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Event preview in association with

Cambridge EnerTech

Welcome to the 42nd International Battery Seminar & Exhibit 2025

On behalf of myself and my colleagues, it is my great pleasure to welcome you to Orlando. As the General Manager of Cambridge EnerTech, it is my privilege to extend this heartfelt greeting to each and every one of you.

This year's conference promises to be an exceptional gathering of industry leaders, innovators, researchers, and enthusiasts in the field of advanced battery technologies. With the landscape of energy storage evolving at an unprecedented pace, our event serves as a pivotal platform for the exchange of knowledge, ideas, and insights that will shape the future of this dynamic sector.

Throughout the duration of the conference, you will have the opportunity to engage in thought-provoking discussions, attend informative sessions, and network with fellow professionals who share your passion for advancing battery science and technology. From cutting-edge research presentations to practical applications and market trends, the program is designed to inspire, educate, and empower all participants.

Founded by Shep Wolsky in 1983, the International Battery Seminar & Exhibit has established itself as the premier event showcasing the state of the art of worldwide energy storage technology developments for consumer, automotive, and industrial applications. We are proud to showcase the latest advancements in materials, product development, manufacturing, and application for all battery systems and enabling technologies as we collectively strive towards a sustainable and electrified future.

As we embark on this journey together, I encourage you to make the most of your time at the conference. Whether you are a seasoned industry veteran or a newcomer to the field, your contributions and perspectives are invaluable to our shared mission of driving progress and innovation in energy storage.

On behalf of the organizing committee, I extend my sincere gratitude to our sponsors, exhibitors, speakers, and attendees for their support and dedication to our global community. Together, we will make the 42nd International Battery Seminar & Exhibit 2025 a catalyst for innovation in the global battery ecosystem.

Thank you for your participation, and I look forward to meeting you all in person in Orlando.

Warm regards,

Craig Wohlers
General Manager
Cambridge EnerTech

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For inclusion in the preview guide, please contact Les Hawkins. Email: les@bestmag.co.uk, Phone: +44 7745 665 513

For more details on the conference, please contact:
Craig Wohlers
Executive Director, Conferences
Cambridge EnerTech
Phone: (+1) 781-247-6260
Email: cwohlers@cambridgeenertech.com

For event sponsorship information, please contact:

Companies A-Q
Sherry Johnson
Senior Business Development Manager
Cambridge EnerTech
Phone: (+1) 781-972-1359
Email: sjohnson@cambridgeenertech.com

Companies R-Z
Rod Eymael
Senior Business Development Manager
Cambridge EnerTech
Phone: (+1) 781-247-6286
Email: reymael@cambridgeenertech.com

Virtual validation of battery cells and analysis of life and aging

Luke Hu, Co Founder & GM, Global Business, Electroder Ltd.

Today announcements of 10,000-15,000 cycle cells are not uncommon. System manufacturers need a better technical approach to evaluate and conduct due diligence on the parts they purchase. Cell manufacturers need better tools to develop long-life products. In this presentation, we introduce a new digital technology to address one of the most critical challenges in the battery industry: efficient and accurate prediction of cell life and aging behavior under various conditions.

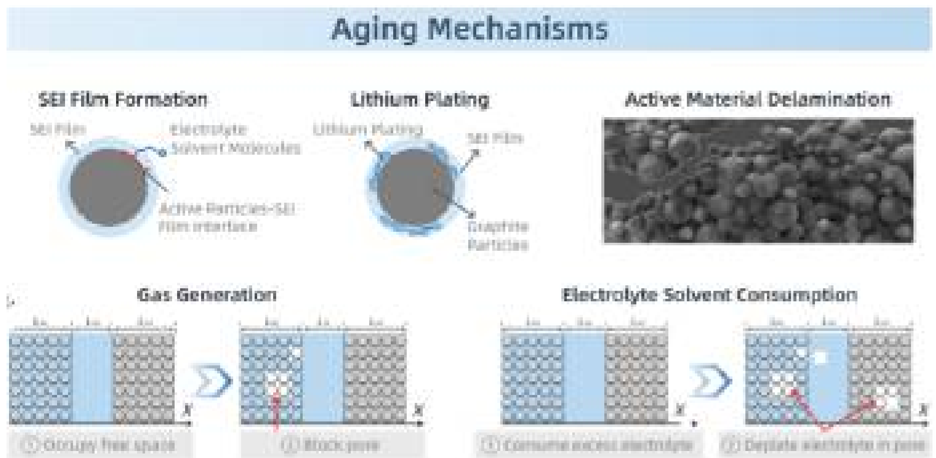
As the demand for high-performance batteries grows, both cell manufacturers and system integrators (Automotive OEM, ESS) face key rising challenges: accurately validating cell life within acceptable period of time and optimizing its durability earliest possible in R&D stage.

Mr. Luke Hu, Co-Founder of Electroder, will explore this topic in his upcoming tutorial presentation, "Virtual Analysis of Cell Aging and Cell Behaviors for the Selection and Development of Long-Life Cells." His talk will delve into the analysis of key aging mechanisms and how digital solution can help achieve the target of reliable prediction as well as better durability.

Recognized as one of the top 100 innovative start-ups providing cutting-edge solutions in energy transition, Electroder provides software tools and engineering services designed to transform the way the industry develops batteries.

ElectroderMOD is an essential software module for building digital twins of electrode and cell. This software allows engineers to define cell materials, recipes, and components, enabling precise balancing, capacity calculations and dimension checks. It supports all popular formats, including prismatic, cylindrical, blade, and pouch cells, and offers comprehensive libraries for materials and parts. This module empowers the speed and precision of building concept design, analyzing cost, checking weight and validating dimensions.

ElectroderLIFE empowers engineering capability in cell life prediction and aging analysis. With physical models, it can conduct comprehensive analysis like SEI film formation, lithium plating, gas generation, and electrolyte consumption. ElectroderLIFE forecasts critical performance including electrochemistry, thermal, capacity degradation, internal resistance and etc. All these analyses can be simulated under standard or highly customized operating conditions.



Cell evaluation report: in-depth insights for better decisions

In addition to powerful software, Electroder offers a comprehensive engineering service supporting customers understanding battery cells. This customized report provides a detailed, in-depth analysis of battery cells, covering facts and insights from mechanical structure and chemistry to cost analysis.

Request our Award-Winning Conference Presentation or Experience Electroder Software in Free-Trial

Download our reports in cell design and evaluation or [apply for software demo](#).

Panel discussion – Beyond the spark: the future of early-stage battery & climate ventures

Join us as we discuss the unique challenges and opportunities within the evolving landscape of venture investing in breakthrough battery and climate technologies, from securing early traction and forging strategic partnerships to the role of emerging technologies in accelerating decarbonization and energy transformation.

The global landscape for energy and transportation is undergoing rapid and significant changes, creating both opportunities and challenges for early-stage startups in these crucial industries. There are several key topics shaping the conversation on how investors, founders, and policymakers can navigate this evolving space.

One timely issue is the recent China export ban on critical battery materials and technologies. As China dominates much of the global battery supply chain, this move has introduced new complexities for companies relying on these materials to drive innovation in energy storage.

The resulting disruptions raise critical questions about the future of supply chains: Can local production in the U.S. and Europe scale fast enough to reduce dependence on imports, or will this delay innovation in battery technologies even further? Solutions for diversifying supply chains and the role early-stage ventures can play in addressing these challenges are at the forefront of the conversation.

Additionally, the architectural advantages of electric vehicles (EVs) over internal combustion engines (ICEs) are driving significant market shifts. The transition to EVs is not just about environmental benefits—it's about the intrinsic performance and design improvements EVs offer. As the price per kWh of batteries drops as the industry scales, higher quality vehicles can be delivered at the same or lower price point.

Electric powertrains allow for better power distribution and the integration of advanced software capabilities, leading to greater efficiency and lower operational costs. These advantages mean that even those indifferent to climate concerns can see the value in EVs, and the opportunities for startups to innovate around battery performance, powertrain optimization, and artificial intelligence integration are vast.

Another pressing issue involves the "first-of-a-kind" (FOAK) funding gap. Early-stage startups pioneering groundbreaking battery and energy technologies often struggle to attract capital due to the high perceived risks and capital intensity involved in scaling such innovations. This funding gap creates uncertainty for early-stage ventures and their investors, a significant barrier to the market.

As this asset class matures, addressing these obstacles will require a multi-faceted approach, including collaboration between venture capital, infrastructure lenders, government incentives, and corporate partnerships. Understanding how to close this gap is crucial to unlocking the full potential of energy-focused startups and accelerating the energy transition.

As the world moves toward cleaner, more sustainable energy solutions, these issues will define the future of early-stage battery and energy ventures. By addressing both immediate geopolitical concerns and long-standing structural challenges, innovators and investors can better position themselves for success in this rapidly evolving sector.

This is a critical time for these technologies, and the opportunities for transformative change are more promising than ever.

Binder-free electrodes enabling high-rate Li-ion battery

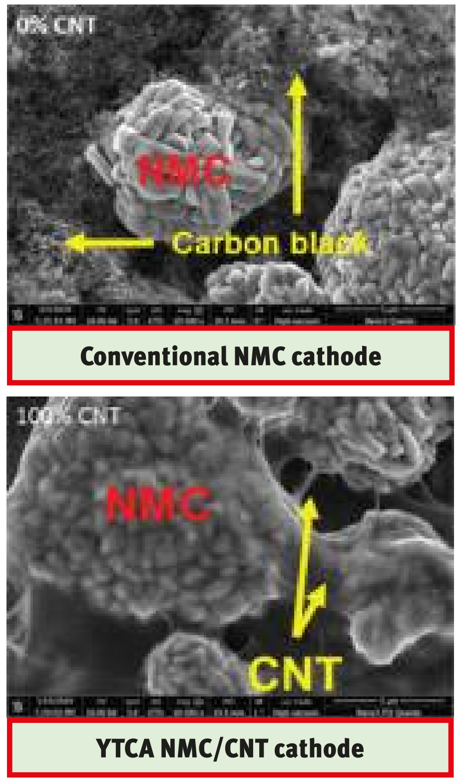
Meet us at Booth #1014

Conventional Li-ion batteries have polymeric binder in their electrodes resulting in high internal electrical resistance and hence long charge times and short product lifetime. **YTC America** has developed binder-free anodes and cathodes containing carbon nanotube (CNT) in lieu of polymer binder as electrodes for Li-ion batteries.

Commercially available CNT dispersions for Li-ion batteries are largely composed of solvent and dispersant with only 4–7 % CNT component and often include a small amount of binder. YTC America's proprietary processing of CNT into viscous organic or water-based slurry without surfactant or dispersant eliminates the need for organic binder and carbon black additives in both anode and cathode electrodes.

Moreover, the absence of binder in electrode formulations facilitates the transition away from costly and toxic Nmethylpyrrolidone (NMP) solvent for slurry preparations. The unique characteristics of our 100% CNT slurry include:

- High purity and structural quality CNT material
- Surfactant-free, dispersant-free, binder-free CNT slurry
- Both organic and aqueous media-based CNT dispersions
- Significantly reduced electrode formulation processing time
- Wide CNT viscosity range



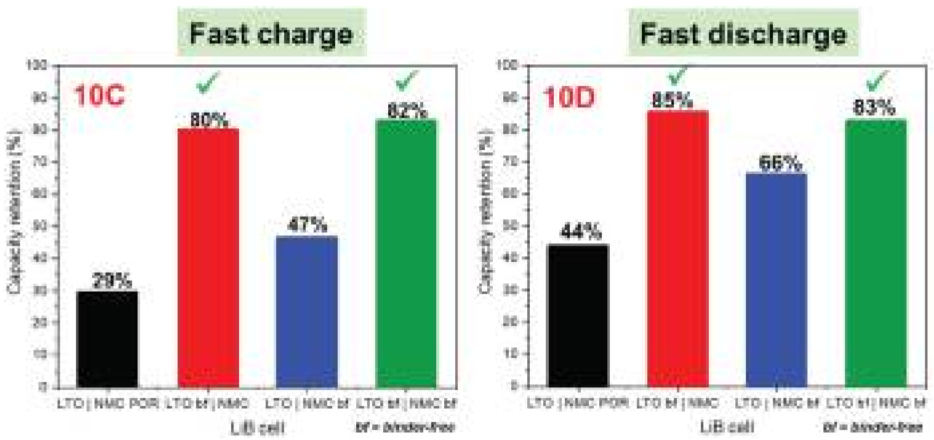
SEM images (10,000x) comparing conventional NMC cathode containing carbon black and polymer binder with YTCA's binder-free NMC cathode containing only CNT.

Our binder-free CNT slurry is chemistry agnostic and can be processed with a wide variety of anode and cathode active materials by simple planetary mixing. We have demonstrated scalable roll-to-roll (R2R) coating of binder-free anodes using graphite and lithium titanium oxide (LTO), as well as binder-free cathodes using Li-Ni-Mn-Co oxide (NMC) and lithium iron phosphate (LFP) cathode active materials.

LiB pouch cells rated at 1.5Ah and 3Ah were subsequently assembled containing the binder-containing/binder-free LTO/NMC electrode combinations. Cells containing YTC America's binder-free electrodes have demonstrated the following performance improvements over conventional cells containing electrodes with binder:

- Significantly reduced internal resistance resulting in up to 10x higher charging rates
- 2x higher capacity retention at 10C/10D-rate (charge/discharge)******10C/10D refers to full charge/discharge in 6 minutes.*
- Considerably improved cycle lifetime with insignificant capacity fade after 1,000 cycles
- 4x reduced heat loss during high-rate operation

Lower cell impedance for cells with binder-free electrodes leads to higher capacity retention under fast charging & discharging



Pioneering the future of energy: ARPA-E's ambitious PROPEL-1K program – A Moonshot for the ages

Halle Cheesman, PhD, Program Director, Advanced Research Program Agency, U.S. DoE

For batteries to contribute in the electrification of planes, trains, and ships, a new generation of ESS will be required. ARPA-E has funded next generation technologies including silicon, solid-state, sodium-ion, and iron-air, and last July embarked upon a new journey to explore electrochemistries that could achieve 1000Wh/Kg. This presentation will discuss the rationale for this program and highlight its lithium air, rechargeable LiCFx, and aluminum projects.

In the year 2000, lithium-ion batteries boasted an energy density of just 150Wh/kg. Fast forward 25 years, and that figure has doubled to nearly 300Wh/kg. With advancements in new chemistries and architectures—such as solid-state batteries, lithium-sulfur chemistries, and silicon anodes—the industry is on track to achieve an energy density of 400Wh/kg by 2030. These advancements mark an exciting era of innovation in energy storage, and ARPA-E is at the forefront of this transformation.

As the Department of Energy's disruptive innovation arm, ARPA-E has been instrumental in funding high-risk, high-reward projects with the potential to produce transformational impacts. Since its inception in 2009, ARPA-E has supported numerous groundbreaking companies in the battery space, including 24M, Solid Power, Ion Storage Systems, Sila Nano, Natron Energy, ESS Inc., and Form Energy. These companies are now in the early stages of commercialization, paving the way for the energy solutions of the future.

Introducing PROPEL-1K: A Bold Vision for Electrification Leadership

In July 2024, after two years of preparation, ARPA-E launched its most ambitious battery program yet: PROPEL-1K (Pioneering Railroad, Oceanic, and Plane ELectrification with 1K Technologies). The program's goal is audacious—to achieve 1,000 Wh/kg of electrochemical energy at the system level and at the end of life. This would enable:

- Regional flights of up to 1,000 miles
- Electrification of all marine vessels operating in U.S. territorial waters
- Complete electrification of U.S. railways

While the goals of this program include cleaner air and quieter transportation, central to these programs is energy efficiency, versatility, resilience and independence. Moreover, as history has taught us – disruptive innovation leads to new business models and revenue opportunities.

Reframing the Battery Challenge

To tackle this monumental challenge, ARPA-E adopted an unconventional approach, reframing the problem to explore new possibilities without traditional constraints. The strategy involves:

- Starting with multi-MWh systems in mind rather than small-scale cells. ***(See Fig 1)***
- Streamlining the packaging of active materials to reduce inefficiencies. ***(See Fig 2)***
- Leveraging high-energy metals as electroactive fuels.
- Eliminating temperature as a design constraint.
- Encouragement of refilling and swapping strategies.
- Solving old problems with new technologies. (Back to the Future Technology Strategy)

Five Bold Technologies for Success

This innovative perspective has led to five bold technologies to meet the PROPEL-1K objectives. As of July 2024, ARPA-E has funded 13 teams to pursue these approaches, with each team receiving $0.9 to $1.5 million to experimentally show the viability of their chosen chemistry. The teams have 18 months to deliver results before a down select phase, as a result of which the most successful projects will receive additional funding to build a 1 kWh prototype.

