

Progress and Status of Battery500 Consortium Phase II

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Project ID bat317

Overview

Timeline

- Project start date: 10/01/2021
- Project end date: 9/30/2026
- Percent complete: 53 percent

Budget

- Total project funding: DOE share \$75M
- Funding received in FY 2023: \$15M
- Funding for FY 2024: \$15M

Barriers

- Barriers addressed
 - Increasing the energy density of advanced lithium (Li) batteries beyond what can be achieved in today's Li-ion batteries is a grand scientific and technological challenge.

Partners

- Project lead: PNNL
- Team: 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 at Austin, Univ. of Washington
- Seedling team: Brown Univ., Iowa State, Penn. State, Univ. of Houston, Univ. of Maryland, Univ of Wisconsin at Milwaukee, Virginia Commonwealth Univ., Virginia Tech.
- Industry Advisory Board



Relevancy:

Project Objectives

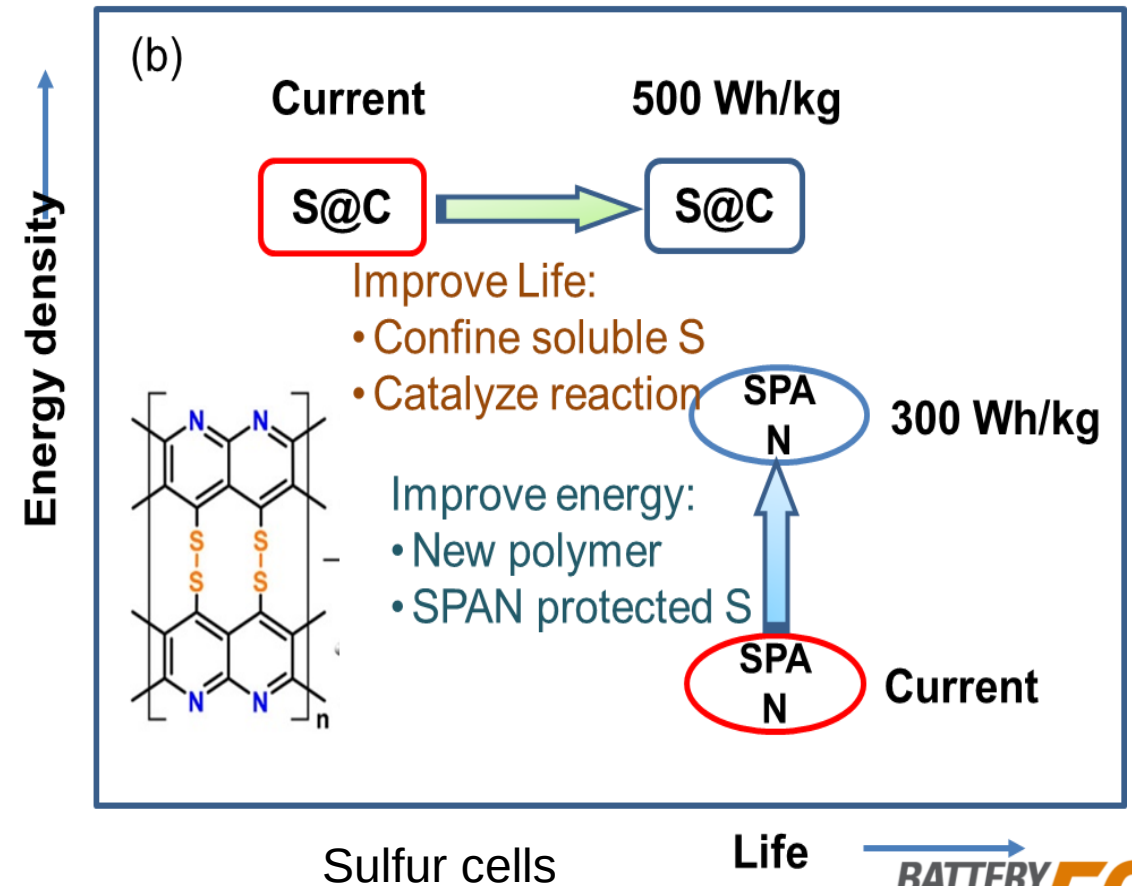
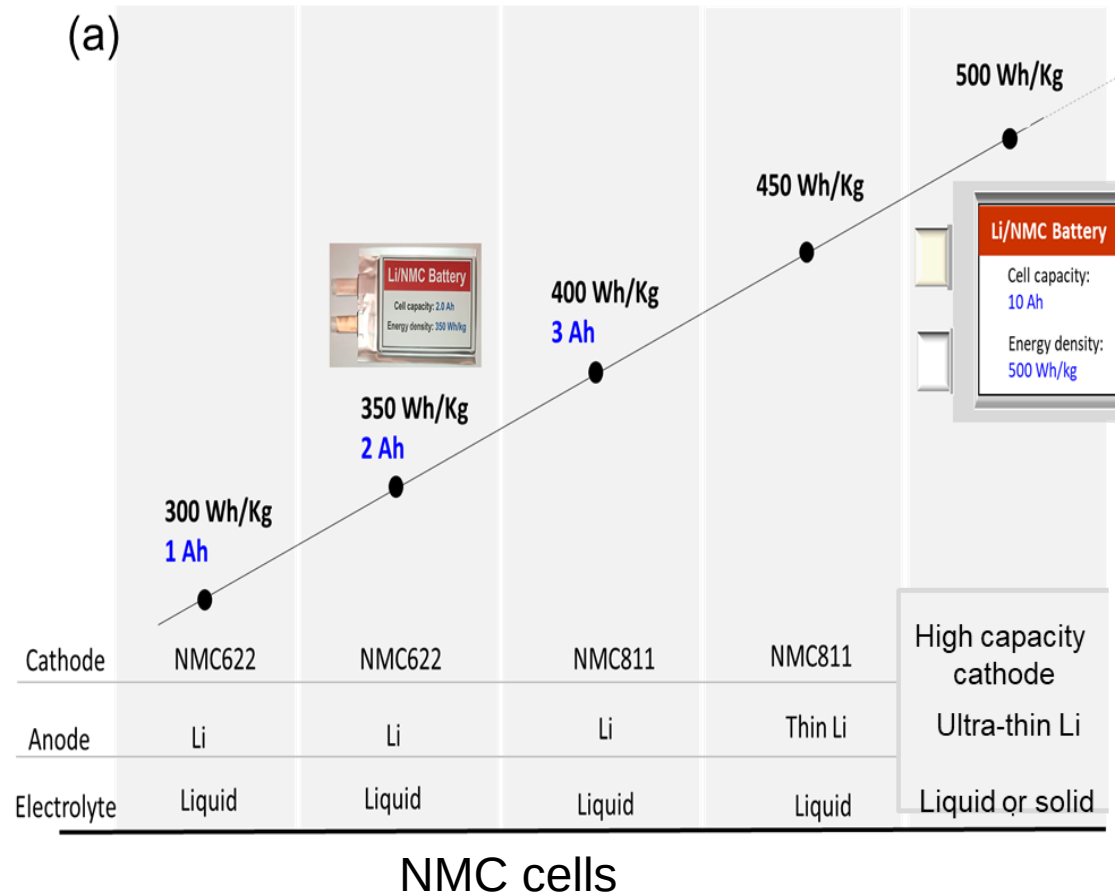
- Develop next generation high-energy, low-cost batteries for electric vehicles
- Design, fabricate and validate high energy pouch cells up to 500 Wh kg⁻¹
- Scale up pouch cell capacity up to 5-10 Ah
- Demonstrate long cycle life of up to 1,000 deep charge-discharge cycles
- Achieve total control of battery chemistries for robust, scalable and commercially viable technologies

