

# Welcome to the Battery Recycling Prize Phase II Demo Day

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- If you lose connection, or want to leave and rejoin, use the link or webinar ID:
  - Registration URL:  
<https://attendee.gotowebinar.com/register/798618583094011663>
  - Webinar ID: 501-130-659
- Videos will be displayed during some presentations, please adjust your audio for computer or headset to ensure you can hear those videos.
- For the best audio and visual connection, minimize external internet usage, such as cell phones.
- Make note of who you would like to contact for one-on-one meetings tomorrow. We will not have time for Q&A during today's session.
- Slides will be provided after the webinar.



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
**ENERGY EFFICIENCY &  
RENEWABLE ENERGY**

# DOE Lithium-Ion Battery Recycling Prize Demo Day

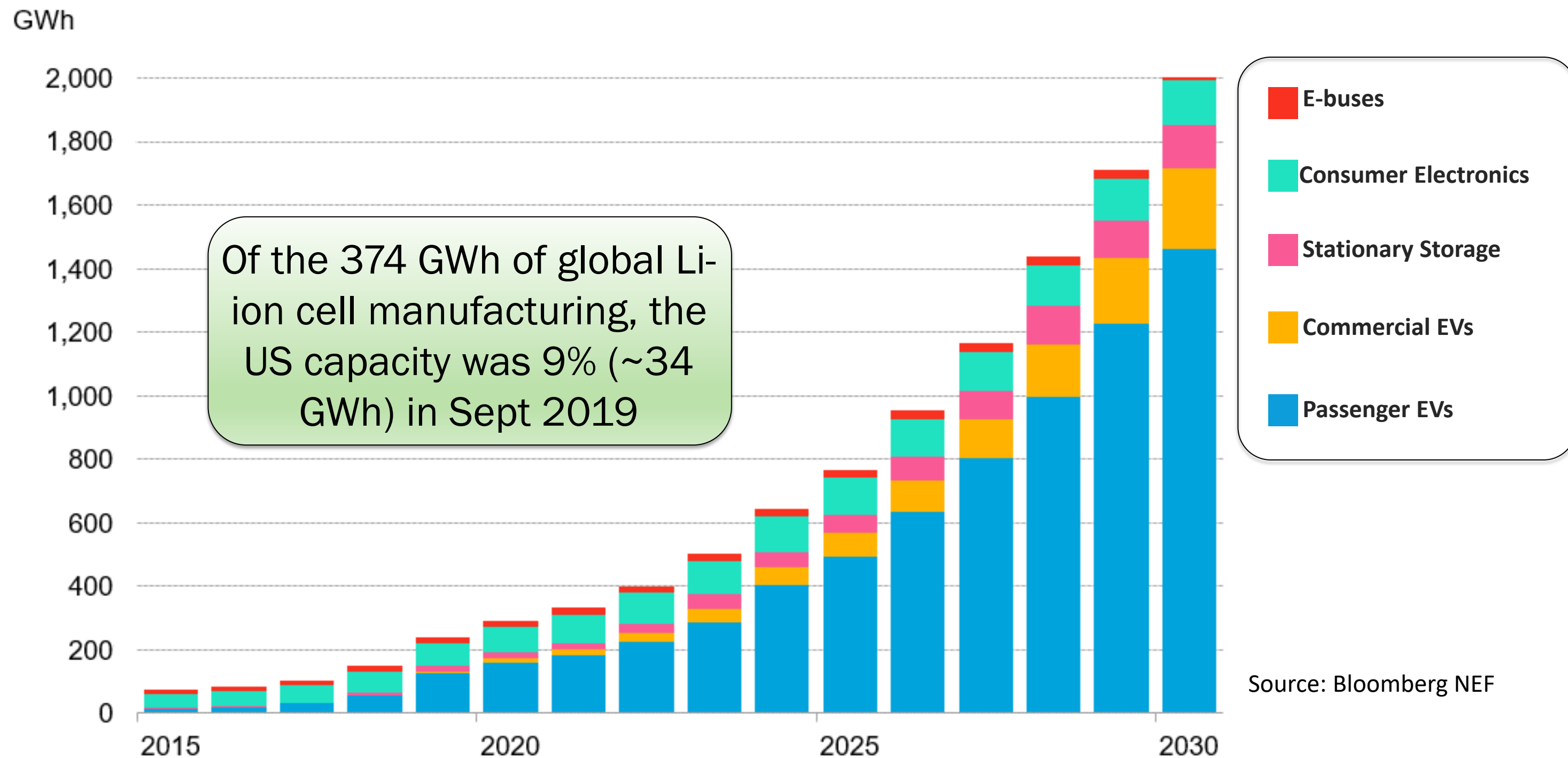
David Howell  
Vehicle Technologies Office

*July 22, 2020*





# EVs will dominate the demand for Li-ion batteries



Lithium-ion battery development and production is a strategic imperative for the U.S., both as part of the clean energy transition and as a key component for the competitiveness of the U.S. automotive industry.



# Electric Vehicle Battery R&D

## THREE MAJOR CHALLENGES

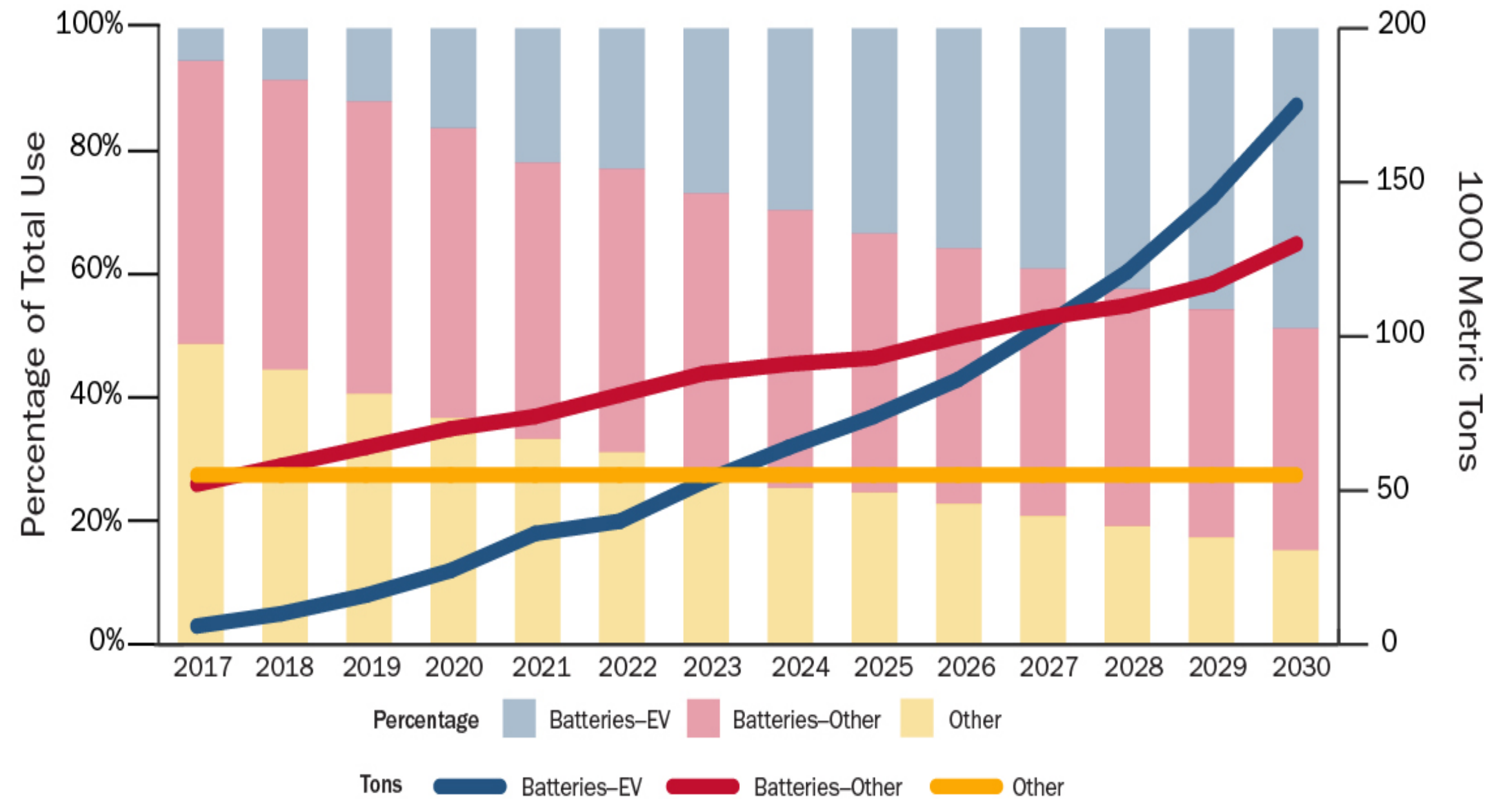
1. Further reduce battery costs

2. Eliminate dependence on critical materials

3. Develop safe batteries that charge in <15 minutes.

### Forecasted Global Cobalt Demand by End-Use

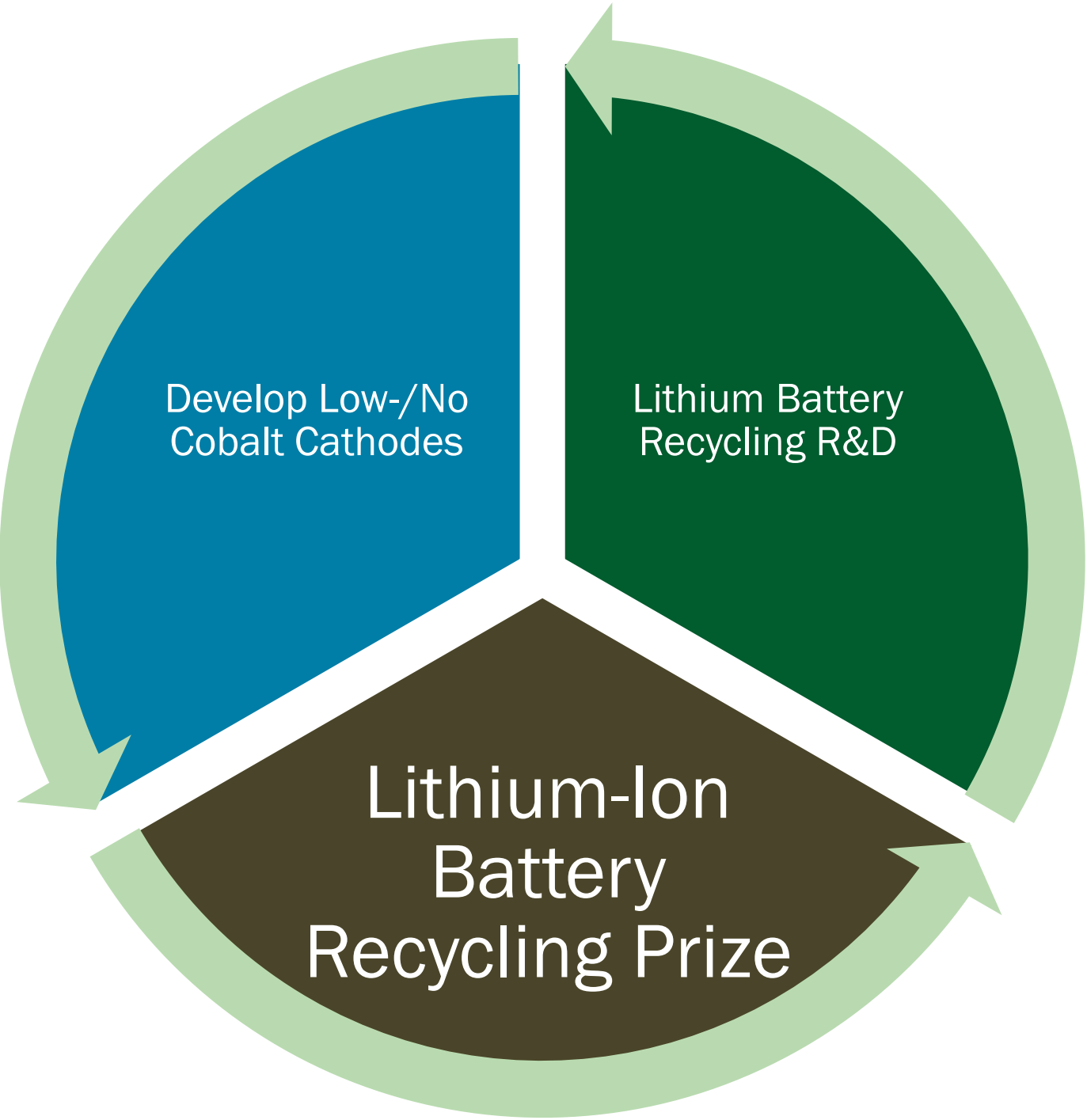
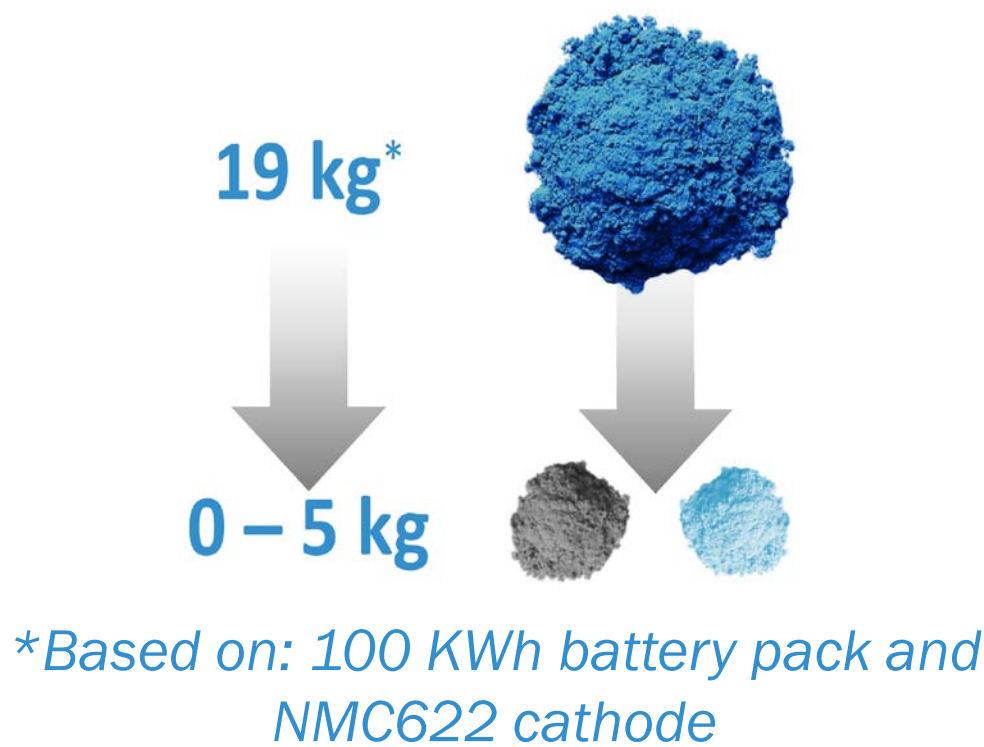
Source: Bloomberg New Energy Finance, 2018





# R&D to Mitigate Potential Critical Material Impacts

## Low/No Cobalt Cathode R&D



- Decrease recycling cost
- Recover critical and high value materials
- Reintroduce recovered materials into the material supply stream

A \$5.5-million phased competition over three years

Innovative Ideas for Collecting, Storing, and Transporting Discarded Li-Ion Batteries



# Battery Recycling Prize

Innovative Ideas for Collecting, Storing, and Transporting Discarded Li-Ion Batteries

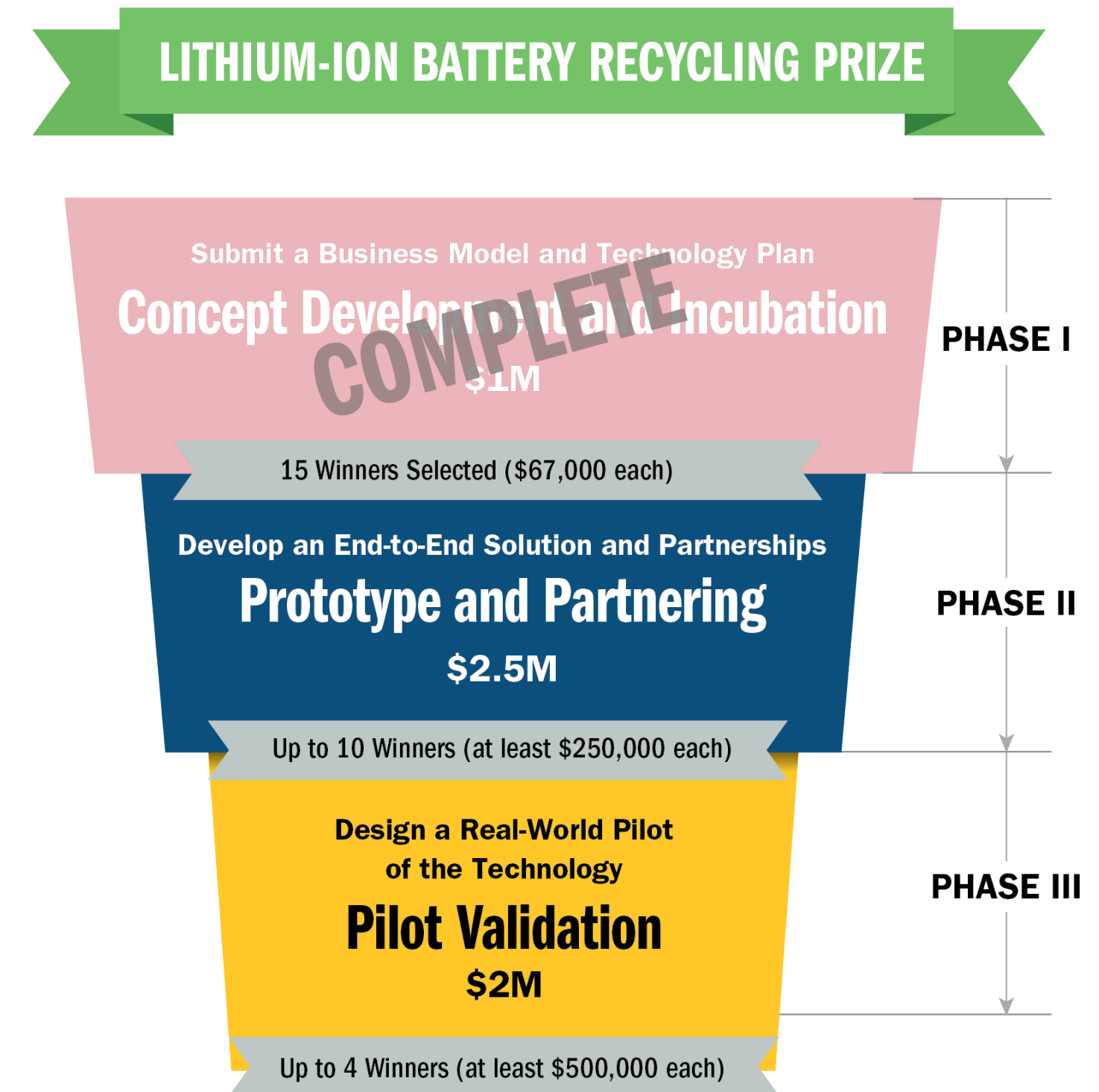


## A \$5.5 million phased competition over three years

- Funded by DOE's
  - Vehicle Technologies Office
  - Advanced Manufacturing Office

## PRIZE GOAL

Demonstrate a process that has the potential to capture 90% of ALL lithium-based battery technology in the U.S. (when scaled), including consumer electronics, stationary, and transportation applications.





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# THANK YOU



U.S. Department of Energy  
**LITHIUM-ION BATTERY RECYCLING PRIZE**



Virtual Demo Day  
**Lithium-Ion Battery Recycling Prize**

July 22, 2020

Disclaimer: All details necessary to participate in the Lithium-Ion Battery Recycling Prize program are provided in the Official Rules document online. The information provided in this presentation is not intended to amend, modify or substitute details provided in the Official Rules. Information presented should be used in conjunction with the Official Rules. In addition, any reference in presentation to any specific commercial product, process, or service, or the use of any trade, firm or corporation name is for the information and convenience of the public, and does not constitute endorsement, recommendation, or preference by the U.S. Department of Energy. Visit [americanmadechallenges.org](https://americanmadechallenges.org)



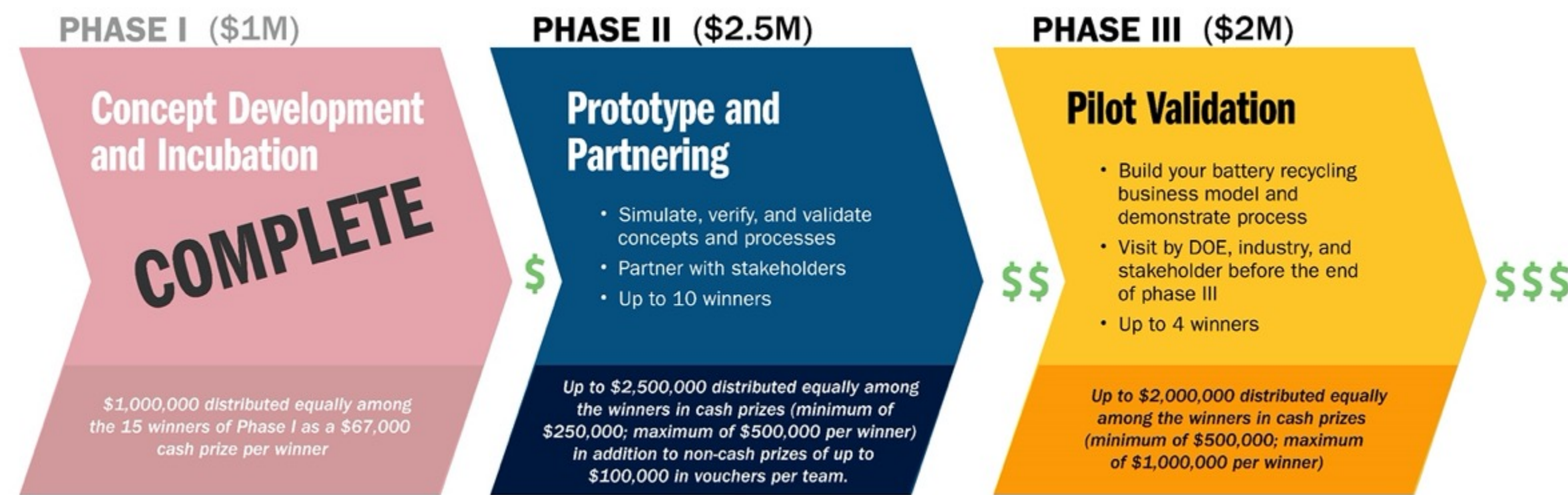
U.S. DEPARTMENT OF ENERGY



# Lithium-Ion Battery Recycling Prize

The Prize is designed to incentivize a diversity of problem solvers to create end-to-end solutions to help DOE achieve an overall lithium-ion battery recovery rate of 90%. This might be accomplished by:

- Increasing collection
- Implementing cost-effective, automated methods or technologies for separation and sorting
- Developing safe methods or technologies for lithium-ion battery storage and transportation
- Optimizing the efficiency of logistics
- Designing an entirely unanticipated solution
- Some innovative combination of all these solutions.





# Phase II Timeline

## PHASE II Prototype & Partnering



# Phase II Prizes

Winners of Phase II will receive \$2,500,000 in cash prizes distributed equally among the teams and up to \$100,000 per team in non-cash vouchers to use in the Phase III Contest.

## About Vouchers

- The provided vouchers will allow winners of Phase II to access tools, equipment, and expertise within the American-Made Challenge (AMC) Network.
  - These experts are approved Connectors/Voucher Service Providers (VSPs) within the AMC Network
- The DOE's 17 national labs, together with the approved organizations and facilities, may provide competitors with:
  - Access to hardware and development tools
  - Access to national laboratories, universities, and private laboratories
  - Specialized facilities with additive, reductive, and manufacturing support
  - Testing and validation capabilities
  - Other expert services.
- More details can be found at: [herox.com/BatteryRecyclingPrize/resource/399](https://herox.com/BatteryRecyclingPrize/resource/399).



# Voucher Process

- **Initiate:** As part of the Phase II Concept Update, participants submit descriptions of technical challenges in a two-page Technical Assistance Request
- **Connect:** Throughout Phase II, participants will have opportunities to learn more about VSPs and how to connect with them
- **Match:** VSPs and Phase II participants contact each other, exchange ideas, and discuss scope and outcomes for using voucher funds
- **Decide & Propose:** Participants must include an overview of potential VSP partnerships in their Phase II Submission.
- **Win & Statement of Work:** Phase II winners develop and negotiate a statement of work for any VSPs they plan to collaborate with no later than 90 days after the Phase II winner announcement.
- **Contract:** Each VSP will have a unique contract process.
- **Begin Work: Phase III Pilot Validation**

# Voucher Payments

- Participants must utilize at least \$50,000 in vouchers with National Labs.
- The competitor must work directly with the selected National Lab to complete a Statement of Work (SOW) within 90 days after winning the Phase II competition.
- Once the NREL Prize Administrator receives this SOW, the Prize Administrator will work with the desired lab to transfer the allocated voucher funds to the selected lab to perform the work as specified.
- Work with VSPs who are not National Laboratories is funded directly by the participant. Once the work is complete, the participant will request reimbursement from the Prize Administrator.
- The period of performance for all voucher work shall be 12 months or shall end on the date that Phase III submissions are due, whichever is shorter.
- For more details on allowability requirements, refer to the Voucher Guidelines document: <https://www.herox.com/BatteryRecyclingPrize/resource/399>

# Virtual Demo Day Objectives

**This event is an opportunity for participants to showcase their business and technology concepts and connect with potential VSPs to brainstorm the best uses for voucher funds.**

- Connect participants with industry experts
  - Forge new partnerships with business, university, and national laboratory stakeholders
  - Identify potential VSP partnerships per Phase II Submission requirement
- National Laboratory researchers will present the capabilities available to Phase III participants as VSPs
- Participants will present their projects and technical assistance gaps
- Business VSPs will also present technical capabilities available to Phase III participants.

*This event is open to all participants and external stakeholders.*



# Virtual Demo Day Agenda

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10:00 a.m.	Introduction from DOE
10:10 a.m.	NREL Prize Update
10:20 a.m.	DOT Travel Regulations and UW Special Permit Requirements
10:30 a.m.	National Lab Capabilities
<b>11:45 a.m.</b>	<b>Break</b>
12:30 p.m.	Team Presentations
<b>1:30 p.m.</b>	<b>Break</b>
2:15 p.m.	Team Presentations, Cont.
<b>3:15 p.m.</b>	<b>Break</b>
3:30 p.m.	VSP Organizations

# PHMSA's Vision and Mission

## Vision

The most innovative transportation safety organization in world.

## Mission

To protect people and the environment by advancing the safe transportation of energy and other hazardous material that are essential to our daily lives.





# Lithium Battery Basics

- Transport Basics
- Shipping Descriptions
- UN 38.3 Tests
- Packaging
- Hazard Communication
- Shipping Scenarios





# Hazards in Transport



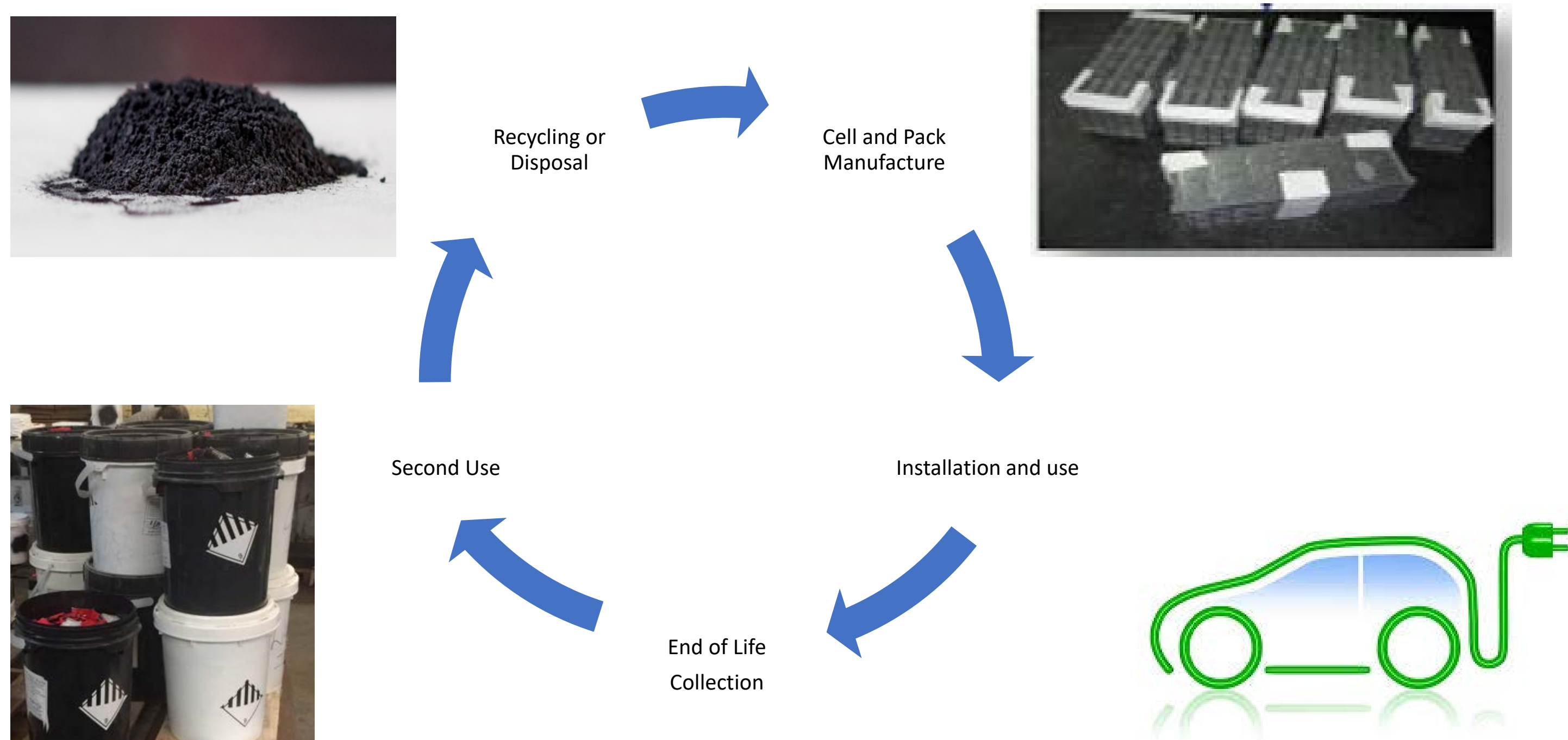
LiCoO<sub>2</sub> cell in catastrophic disassembly



- Dangerous generation of heat and gas
- Source of ignition
- Chemical and electrical
- Short circuit
- Propagation of fire/heat
- Not easily extinguished

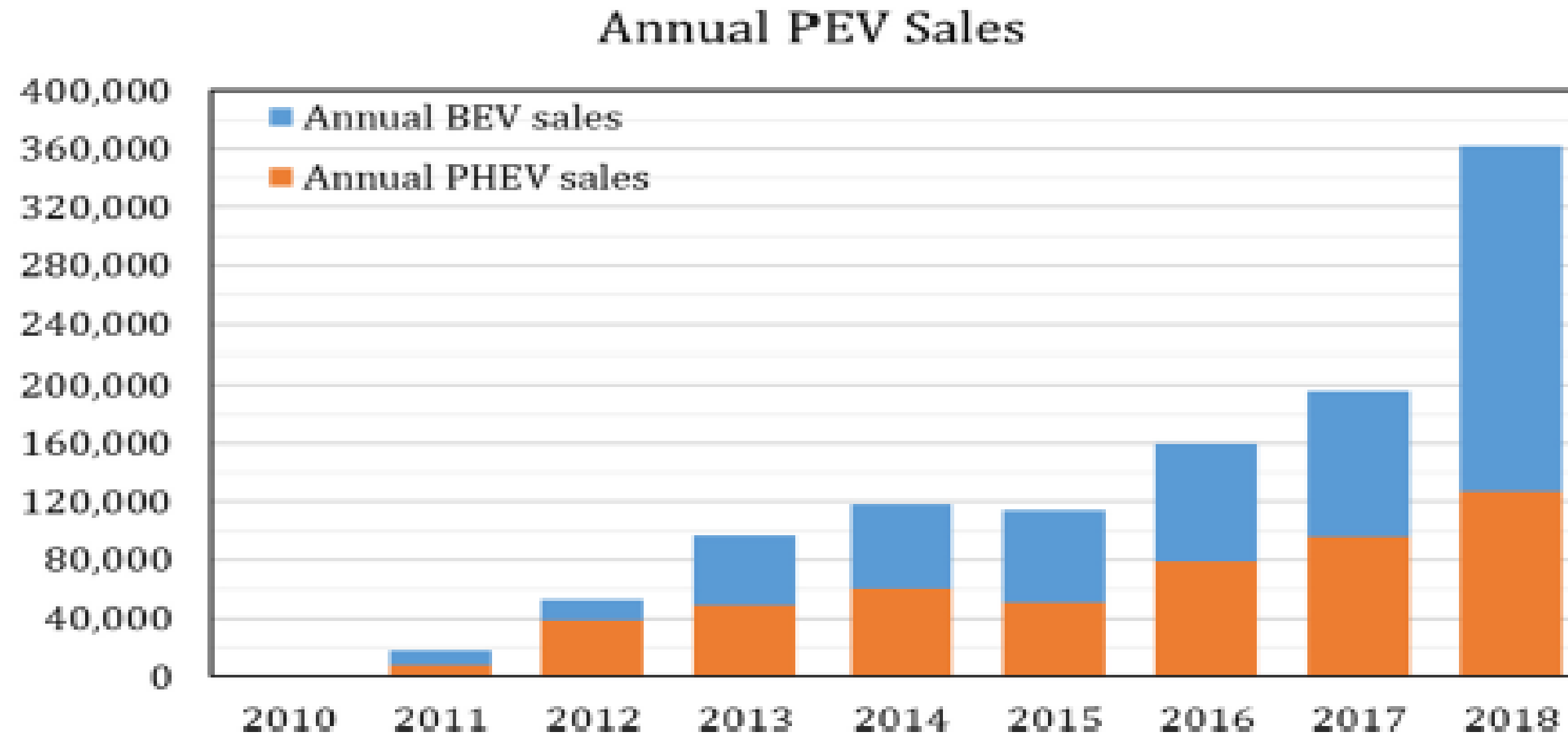
Thermal runaway propagates from cell to cell and package to package

# Transport in the Product Lifecycle





# Future of Lithium Battery Recycling



Source: Assessment of Light-Duty Plug-In Electric Vehicles in the United States, 2010–2018; ANL/ESD-19/2





# Transport Shipping Descriptions

UN3480	Lithium ion batteries
UN3481	Lithium ion batteries contained in equipment
UN3481	Lithium ion batteries packed with equipment
UN3090	Lithium metal batteries
UN3091	Lithium metal batteries contained in equipment
UN3091	Lithium metal batteries packed with equipment



# UN 38.3 Design Tests

**Test T.1** Altitude simulation.

**Test T.2** Thermal test. Conducted using rapid and extreme temperature changes.

**Test T.3** Vibration. Simulates vibration during transport.

**Test T.4** Shock. Assesses the robustness of cells and batteries against cumulative shocks.

**Test T.5** External short circuit.

**Test T.6** Impact/Crush. Simulates mechanical abuse or crush that may result in an internal short circuit.

**Test T.7** Overcharge. Evaluates the ability of a rechargeable battery or a single cell rechargeable battery to withstand an overcharge condition.

**Test T.8** Forced discharge. Evaluates the ability of a primary or a rechargeable cell to withstand a forced discharge condition.





# Packaging





# Hazard Communication



U.S. Department of Transportation  
Pipeline and Hazardous Materials  
Safety Administration

To Protect People and the Environment From the Risks of  
Hazardous Materials Transportation





# Other Shipping Scenarios

## Disposal and Recycling

- Exceptions from UN Testing
- Highway Transport Only

## Damaged or Defective

- Defective for safety reasons
- Sustained Damage
- Unknown additional hazards



## Special Permits

- Authorization granted on a case-by-case basis
- Unique designs or application
- Special Packaging



# How Does a Company Apply for a Special Permit?

Application procedures are in **49 CFR 107.105**

- Routine requests = 120 day turnaround time
- Emergency requests = issued as quickly as possible

**Email:** [specialpermits@dot.gov](mailto:specialpermits@dot.gov)  
**Phone:** 202-366-4535

<https://www.phmsa.dot.gov/approvals-and-permits/hazmat/hazardous-materials-approvals-and-permits-overview>

September 15, 2016



U.S. Department  
of Transportation

Pipeline and Hazardous  
Materials Safety Administration

East Building, PHH-30  
1200 New Jersey Avenue S.E.  
Washington, D.C. 20590

DOT-SP 20325

EXPIRATION DATE: 2017-03-31

(FOR RENEWAL, SEE 49 CFR 107.109)

1. GRANTEE: Samsung Electronics America, Inc.  
Ridgefield Park, NJ
2. PURPOSE AND LIMITATIONS:
  - a. This emergency special permit authorizes the use of alternative packagings for the transportation of recalled lithium ion batteries contained in equipment. This special permit provides no relief from the Hazardous Materials



U.S. Department of Transportation  
Pipeline and Hazardous Materials  
Safety Administration

To Protect People and the Environment From the Risks of  
Hazardous Materials Transportation





# Hazardous Materials Information Center

**Have a question about transporting hazardous materials?**

PHMSA's Hazardous Materials Information Center provides live, one-on-one assistance Monday through Friday from 9 a.m. to 5 p.m.



1-800-HMR-4922

1-800-467-4922

202-366-4488

[infocntr@dot.gov](mailto:infocntr@dot.gov)



# Kevin Leary

Transportation Specialist, International Program

US Department of Transportation  
**Pipeline and Hazardous Materials Safety  
Administration**

1200 New Jersey Ave. SE Washington, DC 20590

Office: 202-366-2944 ♦ Mobile: 202.603.1647

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Know what's **below**.  
**Call** before you dig.







# Lithium-Ion Battery Recycling Prize

Voucher Service Providers - National Laboratory Presentations



U.S. DEPARTMENT OF ENERGY



Lithium-Ion Battery Recycling Prize Demo Day



# ARGONNE'S CAPABILITIES: VIRTUAL DEMO DAY



**JEFF SPANGENBERGER**  
Material Recycling R&D Group Lead

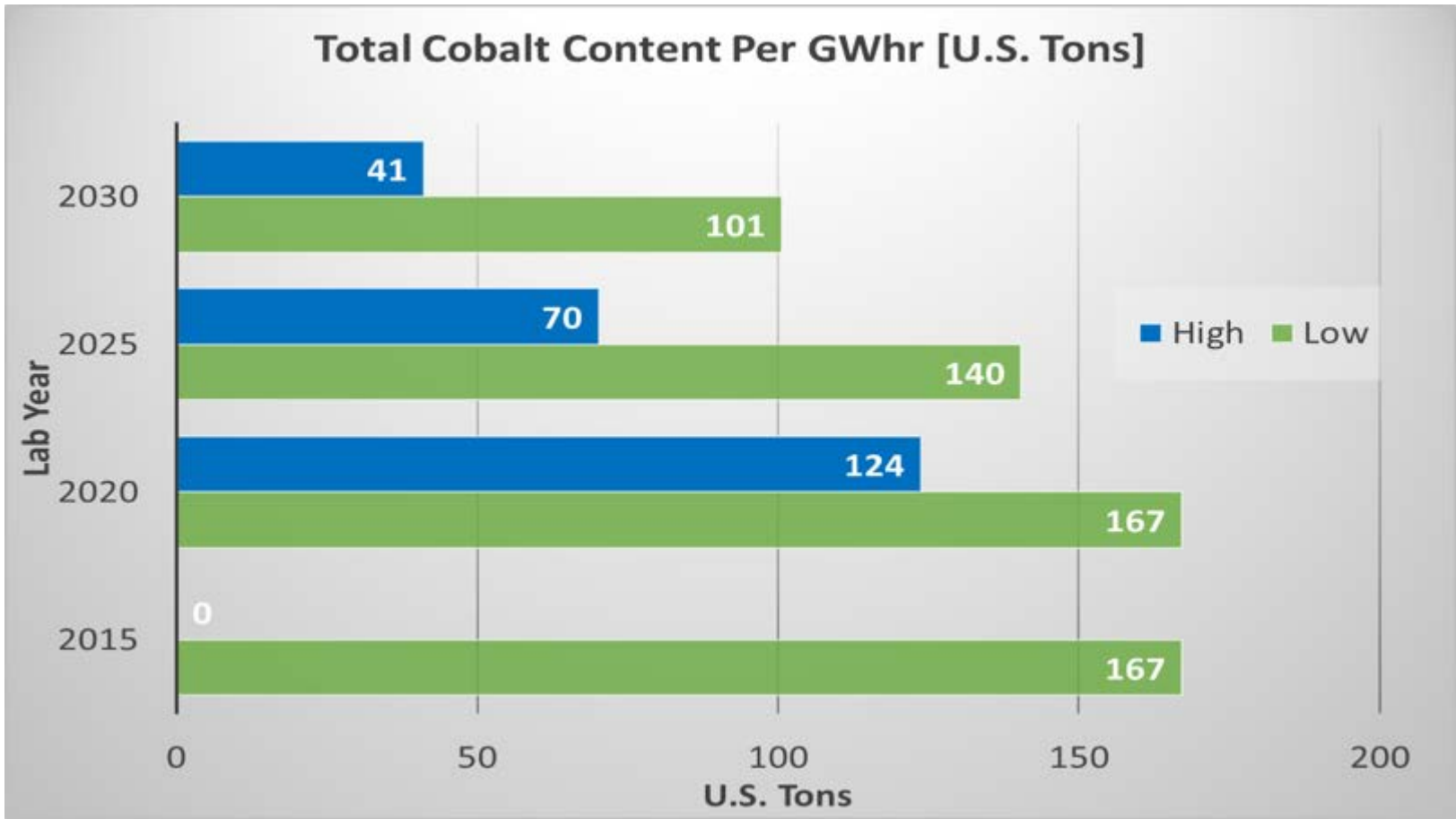
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630-252-5543



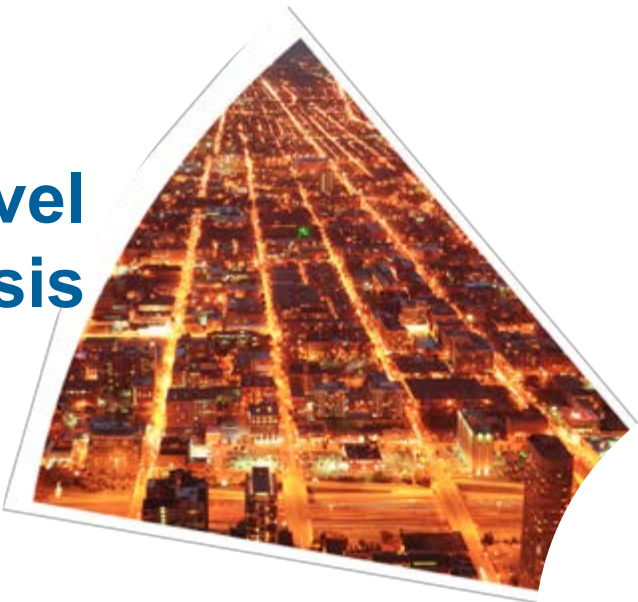
July 22<sup>nd</sup>, 2020



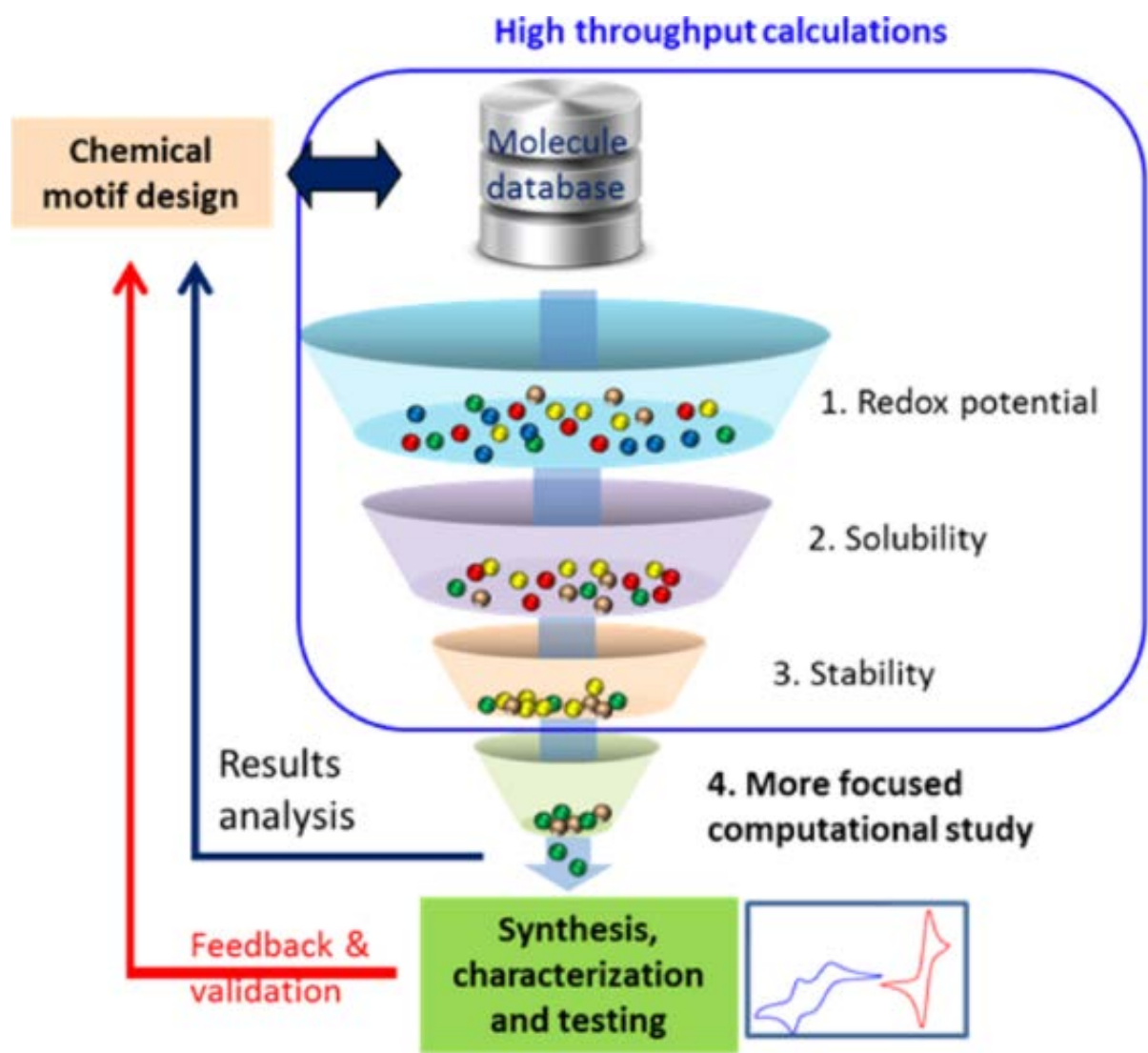
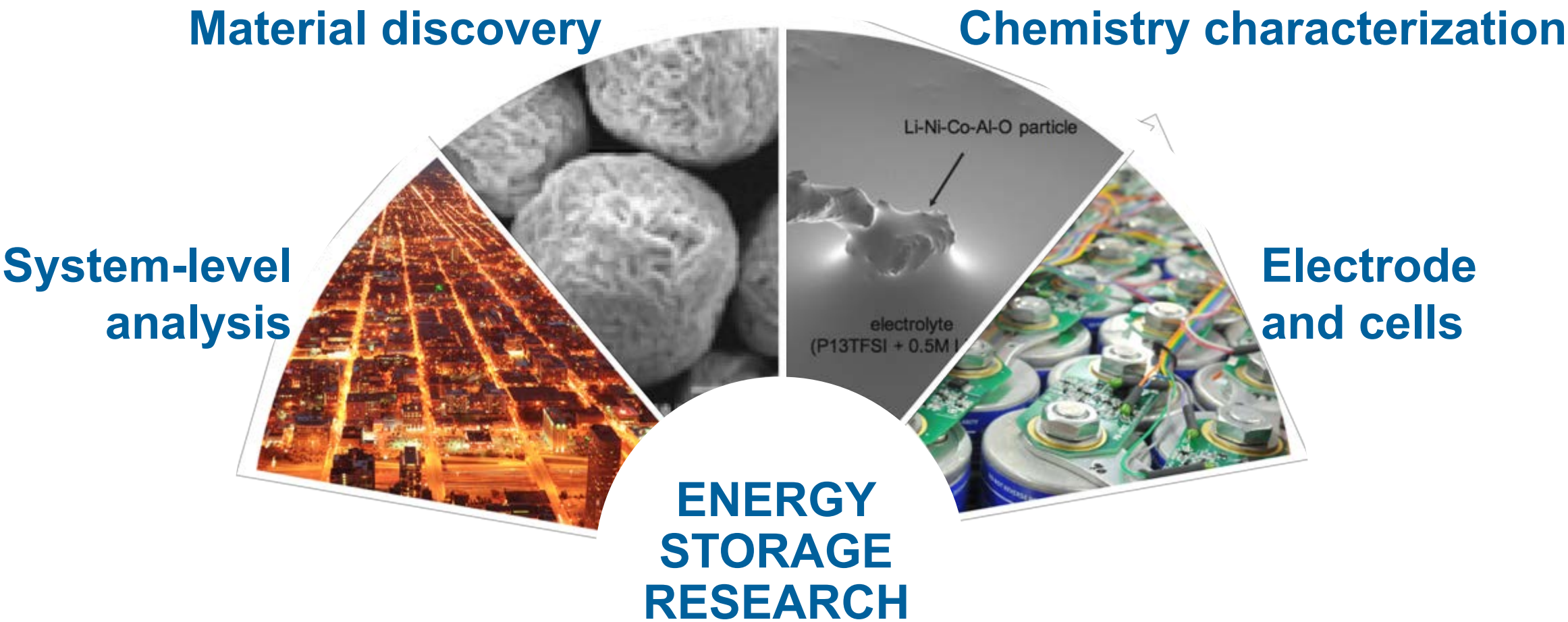
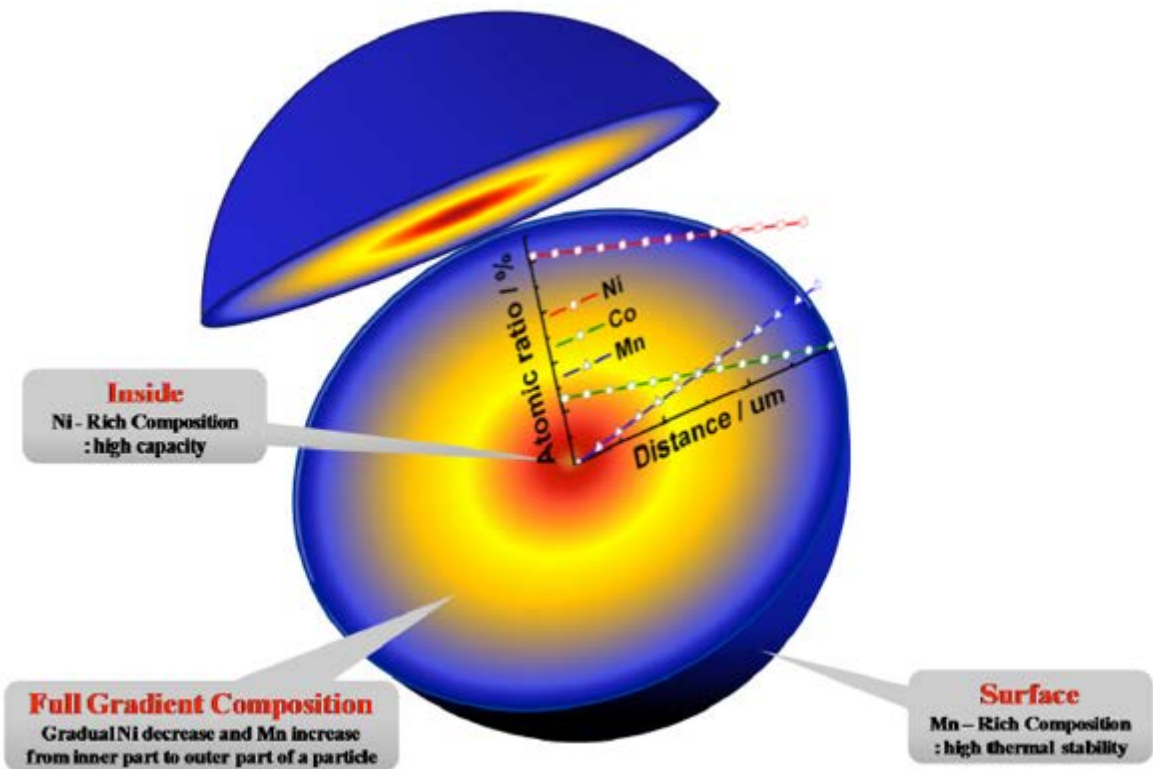
# ARGONNE THROUGH THE VALUE CHAIN