The Teams and Their Focus Areas

1. **Lithium-Air Batteries:** Four teams are pursuing the holy grail of battery chemistries—lithium-air. These teams include researchers from:
   - Illinois Institute of Technology – PI, Mohammad Asadi: masadi1@iit.edu

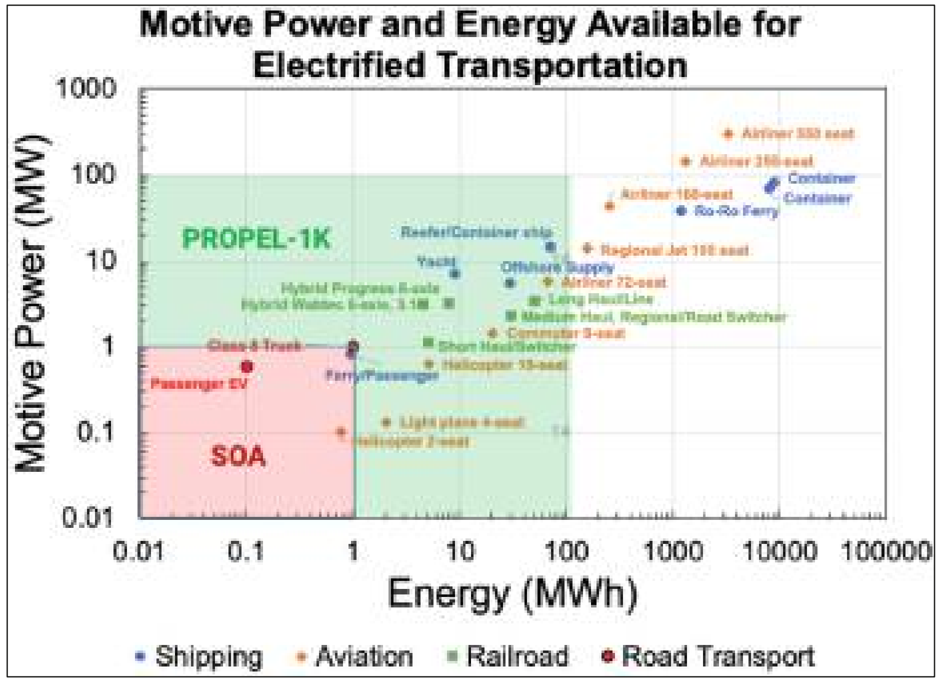


Figure 1. Map of heavy-duty transportation applications in terms of Power and Energy that shows the State of the Art (SOA) and the target arena for the PROPEL-1K Program.

   - University of Illinois, Chicago – PI, Amin Salehi-Khojin: asalehikhojin@mail.smu.edu
   - Washington University in St. Louis – PI, Xianglin Li: lxianglin@wustl.edu
   - Solid Energies Inc – PI, Tim Lin tim.lin@solidenergies.com

2. **Liquid Sodium:** Two teams are re-evaluating liquid sodium as a high-energy anode material. The participating teams are:
   - Propel Aero – PI, Yet Ming Chiang: ychiang@mit.edu
   - Georgia Tech – PI, Matt McDowell: mattmcdowell@gatech.edu

3. **Lithium CFx:** Two teams are exploring high-energy and reversible versions of lithium CFx chemistries. These teams include:
   - And Battery Aero – PI, Venkat Viswanathan: venkvis@umich.edu
   - University of Maryland – PI, Chunsheng Wang: cswang@umd.edu

4. **Hydrogen Storage and Hybrid Systems:** Two teams are focused on chemical hydrogen packaging, and one team is developing a liquid hydrogen fuel cell-battery hybrid. These teams include:
   - Giner – PI, Natalia Bencomo: nbencomo@ginerinc.com
   - Johns Hopkins University – PI, Chao Wang: chaowang@jhu.edu
   - Precision Combustion Inc.- PI, Subir Roychoudhury: sroychoudhury@precision-combustion.com

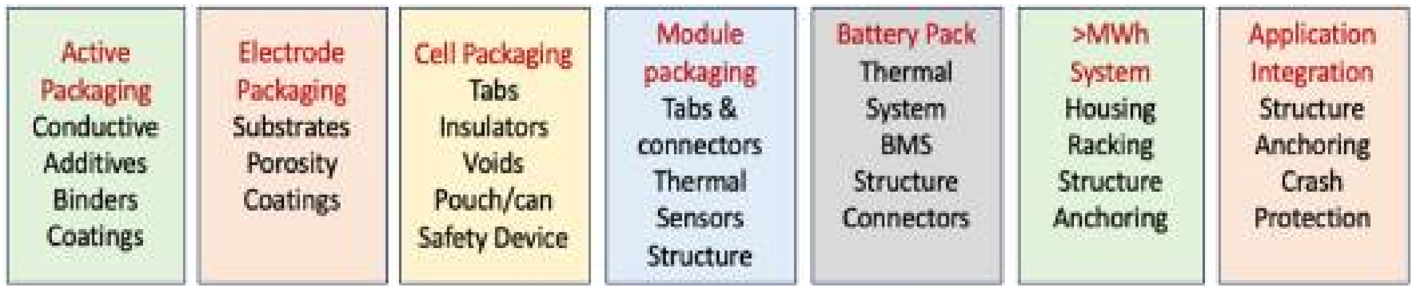
5. **Aluminum:** Two teams are investigating aluminum as an electroactive metal. One team is looking at aqueous aluminum air, and the other, aluminum combustion combined with a SOFC.
   - Wright Electric – PI, Colin Tschida: colin.tschida@weflywright.com
   - Aurora Sciences – PI, Lu Yang: Yang.Lu@aurora.aero

A High-Risk, High-Reward Endeavor

ARPA-E's PROPEL-1K program exemplifies the bold thinking needed to tackle the challenges of electrifying large-scale transportation systems. Early-stage R&D is inherently risky, and ARPA-E's programs reflect this reality. However, if even one of the 13 teams achieves the PROPEL-1K goals, the impact on transportation and energy infrastructure will be revolutionary.

Contact Info:
Halle.Cheeseman@hq.doe.gov

Figure 2. Packaging steps from materials to ISOs based on SOA practices



Advancing sustainability: battery materials technology for a greener future

Tomasz Poznar, Vice President, Strategy, Ascend Elements

As Electric Vehicle (EV) OEMs and battery manufacturers strive to secure their battery supply chains and achieve IRA compliance to advance EV adoption, integrating recycled critical minerals offer a vital solution. Critical minerals used for new battery materials production from recycled sources are IRA-compliant and are infinitely recyclable, without compromising on performance. This presentation will explore the recycling and circular economy in battery manufacturing, including life-cycle assessments of different battery materials, eco-friendly alternatives, and the evolving policy landscape in the U.S. and Europe.

Battery recycling key to advancing sustainability and energy independence

According to Tomasz Poznar, Ph.D., battery recycling and the development of sustainable engineered battery materials are essential if we are to meet the coming demand for lithium-ion batteries and minimize North America's reliance on foreign sources of critical minerals. Recycling also plays a key role in protecting the environment and minimizing pollution and carbon emissions.

As the VP of Strategy at Ascend Elements, Poznar has been deeply involved in the company's efforts to commercialize the Hydro-to-Cathode® direct precursor synthesis technology and build sustainable pCAM manufacturing infrastructure in the United States.

"Battery metals are infinitely recyclable. As electric vehicle OEMs and battery manufacturers strive to secure their battery supply chains, they are finding that recycled battery materials are the best way to make up the shortfall," Poznar said.

Indeed, industry analysts predict a short fall of North American pCAM and CAM production capacity in the coming years.

On Wednesday, March 19 at 5 p.m. ET, Dr. Poznar will present on "Advancing Sustainability: Battery Materials Technology for a Greener Future" at the International Battery Seminar in Orlando, Florida. The presentation will explore the recycling and circular economy in battery manufacturing, including life cycle assessments of different battery materials, eco-friendly alternatives, and the evolving policy landscape in the U.S. and Europe.

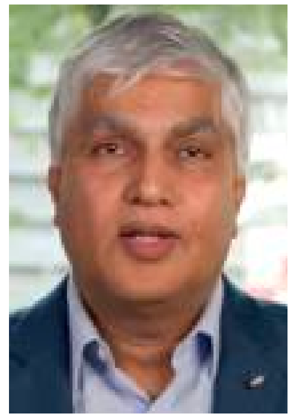
Understanding the intersection of recycling, the circular economy, and domestic compliance is crucial for EV OEMs navigating the rapidly changing battery manufacturing landscape. With the anticipated shortfall in pCAM and CAM capacity, OEMs must explore innovative recycling processes and eco-friendly alternatives to maintain supply chain resilience, reducing reliance on mining for critical raw materials.

During the presentation, Poznar will share details of Ascend Elements' Hydro-to-Cathode® process, including life cycle assessments, decarbonization strategies, and performance data. He will discuss the evolving policy environment in the US and Europe, providing valuable insights for OEMs to stay compliant and competitive. Practical solutions can help OEMs navigate these challenges and ensure compliance and competitiveness in the EV market.

"Yes, battery recycling can help OEMs achieve net zero goals," Poznar said. "That is an important part of the appeal. But, in the short term, battery recycling and domestic manufacturing of pCAM and Lithium carbonate may be the best way to secure critical materials and reduce North America's reliance on Asian battery materials."

On-line elemental composition of black mass and mixed metals for lithium-ion battery recycling.

Getting real-time data when and where you need it most.



Rajendra Mishra, Product Mgr, Malvern Panalytical

Monitoring black mass materials, from OEM scrap to end-of-life batteries, is crucial for optimizing Li-ion battery recycling operations. The elemental composition of these materials can vary significantly based on formulation (NMCs, LFPs), source (closed-source versus open-source), size, type, and region. An effective solution to address this variability is the use of an on-belt PTNFA analyzer, which can identify the elemental composition of materials in real-time. In this talk, we will explore the PTFNA system and discuss how it reports data to enhance operational efficiency.

The shift to electric vehicles is crucial for combating climate change and improving air quality. By adopting electric mobility, we can drastically reduce greenhouse gas emissions and harmful pollutants into the environment.

While EVs help reduce dependence on fossil fuels by offering cleaner alternatives to traditional combustion engines and promote a sustainable future, managing their end-of-life batteries poses a significant challenge. Hence, battery recycling is crucial for conserving natural resources and protecting the environment. By recovering valuable metals like nickel, cobalt, and manganese from old batteries, we reduce the need for mining and lessen the environmental impact associated with extraction.

Black Mass, a powdery extract from crushed LFP and NMC lithium-ion batteries, is essentially a concentrated form of cathode material rich in valuable metals like nickel, cobalt, and manganese. These metals can be recovered through hydrometallurgical or pyrometallurgical processes. Precisely determining the metal content within black mass is vital for optimizing the recovery process and ensuring its efficiency. Unlike the LFP, NMC Lithium-ion batteries have diverse compositions, including variants like 622, 811, 111, 333, and 532. The black mass recovered from spent lithium-ion batteries is highly inconsistent in composition, making traditional laboratory analysis through sampling a challenge. The CNA Pentos, equipped with unique D-T PFTNA electrical neutron generator, offers a solution by enabling direct bulk measurement of incoming black mass.

#BlackMass #PFTNA #OnlineAnalyser #RealtimeAnalyser #CNAPentos #BatteryRecycling

Selection of process drying technology for maximum black mass and electrolyte recovery

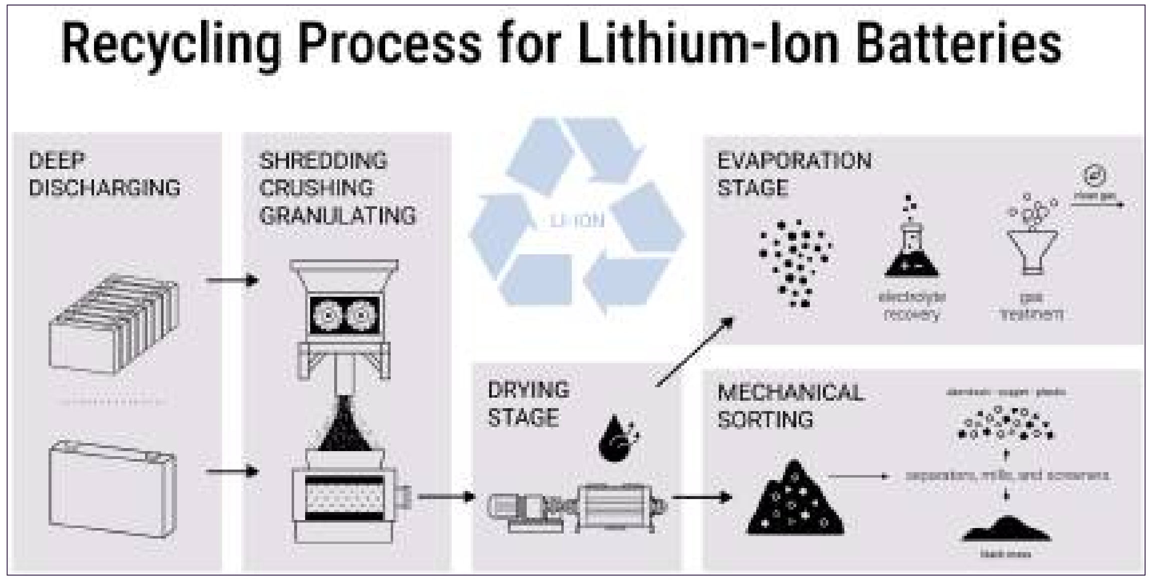
Barry A. Perlmutter, President, Perlmutter & Idea Development (P&ID) LLC

The drying process is fundamental in chemical process engineering for solids handling. The term "drying" usually refers to the thermal removal of a liquid from a solid product. After mechanical shredding of the lithium-ion battery, process vacuum drying is critical for maximum black mass and other solids recovery and for electrolyte recovery. Dryer technologies are discussed including surrounding ancillary equipment, installation, safety, reliability, and troubleshooting.

There are many driving forces for battery chemicals manufacturing for electric vehicles (EV), consumer power tools, electronics, etc. There are also needs for reducing carbon footprints and enabling the circular economy. Through the recycling of end-of-life (EOL) lithium-ion batteries (LIBs) as well as wet and dry production scrap, the recovering of black mass for reuse can achieve these objectives.

Black mass is defined as cathode active material (lithium, nickel, cobalt and manganese). Other recovered materials include anode active material (graphite, silicon and lithium) and residual metals (copper and aluminum) and plastics.

Recycling lithium-ion batteries is a complex, multi-step process that transforms end-of-life batteries, production scrap, and defective cells into valuable recoverable materials. This intricate process can be broken into several critical blocks, including the deep discharging of batteries, dry shredding/crushing/granulating, process drying to recover the electrolyte and advanced classifying and sorting into distinct material fractions. Each step is vital to ensuring safety, efficiency, and maximum resource recovery. This is shown in Figure 1.



First, for safety reasons, the batteries or scrap must be discharged to a "fully-discharged" state-of-charge (SOC). The used batteries still have energy stored in them, which, in the presence of oxygen and an ignition source, can lead to a thermal event. Alternatives for this initial step include soaking in salt-water brine baths or controlled discharge via external circuits. The benefit of controlled discharge is the recovery of the energy back to the grid or to an energy storage system (ESS).

For this second-stage operation, the preferred alternative is dry mechanical shredding-crushing-granulating. In dry shredding, the shredding process is conducted in a nitrogen environment to eliminate safety issues. There is a flow of the inert nitrogen gas creating a blanket and eliminating oxygen.

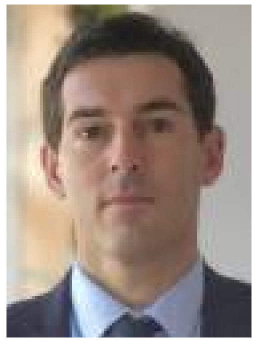
The design of this stage depends upon the type of LIBs (EV pack, module, cell or scrap). Typically, there is a pre-shredder which is a low-speed, high-torque rotary shear shredder designed to shred and liberate materials within the machine until they are small enough to pass through a removable screen below the cutters. The second stage is high-speed and low-torque granulating machine with a rotor with attached blades to cut the LIBs to certain sizes that can pass through the integrated screen.

After mechanical shredding of the lithium-ion battery, process vacuum drying is critical for maximum black mass and other solids recovery and electrolyte recovery. The drying process is fundamental to the recycling process and is the thermal removal of the electrolyte from the black mass. In the vacuum drying process, gas treatment control for volatile organic compounds (VOCs), hydrofluoric acid (HF) and dust are included.

In the final step of sorting and classification, the black mass material is recovered along with a mixture of aluminum, copper and plastics. Screening, mills and separators are used sequentially to recover the materials by size.

Recent innovations to improve sustainability of batteries: a journey from materials to application

Sebastien Patoux, PhD, Head of Battery Technologies department, LITEN institute, CEA



Without dismissing energy density, it is necessary for electric mobility to propose sustainable technological solutions at lower prices using less critical raw materials, less solvent for electrode processing, simplified pack design consideration for easier dismantling and longer lifetime. Our journey will cover materials to systems, including not only Li-ion, but also post-Li and non-Li battery technologies. For the latter, we will address sodium- and potassium-ion batteries, in particular.

To face the huge demand for Li-ion batteries, it is expected to further reduce their carbon footprint and to limit the use of critical raw materials now. In this communication, we will present our recent work on battery technologies focusing on sustainability options. Our journey will cover from materials to the system, including non Li-ion battery technologies.

Who we are ?

Established in 1945, CEA is a non-profit French research and technology organization employing 21,000 people today. As a key player of the French dissuasion policy, CEA guarantees the country credibility and contributes to public safety. Research on the atom remains strategic as it lies at the heart of our new technologies in defence, low-carbon energies (both nuclear and renewable), digital technologies and health. CEA is doing R&D for 700 industrial partnerships, including the US, Japan, and Korea.

CEA is involved on Li-ion batteries for 30 years, and holds more than 600 patent families. Our 300 researchers on this topic cover the whole value chain from materials synthesis to cells and packs assembly, including recycling, life cycle assessment, modelling and characterization tools (see figure below). The work on batteries is mainly carried out at the Liten institute located in the French Alps region.