Approaches

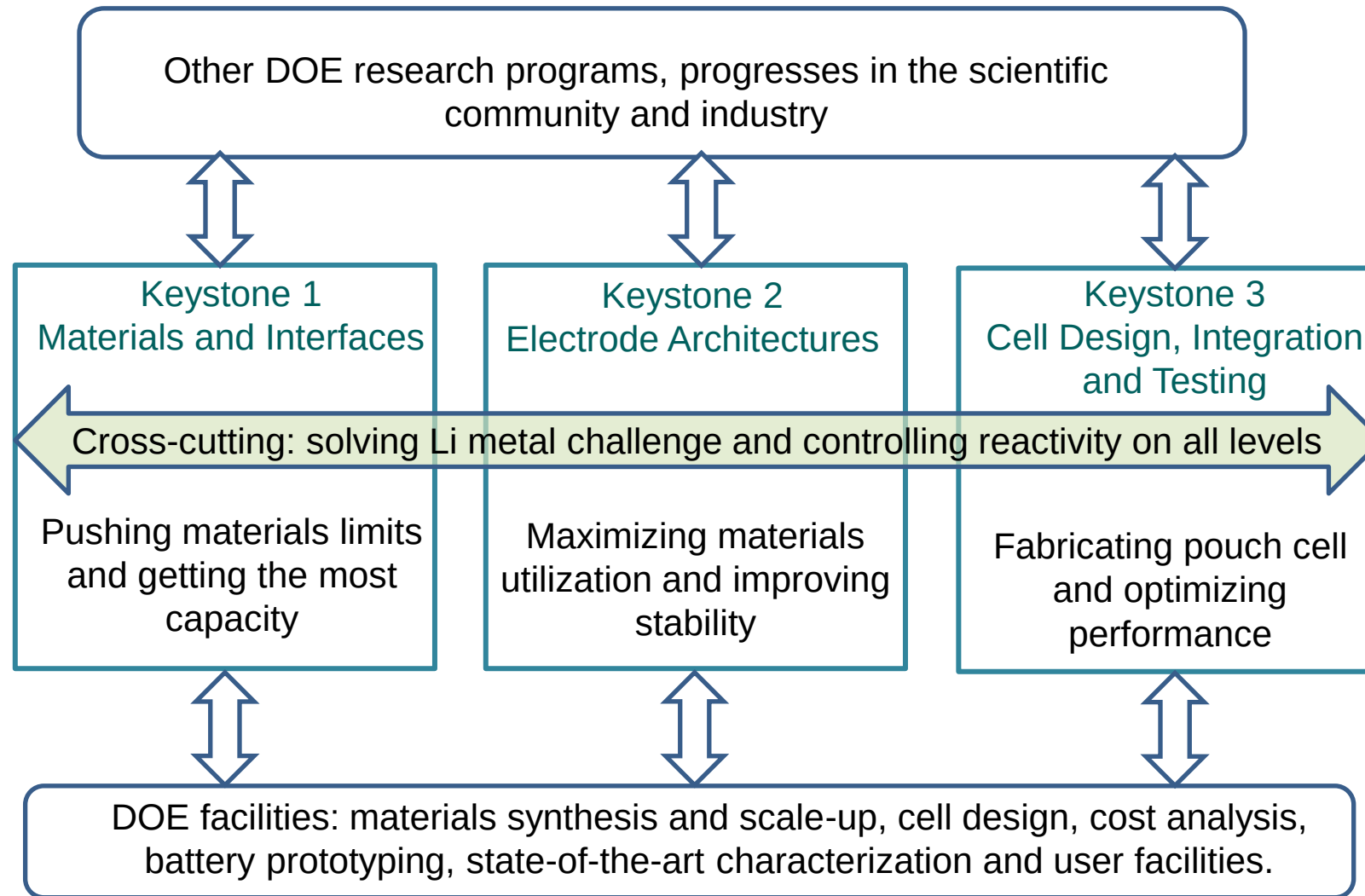
- **Fundamental breakthroughs in controlling the electrochemical reactions in high energy electrode materials and cells for next generation high-energy, low-cost batteries;**
- **Integrating development and discoveries from materials to cell level, and rapidly incorporating and validating latest results in realistic cells;**
- **Leveraging materials developed under other DOE programs, and state-of-the-art DOE facilities to understand and prevent degradation.**
- **Developing and deploying multi-disciplinary approaches and enhancing collaborations between national laboratories, universities and industry.**

Technical Approaches

- Integrate and optimize the best materials at the cell level, and push the limit of materials performance and utilization to achieve high energy density and low cost;
- Understand and control component and system level electrochemical reaction and degradation mechanisms to realize long cycle, safe and reliable performance.



