that while the PI has engaged in collaborations with other DOE programs, universities, and companies, it would be beneficial for the PI to consult with cell manufacturers to gain deeper insights into critical properties during production.

Reviewer 2:

The reviewer observed that there seems to be in use a proactive approach towards discussions and collaborations with teams at other national laboratories and industry stakeholders working on similar challenges.

Reviewer 3:

The reviewer commented on the evident collaboration with various commercial binder and carbon suppliers. They expressed interest in understanding the rationale behind the selection of specific binders for certain formulations.

Reviewer 4:

The reviewer remarked that the project has showcased its collaborations with other government entities and private organizations, providing brief overviews of the collaborative activities. They observed that while there has been significant collaboration with national laboratories, engagement with only one company (Arkema) was mentioned. The reviewer suggested that further industry partnerships would be a valuable addition.

Reviewer 5:

The reviewer praised the project's collaborative efforts, emphasizing the importance of engagement with material suppliers and analytical service providers in such projects. They affirmed that the project has adeptly managed its coordination among all parties involved and has aptly acknowledged their contributions.

Reviewer 6:

The reviewer recognized the effective collaboration between the industry and national laboratories in conducting the research. They suggested that the team use industrial production machinery to validate the findings derived from laboratory equipment further.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer remarked that while the PI is set to further delve into the contributions of carbon, binder, and solvents, there might be added value in considering a larger batch size for a more representative sample.

Reviewer 2:

The reviewer commented that the planned work seems to address some pivotal remaining challenges. However, given the numerous objectives, it might be beneficial to determine and prioritize the most pressing objectives first and then schedule the activities accordingly.

Reviewer 3:

The reviewer suggested that although comparing NMCs or LFPs from different suppliers could provide more insight, it might stray from the main focus of the study. They also stated that a visit to a few electrode manufacturing sites to observe larger-scale mixing, coating, and drying processes might yield additional insights.

Reviewer 4:

The reviewer observed that the proposed future work, while extensive, lacks some clarity in terms of how it directly aims to address certain goals like achieving 1000 cycles or reaching 350 Wh/kg, even though the work will inevitably influence electrochemical performance.

Reviewer 5:

The reviewer encouraged the investigator to reflect on the most effective design rules derived from present and forthcoming work. They emphasized the importance of communicating these rules clearly and prioritizing them in the project's concluding phases.

Reviewer 6:

The reviewer praised the project, noting that the objectives for the upcoming work have been well-articulated and they align harmoniously with the stated technical barriers.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the project's significance lies in its focus on the processibility of electrode manufacturing, a critical component of battery production.

Reviewer 2:

The reviewer articulated that refining and optimizing the processes involved in electrode production is vital for the progression of VTO objectives.

Reviewer 3:

The reviewer affirmed that possessing robust foundational knowledge on processing is essential when creating new designs. They stressed that any design efforts could be undermined by subpar processing conditions. Hence, they deem this project of paramount importance, ensuring that any prototypes are manufactured accurately and consistently.

Reviewer 4:

The reviewer observed that the program aligns well with the VTO subprogram's objectives, particularly in developing batteries that boast high cycle life and exceptional energy/power ratios for emerging chemistries.

Reviewer 5:

The reviewer commented that the project aims to propose ways to reduce the cost of LIBs while also identifying strategies to enhance battery longevity. While they believe the potential for cost-saving is modest, they see the project as an opportunity to potentially refine manufacturing outputs and elevate the predictability and consistency of product performance.

Reviewer 6:

The reviewer said that the project remains dedicated to enhancing electrode formulations and processability, reinforcing the broader objectives set by the VTO subprogram.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the PI is well-equipped with the necessary resources to carry out the planned research.

Reviewer 2:

The reviewer expressed that while the resources are adequate, there’s a need for improved planning to maximize their utilization.

Reviewer 3:

The reviewer observed that given the diverse range of active materials under development, there will likely be an increasing need for projects like this one. They suggested that after examining NMC622 and LFP, it would be wise to determine other materials that might be suitable candidates for evaluation.

Reviewer 4:

The reviewer commented that the resources available for the program appear to match the scope of work being carried out.

Reviewer 5:

The reviewer remarked that there are no discernible issues concerning resources at this juncture of the project.

Reviewer 6:

The reviewer clarified that, based on the presented progress report, the resources at hand are sufficient for the project to meet its outlined milestones in a timely manner.

Presentation Number: BAT280
Presentation Title: Novel Chemistry: Lithium-Selenium and Selenium-Sulfur Couple
Principal Investigator: Khalil Amine (Argonne National Laboratory)

Presenter

Khalil Amine, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

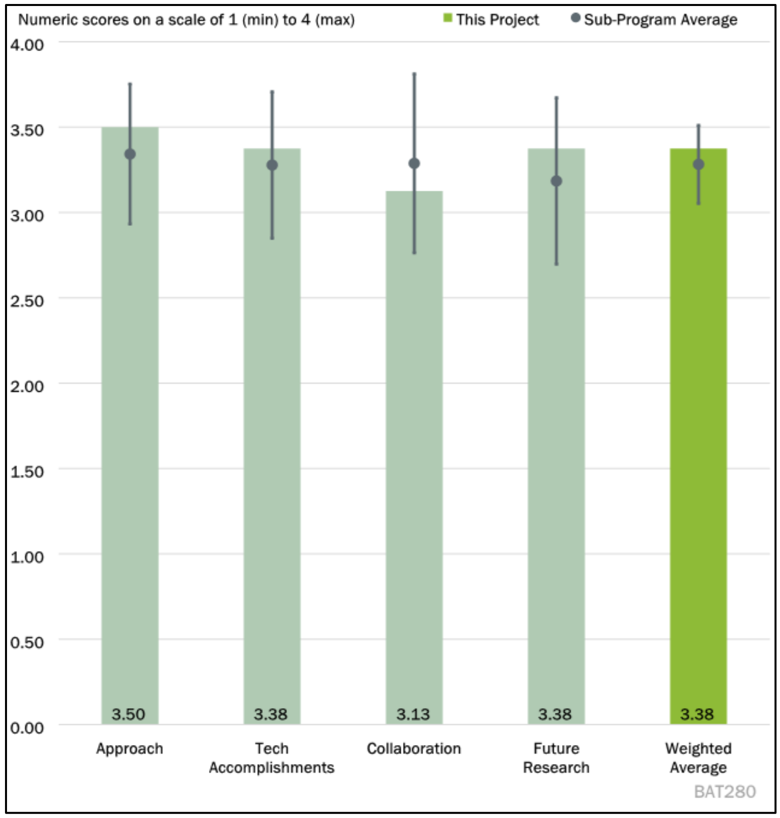

Figure 1-8 - Presentation Number: BAT280 Presentation Title: Novel Chemistry: Lithium-Selenium and Selenium-Sulfur Couple Principal Investigator: Khalil Amine (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer expressed a favorable view of the project, emphasizing that it addresses technical barriers well. The results demonstrate notable progress in overcoming the challenges of decreased capacity upon increased sulfur loading. The novel Se-doped-S macroporous carbon cathode, which allows for an impressive 80% sulfur loading, stands out. Furthermore, pairing this cathode with a fluorinated electrolyte successfully addresses the issue of cycling performance, especially under low electrolyte-to-sulfur (E/S) ratios.

Reviewer 2:

The reviewer commended the organization of the project for its focus on enhancing the cycle life of Li-S cells. The incorporation of Se in sulfur improves electrical conductivity and increases active material loading. This Se doping strategy is not entirely new, as pointed out by the reviewer. Other strategies, such as modifying carbon pore structure and optimizing electrolyte formulation, are crucial to minimize polysulfide dissolution and shuttle. The *in operando* spectroscopic study will provide insights into current distribution and shuttle effects. The project's alignment with DOE goals is clear, emphasizing higher energy, longer life, and reduced cost for EV batteries. However, there are areas for improvement, notably in demonstrating more impressive performance at the cell level with relevant cathode loading and E/S and in enhancing cycle life.

Reviewer 3:

The reviewer highly appreciated the team's comprehensive approach to addressing the challenges of Li-S batteries. They have systematically tackled barriers such as the polysulfide shuttle effect, low electronic conductivity, low active material loading, Li dendrite formation, safety concerns, and limited cycle life. Their multifaceted approach includes Se doping for improved conductivity, examination of carbon pore structure's impact, development of innovative electrolytes, deployment of *in-operando* synchrotron X-ray and spectroscopy probes and leveraging advanced modeling capabilities.

Reviewer 4:

The reviewer felt the project's emphasis on developing innovative SSe cathode materials for Li-S batteries is timely. The results have shown that doping Se into S provides multiple advantages. However, the performance, in terms of areal capacity, seems comparable to existing literature and might not stand out as state of the art. The use of fluorinated ether (HFE), although beneficial, might lead to regulatory challenges. Furthermore, the topic of performance at higher rates has not been adequately addressed.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer observed that the team had made significant progress in achieving their technical goals and presented commendable results. When compared to the preliminary results showcased at the start of their poster, the team's current achievements were promising. Particularly noteworthy were the diagnostic tools they developed. An example was the heterogeneity map, which highlighted the irregular distribution of sulfur (S) and lithium sulfide (Li_2S) in the cell. Such a tool and its resultant data could offer insights into refining cell designs as well as understanding the kinetics and mechanisms of the overarching reactions at the electrode.

Reviewer 2:

The reviewer noted that there was substantial progress in enhancing performance when doping selenium (Se) onto S. Undoped S exhibited notable heterogeneity that led to elevated impedance and suboptimal sulfur utilization. In contrast, Se-doped S demonstrated a consistent S/Li_2S distribution in an organized macroporous carbon cathode with increased sulfur loading. This consistency also decreased polysulfide, as evidenced by *in operando* synchrotron studies. When the electrolytes were further modified by incorporating HFE into the solvent blend, both the cycle life and self-discharge showed improvement in coin cells and pouch cells, especially under high S loading and a diminished E/S ratio. Nevertheless, there were weaknesses identified by the reviewer: (1) While there was undeniable improvement in cycle life even at average sulfur loading levels, the E/S values, particularly in the pouch cells on Slide 12 (E/S: 7.5-10), were exceedingly high, rendering them impractical for genuine cell applications; (2) Slide 11 lacked E/S data; and (3) Reporting specific energy based solely on active material was both incomplete and potentially misleading. In summary, the improvements to cycle life were only slight, suggesting that the exact failure modes remained unidentified, possibly due to a polysulfide shuttle mechanism.

Reviewer 3:

The reviewer highlighted that the team had made several significant advancements in the project. In summary, these included the development of a 1 Ah Li-S pouch cell with an energy density exceeding 300 Wh/kg and a consistent cycle life, cell diagnostics that revealed failure mechanisms at low E/S ratios, the creation of an innovative selenium sulfide (SeS) cathode with an areal capacity surpassing 4 mAh/cm^2 for 100 cycles, and a comprehensive examination of the interface and polysulfide dissolution using time-of-flight secondary ion mass spectrometry (ToF SIMS) and *in situ* X-ray diffraction/X-ray absorption spectroscopy (XRD/XAS). Specific technical accomplishments comprised the fabrication and testing of a 350 Wh/kg Li-S pouch cell at a low E/S ratio of 2.5 ml/mg, uncovering the reaction heterogeneity of Li-S batteries in the Li-S pouch cell via synchrotron X-ray Diffraction (XRD) mapping, electrochemical impedance spectroscopy (EIS) analysis of Li/S batteries under high S loading and sparse electrolytes, and the design and synthesis of a Se-doped S/ordered macroporous carbon composite. Further, the combination of the cathode and HFE electrolytes showcased improved cycling stability and self-discharge. There was also a demonstration of effective cycling stability in practical pouch cells utilizing the new sulfur cathode and HFE electrolytes at reduced E/S ratios. Other accomplishments included the suppression of the shuttle effect, enhanced reaction reversibility through a cathode electrolyte synergy, and a maintained homogeneous S and Se distribution in cycled S cathodes due to the inhibited shuttle effect, thereby augmenting the interface stability of the cycled SeS cathode and Li metal anode.

Reviewer 4:

The reviewer stated that, while promising, the results to date did not surpass findings documented in cutting-edge literature, with an areal capacity below 6 mAh/cm^2. Additionally, the application of HFE could potentially introduce regulatory challenges, particularly if the use of fluoride compounds was prohibited. Furthermore, the cell's performance at elevated rates was not addressed. The reviewer also inquired about the volumetric energy density of the cells.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the project displayed commendable collaboration, especially within ANL and its various teams. However, expanding this collaboration to include other laboratories or universities would be beneficial.

Reviewer 2:

The reviewer noted ongoing collaborations with scientists from ANL. These primarily centered on characterization and understanding sulfur utilization, as well as the polysulfide shuttle mechanism through *in operando* studies. Weaknesses identified by the reviewer included a lack of collaboration with any external B500 team members. Collaborative efforts with institutions such as Idaho National Laboratory (INL) or the project's industrial partner could provide a more rigorous evaluation of selenium-sulfur (Se-S) cathodes.

Reviewer 3:

The reviewer stated the team's collaboration network was impressive. It included partnerships with Dr. C.J. Sun from the Advanced Photon Source (APS) at ANL, who provided expertise in X-ray absorption spectroscopy to understand mechanisms during charge/discharge cycles. Collaborations also extended to Dr. W. Xu and T. Li from APS at ANL, focusing on Synchrotron X-ray characterization of the crystal structure of S_xSe_y cathodes and their phase transitions during charge/discharge. Furthermore, Dr. Z. Yang from the Chemical Sciences and Engineering division at ANL contributed to X-ray photoelectron spectroscopy (XPS) for characterizing the cycled S cathode and Li metal anode. Dr. L. Cheng from the Materials Science Division at ANL provided computational modeling expertise, particularly regarding interactions between polysulfides and host materials.

Reviewer 4:

The reviewer commended the synergistic and complementary efforts demonstrated across the team.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer observed that the project had a clearly defined roadmap for upcoming endeavors. The team aspired to reach a lower E/S ratio (targeting an E/S of less than 2) and increase areal sulfur (S) loading. Present results indicated that the team was progressively advancing toward these objectives. Additionally, there was a plan in place to confront the reaction heterogeneity at the cell level to ensure extended cycle life.

Reviewer 2:

The reviewer stated the proposed future research, which encompassed the development of an interlayer design to diminish polysulfide crossover and the introduction of new electrolytes and electrolyte additives to enhance sulfur homogeneity in cathodes with elevated sulfur loading and diminished electrolyte content (aiming for an E/S close to zero), was seen as beneficial. Such efforts could pave the way for high-energy, long-cycle-life Li-S batteries. The reviewer emphasized the importance of optimizing the selenium (Se) content in the selenium-sulfur (Se-S) cathode to find the optimal balance for achieving a satisfactory cycle life. Modeling endeavors would be employed to support experimental research, ensuring a comprehensive understanding of outcomes. A weakness noted by the reviewer was that the upcoming year's investigations should prioritize showcasing the Se-S cathode in pouch cells with a low E/S, potentially in collaboration with an industry partner. Given the project's duration and significant funding, it was crucial to realize tangible outcomes and benefits.

Reviewer 3:

The reviewer identified challenges identified such as: sulfur utilization under low E/S ratios (2 ml/mg) and elevated areal S loadings (6 mg/cm^2), which currently inhibit the cell energy density of Li-S pouch cells (aiming for 500 Wh/kg). Furthermore, reaction heterogeneity at the cell level was pinpointed as a critical hurdle for achieving prolonged cycle life, and stabilizing Li metal at high current densities was still a challenge, constraining rapid charging capabilities of Li-S pouch cells. The proposed future endeavors were structured to tackle several persistent challenges. These included optimizing the Se ratio in the SeS cathode to boost capacity and voltage retention at higher current densities, designing innovative interlayers to support cycling of high-loading (more than or equal to 5 mg/cm^2) Li/S batteries at elevated current densities, introducing interlayers that would accommodate both high-energy and extended-cycle-life Li-S batteries, and devising electrolytes and additives to address reaction heterogeneity in scenarios of high S loading and lean electrolytes.

Reviewer 4:

The reviewer pointed out certain potential issues: employing interlayers might not be the optimal approach, especially when considering the volumetric energy density.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer asserted that the project aligned with and supported the overarching goals of the VTO and its Batteries subprogram. The project's exploration into Li-S batteries held the potential of delivering high energy densities (500 Wh/kg) at reduced costs, making it suitable for EVs and other energy storage applications.

Reviewer 2:

The reviewer believed the project upheld DOE objectives by developing advanced Li-S cells that offered greater specific energy, diminished costs, augmented safety, and superior cycle life when compared to LIBs. The challenge of harnessing Li-S technology with liquid electrolytes was well-documented, with past studies by the B500 teams not yet identifying a viable route. This particular project's emphasis was on curbing the polysulfide shuttle effect and augmenting the cycle life of the sulfur cathode using selenium (Se) doping. In essence, the project was in sync with the objectives and aims of the DOE VTO Batteries subprogram.

Reviewer 3:

The reviewer noted the project's intent was to surmount various obstacles associated with implementing Li-S in the energy storage domain. These challenges included the shuttle effect, reduced electronic conductivity, inadequate active material loading, Li dendrite formation, safety concerns, and insufficient cycle life.

Reviewer 4:

The reviewer affirmed the project's merit, emphasizing its potential to achieve the targeted energy density of 500 Wh/kg.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer acknowledged that resources allocated to the project were ample for meeting the specified milestones.

Reviewer 2:

The reviewer stated that the resources designated for the entirety of the project were deemed congruent with its scope, ensuring the successful attainment of the targeted milestones.

Reviewer 3:

The reviewer noted that the funding was seen as proportional to the project's scope, and the advancements and discoveries made thus far were noteworthy.

Reviewer 4:

The reviewer believed that the resources furnished for the project appeared fitting.

Presentation Number: BAT285
Presentation Title: Investigation of Sulfur Reaction Mechanisms
Principal Investigator: Deyang Qu (University of Wisconsin at Milwaukee)

Presenter

Enyuan Hu, Brookhaven National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 60% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 40% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

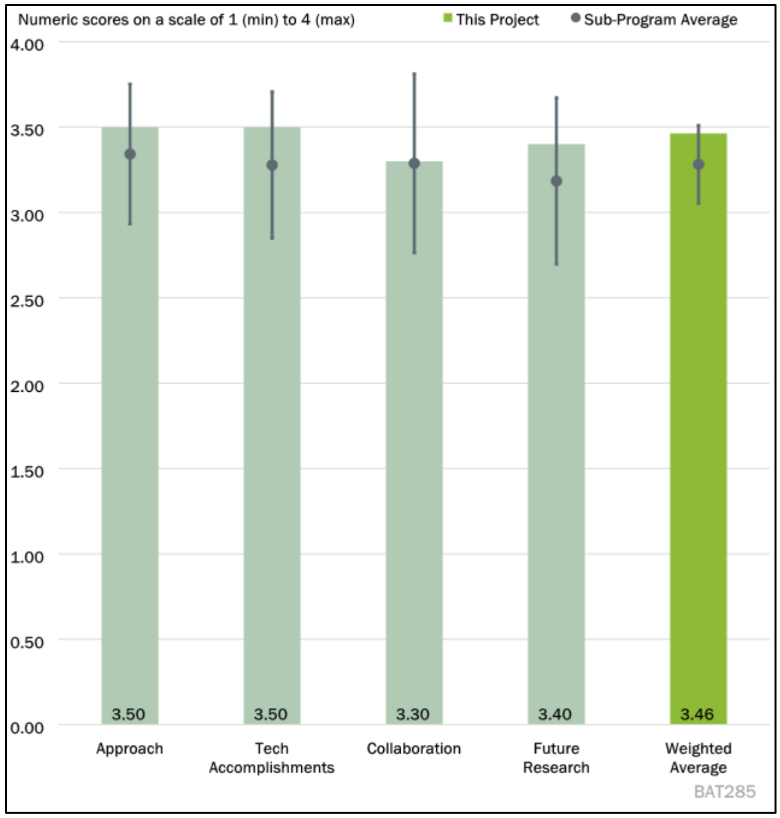

Figure 1-9 - Presentation Number: BAT285 Presentation Title: Investigation of Sulfur Reaction Mechanisms Principal Investigator: Deyang Qu (University of Wisconsin at Milwaukee)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer recognized that the research team employed a comprehensive array of techniques to prepare and analyze Li-S anode and cathode materials, notably the Li_xSi anode and sulfur-hosting carbon, which exhibited high absorption and catalytic capacities. The team also constructed and assessed all-solid-state Li-S batteries, utilizing *in situ* HPLC-MS-electrochemical methodology to monitor soluble polysulfides. *Ex situ* XRD and XPS were employed to inspect the surface characteristics of the sulfur cathode and Li anode.

Reviewer 2:

The reviewer commended the team for their exemplary efforts in tackling challenges. Specifically, they synthesized an organo-sulfur cathode material using thiuram polysulfides (PMTH) combined with a SSE. Even though these materials were susceptible to air and moisture, they effectively tackled polysulfide dissolution. The team’s methods, such as using pre-lithiated Si via a mechanochemical process and the P-5 mechanical mill, were noted. The reviewer also drew attention to specific performance data and sought clarification on several aspects, including reasons for rapid fade, potential Si-related losses, and anode loading specifics.

Reviewer 3:

The team delineated eight strategic approaches, encompassing a range of topics from material selection to advanced characterization methods and extended collaborations. The project’s focus on creating an all-solid-state Li-S battery, paired with *ex situ* and *in situ* investigation methodologies, was viewed as instrumental in deciphering sulfur-sulfur reaction mechanisms. Such insights are critical for refining and enhancing battery performance. The reviewer praised the team's innovative strategies for addressing issues like volume changes and stack pressure, common in Li-S SSBs.

Reviewer 4:

While acknowledging that the technical barriers were being addressed appropriately within the project's scope, the reviewer suggested emphasizing rate capability in forthcoming endeavors.

Reviewer 5:

The project's synthesis of advanced *in situ* characterization techniques with innovative material design was viewed positively, especially in advancing sulfur utilization and enhancing the cycling stability of all-solid-state Li-S batteries. The structured approach and well-organized plan of the project were appreciated by the reviewer.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer observed that the fully synthesized lithiated Si powder exhibited superior performance and cyclability compared to Li-In. The *in situ* electrochemical high-performance liquid chromatography-mass spectrometry (HPLC-MS) tool provided a deeper understanding of the Li-S redox reaction mechanism. It was found that long-chain dissolved polysulfide ions were the primary cause of the shuttle effect. The sulfur-hosting carbon, with high absorption and catalytic activity, was able to disproportionate long-chain polysulfide ions to form elemental sulfur and short-chain polysulfide ions. A reduced presence of dissolved long-chain polysulfide enhanced the cycling performance of the Li-S cell. Regarding the statement, "Thiuram polysulfide cathode showed good reversible volume changes," the reviewer suggested that it would be more informative to compare the volume/pressure changes of the thiuram polysulfide cathode with a benchmark cathode material.

Reviewer 2:

The reviewer acknowledged the team's outstanding technical achievements. Questions for the team included the following: The pre-lithiated Si was presented as the anode with the PMTH cathode and SSE. Given its impressive performance, the reviewer sought clarification on certain aspects. During the pressure measurements while cycling the Li_xSi against lithium titanate, why was not the pressure decrease at the end of the discharge and charge cycle consistent across all cycles? Why did the pressure not return to its initial level? It was understood that the pressure resulted from the expansion and contraction of the pre-lithiated Si. The reviewer hypothesized potential irreversible loss as a cause and inquired if this might be the reason for the observed stress change variation. Additionally, insights were sought on the correlation between pressure changes and changes in coulombic efficiency (CE) and capacity loss. With regard to the dual-function carbon host, the reviewer asked about the nitrogen content in the carbon samples NC750, NC800, NC900, and NC950. The reviewer suggested clarifying the reference to powdered activated carbon (PWA) as well as the ratio of polysulfides to the NC carbons during HPLC. If polysulfides were trapped by the NC carbons, was nitrogen responsible for trapping them? The reviewer also inquired about the dual role of the carbons and where disproportionation occurred – specifically, if it happened at the nitrogen site. If the NC carbons effectively trapped the polysulfides, what caused the initial decrease in capacity for the pouch cells?

Reviewer 3:

The reviewer enumerated seven notable technical accomplishments:

A dual-functional carbon was synthesized, exhibiting high sulfur/polysulfide absorption and catalytic activity. This facilitated the disproportionation reaction, converting long-chain polysulfides to short-chain polysulfides and elemental sulfur.

The *in situ* electrochemical HPLC/MS enhanced the understanding of the Li-S redox reaction mechanism.

It was confirmed that the shuttle effect could be mitigated using the dual-functional carbon by promoting the formation of short-chain polysulfide ions.

An organo-sulfur cathode, promising in terms of energy density and cyclability, was chosen for all solid-state Li-S batteries.

The PI's laboratory developed a method to synthesize fully lithiated Si powder. This powder, when paired with a sulfur cathode in an all-solid-state cell, performed well.

The team showcased a high sulfur cathode loading (17 mg/cm2) for an all-solid-state cell.

Advanced synchrotron-based spectroscopic and microscopic studies provided insights into the structures of polysulfide and polymer sulfur. This research also revealed the distribution of organic and inorganic species on the anode interface.

Given the provided funding and the project's timeline (which began on Oct. 1, 2022), the reviewer commended the significant technical progress achieved.

Reviewer 4:

The reviewer stated that, within the program's scope, the technical accomplishments were commendable.

Reviewer 5:

The reviewer praised the team for making significant progress in the past year, successfully meeting set milestones:

A dual-functional carbon was synthesized, demonstrating high sulfur/polysulfide absorption and catalytic activity. This enabled the disproportionation reaction, converting long-chain polysulfides to their short-chain counterparts and elemental sulfur.

The Li-S redox reaction mechanism was better understood due to *in situ* electrochemical mass spectrometry (MS) studies.

A small organo-sulfur compound, exhibiting the highest energy density in its class, was selected for use in an all-SSB.

The team showcased an all-SSB with high active loading (17 mg/cm2), demonstrating commendable cycle life.

A quality fully lithiated Li_xSi was synthesized and, when tested in an all-solid-state Li-S cell, yielded impressive performance.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the project team comprised a substantial number of collaborators, each bringing distinct research expertise. The University of Washington, Seattle, was responsible for the synthesis of SSEs. Cornell University took charge of organic material synthesis. Pacific Northwest National Laboratory (PNNL) focused on material synthesis and cell configuration. Lastly, Millipore Aldrich contributed organic cathode materials.

Reviewer 2:

While the reviewer acknowledged the team's effective collaboration with four distinct organizations, they expressed concerns about the lack of detailed information. The University of Washington, Seattle, was identified as providing the SSE, yet the specific system and collaborators involved remained unspecified. Similarly, Cornell University's contribution to organic material synthesis lacked specific details and names of team members. The contributions of PNNL and Millipore Aldrich, too, were vaguely described. With regard to Millipore Aldrich's involvement, the reviewer inquired if materials were simply purchased from Aldrich and sought clarification on the nature of the collaboration.

Reviewer 3:

The reviewer stated the roles of the collaborators were as follows:

University of Washington, Seattle: Synthesis of SSEs.

Cornell University: Organic material synthesis.

PNNL: Material synthesis and cell configuration.

Millipore Aldrich: Provision of organic cathode materials.

The reviewer found the milestones, approach, and project objectives to be well-articulated. However, the specifics of collaboration and individual responsibilities were ambiguous. Slide 14 provided a succinct overview of each collaborator's duties, yet there was a lack of discussion regarding the progress achieved by each entity. As a result, the reviewer had to base their evaluation on the collective technical progress of the project.

Reviewer 4:

The reviewer observed that the project reflected a collaborative team effort with clear task delegation.

Reviewer 5:

The project successfully engaged multiple PIs from both national laboratories and universities and incorporated several external partners from academia and industry. The reviewer commended the team for effectively leveraging the diverse expertise within the project to address technical challenges.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer found the outlined future research plans to be generally sound. However, there was some uncertainty regarding the strategy to "prevent dendrite growth and limit 'dead' Li formation." Although the approach section referred to the use of "*in situ* 3D microscopy and electrochemical measurements for dendrite detection during cell operation," the poster failed to present any findings on dendrite detection or strategies being employed to counteract it.

Reviewer 2:

The reviewer believed the future plan was pertinent. Yet, the strategy for exploring alternative dual functional carbon materials to mitigate the shuttle effect remained ambiguous. Given the different NC carbons displayed in the presentation, the changes the team aimed to make—whether adjusting N contents, adding different additives, or others—were not explicitly conveyed. There were also uncertainties surrounding the development of cathode architecture for optimizing the utilization of elemental sulfur and organo sulfur materials. The reviewer inquired about the specific architectural changes and questioned the intent behind enhancing collaborative research with academic institutions. Moreover, a potential hurdle identified was the presence of dendrites in the anode. The project's usage of pre-lithiated Si posed its own set of challenges. Should they switch to the NC carbon for the Li-S system, it would revert to Li metal. The reviewer sought clarity on the proposed strategy to combat dendrite formation in the upcoming research.

Reviewer 3:

For the 2023 research agenda, the reviewer listed:

Conducting a comprehensive interfacial study of both small organo-sulfur and surface-protected Li with SSE: Excellent.

Completing full cell tests with selected small organo-sulfur, surface-protected Li anode, and SSE: Excellent.

Thorough investigation of polysulfides in a solid phase: Excellent.

For 2024, the agenda comprised:

Gaining a deeper understanding of the catalytic behavior of polysulfide disproportionation using *in situ* electrochemical HPLC-MS: Excellent.

Probing alternative dual functional carbon materials to counteract the shuttle effect: Good — though exploration is commendable, an emphasis on refining the existing dual functional cathode might prove beneficial.

Designing a cathode architecture tailored to the effective utilization of elemental sulfur and organo sulfur materials: Excellent — a focus on decreasing stack pressure during battery cycling is advisable.

Fabricating multi-layer pouch cells using sulfur or organo sulfide cathodes: Excellent.

Persisting in refining the S electrode production method to augment sulfur loading and devising techniques to create thick sulfur cathodes: Excellent.

Intensifying collaboration with academic institutions and industry counterparts: Satisfactory — partnering with a SSE material or battery company for cell testing and validation might be beneficial.

Reviewer 4:

From a foundational understanding, the reviewer deemed the future research direction as fitting. The reviewer suggested that a heightened emphasis on addressing the rate capability could bolster the project's practical implications.

Reviewer 5:

The reviewer acknowledged that the project delineated distinct tasks for upcoming research. This included advanced characterization, crafting advanced carbon materials and cathode structures, dry cathode processing, and devising multi-layer pouch cells. Such efforts could potentially overcome the challenges inherent to all-solid-state Li-S batteries.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that the synthesis and characterization of anode, cathode, and electrolyte materials for Li-S batteries aligned seamlessly with the BAT program's objective of fostering high-energy rechargeable battery innovation. The fruition of this project would significantly propel the advancement of state-of-the-art Li-S batteries.

Reviewer 2:

The reviewer affirmed the project's relevance to VTO's ambitions. The pursuit of an all-solid-state Li-S battery was especially pertinent. Likewise, the exploration of alternative sulfur cathodes, exemplified by the organo sulfur cathode, was both innovative and beneficial. Devising strategies to inhibit dendrite growth was deemed crucial.

Reviewer 3:

The reviewer believed that this project was in harmony with the overarching objectives of the VTO subprogram. The initiative sought to pioneer new cathode and anode materials with the aim to enhance the energy density and longevity of all-solid-state Li-S batteries. Concurrently, *ex situ* and *in situ* investigative techniques were employed to gain a comprehensive understanding of sulfur-sulfur reaction mechanisms. Such insights would be instrumental in refining SSB materials.

Reviewer 4:

The reviewer highlighted the program's commitment to advancing materials designed for energy storage. These materials, not only being abundant, held the promise of transcending the existing technological benchmarks in energy storage.

Reviewer 5:

The reviewer stated the project was strategically geared towards crafting high-energy, cost-effective all-solid-state Li-S batteries. Such advancements could alleviate the limitations inherent to contemporary LIBs in relation to energy density, cost-efficiency, safety, and supply chain vulnerabilities. The reviewer emphasized that this direction was congruent with VTO's vision of spearheading battery innovations catering to the escalating demands of automotive applications.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed that the research teams had the advantage of state-of-the-art facilities and had innovated distinct research devices and capabilities. Collaborative efforts among the team members efficiently utilized these facilities, thereby accelerating the pace of research.

Reviewer 2:

The reviewer acknowledged the ample resources shared between Brookhaven National Lab and the University of Milwaukee. Such resources were deemed sufficient to undertake the proposed tasks. Consequently, the reviewer anticipated that the project would achieve its milestones.

Reviewer 3:

The reviewer affirmed that the allocated resources for the project were adequate to realize the stated milestones within the proposed timeframe.

Reviewer 4:

The reviewer inferred from the project's performance that the resources had been satisfactory in meeting the program's milestones.

Reviewer 5:

The reviewer noted that the project was a collaboration of multiple PIs spanning national laboratories, universities, and several external academic and industrial partners. Together, they pooled resources focused on material synthesis, advanced characterization, and cell testing pertinent to the proposed tasks.

Presentation Number: BAT315
Presentation Title: Process R&D for Droplet-Produced Powdered Materials
Principal Investigator: Joe Libera (Argonne National Laboratory)

Presenter

Joe Libera, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

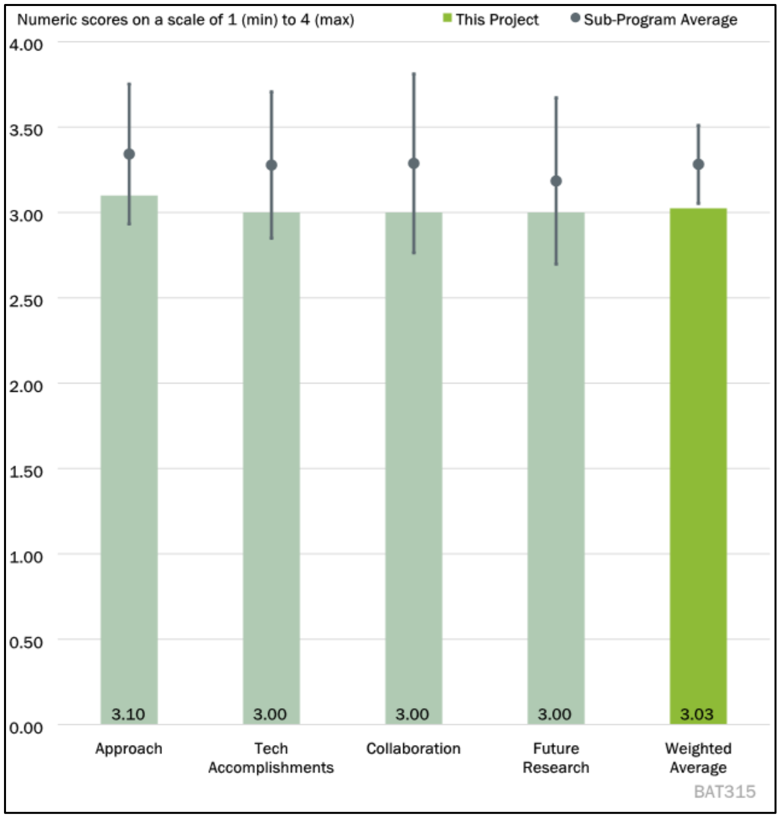

Figure 1-10 - Presentation Number: BAT315 Presentation Title: Process R&D for Droplet-Produced Powdered Materials Principal Investigator: Joe Libera (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer recognized that flame spray pyrolysis (FSP) and related aerosol methods were prevalent and economical industrial techniques for synthesizing functional materials. When these techniques were integrated into battery material studies, the adaptability of their control parameters potentially facilitated new material synthesis pathways and the generation of materials unattainable via other techniques. Unlike conventional methods like sol-gel or co-precipitation that often require multiple stages, FSP offers a one-step production. Additionally, it can yield nanoscale or amorphous formatted, atomistically mixed precursors that set the stage for subsequent heat processing reactions. The reviewer believed that incorporating FSP into VTO's toolkit for materials synthesis and processing was a strategic move to propel advancements in vehicle battery technology.

Reviewer 2:

The reviewer found that the technical barriers were not thoroughly addressed. The term "'Life' barrier" appeared ambiguous. However, the project was meticulously planned, emphasizing aerosol synthesis for scalability. Moreover, maintaining close ties with the industry ensured that the project remained aligned with the evolving requirements.

Reviewer 3:

The reviewer noted that the cathode materials presented were not representative of the current or upcoming generation. Majority of the introduced materials did not seem poised for widespread market adoption.

Reviewer 4:

The reviewer commended the PIs for pioneering a method focused on powder creation to derive CAMs.

Reviewer 5:

The project's objective, as understood by the reviewer, was to tackle the cost, lifespan, and energy aspects of LIB electrode materials by innovating the manufacturing process. The team opted to create powders using aerosol procedures to derive CAMs, solid electrolytes, additive particles for lifespan extension, and filler particles for polymer composites. While the team had successfully advanced its experimental capabilities, the materials' performance did not measure up to the current leading materials. The project's ambitious timeline and the inclusion of a broad spectrum of materials, each demanding unique synthesis conditions, raised concerns for the reviewer about the potential dilution of efforts.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the team completed the facility's construction for a 500 g/hour production and developed *in situ* real-time UV-Raman monitoring capability. Subsequently, the facility was utilized to demonstrate the FSP synthesis of several battery-related materials. Among these, the synthesis of LT-NMC111 via FSP stands out as particularly interesting, as it utilizes a precursor with atomic mixing and rapid quenching, uniquely enabled by FSP. This approach may extend to other NMC materials.

Reviewer 2:

The reviewer stated that the FSP system has been developed at the progressive production scale of 500 g/hour. The addition of the Framework for Self-Driving reactor operation and UV-Raman real-time diagnostic system represents a step closer to industrial manufacturing and is open for further improvement. The reviewer recommended implementing an auto-detection mechanism for abnormalities in real-time UV-Raman diagnostic characterization to handle the large amount of data in real time. FSP and solution precipitation (SP) have been used to produce various active materials, proving their capability to synthesize specific materials that are difficult to achieve otherwise, such as $LiCo_{0.8}Al_{0.2}O_2$ and the spinel/layer composite LT-NMC111. These are unique chemistry systems that can offer additional insights into new strategies for improving CAM quality at the lowest cost.

Reviewer 3:

The reviewer remarked that the project's overall objective does not appear to align with the DOE Vehicle Technologies Office (VTO) goals. The cathode materials reported in this presentation are either high in Co or outdated for EV applications. Furthermore, the cycling performance of the synthesized cathode materials is subpar. XRD plots indicate peak broadening, suggesting a lack of crystallinity. The charge capacity for lithium cobalt aluminum oxide appears to be extremely low, even with such a high surface area material. The reviewer emphasized the need for a thorough investigation to understand the reasons for such poor performance. For FY 2022, all seems acceptable, but there is a lack of detailed information.

Reviewer 4:

The reviewer suggested that the team has synthesized several materials, but their performance is not optimized. The reviewer recommended that the team focuses on a small set of material compositions before expanding efforts to other compositions. The *in situ* Raman diagnostics, the reviewer praised, are particularly impressive.

Reviewer 5:

The reviewer commented that for FY 2022 everything seemed to be OK, but there are detailed pieces of information missing.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer suggested that the collaboration can be broadened by including other national laboratories with synchrotron and neutron facilities for *in situ* structural characterization of the heating process.

Reviewer 2:

The reviewer commented that as a team working as intermediaries between laboratory scale and pilot run of material synthesis, this is a well-rounded team with collaboration within ANL in software integration, with industry partner Cabot Corporation (Cabot Corp.), and the academic institution Purdue University.

Reviewer 3:

The reviewer noted that the team assembled for the project appears to be knowledgeable in the area of the proposed work.

Reviewer 4:

The reviewer pointed out that only collaborations with Cabot Corp. and Purdue University are indicated.

Reviewer 5:

The reviewer recommended that the team has adequate collaborations within the project team but also suggested having external collaborations, especially with experts specialized in conventional synthesis methods. The reviewer emphasized the importance of direct comparisons between the samples produced in this project and those produced by other methods.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer pointed out that there are numerous options for tuning the process parameters to accommodate different material syntheses. The project should concentrate on materials that are uniquely accessible via FSP and should seek more collaborators who can benefit from the products of the FSP facility.

Reviewer 2:

The reviewer observed that the purpose for future work has been clearly defined, and the targets are achievable within the proposed time frame. However, the reviewer suggested that a clearer plan could be achieved by taking negative factors into account. For example, a slower evaporation rate of the FSP system may address the high surface area issue, but on the other hand, it may also reduce the production rate.

Reviewer 3:

The reviewer commented that the proposed work appears to be more driven by academic curiosity than commercial value that could generate interest from cathode manufacturers. High voltage spinels currently lack a stable electrolyte, and disordered rock salt (DRX) is still a long way from creating commercial interest. The work to reduce surface area is considered critical, as it aligns well with commercial needs, particularly in achieving higher solid content in slurry.

Reviewer 4:

The reviewer noted that the proposed future research seems acceptable.

Reviewer 5:

The reviewer commended the team for creating a great facility for the manufacturing process and for providing a variety of different materials in terms of compositions and crystal structures. However, the reviewer suggested that the complexity could become overwhelming and recommended that the team should focus on specific areas. Additionally, the reviewer proposed that the team may consider including TEA and life-cycle analysis to evaluate the practical impact of their work.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that the FSP facility, along with other materials synthesis and processing centers at ANL, such as the hydrothermal synthesis facility and the Materials Engineering Research Facility (MERF), will serve as a strong driving force in new materials discovery and the development of new synthesis protocols, both for laboratory and industrial-scale production.

Reviewer 2:

The reviewer pointed out that the project has demonstrated the potential for continuous high-volume production of various materials, including cathodes, solid electrolytes, and other components for battery production.

Reviewer 3:

With the integration of auto-reactor operation and *in situ* UV-Raman diagnostic characterization, the reviewer said the project has taken a significant step closer to pilot-scale material production in industrial manufacturing. The possibility of synthesizing unique chemistry systems through aerosol methods also broadens the path for improving CAMs.

Reviewer 4:

The reviewer emphasized the importance of alternative manufacturing methods for cathode materials and other battery materials in the context of domestic manufacturing. While the proposal aims for this, the reviewer expressed that the results are not particularly encouraging. The reviewer suggested that the team should focus on present or next-generation cathode or electrolyte materials that can help address some of the technoeconomic challenges in the field.

Reviewer 5:

The reviewer acknowledged that the project has direct relevance to the VTO subprogram objectives and is aligned with the overall goals of VTO programs. The successful outcome of the project, the reviewer affirmed, could be transformative.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the project has sufficient resources for further development, but they may require intra-lab collaborations in machine learning (ML) optimization.

Reviewer 2:

The reviewer affirmed that the resources are adequate for a small team to achieve the stated accomplishments.

Reviewer 3:

The reviewer remarked that the team is well-suited for achieving the goals of this project.

Reviewer 4:

The reviewer concurred, stating that the resources are indeed sufficient.

Reviewer 5:

The reviewer observed that the team has developed ample resources, especially experimental apparatus, to perform the tasks, and suggested that some external experts may offer additional assistance.

Presentation Number: BAT360
Presentation Title: Scale-up, Optimization and Characterization of High-nickel Cathodes
Principal Investigator: Arumugam Manthiram (University of Texas at Austin)

Presenter

Arumugam Manthiram, University of Texas at Austin

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

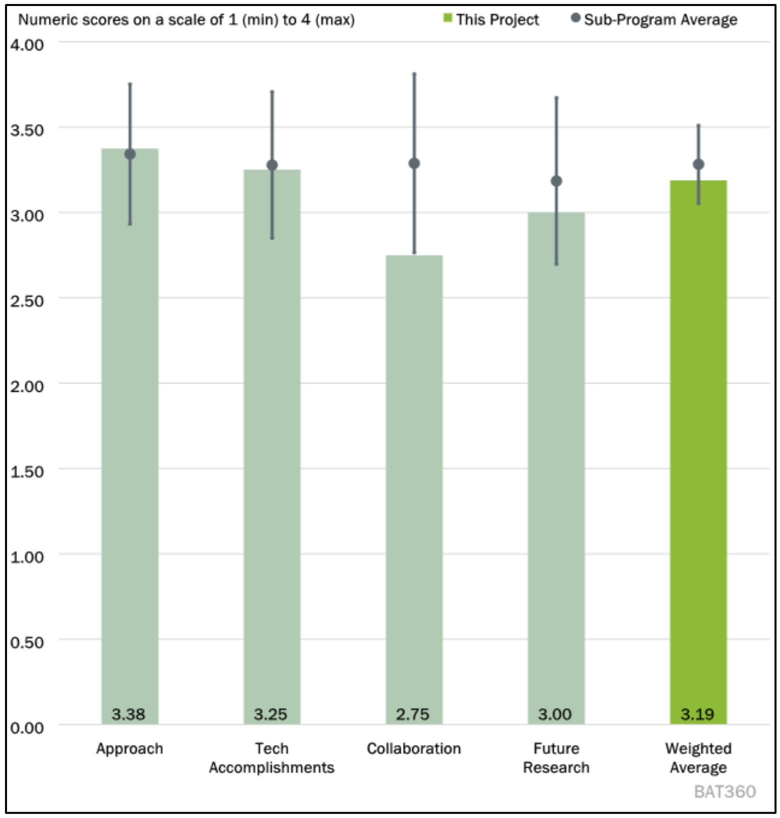

Figure 1-11 - Presentation Number: BAT360 Presentation Title: Scale-up, Optimization and Characterization of High-nickel Cathodes Principal Investigator: Arumugam Manthiram (University of Texas at Austin)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commended the approach taken by Prof. Manthiram's group, noting its excellence. However, the reviewer also pointed out an extraordinarily broad scope in the project, which includes scale-up of high nickel (Ni) NMCs, Li_2S electrocatalyst, SSE development, liquid electrolyte optimization, and gas generation studies.

Reviewer 2:

The reviewer acknowledged that the team is effectively addressing a major technical barrier concerning a no-Co, high-energy-density cathode. Developing advanced electrolytes is considered a promising avenue for improving the high-voltage performance of high-nickel cathodes. The reviewer noted that, as is characteristic of Professor Manthiram's research, the work is conducted systematically and employs excellent diagnostic techniques to complement the investigation.

Reviewer 3:

The reviewer recognized the team's expertise in cathode materials synthesis and material characterizations. However, the reviewer expressed a concern regarding the project's title, which focuses on the scale-up and optimization of Ni-rich materials, while the presentation lacks relevant details in this regard.

Reviewer 4:

The reviewer questioned the purpose of repeating the work on NMC811, as previous knowledge indicated that the work on lithium solid electrolyte (LSE) had been done in a collaboration institute in previous years. The reviewer sought clarification on whether the intention is to establish a baseline at UT-Austin, which did not work on this before.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that there is an impressive amount and quality of data presented.

Reviewer 2:

The reviewer expressed that the team has made outstanding progress over the past year, and this progress has been detailed in numerous reports, papers, and presentations. The reviewer highlighted that the team has effectively demonstrated the critical role of electrolyte stability in the performance of high-nickel cathodes, as well as the benefits of localized saturated electrolytes. However, the reviewer pointed out a potential inaccuracy in the reference on Slide 7, as the paper referred to $LiCoO_2$ and not NMC811.

Reviewer 3:

The reviewer acknowledged that the team has synthesized high-quality cathode materials and designed novel lithium solid electrolyte (LSE) electrolytes. The combination of Ni-rich cathodes and LSE electrolytes, in general, shows much-improved performance. However, the reviewer suggested that since the presentation focuses on the scale-up and optimization of Ni-rich materials, the team should provide more details about the cathodes themselves. Additionally, the reviewer recommended using a high-quality commercial Ni-rich NMC as a baseline to help the reviewer understand the advantages of the Ni-rich cathodes prepared by the team.

Reviewer 4:

The reviewer inquired about quantitative numbers for the in-house scale-up of the high Ni cathode, seeking information about the volume at which the scale-up currently stands. This information, the reviewer noted, would provide insight into the progress over time. The reviewer also expressed surprise that no structural information had been provided, given the numerous collaborators working on X-ray-related characterization. Structural data, the reviewer emphasized, is crucial for the reviewer to judge whether the right material has been synthesized.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer suggested that, given the excellent cycling results shown, increased collaboration with industry may be relevant.

Reviewer 2:

The reviewer pointed out that some of the R&D activities are being conducted by a capable team comprising members from national laboratories and academia. The reviewer noted that the PI mentioned collaboration with an industrial partner, General Motors (GM), in response to the reviewers' comments. The reviewer recommended that this collaboration and GM's specific contributions to the project should be explicitly noted in the presentation slides.

Reviewer 3:

The reviewer acknowledged that this is a highly collaborative team with diverse capabilities from each PI. However, the reviewer noted that the role of the industry partner is not always clear.

Reviewer 4:

The reviewer raised the concern that while many collaborators have been listed, their specific contributions are not clearly marked in the presentation. The reviewer emphasized that it is essential to highlight the specific contributions from these team members. Additionally, the reviewer noted that there were many collaborators working on synchrotron-related work, but no data was provided on the materials synthesized.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer recommended de-emphasizing research on high nickel (Ni) NMC materials, as the industry has made significant progress in commercializing these materials. The reviewer noted that while dopants for high voltage (V) stability are valuable, there may not be a substantial additional energy gain to be obtained in this area.

Reviewer 2:

The reviewer expressed concern about the milestones listed on Slide 4, specifically the ones related to developing a solid electrolyte for Li/S and fabricating Li_2S electrocatalysts. The reviewer indicated that these milestones appear to be out of touch with the project’s focus. In light of this, the reviewer suggested that the project should start investigating next-generation cathode materials and leave further refinement and analysis of transition metal oxide cathodes to the industry.

Reviewer 3:

The reviewer acknowledged that the future plan shifts from Ni-rich cathodes to Li-sulfur (Li-S) batteries, and the team has defined future tasks clearly. However, the reviewer recommended that the team clarify how they intend to transfer optimal electrolyte compositions from Ni-rich cathodes to Li-S batteries.

Reviewer 4:

The reviewer criticized the project’s approach, describing it as a “cook and look” approach with a conservative experimental design that lacks a comprehensive vision regarding the key parameters affecting electrolyte stability. The reviewer expressed concern that there is a lack of clarity and guidance in the project’s strategies for searching or designing electrolytes to address the key challenge.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that the effort is highly relevant.

Reviewer 2:

The reviewer stated that this effort is relevant and will aid B500 in meeting its near-term goals, particularly in moving away from Co and developing a high energy density cell.

Reviewer 3:

The reviewer expressed that this is a very successful project and has the potential to help achieve the VTO objectives.

Reviewer 4:

The reviewer noted that the work is relevant to VTO's objective of achieving high energy density energy storage technologies.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found the resources appropriate and considered the project to be an excellent value for the R&D investment.

Reviewer 2:

The reviewer noted that the team has access to the best resources in the United States, which enables them to successfully meet their project goals. However, the reviewer expressed difficulty in assessing the resources fully when the specific amount devoted to this project is not provided.

Reviewer 3:

The reviewer stated that the team possesses ample and appropriate experimental resources, which can be fully utilized and leveraged to their maximum potential, especially when collaborating with other entities.

Reviewer 4:

The reviewer observed that the project has involved numerous entities with various aspects of battery research and applications. The reviewer suggested that the PI should make efforts to involve these entities and encourage their contributions to the project.

Presentation Number: BAT362
Presentation Title: High Capacity S Cathode Materials
Principal Investigator: Prashant Kumta (University of Pittsburgh)

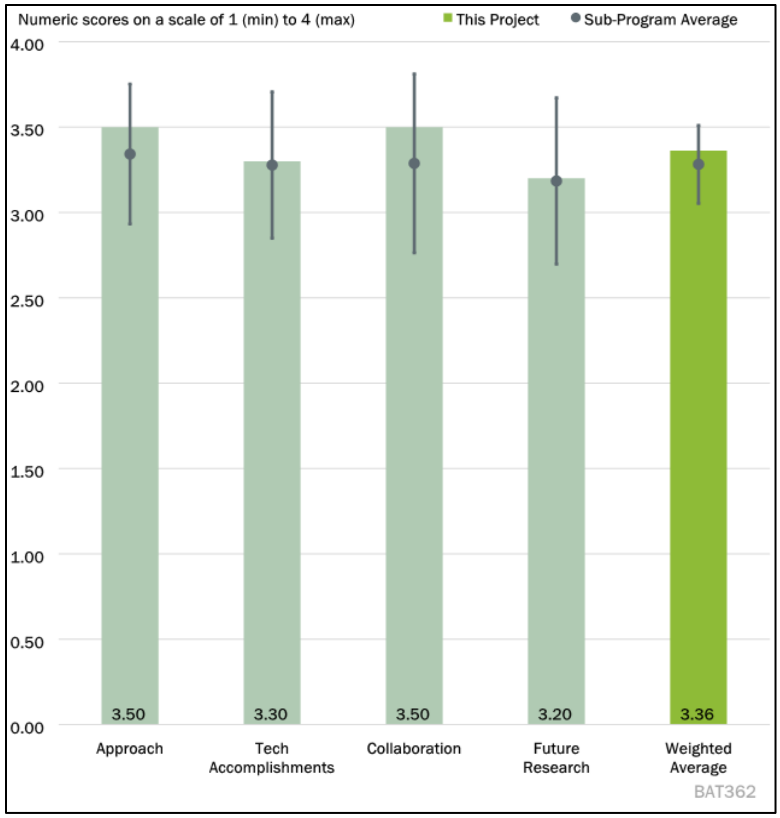

Figure 1-12 - Presentation Number: BAT362 Presentation Title: High Capacity S Cathode Materials Principal Investigator: Prashant Kumta (University of Pittsburgh)

Presenter

Prashant Kumta, University of Pittsburgh

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer found the project to have a reasonable approach to developing high-energy sulfur cathodes, especially in the context of the B500 program. The emphasis on achieving high loading (more than 5 mAh/cm^2) electrodes for EV cells was noted as a positive aspect.

Reviewer 2:

The reviewer pointed out that a carbonized PAN (polyacrylonitrile) fiber mat was used as a sulfur host material, eliminating the need for a binder. The project successfully demonstrated a high areal loading of sulfur in a coin cell. The reviewer emphasized that in addition to areal capacity, the density of the fiber mat and thus the volumetric capacity is also crucial.

Reviewer 3:

The reviewer commended the project team for accurately identifying technical barriers and having a well-planned timeline.

Reviewer 4:

The reviewer expressed several weaknesses and concerns:

The project’s progress is still far from the B500 goals after a year into the second phase.

Achieving 300 Wh/kg in subsequent pouch cells with the capacities and electrolyte content used is doubtful.

The cycle life target for the current year (100 cycles) may not be challenging enough compared to the ultimate goal of 1000 cycles.

Reviewer 5:

The reviewer provided a detailed overview of the project's alignment with the B500 program's general approach and goals, including breakthroughs in controlling electrochemical reactions, materials development, collaboration between national laboratories, universities, and industry, and achieving total control of battery chemistries for scalable technologies.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer expressed concern about the 600–800 mAh/g capacity shown on Slide 12 at C/10, noting that while it is better than NMC, it is not dramatically better. The reviewer pointed out that such high loadings tend to exhibit very high impedances, as evidenced by the 20% capacity drop when the rate is increased from C/20 to C/10.

Reviewer 2:

The reviewer noted that a fiber mat was successfully made, and sulfur was loaded into the mat. The electrode's performance was demonstrated in a coin cell, showing decent capacity and cycle life. However, with 53% porosity, the reviewer raised concerns about the density of the electrode and suggested investigating the rebound or bounce-back of the electrode after compression.

Reviewer 3:

Regarding the infusion of sulfur on conducting carbon and carbon fiber mat (CFM) substrates, the reviewer mentioned that the reported cell-specific energy on Slides 12 and 13 is not provided. Additionally, considering the high sulfur content (78%) in the cathode, the effectiveness of CFM in trapping polysulfide intermediates is unclear. The reviewer suggested conducting a volume ratio analysis for more insight.

Reviewer 4:

The reviewer acknowledged the good progress in developing directly generated sulfur architectures on conducting carbon and integrating them with suitable catalysts. High proportions of sulfur were infused into these carbon mats, leading to cathodes with high areal capacities (5–6.3 mAh/cm^2) and decent cycle life (80 cycles) with good capacity retention. However, the reviewer questioned why the cycling stopped at 80 cycles and inquired about the failure mode. The reviewer recommended testing these cathodes in multi-layer pouch cells under real lean electrolyte conditions (E/S less than 5) with a Li anode or preferably a Li alloy to understand their performance in terms of specific energy and cycle life.

Reviewer 5:

The reviewer noted that the technical progress is good and contributes to overcoming some barriers. However, the reviewer expressed concerns that the achieved performance levels are promising but not on par with program goals. The reviewer suggested focusing on demonstrating performance enhancements in pouch cells in parallel with material development to expedite technology implementation.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the PI collaborates with members of the B500 consortium, indicating good collaboration within the consortium.

Reviewer 2:

The reviewer stated that collaboration between the B500 consortium members appears to be very good.

Reviewer 3:

The reviewer observed that several B500 team members are listed as team members in this project and suggested that collaboration with these team members may be possible later as new cathode materials and binders are developed. However, the reviewer raised a weakness, noting that there appears to be no active collaboration with any of the team members specific to this project. The reviewer recommended considering collaboration with an industrial partner or a national laboratory (e.g., PNNL or INL) to demonstrate the materials in pouch cells in parallel with material development.