Improved sustainability

At the conference, we will share our recent works on batteries focusing our messages on the improvement of sustainability. To this aim, energy density is important, but not the ultimate target, unlike the last three decades paradigm. Here, lifespan is a prime criterion, together with the resource saving.

The first option is to reduce the need for critical materials such as cobalt or nickel. CEA started to make R&D on LFP technologies in 2000, filling patents at the material, cell and system levels, having many industrial collaborations, including IP licensing, and making functional demonstrators as for HEV, EV, eBus and off-road vehicles. According to the European and US markets, we slowed down LFP activities to accelerate on NMC and solid-state batteries in the mid 2010's.

Apart from Li-ion, to reduce materials dependency, we do R&D on Na-ion and K-ion batteries. During the presentation, we will highlight some results on polyanionic frameworks, Prussian blue analogs and bio hard carbons. Organic batteries are also considered as an alternative, but energy density and cycle life we achieved are currently too low to compete with LFP/Graphite in terms of ACV and cost.

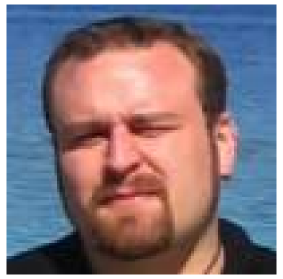
The second complementary option is to develop less energy-intensive and more environmentally friendly manufacturing processes for materials and electrodes. Our main researches focus on low temperature synthesis for materials, water based and dry process for electrodes.

To minimize the environmental impact at the system level, we i) use life cycle analysis methodology, ii) select the right materials and processes, iii) bring eco-design approach to facilitate maintenance and to manage end-of-life, iv) optimize the thermal management system to enhance lifespan, and v) consider the final uses as soon as possible during R&D.

Finally, we recycle batteries with a closed-loop approach to reduce global footprint. Information should be disclosed on an original route to recover materials.

Characterization of process water from lithium-ion battery recycling

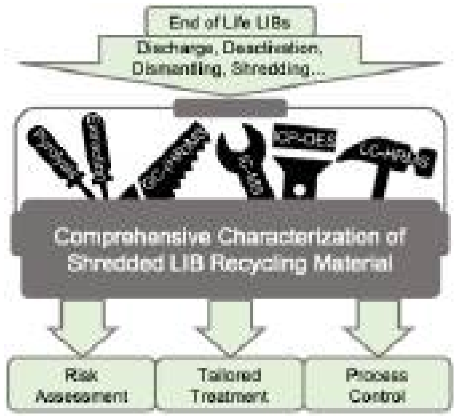
Sascha Nowak, PhD, Head of Analytics & Environmental, Electrochemical Energy Technology, University of Münster



Water-using recycling processes—such as wet crushing and electrohydraulic fragmentation—generate large amounts of contaminated process water, resulting in increased costs for the disposal of hazardous waste and safety guidelines. To improve wastewater management, safety, and sustainability of water-assisted recycling processes, comprehensive knowledge of the battery components in the water are required. Analytical techniques can play an important role during these processes, including wet shredding processes, wastewater management, and analytical techniques.

The lithium ion battery (LIB) is considered as key technology for the electrification of the mobility sector and for stationary storage systems of energy from sustainable resources. However, achieving a circular economy by closing the recycling loop in a highly efficient process is essential for this sustainability of the technology.

Water-using recycling processes—such as wet crushing and electrohydraulic fragmentation—generate large amounts of contaminated process water, including cathode active material, graphite, binders, conductive salt, and also electrolyte solvents, resulting in increased costs for the disposal of hazardous waste and safety guidelines.



Source: Peschel et al. *Chemistry - A European Journal*, Nr. 28 (22): e202200485. doi: 10.1002/chem.202200485.

To improve wastewater management, safety, and sustainability of water-assisted recycling processes, comprehensive knowledge of the battery components in the water are required. Analytical techniques can play an important role during these processes, including wet shredding processes, wastewater management, and quality control.

Therefore, comprehensive application of a wide range of analytical methods enables a deep understanding of elemental composition and present organic species. Despite material complexity and lack of information on material history, deep understanding of the present recycling material can be obtained.

Beside the information about the remaining compounds like metals or other elemental impurities, which are accessible by established methods, especially for the organic compounds (and conducting salt residues) inside the wastewater, quantitative information is needed for regulation and processing.

However, water can harm the GC column and lead to degradation and the large volume expansion demands smaller injection volume, which makes the task challenging. Volatile organic electrolyte solvents and their decomposition products are quantified using different gas chromatography-detectors like flame ionization or mass spectrometry. Nevertheless, here, a different approach is needed. Therefore, a quantitative extraction of the analytes from the wastewater is mandatory.

Solid-phase extraction (SPE) is a common approach to solve these issues, but was so far not applied to lithium ion battery recycling wastewaters. A novel method was established to quantify the amounts of organic solvents in the wastewater.

Enhance battery safety and performance through thermal analysis and in-operando isothermal microcalorimetry

Hang Lau, Segment Marketing Mgr, Segment Marketing, TA Instruments

Thermal analysis techniques are extremely valuable tools for evaluating the thermal stability of battery materials. The decomposition onset temperature, reaction mechanism, and heat of reaction are essential to improving battery safety by design. At the cell level, In-operando isothermal microcalorimetry can simultaneously measure thermal and electrochemical data for a non-destructive determination of performance and stability. Evaluating the thermal properties of a battery during normal operating conditions is crucial for evaluating performance, gaining a deeper understanding of the chemistry, and studying the mechanisms of failure

Thermal analysis techniques are invaluable for evaluating the thermal stability of battery materials. Key parameters such as decomposition onset temperature, reaction mechanisms, and heat of reaction are essential for improving battery safety by design.

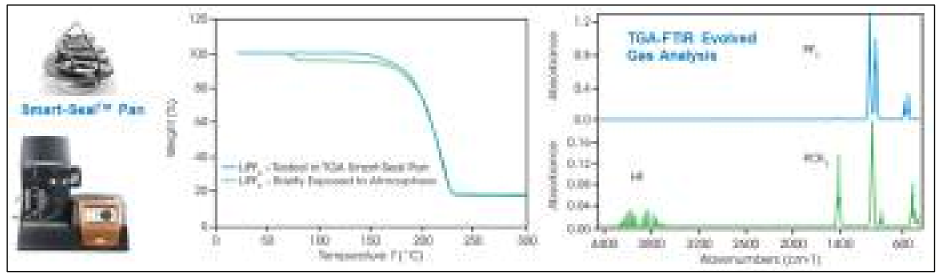
At the cell level, in-operando isothermal microcalorimetry can simultaneously measure thermal and electrochemical data, providing a non-destructive determination of performance and stability. Evaluating the thermal properties of a battery during normal operating conditions is crucial for assessing performance, understanding the chemistry, and studying failure mechanisms.

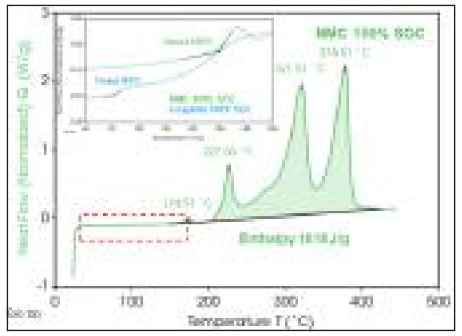
Thermal analysis improves safety

Thermal analysis techniques, including thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC), are commonly used to determine the thermal stability of battery materials. These techniques help identify the onset of exothermic reactions and measure the heat of reactions.

Commercially available lithium-ion electrolytes, which contains lithium salts (such as $LiPF_6$) and organic-based carbonate solvents, are known to be highly flammable, emitting toxic gases (such as hydrofluoric acid) during thermal degradation. TGA is used to determine the temperatures at which battery materials start to degrade, quantifying thermal stability, oxidation, and thermal degradation. By combining TGA with evolved gas analysis techniques, such as infrared spectroscopy (FTIR) or mass spectrometry, researchers can identify the gases produced during thermal degradation. This helps minimize or eliminate toxic gas release during battery thermal runaway.

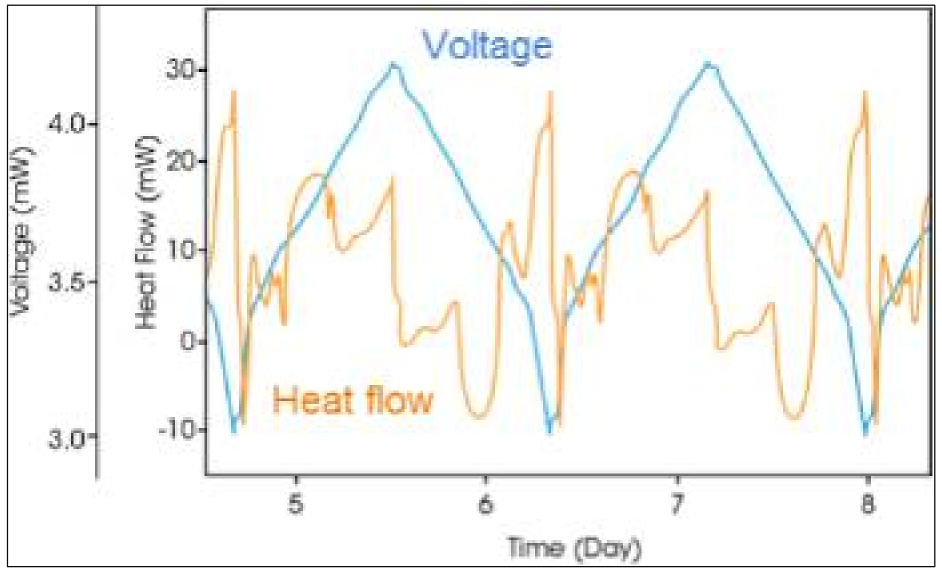
DSC measures the heat absorbed or released by a sample during heating or cooling over a range of temperatures. DSC provides insights into the heat of reactions, heat capacity and phase transitions such as melting point (T_m), heat of fusion, and glass transition (T_g), enabling researchers to evaluate thermal stability of materials used in batteries. Understanding the onset temperature and the amount of heat released during an exothermic reaction can help battery engineers design thermal management systems and perform safety evaluations of cathode and anode materials in different states of charge (SOC). This information is crucial for designing safer batteries.





Gaining insights into battery performance with in-operando microcalorimetry

Evaluating batteries during charge and discharge cycles is crucial for assessing efficiency, quality, and understanding lithium-ion battery chemistry. Batteries are highly dynamic systems, with a mixture of electrochemical reactions, chemical reactions, and structural changes occurring during each cycle, producing heat as a byproduct. Electrochemical analysis can only provide information on processes that affect electrochemical reactions, leaving other processes (chemical, phase, structural changes) uncharacterized. In-operando microcalorimetry is the leading technique for studying parasitic reactions, which are side reactions that can significantly impact the performance and longevity of lithium-ion batteries. This technique provides a comprehensive understanding of all processes occurring within the battery, helping researchers develop more efficient and durable batteries.



Measuring time-correlated voltage and heat flow signals of a battery under charge and discharge cycles (as shown in the chart below) can reveal the thermal contribution of parasitic reactions. Cycling a cell to failure can take many months but emerging in-operando tests with additional thermal insight are able to predict long-term behavior in a matter of weeks. The results help measure cell quality, aid in material formulation, assess additive impacts, study the solid electrolyte interphase (SEI), and predict cycle and calendar life. These data assist researchers in developing new materials, reducing parasitic activity, and screening cells with high parasitic activity for quality control.

Conclusion

In the race to develop safer, better-performing batteries more efficiently, advanced analytical testing provides crucial information for improving battery chemistry and manufacturing. Thermal and electrochemical analyses offer insights ranging from individual material properties to whole-cell battery performance. Embracing the latest technology helps battery developers bring more durable, safer, and cost-effective batteries to market faster.

TA Instruments, a division of Waters Corporation, is the world leader in manufacturing industry-leading systems for thermal analysis, rheology, microcalorimetry and mechanical analysis. We offer innovative and reliable instruments that help scientists in top laboratories test the physical properties of their materials. Our instruments contribute to leading discoveries in medicine, materials science, batteries and other areas of science devoted to improving our world.

Recycling of battery grade graphite

Stefan Bergold, Chief Commercial Officer, Vianode

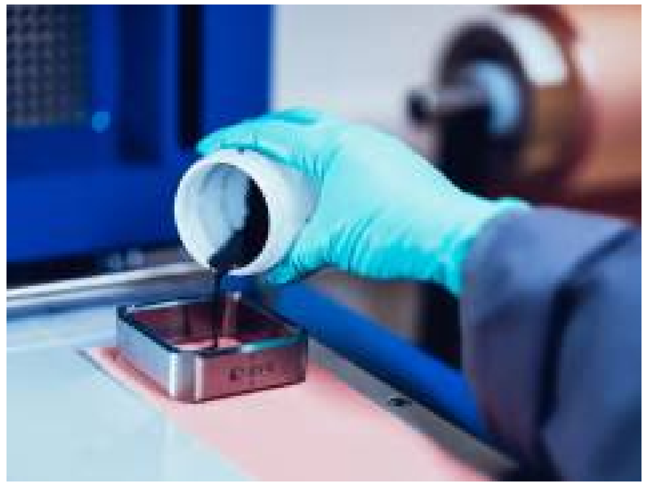
Electric vehicles reduce CO_2 emissions while driving to zero. For the overall CO_2 balance, also the manufacturing process must be considered. Especially the anode of the battery can result in high CO_2 emissions during manufacturing. This presentation discusses how Vianode is manufacturing high volume competitive anode materials with state of the art performance in North America and Europe. The Vianode proprietary production process offers a substantial improvement in product consistency, energy efficiency, CO_2 and other emissions. Vianode's first large scale plant in Norway opened in 2024 and a full scale production plant in North America is under construction and will have SOP in 2027.

Recycling batteries is getting to be a standard as of today. Reasons for this are; re-use of critical minerals, minimizing costs, reducing the carbon footprint and meeting regulatory requirements.

Various battery recycling technologies are developed and running in pilot mode and full-scale mode already.

The biggest blocking point for battery recycling as of today is the availability of recycling material. Forecasts predict much more recycling batteries will be available starting in 2030 and afterwards.

Most recycling is focused on the cathode material, the copper, the aluminum and the steel, because these materials have a higher value. But graphite is getting more and more in the recycling focus as it is a critical material.



Vianode is an advanced battery materials company providing sustainable anode graphite solutions for the battery and electric vehicle value chains in North America and Europe. Vianode's breakthrough solution enables tailored high-performance synthetic anode graphite and a holistic sustainability offering including a 90% reduction in CO_2 footprint

In recent years, Vianode has developed a one-of-a-kind method for converting graphite concentrates from lithium-ion battery production scrap and end-of-life batteries (black mass) back into anode-grade graphite for use in new lithium-ion batteries.

Using a high temperature purification stage, impurities and flaws in graphite can be effectively removed and a purity of over 99.99% can be attained. Cell testing reveals that recycled graphite can achieve the same properties as virgin graphite, including outstanding reversible capacity, first cycle efficiency, fast charge capability, and cycle life.

The results indicate that graphite recycling should be implemented as soon as possible to lessen the reliance on graphite imports and significantly reduce the environmental impact of anode materials in lithium-ion batteries.

Blockchain solution for improving Li-ion batteries recycling and material recovery

Ahmad Mayyas, PhD, Professor, Industrial & Systems Engineering, Khalifa University

This study proposes a blockchain-based solution to optimize the recycling process of lithium-ion batteries, addressing critical challenges in battery lifecycle management as demand surges due to their role in electric vehicles and renewable energy systems.

The urgent need to combat climate change and reduce greenhouse gas emissions has driven a surge in global demand for lithium-ion (Li-ion) batteries, which are extensively used in portable electronics and electric vehicles. However, their widespread adoption faces challenges related to mining ethics, supply chain transparency, sustainability, and waste management.

We proposed a blockchain-based solution to address these challenges in the Li-ion battery supply chain. By utilizing the ERC-721 standard for Non-fungible tokens (NFTs), we can tokenize all items and materials in the supply chain, ensuring effective data management, transparency, and ownership control. This model also integrates the Ethereum blockchain with the Interplanetary File System (IPFS) to manage NFT metadata and large files, thereby reducing storage costs and network congestion.

Ten smart contracts were developed to facilitate various functionalities within the Li-ion supply chain, managing data and ownership of items and materials. Our solution leverages NFTs to promote circular economy principles, enabling secondary market trading, asset reuse, and sustainable recycling practices. This structured decision framework can help help stakeholders navigate operational and ethical challenges effectively.

Economic assessment of hybrid energy storage for multi-energy arbitrage in wholesale electricity markets

This presentation focuses on the commercial application of energy storage and economic potential of hybrid energy storage systems for multi-energy trading and arbitrage in electricity markets.

Power grids with significant shares of intermittent renewable energy often experience imbalances between supply and demand, necessitating energy storage solutions. However, large-scale integration of energy storage faces challenges due to limited commercial attractiveness. This study focuses on the commercial application of energy storage, exploring the economic potential of hybrid energy storage systems for multi-energy trading and arbitrage in selected wholesale electricity markets in the United States, namely CAISO: California Independent System Operator; ERCOT: Electric Reliability Council of Texas, PJM: Pennsylvania-Jersey-Maryland Regional Interconnection, and MISO: Midcontinent Independent System Operator. A linear optimization model was developed to maximize profits at given energy prices by identifying an optimal hybrid energy system configuration and trading pattern.