Technical Approach: Keystone projects and cross-cutting task

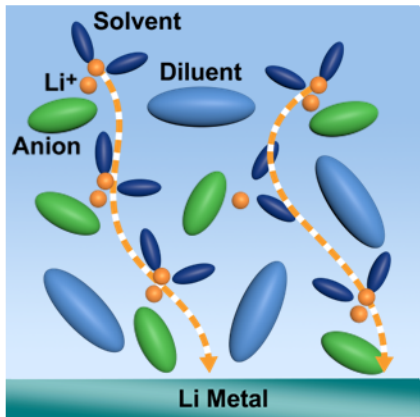


Key Cell Level Milestones

Date	Milestones	Status
FY2024 annual	Demonstrate > 100 cycles for Li-S and Li-SPAN pouch cells up to 300 Wh/kg.	<i>On-track</i>
FY2024 annual	Demonstrate the fabrication and initial cycling of 500 Wh/kg NMC pouch cells (PNNL).	<i>Completed</i>

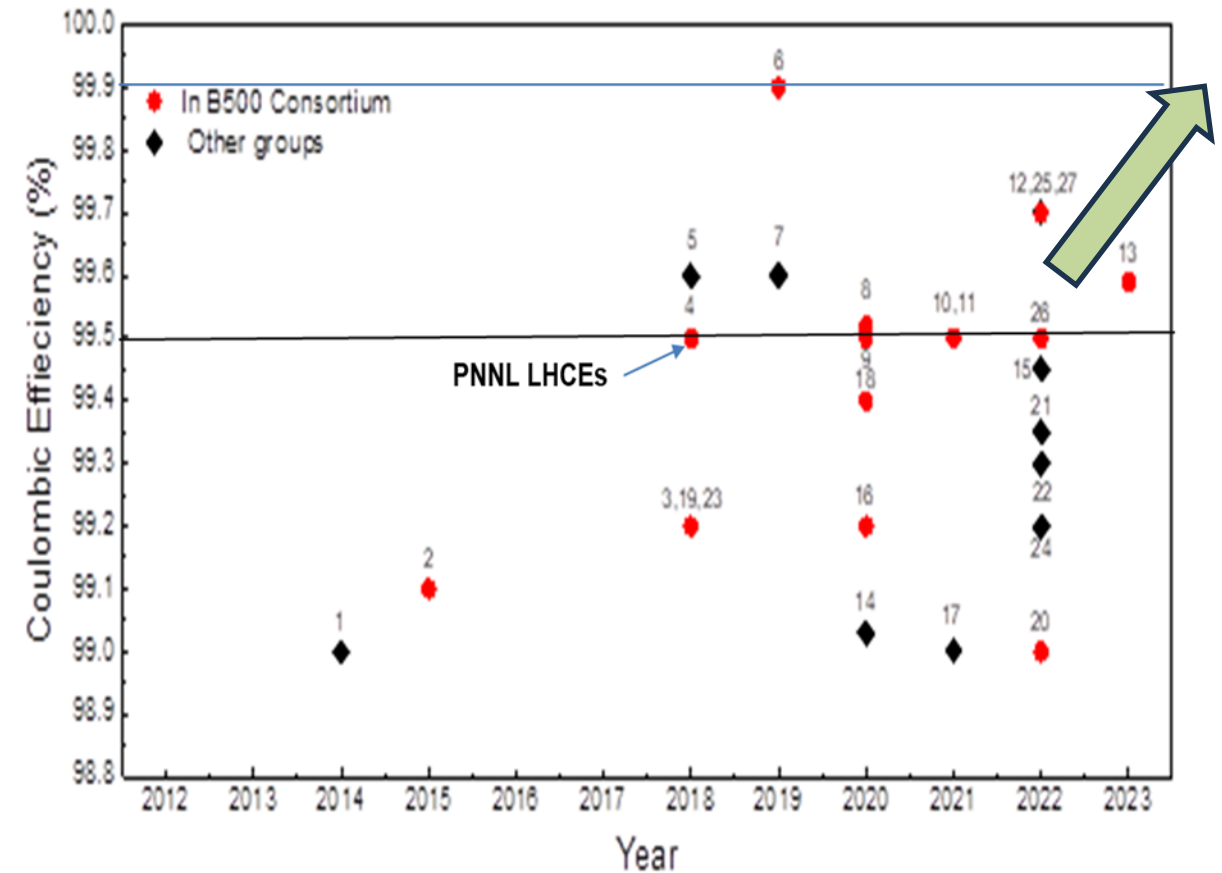
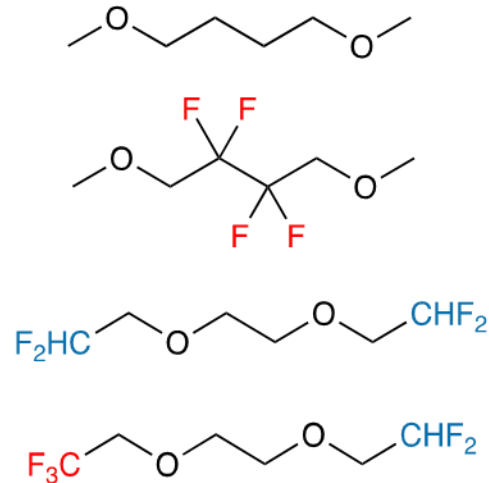
Technical Accomplishment: Development of new electrolytes for Li metal systems

Localized High concentration Electrolyte (LHCE) :



Typical formula: LiFSI:1.2DME:3TTE

Molecular designed electrolytes

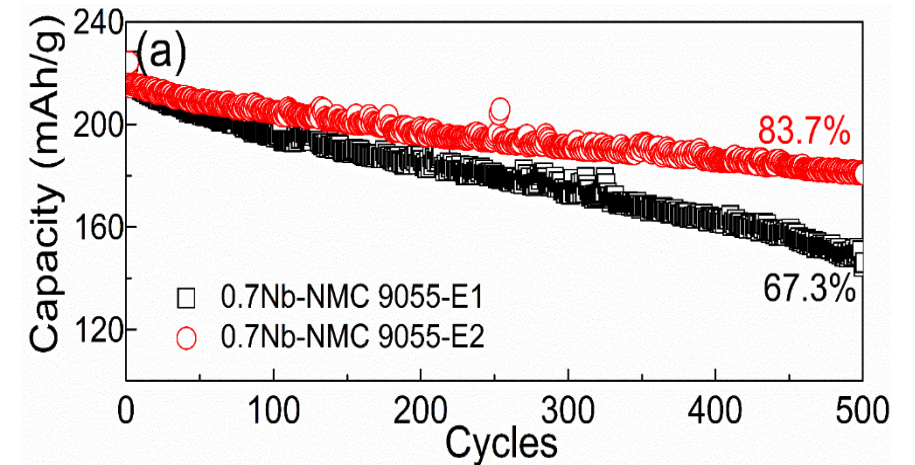


Modified from Gustavo M. Hobold et. Al. Nature Energy, Vol 6, 951-960, 2021.