Reviewer 4:

The reviewer provided information about the project's affiliation with the B500 program and listed the collaborating entities, which include PNNL, Binghamton Univ., BNL, INL, GM, Penn State Univ., Stanford Univ./SLAC, Texas A&M, UC San Diego, Univ. of Maryland, Univ. of Pittsburgh, Univ. of Texas, Austin, and Univ. of Washington, as well as an industry advisory board team.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer commented positively on the proposed future work, particularly noting that it's essential to have means of evaluating sulfur (S) and electrolytes beyond cycle life testing in fundamental work on challenging chemistry.

Reviewer 2:

The reviewer mentioned that future plans will focus on the porous structure of the mat and potential catalyst investigation. However, the reviewer recommended that the PI demonstrate longer cycle life in full cells as part of the future work.

Reviewer 3:

Regarding the proposed future research on incorporating functional electrocatalysts, the reviewer found it to be a reasonable approach.

Reviewer 4:

The reviewer provided an overview of the well-laid-out plans for future studies, including developing new sulfur hosts and catalysts to improve the specific energy, kinetics, and cycle life of Li-S cells. However, the reviewer pointed out that the studies seem to continue focusing on material development and suggested that part of the effort should also focus on demonstrating the performance enhancements from these materials in pouch cells.

Reviewer 5:

The reviewer acknowledged that the team has identified and proposed detailed future work, including the identification of mesoporous ordered ceramics (MOCs) and porous organometallic framework materials (POFM) serving various functions in Li-S cells. The proposed studies were considered effective and valuable in addressing most of the barriers.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized the high relevance of sulfur (S) as a high-energy and EaCAM.

Reviewer 2:

The reviewer stated that the Li-S battery is highly relevant to the VTO objectives.

Reviewer 3:

The reviewer noted that this project aligns perfectly with the mission of the VTO Battery program, emphasizing that Li-S batteries hold great promise in addressing supply constraints associated with high nickel cathodes, making them highly relevant and significant for the program’s objectives.

Reviewer 4:

The reviewer pointed out that the project supports the overall DOE objectives by developing advanced Li-S cells with higher specific energy, lower cost, enhanced safety, and improved cycle life compared to LIBs. The reviewer highlighted the focus on mitigating the polysulfide shuttle and improving cycle life with new sulfur hosts and catalysts, making the project relevant to the DOE VTO Batteries program objectives and goals.

Reviewer 5:

The reviewer mentioned that this project is an integrated part of the B500 program, with a specific focus on Li-S batteries.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found the project’s resources to be reasonable and commensurate with the scope of work.

Reviewer 2:

The reviewer noted that the PI and the B500 consortium have sufficient resources to support the research activities.

Reviewer 3:

The reviewer stated that the resources of the project appear to be sufficient.

Reviewer 4:

While the reviewer mentioned that the resources for the overall project seem commensurate with the scope and adequate to achieve the targeted milestones, the reviewer also noted that it is not clear how much is the allocation specifically for this project, as the numbers given are for the entire B500 program.

Reviewer 5:

The reviewer concluded by mentioning that the fund is comparable to the scope of work, and the progress and findings are significant.

Presentation Number: BAT367
Presentation Title: Multiscale Characterization Studies of Li Metal Batteries
Principal Investigator: Peter Khalifah (Brookhaven National Laboratory)

Presenter

Peter Khalifah, Brookhaven National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

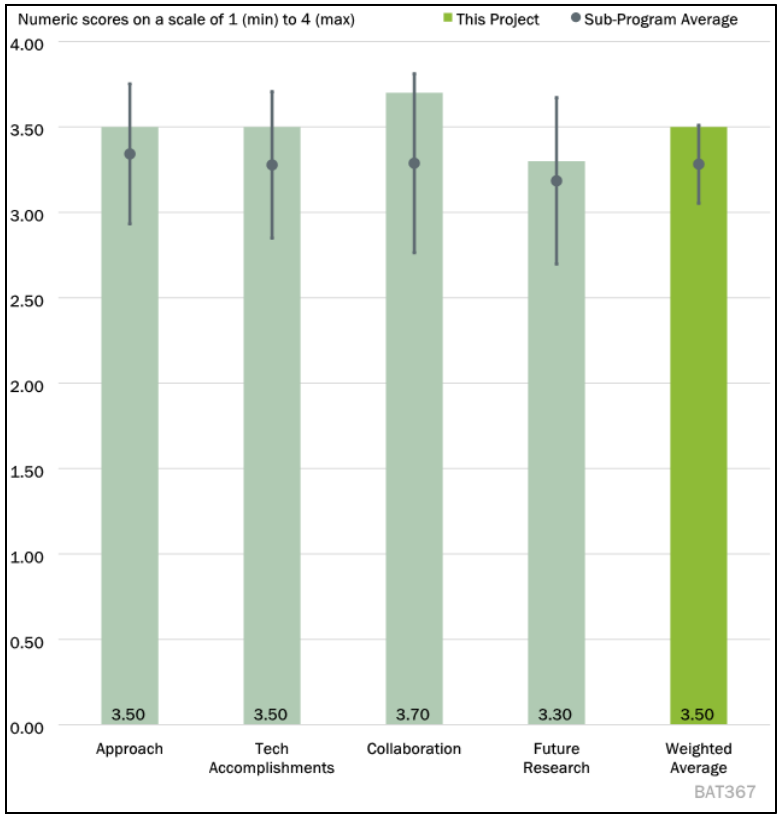

Figure 1-13 - Presentation Number: BAT367 Presentation Title: Multiscale Characterization Studies of Li Metal Batteries Principal Investigator: Peter Khalifah (Brookhaven National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer acknowledged the project's use of synchrotron X-ray diffraction for *operando* probes into the Li-S cell, solvent effects on polysulfides, and the components of the Li metal solid-electrolyte interface (SEI). The results were noted to effectively probe key battery components with superb sensitivity to light elements and were expected to characterize the SPAN cycling mechanism, sulfur polymorphism, and Li metal SEI evolution.

Reviewer 2:

The reviewer stated that the project's objective is to characterize battery materials and their electrochemical processes using synchrotron X-ray-based techniques. The project team was commended for making good use of the large user facilities at DOE laboratories and for employing their expertise in battery materials and synchrotron techniques developed over their long tenure of battery studies.

Reviewer 3:

The reviewer expressed some skepticism about the effectiveness of characterizing the SEI chemically and morphologically in solving critical issues in Li metal batteries. The reviewer mentioned that decades of papers on characterizing the SEI on graphite have contributed to understanding how certain additives work but may not have directly contributed to solving the problem. Industry was noted to have already solved the SEI-related problems a decade or two ago.

Reviewer 4:

Regarding the project's stated technical barrier of increasing the energy density of Li-ion cells, the reviewer noted that the approach seems to be more focused on understanding failure modes of materials used for high-energy batteries rather than directly increasing energy density. The reviewer pointed out that the project develops techniques to understand chemical speciation during cycling but questioned how these results would lead to changing the chemistry.

Reviewer 5:

The reviewer affirmed that the work is part of the larger B500 project and is well-integrated with the efforts within B500. The data obtained from the BNL sub-team was deemed valuable and timely, and it was expected to aid the broader B500 team in understanding the internal processes of cells when varying electrolytes, among other factors.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted the completion of speciation studies in Li-S pouch cells, quantification of transition metal cross-over amounts, and the investigation of the solid-electrolyte interface (SEI) of Li metal anodes.

Reviewer 2:

The reviewer commented the project's research accomplishments were primarily focused on Li-S pouch cell batteries and Li-metal anodes in NMC coin cells. The reviewer acknowledged that the project team had made discoveries that could advance understanding of the SPAN reaction mechanism and Li-metal SEI. However, the reviewer suggested that the team should further develop these findings into electrochemical insights and utilize the knowledge to improve battery performance. The reviewer posed questions about the origin and implications of inhomogeneities in the degree and rate of phase transition in charge products in Li-S batteries and how this phenomenon relates to capacity retention.

Reviewer 3:

The reviewer praised the technical work as excellent but expressed a preference for the work to be aimed at understanding how things work and fail, rather than focusing solely on characterization. The reviewer suggested exploring whether SEI films with specific morphologies or chemical compositions are more durable than others and how insights in sulfur battery chemistry can improve approaches to solving problems.

Reviewer 4:

The reviewer provided detailed information about the accomplishments related to synchrotron diffraction, the detection of polysulfides, transition metal dissolution, and the presence of LiH on the surface of Li. These techniques were considered unique and valuable for understanding the failure modes of Li/S and Li/NMC cells and the impact of electrolyte composition.

Reviewer 5:

The reviewer mentioned that it was not entirely clear from the limited information in the slides how far the interpretation of the data extended. For instance, the data on transition metal dissolution was presented, but the presentation did not provide significant insight into why manganese (Mn) is more likely to dissolve. The reviewer acknowledged the progress as significant, with real findings that have had an impact, describing the effort as very solid.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer highlighted the strong collaborative efforts within the team, particularly between Stony Brook and BNL in the current period. The collaboration was described as well-coordinated.

Reviewer 2:

The reviewer also noted the extensive collaboration within the B500 consortium, which includes national laboratories, universities, and industrial companies. The roles of each institute within the consortium were well-defined, indicating a high level of organization.

Reviewer 3:

While acknowledging the excellence of the collaboration, the reviewer suggested that the team could benefit from the involvement of theorists who could work on leveraging the new information.

Reviewer 4:

The reviewer observed that despite being from a university, one team member appeared to be collaborating with several members of the consortium to help them understand why their specific components were not performing well.

Reviewer 5:

Overall, the reviewer praised the collaboration between BNL and the rest of the B500 team, highlighting the importance of the questions being addressed at the synchrotron and their strong integration with the broader goals of the B500 project. This collaborative aspect was considered a significant strength of the effort.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer mentioned that the team presented a clear plan for future research, which includes several specific areas of focus:

Operando diffraction mapping studies on the Li metal anode to improve Li utilization and understand the differences between anode-free and Li-anode configurations.

Diffraction mapping studies on the Li-S cell to improve S utilization and understand phase transitions, morphology, speciation, and inhomogeneity, along with their dependence on cell conditions.

Further XRD, pair distribution function (PDF), and spectroscopy studies on the Li-metal SEI using the B500 electrolytes.

Reviewer 2:

The reviewer noted that the proposed questions for future research were relevant and specific. However, there was a mention of “N/A” in the section about “Remaining challenges and barriers,” which the reviewer found unusual, as most PIs in other projects typically list the problems to be addressed in their future research.

Reviewer 3:

The reviewer suggested that future research should connect present results to proposed solutions.

Reviewer 4:

The reviewer indicated that the researcher's plans seemed to involve further understanding the failure of Li, S, and NMC and its connection to the electrolyte. The reviewer expressed curiosity about the outcomes of this research.

Reviewer 5:

Overall, the reviewer found future plans to be acceptable and highlighted that the questions to be addressed in the next year were interesting and had the potential for significant impact within the B500 program if the work proved successful.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer found that the project aligns with the VTO objective to develop batteries with a specific energy of 500 Wh/kg and featuring Li metal anodes. They also noted that the project places a strong emphasis on developing and demonstrating effective characterization techniques, particularly through the use of synchrotron diffraction and spectroscopy methods.

Reviewer 2:

The reviewer acknowledged the significance of advanced synchrotron X-ray techniques as powerful tools for *in situ* or *operando* materials characterization across multiple length scales. They believed that the project's efforts would deepen the understanding of material properties and reaction mechanisms in Li-ion batteries, ultimately accelerating their application in EVs.

Reviewer 3:

The reviewer stated that the relevance was "okay."

Reviewer 4:

The reviewer emphasized the importance of achieving 1,000 cycles for high-energy batteries, considering it a critical barrier that must be overcome for practical use in vehicles. They appreciated the researcher's innovative techniques for studying these systems and believed that they could provide valuable insights into the performance of existing battery systems.

Reviewer 5:

Overall, the reviewer concluded that the project was highly relevant to the B500 program and aligned well with the VTO subprogram objectives for batteries. They saw the project's relevance as evident and crucial to advancing battery technology.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that based on the above evaluations, the project's resources were deemed sufficient and appropriate to achieve the stated milestones on time.

Reviewer 2:

The reviewer affirmed that the team had access to the synchrotron facilities and possessed expertise in both battery studies and synchrotron X-ray techniques.

Reviewer 3:

The reviewer stated that the resources were sufficient.

Reviewer 4:

The reviewer observed that the researcher demonstrated a strong understanding of how different techniques could contribute new insights to the problem, noting that they performed well under the current funding.

Reviewer 5:

The reviewer commented that resources appeared to be sufficient because the necessary work was being accomplished. However, the reviewer questioned why the resources allocated to this specific BNL team were not listed in the presentation materials provided. This omission made it challenging to assess how effectively funds were utilized. Nevertheless, the reviewer appreciated the fact that the work was progressing, regardless of the level of funding received. The reviewer recommended including a clear breakdown of the funding allocated to this 3-PI team at BNL in next year’s presentation.

Presentation Number: BAT368
Presentation Title: Full Cell Diagnostics and Validation to Achieving High Cycle Life
Principal Investigator: Eric Dufek (Idaho National Laboratory)

Presenter

Eric Dufek, Idaho National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

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

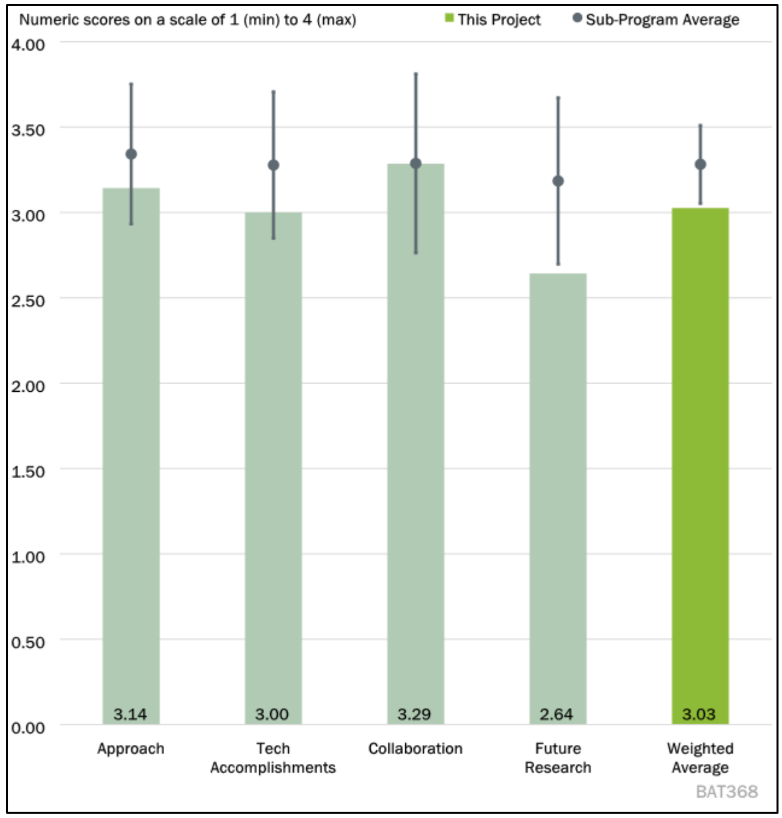

Figure 1-14 - Presentation Number: BAT368 Presentation Title: Full Cell Diagnostics and Validation to Achieving High Cycle Life Principal Investigator: Eric Dufek (Idaho National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted that the project's scope extends beyond "diagnostics and validation," contrary to what its title suggests. It is, in fact, a comprehensive battery research and development (R&D) endeavor, focusing on cell-level development by integrating advancements in materials and cell design. The reviewer affirmed that the project's targets, including 500 Wh/kg energy density, 5–10 Ah capacity, and 1000 deep cycle, along with well-defined milestones, were clearly articulated.

Reviewer 2:

The reviewer stated that the project is appropriately centered on high cathode loading and lean electrolyte, a strategic approach that facilitates the transfer of knowledge and findings to the industry.

Reviewer 3:

The reviewer remarked that while the project is designed to explore the lifetime aspects (cycle life and calendar life) concerning external pressure using sulfur cathode and NMC811 cathode, it has primarily concentrated on Li metal anode to enhance performance and employed advanced analysis techniques such as EOCV (electrochemical open circuit voltage), dQ/dV (change in voltage with change in capacity), and dP/dV (change in pressure with change in voltage). The reviewer expressed the view that it is challenging to conclusively assert that the work fully supports full cell diagnostics and validation, as comprehensive diagnostics should encompass not only the anode but also the cathode, electrolyte, and various internal and external variables.

Reviewer 4:

The reviewer commented that the project's strategy of using coin cells for materials optimization followed by single-layer pouch cells for realistic performance validation and failure mechanism understanding is sound. In the initial stages of materials discovery and development, single-layer pouch cells offer valuable insights without the complexities associated with multiple-layer pouch cells.

Reviewer 5:

The reviewer affirmed that the multi-faceted approach adopted by the project is suitable for a complex program in a field that has been extensively researched.

Reviewer 6:

The reviewer observed that the project appears to involve the INL in the production of Li/S, Li/SPAN, and Li/NMC811 coin cells and pouch cells, as well as the testing of certain electrolytes and the evaluation of pressure levels. However, it was noted that the project's connection to other efforts aimed at producing electrodes from the same materials and its unique contributions were not entirely clear.

Reviewer 7:

Regarding the first task related to SPAN production and slurry development, the reviewer stated that the work seemed to be progressing well and supporting the overall B500 team, including material sent to GM. However, for the second task involving aging of NMC811 cells and the impact of pressure, the reviewer commented that the work appeared to be in its preliminary stages, and the potential impact of the data on the project's objectives was not entirely clear. The reviewer noted that the tests conducted and presented so far may not be sufficient to fully understand how real cells behave under real conditions. Nevertheless, the reviewer acknowledged that it was a promising start and suggested that more information about the testing matrix and ongoing or upcoming activities would have been beneficial.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer acknowledged that the project plan was successfully executed in terms of technical achievements. Significant progress was noted in three key areas: SPAN electrode recipe development, pressure tuning on Li-NMC811, and calendar aging assessment on Li-NMC811 cells. However, the reviewer raised a valid point regarding the calendar life study, emphasizing that solely relying on normalized capacity to track aging effects might not provide a comprehensive evaluation. The reviewer suggested that other parameters, especially those critical for specific applications, should be considered when evaluating different materials and cell designs.

Reviewer 2:

The reviewer expressed appreciation for the valuable new information about coupled mechanical and electrochemical responses, commending the team's efforts in the area of calendar aging.

Reviewer 3:

Regarding technical accomplishments, the reviewer found them to be somewhat achieved. The addition of the form to assess the effect of external pressure on both the anode and cell was viewed as a notable achievement. The utilization of EOCV (electrochemical open circuit voltage) and calendar aging differential analysis to understand battery cycle and calendar life was acknowledged as a standard practice. However, the reviewer pointed out that while the project met the milestones as stated, those milestones were more like general task descriptions than specific, measurable goals. The reviewer suggested that refining the milestones with specific numerical targets would facilitate a clearer assessment of progress.

Reviewer 4:

The reviewer expressed expectations of a high level of accomplishment based on the funding level. However, within the context of the challenging battery chemistry improvements, the accomplishments were considered adequate. The reviewer raised concerns about the project's ability to achieve the stated milestones based on the progress observed to date, suggesting that some industrial efforts might be ahead in meeting state program milestones.

Reviewer 5:

The reviewer provided an overview of the team's accomplishments in each of their objectives. For the first accomplishment involving moving from coin cells to pouch cells with a Li/SPAN system, the reviewer noted good repeatability and cyclability, especially at 10 psi. For the second accomplishment related to finding ways to cycle Li/NMC811 without dendrites, the reviewer mentioned success using a constant volume system with foam support, leading to more uniform and compact Li deposition. Regarding the third accomplishment, it was established that holding a Li/NMC cell at 4V and higher pressure resulted in a longer calendar life compared to 4.4V and lower pressure.

Reviewer 6:

The reviewer reiterated a concern about how the project's results align with the work of other consortium members and emphasized the need for greater clarity in this regard.

Reviewer 7:

The reviewer observed that progress on the first objective, involving SPAN material production and calendaring techniques, appeared more advanced compared to the aging studies on Li-NMC811, which were still in the early stages of producing results. The reviewer also noted the presence of eight publications but requested clarification on which of these publications were the primary outcomes of this team's work within the larger B500 team. Highlighting the team's primary contributions in the publications would have been beneficial.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the project is a part of the B500 consortium, which involves various national laboratories, universities, and industry companies, and commended the well-defined roles of the participating teams.

Reviewer 2:

The reviewer described collaboration with GM as sufficiently deep to have a real impact. However, the reviewer pointed out the need for clarity when using terms like "mAh/g," emphasizing that specifying the unit of measurement (grams of what) is essential. Additionally, the reviewer questioned the utility of mAh/g as a measure and advised against presenting CE on a 0%–100% scale, as it does not provide useful information.

Reviewer 3:

The reviewer acknowledged that collaborative efforts within the consortium have been facilitated through electrode shipments to some partners but expressed a desire to see more bilateral collaboration between team members.

Reviewer 4:

The reviewer appreciated the diverse composition of the team, which included national laboratories, academia, and industry representatives. However, the specific contributions from each team member were not clearly delineated. The reviewer suggested that a breakdown of tasks by team members would be helpful for evaluation.

Reviewer 5:

The reviewer noted that materials were being shared among team members. The reviewer emphasized the need for improved coordination within the entire B500 consortium.

Reviewer 6:

The reviewer observed a clear handoff of work to GM and suggested that more coordination within the B500 consortium would be beneficial.

Reviewer 7:

Regarding the INL-led team's collaboration with the rest of the B500 team, the reviewer noted that efforts were well-coordinated, particularly in ensuring quality SPAN material access. However, there was concern about the schedule for aging studies, and the reviewer recommended accelerating the timeline to provide actionable information to other B500 participants in a timely manner. It was also unclear from the presentation which members of B500 were relying on the data and analysis generated by the INL-led team.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer noted that high-level future plans were provided but suggested that they could be made more specific. Given the demonstrated R&D capabilities, the team was considered highly likely to achieve the targeted objectives.

Reviewer 2:

The reviewer expressed the belief that the project should incorporate a theoretical component and mentioned that the group was planning to do so. Additionally, it was emphasized that state of health (SOH) should not be defined solely by capacity and that decreases in voltage should also be accounted for.

Reviewer 3:

The reviewer mentioned difficulty in discerning all the details of what the PI would undertake in the future. For instance, transitioning from small cells to large format cells, such as moving from coin cells to pouch cells, was suggested to require a consistent approach for advanced analysis to highlight any differences. The reviewer recommended a more detailed description of the future plan, including advancements.

Reviewer 4:

The reviewer recommended more specific future work, particularly in characterizing the calendar life of Li/SPAN SLPC to assess the extent to which the polysulfide issue is mitigated with the SPAN cathode.

Reviewer 5:

The reviewer stated that the program is on the most viable path to achieve the objectives.

Reviewer 6:

While stating that the program was on a viable path to achieve its objectives, the reviewer pointed out that much of the future work seemed focused on better understanding the results obtained thus far.

Reviewer 7:

The reviewer raised concerns about the generic and somewhat vague descriptions of future work. Specific examples were provided, such as the need for prioritization in understanding cell performance with varied use protocols and clarification regarding "Continued integration of Keystone 1 and 2 advancements," as Keystone 1 and 2 were not explained in the presentation. Further context would be beneficial for better comprehension.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer commented that cell-level battery design and fabrication represent the final steps in delivering high-energy, low-cost batteries for vehicle electrification.

Reviewer 2:

The reviewer stated that this was highly relevant.

Reviewer 3:

The reviewer affirmed that the project aligns with the VTO goals and objectives. However, the reviewer noted the absence of many technical details and emphasized the importance of understanding the failure mechanisms of high-energy cells with lithium metal anodes. The reviewer requested more fundamental approaches to elucidate the full cell failure mechanisms, including validation for not only Li metal but also cathode/electrolyte interfaces.

Reviewer 4:

The reviewer acknowledged that achieving 1000 cycles in a 500 Wh/kg cell was highly relevant to VTO objectives but expressed doubts about the feasibility of reaching these targets with a sulfur-based cathode (Li/S system). The reviewer recommended benchmarking Li/S against LFP (lithium iron phosphate) instead of high-energy density NMC cathodes, emphasizing the importance of the abundance of sulfur in the supply chain. The reviewer proposed setting a goal of 1000 cycles in a 300 Wh/kg Li/S cell and incorporating Li/S into the EaCAM rather than B500.

Reviewer 5:

The reviewer found the project relevant to VTO objectives, particularly in achieving high-energy dense batteries with relatively abundant materials.

Reviewer 6:

The reviewer emphasized that the work was focused on advanced batteries with Li-ions and Li metal, aiming to achieve higher energy density with longer life, which was in line with VTO objectives.

Reviewer 7:

The reviewer considered the work highly relevant, provided it was conducted at a comprehensive level. The reviewer noted the importance of gathering extensive data about real systems, as failure in a real system with high loadings and lean electrolyte can differ significantly from laboratory-scale demonstrations.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the resources were efficient for achieving the milestones, with close collaboration with other teams in the B500 consortium.

Reviewer 2:

The reviewer found the resources to be sufficient.

Reviewer 3:

The reviewer expressed reservations about recommending the proposal for renewal based on the following points:

The reviewer believed that the project's purpose was somewhat misleading, as most of the work focused on external pressure applied to Li metal and its diagnosis in full cells, which represented only one aspect of the interaction and understanding of interfacial reactions from the Li metal side.

The reviewer raised concerns about the collaboration with partners, describing it as unilateral or not fully described in the proposal. The reviewer also suggested that the potential impact of the work for the scientific community was limited in this case.

Reviewer 4:

The reviewer reiterated that resources were sufficient for the stated milestones.

Reviewer 5:

The reviewer noted that it was a large program, but it involved relatively mature technology development, which might require higher funding levels.

Reviewer 6:

The reviewer observed that the future research appeared to align with what had already been completed, assuming that the resources for this work were adequate.

Reviewer 7:

The reviewer noted that it was not entirely clear how much funding within B500 was available for this specific project. While funding numbers were provided for B500 as a whole, the reviewer noted that the project appeared to be fairly appropriately resourced, considering the number of people involved and the results achieved thus far.

Presentation Number: BAT377
Presentation Title: ReCell–Overview and Update
Principal Investigator: Jeffrey Spangenberger (Argonne National Laboratory)

Presenter

Jeffrey Spangenberger, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

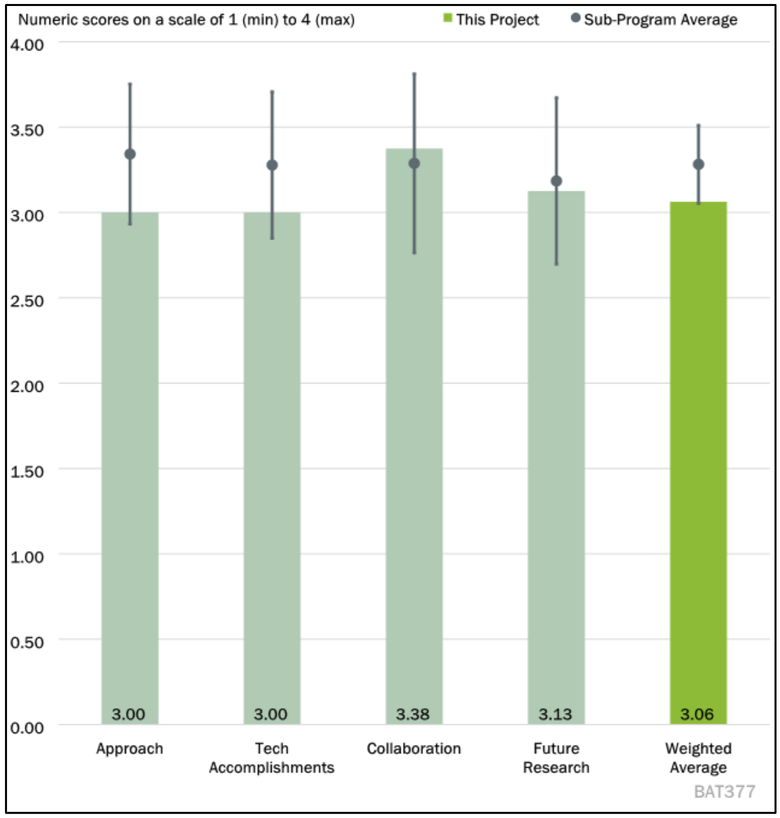

Figure 1-15 - Presentation Number: BAT377 Presentation Title: ReCell–Overview and Update Principal Investigator: Jeffrey Spangenberger (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

During the session, there was a notable emphasis on the goal of making recycling economically viable for the industry, which was deemed a significant objective. However, the reviewer raised several points of concern and suggested the need for a broader approach:

The reviewer pointed out that while there were innovative ideas and plans to try out these ideas at a larger scale for NMC cathodes, there appeared to be limited activity addressing the cost challenges of other materials like LFP. The reviewer highlighted the importance of addressing cost challenges for less economically viable materials, as these would be present in many cells in the future. Making cost-loss materials attractive through recycling innovations could have a more substantial long-term impact.

The reviewer mentioned that the project was planning to build a pilot plant but noted that the outcomes and objectives of this approach were not clearly defined. Questions were raised about whether the pilot plant aimed to prove new technologies developed by ReCell, improve process economics and scale-up models, or enable cell manufacturers to become accustomed to using recycled materials.

Reviewer 2:

The reviewer noted that while the presentation provided a high-level overview and update, it lacked detailed information on the projects within ReCell.

Reviewer 3:

The reviewer appreciated the broad and comprehensive scope of ReCell and stated that the research conducted had meaningfully addressed this scope. The approach of dividing the work into focus areas and ending projects prematurely if they showed minimal promise for commercialization was considered appropriate. However, the reviewer expressed a desire to know if there had been any areas of study terminated due to lack of promise. The reviewer recommended greater outreach to the industry and continuous benchmarking to avoid duplicating efforts that industry may have already solved. Additionally, the reviewer emphasized the importance of ensuring that the parameters of the cooperative research and development agreement (CRADA) model were not prohibitive and did not discourage the adoption of technologies developed by ReCell by recyclers.

Reviewer 4:

The reviewer acknowledged that technical barriers, particularly lowering the cost of recycling as a percentage of the battery cost and decreasing the environmental footprint compared to using natural resources, were discussed in the overview. The approach to address these barriers through direct recycling methods and the use of the EverBatt model to evaluate costs of proposed technologies was considered well-designed. The addition of investigations into second-use and hydro/pyro processing was noted, though the reviewer expressed some reservations about the potential expense of the pyro process and recommended further justification for its research. Overall, the timeline for the project was deemed reasonable.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer acknowledged the major accomplishment of proving the concept for direct recycling but raised some concerns about the overall progress of the project, particularly in relation to the entire battery system and materials beyond the cathode. Despite the involvement of over 80 people and the project's duration of over four years, the reviewer noted that the output of 20 inventions and 40 publications seemed relatively low.

Reviewer 2:

The reviewer mentioned that while progress had been made according to the project plan, more work was needed to demonstrate that direct recycling could work on a larger scale, both technologically and economically.

Reviewer 3:

The reviewer provided comments specific to different technology areas within the project:

Direct Recycling: The reviewer questioned the continued focus on upcycling and cathode separation, suggesting that these approaches might primarily be aimed at end-of-life (EOL) batteries. The reviewer emphasized that the most promising opportunity for direct recycling could be plant scrap if economically justified. While acknowledging that these techniques could be demonstrated at the laboratory scale, the reviewer pointed out that practical implementation could be challenging due to non-idealities and competition with more robust and scaled approaches. The reviewer also found the work on the conversion of polycrystalline to single crystal interesting.

Advanced Resource Recovery: The reviewer noted valuable expansion of ReCell's scope and promising results in multiple areas. The processing of sodium sulfate was recommended as an additional area of focus, despite existing solutions not being economically attractive.

Design for Sustainability: The reviewer expressed doubts about the novelty of some projects in this area and suggested continuous monitoring of companies that are commercializing the explored study areas.

Modeling and Analysis: The reviewer praised the excellent results in this area and highlighted the potential value of the multiple models being developed for supply chain and technology optimization and analysis.

Reviewer 4:

The reviewer noted that the presentation provided an overview of ReCell Center research activities and that most technical accomplishments occurred under other companion projects. The focus of this project was primarily on coordinating with other ReCell partner members, engaging with industry, and expanding facilities, aligning well with the project plan.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer emphasized the importance of clarifying that multiple national laboratories are collaborating within the ReCell Center and coordinating their efforts to address project challenges.

Reviewer 2:

The reviewer stated that the level of collaboration with industry, research institutions, and universities was praised as impressive.

Reviewer 3:

The reviewer pointed out that in certain project areas, such as Design for Sustainability, there should be more discussion and interaction with industry stakeholders. While participation across universities and national laboratories was considered adequate, the reviewer stressed the importance of enhanced collaboration with industry to ensure that successful research findings find interested customers for adoption and scaling. Such collaboration could also help identify practical problems and challenges that may be related to the technology and must be considered.

Reviewer 4:

The reviewer provided information about the ReCell consortium, which consists of four national laboratories and four universities, each with specific roles. The addition of INL to the consortium was commended, and it was noted that the consortium had organized Industry Collaboration Meetings, bringing several industrial partners together to collaborate on various aspects of recycling.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer acknowledged that progress in recycling had been made through ReCell and across the United States in various aspects of recycling. The current structure with a more specific sub-thrust focus on work was deemed agreeable. However, the reviewer suggested several points for consideration going forward:

Reporting progress toward a recycle cell cost goal and updating the percentage of a cell that can be made using recycled parts in a single cell could be helpful metrics for tracking and demonstrating progress.

Clearer outcomes and benefits of scale-up should be defined and justified in future work.

For the lower-value parts of batteries, the reviewer recommended emphasizing additional work on second-life or non-battery product uses.

Given the potential hazards associated with dealing with used batteries, the reviewer proposed that the innovative minds at national laboratories could focus on safety methods or products to protect workers, which could be considered by the recycling center.

Reviewer 2:

Regarding the presentation of future work areas, the reviewer expressed the need for more detail to fully understand if the proposed future work would achieve its targets.

Reviewer 3:

The reviewer found the proposed future work points to be relevant and well-defined. However, the reviewer suggested prioritizing certain items, such as increasing industry involvement and feedback and facilitating technology transfer to recyclers. The reviewer also pointed out important focus areas not explicitly listed, including what to do with lower-value byproducts from recycling (excluding Li, Ni, Co), such as sodium sulfate, plastics, and graphite. Additionally, the reviewer found the work on graphite to graphene interesting. Another emerging focus area highlighted by the reviewer was LFP recycling.

Reviewer 4:

Overall, the reviewer found the proposed future research plan was consistent with the overall objective of the ReCell consortium, and achieving these objectives would continue to make progress toward the eventual goal.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized the critical nature of recycling work and deemed the ReCell Center relevant in this context.

Reviewer 2:

The reviewer noted that the project and activities conducted at ReCell supported the objectives of the VTO related to reducing the cost of EV battery packs.

Reviewer 3:

The reviewer found the comprehensive approach to a wide range of process options in battery recycling and EOL redeployment highly relevant. Identifying sustainable recycling approaches and separation techniques was considered critical, particularly in maximizing the benefits as society transitions to e-mobility.

Reviewer 4:

The reviewer concluded that the project was very relevant to addressing several concerns related to the broader adoption of battery EVs, aligning with VTO's subprogram objectives. These concerns included addressing EOL battery issues, recycling to recover valuable materials for future batteries, and addressing supply chain concerns.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that for the number of people involved and the project goals, the resources were currently deemed sufficient. However, the reviewer cautioned that resource use could become excessive if the project team failed to define and then achieve the outcomes sought by building a pilot plant.

Reviewer 2:

The reviewer stated that there appeared to be sufficient support from stakeholders.

Reviewer 3:

The reviewer commented that the resources seemed sufficient and, in some cases, possibly more than sufficient, particularly for topic areas with limited promise for wide deployment by industry.

Reviewer 4:

Regarding funding, the reviewer provided that in the first two years, the funding was $14.68 million, and for FY 2022 and FY 2023, it was $18.9 million. The reviewer noted that the amount of funding appeared to be more than sufficient but pointed out that it was not clear how much of the funding went to the operation, project management, and collaborations within ReCell.

Presentation Number: BAT386
Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Overview and Progress Update
Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

Presenter

Venkat Srinivasan, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

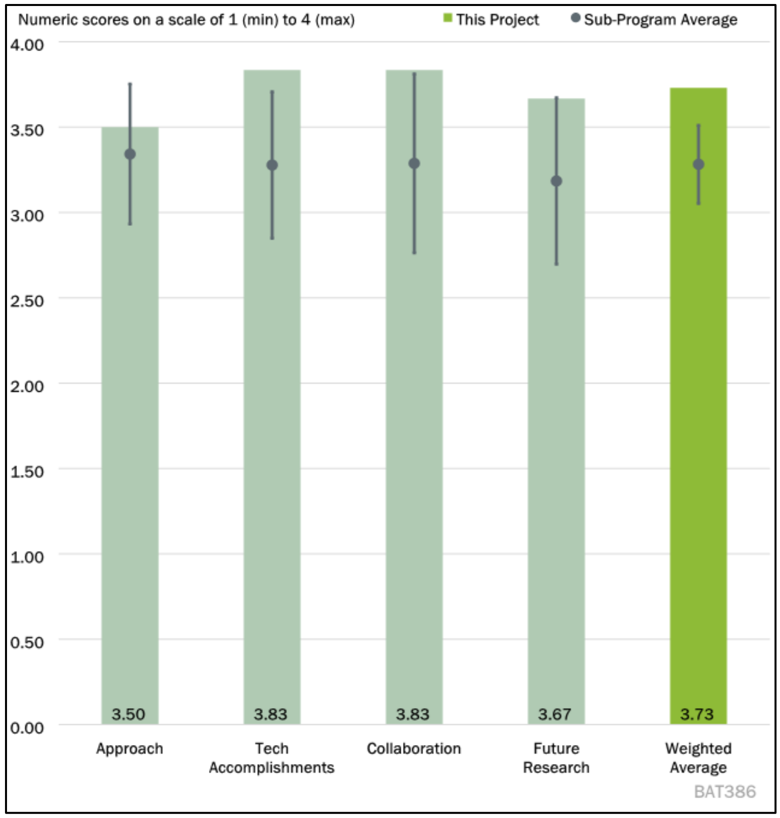

Figure 1-16 - Presentation Number: BAT386 Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Overview and Progress Update Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commended the program for effectively addressing technical barriers related to extreme fast charging (XFC), including cell degradation under fast charging conditions, and reducing high cell costs to increase recharge acceptance.

Reviewer 2:

The reviewer noted that the team had done excellent work by pursuing various directions to design a unified approach to eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL). They emphasized that the parallel development of advanced anode, cathode, and electrolyte components was critical in addressing degradation mechanisms in fast charging. The reviewer also emphasized the importance of considering long-term cycling and calendar life impacts. The proposed ML approach was regarded as an excellent next step in the program.

Reviewer 3:

The reviewer highlighted that the project correctly identified the three critical barriers (Li plating, temperature rise, cathode particle cracking) preventing LIB chemistry from being charged at a fast rate. The project adopted separate approaches to address these challenges, and through inter-lab collaboration, some progress had been made. This progress allowed LIBs of graphite/NMC811 to be charged at a 6C rate with minimal fading and Li plating.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that progress had been made, and major go/no-go milestones had been met in the project.

Reviewer 2:

The reviewer stated that the team had achieved all the targets they had set for the project. They mentioned that there were some advances in certain topics and roadblocks had been identified.

Reviewer 3:

The reviewer highlighted that the researchers had adopted new electrolyte compositions, redesigned anode architecture, and integrated CNTs to facilitate fast ion transport and charge transfer. These novel techniques had contributed to the project's achievements in fast charging capability.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer stated that the collaborations among team members are excellent.

Reviewer 2:

The reviewer said that the collaboration and coordination across the project teams are outstanding.

Reviewer 3:

The reviewer commented that the researcher in the national laboratories have shown highly collaborative working manner in pursuing the resolution of technical barriers.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer found the proposed future work to be properly illustrated, suggesting that it aligns with the overall scope of the project. However, they expressed a desire to see a technology transition plan illustrated and raised uncertainty about the involvement of battery OEMs in the program. Additionally, the reviewer recommended considering the impact on battery shelf life, even though some new designs appear to facilitate XFC, and some understanding of XFC mechanisms has been achieved in the program.

Reviewer 2:

The reviewer emphasized the critical nature of identifying degradation mechanisms as various enablers are studied, seeing this as essential for the project's success.

Reviewer 3:

The reviewer suggested that future efforts should focus more on electrolyte improvement. They pointed out that knowledge gained from low-temperature electrolyte projects funded by DOE and the new electrolyte classes invented by PNNL could provide an excellent starting point for enhancing fast-charging capabilities.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer consistently emphasized the high relevance and importance of the project in the context of electrification and the adoption of EVs on a large scale.

Reviewer 2:

The reviewer noted that XFC remains a critical issue for the widespread adoption of EVs and that this program provides strong support to the objectives of the VTO.

Reviewer 3:

The reviewer found the project to be extremely highly relevant, underscoring its significance in addressing the challenges and advancements needed for the adoption of electrification and EVs.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources assigned to this program are appropriate.

Reviewer 2:

The reviewer commented that the funding planned for this project is sufficient to achieve the proposed goals.

Reviewer 3:

The reviewer stated that the resources provided are sufficient.

Presentation Number: BAT423
Presentation Title: Development of New Electrolytes for Lithium-Sulfur Batteries
Principal Investigator: Gao Liu (Lawrence Berkeley National Laboratory)

Presenter

Gao Liu, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

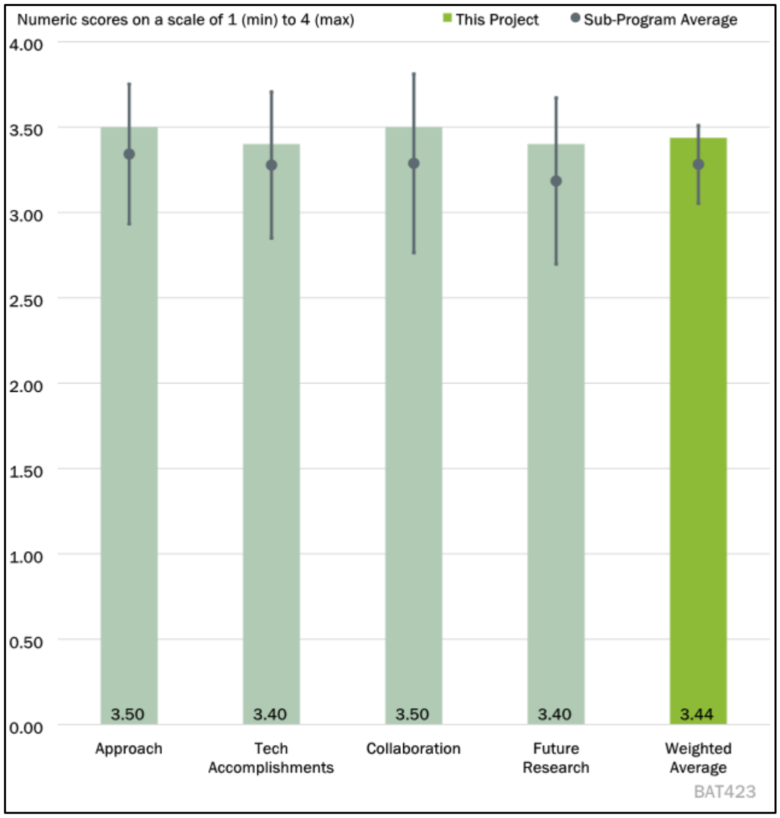

Figure 1-17 - Presentation Number: BAT423 Presentation Title: Development of New Electrolytes for Lithium-Sulfur Batteries Principal Investigator: Gao Liu (Lawrence Berkeley National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said that new concepts were introduced for electrolytes of Li-S batteries, effectively addressing most associated issues. They also remarked on the synthesis, characterization, and testing of the new electrolytes in electrochemical cells and the investigation into mechanisms of polysulfide retention.

Reviewer 2:

The reviewer commented on the successful mitigation of technical barriers related to polysulfide reactions with Li-containing anodes using the new electrolyte. They acknowledged the project’s proper design and the group’s reasonable approach, combining amphiphilic molecules with Li salt and cosolvent. Additionally, they noted the identification of potential issues and proposed strategies to address them.

Reviewer 3:

The reviewer expressed that the technical barriers were effectively addressed, particularly in terms of cycle life performance. They praised the well-designed project with a reasonable timeline schedule. Specific achievements were articulated, such as the identification of T5FDLiTF electrolyte and impressive performance metrics, including high capacity and cycle efficiency.

Reviewer 4:

Regarding the project's overarching goal, the reviewer affirmed that it aims to improve the energy density and cycling/calendaring life of Li-S batteries. They observed the project's focus on promoting polysulfide affiliation with the electrode substrate to prevent the shuttle effect and enable stable Li metal deposition or high-capacity alloy anodes. Moreover, they verified the utilization of advanced characterization facilities and found the approach promising and the timeline reasonable.

Reviewer 5:

The reviewer commended the investigators for their work on novel electrolytes and additives aimed at addressing barriers in Li-S batteries. However, they questioned the project's failure to meet the objective of developing high-ion conductivity electrolytes. The reviewer noted that the reported conductivity values fell short of industry standards. Additionally, they clarified the absence of commentary on this matter and the neglect of electrolyte viscosity. Concerns were raised about the potential impact of micelles on viscosity as they become more concentrated.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that electrolytes have been proposed, synthesized, and tested. They found the results promising, although there is still some clear cell degradation effect that needs to be addressed.

Reviewer 2:

The reviewer commented that the team has demonstrated systematic studies towards their final target and distributed their workload evenly within a suitable timeline. They acknowledged that the team accomplished their work on time and made good progress. The new electrolyte shows promising performance and a strategy to address soluble polysulfide reaction with the Li anode. However, the reviewer suggested that it would be beneficial to account for potential issues that may arise in future studies.

Reviewer 3:

In terms of technical progress, the reviewer mentioned that the team has made significant advancements. For instance, they identified an optimized T5FDLiTF electrolyte with superior cell performance for Li-S batteries using amphiphilic fluorinated additives. The inclusion of full cell tests with pre-lithiated alloy anodes was recognized as a significant step towards practical high-energy, low-cost batteries. However, the reviewer pointed out that no data were provided for the characterization of solvation and polysulfides dissolution.

Reviewer 4:

The reviewer highlighted the team's achievements over the past year, noting that they have met milestones effectively. Specifically, the team optimized the structure of electrolytes with amphiphilic fluorinated additives, hydrofluoroether solvents, dioxane solvent, and Li salts. The reviewer also commended the identification of the T5FDLiTF electrolyte combination as a superior composition for Li-S battery applications. Additionally, the team's implementation of diffraction characterization techniques to understand the micelle solvation mechanism of the electrolytes and their use of a protected pre-lithiated alloy anode for sulfur cathode-based batteries were recognized as important contributions.

Reviewer 5:

The reviewer pointed out that the electrochemical results were not documented in the review regarding cathode loadings and the ratio of electrolyte to active cathode material. They stressed that this information is crucial for comparison with other research since specific capacities and cell cycle life are highly sensitive to these variables. The reviewer suggested that the investigators include this type of information or at least provide a basis for comparison in their reports, given the extensive research conducted on these systems in recent years. Furthermore, they recommended testing the cells to higher cycle life, such as 100 cycles compared to the reported 20 cycles, as the Li-S system is known to suffer sudden declines in performance as the anode degrades.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer suggested that while numerous collaborations are mentioned, it would be beneficial to demonstrate more about the integration of this project with its long list of collaborators in the future.

Reviewer 2:

The reviewer noted that the collaboration within the project team seems strong, with a well-defined list of collaborators, and potentially, there may not be a need for more collaboration. Roles and responsibilities for the various collaborations are clearly defined, and cross-functional cooperation and communication among team members appear cohesive, indicating a commitment to accomplishing the project.

Reviewer 3:

The reviewer found the collaboration within the project team to be excellent. They highlighted successful X-ray characterization of electrolyte micelle structures, polysulfide dissolution, and precipitation in collaboration with synchrotron physicists. The micro- and nanostructures of the amphiphilic electrolytes were characterized in collaboration with ORNL and Texas A&M University. Additional collaborations were mentioned, including General Motors for verifying the Li-S performance, Conamix Inc for testing the amphiphilic electrolytes, and BAE for technology inputs and commercial aspects of this technology for potential defense applications.

Reviewer 4:

The reviewer recognized that the team has involved multiple researchers from two national laboratories, two universities, and three industries in this project. They also noted that the PI has collaborated effectively with these partners on material synthesis, characterization, and cell testing.

Reviewer 5:

The reviewer pointed out that a large group of collaborators has been assembled, which should serve the project's goals well and could potentially provide answers to questions raised by the reviewer, such as testing to higher cycle life and measuring additional electrolyte properties.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer noted that the project has clear future goals, and based on the current report, they are likely to be successfully accomplished.

Reviewer 2:

The reviewer observed that the future work aligns with the project plans and will help provide an in-depth understanding for further development.

Reviewer 3:

The reviewer pointed out that the project has clearly defined a purpose for future work with a clear milestone planned for FY 2023. They mentioned that, based on the PI's collaborations and detailed schedules, the plans could be executed on time.

Reviewer 4:

The reviewer stated the proposed future work will be primarily focused on the optimization of electrolytes to improve their properties, such as ion transport, to enhance performance. Additionally, the team plans to work on cathode electrode design, specifically targeting high sulfur (S) loading and lean electrolyte conditions for Li-S batteries.

Reviewer 5:

The reviewer stated the future work intends to address some of the previous issues. The reviewer suggested paying attention to cathode loading and the electrolyte-to-cathode ratio to meet current standards in the field.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that the project is well aligned with VTO objectives.

Reviewer 2:

The reviewer noted that the project demonstrates strong relevance to VTO's goals, particularly in the context of low-cost, high-energy-density batteries for electrification and support of the stated objectives.

Reviewer 3:

The reviewer emphasized that this project supports the overall VTO subprogram objectives for low-cost and high-energy Li-S batteries, which have potential applications in electrical energy storage.

Reviewer 4:

The reviewer articulated that the success of the project can address the challenges associated with the high cost and low energy density of Li-ion rechargeable batteries. They highlighted the potential of emerging Li-S batteries to be both high energy-density and low cost, enabling the utilization of low-cost and abundant sulfur as a major chemical component for electrical energy storage.

Reviewer 5:

The reviewer underscored the high relevance of this work in supporting the VTO subprogram objectives for developing low-cost, high-energy batteries for electric transportation.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that the resources are sufficient to carry out the proposed plans.

Reviewer 2:

The reviewer mentioned that the project's resources include a dedicated workforce with the necessary expertise to execute the project. The reviewer expressed confidence that these sufficient resources should enable the project to accomplish its goals and address potential technical challenges in future studies.

Reviewer 3:

The reviewer acknowledged the resourceful collaborations that the PI listed and stated that these collaborations should be sufficient for the project to achieve its stated milestones in a timely fashion.

Reviewer 4:

The reviewer noted that the project has involved a team with complementary expertise from national laboratories, universities, industry, and original equipment manufacturers (OEMs) to develop high-energy and low-cost Li-S batteries. The reviewer concluded that the project has sufficient resources to accomplish the proposed work.

Reviewer 5:

The reviewer deemed the collaboration provides excellent resources to carry out the work.

Presentation Number: BAT427
Presentation Title: *In Situ* and *Operando* Thermal Diagnostics of Buried Interfaces in Beyond Lithium-Ion Cells
Principal Investigator: Sumajeet Kaur (Lawrence Berkeley National Laboratory)

Presenter

Sumajeet Kaur, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

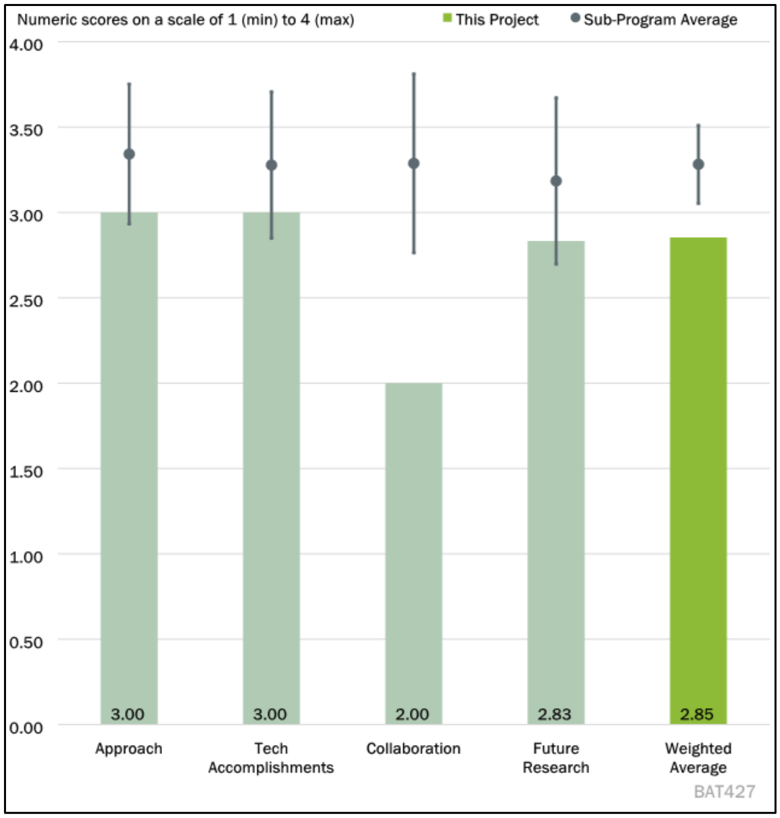

Figure 1-18 - Presentation Number: BAT427 Presentation Title: *In Situ* and *Operando* Thermal Diagnostics of Buried Interfaces in Beyond Lithium-Ion Cells Principal Investigator: Sumajeet Kaur (Lawrence Berkeley National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer praised the research for establishing a novel diagnostic technique that can *in situ* and *ex situ* characterize the buried interfaces in SSBs. They noted its effectiveness in distinguishing different phenomena, including entropic, kinetic, and transport properties, based on harmonics and frequency. Importantly, the reviewer highlighted that it is a non-invasive measurement method with the potential to provide valuable information, especially when combined with the new electrochemical method multiharmonic electrothermal spectroscopy (METS). They also mentioned that the project is currently in progress, displaying promising results, and aligning well with its milestones.

Reviewer 2:

The reviewer commended the project for successfully identifying potential issues related to interfacial problems in the Li-metal anode for SSB systems. They acknowledged that the project has proposed specific strategies using the thermal wave sensing technique to characterize and address these issues.

Reviewer 3:

The reviewer noted that the timeline for 2022 has been completed and highlighted the capability of METS to measure resistances at the interface of the solid electrolyte, Li-metal, and solid electrolyte.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the presented poster showcased the accomplishment of the technical part as planned and in good progress. However, they suggested that the PI should present the results following the setup milestones to make it easier for the audience to follow.

Reviewer 2:

The reviewer commented that the team presented the setup and testing results for characterizing the interface and obtained useful information for understanding the Li metal anode. They found the project plan to be reasonably planned, with milestones aligned with the project's objectives. However, they suggested that it would be beneficial to include some discussion of combining other conventional characterization techniques to comprehensively present the identified interface properties.

Reviewer 3:

The reviewer stated that the project plan was accomplished according to schedule. They recommended that impedance measurement using METS should be compared with other methods that measure resistance and resistivity for a more comprehensive assessment.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that there might have been some collaboration related to the *ex situ* morphology and structure of the interfaces, and they suggested that the PI should clarify or emphasize this aspect.

Reviewer 2:

The reviewer pointed out that the collaboration was not listed. They emphasized that collaboration using other characterization techniques could be helpful in enhancing the understanding of interfacial properties as illustrated by the thermal wave sensing techniques.

Reviewer 3:

The reviewer highlighted the absence of pronouncements regarding contributions made by universities, national laboratories, and industry. They suggested expanding the testing of more cathode samples, particularly transforming them from polycrystalline to monocrystalline, especially in cases where cathodes do not contain Ni, Mn, and Co. The reviewer recommended broadening the materials for the cathodes being tested by seeking input and ideas from industry partners.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer acknowledged that the proposed future research is well-defined, targeting the remaining challenges and ongoing experiments. They also noted that the PI needs to validate the METS technique for different materials and verify its applicability on the model electrochemical system.

Reviewer 2:

The reviewer mentioned that the future work aligns with the project plans, but they suggested that it would be beneficial to have more detailed characterization results or information on material structural properties to verify the obtained results.

Reviewer 3:

The reviewer expressed a need for more information on the purpose of the future work. While they acknowledged that the project had achieved its proposed objectives, they also stated that it is very likely that the objectives will be achieved based on the proposed work.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that the research aligns with the overall VTO batteries subprogram objectives, particularly within the SSBs program. They noted that the developed techniques have the potential to be supportive for other battery systems, aiding in understanding different phenomena on the interfaces.

Reviewer 2:

The reviewer also emphasized that the project demonstrates relevance to VTO’s goals and supports its objectives.