A case study involving a combination of Li-ion battery and Solid Oxide Reversible Fuel Cell technologies evaluates the trading economics for electricity-only and electricity-hydrogen arbitrage across four wholesale electricity hubs in the United States. The results indicate that electricity-only arbitrage is generally unprofitable due to high storage capital costs.

In contrast, multi-energy arbitrage shows promise, with electricity and hydrogen arbitrage via reversible fuel cells generating annual profit margins of at least 20% in all four markets. These findings are crucial for expanding economically viable options for grid-scale energy storage adoption.

A new dry coating process is about to shake up the battery industry

Hieu Duong, Chief Manufacturing Officer, AM Batteries

The electrification of every major industry has pushed conventional battery manufacturing techniques to their breaking point.

The evolving needs of OEMs and other end users have driven the commercialization of solid-state, silicon anode, and other chemistries to meet the requirements of new applications for battery storage. But the limitations of conventional manufacturing processes—particularly for battery electrodes—have been a bottleneck in bringing these new battery chemistries to market at scale.

Beyond Slurry Coating

For decades, the wet slurry-casting approach has been the industry standard for electrode manufacturing. The refinement of this technique has been critical to driving down the cost of lithium-ion cells and accelerating their widespread adoption. But we are quickly reaching the point of diminishing returns for optimizing wet electrode manufacturing processes.

Dry coating is a catchall term for electrode manufacturing processes that don't use a slurry as their input. Instead, a dry powder is mixed and then deposited directly on the collector. Dry coating eliminates the drying and solvent recovery step in slurry-based processes, which conserves space, time, and operating capital at manufacturing facilities. It also enables far more versatile electrode chemistries because they aren't constrained by the type of binder used in the slurry and can be integrated with existing wet manufacturing processes.

Dry electrode manufacturing processes will be critical for meeting the surging global demand for batteries. For more than a decade, the general consensus has been that dry coating technology is promising, but still too immature to be commercially viable.

The Electrostatic Electrode Era

The successful commercialization of the world's first dry electrode by Tesla using the Maxwell process—a program that I co-led—was a shot across the bow for the battery industry. Manufacturers can't afford to not have a dry electrode research program. But so far those R&D efforts have not leapt out of the lab and into commercial products. The reason is simple—dry electrode manufacturing is hard.

One of the biggest challenges for dry electrodes has been achieving precise, uniform coatings. Some extrusion-based dry coating processes are able to clear the consistency bar, but they are limited to thicker electrodes and binder materials such as PTFE. To unlock the scaled production of next-generation batteries that use thin electrodes or require different binder chemistries requires a more dynamic dry coating method.

Electrostatic dry coating is the only approach that can meet this lofty standard. Like extrusion-based dry coating, this method begins with dry mixing of the active materials, binders, and conductive additives into a composite powder. The crucial difference is that this powder is applied to a charged metal foil using an electrostatic powdering process, which eliminates the need for gap dosing roller systems found in extrusion-based dry coating processes.

After the powder is electrostatically deposited on the foil, it undergoes a hot calendering process that sets and bonds the powder layer into an electrode. This streamlined three-step process not only eliminates hazardous solvents and dramatically reduces energy consumption, it also provides manufacturers with unmatched control over electrode properties. It achieves uniform deposition across the electrode and is materials agnostic.

Electrostatic dry coating will unlock solid-state, sodium-ion, and other emerging battery chemistries while continuing to push down the cost curve. It doesn't require a complete overhaul of production lines, enabling a smoother integration with existing processes. But perhaps most importantly, it's the dry coating method that breaks the trade-off between current needs and future possibilities - allowing you to confidently scale production today while staying ready for tomorrow's innovations.

Fiber-based separators— the key to efficient manufacturing and enhanced battery performance

Alexander Onz, Technical Program Manager IonPort, Sales, Delfort

Often disregarded but crucial in every aspect, separators play an important role in battery development & production. Delfort's latest innovation, IonPort separators, bring significant benefits to both manufacturing efficiency and battery performance. Delfort has developed cutting-edge separators specifically designed for secondary batteries. With its exceptional thermal stability and ability for rapid electrolyte absorption, IonPort separators contribute effectively to enhanced and energy-saving cell production. Moreover, its unique innovative porous cellulose-fiber structure enhances ion flow, boosting charge/discharge rates and extending the battery's lifespan.

Often disregarded but crucial in every aspect - separators play an important role in battery production and development. delfort's IonPort® separators bring significant benefits to both manufacturing efficiency and battery performance. As a leading supplier of ultralight specialty papers, delfort has developed cutting-edge separators specifically designed for secondary batteries. With its exceptional thermal stability and ability for rapid electrolyte absorption, IonPort®

separators contribute effectively to enhanced and energy-saving cell production.

Thanks to their exceptionally high heat resistance, IonPort® separators feature almost no shrinkage even at temperatures of up to 320°F (160°C). They maintain their integrity as well as their pore and fiber structure without compromise. This makes IonPort® safe and the ideal separator for jelly-roll or stack drying and cell baking - manufacturing process steps that allow for the minimization of dry room requirements and, consequently, the associated investment and operating costs.

Cells with the thermally-stable IonPort® separator can be dried at higher temperatures, reducing drying time by up to 40%. This significantly lowers production time and manufacturing costs.

Beyond their thermal advantages, IonPort® separators are characterized by their high surface energy and exceptional wettability. As a result, electrolyte filling can be completed much faster, saving approximately 25% in time. Further, the electrolyte is evenly distributed throughout the cell, reducing cell wetting time by up to 50%.

Compared to a conventional cell assembly process in a dry room, the use of IonPort® separators in combination with cell baking can reduce manufacturing costs by up to 7.5%.

Moreover, IonPort® separators positively impact cell performance for a wide range of cell chemistries. Its unique porous cellulose-fiber structure enhances ion flow, boosting charge/discharge rates and extending the battery's lifespan, whilst featuring highest battery safety by its thermal stability.

Come and see for yourself - during our speech or personally at booth 1120 at the International Battery Seminar in Orlando, FL, from March 17-20, 2025.

Revolutionizing lithium-ion batteries: SILO Silicon™ delivers double the range, half the weight

Jeff Norris, CEO, Paraclete Energy Inc.

Explore Paraclete Energy's SILO Silicon technology, a breakthrough in silicon-anode materials for electric vehicles. With 300% the energy density of traditional graphite, SILO Silicon delivers a cost of just $35/kWh, outperforming LFP by 34%. This innovative, silane-free solution enhances battery safety, sustainability, and scalability, paving the way for faster charging, longer range, and significant cost savings. Learn how our silicon/polymer architecture eliminates silane gas, enabling safe, location-flexible production that supports the next generation of clean, affordable energy storage solutions for EVs and beyond.

As the demand for high-performance lithium-ion batteries grows—whether for EVs, consumer electronics, or energy storage—manufacturers need solutions that offer greater power, lower costs, and a smaller environmental footprint. SILO Silicon™ is that solution.

Built on an advanced polymer matrix platform, this breakthrough silicon anode material doubles energy density, slashes costs, and enhances sustainability—transforming battery technology beyond incremental improvements.

Paraclete Energy is the only silicon anode material supplier identified by Cairn Energy Research to be at "Technology Readiness Level 9: Actual system proven through successful mission operations."

Evaluation samples are available! Contact info@paracleteenergy.com to explore SILO Silicon™ for your application.

A new sstandard in battery performance

Imagine a battery that doubles the range at half the weight—with SILO Silicon™, that vision is now a reality.

At its core, SILO Silicon™ features a proprietary polymer matrix platform that forms an elastic, porous cocoon around silicon nanoparticles, encased in a flexible yet inelastic polymer. This structure minimizes silicon expansion to just 1%, solving a critical challenge in battery design while ensuring superior ionic and electronic conductivity.

Unlike traditional graphite anodes or silane gas-based silicon alternatives, SILO Silicon™ contains up to 80% silicon—far exceeding the industry standard of 20%. It captures 75% of silicon's theoretical energy density, compared to less than 10% for competing materials. The result? A leap forward in battery performance.

Unmatched advantages

1. **Double the range, half the weight**
   SILO Silicon™ enables energy densities exceeding 520 Wh/kg, delivering up to 580 miles per charge while reducing battery pack weight by 50%.

2. **33% lower cost per kWh**
   This technology lowers costs by a third, making lithium-ion batteries more affordable and accelerating adoption across industries.

3. **Faster charging & greater efficiency**
   SILO Silicon™ recharges faster, lasts longer, and matches graphite-anode performance at just a quarter of the weight—requiring one-third the number of cells.

Sustainability & supply chain advantages

- **No hazardous silane gas**—SILO Silicon™ eliminates the need for silane gas, using a safer, metallurgical-grade silicon process.
- **Localized, energy-efficient production**—Reduces costs, shortens supply chains, and minimizes environmental impact.
- **Maximizes silicon utilization**—1,000 tons of SILO Silicon™ powers nearly 10 times more EVs than silane gas-based alternatives.

Experience SILO silicon™ at IBS

Years of research back SILO Silicon™'s revolutionary potential. In a study, an 80 kWh battery pack using SILO Silicon™ reduced weight by 73%, requiring only 2,000 cells instead of 7,000. A 300 kg battery pack can now reach up to 160 kWh, doubling today's EV driving range.

- **Join us at booth 801** to meet the Paraclete Energy team and discover how SILO Silicon™ is redefining battery performance.
- **Don't miss our technical session!**
- **Paul Jones, VP of Corporate Strategy** will present in-depth insights on SILO Silicon™'s architecture, performance benchmarks, and research-backed advantages.
- **Tuesday at 12 pm**

The future of lithium-ion battery performance is here.

Contact info@paracleteenergy.com to request evaluation samples today.

Technology startups, provisional patent applications, and due diligence – what you need to know

Grant M. Ehrlich – Stites & Harbison, PLLC

Coffee Talk: interactive roundtable discussion with coffee & pastries. Roundtable discussions are informal, moderated discussions with brainstorming and interactive problem-solving, allowing participants from diverse backgrounds to exchange ideas and experiences and develop future collaborations around a focused topic.

Filing provisional patent applications is often one of the first actions taken by a technology startup. To secure a 'first-to-file' status, it is often essential to file provisional patent applications promptly, especially when they contain critical concepts. These applications, or applications derived from them, may later be inspected by potential investors before a capital raise or other transaction in a due diligence investigation.

Due diligence investigations can either confirm clear title or assess the substance of the intellectual property, evaluating factors such as its scope, resilience against invalidity challenges, ease of detecting infringement, and whether the commercial product is protected globally.

In this discussion, attorney Grant M. Ehrlich of Stites & Harbison, PLLC, will explore a few examples to highlight what is necessary to secure the expected protection from a provisional application and what to anticipate during a due diligence review.

Ehrlich supports technology-based companies in the development and implementation of effective intellectual property strategies. He has drafted and prosecuted patents and has prepare non-infringement, invalidity, and freedom-to-operate opinions in fields spanning batteries, fuel cells, thermoelectrics, electrolysis, metallurgy, nanotechnology, displays, sensors, medical devices, magnetic and magnetocaloric materials, ceramics, water treatment, heating systems, lubricants, detergents, coatings, and phosphors.

Ehrlich has significant experience in the preparation and negotiation of domestic and international patent license agreements, technology transfer agreements, and material transfer agreements.

Stites & Harbison is a full-service law firm representing clients across the United States and internationally. The firm represents a broad spectrum of clients including multinational corporations, financial institutions, start-up entities, pharmaceutical companies, manufacturers, health care organizations, private companies, nonprofit organizations, and individuals.

Tracing its origins to 1832, Stites & Harbison is one of the oldest law practices in the nation. The firm has 12 offices across seven states: Connecticut, Georgia, Indiana, Kentucky, Ohio, Tennessee, and Virginia.

North America's battery plans hinge on the localization of supply chains, but how?

Kimberly Berman, Independent Consultant

As automakers re-tool their EV strategies, the elephant in the room remains how to secure the necessary supply chains for the energy transition. Nickel supply has been severely impacted by mine closures and social unrest, but incentive pricing remains low. Phosphate might be abundant, but supply chains are earmarked for the agricultural industry. Processing methods for battery materials in China will not pass the permitting process in Europe and North America.

The profitable production of vehicles involves the creation of local automotive clusters to ensure dependable sourcing of parts, chips, and components to reduce the risk of costly production shutdowns. As a result, the North American auto industry has streamlined the value chain for traditional gas-powered vehicles to maximize profitability by creating clusters of supplies around assembly plants.

Although electric motors are comparatively easier to build, the first point of the EV value chain starts with the extraction and refining of critical minerals and these are inconveniently located, sourced from geo-politically risky countries, or both. Adding further supply chain risk is that processing to produce battery grade materials at the scale necessary is mostly a China-only phenomenon. Of the many critical materials needed to produce batteries, nickel's changing market dynamics over the last few years magnifies the supply chain woes impacting the industry.

Once viewed by battery engineers as the answer to supply chain risks associated with cobalt, nickel experienced extensive price volatility at the start of the Russian-Ukraine war as Russia produced 11% of global supply in 2021. However, while this may have spooked the nickel market, it is the meteoric rise of Indonesia as a source of battery grade nickel, that has cornered the automakers outside of China even though prices remain at 4-year lows.

There are multiple pathways to produce nickel and lower grade resources (laterite ores) have a higher emission intensity compared to higher grade resources (sulphide ores). Nickel mining from sulfide ores in the Northern hemisphere is straight forward and more importantly, they are reliable. Nickel supply chains in Canada are mature and production of key mine sites have been extended, this supply is mostly earmarked for traditional industries such as stainless steel. The only nickel operation in the U.S. is set to close in 2027.

By contrast, the production of battery grade nickel from low grade laterites from Indonesia is emissions intensive and produces vast amounts of toxic wastes that is difficult to treat. Currently, Indonesia represents an estimated 59% of global nickel production, up from 30% five years ago, and Chinese firms control 75% of their capacity. What this ultimately means is that nickel is mostly earmarked for Chinese firms regardless of the current oversupply market conditions.

This reality has already caused the closure of at least 10 nickel mines in Australia last year along and the only operation left is set to run out of reserves in 2027. The consensus among the analysts covering nickel forecast that the market will stay in this oversupply condition for 3-5 years despite social unrest in other nickel producing countries such as Myanmar and New Caledonia disrupting supply.

Nickel is a vital component to the energy transition, but market conditions have reduced production capacity in geographically and geopolitically favourable countries by too much. Moving to non-nickel battery formulations will take time and the materials used will come with their own unique supply chain risks and are at a high risk of being monopolized in the same manner.

Pure Lithium— introducing the lithium-metal vanadium-oxide battery and reinventing the global battery supply chain

Emilie Bodoin, Founder & CEO, Pure Lithium

Pure Lithium's Brine to Battery extraction technology creates a lithium-metal battery-anode in one day. Our lithium-metal anode is paired with a non-flammable vanadium cathode to power an energy-dense, low-cost battery that can be completely sourced and manufactured in North America, ending all reliance on graphite, nickel, cobalt, and manganese. Led by Founders CEO Emilie Bodoin and world-renowned battery expert, MIT Emeritus Professor Donald R. Sadoway, CSO.

Pure Lithium has developed the first commercially viable lithium metal (Li-M) battery. Our next-generation battery offers twice the energy and half the weight of traditional lithium-ion batteries, all at a lower cost— without relying on graphite, nickel, cobalt, or manganese.

At the core of our innovation is our Brine to Battery™ technology, supported by a robust patent portfolio of over 100 patents and applications. This technology seamlessly integrates lithium extraction with anode production, eliminating the need for traditional lithium compound production, and creating a battery-ready Li-M anode in one step.

We combine this anode with a safe, high-capacity vanadium oxide cathode, developed by Nobel Laureate Professor Sir M. Stanley Whittingham—the inventor of both the lithium-ion and Li-M batteries. Our approach co-locates battery manufacturing with lithium sources, streamlining the process from raw materials to finished batteries while enabling domestic supply chains fueled by abundant North American resources.

We utilize a proprietary membrane to selectively extract lithium from aqueous solutions, paired with a novel electrodeposition process that plates ultra-pure Li-M onto copper, forming the battery-ready anode. Our extraction method is not direct lithium extraction (DLE); it is exponentially faster and far more environmentally friendly. This integration of lithium extraction and Li-M production results in the purest Li-M at a fraction of the cost of current methods, such as ingot extrusion and physical vapor deposition.

To date, we've produced 10,000 cells and achieved an unprecedented 2,700 cycles in a Li-M cell at 1C:1D and 100% DOD. Our Li-M vanadium cells can be produced for $40/kWh at the materials level, compared to $75/kWh for Li-ion cells, with an energy density exceeding 400 Wh/kg.

We've secured a joint development agreement (JDA) with French conglomerate Saint-Gobain to commercialize our patented membrane technology, a JDA with E3 Lithium to secure enough lithium for 80 million EVs, and we've acquired and integrated all assets of a vanadium cathode company, securing our vanadium IP while accelerating commercialization.