Technical Accomplishment: pushing all cell components to their limits

- Control reactivity of all cell components,
 - Both active and inactive materials
 - Electrolytes and cathodes
 - Ambient and elevated temperature
 - Multicomponent Systems
 - Electrolyte/cathode reactivity
 - Impact of electrolyte
 - Chemistry, charging voltage and cell components
 - Impact of modifying cathode
 - Coating and substitution (also anode and separator)
 - Morphology: Single crystal vs meatball

Improving high Ni NMC with Nb coating and new electrolytes

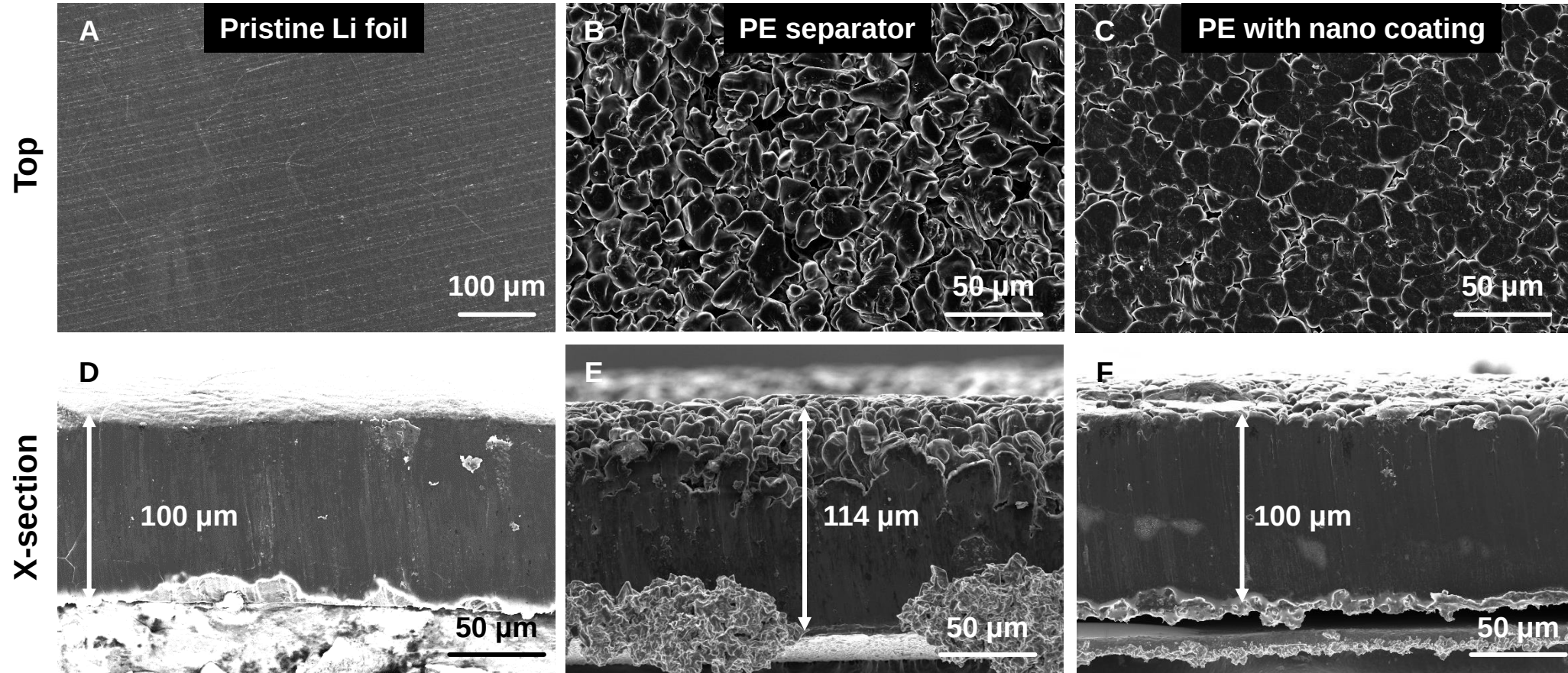


Develop thermal analysis capability for component and operando studies



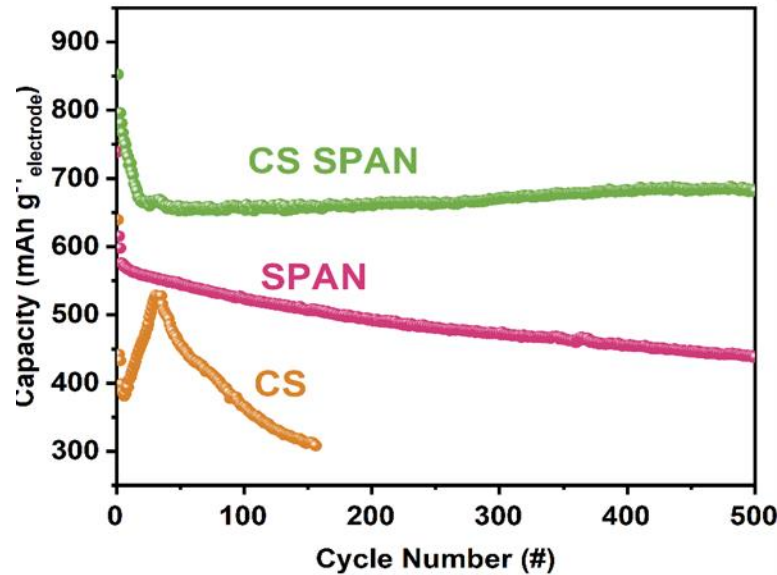
Technical Accomplishment:

Separator coating with a nano coating to reduce Li Pulverization

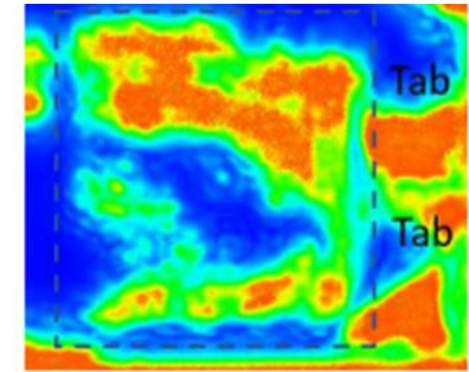
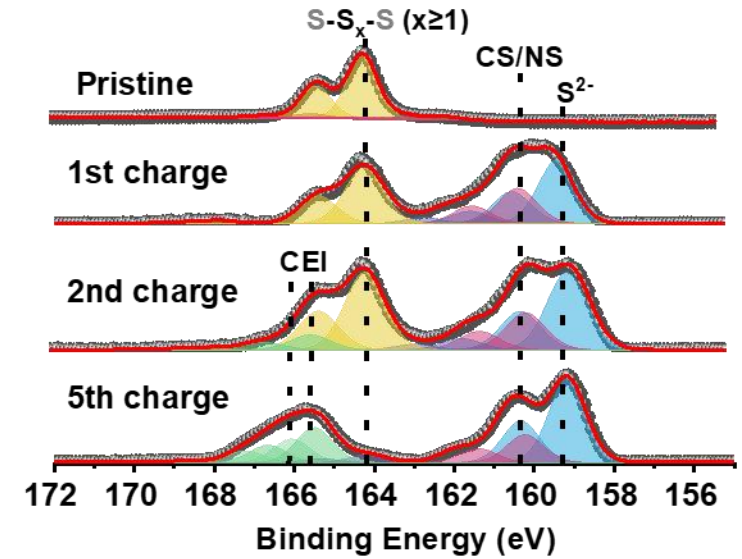
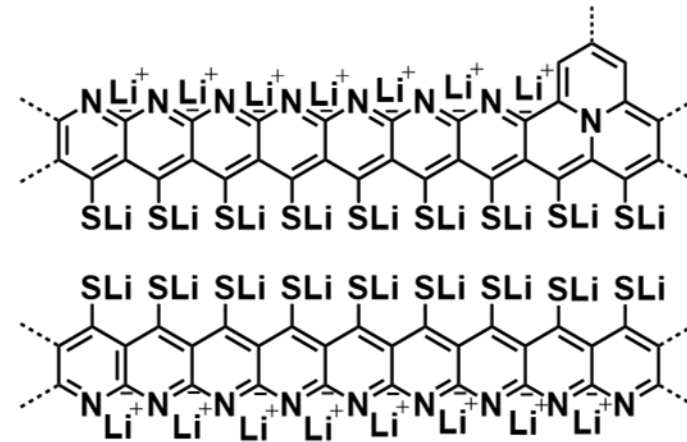
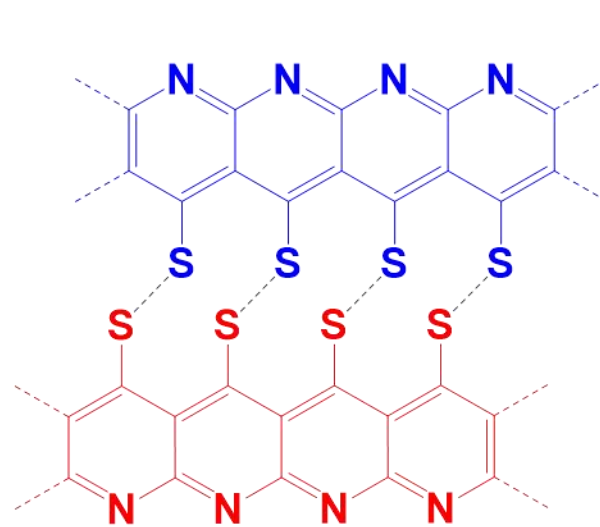


- The nano coating on PE separator produces dense LI deposition, reduces lithium metal pulverization during cycling, and reduces electrode swelling.