System-level  
analysis



# ARGONNE THROUGH THE VALUE CHAIN





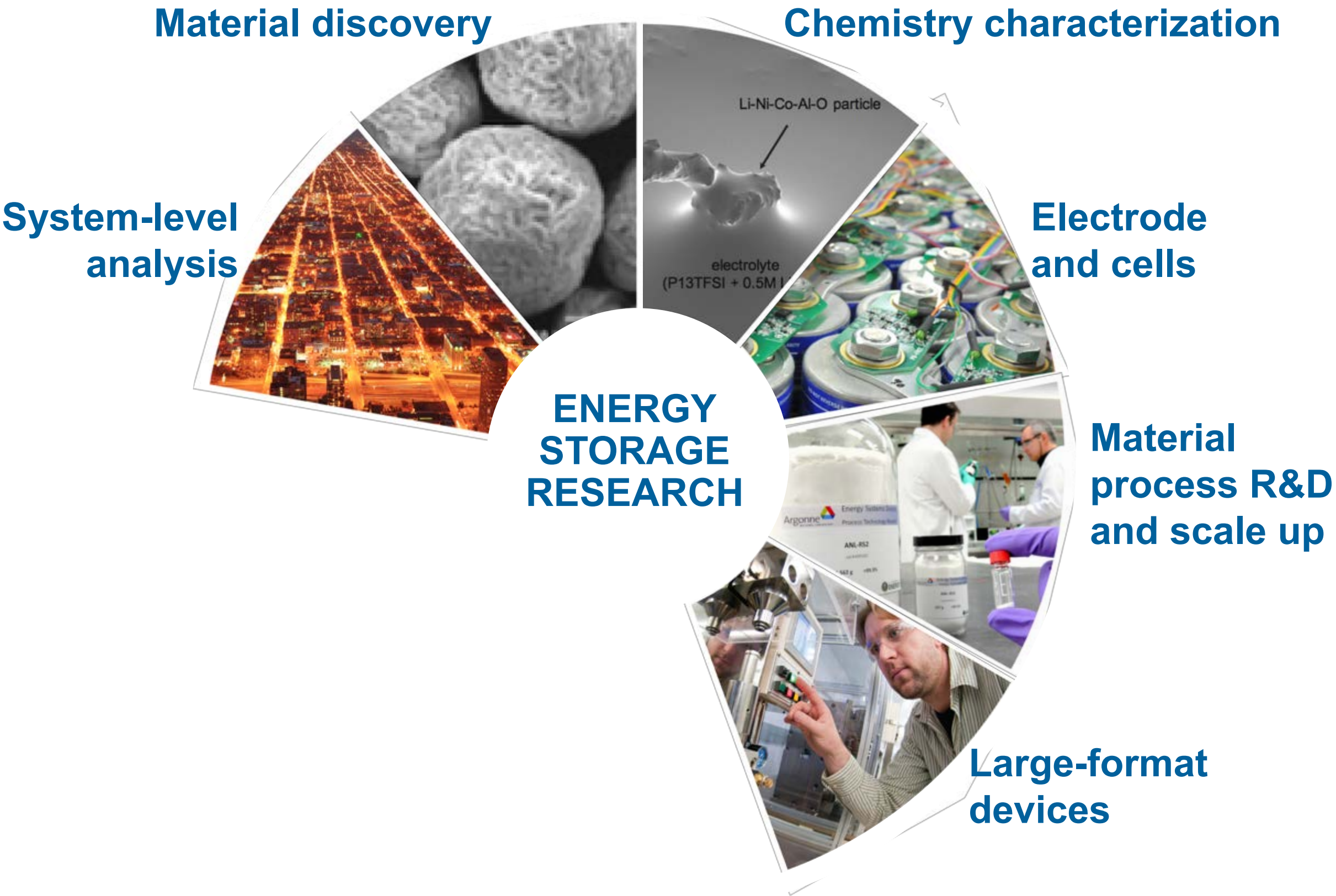
# ARGONNE THROUGH THE VALUE CHAIN



Materials Engineering research Facility (MERF)



Cell Analysis, Modeling, and Prototyping (CAMP) Facility





# ARGONNE THROUGH THE VALUE CHAIN

Testing Lab

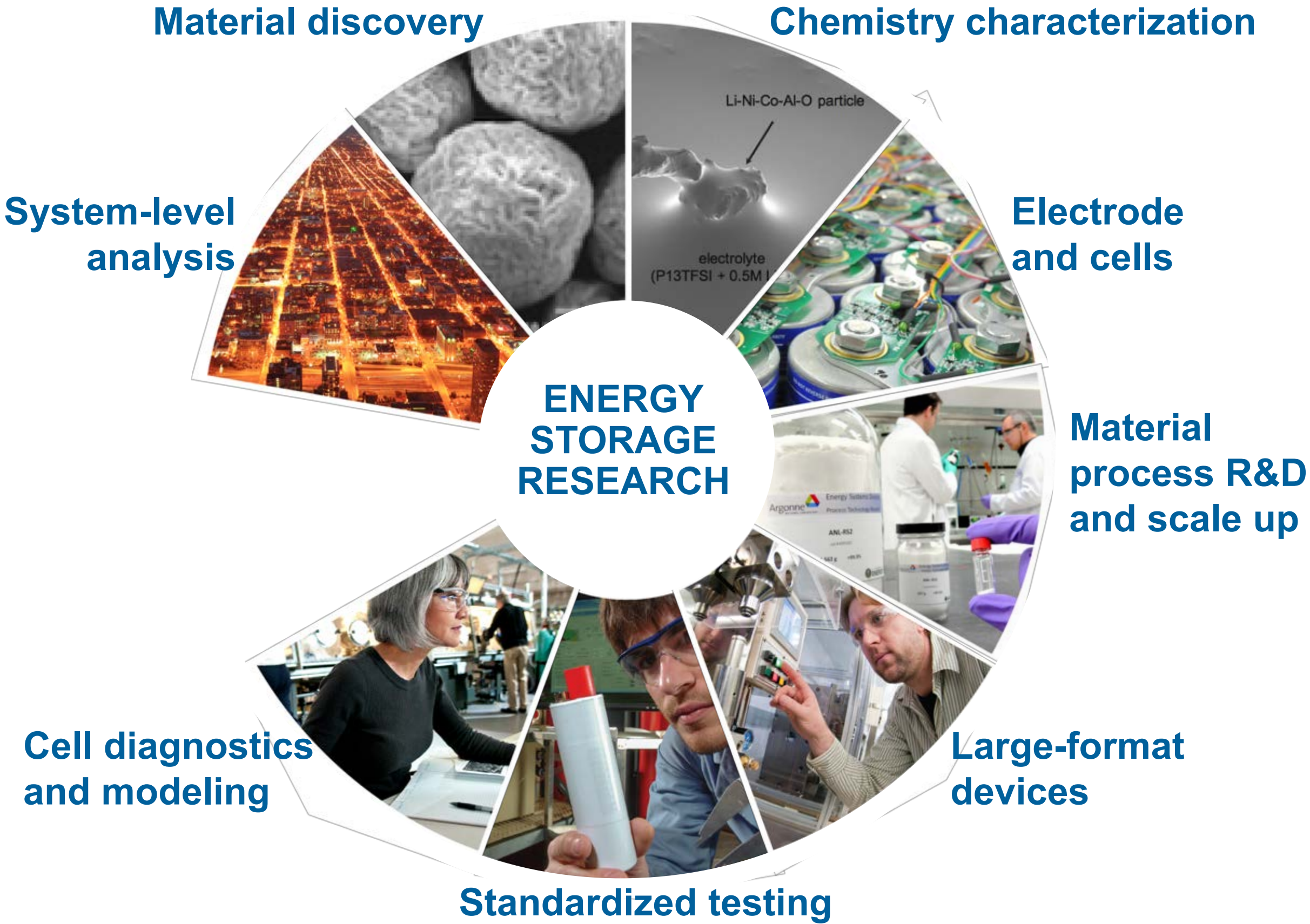
Machine learning



## BLE: Battery Life Estimator

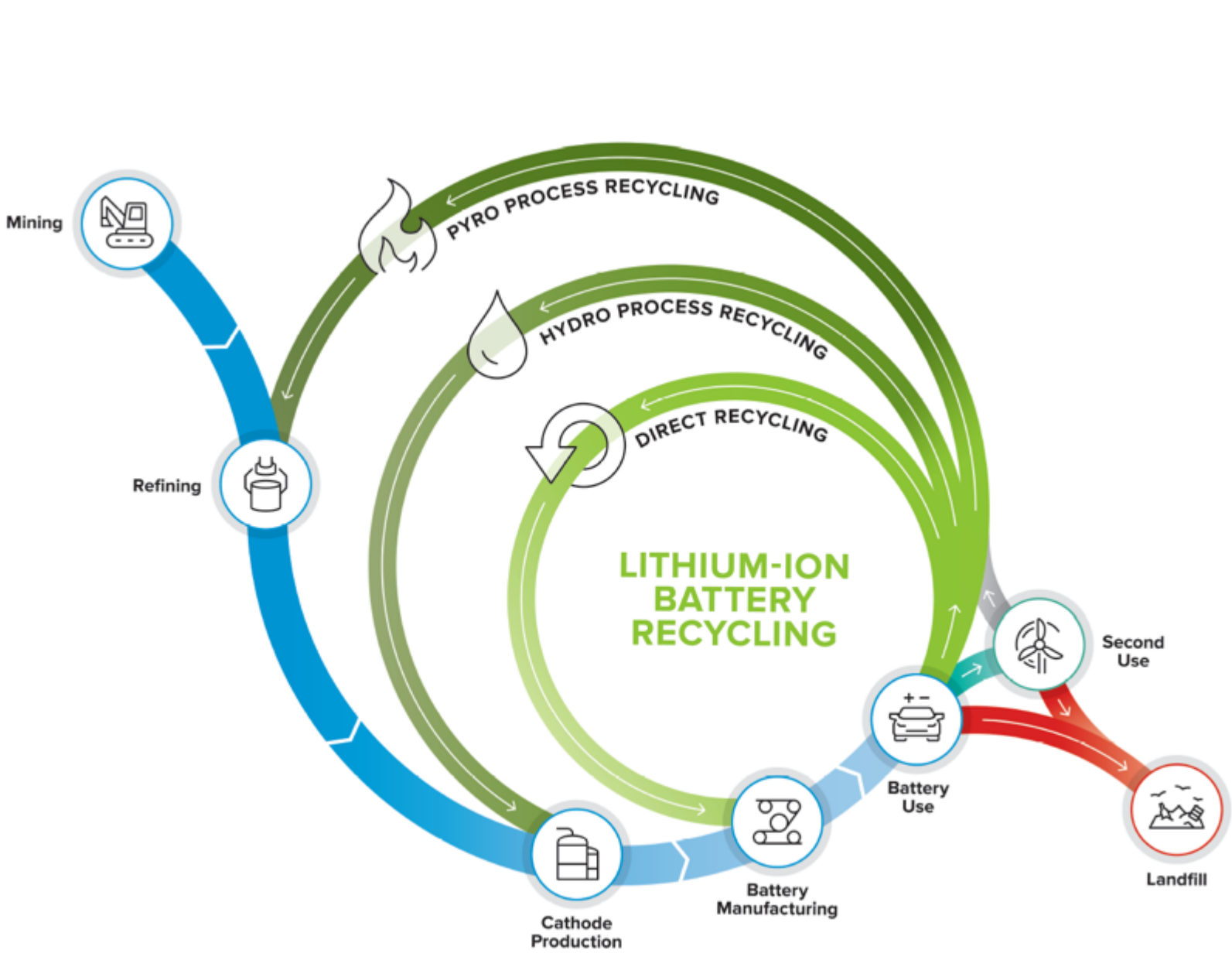


Argonne's Battery Life Estimator (BLE) software is a state-of-the-art tool kit for fitting battery aging data and for battery life estimation. It was designed to make life-cycle estimates using two years of aging data.

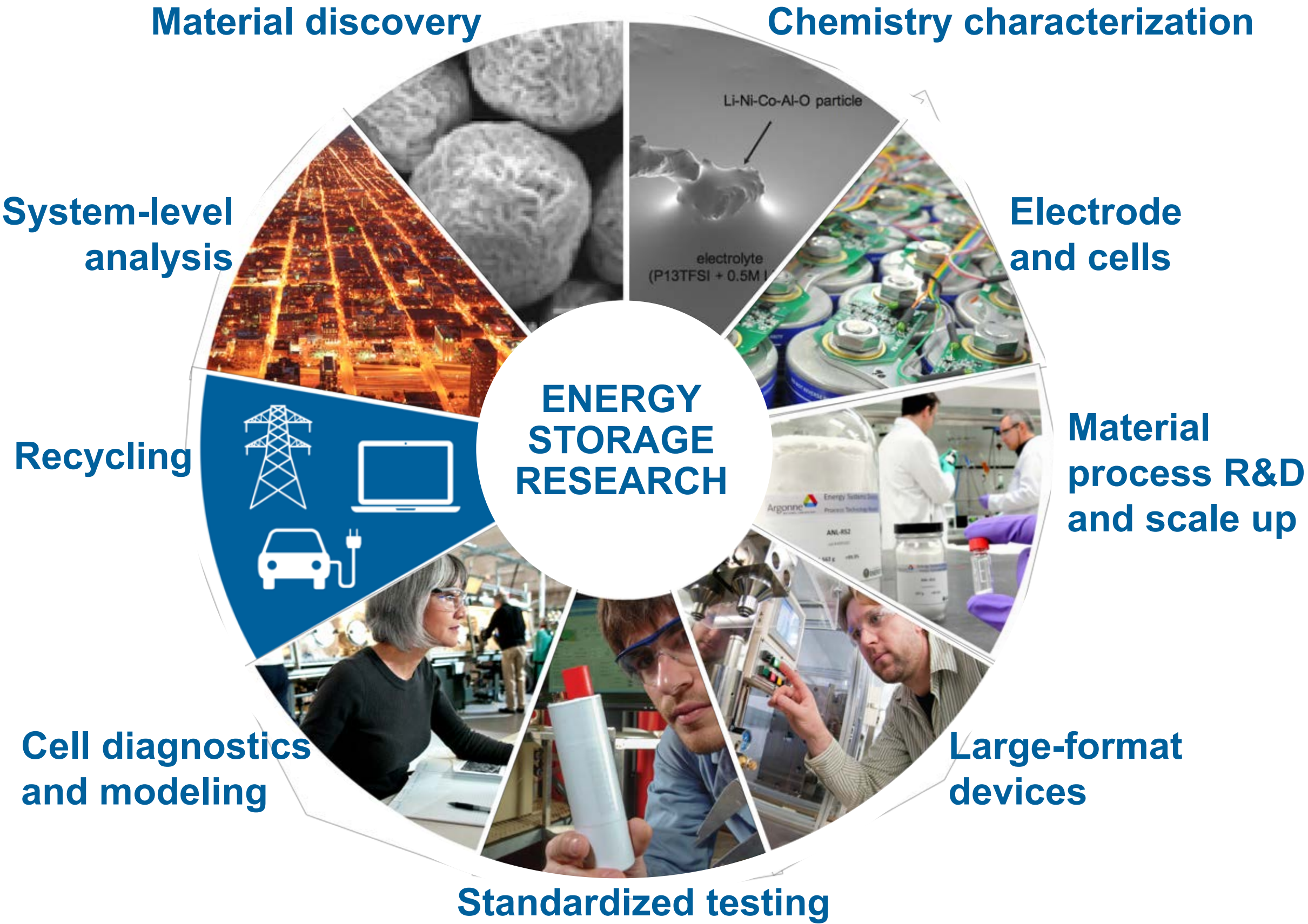




# ARGONNE THROUGH THE VALUE CHAIN



The ReCell Center

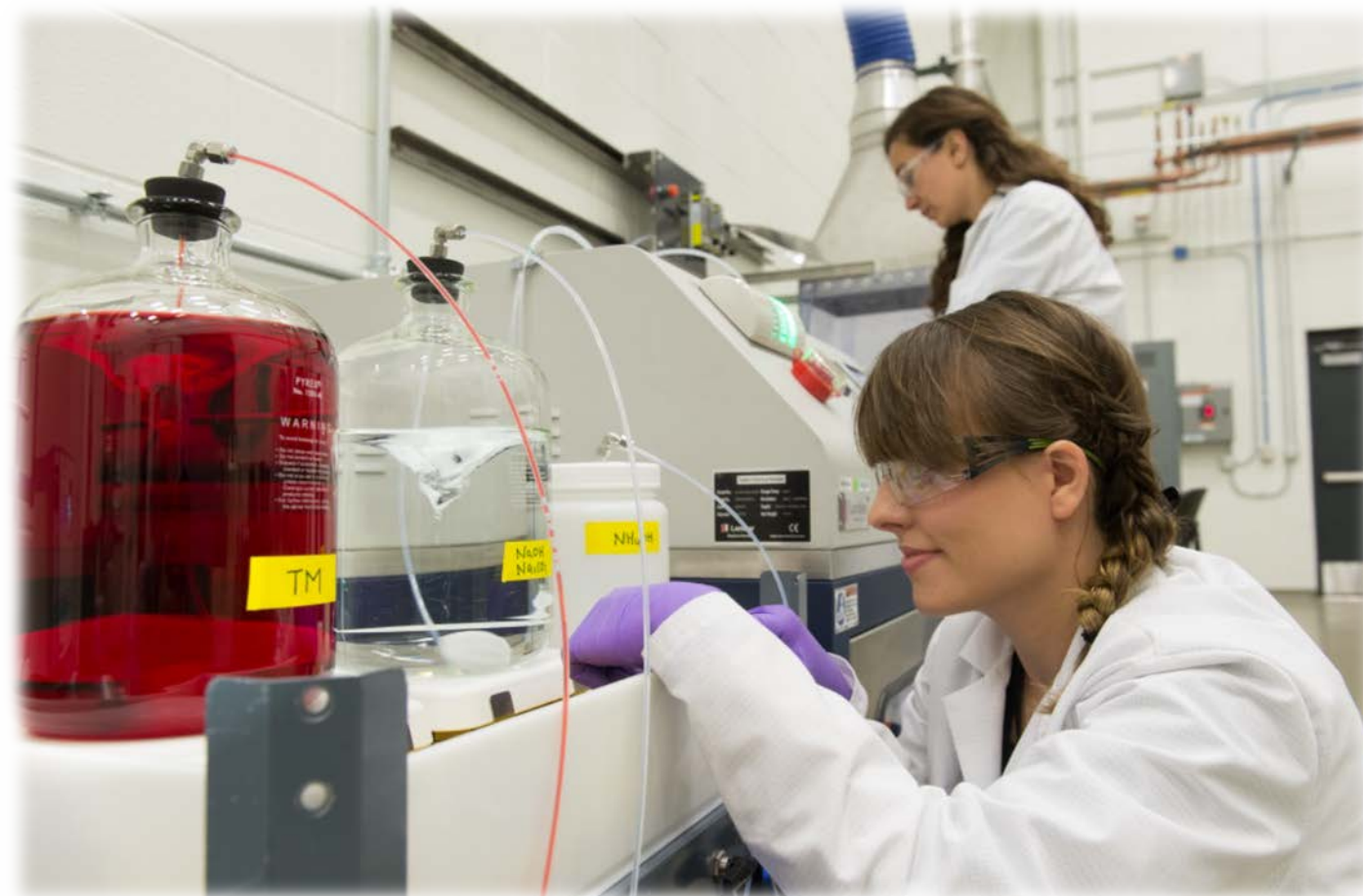




# MATERIAL ENGINEERING RESEARCH FACILITY

## MERF

- Process optimization: Takes something from an experimental lab and creates/improves a scalable process
- Process Scale up: Moves a process to the next level
- Material Characterization: Full analytical lab





# CELL ANALYSIS, MODELING AND PROTOTYPING CAMP

- Designs, fabricates, and characterizes high-quality prototype cells
- Enables realistic, consistent, and timely evaluation of candidate chemistries in a close-to-realistic industrial format: xx3450 Li-ion pouch cells (200-500 mAh) and 18650 Li-ion cells (1-3 Ah)





# ELECTROCHEMICAL ANALYSIS AND DIAGNOSTICS LABORATORY

## EADL

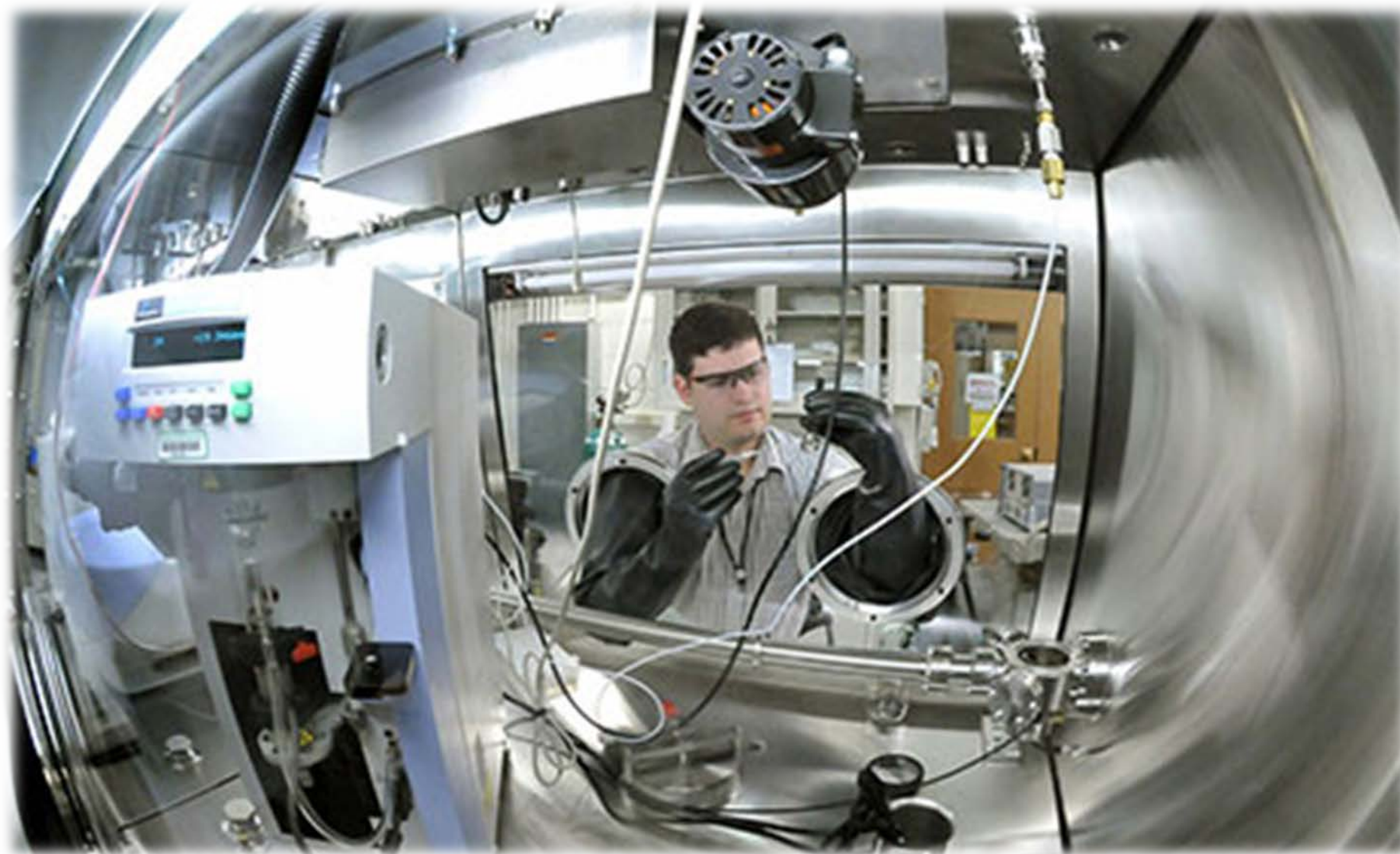
- Conducts independent performance and life evaluation of cells, modules and battery packs
- Can perform 240 concurrent advanced battery studies under operating conditions that simulate various applications
- Utilizes life test data to develop life prediction models





# POST-TEST

- Assists with challenges related to battery failure modes.
- Designed to handle air-sensitive materials, such as those from lithium-based or sodium-based battery technologies





# MATERIAL RECYCLING FACILITY

## Decades of material separation and recycling experience

- Bench-scale separation and processing
- Pilot-scale separation and processing

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- Shredding/granulation
- Sizing
- Furnaces/ovens
- Powders hoods
- Sink/float tanks
- Air aspiration
- Continuously stirred tank reactors
- Magnetic separation
- Froth flotation
- Battery cyclers
- Battery material samples





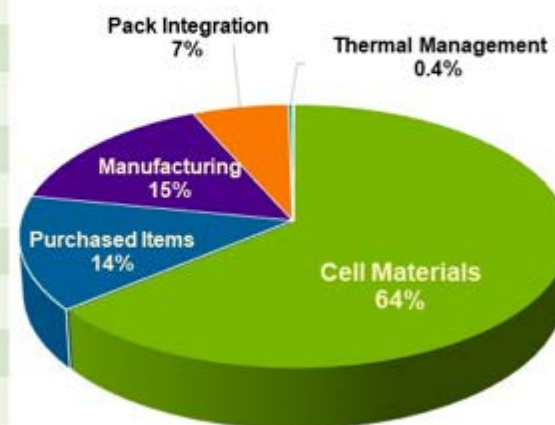
# MODELING

## Cost, Environmental Impact, Performance

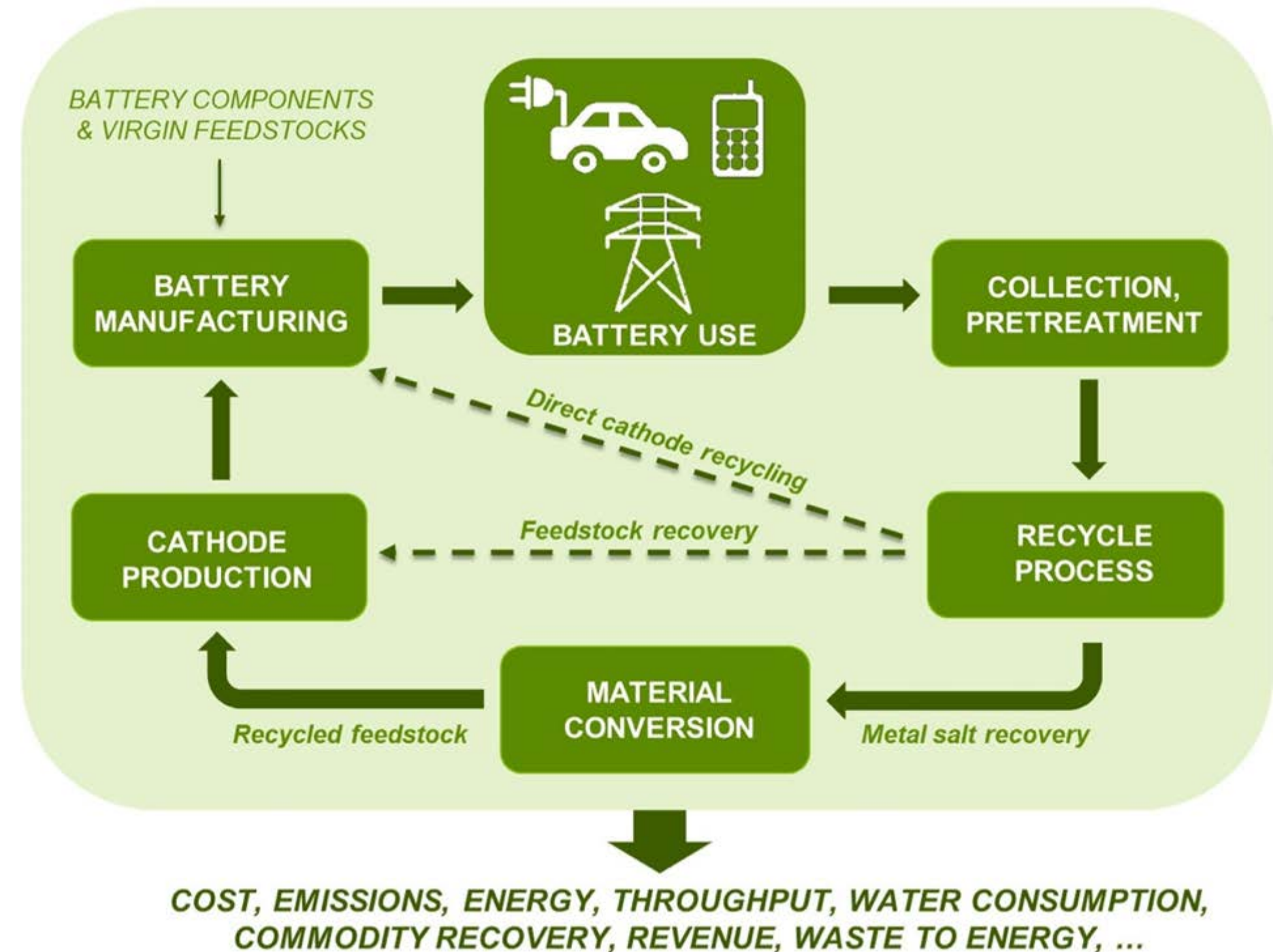
- EverBatt: Evaluates cost and environmental impacts at every stage of a batteries life
- BatPaC: A battery performance and manufacturing cost estimator

Cell materials represent 64% of the 2019 pack cost

Pack Cost to OEM, \$		\$14,814	% of Total
Pack Cost to OEM, \$/kWh		\$185	
Cell Materials		\$9,482*	64.0%
Purchased Items		\$2,081*	14.1%
Manufacturing		\$2,266*	15.3%
Electrode Processing	660		4.5%
Cell Assembly	419		2.8%
Formation Cycling, Testing, Sealing	531		3.6%
Module and Battery Assembly	325		2.2%
Cell Materials Rejection/Recycle	33		0.2%
Receiving and Shipping	244		1.6%
Control Laboratory	54		0.4%
Pack Integration (BMS, ...)		\$945	6.4%
Thermal Management		\$40	0.3%



BatPaC

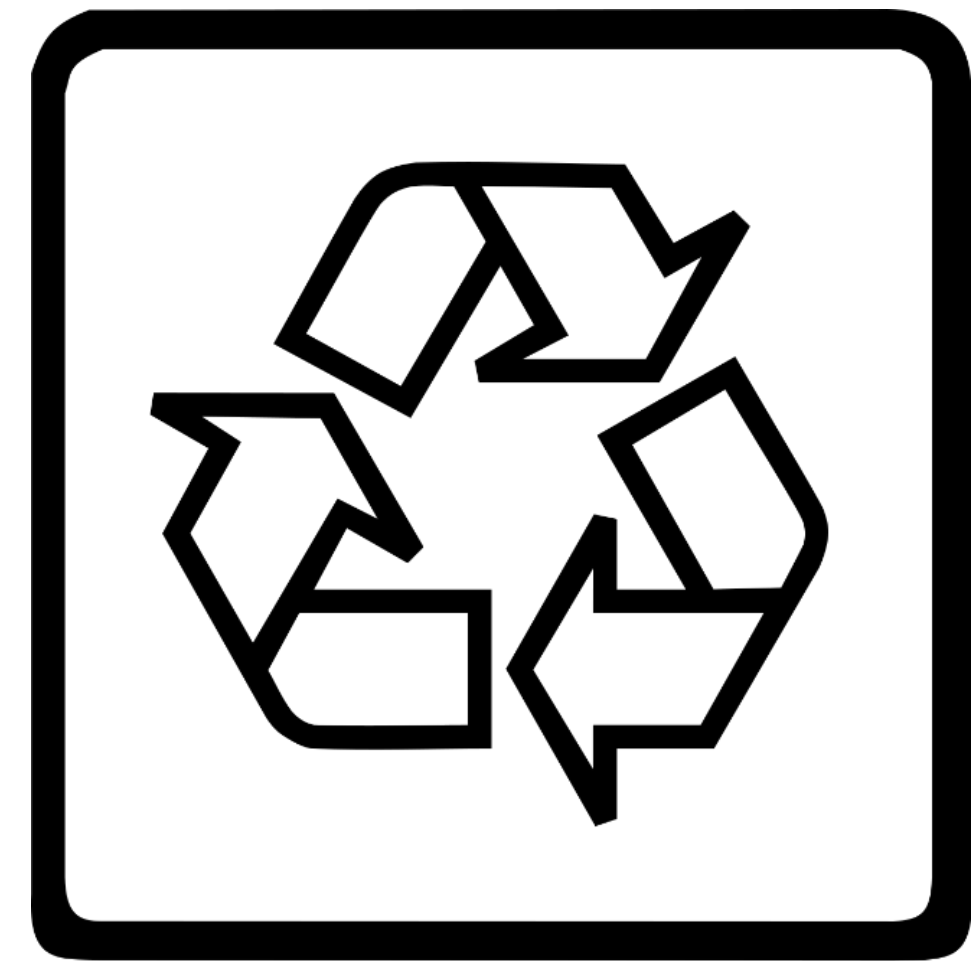


EverBatt

# EXAMPLES OF HOW WE CAN HELP YOU...

## What can we do for you?

- Make cells with recycled material
  - Act as a small city for testing a collection concept
  - Model your process using EverBatt or BatPaC
    - Cost
    - Environmental impact
    - Performance
  - High bay/laboratory space
  - Make, cycle, tear down pouch and cylindrical cells
  - Nearly any type of analytical capability
  - Incorporate machine learning and artificial intelligence
- 
- Argonne has scientists, engineers and analysts to help tackle any challenge and we want to help you
  - Ask me how we can help on your project!



# Li-ion





THANK YOU!



**JEFF SPANGENBERGER**  
Material Recycling R&D Group Lead

[jspangenberg@anl.gov](mailto:jspangenberg@anl.gov)  
630-252-5543

# National Renewable Energy Laboratory

## Lab Capabilities

Matthew Keyser

Vehicle Electrification Group  
National Renewable Energy Laboratory, Golden CO





# NREL Activities under ReCell

## ReCell Activities

### Binder Removal

- Soxhlet Extraction

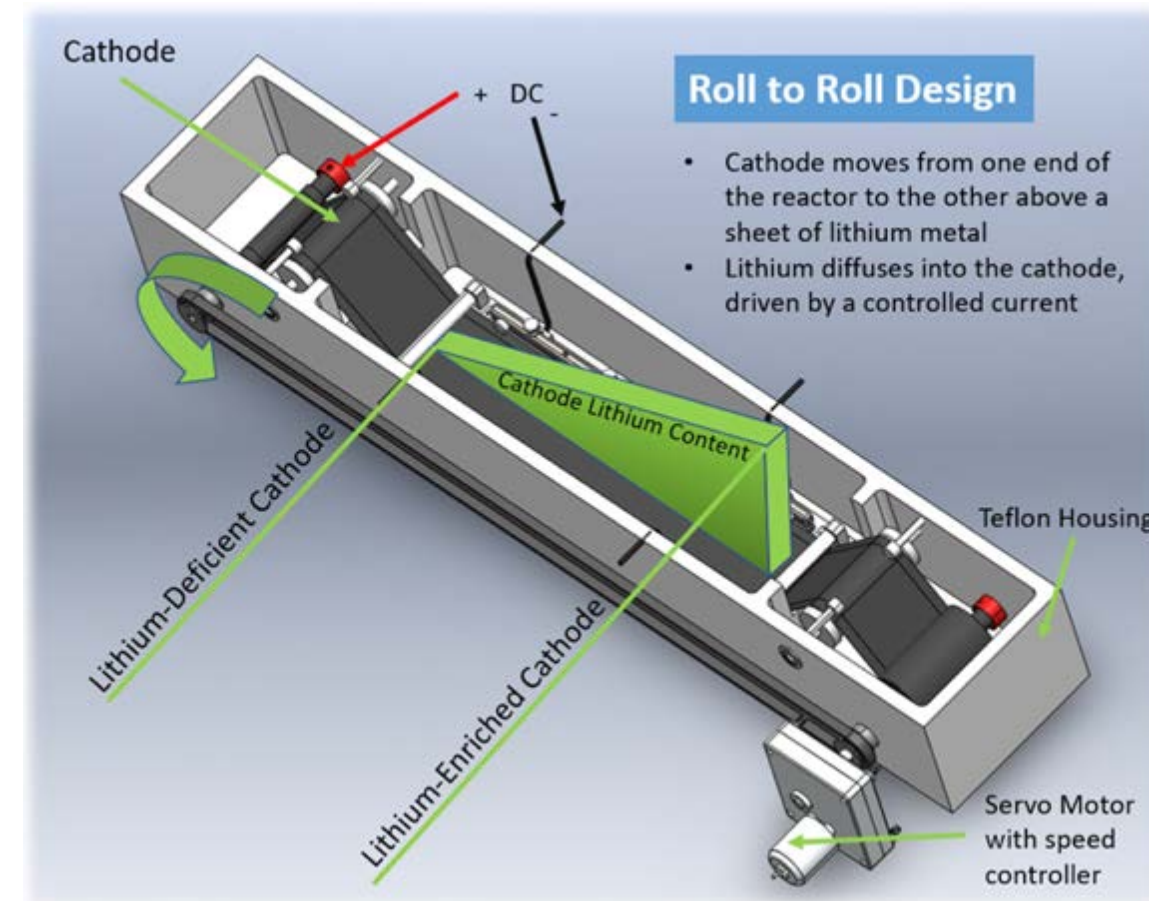
### Relithiation

- Electrochemical
- Redox Mediators

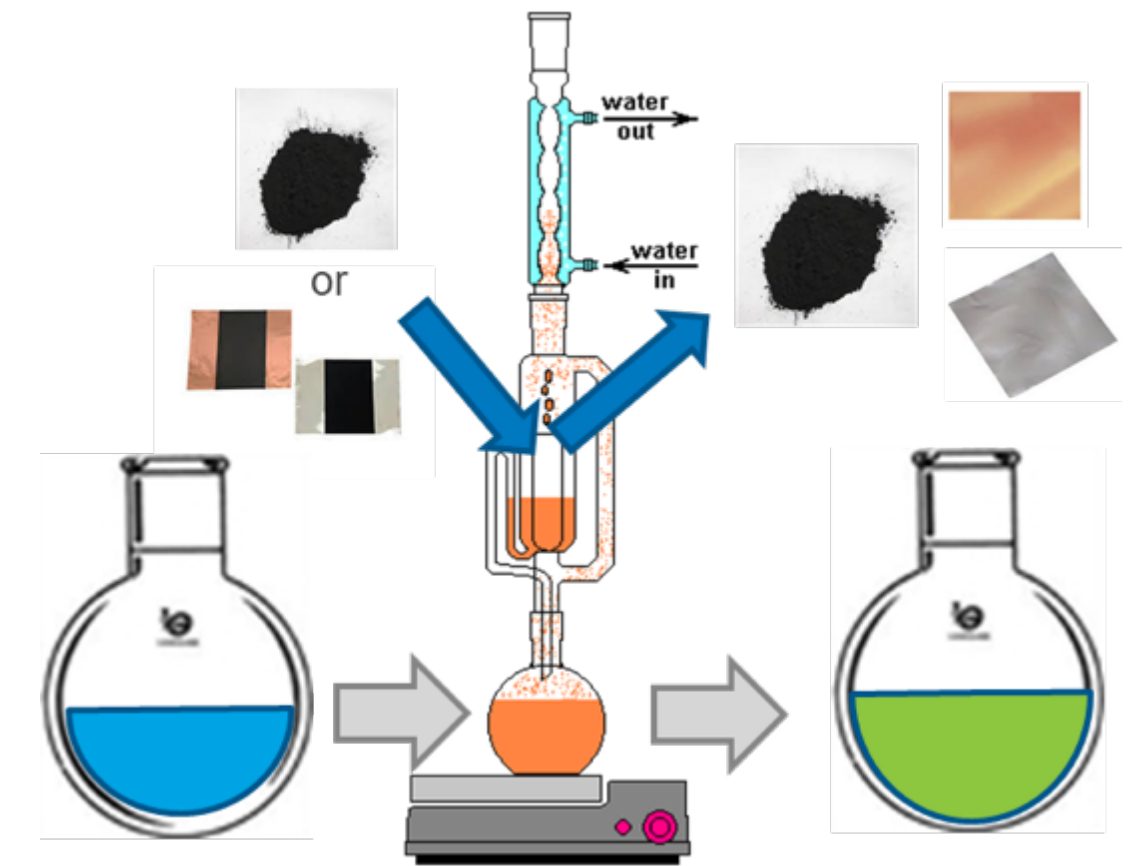
### Diagnostics

- Microcalorimetry
- EBSD – Electron back scatter diffraction

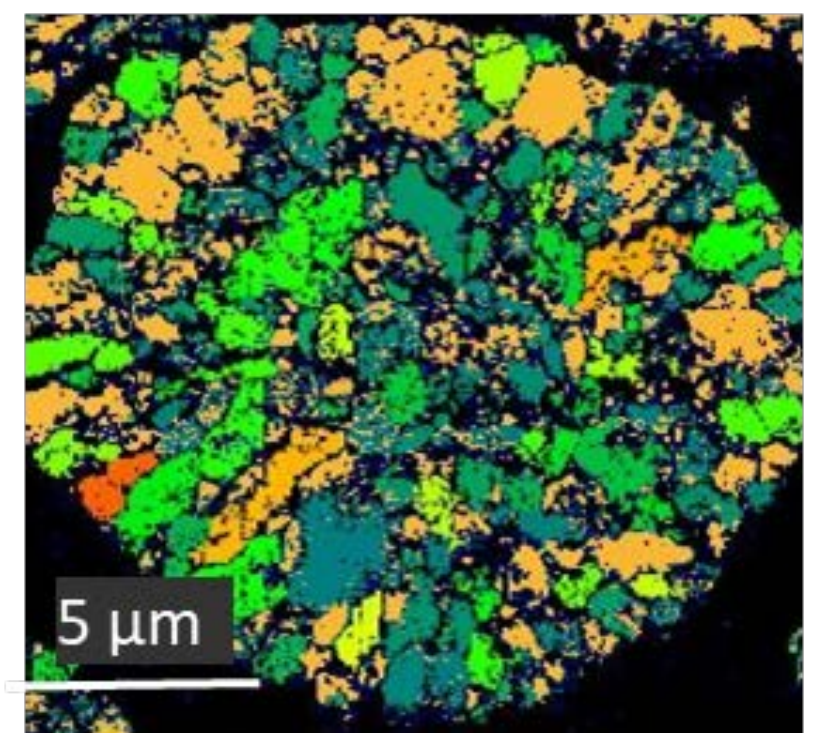
## Electrochemical Relithiation



## Soxhlet Extraction

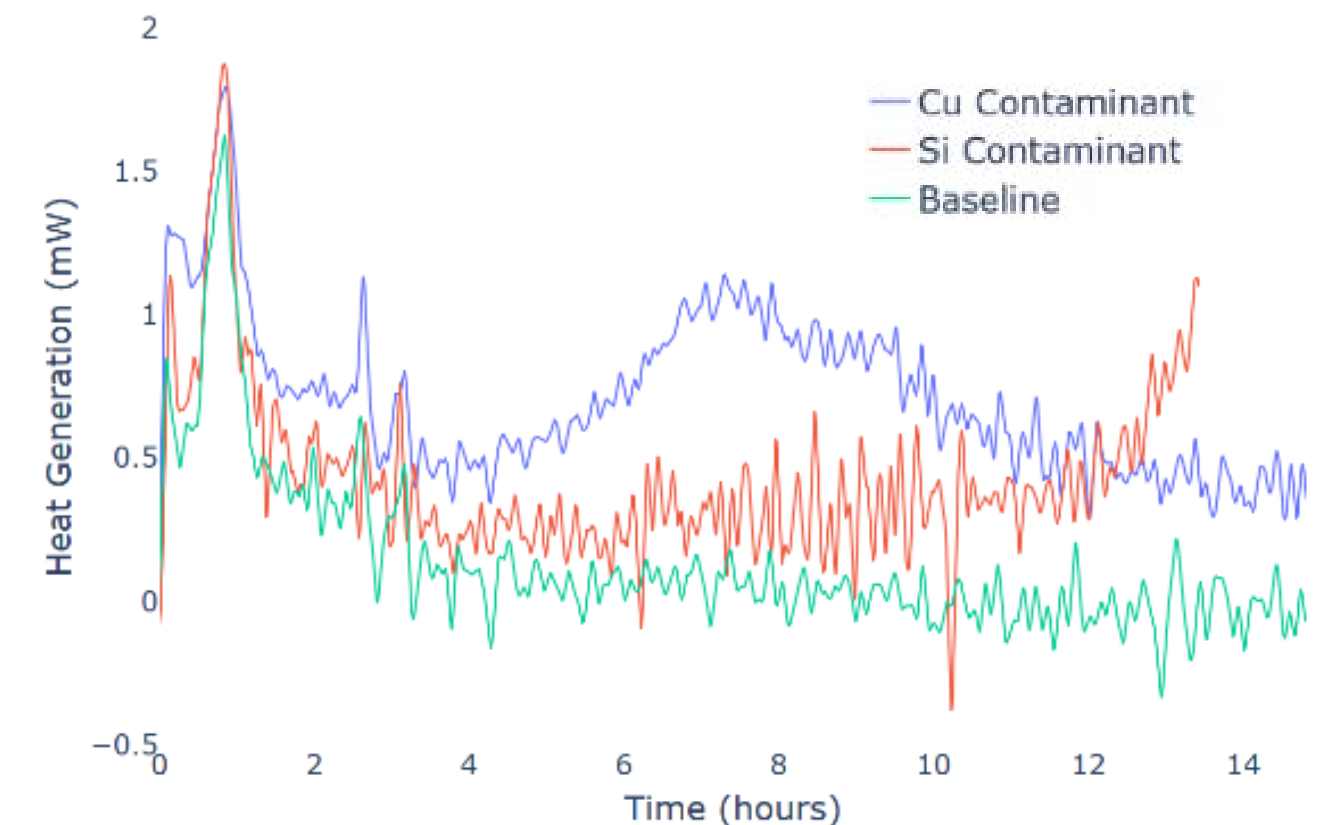


## EBSD – Identify Cracking



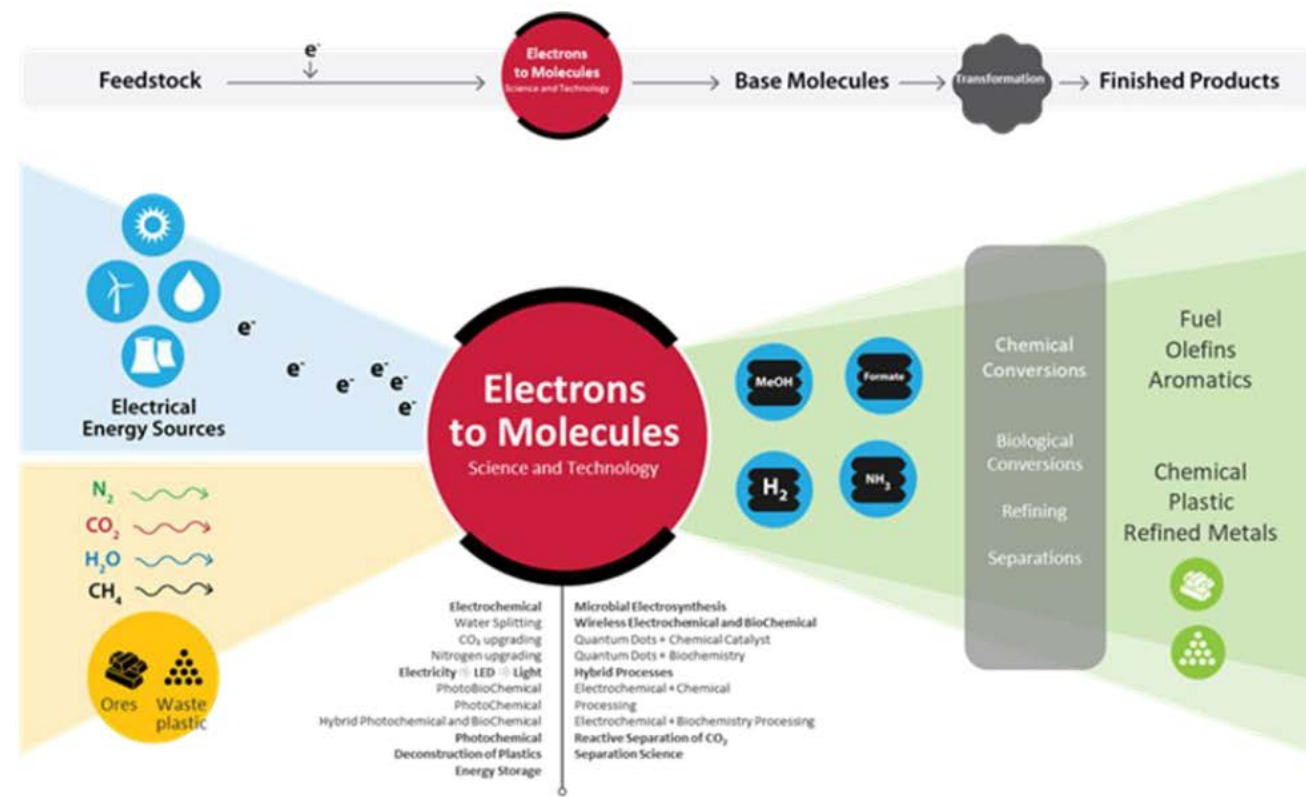
40% Capacity Loss

## Microcalorimetry – Identify Contaminants

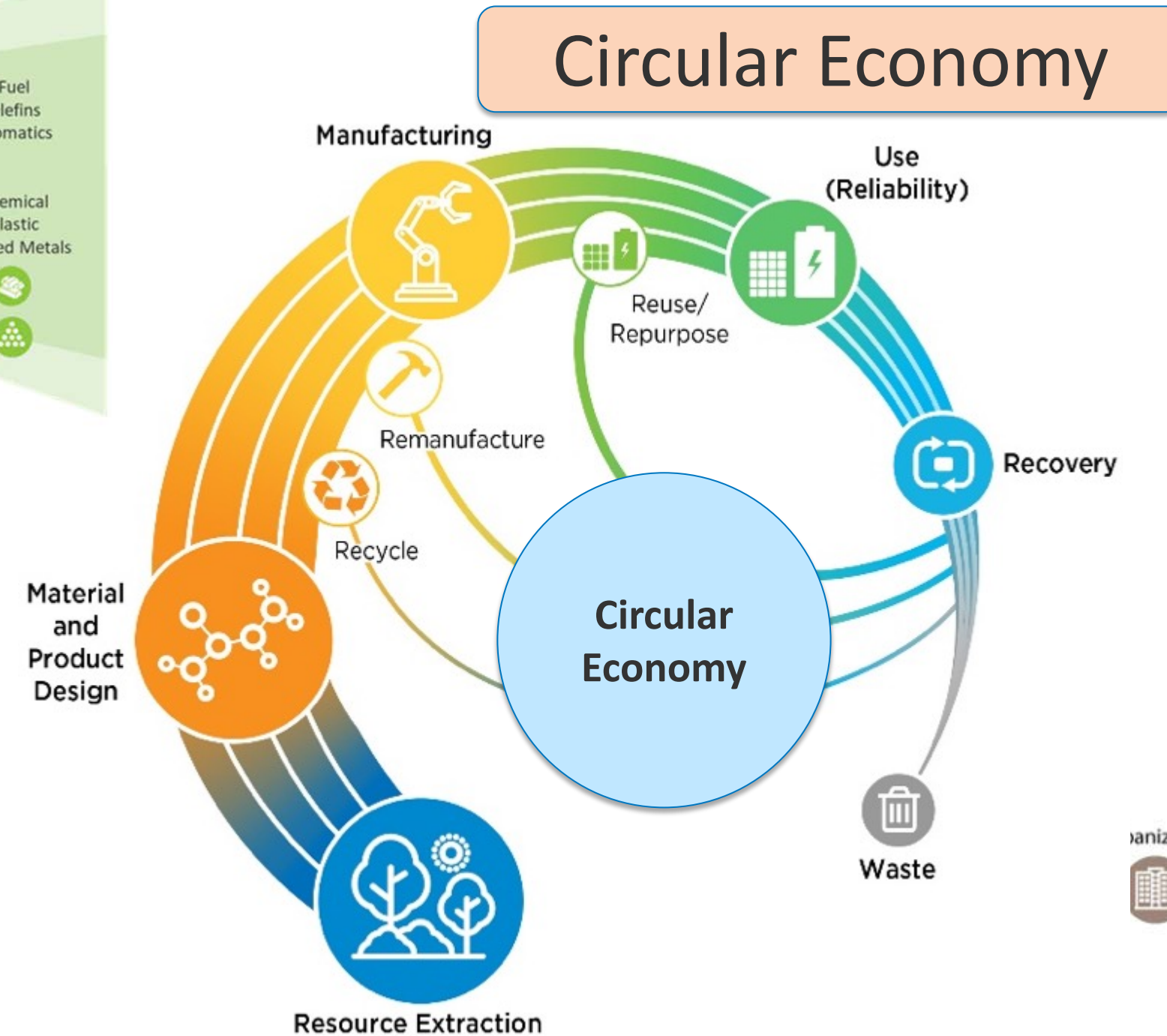




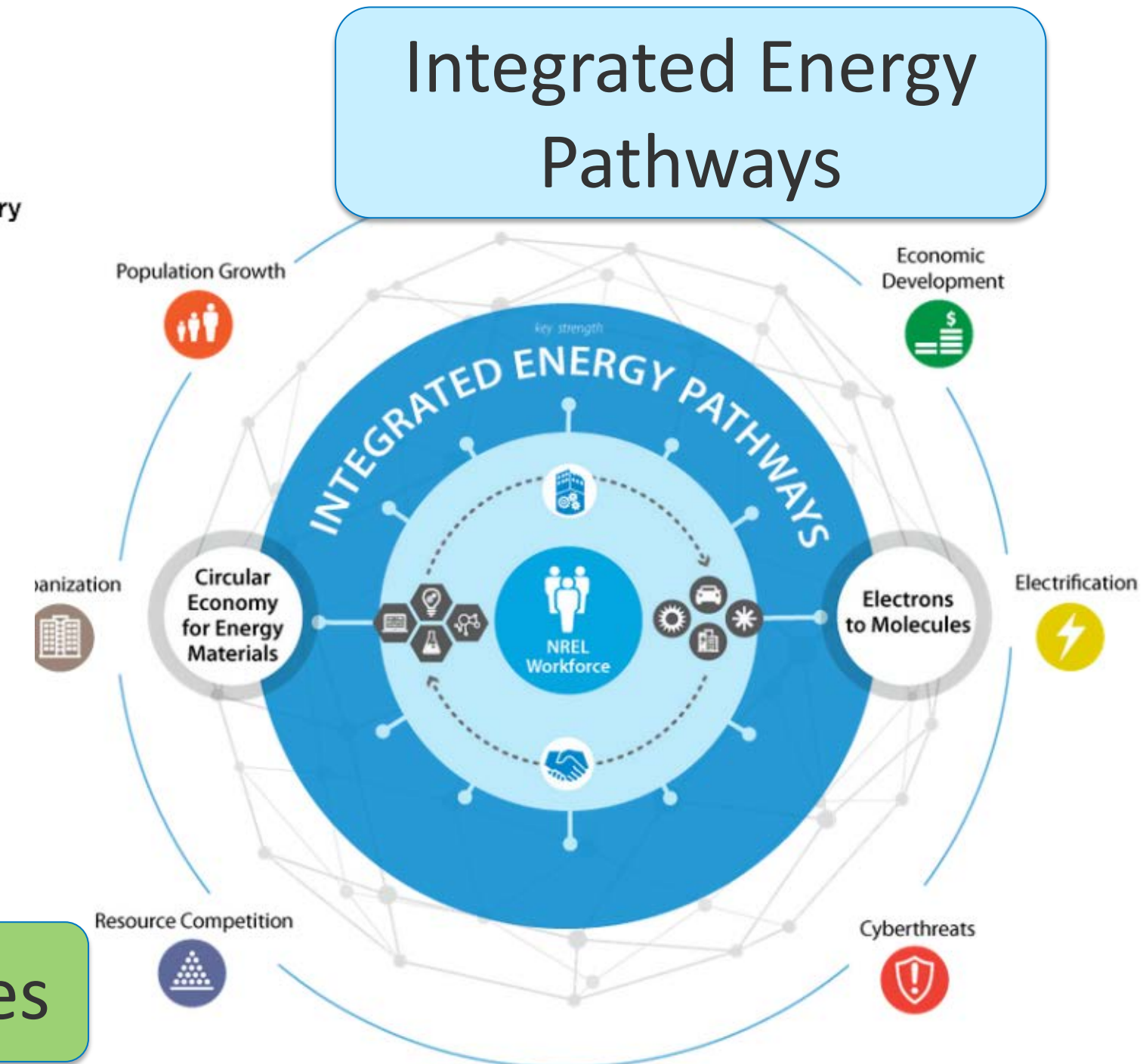
# NREL Critical Objectives



Electrons to  
Molecules



Circular Economy



Integrated Energy  
Pathways

Batteries are the front and center of NREL's Critical Objectives



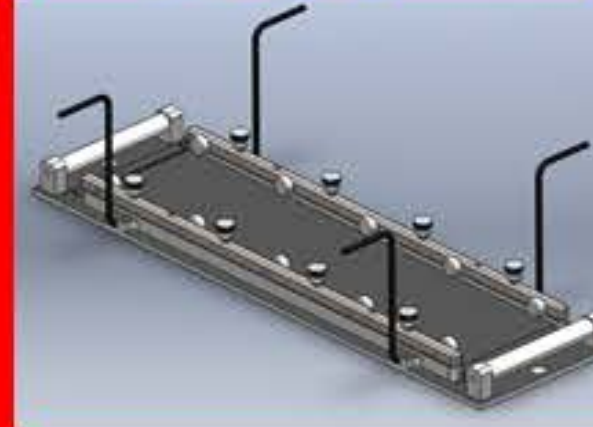
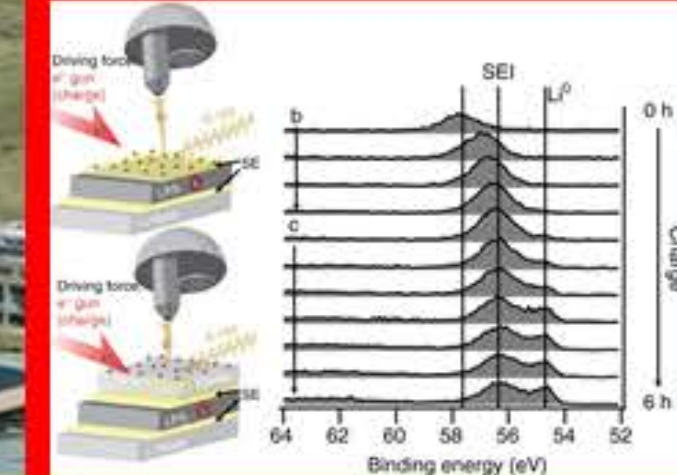
kWh