Reviewer 3:

The reviewer pointed out that the project supports the analysis of batteries, energy-efficient mobility systems, and materials. They highlighted the significance of characterizing the solid electrolyte interface without a need to insert external agents or devices into the sample, allowing for specific morphological characterization.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer mentioned that resources are adequate to achieve the milestone in a timely fashion. However, they suggested that if more work is proposed related to the deeper analysis of the data and so on, the budget could be reconsidered.

Reviewer 2:

The reviewer noted that the project’s resources include a dedicated workforce with the necessary expertise to execute the project. They expressed confidence that these resources should enable the project to accomplish its goals and tackle potential technical challenges. The reviewer also highlighted that additional resources from collaboration could enhance the understanding of the proposed work.

Reviewer 3:

The reviewer affirmed that the resources are sufficient, and they noted that the implementation of METS was achieved successfully.

Presentation Number: BAT429
Presentation Title: Electrolytes and Interfaces for Stable High Energy Sodium-Ion Batteries
Principal Investigator: Jason Zhang (Pacific Northwest National Laboratory)

Presenter

Jason Zhang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

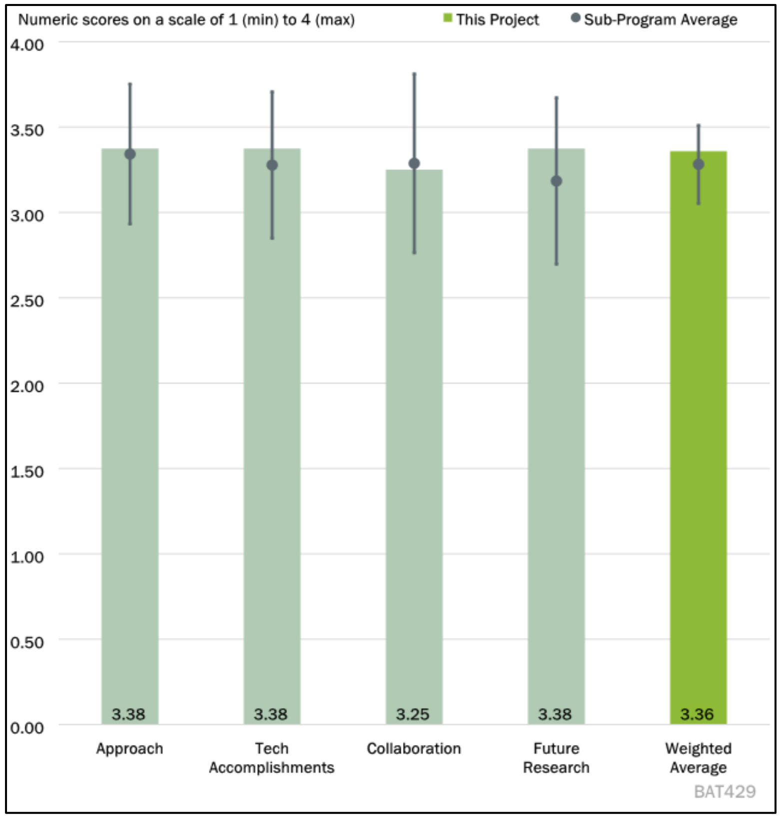

Figure 1-19 - Presentation Number: BAT429 Presentation Title: Electrolytes and Interfaces for Stable High Energy Sodium-Ion Batteries Principal Investigator: Jason Zhang (Pacific Northwest National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked that the project is well designed. They noted that the development involves Prussian blue electrodes and fluorine-containing electrolytes, with the electrodes displaying a decent response in the fluorinated solvent. However, the reviewer expressed concern about initial instabilities in CE and requested the authors to comment on the reasons behind these instabilities. The reviewer sought an explanation for the incompatibility of the system with other carbonate and tetraethylene glycol dimethyl ether (TEGDME)-based electrolytes. The reviewer questioned the authors' goals regarding cycle life enhancement. They pointed out that the authors mentioned short cycle life as a barrier but requested clarification on both short-term and long-term objectives in addressing this issue. Regarding the SEM images of the electrodes, the reviewer inquired about the pressure applied during pressing to reduce porosity. They asked for clarification on the pressure levels used. Additionally, they raised a concern about how the electrodes are protected from contact with air and moisture, given the presence of water of crystallization. In terms of testing the non-flammable characteristic of the electrolyte, the reviewer sought clarification on the methodology. They asked whether the electrolyte is soaked in the membrane and inquired about the quantity of electrolyte used for this test.

Reviewer 2:

The reviewer praised the project for effectively addressing technical barriers through a well-designed approach. They commended the comprehensive strategy and logical task sequence, highlighting a robust and well-thought-out project plan.

Reviewer 3:

Recognizing that the technology is in its infancy, the reviewer affirmed that the project is addressing key technical barriers, especially cycle life, by developing novel electrolytes. They noted the application of successful design principles from other battery systems to this investigation.

Reviewer 4:

The reviewer acknowledged the project has a clear approach to investigating and optimizing stable 4V electrolytes compatible with the cathode for high-energy Na-Ion batteries. They found the timeline and work plan reasonable and suggested including details on cycling conditions to better understand material performance.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the technical progress made by the team is excellent. They highlighted the development of the fluorinated solvent for the NaFSI electrolyte. However, they requested more details on the amount of electrolyte used in the tests and the concentration of the salt in the fluorine-containing solvent. They also noted the low conductivity of approximately 0.05 mS/cm and inquired about its impact on the rate capability of the system and whether there are plans to study this further.

Reviewer 2:

The reviewer noted the Prussian blue electrode developed by the team showed a decent response. The reviewer raised questions about the long-term stability of this system and its structural stability as sodium is removed. They also mentioned a voltage plateau at 3V–3.2V and inquired about the possibility of crystallographic changes. Furthermore, they sought clarification regarding the self-extinguishing time for the non-fluorinated solvent, particularly whether it is zero and what that signifies. They asked about the material shown in the figure that appears to support a flame.

Reviewer 3:

The reviewer praised the project's aim to design a non-flammable fluorinated solvent-based electrolyte compatible with high-energy-density Prussian blue and $NaFe_xMn_{1-x}O_2$ (NFM) cathode materials. They commended the excellent progress made by the project team in addressing this goal. The reviewer noted the thorough characterization efforts and the exploration of a new ether-based electrolyte, which they found to be commendable advancements in achieving stable sodium stripping/plating processes.

Reviewer 4:

The reviewer mentioned good progress in characterizing the commercial cathode material and producing electrodes of various densities for electrolyte analysis. They acknowledged the identification of a new electrolyte containing NaFSI, which displayed good cycling and oxidation stability. However, they expressed minor concerns about its low ionic conductivity (IC).

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer stated that the team has established collaboration with ANL and Lawrence Berkeley National Laboratory (LBNL). They noted that the team plans to provide electrode materials to ANL and LBNL for interface and materials characterization but mentioned that it is not very clear what each of the collaborators is doing. The reviewer suggested providing more details in this regard.

Reviewer 2:

The reviewer commented that the collaboration efforts with ANL and LBNL appear to be reasonable.

Reviewer 3:

The reviewer remarked that the efforts with ANL and LBNL seem to be well-coordinated and effective.

Reviewer 4:

The reviewer praised the collaborations on this project, highlighting that they span three national laboratories, each contributing their individual expertise to the project.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer acknowledged the team's plans to optimize the electrolyte and additives to tailor the solvation characteristics, demonstrate performance in a pouch cell, and investigate the feasibility of anode-free sodium batteries using the designed electrolytes and additives. They stated that the data so far is very good and expressed confidence that the team is likely to achieve their goals in future work.

Reviewer 2:

The reviewer commented that the future research direction demonstrates an innovative approach to enhancing the long-cycling performance of Na-ion batteries. They found the focus on optimizing electrolyte co-solvents and additives to tailor solvation structures promising for achieving significant improvements.

Reviewer 3:

The reviewer noted that the proposed future work was briefly described and appeared to be appropriate.

Reviewer 4:

The reviewer found the proposed future work to be appropriate and providing logical next steps. They emphasized the importance of full cell studies involving the best cathode, anode, and electrolyte developed from this work. They suggested that such studies would provide a clear picture of the capabilities of a Na-ion system and reveal any gaps that may be missing from just half-cell studies.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer mentioned that the goals of the project are to study and develop high-energy density sodium-ion batteries while maintaining cost-effectiveness. They requested more details on the cost-effectiveness of the system using Prussian blue and how it generates high-energy density. Additionally, they noted that the project mentions the NFM system but lacks specifics regarding the targeted energy density and the strategies to achieve it. They suggested providing more details in these areas. However, the reviewer acknowledged that the project aligns with the goals of the VTO program.

Reviewer 2:

The reviewer commented that the project aligns perfectly with the mission of the VTO Battery program. They highlighted the potential of Na-ion batteries to address supply constraints associated with LIBs, making them highly relevant and significant for the program's objectives.

Reviewer 3:

The reviewer noted that this is a highly relevant area of research and supports the VTO program. They emphasized the abundance and even distribution of sodium resources worldwide, which could ultimately lower battery costs.

Reviewer 4:

The reviewer affirmed that the project supports the overall VTO Batteries program objectives. They mentioned that the project aims to develop a competitive alternative to commercial Li-ion batteries, which could help reduce battery and EV costs.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that PNNL is a very strong national laboratory with excellent resources and expressed confidence that they should be able to achieve and meet all the milestones.

Reviewer 2:

The reviewer remarked that the project team appears to have sufficient resources to carry out the proposed research in a timely fashion.

Reviewer 3:

The reviewer commented that the project appears to be adequately funded to complete the proposed tasks successfully.

Reviewer 4:

The reviewer affirmed that the resources are sufficient for the project to achieve its stated milestones.

Presentation Number: BAT456
Presentation Title: eXtreme Fast Charge Electrode and Cell Design Thrust
Principal Investigator: Andrew Jansen (Argonne National Laboratory)

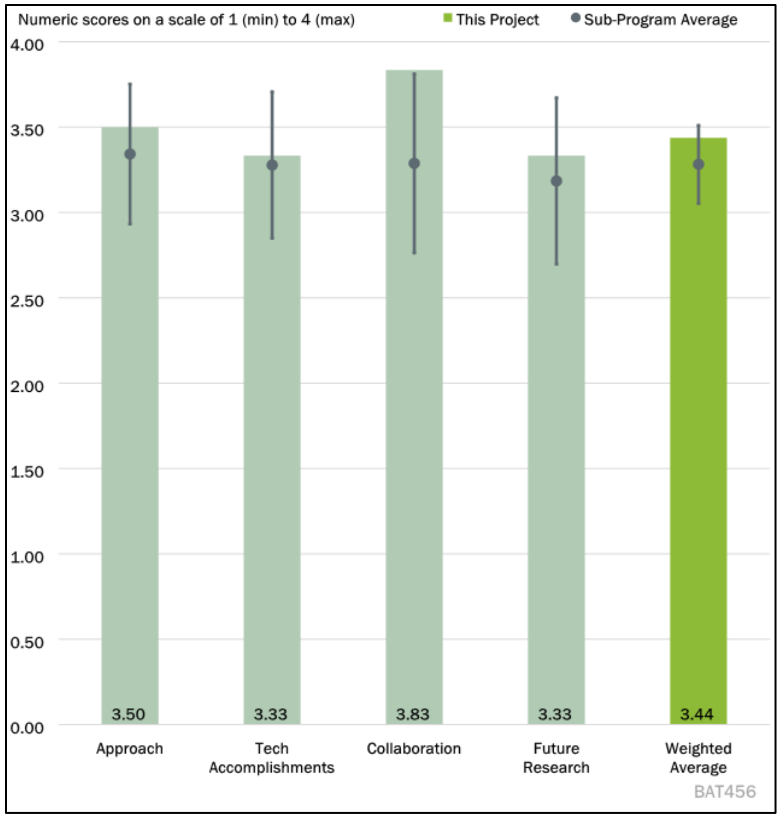

Figure 1-20 - Presentation Number: BAT456 Presentation Title: eXtreme Fast Charge Electrode and Cell Design Thrust Principal Investigator: Andrew Jansen (Argonne National Laboratory)

Presenter

Andrew Jansen, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the project addresses major technical barriers for fast charging, including cell and electrode design, and has employed some effective characterization techniques. They noted that the research of the project is in alignment with DOE goals.

Reviewer 2:

The reviewer remarked that studying electrode structures to design them specifically for XCEL has been one of the enablers across the battery community. They found it interesting to see the achievements in making large-scale layers and structured electrodes. They also pointed out that tomography studies to understand ion concentration in these structured electrodes complement the better design of these electrodes. However, they emphasized that further development of these methods is critical in identifying the mechanisms when these electrodes are cycled. Additionally, the reviewer suggested that cost analysis of developing these structured electrodes should be part of the study.

Reviewer 3:

The reviewer noted that this project under XCEL addresses the challenge from the electrode architecture. They described the design of a layered structure, with a more porous part next to the separator and a denser part next to the substrate. They highlighted that the more accessible porosity allows for better ion transport under high drain rates.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer observed that a lot of good research has been achieved in this project and highlighted the detailed study conducted on both the anode and cathode potentials during XFC. They suggested that state of charge (SOC) be included in future presentations or studies (if not already planned), as it is unclear if the battery could be charged to 80% after completing XFC in the test.

Reviewer 2:

The reviewer commended the achievement of making these electrodes in large scale to create pouch cells. However, they pointed out the need for more pre-validation tests of the proposed characterization techniques and emphasized the importance of studying how these techniques are affected by the special structured electrodes in detail.

Reviewer 3:

The reviewer praised the technical approaches used in the project, noting that the new electrode, as shown by tomography, indeed possesses the designed architecture. They also mentioned that the final performance in the LIB cell exhibits certain improvement.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commented on the organization and collaboration within the project team. The reviewer stated that the team, which consisted of researchers from several closely collaborated organizations, is well-organized.

Reviewer 2:

The reviewer remarked that the collaboration and coordination across the project teams are outstanding.

Reviewer 3:

The reviewer noted that the project was carried out in a highly collaborative manner.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer remarked that the future work illustrated is sound. They noted that it is unclear if the cell size affects charging current distribution during XFC performance and suggested that it might be interesting to use big size cell(s) for a comparison study.

Reviewer 2:

The reviewer commented that the proposed future work is in line with the overall scope of the project. They emphasized that identifying degradation mechanisms as the various enablers are studied is critical for success and suggested that future work should include a deep dive into these techniques and how they are affected by the structured electrodes.

Reviewer 3:

The reviewer stated that the proposed future pathway seems to be viable.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that this project is a direct support to DOE goals.

Reviewer 2:

The reviewer commented that this project is extremely relevant to adoption of electrification on a large scale.

Reviewer 3:

The reviewer noted that this project is highly relevant to fast charge efforts.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that the funding level seems appropriate for this project.

Reviewer 2:

The reviewer expressed that the funding planned for this project is sufficient to achieve the proposed goals.

Reviewer 3:

The reviewer stated that the resources are sufficient for the project.

Presentation Number: BAT463
Presentation Title: eXtreme Fast Charge Electrochemical and Thermal Performance Thrust
Principal Investigator: Eric Dufek (Idaho National Laboratory)

Presenter

Eric Dufek, Idaho National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

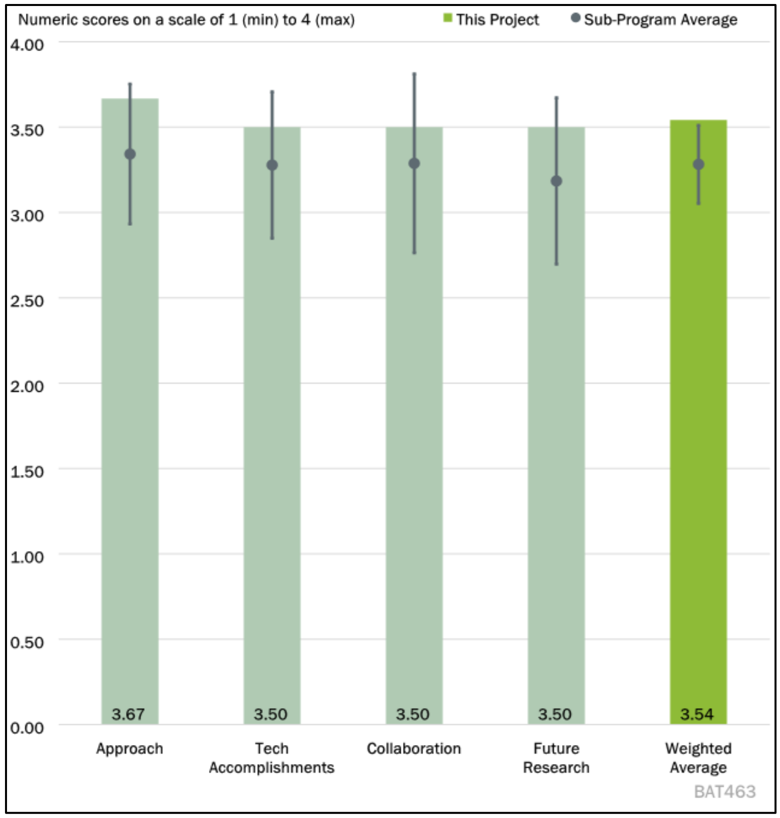

Figure 1-21 - Presentation Number: BAT463 Presentation Title: eXtreme Fast Charge Electrochemical and Thermal Performance Thrust Principal Investigator: Eric Dufek (Idaho National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer praised that the technical barriers are well addressed, and they appreciated the interesting progress made on XFC limitations in this project.

Reviewer 2:

The reviewer emphasized that developing a thermal strategy specific for fast charging is very critical. They also highlighted that the team's plans to use ML to understand the enablers and their effects on cycle life are critical for understanding the project's goals.

Reviewer 3:

The reviewer commented that this approach integrates the new electrolyte and dual-layer electrode work performed by the other two approaches and studies how an advanced charging protocol could manage the thermal effects of the LIB under fast charge conditions.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the approach to perform the work is appropriate, and they found the progress for year 1 impressive. They mentioned that the proposed milestones were met.

Reviewer 2:

The reviewer expressed that the scorecard proposal is excellent. However, they noted that since a multi-level comparison is presented, it is sometimes difficult to follow. They suggested that thermal strategies need to continue to track vehicle constraints. While acknowledging that the study focuses on ideal conditions, they suggested adding remarks about how close or far it is from real implementation.

Reviewer 3:

The reviewer remarked that the approaches led to certain improvements in LIB performances under fast charge. However, they pointed out that cathode degradation and Li^0 deposition are still observed.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer stated that the contractor has good collaboration among team members. They suggested that it would be better if the contribution from each team member could be detailed.

Reviewer 2:

The reviewer expressed that the collaboration and coordination across the project teams are outstanding.

Reviewer 3:

The reviewer noted that the PI has been working in a highly collaborative manner with other national laboratories in the project.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer commented that the proposed future study is reasonable.

Reviewer 2:

The reviewer remarked that the proposed future work is in track to the overall scope of the project. They emphasized that identifying the degradation mechanism as the various enablers are studied is critical for success.

Reviewer 3:

The reviewer stated that the proposed direction focuses on the new electrolyte, which is undoubtedly correct.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the project supports DOE goals by studying to understand XFC limitations and polarization and mechanical impacts of rapid transitions from discharge-charge-discharge across SOC windows.

Reviewer 2:

The reviewer commented that this project is extremely relevant to the adoption of electrification on a large scale.

Reviewer 3:

The reviewer affirmed that the project is highly relevant.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that the funding level is appropriate for the scheduled work.

Reviewer 2:

The reviewer expressed that the funding planned for this project is sufficient to achieve the proposed goals.

Reviewer 3:

The reviewer verified that the funding is sufficient.

Presentation Number: BAT470
Presentation Title: Process R&D Using Supercritical Fluid Reactors
Principal Investigator: Youngho Shin (Argonne National Laboratory)

Presenter

Youngho Shin, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

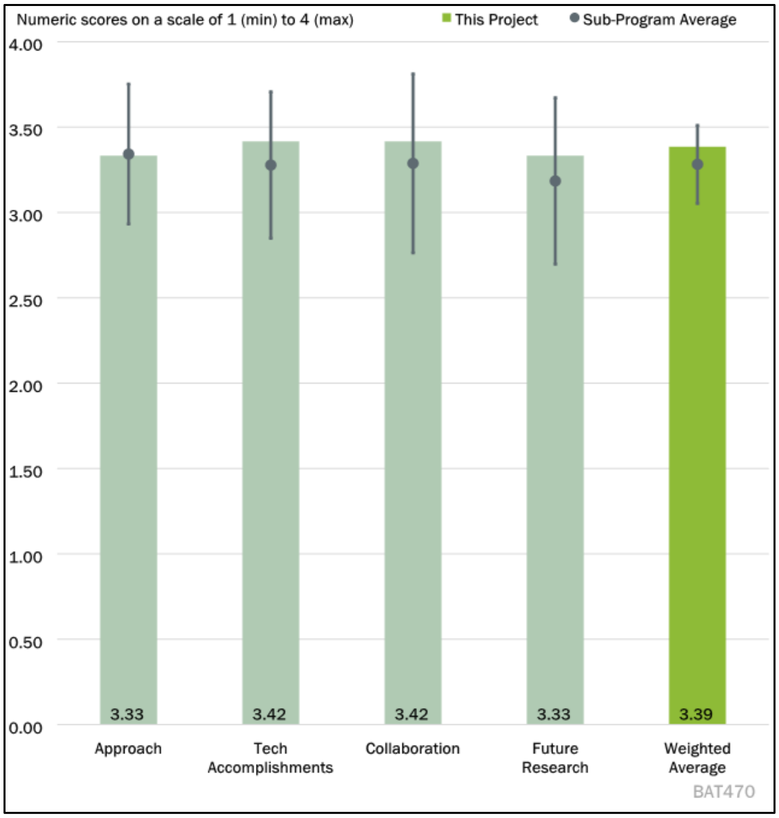

Figure 1-22 - Presentation Number: BAT470 Presentation Title: Process R&D Using Supercritical Fluid Reactors Principal Investigator: Youngho Shin (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer expressed that this is another important BAT project at ANL that emphasizes battery materials synthesis. They found the study on hydrothermal synthesis under sub or supercritical conditions to be a unique research thrust with great potential. They noted that the successful development of the hydrothermal synthesis approach could help reduce the cost and environmental impact of CAM production while creating novel materials with properties and morphology that cannot be reached with conventional approaches.

Reviewer 2:

The reviewer raised doubts about whether the supercritical hydrothermal (SCHT) approach does better than conventional processing approaches. They pointed out that the cycle life data shown on Slides 8 and 10 could be better and that commercial 811 cells last many thousands of cycles. They suggested that perhaps the measurements were taken on relatively poor electrodes and may not reflect the inherent quality of the active material.

Reviewer 3:

The reviewer noted that the PI’s program is dedicated to advancing the methodology and instruments used in the fabrication of single crystal CAMs, emphasizing the criticality of supporting R&D and instrumentation efforts at DOE facilities. They highlighted the significance of the supercritical point manufacturing approach, which is typically financially inaccessible for university investigators.

Reviewer 4:

The reviewer emphasized that transitioning from a traditional CSTR to a faster economical process is critical for the large-scale mass adaptation of LIBs. They acknowledged that this project aims to achieve this goal.

Reviewer 5:

The reviewer mentioned that the timeline for 2022 has been completed and that the continuous flow subcritical hydrothermal process allows cathodes to be tested and mass-produced for industries to reduce their costs. They suggested adding tests of cathodes made from materials other than Ni, Co, and Mn to the project.

Reviewer 6:

The reviewer concluded that, for the current funding levels, the team's focus and the scale of the work are appropriate. They appreciated the comparisons of the three different processes and their impacts on single crystal CAMs. They noted that the range and scale of the different materials produced and studied is quite an undertaking.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked that in FY 2022, the project undertook the commissioning of the continuous-flow supercritical hydrothermal system and carried out the synthesis of monocrystalline NMC811 using conventional co-precipitation CSTR. In 2023, they synthesized single-crystal cathode material cg-$LiFePO_4$ (cg-LFP) through the newly constructed continuous-flow supercritical hydrothermal system. The reviewer observed that the team also conducted structural and morphological characterizations, collaborating with other teams on these materials, including SEM, XPS, Bragg coherent diffraction imaging (BCDI), and *in situ* synchrotron XRD.

Reviewer 2:

The reviewer expressed the view that significant progress had been achieved against the project's goals. A central concern raised by the reviewer was the ability to scale up the technique cost-effectively, given the necessity for very high-pressure and high-temperature operation. The reviewer questioned how the transition from 100-gram batches to tons could be managed.

Reviewer 3:

The reviewer affirmed that the PI's successful demonstration of the formation of single-crystal CAMs through three distinct approaches. These approaches included the traditional sintering method, the supercritical point synthesis of monocrystalline oxide preCAMs, and a continuous manufacturing approach. The reviewer observed that the second and third research directions represented highly innovative avenues with the potential to establish a solid foundation for the future commercialization of these novel fabrication technologies.

Reviewer 4:

The reviewer praised the presentation for its focus on an important aspect of battery research: new methods of cathode synthesis that could offer a cost advantage without compromising performance. However, the reviewer had a few comments and questions. The reviewer asked about the lower capacity of monocrystalline NMC compared to its polycrystalline counterparts on Slides 7 and 8, inquired about the influence of monocrystalline material synthesis at 920°C, and questioned whether any cation mixing had been observed. Additionally, the reviewer sought clarification on whether the polycrystalline material in the cycling performance comparison on Slide 10 had a surface coating. The reviewer also articulated the importance of extracting key takeaways from Slide 16 regarding diffraction contrast diffractive imaging (DCDI) for NMC811 from the three different synthesis methods.

Reviewer 5:

The reviewer verified that the team had successfully tested the three methods to produce monocrystalline cathodes, resulting in higher density, larger cycling capacity, reduced surface defects, and an improved surface coating effect. The reviewer also clarified that the project intended to explore different cathodes beyond NMC811, although the specific next cathodes had not yet been selected.

Reviewer 6:

In the reviewer's overall assessment, the processes and accomplishments of the project were deemed impressive, with a noteworthy emphasis on processing time. However, the reviewer suggested that future presentations could benefit from improved communication of the process operation. The reviewer emphasized that understanding the operation of the process was critical for reviewers and the general audience to better grasp the project's impact and results. Furthermore, the reviewer remarked that including comments on the safety of the new processing systems at scale would be beneficial, considering whether the same safety management practices at a pre-pilot scale would apply at larger scales or if adjustments would be necessary. The reviewer noted that this aspect might be more appropriate as a barrier or future work and might not be addressable within the current funding scope.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the project team has collaborations within ANL and BNL for various characterizations using their testing facilities, as well as with Hunt Energy for atomic layer deposition (ALD) Al_2O_3 surface coating.

Reviewer 2:

The reviewer expressed some confusion regarding the decision to coat LFP using ALD. Given that LFP is a low-voltage material, the reviewer did not expect any electrolyte instability in this context.

Reviewer 3:

The reviewer acknowledged the PI for establishing a robust team of collaborators to explore diverse mechanistic and structural aspects of single-crystal CAMs.

Reviewer 4:

The reviewer emphasized the importance of the project's collaborations, which range from universities to cathode manufacturers. The reviewer stressed that understanding the practical realities of mass production is crucial.

Reviewer 5:

The reviewer commended the project for clearly articulating the contributions of universities, national laboratories, and industry. The reviewer pointed out the project's goal to test more cathode samples and transform them from polycrystalline to monocrystalline, particularly cathodes that do not contain Ni, Mn, and Co. The reviewer encouraged expanding the range of materials for cathodes being tested by seeking additional ideas from industry partners.

Reviewer 6:

The reviewer highlighted the project's significance as addressing a missing link between the discovery of new battery materials, market evaluation of these materials, and high-volume manufacturing. While acknowledging the strong collaborations between universities and national laboratories, the reviewer expressed a desire to see more external input on the material and/or process in future years, with increased involvement from industry.

The reviewer acknowledged that industry may often hesitate to take on the financial risk associated with process scale-up and the development of materials that have not been validated. However, the reviewer stressed that incorporating more industry feedback early in the project could further advance the technology and reduce the DOE investment risk before reaching pilot and production scales.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer acknowledged that the team has clearly outlined their plans for future research, which are highly likely to be achieved. Among the listed remaining challenges and barriers, the most critical and relevant target was identified as systematic research on hydrothermal synthesis to optimize the structure and morphology of CAMs. The reviewer encouraged the team to investigate the hydrothermal process using *in situ* XRD and PDF techniques.

Reviewer 2:

The reviewer expressed difficulty in understanding how particle morphology could be controlled or changed using SCHT reactions. Given that the project is scheduled to conclude in September 2023, the reviewer concluded that there may be no need for further evaluation.

Reviewer 3:

The reviewer deemed the fabrication of single crystal Li metal rich (LMR) materials as having great significance, as LMR plays a crucial role in enabling cost-effective CAMs that can deliver high energy density per dollar spent.

Reviewer 4:

The reviewer acknowledged that the team's future work proposal is well-aligned with market needs, specifically highlighting particle morphology engineering and the development of the next-generation lithium iron phosphate ($LiFePO_4$) cathode material with Mn, referred to as LMFP.

Reviewer 5:

The reviewer expressed the need for more information regarding the purpose of future work. While noting that the team had achieved the proposed objectives, the reviewer believed it was very likely that they would achieve the objectives based on the proposed work.

Reviewer 6:

The reviewer noted that the project is set to conclude in September 2023, and commenting on future work is contingent on subsequent funding. If funded for FY 2024, the current future work plan was considered appropriate for addressing the remaining material challenges identified by the presenter. The reviewer suggested that, if funding permits, incorporating more feedback or input from additional industrial partners would be invaluable to the project.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that the hydrothermal synthesis of CAMs represents a unique and effective approach for battery materials R&D, supporting the VTO objective in vehicle electrification.

Reviewer 2:

The reviewer expressed agreement with the relevance of the research efforts, emphasizing the importance of evaluating novel processing techniques. However, the reviewer also mentioned a desire to have seen a cost study conducted early in the project.

Reviewer 3:

The reviewer pointed out that the research efforts closely align with VTO's missions, particularly highlighting the advantages of single crystal CAMs in terms of longer cycle life due to their chemo-mechanical robustness. The development of novel, cost-effective, and scalable approaches for fabricating single crystal CAMs was deemed of immense importance for the US EV battery research community.

Reviewer 4:

Regarding specific questions and comments, the reviewer inquired about the lower capacity of monocrystalline NMC compared to its polycrystalline counterparts on Slides 7 and 8, the influence of monocrystalline material synthesis at 920°C, any observed cation mixing, and whether the polycrystalline material in the cycling performance comparison on Slide 10 had a surface coating. The reviewer also recommended extracting key takeaways from Slide 16 regarding DCDI for NMC811 from the three different synthesis methods.

Reviewer 5:

The reviewer emphasized that the project supports the analysis of batteries, energy-efficient mobility systems, and materials.

Reviewer 6:

In the reviewer's overall assessment, the project was deemed highly valuable and much-needed battery research, addressing a critical need for rapid material synthesis and continuous material production.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The project team has successfully commissioned the capabilities for the subcritical hydrothermal batch process and the supercritical hydrothermal continuous process. Additionally, they have established collaboration for materials and process characterization, and they possess sufficient resources to achieve the remaining milestones in a timely fashion.

Reviewer 2:

The reviewer expressed a positive assessment with a simple "Good."

Reviewer 3:

The reviewer pointed out the evident need for increased funding in FY 2023, considering the prevailing inflationary pressures impacting various aspects of research and development.

Reviewer 4:

The reviewer reiterated that the resources allocated to this project are deemed sufficient to achieve the project goals.

Reviewer 5:

The reviewer cited successful implementation of the continuous supercritical hydrothermal process and the batch subcritical hydrothermal process.

Reviewer 6:

The reviewer concluded that the resources appear sufficient for accomplishing the stated milestones, with the assumption that no major new equipment purchases or modifications are needed.

Presentation Number: BAT475
Presentation Title: Towards Solventless Processing of Thick Electron-Beam (EB) Cured Lithium-Ion Battery Cathodes
Principal Investigator: Zhijia Du (Oak Ridge National Laboratory)

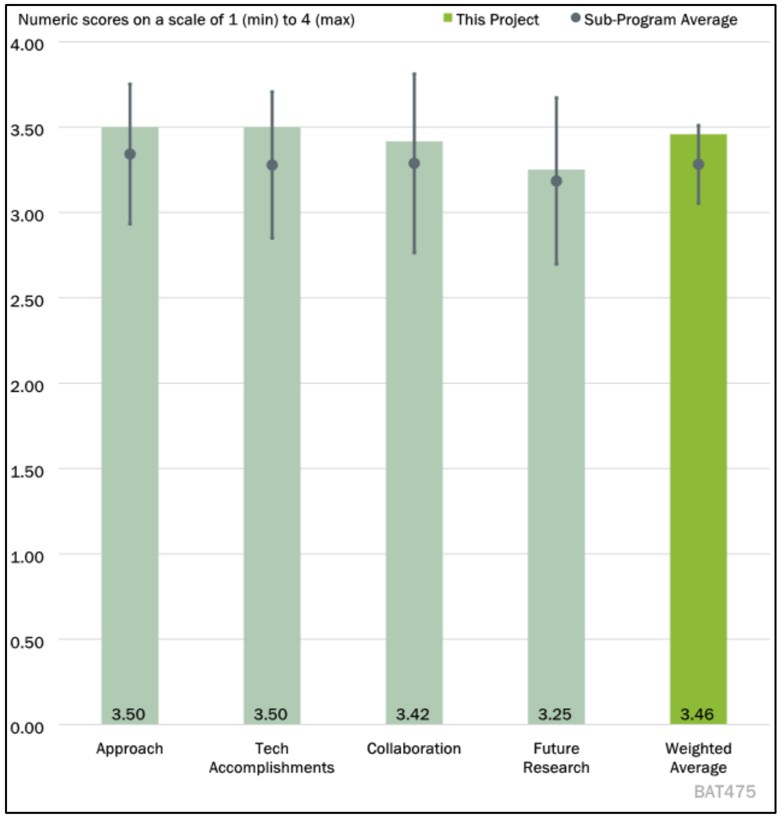

Figure 1-23 - Presentation Number: BAT475 Presentation Title: Towards Solventless Processing of Thick Electron-Beam (EB) Cured Lithium-Ion Battery Cathodes Principal Investigator: Zhijia Du (Oak Ridge National Laboratory)

Presenter

Zhijia Du, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the use of electron-beam (EB) technology to cure oligomers for electrode manufacturing, replacing the conventional slurry casting method, represents a novel approach to achieve solventless manufacturing of thick electrodes. It was acknowledged that EB technology allows for the production of ultra-thick electrodes due to its substantial penetration depth compared to laser or UV curing. However, the reviewer pointed out that the current approach, while reducing the need for liquid or solvent, has not achieved complete solventless manufacturing. The reviewer highlighted the necessity of developing new binder or polymer formulations to make the EB process viable, particularly for anode development.

Reviewer 2:

Regarding the project’s objectives, the reviewer remarked that the primary goal is to address the EV battery cost, aiming for a target of $60/kWh and a 1000-cycle life by optimizing material processing and increasing electrode thickness. However, the reviewer expressed some skepticism about achieving the cost target solely through the proposed work. Additionally, the reviewer noted that the project’s duration of six years appears relatively long compared to regular DOE projects.

Reviewer 3:

The reviewer observed that a low-cost, solvent-free process for fabricating thicker cathodes has been developed and tested. The potential of a solid-state Li battery with a polymer electrolyte through an EB-cured polymer membrane and a polymer/LFP composite cathode was recognized as a promising approach. However, the reviewer also pointed out that several challenges remain to be addressed.

Reviewer 4:

The reviewer verified that EB cure technology was successfully demonstrated for Li-ion batteries, achieving the principal objective of establishing an EB curing capability at ORNL. However, the reviewer expressed curiosity about the use of solvents in achieving desired coatings and sought more information regarding its necessity, volume used, solvent type, and whether the coating line includes a drying zone upstream of the EB curing module. The reviewer also inquired about achievable line speeds, limitations, depth-of-cure concerns, and cure dynamics. Furthermore, the reviewer asked if there were any issues with binder not being fully cured, leaving low molecular weight components in the electrode.

Reviewer 5:

In summarizing the project's scope, the reviewer articulated that it is well-designed for addressing technical barriers and commended the team for effectively presenting Phase 1–3 goals. However, the reviewer suggested that the project could benefit from further explanation of how EB curing will lead to the targeted $60/kWh cost reduction, potentially through modeling or process extrapolation. The project was praised for its well-designed focus on achieving low-cost, long cycle life, high-power cells.

Reviewer 6:

The reviewer found the project to be well designed and sharply focused on the low-cost production of long cycle life high power cells.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the manufacturing of NMC and LFP cathodes using EB curing has been successfully demonstrated. In the case of LFP cathodes, the use of CNTs to reduce carbon additives was found encouraging, although the reviewer suggested that further reduction of binder content may be needed to meet industrial requirements. The reviewer suggested that it would be beneficial to conduct a direct comparison with slurry-casted thick electrodes (using PVDF) concerning mechanical properties (following industrial standards) and electrochemical properties to benchmark the performance of EB cured electrodes and demonstrate their advantages. Additionally, there was a question raised about the uniformity of the coating and whether the minimum liquid/solvent used might affect coating uniformity.

Reviewer 2:

The reviewer acknowledged the project's good technical progress and its execution in five phases, each addressing specific aspects of EB curing technology. However, the reviewer expressed some difficulty in assessing the current year's results due to incomplete information and improperly labeled graphs, making it challenging to interpret data related to current vs. voltage and capacity vs. cycling. The reviewer questioned whether the modest improvement achieved with CNTs justified the cost of their use and expressed interest in knowing what analysis would be conducted to identify the failure mechanism for the EB-cured polymer.

Reviewer 3:

While noting that some major milestones had been achieved, the reviewer expressed interest in learning more about the challenges overcome and potential compromises made during the project, such as the use of solvent.

The reviewer suggested that providing a historical perspective on EB curing for battery electrodes would be informative, offering insights into its previous use and success in electrode manufacturing.

Reviewer 4:

The reviewer appreciated the team's demonstration of the compatibility of the EB process with NMC and LFP systems, as shown by the cycling and capacity retention data. The addition of CNTs to reduce inactive materials was commended, and the reviewer expressed anticipation regarding the analysis of failure mechanisms in pouch cells. However, the reviewer pointed out that there was no mention of cathode loading in the data and requested more information on processing conditions, excluding proprietary details.

Reviewer 5:

In the reviewer's assessment, the project was progressing well according to the plan, with significant improvements in resin selection and the use of CNTs and carbon black blends for cathodes. While acknowledging that cycle life tests of pouch cells were ongoing, the reviewer noted improvements observed in early-stage results and emphasized their importance, even though some solvent had been used during electrode processing.

Reviewer 6:

The reviewer stated that the overall processes and what the authors have accomplished are impressive. The processing time is also impressive. One item which could be improved upon in future presentations is better communicating the process operation. The reviewer stated it was not fully clear how the process worked or operated and that is critical for a reviewer to understand to put the materials and their results in better context. The presentation focused on material results and performance but a clearer presentation on how the process works would help reviewers and the general audience better understand the impact of the project as well as its overall results. The reviewer believed this would also be appreciated by industry if the goal is to eventually transition this technology to a larger scale. The reviewer also felt safety of the new processing systems at scale would also be helpful for industry. The reviewer inquired whether the same safety management at a pre-pilot scale would also apply at larger scales or do things change? This might be more appropriate to note as a barrier or future work and is not something that can likely be addressed with the current funding.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer emphasized the importance of expanding collaboration beyond equipment suppliers, material suppliers, and battery manufacturers to include EV companies that may be interested in adopting solventless battery manufacturing technology. The reviewer noted that many EV companies have shown a keen interest in evaluating and adopting such technologies recently.

Reviewer 2:

While acknowledging the collaboration with equipment suppliers, battery manufacturers, and raw material suppliers, the reviewer expressed some confusion about how these suppliers are involved in the work due to the absence of a budget allocation for them.

Reviewer 3:

The reviewer commended the project for its industry collaboration.

Reviewer 4:

The reviewer recognized the vital role played by collaboration with EB equipment suppliers and raw material (binder) suppliers in the project's success. There was a specific inquiry about how the processing of the solvent-containing coating formulation was handled, including whether there was a retrofitting of a drying zone prior to EB cure on the coating line or if pre-drying of samples was done before passing them through the EB station. Long-term plans for modifications to the EB line to accommodate such formulations were also of interest.

Reviewer 5:

The reviewer expressed the desire for more information on how partners actively participate in the program and the extent of their involvement.

Reviewer 6:

The reviewer praised the project's well-coordinated efforts and the clear definition of roles and responsibilities among collaborators.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer observed that future work related to anode manufacturing has been identified; however, there is a lack of clarity regarding the clear path for developing anodes, particularly concerning potential adhesion issues. Additionally, reducing the binder amount for LFP cathodes is considered an important future task, but achieving a completely solventless process for LFP with low binder content may pose challenges.

Reviewer 2:

The reviewer pointed out that there will be over one year remaining until the project's completion and proposed specific areas for future research. The reviewer suggested that the team should prioritize focusing on producing industrial-quality electrodes that can be used in larger cells, as this is crucial for industry adoption of the technology. The areas of exploring radiation-curable binder formulations for the next generation of anode processes, studying LFP cathode loading and its EB process conditions for good electrochemical performance, and understanding the failure mechanism of EB/UV cured polymer electrolyte and catholyte in lithium metal batteries were all deemed important.

Reviewer 3:

In general, the reviewer noted that the proposed research appears to align with the project's original plans, although the development of EB-cured anodes seems to be a new objective. The reviewer highlighted a lack of clarity regarding how the failure mechanisms will be investigated.

Reviewer 4:

The reviewer expressed interest in the next objectives, such as achieving higher LFP loading, developing EB-cured anodes, and working on SSB technology, considering these areas as intriguing for exploration with the EB curing technology.

Reviewer 5:

The reviewer acknowledged the team's good understanding of current technical barriers, especially those related to LFP cathodes and anodes. However, the reviewer requested additional clarification and direction regarding how curable binder formulations and process conditions for anodes and LFP cathodes would be addressed.

Reviewer 6:

The reviewer recognized the challenging nature of achieving high-quality electrodes with a solventless process and noted that understanding the failure mechanisms behind Li metal polymer prototype cells would require significant effort to produce cells with satisfactory cycle life.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer highlighted the significance of developing solventless manufacturing of electrodes, emphasizing its potential to reduce the cost of EV battery manufacturing and increase energy density. The reduction in the footprint of electrode manufacturing equipment was noted as an additional advantage. The project's ability to enable thick electrodes, thus reducing the amount of inactive material in the cell and material/manufacturing costs, aligns with the objectives of the VTO batteries subprogram.

Reviewer 2:

The reviewer affirmed that the project supports the broader objectives of the VTO battery program in terms of cost reduction.

Reviewer 3:

The reviewer underscored the project's relevance to the development of thicker, low-cost cathode materials with good performance.

Reviewer 4:

The reviewer found a strong emphasis was placed on the importance of investigating alternatives to the traditional n-methyl-2-pyrrolidone (NMP)-based coating method for lithium-ion cathode production. The limitations associated with NMP, particularly its evaporation speed and health and environmental concerns, make alternatives that address these limitations highly welcome.

Reviewer 5:

The reviewer deemed the program relevant to supporting the VTO subprogram objectives for batteries, specifically in terms of decarbonizing the battery supply chain through the use of EB processing instead of traditional slurry casting, reducing the cost per kilowatt-hour ($/kWh) of batteries, and enabling next-generation cell chemistries.

Reviewer 6:

While recognizing the solventless EB-cured Li-ion cathode as an enabling technology for low-cost electrode production that aligns with the VTO subprogram objectives, the reviewer suggested that the electrode EB processing might be further controllable when using a limited amount of environmentally friendly solvent.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the team has sufficient resources to perform the proposed research and achieve the stated milestones.

Reviewer 2:

The reviewer remarked that, indeed, the team has enough resources to conduct the proposed research. The reviewer also suggested involving companies in the project as early as possible.

Reviewer 3:

The reviewer observed that the resources appear to be adequate.

Reviewer 4:

The reviewer questioned whether equipment modifications were needed to handle formulations containing solvents and whether the necessary resources and funding were available for this purpose. The reviewer noted that this aspect was not presented, leaving it unclear if it is still an issue or already addressed.

Reviewer 5:

The reviewer affirmed that, based on the results, the resources provided are sufficient, and the team seems to be on track to meet their stated milestones in a timely fashion.

Reviewer 6:

The reviewer expressed the opinion that the resources are sufficient for the project to achieve the stated milestones on time. Additionally, the reviewer suggested that more collaborators from industry may be needed to expedite progress in high-speed electrode preparation.

Presentation Number: BAT524
Presentation Title: Advanced Electrolytes for Li Metal Batteries
Principal Investigator: Chunsheng Wang (University of Maryland)

Presenter

Chunsheng Wang, University of Maryland

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

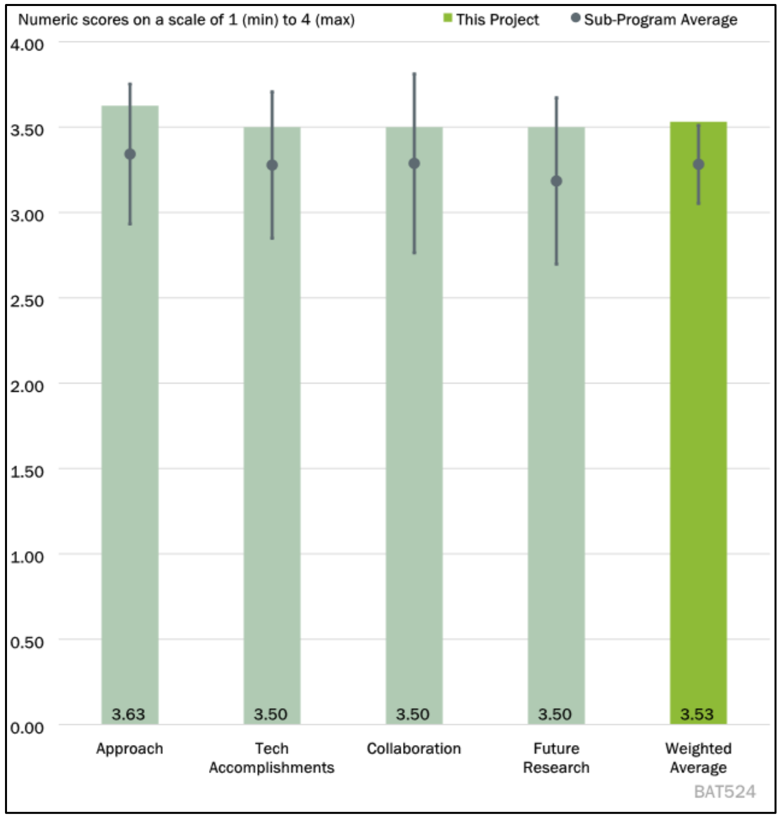

Figure 1-24 - Presentation Number: BAT524 Presentation Title: Advanced Electrolytes for Li Metal Batteries Principal Investigator: Chunsheng Wang (University of Maryland)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer praised the team's aim to develop high-energy Li-metal batteries and acknowledged the challenge of forming a LiF interphase to passivate interfaces between Li metal anode and high-energy NMC811/SPAN cathode, inhibiting dendrite growth and cathode penetration by the liquid electrolyte. The reviewer noted that the team addresses this challenge by designing and using solvent-free ionic liquid electrolytes, promoting anion reduction for LiF formation, and suppressing solvent reduction that could lead to unwanted organic-inorganic interphases. The reviewer found these approaches effective and promising.

Reviewer 2:

The reviewer expressed overall satisfaction with the approach, considering it excellent and with very promising results.

Reviewer 3:

The reviewer highlighted the team's focus on electrolyte design for Li-metal/NMC or SPAN cathodes to achieve longer cycle life and capacity retention. The project's utilization of modeling input on various liquid electrolyte formulations, with the goal of developing a robust cathode electrolyte interphase (CEI), particularly for NMC811 and sulfur-based cathodes, was acknowledged. The reviewer appreciated the use of density functional theory (DFT) and molecular dynamics-based calculations to determine the energies and stability of electrolyte (solvent and salt) decomposition at both cathodic and anodic interfaces, providing a good design of experiments for robust solid electrolyte interphase (SEI) and CEI.

Reviewer 4:

The reviewer recognized the PI's aim to address interphase stability issues in full-cell Li-metal batteries using NMC as the cathode and Li metal as the anode. The approach of designing advanced electrolytes capable of producing the desired interphases, with LiF identified as a key component, was noted. The reviewer highlighted LiF's high oxidation stability on the cathode side and its ability to suppress vertical Li dendrite growth and promote Li migration along the LiF/Li interface on the anode side.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer provided an overview of the project's milestones for FY 2023, noting that one milestone, achieving high CE and cycle numbers for SPAN/Li, has been completed. Another milestone, testing the designed electrolytes for NMC811/Li, is ongoing. Three of the five milestones are still on track, with the reviewer emphasizing the need for testing collaborations for the University of Washington (UW) and INL.

Reviewer 2:

The reviewer stated that the approach is excellent, with very promising results.

Reviewer 3:

The reviewer highlighted several outstanding accomplishments of the PI and the team:

Electrolyte design for stabilizing high voltage NMC cathode: The team achieved FSI-derived LiF interphases on both the Li anode and NMC811 cathode, effectively suppressing Li dendrites and preventing electrolyte penetration into cracked NMC811. This enabled a 4.5 mAh/cm² NMC811/Li cell to achieve 200 cycles at a wide cutoff voltage range of 2.8V–4.7V, cycling at a rate of 0.3C and with a lean electrolyte of 5 g/Ah.

Electrolyte design for SPAN cathode: The use of ether electrolytes promoted the formation of inorganic LiF-rich SEI with a Li, CE of greater than 99.4% at 0.5 mA/cm² and a capacity of 4.0 mAh/cm² for SPAN cathodes. The achieved high CE and cycle numbers for SPAN/Li (CE greater than 99.9%, more than 200 cycles) using SPAN cathodes supplied by the Idaho National Laboratory were noted.

The reviewer emphasized that their study concluded that FSI-derived LiF interphases on both the Li anode and cathodes effectively suppressed Li dendrites and prevented electrolyte penetration into the cathode, providing high-capacity retention at higher anodic voltages.

Reviewer 4:

The reviewer acknowledged the significant progress made by the PI's team, particularly regarding anodeless pouch cells and NMC811||Li cells. They highlighted that the ionic liquid electrolyte enabled stable cycling of a 30 mAh Cu||NMC811 pouch cell with 2 mAh/cm² loading, maintaining over 80% initial capacity after more than 300 cycles under lean electrolyte conditions. Similarly, the carbonate electrolyte enabled stable cycling of a coin cell with 4.5 mAh/cm² loading in the voltage range of 2.8V–4.7V, maintaining more than 80% of the initial capacity for over 200 cycles. The reviewer noted that characterization results would be needed to support the claim that LiF is the key interphase component stabilizing both NMC/SPAN cathode and Li metal anode.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer acknowledged the team's collaborations with various institutions, including the University of Washington (UW), INL, BNL, the Army Research Laboratory (ARL), and SAFT. The ongoing collaborations with UW and INL for testing the designed electrolytes and Li/NMC and Li/SPAN cells were noted. The reviewer also mentioned that the poster might not contain enough collaborated results with ARL on the simulations of solvation structures, likely due to space limitations.

Reviewer 2:

The reviewer praised the excellent collaboration.

Reviewer 3:

The reviewer described the teamwork and collaboration within the team as excellent, as evidenced by the technical accomplishments. The reviewer specifically praised the collaboration with ARL, highlighting its value in guiding research directions.

Reviewer 4:

The reviewer noted that the PI has extensive collaborations with national laboratories and industry, underscoring the collaborative nature of the project.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer acknowledged the proposed future work, which includes further characterization of the newly developed electrolytes and cell optimizations. The reviewer suggested that it would be even better if more details could be provided on the simulation aspect of the research and how it can enhance electrolyte design and cell performance in conjunction with experiments. Specific questions raised included how the LiF interphase is formed by promoting the reduction of fluorinated salts, possible reaction mechanisms, and how the formation of other interphases is suppressed.

Reviewer 2:

The reviewer stated that the proposed future research is excellent.

Reviewer 3:

The reviewer praised the team’s clearly defined goals and metrics for future research. They noted that the team intends to continue characterization and performance testing of their new electrolytes on Li-metal and high-capacity (and voltage) cathodes to meet the VTO battery targets. The development of electrolyte compositions that can lead to the formation of stable SEI and CEI with high CE was seen as an acceleration of R&D in this field.

Reviewer 4:

The reviewer acknowledged the PI’s proposal to carry out more characterizations for the developed systems as the next step. The proposal to optimize cell parameters for even better electrochemical performance was also noted and considered appropriate.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized that the project aligns very well with the VTO objective, which is to achieve high-energy Li-metal batteries with a long cycle life.

Reviewer 2:

The reviewer described the project as highly relevant to this objective.

Reviewer 3:

The reviewer pointed out that the project goals are in alignment with VTO's battery R&D performance targets, specifically aiming for 500 Wh/kg with 1000 deep cycles. The reviewer noted that the team's aim to demonstrate these results in a 5–10 Ah pouch cell format demonstrated scalability.

Reviewer 4:

The reviewer noted that the project was relevant to the B500 Consortium's focus on developing new electrolyte systems to support Li metal batteries. This is a significant contribution to the project's relevance to VTO's subprogram objectives.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that based on the progress of the project, the current resources are deemed sufficient and appropriate to reach the set milestones on time.

Reviewer 2:

The reviewer described the resources as sufficient.

Reviewer 3:

The reviewer mentioned that the project is funded at an appropriate level, allowing it to meet the deliverables as required.

Reviewer 4:

The resources for the project were assessed by the reviewer as sufficient to achieve the stated milestones in a timely fashion.

Presentation Number: BAT528
Presentation Title: Structurally and Electrochemically Stabilized Silicon-rich Anodes for Electric Vehicle Applications
Principal Investigator: John Thorne (Enovix)

Presenter

John Thorne, Enovix

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

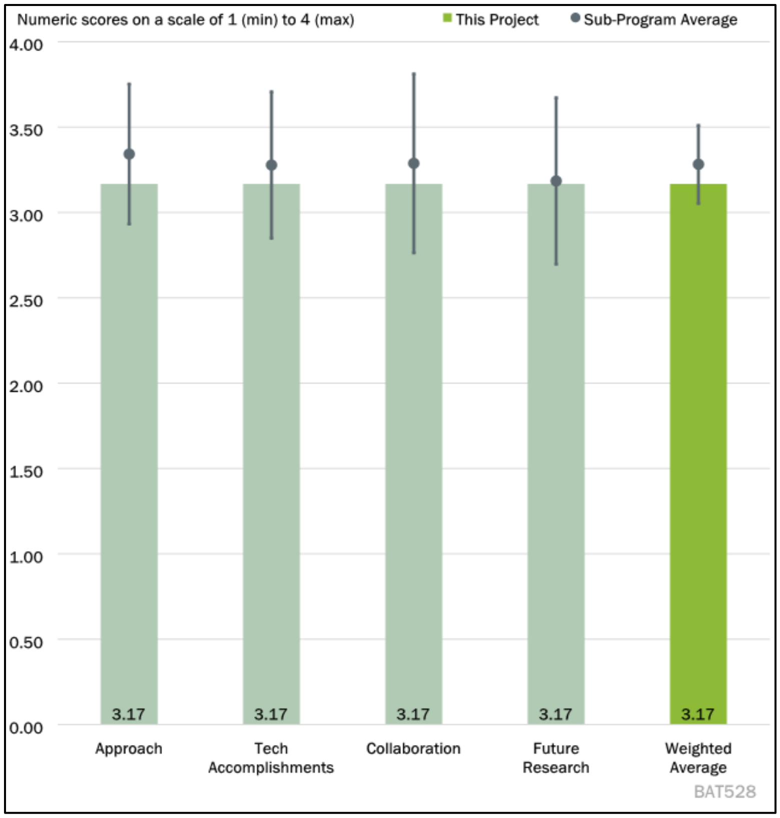

Figure 1-25 - Presentation Number: BAT528 Presentation Title: Structurally and Electrochemically Stabilized Silicon-rich Anodes for Electric Vehicle Applications Principal Investigator: John Thorne (Enovix)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked that a cycle life of 1000 cycles had been achieved for all presented combinations of the low/high loading and [unspecified] pressures. Nonetheless, it remained unclear how much the pressure system added to the weight/volume of the pack, and whether the modeled approximate 270 Wh/kg energy density in the 100 Ah size included the pressure system or not. Additionally, there was ambiguity on how the proposed approach intended to meet the program target of 350 Wh/kg of specific energy. Another point of obscurity was why high loading (lower electrolyte to cathode ratio) data was presented only up to 2 months, making it difficult to extrapolate/estimate calendar life for 4.2V needed to reach 270 Wh/kg. The reviewer expressed hope that the 3 Ah cells to be built in FY 2023 would provide more reliable data.

Reviewer 2:

The reviewer noted that Enovix's utilization of 100% active silicon (Si) was quite impressive. However, it was unclear whether the projected values reported for nickel manganese cobalt 622 (NMC622) and nickel manganese cobalt 811 (NMC811) were core volumetric energy density (VED) or packaged VED.

Reviewer 3:

In the assessment of the overall presentation, the reviewer observed that it was very good, and the technical barriers being addressed were clearly indicated. However, what remained unclear was whether the project intended to meet all or part of the goals.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the presented data indicated significant progress in the evaluation of the proposed technology. However, it was acknowledged that there were limitations to the approach, which would reach only 270 Wh/kg, a value notably lower than the 350 Wh/kg program target.