Technical Accomplishment: New materials (CS SPAN) from molecules to cells

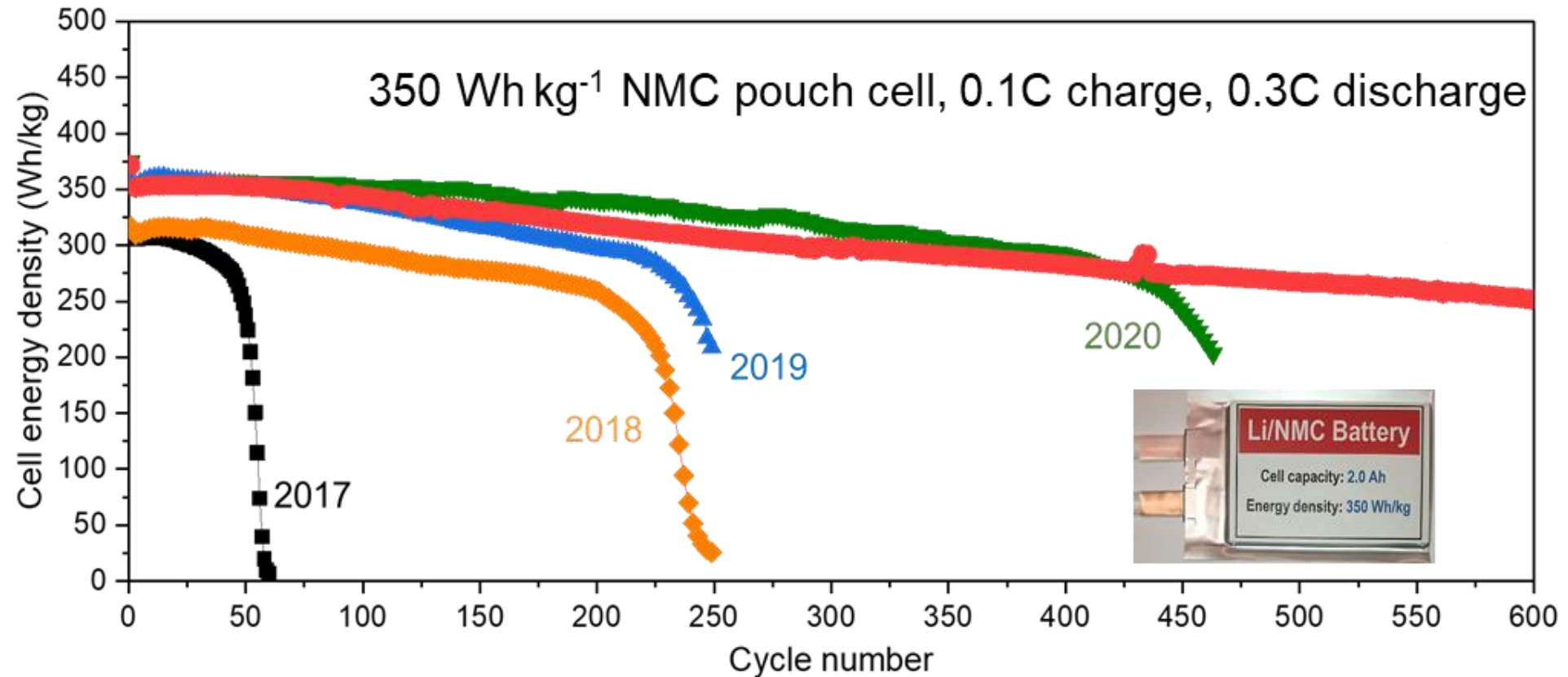


16th cycles



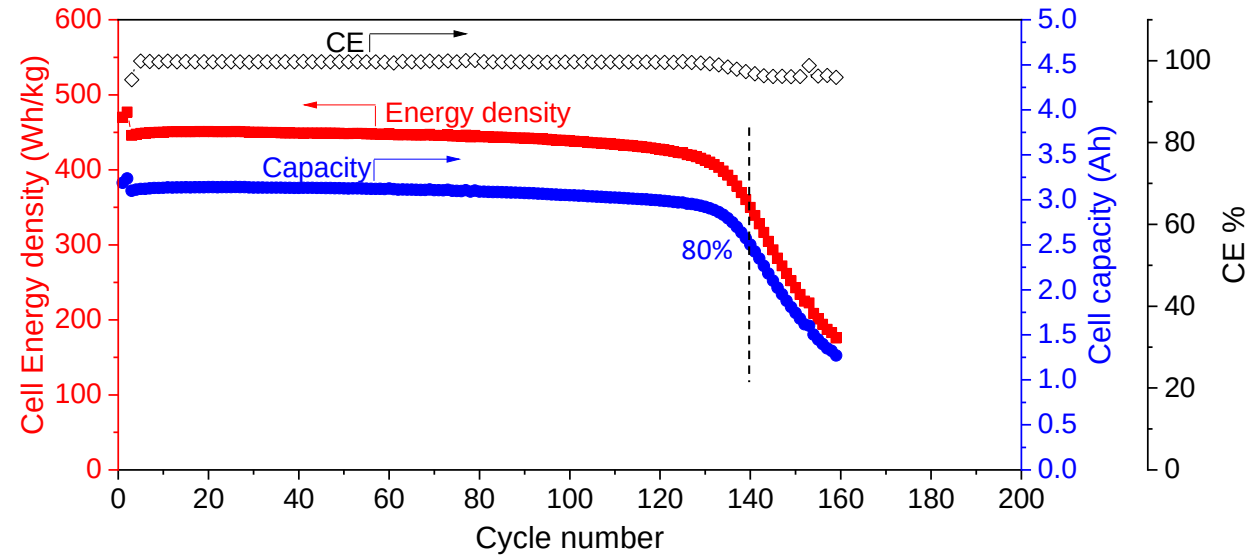
CS SPAN exhibits increased sulfur reactivity and a boosted overall capacity.