MWh – GWh

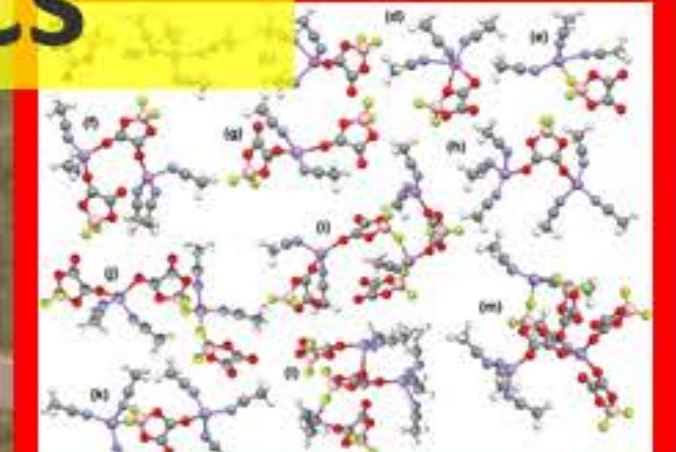
Recycling, 2<sup>nd</sup> Use



$\mu$ Wh – mWh



Diagnostics



Modeling & Analysis

Battery Projects at NREL

Wh





# NREL Test Capabilities

Environmental  
Testing

Calorimeters

Thermal Conductivity

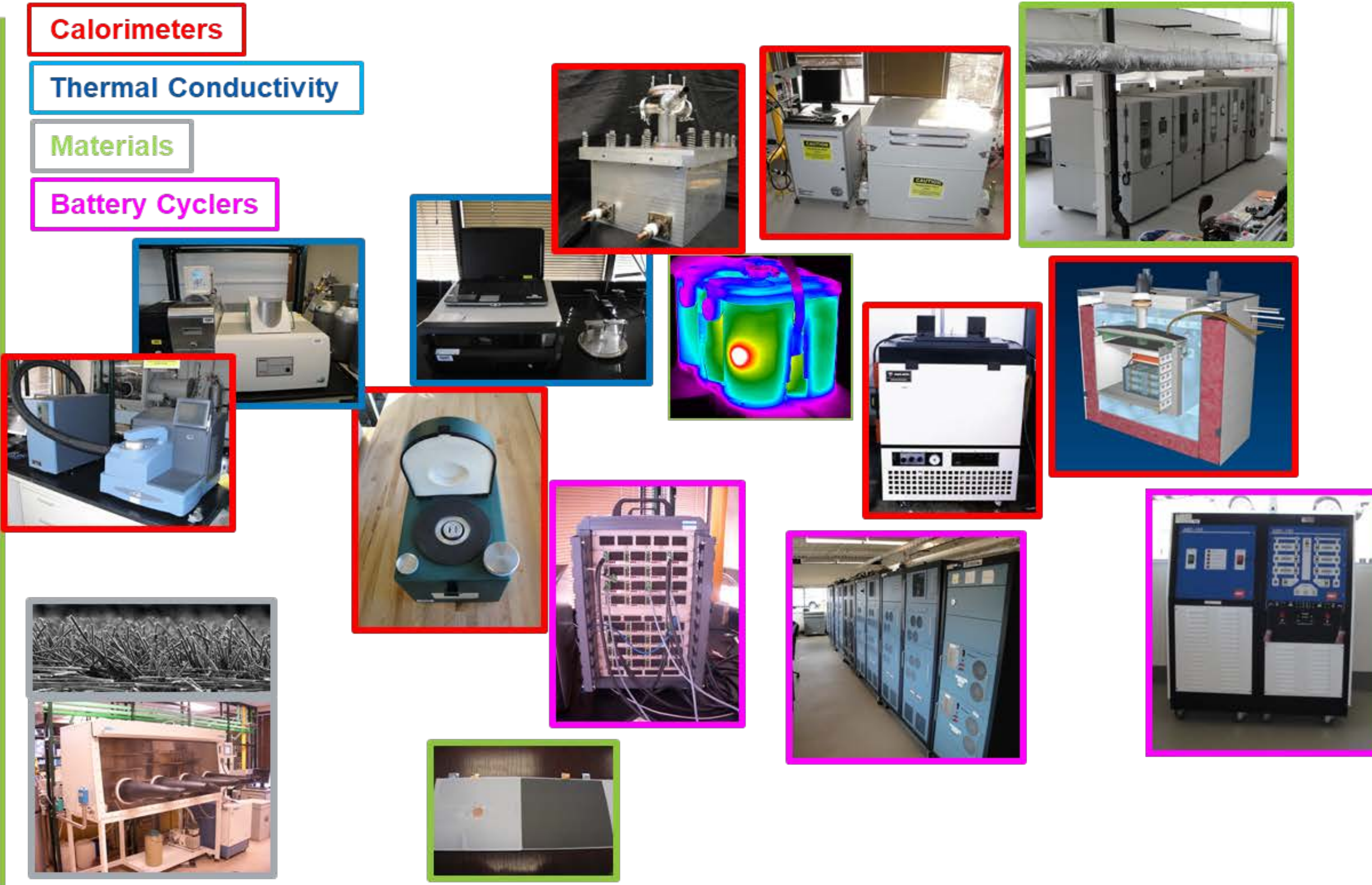
Materials

Battery Cyclers

Thermal  
Testing

Electrical  
Testing

Fabrication



Materials

Cells

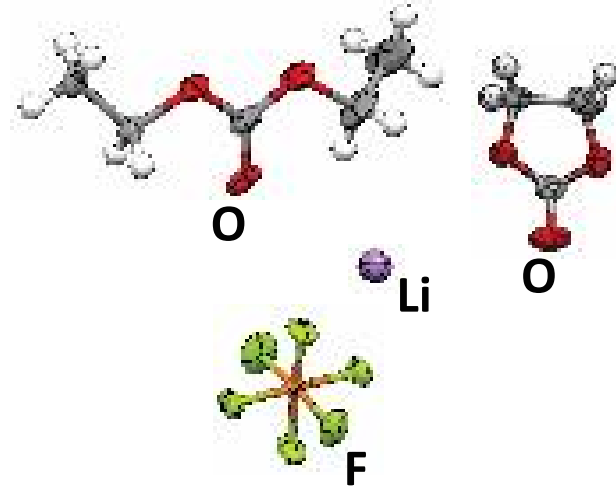
Modules

Packs



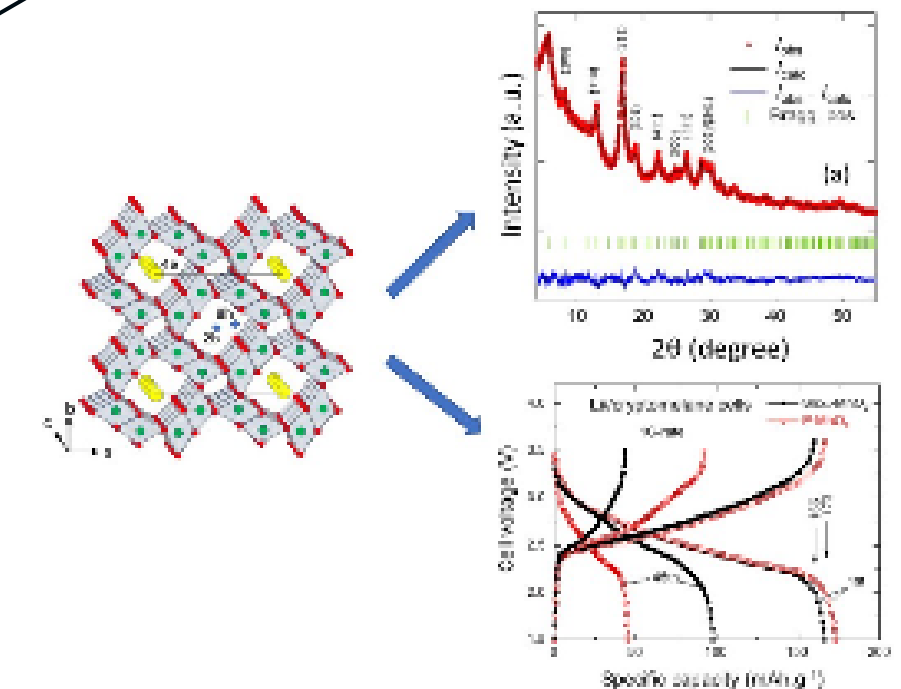
# Battery Materials Capabilities

## Advanced Electrolyte Research



Molecular-level electrolyte structure/interactions and properties analysis

## Materials Research

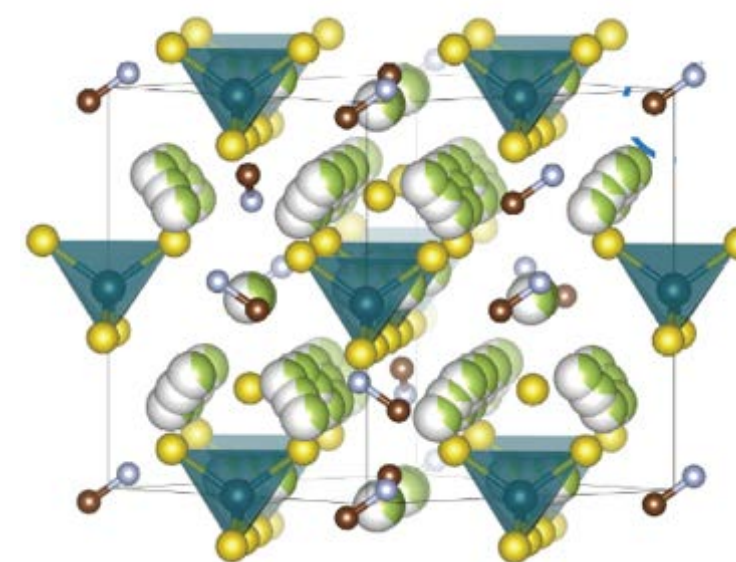
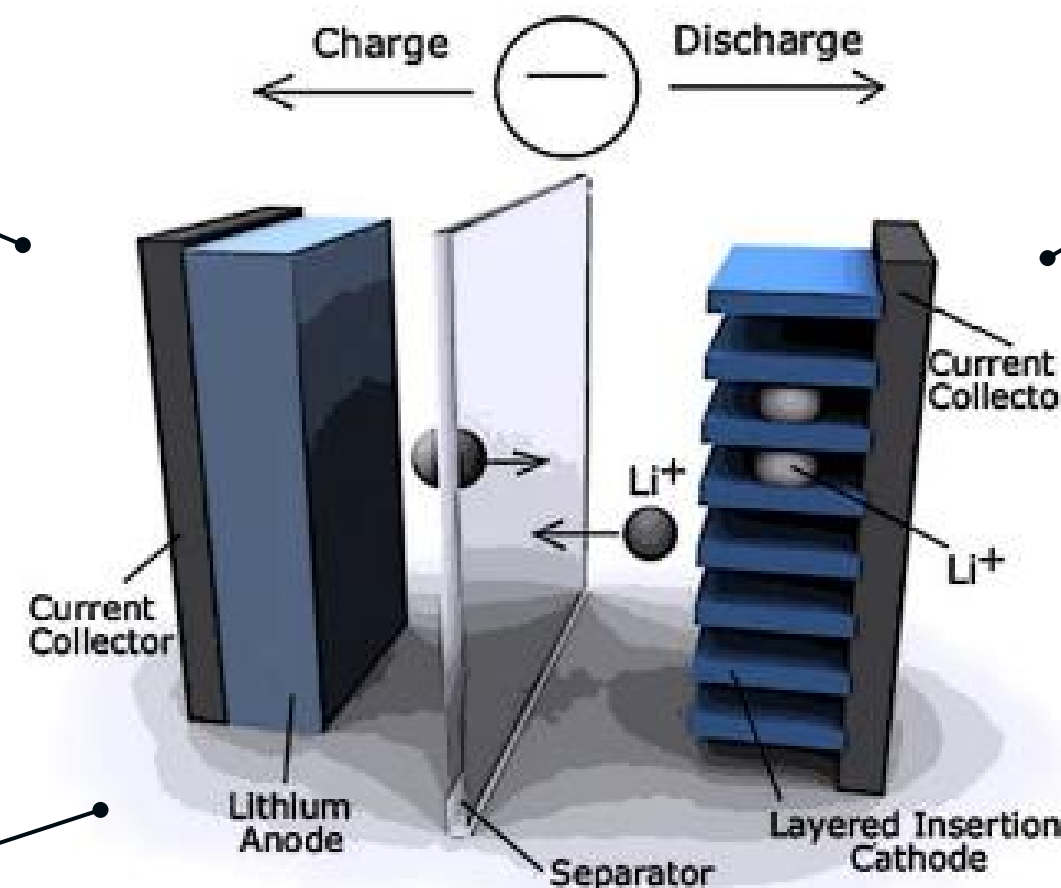


Synthesis and electrochemical characterization of advanced battery materials for a number of energy storage application

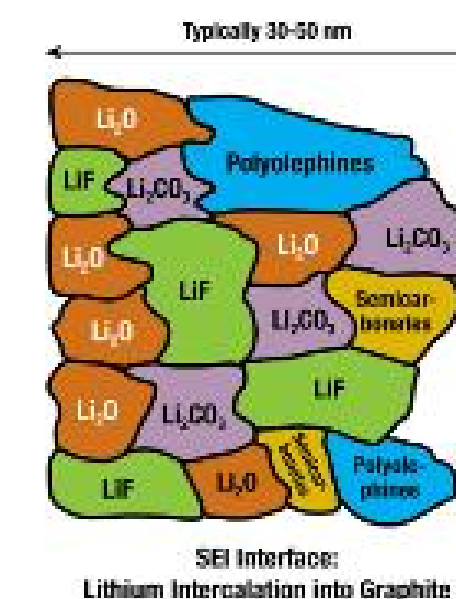
## Electrochemical Analysis and Diagnostics



Battery testing for performance and life evaluations, and post-test analysis for physical and chemical changes identification in aged batteries



## Solid-state Synthesis



## Interfacial Materials Chemistry

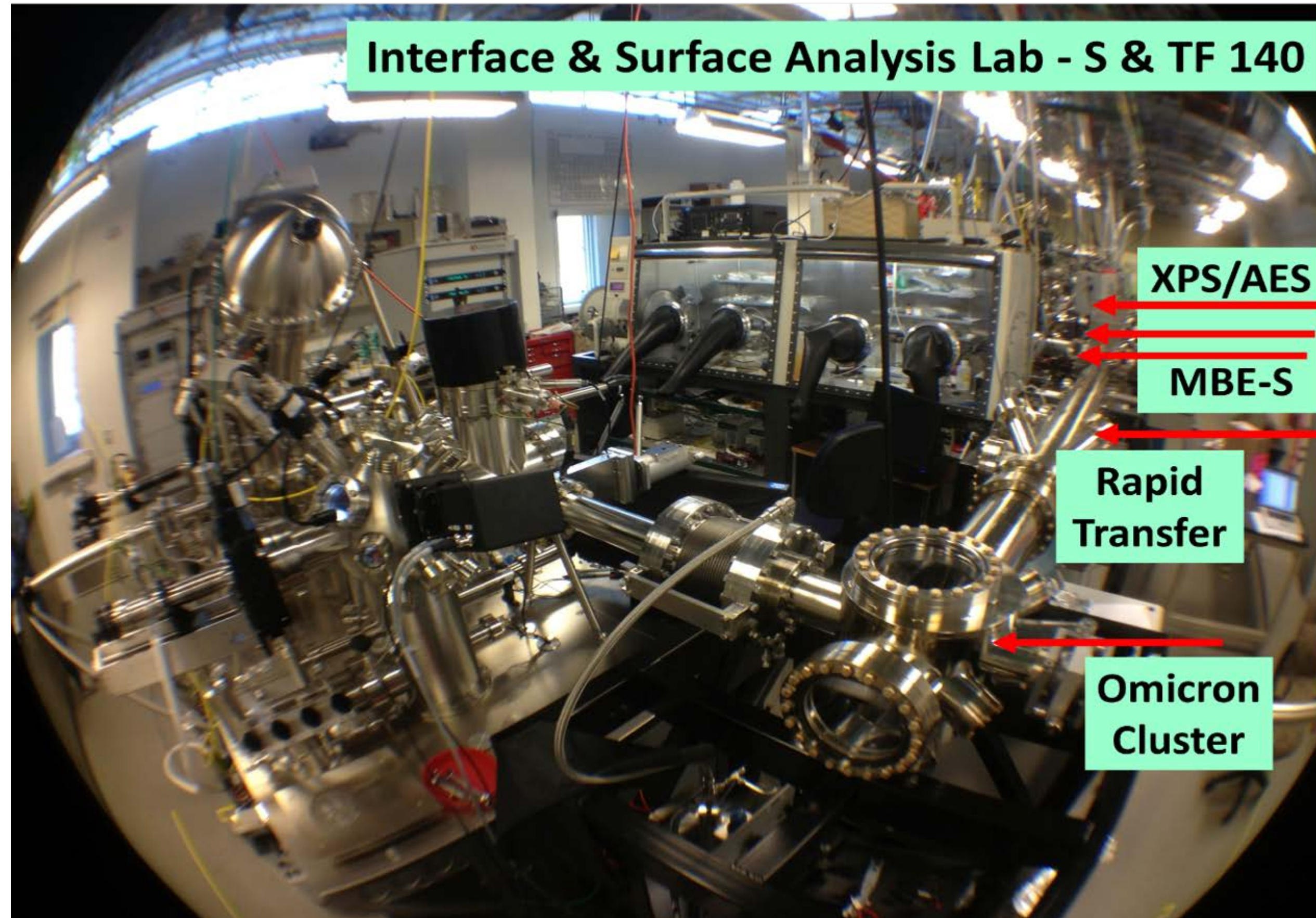
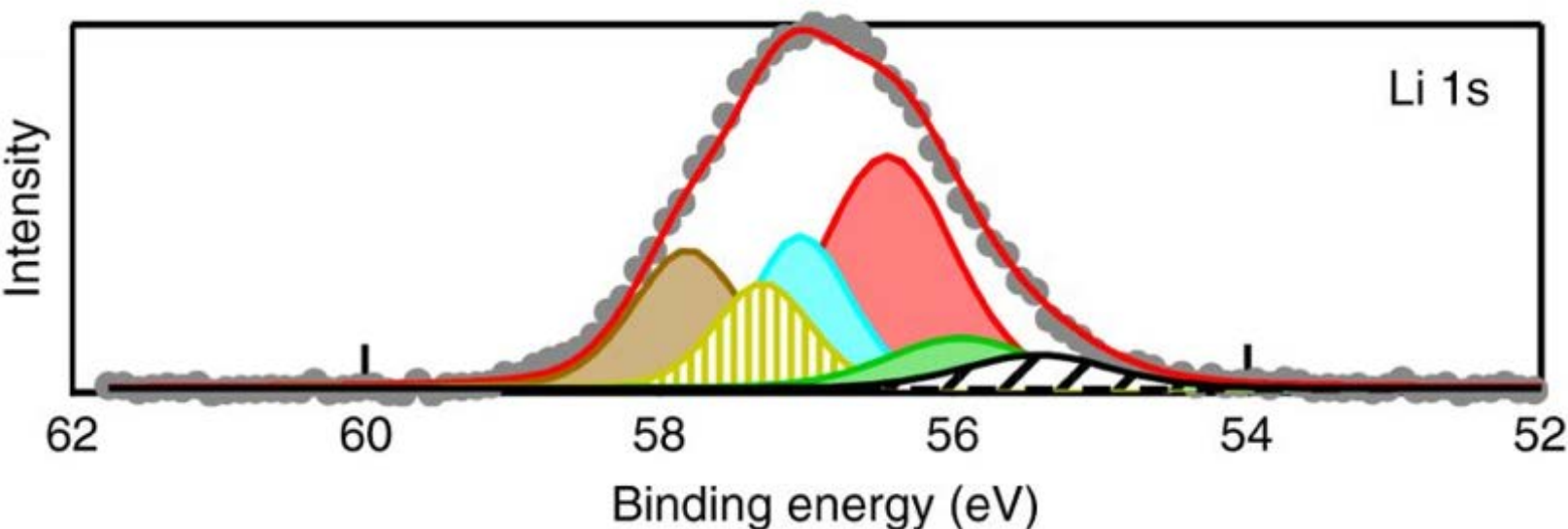
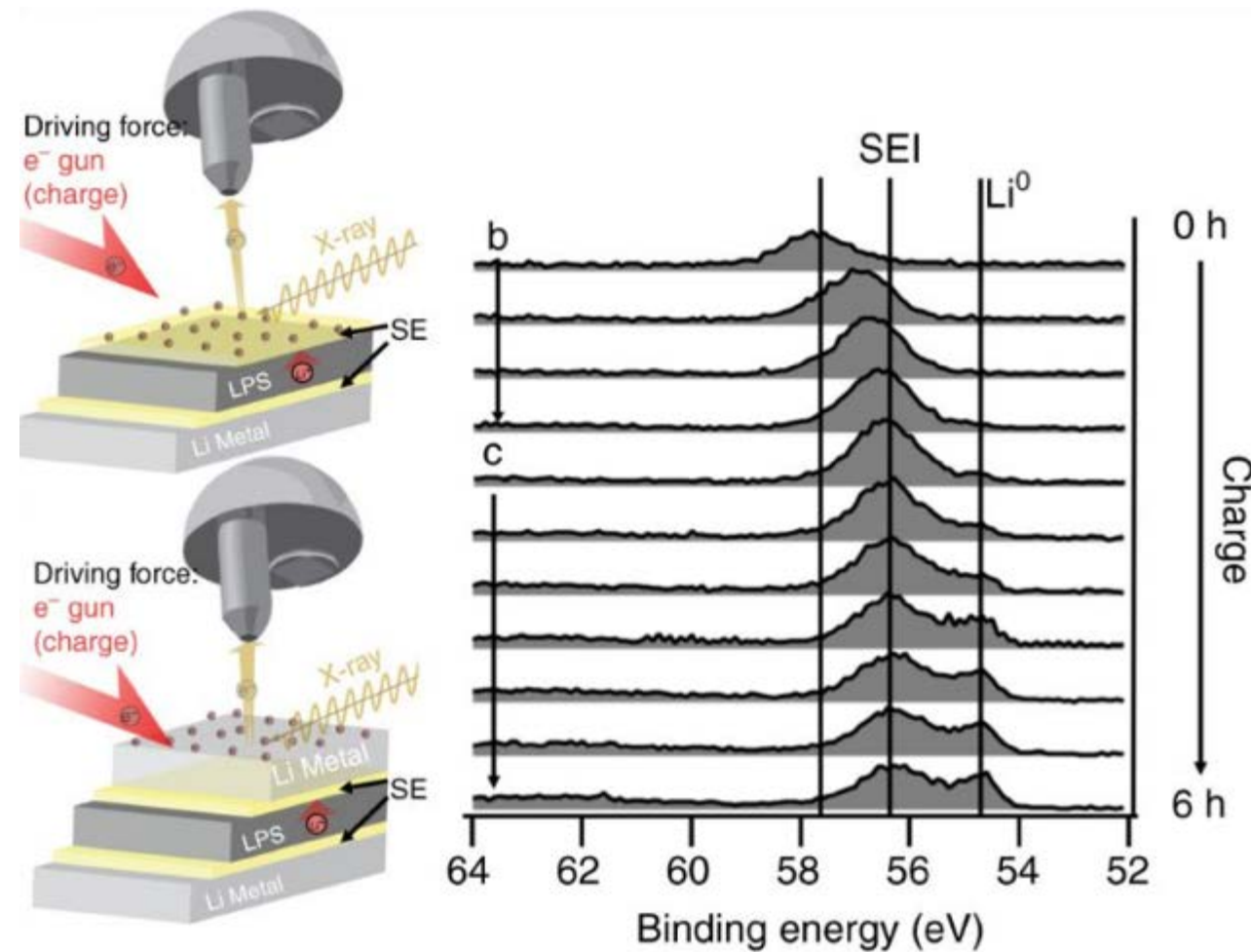
Structure and transport properties analysis of materials at the interface between electroactive materials and either a liquid or solid electrolyte.



- Focused ion beam (FIB)
- Microscopy (SEM, TEM, AFM)
- Time-of-Flight Secondary Ion Mass Spec (TOF-SIMS)

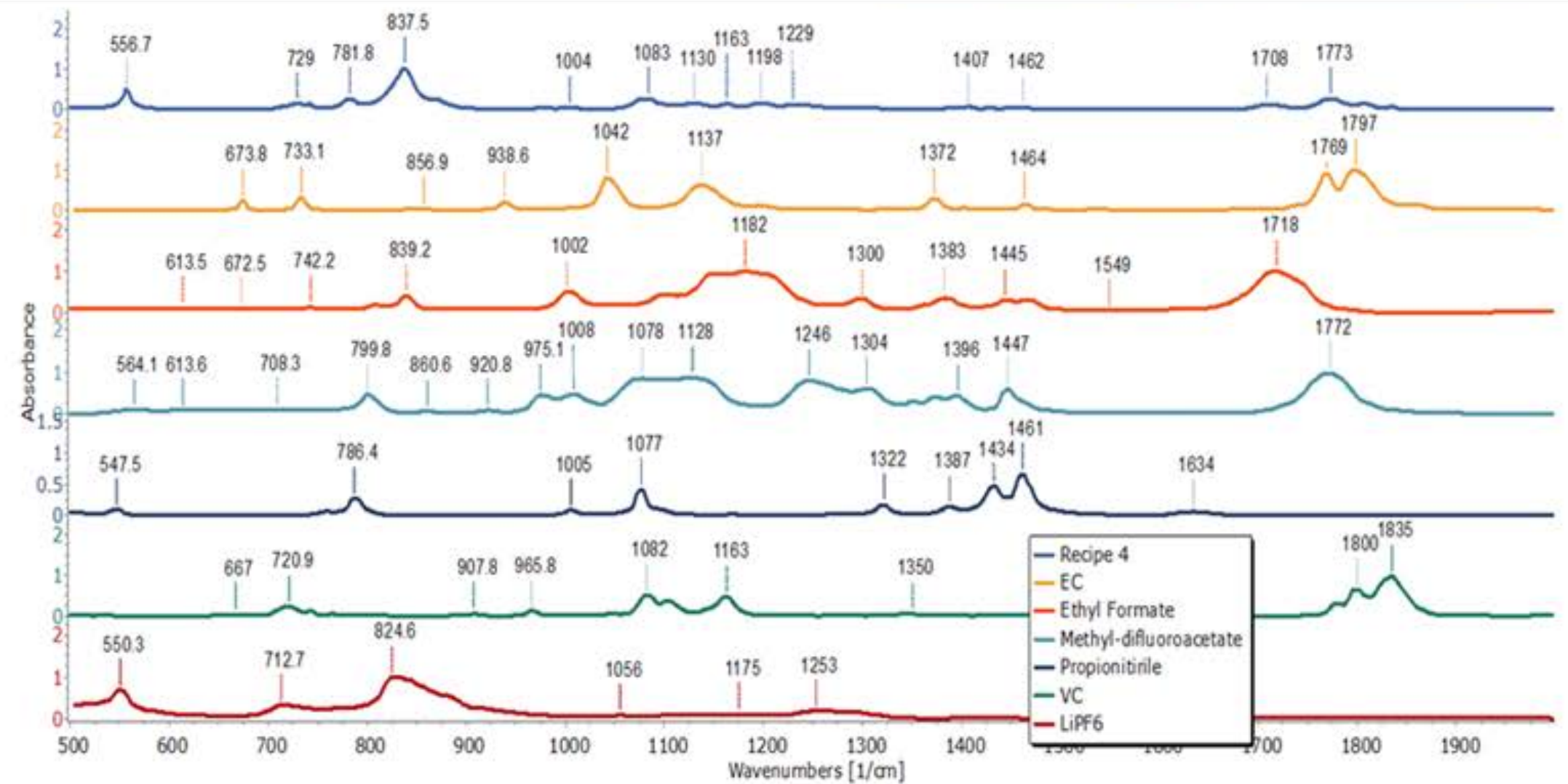
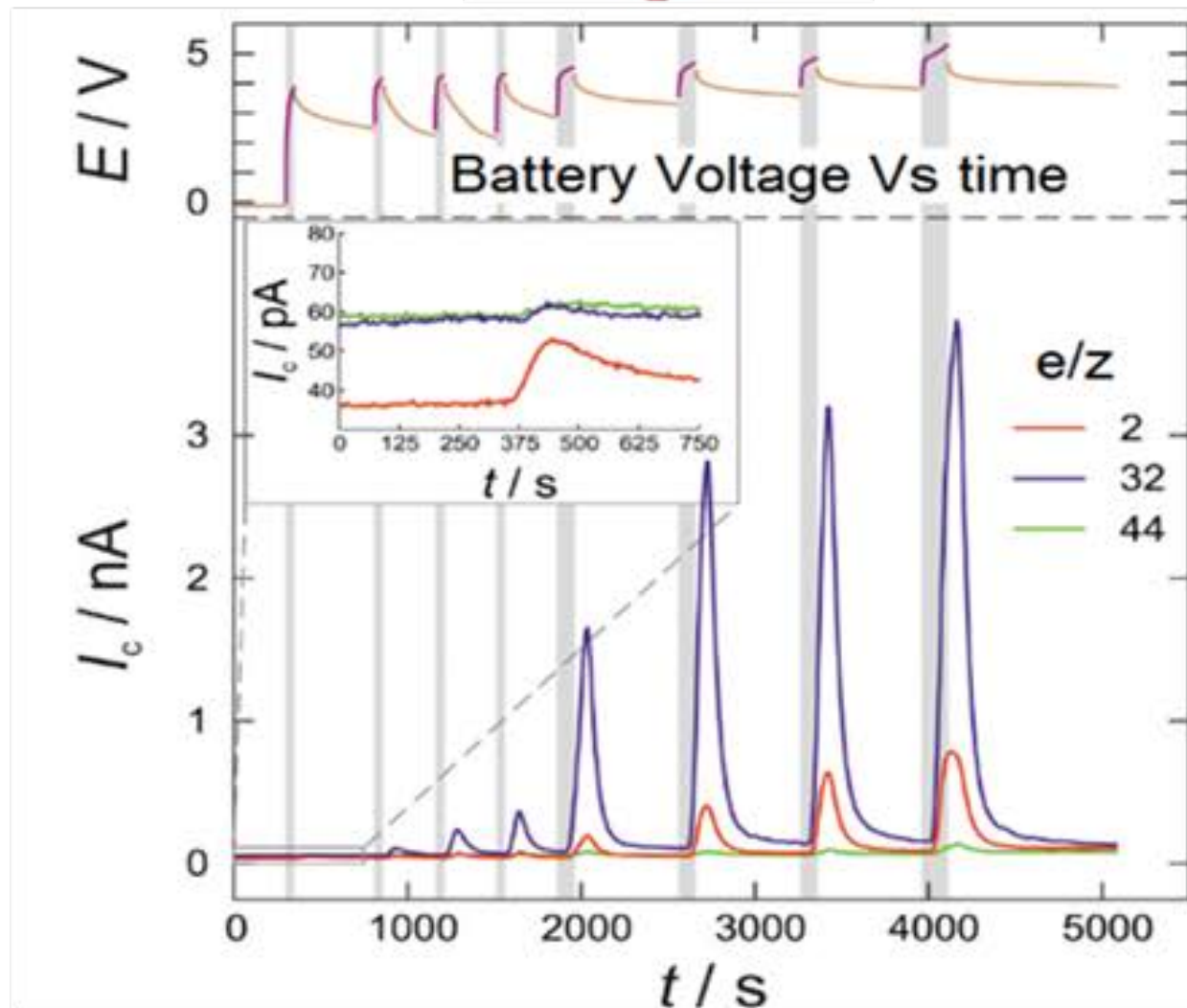
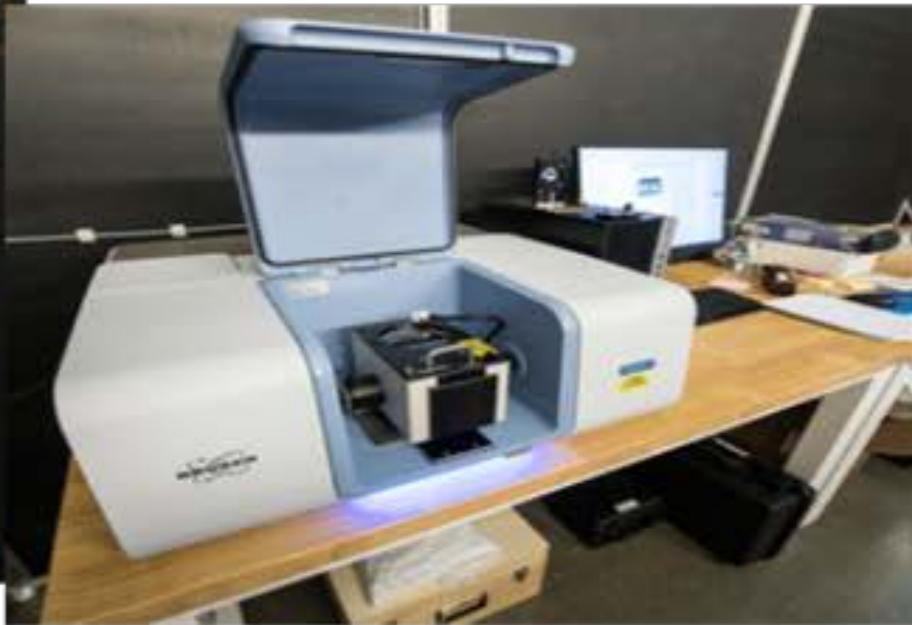
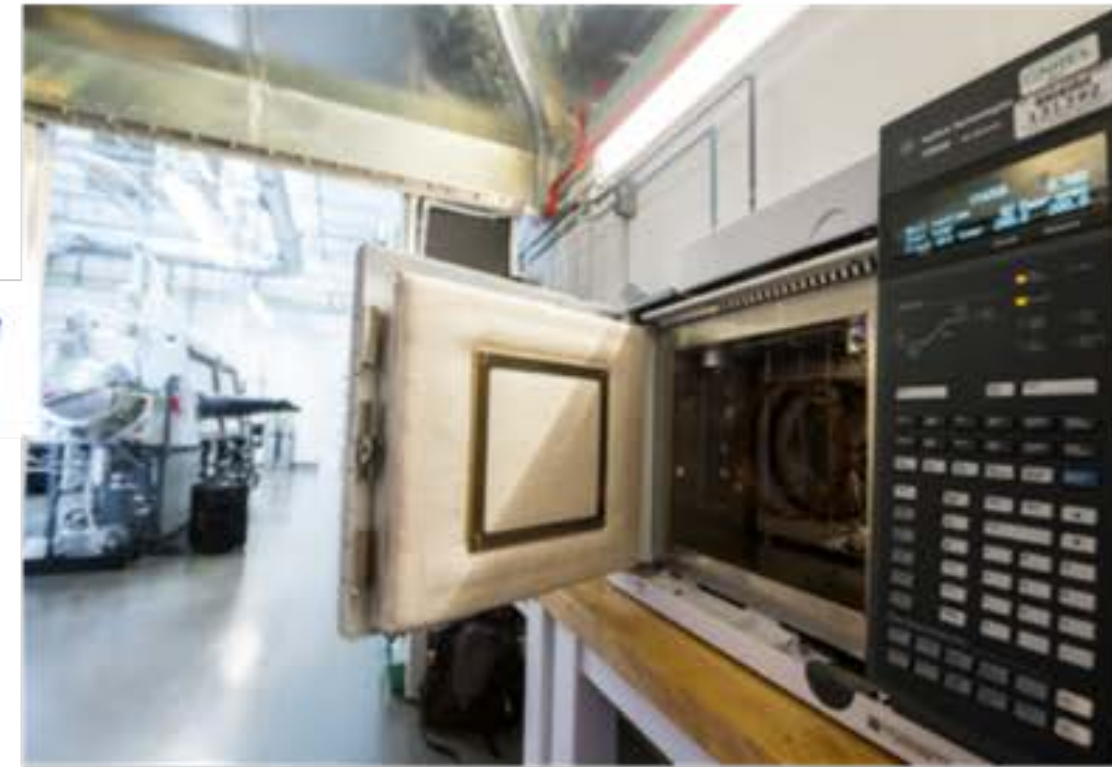
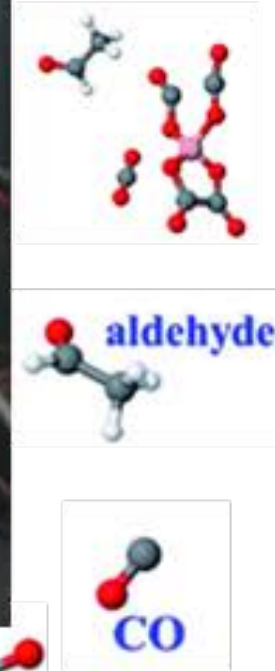
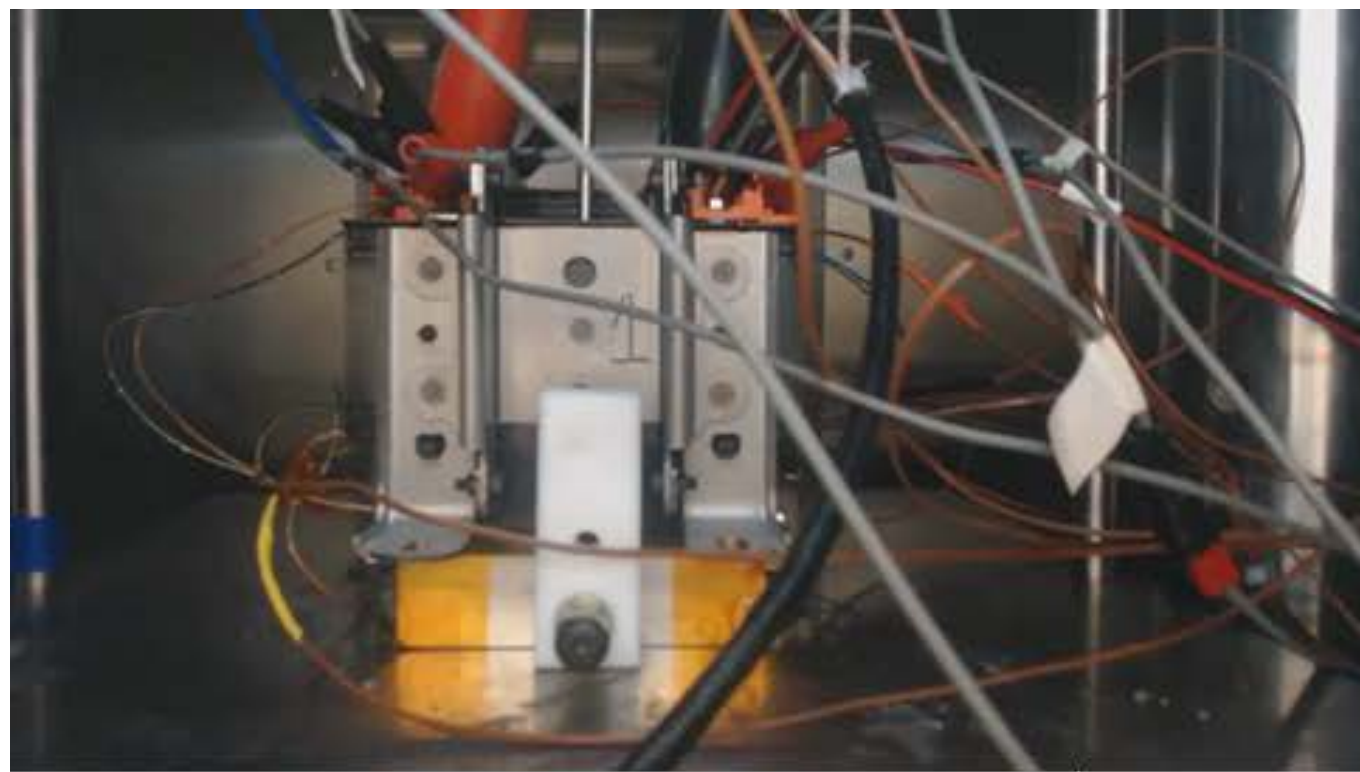
# Materials Characterization

## Interface & Surface Analysis Lab - S & TF 140



*Turn-key probes for interphase studies coupled with a surface-analysis cluster tool*





In-line effluent gas analysis using GC-MS

Liquid electrolyte degradation analysis at extreme voltages and temperatures using FTIR, Raman



# Battery Calorimetry

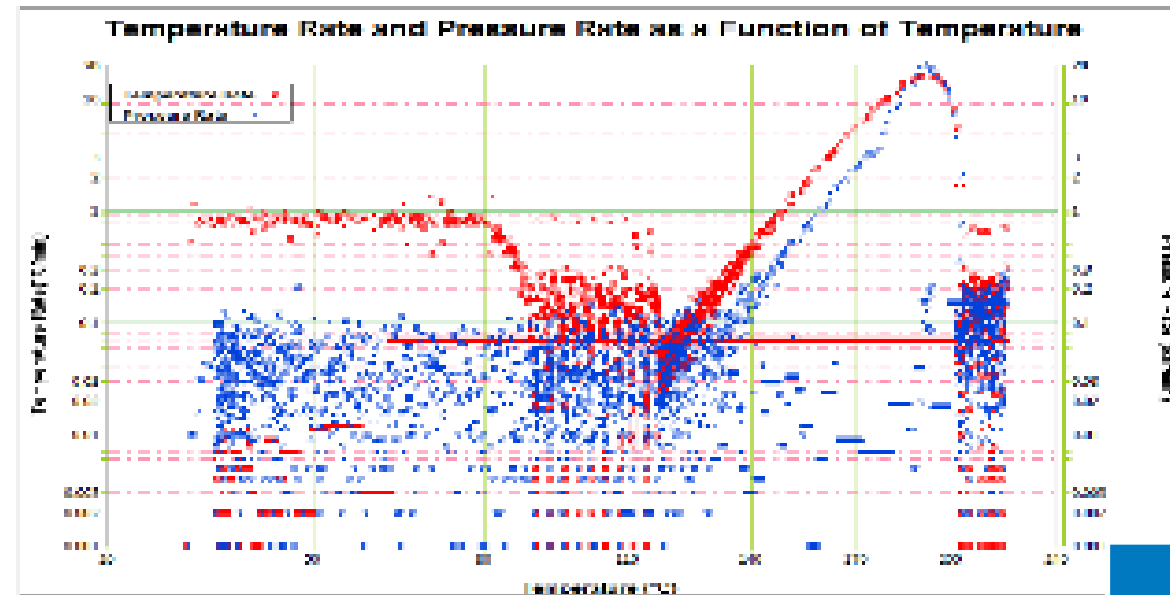


Extended Volume Accelerating Rate Calorimeter for Vehicle Battery Cells and Modules

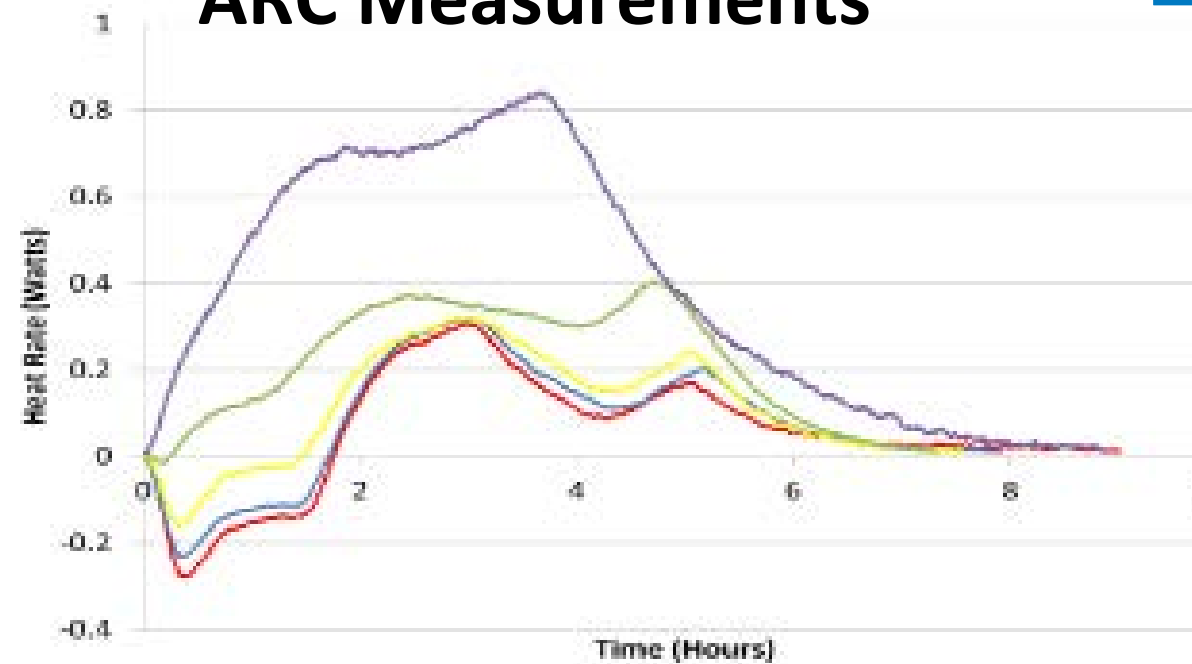
Regress Abuse Reaction Parameters

*C. Yang et al., Presented at the 225th ECS Meeting, Orlando FL, 2014*

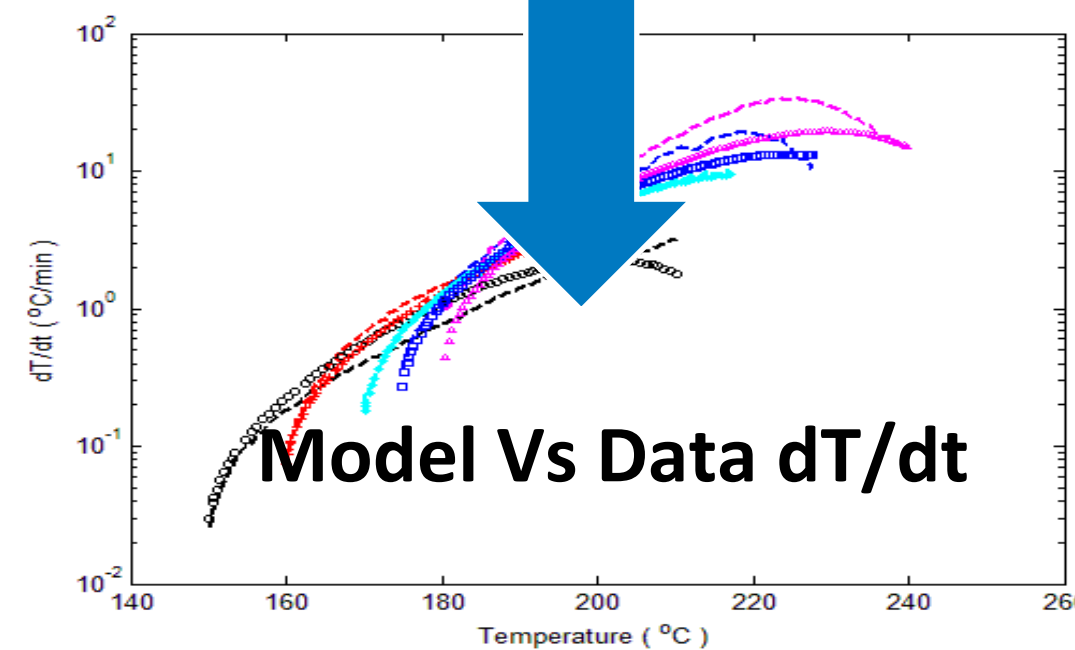
This information is used to predict multi-cell results and compared against experimental results