Reviewer 2:

Regarding the cycling performance, the reviewer regarded the achievement of 1000 cycles to about 90% capacity retention as quite good. The reviewer suggested presenting the data at a higher resolution scale to facilitate the clear observation of differences due to loading and pressure. There was also praise for the impressive calendar life, but a request for clarification whether it pertained to storage life or followed the USABC calendar life test procedure. Furthermore, the reviewer suggested including specific timeframes (month and year) in the milestone table, as the current notation of "on track" lacked specificity.

Reviewer 3:

In evaluating the overall project, the reviewer acknowledged its success but expressed concerns about its ability to meet most of the target goals outlined in the Program. Despite this, the performance was deemed convincing. The reviewer suggested that the presentation could have been enhanced by illustrating the starting point of the program and the current status to better showcase the progress made.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that NREL had participated in the modeling and cell design efforts.

Reviewer 2:

The reviewer asserted that NREL was the right partner for conducting modeling work in collaboration.

Reviewer 3:

The reviewer pointed out that it was not clear which parts of the presentation were contributed by NREL. To enhance clarity, the reviewer recommended adding a small footnote on the appropriate tables and plots to indicate NREL's involvement and contributions.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the proposed BP3 cell (3 Ah) appeared promising for providing more reliable and realistic estimates of both calendar and cycle life. However, the reviewer noted that no research plans had been presented that would further enable an increase in energy density beyond 270 Wh/kg to meet the program target.

Reviewer 2:

The reviewer acknowledged that fabricating and testing the 3 Ah cell was a commendable future work plan. To enhance understanding, the reviewer requested details on how Enovix cell architecture enabled pre-lithiation and inquired whether the cells tested thus far in this program had been pre-lithiated.

Reviewer 3:

The reviewer expressed anticipation for future data to support the model and encouraged additional calendar test work as a valuable component of the research.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that this project aligned with the VTO subprogram objectives, indicating a clear alignment with VTO’s goals. However, the reviewer pointed out that the project fell short of achieving the target energy density.

Reviewer 2:

The reviewer noted that this project was directly related to the Batteries subprogram objective within the broader context of VTO’s overarching objective.

Reviewer 3:

In assessing the project’s achievements, the reviewer highlighted that it demonstrated the feasibility of utilizing a pure Si anode successfully. However, the question of calendar life had not yet been fully addressed, and resolving this aspect would enhance the program’s relevance and significance.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources are adequate for the planned work.

Reviewer 2:

The reviewer commented that the resources are sufficient.

Reviewer 3:

The reviewer stated that there were no issues on this project, and none were mentioned by the research team.

Presentation Number: BAT529
Presentation Title: Rationally Designed Lithium-Ion Batteries Towards Displacing Internal Combustion Engines
Principal Investigator: Rick Costantino (Group 14 Technologies)

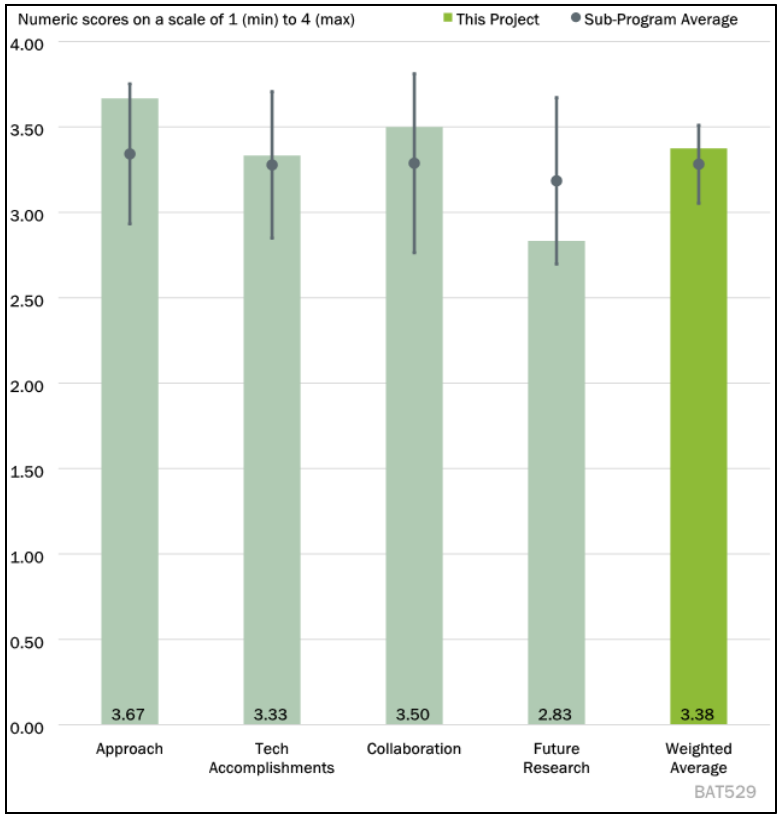

Figure 1-26 - Presentation Number: BAT529 Presentation Title: Rationally Designed Lithium-Ion Batteries Towards Displacing Internal Combustion Engines Principal Investigator: Rick Costantino (Group 14 Technologies)

Presenter

Rick Costantino, Group 14 Technologies

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer praised the overall development and commercialization approach presented, considering it excellent. In addition to the positive feedback, the reviewer suggested that it would be beneficial to include a mechanism for understanding calendar life degradation, examining aspects such as cell swelling over time, and exploring the dependence of calendar life on the cutoff voltage, cell energy density, and loading or the ratio of electrolyte to anode particle surface area.

Reviewer 2:

The reviewer commended the project for its well-designed structure and noted that it had been executed very well up to the current stage.

Reviewer 3:

The reviewer acknowledged that the project had been well-constructed, particularly in light of its objectives.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer affirmed that the presented data indicated a high probability of project success, suggesting optimism regarding the project’s outcomes.

Reviewer 2:

The reviewer acknowledged the excellent work and substantial progress made with respect to the project goals. It was noted that milestones had been consistently met within the promised timeline, which was considered commendable.

Reviewer 3:

Regarding progress, the reviewer remarked that it had been very good. However, there was a suggestion that expanding the scope of calendar life testing could enhance the ability to make more predictive outcomes based on the dataset.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer stated that while many partners were listed with their tasks, there was no demonstrated progress in each category that would allow for an evaluation of their contributions in each task. Specifically, the reviewer questioned how electrolyte optimization by Silatronix or binder optimization by Arkema had contributed to progress towards achieving the project's milestones.

Reviewer 2:

The reviewer affirmed that the partners involved in the project were among the best in their respective fields, particularly for components like binders, electrolytes, and conductive carbon. It was acknowledged that their expertise was critical for optimizing anode performance.

Reviewer 3:

The reviewer praised the project as a model of a well-organized and coordinated team. However, there was a suggestion that more transparent information on the contributions of individual partners to specific project tasks would enhance the overall understanding of progress and collaboration within the team.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed that only limited details were presented to evaluate the question of protecting the Si-C anode from degradation while exposed to high temperatures at 100% state of charge. The only information provided was related to the "Suitability of test cells for calendar life evaluation methods." However, the reviewer asked for an elaboration on why the current cells were considered suitable for calendar life evaluation.

Reviewer 2:

The reviewer strongly recommended conducting cycle life tests using dynamic stress test (DST) type cycling, which closely resembles real-life vehicle requirements as outlined in the USABC test manual. Additionally, there was a suggestion to study the fast-charging capability of these cells. The reviewer also recommended measuring thickness expansion during both cycle and calendar life tests and observing the formation of gases to gain a better understanding of cell behavior.

Reviewer 3:

The reviewer expressed that it was not perfectly clear what specific actions were being taken to close the final target gap. To improve clarity, the reviewer suggested providing a more detailed description of the steps being taken to bridge this gap in achieving project objectives.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that this project clearly aligned with and supported VTO objectives, spanning from materials development to cell fabrication and eventual commercialization.

Reviewer 2:

The reviewer noted that this project was directly related to the Batteries subprogram objective within the broader context of VTO's overarching objective.

Reviewer 3:

The reviewer affirmed that the development of a low-cost Si-carbon composite had the potential to be a key enabler for cost reduction, as well as a means to potentially reduce CO_2 emissions, highlighting the significance of this aspect within the project.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that there were adequate resources in place to accomplish the proposed tasks, indicating confidence in the resource allocation for the project.

Reviewer 2:

The reviewer remarked that the resources appeared to be sufficient for the remaining phases of the project, suggesting that there were no immediate concerns in this regard.

Reviewer 3:

The reviewer observed that the project boasted a well-balanced team, signifying that the team composition was deemed appropriate for the project's objectives and goals.

Presentation Number: BAT531
Presentation Title: Solid State Lithium-ion Batteries Using Silicon Composite Anodes
Principal Investigator: Pu Zhang (Solid Power Battery)

Presenter

Pu Zhang, Solid Power Battery

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

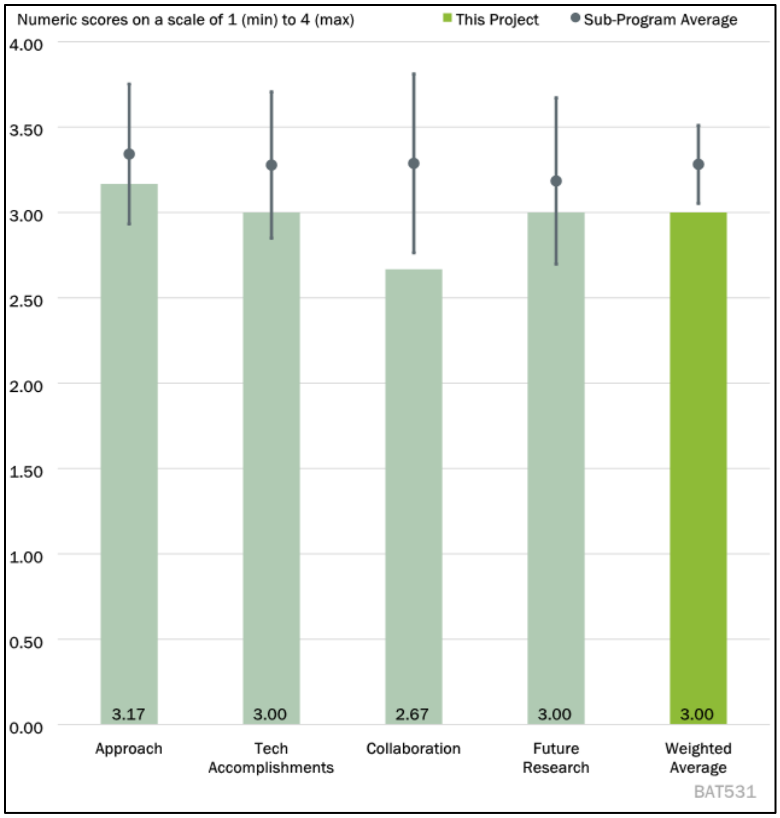

Figure 1-27 - Presentation Number: BAT531 Presentation Title: Solid State Lithium-ion Batteries Using Silicon Composite Anodes Principal Investigator: Pu Zhang (Solid Power Battery)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commented that a good approach had been presented, although there were some inconsistencies within the project documentation. Specifically, the reviewer highlighted an inconsistency in the response from the PI regarding electrode loading, where it was mentioned that electrodes with higher loading at 4 mAh/cm^2 had been developed in Year 2 to meet specific energy goals. However, the technical accomplishments on Slide 12 still showed results for 3 mAh/cm^2 cathode loading without specifying energy density or separator thickness. The reviewer inquired about the energy density for the cells presented on Slide 12, which achieved a cycle life of 800. Additionally, the reviewer pointed out that calendar life and impedance growth data had not been reported, making it difficult to assess progress and the likelihood of project success.

Reviewer 2:

The reviewer noted that the project was well-defined with clear goals and targets. There was a desire to see Solid Power study C-rates capability, including at lower temperatures.

Reviewer 3:

The reviewer stated that, overall, the project was in a very good state. However, the reviewer noted that the absence of work related to calendar life and cost modeling was noticeable.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer commented that good progress had been made toward increasing anode capacity and demonstrating cycle life. However, the reviewer noted that only initial calendar life had been evaluated, and there was no specification of the cell's energy density and size. Additionally, the overall energy density of the tested cells had not been reported. The reviewer had questions regarding the cycle life at room temperature and whether pressure had been applied during cycling.

Reviewer 2:

The reviewer praised the team for delivering milestones and meeting go/no-go decisions on time. There was hope expressed that the team would work on further improving first cycle efficiency above the current 91%. The reviewer also suggested considering the use of NMC811 cathode in future cell builds.

Reviewer 3:

The reviewer highlighted excellent progress in terms of cycle life and energy density. However, the reviewer pointed out that progress on calendar life and cost was noticeably absent and suggested that this aspect should be better illustrated within the project documentation.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that no results, such as degradation mechanisms from ANL, had been reported, which made it challenging to evaluate if the collaborators had contributed to the project's success.

Reviewer 2:

The reviewer mentioned that there was no visible data or results emerging from ANL.

Reviewer 3:

The reviewer emphasized the importance of better illustrating the work products of ANL within the project's results and documentation.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer noted that the development of high-loading electrodes and testing of 2 Ah cells would be combined with impedance growth measurements and calendar life versus temperature assessments.

Reviewer 2:

The reviewer outlined several suggestions for the proposed future research plan:

Utilize ANL facilities and expertise to gain a better understanding of failure modes.

Consider studying cells with higher loading at 4.5 mAh/cm^2.

Measure cell thickness and pressure growth during and at the end of cycle life and calendar life testing.

Given that the project is scheduled to conclude by December 2023, it is essential to quantify performance at ambient temperatures, such as 25°C, and if possible, even at lower temperatures. This is important because all the data presented thus far has been at elevated temperatures of 45°C. Understanding cell capabilities at different temperatures is crucial.

Reviewer 3:

The reviewer emphasized the need to present work on calendar life and cost in addition to efforts to achieve a specific energy target of 350 Wh/kg while retaining cycle life. These aspects should also be a part of the project's focus and reporting.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the development of SSEs working with Si anodes clearly supports VTO subprogram objectives.

Reviewer 2:

The reviewer commented that this project relates well to the Batteries subprogram to support overall VTO objectives.

Reviewer 3:

The reviewer said that this is a high energy density project, enabling pure Si-anodes, which supports the overall goals of longer range and lower cost.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer expressed that there appeared to be sufficient resources allocated for the project, indicating no immediate concerns in this regard.

Reviewer 2:

The reviewer emphasized the need to utilize the resources at ANL to understand cell degradation mechanisms, as no results in that direction had been observed thus far.

Reviewer 3:

The reviewer raised concerns about the areas of calendar life and cost modeling, suggesting that unless demonstrated otherwise, there might be insufficient work being conducted in these specific areas. The reviewer highlighted the importance of addressing these aspects within the project.

Presentation Number: BAT532
Presentation Title: Electrolytes with Lithium-ion Batteries with Micro-sized Silicon Anodes
Principal Investigator: Chunsheng Wang (University of Maryland)

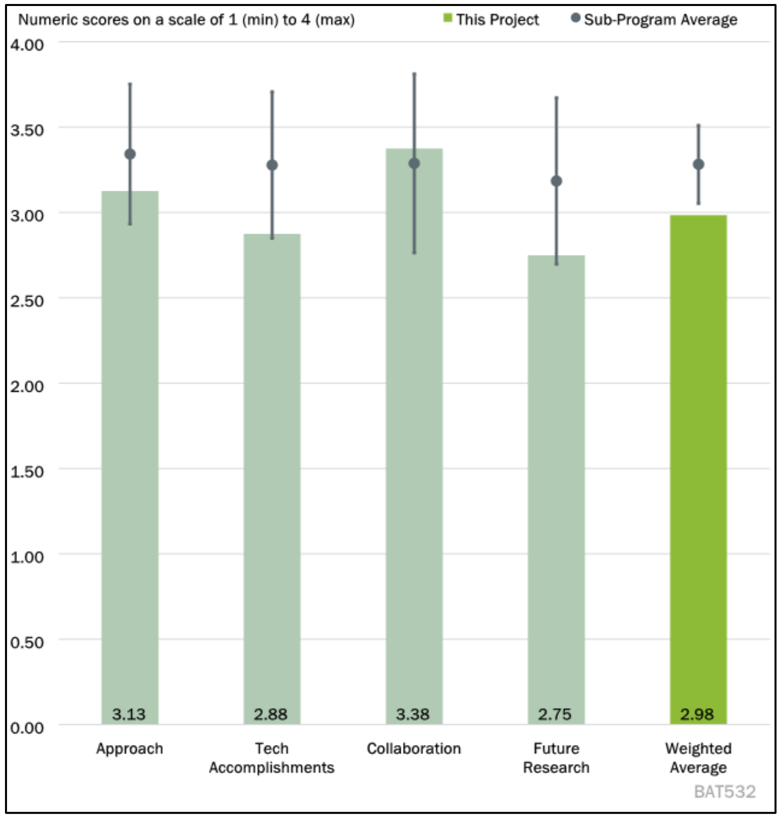

Figure 1-28 - Presentation Number: BAT532 Presentation Title: Electrolytes with Lithium-ion Batteries with Micro-sized Silicon Anodes Principal Investigator: Chunsheng Wang (University of Maryland)

Presenter

Chunsheng Wang, University of Maryland

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commented that the project was nearing completion and noted that the overall project planning had been presented well.

Reviewer 2:

The reviewer provided a technical assessment of the project, highlighting the use of anion-directed solid electrolyte interphase (SEI) with a high content of LiF-Li_2O for addressing the technical barrier, as well as the use of LiF for Si)-doped anodes in the formation of the CEI. The use of ionic liquid was mentioned as a potential approach to achieving different solvation properties. The reviewer pointed out the importance of considering the reactivity of Si and the solvent when determining the optimal SEI formula. The use of acronyms such as FST, FFT, and EE was mentioned in the presentation, and the reviewer recommended including the chemistry of the solvent choices in future AMR slides for clarity.

Reviewer 3:

The reviewer commended the project for being well-defined and praised the thoughtful approach of forming inorganics in SEI and CEI, particularly at decent loading levels of 4 mAh/cm^2.

Reviewer 4:

The reviewer also noted that the project was lacking a demonstration of the starting point and the improvements to be accomplished. Providing this context could enhance the understanding of the project's progression.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the project was focused on addressing the issue of unstable Si-anode SEI layers by designing a new electrolyte that forms a LiF-rich SEI. It was mentioned that the data obtained so far were comparable to the graphite baseline, and evaluations of full cells to meet the project target were in progress. However, the reviewer expressed a desire for more physical characterizations of the SEI layer on the micro-Si, even if these characterizations were part of earlier milestones.

Reviewer 2:

The reviewer acknowledged significant work on the plans for electrolytes and the performance of FST, which was identified as the best performer. Some minor comments and clarifications were provided, including the use of the term "volatile solvent-free" instead of "solvent-free" and the need for proper scale in leakage current measurements. The reviewer also questioned the counterintuitive increase in CE as the leakage current increased.

Reviewer 3:

The reviewer sought clarification on the acronyms FSE, FFT, and EE, assuming that they represented cells made with three different electrolytes. The reviewer recommended measuring thickness and pressure growth during cycling and calendar life for pouch cells. Additionally, there was a suggestion to improve cycle life, as 120 cycles to about 89% capacity retention were considered suboptimal.

Reviewer 4:

The reviewer found it challenging to discern progress in the project based on the presented information. The reviewer expressed a need for more key takeaways and emphasized the importance of clarity in project documentation.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer observed that each partner (UMD, ARL, Saft, SBU) appeared to have relevant and appropriate project tasks, reflecting a well-structured collaborative effort. While the reviewer expressed a desire to see more representation from collaborators on the poster, it was recognized that space constraints might have limited their inclusion.

Reviewer 2:

The reviewer noted that the team had a good combination of expertise, highlighting the diversity of skills and knowledge within the project.

Reviewer 3:

The reviewer praised ARL as an excellent collaborator for electrolyte modeling and related work, underscoring their valuable contribution to the project.

Reviewer 4:

The reviewer commended the project for clearly defining and demonstrating roles and responsibilities, which contributed to the overall organization and effectiveness of the collaboration.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer noted that the project was nearing completion and highlighted the focus of future work, which was to demonstrate good cycling and calendar life in multi-layer pouch cells.

Reviewer 2:

The reviewer commented that future plans were centered on pouch cells and aging mechanisms, as well as testing to understand different SOC and high-temperature performance.

Reviewer 3:

The reviewer pointed out that there were limited details provided about future work, with the statement merely indicating a "focus on modifying the cell configuration."

Reviewer 4:

The reviewer expressed skepticism about achieving the performance goals based on the information presented in the project documentation.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that this project aligned with the DOE objective to achieve greater energy density in LIBs by introducing a stable form of Si into the anode.

Reviewer 2:

The reviewer noted that the project was relevant to VTO as it aimed to enable microsized Si anode technology.

Reviewer 3:

The reviewer sated that the project was primarily related to the VTO Batteries subprogram, supporting overall objectives of the VTO.

Reviewer 4:

The reviewer pointed out that while specific performance goals had been indicated, the project primarily aimed to better understand certain electrolyte phenomena in support of an SEI composition hypothesis. While some improvement in understanding had been achieved, a clear pathway to achieving the performance targets was not evident in the project documentation.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that resources appeared to be sufficient, expressing confidence in the adequacy of available resources.

Reviewer 2:

The reviewer affirmed that the resources were sufficient.

Reviewer 3:

The reviewer noted that the resources seemed sufficient to complete the stated goals of the project.

Reviewer 4:

The reviewer raised a concern, suggesting that if the performance goals were the primary objectives of the project, then the resources were insufficient to achieve those goals. This implied a potential misalignment between the goals and the available resources.

Presentation Number: BAT533
Presentation Title: Fluorinated Local High Concentration Electrolytes Enabling High Energy Density Silicon Anodes
Principal Investigator: Amy Marschilok (Stony Brook University)

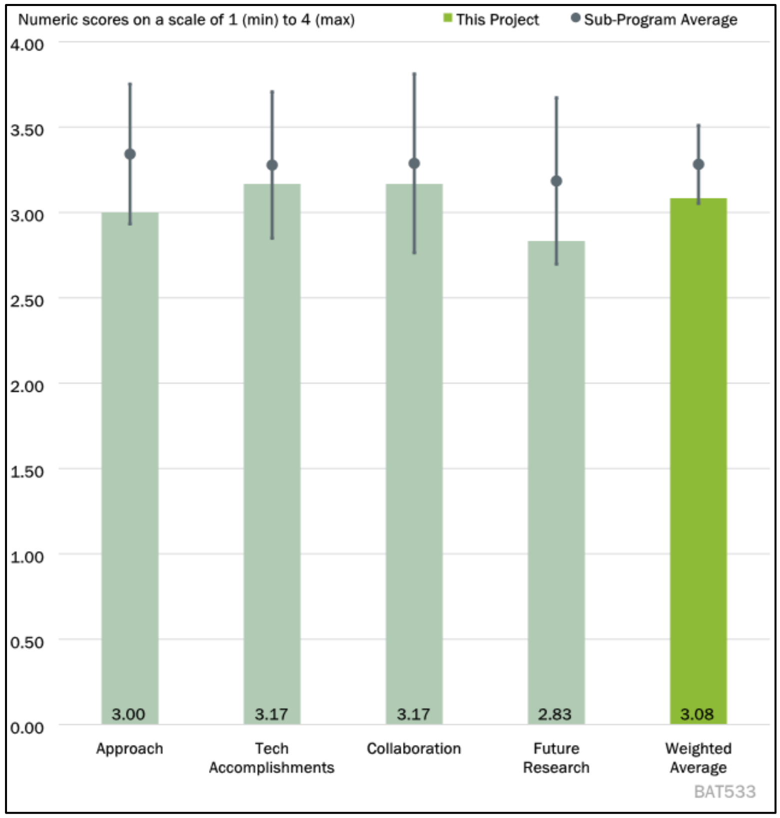

Figure 1-29 - Presentation Number: BAT533 Presentation Title: Fluorinated Local High Concentration Electrolytes Enabling High Energy Density Silicon Anodes Principal Investigator: Amy Marschilok (Stony Brook University)

Presenter

Amy Marschilok, Stony Brook University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer pointed out that the main metric of success, which was a 20% improvement in capacity retention over the baseline electrolyte (1M $LiPF_6$ EC/DMC + xFEC) with x ranging from 0% to 10% of fluoroethylene carbonate (FEC), could be misleading for two reasons. Firstly, the reviewer referenced the work of the Gasteiger group, which demonstrated that capacity retention is proportional to FEC consumption in this electrolyte. Thus, increasing FEC concentration under lean electrolyte conditions could potentially increase capacity retention, which may not align with the expected outcome. Secondly, the reviewer suggested that if the PI were to choose 20% FEC instead of 10% FEC in the baseline electrolyte under lean electrolyte conditions, the claimed 20% improvement in delivered capacity might not be observed, potentially resulting in an unsuccessful project outcome by December 2022.

Reviewer 2:

The reviewer commended the project for being well thought out and defined. However, there was a question about the potential cost increase when each component contains fluorine, as fluorinated materials are typically more expensive.

Reviewer 3:

The reviewer praised the general approach as excellent but suggested that an explicit description of the investigative structure of the study could have been improved for greater clarity.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer suggested that the modest improvement in capacity retention after 100 cycles in the LHCE versus the baseline electrolyte might be observed because of the deliberate choice of an electrolyte with 10% of FEC, as opposed to an increase to 20% FEC, which would consume FEC and potentially degrade faster. The reviewer recommended reporting realized energy densities of electrolytes, electrolyte loading, gassing behavior, and impedance rise to provide evidence of performance improvement compared to baselines, which should include a higher fraction of FEC.

Reviewer 2:

The reviewer acknowledged that the project had met all its milestones. However, there was a question about why it was crucial to quantify parasitic heat generation at this stage of development. Regarding the presentation of the "Best Gen 2 cell," on Slide 9, the reviewer noted that it showed only about 60 cells retaining 80% capacity, suggesting that significant improvements were needed for cycle life performance. The reviewer inquired if there were any concerns about handling FLHCE (fluorinated lean high-capacity electrolyte) in terms of storage, moisture sensitivity, or other factors.

Reviewer 3:

The reviewer commended the bulk and analytical accomplishments, finding them well-executed and clear.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commented that the collaborators had made meaningful contributions by providing valuable characterization data to aid in the understanding of capacity fade, indicating a fruitful collaboration.

Reviewer 2:

The reviewer stated that the collaboration with BNL and the National Institute of Standards and Technology (NIST) was described as very appropriate, highlighting the significance of these collaborations for the project.

Reviewer 3:

The reviewer commended the project for being well-described and demonstrated, suggesting that the project's objectives and achievements were effectively communicated and substantiated.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed uncertainty about how the proposed remaining work for the project, which includes characterizing the chemical composition of derived interfaces using hard X-ray photoelectron spectroscopy (HAXPES) and quantifying parasitic heat using isothermal microcalorimetry, would aid in improving performance. The reviewer suggested adding benchmark electrolytes with a high fraction of FEC to the proposed characterization of the electrochemical behavior of the localized high concentration electrolyte against a control electrolyte in 0.2 Ah cells to establish improved baselines. The reviewer also requested comments on the environmental effects of the proposed semifluorinated electrolytes.

Reviewer 2:

In terms of proposed future work, the reviewer noted that it was well-defined. There was a question regarding the 500 cycles goal, whether it aimed to achieve 80% capacity retention or 50% capacity retention, with the hope that it was the former. Additionally, the reviewer recommended studying cell thickness and pressure increase during cycling and at the end of cycling for 0.2 Ah multi-layer pouch cells.

Reviewer 3:

The reviewer concluded by stating that the proposed future work was well-aligned with the work done to date and appreciated that it incorporated feedback from previous reviewers. However, there was a suggestion to conduct additional calendar life testing, which would be beneficial.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the project objectives were aligned with and supportive of VTO goals.

Reviewer 2:

The reviewer noted that the project was related to the VTO Batteries subprogram within the context of the overall VTO objectives.

Reviewer 3:

The reviewer commented that this area of study was well-regarded by both industry and academia as a pathway to improve the life of high-Si content anodes, emphasizing its significance within the field.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that resources appeared to be sufficient for the results that were shown, indicating that the allocation of resources was appropriate for the achieved outcomes.

Reviewer 2:

The reviewer affirmed that the resources seemed to be sufficient to complete the stated goals of the project, suggesting that there were no immediate concerns regarding resource availability.

Reviewer 3:

The reviewer noted that while resources were sufficient, there might be a slight time constraint, given the project’s learnings. This indicated that the timeline may need careful management to ensure that the project stays on track.

Presentation Number: BAT534
Presentation Title: Devising mechanically compliant and chemically stable synthetic solid-electrolyte interphases on silicon
Principal Investigator: Pierre Yao (University of Delaware)

Presenter

Pierre Yao, University of Delaware

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

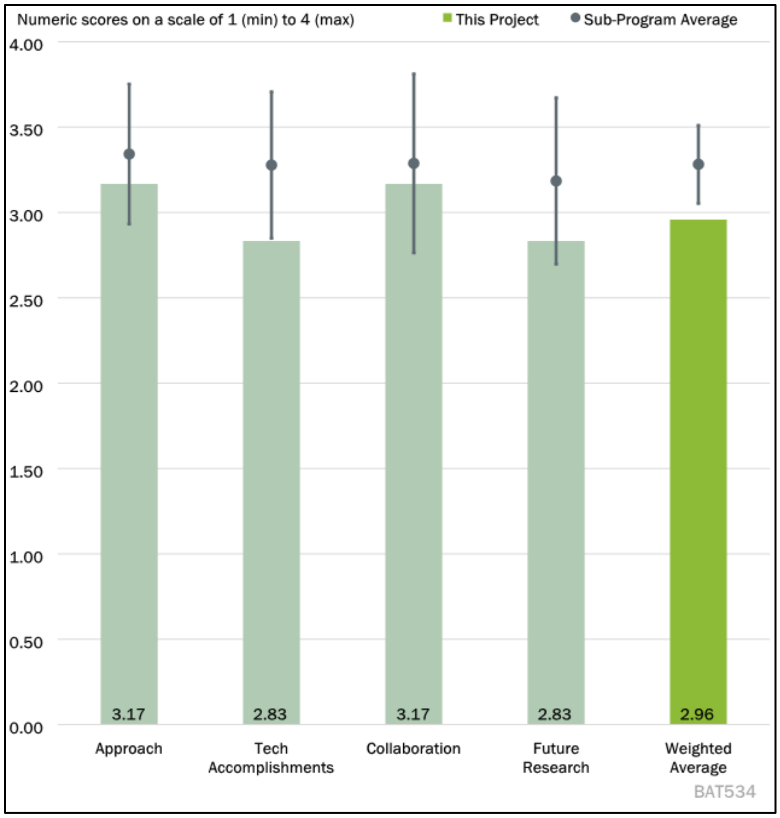

Figure 1-30 - Presentation Number: BAT534 Presentation Title: Devising mechanically compliant and chemically stable synthetic solid-electrolyte interphases on silicon Principal Investigator: Pierre Yao (University of Delaware)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted that while the project had demonstrated a significant improvement in the isoprene EP-coated Si in the FEC-free electrolyte, the performance was still poor. The reviewer suggested that it would be more informative to compare the performance of the new approach in state-of-the-art electrolytes rather than choosing a very poor baseline for comparison. This would provide a clearer understanding of the benefits of using the proposed approach in different electrolyte formulations.

Reviewer 2:

The project was described as well-defined in its exploration of new methods to stabilize the SEI layer, with the hope of improving the cycle and calendar life of a 100% Si-based anode. However, the reviewer considered the goal of achieving 1000 cycles to be very ambitious.

Reviewer 3:

The reviewer acknowledged the presence of a solid hypothesis and a plan to address that hypothesis. However, the reviewer pointed out a potential weakness in addressing other factors that may play as significant a role as the factors within the hypothesis, which could limit the degree of success achievable.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that while the project had demonstrated performance improvement for high (80%) loading of Si through electropolymerization, the performance was still far below what was needed to achieve a successful year 2 go/no-go decision.

Reviewer 2:

The reviewer mentioned that all the milestones were completed on time, including a successful Go decision. However, the reviewer suggested that the proposed new methods, such as electropolymerization (EP) and electrophoretic deposition, were claimed to be low cost and low capital-intensive. The reviewer recommended showing some cost analysis to support these proposals. The reviewer inquired whether the authors understood why rapid capacity fade was occurring during the first approximately 10 cycles, as this issue needed to be addressed. The cycle life was considered very limited compared to the target, and it was suggested that significant improvements were required.

Reviewer 3:

In terms of future work, the reviewer acknowledged that the results had been good and that the proposed future work aligned well with the work done to date. However, the reviewer encouraged additional post-cycling cell characterization to better connect the effects of failure modes to the SEI modifications under test.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commented that surface characterization, impedance, and FTIR (Fourier transform infrared spectroscopy) data had provided additional information but emphasized the need to present gassing and full cell data to provide a more comprehensive view of the project's progress.

Reviewer 2:

The reviewer noted that the facilities and expertise at ANL appeared to be utilized in the most effective manner, indicating the successful collaboration with ANL.

Reviewer 3:

The project was praised for its excellent description of team collaboration. However, the reviewer suggested that footnoting collaborators' contributions in the images would be helpful to provide clarity and credit to the collaborators for their specific contributions.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed uncertainty about how long-term stability studies would contribute to material design if the capacity fade had already exceeded 20% after 30 cycles. Additionally, the very low CE of 76% on the first cycle suggested that a change in approach might be needed before conducting extensive long-term cycling and calendar life studies. The reviewer questioned the rationale for performing these studies if the performance deteriorated significantly after only a few cycles.

Reviewer 2:

The reviewer noted that the future plan was well-defined and potentially aligned with the project's targets.

Reviewer 3:

The reviewer emphasized that any improvement in achieving the targets would be dependent upon the analyses and feedback generated during the course of the work. The reviewer also highlighted that the gap to reach 1000 cycles appeared to be very large, and it was unclear how likely it was to be achieved based on the current performance.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer agreed that the project is relevant.

Reviewer 2:

The reviewer stated that this project was related to the VTO Batteries subprogram of the overall VTO objectives, aligning it with the broader goals of VTO.

Reviewer 3:

The reviewer noted that the hypothesis being pursued in the project was well-accepted by both academia and industry. This indicated that the work being undertaken in the project was consistent with ongoing efforts in both academic and industrial research.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed that significant resources had been allocated to the project, indicating a substantial commitment to its success.

Reviewer 2:

The reviewer affirmed that the resources appeared to be sufficient and appropriate to meet the stated goals of the project, suggesting that there were no immediate concerns regarding resource adequacy.

Reviewer 3:

The reviewer noted that there was no indication in the project's work that resources were insufficient, and that milestones were being achieved at a pace like the original project proposal, reflecting a well-managed allocation of resources.

Presentation Number: BAT544
Presentation Title: Machine Learning for Accelerated Life Prediction and Cell Design
Principal Investigator: Eric Dufek (Idaho National Laboratory)

Presenter

Eric Dufek, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

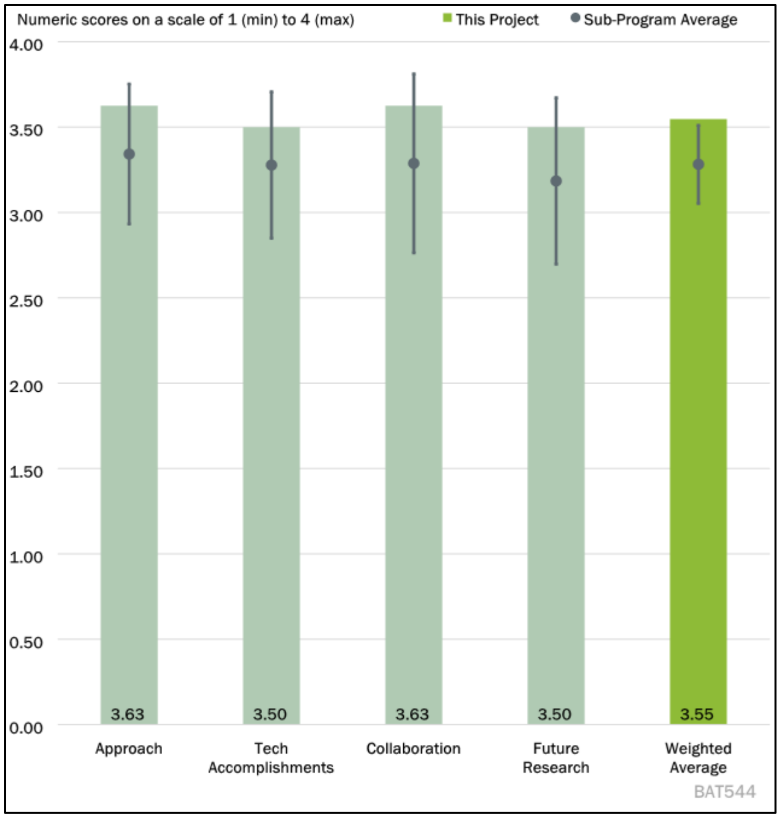

Figure 1-31 - Presentation Number: BAT544 Presentation Title: Machine Learning for Accelerated Life Prediction and Cell Design Principal Investigator: Eric Dufek (Idaho National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer praised the project for establishing a thorough approach to coupling existing data, database management, and a public platform. The development of milestones was acknowledged as providing a clear path toward achieving project objectives.

Reviewer 2:

The reviewer noted that many of the predictions in the project depended on synthetic data that had been generated. It was emphasized that the quality of predictions relied on the quality of the synthetic data generated. The reviewer also pointed out that validation over 600 cycles had been minimal due to a lack of data availability and suggested that analysis with fast charging rates would have been more helpful.

Reviewer 3:

The reviewer commended the width and depth of the project, saying it was well thought out. Predicting battery life and understanding failure modes were deemed crucial for the rapid development of battery technology.

Reviewer 4:

The reviewer highlighted several key aspects of the project, including the use of a battery physics-based P2D (pseudo-2D) model to generate synthetic data, the exploration of physics-informed neural networks to improve model quality, the utilization of deep learning algorithms to identify battery failure modes, and the comparison and evaluation of different performance and failure mode prediction frameworks in a systematic manner.

Additionally, electrochemical signatures were used to identify and classify aging modes, and a decision tree algorithm was employed to enhance classification quality.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer observed that the accuracy and usability of the physics-informed cross-barrier charging method were clearly demonstrated, reducing the need for inefficient rate performance test (RPT) - low C rate battery health assessments and leading toward the ability for real-time monitoring. The reviewer stated that the project demonstrated the feasibility of a physics-informed neural network approach, supporting a primary objective. The reviewer also remarked that the project demonstrated predictiveness as well as descriptiveness (i.e., establishing aging modes), further supporting a primary objective.

Reviewer 2:

During the evaluation, the reviewer commented that one of the points raised was the prediction of catastrophic failure, while another reviewer expressed the view that the model was not particularly useful for detecting abnormalities from a single cell. In essence, the model was observed to predict only “average” degradation. These points were deemed in need of addressing.

Reviewer 3:

The reviewer questioned why tasks that were due by June 2, 2022, were still in progress status—a delay of almost one year. Similarly, the other two tasks were delayed by almost 9 months.

Reviewer 4:

The reviewer affirmed that the project had accomplished most of the proposed objectives in the current fiscal year.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer remarked that the project has clearly developed and fostered an extensive collaboration and cooperative approach to access, collect, manage, and evaluate data and simulations.

Reviewer 2:

The reviewer stated that while this is primarily a national laboratory oriented project, it is worth noting that incorporating real-world data from vehicle OEMs would be valuable. This becomes especially critical considering the newly proposed U.S. Environmental Protection Agency (EPA) standards for battery health monitoring algorithms beyond Model Year 2027. The reviewer stated confidence that several vehicle OEMs are likely pursuing similar approaches for future compliance, and establishing collaborations with the industry could provide a common framework.

Reviewer 3:

The reviewer praised the initiative of the PIs in reaching out to behind-the-meter-storage for elaborate collaboration, in addition to other projects.

Reviewer 4:

The reviewer pointed out that the project, led by INL, involves collaboration among several national laboratories. It was verified that stakeholder interviews have been conducted to collect industry opinions. The reviewer clarified that the project may further benefit from university collaboration, especially in the realm of battery physics knowledge. While the P2D model is a good starting point, it was observed that some assumptions of the model have been proven incorrect. The reviewer articulated that incorporating new and key physical insights into battery physics and failure mechanisms may significantly enhance the model's quality.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the project identifies and plans to address the large variability in data quality.

Reviewer 2:

The reviewer noted that the project is 80% complete, and there is not much left to comment on for future work.

Reviewer 3:

The reviewer found the proposed future work to be well defined. The reviewer strongly suggested conducting modeling work for the cells that use practical loading of at least 3.5 mAh/cm^2 and quickly transitioning to preferred loading of 4.0–4.5 mAh/cm^2.

Reviewer 4:

The reviewer found the proposed future research to be comprehensive. It was suggested that the failure mode analysis may benefit from new knowledge in battery physics and failure mechanisms, especially under demanding conditions such as high charging rates, low temperatures, and so on.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that this work aligns closely with the VTO objectives.

Reviewer 2:

The reviewer pointed out that battery state of health monitoring algorithms will be needed beyond Model Year 2027. They emphasized that these types of work conducted at national laboratories are critical and support the mission of the agency.

Reviewer 3:

The reviewer observed that the project is highly relevant to Batteries subprogram of VTO.

Reviewer 4:

The reviewer commented that the project is a great asset to the VTO program, as it provides a unique and important angle to examine, understand, and optimize batteries at both the cell and system levels. They highlighted that it complements material research efforts. The developed model, tools, practices, and methods for combining data with a physical understanding can be generalized to different battery chemistries, batteries of various scales and sizes, thereby enabling improved battery usage for enhanced safety and lifespan.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer asserted that the project's funding and effort are sufficient to successfully accomplish its objectives, which primarily involve evaluating battery performance, specifically lifetime and health.

Reviewer 2:

The reviewer noted that the project has been nearly completed.

Reviewer 3:

The reviewer commented that the team is very well equipped in terms of resources.

Reviewer 4:

The reviewer stated the work has a very wide scope, bringing together experts with different backgrounds, including computation specialists, experimentalists, chemists, physicists, battery engineers, and data scientists. The reviewer emphasized the importance of such a multi-disciplinary team to the success of this project, as it requires the integration of a deep physical understanding of battery operation, chemical insights into battery failure, electrochemical modeling of batteries, battery testing, ML modeling, and the establishment of data infrastructure to achieve the project's goals. The reviewer also pointed out that this project differs significantly from a "typical" VTO project. Given the project's scope, the reviewer suggested that the team may benefit from an increased budget to ensure that all the key expertise required for the project's success can be included and any potential weaknesses can be addressed.

Presentation Number: BAT546
Presentation Title: Scaling-Up and Roll-to-Roll Processing of Highly Conductive Sulfide Solid-State Electrolytes
Principal Investigator: Dongping Lu (Pacific Northwest National Laboratory)

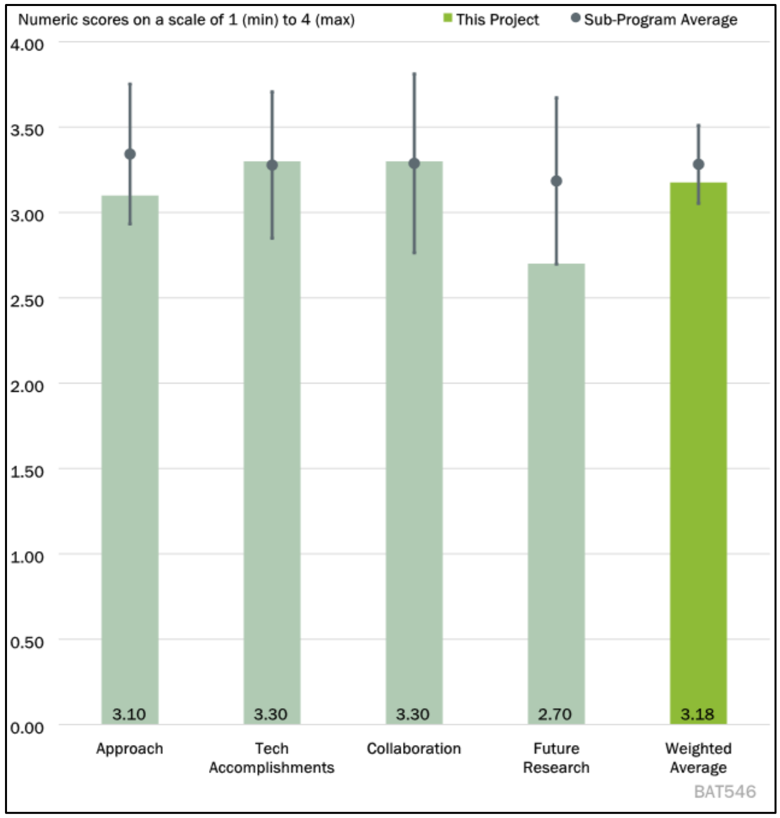

Figure 1-32 - Presentation Number: BAT546 Presentation Title: Scaling-Up and Roll-to-Roll Processing of Highly Conductive Sulfide Solid-State Electrolytes Principal Investigator: Dongping Lu (Pacific Northwest National Laboratory)

Presenter

Dongping Lu, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 60% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient,20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer appreciated the overall approach but noted that relying solely on conductivity as a screening parameter may be insufficient, as most sulfur-based electrolytes are not stable at high or low voltages.

Reviewer 2:

The reviewer noted the approach primarily focuses on the synthesis of sulfide SSEs using liquid-phase processing methods. The reviewer found the work to be well-presented and relevant. However, they raised concerns about the project's limited scope in terms of evaluating materials and components in a cell environment under relevant pressure and temperature conditions. The reviewer stressed the importance of including testing in a device at pressures below 1 MPa and at temperatures relevant to link synthesis changes with their impact on device processing.

Reviewer 3:

The reviewer pointed out that the project mainly addresses lower technology readiness level (TRL) development and does not emphasize scalability and handleability at the higher levels required for larger batch synthesis for cell scale-up. They also noted the importance of the project's focus on lower-temperature synthesis rather than ultra-high temperatures.

Reviewer 4:

The reviewer stated the project's goal is to develop a process for making a separator of a solid electrolyte based on a halide-doped sulfide. The reviewer highlighted the use of a robot to assist in the screening process and suggested that selecting an appropriate solvent and binder could enable the creation of slurries, film casting, and performance measurement.

Reviewer 5:

The reviewer observed that the team is utilizing a high-throughput screening method to identify optimized solvents and binders for processing sulfide SSEs. They proposed the creation of a database or library to determine the solubility and other physical properties of solvents and binders, which would be critical for scaling SSBs. Additionally, the reviewer praised the emphasis on dry processing of solid electrolyte membranes, which can save costs and avoid the use of organic toxic solvents.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer acknowledged good progress in the project but expressed concerns regarding certain parameters that may limit its applicability for automotive applications. Specifically, the requirement for 500 MPa pressure, equivalent to about 5000 atmospheres, was deemed impractical for automotive use. Additionally, a thickness of 41 microns and a conductivity under 1 mS/cm raised concerns about the material's suitability for room temperature performance, as the resistance could potentially be too high.

Reviewer 2:

The reviewer commended the technical progress made within the project, especially considering the $500,000 annual budget. They noted that the project had explored synthesis, measured IC, and conducted work on component fabrication, such as separators.

Reviewer 3:

The reviewer emphasized the need for further work in balancing electrochemical properties with mechanical properties to achieve the highest performance while maintaining low interfacial resistance and high flexibility. Moisture absorption by the SSE was highlighted as a significant issue for scale-up and handleability. The reviewer suggested that addressing this challenge might require more than proper sealing and potentially involve reworking the materials within the SSE. While initial data on cell performance with the SSE appeared promising, the reviewer raised concerns about rate capability and cycle life, particularly considering the current stage of the project. The reviewer also noted that the project seemed to be lagging other efforts with later start dates.

Reviewer 4:

The reviewer provided specific insights into the project's achievements, including the development of a database of compatible solvents for SSEs, the correlation between solvent polarity and solubility, and the importance of sealing during scale-up. They highlighted the successful development of a binder and solvent, as well as process conditions suitable for industrial scale-up. The collaboration with Ampcera to develop a complete NMC/SSE/Li cell was also noted as an accomplishment.

Reviewer 5:

The reviewer recognized several excellent accomplishments, such as the database of compatible solvents and the successful scaling up of $Li_7P_2S_8Br_{0.5}I_{0.5}$ solid electrolyte. However, they also raised valid concerns about the project's feasibility for automotive applications and the need for further improvements in cell performance.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer observed collaboration across the team seems to be working well but was not discussed in detail.

Reviewer 2:

Regarding Ampcera's role, the reviewer noted there was uncertainty about how their contributions complemented the work of PNNL. It was unclear to the reviewer what Ampcera was doing for this project that was not already part of their current work. Additional information on the specific role and contributions of Ampcera to the project would provide clarity. The reviewer also mentioned Thermo Fisher's involvement in electrode characterization, but no further details were provided about their role within the project.

Reviewer 3:

The reviewer noted there was good collaboration.

Reviewer 4:

The reviewer commended the small team of partners for their successful collaboration, particularly in achieving scale-up and the fabrication of a full cell.

Reviewer 5:

The reviewer highlighted the excellent teamwork among partners, which included national laboratories, industry, and a research university. The achievement of scale-up up to 250 g of solid electrolyte powders using industrial milling process was noted as an example.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed concerns about the project's focus on scale-up, suggesting that the current batches' performance and parameters were not yet suitable for automotive cells. They emphasized that the project should prioritize improving the performance of current batches to meet the required standards.

Reviewer 2:

The reviewer noted the future work plan was to be primarily centered on synthesis and IC measurements. The reviewer reiterated the importance of establishing a strong connection between the synthesis efforts and the evaluation of components and devices for the project to have a high impact. For instance, creating an ultra-thin separator is valuable, but its effectiveness in a device context should be a key consideration.

Reviewer 3:

The reviewer acknowledged that future plans address significant barriers to implementing SSE on a large scale. However, they pointed out that the mechanical integrity of the SSE regarding preventing Li dendrite growth had not been discussed. Evaluating whether the SSE has this property would be a useful assessment.

Reviewer 4:

The reviewer stated the project's desire to achieve a more uniform particle size and find a suitable binder for making thin separators. The reviewer noted that it was unclear whether the project had a list of binders to try or specific methods to address the particle size issue.

Reviewer 5:

The reviewer highlighted the team's goal to develop approaches to reduce particle size while maintaining high IC for sulfide SSE. Additionally, they mentioned the intention to use the solvent and binder information developed thus far to fabricate ultra-thin solid separators and cathode films at relevant scales.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that the project is very relevant.

Reviewer 2:

The reviewer commented that the project is highly aligned with the goals of the Batteries program. SSEs were recognized as being of high relevance to the program's objectives.

Reviewer 3:

The reviewer saw the project as a valuable contribution to the Advanced Materials R&D efforts and to be closely aligned with the goals of the VTO.

Reviewer 4:

The reviewer acknowledged that while sulfides have good conductivity, their stability poses a significant challenge. The project was commended for addressing this challenge by working on ways to create electrolytes and composite electrodes using sulfides.

Reviewer 5:

The reviewer emphasized that the processing and scaling of SEs, as pursued in the project, would play a crucial role in accelerating the development of SSBs that align with VTO's battery R&D performance targets, which include achieving 500 Wh/kg and 1000 deep discharge cycles.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found the project's funding level to be somewhat high, particularly considering the active efforts of the industry in addressing similar challenges.

Reviewer 2:

The reviewer expressed concerns about the project's ability, with an annual funding of $500,000 from the DOE, to establish a strong connection between synthesis and processing work and the evaluation of these materials in a device setting, especially regarding relevant applied pressures and temperatures. The reviewer recommended enhancing the alignment of the project with cell building efforts to maximize its impact.

Reviewer 3:

In terms of resources for achieving full project success, the reviewer deemed them reasonable based on the project's approach and progress.

Reviewer 4:

The reviewer stated that from the research team's approach and progress, the team seems to have reasonable funding.

Reviewer 5:

The reviewer noted that the project's funding level appeared to be appropriate for its objectives and milestones, supporting optimal execution.

Presentation Number: BAT547
Presentation Title: Continuous high yield production of defect-free, ultrathin sulfide glass electrolytes for next generation solid state lithium metal batteries
Principal Investigator: Tim Fister (Argonne National Laboratory)

Presenter

Tim Fister, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

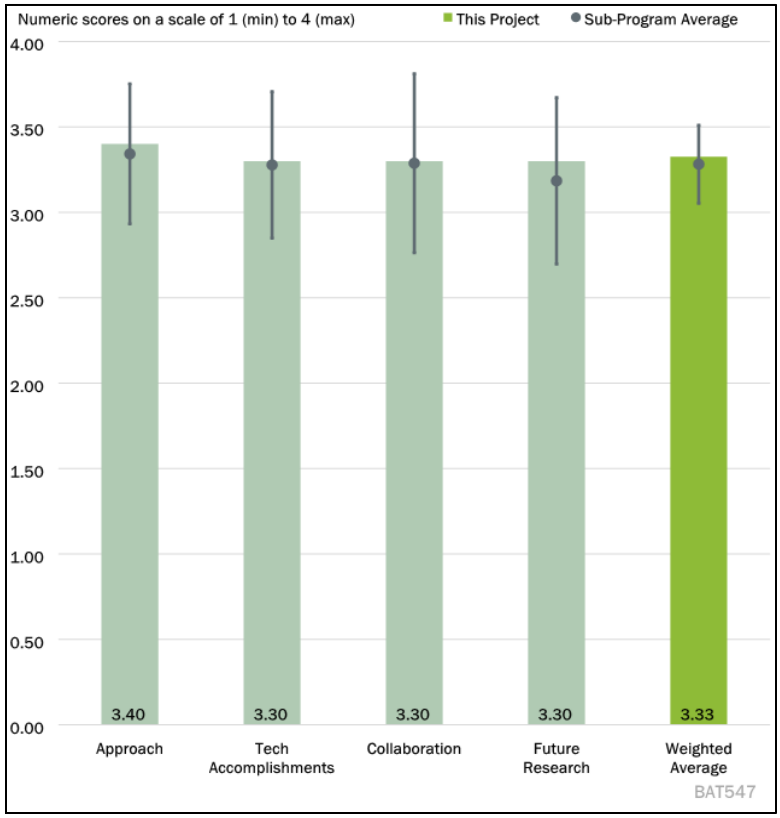

Figure 1-33 - Presentation Number: BAT547 Presentation Title: Continuous high yield production of defect-free, ultrathin sulfide glass electrolytes for next generation solid state lithium metal batteries Principal Investigator: Tim Fister (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer expressed positive feedback on the project's approaches to improving thin sulfide SSEs and found no major issues with the project.

Reviewer 2:

The reviewer noted that the project was well-targeted at addressing a characterization need for a material and component from PolyPlus. The characterization work was seen as contributing to the development of glass at PolyPlus by identifying the composition and potential sources of impurities.

Reviewer 3:

The reviewer stated that the presentation effectively conveyed that sulfides can be made into glasses, and thin glasses exhibit flexibility and conductivity, making them suitable for roll-to-roll processing of batteries. The negative impact of impurities on conductivity was also clearly communicated. The project's approach involved using multiple diagnostic tests to identify the location and type of impurities formed in sulfide laminates during production, from powder to ingot to preform (thick slab) to thin film (final product).

Reviewer 4:

The reviewer appreciated the use of total X-ray scattering methods to characterize the local and bulk structure of sulfide glass electrolytes. They noted that even tiny amounts of crystalline or non-crystalline impurities can affect the formation of defect-free ultra-thin glass solid electrolytes. The combination of powder diffraction and PDF methods was recognized for determining impurity levels and concentrations. Surface/interfacial defects were characterized using various techniques, including SEM/energy-dispersive X-ray spectroscopy (EDS), glow discharge optical emission spectrometry (GDOES), and digital holographic microscopy (DHM).

Reviewer 5:

The reviewer was concerned about the large background in the PDF measurement due to the use of SiO_2 as the container. They suggested considering alternative containers, such as polyimide-based or single-crystal sapphire containers, which produce negligible backgrounds and may improve PDF data processing.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer expressed concerns about the thickness of the SSEs, which were stated to be between 100 and 1000 microns thick. They pointed out that for use in automotive cells, thinner SSEs of around 20 microns may be necessary. Additionally, the reviewer noted that defects, which were already an issue in relatively thick films, might become more prevalent in thinner ones. They raised questions about how to avoid defect formation, especially if post-processing thermal treatment is the cause.

Reviewer 2:

The reviewer praised the project's alignment with contributing to the PolyPlus workflow, and they found that specific contributions by the characterization work were evident. They noted that the project's goals appeared to have been achieved.

Reviewer 3:

The reviewer commented the presentation for presenting the results of PDF and powder XRD analysis, demonstrating the presence of few defects in the core and the ability to measure their location and concentration after pressing. The project's approach to ion-cleaning to remove defects formed during the preform step was noted. The reviewer outlined the project's hypothesis about the sources of defects and demonstrated that the material itself slightly crystallizes during the preform process, likely due to internal heating. A comparison between the boron-based glass of interest and a more popular phosphorus-based sulfide glass was provided, indicating that the phosphorus-based glass was less susceptible to internal crystallization during the preform step. The preliminary results of a Raman probe were also noted as promising.