Pure Lithium's team of nearly 60 people is based in our lab and office in Boston, MA. Founder, CEO, and Chairman Emilie Bodoin is a leading lithium metal expert and inventor, with 18 patents and pending applications. Emilie, who was previously a Principal Investigator at Argonne National Laboratory working on lithium metal production and held several finance roles in NYC, co-founded the company in 2020 with Donald R. Sadoway, MIT Professor Emeritus, Co-Founder, and CSO. Don is a world-renowned inventor and metallurgist, with over 180 publications and 50 patents. He is the inventor of the liquid metal battery and molten oxide electrolysis for carbon-free metal production— technologies that power companies like Ambri, and Boston Metal.

Global supply chain for battery raw materials

Rio Glowasky, Study Lead Battery Anode Materials, Insights, WorleyParsons

In response to rising lithium-Ion battery production and the demand for needle and ultra-low-sulphur petroleum coke to manufacturer synthetic graphite, we have developed a study that provides a quantitative and qualitative strategic market analysis of the global battery anode value chain, by major component. Our presentation will cover key findings from this yearlong study.

In response to rising lithium-ion battery production and the demand for needle and ultra-low-sulphur petroleum coke, the Worley Insights group developed a market analysis study of the global battery anode value chain, by major component.

The anode is a vital element of lithium-ion batteries. Significant research and investments are being made to enhance anode performance, sustainability, and cost-effectiveness.

In 2024, the global demand for anode material is estimated to be 1,200 kmt, with a mix of natural and synthetic graphite being the preferred choice due to consistency and superior performance. Worley Insights will present a comprehensive overview and forecast of natural and synthetic graphite, including the important role of coal tar pitch, and petroleum coke as feedstock to its manufacturing process.

Research and development of alternative battery anodes has become increasingly important for several reasons. Many countries are seeking less dependence on the material, and current commercial graphite anodes are at the upper threshold of their specific energy density. Alternative anode materials have been identified to gain market share and impact the demand for natural and synthetic graphite. These include silicon anodes, lithium titanate, lithium metal-based anodes, and niobium anodes with silicon anodes.

Although graphite resources are concentrated in ten countries, China dominates nearly every stage of the graphite global value chain. Other countries participating include Japan, South Korea, the United States, and Western Europe. Currently the supply of battery anode materials is higher than the demand. Thus, many battery anode plants are unable to operate at full capacity. Worley insights will discuss the current gap and forecasted supply to meet demand by region.

Worley Insights will conclude their presentation with an overview of the carbon intensity to manufacturer anode materials, and what manufacturers are doing to lower the carbon footprint.

No graphite, no power: delivering localised anode active material production to the North Americas

Shaun Verner, Managing Director & CEO, Syrah Resources Ltd.

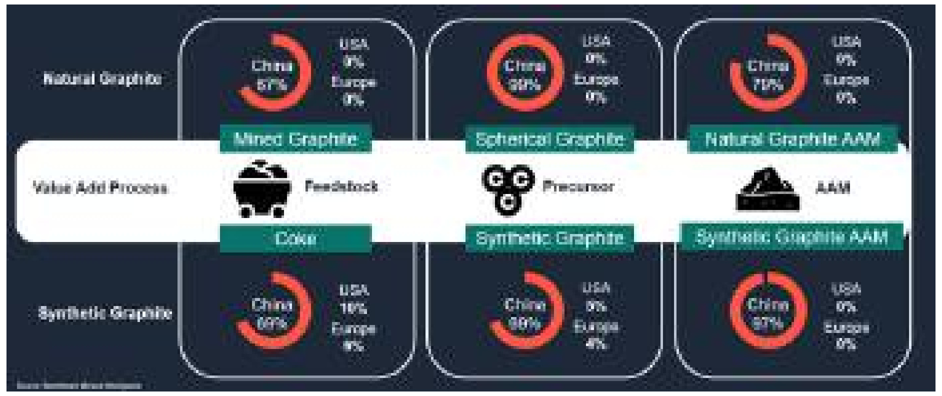
Syrah Resources has developed the worlds premier flake graphite mine and processing facility in Mozambique, delivering significant volume underpinning the lithium-ion battery materials market since 2018. Subsequently, the company has delivered commercial production of anode active materials in North America, further strengthening supply-chain resilience and providing local sourcing optionality for the first time.

Syrah Resources leads the way in delivering scale and quality in natural graphite and AAM products

The global graphite active anode materials (AAM) supply chain is one of the most concentrated in the lithium-ion battery ecosystem, with China occupying a dominant supply position. Currently, China supplies 99% of natural graphite AAM precursors and 97% of finished synthetic graphite AAM, creating a reliance that presents significant risks. As the demand for AAM grows, the need for production facilities outside of China is abundantly clear to ensure greater security and resilience in the supply chain.

At the same time electric vehicle and battery manufacturing operations and project pipeline outside China is growing strongly, and North America is emerging as a key electric vehicle consumer market and manufacturing region. However, there is a stark geographic mismatch in co-located supply of the necessary critical material inputs for this supply chain.

Increasing geopolitical tension and government policies are supporting the scaling of an AAM supply chain outside China, and particularly one that supplies the North America market.



Syrah Resources is a globally significant, vertically integrated natural graphite and battery anode company, supplying battery and industrial markets with high-quality, environmentally differentiated, and customer qualified products. The Company owns and operates a natural graphite mining and processing operation in Balama, Mozambique ("Balama") which is endowed with the largest high-grade natural graphite resource in the world. With a 110Mt ore reserve at 16% total graphitic carbon, Balama has a mine life exceeding 50 years at its currently installed production capacity of 350ktpa and further expansion potential. The company also owns and operates a downstream natural graphite AAM processing facility in Vidalia ("Vidalia"), located in Louisiana, United States of America ("USA"). Both Balama and Vidalia operations are critical to supporting a resilient electric vehicle and battery supply chain.

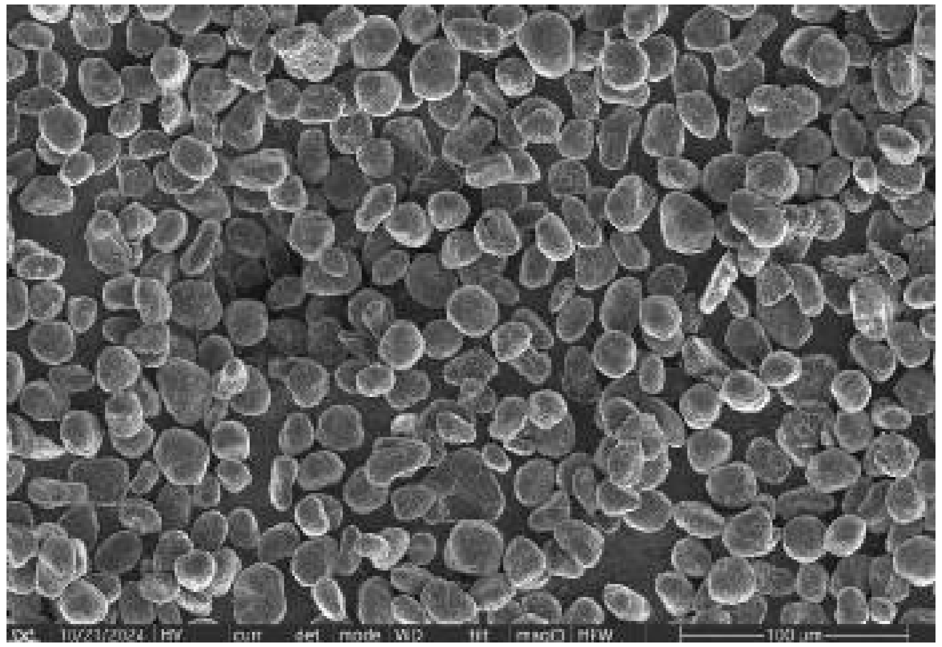
Syrah's Vidalia facility, which commenced commercial operations in 2024, has an installed capacity of 11.25ktpa AAM and employs commercially proven processes to produce high-performance AAM for lithium-ion batteries:

1. **Spheroidization & Classification:** Natural graphite concentrate from Balama undergoes grinding, shaping, and polishing through milling and classifying equipment to form spherical graphite particles in the milling area.
2. **Hydrometallurgical Purification:** A high-efficiency acid-based leaching process, combined with counter-current displacement washing and filtration, purifies the graphite to 99.9%+ carbon content in the purification area.
3. **Pitch Coating & Carbonisation:** Purified graphite is coated with pitch and carbonised using sequential drying, mixing, and heat treatment in the furnace area.

AAM mass produced at Vidalia is an 18-micron, high density and extremely high purity powder. This specification will be demanded in the greatest quantities by the broadest array of target customers in the North American EV lithium-ion battery market. The Vidalia facility and Vidalia AAM is well progressed through qualification processes with many tier 1 customers, and Syrah has qualification feedback from a number of these customers. Vidalia AAM production is consistently achieving particle size distribution, graphite purity, first cycle efficiency in cells, and other targeted requirements. The company expects that customers will complete qualification of Vidalia and commence purchasing AAM from Vidalia this year

Vidalia is already positioned to play a key role, being the only operational commercial-scale AAM facility in North America. In April 2023, Syrah completed a definitive feasibility study confirming both the technical and financial viability of expanding the Vidalia facility's capacity to 45ktpa AAM. A final investment decision on this expansion is awaiting AAM sales from Vidalia and is dependent on customer and financing commitments. This expansion is expected to target tier 1 battery manufacturers in the North American, as well as OEMs, strengthening U.S resilience in the supply of AAM for electric vehicles.

The Vidalia AAM facility is currently operational. Should you wish to discuss AAM supply, reach out to marketing@syrahresources.com.au



Rethinking the battery test laboratory environment to meet future testing demands

Bob Zollo, Strategic Portfolio Planner, Automotive & Energy Solutions, Keysight Technologies

New EV battery pack designs with higher capacities require a new way of thinking about the test laboratory environment to achieve efficiency while maintaining flexibility. We will present an innovative, demand-driven power allocation approach with up to 20% savings in both the footprint and price, while guaranteeing sufficient power.

The movement toward mainstream adoption of EVs will require massive innovation in EV batteries to reduce cost, increase range, and improve safety. This innovation will require extensive expansion of test lab capacity and capabilities to validate battery pack designs and to characterize their performance.

A key driver in innovation in EV battery pack design is to extend EV range and shorten recharge time. To extend range, larger EV packs will be needed, which demand test systems with higher power. Shortening recharge time means chargers need to move from Level 2 to Superchargers and beyond, and therefore testing this charging capability once again drives the need for higher power testers. The capital cost of this equipment is quite large, with a corresponding high cost for the ac power connection to the grid.

Therefore, the costs to build up a lab (capital cost) and to operate a lab (energy cost, people, time) will continue to grow to facilitate innovation in battery design.

To address and optimize new lab scale up, new concepts for test system architecture will need to be considered to save on capital costs and operational costs. These new concepts will permit companies to cost-effectively deploy new labs while achieving the necessary flexibility in test. Along with saving on capital and operating expenses, proper lab design can provide future proofing of test capabilities to ensure they can meet ever-changing test requirements.

Today, EV battery pack testing employs general driving profiles that require low power at the test stand for the majority of the testing period. However, there are short duration tests with maximum power peaks that occur less frequently. These peak power tests drive the size and cost of the equipment even though the duty cycle of the high-power tests are low. This power delivery duty cycle can be exploited for savings.

Keysight Technologies is a market leader in solutions for testing battery cells, modules, and packs for EVs and the electric mobility industry. To aid in the deployment of labs to meet high peak power requirements while optimizing test system capital costs, Keysight has developed a Power Allocation Management solution, consisting of a common "power lake" that is distributed via smaller power units at individual test stands that can be combined in a flexible configuration. This architecture delivers a variable, demand-driven power flow in the lab, with a capital equipment scaled down but capable of allocating the power where needed when peak power demands occur. With Power Allocation Management, the bigger the lab, the higher the saving potentials, and with easy expandability for future increased power requirements.

Please join Keysight on Wednesday March 19 at 9:45am for *"Rethinking the Battery Test Lab Environment to Meet Future Testing Demands"*, where we will present a demand-driven power allocation approach with up to 20% savings in both the footprint and price while guaranteeing sufficient power for all test cases.

Keysight also invites you to **booth 600** to learn more about Keysight's Power Allocation Manager.

USABC: accelerating commercialization of domestic EV battery technology in 2025 and beyond

Matt Denlinger, USABC Technical Advisory Committee Chair & Ford Battery Research Engineer
Meng Jiang, USABC GM lead of Technical Advisory Committee & GM Battery R&D Staff Researcher

Who we are

For over 30 years, the United States Advanced Battery Consortium LLC (USABC) has sought to accelerate the development of advanced US-based battery technology for electrified vehicles (EVs). We are a collaborative research organization comprised of technical personnel from Ford, General Motors, and Stellantis, who partner with the US Department of Energy, National Labs, and battery companies to develop next generation technologies throughout the cell materials, design, and build processes.

Our efforts are primarily focused on funding targeted development programs, in which we award DOE-provided, cost-shared financial support (up to 80% of total program cost) to companies working on compelling battery technology within the US. The consortium defines areas of interest for long term EV battery development, then prioritizes work within the technology readiness level range of 4-7.

This means that companies that would like to work with USABC should already be able to demonstrate their basic technology feasibility, but do not yet have a product mature enough to begin production scale-up and program launch.

Development programs typically last 2-3 years, starting with the delivery of relevant cell hardware or prototypes to establish a performance baseline. This hardware often takes the form of multi-Ah cells delivered to a National Lab for testing (at no cost to the developer), but the exact specifics of the tested deliverable can vary based on the proposal and technology. Milestone deliverables continue periodically, roughly once per year for the duration of the program.

Throughout the program, developers will meet quarterly with engineering representatives from each of the three participating OEMs to review program progress and provide voice of the customer feedback on areas of interest. Ideally, this provides opportunities for cell developers to receive valuable input from potential future customers earlier in their development process and informs the members of USABC of promising new technologies for potential future collaboration more quickly.

What's next

During 2024, the Department of Energy announced a new $60 million funding award for USABC to continue this work through 2030. Based on this support, the consortium intends to announce new funding opportunities for domestic research and development in early 2025.

While USABC's most recent cooperative agreement focused heavily on pushing the envelope for energy density and fast charge capability, new focus areas will likely look more closely at improvements to cell capabilities that could improve overall system cost, simplicity, and abuse tolerance by 2030. This includes characteristics such as wider operating temperature windows, alternative cell chemistries for better abuse tolerance or lower cost, recycling technologies, and development of novel technologies that address shortcomings in the supply chain.

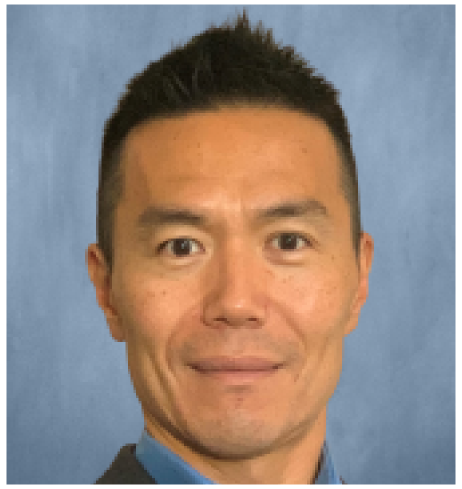
These requests for proposal announcements will be released through our website, uscar.org/usabc, over the coming months.

Anticipated 2025 research focus areas

Next Gen EV Cells	Cell Components	Supply Chain	Recycling
Energy Density	Active Materials	Cost	Next Generation Materials
Cost	Separator	Green Manufacturing	Low Cost Materials
Earth Abundant Materials	Electrolyte		
	Inactive Components		

AI-based smart charging algorithm for next-generation lithium-ion batteries

Naoki Matsumura, Principal Engineer, Intel Corporation



While always full-charging and fast-charging lithium-ion batteries gives users psychological safety, batteries degrade more quickly. Today's "if-then" based adaptive charging automatically reduces charging level and charging speed. This session explains context-based charging, a machine-learning/deep-learning hybrid algorithm, that extends battery longevity even further.

Artificial Intelligence (AI) plays a pivotal role in various sectors, including search engines, autonomous vehicles, and content generation. Typically trained on substantial datasets, AI excels at uncovering hidden relationships between inputs and outputs. The integration of domain knowledge, such as battery technology, significantly enhances AI performance. This presentation explores how the synergy of battery expertise and AI can improve user experience through context-based charging and battery health prediction.

Conventional charging practices, such as frequent full charges and fast charging, may provide users with a sense of psychological safety but often lead to accelerated battery degradation. Users may not be aware that these habits can shorten the longevity of their batteries. Current adaptive charging strategies, based on "if-then" conditions, aim to optimize charging levels and speeds, potentially extending battery life. However, a more tailored approach that considers individual usage patterns presents a valuable opportunity for further longevity enhancement. By employing machine learning and deep learning techniques, AI can customize charging algorithms to suit unique user behaviors, thereby improving battery performance over time.

Context-based charging represents an advanced AI algorithm that assesses each user's battery usage history while integrating domain knowledge to engineer input/output data effectively. This approach predicts the necessary charging levels and the need for fast charging, avoiding unnecessary full charges and fast charging. As a result, battery longevity can be significantly extended. Importantly, this algorithm is relevant not only to contemporary lithium-ion batteries with graphite anodes but also to next-generation batteries utilizing silicon or lithium-metal anodes. For these future batteries, the AI algorithm accounts for specific degradation mechanisms linked to new anodes, effectively avoiding conditions that could lead to rapid degradation.