ARC Measurements

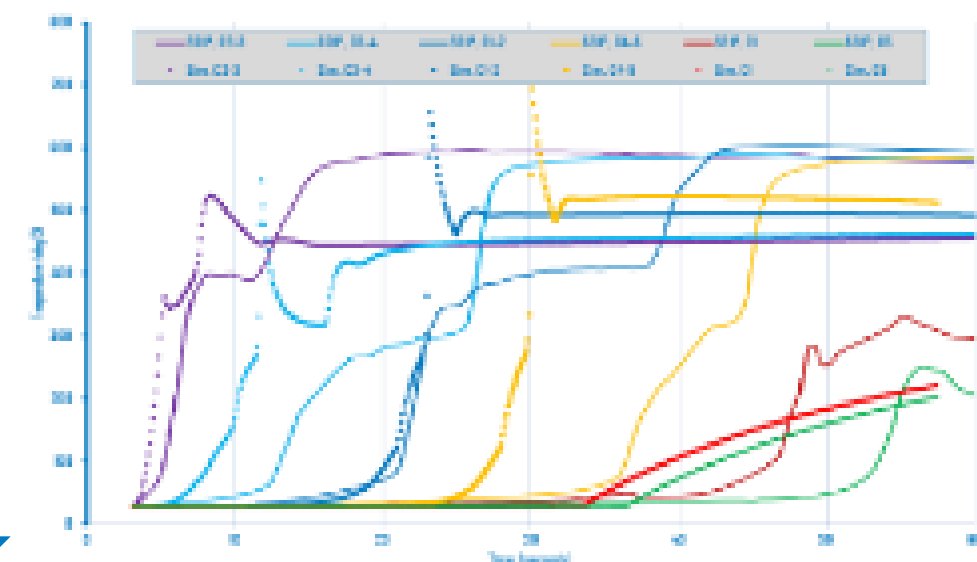


Isothermal Calorimetry

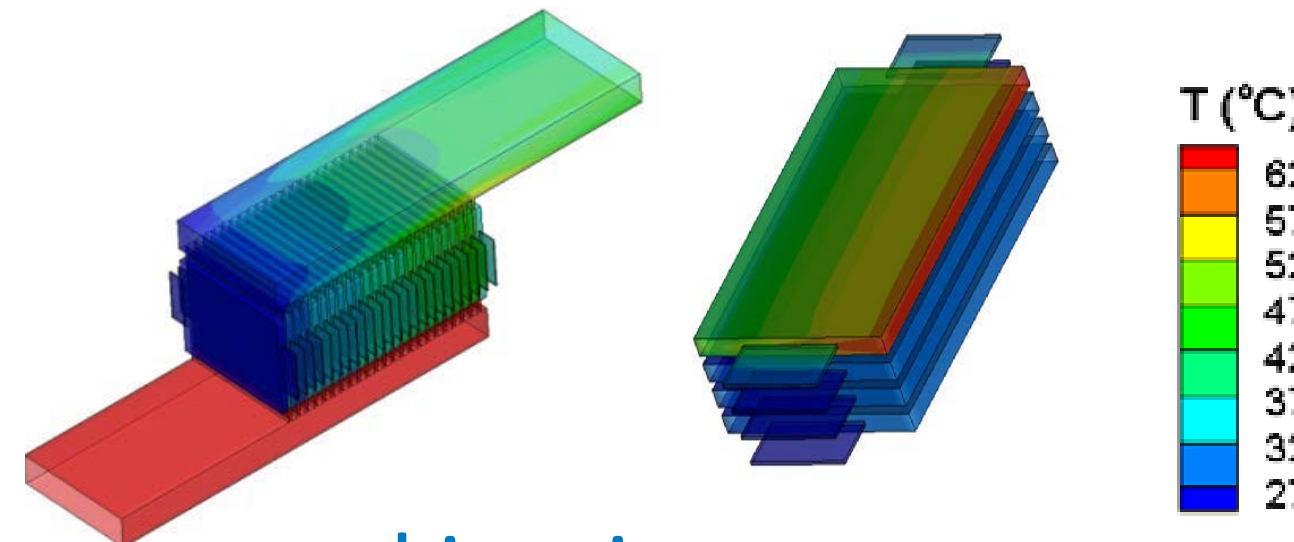


Model Vs Data dT/dt

Feed to Multi-Cell Models as Input



Propagation of Temperature Short Circuit in a Module: Model Vs Data



Data used to regress kinetic parameters for abuse reactions



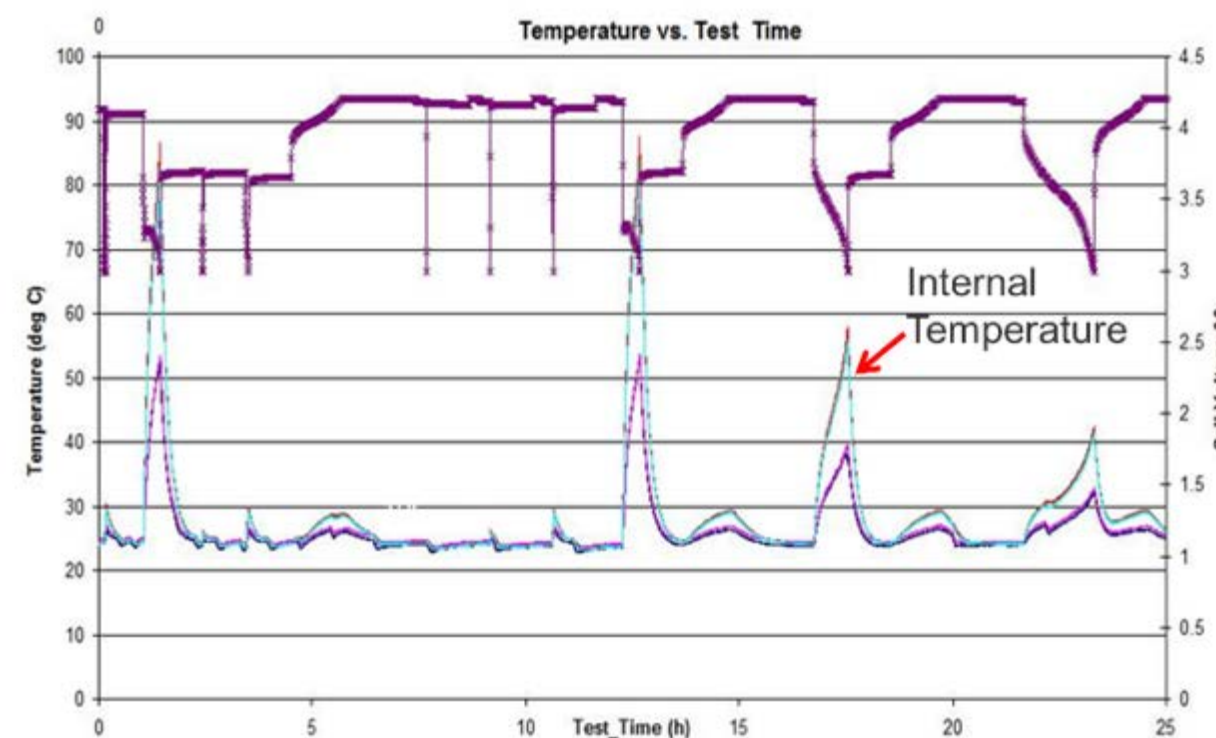
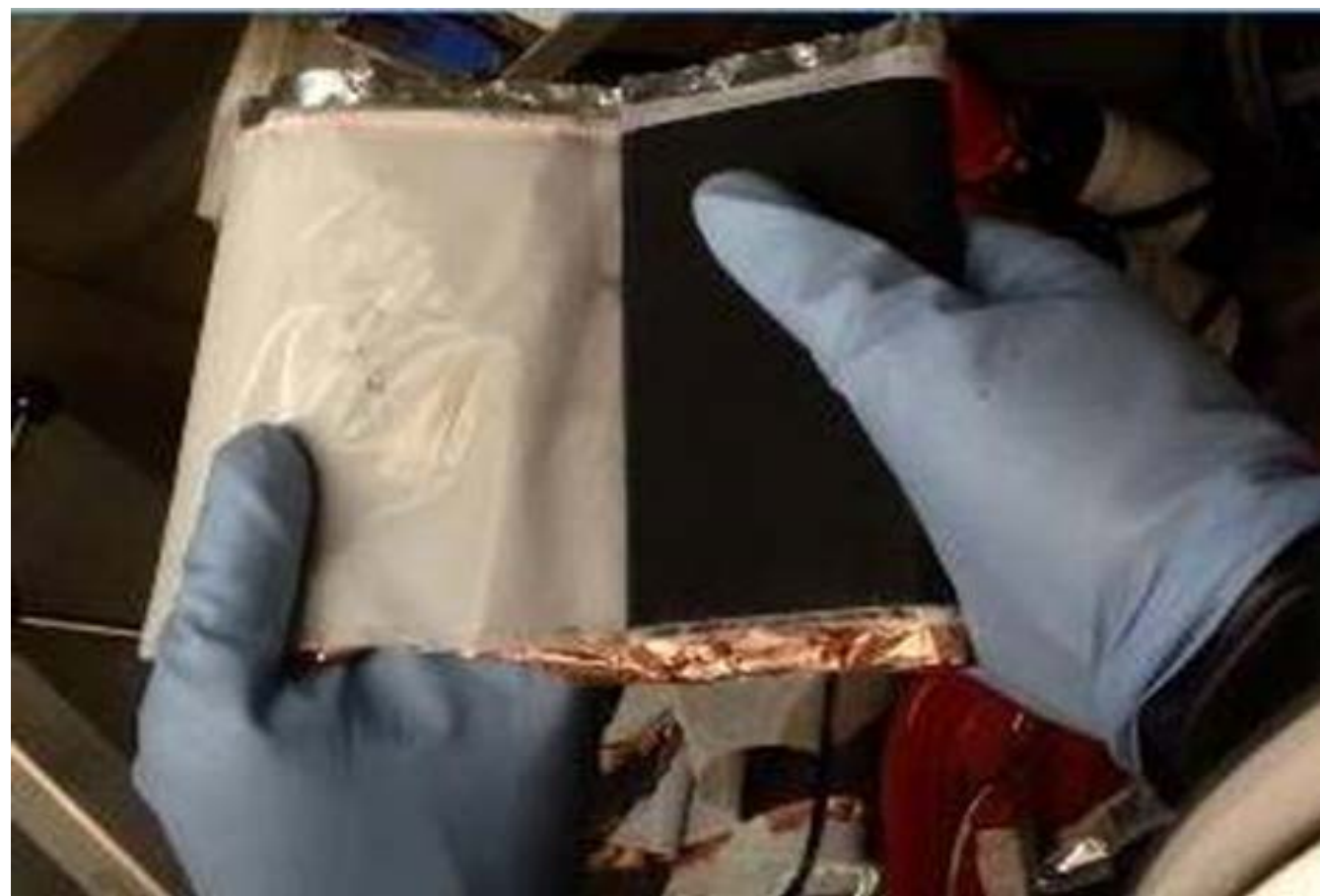
# Cell Fab, Analysis and Breakdown



**Coating Line**



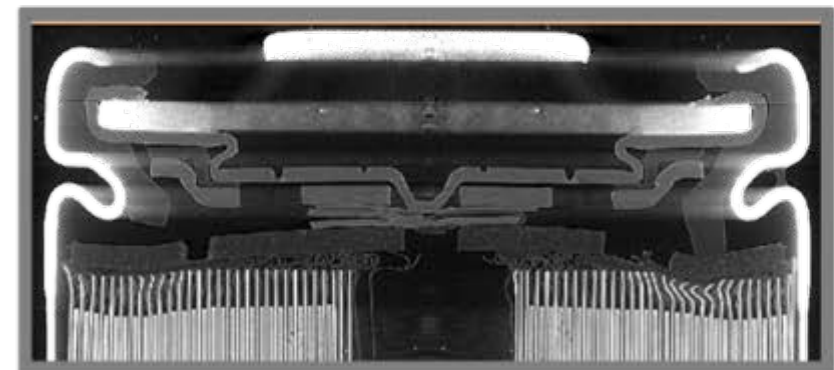
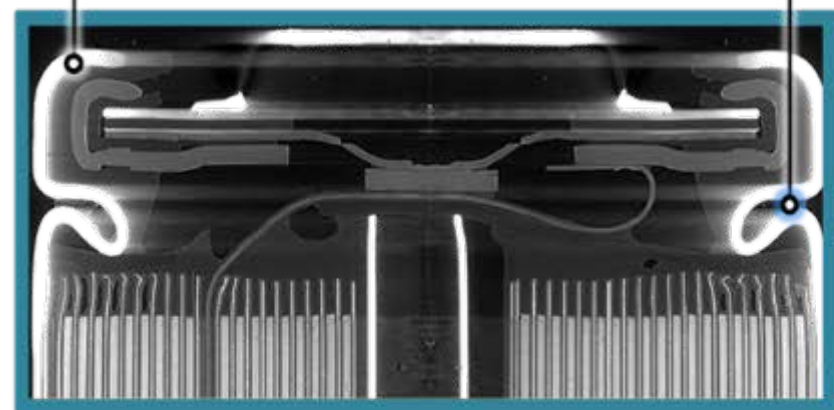
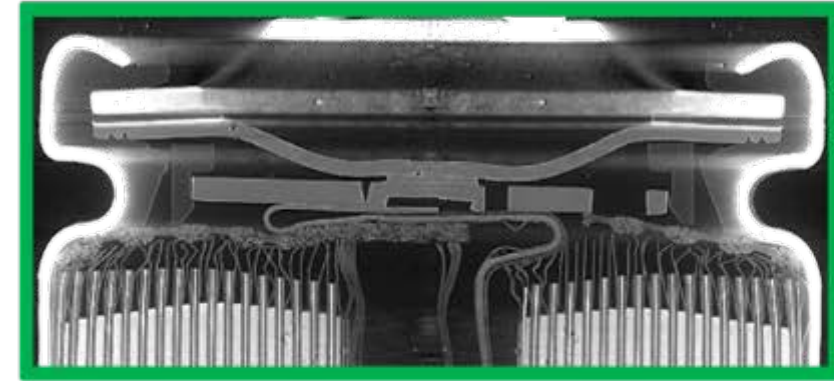
**Cell Fabrication**



**Custom pouch cell fabrication with small batches of material, vehicle cell tear down and diagnostics**



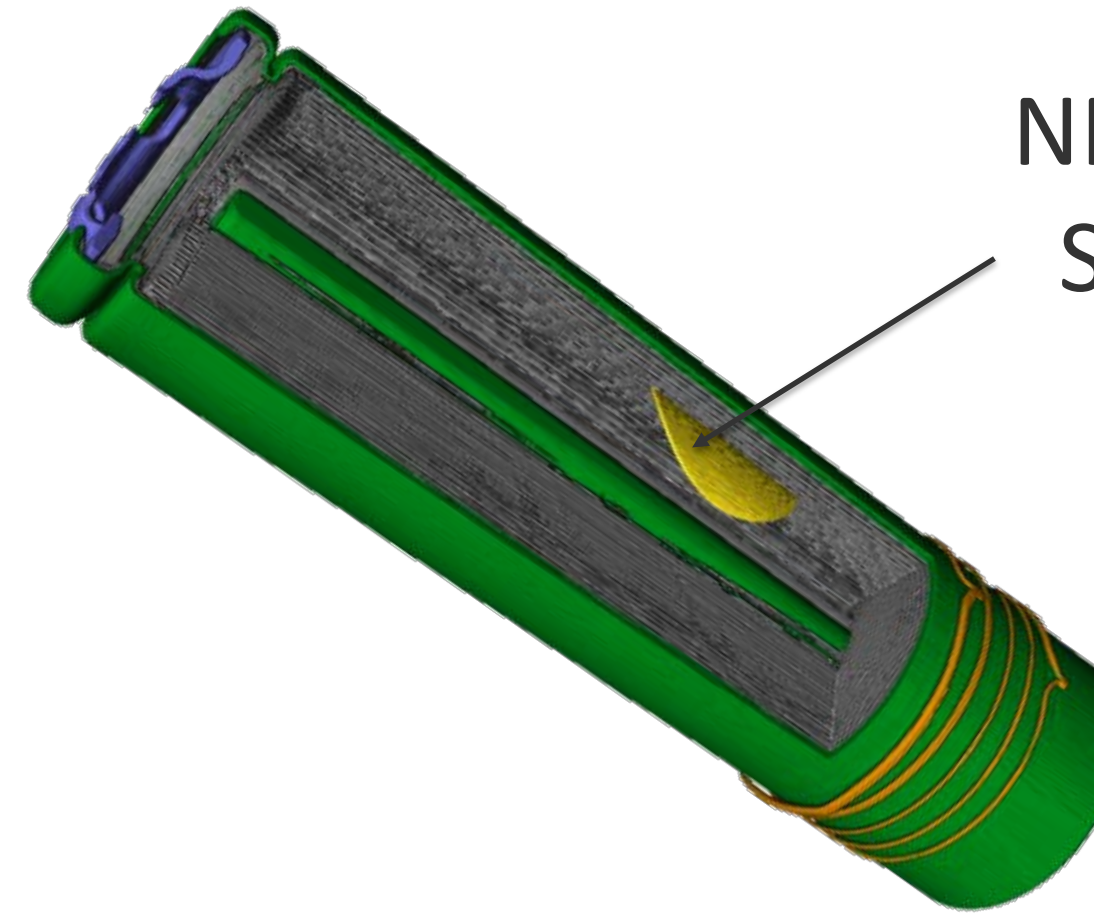
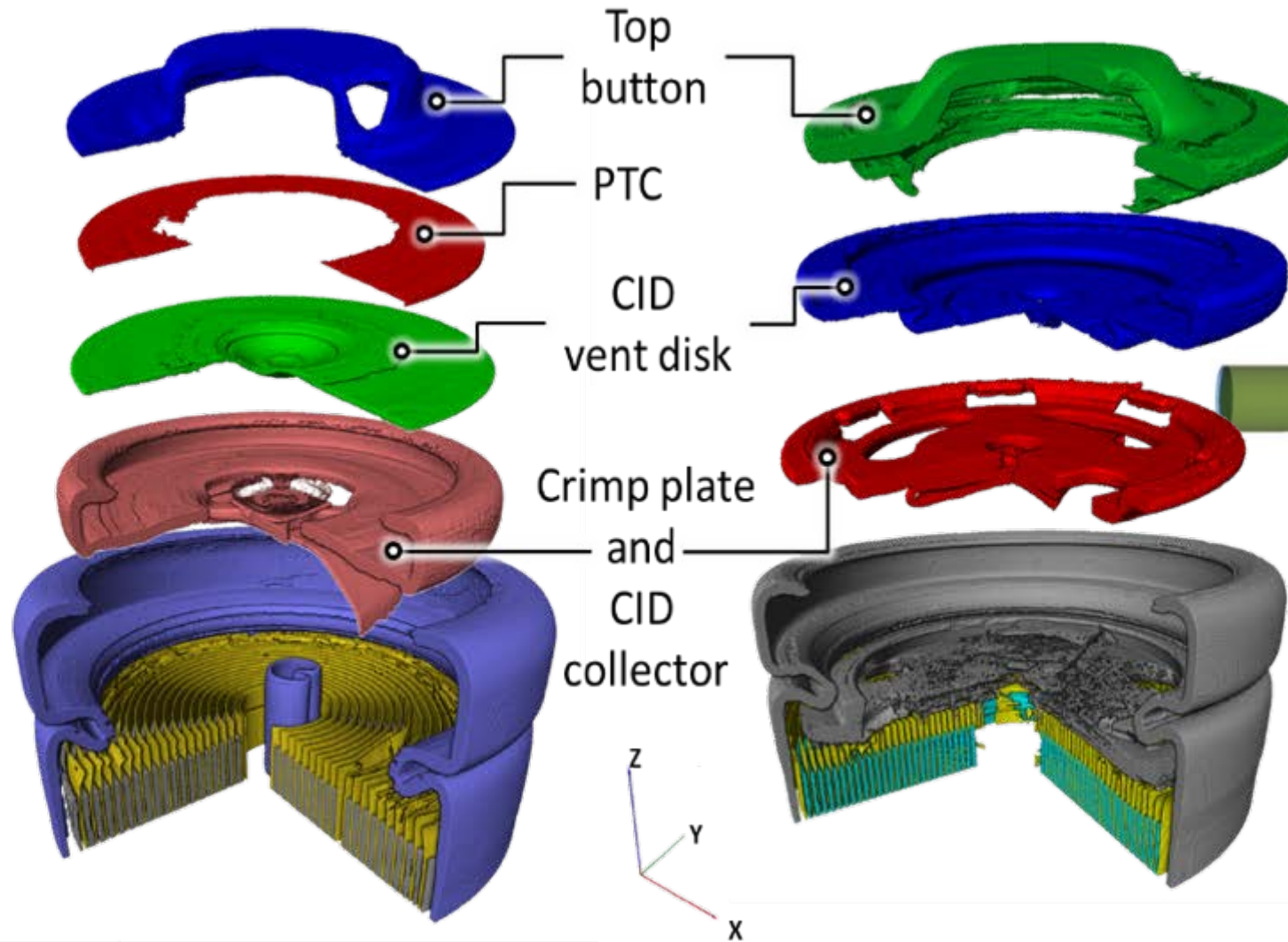
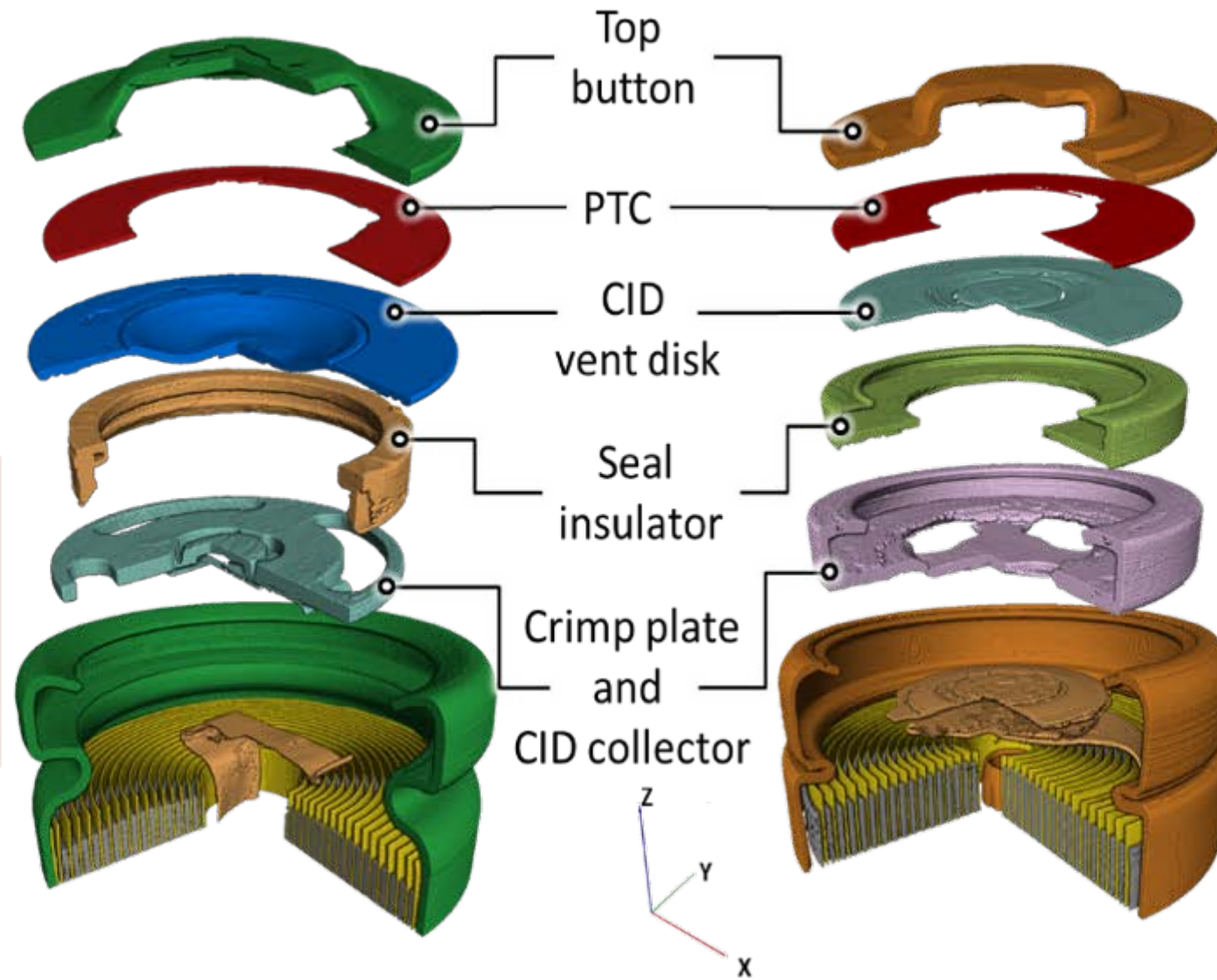
# Tomography



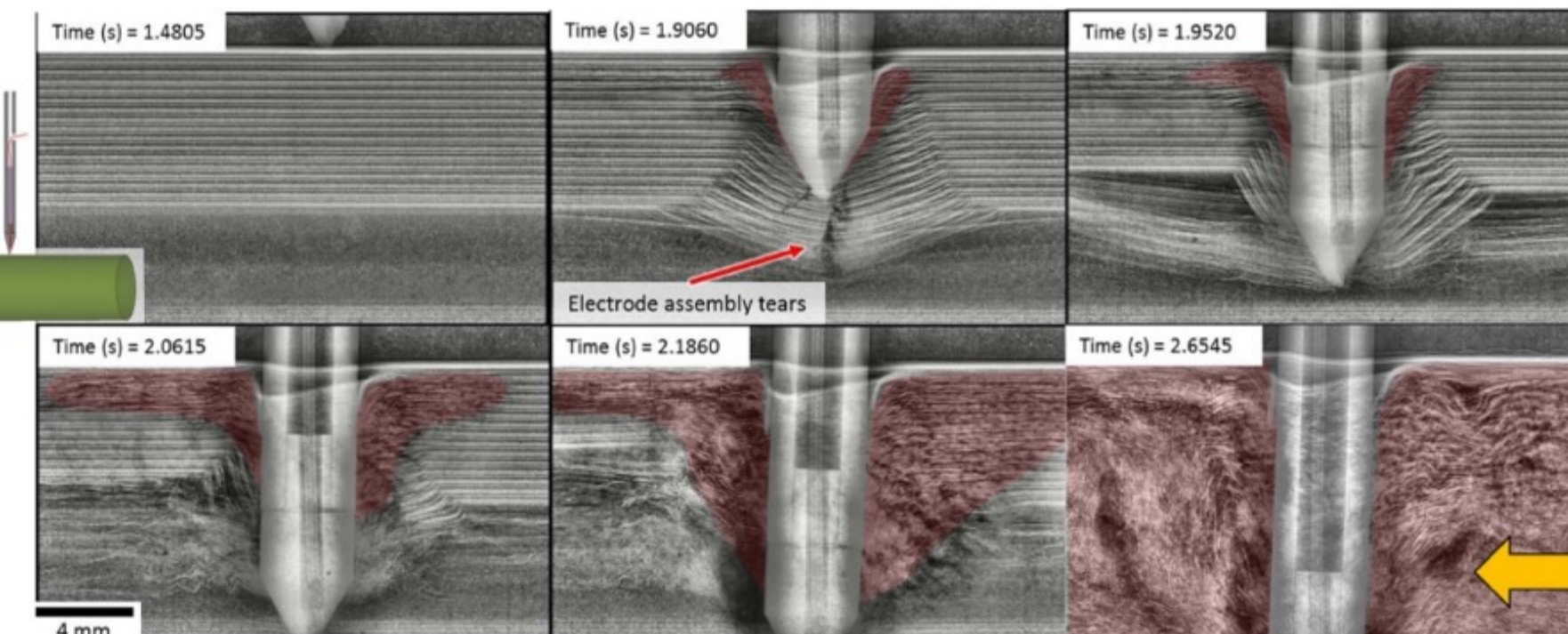
Top fold

Spin groove

5 mm



NREL's Internal Short-Circuit Device

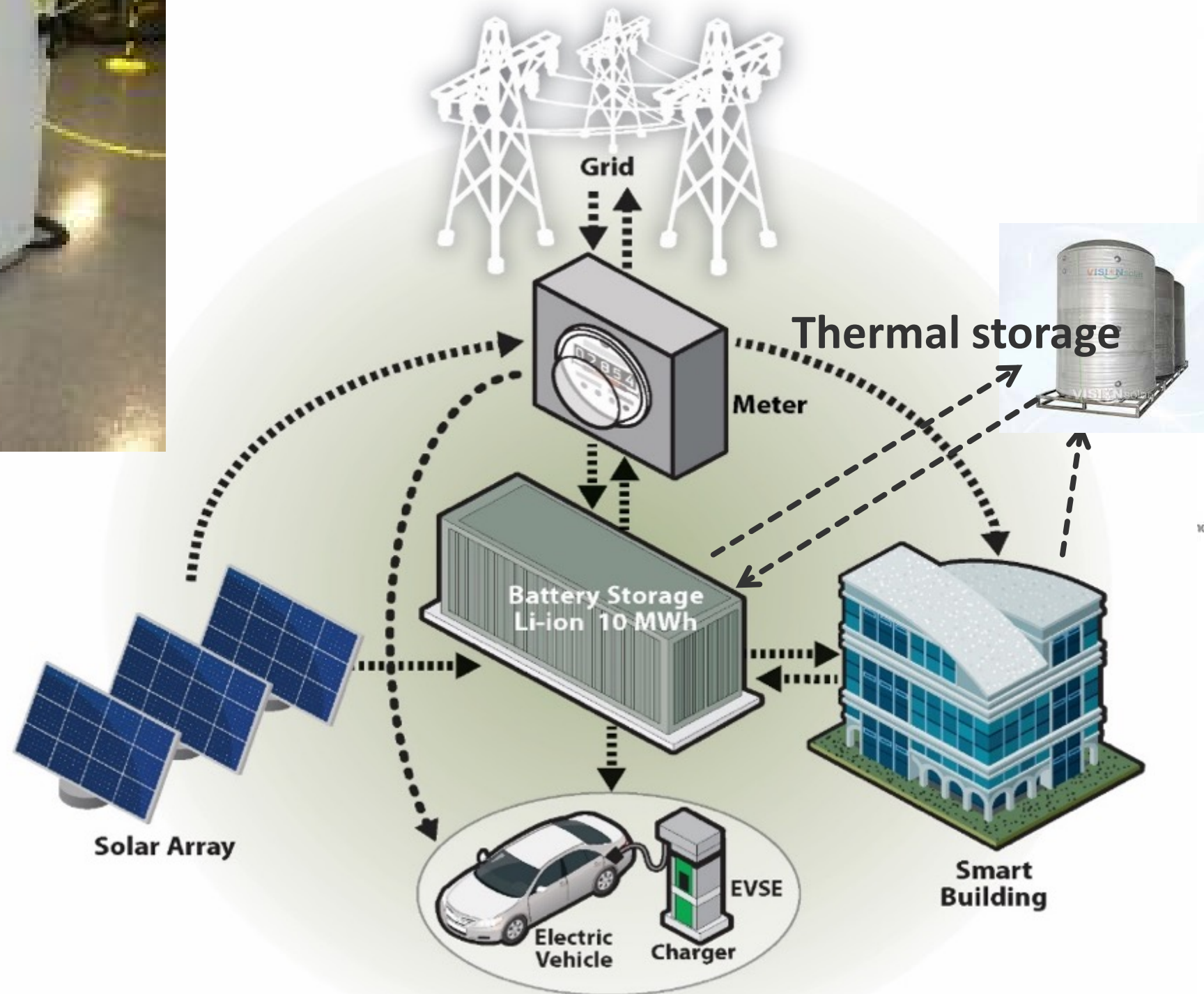




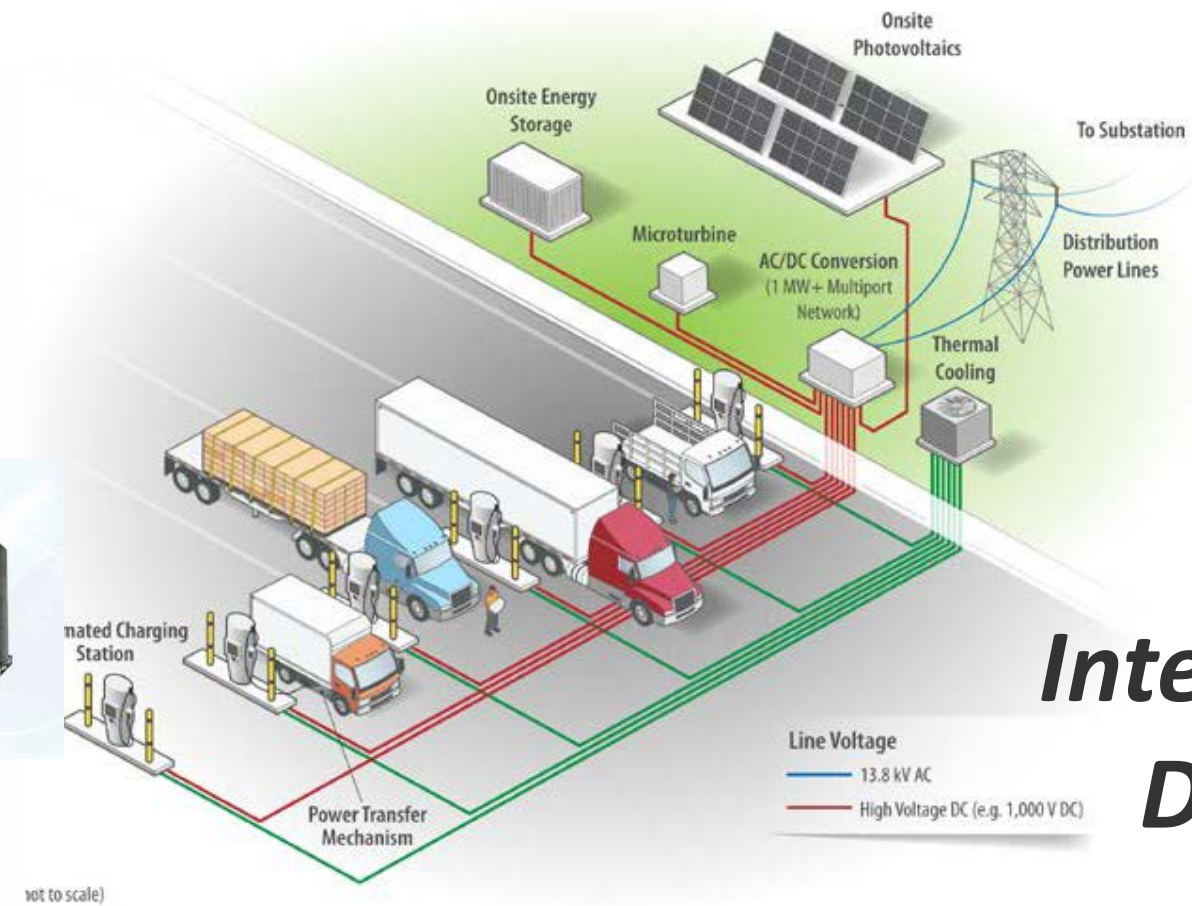


## Battery 2<sup>nd</sup> Use

# Integration & Analysis



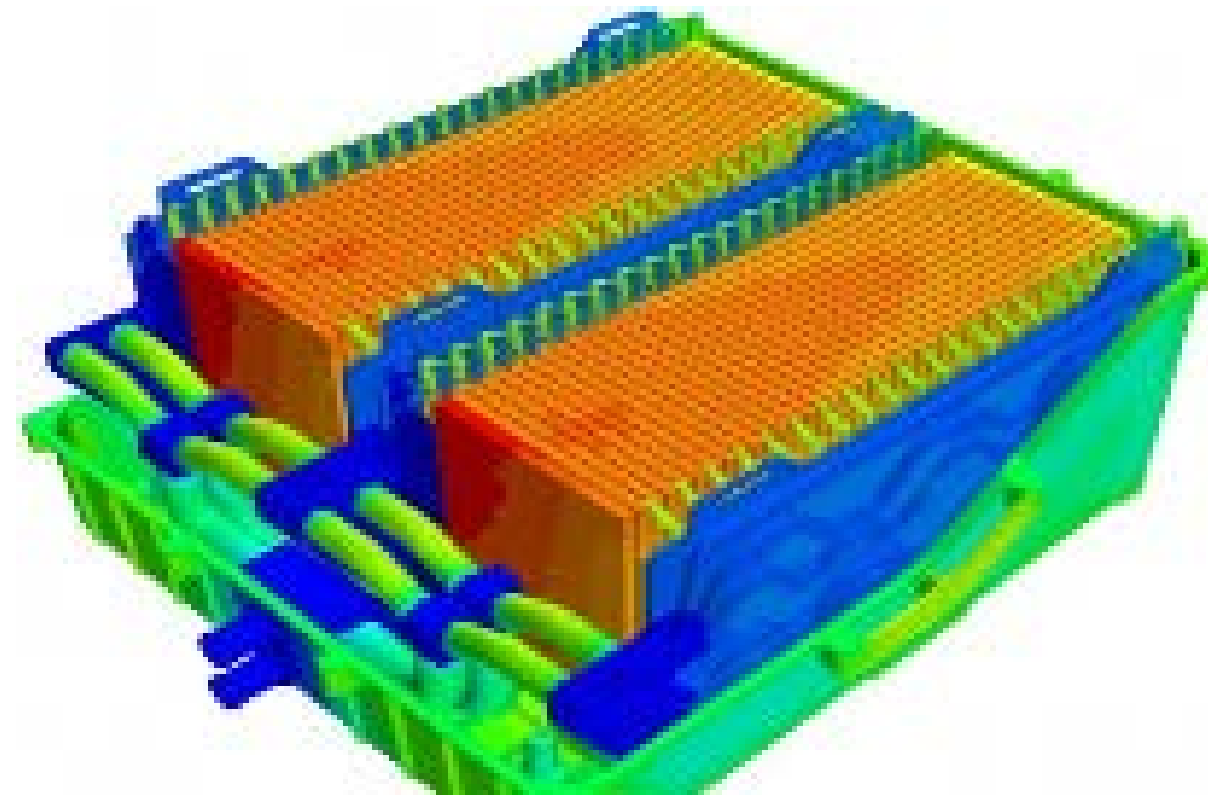
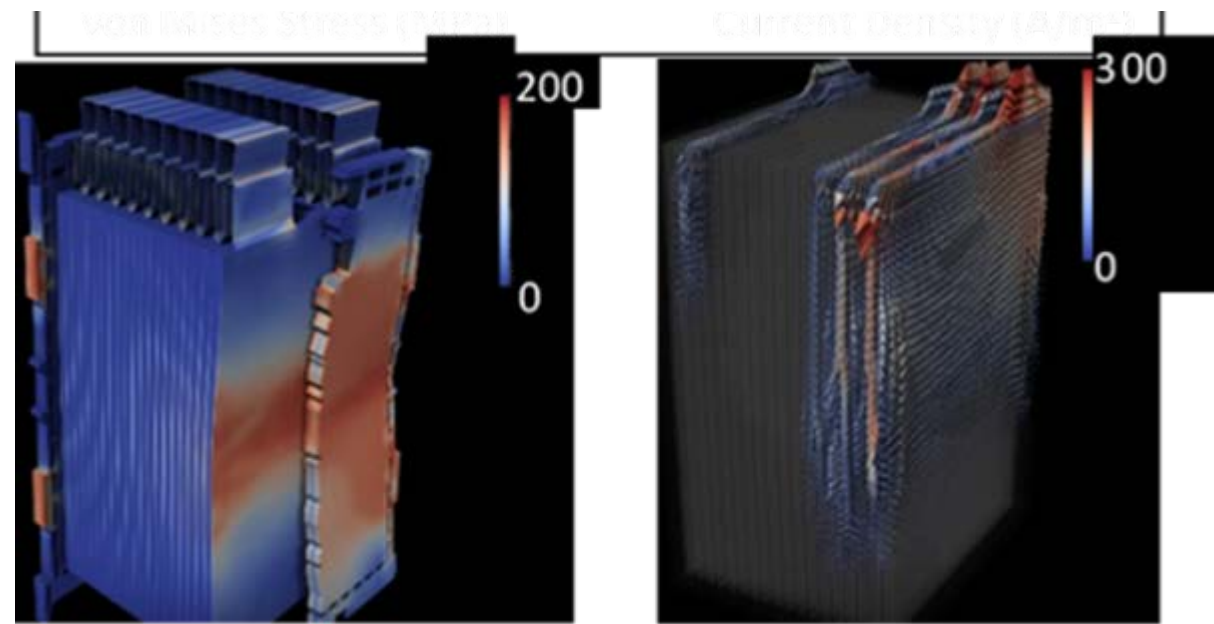
*Behind the Meter Storage*



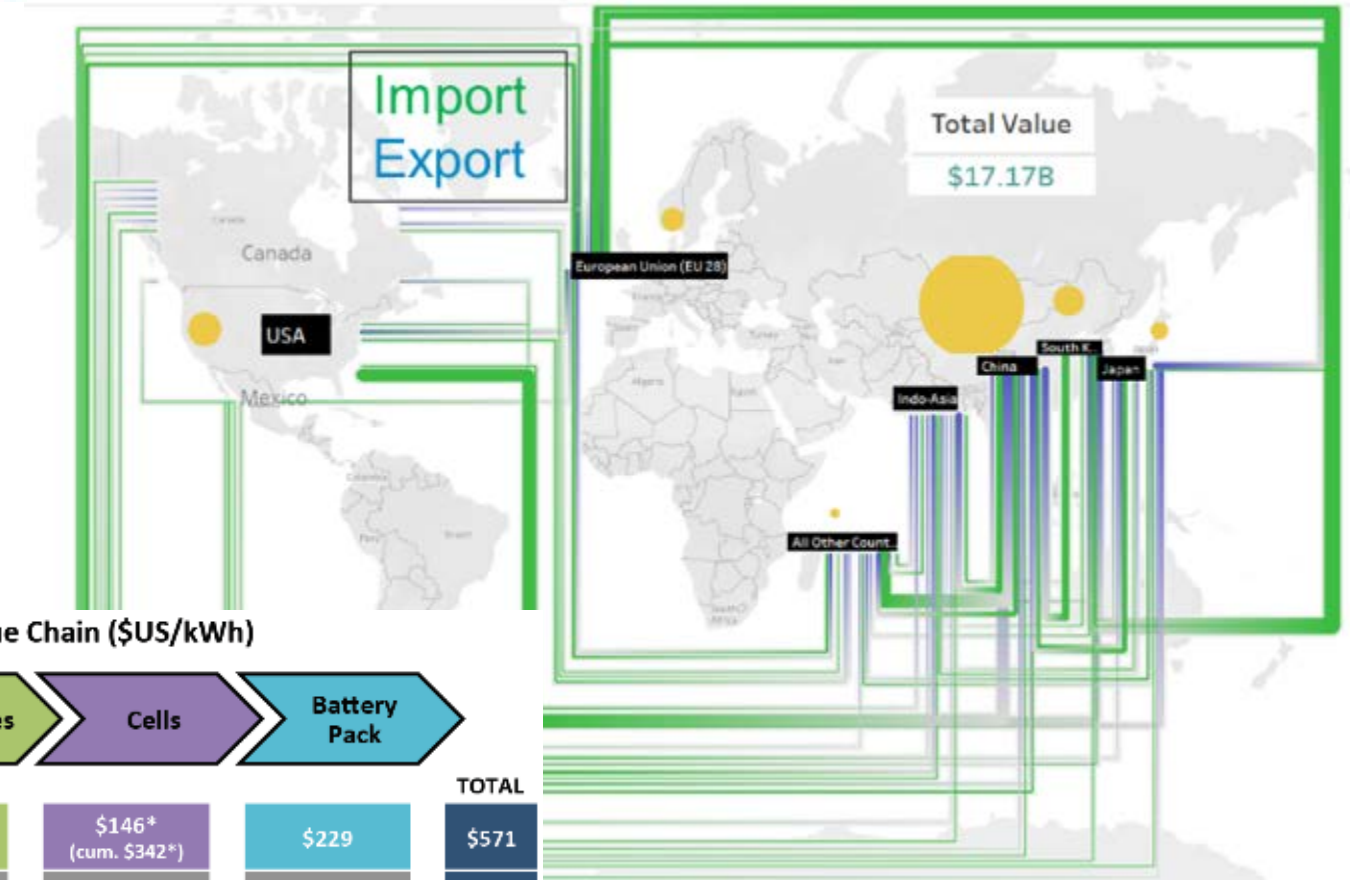
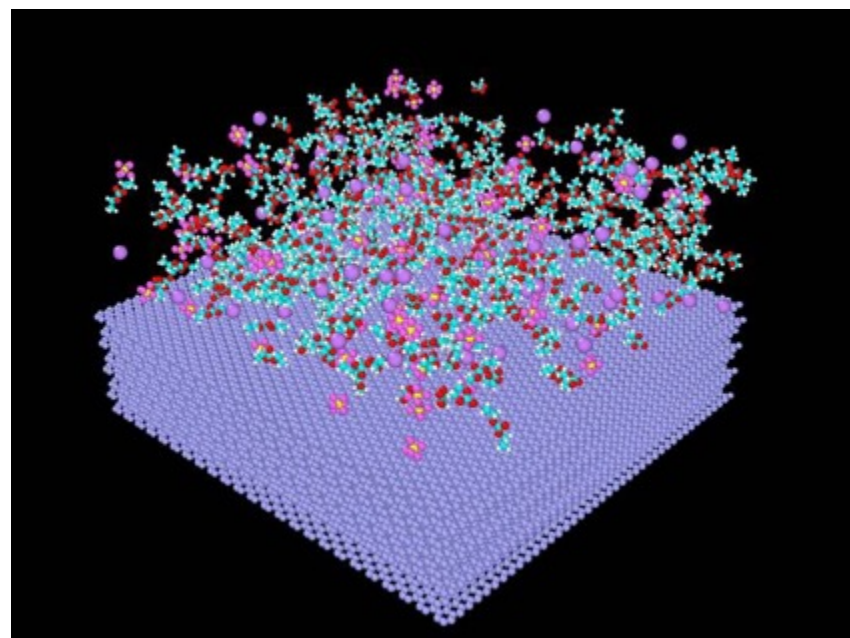
*Vehicle  
Integration and  
Drive Profiles*







- ✓ Commercially available tools implementing rigorous electrochemistry
- ✓ Realistic geometries, CAD capabilities, validated models
- ✓ Active participation from cell-makers, OEMs



2014 Best-in-Class PHEV LIB Value Chain (\$US/kWh)

	Raw Materials	Processed Materials	Electrodes	Cells	Battery Pack	TOTAL
VALUE		\$168	\$28	\$146* (cum. \$342*)	\$229	\$571
SHARE		29%	5%	26%	40%	100%
CURRENTLY SHIPPED	Globally	Globally	Regionally	Globally	Locally	

*Supply Chain modeling using LIBRA*



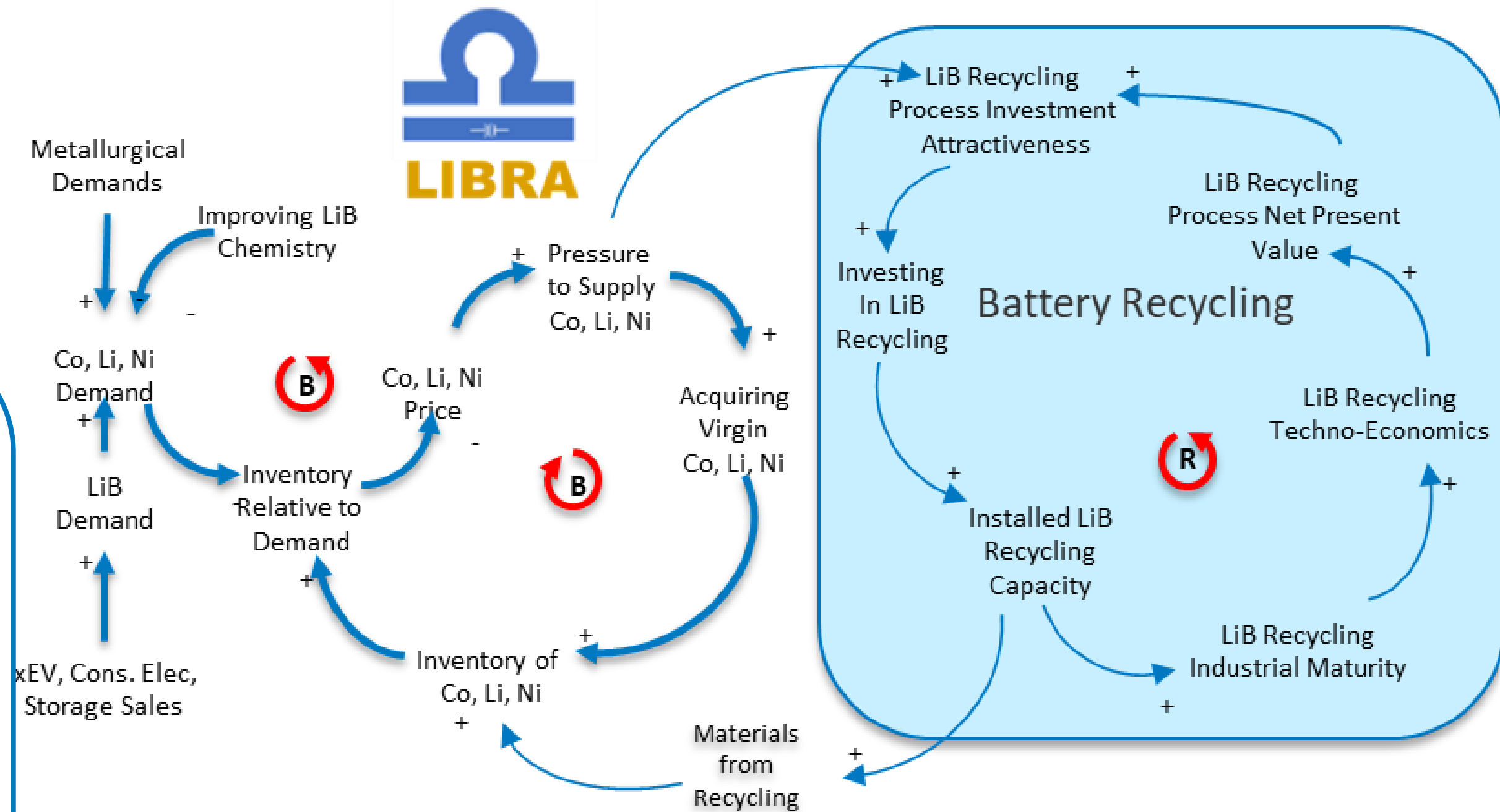
# Dynamic Analysis of the Battery Supply Chain – The Lithium-Ion Battery Recycling Analysis Model (LIBRA)

**NREL's LIBRA model evaluates the macro-economic viability of the battery recycling industry under differing dynamic conditions.**

**Key Question: What are the most important factors in the development of a domestic LIB recycling industry?**

For Example:

- How does recycling affect global demand for battery materials?
- How does used battery collection success affect industry build-out and economics?
- How will the industry handle changes in battery chemistry over time?
- What investments are needed to achieve goals?
- Under what conditions is recycling favored over virgin LIB manufacturing?

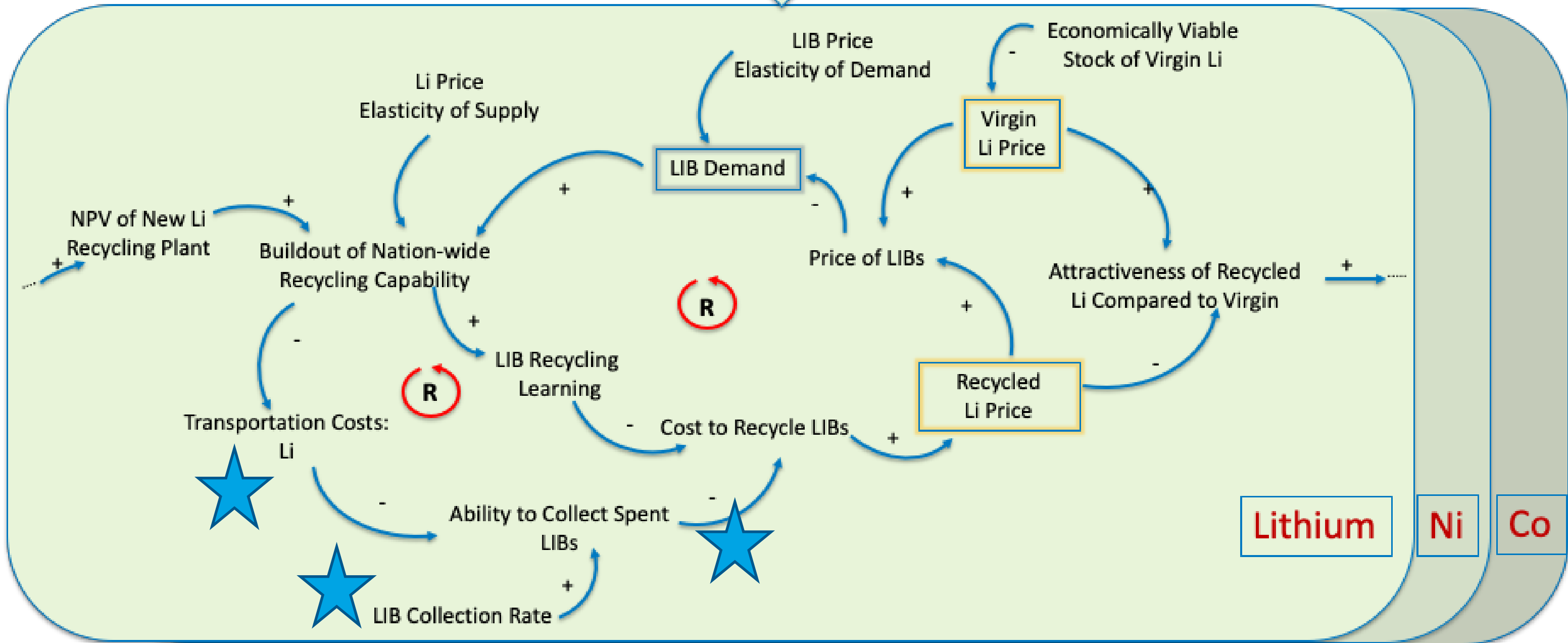
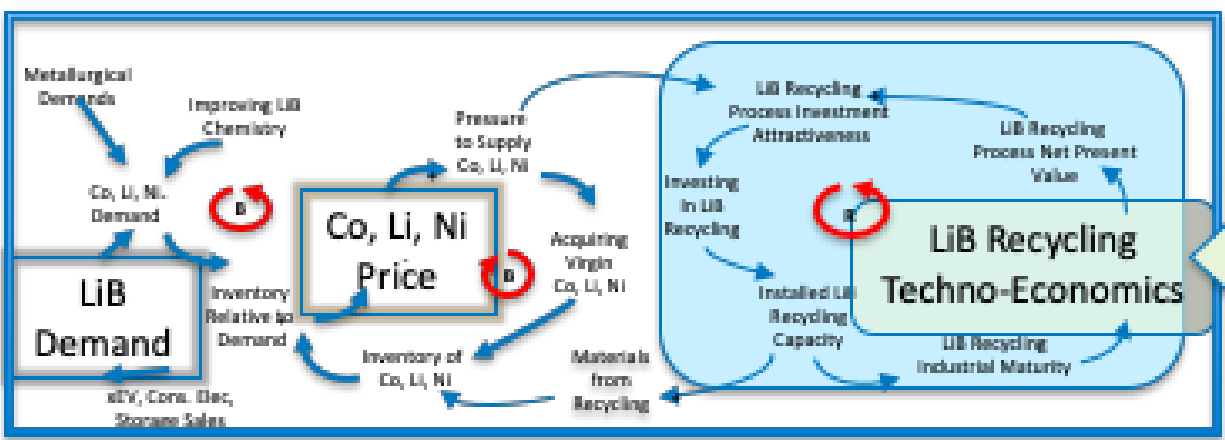


*The success of battery recycling depends on the rest of the supply chain, including battery production, use, and materials acquisition.*



# Each Part of the Supply Chain Impacts the Success of Battery Recycling

How much can a successful battery recycling operation afford to pay for collection & transportation of spent batteries? Which approaches (and where) are more cost-effective?