Reviewer 4:

The reviewer highlighted specific objectives related to studying the origin of impurity formation during glass formation, monitoring the onset of crystalline phases, and analyzing extensive X-ray and PDF measurements on borate-based sulfide glass electrolytes at various stages of the glass formation process.

Reviewer 5:

The reviewer acknowledged that the PI had successfully identified and quantified the crystalline defects, particularly noting that impurities had similar local structures to the LiB_xS_y glass electrolyte but exhibited long-range order. This knowledge had contributed to optimizing the LiB_xS_y electrolyte synthesis process. Comparisons and mapping had also been conducted for both LiB_xS_y and LiP_xS_y electrolytes. Overall, the reviewer praised the project's research efforts and results.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the collaboration between the project team and PolyPlus appeared to be working well.

Reviewer 2:

The reviewer noted that ANL received samples from PolyPlus and provided specific feedback to them, which was deemed useful. This collaboration was recognized as a positive and functional example.

Reviewer 3:

Despite not having many partners on the team, the reviewer acknowledged the project as having a strong industrial partner, PolyPlus Battery Company, which was seen as having the potential to convert the research results into improved battery components. Additionally, the project’s collaboration with researchers at the Advanced Light Source (ALS) was mentioned as a positive aspect of the teamwork.

Reviewer 4:

The reviewer expressed interest in knowing whether the samples used in the project were synthesized by the ANL team or supplied by PolyPlus.

Reviewer 5:

The reviewer said that the PI’s collaboration with individuals within ANL and with industry partner PolyPlus Battery Company, known for its capability to produce very thin glass electrolytes, contributed to the project’s success.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer commended the project’s good focus on defect formation and its consideration of ways to minimize defects in future work.

Reviewer 2:

The reviewer stated that the future work proposed, particularly focusing on interfaces, was important and relevant. They expressed a particular interest in this aspect of the project.

Reviewer 3:

The reviewer remarked on the project’s plan to modify its equipment to investigate batteries for the formation of impurities in both the bulk and on the surface. They also noted the project’s intention to use materials produced by the industrial partner.

Reviewer 4:

The reviewer observed the team’s plan to examine impurities at the Li/glass interface and the inclusion of imaging methods such as tomography and DHM to measure the topography of the glass and buried glass/Li interface.

Reviewer 5:

The reviewer questioned whether the project’s plan to carry out *in situ* PXRD and tomography during battery cycling to gain a better understanding of defect development and crystalline impurities in the solid electrolyte at different battery life cycles was reasonable. The reviewer asked for clarification on the project’s plan to study impurities at the Li-glass electrolyte interface and sought more information on how this aspect of the research would be conducted.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that the project is highly relevant.

Reviewer 2:

The reviewer found the PolyPlus approach to be interesting and noted that the project is contributing to the development of that approach.

Reviewer 3:

The reviewer stated that the work aligns well with the efforts of VTO to better understand SSBs and their potential as a replacement for Li-ion batteries. They recognized that this project supports VTO's efforts in this regard.

Reviewer 4:

The development of thin, flexible glassy solid electrolytes was seen by the reviewer as having the potential to accelerate the development of all SSBs, and the project was noted to be aligned with VTO's battery R&D target of achieving 500 Wh/kg with 1000 deep cycles.

Reviewer 5:

Overall, the reviewer emphasized that this SSE project, focused on studying glass electrolytes, supports the broader objectives of VTO's Batteries subprogram.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that the project offers good value for its R&D investment.

Reviewer 2:

Despite having a small budget, the reviewer commented the project to be productive and effectively collaborating with industry partner PolyPlus, which was seen as a positive aspect.

Reviewer 3:

The reviewer observed that the researchers had made excellent progress, generated interesting results, and had a clear plan for moving forward.

Reviewer 4:

The project's funding level was considered adequate by the reviewer to support the project's collaboration with PolyPlus, reinforcing the notion of effective resource utilization.

Reviewer 5:

The reviewer affirmed that the project had sufficient resources to achieve its stated milestones in a timely manner.

Presentation Number: BAT548
Presentation Title: Scale-Up of Novel Li-Conducting Halide Solid State Battery Electrolyte
Principal Investigator: Mike Tucker (Lawrence Berkeley National Laboratory)

Presenter

Mike Tucker, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

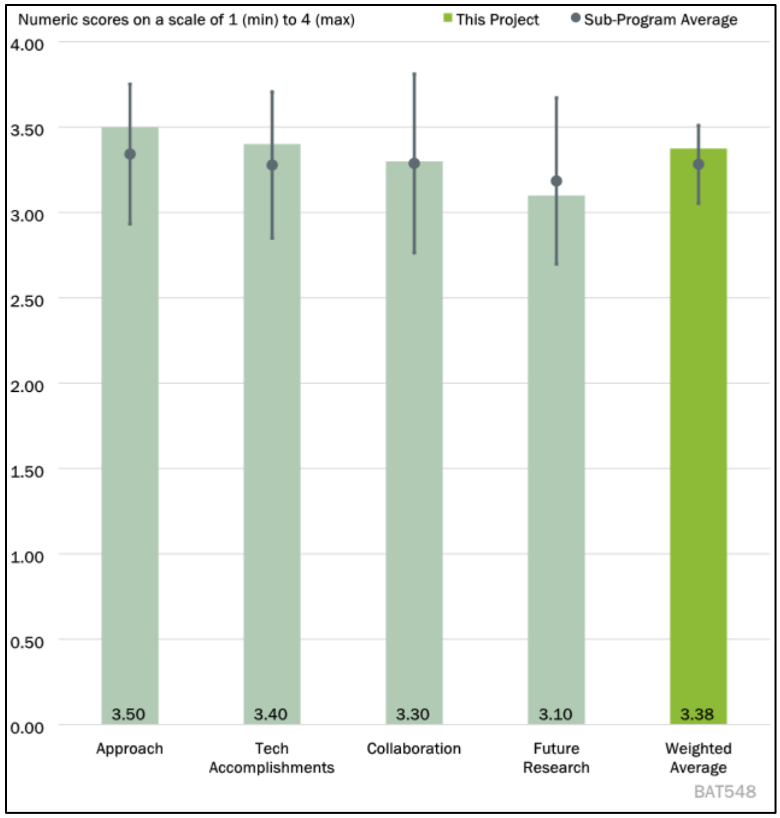

Figure 1-34 - Presentation Number: BAT548 Presentation Title: Scale-Up of Novel Li-Conducting Halide Solid State Battery Electrolyte Principal Investigator: Mike Tucker (Lawrence Berkeley National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer affirmed that the approach taken in the project was appropriate and aligned with the goal of developing a halide SSE in collaboration with Saint-Gobain.

Reviewer 2:

The reviewer noted that the project's approach made sense, which involved obtaining a powder from a commercial supplier and attempting to make a device with it while addressing challenges in component processing and device construction. The chosen powder was considered a reasonable candidate compared to other materials under investigation, and the approach leveraged the significant expertise of the PI and LBNL to seek progress.

Reviewer 3:

The reviewer suggested that the PI further investigate the substrate for the coating process, particularly how easy or difficult it is to remove the SSE coating. Additionally, they recommended investigating the threshold moisture level for casting.

Reviewer 4:

The reviewer stated the project's approach addresses key barriers to implementing a full halide battery, including barriers at each component level. The transition from coin cells to pouch cells was seen as a significant step, as it would help identify and address scale-up issues early in the effort.

Reviewer 5:

The reviewer recognized the project team's goal is to develop a scalable processing and fabrication method for designing SSBs using halide-based SEs. The reviewer mentioned that the demonstrated approach included using tape casting to fabricate thin halide-based membranes and integrating them with a thick NMC and thin Li anodes. The use of Li-In as the anode material for solid-state cathode testing was mentioned as an intermediate step. Year-I goals included selecting the appropriate binder and solvent for tape casting halide solid electrolytes supplied by the industrial partner, Saint-Gobain, and using Li_3N as an interfacial coating to stabilize the halide solid electrolyte with Li-metal.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer expressed concerns about the project performance, stating that it was quite poor and faced significant challenges. They noted that instability at both the NMC cathode and the Li anode posed major challenges. The reviewer expressed skepticism about the likelihood of success for this class of material and pointed out relatively poor conductivity, as evidenced by the significant drop in capacity at 0.2C compared to 0.02C, which was almost 50%. They also mentioned that the low-rate capacity was quite low and suggested a need to investigate this further. However, the reviewer acknowledged that LBNL's work was of high quality.

Reviewer 2:

The approach taken by the project was considered reasonable, but the reviewer noted that it was clear that the project faced significant challenges, including those commonly associated with SSBs. One of the known challenges was the requirement for high pressures (tens of MPa), which had proven difficult to overcome elsewhere. A unique challenge identified by the team was the inability to use binder burnout due to the 300°C stability window of the solid electrolyte. This was expected to make cycling the cell more challenging and limit performance due to the presence of remaining binder, which could reduce IC. The reviewer recognized the PI's awareness of these challenges and their focus on addressing them, with additional technical progress expected.

Reviewer 3:

The reviewer acknowledged great progress in several areas, including the screening of solvents and binders for compatibility with the halide SSE, determination of binder burnout temperature, conductivity assessment, and cell performance testing. They also mentioned their expectation to learn about the compatibility of Li metal with the halide in the following year.

Reviewer 4:

The reviewer noted the approach's flexibility in terms of which cathode the system is paired with and its assessment of different chemistries to demonstrate this. However, the reviewer pointed out the high risks associated with the required stack pressure and its potential impact on the final watt-hour per kilogram. There was also concern about limitations based on the instability of the electrolyte at higher potentials, which the project was addressing through new materials studies.

Reviewer 5:

The reviewer recognized several technical accomplishments by the team, including screening the binder and solvent system, achieving a critical current density (CCD) of 1.5 mA/cm^2 using Li-In electrodes, and conducting SSB testing using halide solid electrolyte and tape-casted NMC and LFP electrodes. However, they emphasized the need for further investigation into the poor capacity retention and optimization of the Li_3N interfacial coating approach compared to the Li-In anode.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer recognized the value of the project's collaboration with industry on SSEs.

Reviewer 2:

The reviewer noted that the collaboration appeared to be functioning well, with Saint-Gobain providing the solid electrolyte and cost sharing while LBNL focused on making a cell.

Reviewer 3:

The reviewer emphasized the critical nature of the PI's collaboration with Saint-Gobain, given the company's expertise in producing halide chemicals. They suggested that the PI consider extending the collaboration to other SSE producers.

Reviewer 4:

The partnerships within the project were seen by the reviewer as going well, and the work was noted to be coordinated effectively across the various groups involved.

Reviewer 5:

The reviewer mentioned the involvement of the ALS and SLAC to support degradation studies of SSB cells. They suggested the need for a detailed plan to be laid out in this regard. Additionally, they noted that the industry partner had scaled the halide solid electrolyte synthesis to the kilogram level and was currently optimizing new compositions.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed concerns about the readiness of the material for scale-up and suggested caution in pursuing it. They noted that the cathode should not be cracking and recommended collaborating with other national laboratories or industry partners to improve electrode processing. The reviewer also highlighted the importance of reducing pressure, as maintaining 500 atmospheres of pressure in an automotive battery was considered challenging.

Reviewer 2:

The reviewer remarked that the proposed work was reasonable, with a focus on creating a high-energy cell that would require the use of Li metal and an anode protection layer. They acknowledged that the team would encounter and identify challenges while working with this material.

Reviewer 3:

In the short term, the reviewer advised the PI to focus on assessing the compatibility of metallic Li anode with the halide SSE.

Reviewer 4:

The reviewer articulated that the shift towards pouch cell demonstrations was seen as a positive move, as it would help uncover scale-up issues early in the project's development.

Reviewer 5:

The reviewer noted that the future work plan addressed barriers for each component and outlined plans for moving forward. They recognized the team's clearly defined goals and metrics for future research, including the continued optimization of solid-state cathodes and anode interlayer coatings, scaling the tape casting capability, assessing the impact of stack pressure on cell performance, and minimizing interfacial resistance between tape-casted cathode sheets.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed the relevance of the SSE R&D in the project, considering the solid electrolyte as a reasonable candidate.

Reviewer 2:

The reviewer noted that working on making a cell with it was a good approach to identify issues and address Battery program goals.

Reviewer 3:

The reviewer articulated that the project's relevance rested on the development of a processing technology to enable the continuous production of SSBs.

Reviewer 4:

The reviewer expressed that this effort was very well aligned with the Advanced Materials R&D work funded by VTO.

Reviewer 5:

The reviewer observed that the processing and scaling of halide-based solid-electrolyte would enable the development of all SSBs, and they emphasized the strong alignment of the project with VTO's battery R&D performance target of 500 Wh/kg with 1000 deep cycles.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources allocated to the project were reasonable.

Reviewer 2:

The reviewer pointed out that achieving a 300 Wh/kg cell with good performance is an extremely challenging task. They noted that startups working on such projects typically have larger teams. The reviewer suggested that the project is more likely to identify issues to address rather than to create a compelling 300 Wh/kg cell, especially considering challenges like high stack pressure. Nevertheless, they recognized that identifying unique issues with this material could still be valuable to the DOE and the Saint-Gobain Corporation.

Reviewer 3:

The reviewer affirmed that the PI had adequate resources to conduct the proposed research.

Reviewer 4:

The reviewer expressed that the resources were sufficient to fully execute the project.

Reviewer 5:

The reviewer concluded that the project was funded at the appropriate level to deliver towards the milestones.

Presentation Number: BAT571
Presentation Title: ReCell Center-Direct Recycling of Materials
Principal Investigator: Jessica Durham Macholz (Argonne National Laboratory)

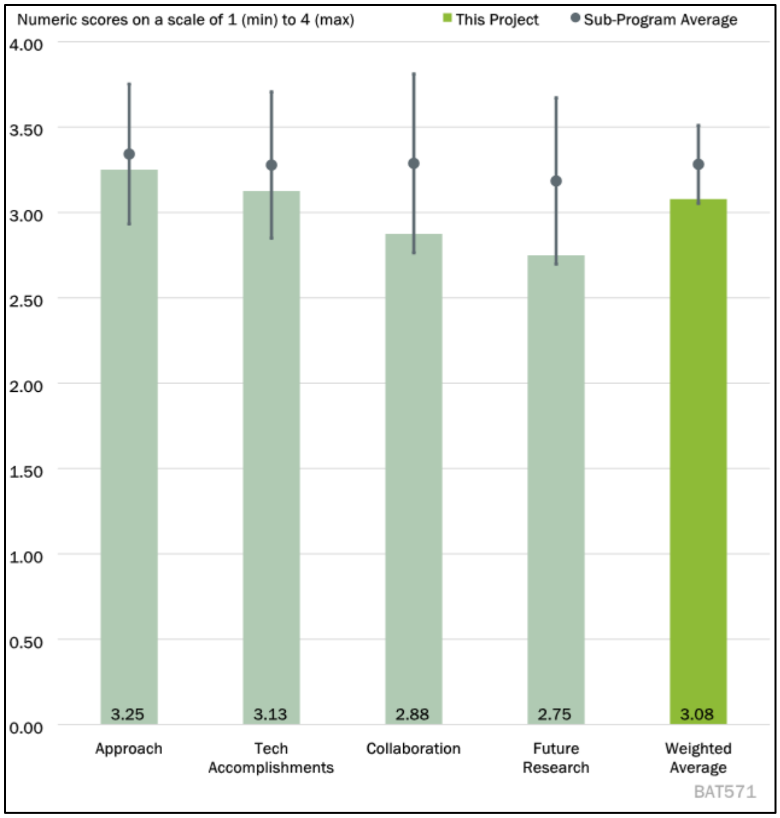

Figure 1-35 - Presentation Number: BAT571 Presentation Title: ReCell Center-Direct Recycling of Materials Principal Investigator: Jessica Durham Macholz (Argonne National Laboratory)

Presenter

Jessica Durham Macholz, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the approach from used cell/material to recycled product was clear, and many of the challenges raised by reviewers were already being addressed. However, they expressed a concern that the methods appeared to be primarily focused on being cost-competitive for transition metal oxides, and they suggested that direct recycling methods could be useful for polyanion cathodes or anode materials if a way to justify the economics could be found.

Reviewer 2:

In reviewing the overall projects in this area, the reviewer commented that the projects were well designed, and the timeline appeared to be reasonably planned.

Reviewer 3:

The reviewer acknowledged that the technical barriers were identified, and the corresponding timeline seemed reasonable. However, they raised a question about whether a technical solution, once found, would be practical and adoptable by industry at scale. They suggested re-evaluating the distribution of the 26 projects across sub-topics, as they felt that the 20 projects assigned to cathode and anode separation and relithiation/upcycling might be excessive. They also expressed uncertainty about the likely application areas for cathode separation and upcycling.

Reviewer 4:

The reviewer pointed out that the project did not clearly identify the technical barriers specific to direct recycling of materials, beyond cost. They noted that there were many other potential barriers. They also mentioned that the presentation lacked information about which partners in the consortium were involved in each of the 26 projects, and they suggested it would have been appropriate to indicate partner involvement for clarity.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked that the projects had shown good progress, with many efforts achieving over 95% recovery, purity, or yield. They noted that there were numerous proof-of-concept demonstrations that showed the feasibility of the direct recycling concept. However, the reviewer pointed out that the challenge going forward would be to improve towards battery-grade materials.

Reviewer 2:

In evaluating the projects, the reviewer commented that they seemed to be at various stages of technical progress, but all were progressing according to the project plan.

Reviewer 3:

The reviewer acknowledged that progress had been made in most of the projects and anticipated additional progress as research activities continued. However, they emphasized the critical importance of adhering to rigorous specifications for battery-grade qualifications and ensuring that the end objective of achieving parity with virgin materials was achievable. They suggested that achieving a maximum purity of 99% might not be sufficient for large-scale use by the battery industry, which could require even higher purity levels.

Reviewer 4:

The reviewer noted that more than 20 technical approaches were investigated, and it was challenging to discern which activities were part of the project plan. They suggested that the researchers should quickly down-select the more promising approaches and focus on those rather than pursuing every possible approach.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer observed that there were numerous people involved in the effort, and it was a bit challenging to discern how much work was standalone by different groups and how much involved collaboration.

Reviewer 2:

The reviewer commented that collaboration with laboratories and other entities appeared to be adequate.

Reviewer 3:

The reviewer praised the collaboration between project teams and national laboratories, describing it as very good. They also encouraged further collaboration with partners who would be the end-users of the materials, as well as recyclers who would use the recycling processes developed. They noted that these entities would provide valuable insights into practical challenges beyond technical ones.

Reviewer 4:

The reviewer stated that there seemed to be good collaboration but mentioned that it was not clear which partner was responsible for each project. They also highlighted that it was unclear if industry partners were involved in each of the activities.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer intimated that moving the efforts into kg scale/pilot scale trials is a logical next step for the technology development. However, the purpose of the scale-up and how the ReCell center will use the effort to eventually enable industry is not so clear.

Reviewer 2:

The reviewer stated the proposed future work was presented at a high level; however, it is defined and the work will likely achieve its targets.

Reviewer 3:

The reviewer believed that collaborating with the EverBatt team is critical, although understandably difficult to extrapolate scaled process costs from laboratory work. The reviewer fully supports the proposal to work more closely with 2680 Bipartisan Infrastructure Law (BIL) Funding Opportunity Announcement (FOA) awardees but would further encourage seeking more industry collaborators to validate the prospects of the recycled materials. Scaling the promising processes is a good and necessary next step. As previously noted, it would be useful to understand under which scenario upcycling would be a practical solution. Presumably this would be for EOL batteries of earlier generations. These would typically be mixed in an unpredictable and variable stream. As such, the upcycling parameters would have to be continually modified, and if the approach involves core-shell (for example higher Ni on the exterior) this will not yield a consistent product robust to incoming variations and usable by our industry where variation is the enemy. So again, just because it is possible does not mean that it is practical, and projects should be evaluated judiciously in this manner. Another questionable issue noted under the new projects is the graphite recovery with intact SEI layer. This seems very impractical, as unless the recycled graphite is used exclusively, one would presume that a new SEI adapted to and optimized for specific cell parameters (electrolyte etc.) would be needed. i.e., making a cell using some Gr with SEI mixed with virgin with no SEI seems impractical, as this would result with a cell with 2 potentially different SEI layers post formation.

Reviewer 4:

The reviewer commented that the proposed future R&D is reasonable. Downselecting the processes will be effective for direct recycling batteries. It is one of the important considerations for future so the investigators can focus on a few good solutions rather than pursuing many ideas.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that the project supports VTO objectives.

Reviewer 2:

The reviewer stated that the work in this area aligns with the VTO subprogram objectives.

Reviewer 3:

The reviewer expressed some reservations, noting that some of the areas being pursued may not offer practical solutions for the recycling industry. They did acknowledge that important learnings could be applied in material synthesis and separation applications, both within and outside of recycling.

Reviewer 4:

The reviewer commented on the potential cost-effectiveness of direct recycling of battery materials, emphasizing the benefits of lowering the cost of battery materials, reducing the environmental footprint, and improving the supply chain. These factors, they noted, could contribute to lower battery costs and increased adoption of EVs.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources for the project are sufficient to prepare and trial direct recycle materials.

Reviewer 2:

The reviewer mentioned that the resources appear to be sufficient.

Reviewer 3:

The reviewer suggested a slight recalibration of resources toward projects that show more promise of success.

Reviewer 4:

The reviewer noted that the budget for the specific direct recycling project was not identified in the presentation but expressed the belief that there is more than enough funding for this project to achieve its stated milestones in a reasonable timeframe.

Presentation Number: BAT572
Presentation Title: ReCell Center-Advanced Resource Recovery
Principal Investigator: Yaocai Bai (Oak Ridge National Laboratory)

Presenter

Yaocai Bai, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

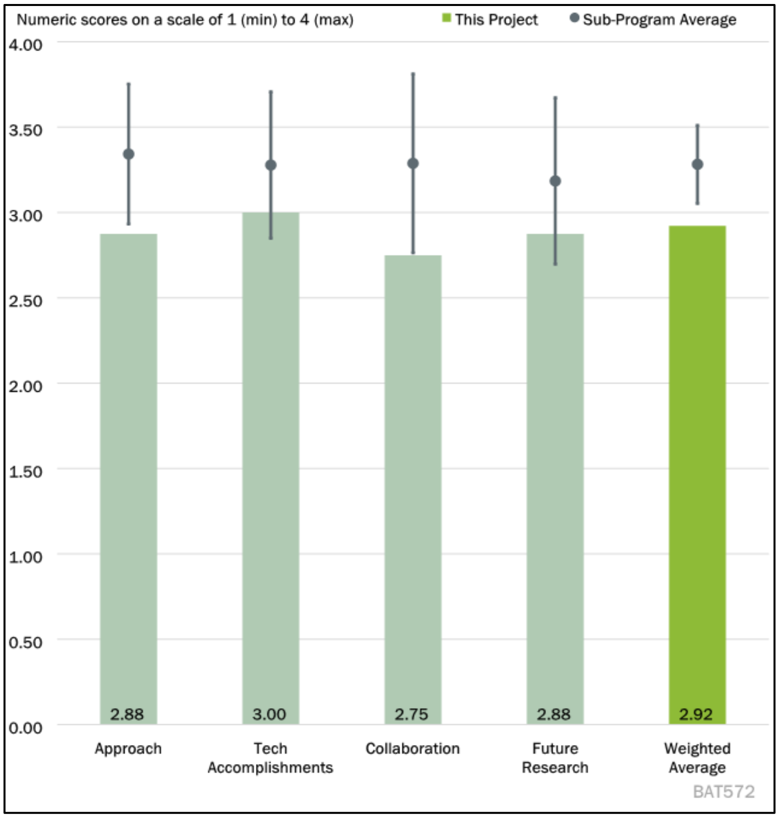

Figure 1-36 - Presentation Number: BAT572 Presentation Title: ReCell Center-Advanced Resource Recovery Principal Investigator: Yaocai Bai (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the approach of exploring multiple new processing paths and ending projects that do not show promise is acceptable. However, they highlighted the potential value of developing engineering data to support optimized equipment and process designs, citing the oil and chemical industry as an example of industries with excellent foundational data for process design.

Reviewer 2:

The reviewer mentioned that there are 11 different projects in this area, all of which seem to be well designed with reasonably planned timelines.

Reviewer 3:

The reviewer emphasized that the project addresses critical needs and takes a fundamental unit operations approach but recommended regular benchmarking with industry/start-ups to ensure that the pursued approaches remain novel.

Reviewer 4:

The reviewer noted that the objectives of this project are not well defined, and limited justification is provided for the selection of subprojects. They mentioned that some of the projects discussed are innovative, while others have already been undertaken by other entities.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer expressed that the technical progress achieved so far is sufficient, noting that many different process routes are being explored, and proof of concepts has been demonstrated.

Reviewer 2:

The reviewer mentioned that most of the projects appear to be in the early stages of research, which is positive progress.

Reviewer 3:

The reviewer raised some concerns about how the presented work relates to the state-of-the-art solutions or approaches pursued by established or start-up companies. The reviewer specifically mentioned the graphite to graphene example and suggested that clarity is needed regarding the suitability of the work for natural or synthetic graphite. If suitable for both and can be used to obtain a normalized output from a variable stream, that would be very compelling. If primarily suited for NG or AG but not both, this should be clearly stated, as it restricts suitability to plant scrap for practical considerations. The reviewer emphasized the importance of industry involvement, acknowledging that it may be easier to engage with industry partners after significant results have been obtained. Still, they stressed the need for early input and engagement from industry to ensure that the research focuses on actual needs and has promise of economic viability.

Reviewer 4:

The reviewer noted that good progress was demonstrated in several sub-projects, such as graphite to graphene and membrane solvent extraction. However, they expressed a desire to see how these sub-projects fit into the overall project plan.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer mentioned that there are various process approaches being studied, but they found it challenging to evaluate the exact level of collaboration based on the provided overview summary.

Reviewer 2:

The reviewer noted that collaboration with laboratories and other entities is generally good.

Reviewer 3:

The reviewer said collaboration is good but expressed concern about the absence of industry partners. They emphasized that engaging industry partners early in the process is essential to ensure interest in the solutions being developed and to increase the likelihood of eventual scaling and commercialization.

Reviewer 4:

The reviewer highlighted that three national laboratories are involved in the 11 sub-projects, and it’s not clear how they work together. They suggested that the projects appear to be led by individual PIs for each laboratory, and there may be a need for better coordination among the laboratories, other consortium partners, and industry stakeholders.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer emphasized the importance of future work involving more interaction with industry partners. They noted that this collaboration is critical to defining the current expectations for extracted metal purification specifications and to isolate which recovery technologies companies would or would not take upon themselves regarding recycling technologies explored. The reviewer also suggested that the role of feedstock variations, particularly from coatings, doping, and degradations of different batteries, should be investigated, as it is an important aspect to consider in recycling processes.

Reviewer 2:

The reviewer commented that the future research outlined in the presentation was somewhat vague.

Reviewer 3:

The reviewer recommended focusing on finding higher value for mixed natural graphite/artificial graphite (NG/AG) graphite streams recovered from battery recycling, addressing challenges related to sodium sulfate, exploring integration opportunities for mixed hydroxide precipitate (MHP) with black mass feedstock, and considering the recycling of LFP batteries given the market's move towards this chemistry. They also suggested benchmarking alternate approaches in the recycling space and involving industry partners more actively.

Reviewer 4:

The reviewer emphasized the need for more specific and targeted future research, down-selecting promising approaches, and increasing collaboration with industry partners to address practical issues and industrialization opportunities.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer expressed agreement with the importance of recovering critical metals.

Reviewer 2:

The reviewer indicated that the project aligns with VTO subprogram objectives.

Reviewer 3:

The reviewer emphasized that the project is relevant to VTO's mission of accelerating electrification, as it contributes to affordable batteries, affordable raw materials, and a domestic supply chain.

Reviewer 4:

The reviewer felt recycling of materials from EOL batteries as an essential part of VTO's Battery R&D efforts, with the potential to reduce the cost of battery EVs, lower the environmental impact of battery mining, and address supply chain concerns. Overall, the reviewer affirmed that this project supports VTO's Battery R&D sub-program objectives.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented on the lack of clear alignment between the shown milestones and advanced metal recovery, making it difficult to evaluate the project's progress in the context of the ReCell project.

Reviewer 2:

The reviewer noted that the resources seem sufficient based on the provided overview.

Reviewer 3:

The reviewer suggested that while the number of projects and resources currently allocated appears reasonable, some projects may need to be reconsidered or replaced in the future if they are not yielding desired results or attracting interest from industrial partners.

Reviewer 4:

The reviewer pointed out that the specific funding allocated to this project is not clear, but the overall funding for the ReCell Center in FY 2022 to FY 2023 is $18.9 million.

Presentation Number: BAT573
Presentation Title: ReCell Center-Design for Sustainability
Principal Investigator: Andrew Colclasure (National Renewable Energy Laboratory)

Presenter

Andrew Colclasure, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

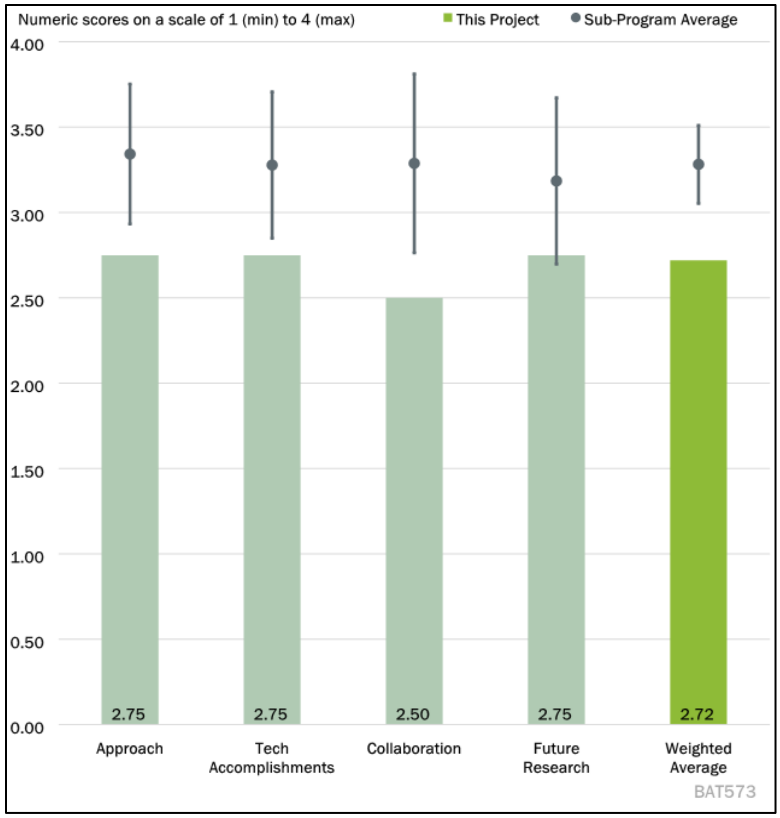

Figure 1-37 - Presentation Number: BAT573 Presentation Title: ReCell Center-Design for Sustainability Principal Investigator: Andrew Colclasure (National Renewable Energy Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer found that the activities aimed at grading a used battery cell and identifying its value for second-life applications were clearly geared towards technical barriers.

Reviewer 2:

In the reviewer's assessment, some of the projects in this section were currently being worked on by automotive OEMs and battery recyclers. It did not appear that research was done to determine if these topics were already being addressed.

Reviewer 3:

The reviewer noted that while the barriers addressed by the projects were real, it was not apparent that the problems addressed by some of the projects were not better tackled by battery system producers or OEMs, as the solutions were heavily indexed to a particular model/design. Furthermore, the reviewer observed that some of the projects appeared to be developing solutions that may already exist or be in a reasonably advanced TRL and being developed by companies (often in conjunction with OEMs) or recyclers. To maximize the usefulness of the work, the reviewer recommended an intensive survey of the current status of the industry (including startups) solutions. Ideally, ReCell could engage with some potential users of the techniques being studied, both to confirm that there is a need for new solutions and to ensure that the work by ReCell and participating laboratories is guided by the practical barriers relayed by the industry stakeholders. The reviewer also provided specific comments on a few of the projects/research areas:

Regarding (end-of-life) EOL cell passivation by heat treatment, the reviewer pointed out that the practical difficulty of placing an entire pack into a heating chamber should be considered, especially with increasing size of EV batteries. The reviewer noted that companies were developing deep-discharge technology (electrical discharge) that is likely more practical.

Concerning BTM second use, the reviewer emphasized that this is highly specific to a given battery design, and solutions must be developed in conjunction with OEMs who might ultimately be liable. The reviewer also mentioned that home storage may be a higher-risk application relative to other possible second-life applications.

On the topic of PV Si recovery, the reviewer mentioned that there does appear to be a need to find recycling solutions for PVs. In this case, the reviewer suggested that rather than conducting small-scale studies looking at the impacts of contaminants, the focus should be on developing processes to remove the contaminants. The reviewer pointed out that the presence of contaminants (likely in fluctuating amounts) would introduce variability, which would preclude use in highly engineered battery materials.

In the area of ML for SOH determination, the reviewer noted that OEMs know how to determine and evaluate SOH and will communicate results to trusted certified partners. The reviewer also raised questions about whether many startups were working on various techniques (EIS, acoustics, etc.) and whether these had been extensively benchmarked. The reviewer expressed some concern regarding the controller area network.

Regarding robotic disassembly, the reviewer commented positively on the idea of developing a database of fastener/joining types and recommended separation/dismantling techniques. The reviewer suggested that cell-level replacement would be highly unlikely (value not justified by complexity and cost). For diagnostics, the reviewer recommended comprehensive scouring of available tech and startups working in this area, citing examples such as Feasible, Voltaiq, ReJoule, B2U, Smartville, etc., to ensure the novelty of work.

Reviewer 4:

The reviewer observed that there seemed to be no cohesive overarching goals and objectives discussed for Design for Sustainability Projects. The reviewer found that the approach discussed was generic for the ReCell projects. The reviewer appreciated the addition of second use and handling of EOL batteries, considering it important, and noted that it was missing in the first phase of ReCell; it was good that they had been added. The reviewer concluded that it did not seem that the PV Si recovery was a fit for ReCell. The reviewer pointed out that the use of Si still had not entered the electric commercial vehicle market, and because of life limitations, it may be several years before entering the market. The reviewer suggested that the recovered Si from PV could go back to the production of PVs, but the cost of this approach compared to existing practices of making Si was not discussed.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer observed that some efforts appeared to be further along than others in terms of development and usefulness; however, overall, the technical progress seemed acceptable.

Reviewer 2:

According to the reviewer, the projects were initiated recently, and there was little to no progress to consider at this point in time.

Reviewer 3:

The accomplishments listed on Slide 19 were deemed reasonable by the reviewer, but the level of detail provided was insufficient to support a higher ranking.

Reviewer 4:

The reviewer noted that no project plan had been discussed, making it challenging to make comparisons. It appeared that there were several individual, unrelated sub-projects within the overall initiative. The technical achievement for the end of ML for SOH and remaining useful life was considered notable.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer remarked that the presenter mentioned working with some industry partners for feedback and acknowledged the ongoing effort to avoid duplicate efforts with the industry.

Reviewer 2:

The reviewer commented that there did not seem to be much discussion or interaction with the industry in some of the projects in this area. As previously stated, automotive OEMs and others in the industry are already working on some of these topics.

Reviewer 3:

The reviewer praised the collaboration with academia and national laboratories but recommended an increased effort to collaborate more extensively with industry.

Reviewer 4:

The reviewer observed that the project appeared to have several sub-projects that did not require coordination among other partners, and there seemed to be no collaboration with the industry in these sub-projects.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer emphasized that if findings were disseminated effectively, the TEA and methods for battery diagnostics could prove highly beneficial. The reviewer pointed out a noteworthy omission, suggesting that the team consider focusing on guidelines and innovations to protect workers involved in handling, installing for second use, or dismantling battery packs.

Reviewer 2:

In the reviewer’s assessment, the project presented a clear definition of future work and appeared capable of achieving its targets.

Reviewer 3:

Regarding the topic of cell passivation, the reviewer advised against allocating excessive effort to it. Instead, the reviewer recommended exploring potential solutions targeted at EV or array-level applications. The reviewer acknowledged the feasibility of early testing with cells but stressed the importance of outlining a clear path toward larger assembly suitability. Concerning photovoltaic (PV) contaminants, the reviewer stressed the significance of addressing them, noting that Resource Material developers were unlikely to compromise on lower-grade materials/contaminants. The recommended focus, according to the reviewer, should center on the removal of these contaminants. When discussing Battery-as-a-Service (BaaS) and advanced diagnostics, the reviewer questioned whether collaboration with companies already active in this field was possible. The reviewer recommended separating the assessment of TEA for second use versus recycling by chemistry, specifically distinguishing between NMC/NCA and LFP.

Reviewer 4:

Regarding cell disassembly and electrode separation, the reviewer suggested that this approach could prove useful for solid-state chemistry structures. In conclusion, the reviewer found the proposed future work to be reasonable.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The project was noted by the reviewer to support the VTO mission.

Reviewer 2:

In response to whether VTO subprogram objectives are supported by this project, the reviewer affirmed that they are.

Reviewer 3:

The reviewer added that this support is somewhat marginal, given that many of the areas of focus might be more effectively pursued by industry.

Reviewer 4:

The reviewer emphasized that the project is relevant to the VTO Battery R&D Recycling project, as it aims to lower the cost of batteries through recycling and reuse.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer expressed concerns that the remaining milestones do not seem to relate closely to the work presented. The reviewer suggested that it might be beneficial to define more sub-project-specific milestones.

Reviewer 2:

Regarding resources, the reviewer noted that they appear to be sufficient to meet milestones in a timely fashion.

Reviewer 3:

The reviewer mentioned that it is not clear how much of the total funding is allocated to this group of projects.

Reviewer 4:

The reviewer pointed out that only the overall funding for the ReCell Center is provided, which is $18.9 million for FY 2022-FY 2023. The specific funding allocation for this project is not clear.

Presentation Number: BAT574
Presentation Title: ReCell Center-Modeling and Analysis
Principal Investigator: Allison Bennett Irion (Argonne National Laboratory)

Presenter

Allison Bennett Irion, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

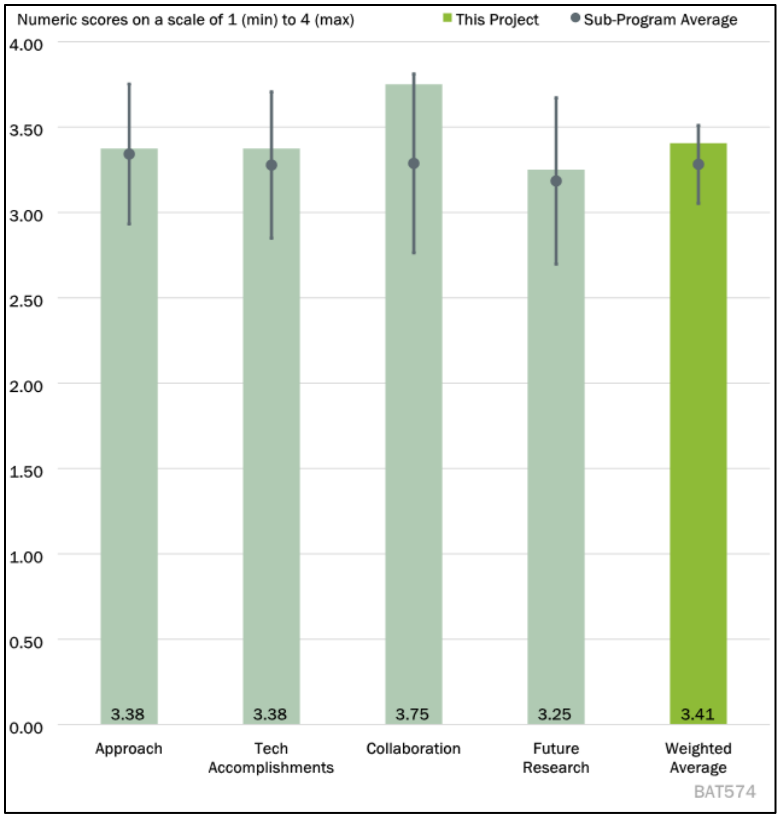

Figure 1-38 - Presentation Number: BAT574 Presentation Title: ReCell Center-Modeling and Analysis Principal Investigator: Allison Bennett Irion (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer acknowledged that the tools being developed for recycling process evaluation will be helpful in determining areas of need and assessing the potential impact of new technologies.

Reviewer 2:

In general, the reviewer noted that the various models presented address the need to compare and understand costs related to battery recycling, assess impacts on the supply chain, and understand cell performance. The projects in this area were designed to support other projects and have met that requirement in a timely manner.

Reviewer 3:

While most of the projects were deemed very valuable with impressive progress, the reviewer found it challenging to assign general comments to such a mixed set of topics being modeled. The reviewer then provided specific comments by category of projects:

For the higher-level projects aimed at supply chain analysis, cost assessment, overall recycling, separation processes, and resource assessment (e.g., EverBatt, LIBRA, GCMat, AMUSE), the reviewer found them practical and powerful. The completion of these projects could provide a valuable resource for the industry.

However, some of the efforts focused on developing models to study the impacts of artifacts from direct recycling, such as imperfect separation of cathode materials, were considered to have very little value. The premise that direct recycling is a suitable solution for EOL batteries, from which this fluctuating mixture would originate, has been challenged repeatedly. Most experts acknowledge that if direct recycling has a role, it would primarily be for plant scrap with consistent cathode chemistry. The reviewer suggested that unless ReCell can find global cell/cathode producers advocating for introducing inconsistency and associated risks of inconsistent cathode materials, especially for automotive applications, this work should be reevaluated.

Similarly, for upcycling, the reviewer questioned its practicality. While it is technically possible to upcycle a known and discrete lower Ni-NMC to a higher Ni one in the laboratory, the reviewer raised concerns about how to handle large and ever-fluctuating incoming blends and generate uniform upcycled materials lot after lot. The reviewer indicated that this may not be a practical solution for automotive/EOL applications. However, the reviewer also noted that if the learnings from these efforts can inform general cathode synthesis work, there may be some value in terms of better understanding underlying thermodynamics, kinetics, interdiffusion, and so on.

Reviewer 4:

The reviewer found these plans to be clear and categorized their comments accordingly.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the models under development are valuable for evaluating the techno-economic prospects of recycling technologies. The inclusion of a solvent extraction model in the study was appreciated, as it can contribute to scale-up and process design optimization.

Reviewer 2:

In terms of technical accomplishments, the reviewer observed that they supported current ongoing projects and improved existing software models.

Reviewer 3:

The reviewer provided a rating that represents an average of the higher and more relevant accomplishments achieved in the projects, excluding upcycling and cathode mixture effects. The latter was viewed as less relevant to solving the large-scale needs of the recycling ecosystem. The reviewer suggested that unless it can be demonstrated that direct recycling has a real opportunity for EOL batteries, which will be the dominant feed-source in about 10 years, the work should focus mostly on manufacturing scrap. In such cases, upcycling and mixed cathode problems are less prevalent, and related modeling efforts have limited value. However, the reviewer found the EverBatt, LIBRA, GCMat, and AMUSE work to be very promising, practical, and valuable. The reviewer recommended making more efforts to disseminate information about these tools to encourage their use.

Reviewer 4:

The reviewer concluded by noting that the progress of the projects is in line with the plan.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer observed that the models appear to be designed with other project models in mind, and it seems that the project team is making efforts to minimize overlap with tools under development.

Reviewer 2:

The reviewer noted good collaboration across project teams, which is seen as valuable for maximizing integration, synergy, and cross-functional learning among EverBatt, LIBRA, and GCMat tools.

Reviewer 3:

The reviewer highlighted the "great" collaboration among various ReCell members and industry partners.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer noted that most of the future work appears to heavily emphasize the application of existing models to different recycling scenarios. The reviewer raised a question about the importance of measuring tortuosity and NMC particle cracking in future work. It was pointed out that results may vary depending on cell manufacture and cell use history, and the reviewer did not see a clear connection between having that data and achieving lower-cost recycling or improved ability to address varied recycle streams.

Reviewer 2:

The reviewer affirmed that the purpose of the work continues to support the overall goals of ReCell.

Reviewer 3:

Regarding proposed future work, the reviewer found it well designed and relevant to the mission of ReCell.

Reviewer 4:

The reviewer noted that the proposed future plans are clearly defined.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer confirmed that the project supports the VTO objectives.

Reviewer 2:

The reviewer stated that the project supports the overall VTO objectives.

Reviewer 3:

The reviewer noted that the projects assembled within this group are mostly highly relevant and applicable to VTO subprogram objectives. However, the reviewer reiterated the previous critique, both in this section and other subprogram groupings, concerning the allocation of high amounts of resources and time to study aspects of direct recycling that would only be applicable to EOL batteries as opposed to manufacturing scrap. This was the only negative feedback provided.

Reviewer 4:

The reviewer acknowledged that the model developed in this project helps identify cost-positive recycling technologies in support of the VTO Battery R&D recycling and reuse program.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found that the models under development appear to be useful for policy makers and industry in evaluating recycling options. The team seems prepared to meet the remaining modeling milestones, though there could be potential delays if the experimental side takes longer than expected to generate the necessary information.

Reviewer 2:

In terms of resources, the reviewer assessed that they appear to be sufficient to achieve the milestones in a timely manner.

Reviewer 3:

The reviewer reiterated the previous point regarding the allocation of resources to studying the impact of mixed cathodes on performance and upcycling. These efforts, while possibly of academic interest, were considered to address problems with little application in the industry, particularly when applying direct recycling to the challenging case of EOL batteries. The reviewer pointed out that battery manufacturers are unlikely to willingly introduce a potential source of variability into their processes, especially considering the availability of increasingly sustainable and efficient recycling processes capable of producing uniform, consistent materials with high purity levels from highly variable feeds.

Reviewer 4:

The reviewer noted that only the overall funding for the ReCell Center is shown ($18.9 million for FY 2022 to FY 2023), and it is not clear how much funding is specifically allocated to this project.

Presentation Number: BAT575
Presentation Title: eXtreme Fast Charge Electrolyte Development Thrust
Principal Investigator: Bryan McCloskey (Lawrence Berkeley National Laboratory)

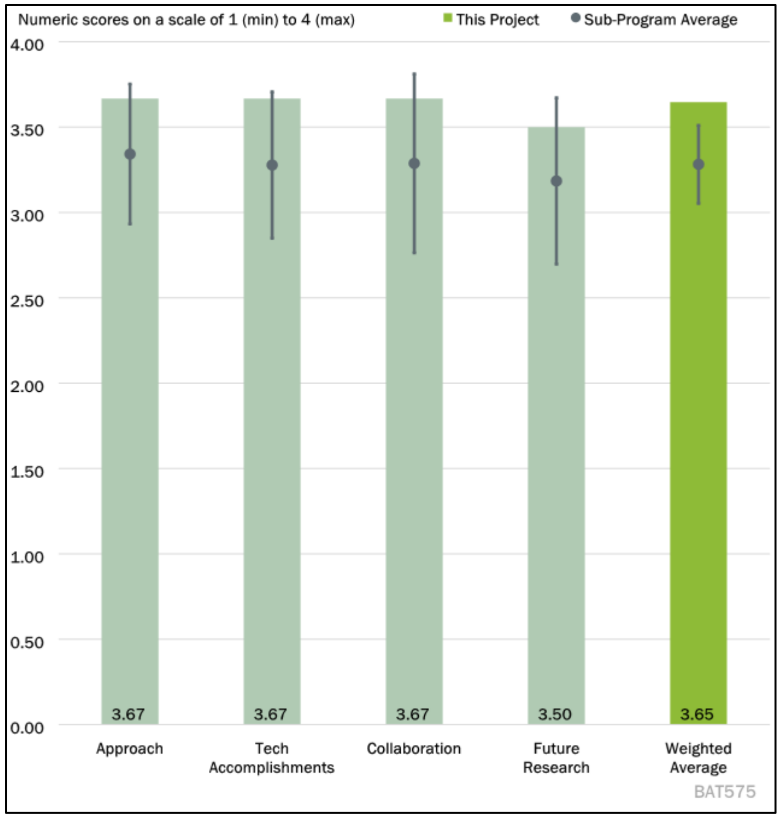

Figure 1-39 - Presentation Number: BAT575 Presentation Title: eXtreme Fast Charge Electrolyte Development Thrust Principal Investigator: Bryan McCloskey (Lawrence Berkeley National Laboratory)

Presenter

Bryan McCloskey, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted that the effort of this project aligns with the DOE goals by focusing on developing electrolytes with enhanced thermal stability, reducing cell impedance (both bulk and interfacial), and eliminating the formation of dead Li for XFC realization. The technical challenges related to electrolyte performance under XFC conditions are being addressed.

Reviewer 2:

The reviewer pointed out that electrolyte studies aimed at improving fast charging are considered a major enabler that is being explored in the automotive industry. The reviewer expressed excitement about the continued progress in this area. Additionally, the reviewer found Li solvation studies interesting and suggested that more temperature conditions should be explored.

Reviewer 3:

The reviewer commented that the project’s primary focus is on electrolyte improvement, and it employs various approaches, such as dual salt, high ester, and high salt concentration, to accelerate ion transport across the cell.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer mentioned that dual salt electrolytes have been identified to improve plating reversibility and charge acceptance at high C-rates. Specifically, the use of LiFSI/ester co-solvent was noted to lead to improved conductivity and improved interfacial properties, resulting in reduced Li plating.

Reviewer 2:

The reviewer noted that the dual salt study and high concentration studies have shown some continued progress and suggested that the effect on high-density electrodes should be the next focus.

Reviewer 3:

The reviewer mentioned that certain improvements were achieved with the new electrolyte composition. Notably, Li^0 deposition was apparently reduced in dual salt and ester-based electrolytes. The reviewer highlighted a novel electrospray ionization mass spectrometry (ESI-MS) study conducted at various temperatures, which allowed for the plotting of solvation activation energy. This was considered very helpful in understanding the electrolyte properties under extreme conditions.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer praised the successful collaboration across the team, which led to good research progress.

Reviewer 2:

The reviewer emphasized that collaboration and coordination across the project teams were outstanding.

Reviewer 3:

The reviewer stated that the projects were highly collaborative, reflecting the effective teamwork within the research efforts.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer found that the proposed future work is well illustrated. The reviewer suggested that it might be of interest to explore the impact of the new electrolyte on battery calendar life and battery performance at different temperatures. Additionally, considering technology transition and establishing connections with battery OEMs and/or battery components suppliers may be useful, especially as the research is in the first year of the project.

Reviewer 2:

The reviewer noted that the proposed future work aligns with the overall scope of the project and emphasized the importance of identifying degradation mechanisms as various enablers are studied, highlighting its critical role in achieving success.

Reviewer 3:

The reviewer expressed optimism about the further study of new electrolyte systems, particularly those developed by B500 for lithium metal batteries (LMBs) and found the direction to be very promising.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized that the development of electrolytes to support XFC is an integral part of the efforts to realize the VTO goals, particularly within the XCEL program.

Reviewer 2:

The reviewer expressed that this project is extremely relevant to the adoption of electrification on a large scale.

Reviewer 3:

The reviewer considered this project to be highly relevant in the context of achieving VTO goals and the broader adoption of electrification.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found that the funding level and timeframe appear to be sufficient to support the research on electrolyte research to a level that demonstrates the capability of the technique.

Reviewer 2:

The reviewer noted that the funding planned for this project is deemed sufficient to achieve the proposed goals.

Reviewer 3:

The reviewer assessed the funding as sufficient for the research efforts in this project.

Presentation Number: BAT576
Presentation Title: Solid State Batteries with Long Cycle Life and High Energy Density
Principal Investigator: Haegyum Kim (Lawrence Berkeley National Laboratory)

Presenter

Haegyum Kim, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

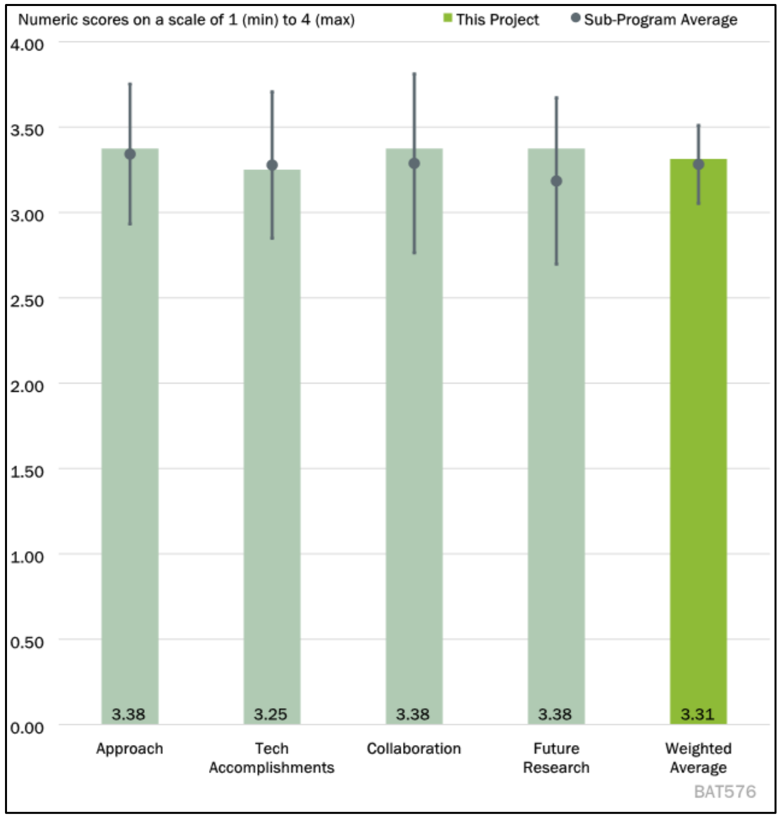

Figure 1-40 - Presentation Number: BAT576 Presentation Title: Solid State Batteries with Long Cycle Life and High Energy Density Principal Investigator: Haegyum Kim (Lawrence Berkeley National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer found that, after reviewing the Approach to Performing the Work, the technical barriers are mostly addressed successfully, and the project is properly designed. The group has outlined reasonable methods to overcome the tasks, identified potential issues within their systems, and proposed specific strategies to solve them. They have planned various experiments and testing to demonstrate an excellent outcome.

Reviewer 2:

The project aims to create a protective layer on the Li anode, between the Li anode and SSE. Metal-based protective layers and SSE polymer composites have been reported as part of this approach. The reviewer commended the project's approach to mitigating Li dendrite growth by engineering a protective layer. However, the reviewer suggested that the PI carefully investigate the impact of the metal layer, especially those with large differences in physical properties, such as hardness, and potential differentials compared to Li metal. Additionally, the PI should be mindful of SSE reactions with polar and/or protonic solvents.

Reviewer 3:

The reviewer stated the project aims to address critical challenges facing SSBs, primarily through electrode and interface design. The reviewer noted that the project team has a good combination of expertise and a well-structured project plan with a reasonable timeline.

Reviewer 4:

The reviewer mentioned that the proposed work directly addresses the barriers present in SSBs. The project is well designed, and the combined efforts of scientists with different expertise are coordinated effectively. The proposed tasks cover anode interface, high voltage stability, SSE membrane, cathode thickness, and the scale-up issue of SSEs, all of which are crucial aspects of SSBs. The timeline is considered reasonable, provided that all proposed tasks are successful.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the team has presented a clear roadmap toward their final target and distributed their workload evenly within a suitable timeline. The team has managed to accomplish their work on time and has made good progress. The project plan is reasonably planned, and the milestones align with the project's objectives. However, the reviewer suggested that it could be beneficial to account for potential issues that may arise in future studies.

Reviewer 2:

Regarding the evaluation of different metal protective layers, the reviewer mentioned that tin (Sn) and silver (Ag) were found to be effective. Polymer SSE composites were synthesized and tested in a symmetric cell. The reviewer recommended that the PI test the SSEs in a full cell and cycle it for a longer duration to further assess their performance.

Reviewer 3:

The reviewer acknowledged that the team has made good progress in multiple directions. However, they also noted that there is still some room for improvement in battery performance.

Reviewer 4:

The reviewer highlighted the positive progress made, such as the development of an active buffer layer to stabilize the interface between Li and SSE. The PIs have discovered interesting clues that they plan to further explore. The halide solid electrolyte has also demonstrated reasonable high voltage stability on the cathode side. The reviewer suggested that, in addition to the current modeling work, the PI may consider using modeling to understand existing materials and their interfaces/interphases. Additionally, the cost of adding graphene oxide in the cathode should be considered.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that collaboration within the project team is strong, and the work is well-distributed. It appears that there may not be a need for more collaboration, as roles and responsibilities are clearly defined. The cross-functional cooperation and communication among team members are cohesive, demonstrating a commitment to accomplishing the project's goals.

Reviewer 2:

The reviewer stated the PI has collaborated with colleagues at LBNL and universities. The reviewer recommended that the PI emphasize the results of this collaboration in their work.

Reviewer 3:

While the team has adequate collaborations within the project team, the reviewer mentioned that it’s not entirely clear from the presentation what specific contributions each team member made in the reviewed fiscal year.

Reviewer 4:

The reviewer noted that the project team is well-coordinated within LBNL but observed that there is no industry partner for this project. Additionally, the modeling work appears to be separate from the presentation, and the reviewer suggested that more experiments are needed to support the modeling efforts.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer found that the future work aligns with the project plans, and some of the updated data show clear and promising results that can strongly support their future studies. However, the reviewer suggested that it would be beneficial to have more detailed characterization results or materials structure information for progress monitoring.