Technical Accomplishment: Long cycling of baseline 350 Wh kg⁻¹ pouch cell

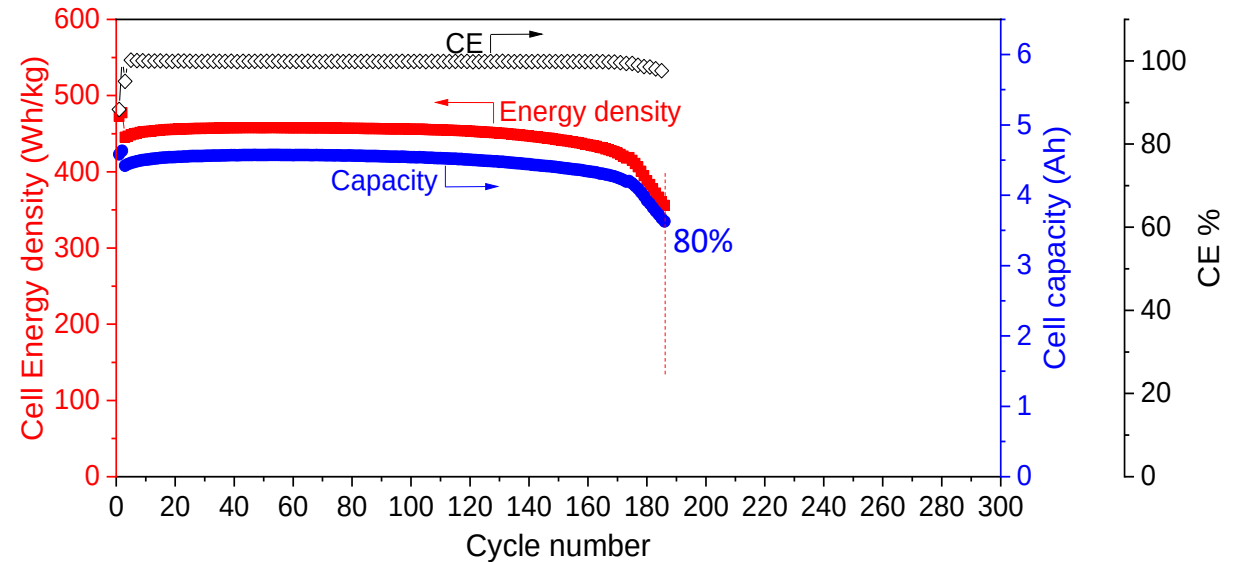


Technical Accomplishment: 450Wh kg⁻¹ Li Metal Pouch Cells

FY23 450 Wh kg⁻¹ Li metal pouch cells tested at PNNL

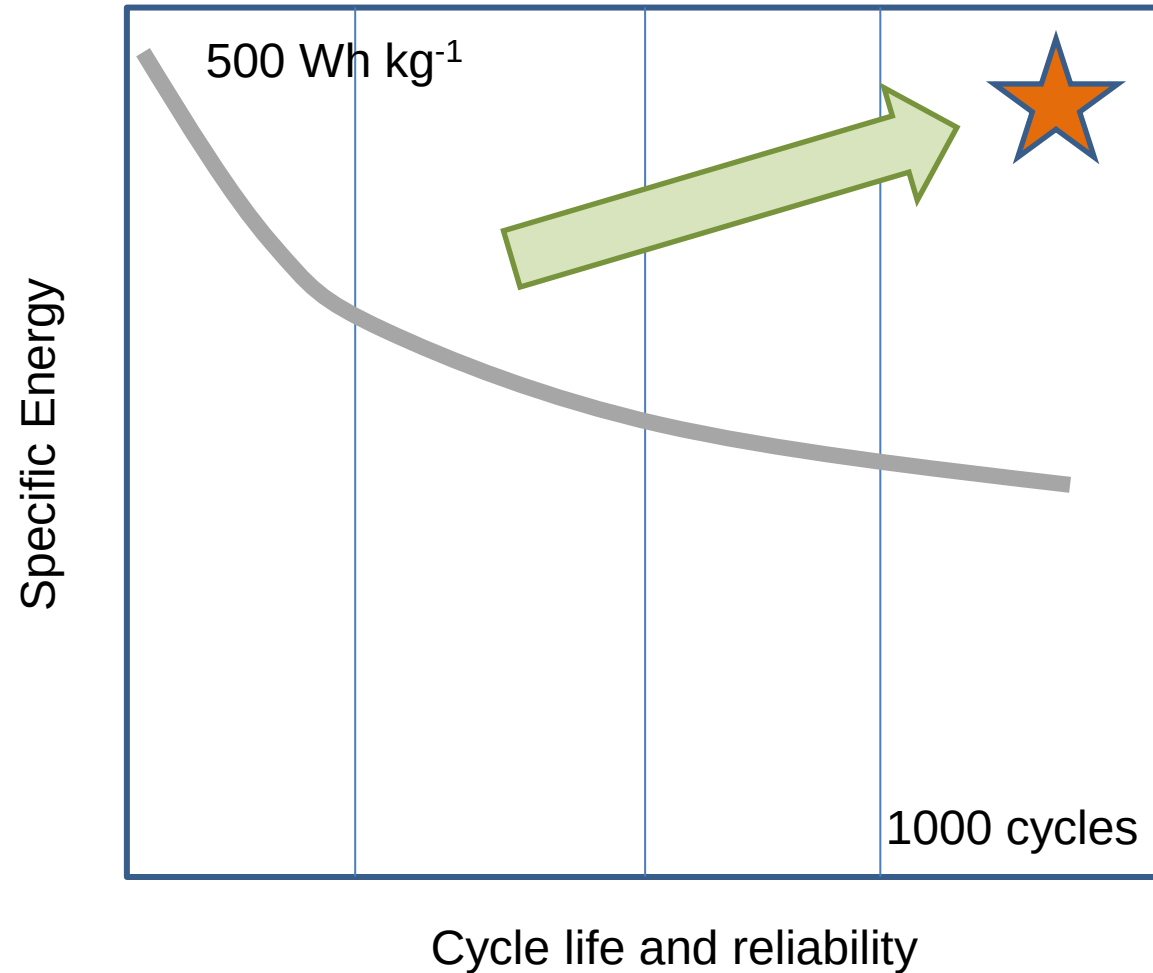


FY24 450 Wh kg⁻¹ Li metal pouch cells tested at GM



- 500 Wh kg⁻¹ pouch cells have been fabricated and are under testing
- The specific energy increases with cell sizes

Remaining Challenges: fabrication and validation of high energy cells with robust performance



Future Work

- Address Li metal anode challenges at full cell levels and achieve more than 99.9% Coulombic efficiency (CE) for Li deposition
- Achieve total control of battery chemistries for robust, scalable and commercially viable technologies
- Scale up pouch cell capacity up to 5-10 Ah
- Demonstrate long cycle life of up to 1,000 deep charge-discharge cycles
- Fabricate alternate low-cost and resource-secured Li||S cells of $\sim 300 \text{ Wh kg}^{-1}$ with up to 1,000 cycles
- Perform cost analysis and develop strategies to significantly less than \$100 (kWh)⁻¹
- Independently validate cell performances by industry.

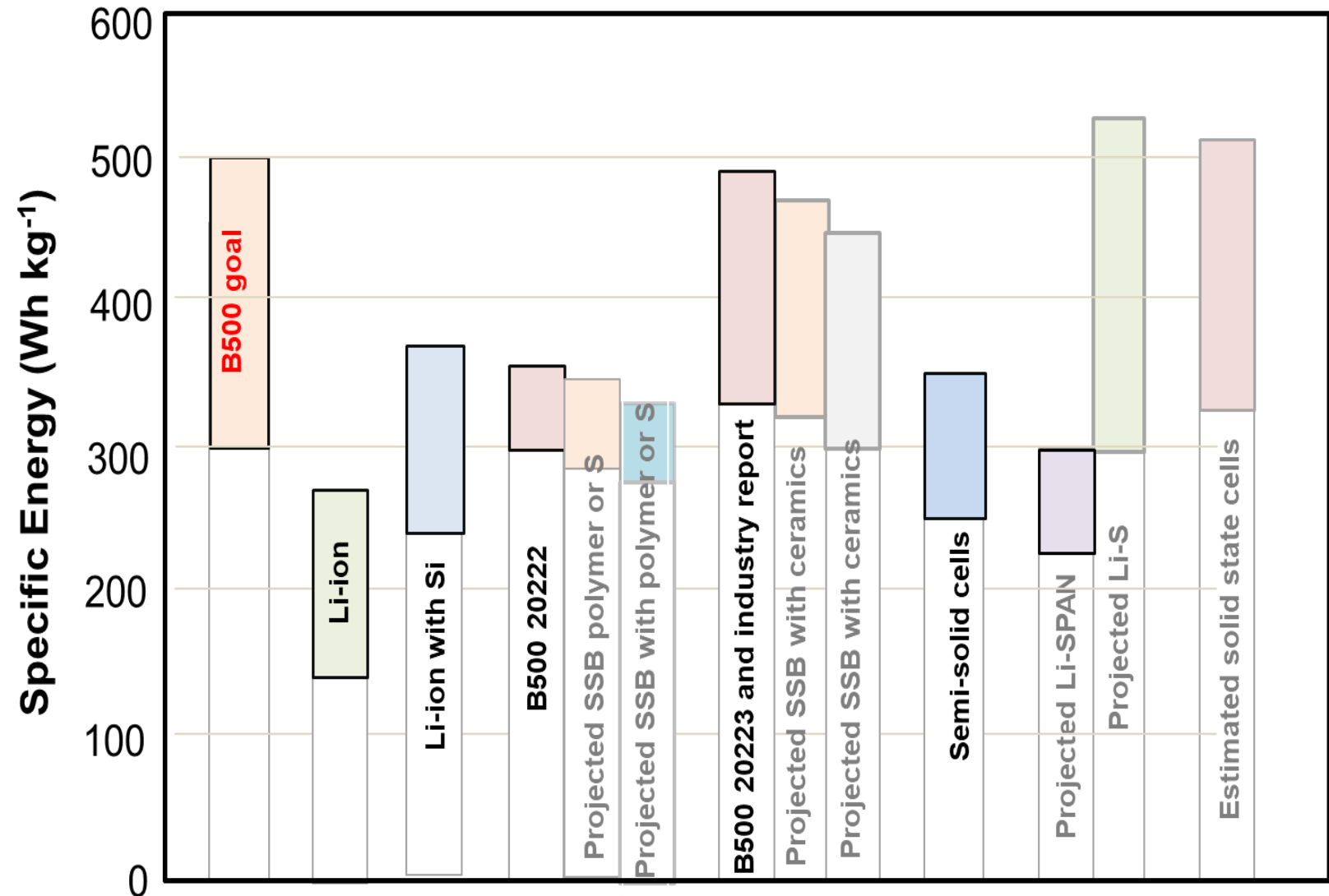
Battery500 Consortium Seedling Projects on Solid Electrolytes: Scalable, Deployable