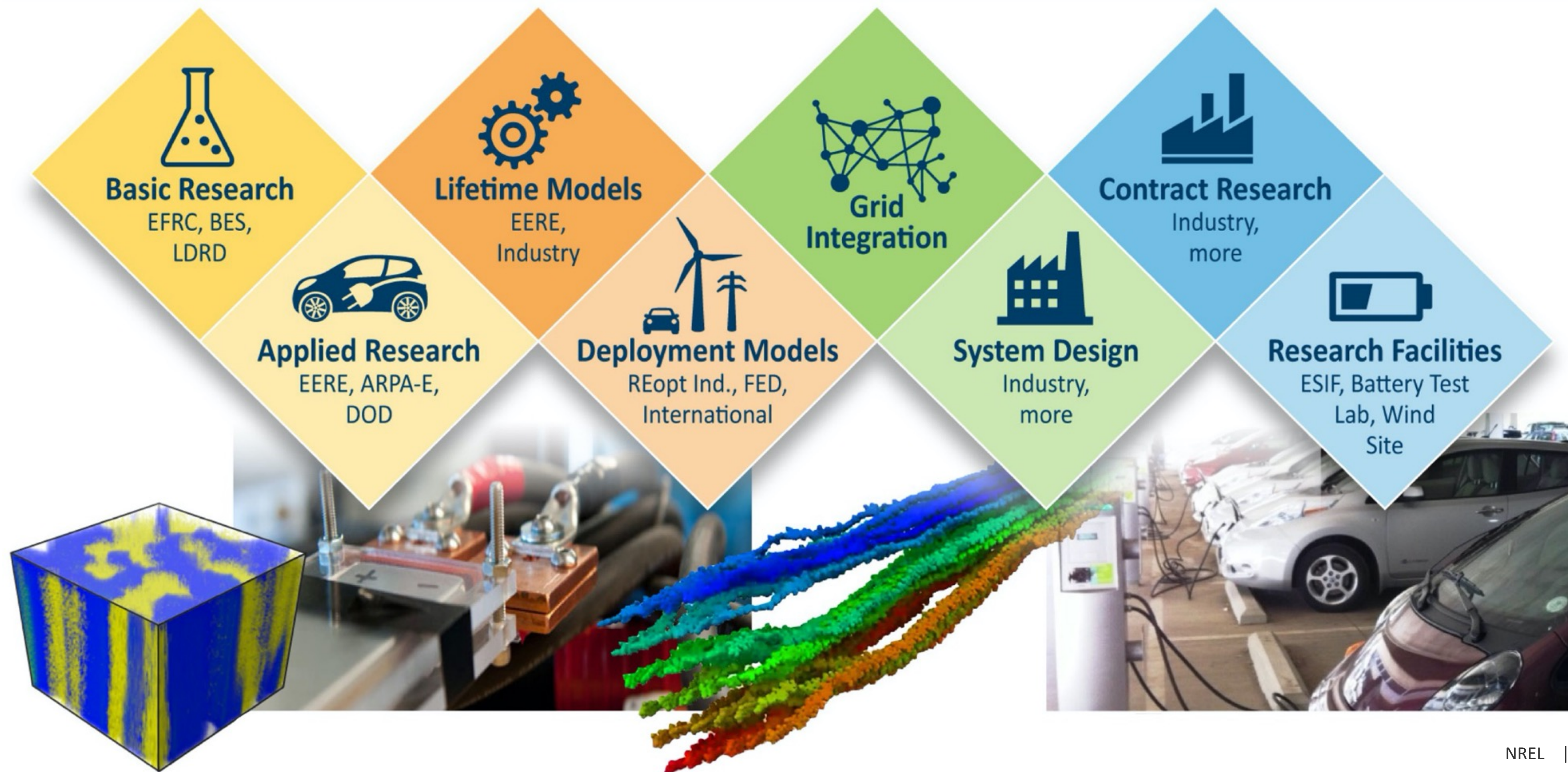


The LIBRA model's user interface allows for real-time evaluation of the sensitivity of model results. The most significant factors that affect availability of cobalt available from recycling are:

- Recovery of EV Batteries
- EV Sales
- Battery Chemistry



# NREL's Range of Energy Storage Capabilities Span the Spectrum





# Thank you

---

***For more information please visit:***

<https://www.nrel.gov/transportation/energy-storage.html>





# Battery Manufacturing Facility (BMF) at ORNL

ILIAS Belharouak

belharouaki@ornl.gov

ORNL is managed by UT-Battelle, LLC for the US Department of Energy



# ORNL innovations have billion-dollar impacts



1940s

Radioisotopes: Multibillion dollar industry (>100 million procedures per year)

>\$5B/  
year

PUREX: Basis for nuclear fuel reprocessing techniques used worldwide

Reactor technology: Concepts for light water, high temperature, and molten salt reactors

Instrumentation: Products and spinoffs from ORTEC and TENNELEC

>\$1B

Centrifuge technology: Basis for vaccine purification and US enrichment industry

Cryopreservation (mouse embryos): Livestock reproduction

Ion implantation: Integrated circuits and medical implants

Advanced alloys: Chrome-moly steel in widespread use

Reactor life extension: \$20B cost avoidance

\$20B

Cesium extraction: Basis for waste processing plant

\$1.3B

Lab-on-a-chip: Caliper acquired by PerkinElmer

\$0.6B

Ceramic matrix composites for gas turbines

\$150B

Fueleconomy.gov: \$1B in cost savings

\$1B

Big-area additive manufacturing: US investment

>\$1B



Today



# We made significant progress on all of our major S&T initiatives

Advance ORNL's science and Innovation culture

Accelerate the discovery and design of new materials for energy

Advance the science and impact of neutrons

Scale computing and data analytics to exascale and beyond

Advance scientific basis for break-through nuclear technologies and systems

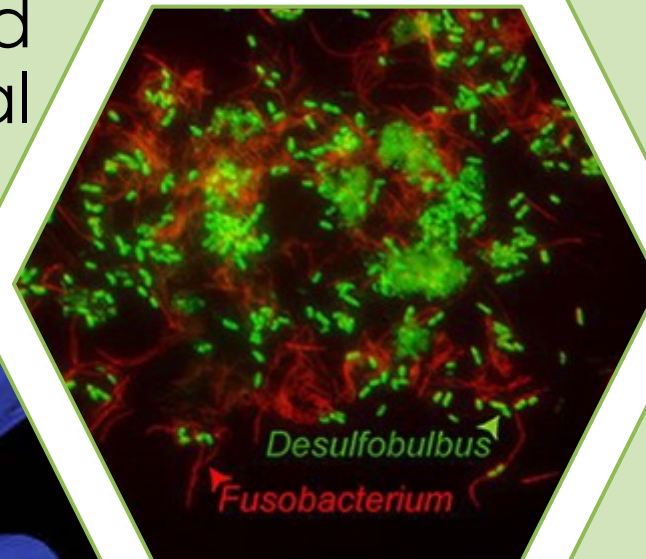
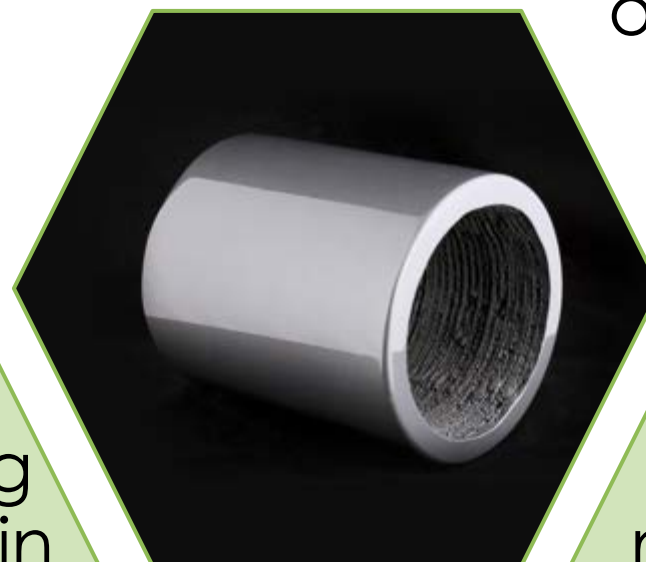
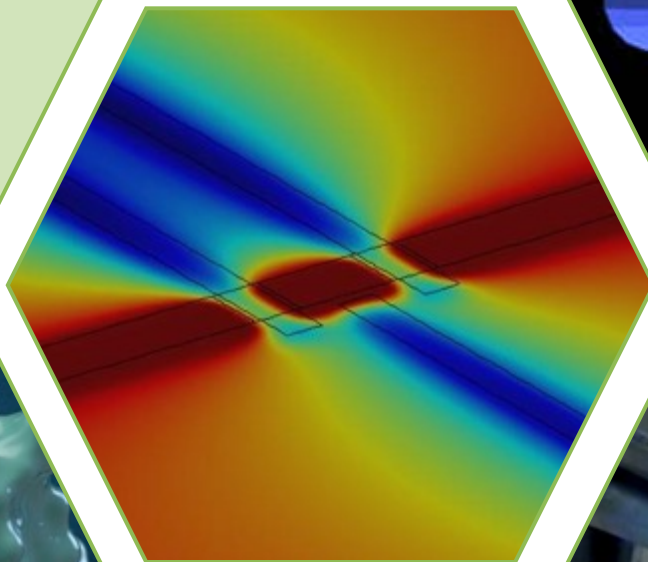
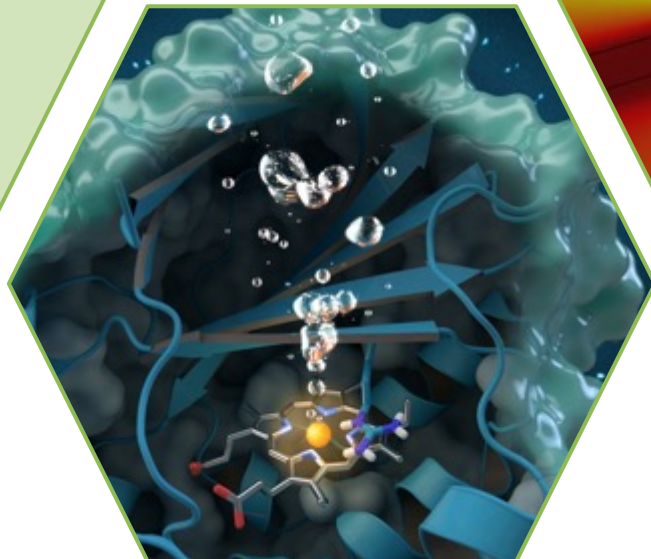
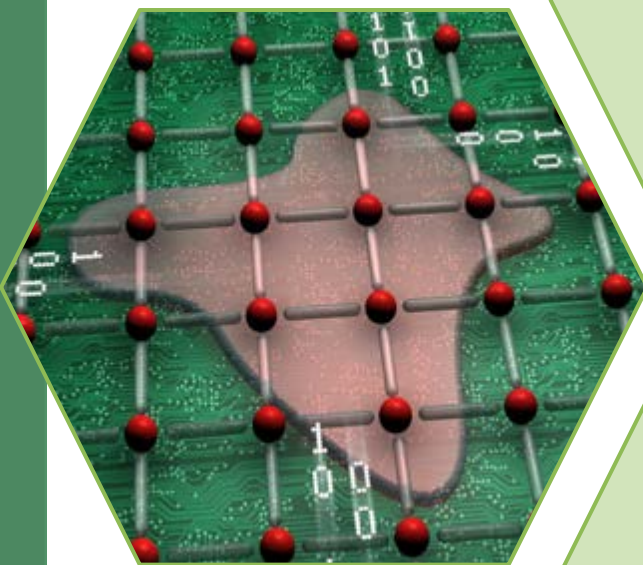
Advance understanding of complexity in biological and environmental systems

Accelerate deployment of DOE IP and engagement with universities and industry

Accelerate R&D and manufacturing of integrated energy systems

Deliver S&T to address complex security challenges

Enhance strategic capabilities in isotopes





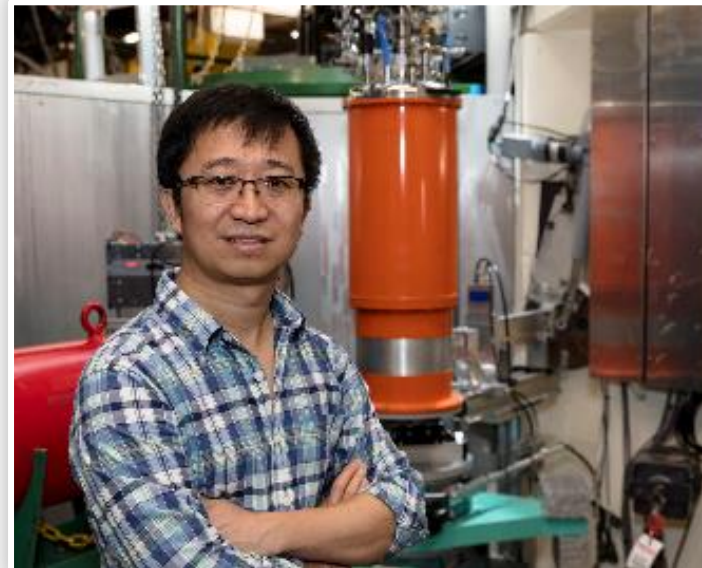
# ORNL's distinctive facilities bring thousands of R&D partners to Tennessee each year



Building Technologies Research and Integration Center



Carbon Fiber Technology Facility



Center for Nanophase Materials Sciences



High Flux Isotope Reactor



Manufacturing Demonstration Facility

National Transportation Research Center

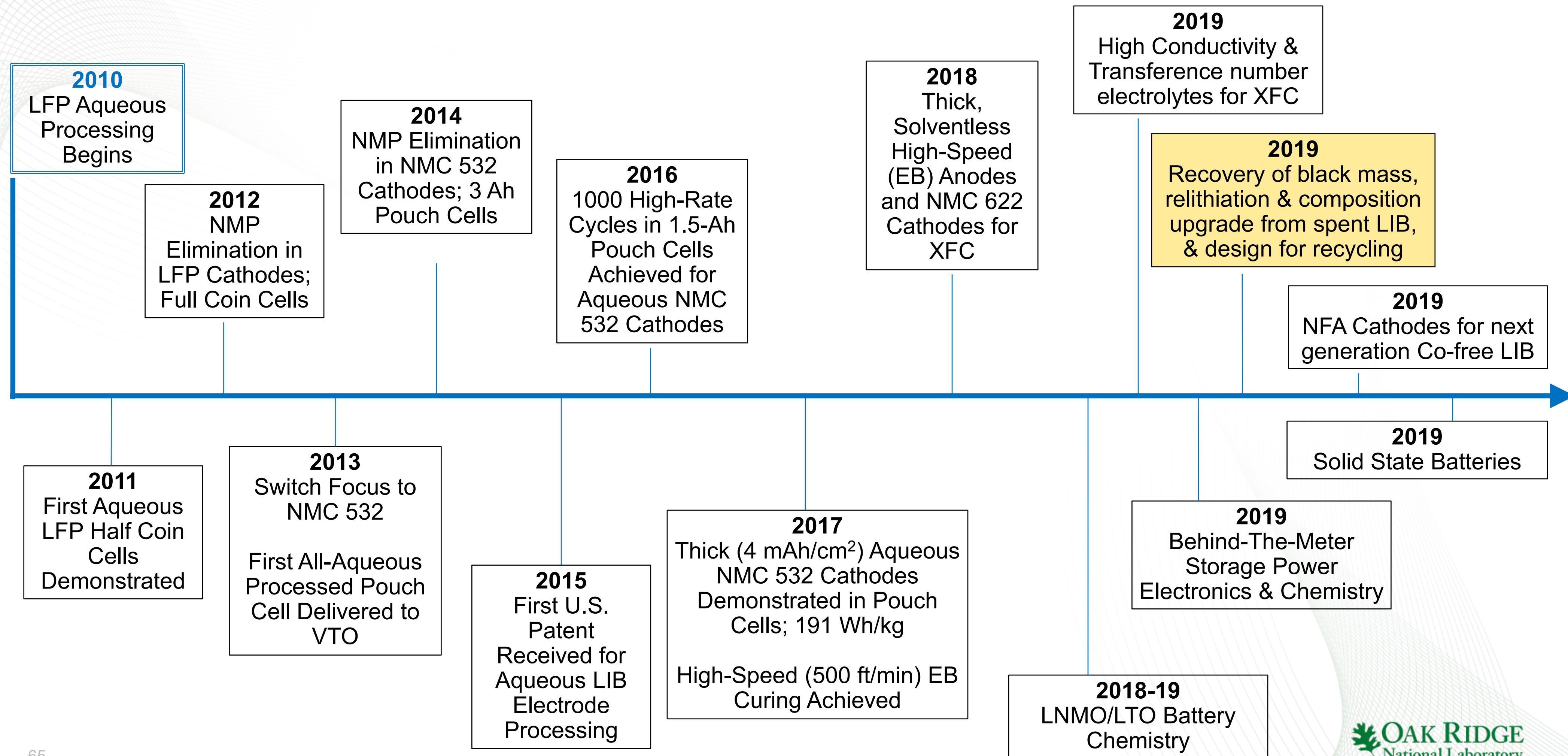
Spallation Neutron Source

Oak Ridge Leadership Computing Facility





# Major R&D Advancements at DOE's Battery Manufacturing Facility





# Battery Manufacturing Technical Outline at Oak Ridge National Lab

## Barriers To Overcome



1- Energy density  
Materials & Components  
(beyond 250 Wh/kg)

2- Cost  
Materials & Manufacturing  
(less than \$100/kWh)

3- Safety & Performance  
Materials, Electrolytes, Cells  
5000-8000 cycles

## Technical Approach



- High-capacity cathodes > 200Ah/kg
- High-voltage cathodes > 4.3V
- Reduction of inactive components

- Co-free next generation cathodes
- Slurry & electrode processing
- Electrode & cell design

- Surface modification
- Electrolytes & additives
- Electrode balancing & cell formation

## Remaining Challenges



### Electric Vehicles (Li-ion)

- Poor LT & HT Performance
- Extreme fast charging
- Recycling (only 5% recycled)

### Stationary Batteries

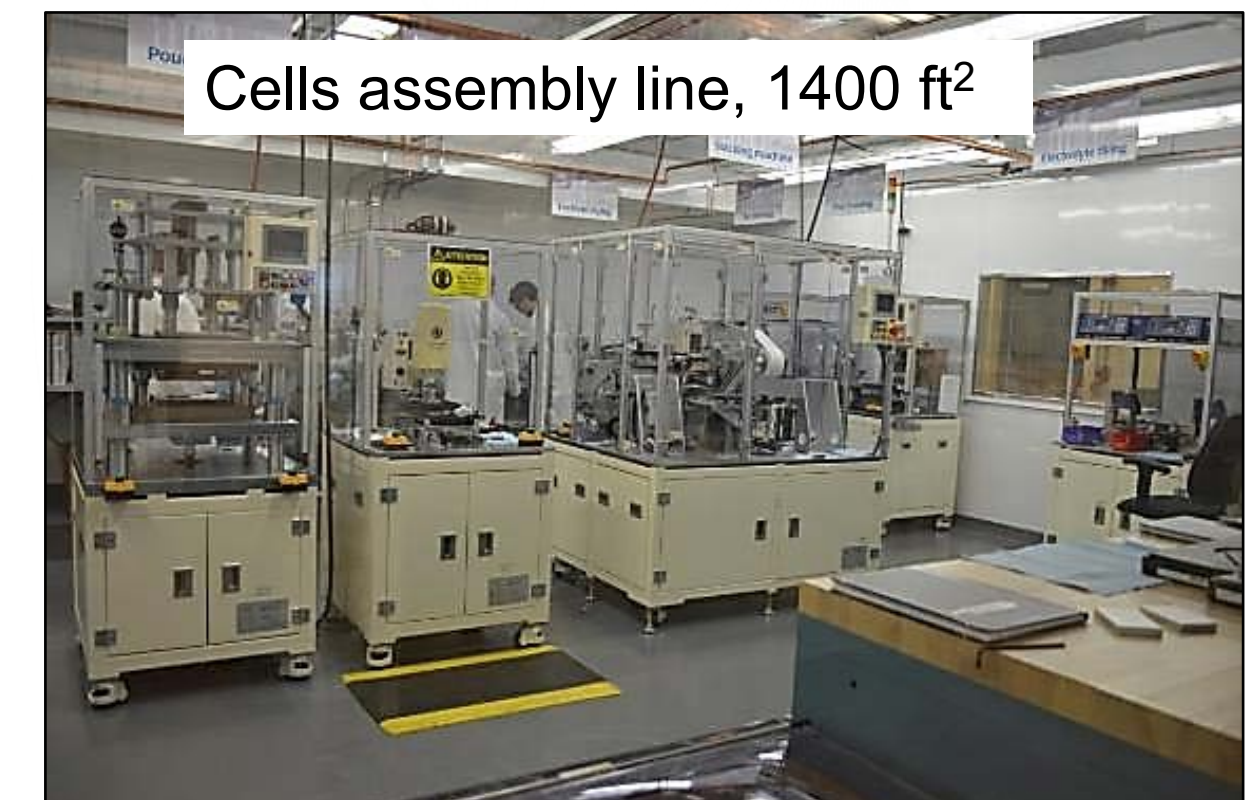
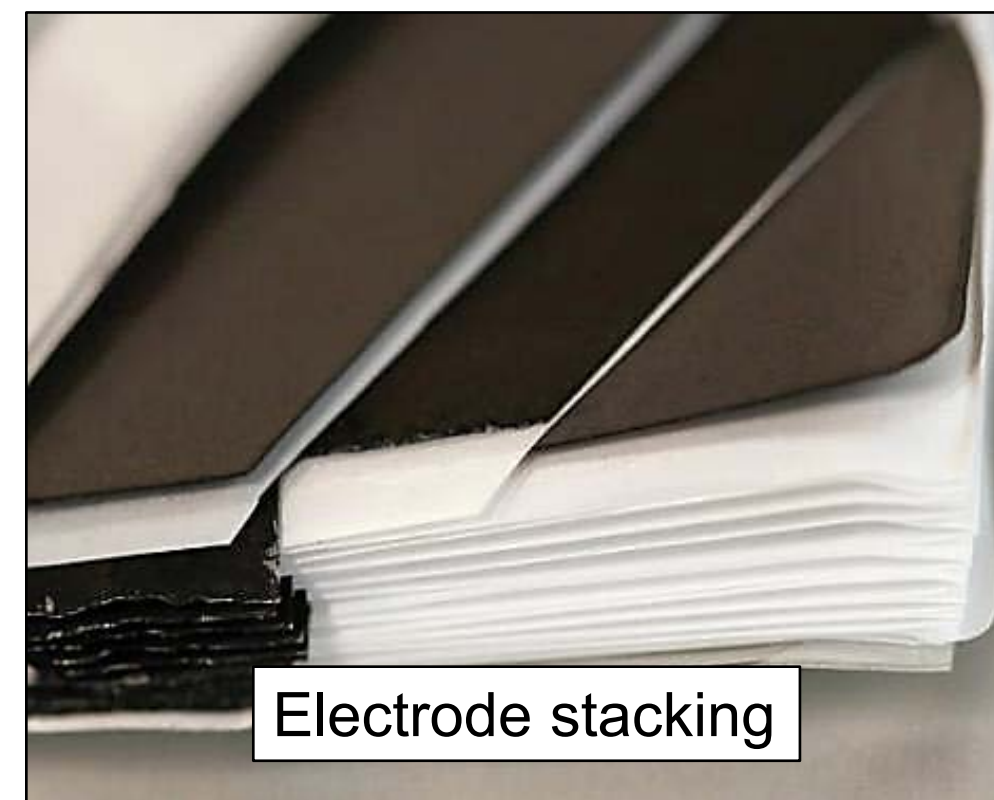
- Li-ion (low duration)
- Flow batteries (VRFB, FFB) (cost)
- Lead Acid, Zinc-air (Life issues)

### Emerging Battery Technologies

- Li-metal batteries (incl. sulfur, air)
- Sodium-ion batteries
- Solid State batteries



# DOE's Battery Manufacturing Facility Capabilities at ORNL





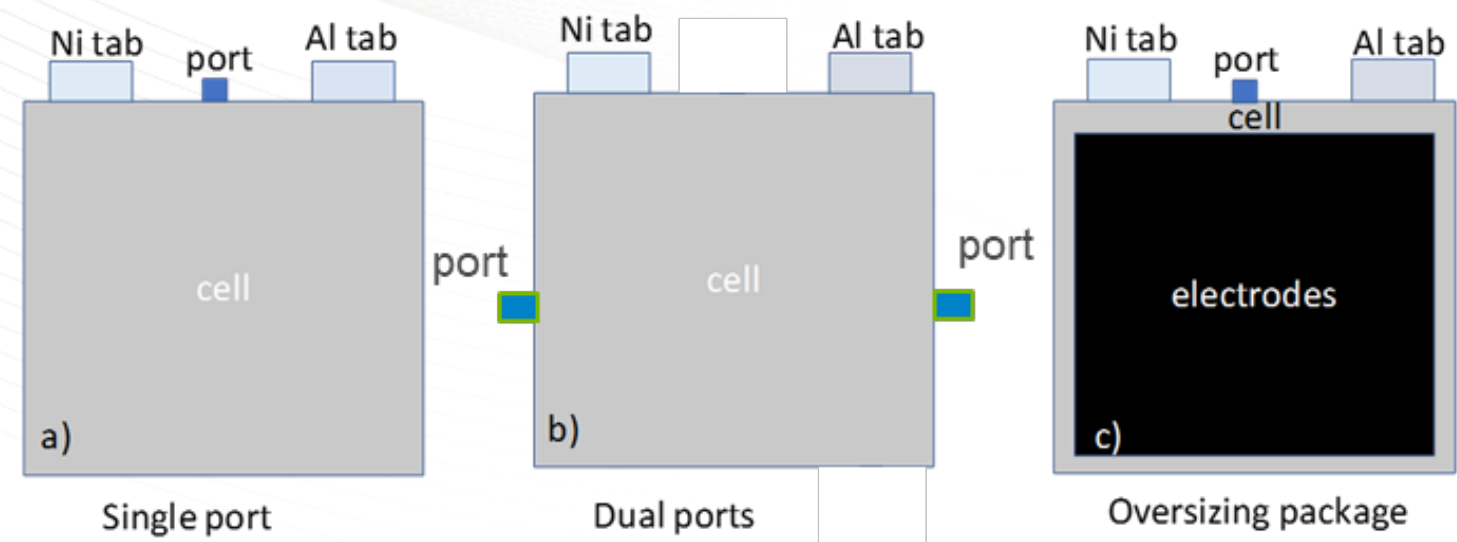
# DOE's Battery Manufacturing Capabilities Snapshots

- ❑ DOE Battery Manufacturing R&D Facility (BMF) at ORNL launched in 2010 with an initial investment from AMO and VTO.
- ❑ BMF expedites innovations in advanced battery materials research, battery manufacturing and cell prototyping that enable low-cost, high-energy, safer and long-life cells capable of fast charging.
- ❑ BMF provides the ability to analyze every aspect of battery cell development, from raw materials and electrode dispersion preparation to finished product and performance testing.
- ❑ BMF provides the ability to integrate any component into a complete battery and analyze how well it works and how it can be improved.
- ❑ BMF houses the equipment and instrumentation necessary to research every step in the battery manufacturing process with an emphasis on advanced materials, electrode formulation chemistry, rheology of slurries, innovative coating technology, and high-performance electrode architectures.
- ❑ Resources include three coating lines, E-beam coating, freeze tape casting, a 1400 ft<sup>2</sup> dry room, and a cell assembly line. BMF can produce pouch cells of up to 66 × 99 × 12 mm and 5 Ah capacity, large enough to make market decisions yet small enough to affordably demonstrate the impact of innovative technologies. 500 battery channels are available to evaluate performance and life of cells on a regular basis.
- ❑ BMF has access to multi-user cutting-edge characterizations to strengthen manufacturing science including advanced microscopy and neutron sciences at ORNL.

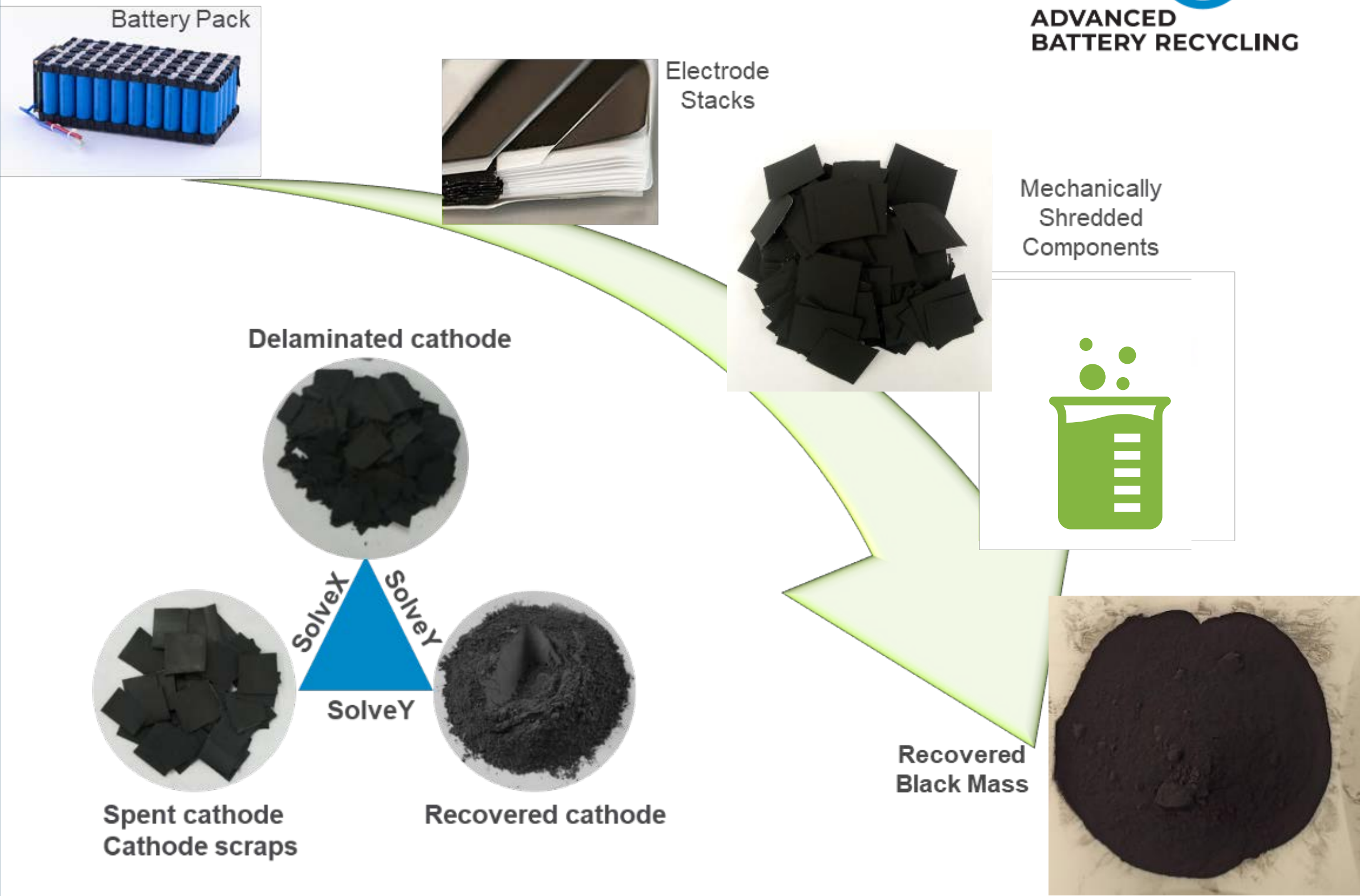


# ORNL Contributions to ReCell Advanced Battery Recycling

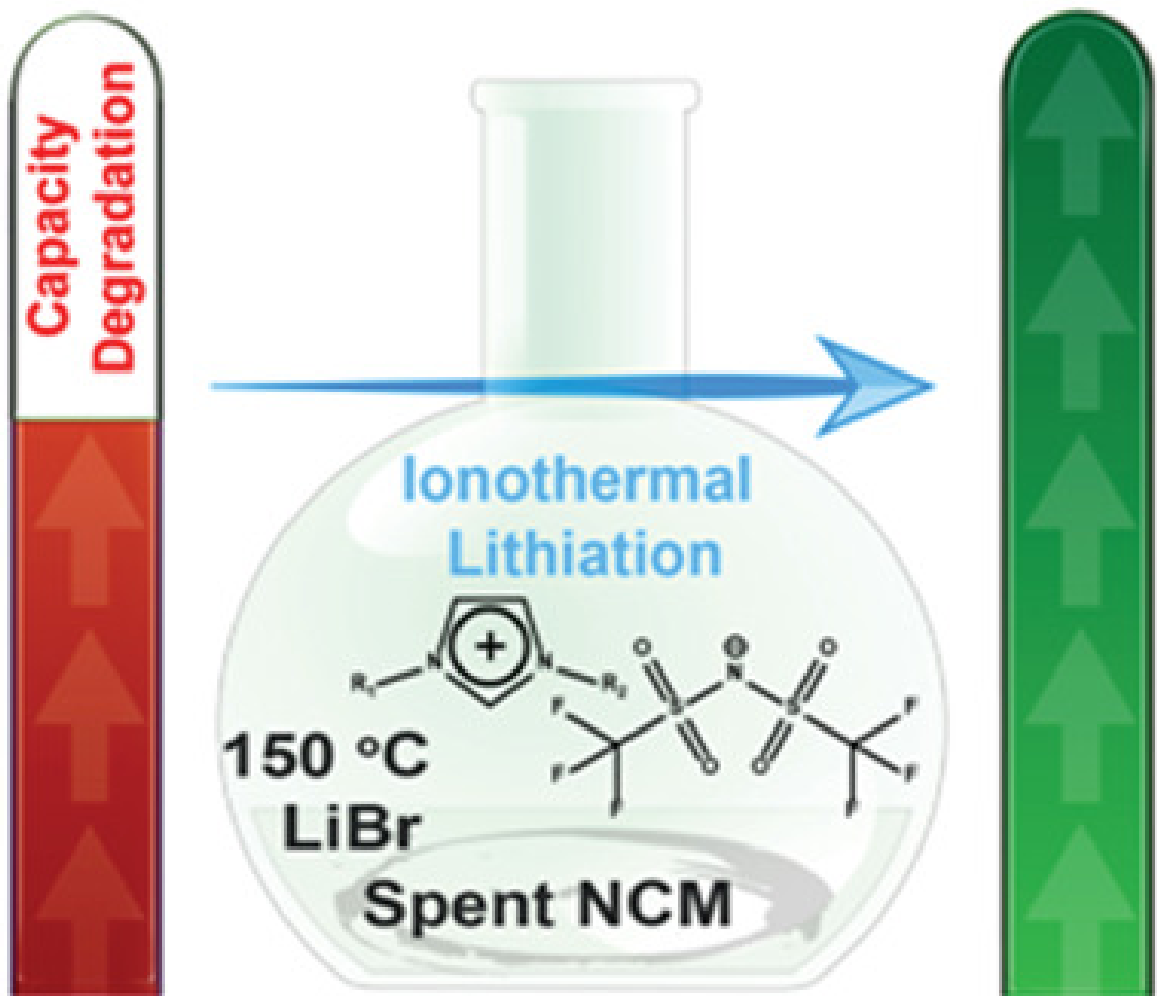
## Design for Recycle – Cell Design



## Solvent-based Electrode Recovery



## Direct Recycling of Spent NCM Cathodes

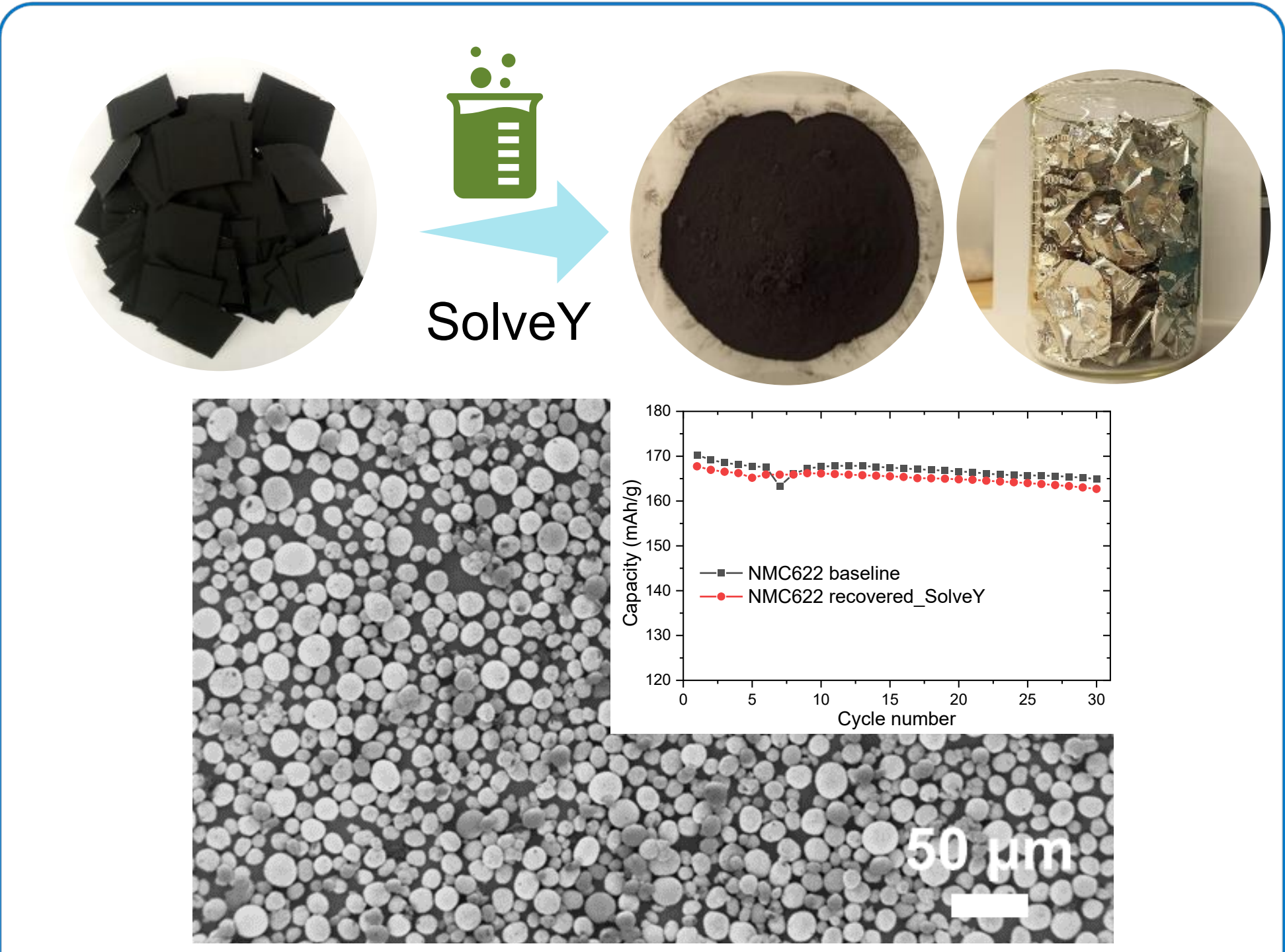




# Solvent-based Electrode Recovery



A green solvent X based separation process is developed to efficiently and rapidly delaminate electrode materials from current collectors without damaging active materials nor corroding current collectors.

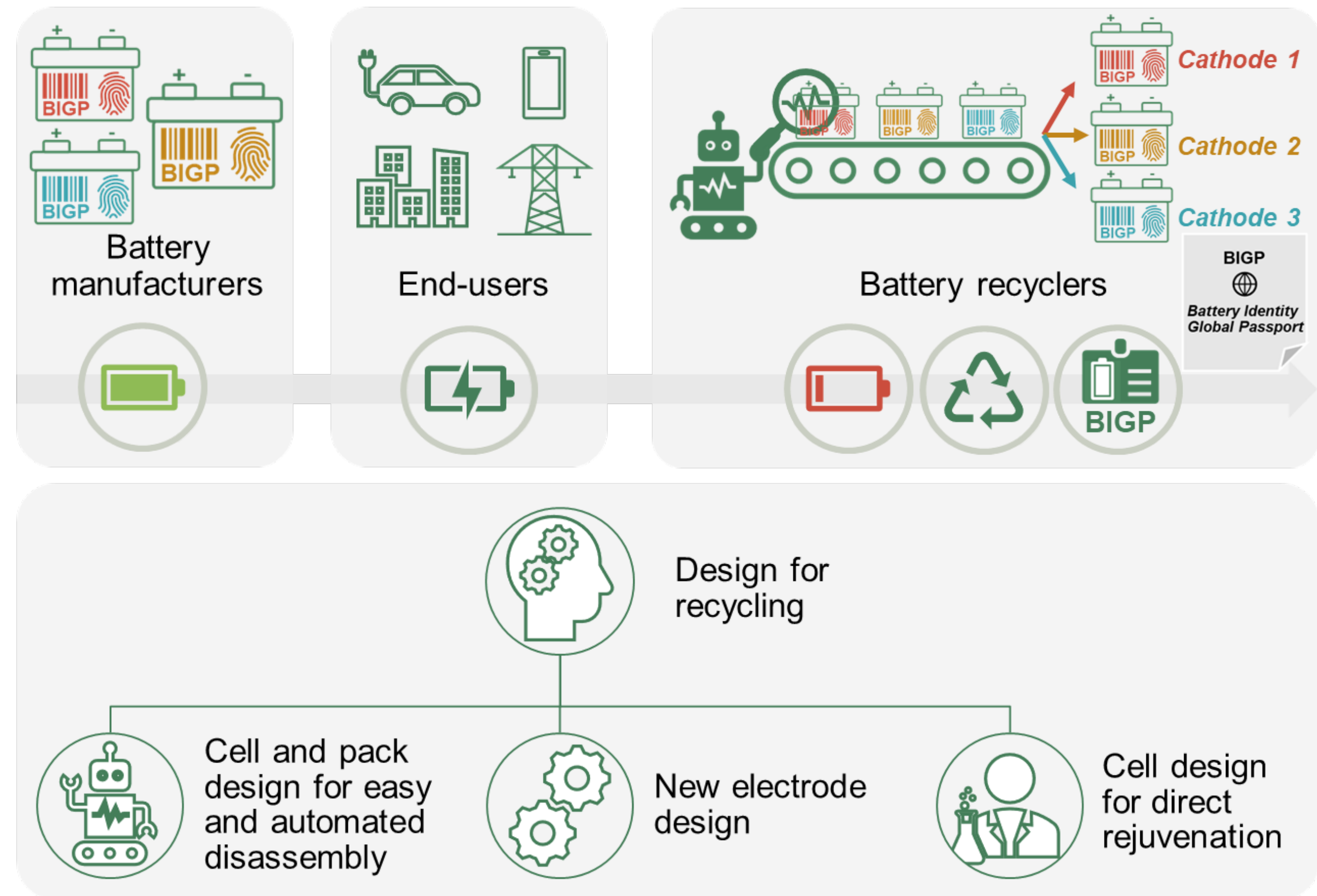


A green solvent Y based separation process is developed to efficiently reclaim cathode powder without damaging active materials in terms of structure, morphology and electrochemical performance.



# Design for Recycling: Battery Identity Global Passport (BIGP)

- Battery Identity Global Passports (BIGP) will help to efficiently unveil the identity of the components in the cells to support quick and automated sorting, and hence could lead to streamlined separations.
- In addition to being explored on pack and module levels, innovative designs should be investigated on electrode and cell levels.





# Welcome to visit us at ORNL's Hardin Valley Campus

Contact: Ilias Belharouak  
[belharouaki@ornl.gov](mailto:belharouaki@ornl.gov)







# *Idaho National Laboratory Battery Recycling Demo Day: Quantification, verification & validation*

*July 2020*

Eric J. Dufek, Ph.D., [Eric.dufek@inl.gov](mailto:Eric.dufek@inl.gov)  
Department Manager, Energy Storage & Adv. Trans.

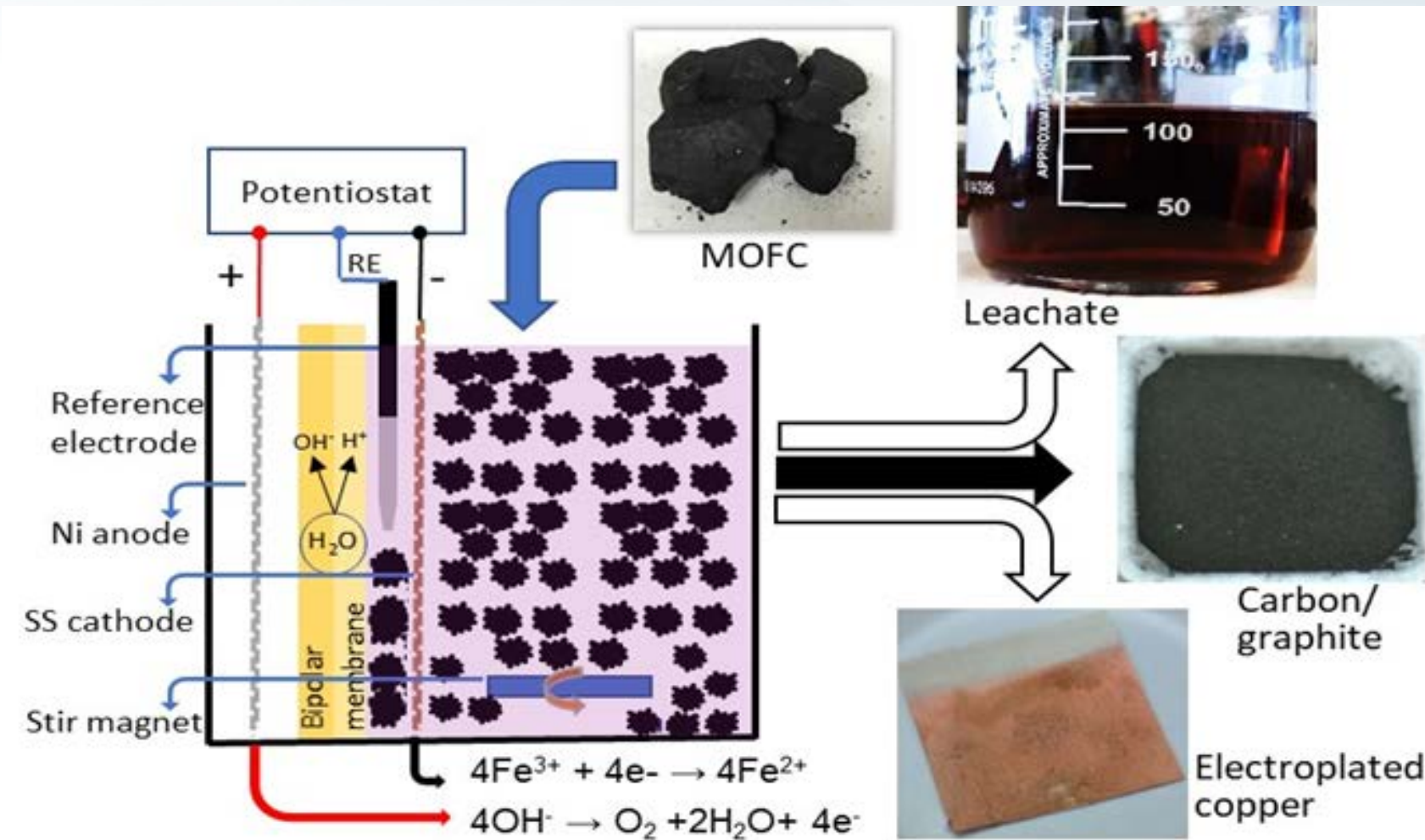
Seth W. Snyder, Ph.D., [Seth.Snyder@inl.gov](mailto:Seth.Snyder@inl.gov)  
Program Director, Energy & Environment S&T

[www.inl.gov](http://www.inl.gov)





## INL Battery Recycling



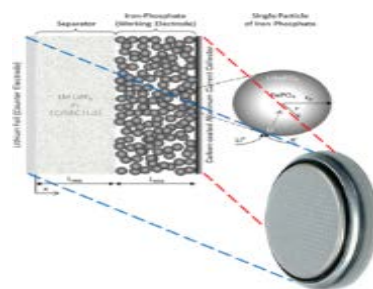
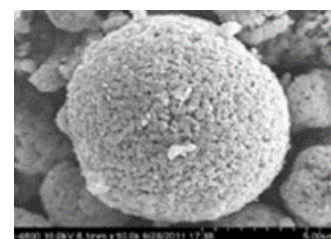
### *LiB electrochemical leaching technology (with the Critical Materials Institute)*

- INL is developing recycling processes for Lithium ion Batteries (LiBs). The development effort has two components, metal leaching based on electrochemistry and metals separations.
- The leaching step uses electrons to regenerate iron 2+ ( $\text{Fe}^{2+}$ ) from iron 3+ ( $\text{Fe}^{3+}$ ) which in turn reduces the LiB metals so they can be stripped from the battery black mass using only limited amounts of acid. The leaching generates a mixed metal leachate. The process cleans the battery graphite enabling it to potentially be reused in new batteries.
- In the separation process development research solvent extraction and ion exchange are being explored to isolate individual metals for recovery. Industrial partners providing battery black mass (also known as metal oxide filter cake or MOFC).

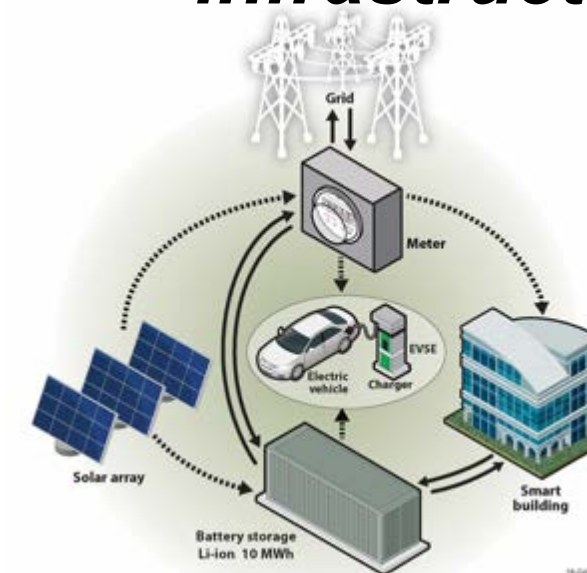


## ***INL Advanced Transportation***

### ***Understanding material limitations***



### ***Secure, intelligent, connected infrastructure***



### ***Advanced Battery Characterization***

**Quantification, verification and validation across temporal and spatial domains**

***Encompassing materials to advanced mobility***

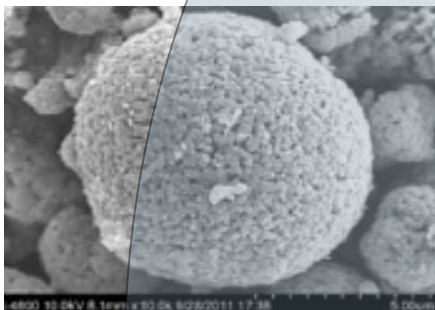


# INL Approach

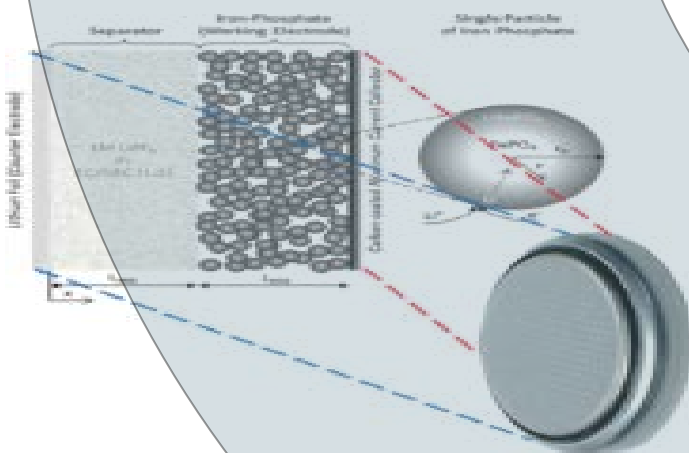
Safety, Reliability, Durability

## Materials

- Classical materials development



Tier 1 – Initial Technology Development



Structure, Integration And Combination

- Optimization for cross talk, minimize impact to components/integrated system

Tier 2 – Key Advancement Characterization

Tier 3 - Cross Program Comparison and Gap Analysis

Full Cell

- Increased depth and length

FMEA

Quantitative Analysis

Diagnostics

Prognostics

## Technology Goals

5. U.S. Advanced Battery Consortium Goals for Electric Vehicle Batteries

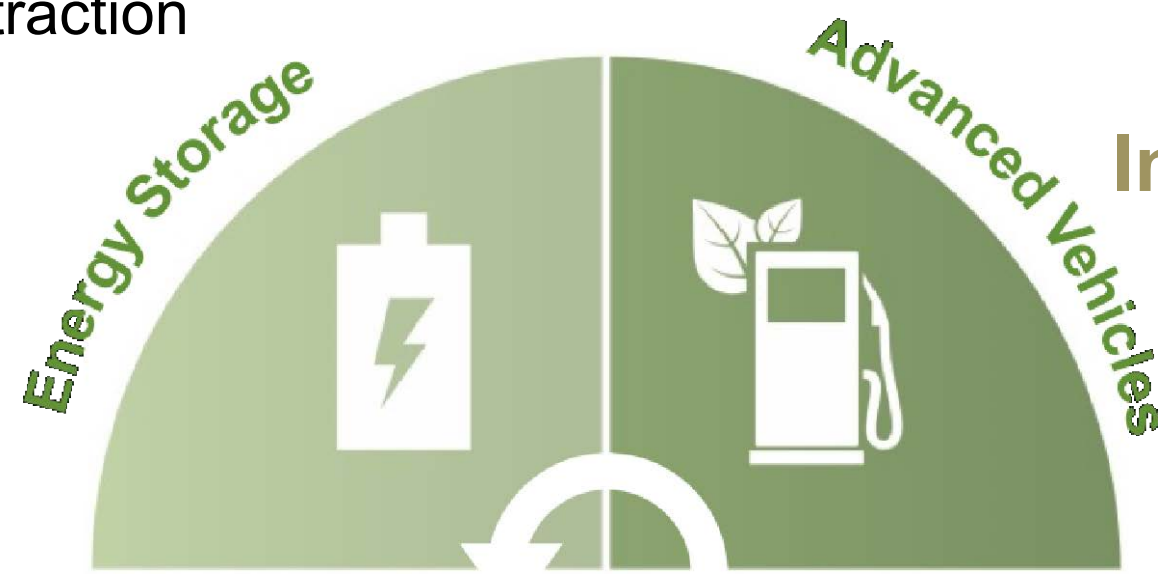
Primary Criterion	Long-term goals* (2005-2008)
ensity, W/L	460
Power, W/kg (80% DOD/30 sec)	300
Density, Wh/L (C/3 discharge rate)	230
Energy, Wh/kg (C/3 discharge rate)	150
rs	10
Life (cycles)	1000 (80% DOD) 1,600 (50% DOD) 2670 (30% DOD)
Power and capacity degradation† (% of rated spec)	20%
Ultimate price\$ \$/kWh (10,000 units @ 40 kWh)	<\$150 (desired to 75)
Operating environment	-30C to 65 C
Recharge time	< 6 hours
Continuous discharge in 1 hour (no failure)	75% (of rated energy capacity)
Secondary Criteria	
Efficiency (C/3 discharge and C/6 charge*)	80%
Self-discharge	<20% in 12 days
Maintenance	No maintenance. Service by qualified personnel only.
Thermal loss	Covered by self-discharge
Abuse resistance	Tolerant. Minimized by on-board controls.
Specified by contractor. Packaging constraints, Environmental impact, Safety, Recyclability, Reliability, Overcharge/over-discharge tolerance	



# Vehicles, Energy Storage & Infrastructure

## Using known operational conditions to understand limitations and provide solutions

- Benchmark, advanced aging and activities with USABC (Ford, GM and FCA)
- 30+ years experience in energy storage
- Advancing fundamentals of durability, reliability and safety – *high power and energy*
- Evaluation from cell level to full vehicle packs (850+ channels, up to 1000V, 440 kW)
- Standard and aggressive operating conditions
- Lab facilities for coin cell and single layer pouch cell preparation, evaluation and materials characterization
- Ability to discern kinetic and thermodynamic drivers of performance fade/failure
- Experience in pack disassembly and cell extraction



## Battery Test Center (BTC)



## Non-destructive Battery Evaluation Lab (NOBEL)



## Electric Vehicle Infrastructure Lab (EVIL)





## ***Battery Test Center***

BTC, is the lead battery life and performance testing facility for the Vehicle Technology Office. The BTC has more than 800 battery test channels with the capability from coin cell to vehicle level pack testing. The BTC uses advance diagnostics and prognostics to estimate the calendar and cycle life of different high energy and high-power battery technologies. BTC stands out because of its status as one of the nation's most reliable laboratories for third-party, independent testing of EV batteries and because it backs up that testing with its own state-of-the-art research to more accurately understand and predict battery behavior. The BTC works closely with the OEM automakers through the USABC to validate the life and performance of advanced battery systems. In addition to testing activities for USABC, the BTC is the author for all USABC life and performance battery test manuals.





## ***Non-destructive Battery Evaluation Laboratory***

NOBEL can test batteries in off normal conditions and outside the specifications. Testing can include temperature and electrochemical extremes, and mechanical stress such as vibration and shock. NOBEL has been instrumental in evaluating/developing different module/ pack level advanced diagnostics and prognostics methods.





## ***Key Battery R&D Projects***

### ***Battery 500 consortium***

Battery500 is developing the next-generation battery technologies with higher energy, lighter weight, and long cycle life to power future's electric vehicles. The overarching goal of Battery500 is to build a battery with a specific energy of 500 Wh/kg. Li metal-based batteries, such Li-Sulfur and Li-High Ni content NMC, hold the great potential due to high energy density. However, they suffer from short cycle life. INL is addressing these issues in terms of building stable SEI on anode surfaces, rationally designing cells, optimizing testing conditions, and increasing utilization of cathode materials as well as improving the electrode kinetics.

### ***Enabling extreme fast charging (XFC)***

Extreme fast charging (XFC) has a goal to recharge a LIB in <10 min at a charging rate of >6C. INL, as one of partners in the DOE-sponsored eXtreme Fast Charge Cell Evaluation (XCEL) program, is identifying the bottlenecks of applying such high rates to batteries and the relevant implications to performance, life and safety.