Reviewer 2:

The reviewer recommended that the PI should focus more on a specific system, as it appears that they are trying to cover too many areas in the coming year.

Reviewer 3:

The reviewer noted that the proposed future research is clearly defined. It was suggested that the team should develop a plan to standardize the electrochemical measurements, including cell pressure.

Reviewer 4:

In terms of future work, the reviewer suggested that the team may consider starting with relatively thin cathodes before moving on to very thick cathode structures.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized that the project shows strong relevance to the VTO goals and supports its objectives. The project’s impact on energy development and sustainability is evident, and it has a clear influence on VTO’s program, making it likely to support their objectives.

Reviewer 2:

The reviewer stated the prevention of lithium dendrite growth was relevant to the overall VTO subprogram objectives by the reviewer.

Reviewer 3:

The reviewer noted that the project is highly relevant to the overall goals of VTO programs.

Reviewer 4:

The project's focus on interfaces and materials/electrode-level research was seen by the reviewer as supportive of overall VTO subprogram objectives. The fundamental research conducted in this project was also regarded as good.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found that the resources of the project appear to include a dedicated workforce with the necessary expertise to execute the project. The anticipated scope and stated milestones were considered reasonable and achievable. The reviewer believed that the sufficient resources from this team should enable them to accomplish their goals and address potential technical challenges in future studies.

Reviewer 2:

The reviewer mentioned that the PI has sufficient resources to conduct the proposed research.

Reviewer 3:

The reviewer noted that the team has enough resources and funding to make great progress in this project. However, they recommended that the team consider including some industry collaborations, possibly through sample exchange, to enhance their research efforts.

Reviewer 4:

The reviewer stated that LBNL has all the resources needed for this fundamental research.

Presentation Number: BAT577
Presentation Title: Low-Pressure All-Solid State Cells
Principal Investigator: Tony Burrell (National Renewable Energy Laboratory)

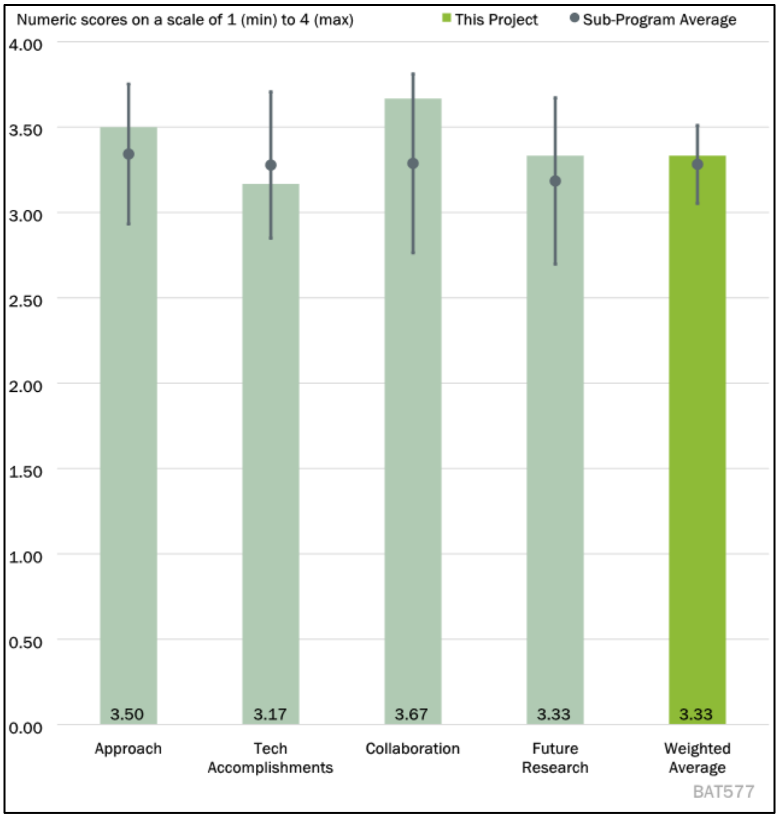

Figure 1-41 - Presentation Number: BAT577 Presentation Title: Low-Pressure All-Solid State Cells Principal Investigator: Tony Burrell (National Renewable Energy Laboratory)

Presenter

Annalise Maughan, Colorado School of Mines

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted that the approach undertaken by the team is multi-pronged and well-designed to achieve the technical goals. However, they suggested that more focus should be placed on testing materials in device configurations compared to idealized scenarios.

Reviewer 2:

The technical barrier was considered to have been effectively addressed, and the reviewer commended the collaboration among materials development, characterization, modeling, and cell design. The project was seen as demonstrating a well-thought-out design, and the timeline was viewed as reasonable and feasible.

Reviewer 3:

Overall, the reviewer cited the team's objective is to achieve high-energy-density, low-stack-pressure SSBs by focusing on: (1) tuning the chemistry of current state of the art in argyrodite-based solid electrolytes (ASEs); (2) interface modification, and (3) *operando* testing and characterization. The reviewer also highlighted that the team is well-integrated, working on synthesis, interfacial characterization, electrochemical testing, and cell fabrication.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that in their plans for FY 2023, the research team included the development of SEs and interface modifiers, as well as the investigation of pressure-dependent transport and *in situ* characterizations. The team reported that the conductivity of the SEs synthesized is high. However, they mentioned that the interfacial additive has fairly low conductivity, which might pose a challenge. They also noted progress in the *in situ* analysis of interface evolution.

Reviewer 2:

The reviewer pointed out that the report did not include information on the conductivity of lithium carbonate. They mentioned that the interfacial issue of the electrolyte against Li metal was investigated using XPS.

Reviewer 3:

The reviewer commended the team for making very good progress toward their FY 2023 objective of tuning the argyrodite chemistry to achieve higher IC. This was achieved by substituting P with Sb and Ge, which is related to Li interstitials and cation disorder. The *in situ* XPS method for studying the SEI of ASE (all-solid electrolyte) with Li metal was considered interesting. However, the reviewer expressed curiosity about whether the effect of the EB charging could create charge accumulation or local effects that might shift the reaction pathways differently from real electrochemical and chemical effects under working conditions. The reviewer asked if any new insights had been gained in this regard. The decomposition products observed were noted to be similar to what had been reported earlier for Li_6PS_5Cl. The reviewer inquired about the origin or source of the oxygen contamination. The team's approach of using a sulfonated polymer coated Li_6PS_5Cl (LPSCL) was considered interesting. The reviewer asked if the polymer layer has Li-ion conductivity and what the typical interfacial resistance between the polymer phase and the solid electrolyte is. They also raised questions about the intrinsic reasons for the current density not exceeding 200 $\mu A/cm^2$ in a symmetric cell measurement for the Sb-Ge composition and what approaches the team is considering to address this issue.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer suggested that the project can begin leveraging its collaboration with NREL to test the materials developed in a device setting, as that is where most bottlenecks are anticipated to arise.

Reviewer 2:

The reviewer noted that there is cooperation among the material development group, cell design and build group, and advanced characterization group, indicating teamwork and collaboration within the team.

Reviewer 3:

The reviewer mentioned that there are no external collaborators at present.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer commented that the end goal of achieving a 2 Ah cell working at less than 1 MPa pressure sounds aggressive, especially with thicker cathodes. They suggested that the team should consider expanding pressure-dependent transport measurements to composite cathodes as well as anodes to identify potential bottlenecks.

Reviewer 2:

The reviewer remarked that the proposed future research is an extension of the current research, and the purpose is clarified.

Reviewer 3:

The reviewer stated that the team has clearly defined goals and metrics as part of future research. These goals include the integration of highly conducting solid electrolyte for full cell testing and testing the solid electrolyte with a working Ni-rich cathode.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that the program is aligned with VTO goals.

Reviewer 2:

The reviewer commented that the project aims to develop a high ionic conductive and stable electrolyte against Li, which can support all-SSBs with high energy density. Therefore, the project was seen as supporting the overall VTO subprogram objectives.

Reviewer 3:

The reviewer stated that the project goals are directed towards developing SSBs with energy density exceeding 500 Wh/Kg for EVs.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that the resources are adequate for this project.

Reviewer 2:

The reviewer expressed that there are sufficient resources to complete the project, including material design, characterization, modeling, and electrochemical performance tests.

Reviewer 3:

The reviewer stated that the project is funded at an appropriate level for delivering towards milestones and deliverables.

Presentation Number: BAT578
Presentation Title: Stable Solid-State Electrolyte and Interface for High-Energy Density Lithium-Sulfur Battery
Principal Investigator: Dongping Lu (Pacific Northwest National Laboratory)

Presenter

Dongping Lu, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

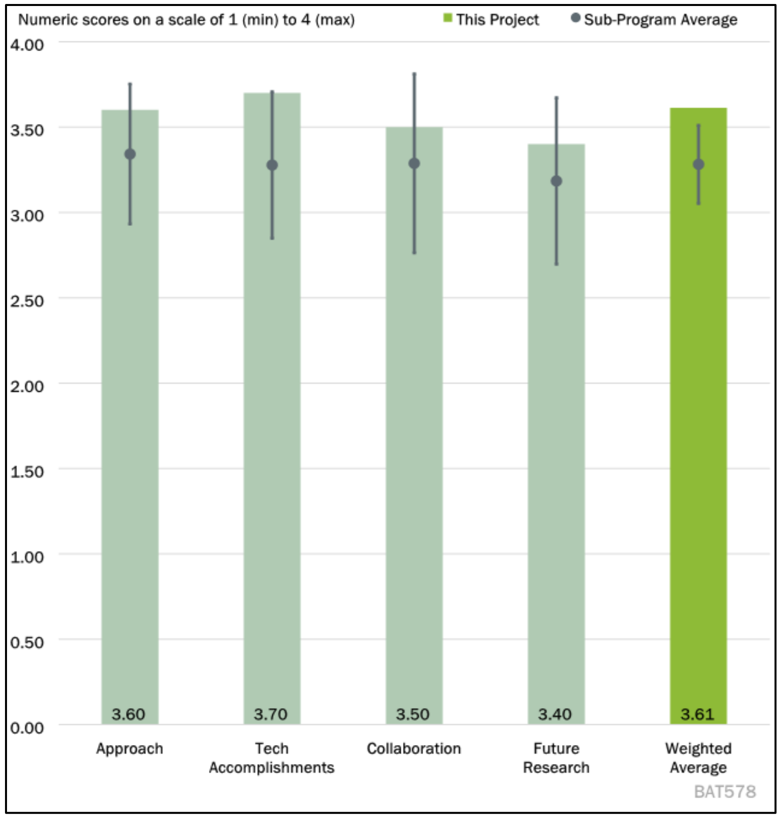

Figure 1-42 - Presentation Number: BAT578 Presentation Title: Stable Solid-State Electrolyte and Interface for High-Energy Density Lithium-Sulfur Battery Principal Investigator: Dongping Lu (Pacific Northwest National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted that the technical accomplishments to date include the synthesis and testing of a SSE, demonstration of symmetric Li cell cycling, and performance of an all-solid-state Li-S cell using a solid electrolyte. Additionally, the fabrication and processing of sulfur cathode sheets were achieved. These technical accomplishments address barriers related to solid-state IC and stability with Li metal anodes. The reviewer found the timeline and progress to date to be reasonable.

Reviewer 2:

The reviewer stated that the project’s research plan was excellent, with progress made toward resolving critical challenges facing solid-state Li-S batteries. The project’s design and experimental execution timeline were also commended.

Reviewer 3:

The reviewer stated that the technical barrier of achieving good Li interfacial stability for solid-state Li-S batteries has been effectively addressed. The long-term cycling of all-solid-state Li-S cells has been achieved, reflecting a well-thought-out design with a reasonable and feasible timeline. However, there was a mention that the demonstration for the cathode configuration was not entirely clear.

Reviewer 4:

The reviewer stated the project's focus is on addressing low IC of solid electrolytes, poor Li/solid electrolyte stability, low sulfur utilization, and limited cycle life in all-solid-state Li-S batteries. The design and synthesis of novel SSEs to overcome these challenges were deemed well-planned.

Reviewer 5:

The reviewer highlighted the project's alignment with the goals of the B500 program, aiming to develop SSEs with high IC and Li interfacial stability, improved sulfur utilization, and scalability for integration into all-solid-state Li-S batteries. The project was considered well-aligned with DOE goals for high-energy and long-life batteries for EVs. However, the reviewer also pointed out some weaknesses, including the lack of quantitative milestones in the project's progress representation, such as specifying the thickness of the ultra-thin layer in milestone 3 and the limits of external pressure targeted in milestone 4. The reviewer suggested providing a projected timeline to meet the B500 goals of 500 Wh/kg and 1000 cycles based on the current approach.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the project had achieved several technical accomplishments in the past year. These accomplishments included the synthesis and testing of a SSE, the demonstration of symmetric Li cell cycling, and the performance of an all-solid-state Li-S cell using a solid electrolyte. Additionally, the project had made progress in the fabrication and processing of S cathode sheets. The reviewer found these technical accomplishments to be relevant to addressing the technical barriers related to solid-state IC and stability with Li metal anodes. Furthermore, the reviewer considered the project's timeline and progress to be reasonable.

Reviewer 2:

The reviewer remarked that the project's research plan and progress in addressing critical challenges facing solid-state Li-S batteries were deemed excellent. The project was well-designed and had a well-thought-out experimental execution timeline.

Reviewer 3:

While the technical barrier related to solid electrolyte had been effectively addressed, the reviewer mentioned that the interlayer mentioned in the project plan had not been clearly illustrated in the evaluation. Additionally, the operation of the 2 mAh/cm^2 cycle at 100°C was considered unpractically high, although the performance of full cells was described as surprising and interesting.

Reviewer 4:

The reviewer observed that in the past year, the project had achieved three main advancements, including the synthesis of a $Li_7P_2S_8Br_{0.5}I_{0.5}$ solid electrolyte with high IC, improved cycling stability of all-SSBs with high areal capacity and sulfur loading, and progress in the development of all-solid-state Li-S pouch cells through dry processing.

Reviewer 5:

The reviewer found the project's technical accomplishments and progress to be promising for long-life Li-metal based solid-state cells. However, they questioned some "weaknesses" in the evaluation, including the lack of detailed information on the composite cathode, particularly concerning achieving good sulfur utilization with high loadings and low proportions of catholyte. Additionally, it was not entirely clear whether the project exclusively used SSEs or if any liquid electrolyte was employed for interfacial purposes.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commented on the collaboration within the project, noting that it involved collaboration between PNNL, the University of Wisconsin at Milwaukee, and Thermo Fisher. They suggested that highlighting the role of the partners in technical accomplishments would directly emphasize the importance of collaborative efforts.

Reviewer 2:

The reviewer expressed satisfaction with the collaboration network developed by the team and did not offer any comments on additional collaborations.

Reviewer 3:

The reviewer observed cooperation among the material development group and advanced characterization group. They also mentioned that the thin film cathode and SSE were developed by the University of Wisconsin at Milwaukee.

Reviewer 4:

The reviewer stated that the project involved researchers from the universities, national laboratories, and industry, all of whom brought complementary expertise to the collaboration. They found the collaboration to be effective in advancing the project.

Reviewer 5:

The reviewer noted that there were ongoing collaborations within PNNL for characterization and modeling, as well as external partnerships with the University of Wisconsin at Milwaukee for separator/electrode processing and Thermo-Fisher Scientific for electrode characterization.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer commented on the future work of the project, noting that while it lists general high-level goals to address technical challenges and barriers, it could benefit from more specificity in the approach to these ongoing goals.

Reviewer 2:

The reviewer expressed satisfaction with the team’s future research plan and did not identify any weaknesses in it.

Reviewer 3:

The reviewer stated that the proposed future research is an extension of the current research and that the purpose is clarified.

Reviewer 4:

The reviewer highlighted that the project aims to further improve the performance of all-solid-state Li-S batteries through various approaches, including constructing Li or SSE interlayers, optimizing Li cycling pressure, understanding Li nucleation and growth, identifying optimal sulfur host materials, and optimizing dry processing for separator or electrode fabrication. They believed these efforts were likely to address the remaining challenges.

Reviewer 5:

The reviewer acknowledged that there are still significant challenges with all-solid-state Li-S batteries, such as eliminating dendrite formation during deep Li plating/stripping and achieving good utilization rates with high sulfur loading cathodes. They noted that the future studies are aimed at addressing these shortcomings and emphasized the need to demonstrate solid electrolyte in full cells with optimal sulfur host materials under practical, relevant conditions. However, they mentioned that while progress has been good and results are promising, it is unlikely that the technology can mature to the level of implementation within the project period. They recommended presenting a reasonable timeline and strategy to support these studies in meeting DOE performance goals.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer commented on the alignment of the project's goals and efforts with the VTO Battery R&D programmatic goals, emphasizing the project's focus on high-energy density all-solid-state cells that are compatible with Li metal and offer improved cyclability.

Reviewer 2:

The reviewer stated that the project is highly relevant to the overall goals of VTO programs and noted the synergistic relationship between the development of solid-state Li-S chemistry in this project and other Li-S projects.

Reviewer 3:

The reviewer expressed that the project's development of high ionic conductive and stable electrolytes for high-loading Li-S batteries enables all-SSBs with high energy density, thus supporting the overall VTO subprogram objectives.

Reviewer 4:

The reviewer highlighted that the project's focus on designing high-energy and low-cost all-solid-state Li-S batteries aligns well with VTO's goal of developing advanced batteries to meet the increasing demand in automotive applications. They mentioned that these batteries have the potential to address energy density, cost, safety, and supply chain risk concerns associated with existing LIBs.

Reviewer 5:

The reviewer affirmed that the project supports the overall DOE objectives by working on advanced Li-S cells with higher specific energy, lower cost, enhanced safety, and improved cycle life compared to LIBs. They pointed out that SSEs offer a viable solution for long-life Li-S batteries by addressing challenges related to polysulfide shuttles in liquid electrolytes. They considered the results obtained so far as promising, making the project relevant to the DOE VTO's battery program objectives and goals.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources allocated to the project are sufficient to achieve the milestones and goals.

Reviewer 2:

The reviewer remarked that the resources and funding level are adequate to make good progress and did not identify any weaknesses in this regard.

Reviewer 3:

The reviewer expressed that there is sufficient resource to finish the project, including materials design, characterization, and multiscale modeling.

Reviewer 4:

The reviewer observed that the project has involved scientists from multiple institutions with complementary expertise and capabilities, which provides enough resources to accomplish the proposed work.

Reviewer 5:

The reviewer commented that the resources for the overall project seem to be commensurate with the scope and adequate to achieve the targeted milestones.

Presentation Number: BAT579
Presentation Title: Multifunctional Gradient Coatings for Scalable High-Energy Density Sulfide-Based Solid-State Batteries
Principal Investigator: Justin Connell (Argonne National Laboratory)

Presenter

Justin Connell, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

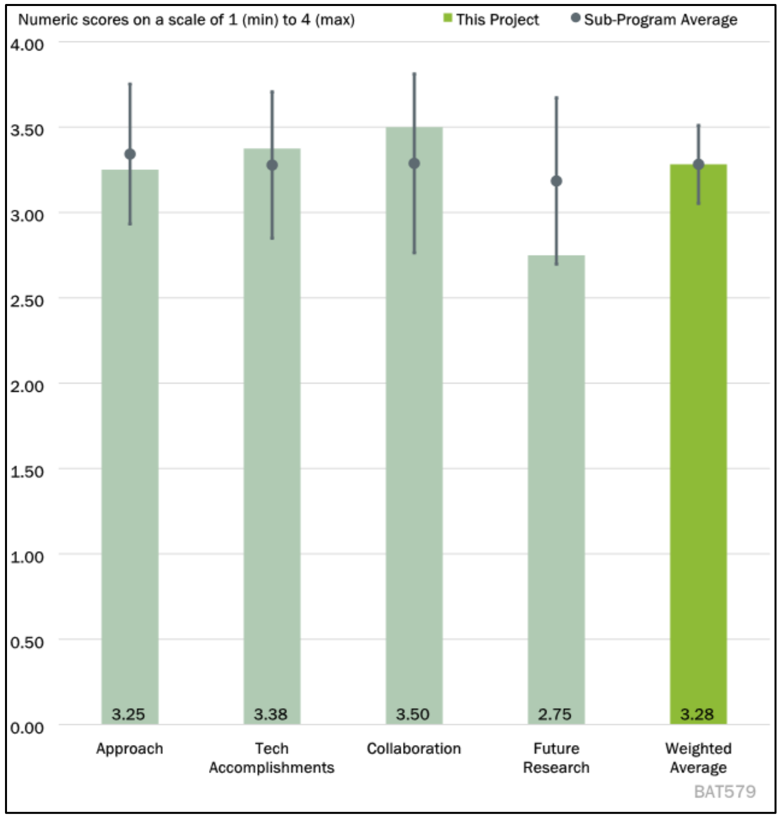

Figure 1-43 - Presentation Number: BAT579 Presentation Title: Multifunctional Gradient Coatings for Scalable High-Energy Density Sulfide-Based Solid-State Batteries Principal Investigator: Justin Connell (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer mentioned that the approach involves purchasing commercially available argyrodite powders and coating them with a thin oxide layer, such as Al_2O_3. They raised concerns about the need for appropriate testing methods for components and cells using these coated powders, especially regarding densification, cycling at relevant rates and areal capacities, and components with relevant thicknesses. The reviewer pointed out that the approach slide, lacks quantitative testing methods for cell-relevant testing of the powders.

Reviewer 2:

The reviewer affirmed that the project aims to address concerns related to argyrodite stability with Li metal anodes and high voltage cathodes, as well as to improve air/moisture tolerance. They noted that the application of ALD coatings results in improved electrochemical and environmental stability of the ASE. The reviewer found the timeline and approach reasonable.

Reviewer 3:

The reviewer stated that the technical barrier of sulfide electrolyte stability to dry air is critical for practical applications of all-SSBs. They noted that the team improved the dry air stability of the Li_6PS_5Cl electrolyte by coating it with Al_2O_3, resulting in improved stability to Li metal compared to the uncoated version. However, the reviewer pointed out that the stability of Li_6PS_5Cl to Li metal is not fully addressed, as reduction of the electrolyte still occurs after Li plating, evidenced by the presence of reduction products (Li_2S and Li_3P) and an increased overpotential during Li plating/stripping cycles.

Reviewer 4:

The reviewer clarified that the project's approach involves making a sulfide-based electrolyte more stable by applying a thin coating of Al_2O_3 through ALD. They noted that the project used diagnostic tools to confirm the coating's presence, assess bulk chemistry changes, evaluate conductivity, and test the stability of a separator made from the coated electrolyte against Li and a cathode.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer expressed that relative to the project plan, technical progress appears good. They mentioned the availability of a publication that reports on the project's work and noted that goals related to moisture reactivity have been achieved. Additionally, the reviewer observed that some Li/Li cycling has been demonstrated.

Reviewer 2:

The reviewer deemed technical progress to be aligned with the project plan and timeline. The reviewer acknowledged that the team has made progress in understanding the role of ALD coatings in enhancing the stability of argyrodite electrolytes and has plans to further investigate how coated materials perform in electrochemical cells.

Reviewer 3:

The reviewer indicated that the technical progress meets the milestones set for the project. They detailed some of the findings, including the confirmation of the presence of the coating on the electrolyte surface through EDS analysis, the protective effect of the coating in dry and wet air, and the reduction in Li_2S formation when in contact with Li metal due to the Al_2O_3 coating. However, the reviewer expressed uncertainty regarding the improvement in intergranular contact with the coating and questioned why the IC increased without a clear explanation.

Reviewer 4:

The reviewer raised concerns about the thickness of the coatings, as it is not clear how the team plans to achieve thinner coatings without using a binder. They noted that no work has been performed in this regard. Nonetheless, the reviewer acknowledged that the project has demonstrated good cyclability between Li, the SSE, and Li.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer suggested that the role of Solid Power could be further described in the project. They mentioned that the project involves purchasing commercially available powders and indicated that Solid Power may be involved in coatings in the coming year. The reviewer sought clarification on whether Solid Power has had a role in the project to date. Additionally, the reviewer noted that collaborations within ANL appear to be strong.

Reviewer 2:

The reviewer acknowledged that collaborations and teamwork within the project are well-integrated, as evidenced by the combined experimental-computational publication and the use of major research facilities.

Reviewer 3:

Regarding collaborations, the reviewer mentioned that there is collaboration with ANL for materials synthesis and characterization, as well as cell assembling and testing. They expressed the view that no additional collaboration is needed at this stage.

Reviewer 4:

The reviewer noted that there was good collaboration within ANL but no collaborations with outside partners mentioned in the project. However, they did mention that there are plans to start working with Solid Power.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer emphasized the need for testing that is more relevant and specific to component or device performance to ensure that the coating and compatibility work done so far is not rendered irrelevant due to its impact on component and cell fabrication and performance. They suggested assessing factors such as areal capacity, current density, and stack pressure to provide a comprehensive understanding of the coatings' effects.

Reviewer 2:

Regarding future work, the reviewer stated that the proposed research aligns with the project's goals and is programmatically in line with VTO subprogram goals. They noted the importance of understanding reactivity and compatibility at the interphase region between the coating and electrolyte. Additionally, they mentioned the need for computational models to address band alignment and phase stability of potential SEI phases.

Reviewer 3:

The reviewer provided two specific points for consideration in future work:

They suggested that the team needs to provide a more detailed plan for designing new coating layers at the cathode/SSE interface, including principles for preselecting coating materials.

They recommended that a detailed plan be developed for the scale-up of the coated SSE for integration into roll-to-roll processing, taking into account the stability of the coating materials to solvents or binders used in the roll-to-roll process.

Reviewer 4:

The reviewer mentioned that the team plans to test cathode compatibility next, explore other coatings for the cathode, and consider how to make thinner separators in the future.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer expressed that the powders and processing techniques employed in the project are relevant to Battery program goals.

Reviewer 2:

The reviewer mentioned that the project supports VTO programmatic goals by focusing on enabling SSBs for use with Li metal anodes and high voltage cathodes through the design of interfacial coatings using ALD.

Reviewer 3:

The reviewer highlighted that this project developed a Li_6PS_5Cl electrolyte with improved stability to the Li metal anode, which facilitates the development of high-energy density Li-metal batteries. This development aligns with the VTO subprogram objectives.

Reviewer 4:

The reviewer noted that VTO is interested in advancing solid electrolyte batteries, and this project's demonstration of using ALD coatings on separator materials opens up a new avenue for researchers to explore in this field.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer expressed that the resources for the project appear sufficient for the current scope of work.

Reviewer 2:

The reviewer noted that additional resources might be required if the project were to seriously pursue component and cell fabrication and testing in the future.

Reviewer 3:

The reviewer mentioned that ANL has strong capabilities for materials synthesis and characterization, and the collaboration with Solid Power provides access to facilities for materials scale-up.

Reviewer 4:

The reviewer indicated that, based on the future work and progress achieved so far, it appears that the project has sufficient resources to meet its objectives.

Presentation Number: BAT580
Presentation Title: Thick Selenium-Sulfur Cathode Supported Ultra-thin Sulfide Electrolytes for High-Energy All-Solid-State Batteries
Principal Investigator: Guiliang Xu (Argonne National Laboratory)

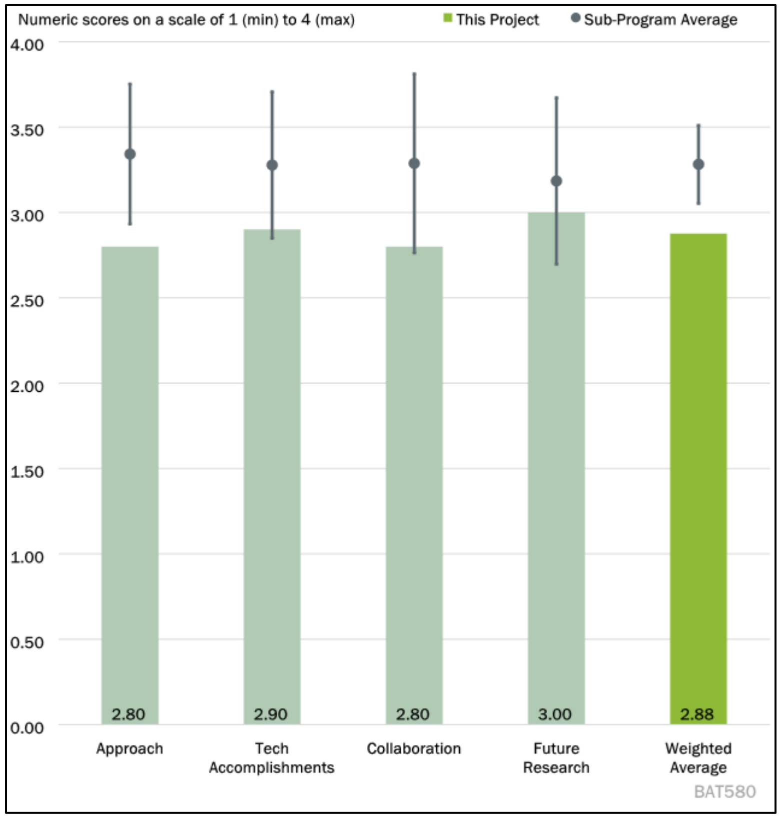

Figure 1-44 - Presentation Number: BAT580 Presentation Title: Thick Selenium-Sulfur Cathode Supported Ultra-thin Sulfide Electrolytes for High-Energy All-Solid-State Batteries Principal Investigator: Guiliang Xu (Argonne National Laboratory)

Presenter

Guiliang Xu, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer found that the project was well-designed, and the timeline appeared to be reasonably planned.

Reviewer 2:

The reviewer observed that the presented approach aimed to incorporate oxygen into the sulfide argyrodite structure as a strategy to enhance the air/moisture stability of sulfides. The work conducted thus far seemed preliminary, with initial efforts primarily focused on building laboratory capabilities for electrolyte synthesis and *in situ* experiments. While the timeline for argyrodite synthesis and testing appeared reasonable, the reviewer expressed concerns about the ambitious nature of the timeline for optimizing the sulfur cathode structure/architecture (SCSA), given the project's progress to date.

Reviewer 3:

The reviewer commented on the program's progress in the synthesis of ASE. According to the reviewer, the program had generated few significant new insights or advances in this crowded research area. The highlight appeared to be grinding materials and heating them to follow crystallization using X-rays. This approach had been extensively utilized in the past, and the reviewer did not perceive the program as contributing significantly to this existing body of work. The reviewer also expressed expectations for the team, given the extensive resources available at DOE facilities, to deliver more substantial advances in comparison to simply grinding and heating materials.

Reviewer 4:

The reviewer recognized the project's focus not only on materials property improvements but also scale-up and performance enhancements, such as cycle life and fast charging.

Reviewer 5:

The reviewer made two key observations. First, they emphasized the importance of air stability for the dry-room synthesis of the sulfide solid electrolyte. However, IC is more important for the electrochemical performance of SSBs. The obtained IC (0.4 mS/cm) of the work was insufficient for a high-performance SSB. Second, the reviewer stressed the significance of stabilizing the Li solid electrolyte interface to attain a high critical current, which was deemed necessary for SSB with a thick SeS cathode.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the technical progress made so far aligns with the project plan.

Reviewer 2:

The reviewer remarked that the team has shown preliminary progress in synthesizing doped argyrodites and conducting initial measurements of IC and critical current density (CCD). Additionally, the team has developed *in situ* X-ray methods for assessing the impact of humidity on solid electrolyte stability. The reviewer emphasized the need for further research to comprehend the differences in degradation pathways resulting from oxygen substitution. They also raised a question regarding the extent of oxygen successfully incorporated in the doped argyrodite compared to the oxygen contamination present in commercial argyrodite.

Reviewer 3:

Commenting on the project's milestones, the reviewer noted that while accomplishments were evident, there was a noticeable absence of efforts to advance the technology beyond basic synthesis. Furthermore, the reviewer expressed concerns about the inadequate documentation of degradation studies, suggesting that these studies could have been conducted at various universities.

Reviewer 4:

The reviewer affirmed that the project had not adequately addressed the stresses imposed on the material during processing, along with strategies to mitigate issues such as grain boundary cracking or deformation. The reviewer underscored that if interfacial resistance remains unaddressed, functionality would significantly fall short of expectations. The reviewer highlighted the potential benefits of the new synchrotron setup in addressing moisture instability, a persistent challenge with these materials.

Reviewer 5:

The reviewer verified that the project had successfully synthesized the solid electrolyte $Li_6PS_{4.8}O_{0.2}Br$ and achieved similar room temperature IC and CCD as Li_6PS_5Cl from the vendor. However, the reviewer pointed out that air stability had improved but had not been completely prevented. The reviewer emphasized the insufficiency of the achieved low IC and CCD, stressing the need for further improvement to meet the requirements of high loading cathodes, which demand high currents for achieving a large energy density.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer affirmed that the collaboration within the project team is close and appropriate. They noted the presence of contributions from national laboratories and emphasized that there appeared to be no areas where additional collaboration was required.

Reviewer 2:

The project effectively leverages collaboration among synthetic, microscopy, and synchrotron X-ray experts. The preliminary technical achievements, according to the reviewer, indicate that the project team is effectively working together.

Reviewer 3:

The reviewer expressed a lack of extensive collaboration within the solid electrolyte program at DOE. They pointed out that, given the extensive work on argyrodites in the portfolio, the project appeared somewhat insular in its efforts. The reviewer also noted the absence of work at the National Synchrotron Light Source (NSLS) or ALS.

Reviewer 4:

The reviewer praised the collaboration across the team, indicating that it seemed to be in good shape.

Reviewer 5:

Regarding the project's illustration of collaboration with team members through assigned test works, the reviewer suggested that while the project does show these assignments, there is room for further improvement in terms of close coordination.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer affirmed that the project had clearly defined a purpose for future work and expressed confidence that the upcoming work was very likely to achieve its targets.

Reviewer 2:

The proposed future work was regarded as purposeful and in alignment with the programmatic goals of VTO Battery R&D, which aim to develop high energy density all-SSBs. However, the reviewer noted that, based on the preliminary work conducted thus far, there were concerns regarding the ambition of the future work focused on S cathode fabrication in FY 2023-Q4, especially since the technical accomplishments of those efforts were not presented.

Reviewer 3:

The reviewer stated the previous comments on the project served as the evaluation.

Reviewer 4:

The reviewer noted that the future plans outlined by the project included addressing S loading, a significant issue for optimizing the performance of S-based cathodes, as well as addressing the mechanical properties of the sulfide solid membranes. The approach to identifying solid-state Li-S failure mechanisms was viewed as potentially highly informative for guiding future work.

Reviewer 5:

Regarding the proposed future work, the reviewer noted that it addressed most of the requirements for current SSBs. They expressed optimism that Q4-2023, Q1-2024, and Q2-2024 were likely to be realized, as similar works had been reported. However, the reviewer cautioned that Q3-2024 and Q4-2024 could be more challenging due to the substantial uncertainty associated with the proposed strategies and approaches during those periods.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that the project supports the overall VTO subprogram objectives.

Reviewer 2:

The technical goals outlined in the project, aimed at improving the stability and conductivity of ASEs and developing high sulfur (S) utilization cathodes, were seen as aligned with the programmatic goals of VTO Battery R&D.

Reviewer 3:

The reviewer noted that while solid electrolytes are undoubtedly an important topic area, the project team appeared to be lagging approximately three years behind their peers. The reviewer recommended better integration with other programs within DOE, including those within ANL.

Reviewer 4:

The reviewer emphasized that this effort was in line with VTO's Advanced Battery Materials R&D efforts for next-generation batteries, further supporting the overall VTO subprogram objectives.

Reviewer 5:

The reviewer felt the project's focus on solid electrolyte materials synthesis and analysis, along with its target of developing SSBs, is promising for energy storage systems related to electrification, advanced engine and fuel technologies, and energy-efficient mobility systems.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that the resources available are sufficient for the project to achieve the stated milestones in a timely fashion.

Reviewer 2:

The reviewer felt resources for the program overall were adequate to accomplish the milestones. However, the reviewer did note that the shutdown of the APS could pose challenges for *in situ* X-ray scattering work. Nevertheless, the partnership with NSLS-II at BNL was expected to help mitigate these challenges.

Reviewer 3:

While acknowledging the value of using X-rays for tracking structural evolution, the reviewer expressed the view that there appeared to be more potential applications or avenues to explore beyond what was presented.

Reviewer 4:

Regarding the project's stage of development, the reviewer indicated that, although it was in its early stages, the available resources appeared sufficient to complete the work as scoped.

Reviewer 5:

The reviewer pointed out that the project, hosted by ANL, benefited from having sufficient resources due to the laboratory's reputation for advanced characterization, testing, and simulation resources. Moreover, their partnerships with BNL and LBNL, both known for their strong backgrounds in relevant fields, further contributed to the project's resource adequacy.

Presentation Number: BAT581
Presentation Title: Precision Control of the Lithium Surface for Solid-State Batteries
Principal Investigator: Andrew Westover (Oak Ridge National Laboratory)

Presenter

Andrew Westover, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

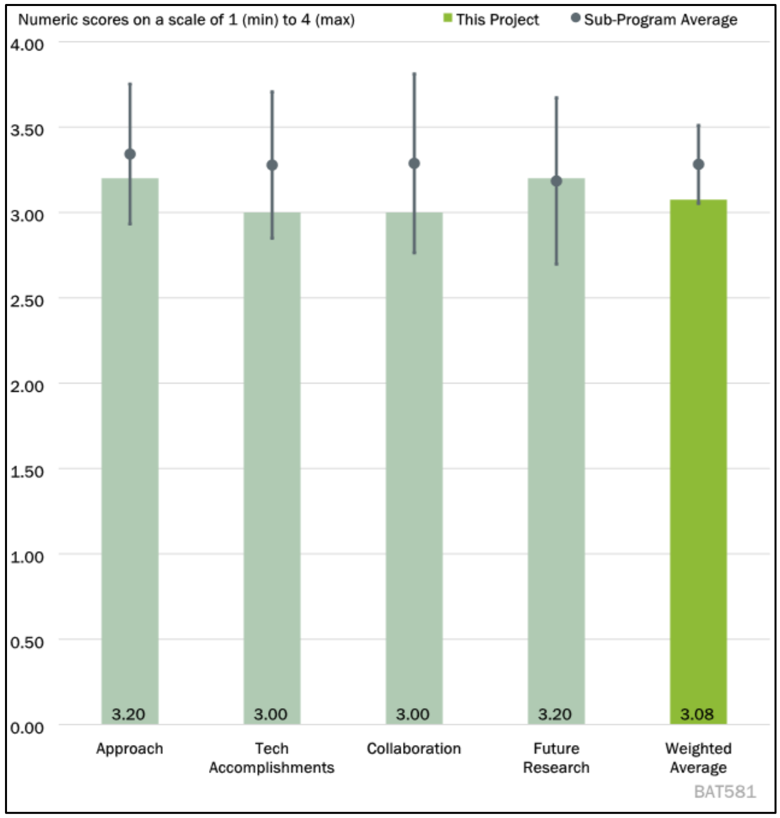

Figure 1-45 - Presentation Number: BAT581 Presentation Title: Precision Control of the Lithium Surface for Solid-State Batteries Principal Investigator: Andrew Westover (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commented on the project’s approach to studying Li surfaces, noting that while it was reasonable, this topic had been previously investigated multiple times in the past. The reviewer also pointed out the complicating factor of the interpretation of results because a dirty Li surface can protect the cell from excessive Li loss.

Reviewer 2:

The reviewer praised the work as excellent and an interesting approach. They emphasized the potential for important scientific outcomes from the team’s efforts. However, the reviewer provided two critiques: First, they questioned the relevance of the study’s basis, considering that the main commercial path for a Li metal cell may not involve Li foil initially. Second, the reviewer suggested that more aggressive cycling conditions were needed to evaluate the impact of the Li source, as the proposed metrics were comparatively less aggressive and of limited relevance for eventual cells.

Reviewer 3:

The reviewer expressed enthusiasm for the project, considering it excellent and interesting. They highlighted the appropriateness of the ORNL team for conducting such research, citing clear experimental tasks and a well-defined timeline.

Reviewer 4:

The reviewer commended the PI's focus on the Li metal anode for SSBs, including understanding and engineering the Li metal surface. However, they raised two concerns: First, the apparent lack of attention to the cathode's importance for SSBs and its potential influence on the choice of solid electrolyte and crosstalk effects with the Li metal. Second, they expressed concerns about the use of In, Ag, Cu, and Au for Li metal surface treatment, especially given that Cu and Au are not generally miscible with Li. The potential reactivity of alcohols used for Li metal surface treatment was also noted.

Reviewer 5:

Regarding the investigation of surface properties of original Li metal from different sources, the reviewer recognized its importance for understanding the stability of the Li anode. They suggested comparing Li metal with the same thickness initially.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer expressed disappointment that the project discovered discrepancies in the advertised thickness of Li only relatively late in the work stream. They emphasized that Li thickness has a substantial impact on cycling, making this issue of significant concern.

Reviewer 2:

The reviewer commended the team for their excellent work. They noted that the team had successfully characterized the surface of several Li foils and evaluated cycling on various solid electrolytes. Additionally, the team was exploring how surface layers influenced fundamental properties, including mechanical behavior.

Reviewer 3:

The reviewer highlighted that the team had established baseline metrics for Li provided by different suppliers, which represented a positive initial step toward achieving their project goals. They also pointed out the importance of uniform pressure across samples, as cell pressure played a vital role in the project.

Reviewer 4:

The reviewer acknowledged the depth-profile XPS work conducted by the PI on Li anodes from various sources. They noted the findings that the Li metal surface was highly dependent on the source and that different Li sources exhibited different stress relief properties. The reviewer also mentioned that the PI concluded that surface chemistry did not appear to significantly affect the overall stress relief properties. The PI had also characterized Li stripping plating efficiency using various Li metal anodes, with results indicating high dependence on the Li source.

Reviewer 5:

The reviewer stated that the project had made good progress and anticipated that the team would continue to study the grain boundary effects of different Li metals.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer emphasized the critical importance of determining the impact of the surface films on cell performance, highlighting it as a crucial missing piece in the current understanding. They noted that this task could be challenging without collaboration with a high-quality cell manufacturer, which was currently lacking in the team.

Reviewer 2:

The reviewer mentioned the existence of a positive collaboration with Michigan Tech. Furthermore, it was mentioned that the Michigan Tech PI would potentially move to ORNL, which was viewed as a positive development for the collaboration.

Reviewer 3:

The reviewer acknowledged that the team had demonstrated adequate collaborations within their own team. However, they recommended expanding collaborations with other VTO performers, especially after completing the tasks for Year 2.

Reviewer 4:

The reviewer deemed the PI’s collaborations within ORNL and with Michigan Technological University as a positive aspect of the project.

Reviewer 5:

The reviewer regarded the team as good, with coordinated efforts and good collaboration demonstrated.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stressed the critical importance of determining the impact of surface films on cell performance, noting it as a significant missing piece in current knowledge. However, they also pointed out that this could be challenging without collaboration with a high-quality cell manufacturer, which was currently absent from the team.

Reviewer 2:

Regarding the proposed future work, the reviewer found it sensible, particularly the plan to go beyond existing commercial foils and engineer the surface. They acknowledged that cycling depended not only on the Li side but also on the electrolyte side, emphasizing the need for careful control in both areas. Additionally, the reviewer mentioned that several reviewers had suggested looking at electrochemically deposited Li as part of the scope, which appeared promising, although it might not be within the current scope.

Reviewer 3:

The reviewer commended the clearly defined nature of the proposed future research, highlighting its potential to be transformative.

Reviewer 4:

The reviewer felt the PI’s proposal to study the microstructure, surface composition, and solid electrolyte-Li adhesion for future studies was a sensible direction. The reviewer also noted the proposal to develop a high-performance Li anode using the approaches suggested for the project.

Reviewer 5:

The reviewer found the proposed work to be reasonable and the future research directions to make sense.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer provided a somewhat weak affirmation, expressing doubt about the large impact of a surface film on long-term cycling given the significant movement of Li during cycling. They noted that while a film on Li could impact interfacial contact resistance, it was unclear how a very thin surface layer would affect the cycling process.

Reviewer 2:

The reviewer acknowledged that the work was focused on how the properties of Li metal could affect cycling, with a particular emphasis on the Li surface. They considered this relevant to the goals of the Battery program.

Reviewer 3:

The reviewer stated that the project was highly relevant to the overall goals of VTO programs, emphasizing the importance of Li metal as a crucial component. They also noted that the knowledge developed in this project could potentially benefit other projects if efforts were made to disseminate the knowledge in a timely manner.

Reviewer 4:

The reviewer recognized the project as a SSE project and indicated that it supported the broader VTO beyond Li-ion battery project portfolio.

Reviewer 5:

The reviewer stressed the importance of investigating the surface properties of Li metal foils, underscoring the project’s relevance to VTO objectives.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the resources were “fine.”

Reviewer 2:

The reviewer found that the resources were well aligned with ORNL capabilities and appeared to be sufficient.

Reviewer 3:

The reviewer noted that the resources and funding level were adequate for making good progress, with the possibility of the team utilizing surface-sensitive characterization techniques available at synchrotron facilities, such as soft X-ray absorption spectroscopy (XAS) and grazing incidence X-ray diffraction (GIXRD).

Reviewer 4:

In the reviewer’s assessment, the resources were deemed sufficient for the project to achieve the stated milestones in a timely fashion.

Reviewer 5:

The reviewer observed that ORNL possessed all the necessary resources for the proposed work.

Presentation Number: BAT582
Presentation Title: Inorganic-Polymer Composite Electrolytes with Architecture Design for Lithium Metal Solid-State Batteries
Principal Investigator: Enyuan Hu (Brookhaven National Laboratory)

Presenter

Enyuan Hu, Brookhaven National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

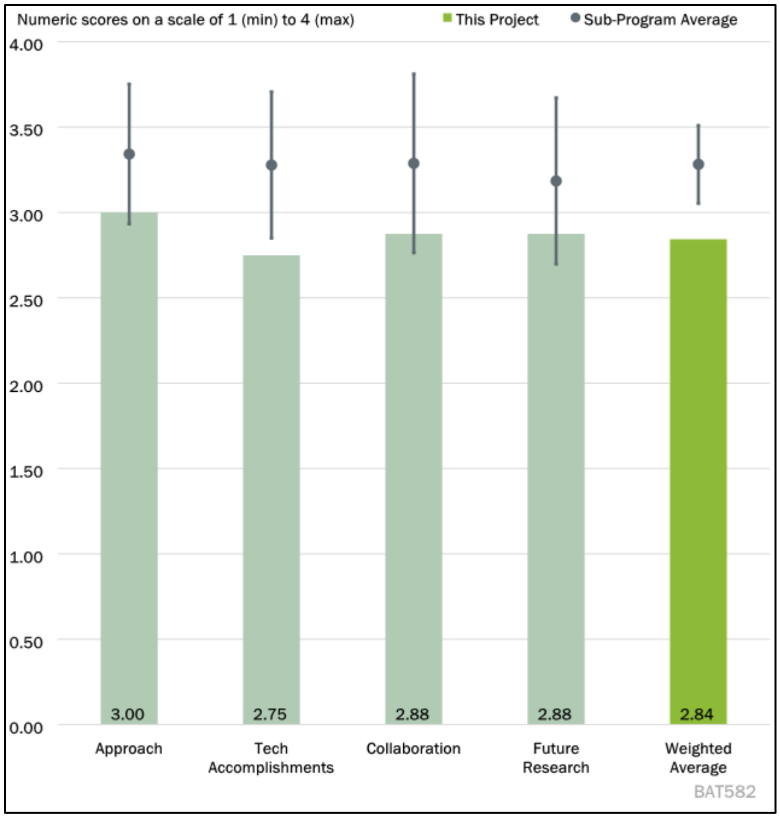

Figure 1-46 - Presentation Number: BAT582 Presentation Title: Inorganic-Polymer Composite Electrolytes with Architecture Design for Lithium Metal Solid-State Batteries Principal Investigator: Enyuan Hu (Brookhaven National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer assessed that the project plan was well designed to achieve the identified end goals.

Reviewer 2:

The reviewer recognized the merit of combining a polymer electrolyte with a stiffer sulfide electrolyte, considering it a promising approach. They also acknowledged that the investigators possessed the qualifications necessary to carry out this work. The reviewer noted the importance of improving conductivity in the polymer, especially in the context of composite systems. However, they suggested that some preliminary experimental work with the inorganic material would have been beneficial at this stage.

Reviewer 3:

The reviewer viewed the team’s aim to develop a practical SSB with a focus on a polymer and ceramic composite electrolyte positively. They noted that the team had adopted an excellent approach to address the issue, involving the design and synthesis of polymer materials with specific properties, design and synthesis of ceramic electrolyte materials, optimization of the composite electrolyte composition, and exploration of polymer electrolyte additives for Li metal anode and NMC cathode protection. The use of theoretical calculations, synchrotron, and cryogenic electron microscopy (EM) for characterization was also commended.

Reviewer 4:

The reviewer expressed concerns based on their attendance at a presentation, detailed analysis of presentation slides, and interactions during the presentation and subsequent quarterly reports. They indicated that the PIs did not appear to be aware of critical analysis techniques or synthetic strategies for developing true polymer networks or single-ion-conducting polymer electrolytes. There were concerns about the lack of details regarding the chemical compositions of the electrolytes and the inability to specify precise information during the question and answer session. The reviewer pointed out that the PIs seemed to understand the technical barriers in battery technology but lacked a clear understanding of how to develop and characterize materials effectively to overcome these barriers. Two specific instances of concern were highlighted: (1) the failure to quantify residual "sol" phase in the gel/network systems and the absence of quantification for residual solvents in PVDF or "single-ion" systems; and (2) the lack of specification regarding the chemistry of the putative single-ion system, making it uncertain if any ions were chemically bound to the polymer backbones. The reviewer found it difficult to assess the reasonableness of the timeline based on the broad and undefined "Approach" bullet points and the lack of well-justified strategies for creating new materials.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer evaluated the milestones for FY 2023 and noted that the progress, while not hitting the exact metrics identified, was satisfactory. They emphasized the importance of further work on process optimization to deliver high-performance materials.

Reviewer 2:

Regarding the two objectives listed for the period, the reviewer observed that there was generally good progress on developing the polymer electrolyte, but it was unclear if the goal of achieving "good mechanical strength" had been met. They noted the lack of clarity regarding whether the primary interest was the material's stiffness or its fracture resistance. For the second objective, the reviewer mentioned that work on the polymer/ceramic interface had not been presented.

Reviewer 3:

The reviewer acknowledged that the project had made a promising start and had achieved the defined milestone on time. The accomplishments included the optimization of the composition of a single-ion-conducting SPE to meet specific criteria, such as interfacial resistance, limiting current density, and membrane thickness under stacking pressure. Additionally, the team completed synchrotron-based characterization of a PVDF polymer-based solid electrolyte to assess its stability against Li metal and NMC cathode. Specific technical accomplishments highlighted by the reviewer included the successful fabrication of a PVDF-based polymer electrolyte using the solvent casting method and gaining an understanding of the degradation mechanism of SSBs using this electrolyte. It was noted that residual NMP solvent was found to be unstable against Li metal. The team also designed and synthesized a PUA-based polymer electrolyte using a solvent-free method. The reviewer mentioned the tuning of polymer electrolyte properties through adjustments in the degree of crosslinking in the polymers, with preliminary results indicating its suitability for cycling in NMC||Li SSBs. Furthermore, the team designed and synthesized a single-ion-conducting polymer electrolyte with specific characteristics, such as small thickness, high transference number, and a wide electrochemical window. The reviewer pointed out that a critical current density of 2.4 mA/cm^2 was achieved in SSBs using this polymer electrolyte. The team also obtained insights into how the coupling between Li cation hopping and anion movement influenced Li ion conduction in ceramic electrolyte. Additionally, possible strategies for improving IC in halide electrolytes were proposed. Overall, the reviewer considered these accomplishments as a positive reference point for major parts of the project, indicating a promising start to the research efforts.

Reviewer 4:

The reviewer pointed out several critical concerns regarding the project's approach to polymer-based electrolytes and the lack of essential information and characterizations. They noted that the PIs had pursued three drastically different strategies for polymer-based electrolytes, which required expertise in various areas of polymer electrolyte science. The reviewer suggested that a reduction in scope or a shift/increase in activity/manpower in this area might be warranted at this point. One major concern raised by the reviewer was the lack of detailed chemical compositions for any of the developed systems. They emphasized the necessity of characterizing critical parameters such as the amount of residual NMP solvent in the PVDF electrolyte and the mass fraction of residual monomers/liquid in the PUA system. These measurements, including solvent or monomer extraction and gravimetric quantification, were considered essential for assessing the suitability of these systems as solid electrolytes and understanding the components present, potentially including other solvents like water, and their effects on conduction and mechanical properties. Regarding the "single ion" system, the reviewer noted that there was insufficient information about how ions were attached to the polymer chain. They also pointed out the absence of details about the amount and nature of the solvent and/or small molecule content in this system. The reviewer expressed doubts about the accuracy of transference number measurements and emphasized the difficulty of conducting these measurements without large artifacts/errors. The reviewer highlighted the absence of mechanical or thermomechanical measurements, such as stress-strain, oscillatory shear rheology, and dynamic mechanical thermal analysis, on any of these systems. They stressed that these measurements were critical for understanding the nature of these materials for battery applications. Lastly, the reviewer noted that the computational/theoretical work had focused on ceramic conductors and had not addressed transport in the polymeric electrolytes generated or interfacial processes between ceramics and polymers in a composite electrolyte. They concluded that the lack of sufficient and appropriate information about the materials under study made it difficult to assess technical progress effectively.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer assessed the collaboration within the project team as "fairly collaborative" in delivering on the project objectives.

Reviewer 2:

The reviewer noted that the proposed contributions of different team members were well defined, and the collaboration on polymer electrolytes between Brookhaven and University of California Irvine appeared to be working well. However, the reviewer expressed concerns about the lack of discussion regarding collaboration with researchers working on sulfide electrolytes. They suggested that these interactions might become more relevant later in the project, but clarity on this matter was needed in the presentation. Additionally, the integration with modeling was not clearly explained, including plans for validation with experiments.

Reviewer 3:

The reviewer acknowledged that the PI had excellent partners for the project, including Prof. Huolin L. Xin from the University of California, Irvine, and Prof. Xin Li from Harvard University.

Reviewer 4:

The reviewer pointed out that while the PIs had substantially different expertise and experience, there was a lack of effective utilization of their skills in collaboration. Each PI had different capabilities, such as materials analysis, characterization, materials synthesis, computational/theoretical expertise, and battery assembly and testing expertise. It appeared that the PI making the presentation may not have had sufficient background to explain results from the other PIs, and there was a lack of close integration and collaboration among the PIs. The reviewer suggested that the range of topics studied by the team seemed widely disparate and not well-integrated, making it challenging to achieve effective collaboration.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer found the proposed research outline to be sound but lacking in detail. They noted that some targets, such as increasing the conductivity of the polymer electrolyte, were not clearly explained in terms of how they would be achieved. The reviewer suggested that further clarification about methods and approaches would be helpful to better understand the research plan.

Reviewer 2:

The reviewer found the overall direction of the future work to be well defined and logical. They pointed out that Slide 14 listed activities that were likely to be completed.

Reviewer 3:

Regarding the challenges and barriers identified by the PI, the reviewer noted that there were still challenges to address, such as further increasing the IC of the polymer electrolyte at room temperature, improving compatibility with NMC cathode and Li metal anode, and better understanding the interfacial properties between the polymer/ceramic electrolyte and electrodes. The proposed future research included decreasing the thickness of the PUA-based polymer electrolyte and improving its IC at room temperature, characterizing the compatibility between the single-ion conducting polymer electrolyte and NMC cathode, increasing the cathode loading in NMC||hierarchical ceramic electrolyte||Li cells to 8 mg/cm², and conducting synchrotron-based *in situ*/*ex situ* studies of the ceramic-based solid-state cells to understand the stability of electrode-electrolyte interphases.

Reviewer 4:

The reviewer reiterated their concern that achieving battery-relevant goals might be challenging without a more in-depth understanding of the materials through detailed characterization. They also noted that the proposed future research did not include the determination of basic properties of the electrolyte systems, which they believed should be a priority before pursuing further research.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the program supports the goals of the VTO subprograms.

Reviewer 2:

The reviewer stated improving solid electrolyte materials for the development of SSBs is critically important. The reviewer recognized the project's focus on a promising approach and its high relevance to VTO program objectives.

Reviewer 3:

The reviewer mentioned that the project is concentrating on critical areas, including the design and synthesis of polymer materials with high IC and good mechanical strength, optimization of polymer fabrication methods to improve compatibility with electrodes, and gaining an understanding of the correlation between cation and anion movement coupling and Li conduction.

Reviewer 4:

The reviewer expressed concerns about the direction and work done so far in the project, suggesting that they may not be appropriate for achieving the program objectives. They referred to previous comments made in this regard.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources are adequate for this project.

Reviewer 2:

The reviewer mentioned that the investigators have complementary expertise and appropriate resources to conduct the proposed work.

Reviewer 3:

The reviewer noted that the funding level is comparable to the scope of work, and the progress and findings are significant.

Reviewer 4:

The reviewer expressed concerns about the utilization of resources in collaboration. They mentioned that the different PIs have substantially different resources that complement each other, but it appears that these resources are not effectively used in collaboration. They specifically pointed out that synthetic abilities, materials analysis capabilities, and computational/theoretical resources may not be fully leveraged to achieve the project objectives.