- Eric Wachsman, Optimizing Cathode Architecture for Solid-State Li Metal-Sulfur Batteries
- Chunsheng Wang, Thin Composite Solid Electrolyte for Li Metal Batteries
- Yan Yao, Scalable Noble-metal-free Interlayer Design for Sheet-type Dendrite-free Solid-state Lithium Metal Batteries,
- Deyang Qu, Battery500 Solid-State Battery Seedling Projects
- Brian Sheldon, Blocking Li Metal Dendrites In Solid Electrolytes With Ion-Exchange Induced Residual Stresses
- Donghai Wang, Developing Materials to Enable High-Energy-Density Cathode and Stable Li Anode for Solid-State Li-S Batteries
- Louis Madsen, Molecular Ionic Composite Solid Electrolytes for Long-Cycling and High Voltage Li-Metal Batteries
- Puru Jena, Stable Sulfide-based Anode-Free and Anode-Limited All-Solid-State Lithium Battery
- Steve Martin, Development of Thin, Robust, Lithium-Impenetrable, High-Conductivity, Electrochemically Stable, Scalable, and Low-Cost Glassy Solid Electrolytes for Solid State Lithium Batteries that Meet Battery500 Consortium Targets

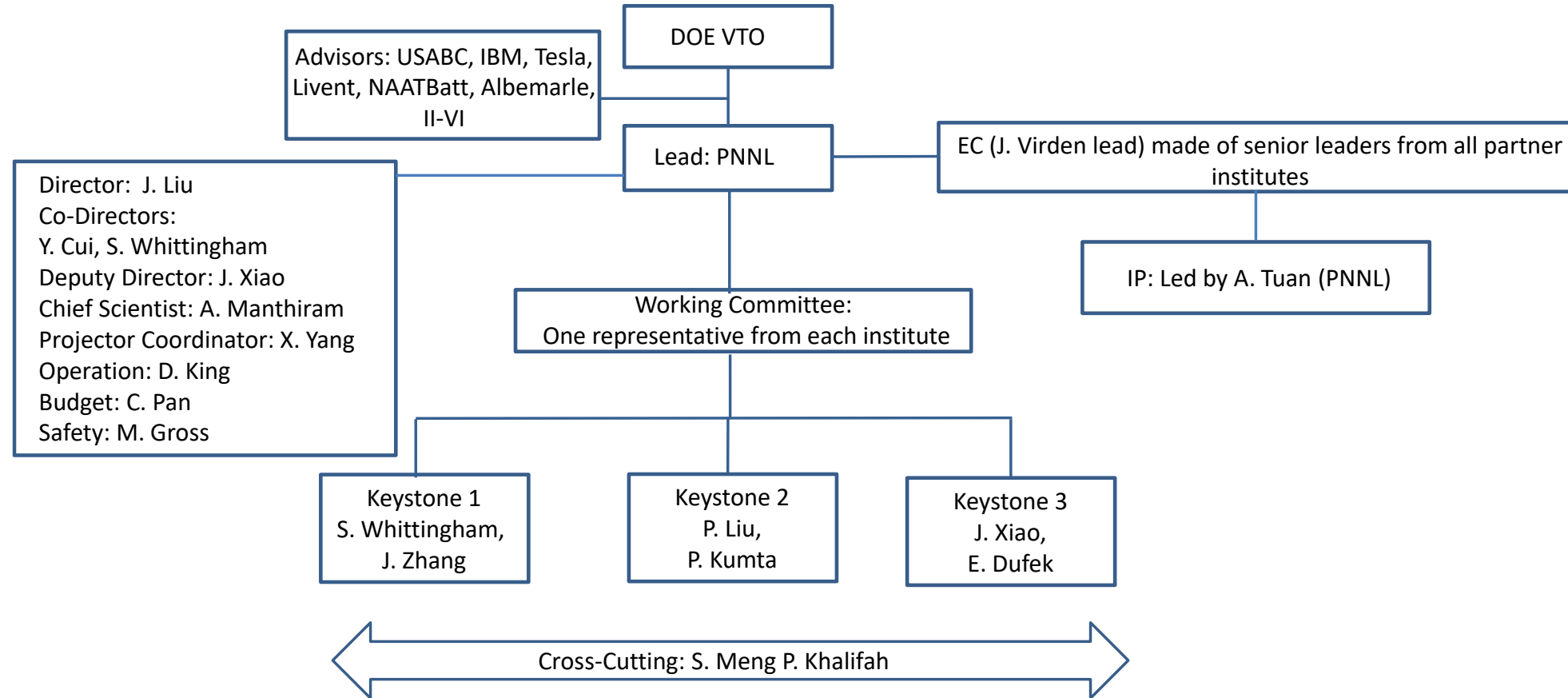


Summary

- High energy rechargeable Li batteries can be fabricated with good cycling stability.
- The Li metal anode problems have not been completely resolved.
- Understanding and controlling the reactivity and degradation from component to cell level is the key.



Collaboration: multi-disciplinary team to take advantage of the best capabilities in materials sciences, materials chemistry, electrochemistry, synthesis, battery engineering, characterization and testing.



Core t Team: Z. Bao (SLAC/Sanford), P. Balbuena (Texas A&M), W. Chueh (SLAC/Stanford), M Cai (GM), Y. Cui (SLAC/Stanford), E. Dufek (INL), P. Kumpta (U Pittsburgh), J. Goodenough (UT Austin), P. Khalifah (BNL), E. Hu (BNL), B. Liaw (INL), J. Liu (PNNL/UW), P. Liu (UCSD), A. Manthiram (UT Austin), S. Meng (UCSD), C. Wang (Maryland), D. Wang (Penn State), M. S. Whittingham (Binghamton), J. Xiao (PNNL), W. Xu (PNNL), J. Yang (UW), X. Yang (BNL), J. Zhang (PNNL)

Response to last year's reviewer comments

N/A This presentation was not reviewed.
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