Additionally, the application of AI in predicting battery health addresses the complexities of battery degradation. This degradation arises from a mix of chemical and mechanical factors, as well as user behaviors such as charging frequency and storage practices. Unlike standard cycle tests that assess specific battery models under controlled conditions, real-world usage patterns have been challenging to predict. The battery clinic, an AI-driven prediction model, leverages user data and domain knowledge to forecast the State of Health (SOH) of batteries. This model enables early detection of potential battery health issues, encouraging users to adopt context-based charging that promotes better battery longevity.

Furthermore, AI implementations that incorporate domain knowledge contribute to sustainability by reducing battery waste, which is critical in today's environmentally conscious landscape. While this session focuses on consumer electronics, the insights and methodologies discussed are applicable across various industries relying on battery technology, including automotive and data centers.

For further inquiries on these AI-driven battery technologies, please contact Naoki Matsumura, Principal Engineer at Intel Corporation.

Unlocking next-level battery performance through electrolyte additives: enhancing capacity, efficiency, and lifetime

Emily Dickens, Chief Commercial Officer, Octet Scientific

Electrolyte additives represent a powerful yet often underexplored avenue for improving the performance of both traditional and next-generation battery technologies. By incorporating simple yet highly effective ingredients into the electrolyte, significant gains can be achieved in battery lifetime, efficiency, and capacity. In this talk, we will explore the critical role that electrolyte optimization plays in advancing battery performance. Octet, a leader in battery chemistry innovation, specializes in identifying, developing, and scaling up tailored electrolyte solutions to meet diverse customer needs. We will highlight key case studies and share insights into how the right electrolyte chemistry can unlock unprecedented battery potential.

Electrolyte additives, and organic molecules in particular, have been an underdeveloped tool in battery chemistry, yet they have the potential to dramatically enhance battery lifetime, efficiency, and capacity. Octet Scientific has found that strategic molecular design of electrolyte additives can lead to 10% improved efficiency, 20% improved capacity, and 100% longer lifetimes with just a small addition of the right additive(s).

Octet Scientific is at the forefront of electrolyte development by exploring the previously underdeveloped space of organic molecular electrolyte additive design. While prior research has explored off-the-shelf chemistry taken from other industries and applied as electrolyte additives for battery technology, Octet takes a different approach by designing molecules specifically for use in batteries.

Understanding the complexity of battery systems, Octet recognizes that there is no one-size-fits-all solution when it comes to electrolyte additives. Instead, their team of engineers works closely with battery manufacturers to test and fine-tune additives to ensure they perform optimally within each specific battery system. Octet offers consulting services to tweak electrolytes with small additive adjustments or support entire electrolyte optimization efforts.

Octet has been working with aqueous battery technologies since 2018, building not only a catalog of specialized additives but also a deep expertise in understanding and testing their impact. Small molecular adjustments can lead to significant performance gains, making even a minor additive modification a game-changer in battery capacity, efficiency, and longevity.

By sharing real-world case studies and highlighting recent advancements in electrolyte research, Dickens will demonstrate how strategic electrolyte formulations can unlock new levels of performance, making aqueous batteries more competitive. Her insights will provide valuable guidance to battery manufacturers and researchers looking to explore innovative solutions in an increasingly diverse energy storage landscape.

Lightweighting in automotive batteries – conflicts and contradictions

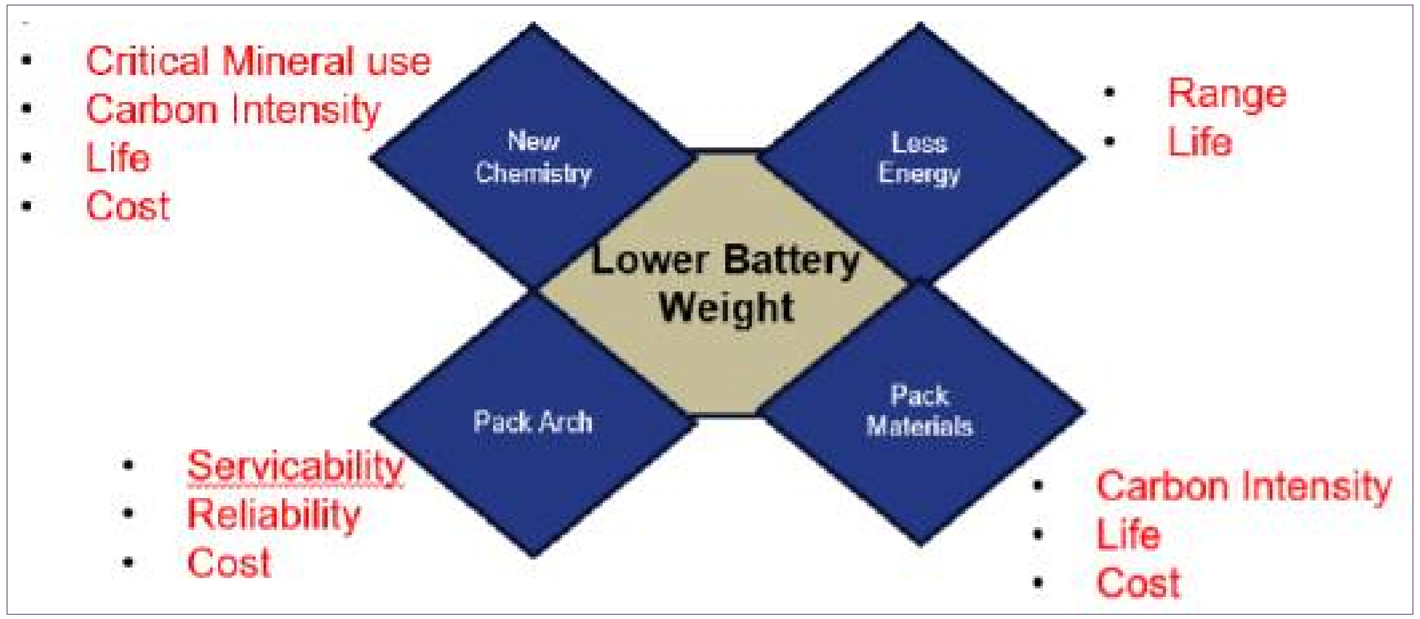
Oliver Gross, MASc, SME Energy Storage and Conversion, Advanced Propulsion Technology, Stellantis

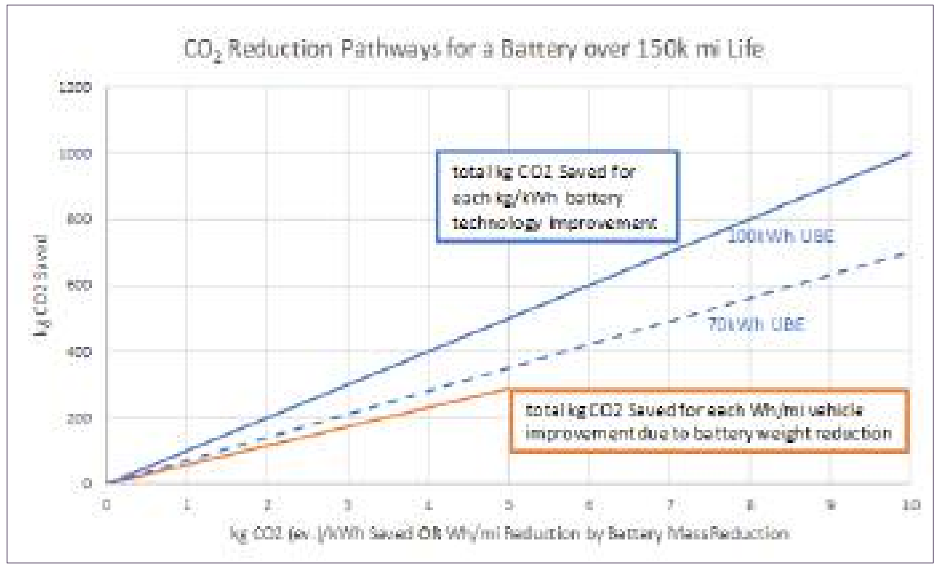
A lower weight EV battery will improve overall vehicle efficiency and energy use when the vehicle is in operation. There are many paths to reducing battery weight, through new materials and technologies, but also through prudent synergistic design and use cases. These routes can introduce other significant drawbacks as well, which need to be addressed in both the battery and vehicle design processes. This talk will compare and contrast different drivers and their respective figures of merit on battery lightweighting.

Weight reduction in EVs is crucial for enhancing vehicle efficiency and range. Heavier vehicles demand more energy, which directly impacts the vehicle demand energy (VDE) measured in Wh/mi.

Reducing the weight of the vehicle, particularly the battery, can lead to substantial improvements in overall vehicle efficiency. This is because a lighter vehicle requires less energy to operate, thereby extending the range and reducing the frequency of charging.

Battery weight reduction has a positive, direct impact on vehicle performance and sustainability. There are several strategies and technologies aimed at reducing battery weight:





1. **New Chemistries:** Emerging battery technologies, such as solid-state batteries (SSB) and lithium-sulfur (Li-S), offer potential weight savings. These technologies promise higher energy densities, which means more energy can be stored in a battery pack for the same given weight.

2. **Pack Architecture and Materials:** Innovations in pack design, the use of lighter materials and optimized architectures enables manufacturers to reduce the overall weight of the battery pack.

Reducing the weight of EV batteries has significant environmental benefits, particularly in terms of carbon reduction:

1. **Lower Carbon Intensity:** Lighter batteries contribute to lower carbon emissions over the vehicle's lifecycle. Reducing battery weight can decrease the carbon intensity (measured in kg CO_2/kWh) of the vehicle. This reduction is achieved by lowering the energy required for vehicle demand energy (VDE) and subsequently reducing the battery size required to achieve a given vehicle range.

2. **Increased Efficiency:** A lighter vehicle is more efficient, requiring less energy to travel the same distance. This efficiency translates to fewer emissions per mile driven, contributing to overall carbon reduction.

3. **Sustainability:** New battery technologies that reduce weight also tend to use fewer critical minerals, which are often associated with high environmental and social costs. By minimizing the reliance on these materials, manufacturers can produce more sustainable batteries with a lower environmental footprint.

By adopting new chemistries, optimizing pack design, and reducing the use of critical minerals, manufacturers can produce lighter, more efficient, and more sustainable batteries. These efforts enhance vehicle performance and contribute to significant carbon reductions, supporting broader environmental and sustainability goals.

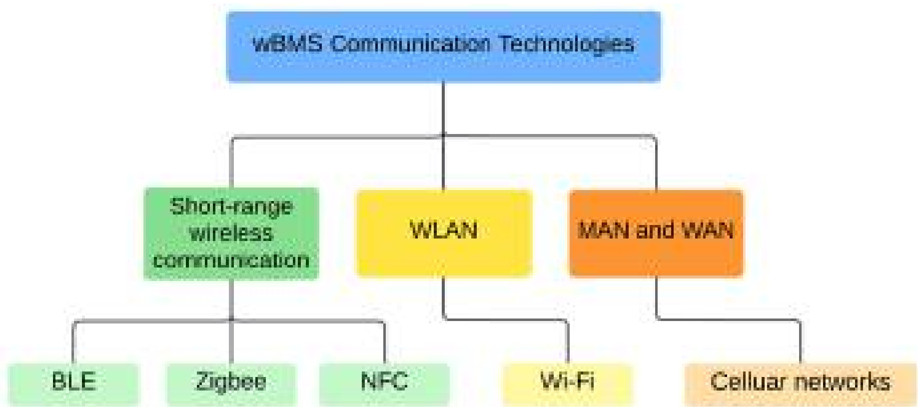
Wireless Battery Management Systems for Electric Vehicle and Storage Applications

Chris Mi, PhD, Fellow, IEEE & SAE; Distinguished Professor, San Diego State University

The effective management of battery systems has become increasingly critical. The advent of Wireless Battery Management Systems (wBMS) represents a significant innovation in battery management to overcome the challenges of traditional wired BMS.

Battery management systems (BMS) are critical in maintaining the safety and longevity of lithium-ion batteries in electric vehicles and energy storage system. Currently, wired BMS is prevalent. However, wired BMS must connect each battery cell with the BMS via wires, resulting in bulky wire harnessing, large voltage drops, which impact the accuracy of measurement and state calculations. In addition, wired BMS is heavy, costly, and contain more failure points.

On the contrary, wireless BMS remove the wiring in the BMS, hence, reduce weight, cost, and failure points; increase measurement accuracy, reliability, and scalability. However, wireless BMS, if not designed properly, will be susceptible to signal interference, latency, and EMI issues. In this talk, Dr. Chris Mi, Fellow of IEEE and SAE, will review the state-of-the-art wireless BMS technology and demonstrate how wireless BMS can help increase reliability and measurement accuracy, and reduce weight and cost.



Dr. Mi is the Distinguished Professor of Electrical and Computer Engineering at San Diego State University. He is also the Director of the Caili & Daniel Chang Center for Electric Drive Transportation at SDSU. Dr. Mi is a world-renowned expert in battery management. He has published five books, one book chapter, 226+ journal papers, 130 conference papers, and 20+ issued and pending patents. He served as Editor-in-Chief, Area Editor, Guest Editor, and Associate Editor of multiple IEEE Transactions and international journals, as well as the General Chair of over ten IEEE international conferences. Dr. Mi has won numerous awards, including the "Distinguished Teaching Award" and "Distinguished Research Award" from the University of Michigan-Dearborn, IEEE Region 4 "Outstanding Engineer Award," IEEE Southeastern Michigan Section "Outstanding Professional Award," and SAE "Environmental Excellence in Transportation (E2T) Award." He is the recipient of three Best Paper Awards from IEEE Transactions on Power Electronics and the 2017 ECCE Student Demonstration Award. In 2019, he received the Inaugural IEEE Power Electronics Emerging Technology Award. In 2022, he received the Albert W. Johnson Research Lectureship and was named the Distinguished Professor, the highest honor given to an SDSU faculty member, and only one award is given each year. He received the 2023 IEEE PELS Vehicle and Transportation Systems Achievement Award, the IEEE Transactions on Industry Applications Best Paper Award, and the SDSU Innovator of the Year Award. In 2024, he received the prestigious Alumni Distinguished Faculty Award from SDSU.

At the intersection of micromobility, aftermarket batteries, and product safety

Ibrahim Jilani, Global Director, Consumer Technology, UL Solutions

This presentation will go into the latest regulations for micromobility and their batteries, as well as the safety concerns of aftermarket batteries (whitepaper issued by UL Solutions in 2024) and its intersection with product safety.

The rapid growth of micromobility devices, such as electric scooters and bikes, has brought significant attention to the performance and safety of those products and their batteries. This presentation will focus on the critical aspects of battery certification, safety and performance, which are essential for ensuring the reliability and safety of battery-powered devices. In addition, the recent statistics tracked by UL Solutions on lithium-ion battery incident reporting will also be shared.

The presentation will also cover our research on aftermarket batteries, delving into the current standards and certification processes for smartphone batteries, highlighting the gaps and challenges manufacturers and regulators face. We examine the common safety issues associated with these batteries, including thermal runaway, short circuits and overcharging, and propose strategies to mitigate these risks. Additionally, we discuss new battery regulations being implemented in the U.S. and Europe, emphasizing the importance of safety certification as a key method of decreasing the risk of such incidents.

We also explore the difference between certification and testing, sharing how certification provides a more comprehensive assessment of battery safety and performance. Furthermore, we highlight the importance of performance assessment for both batteries and end products, which is crucial for differentiating products in the competitive micromobility market.

This presentation is aimed at industry professionals, researchers and policymakers who are involved in the development, regulation and use of batteries and battery-powered products. By addressing the intersection of battery certification, safety and performance, we aim to contribute to the advancement of safer and more reliable battery technologies.

Fast Track to Superior Automotive Batteries: Virtual System Validation and AI-Driven Testing

Gerald Sammer, PhD, Principal Business Development Manager, AVL List GmbH

The proposal highlights the use of advanced AI and virtual testing methods to enhance battery performance and quality for automotive applications in much shorter time. By integrating state-of-the-art simulation tools and virtualization solutions, this approach allows for rapid, cost-effective development and optimization of battery systems. Utilizing predictive modeling and iterative design optimization, engineers can explore diverse scenarios, accelerating the development process and significantly improving quality and cycle-life of lithium-ion batteries.

The global transition to electric mobility demands more efficient, reliable, and longer-lasting batteries. However, traditional battery development faces significant challenges, including lengthy testing cycles and unpredictable aging behaviors. AVL, a leader in automotive engineering, is addressing these challenges with Virtual System Validation and AI-Driven Testing, accelerating the path to superior batteries.

The Challenge: Late System Validation and Long-Lasting Battery Tests

Battery testing is a time-intensive process, often requiring months or even years to evaluate performance and aging characteristics. Factors such as charge/discharge cycles, temperature, and mechanical stress influence battery health, making it difficult to predict real-world behavior without extensive testing. Every parameter variation requires months of measurement, potentially delaying market readiness and increasing development costs. Late-stage system validations conducted during road testing introduce significant risks at the final phase of development, potentially resulting in product recalls or delays in the start of production (SOP).

The Solution: Virtual Validation & AI-Enhanced Testing

AVL is pioneering a Battery-in-the-Loop approach, integrating real-time vehicle simulation with physical testing of the battery. This enables the calibration of battery management systems (BMS) under real-world conditions while significantly reducing testing time. By leveraging high-frequency simulations (up to 10 kHz) and third-party model integrations, AVL ensures accurate battery validation in a controlled lab environment.