Presentation Number: BAT583
Presentation Title: Development of All-Solid-State Battery Using Anti-Perovskite Electrolyte
Principal Investigator: Zonghai Chen (Argonne National Laboratory)

Presenter

Zonghai Chen, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

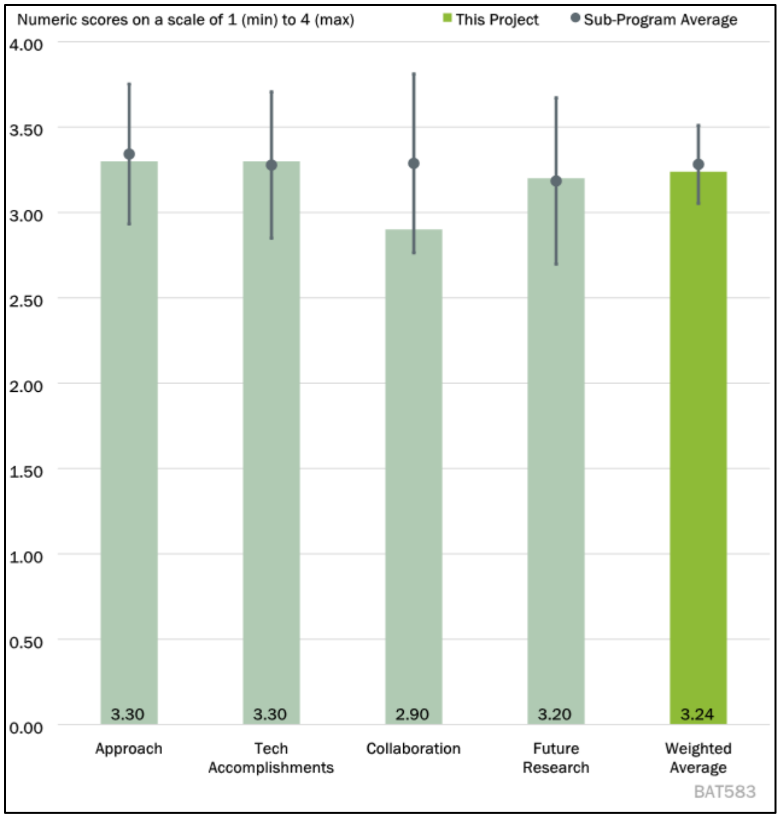

Figure 1-47 - Presentation Number: BAT583 Presentation Title: Development of All-Solid-State Battery Using Anti-Perovskite Electrolyte Principal Investigator: Zonghai Chen (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer assessed the project's objectives, which included optimizing the synthesis of anti-perovskite solid-state electrolyte (AP-SSE), investigating the structure and interfacial stability, and exploring composite electrolytes to enhance Li-ion conductivity. The reviewer noted a suggestion to include a full cell test in the material development.

Reviewer 2:

In terms of project management, the reviewer found the proposed timeline to be reasonable. The team's achievements were acknowledged, particularly in materials synthesis, the chemistry of AP-SSE, understanding ion transport, and grasping the chemical and electrochemical degradation pathways. The reviewer observed that the project's primary focus so far had been on anion alloying/doping within the antiperovskite family, as outlined in the project's Approach.

Reviewer 3:

The reviewer expressed positive impressions of the program, highlighting the intriguing idea of utilizing AP-SSE and the importance of high-precision measurements. However, the reviewer also raised some concerns. They suggested that the research team should consider expanding collaborations, especially with other groups funded within the Battery Materials Research (BMR) program working on similar materials. The reviewer emphasized the potential of anti-perovskite materials as faster ion conductors when reacting with Li metal, suggesting that this valuable knowledge appeared underutilized in the current research approach. The reviewer also identified challenges related to electrode thickness and questioned the roles of the numerous project partners, suggesting that the involvement of 13 individuals might dilute the overall effort. Finally, the reviewer recommended that the program should establish more robust collaborations within the BMR portfolio, particularly with groups that seem to be further advanced in similar research.

Reviewer 4:

Regarding the technical aspects of the project, the reviewer highlighted the project's unique interfacial stability achieved through steady leakage current measurement. The use of antiperovskite materials as an ionic conductive binder to effectively bind lithium lanthanum titanate oxide (LLTO) was noted as an intriguing aspect of the research.

Reviewer 5:

In terms of the project's goals, the reviewer noted the ambition to develop a SSB with enhanced stability to Li metal and an NMC cathode. The reviewer summarized the project's approach, which involved starting with an AP-SSE, finding a low-cost method for synthesizing it, testing its stability using high-precision coulometry, exploring the substitution of different halides for improved stability, and ultimately finding a cost-effective method for preparing a separator with this material.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked that significant progress had been made in material synthesis, interfacial electrochemical and chemical stability, which collectively contributed to a deeper understanding of AP-SSE. In contrast to liquid electrolytes, SSEs can exhibit electronic and IC, particularly in the case of semiconductors like anti-perovskite. It is suggested that the PI design an experiment to distinguish between these two types of conductivity.

Reviewer 2:

The reviewer observed that the project's approach encompassed electrolyte design, interface design, and process development. The reviewer noted significant strides in designing and synthesizing ASE and in the alloying of bromide/chloride analogs to fine-tune IC. Additionally, the team made progress in comprehending interface formation involving ASE, including their cycling stability with Li metal and stability when used in conjunction with LLZO as a composite electrolyte.

Reviewer 3:

Regarding the concept of a composite solid electrolyte, the reviewer expressed intrigue. However, the reviewer questioned whether there was a dearth of knowledge regarding the underlying mechanisms in this system, warranting reevaluation.

Reviewer 4:

The reviewer highlighted that the material synthesis process involved a solid-state method to produce anti-perovskite electrolytes, enhancing structural stability through doping with larger anions. Furthermore, the reviewer noted the development of a composite electrolyte to achieve high Li-ion conductivity at lower processing temperatures. The study investigated interfacial stability and identified an aggressive reaction between Al foil and anti-perovskite electrolytes, while confirming good chemical and electrochemical stability at the anode side.

Reviewer 5:

The reviewer stated that the research team had discovered a cost-effective method for preparing anti-perovskites and substituting boron for chlorine. The materials exhibited a melting point below 300°C. The reviewer noted that conductivity measurements at different temperatures revealed relatively low conductivity, approximately 0.01 mS/cm at room temperature. Subsequently, by mixing the material with LLZTO, a conductivity of 0.05 mS/cm at 25°C was achieved in a 40/60 AP/LLZTO blend. A thick separator (approximately 300 microns) was assembled and cycled between two Li electrodes at 0.1 mA/cm² for 1 mAh/cm², demonstrating over 250 cycles. The reviewer affirmed that a cathode composed of AP and NMC 622 was subjected to a voltage of 4.4V, and upon examination of the NMC surface after removal from the cell, a significant reduction of surface Ni was observed. This led the reviewer to suggest that AP may not be stable above 4.25V. In cell tests against Li metal, it was determined that Al was not stable against AP at 3.5V, whereas Ni and Ti exhibited stability at high voltages. Additionally, the reviewer commented that it was reported that AP exhibited instability in air at a relative humidity of 40%. Consequently, it appeared to the reviewer that the electrolyte demonstrated reasonable stability against Li-metal, although measurements of average CE through Li/Cu cells or limited Li/Li cells were not attempted. The reviewer, however, noted that the low conductivity and questionable stability against the cathode posed challenges to the viability of this electrolyte.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the PI has a long list of collaborators in universities and national laboratories, covering a wide area of expertise.

Reviewer 2:

The reviewer emphasized that while collaborative efforts are evident in the program's progress, it is essential to demonstrate how the team leverages this collective expertise and how these collaborations contribute to the presented progress.

Reviewer 3:

The reviewer expressed a desire for improved interaction with the other BMR programs, given the presence of 13 individuals listed as part of the project. The reviewer suggested that enhanced coordination and synergy with other programs would be beneficial.

Reviewer 4:

The reviewer acknowledged that the PI has successfully established numerous collaborations with universities and national laboratories, fostering strong partnerships in research and development.

Reviewer 5:

The reviewer pointed out that while several collaborators are listed at the end of the presentation, their specific contributions do not appear to be reported in the current context.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer commended the PI for having a clear plan for future work and expressed appreciation for the planned future full cell investigation.

Reviewer 2:

The reviewer also acknowledged that the proposed future research has a well-defined purpose and is aligned with programmatic and scientific goals. Furthermore, the reviewer found the future goals to be reasonable in scope.

Reviewer 3:

The reviewer expressed a desire for improved interaction with the other BMR programs, given the presence of 13 individuals listed as part of the project. The reviewer suggested that enhanced coordination and synergy with other programs would be beneficial.

Reviewer 4:

The reviewer highlighted that the proposed research efforts make sense. The reviewer noted that the team plans to map out the critical current density of their electrolyte vs stack pressure. However, there was some uncertainty regarding the team's direction in developing another electrolyte for the cathode and creating thinner separators, as the specific strategies were not clearly outlined.

Reviewer 5:

The reviewer observed that the team intends to build and test full cells with the available materials and investigate the source of failure. However, the reviewer expressed concern about the lack of clarity regarding the project's future trajectory and how it leads to improvement.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that developing a structurally and chemically stable AP-SSE with the potential to lead to a long-cycle SSB aligns with the objectives of the VTO.

Reviewer 2:

The reviewer confirmed that the project goals are in support of the programmatic objectives of VTO, specifically concerning the development of all-SSBs with Li metal anodes.

Reviewer 3:

The reviewer expressed agreement with the significance of SSBs and suggested that improvements could be made in framing questions and enhancing collaboration within the team.

Reviewer 4:

While the project primarily focuses on the anti-perovskite electrolyte that is chemically compatible with metallic Li, the reviewer acknowledged that it remains a challenge to create functional full cells.

Reviewer 5:

The reviewer emphasized the importance of research into SSBs as a vital element within the DOE portfolio, considering it as another crucial piece of the broader puzzle in advancing energy storage technology.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that the PI has sufficient resources to conduct the proposed research.

Reviewer 2:

The reviewer stated that the resources allocated for the project are deemed sufficient to attain the project's goals.

Reviewer 3:

The reviewer noted that the resources appeared to be sufficient.

Reviewer 4:

The reviewer expressed uncertainty about the project's chemistry being a winning solution. Despite this uncertainty, the reviewer noted that there are adequate resources to follow this research path to its conclusion.

Presentation Number: BAT584
Presentation Title: Integrated Atomic-, Meso-, and Micro-Scale Diagnostics of Solid-State Batteries
Principal Investigator: William Chueh (Stanford University/SLAC National Accelerator Laboratory)

Presenter

William Chueh, Stanford University/SLAC National Accelerator Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

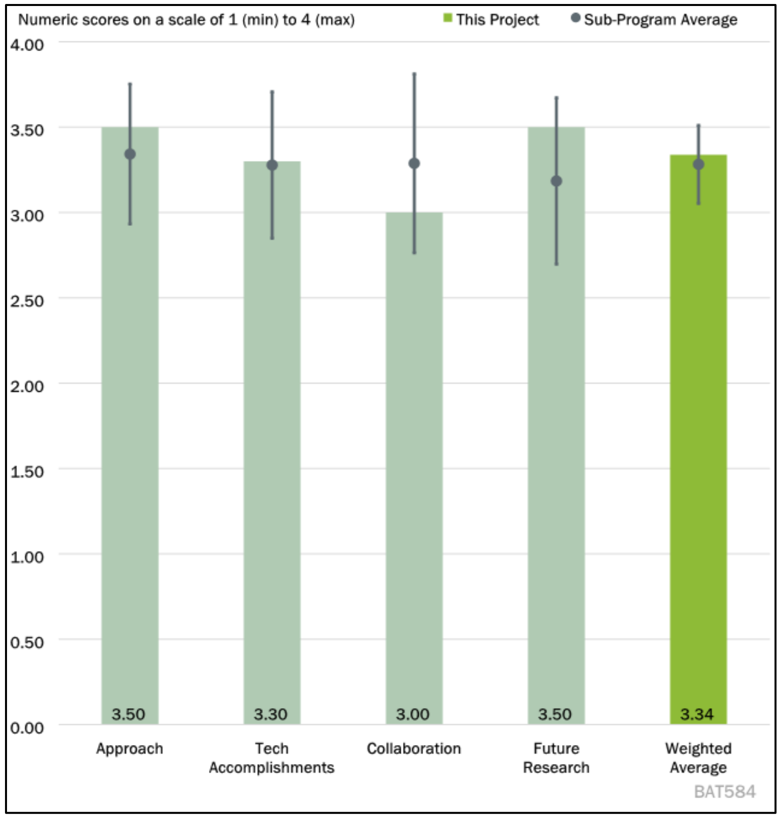

Figure 1-48 - Presentation Number: BAT584 Presentation Title: Integrated Atomic-, Meso-, and Micro-Scale Diagnostics of Solid-State Batteries Principal Investigator: William Chueh (Stanford University/SLAC National Accelerator Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commented on the proposed material characterization approaches and *in situ* studies, stating that they are scientifically sound. They noted that many of the proposed approaches and tools are unique. However, the reviewer pointed out that while the PIs proposed using conducting atomic force microscopy to observe ionic and electronic transport at grain boundaries, no results on ionic and electronic transport were presented in the poster. Additionally, the reviewer expressed concerns that the proposed X-ray micro and diffraction tomography might lack the resolution needed to track solid electrolyte and Li microstructure evolution effectively.

Reviewer 2:

The reviewer acknowledged that the project effectively utilizes various surface science techniques to characterize interfaces in SSB, particularly focusing on Li plating in contact with LLZO electrolytes.

Reviewer 3:

The reviewer noted that the project had clearly outlined barriers and reasonably planned project milestones, demonstrating significant progress and results that contribute to the overall program. The approach involved the use of several microscopy methods to evaluate different aspects of the SSB, including microstructural changes, stress, and ionic transport.

Reviewer 4:

The reviewer highlighted the application of *in situ* EM to study the formation of Li dendrites with and without the presence of external pressure. They mentioned the observation of Li dendrite formation from remote areas during *in situ* experiments, leading to the conclusion that an electronic conducting path exists in garnet electrolyte pellets, promoting electron conduction to a remote area. The reviewer considered this technique novel and the conclusion significant for addressing the dendrite problem with mechanically strong electrolyte candidates. They also commended the strong support provided by the collected data. However, the reviewer suggested that developing techniques with larger detecting areas could complement this localized tool.

Reviewer 5:

The reviewer praised the excellent progress reported in the presentation and highlighted the importance of the characterizations in providing insight into processes at the Li metal to solid-state electrolyte (SSE) interface. While acknowledging the project's significance, the reviewer raised questions about whether the project alone could address the technical barriers to using Li metal and/or SSE in commercial batteries, given the broad scope of these technical challenges. Nonetheless, the detailed work described was considered a significant step in the right direction.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The research team employed *operando* SEM and cryo-TEM to characterize the nanoscale structure and short-circuiting in LLZO. It was noted that defects initiate Li intrusion, and higher mechanical loading increases the likelihood of intrusion, leading to intrusions at smaller Li-whisker diameters. Ultrathin metallic films were grown on LLZO to enhance defect tolerance and reduce the probability of Li intrusion and short-circuiting. However, characterization of these ultrathin film coatings was missing from the presentation, with the team planning to include them in future research. Additionally, the approach to growing the ultrathin film coating was unclear, and there was uncertainty regarding whether it had been reported in previous years. The size of the crack widths that trigger Li intrusion was not specified, and the reviewer suggested that characterization of the lithiophilicity of the LLZO material could be helpful.

Reviewer 2:

The reviewer noted that the experiments were well-designed to answer critical questions regarding the mechanical response of the solid electrolyte during plating. However, there was some uncertainty about how connections between the intrusion crack network and subsurface pores were established and how changes in porosity were determined. The type of defects that initiate intrusion was also raised as a question.

Reviewer 3:

The reviewer commended the authors for providing detailed results regarding the evaluation of solid electrolyte fracturing and Li plating. However, they noted that the effect of ultrathin metallic coatings on Li plating was described briefly, with silver and platinum showing the greatest benefit. The reviewer suggested that additional detail on some of the other milestones and accomplishments would have been beneficial.

Reviewer 4:

The reviewer appreciated the project team's commitment to developing novel characterization tools that could be valuable for other research teams. They recognized the clear research and development value demonstrated using garnet electrolytes as an example.

Reviewer 5:

Regarding the progress made in FY 2023, the reviewer noted significant achievements related to Q1-Q2 milestones concerning metal coating and visualizing their effect on Li metal intrusion and failure. However, there was uncertainty about the progress on Q3–Q4 milestones, as it was listed as “in progress” without specific details. The presentation primarily focused on nanoindentation and microscopy studies, which helped identify the probability of failure with and without thin metal coatings under various mechanical pressures and critical currents.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer acknowledged that the PIs already have excellent facilities and experience in material characterizations. They noted that the collaboration with LBNL-ALS is positive. However, the reviewer raised concerns about the absence of results from the X-ray microscopy experiments. The source of LLZO electrolytes was unclear, and the reviewer suggested that collaborations to fabricate and characterize LLZO would be helpful. Additionally, the reviewer found it unusual to list a student as a collaborator.

Reviewer 2:

The reviewer observed that no external collaborations were reported, which raised some concerns.

Reviewer 3:

The reviewer noted that the project team had a successful proposal to make use of facilities available at LBNL. They also mentioned that a student was shared on this project between both institutions.

Reviewer 4:

The reviewer recognized that the project team has a good collaboration with DOE-funded national user facilities for the project, and the accomplishments are beneficial to both the user facilities and the user community.

Reviewer 5:

In terms of teamwork and coordination, the reviewer found them to be fine. They noted that extensive use of national laboratory facilities requires coordination and commended the project for its effective collaboration among the team and external partners needed to conduct the work.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer found the proposed future research to be reasonable.

Reviewer 2:

The reviewer noted that the future plans are aligned with the proposed research.

Reviewer 3:

The reviewer stated the future work includes plans for additional characterization and optimization of the SSB. The reviewer considered the targets achievable and believed that they would increase the impact of the work.

Reviewer 4:

The reviewer mentioned that the project has a comprehensive forward-looking plan.

Reviewer 5:

The reviewer emphasized that, although briefly stated in the presentation, the work to be completed next, especially item #3, is likely the most strategically important to target. The reviewer explained that if the failure mechanism is defect-driven and will be limited by defect levels obtainable in manufacturing, it would be essential, before the project completes in FY 2024, to get an initial look at the level of defects in "typical" SSEs as manufactured. If the critical current is not inherently limited by the composition of the SSE but is instead limited by the level of defects, the focus should shift to that aspect.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized that this project is expected to generate valuable insights for engineering LLZO SSEs, and the success of this project will significantly benefit the development of advanced SSBs.

Reviewer 2:

The reviewer noted that the project is relevant to furthering the understanding of all-SSBs.

Reviewer 3:

The reviewer described the project's aim to design SSBs for use in EVs, which includes developing coatings for improved fast charging, enhancing safety by inhibiting short circuits, and engineering cell component compositions and surfaces to reduce degradation.

Reviewer 4:

The reviewer highlighted the importance of developing safe and high-energy-density Li batteries as a long-term strategy for DOE to electrify the transportation system. The execution of this project aligns well with the mission of DOE, and the knowledge and characterization tools obtained from this project would be valuable assets for the research and development community to rationally design high-performance SSBs for vehicle applications.

Reviewer 5:

The reviewer also pointed out the clear relevance of the work to the VTO objectives, particularly VTO's investment in Li metal anode. However, the reviewer cautioned against overselling the results and insights from the project thus far. While acknowledging the excellence of the work and its contribution to understanding SSE failure and suspected Li metal intrusion, the reviewer noted that claiming to have discovered the mechanisms may be premature. The presentation itself mentioned that finding Li metal penetration from surface intrusion to an inner pore had been "elusive." The reviewer acknowledged the importance of the data and observations, as well as the identification of suspects, but cautioned that the full story is not yet complete.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the PIs' teams have access to excellent facilities and unique research capabilities, indicating a positive aspect of the project.

Reviewer 2:

The reviewer stated that the resources were adequate.

Reviewer 3:

In terms of resources, the reviewer stated that the available resources appear sufficient to accomplish the project with their staff.

Reviewer 4:

The reviewer observed that the project team effectively utilizes DOE resources to accomplish the planned activities.

Reviewer 5:

The reviewer expressed no concerns about the resources, acknowledging that while additional resources might enable more extensive studies, results, and conclusions, the current level of investment appears appropriate for conducting the most important studies within the project.

Presentation Number: BAT585
Presentation Title: Anode-Free Lithium Batteries
Principal Investigator: Ji-Guang Zhang (Pacific Northwest National Laboratory)

Presenter

Ji-Guang Zhang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

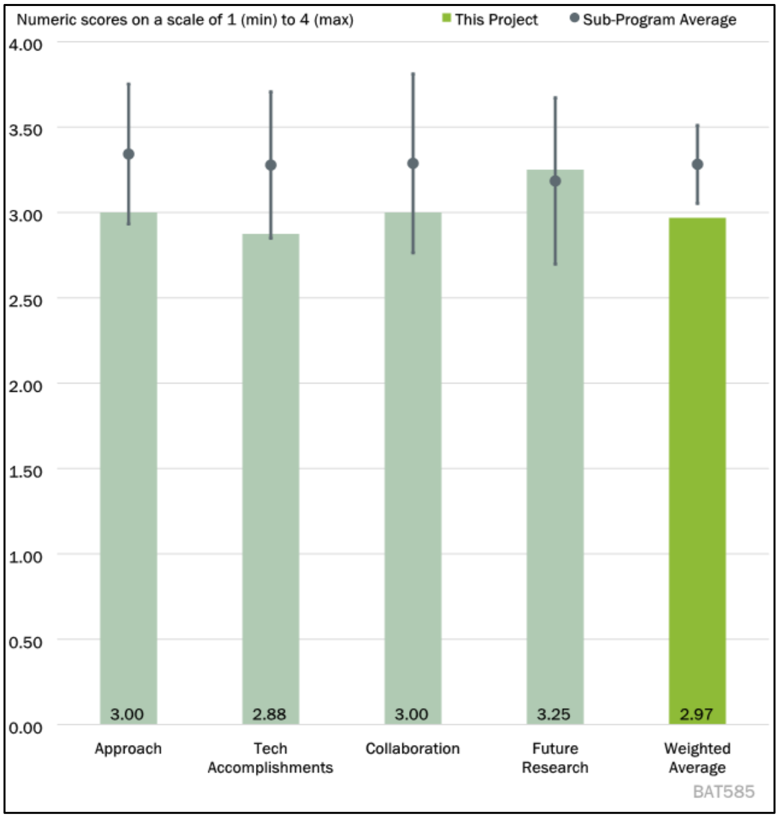

Figure 1-49 - Presentation Number: BAT585 Presentation Title: Anode-Free Lithium Batteries Principal Investigator: Ji-Guang Zhang (Pacific Northwest National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer cited the project's strategy for enabling high-energy-density batteries involves four key objectives: increasing CE to enhance cycle life; developing an artificial protection layer to improve Li utilization and CE; understanding SEI formation and dissolution; and enhancing safety characteristics.

The project primarily focuses on two main experimental approaches for achieving these improvements: electrolyte development and copper (Cu) substrate coatings. However, the reviewer raised concerns that while these approaches are typical, the results obtained so far do not indicate substantial improvements over the standard technical barriers observed in Li metal systems. Additionally, the reviewer noted that the approach and barriers for the SEI work were not discussed in the review. The reviewer highlighted ongoing challenges related to plating dense Li, including issues such as non-uniform Li deposition, dead Li, and short cycling life. Also noted was that pressure requirements remain a significant challenge for the program, and these challenges have been marginally addressed. The reviewer expressed uncertainty regarding the program's timeline, indicating a lack of clarity in this regard. Furthermore, the technical accomplishments mentioned in the review suggest that the technical barriers to improving cycle life and cell performance may not be fully addressed by increasing CE. The reviewer questioned why the Cu/Li system with a 99.7% CE exhibited the worst cycle life in the Cu/NMC cell. The reviewer pointed out that pressure is a known mechanism for improving cycle life and recommended that the project should place more emphasis on the proposed SEI work, which was not discussed in the review.

Reviewer 2:

The reviewer noted that the project aimed to address technical barriers associated with anode-free LIBs. The project's focus included the development of innovative localized high-concentration electrolyte formulations and gaining insights into the SEI formation and dissolution process. Additionally, the reviewer mentioned that the inclusion of tomography as a characterization technique could potentially enhance the project's approach, although it remained uncertain whether this technique was currently part of the project's scope.

Reviewer 3:

The reviewer emphasized that electrolyte development is crucial for achieving anode-free batteries. They commended the project for its well-designed approach, highlighting its potential to study the effects of electrolytes on SEI formation, thickness variation, and differences between coin cells and pouch cells. The reviewer noted that these investigations could yield critical insights into the feasibility of using localized high-concentration electrolytes for anode-free batteries.

Reviewer 4:

The reviewer found the review challenging due to several factors:

The four electrolytes, denoted as E1 to E4, were not chemically identified in the report.

The first approach mentioned, which is to "understand SEI formation and dissolution process and form SEI in the initial cycles," was not discussed in the report, making it unclear how this approach was implemented or what insights were gained from it.

In full cell testing on Slide 6, one of the electrolytes, E2, showed a significant failure after only 10 cycles, while the others exhibited similar cycling performance with approximately 60% to 70% retention after 100 cycles. The reviewer noted that the standard for cell cycling is to achieve 80% of the initial capacity after formation. Additionally, the cell with electrolyte E2 experienced severe shorting after about 20 cycles, which was not observed in the other cells. However, the report did not provide indications of what was learned from these tests regarding the effect of electrolytes on SEI formation, despite this being an important distinction among the electrolytes.

Subsequent testing in the report focused exclusively on electrolyte E1, but the basis for selecting this particular electrolyte was not provided.

On Slide 7, the report described the use of the E1 electrolyte with and without a polymer coating on the Cu substrate. While the initial cycles showed higher capacity with uncoated Cu, there appeared to be a slight advantage to the coated Cu cell during cycling. However, the difference was very small and possibly within experimental error, making it challenging to evaluate the test results.

The disappointing cycling results with the cells provided by LiFun indicated that the key variables for anode-free cells have not yet been identified.

Given these challenges, the reviewer recommended that the investigators broaden their evaluation of the electrolytes. This could include assessing factors such as conductivity (higher conductivity is preferable), viscosity (lower viscosity is preferable), projected cost (estimation is acceptable), safety (including considerations related to runaway reactions and environmental impact, such as the effect of high fluorine content), as well as cell performance metrics (rate capability, cycling capability, current handling, and energy efficiency).

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The technical progress in the project has yielded some valuable results, including the achievement of a CE milestone of 99.7%. The polymer coating on the Cu substrate showed a slight improvement, and there is a better understanding of the effects of pressure on the system. The successful cycling of multilayer pouch cells and encouraging safety performance in nail penetration tests were also noted as positive outcomes. However, the reviewer raised several concerns:

Technical results for two out of the three milestones required by December 2022 and March 2023 regarding SEI analysis and evaluation were not presented in the review.

While the CE efficiency milestone was technically met in a Cu/Li cell, it was observed that this cell had the worst cycle life in a Cu/NMC cell. This raised questions about the translation of high CE to improved cycling in an NMC cell.

It was not clear whether the cycle data for the polymer-coated anode and the multilayer stacked cells were obtained under pressure or ambient cycling conditions. However, the reviewer found the cycling and CE results for the Li-Fun cells encouraging.

The reviewer recommended addressing these technical weaknesses in future reviews to provide a more comprehensive assessment of the project's progress.

Reviewer 2:

The reviewer acknowledged the considerable progress achieved in developing localized high-concentration electrolytes. However, they suggested that further research might be needed to enhance charge/discharge CE. The findings related to pressure distribution in coin cells and pouch cells were deemed useful for addressing technical barriers in anode-free Li batteries (AFLBs). The nail penetration test demonstrated the safety of the studied AFLB; however, the reviewer questioned the link between this study and the project's overall goals. Lastly, it was noted that while coin cells with optimized pressure outperformed small pouch cells, it remained unclear how the ratio of cell components (e.g., electrolyte content) affected the comparison results.

Reviewer 3:

The reviewer expressed several concerns regarding the project's milestones for Dec. 2022 and Mar. 2023. These concerns include: (1) The milestones indicated a study on SEI formation and dissolution at different SOC levels as complete, but the presentation did not include any experimental results related to SOC dependence; and (2) The PI provided critical results comparing coin cells and pouch cells, which were not originally included in the milestones. Additionally, the reviewer expressed concerns about the lack of alignment between the cycling of full cells and anode half-cell cycling. They highlighted examples where the highest half-cell current efficiency did not correlate with successful full cell cycling. For instance, electrolyte E2 demonstrated the highest half-cell current efficiency but failed in full cell cycling beyond approximately 20 cycles. On the other hand, E1 had the lowest half-cell current efficiency but performed similarly to E3 and E4 in full cell cycling tests. E4 exhibited the best full cell cycling efficiency at the 100th cycle, reaching 74.5% of the initial capacity and the second-highest half-cell current efficiency.

Reviewer 4:

The reviewer recommended a shift in focus toward identifying critical variables that govern cycling on bare Cu and improving both half-cell and full-cell current efficiencies. They suggested exploring factors such as the smoothness of the Cu substrate's effect on initial Li growth, the nucleation energy of Li using the test electrolytes, and the impact of various types of Cu coatings, as these factors could have a significant influence on the cycling characteristics of Li metal.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer acknowledged the collaboration efforts within the project, specifically highlighting the collaboration with the EIC Laboratory for nail tests of pouch cells and with Binghamton University for thermal analysis of electrolytes.

Reviewer 2:

The reviewer noted that collaboration across team members appeared to be good.

Reviewer 3:

The reviewer mentioned that it would be beneficial to carry out the thermal analysis of electrolytes as suggested by Binghamton University to provide a more complete understanding of the capability of the electrolytes.

Reviewer 4:

The reviewer suggested that it would be beneficial to conduct thermal analysis of electrolytes, as recommended by Binghamton University. This analysis would contribute to a more comprehensive assessment of the capabilities of the electrolytes, providing valuable insights into their performance under different thermal conditions.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed uncertainty about the potential success of the project's future work based on the data presented in the review. They found it challenging to determine what new information the program had acquired about anode-free NMC architectures that would enhance cycling and safety performance in the future. The proposed future work included goals such as optimizing electrolyte composition to achieve a Li, CE greater than 99.8%, understanding SEI formation and dissolution mechanisms in the electrolyte, optimizing protection layers on Cu substrates, and improving electrolyte composition for enhanced safety in AFLBs.

Reviewer 2:

The reviewer noted that the approach to achieving these goals was not discussed in detail, and the proposed work seemed similar to what had been completed so far.

Reviewer 3:

The reviewer emphasized the importance of further developing electrolytes to achieve a CE greater than 99.8% and suggested conducting more careful comparisons between coin cells and pouch cells. They recommended using the same cathode material for both cell types to ensure consistent results, as the choice of cathode could significantly affect SEI formation.

Reviewer 4:

The reviewer pointed out the need to improve half-cell cycling efficiency, but they noted that the methodology for achieving this improvement was not addressed. They expressed concern that the key variables limiting the cycling of anode-free cells had not been identified and suggested that addressing this issue might require additional considerations beyond solvent and salt choice, such as the use of additives or treatments for the base

Cu substrate. The reviewer also questioned the reasons behind the notably worse performance of electrolyte E2 compared to others and sought further insights into this discrepancy.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized the significance of electrolyte development in the context of enabling high-energy density batteries and its relevance for advancing DOE goals in EV battery technology.

Reviewer 2:

The reviewer highlighted that the research on AFLBs contributes to increasing knowledge and can potentially lead to the development of high-energy batteries, aligning with DOE objectives in EV battery advancement.

Reviewer 3:

The reviewer underscored that electrolyte development is a critical factor in achieving high-energy density anode-free batteries.

Reviewer 4:

The reviewer noted that improving the cycling characteristics of such batteries could not only enhance cell capacity but also improve rate performance in Li metal batteries, making it an important area of research.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources appear to be sufficient for the project.

Reviewer 2:

The reviewer mentioned that the funding for the existing project seems appropriate, but they suggested that more funding for the proposed future work may be necessary to employ additional characterization techniques for the study of the SEI.

Reviewer 3:

The reviewer noted that the resources are reasonably sufficient.

Reviewer 4:

The reviewer mentioned that the resources seem to be adequate.

Presentation Number: BAT586
Presentation Title: Earth-abundant Cathode Active Materials for Li-Ion Batteries: Cathode Design and Synthesis
Principal Investigator: Jason Croy (Argonne National Laboratory)

Presenter

Arturo Gutierrez, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

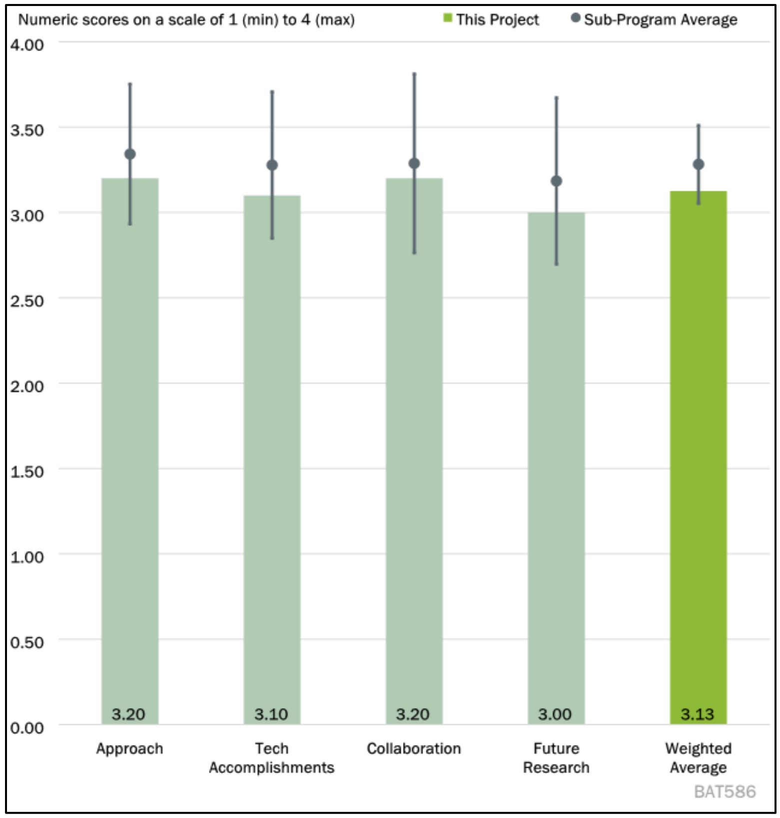

Figure 1-50 - Presentation Number: BAT586 Presentation Title: Earth-abundant Cathode Active Materials for Li-Ion Batteries: Cathode Design and Synthesis Principal Investigator: Jason Croy (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted that the project appeared to be a scatter-shot effort to investigate how to dope manganese-based cathodes (Mn-based cathodes) to enhance their performance. They observed that no justification was provided for why Sn was chosen as a dopant.

Reviewer 2:

The reviewer expressed some confusion regarding the relationship between BAT586 and BAT569 and felt that further clarification would have been helpful. Overall, the reviewer commended the large, integrated nature of the program, which focused on low-Co and EaCAM and noted that it effectively leveraged numerous national laboratory capabilities. They also pointed out that the specific presentation focused on LMR materials, including dopants and precursors, and seemed to align well within the larger framework. The reviewer appreciated the integration of TEA as a positive aspect of the work.

Reviewer 3:

The reviewer considered it a sound approach to select manganese-based cathodes for the EaCAM due to the abundance of Mn compared to Ni or Co. They acknowledged that the team identified critical issues with Mn-based cathodes, such as voltage fade and Mn dissolution, and proposed a sound approach to address them. However, they suggested that it would be helpful for the team to clarify why Sn was chosen as a dopant to mitigate the Li/Mn migration issue in LMR. Additionally, given the numerous variables involved in optimizing the LMR (e.g., precursors, synthesis conditions, surface vs. structural modifications), the reviewer recommended the inclusion of a flowchart outlining their down-selection methodology.

Reviewer 4:

The reviewer pointed out that the stated program barriers included plug-in electric vehicle (PEV) battery cost, performance, safety, and Co content in relation to DOE goals and noted that the approach had the potential to overcome each barrier. They mentioned the absence of a provided plan timeline and explicit task outlines.

Reviewer 5:

In evaluating the project, the reviewer observed that it aimed to develop new strategies for high-energy, EaCAMs, particularly Mn-based materials. They noted that the project leveraged multi-year efforts on LMR cathodes and concluded that the project was well-designed. They found the approaches, which encompassed protocol development, composition optimization, synthesis/processing optimization, and modeling, to be reasonable and effective in achieving the project’s goals.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked that the team had collected a significant amount of data, but they noted a notable absence of effort to comprehend the data. Specifically, the reviewer questioned why Sn may accumulate at grain boundaries and pointed out that there was no attempt to elucidate whether this was advantageous or detrimental.

Reviewer 2:

The reviewer expressed praise for the technical accomplishments of the project. However, they commented that the presentation slides were densely packed with details, making it challenging to discern the specific achievements of this project over the past year. They also remarked that the summary slide seemed to focus more on the overall EaCAM program rather than providing a clear summary of this specific presentation.

Reviewer 3:

The reviewer affirmed that the team had done well in identifying the solubility limit of Sn dopant in LMR cathodes and its impact on structure and grain size. Nevertheless, they pointed out the notable gap of lacking electrochemical data to assess the effect of Sn dopant. They also commented positively on the investigation of the influence of the precursor (hydroxide vs. carbonate) on the first-cycle activation of LMR, considering it valuable information, especially at this stage when the project is only 15% complete.

Reviewer 4:

Stating that the technical progress achieved since the initiation of the program in October 2022 was impressive, the reviewer affirmed that it was accomplished in just six months. They praised the team’s effective review, organization, and prioritization of a vast amount of background data based on program metrics. They also praised the initiation of studies on the use of Sn dopants to modify cathode material structure and the coordination of powerful and comprehensive techniques to investigate Sn solubility and phase structures. However, they pointed out that the modest actual performance improvements demonstrated so far were mitigated by the development of techniques that would facilitate expanded studies involving various chemical modifications.

Reviewer 5:

The reviewer began by noting that the project commenced on Oct. 1, 2022, and affirmed that the team had already generated promising results concerning the effects of Sn doping, grain size, and the choice of Li precursor for synthesis. However, they questioned whether more clarification could be provided regarding the precise impacts of Sn. They pointed out that PDF analysis revealed local structural evolution in the bulk, but TEM analysis indicated that Sn was primarily concentrated at grain boundaries. They questioned whether the effect of Sn was predominantly attributable to changes in the bulk or to the confinement of grain growth.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer acknowledged that there were numerous collaborators involved in the project but noted that the amount of data appeared relatively limited. However, they acknowledged that this limitation could be mitigated by the fact that the project had less than a year to work on it.

Reviewer 2:

The reviewer pointed out that the project involved a large team that leveraged many capabilities. However, they remarked that the specific collaborations for this particular work were not as clear.

Reviewer 3:

The reviewer commented that the team consisted of a good mix of national laboratories and academia. However, they stated that the specific contributions from each team member were not clear. They suggested that having an industrial partner could be helpful to guide the TEA.

Reviewer 4:

Regarding collaboration, the reviewer mentioned that about 80 highly capable team members and 12 major research facilities were involved in supporting the EaCAM programs. However, they noted that specific details on the collaboration were not included in the presentation.

Reviewer 5:

The reviewer highlighted the composition of the team, consisting of investigators from almost all national laboratories. Additionally, they commended the team's efforts in supporting graduate students from more than half a dozen universities.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer questioned the basis for choosing future dopants, noting a lack of clarity on this matter. They observed that the remaining future goals appeared highly empirical, and they expressed a desire to see more effort put into systematizing what is learned from the research.

Reviewer 2:

The reviewer acknowledged that the proposed work was well-designed for cathode development. However, they commented that the placement of this project within the overall context of EaCAM was not entirely clear and suggested that this aspect could be improved for better contextualization.

Reviewer 3:

Commenting on the broad scope of future work proposed, the reviewer recommended the inclusion of a flow chart to illustrate a systematic and rational approach that would guide future efforts in addressing the critical issues.

Reviewer 4:

The reviewer noted the temptation to focus on sophisticated analysis techniques and their further development, as well as seeking deeper insights into existing materials and material classes. However, they emphasized that to overcome barriers, the development of new materials often requires exploring many variations of chemistry, potentially involving dozens of dopant combinations and synthetic variations. They suggested that while detailed physical characterization techniques can provide valuable insights, a greater focus on electrochemical performance might expedite the development of lower Co materials with higher energy density more directly and efficiently.

Reviewer 5:

Regarding the future plan, the reviewer found it reasonable but recommended a more systematic approach. They suggested that, given the numerous parameters involved, such as composition, crystal and local structure, and microstructure, it would be beneficial to reveal the precise effect of one parameter while keeping other parameters constant. Additionally, the reviewer encouraged the integration of more materials modeling work into the future work plan, noting that although it was listed in the milestones slide, it was not explicitly mentioned in the future work slide.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that the endeavor to create superior cathodes was indeed relevant.

Reviewer 2:

The reviewer emphasized the high relevance of EaCAMs within the context of the Batteries program.

Reviewer 3:

The reviewer underscored the high relevance of the proposed Mn-based cathode, particularly in the context of ensuring a resilient battery supply chain.

Reviewer 4:

The reviewer noted that this project held significant relevance to the overarching objectives of the VTO subprogram. This included supporting the development of sustainable supply chains, advancing lower-cost materials, and addressing supply chain challenges associated with materials like Co. The reviewer also highlighted the importance of maintaining or enhancing energy density performance while focusing on full performance objectives related to power, life, and safety.

Reviewer 5:

The reviewer stressed the project’s importance in the development of low-Co cathodes with high energy density, aligning with critical objectives in battery technology.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources appeared to be sufficient.

Reviewer 2:

The reviewer stated that the resources appeared to be sufficient for this work.

Reviewer 3:

The reviewer remarked that the resources seemed sufficient, and this assessment was based on the FY 2023 budget.

Reviewer 4:

The reviewer expressed that excellent facilities and capabilities appeared to be in place to undertake this challenging program. They further noted that funding seemed to be adequate and not excessive.

Reviewer 5:

The reviewer concluded that the resources appeared sufficient for the proposed research.

Presentation Number: BAT588
Presentation Title: Earth-abundant Cathode Active Materials for Li-Ion Batteries: System Analysis
Principal Investigator: Daniel Abraham (Argonne National Laboratory)

Presenter

Daniel Abraham, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

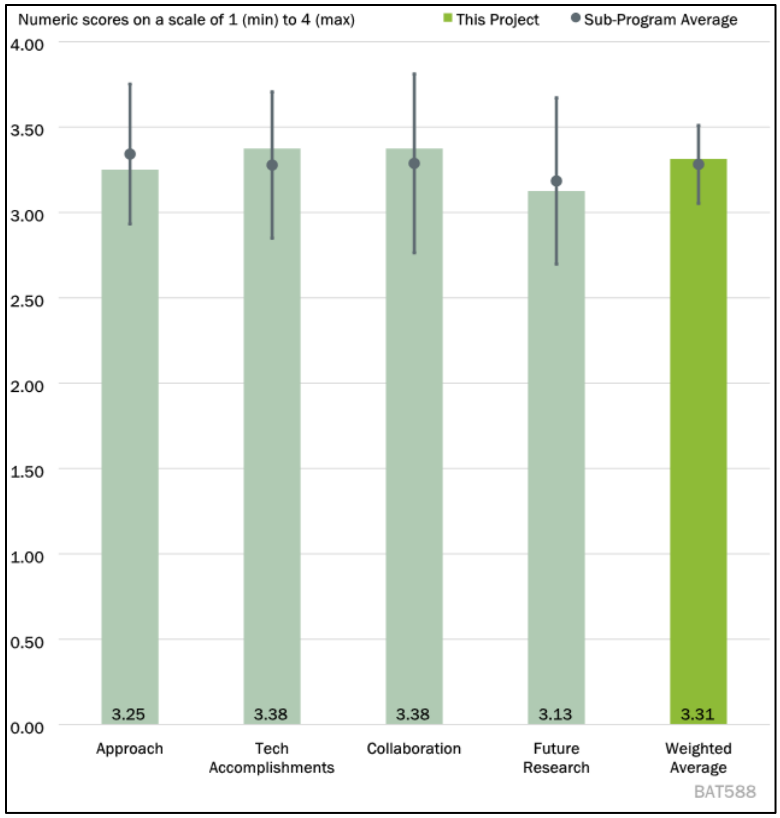

Figure 1-51 - Presentation Number: BAT588 Presentation Title: Earth-abundant Cathode Active Materials for Li-Ion Batteries: System Analysis Principal Investigator: Daniel Abraham (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer outlined the two main objectives of the effort: (1) to develop and examine CAMs that are manganese-rich and obtain information on structure-property-performance relationships; and (2) to identify mechanisms associated with the performance loss (capacity fade, impedance rise, voltage fade) during extended cycling of these cathodes in cells containing anodes such as graphite. They noted that these objectives were an appropriate description of the intended work and effectively leveraged the strengths of the team. The reviewer also commented on the choice of target materials, $Li_{1.1}Mn_{0.55}Ni_{0.35}O_2$ (LMR-NM) and $LiNi_{0.5}Mn_{1.5}O_4$ (LNMO), and the extensive suite of characterization techniques deployed by the team to gain a deeper understanding of material and device performance.

Reviewer 2:

The reviewer found the approach to identify and solve the performance loss of EaCAM to be reasonable. They mentioned the application of a reference electrode and the challenge of electrolyte and additive selection, which may require trial and error. They suggested that theoretical understanding of the electrolyte and electrode interaction could provide valuable guidance for narrowing down electrolyte selections. The reviewer also questioned the need for evaluating LNMO/Graphite cells at 30°C and then 50°C, as the cell capacity fade and impedance rise mechanisms might differ between LMR-NM and LNMO CAMs.

Reviewer 3:

The reviewer highlighted the importance of systems analysis in the EaCAM project and emphasized the significance of measuring and modeling of anode surface interphase, degradation studies, and pouch cell studies with 3D imaging. They noted that standardized protocols were essential to evaluate the significance of the work appropriately and identify promising developments.

Reviewer 4:

The reviewer commended the project's design and timeline, noting that through rational cell design, the main technical issues for different cathode materials had been successfully discovered. They provided an example of how additives into Gen2 played a more important role in improving capacity retention for LMR-NM than coating on cathodes. Additionally, the reviewer highlighted the difference in capacity fading and cell resistance increase between LMR-NM and LNMO cathodes, attributing them to the graphite anodes.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that despite this project being active for less than a year, substantial progress had been achieved in various directions by the research team. They acknowledged that the activities among different groups had been well-coordinated and focused, and progress had been distributed effectively across a wide range of materials and techniques, aligning with the project's stated goals. However, the reviewer pointed out an exception related to Li inventory tracking work, which pertained to different cathode and anode materials than the rest of the presented work.

Reviewer 2:

The reviewer highlighted that this was a relatively new project, commencing in October 2022, and mentioned that it had successfully completed its first milestone, remaining on track to meet other planned milestones.

Reviewer 3:

Several of the methods described were deemed important by the reviewer, indicating excellent progress. They acknowledged that while there was room for improvement in developing better cathode powders, the technical accomplishments in systems analysis were clear and valuable. The reviewer also encouraged the continued use of standard methods and cell builds.

Reviewer 4:

The reviewer commended the team for making good progress and identifying issues that affected the performance of full cells with different cathode materials. They praised the proposed approaches, such as coating and electrolyte optimization, and noted that these had been thoroughly compared and validated through advanced characterizations.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer expressed that the coordination within the team was impressive, especially considering the diversity of efforts represented. They noted that the research accomplished thus far appeared to have been carried out relatively independently within groups, and they identified opportunities to transition from mere coordination to a more highly collaborative approach as the project progresses.

Reviewer 2:

While the project included a comprehensive list of collaborators, the reviewer mentioned that the contributions from major collaborators and partners were not very clear from the presentation.

Reviewer 3:

The reviewer generally observed that collaboration appeared to be positive, albeit challenging to evaluate in such a large program.

Reviewer 4:

The reviewer described the collaboration within the consortium as good.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer commented that while the proposed future work seemed generally reasonable, it lacked specificity. They expressed the hope that clearer pathways to further improvements and focused efforts would have been identified at this stage in the project.

Reviewer 2:

Regarding diagnostic tests, the reviewer found them promising and emphasized the importance of electrochemical models that can illustrate interfacial transport and kinetic parameters. They also highlighted the need for eventual scale-up of the coating technique but noted that the team should focus on developing stable and high-performance coating materials before addressing scale-up. The absence of a clear plan for developing multi-component electrolytes with improved performance was noted, and the reviewer suggested that electrochemical models could be helpful in this regard.

Reviewer 3:

The reviewer stated that the proposed work appeared to align with program goals.

Reviewer 4:

In evaluating the proposed future work, the reviewer found it sensible, with some aspects being particularly vital. They emphasized the importance of evaluating cathodes with standard testing protocols, as it would benefit the larger team, and they also recognized the significance of *in situ operando* tools development to enhance the understanding of performance decay.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized the importance of developing EaCAMs with excellent electrochemical performance in batteries, noting that it was a central goal of the VTO Battery program.

Reviewer 2:

The reviewer stated that this project’s focus on developing CAMs based on earth-abundant elements, such as manganese (Mn), was highly relevant to the EaCAM program’s goal of discovering new strategies in materials design and synthesis using earth-abundant elements for the next generation of Li-ion cathodes.

Reviewer 3:

The reviewer found the work to be relevant to the Battery program goals.

Reviewer 4:

The reviewer found the work to be supportive of the VTO Battery subprogram objectives.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that extensive resources had been allocated to a range of national laboratory and academic partners and anticipated a high return on this level of investment.

Reviewer 2:

The reviewer observed that the project had a decent number of collaborators and access to key material research facilities. To maximize resource utilization, the reviewer suggested focusing on fundamental and theoretical studies of SEI formation and electrode-electrolyte instability mechanisms, rather than relying on trial and error when selecting electrolytes and additives.

Reviewer 3:

The reviewer stated that the program was large, and the resources appeared to be sufficient for its needs.

Reviewer 4:

The reviewer noted that the resources were deemed sufficient for achieving milestones in a timely manner.

Presentation Number: BAT589
Presentation Title: Cation-disordered Cathode Materials (DRX+) - Synthesis, Scale-up and Cell Testing
Principal Investigator: Guoying Chen (Lawrence Berkeley National Laboratory)

Presenter

Guoying Chen, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

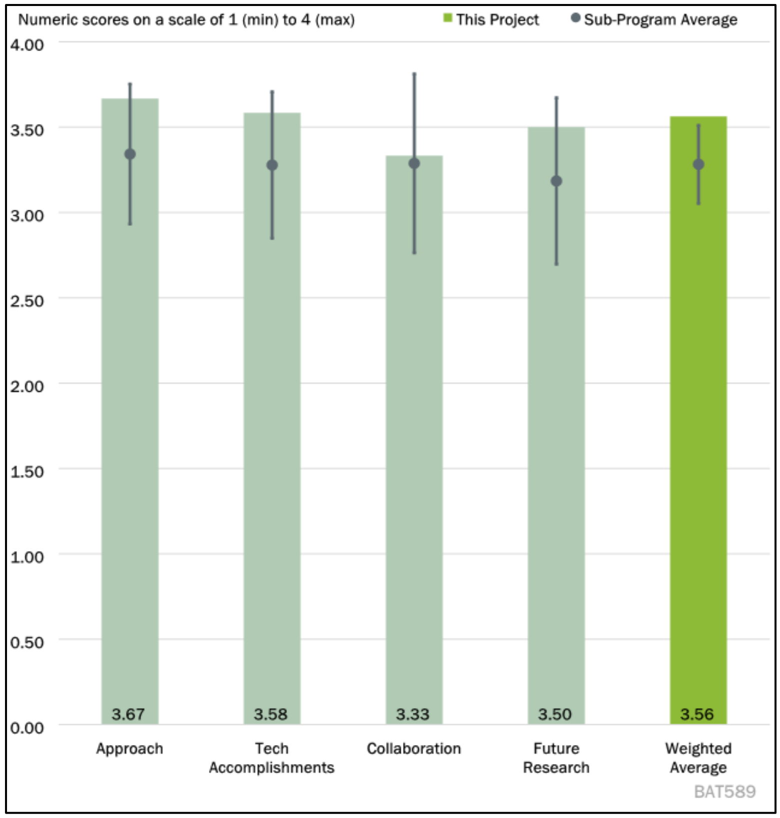

Figure 1-52 - Presentation Number: BAT589 Presentation Title: Cation-disordered Cathode Materials (DRX+) - Synthesis, Scale-up and Cell Testing Principal Investigator: Guoying Chen (Lawrence Berkeley National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer expressed some challenges in evaluating this portion of the DRX+ effort, as the approach described in the presentation seemed to be defined for the entire DRX+ effort rather than for this specific sub-team. They noted the importance of clearly defining the goals specific to this sub-team to facilitate evaluation.

Reviewer 2:

The reviewer acknowledged that the team had employed a combination of synthetic, electrochemical, and structural methods to gain enhanced control over DRX cell performance and understand the cycling-dependent changes in these materials. However, they suggested that while there had been a strong focus on understanding structural changes during electrochemical cycling, complementary efforts to use synthetic methods to control the domain structure and structural changes could be more impactful. The reviewer also raised the possibility of post-synthesis annealing and *in situ* annealing studies to tune phases and domain size for improved electrochemical performance.

Reviewer 3:

The reviewer found the project well-designed with a reasonable timeline and noted that it focused on high-Mn cathode development, which showed promise for high energy density and low cost. However, they indicated that it was still too early to comment on its life since the project had started only 8 months ago, and the material development was in its early stages. The reviewer also suggested demonstrating the total energy above 2.5V for practical applications.

Reviewer 4:

The reviewer outlined the five approaches presented in the project: fine-tuning synthesis conditions, developing conformal coatings, optimizing electrolyte formulation, optimizing electrode fabrication processes, and investigating partially disordered Mn-based high-energy cathode materials. They found the project well-designed with a reasonably planned timeline, aligning with the goal of developing high-capacity cathodes to enhance the energy density of LIBS.

Reviewer 5:

Regarding the continued effort of DRX with the aim to develop cation-disordered Li-excess rock salt cathodes free of Ni and Co, the reviewer commended the combination of computational and experimental work. They expressed satisfaction with the team's focus on coating, electrolyte optimization, and synthesis/process optimization to promote practical applications of these cathodes.

Reviewer 6:

The reviewer noted that the program had just started, and their judgment was based on the proposed work, suggesting a positive path forward. They found the project well-designed, with a reasonably planned timeline, focused on understanding the relationships among performance, composition, and structure of DRX cathodes through advanced characterizations and adjusted testing protocols.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer recognized the team's substantial progress in various project goals, which included scale-up, alternate synthesis methods, identification of structural phase transition signatures, correlation of structure with performance, and the establishment of a high baseline performance floor.

Reviewer 2:

The reviewer commented on the excellent accomplishments in materials synthesis and characterizations within the first 8 months of the project. The reviewer also noted the importance of planned performance tests in full cells to understand side effects on the cathode surface at high charge voltages, particularly because the discharge capacity over cycling in half cells using Li metal as anode may not reflect this type of Li loss.

Reviewer 3:

The reviewer summarized the project's achievements, which included developing a Gen-1 DRX High-Mn class cathode with Mn content up to 0.8, demonstrating high voltage stability, observing anomalous capacity increases and cell impedance decreases, correlating capacity increase with local structural transformation via Li nuclear magnetic resonance spectroscopy (^{7}Li NMR), determining the key role of Mn content in structural properties, and demonstrating scale-up synthesis of GRX Gen-1. The reviewer noted that these accomplishments were particularly impressive given the short timeframe since the project's inception in October 2022.

Reviewer 4:

The reviewer raised questions about the implication for cell balancing negative-to-positive (N/P) ratio if the cathode's capacity continued to increase with cycles and inquired about planned efforts to manage this activation process.

Reviewer 5:

The reviewer noted the team's prolific publication record and the abundant increase in understanding based on these publications.

Reviewer 6:

The reviewer appreciated the team's deep understanding of High-Mn DRX cathodes regarding phase transformation and electrochemical behavior. The reviewer highlighted the significance of this understanding for future materials optimization and performance improvement. Additionally, the reviewer commended the team for achieving the scaling-up of cathodes (60 g/batch), which would benefit other partners and facilitate cathode development.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer pointed out that this project had a large team with a complementary set of skills. However, the reviewer noted that examples of strong collaborations and synergy between team members had not yet been demonstrated, both within this subtask and across the entire DRX+ team.

Reviewer 2:

The reviewer acknowledged that there were sufficient internal and external collaborations with national laboratories and universities but strongly recommended more collaborations with cathode materials suppliers and battery manufacturers. The reviewer also highlighted the potential benefits of the planned collaboration with ANL for scaling up.

Reviewer 3:

The reviewer noted that the impact of LBNL and ANL on the project was well-documented. However, the reviewer found it unclear what role PNNL, ORNL, SLAC National Accelerator Laboratory, and UC Santa Barbara had in the project or their accomplishments. The reviewer mentioned that collaboration and coordination could only be assessed based on the overall technical progress made.

Reviewer 4:

The reviewer considered the team, which involved five national laboratories and one university, to be excellent for this part of the project.