Understanding of the implications of XFC to battery is crucial to optimize material, electrode and cell design, and operating conditions to enable XFC targets.



## ***Key Battery R&D Projects***

### ***Enabling advanced diagnostics, prognostics and life prediction for improving battery performance and safety***

INL has also developed a significant leadership in battery cell level diagnosis, prognosis, and failure analysis. Notable techniques include quantitative electrochemical analyses, pressure-induced cell performance improvements, fast diagnosis of failure mechanisms and lifetime prediction, and quantification of performance metrics to aid cell design and performance improvement strategies using standardized testing protocols. INL is also extending some of these cell level diagnostics to module and pack levels to identify imminent safety critical issues and faults that could potentially develop into a safety critical fault down the road.

### ***Physics-based Machine Learning***

Testing of batteries in this manner can take upwards of a year to make reasonable estimations of life and to clearly identify failure modes and rates. The need to shorten the design and testing cycle is critical. *Connection of physics-based life models and machine learning (ML) provides the opportunity to enable more robust assessment of battery aging, failure mechanism identification and understanding as new use case scenarios are proposed.* The current project sponsored by DOE is focused on means to apply ML to enhance the estimation of life while also identifying key failure pathways.



## ***Electric Vehicle Infrastructure Laboratory***

EVIL develops and evaluates solutions for EV charging infrastructure integration with the electric grid. The research activities include high power EV charging grid interaction, cyber-physical security, EM-field safety, and operational performance characterization. These research areas primarily focused on conductive charging and wireless charging technologies.

- Grid integration interaction of emerging EV charging infrastructure technologies
- Wireless power transfer (WPT) electromagnetic-field (EM-field) safety for stationary & in-motion WPT: design, develop, and verification testing
- Cyber-physical security assessment, analysis, penetration testing, and mitigation solution development for high-power EV charging infrastructure
- Characterization of high power EV charging infrastructure



*High-power conductive charging (350kW)  
for light, medium, and heavy duty EVs*





## ***INL Research Leadership***

- Energy & Environment S&T – Seth W. Snyder
- Energy Storage and Advanced Transportation – Eric Dufek
- Battery Testing and Validation – Lee Walker
- Battery Materials – Tanvir Tanim
- Vehicle System – John Smart
- Charging Infrastructure – Tim Pennington
- Cyber Security – Richard “Barney” Carlson
- Battery Recycling – Dan Ginosar

<https://cet.inl.gov/SitePages/Home.aspx>

<https://am.inl.gov/SitePages/Home.aspx>

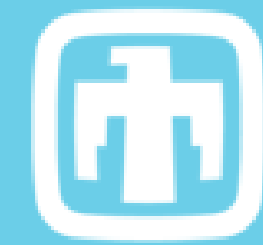
- INL Voucher Representative: Dustin Crowton, [Dustin.Crowton@inl.gov](mailto:Dustin.Crowton@inl.gov)





Idaho National Laboratory





Sandia  
National  
Laboratories



CENTER 2500  
**CSEP**



COMPONENT SCIENCE, ENGINEERING, & PRODUCTION



# Power Sources Products & Capabilities

July, 2020

*PRESENTED BY*

**Kyle Fenton, PhD**

**Manager, Power Sources R&D**



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# Power Sources Technology Group portfolio



**Nuclear Deterrence**



**National Security**



**Transportation Energy**



**Stationary Storage**

**Energy Storage Technologies**

**Core Competencies and Capabilities**



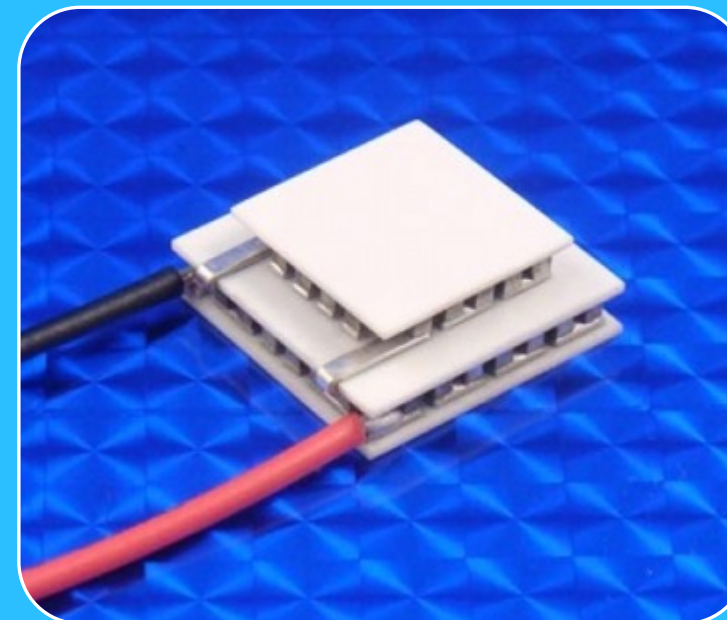
# Power Sources Technology Group products



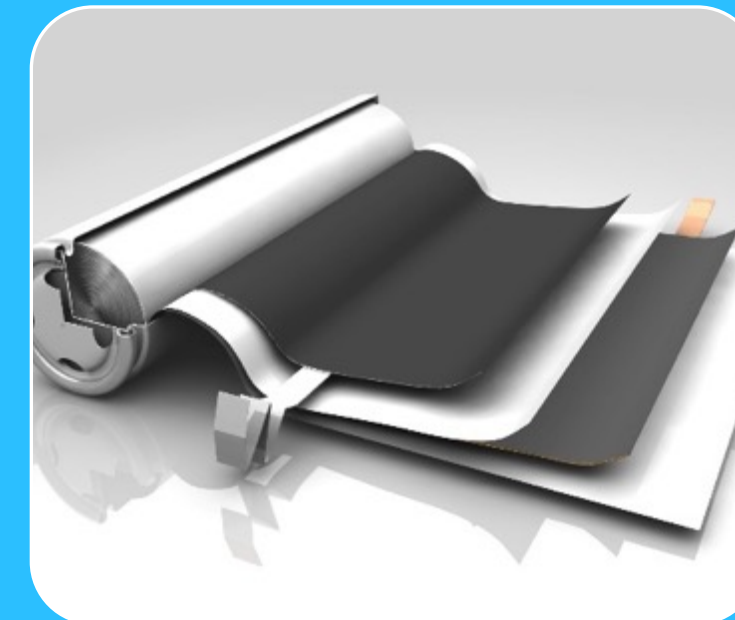
**Thermal Batteries**



**Li-Primary Batteries**



**Conversion  
Technologies**



**Lithium-ion Batteries**

**Manufacturability**

**Agility**

**Strategic Materials**



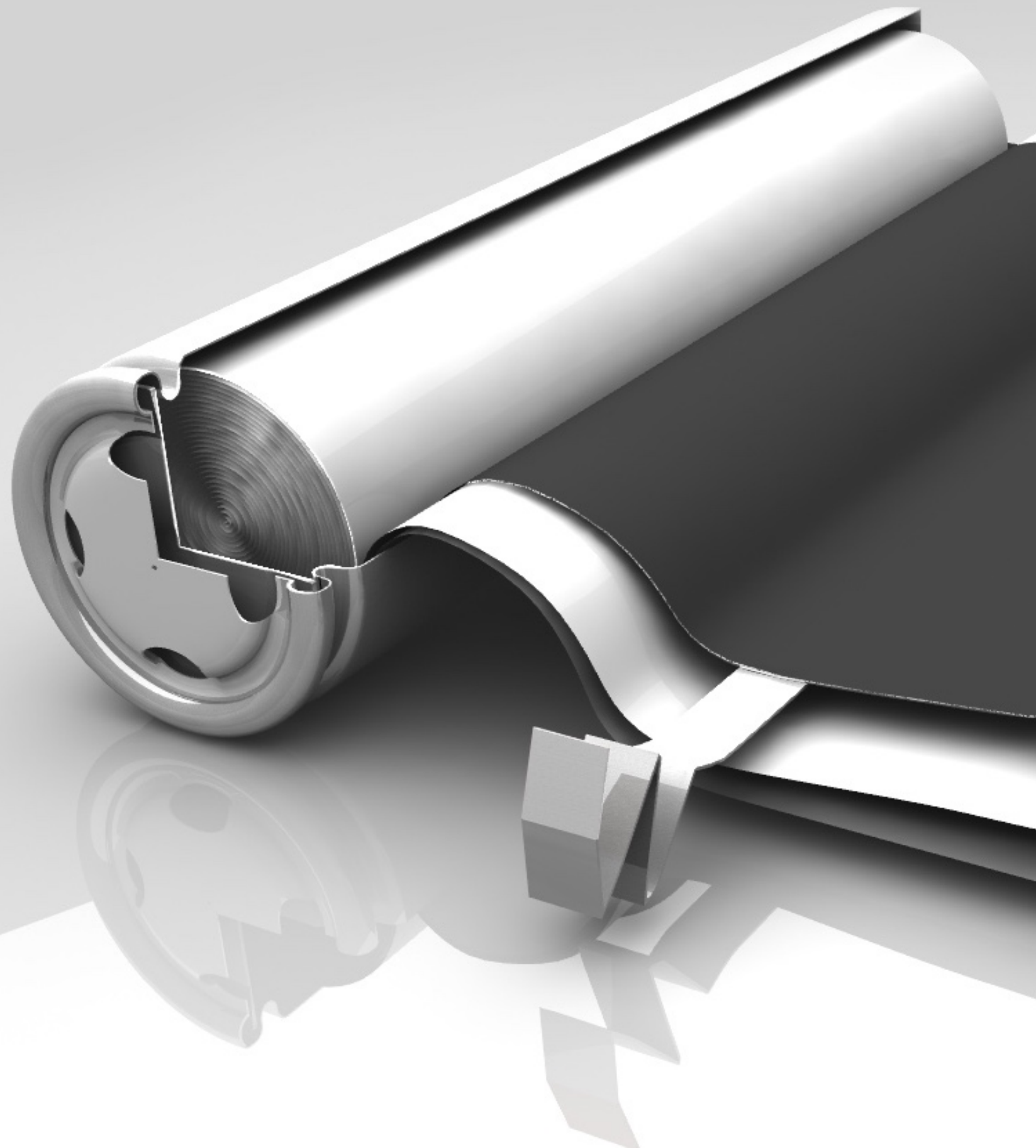
# Program support & collaboration examples











## Needs for prototyping capabilities:

- Customizable solutions
- Control over materials/processes
- Small lots
- Flexibility and agility across programs and customers

## Core Competencies:

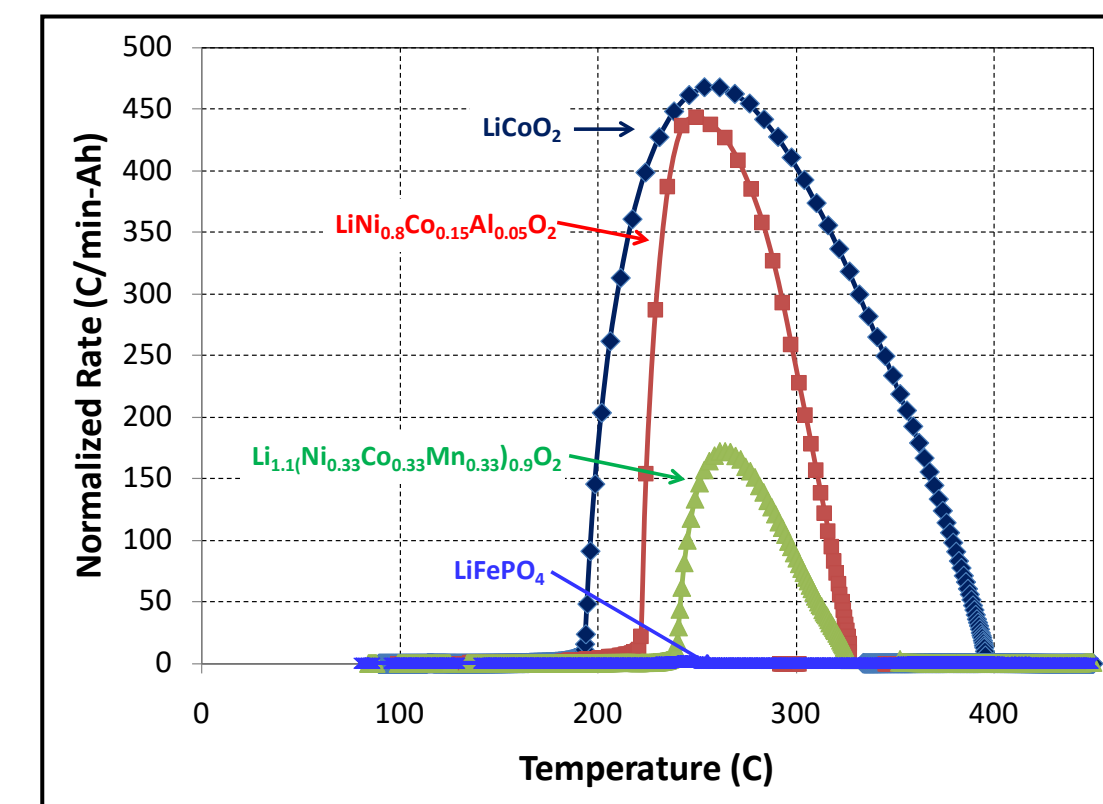
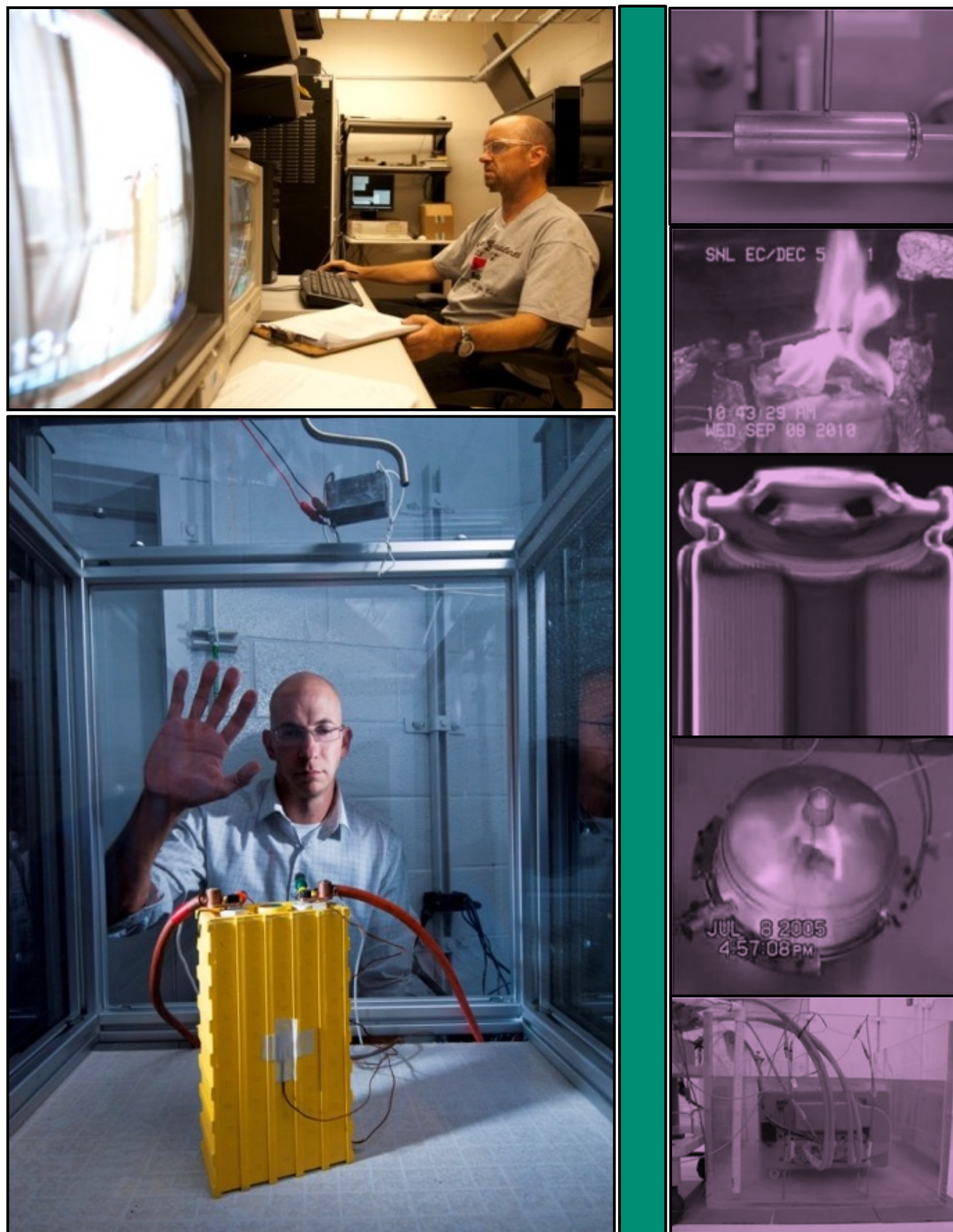
- Thermal batteries
- Lithium-ion cells & batteries
- Lithium cells & batteries
- Conversions technologies



# Battery Abuse Testing Laboratory (BATLab)



- Comprehensive abuse testing platforms for safety and reliability of cells, batteries and systems from mWh to kWh
- Mechanical abuse
  - Penetration
  - Crush
  - Impact
  - Immersion
- Thermal abuse
  - Over-temperature
  - Flammability measurements
  - Thermal propagation
  - Calorimetry
- Electrical abuse
  - Overvoltage/overcharge
  - Short circuit
  - Over-discharge/voltage reversal
- Characterization/Analytical Tools
  - X-ray computed tomography
  - Gas analysis
  - Surface characterization
  - Optical/electron microscopy





# Additional capabilities



- 8,000 sq. ft. dry room space
- Prototyping for thermal batteries, Li primary, and Li-ion cells and batteries
- Battery design & development
- Performance and abuse testing
- Synthesis of battery materials
- Forensics and analysis
- Fundamental electrochemistry
- Modeling and simulation
- Environmental testing
- High hazard test facilities (Burn Site)





# Dedicated facility for battery testing



- Hundreds of independent channels for testing, from coin cells to kWh modules
- 150  $\mu$ A to 2000 A current range capability
- R&D 100 Green Technology-awarded high-precision testers
- 70+ thermal chambers, ranging from 1.2 ft<sup>3</sup> to 25 ft<sup>3</sup>
- -72°C to 95°C temperature capabilities
- Static-controlled assembly benches
- Welding capabilities, including resistance, pinch, and spot



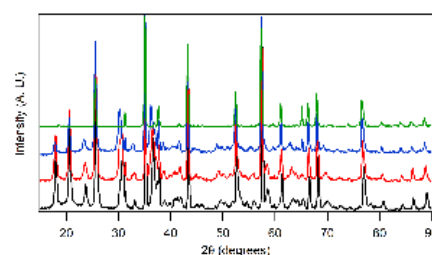




## SELECT PROGRAM HIGHLIGHTS



# Power sources safety R&D portfolio



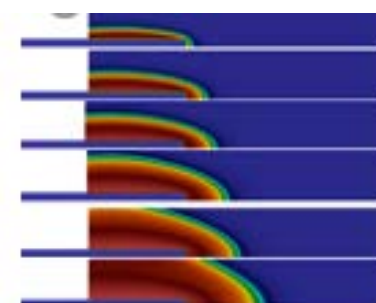
## Materials R&D

- Thermal stability and impact of aging on battery components
- Vent gas composition



## Cell and Module Safety Science

- High precision cell cycling and degradation
- Electrical, thermal, mechanical abuse testing
- Failure propagation testing on batteries/systems



## Simulations and Modeling

- Multi-scale models for understanding thermal runaway
- Fire Dynamic Simulations to predict the size, scope, and consequences of battery fires



## Procedures, Policy, and Regulation

- Energy storage safety working group
- IEEE battery management system standard



# Approaches to designing in safety



The current approach is to test our way into safety.

- Large system (>1MWh) testing is difficult and costly.

Supplement testing with predictions of challenging scenarios and optimization of mitigation.

- Develop multi-physics models to predict failure mechanisms and identify mitigation.
- Build capabilities with small/medium scale measurements.
- Still requires some testing and validation.



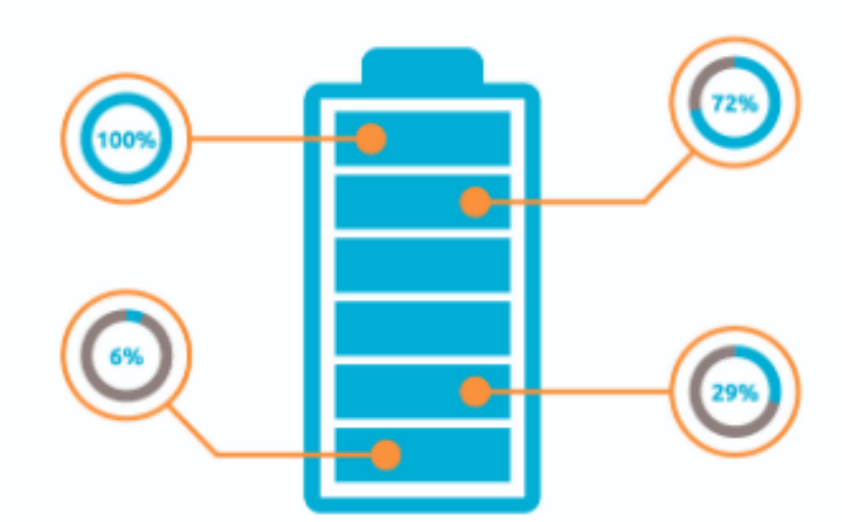




## BatteryArchive.org

A repository for easy visualization, analysis, and comparison of battery data across institutions

View Data



## Features

1

Filter battery data

Cell list							
Name: Cell list							
Columns: Capacity (Ah) Temperature (°C) Min SOC Max SOC Discharge Rate							
100% 20% 10% 5% 1% 0.1% 0.01% 0.001% 0.0001% 0.00001% 0.000001% 0.0000001% 0.00000001% 0.000000001% 0.0000000001%							
Cell ID	Capacity (Ah)	Temperature (°C)	Min SOC	Max SOC	Discharge Rate	Discharge Rate	Discharge Rate
SPAL_000001_001	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_002	2.030	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_003	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_004	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_005	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_006	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_007	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_008	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_009	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_010	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_011	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_012	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_013	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_014	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_015	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_016	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_017	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_018	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_019	2.040	12.0	1.0	25.00	10.00	0.00	10.00
SPAL_000001_020	2.040	12.0	1.0	25.00	10.00	0.00	10.00

Query and filter for specific experimental conditions.

2

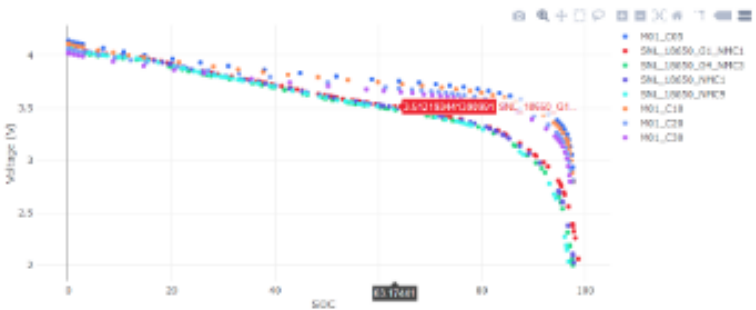
Visualize and compare data



Display battery data, including voltage curves and capacity fade.

3

Compare data with models



Apply performance and degradation models to battery data.



# Energy Storage Field Demonstrations

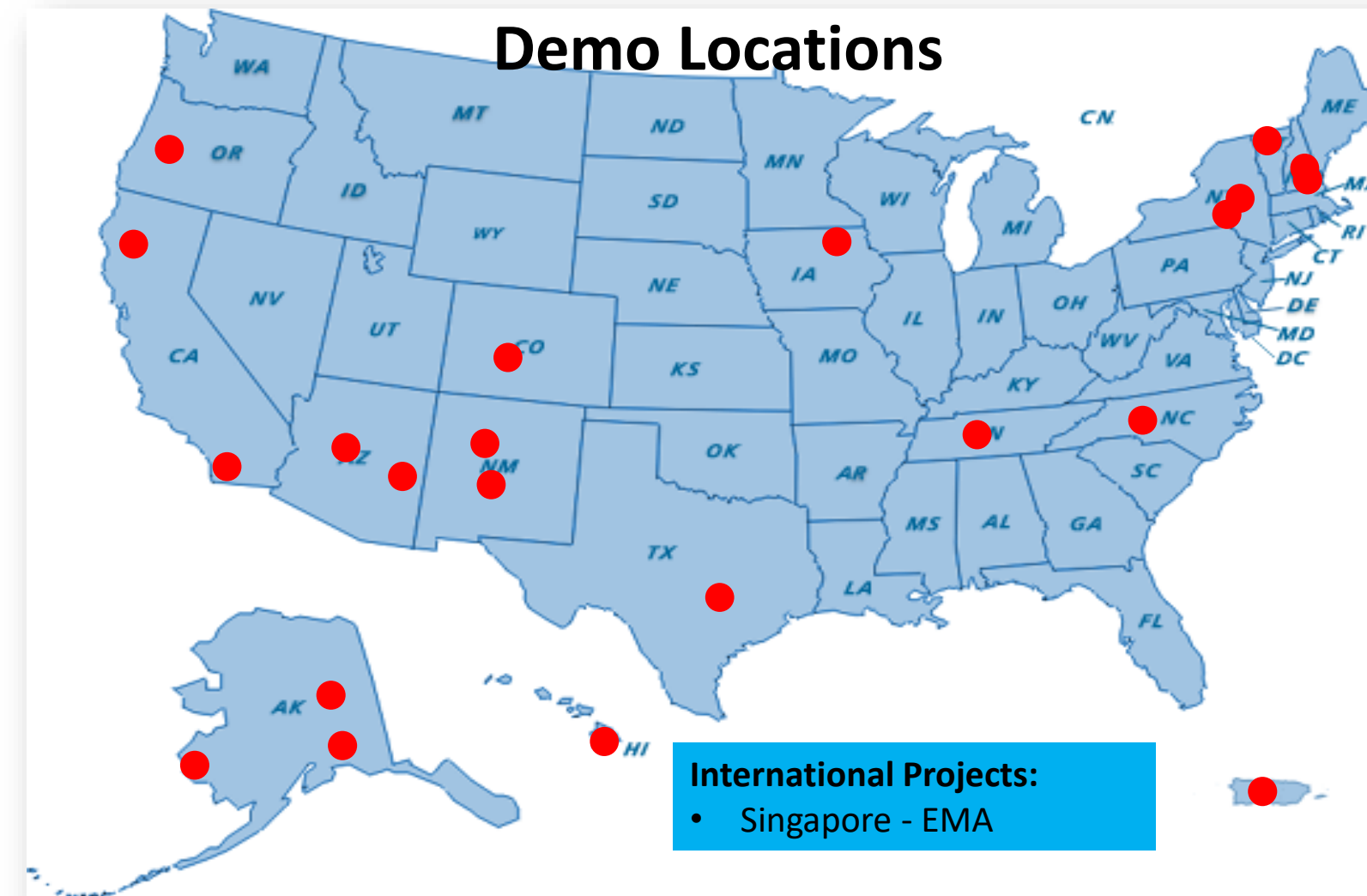


## Collaborate with Utility, Industrial, Commercial, Private, State and International entities to:

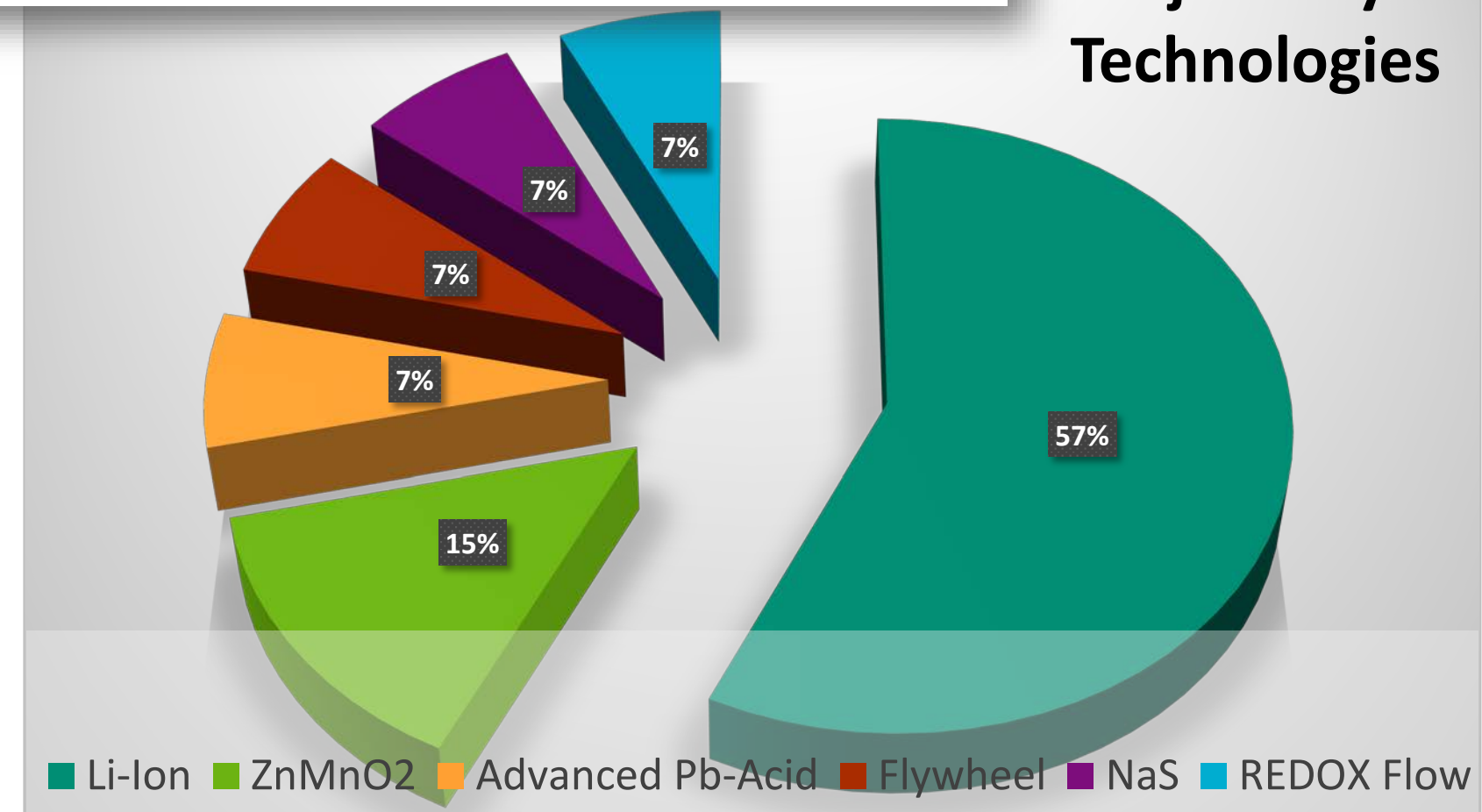
- Provide third party independent analysis for cells and systems
- Support the development and implementation of grid-tied ES projects
  - Application/Economic analysis
  - RFI/RFPs
  - Design and Procurement Support
  - Commissioning Plan Development
- Monitor, collect and analyze operational data
  - Various applications
  - Optimization of energy management and lifecycle
  - Operational performance (State of Health, Degradation, etc.)
- Develop public information programs

## Goal

- Inform the public, work with standard groups and encourage investment



## Projects by Technologies

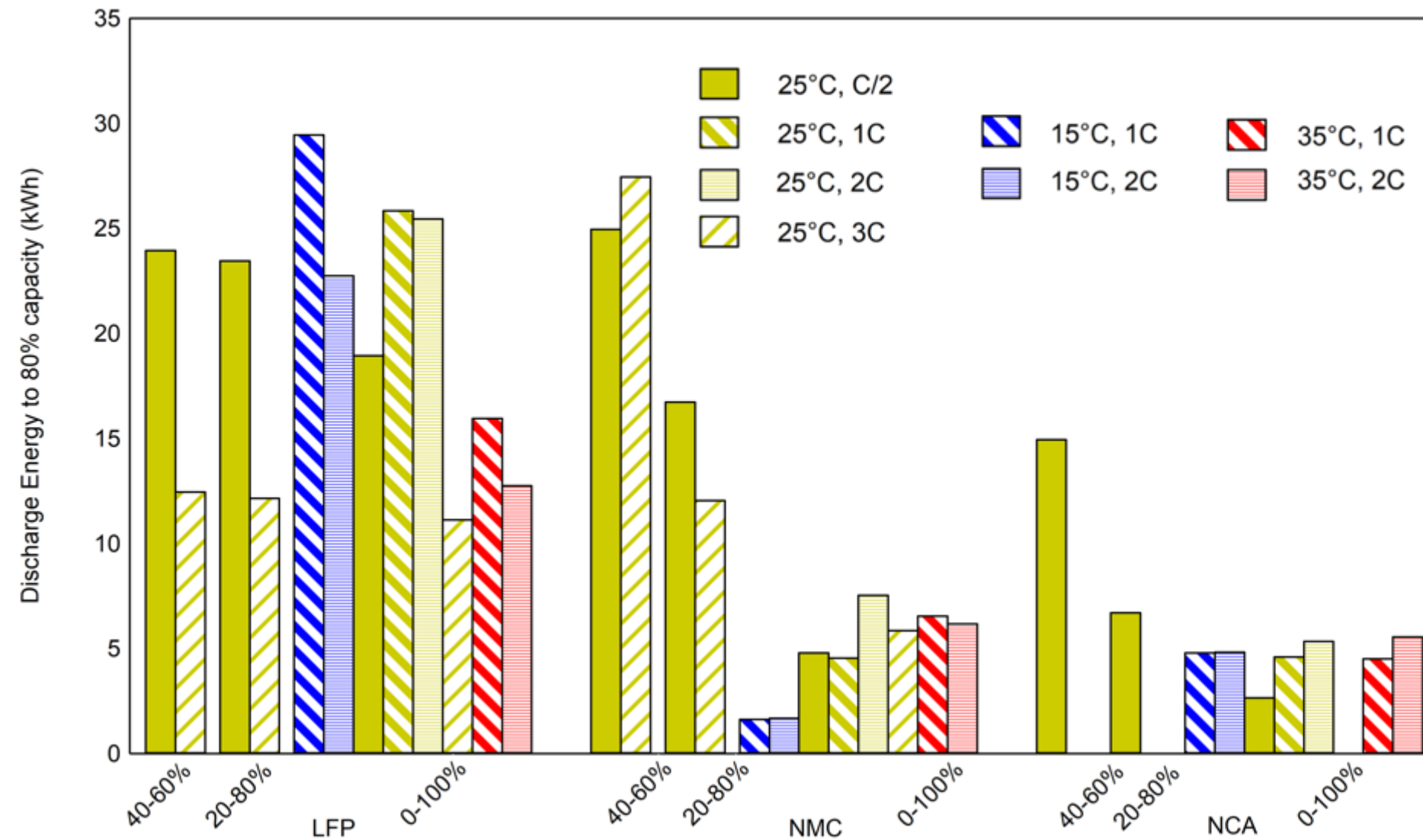




# Commercial Battery Analysis



Quantify performance of popular Li-ion cells in apples to apples approach and identify 'tipping points'



Link cell-level performance to system level performance



Performance Data

Determine

- Degradation
- State of Health
- Predicted Life Cycle
- Etc.





# Leveraging broad Sandia capabilities



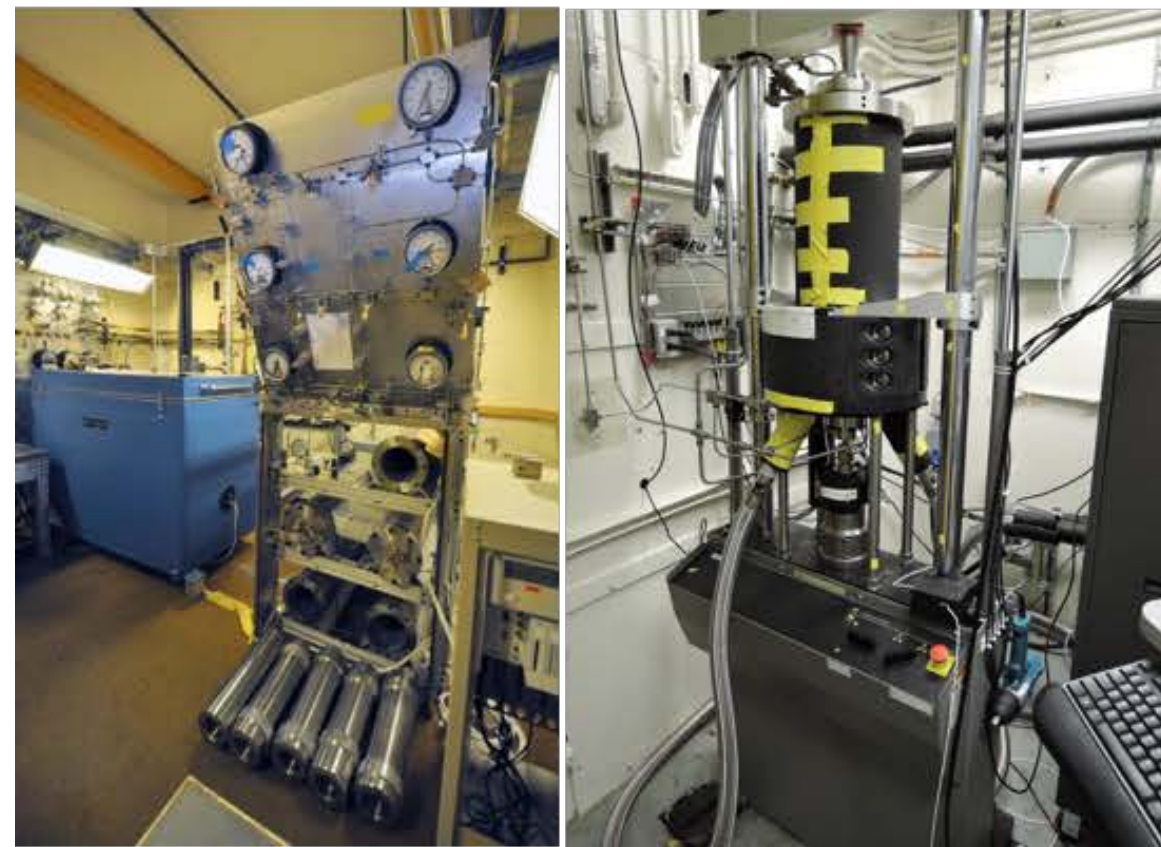
MESA MICROFAB  
(ND)



JOINT BIO-ENERGY INSTITUTE  
(AST)



COMBUSTION RESEARCH FACILITY  
(AST)



MATERIAL MECHANICS IN HIGH-PRESSURE  
HYDROGEN FOR NUCLEAR WEAPONS  
& ENERGY SCIENCE  
(ND) & (E/HS)



COMPUTING & INFORMATION SCIENCE  
(ND & AST)



CENTER FOR INTEGRATED  
NANO TECHNOLOGIES  
(AST)



# Break

Please return at 12:30 p.m. ET for presentations from Phase II teams.

Coming up next...

12:30 – Team Umicore

12:40 – Team LIB-IoT

12:50 – Team Powering the Future

1:00 – Team OnTo Technology

1:10 – Team Renewance

1:20 – Team RRCO







# Lithium-Ion Battery Recycling Prize

Phase II Team Presentations



U.S. DEPARTMENT OF ENERGY



U.S. Department of Energy  
LITHIUM-ION BATTERY RECYCLING PRIZE

# Store Packs Umicore

## XEV Collection & Storage Network





# Team Introduction

## Team Members:

- Mark Caffarey: President, Umicore USA
- Erika Warner: North American Battery Recycling Coordinator, Umicore USA
- Casey Westhoff: US Government Affairs Manager, Umicore USA

## Phoenix Group Metals

- Nathan Laughlin: Operations Manager
- Matthew Steger: Regional General Manager

## Spiers New Technologies

- Bryan Schultz: Director of Engineering

## Schnitzer Steel Inc:

- Judodine Nichols: VP of Innovation
- Thomas Novak: VP of Business Development

## United Catalyst Corporation:

- Becky Berube: President





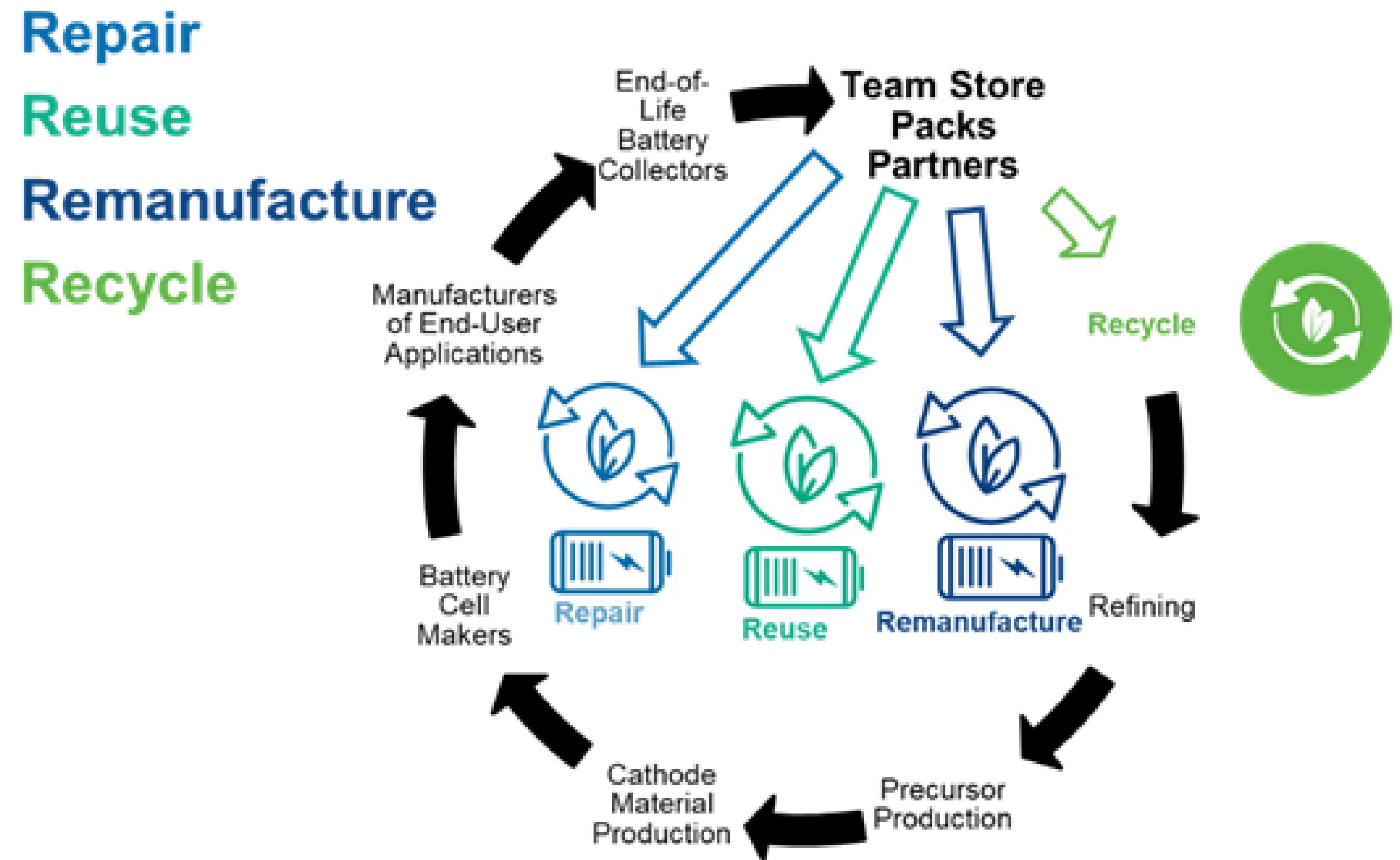
# Concept Overview Information

- Umicore is working with the following four partners to create a xEV EOL storage & collection program for batteries that end up at automotive scrapyards; Phoenix Group Metals (PGM), Schnitzer Steel Inc., United Catalyst Corporation (UCC), Spiers New Technologies (SNT).
- Our goal is to service the parts of the value chain that are presently being missed (automotive scrapyards) and educate these stakeholders now before the industry is flooded with end of life Li ion vehicle battery packs in the next 5 to 10 years. Currently there is no outlet for automotive scrapyards that collect small number of xEV batteries.
- PGM, Schnitzer Steel, and UCC will all serve as collection locations across the United States. These sites will all have EPA Identification numbers, and be NFPA, DOT, and IMDG compliant in order to properly handle and store xEV EOL batteries.
- Our partners are geographically diverse giving us access to all major US metropolitan areas.



# Concept Overview Information

- When our sites collect enough batteries from automotive scrapyards to meet the requirements for a full shipment, batteries will be shipped to SNT for assessment of potential second life opportunities. Batteries that do not have second life potential will be sent to a certified recycler for recycling.





# Potential Voucher Uses

- **Simplified way to measure state of health (SOH) of batteries for our partner locations**
  - A key aspect of our project is ensuring that electric vehicle (EV) and hybrid electric vehicle (HEV) battery packs live to their fullest potential and have the least environmental impact possible. This includes both recycling and second life. Therefore, we have partnered with Spiers New Technologies (SNT), an expert in second life technology, who can ensure that batteries will be tested for second life potential before they are recycled.
- **Prevent batteries going to SNT only to be immediately tagged for recycling**
  - Create a technology intervention that can be used at collection sites prior to batteries being shipped to SNT
  - This potential technology intervention would save time, money, and decrease environmental impact of the battery. With this intervention, only batteries that have second life potential would go to SNT, and the rest would be sent directly from our other team members to a certified recycler.
- **With the assistance of the national labs we envision creating a device that allows for our partner sites to measure the SOH of EV or HEV batteries that come into their possession.**
  - The device would be small, portable, and something that could be distributed to many locations across the United States.



# Contact Information

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**Casey Westhoff, Government Affairs Manager  
Umicore USA Inc.**

**[casey.westhoff@am.umicore.com](mailto:casey.westhoff@am.umicore.com)**

**919-641-1351**

**Erika Warner, Battery Recycling Coordinator  
Umicore USA Inc.**

**[erika.warner@am.umicore.com](mailto:erika.warner@am.umicore.com)**





## Cloud & IoT System for LIB Collection & Management



Outline:  
Team Introduction  
Concept Overview Information  
Potential Voucher Uses



# Team Introduction

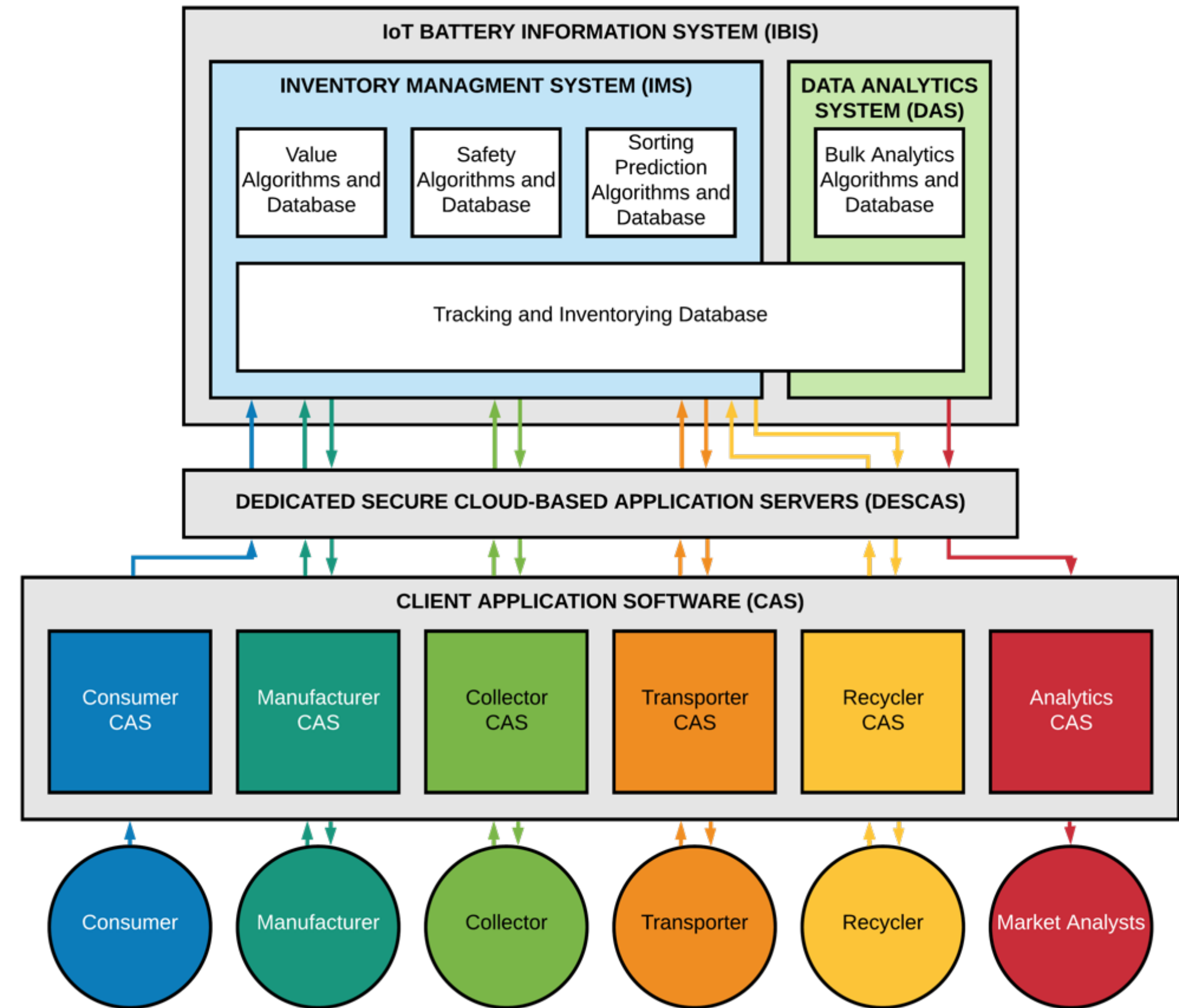
- ❖ Lithium-Ion Batteries and The Internet of Things (LIB-IoT) is a recently created research and technology development business line focusing on technologies and practices related to lithium-ion batteries
- ❖ The team has extensive experience in the field of LIBs and includes engineers, IT experts, and cyber security specialists with expertise in:
  - Cloud-based IT systems and cyber security
  - Battery technology, usage, and life-cycle
  - Data analytics and computational modeling
  - Infrastructure asset management systems
  - Business development and marketing





# Concept Overview Information

- ❖ The LIB-IoT concept centers around establishing a unique ID for end-of-life batteries, enhancing collection, and tracking LIBs and their components through the recycling process
  - Using data from consumers and other sources, it provides sorting criteria, quantifies extractable value, manages risk, etc.
- ❖ LIB-IoT implements novel IoT labeling standards, such as RFID, to associate collected data with individual batteries to populate a cloud-based database
  - Cloud-based approach facilitates scalability and real-time accessibility by multiple users in many locations





# Concept Overview Information (cont'd...)

- ❖ LIB-IoT will also enable users of the cloud-based database system to access a proprietary Battery Exchange and Auction Marketplace (BEAM)
  - This platform will provide a mechanism for holders of batteries to make the industry (battery repurposers and recyclers) aware of the availability of batteries, including quantities and specific information about them
  - LIB-IoT may act as an intermediate to aid in negotiations and optimize value to both the battery owners and repurposers/recyclers
- ❖ This cloud-based system will provide an economic incentive to both industry members and to individuals, which will improve the rate at which batteries are recycled



# Potential Voucher Uses

1. As a part of the concept, LIB-IoT will be creating cloud-based analytics and data processing algorithms

- Voucher Service Providers (VSPs) may support the development of data processing analytics and algorithms by:
  - Availing existing software packages for SOH estimation
  - Providing battery models and/or data to create said models
    - Models may be created to quantify materials, second life potential, predicted volumes of batteries to be recycled, and more
  - Providing expertise and consultation on algorithm development



# Potential Voucher Uses (cont'd...)

2. LIB-IoT will also be generating data through in-house LIB testing

- VSPs may support in-house testing of LIBs by:
  - Aiding in development of dedicated testing equipment configurations
  - Providing access to existing testing equipment for trials

3. Data will also be sourced through existing battery management system (BMS) interfaces

- VSPs may support the development of BMS and data interfaces for:
  - Existing and
  - Next generation BMSs



# Team Clarios:

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- Powering the Future





# Team Introduction

❑ Clarios



Partners (in alphabetical order)

❑ Battery Resourcers



❑ Environmental Restoration



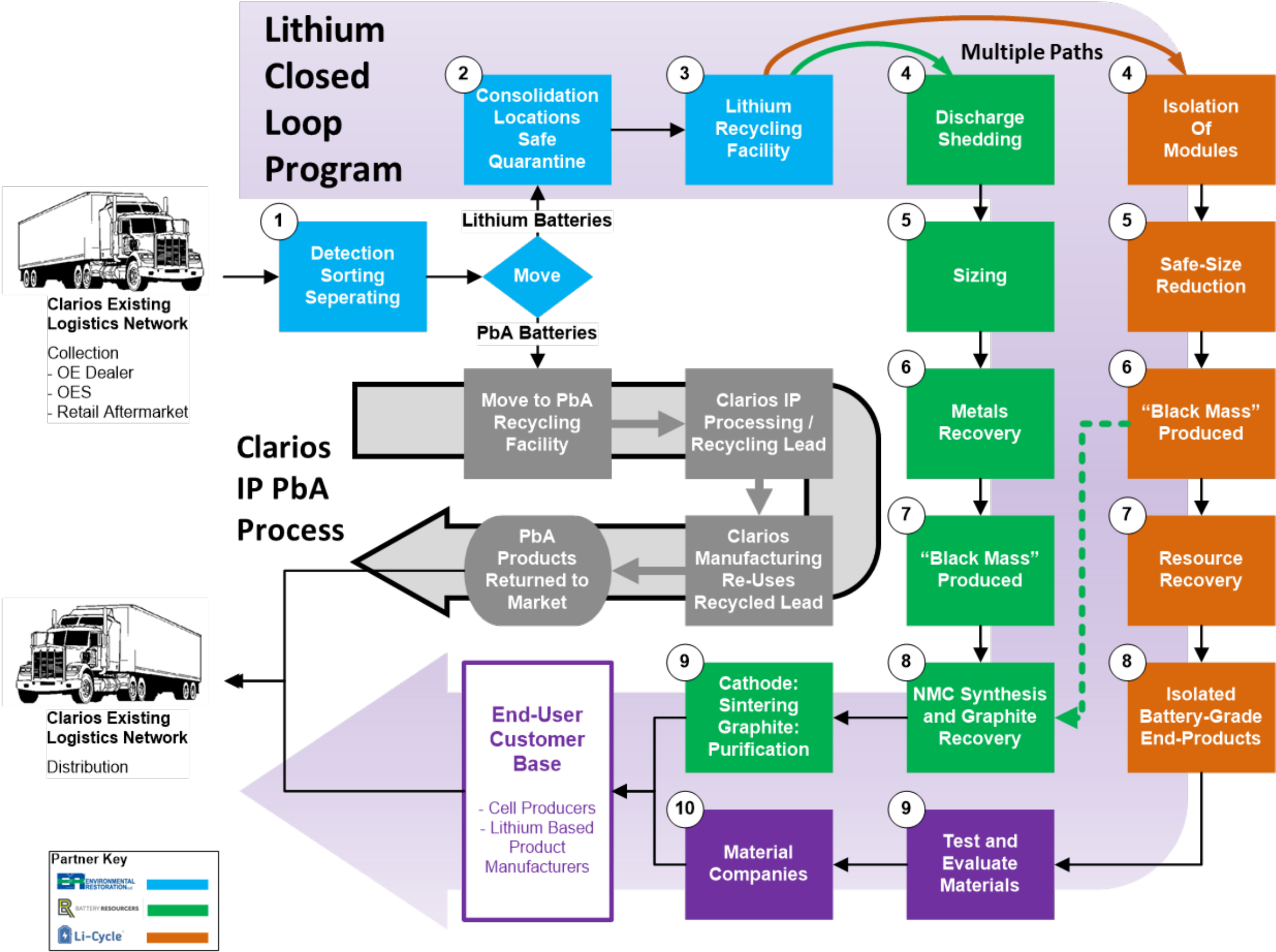
❑ Li-Cycle





# Concept Overview Information

## Powering the Future Team



- ❑ Clarios: Collection Network and Customer Channels
- ❑ Technology Partners: lithium critical mineral recycling and other cell components
- ❑ Logistics partner: transporting lithium-ion batteries
- ❑ Detection Technology: process and equipment development and installation



# Potential Voucher Uses

Task 1: Cathode material quality analysis and Purity Evaluation

Task 2: Cell performance evaluation (pouch or coin cell)

Task 3: Hard Case Cell Build and evaluation



# Detail of Voucher Use

## **Task 1) VSP to conduct: BR Cathode Powder Quality Analysis and Li-Cycle Pre-Cursor Purity Evaluation**

- ☐ Analyze Lithium metal ratio content
- ☐ Analyze Nickel, Manganese, Cobalt ratio
- ☐ Evaluate Impurity levels: Fe, Cu, Al, Cr, Zn, Ca, Mg, Na, K, S
- ☐ Analyze for: LiOH content, Li<sub>2</sub>CO<sub>3</sub> content, H<sub>2</sub>O content
- ☐ Analyze Surface Area, Particle size distribution, Tap density
- ☐ Analyze Crystallographic properties
- ☐ Electro-chemical analysis: First Charge Capacity/First Discharge Capacity – coin cell half cell
  - ☐ Measure discharge resistance (mOhm/cm<sup>2</sup>)
  - ☐ AC Impedance
- ☐ Evaluate precursor materials made by Battery Resourcers and Li-Cycle from recovered battery materials. in comparison to commercially available materials. The following materials to be tested for purity and quantities of other constituents (on ppm basis), preferably by ICP: cobalt sulphate, nickel sulphate and lithium carbonate.