Additionally, AVL's AI-driven predictive models improve test efficiency. Using machine learning and empirical aging models, battery aging characteristics can be extrapolated from fast-aging cells to predict the end-of-life of slower-aging cells. This results in up to 40% reduction in aging test durations, allowing manufacturers to bring high-performance batteries to market faster.

Driving the Future of Battery Innovation

AVL's Virtual System Validation and AI-Driven Testing are redefining battery development, enabling automotive manufacturers to reduce recalls and avoid SOP delays. By combining advanced simulations, AI predictions, and real-world testing, AVL is paving the way for next-generation, high-performance batteries - faster, safer, and more reliable than ever before.

For more details, contact:
Dr. Gerald Sammer, Principal Business Field Owner, Battery & BEV, AVL
gerald.sammer@avl.com
AVL List GmbH, Hans-List-Platz 1, 8020 Graz, Austria

Advancing automotive battery pack safety with innovative venting units

Michael Harenbrock, PhD, Principal Expert, Engineering Electric Mobility, MANN+HUMMEL GmbH

Vents are crucial for battery pack safety, especially under thermal runaway conditions. As battery cell chemistry and pack designs evolve, selecting appropriate venting units becomes increasingly important. The presentation provides an overview of regulatory and technological trends influencing vent design and introduces additional features like gas sensors and hot particle filters.

Battery pack safety is of highest importance for both OEMs and customers. Although electric vehicle battery fires happen less frequently than fires in cars with combustion engines, they are more difficult to extinguish and gain a lot of attention in the media. Battery pack safety regulations aim to reduce the likelihood of battery fires, with a special focus on requirements on thermal runaway, thermal propagation and subsequent fires.

For example, GB 38031 (2021) and UN ECE R100 Rev3 (2023) mandate that – after the first indication of a battery cell defect – an early warning shall provide at least five minutes for passengers to safely exit the car, before harmful gases enter the cabin, and/or a visible battery fire occurs.

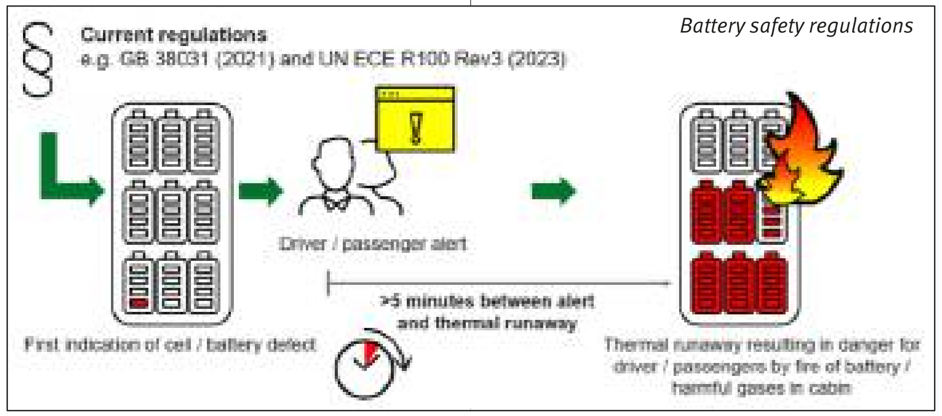
In holistic battery pack safety concepts, multi-functional venting units with integrated burst disc functionality play an important role as they enable pressure equalization between the battery pack interior and the ambient atmosphere, and the fast and controlled release of vent gases from the battery pack.

Here, technical trends in battery cell and battery pack design drive the technical requirements and thus the design of individual venting units. The reduction of free airspace in battery packs in modern cell-to-pack designs reduces the need for pressure equalization, while increasing cell energy density leads to higher requirements on gas release rates. Furthermore, lower trigger overpressures to initiate venting are sought after.

Beyond these functions, venting units can also play an important role in the delay or even prevention of battery fires by capturing hot particles ejected from battery cells, which could ignite flammable gas mixtures, also outside the pack. Furthermore, venting units can act as carriers for gas sensors, measuring an increase of vent gas concentrations as an additional feature in the overall pack safety concept.

To provide battery pack design engineers with guidance on how to choose the right venting units concept for their individual product - and how to integrate them into holistic battery pack safety concepts - the new SAE J3325 Technical Information Report on Battery Pack Venting Units is currently introduced.

Although venting units have significantly evolved and serve diversified technical requirements, more research is still needed, especially for packs with upcoming solid state or sodium ion battery cells.



Battery safety regulations

Big data for the diagnosis and prognosis of deployed battery systems

Matthieu Dubarry, PhD, Assistant Researcher, Battery Testing & Evaluation & Modeling, University of Hawaii

The diagnosis and prognosis of deployed batteries is complex because the cells might never experience controlled conditions during operation as both the charge and discharge duty cycles could be sporadic. To circumvent this issue new methodologies must be implemented and thoroughly validated. This work presents a new methodology for diagnosis that used real observed solar irradiance, modeled clear sky irradiance, a load usage model, and synthetically-generated battery data from a battery digital twin to diagnose the degradation of commercial Li-ion batteries connected to photovoltaic systems.

Battery diagnosis and prognosis are especially challenging in deployed systems because the batteries are undergoing sporadic usage and are often lacking the controlled conditions required to perform traditional state of health estimation methodologies. To circumvent this issue, the use of data-driven methods has been heavily investigated in recent years but, while many algorithms have been considered, the training has not received enough attention, which might be the limiting factor in replicating the results in the field.

The issue lacks in the path dependency of battery degradation: depending on how the battery is used, it will experience a unique mix of degradation mechanisms that will not only affect its capacity but also its durability with the possibility of accelerated aging.

To ensure that an algorithm can detect and predict these unique circumstances, it is necessary to train the model on a dataset representative of the application and diverse enough to encompasses most, if not all, of the possible usages for the cells. This will require complex, expensive, and long experimental campaigns.

The emergence of public battery databases, like www.batteryarchive.org, is a step in the right direction but the data is still often not varied enough to cover multiple applications and degradation scenarios.

A possible solution to alleviate this problem is to use synthetic datasets that could cover the entirety of the degradation spectrum without the need for lengthy experiments. As the changes of voltage associated with most degradation mechanisms are well understood, they can be replicated using high fidelity battery models.

Multiple examples of this approach are available in the literature and some of these large datasets have already been successfully used to train machine learning algorithms where they highlighted the limitations of some of the solutions deciphered from training on incomplete datasets.

However, most of these datasets still contain only low-rate constant current data which is not representative of deployed system operation which significantly hampers their deployability.

This limitation was removed in 2022 when we proposed a new methodology to use degradation modes modeling outside of constant current and presented a proof-of-concept study to diagnose cells directly connected to photovoltaic systems. While this improved the applicability to field data, it still lacked some essential parameters like the influence of additional usage on the cells (i.e. normal residential usage while the battery is charging) and the influence of using battery packs instead of single cells.

This presentation will report for the first time on the removal of these limitations.

Understanding the EVSE Ecosystem: Strategic Initiatives and Guidance for Advancing Secure Fast Charging

Sabrina Rodriguez, Research Engineer, Southwest Research Institute (SwRI)

As electric vehicle (EV) charging infrastructure expands, so does the risk of cyberattacks. This presentation addresses the role of cybersecurity in EV charging infrastructure, highlighting high-profile cyberattacks, as well as cybersecurity best practices and guidance solutions. This presentation focuses on known vulnerabilities and exploits seen in EV charging infrastructure, as well as discusses Southwest Research Institute's (SwRI) applied research conducted on EV chargers (L2 and Direct Current Fast Charging (DCFC)).

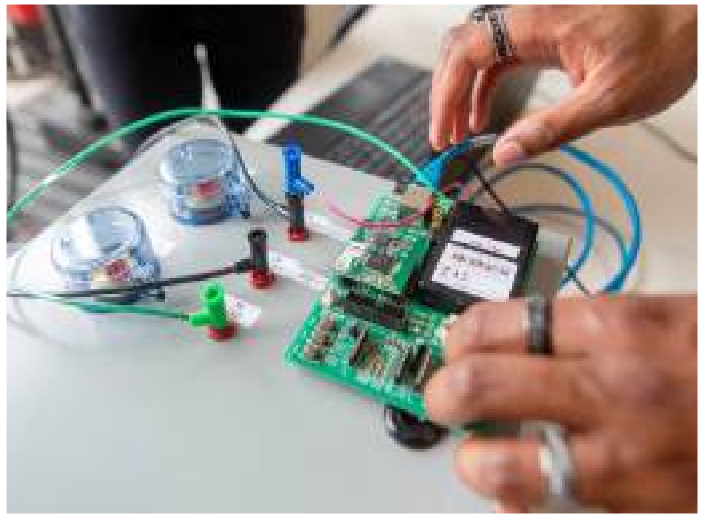
As EV charging infrastructure expands, so does the risk of cyberattacks. The EV charging ecosystem, also referred to as the electrification ecosystem, consists of seven roles: Vehicle Manufacturers, Electric Vehicles, Electric Vehicle Supply Equipment (EVSE), Distribution System Operators, Charge Point Operators, eMobility Service Providers, and a Roaming Hub.

A cyberattack aimed at the EV or EVSE may laterally impact one of the other roles. For example, with the advancement of bidirectional charging capabilities, an attack at the EVSE may open the door for an attack on the Distribution System Operator, thus putting additional critical infrastructure at risk.

Understanding the risks and vulnerabilities of the charging infrastructure will help develop better cyber standards, provide guidance for Plug & Charge interoperability, improve the EV charging experience, and enhance the resilience of critical infrastructure. As more vehicle manufacturers join the EV trend the need for interoperability grows.

This presentation focuses on the role of cybersecurity in EV charging infrastructure while highlighting high-profile cyberattacks, as well as existing cybersecurity best practices and guidance solutions. Known vulnerabilities and exploits will be discussed, as well as results from SwRI's testing of EV chargers (L2/AC and DCFC).

The goal of this presentation is to provide an understanding of the industry's current cyber standing and begin discussions over vulnerability/risk ownership in the electrification ecosystem. The identification of risk ownership will open the door for improved cyber security best practices in the electrification ecosystem and ease the transition into Plug and Charge.



Ms. Rodriguez is in the Intelligent Systems Division at Southwest Research Institute (SwRI). She has a broad range of experience including hardware engineering, software development, firmware, penetration testing, and embedded systems. She provides technical and project leadership to the Cyber-Physical Systems section by leveraging her background in computer engineering. She primarily supports projects related to automotive and fast charging cybersecurity.

Currently her work focuses on securing the electric vehicle (EV) charging ecosystem. Ms. Rodriguez has been an asset to projects by applying her expertise on topics including penetration tests and TARAs for EVs and charging stations (Level 2 (L2), Direct Current Fast Charging (DCFC)).

Predicting rapid degradation onset in lithium-ion batteries during real-time operation using machine learning

Vikas Tomar, PhD, Faculty Lead, Innovation and Commercialization, School of Aeronautics and Astronautics, Purdue

Accurate lithium-ion battery (LIB) cycle life prediction is critical for optimizing energy storage systems in applications ranging from electric vehicles to grid storage. This work introduces a machine learning (ML)--driven framework that addresses key challenges in battery aging analysis, health assessment, and real-time deployment—enabling precise energy manoeuvrability across dynamic operational environments.

Battery aging features and data-driven health assessment

Factors like charge protocols, temperature, and operational stress influence LIB degradation. Modern ML models extract actionable insights from early-cycle data, such as voltage relaxation curves and capacity fade trajectories, to predict remaining useful life (RUL) with errors as low as 4.9% using just the first five cycles. Techniques like symbolic regression and transformer networks identify physically interpretable aging patterns, such as lithium plating and electrode cracking.

At the same time, hybrid models combine physics-based equations with data-driven learning for robustness. For state-of-health (SOH) assessment, bidirectional gated recurrent units (BiGRU) with attention mechanisms analyze real-world operational data, including ohmic resistance and maximum output power, to deliver comprehensive health metrics.

Overcoming data limitations via synthetic generation

Data scarcity remains a barrier to model generalizability. Synthetic data generation—using generative adversarial networks (GANs) and diVusion models—creates realistic degradation curves that augment limited experimental datasets. For example, DiVBatt, a diVusion-based framework, synthesizes capacity fade trajectories while capturing uncertainty in aging behaviors, improving prediction accuracy by 38% in extrapolation tasks. This approach reduces reliance on costly long-term cycling tests and enables rapid iteration in cell development.

Practical deployment for accelerated development and real-time management

The proposed ML framework operates at two critical stages:

1. **Cell development & manufacturing:**
   - Predicts rejection thresholds during manufacturing by correlating early-cycle electrochemical signatures with end-of-life performance.
   - Recommends optimal C-rates for target applications (e.g., fast-charging Evs vs. grid storage) using cycle-life projections under varied stress conditions.
2. **Onboard energy management:**
   - Deploys lightweight AI models on edge devices for real-time SOH monitoring. For instance, BatLiNet's inter-cell learning contrasts aging patterns across batteries, reducing prediction errors by 40% compared to single-cell models.
   - Integrates with battery management systems (BMS) to dynamically adjust charging protocols, mitigating degradation during operation.

Impact on energy manoeuvrability

The presented ML framework enhances energy systems' responsiveness to fluctuating demands by bridging data-driven insights with operational adaptability. For example, predictive maintenance algorithms extend battery lifetimes in renewable microgrids, while real-time RUL updates enable EVs to optimize route planning based on remaining capacity.

Future work will prioritize federated learning to harmonize data across diverse aging conditions and battery chemistries, further solidifying ML's role in sustainable energy storage. This advancement accelerates LIB development and ensures reliable, adaptable energy storage—key to achieving global decarbonization goals.

Zeta Energy: revolutionizing energy storage

Meet us at Booth #1114

Zeta Energy is a leading innovator in the energy storage sector, committed to developing advanced battery technologies that meet the growing demands of a sustainable future. With a focus on safety, performance, and cost-effectiveness, Zeta Energy is poised to transform the way we store and utilize energy.

Advanced Battery Technology

At the heart of Zeta Energy's innovation lies its proprietary lithium-sulfur battery technology, which leverages advanced materials and cell architectures to deliver superior energy density, power output, and cycle life. This cutting-edge technology enables Zeta Energy to create batteries that are lighter and more efficient than traditional lithium-ion batteries, while also offering enhanced safety features and a reduced environmental impact.

Applications

Zeta Energy's award-winning battery technology has a wide range of potential applications, spanning across multiple industries and sectors:

- Electric Vehicles (EVs): Zeta Energy's batteries can power the next generation of electric vehicles, enabling longer driving ranges, faster charging times, and improved overall performance.
- Aerospace: By providing a superior energy-to-weight profile, Zeta Energy's batteries unlock a wide range of opportunities to efficiently and effectively electrify air transportation.
- Grid Storage: Zeta Energy's batteries can be deployed in grid-scale energy storage systems, helping to stabilize the grid, manage peak demand, and enhance overall grid resilience.
- Consumer Electronics: Zeta Energy's battery technology can also be used in consumer electronics, providing longer-lasting and more powerful batteries for smartphones, laptops, and other devices.

Sustainability

Zeta Energy is committed to sustainability and environmental responsibility. The company's battery technology is designed to minimize environmental impact through the use of sustainable materials and manufacturing processes. Additionally, Zeta Energy's batteries are designed for recyclability and reuse, further reducing their environmental footprint.

Innovation and Collaboration

Zeta Energy fosters a culture of innovation and collaboration, working closely with partners, researchers, and industry leaders to advance the development and commercialization of its battery technology. The company is dedicated to pushing the boundaries of energy storage and driving the transition to a cleaner, more sustainable energy future.

Navigating the future of energy storage safety

We recently interviewed Tom Farrell, Principal Engineer of Test and Validation Engineering at Fike Corporation about the dangers of thermal runaway, the solutions currently used to mitigate its effects, the effectiveness of Fike's solution Fike Blue, and more about the advancement of safety in the energy storage industry. **Meet us at booth #101**

Q. Why aren't energy storage systems used more often in populated areas?
Obviously, these batteries burn. We know they burn. They catch fire when they've been abused or when a defective cell begins thermal runaway inside of a module.

Early on when we had these fires, the first thought was to treat it like a fire by using Class B sizing and protective methodologies and prove the results with small-scale testing. A lot of organizations offered testing advice based on this kind of approach; however, it hasn't worked out terribly well because a number of notable events have occurred.

Specifically looking at the unfortunate event in Surprise, AZ, protective systems were in place that were supposed to stop what we considered to be a fire. Yet, these fires continued to burn and go for quite some time, releasing enormous amounts of toxic and explosive gases and thermal load to other adjacent structures, and it's extremely problematic.

The question is, did the fire protection system put out the fire? Arguably, yes. It triggered, reduced the initial heat and diffused flames that were being generated from those batteries.

"But when you look at pictures from the event in Surprise, does it look like it was suppressed? No, because it didn't address the real problem, the problem of propagating

thermal runaway. It's extremely dangerous and unpredictable, and traditional fire suppression systems simply don't solve the issue."

Because there hasn't been a reliable solution to cascading thermal runaway, AHJs are cautious to allow ESS's into their jurisdictions and are one of the primary reasons why ESS's are usually isolated to remote locations.

Q. Do ESS owners and operators generally believe they are protected from thermal runaway?
In the current state of the market, there are a lot of disclaimers that protective system manufacturers will provide in their quotes that say yes, we will absolutely deal with your fire hazard. Oftentimes, that satisfies the fears of ESS owners.