Reviewer 5:

Regarding collaboration, the reviewer mentioned that a standard sample had been shared among the team but found it challenging to judge at this early stage of the program.

Reviewer 6:

The reviewer highlighted the importance of scaling up high-quality DRX cathode powders and the development of new approaches to synthesize cathodes, which could benefit other partners in the consortium. The reviewer also noted that suggestions from industries for scaling up were always helpful.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer remarked that at this early stage, the future goals of the project align with the overall project goals. They noted that the identified needs for DRX improvement were clearly relevant to developing a pathway towards industrial relevance. However, the reviewer pointed out that it was not yet clear whether viable pathways to these goals existed, though this would likely become clearer as the project progressed beyond its initial stage.

Reviewer 2:

The reviewer expressed that the plan for scaling-up was well-constructed, emphasizing the importance of evaluating the high-Mn cathode in larger full cells for practical applications.

Reviewer 3:

The reviewer commented on the project's outline of five proposed future work items:

Further understand the behavior of high-Mn DRX to better utilize their potential as high-energy and high-rate cathode materials.

Improve DRC Gen-1 performance through materials optimization, including composition refinement, structure, and morphology tuning.

Develop new scalable synthesis routes for large-scale powder production.

Optimize composite cathode formulation to reduce carbon content and improve performance.

Develop testing protocols to maximize DRX performance.

Reviewer 4:

The reviewer noted that the project had clearly defined the purpose of future work and expressed confidence that the future work was likely to achieve its targets.

Reviewer 5:

The reviewer stated that the plan for future work appeared reasonable. They also suggested that, given this is DRX-2, it would be beneficial if the developed CAMs could be tested beyond coin cells by leveraging large cell fabrication facilities at national laboratories.

Reviewer 6:

The reviewer affirmed that the proposed future work made sense and that there was a high possibility that the targets could be reached as expected in the plan.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer acknowledged that the DRX system had the potential to meet some important goals of the batteries program, including achieving very high energy densities and developing battery systems using earth-abundant materials exclusively or nearly exclusively. However, they pointed out that this potential was tempered by the uncertainty regarding whether the very large impedances of these systems could be effectively mitigated. The reviewer noted that the sooner and more effectively this mitigation could be achieved, the clearer the need for further investment and development of this system would become.

Reviewer 2:

The reviewer affirmed that the project supported the overall VTO subprogram objectives, particularly in the development of high-energy and low-cost alternative cathodes, especially for EV applications.

Reviewer 3:

The reviewer expressed agreement that the project supported the overall VTO subprogram objectives. They emphasized the project's relevance in achieving high-capacity cathodes with a high Mn content (High-Mn content DRX-cathodes), which had been a bottleneck in high-energy density LIBs.

Reviewer 4:

The reviewer stated that the project would improve energy density and reduce the cost of today's Li-ion batteries.

Reviewer 5:

The reviewer highlighted that this approach represented one of the few ways to develop a high-energy storage cathode that could exceed the energy storage capability of high-Ni NMC cathodes.

Reviewer 6:

The reviewer concluded by affirming that this project fully supported VTO Battery subprogram objectives.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that very substantial resources were devoted to this project.

Reviewer 2:

The reviewer affirmed that the resources were sufficient. They suggested that it might be more helpful to have industrial partners in addition to ANL to scale up to kilogram levels.

Reviewer 3:

The reviewer expressed agreement that the resources for this project were sufficient to achieve the stated milestones in a timely fashion.

Reviewer 4:

The reviewer commented that the resources looked reasonable.

Reviewer 5:

The reviewer noted that the resources for the entire program were sufficient for the fundamental work of this effort.

Reviewer 6:

The reviewer concluded that the resources were sufficient for the milestones to be achieved on time.

Presentation Number: BAT592
Presentation Title: Advanced Anode Manufacturing Through Ultra Thin Li Deposition
Principal Investigator: Subramanya Herle (Applied Materials, Inc.)

Presenter

Subramanya Herle, Applied Materials, Inc.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

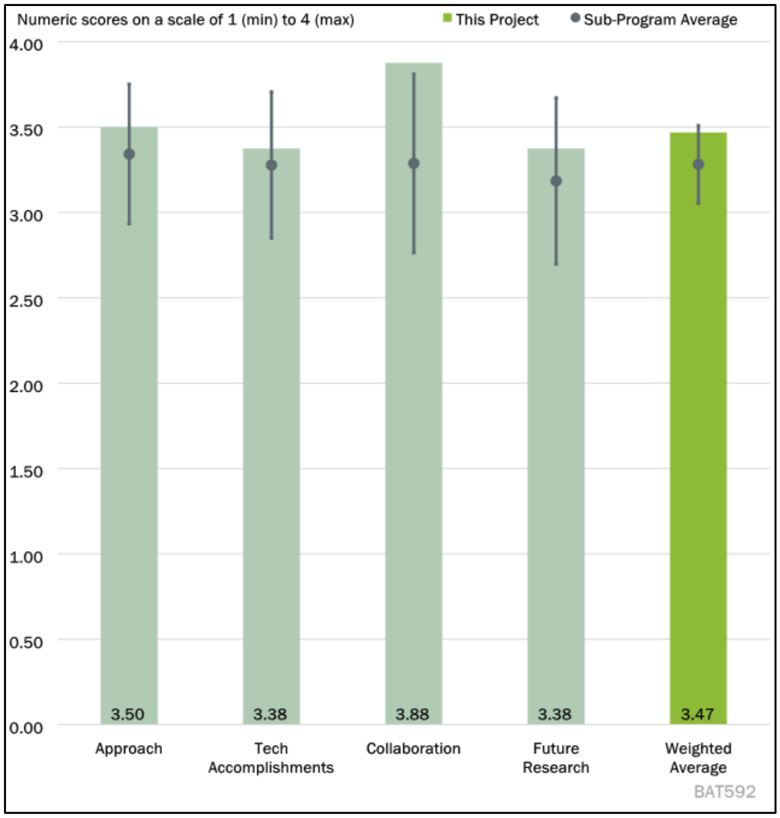

Figure 1-53 - Presentation Number: BAT592 Presentation Title: Advanced Anode Manufacturing Through Ultra Thin Li Deposition Principal Investigator: Subramanya Herle (Applied Materials, Inc.)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the main technical barrier was clearly stated in terms of addressing high-volume manufacturing (HVM) of high-energy density anodes for Li-ion/metal batteries.

Reviewer 2:

The reviewer commented that the technical approach was well laid out, specifically mentioning the use of a roll-to-roll Li-deposition approach to enable pre-lithiation of SiO_x-C anodes and the fabrication of ultra-thin Li-metal anodes. They also noted the strong partnership with industries and national laboratories for performance validation and techno-economic evaluation, with clearly defined targets (energy density, cycling life, cost), which was crucial for demonstrating the final project deliverables. The reviewer acknowledged that this was a challenging project but highlighted the expertise of the assembled team and their significant progress in the past two budget periods. They mentioned that although there had been some delay, all the milestones were scheduled to be delivered.

Reviewer 3:

The reviewer described the project's aim to provide high-volume manufacturing capability for roll-to-roll Li-metal deposition, for pre-lithiation of SiO_x-C anodes, and Li-metal anodes. They noted that the major tasks were mainly completed with a commercial SmartWeb™ platform but expressed some uncertainty regarding the technical barriers addressed to acquire this capability. The reviewer mentioned that the project provided Li-metal deposition and surface coating services to collaboration partners for pouch cell fabrication and testing.

Reviewer 4:

The reviewer explained that the investigators were developing lithiation processes for Li deposition and pre-lithiation of SiO_x to increase the energy density of these systems while aiming not to negatively impact cycle life. They noted the plan to develop high-rate processes that added little cost to manufacturing to make the overall battery cheaper. The reviewer observed that the team appeared to be making progress on multiple fronts and considered the project well-designed, having addressed its technical barriers effectively.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer praised the significant progress made in demonstrating roll-to-roll Li deposition for high-volume manufacturing (HVM), particularly for pre-lithiation of SiO_x-C anodes and the fabrication of ultra-thin Li-metal anodes. They noted that the targeted performance for budget period (BP) 2 had been achieved, and good progress was being made towards achieving the target performance for BP3. The reviewer commended the PIs/reporters for their presentation of electrochemical performance, stating that they had done fantastic work by including all technical details, clearly defined experimental procedures, and measurement parameters. However, they suggested that in the final report, the PIs may want to clarify how the N/P ratio of 0.5:1 was defined (Slide 13). Additionally, the reviewer mentioned that it might be necessary to provide clarification on the very high specific capacity, up to 200 mAh/g, reported for the NMC622/Li cell within the limited voltage range of 2.7V–4.4V (Slide 25).

Reviewer 2:

The accomplishments of the project were detailed, including the fabrication of pre-lithiated SiO_x anodes used in the R&D cells of Ionblox and the delivery of Li-metal anodes to SAFT America for 10 Ah pouch cells. The reviewer noted that in the comparison test, the cell with the pre-lithiated SiO_x anode and the SiO_x cell without pre-lithiation had similar performance, with the pre-lithiated SiO_x anode delivering slightly less capacity and poorer retention at the end of 900 cycles. They mentioned that the benefits of the ultra-thin Li deposition were not shown in the test. The reviewer also highlighted the accomplishment of the 300 Wh/kg pouch cell with NMC622 cathode and 10 um Li anode, which met the targeted 70% retention after 300 cycles. They noted that the purpose of the pre-lithiation procedure was to compensate for the first-cycle Li loss in the SiO_x anode, but this effect was not demonstrated in the report.

Reviewer 3:

The reviewer provided additional information about the performance of cells with pre-lithiated SiO_x built with IonBlox and Li-metal/NMC cells built with Saft America. They mentioned energy densities, cycle numbers, and capacity retention percentages for these cells. However, they raised a concern about whether the cells utilizing a small initial amount of Li metal would eventually succumb to catastrophic failure once the Li ran out.

Reviewer 4:

The reviewer acknowledged that the team had discovered some opportunities to evaluate alternative methods, which had led to a pivot in the direction for some products. They commended this innovation in development.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer highlighted the strong collaborations across national laboratories and industries that have been demonstrated under this project. They mentioned that these collaborations encompass a broad range of topics, including large-format cell fabrication, performance validation, and techno-economic modeling.

Reviewer 2:

The reviewer noted that the project's main charged task is to provide high-volume and large-format Li deposition services, and as such, they rely heavily on collaborators for cell manufacturing and testing, electrolyte development, and metrology support.

Reviewer 3:

The reviewer acknowledged that there is a significant number of contributors to this program, all making significant contributions based on their expertise.

Reviewer 4:

Despite some program delays, most of which were attributed to COVID-related events, the reviewer expressed that an excellent level of collaboration has been exhibited.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer noted that the future work for this project is well defined, particularly with a focus on cell fabrication by industrial partners and final performance validation by INL.

Reviewer 2:

The reviewer recommended approving the no-cost extension to allow the team to complete the listed works.

Reviewer 3:

The reviewer mentioned that the modeling suggests there is room for further improvements, which the team intends to pursue.

Reviewer 4:

The reviewer suggested that the team should emphasize which preferred coated products will be used in the final builds and make this information more explicit.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer expressed agreement with the project's relevance in supporting the needs of manufacturing high-energy density anodes, which is a focused area under the VTO program.

Reviewer 2:

The reviewer noted that developing high-volume manufacturing for large-format Li metal deposition capability contributes to building a strong US Li-ion battery industry.

Reviewer 3:

The reviewer acknowledged that the project is making significant advances in energy density and cost reduction for batteries related to the VTO program.

Reviewer 4:

The reviewer emphasized the importance of supporting advanced technology processes that benefit the US industrial workforce.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that the project has access to significant resources through broad collaborations.

Reviewer 2:

The reviewer stated that the project is close to completion and can be completed with enough resources.

Reviewer 3:

The reviewer mentioned that the project is close to completion and can be successfully completed with the resources available.

Reviewer 4:

The reviewer found no issues with the funding or resource allocation for the project.

Presentation Number: BAT593
Presentation Title: Strategies to Enable Lean Electrolytes for High Loading and Stable Lithium-Sulfur Pouch
Principal Investigator: Shirley Meng (University of California at San Diego)

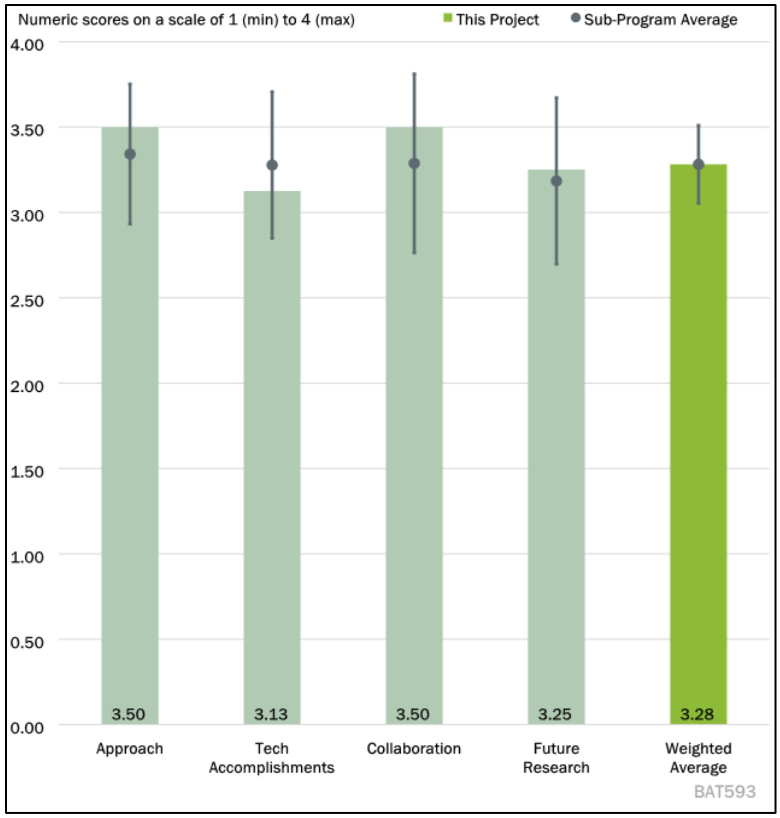

Figure 1-54 - Presentation Number: BAT593 Presentation Title: Strategies to Enable Lean Electrolytes for High Loading and Stable Lithium-Sulfur Pouch Principal Investigator: Shirley Meng (University of California at San Diego)

Presenter

Shirley Meng, University of California at San Diego

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated "The project aims to enable lean electrolytes through the development of a strategy focused on creating and utilizing a dense stacking redox-active hexaazatrinaphthylene (HATN)-based cathode." It was noted that it remains unclear whether the approach prioritized cathode development or additive development to address polysulfide dissolution, which leads to sulfur inventory loss and continuous electrolyte consumption.

Reviewer 2:

The reviewer praised the work, remarking that it was excellent in the realm of thick, high-loading sulfur electrodes and electrolyte modifications. Specifically, the reviewer expressed that it effectively facilitated lean electrolyte cycling, which is deemed critical for achieving high Wh/kg cells.

Reviewer 3:

The reviewer articulated that the project, as reviewed, was well-designed to enhance and demonstrate the performance of Li-S cells with a capacity exceeding 1 Ah under conditions pertinent to practical cells. These conditions include a high capacity of 10 mAh/cm^2 and lean electrolyte environments. The overarching goal, as observed, is to align with DOE objectives of achieving high specific energy (more than 500 Wh/kg) and low cost ($80/kWh). The reviewer stated that the approach adopted involved the development of low-porosity, high-S loading cathodes featuring a redox-active HATN conjugated polymer. The project also includes efforts to identify life-limiting mechanisms, pinpoint advanced electrolytes functional at low E/S ratios, and devise methods to estimate sulfur and Li inventories during cycling. This review affirmed that the project is relevant to and consistent with DOE’s mission of advancing battery technology (Li-S) with higher energy density, extended lifespan, and reduced cost compared to current Li-ion batteries used in EVs. The reviewer questioned the project’s direction, identifying two key weaknesses: (1) Despite the promising nature of the electrolyte additive, the reviewer asked why the active material loadings examined in the project remained relatively low, not aligning with the stated target of 10 mAh/cm^2. Furthermore, it was observed that the E/S values appeared high, deviating from the requirements for high-energy cell designs; and (2) The reviewer also noted a discrepancy, as it seemed that the data presented here pertained to coin cells rather than the pouch cells mentioned in the project’s stated objectives.

Reviewer 4:

Upon review, the reviewer verified that the project had concentrated its efforts on R&D endeavors aimed at enabling the operation of Li-S cells under lean electrolyte conditions. The approaches proposed, involving dense electrode materials, new electrolytes, and advanced characterization and quantification methodologies, were deemed scientifically sound and applicable to real-world conditions.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer observed that the identification of an additive to replace the conventional $LiNO_3$ showed promising improvements in cyclability. However, there were limitations due to Li inventory loss, and it was suggested that future work should establish a link between this loss and longer-term performance. On Slide 8, it was noted that the claim of ‘good capacity retention’ seemed overly optimistic, given that the cycle results were limited to 76 cycles, before any potential significant drop-off. Additionally, the reviewer pointed out that the claim of 65% capacity retention was not immediately evident from the data displayed. There appeared to be a discrepancy between the observed S inventory loss and polysulfide corrosion compared to the assessment of baseline performance.

Reviewer 2:

The reviewer remarked that preliminary cycling data was presented, showing relatively poor performance with a 35% fade in 75 cycles. It was acknowledged that this performance was being pushed to the limits of loading and electrolyte capacity.

Reviewer 3:

The reviewer commented on the progress made in demonstrating the fabrication of dense sulfur (S) cathodes with high loadings and low porosity (7 mAh/cm^2). However, it was highlighted that the electrode exhibited poor performance even at low rates (C/10) and demonstrated poor cycle life, even at high E/S ratios. The new electrolyte additive showed promise as a potential alternative to $LiNO_3$ in Li-S cells. Notably, the thermogravimetric analysis (TGA) of the cycled hexaazatrinaphthylene/carbon nanotube-sulfur (HATN/CNT-S) cathode revealed significant sulfur inventory loss. Additionally, severe polysulfide-induced corrosion in the cycled Li anode was observed. Two weaknesses were identified: (1) The test conditions employed, particularly E/S and N/P ratios, did not align with the targeted values for high-energy cells, and the cycle life of the dense cathode was suboptimal; and (2) The data presented appeared to pertain to coin cells, which may not fully align with the project's goals of pouch cell demonstration.

Reviewer 4:

The reviewer acknowledged that the project had made commendable progress in cathode materials, electrolyte development, and advanced characterization during the budget period. However, there were some technical questions that needed clarification. Notably, the cathode material had been previously reported by the team. It would be valuable to understand the differences or improvements achieved with the hexaazatrinaphthylene/carbon nanotube-sulfur (HATN/CNT-S) compared to the previous iteration. While the sulfur electrode had achieved the target mass loading of 5 mg/cm^2, it remained unclear what the sulfur utilization rate (mAh/g) was at such loading and low porosity. Furthermore, the proposed low E/S ratio of 3 g/Ah had not been applied in the cell tests, leaving uncertainties regarding how well the HATN/CNT or dense electrode functions under lean electrolyte conditions.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the project effectively manages the collaboration and roles of each contributor.

Reviewer 2:

The reviewer praised that the team is working alongside GM and Ampcera.

Reviewer 3:

The reviewer mentioned that there are ongoing collaborations with General Motors, led by Dr. Mei Cai, for pouch cell fabrication, and with Dr. Hui Du from Ampcera Inc for the scale-up of electrode materials. The reviewer suggested that it would be beneficial if the team could foster more collaboration with the B500 team, particularly concerning the determination of Li and S inventory losses in their systems.

Reviewer 4:

The reviewer acknowledged the project’s strong collaborations with industries for materials scaling up and pouch validation.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer recommended that, given the limitations of the baseline data, more emphasis should be placed on identifying the limiting factors affecting cycle life under lean electrolyte conditions.

Reviewer 2:

The reviewer suggested that perhaps the scalable synthesis of this electrode should not be prioritized until there is a significant improvement in performance. The reviewer noted that improved cycle life and a better understanding of what is causing the fade are on the future task list, which is seen as a positive development.

Reviewer 3:

The reviewer acknowledged the proposed future studies as well-laid-out, starting with the identification of the life-limiting processes during cycling for Li-S under very lean electrolyte conditions. The plan includes establishing mitigation strategies to demonstrate improved cycle life compared to the baseline, with goals of achieving over 100 cycles and exceeding 300 Wh/kg. Additionally, there are plans to scale up fabrication methods for HATN polymer. However, the reviewer expressed uncertainty about what is being planned to decrease the cost of raw materials for Li-S cells toward DOE cost goals of less than $68/kWh. A weakness identified was that one or two tasks should be dedicated to demonstrating these materials in pouch cells and identifying and mitigating the pouch cell environment under lean electrolyte conditions.

Reviewer 4:

The reviewer concluded by acknowledging that the future research plan presented measurable deliverables, which was considered positive.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized that this project directly addresses the achievement of energy density and cost goals outlined in the VTO objectives, making it highly relevant.

Reviewer 2:

The reviewer noted by the reviewer that the project’s relevance is underscored by the fact that sulfur (S) is abundant and offers high energy potential.

Reviewer 3:

The reviewer highlighted that the project aligns with the overall objectives of DOE by working towards the development of advanced Li-S cells with higher specific energy, lower cost, enhanced safety, and improved cycle life when compared to LIBs. It was also mentioned that while Li-S technology with liquid electrolytes presents challenges, this project is focused on mitigating the polysulfide shuttle and enhancing cycle life through the use of a new binder and electrolyte additive. Overall, the project’s alignment with DOE VTO’s Batteries subprogram objectives and goals was affirmed.

Reviewer 4:

The reviewer pointed out that the focused research on Li-S batteries directly supports VTO’s vehicle electrification objectives by contributing to the development of high-energy and cost-effective energy storage technologies.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the project funds are sufficient for achieving the goals of the project.

Reviewer 2:

The reviewer described the resources as reasonable.

Reviewer 3:

The reviewer noted that resources for the overall project are commensurate with the scope, which is seen as adequate to achieve the targeted milestones. However, there was a lack of clarity regarding the allocation of funds specifically for this team.

Reviewer 4:

The reviewer expressed that the team has sufficient resources to achieve the proposed research plan and milestones. Notably, collaborations with industries were highlighted as valuable resources that would support materials scaling up and pouch cell validation targets.

Presentation Number: BAT594
Presentation Title: New Engineering Concepts to High Energy Density Li-S Batteries
Principal Investigator: Prashant Kumta (University of Pittsburgh)

Presenter

Prashant Kumta, University of Pittsburgh

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

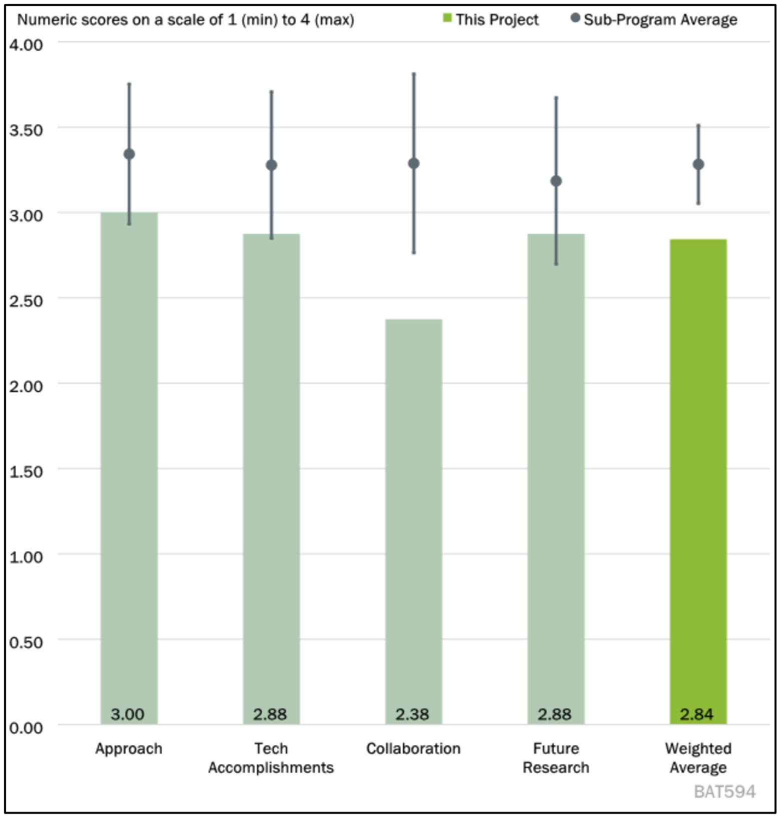

Figure 1-55 - Presentation Number: BAT594 Presentation Title: New Engineering Concepts to High Energy Density Li-S Batteries Principal Investigator: Prashant Kumta (University of Pittsburgh)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

In response to the project's goals and approach, the reviewer noted that taking on the improvement of both the Li and sulfur electrodes is impressive for a project of this size. However, there were concerns about the battery design table, which outlines the ideas for achieving high specific energy, particularly the need for 15 mAh/cm^2 electrodes. The reviewer pointed out that this electrode size might be suitable for stationary applications but could pose challenges in transportation applications requiring higher discharge rates. Additionally, the high weight of the electrolyte in the cells was noted as an issue, suggesting high porosity in the electrodes. The reviewer expressed interest in seeing the cell's volumetric energy density as well. The reviewer found it disappointing that the project lacked specifics on the exact methods and approaches being used, making it difficult to judge the uniqueness of the effort. They mentioned concerns about the lack of details on the composite alloy Li electrode and the shell-core structure for sulfur containment. While the importance of protecting intellectual property was acknowledged, the reviewer suggested finding a better balance.

Reviewer 2:

Regarding the project's alignment with the B500 program's needs for high-energy and long-life battery technology, the reviewer highlighted the focus on advancing Li-S technology through various components and modeling techniques. The project's comprehensiveness and relevance to DOE goals for high-energy battery technology were acknowledged. However, the reviewer identified weaknesses in the project. Firstly, they believed that the project's approach, while multipronged, did not adequately address the key barrier of the polysulfide shuttle and poor cycling, hindering the achievement of performance goals. Secondly, the reviewer found the technical milestones, especially the year 2 go/no-go milestone, to be too optimistic and unrealistic, particularly in achieving specific performance metrics.

Reviewer 3:

The reviewer concluded by recognizing the project's promising goals and practical targets but recommended that more research efforts be directed towards materials, electrode development, and cell-level integration to better approach and achieve these goals.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer acknowledged that the Li stripping and plating aspects appeared excellent, but they expressed confusion regarding why the utilization of S remained low. They noted that one of the project's goals is to make better use of the theoretical capacity of 1675 mAh/g, and none of the cathode constructions had come close to achieving that goal.

Reviewer 2:

The reviewer mentioned that there was a range of electrochemical technical results from the development of both electrodes, supported by theoretical calculations, indicating significant progress. However, they expressed uncertainty about whether all the Year 2 deliverables could be accomplished based on the presented results. The reviewer also noted that there appeared to be current efficiency issues with the cell, suggesting that not all the sulfur was contained.

Reviewer 3:

Regarding the identification of electrocatalysts and new Li alloys, the reviewer acknowledged that significant progress had been made, especially with ternary systems showing enhanced kinetics for reversible polysulfide conversion. They also noted the promising performance of the MCA4 alloy. New electrolyte additives and stabilization of the Li anode during plating and stripping were mentioned as accomplishments. Integration of these components into pouch cells with improved cycle life was also recognized. However, the reviewer pointed out several weaknesses in the project:

The achieved performance levels were considered promising but not on par with program goals. Achieving 500 Wh/kg and 1000 cycles was viewed as potentially unrealistic with the selected cell components, and there was a substantial risk of missing the year 2 go/no-go milestone.

The project lacked information on the chemistry or composition of the catalysts and alloys, which was considered unusual for a university-led and DOE-funded research project.

The reviewer suggested that the project did not appear to address the most significant deterrent mechanism, the polysulfide shuttle, with the current cathode design or other cell components. Additionally, the reviewer noted that the amount of electrolyte being used E/S was too high for the high specific energies targeted.

Reviewer 4:

The reviewer mentioned that while the team reported accomplishments in modeling, cathode materials, electrolyte additives, and Li anode current collector, they found it challenging to identify useful information on chemistry or composition throughout the report. They suggested that the project placed too much emphasis on simulation, which they deemed less relevant to the project's goals. Additionally, it was noted that many materials, including Li-ion conductor-carbon fiber mat-sulfur (LIC-CFM-S), had been reported previously, and it was unclear what new progress and improvements had been achieved in the budget period under this project.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that there is little planned collaboration in the project, and they found this to be acceptable.

Reviewer 2:

The reviewer commented that collaboration appeared to be minimal, at best, based on the information available to them. They were surprised that there was limited collaboration even with the B500 team members.

Reviewer 3:

The reviewer identified the weakness that it would be helpful to have some form of collaboration, whether in the development of electrolytes or in the design and fabrication of pouch cells, possibly with a national laboratory or an industry partner within the B500 team.

Reviewer 4:

The reviewer pointed out that there was no collaboration slide included in the report, and they were unable to identify any collaborators. Blomgren Consulting, Ltd was mentioned in the overview slide, but their contributions were unclear.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed that the project has a very full and comprehensive plan to address its remaining objectives.

Reviewer 2:

The reviewer noted that the PI seems determined to continue pushing the technology forward. However, due to the limited details provided, they found it challenging to suggest specific next steps.

Reviewer 3:

The reviewer commended plans for future studies as being well laid out. These plans include the development of the next generation of high sulfur-loaded CFM systems with electrocatalysts and Li-ion conductor (LIC) coatings derived from DFT calculations. Additionally, further development of the MCA alloy and the Li-SIA alloy (although it was noted that the nature of the latter is unclear) and the identification of new electrolyte additives with reduced polysulfide solubility were mentioned. These studies were seen as aligned with the initial proposals and were expected to address issues related to the slow kinetics of solid polysulfides and the performance losses caused by the sulfide shuttle. However, the reviewer identified weaknesses in the project:

The reviewer expressed doubts about the project’s ability to significantly improve the performance of Li-S cells to levels close to the targeted goals, particularly in terms of catalysts, alloys, electrolytes, and the CFM sulfur cathode.

The project was noted to be similar to another project being conducted by the same team, with the primary difference being the sulfur host material (carbon to ceramic). The reviewer raised concerns about the extent of overlap between the two projects and suggested that consolidation might be necessary.

Reviewer 4:

The reviewer found that there was no reasonable action plan closely adhering to the upcoming measurable milestones or go-no/go goals. The reviewer believed that giving experimental work a higher priority over simulation could aid in achieving the Year 2 goals.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized the high relevance of the project, particularly highlighting the need for high-loading and highly utilized sulfur (S) electrodes.

Reviewer 2:

The reviewer stated that the work is very relevant to the advancement of battery technology.

Reviewer 3:

The reviewer pointed out that the project aligns with the overall objectives of DOE by working towards the development of advanced Li-S cells with higher specific energy, lower cost, enhanced safety, and improved cycle life compared to LIBs. The challenge posed by the polysulfide shuttle in Li-S technology with liquid electrolytes was acknowledged, and the project was noted to focus on mitigating this issue while improving cycle life using new sulfur hosts, catalysts, anodes, and electrolyte additives. Overall, the project was seen as relevant to VTO Batteries subprogram objectives and goals.

Reviewer 4:

The reviewer recognized the promising advantages of Li-S battery technology in terms of energy density, safety, and cost. They stated that the success of the project would directly support the VTO’s objectives of vehicle electrification and decarbonization.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found that the resources allocated to the project were reasonable and represented good value for the research and development investment.

Reviewer 2:

The reviewer noted that the PI had promised a lot for the funds available, but the PI was clearly attacking all the major challenges of the technology, which is impressive.

Reviewer 3:

The reviewer mentioned that the resources for the overall project appeared to be commensurate with the scope and adequate to achieve the targeted milestones.

Reviewer 4:

The reviewer suggested that while the team had sufficient resources, it was essential for the team to prioritize their research efforts towards the project goals.

Presentation Number: BAT595
Presentation Title: Development of Li-S Battery Cells with High Energy Density and Long Cycling Life
Principal Investigator: Donghai Wang (Penn State University)

Presenter

Donghai Wang, Penn State University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

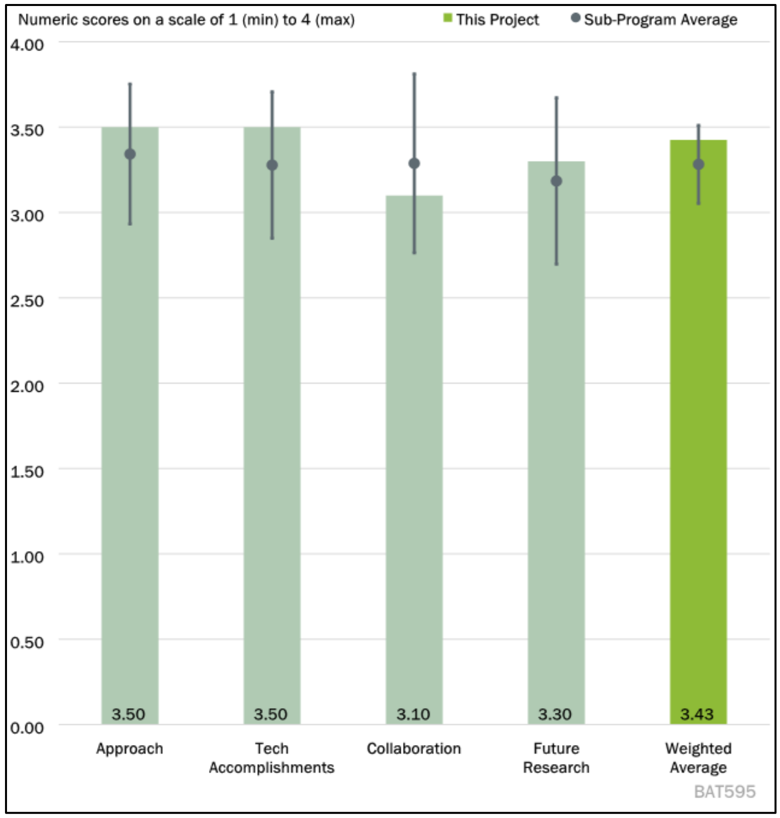

Figure 1-56 - Presentation Number: BAT595 Presentation Title: Development of Li-S Battery Cells with High Energy Density and Long Cycling Life Principal Investigator: Donghai Wang (Penn State University)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked that the project has a well-defined approach to developing sulfurized polymer composite (SPC) active material to mitigate capacity fade caused by Li inventory loss, specifically polysulfide formation and shuttling.

Reviewer 2:

The reviewer praised the project for its effective strategy in developing high-loading sulfur cathodes and stable electrolytes.

Reviewer 3:

The reviewer expressed that the approach of attaching sulfur to a polymer backbone to prevent polysulfide dissolution in the electrolyte has been shown to be valid. The reviewer mentioned the use of polyacrylonitrile (PAN), in previous literature and noted the undisclosed polymer used by the PI. Furthermore, the reviewer questioned the need for a simple calculation regarding cell-specific energy and energy density and expressed a desire for more interaction with the PI.

Reviewer 4:

The reviewer stated that the project is well-designed to develop Li-S cells with sulfurized polymers as active material to address the polysulfide shuttle problem and extend cycle life, albeit with lower specific energies. The reviewer outlined specific objectives related to sulfur composite materials, binders, and diagnostics.

Additionally, the reviewer questioned the feasibility of certain energy goals and the necessity for a high E/S in a cathode without soluble polysulfides.

Reviewer 5:

The reviewer affirmed that the project proposes to use SPCs and functional binders to resolve polysulfide-related issues in liquid Li-S batteries. The reviewer commended the project for its approach, which draws on careful investigation of state-of-the-art techniques and proven effectiveness.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the technical accomplishments indicate good stable performance with a high E/S and specific capacity retention relative to conventional baseline approaches.

Reviewer 2:

The reviewer expressed curiosity about the plot shown on Slide 13 with the 4 mAh/cm^2 sulfur cathode, particularly regarding the discrepancy between the goal of 1000 mAh/g and the specific capacity not being shown. The sharp drop-off in capacity observed at around 120 cycles also raised questions about its cause.

Reviewer 3:

The reviewer acknowledged the PI's clear progress while also suggesting that there is still work to be done to reduce the E/S ratio and increase the aerial capacity. Furthermore, the reviewer mentioned the desire to see efficiency presented on an expanded scale. The analytical work indicated that the polymer may not completely hold the sulfur, and it would be beneficial to determine whether the issue lies in sulfur detachment from the polymer during cycling. The reviewer suggested conducting cycle life studies at relatively high rates, ideally C/3 or higher, and increasing the number of cycles. The potential use of a thick lithium titanium oxide (LTO) electrode as a replacement for the Li electrode was also mentioned.

Reviewer 4:

The reviewer commended the project's progress in synthesizing new SPC material, which demonstrated a higher discharge capacity of 1000 mAh/g, showed the generation of polysulfides in carbonate electrolytes, and exhibited better kinetics compared to conventional sulfurized polyacrylonitrile (SPAN) materials. The redox behavior of SPC, including lithiation and delithiation, was well-characterized. Additionally, a SPC-based cathode with a moderate aerial capacity (4 mAh/cm^2) and a polymeric binder was fabricated, demonstrating fairly decent cycle life. However, the reviewer pointed out several weaknesses: (1) The discharge voltage is too low, making a 4 mAh/cm^2 aerial capacity inadequate to provide sufficient energy, especially with an E/S of 5; (2) The cycle life of 150 cycles is not impressive, especially considering the absence of a sulfide shuttle; (3) The reviewer emphasized the need for a working performance model to guide the project and determine key performance parameters of the cell components, as well as the expected specific energy at the prototype pouch cell level (which should be at least 250 Wh/kg); and (4) Lastly, the reviewer emphasized the importance of demonstrating specific energy and cycle life at the pouch cell level to establish the project's high relevance to DOE goals.

Reviewer 5:

The reviewer concluded by highlighting the team's successful development of the SPC cathode, compatible binder, and their deep understanding of the reaction mechanism. The material's impressive performance in a Li-S coin cell, outperforming conventional SPAN materials, indicated a good potential for practical cell demonstration. The use of carbonate-based electrolytes was also noted as advantageous in terms of durability and safety, although the reviewer mentioned that addressing the issue of low first-cycle efficiency would be a future focus of the project.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commented that it is unclear what role the UIC (University of Illinois at Chicago) team contributes to the project.

Reviewer 2:

The reviewer commended the PI for reaching out to collaborators to assist with some of the analytical studies.

Reviewer 3:

The reviewer cited ongoing collaborations with the University of Illinois at Chicago and the Brookhaven National Laboratory. The latter is being utilized for XAS and PDF experiments, but it is not clear what UIC is subcontracted for, perhaps DFT calculations? A suggestion by the reviewer was that it would be useful to collaborate with an industrial partner or, at the very least, a national laboratory (e.g., PNNL or INL) to demonstrate the materials in pouch cells in parallel with material development.

Reviewer 4:

The reviewer noted that the team has good collaborations with other universities and national laboratories for modeling and advanced characterization.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the future work related to the SPC is identified and consistent with the project objectives. However, the reviewer pointed out that while the goal of improved polymer binder development is important, the proposed future effort toward this goal is not thoroughly identified. Based on the results and analysis, specific directions for this aspect are not readily apparent.

Reviewer 2:

The reviewer remarked that the project is focused on the correct issues as expected.

Reviewer 3:

The reviewer expressed concern that there are not a lot of specifics in the future work. The impression given is that the PI believes they have what they need to reach their goals and only need to optimize things. The reviewer remained unconvinced by this approach.

Reviewer 4:

The reviewer acknowledged that there are still significant challenges in achieving high specific capacity without generating soluble polysulfides with the SPC materials and in achieving good performance in higher aerial-capacity cathodes at low E/S and N/P. The proposed future studies are seen as partially addressing these challenges, such as developing and demonstrating a high capacity of 800 mAh with SPC-based cathode materials in optimized electrolytes without polysulfide generation and achieving good cycle life. The reviewer also noted the plan to fabricate cathodes with higher aerial capacity using new polymer binders. A weakness highlighted by the reviewer was the need for a performance model that supports the performance goals, demonstrating that with these performance values, a high specific energy of at least 250 Wh/kg is possible. Additionally, the reviewer emphasized the necessity for quantification of the targeted cycle life.

Reviewer 5:

The reviewer recognized that the proposed future research aims to further improve the specific capacity of cathode material and the processing of high mass loading electrodes, which are considered reasonable and relevant to the high-energy target. Furthermore, the reviewer mentioned that future research would focus on understanding and addressing the issue of low first-cycle efficiency.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that this project is directly relevant to the energy density and cost goals of the VTO subprogram objectives.

Reviewer 2:

The reviewer noted that the project is highly relevant for next-generation batteries using earth-abundant materials.

Reviewer 3:

The reviewer expressed that this work is very relevant to the battery area.

Reviewer 4:

The reviewer emphasized that the project supports the overall DOE objectives by developing advanced Li-S cells with higher specific energy, lower cost, enhanced safety, and improved cycle life compared to LIBs. They mentioned that Li-S technology with liquid electrolytes and elemental sulfur faces challenges due to the persistent polysulfide shuttle, which limits cycle life. However, this project is focused on mitigating the polysulfide shuttle and improving cycle life with SPC cathodes without soluble polymers, thereby expectedly achieving good cycle life, albeit at lower energy. In summary, the project aligns with the DOE VTO's battery program's objectives and goals.

Reviewer 5:

The reviewer pointed out that Li-S battery technology is a promising energy storage technology due to its high energy and low cost. They highlighted that the success of the project directly supports VTO's objectives of vehicle electrification and decarbonization.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources assigned and utilized by this project are sufficient for the completion of the project goals.

Reviewer 2:

The reviewer commented that the funding seems good for what the PI is trying to accomplish.

Reviewer 3:

The reviewer expressed that resources for the overall project are commensurate with the scope and adequate to achieve the targeted milestones.

Reviewer 4:

The reviewer affirmed that the team has sufficient resources and experience to achieve the proposed milestones, both through their own capabilities and through collaboration with other institutes.

Presentation Number: BAT596
Presentation Title: Development of a High-Rate Li-Air Battery using a Gaseous CO_2 Reactant
Principal Investigator: Amin Salehi-Khojin (University of Illinois at Chicago)

Presenter

Amin Salehi-Khojin, University of Illinois at Chicago

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

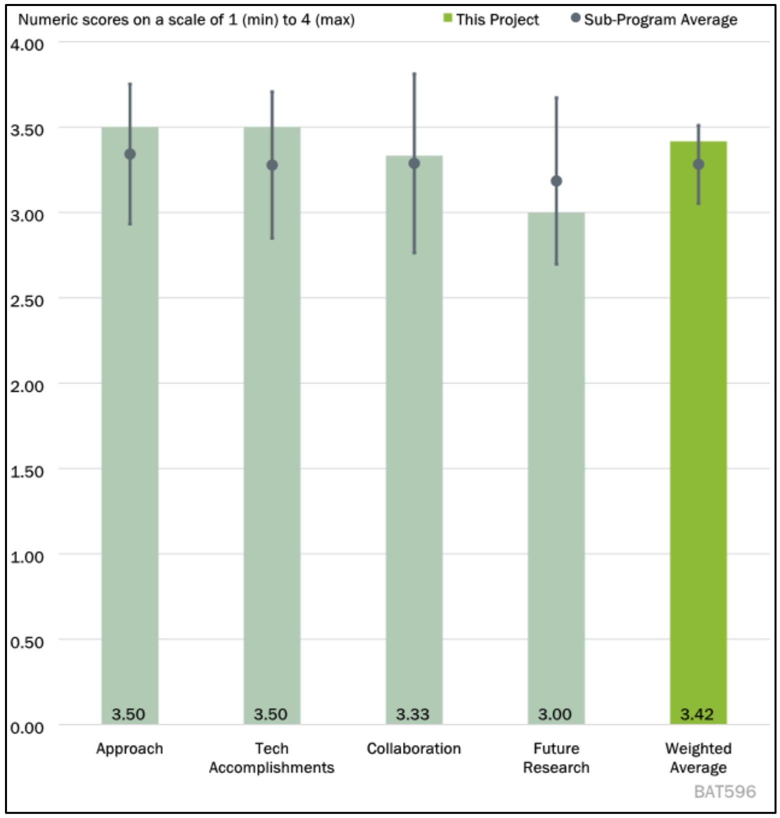

Figure 1-57 - Presentation Number: BAT596 Presentation Title: Development of a High-Rate Li-Air Battery using a Gaseous CO_2 Reactant Principal Investigator: Amin Salehi-Khojin (University of Illinois at Chicago)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer provided a comprehensive evaluation of the project, which focuses on the development of a layered sulfide catalyst (niobium, tantalum, bismuth sulfide) to facilitate efficient and reversible Li-CO_2 electrochemistry. The catalyst material is synthesized with high purity and characterized by the PIs. CO_2 electrochemistry is explored using an ionic liquid/dimethyl sulfoxide electrolyte with the sulfide catalyst and selected control catalysts (Pt, Au, and C). The reviewer noted the observation of high current densities at a given applied overpotential for the sulfide catalysts and good voltage stability during galvanostatic cycling. Qualitative characterization of the products suggests consistency with Li_2CO_3 and pure carbon formation. However, the reviewer pointed out that it remains unclear from the results if this reaction is reversible. DFT calculations are employed to identify niobium surface sites as the likely catalytic sites for the reaction. In summary, the project is well-designed, with a reasonably planned timeline, and addresses key technical barriers related to the kinetics of CO_2 reduction. The reviewer also recommended further investigations into the charge process and electrolyte stability in the presence of carbonate and carbon oxidation in subsequent years.

Reviewer 2:

The reviewer acknowledged the significant challenges in developing a Li-air battery based on CO_2 as a reactant and commended the team for addressing these challenges with a well-thought-out plan. The integrated approach, which encompasses materials synthesis, testing, characterization, and computation, is considered effective in improving cell reversibility and rate capability. The milestones and timeline were deemed appropriate.

Reviewer 3:

The reviewer praised the project's excellent approach, highlighting the critical role of electrolyte and catalyst in the performance of Li-CO_2 batteries. They specifically appreciated the focus on developing a novel catalyst, which yielded very promising results.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer summarized the technical accomplishments of the project and noted that overall, the project has made very good progress in the past year.

Reviewer 2:

The reviewer highlighted significant progress made by the team, including the identification of a new medium-entropy cathode catalyst and an ionic liquid-based electrolyte blend that allowed for electrochemistry to operate at current densities of 0.5 mA/cm^2 for 125 cycles. This achievement was noted to exceed reports in the literature.

Reviewer 3:

The reviewer praised the PI for synthesizing and characterizing a new catalyst, $(NbTa)_{0.5}BiS_3$, which demonstrated excellent CO_2 reduction and evolution reaction capabilities. When used with a dimethyl sulfoxide/ionic liquid (DMSO/IL) electrolyte, excellent cycling stability was achieved. The group's characterization of reduction and oxidation products on the cathode and anode, along with the verification of the proposed reaction mechanism, was seen as establishing a solid foundation for further development of Li-CO_2 batteries.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer observed that the project appears to be collaborative, although it is not clear which team members performed the various studies throughout. However, they noted that collaboration appears good, given the number of different characterization techniques employed.

Reviewer 2:

The reviewer expressed that a good team, consisting of both experimentalists and theoreticians, has been assembled to address the scientific challenges of a Li-CO_2 battery. The team includes members from ANL, the University of Illinois Chicago, and Stockholm University. The absence of industrial partners was mentioned but considered unnecessary at this stage of development.

Reviewer 3:

The reviewer highlighted that the PI has established broad collaborations with other groups actively working in this field, including L. Curtiss (ANL), J. Cabana (UIC), Z. Huang (Stockholm University, Sweden), and A. Subramanian (UIC), among others.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer noted that future research is relatively sparse, offering only high-level directions without providing specific details on how those directions would be achieved through additional science and engineering. However, they mentioned that the three directions provided appear to be reasonable.

Reviewer 2:

The reviewer characterized the proposed future research plan as vague but considered the overall approach to design more stable materials and increase rate capability to be reasonable, based on the results achieved so far.

Reviewer 3:

The reviewer highlighted the PI's proposal to focus on increasing the rate capability of Li/CO_2 batteries in their future work. They emphasized that rate capability is one of the key barriers in these batteries and viewed this research plan as a logical next step.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer recognized that the project focuses on an emerging battery chemistry that faces kinetics limitations and is relevant to the VTO's battery portfolio.

Reviewer 2:

The reviewer emphasized the relevance of this project to VTO. They noted that Li-air or Li-CO_2 batteries are considered potential alternatives to Li-ion batteries for transportation applications due to their high theoretical specific energy. Batteries utilizing CO_2 are known for their very high theoretical specific energy density. The reviewer mentioned that this project is expected to contribute to a comprehensive understanding of key chemical and electronic parameters governing the operation of Li-CO_2 batteries under realistic conditions.

Reviewer 3:

The reviewer stated that the project is an integral part of the VTO portfolio for the next generation of high-energy batteries. They characterized it as a high-risk, high-reward project that can significantly contribute to the knowledge base of energy storage. If the battery technology can be successfully scaled up, it was noted that it would also align with DOE's overall goal of CO_2 reduction.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources are sufficient.

Reviewer 2:

The reviewer commented that the project appears to have the necessary resources to achieve the milestones in a timely fashion.

Reviewer 3:

The reviewer affirmed that the resources of the project are sufficient.

Acronyms and Abbreviations – BAT

Abbreviation	Definition
3D	Three-dimensional
^{7}Li NMR	Lithium nuclear magnetic resonance spectroscopy
AFLB	Anode-free lithium-ion batteries
AG	Artificial graphite
Ah	Ampere-hour
ALD	Atomic layer deposition
ALS	Advanced Light Source
ANL	Argonne National Laboratory
APS	Advanced Photon Source
ARL	Army Research Laboratory
ASE	Argyrodite-type solid electrolytes
ASSLSB	All-Solid-State Lithium-Sulfur Battery
B500	Battery 500 Consortium
BAT	VTO Battery Advanced Technology subprogram
BCDI	Bragg coherent diffraction imaging
BIL	Bipartisan Infrastructure Law
BMR	Battery Materials Research
BNL	Brookhaven National Laboratory
BP	Budget Period
CAM	Cathode active materials
CAMP	Cell Analysis, Modeling, and Prototyping (CAMP) Facility
CCD	Critical current density
CE	Coulombic efficiency
CEI	Cathode electrolyte interphase
CFM	Carbon fiber mat
CNT	Carbon nanotube
CNT-S	Carbon nanotube-sulfur
Co	Cobalt
CO_2	Carbon dioxide

Abbreviation	Definition
COVID	Coronavirus disease (COVID-19), infectious disease caused by the SARS-CoV-2 virus
CRADA	Cooperative Research and Development Agreement
CSTR	Continuous stirred-tank reactor
Cu	Copper
DCDI	Diffraction contrast diffractive imaging
DFT	Density functional theory
DHM	Digital holographic microscopy
DMSO/IL	Dimethyl sulfoxide/ionic liquid
DOE	U.S. Department of Energy
dP/dV	Change in pressure with change in voltage
dQ/dV	Change in voltage with change in capacity
DRX	Disordered rock salt
DST	Dynamic stress test
EaCAM	Earth-abundant cathode materials
EB	Electron-beam
EDS	Energy-dispersive X-ray spectroscopy
EERE	Office of Energy Efficiency and Renewable Energy
EIC	Electron-Ion Collider
EIS	Electrochemical impedance spectroscopy
EM	Electron microscopy
EOCV	Electrochemical open circuit voltage
EOL	End-of-life
EP	Electropolymerization
EPA	U.S. Environmental Protection Agency
ESI/MS	Electrospray ionization / mass spectrometry
EV	Electric vehicle(s)
FDMB	Fluoro-dimethoxylbutane
FEC	Fluoroethylene carbonate
FLHCE	Fluorinated lean high-capacity electrolyte
FMMB	2-Fluoro-1-methoxy-4-(methylsulfonyl)benzene, also known as FMMB, an organosulfur compound

Abbreviation	Definition
FOA	Funding opportunity announcement
FSI	Fluoromethanesulfonimide
FSP	Flame spray pyrolysis
FTIR	Fourier transform infrared spectroscopy
GDOES	Glow discharge optical emission spectrometry
GHG	Greenhouse gas
GIXRD	Grazing incidence X-ray diffraction
GM	General Motors
HATN	Hexaazatrinaphthylene
HATN/CNT	Hexaazatrinaphthylene/carbon nanotube
HATN/CNT-S	Hexaazatrinaphthylene/carbon nanotube-sulfur
HAXPES	Hard X-ray photoelectron spectroscopy
HFE	Fluorinated ether
HPLC	High-performance liquid chromatography
HVM	High-volume manufacturing
IC	Ionic conductivity
ID	Identification
INL	Idaho National Laboratory
Kg	Kilogram
kWh	Kilowatt-hour
LBL	Lawrence Berkeley National Laboratory
LC	Liquid chromatography
LFP	Lithium iron phosphate
LHCE	Lean high-capacity electrolyte
Li	Lithium
Li_2S	Lithium sulfide
LIB	Lithium-ion battery
LiB_xS_y	Any compounds including lithium, boron and sulfur
LIC	Lithium-ion conductor
LiFSI	Lithium bis(fluorosulfonyl)imide
$LiNO_3$	Lithium nitrate

Abbreviation	Definition
LiP_xS_y	Any compounds including lithium, phosphate and sulfur
LiS or Li-S	Lithium sulfur
LiTFSI	Lithium bis(trifluoromethanesulfonyl)imide
LLTO	Lithium lanthanum titanate oxide
LLZO	Lithium lanthanum zirconate
LLZTO	Garnet-type fast lithium-ion conductor $Li_{6.75}La_3Zr_{1.75}Ta_{0.25}O_{12}$
LMFP	Lithium iron phosphate ($LiFePO_4$) cathode material with manganese (Mn)
LMR	Lithium metal rich
LMR-NMC	Lithium manganese rich-nickel manganese cobalt material.
LNMO	Lithium-nickel-manganese oxide
LSE	Lithium solid electrolyte
LTO	Lithium titanium oxide
mA	Milliampere
mAh	Milliampere-hour
MCA	Magnetocrystalline anisotropy
MERF	Materials Engineering Research Facility
METS	Multiharmonic electrothermal microscopy
MHP	Mixed hydroxide precipitate
ML	Machine learning
Mn	Manganese
MS	Mass spectrometry
N/P	Negative-to-positive ratio
NC	Nitrogen doped (N-Doped) carbon
NCA	Nickel cobalt aluminum
NCM	Lithium nickel manganese cobalt oxides (abbreviated NMC, Li-NMC, LNMC, or NCM) are mixed metal oxides of lithium, nickel, manganese and cobalt
NG	Natural gas
Ni	Nickel
NIST	National Institute of Standards and Technology
NMC	Nickel manganese cobalt

Abbreviation	Definition
NMP	N-methyl-2-pyrrolidone
NMR	Nuclear magnetic resonance spectroscopy
NREL	National Renewable Energy Laboratory
NSLS	National Synchrotron Light Source
ORNL	Oak Ridge National Laboratory
P2D	Pouch-to-depletion
PAN	Polyacrylonitrile
PDF	Pair distribution function
PEGDA	Polyethylene glycol diacrylate polymer
PEV	Plug-in electric vehicle
PI	Principal investigator
PMTH	Thiuram polysulfides
PNNL	Pacific Northwest National Laboratory
POFM	Porous organometallic framework materials
PUA	Polyurethane acrylate
PV	Photovoltaic
PVDF	Polyvinylidene fluoride
PWA	Powdered activated carbon
PXRD	Powder X-ray diffraction
Q1, Q2, Q3, or Q4	Annual quarters
R&D	Research and development
RDD&D	Research, development, deployment, and demonstration
RPT	Rate performance test
S	Sulfur
SCHT	Supercritical hydrothermal
SCSA	Sulfur cathode structure/architecture
Se	Selenium
SEI	Solid-electrolyte interface/interphase
SEM	Scanning electron microscopy
SeS	Selenium sulfide
Si	Silicon

Abbreviation	Definition
SLPC	Single-layer pouch cells
Sn	Tin
SOC	State of charge
SOH	State of health
SP	Solution precipitation
SPAN	Sulfurized polyacrylonitrile
SPC	Sulfurized polymer composite
SPE	Solid polymer electrolyte
SSB	Solid-state battery
SSE	Solid-state electrolyte
TCI	Lithium tricyanoimidazole
TEA	Techno-economic analysis
TEGDME	Tetra (ethylene glycol) dimethyl ether
TEM	Transmission electron microscopy
TGA	Thermogravimetric analysis
ToF SIMS	Time-of-flight secondary ion mass spectrometry
TRL	Technology readiness level
TVR	Thermal vapor recompression
UC	University of California
UIC	University of Illinois at Chicago
UMD	University of Maryland
US	United States
USABC	U.S. Department of Energy/U.S. Advanced Battery Consortium, a subsidiary of USCAR
UV	Ultraviolet
UW	University of Washington
VED	Volumetric energy density
VTO	Vehicle Technologies Office
W	Tungsten
XAS	X-ray absorption spectroscopy
XCEL	eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries

Abbreviation	Definition
XFC	Extreme fast charging
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
XRD/XAS	X-ray Diffraction/X-ray Absorption Spectroscopy

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