# Detail of Voucher Use

## **Task 2) VSP to conduct Cell performance - 1 Ah Pouch - Cells preferred, Full coin cell acceptable if pouch cells unavailable**

- ☐ Team would like to request VSP's support building cells by using the cathode materials produced by Battery Resourcers and evaluate the performances of the cells and compare with the control cells made with new materials.
- ☐ Would like VSP to use BR's recycled materials to coat electrodes based on Clarios' specs.
- ☐ Would like VSP to use commercial materials to coat electrodes based on Clarios' specs.
- ☐ Would like VSP to test statistically significant number of half cells (cathode vs lithium) to determine utilization (mAh/g) of the cathode materials with both electrode designs.
- ☐ High Temp calendar life storage (70°C, 60°C, 45°C @ 100% and 50% SOC)
- ☐ Cycle Life Testing: 1C/1C 5C/5C, 10C/10C, 15C/15C
- ☐ Tear down analysis @ 10%, 20%, 30% DCIR increase
  - X-Ray Crystallography on cathode to compare to commercially available powder
  - Check the capacity (mAh/g), using lithium half cell.
  - Measure discharge resistance (mOhm/cm<sup>2</sup>)
  - AC Impedance



# Detail of Voucher Use

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## Task 3) VSP to 10Ah Hard-Case Cell Build and Performance evaluation

- ☐ After proven the quality and performance, ask VSP to make preferably hard-case 10Ah cells.
- ☐ Storage Test: under 80°C, 70°C, 60°C, 45°C at 50% and 100% SOC.
- ☐ Would also like cycle life (1C/1C, 5C/5C, 10C/10C, 15C/15C) at an elevated temperature 25C°, 45C° and 60C°. (3 cells per condition)
- ☐ Additionally, would like 20 more cells for characterization test.



# OnTo Technology

**DISCC: Towards a circular economy**  
Deactivate, Identify, Sort, Cut, Cathode-Healing



U.S. DEPARTMENT OF ENERGY





# Team Introduction



**Steve Sloop, Ph.D.**

Founder and President of OnTo  
Pioneer in direct recycling  
14 patents



**Lauren Crandon, Ph.D.**

Chemical & Environmental engineer  
Expert in nano-particulate  
environmental health & safety



**Marc Gossack**

30 yrs experience in systems  
engineering, software architecture  
design, hardware automation



**Talon Swanson**

Environmental Health & Safety,  
Seattle King County Metro Transit



**Dylan Howes**

VP, Global Business Development  
Shape Technologies Group.



**Michael Lerner, Ph.D.**

Oregon State Univ. program director  
World leader in solid state materials.



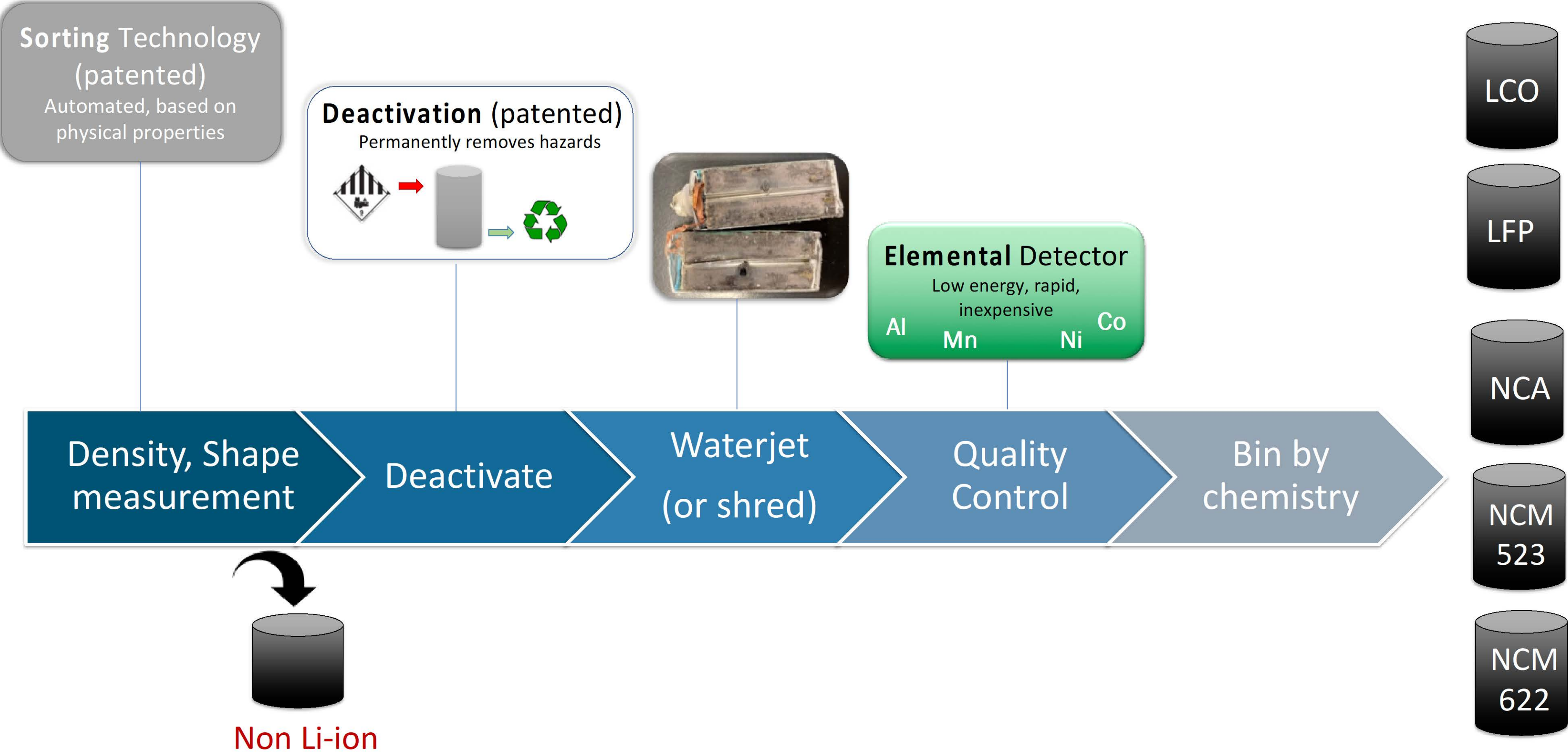
**Josie Alberts**

Graphic designer, skilled in CNC  
cutting software



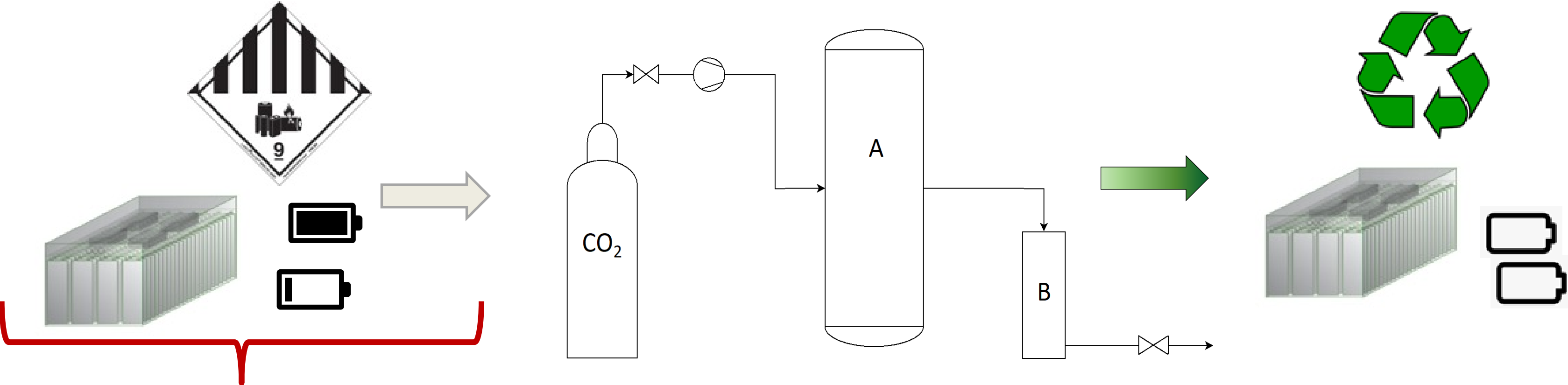


# Sorting-Concept Overview Information

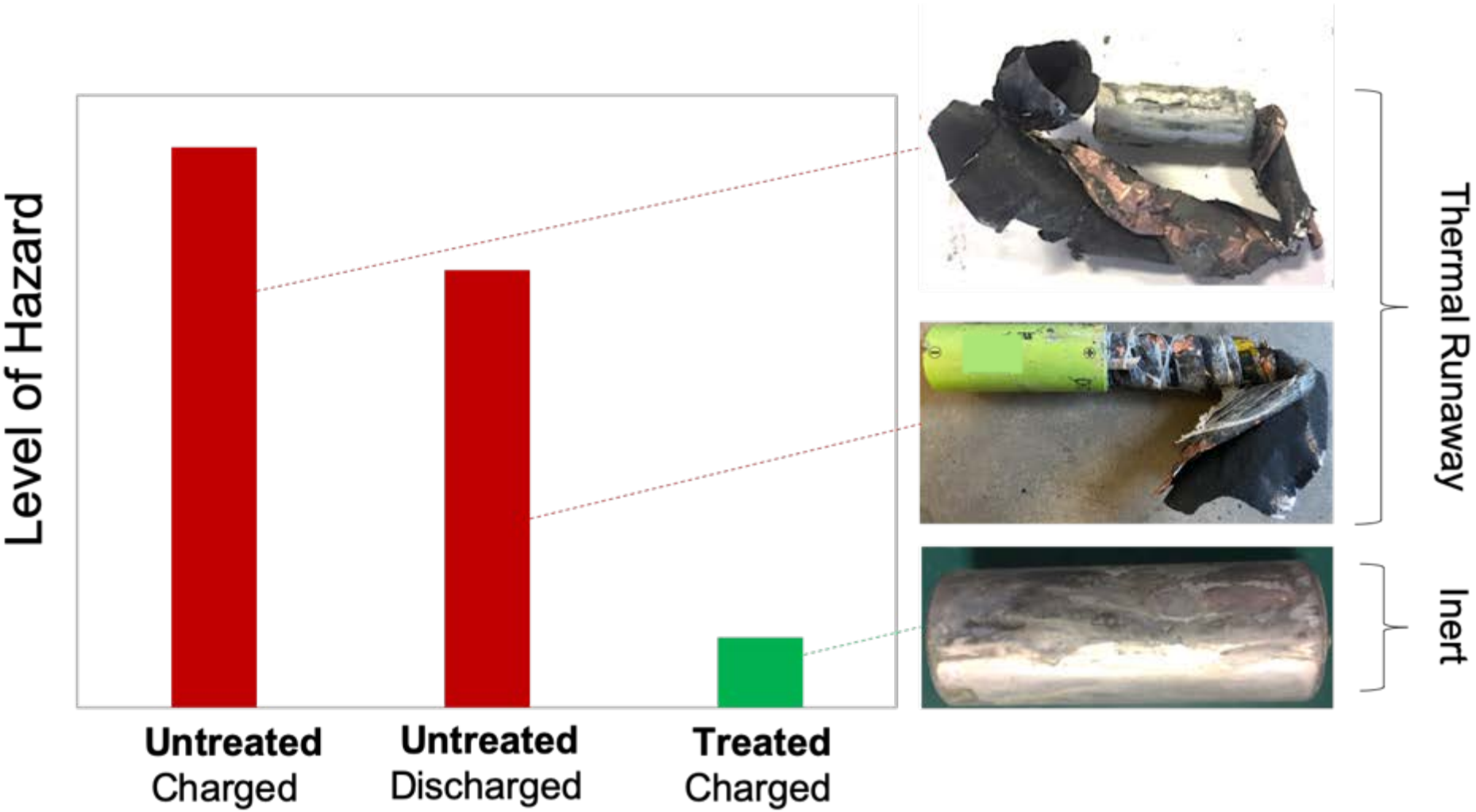




# Deactivate



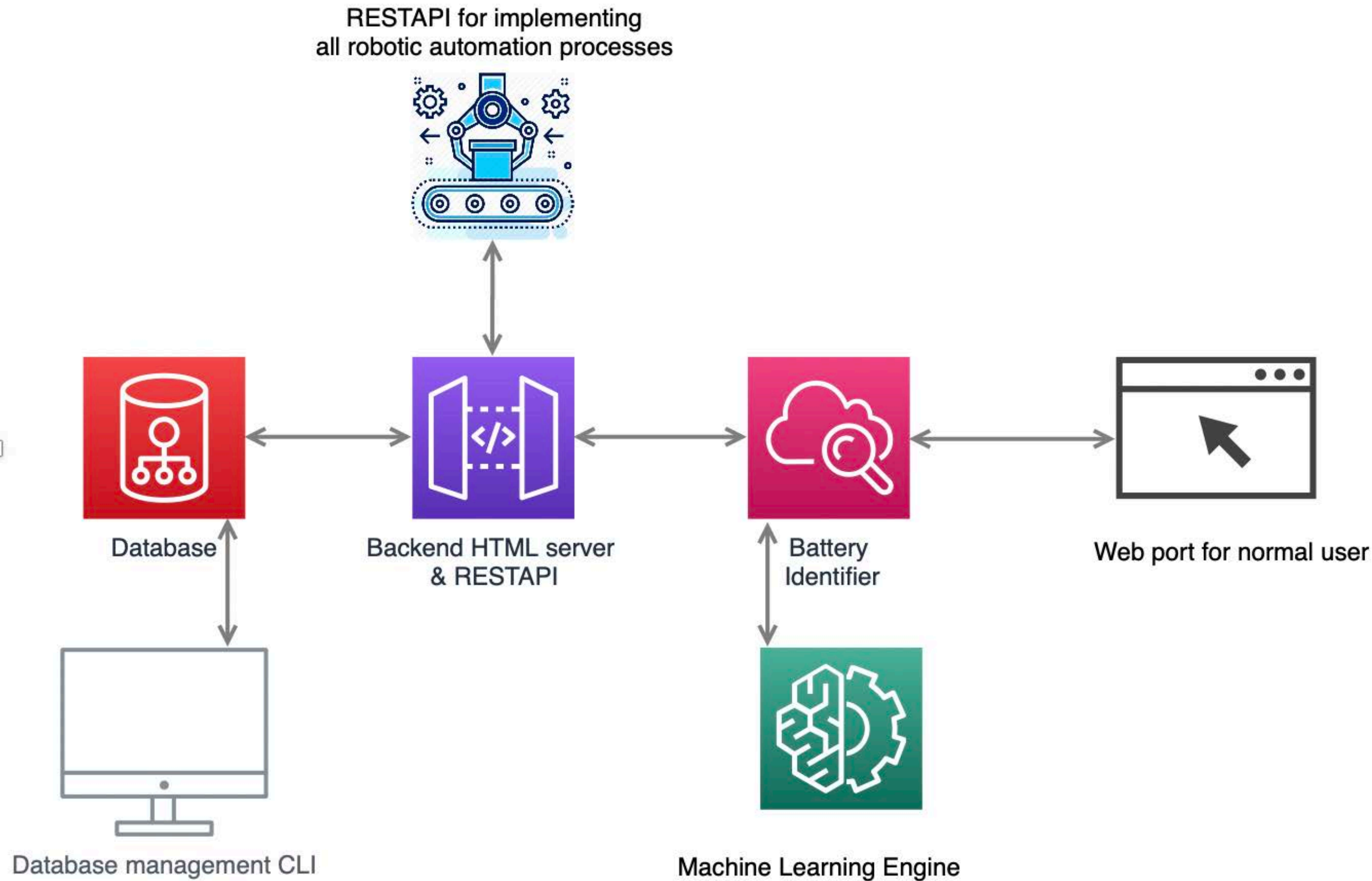
Any: State of charge  
State of health  
Chemistry  
Format



Patents: 8,497,030; CN102160220A; 7,198,865, and pending

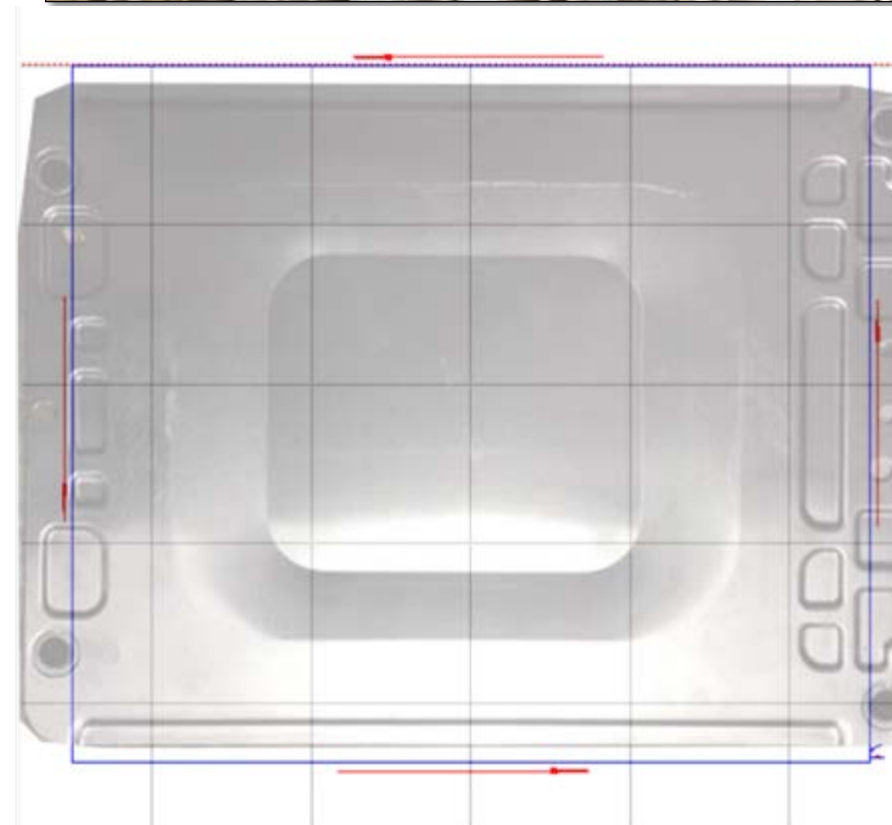
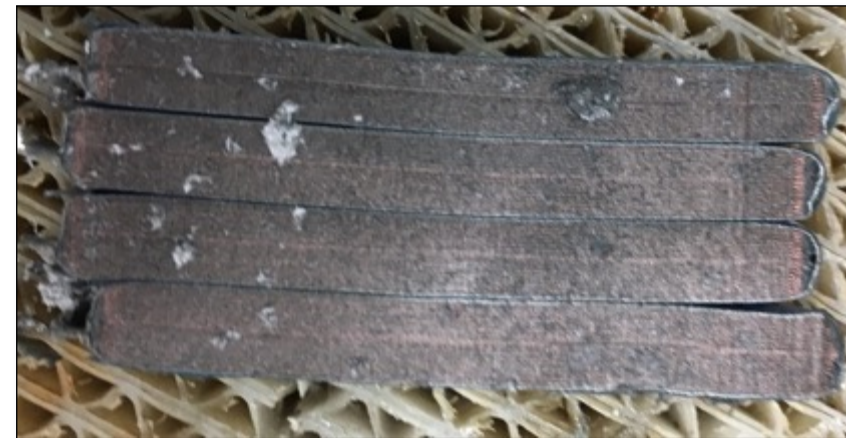


# Identify & Sort





- Waterjet disassembly
- Safe
- Readily programmable for each pack/cell
- Improves purity and yield

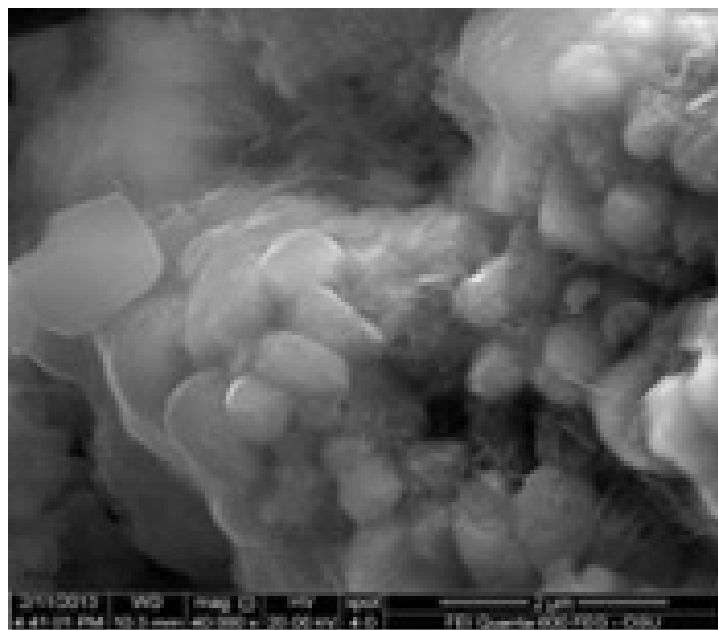




# Cathode-Healing

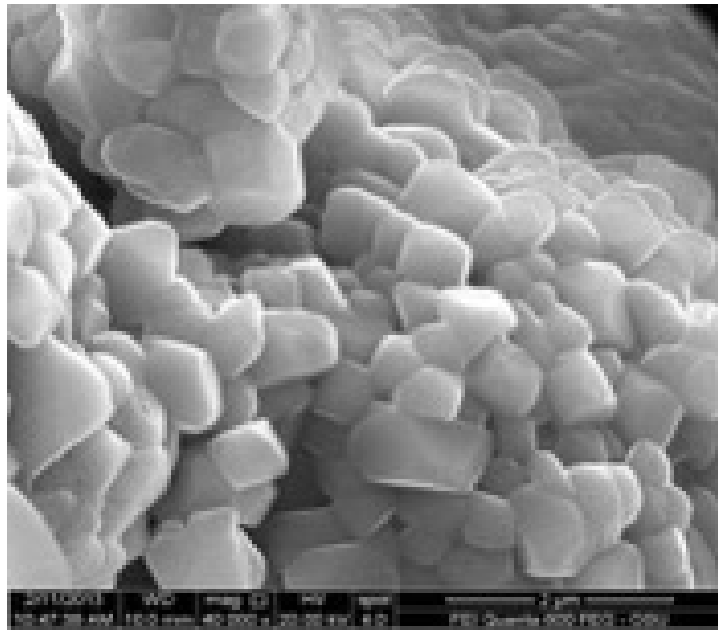
## Harvest

Cu: 25ppm  
Fe: 81ppm  
Al: UD



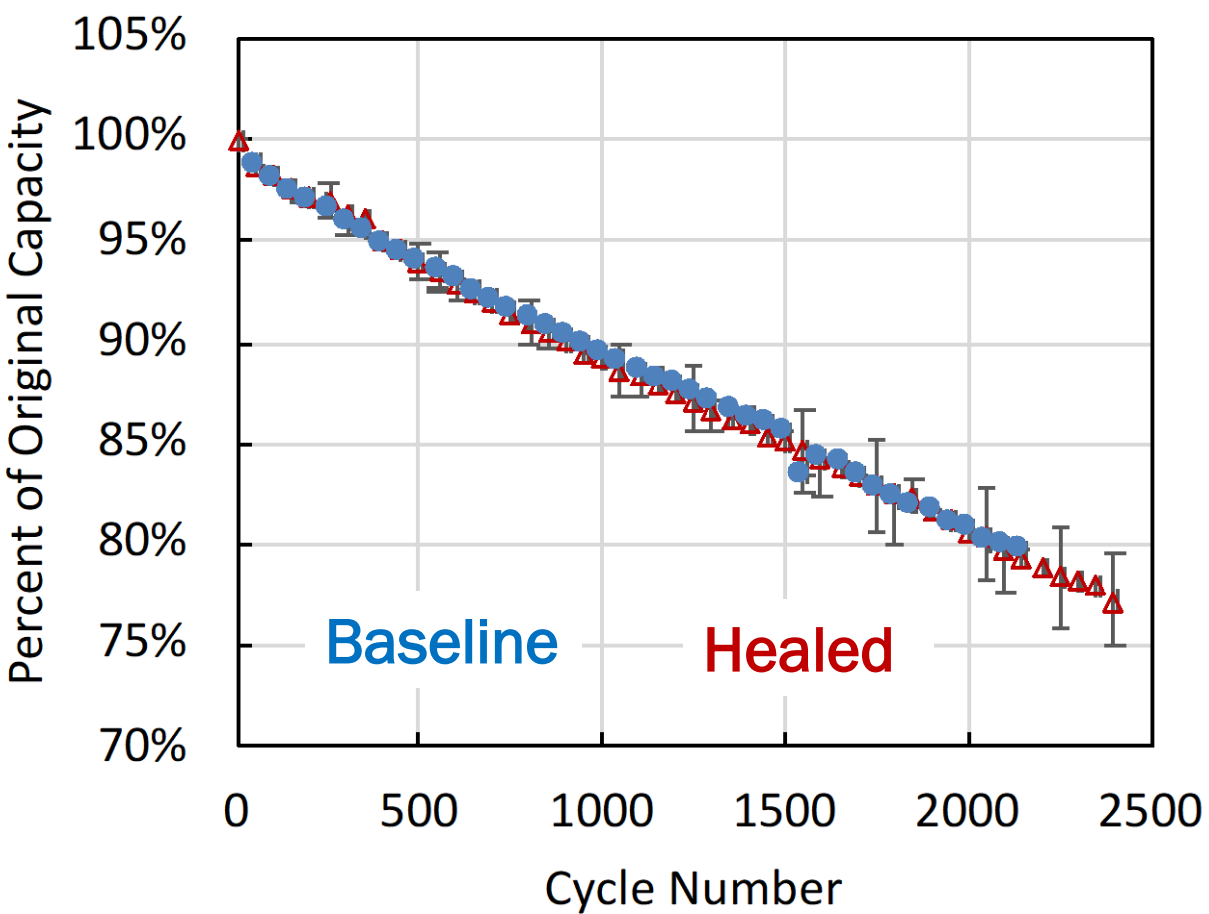
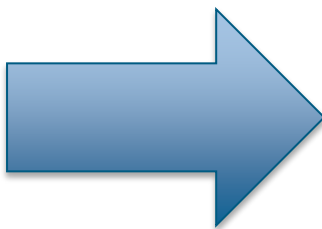
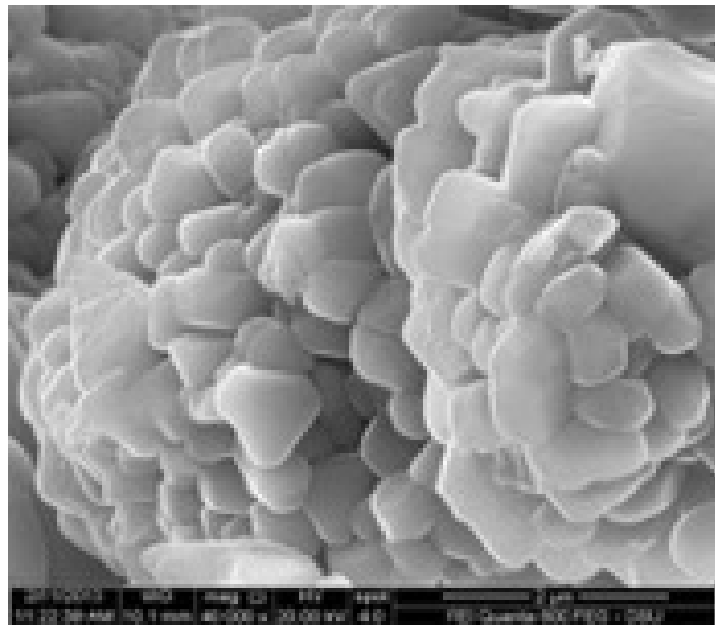
## Hydrothermal

Cu: Undetected  
Fe: 12ppm



## Sintered (Healed Material)

Cu: Undetected (Baseline: UD)  
Fe: 12 ppm (Baseline: 50 ppm)



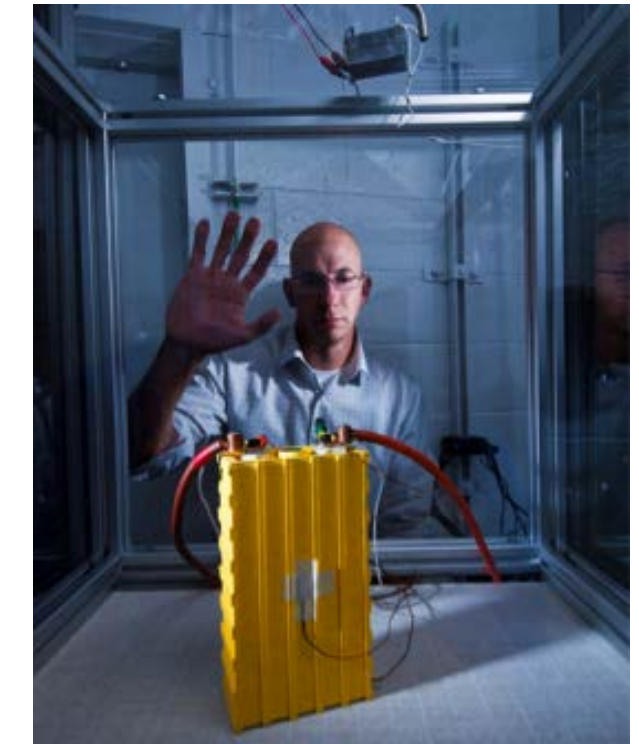
- Low-cost, pure material
- Healed EV grades electrodes perform like new





# Potential Voucher Uses

- Battery Abuse Testing: Sandia National Laboratories
  - Evaluate packs for safety, thermal runaway, and toxic byproducts using battery calorimetry and gas analysis
- OEMs: Battery building
  - Civilian and defense.
  - Build batteries from recycled cathodes and anodes.
  - Benchmark and demonstrate that material recovered using OnTo process is compatible with existing manufacturing processes, has high quality, and is inexpensive.





# Contact

Lauren Crandon

[lcrandon@onto-technology.com](mailto:lcrandon@onto-technology.com)

[www.onto-technology.com](http://www.onto-technology.com)



OnTo  
Technology  
LLC



# Renewance

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## Reverse Logistics





# Team Introduction

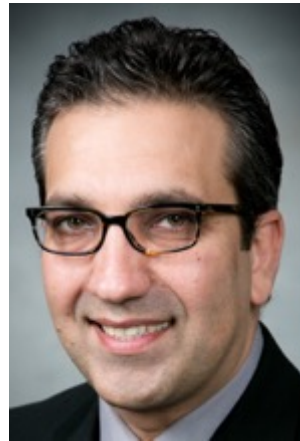
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- Team Name: Team Renewance  
Contact: [David.Mauer@Renewance.net](mailto:David.Mauer@Renewance.net) / (312) 351-5180
- Competition Track: Reverse Logistics
- Partners (on-going engagement):
  - Parties operating battery assets that reach end-of-life
    - Large public utilities, IPP, Commercial EV fleet operator
  - Providers of collection services
    - Logicsols, Everest Transportation Systems
  - Recycling service providers
    - LiCycle
  - Environmental impact analysis
    - Argonne National Laboratory
  - Reuse assessment and deployment partners
    - Repurpose, Rejoule, Eclipse Energy



# Team Introduction (2)

- Team Members



**JAMAL BURKI (CEO)**

20+ years of high-tech development and global deployment experience. Seasoned entrepreneur with track record of launching successful ventures in telecom and energy storage industries



**THOMAS NEWHALL (COO)**

25+ years in Energy industry, with specific focus in developing global battery stewardship solutions. Demonstrated expertise with global regulations governing proper management of industrial batteries throughout the lifecycle



**SANDER JACOBS (CMO)**

25+ years international experience with product, marketing and sales management positions in materials, machinery and energy sector. Proven expertise in global commercialization of new products and technologies



**DAVID MAUER (VP SALES & SERVICE)**

20+ years in high growth tech business development, operations, and strategy. Strong track record of defining and scaling highly successful products in nascent industries



**GANESH BALASUBRAMANIAN (DIR. SALES)**

20+ years of commercial & technical experience with over 10 years in the Energy Storage industry. Expertise in commercializing battery technologies in over 25 countries



**DAVID PARRY (DIR. SERVICES)**

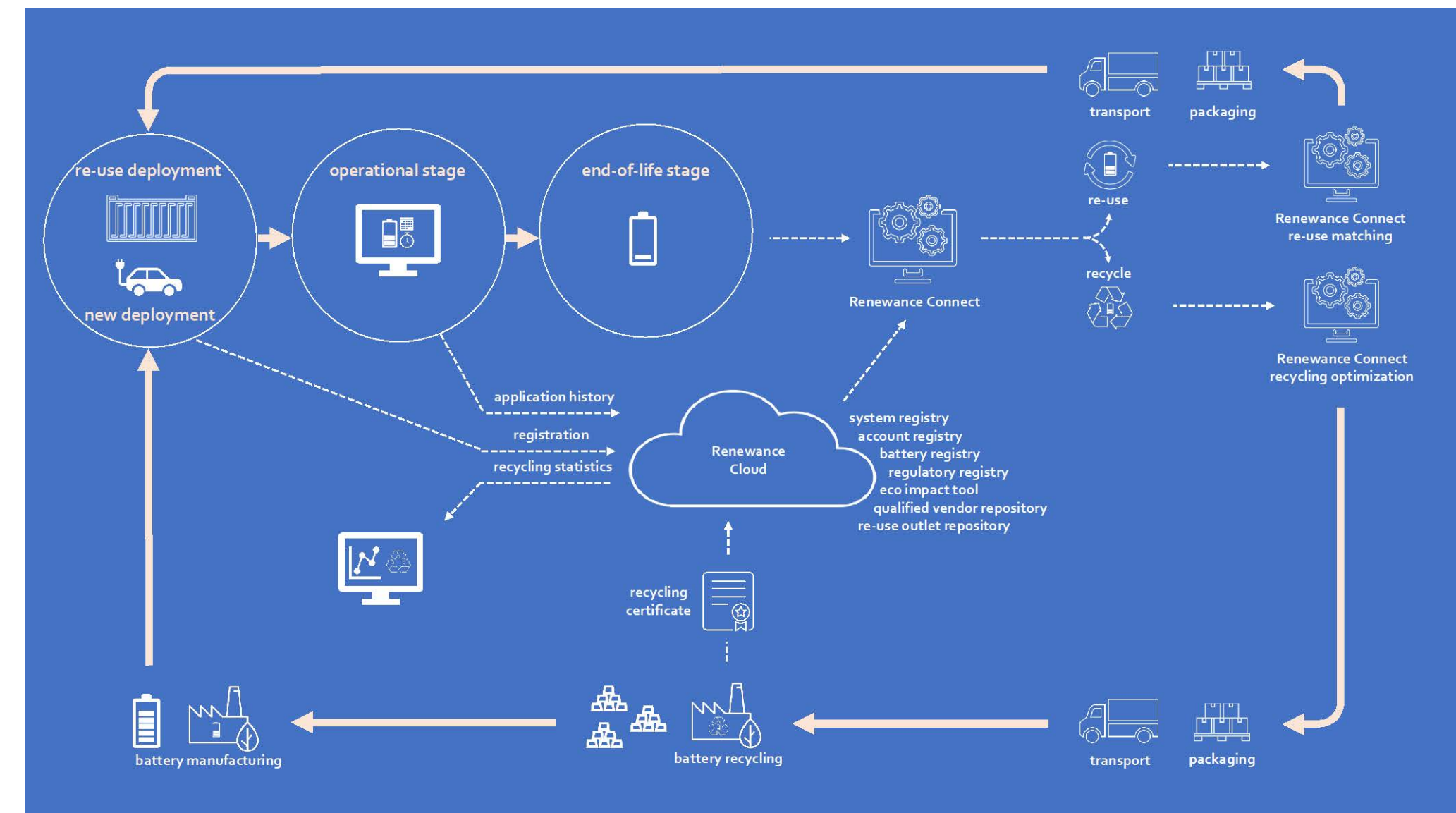
35+ years of experience in power systems including program/project management, electro-mechanical system design, new product development, system installation and commissioning, long term service programs, and major upgrades to existing installations



# Concept Overview Information – Model

## Renewance Connect end-to-end solution enabled by marketplace mechanism

- Life-cycle Tracking
  - Enables recycling rate reporting
  - Application history enables reuse option identification
- One-Stop solution for battery owners
  - Regulatory compliance
  - Environmentally responsible & cost competitive
- Re-use and recycling providers get qualified access to demand for their services
- Optimizing collection and recycle / reuse options through
  - application history insights
  - volume aggregation by form factor, location and chemistry
  - marketplace mechanism to match supply and demand

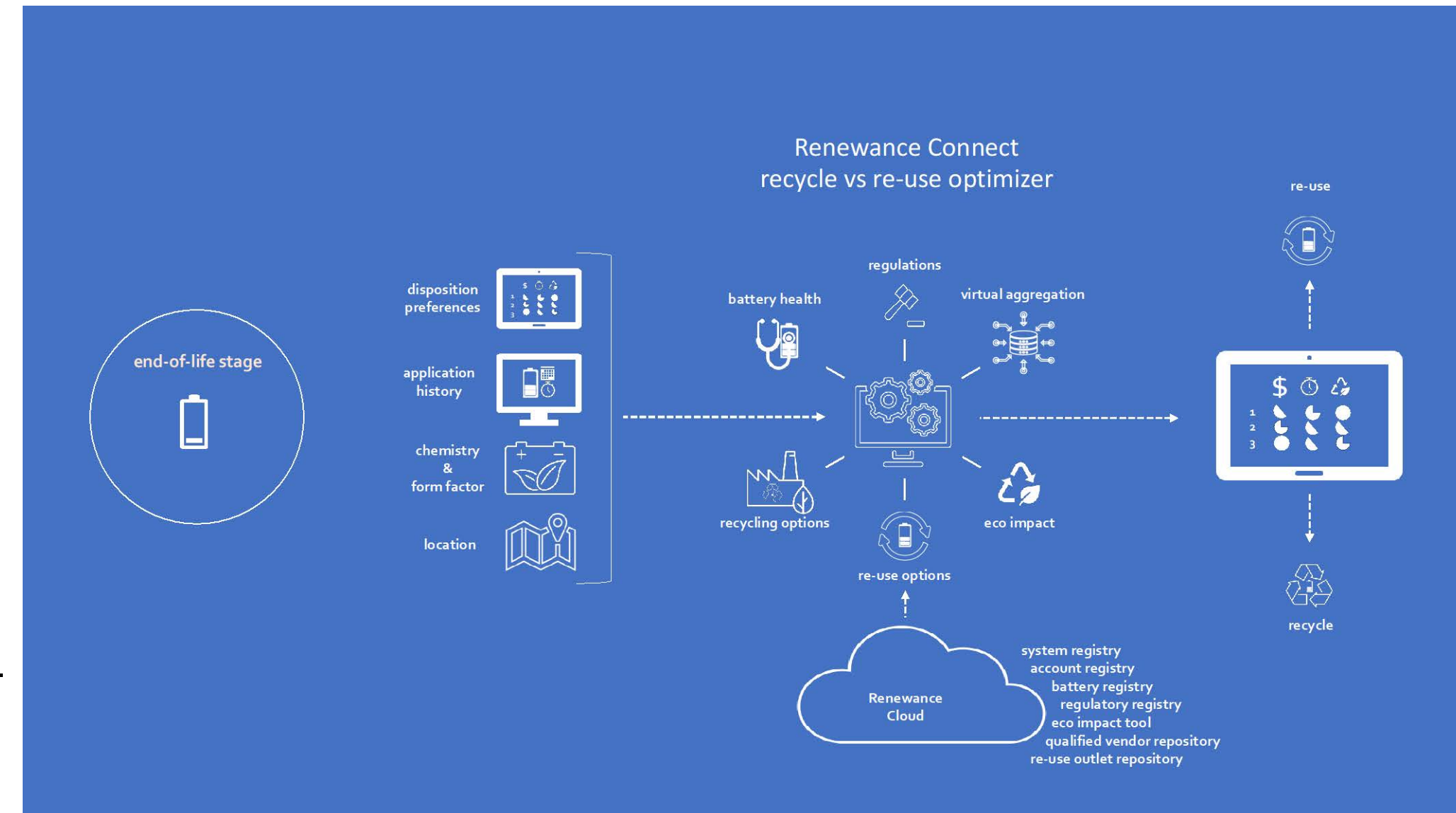




# Concept Overview Information (2) – Architecture


## Key components of close-loop solution


- ***Account & battery registry***
  - Database of installed assets (location, formfactor, chemistry) and application history
- ***Services provider registry***
  - Database of logistics, reuse-recycling services providers
- ***Regulatory engine***
  - Identifies applicable regulatory requirements and provides compliance guidance
- ***Environmental impact tool***
  - Calculates environmental impact of collection and reuse-recycling options
- ***Reuse-recycle optimization engine***
  - Optimizes solution based on input of user preferences and battery's chemistry, form factor, location, and application history & state of health





# Solution Demonstration – [www.batterystewardship.com](http://www.batterystewardship.com)




[Open Access](#)  [RENEWANCE CONNECT LOGIN](#) [+1-312-351-5180](#)

[How We Help](#) [Renewance Connect Services](#) [Resources](#) [About Us](#) [Request A Quote](#)

[Regulatory Compliance](#)[Warranty Management](#)[Asset Management](#)[End of Life Management](#)[Tools & Consulting](#)

[Photo Gallery](#)[Case Studies](#)[Whitepapers](#)



INDUSTRIAL

# BATTERY LIFE CYCLE MANAGEMENT COMPANY


You take care of your business.  
We'll take care of your batteries.

[HOW WE HELP →](#)


Responsible Life Cycle

## Management of Battery Assets

Our purpose is to help drive a decarbonized economy through enabling safe and sustainable use of battery-based applications or products. Renewance helps companies:



Safely recycle or reuse batteries in an economically viable, regulatory compliant and environmentally responsible manner.



Manage industrial batteries more effectively and responsibly throughout their active operating life through advanced software solutions and services.

Helping Large Battery Energy Storage Companies Worldwide

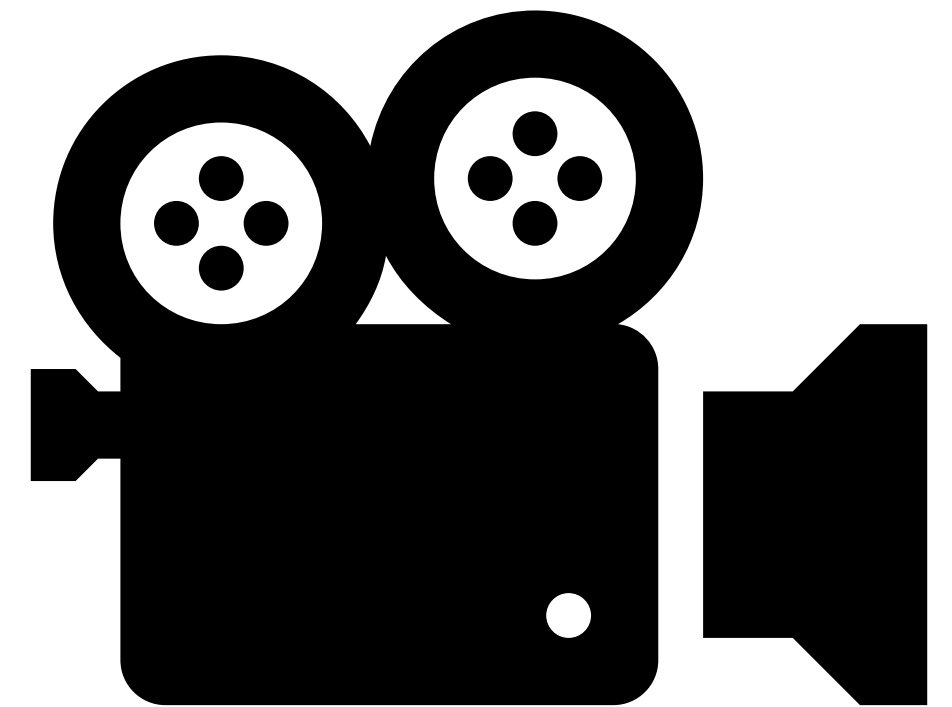
*Product Demonstration – Next*



# Solution Demonstration

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- **A video demonstration will play shortly**
- **Check the audio settings on both your computer and your headset to hear the video.**



# Conclusion

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- Industry requires holistic approach to the battery recycling challenge – Renewance Connect close-loop solution allows for the management of complete life-cycle of battery assets through optimized use of existing service infrastructure
- Renewance Connect commercialized and being further optimized for stationary energy storage and commercial EV fleet batteries; marine and private EV segment model under consideration
- Ongoing research towards solution environmental score development
- Ongoing research towards 2<sup>nd</sup> life battery market, applications and credible-responsible off takers



# Potential Voucher Uses

## 1. Reverse logistics environmental impact score

- Industry need is a simple to interpret environmental impact score for evaluating reverse supply chain options. Model impact of various logistics scenarios (e.g. dismantle locally, at a hub or at a recycler and various transportation modes)
- On Renewance's road map and it would be ideal to partner with a group that has related expertise such as Argonne National Laboratories

## 2. Battery reuse / 2<sup>nd</sup> life options & battery state of health determination

- Extending useful life through identification of 2<sup>nd</sup> life deployment options prior to ultimate recycling improves overall economics and environmental footprint
- Requires insights to the battery state of health. When the application history of the battery with associated health data is not available, a simple, effective and economically viable health check is needed
- On Renewance's road map and it would be ideal to partner with a group that has related expertise

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# THANK YOU



# Team RRCO/Conductive Media

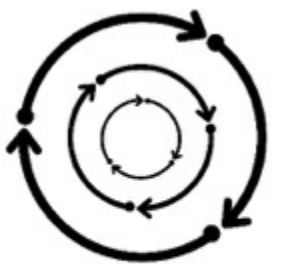
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## Composite Discharge Media



# Team Introduction

- Conductive Media, LLC
  - Team Captain – Roland Bruyns, P.E.
  - Business started to pursue battery recycling prize
  - [Info@Conductive-Media.com](mailto:Info@Conductive-Media.com)
- Track 3. Safe or Inert Storage and Transportation
  - *“Participants are encouraged to devise a cost-effective solution that renders LIBs externally electrochemically inactive for safe transport and/or storage.”*
  - Leveraging expertise in Materials Science to develop techniques and materials for solid state discharge media

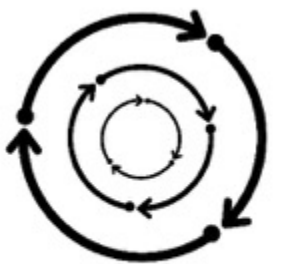


CONDUCTIVE MEDIA



# Concept Overview Information

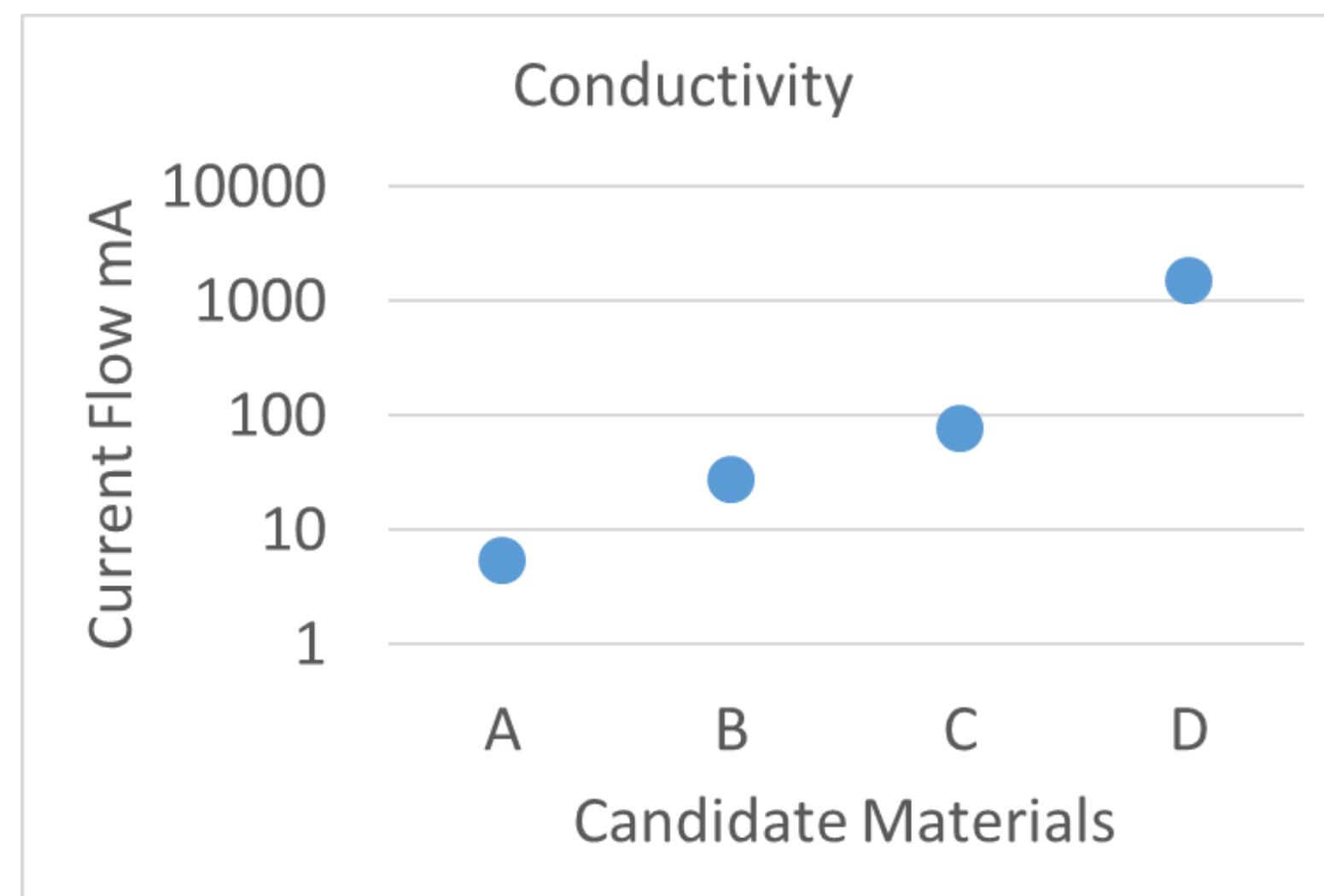
- Concept uses conductive beads to establish an electrical network between the terminals of a battery/module/cell
  - Batteries can be placed in media, or media can be poured over the batteries
- Solid beads are simpler and cleaner than alternatives such as brine solution soaking



CONDUCTIVE MEDIA

# Concept Overview Information

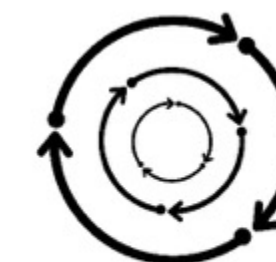
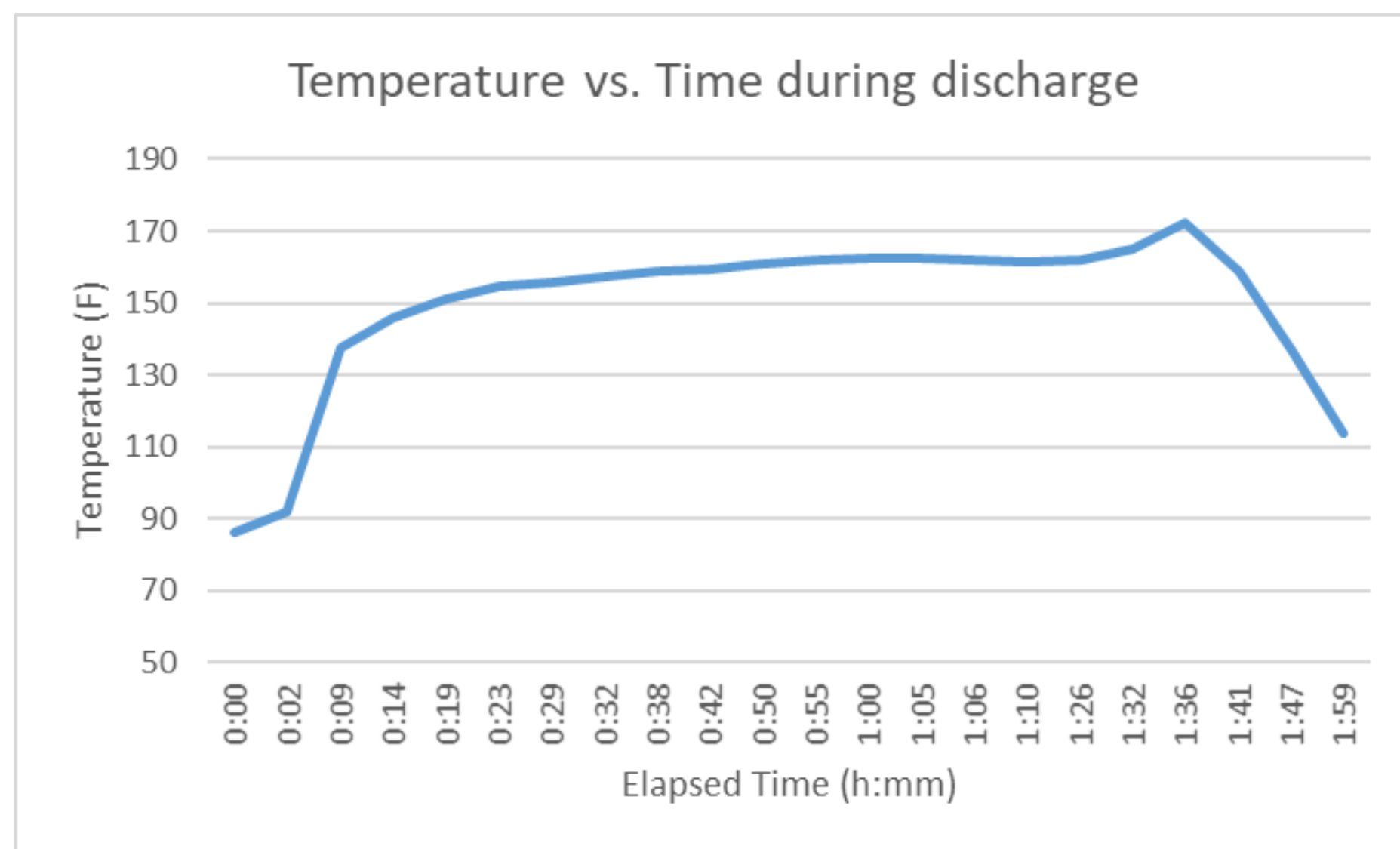
- Size, geometry and electrical properties of beads are tailorable
  - Discharge rate can vary based battery voltage, geometry and discharge capacity
  - Intent is to develop several candidate materials to meet industry needs
  - Performance metrics:
    - Maximum Temperature Capability
    - Conductivity
    - Density
    - Cost





# Preliminary Data

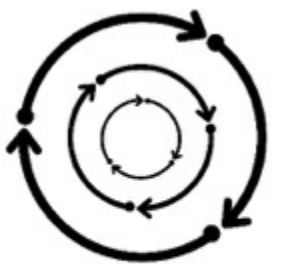
- 18650 (3400mAh) cell used as a baseline for candidate material evaluation
  - Instrumented with a thermocouple for monitoring cell temperature
- Minimum discharge time of 2 hours achieved with acceptable temperature rise
  - 3.95V → 1.25V with a temp rise to 170°F



CONDUCTIVE MEDIA

# Potential Voucher Uses

- Analytical modeling of discharge rates
  - Thermal management
  - Electrical resistivity of packed particle bed
  - Bulk discharge of batteries
- Thermal processing of discharge media
  - Several candidate materials have electrical conductivity that can be tailored with thermal processing



CONDUCTIVE MEDIA



# Break

Please return at 2:15 p.m. ET for more presentations from Phase II teams.