However, the fire protection manufacturers know that there is a thermal management problem in the background that they aren't going to touch.

Again, the fire can be put out with a lot of traditional means: chemical agents, water, water mist and inert gases, but that threat is still there. You still have a real thermal management problem. Because a lot of those systems discharge and deplete, the next time a cell goes off and generates more toxic gases, it pushes the protective gases out of the system, and you no longer have any protection at all within that module.

This leads to a situation where we need a solution that's not just a fire protection solution but also a thermal management solution to deal with this threat of cascading thermal runaway. Far too many owners of ESS's are unaware of this issue, as they believe they are protected.

Q. Can you tell us about Fike's current testing capabilities and any notable initial takeaways when testing these batteries?
Fike's Innovation and Testing Center located in Blue Springs, Mo., just outside of Kansas City, focuses on unit- and installation-level testing, so we aren't just dealing with cells, but we are also dealing with modules and racks of modules. We take a lot of measurements on temperatures, heat flux, thermal load and much more, and we have high-speed cameras and

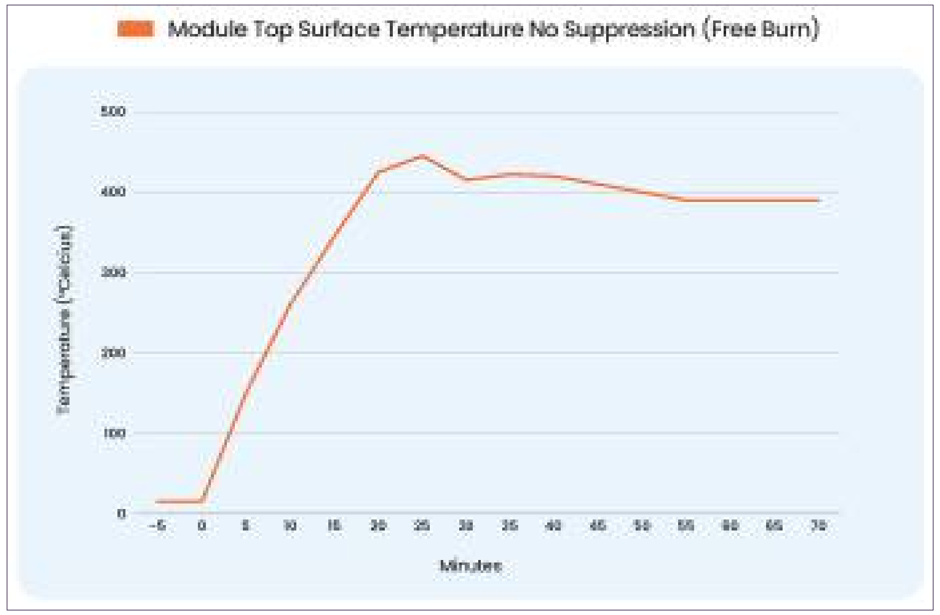


Figure 1

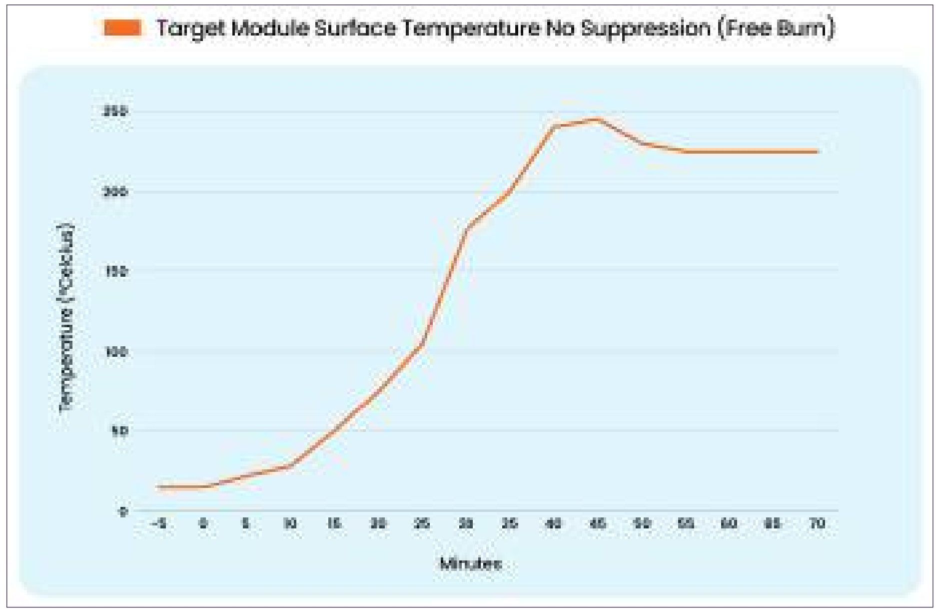
thermal imagery to visualize the data. Offgas testing is still under development but will be deployed in the coming months. It's basically a UL 9540A test without the gas sampling. We can test a variety of battery types, and this facility is where we've done the vast majority of our R&D work to date.

After several weeks of initial testing with a customer's lithium ion batteries, the end result was a lot of frustration because we were just confirming to ourselves the theory that everyone else was believing: thermal runaway cannot be stopped.

We did an initial module test and all we did was let it burn and set into thermal runaway. There was an extreme amount of smoke generated. We had a ventilator running at about 20,000 CFM to extract that, and even still our test cells were completely filled with smoke and overwhelmed with gas generation, which is another reason these ESS's can't be deployed near populated areas because that gas is toxic and there's a lot of it. ***Figure 1***

This test was also characterized with extremely high temperatures on the surface of the module itself. As you can see (Figure 1), about 450 degrees celsius of the skin, and anything nearby is also receiving that heat. There's nothing anyone can do with this until it cools down. At the conclusion of this test, it took about 18 hours for the skin to come back down below 100 degrees celsius. So it takes a long time, especially when

Figure 2



you think about. ***Figure 2***

We had a module directly above our "target module," and the temperatures were also extreme and reached about 250 degree celsius (Figure 2). If you've done any testing with these batteries, you know at 250 degree celsius your battery is already going into thermal runaway if you subject it to those temperatures. You're a long way into that, which means you've already set the next module off and it will keep going and going.

There's nothing to stop this cascading reaction, until we finally found the solution. And that would ultimately be named Fike Blue, an agent that showed promising results to not only suppress a fire like your typical fire protection system but also had the added benefit of stopping cascading thermal runaway at the module level.

Q. Did you attempt using Fike Blue in this series of testing, and if so, what were the results?
We decided to apply this new solution to those same batteries.

In the test, we only lost six of the 36 cells. The ones that were lost were two groupings of three cells: one with the heater applied and the one on the immediate other side. Everything else in the case was unharmed and it drastically reduced the thermal output and offgas that came off the system all the way down to about 60-70 degrees celsius (Figure 3), a far cry from 450 degree celsius in the "let it burn scenario" in the very beginning.

Figure 3

These are extremely low temperatures for these kinds of fires, low enough where immediately after an event that first responders and utility personnel can enter and extract that module that is having the issue using typical PPE. It did still generate some offgas, but it reduced the gas generated by 36 cells to six cells, assisting in the ventilation system's job to dilute and diffuse it. This means that if you've reduced those toxic emissions, you can bring these systems much closer to populated zones.

And if you look at the temperature of the module above the test module, it barely even heated to just 19 degree celsius.

Q. Can you speak more about the heat absorbed by surrounding modules?

The heat flux being generated off of these is extremely important because it goes back to the discussion of keeping first responders safe, allowing them to enter and do their jobs safely. The standards say that you can't exceed about 1.3kw/m^2 out to the center of your occupied space, so we went ahead and measured the heat flux at six inches.

During the free burn test, we were up to around 2.5kw/m^2, but with Blue applied it almost didn't register

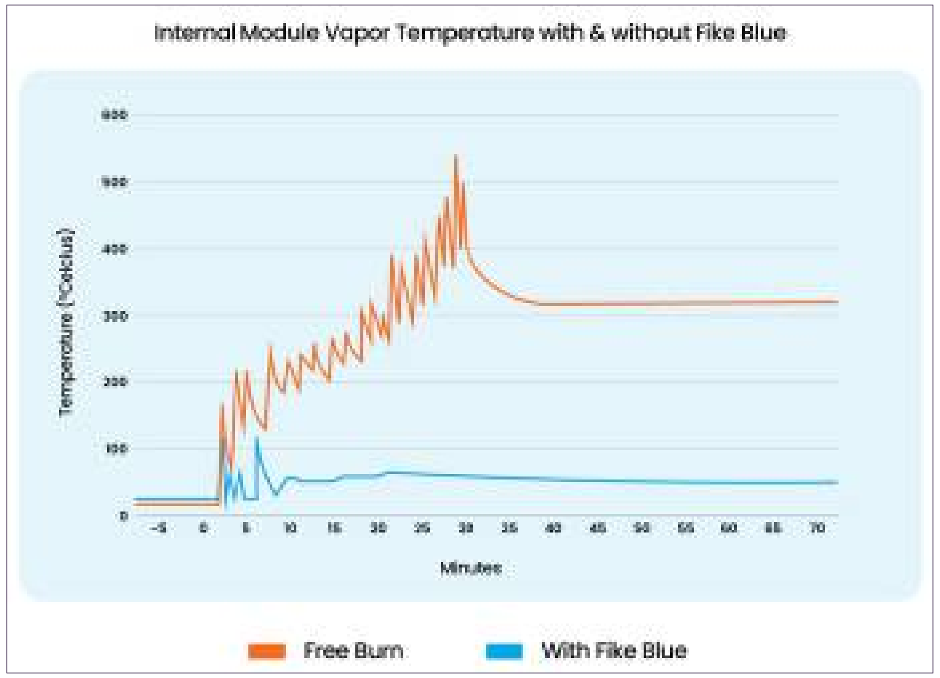


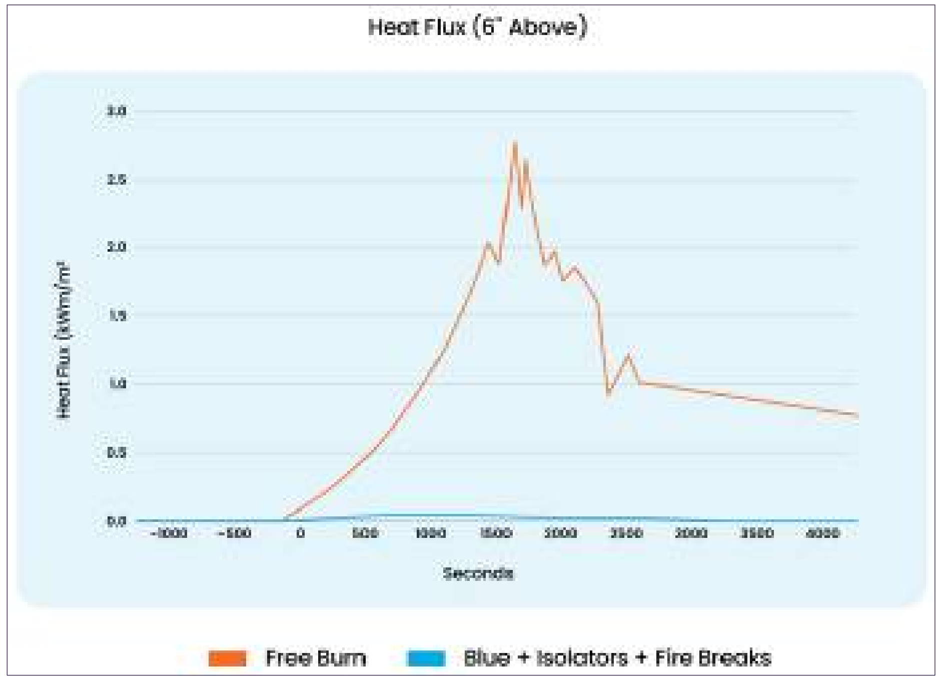
Figure 3

(Figure 4). This means a couple of things: protection for first responders, and a whole lot less heat imparted to additional modules that are above, to the sides and below inside of a rack configuration. And that means less likely for continued propagation into other models.

Q. Was this the only testing you've performed for Fike Blue?

Not at all. For example, we also performed this test at CSA, a nationally recognized test lab (NTRL)

Figure 4



with a full rack of batteries ***(Figure 5)***. We used the same setups, and the event was over in about five minutes. The experts that were there had commented they had never seen this done before, and we've done it several times now in front of those experts. They are unaware of any agent that was able to successfully stop thermal runaway inside of a module.

Q. Why does Fike Blue work so effectively to suppress the propagation of thermal runaway?

Fike Blue is a liquid, directly injected into the module and intended to manage the thermal event by absorbing the heat. It has a very high boiling point, much higher than water, which helps it stick around for a long time and keep doing its job. It doesn't dissipate like gases would in a typical fire suppression system.

In the testing we ran, only used about 26 gallons of Fike Blue as opposed to the thousands of water that would be required with traditional sprinkler systems or from a fire hose. It's not very electrically conductive, so it doesn't cause any cells to also go into thermal runaway like water has the ability to. Also, it's completely non-toxic, biodegradable, and because you use so much less of it, the concerns about contaminating groundwater or having a massive EPA issue is significantly less.

Q. Knowing what you know now, what is your opinion on the "let it burn" strategy for ESS's?

The "let it burn" philosophy is one I find to be irresponsible at best and dangerous in typical scenarios for two main reasons. One, is the incredible thermal load you subject other structures to and other batteries to, and the other being the immediate danger to the environment and life in occupied spaces. If you let a battery burn, you generate fire obviously but also an enormous amount of toxic gases. Letting it burn takes care of the flammable gases just fine if things are on fire, but all those toxic gases have to go somewhere. If you have 1000 cells inside a battery, and you let all those burn, you generate 1000 cells worth of toxic gas that is going into occupied spaces and render them unoccupiable for some time.

If this is in an urban setting, this can have disastrous consequences. If you're able to suppress it and stop propagating thermal runaway, instead of losing 1000 cells, you may only lose 50, which means that can be dispersed and get to levels which are not quite so toxic to people in the immediate vicinity.

Fike Blue opens up a very real possibility that ESS's may be safely deployed into various urban environments. In our opinion, this makes the let it burn strategy adopted by various industry professionals and decision makers one that is non-sustainable and ultimately unsafe, particularly when a better solution like Fike Blue exists.

This offgassing will cause hazards especially for those in populated areas, so there's a vested interest in minimizing what comes off that. The agent also has other additives that will absorb things like HF, so you are reducing those other hazards, and just by cooling everything down you are generating less gas.

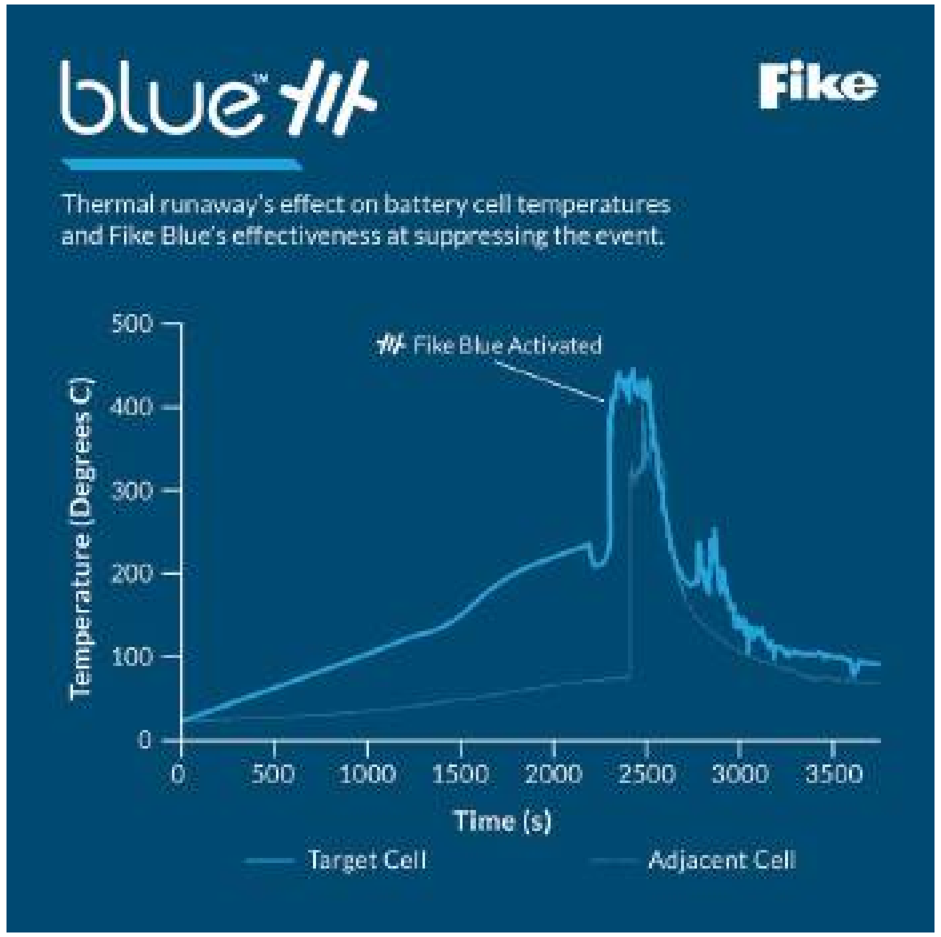


Figure 5