Coming up next...

2:15 – Team Li Industries

2:25 – Team Holman Parts

2:35 – Team UAH

2:45 – Team EVBs

2:55 – Team Admiral instruments

3:05 – Team Portables



# Li Industries

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## Smart Battery Sorting System





# Team Introduction

## Li Industries, Inc.

Our Mission: Revolutionize lithium-ion battery sustainability by developing automated recycling technologies for direct battery recycling

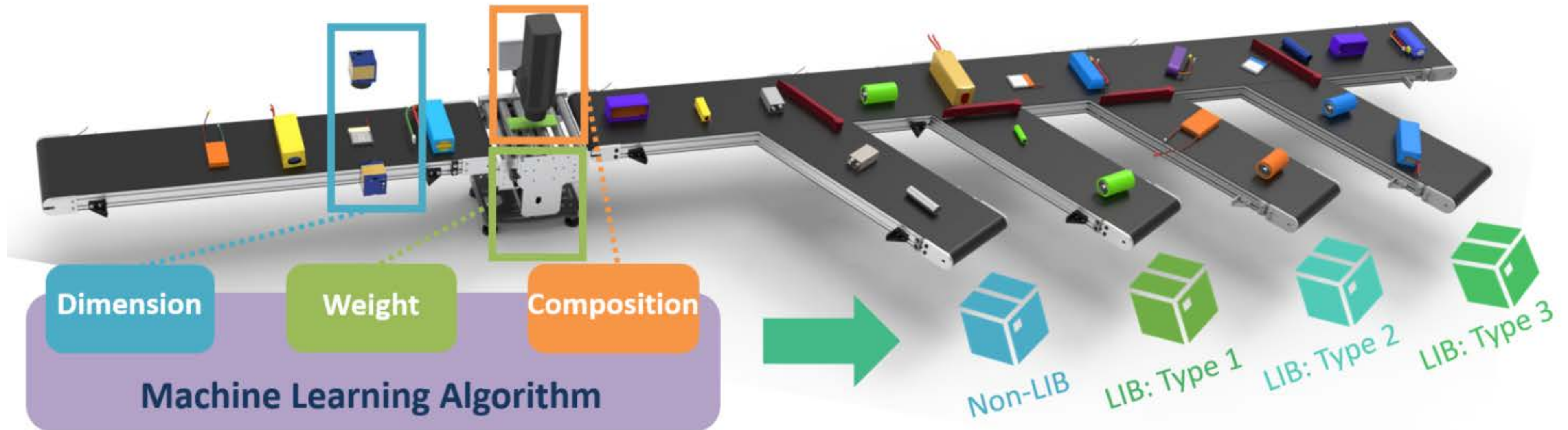
### Smart Battery Sorting Team:

- David Young – Chief Technology Officer
- Zheng Li – Chief Science Officer
- Nolan Schmidt – Chief Executive Officer
- Henry Han – Chief Financial Officer
- Michael Ellis – Chief Engineer
- Panni Zheng – Research Engineer



# Smart Battery Sorting System

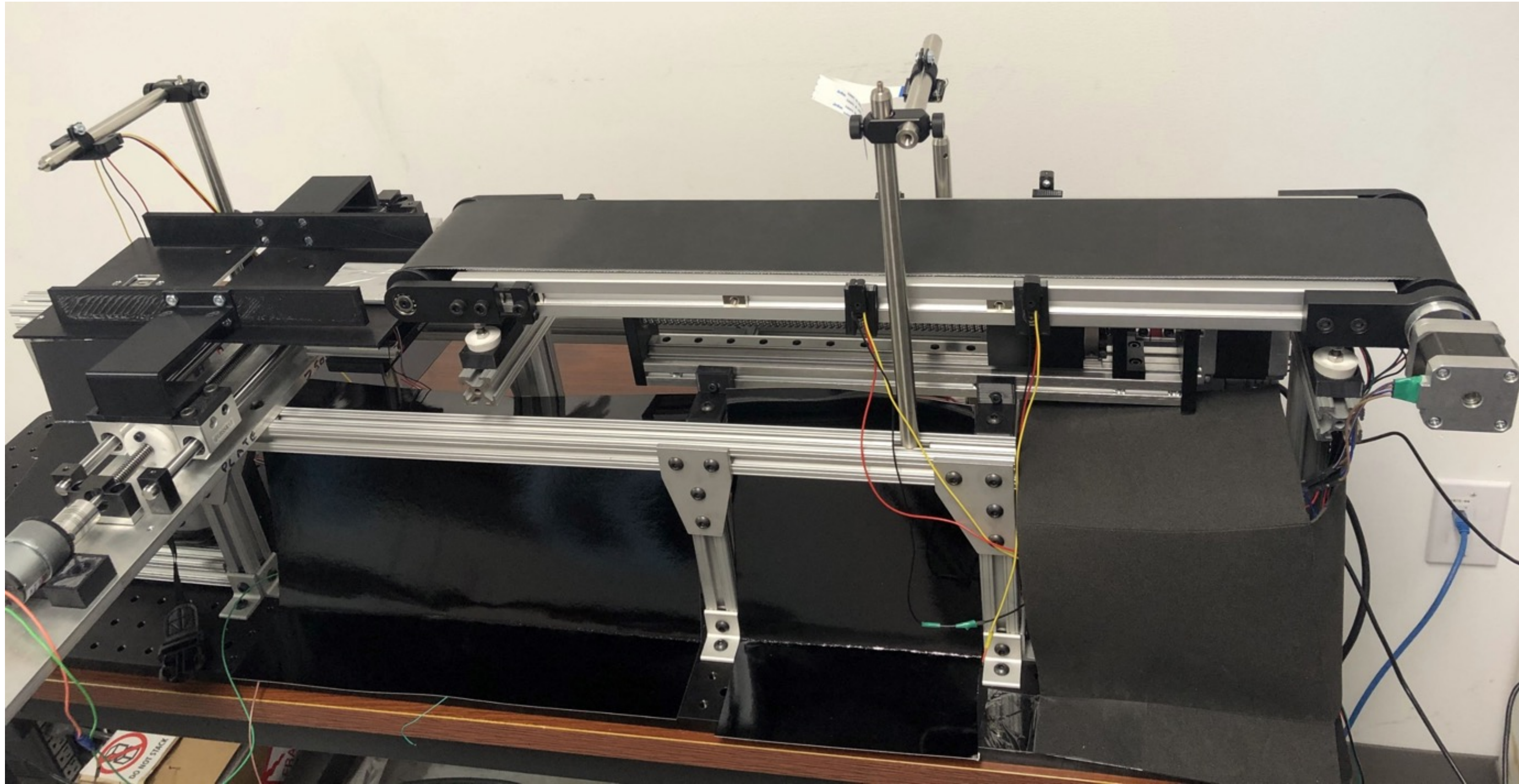
Our automated system sorts batteries by cathode composition using machine learning.



Faster | More cost effective | Improves efficiency of direct battery recycling



# Our Prototype Demonstrates Automated Data Collection



Dimension



Mass



Composition

# Batteries Are Fed Into the System



Dimension



Mass



Composition



# Vision Station Captures Battery Visual Information



Dimension

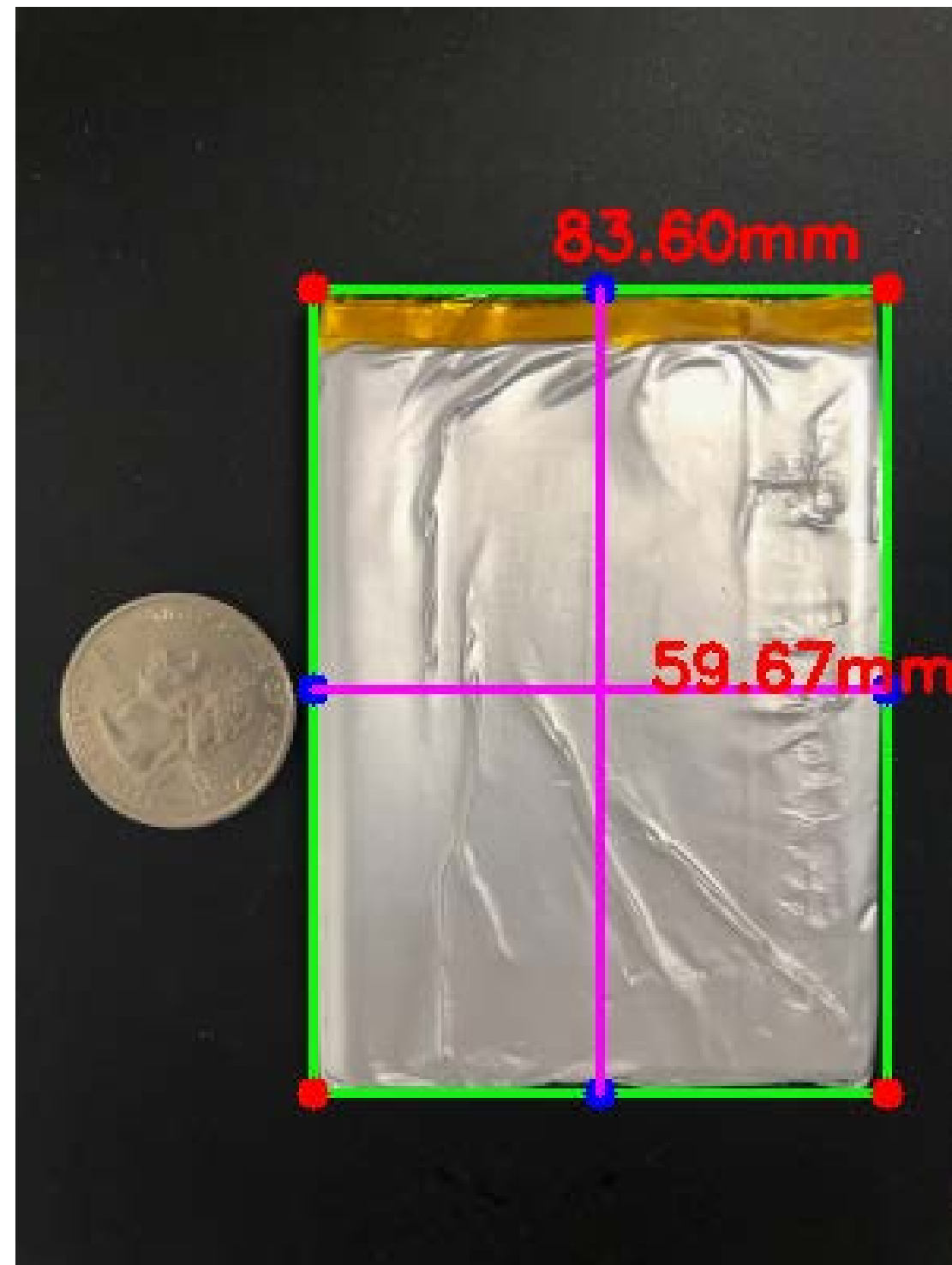


Mass



Composition

# Images Are Analyzed to Extract Dimensional Data



Dimension



Mass



Composition



# Battery Progresses to Weighing Station



Dimension



Mass

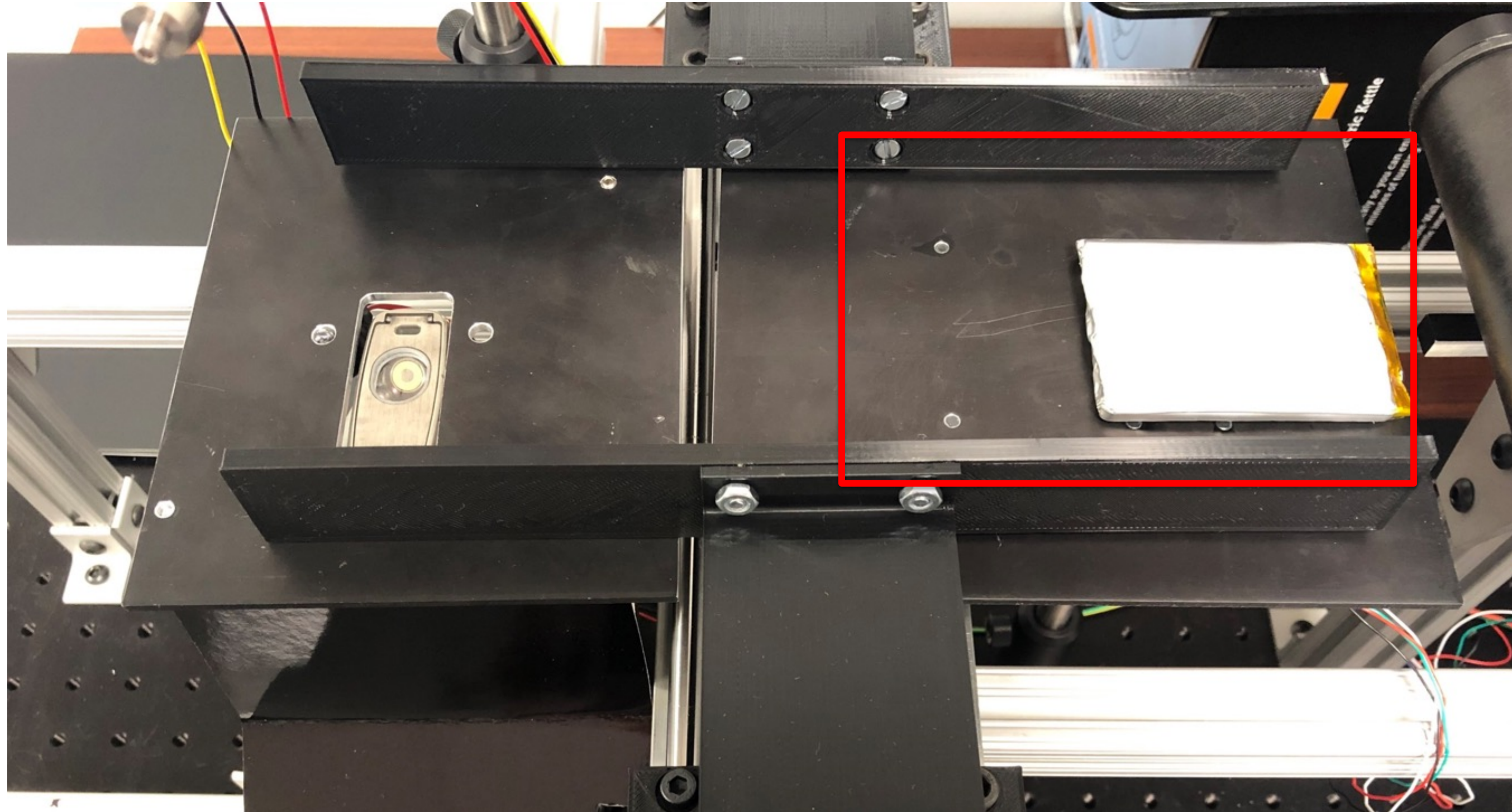


Composition



**Li Industries**

# Weighing Station Captures Mass Data



Dimension



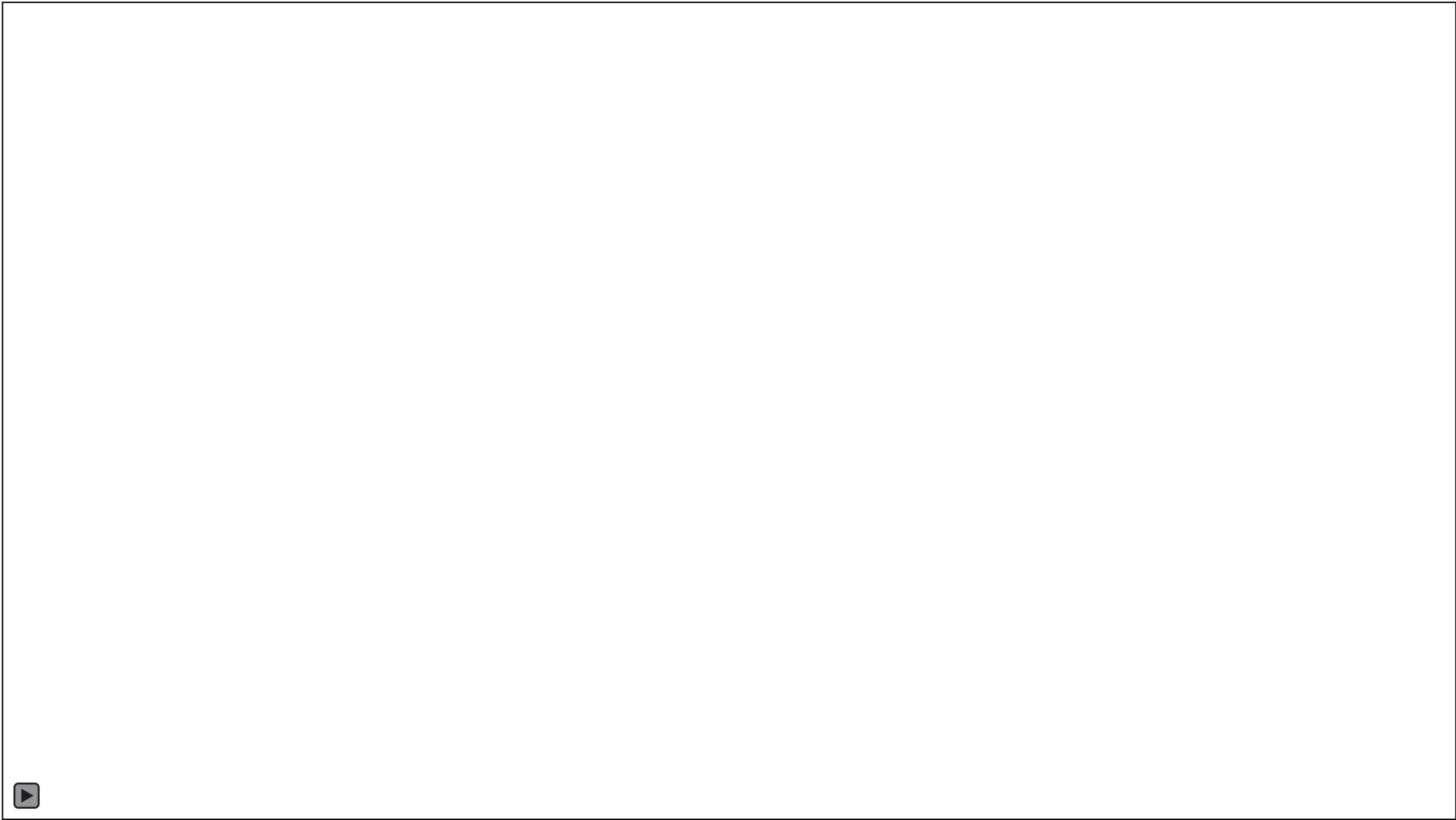
Mass



Composition



# Battery Progresses to Elemental Analysis Station



Dimension



Mass



Composition



**Li Industries**

# Compositional Data Is Extracted

ELEMENT	%	+/-
Co	66.17	0.519
Al	26.08	0.756
Fe	4.24	0.150
P	1.01	0.048
Cu	0.91	0.089
Hf	0.70	0.122
Si	0.45	0.056
Ni	0.44	0.042

Dimension



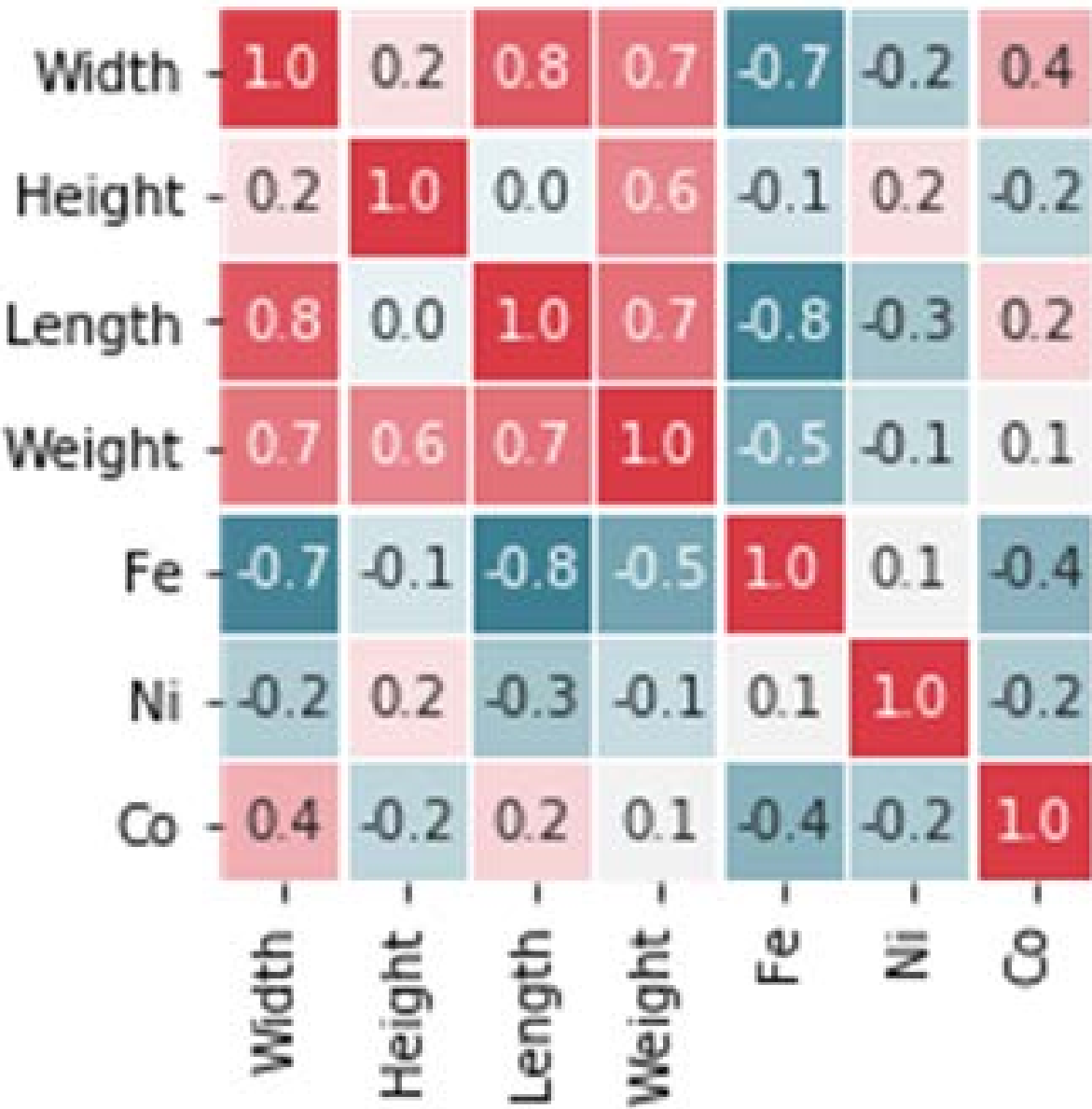
Mass



Composition



# Machine Learning Algorithm Is Trained on Known Batteries



Training



Validation

# Unknown Batteries Are Introduced Into the System

Width	-1.0	0.2	0.8	0.7	-0.7	-0.2	0.4
Height	-0.2	1.0	0.0	0.6	-0.1	0.2	-0.2
Length	0.8	0.0	1.0	0.7	-0.8	-0.3	0.2
Weight	0.7	0.6	0.7	1.0	-0.5	-0.1	0.1
Fe	-0.7	-0.1	-0.8	-0.5	1.0	0.1	-0.4
Ni	-0.2	0.2	-0.3	-0.1	0.1	1.0	-0.2
Co	-0.4	-0.2	0.2	0.1	-0.4	-0.2	1.0
	Width	Height	Length	Weight	Fe	Ni	Co

Training



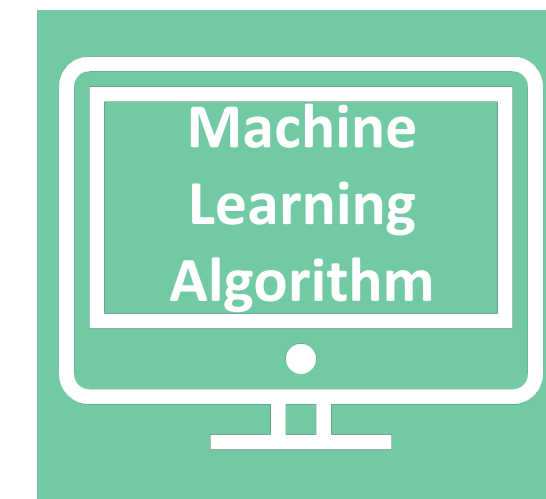
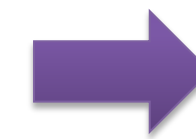
Validation



# Machine Learning Algorithm Analyzes Battery Parameters

Width	-1.0	0.2	0.8	0.7	-0.7	-0.2	0.4
Height	-0.2	1.0	0.0	0.6	-0.1	0.2	-0.2
Length	0.8	0.0	1.0	0.7	-0.8	-0.3	0.2
Weight	0.7	0.6	0.7	1.0	-0.5	-0.1	0.1
Fe	-0.7	-0.1	-0.8	-0.5	1.0	0.1	-0.4
Ni	-0.2	0.2	-0.3	-0.1	0.1	1.0	-0.2
Co	-0.4	-0.2	0.2	0.1	-0.4	-0.2	1.0
	Width	Height	Length	Weight	Fe	Ni	Co

Training



Validation

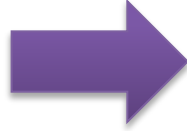
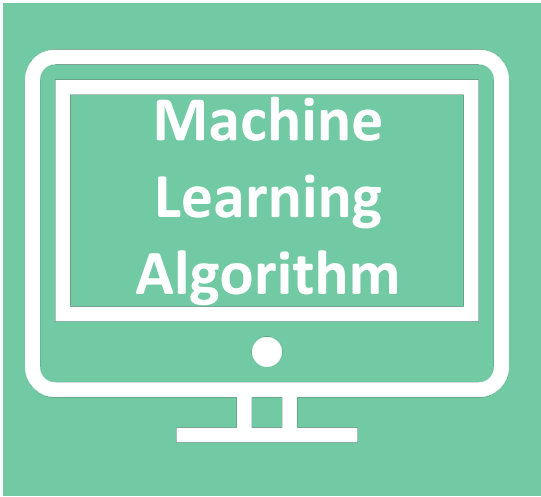
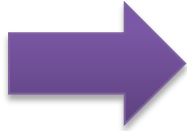


Li Industries

# Machine Learning Algorithm Automates Sorting Decision

Width	-1.0	0.2	0.8	0.7	-0.7	-0.2	0.4
Height	-0.2	1.0	0.0	0.6	-0.1	0.2	-0.2
Length	0.8	0.0	1.0	0.7	-0.8	-0.3	0.2
Weight	0.7	0.6	0.7	1.0	-0.5	-0.1	0.1
Fe	-0.7	-0.1	-0.8	-0.5	1.0	0.1	-0.4
Ni	-0.2	0.2	-0.3	-0.1	0.1	1.0	-0.2
Co	-0.4	-0.2	0.2	0.1	-0.4	-0.2	1.0
	Width	Height	Length	Weight	Fe	Ni	Co

Training



Measuring...  
Processing...  
Result: LCO

Validation



# Where You Can Help: Potential Voucher Uses

- Study the impact of smart battery sorting on the battery lifecycle
  - Increased efficiency and reductions in cost in collecting and recycling
- Development of scalable, high-throughput compositional analysis
  - Increase speed and accuracy of elemental detection for this application
- Study impact on battery materials and manufacturing supply chain
- Optimizing software and hardware design



Contact: [david.young@li-ind.com](mailto:david.young@li-ind.com)

# Holman Parts Distribution

## Reverse Logistics Lithium-Ion Battery Solution Team Track – Collection





# Team Introduction – Holman Parts Distribution



Anne Williams  
President



Robert Scott  
Logistics Supervisor



Ray Roller  
Vice President



Chelsea Short  
Logistics Analyst



Steve Chung  
Logistics Manager



Mike Rusak  
Safety and Loss Specialist



Andy Chen  
Operations Manager



Chelsea Feast  
Sustainability Analyst



# Concept Overview Information

- ❑ Utilize our current automotive core recovery routes to pickup and transport lithium-ion batteries creating a circular recycling economy.
- ❑ Provide a reverse logistics lithium-ion battery closed-loop solution to support recycling.
- ❑ Partner with automotive OEM's, recyclers, and distributors to collect lithium-ion batteries at automotive dealerships.
- ❑ Research and develop new safety processes and procedures.





# Partnerships





# Potential Voucher Uses

1

- Partner with external companies to research indoor and outdoor safe automotive lithium-ion battery storage solutions.

2

- Partner with external companies to research, develop, and manufacture transportation dunnage for lithium-ion batteries.

3

- Research personal protective equipment and material handling equipment to help keep Holman Parts Distribution personnel and the public safe.



# Future Outlook

Scale to all 48 states through our partnerships in the automotive National Powertrain Network

Participate in the United States lithium-ion battery life cycle to create second life renewable energy opportunities

Safely collect and store automotive lithium-ion batteries for efficient and green transport

Partner with additional automotive OEM's, recyclers, and other companies to create a lithium-ion battery logistics program to support recycling for the automotive industry.





# Thank You

**Holman**  
— PARTS —  
DISTRIBUTION



# UAH-Summit Team

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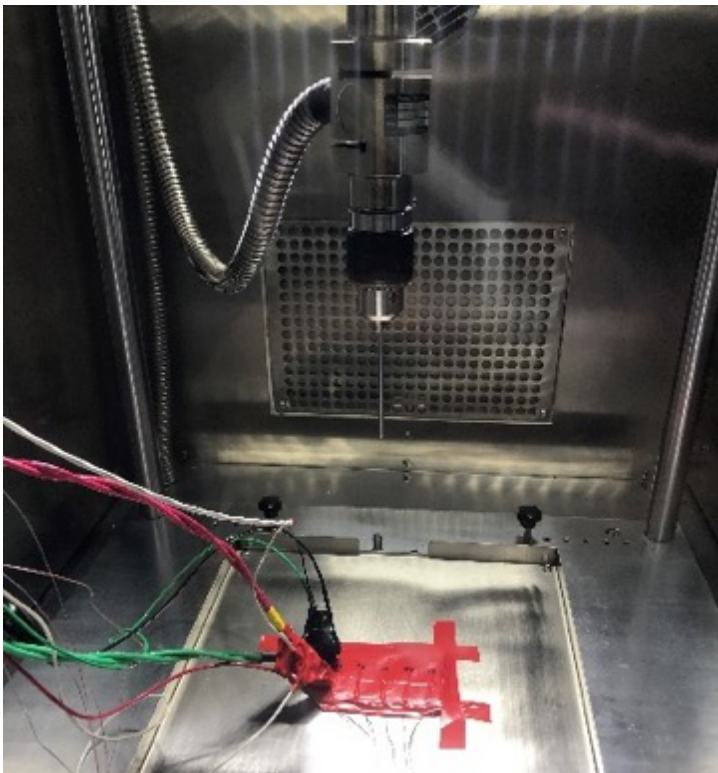
Self Cooling for Safer Recycling of  
Consumer Electronics Lithium-ion Battery





# Team Introduction

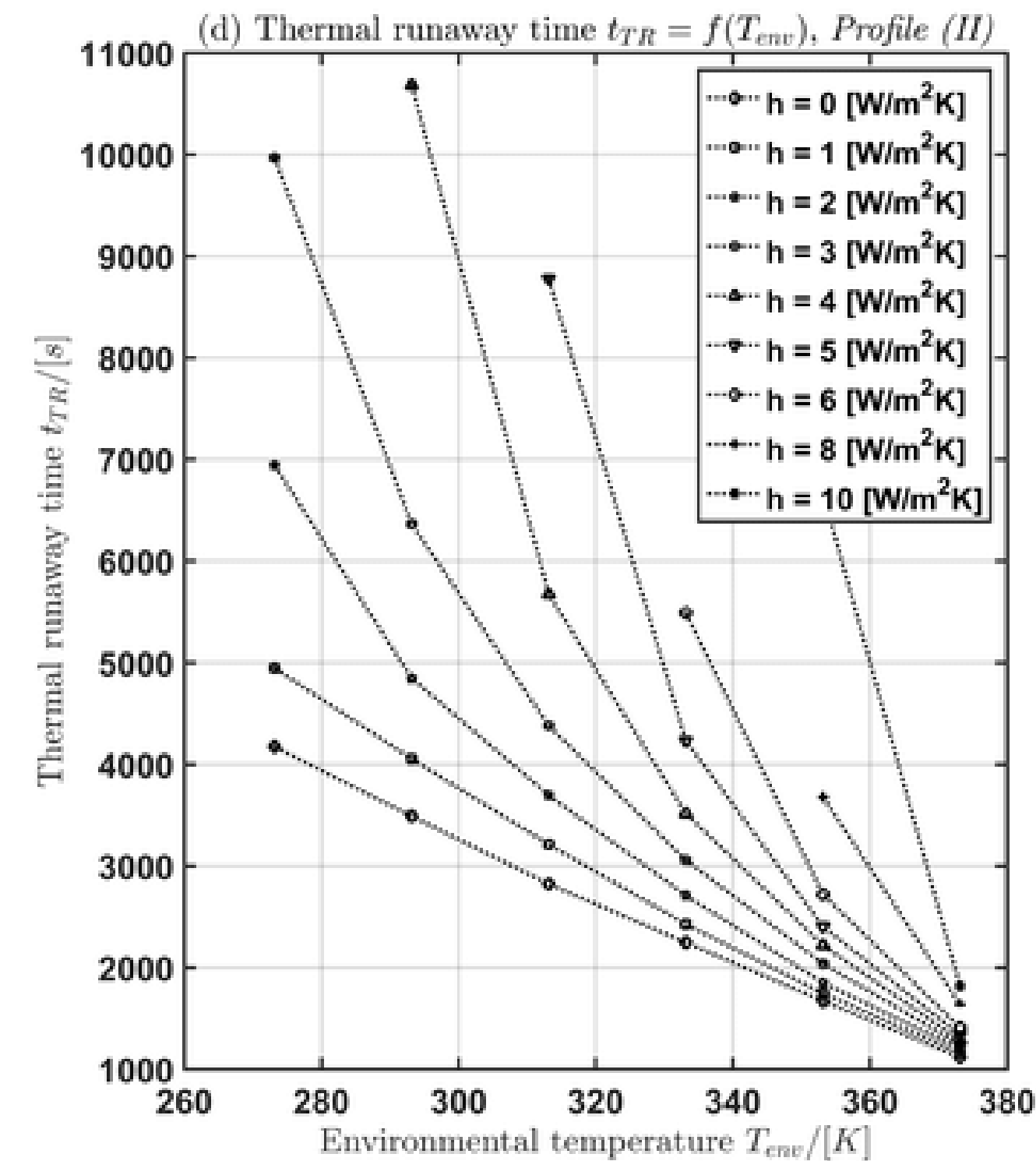
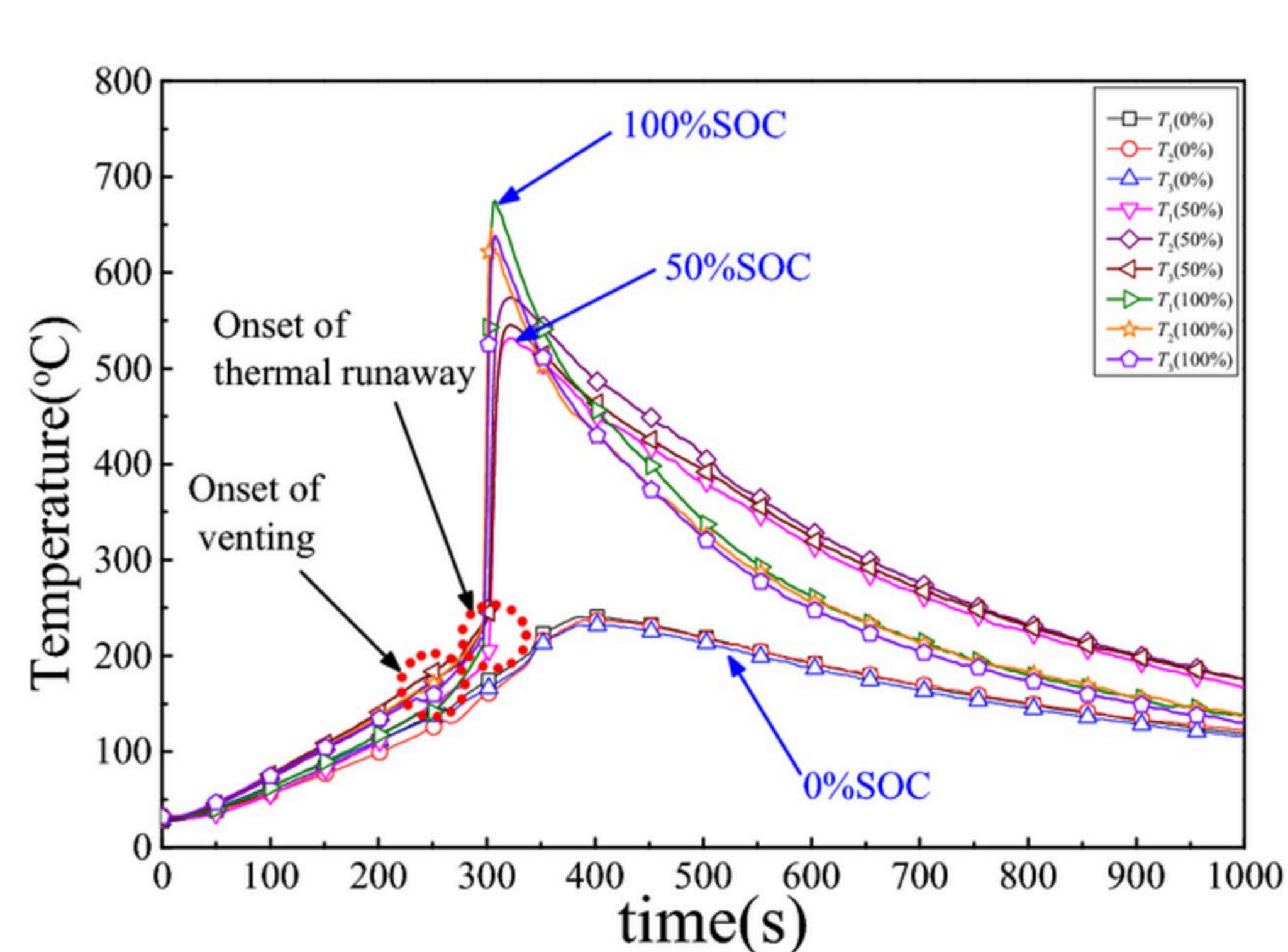
UAH (University of Alabama in Huntsville)		Summit (Summit Information Solutions, Inc.)
EEDD Lab (Phase 1 winner)	Office of Technology (OTC)	
Technical development	Guiding commercialization & facilitating collaboration	Business development (Phase II lead)
Guansheng Zhang: PhD, Lab PI	Kannan Grant: Director of OTC	Dustin Winslow: PhD, Chief Scientist (Captain)
Siyi Liu: PhD student		Chen Zhang: PhD, Researcher
Takuto Iriyama: Masters student		Aaron Caradonna: J.D., General Counsel/Business Development Manager





# Research background

Past research showed that the risk of thermal runaway is dramatically reduced if a Li-ion battery is (a) fully discharged or (b) kept at low temperatures.



Zhong, G., Li, H., Wang, C., Xu, K. & Wang, Q. *J. Electrochem. Soc.* 165, A1925 (2018)

Melcher, A., Ziebert, C., Rohde, M. & Seifert, H. J. *Energies* 9, 292 (2016)

# Concept Overview Information

- EEDD Lab at UAH proposed a concept: *Battery Self Cooling for Safe Recycling.*
- By recovering energy from recycled batteries for cooling, batteries could be kept inactive and cool for safe storage and transportation.

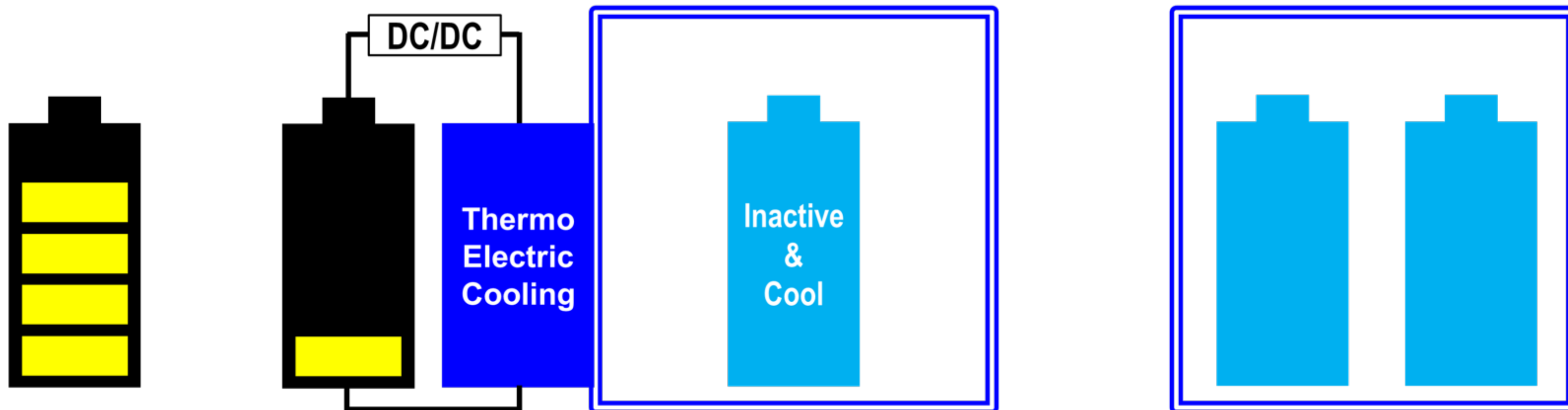
Battery to Recycle  
with Uncertain  
Energy & Risk



Battery Energy  
Reduced & Recovered  
for Inactivity & Cooling

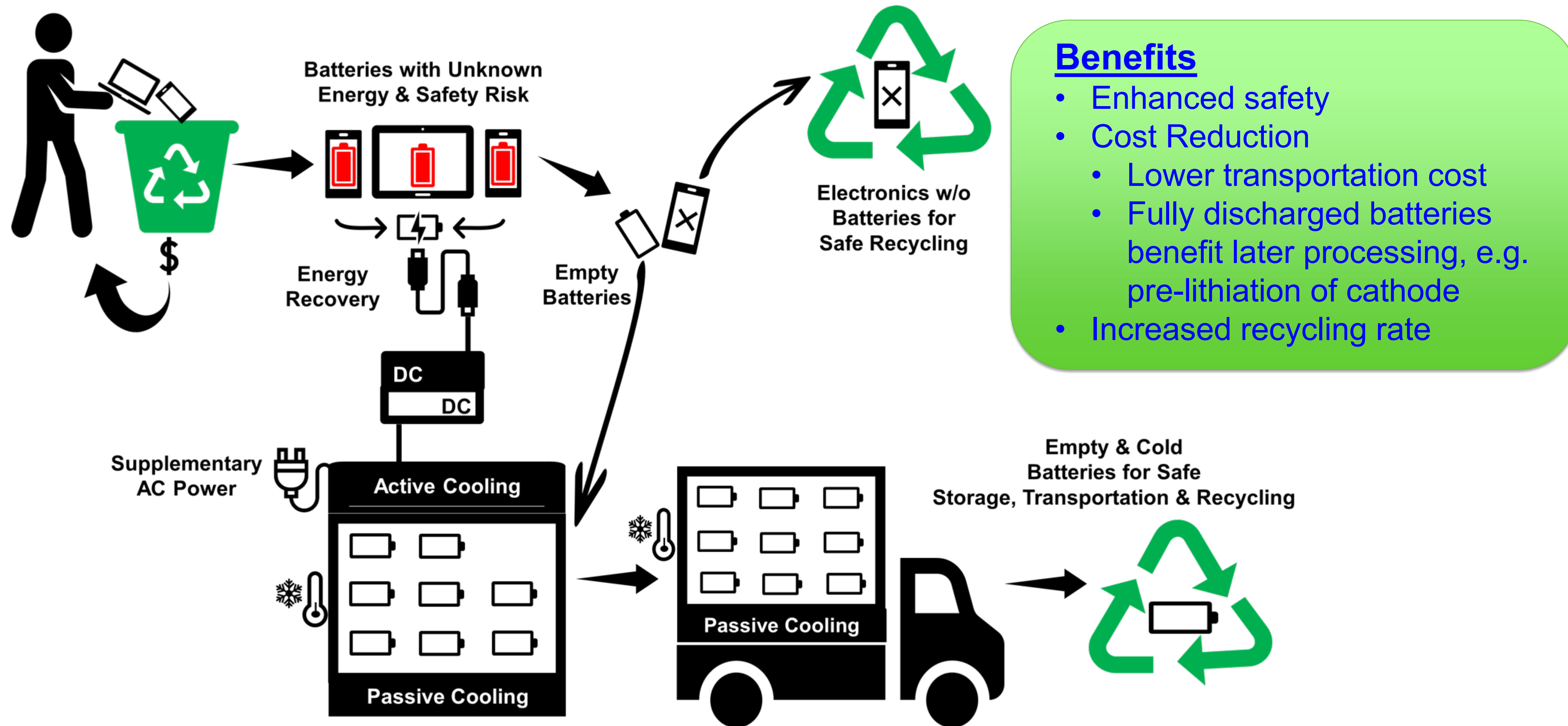


Passive Thermal Management  
Keeps Batteries Cool & Safe  
for Storage & Transportation





# End-to-End Solution focusing on consumer electronics



# Potential Voucher Uses

- Analysis of battery recycling cost and environmental impacts, such as using Argonne National Laboratory's EverBatt model.
- Analysis of materials from recycled lithium-ion batteries and evaluation of potential reuse in battery manufacturing, such as using Oak Ridge National Laboratory (ORNL)'s Battery Manufacturing Facilities.
- Development of discharging system for effective recovery of electric energy from batteries without removing them from devices. The recovered energy will be used to power cooling devices.
- Development of low cost, small size and efficient cooling techniques.
- Continued innovations/developments, as we learn more about opportunities throughout Phase II of the competition (started business development conversations).



# Team EVBs

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## A Circular Economy for Electric Vehicle Batteries

*A demonstration whereby electric vehicle batteries and components are given a digital identity to connect all stakeholders in battery lifecycles to share data critical for optimal battery management and recovery*



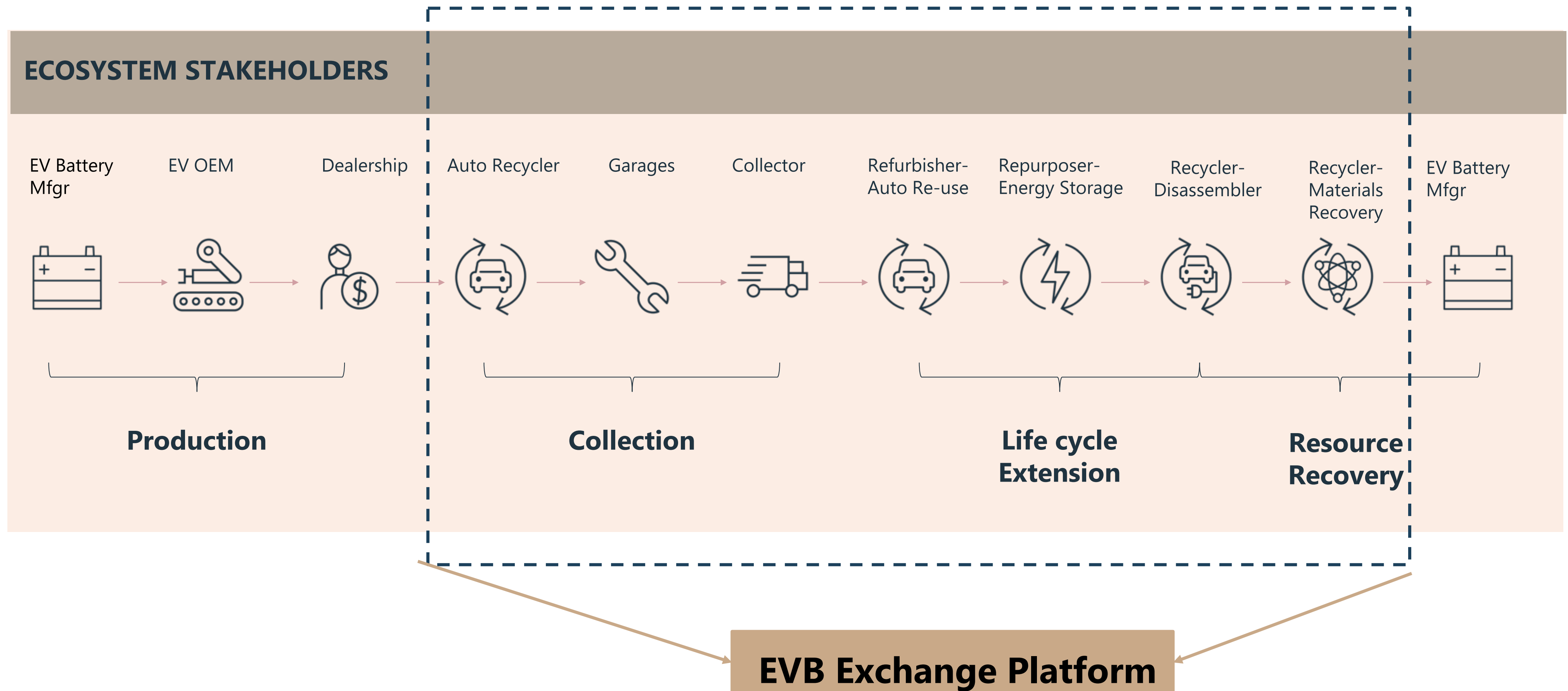
# Team EVBs Introduction - Submission Track 5: Other Ideas

## **Team Lead: Lauren Roman, Business Director Metals & Minerals Ecosystem - Everledger**

- Laura Wagner, Battery Lifecycle Manager, Ford Motor Company
- Kris Hunter, Managing Partner - Global Battery Solutions
- Todd Coy, Executive VP - KBI Recycling/Retriev
- Mark Caffarey, President - Umicore USA Inc.
- Mike Smyth, Interim Director - National Alternative Fuels Training Consortium
- Ginny Whelan, Director - Automotive Recyclers Association
- David Waggar, Chief Scientist - Institute of Scrap Recycling Industries (ISRI)
- Scott Wiggins, VP Environmental Health & Safety - ISRI
- Ron Lembke, Standards Committee Chair Reverse Logistics Association
- Yorke Rhodes, Microsoft
- Steve Christensen, Executive Director Responsible Battery Coalition (RBC)
- Carrie George, VP and Head of Sustainability - Everledger
- Matt Davidson, Pre-Sales Technical Coordinator – Everledger

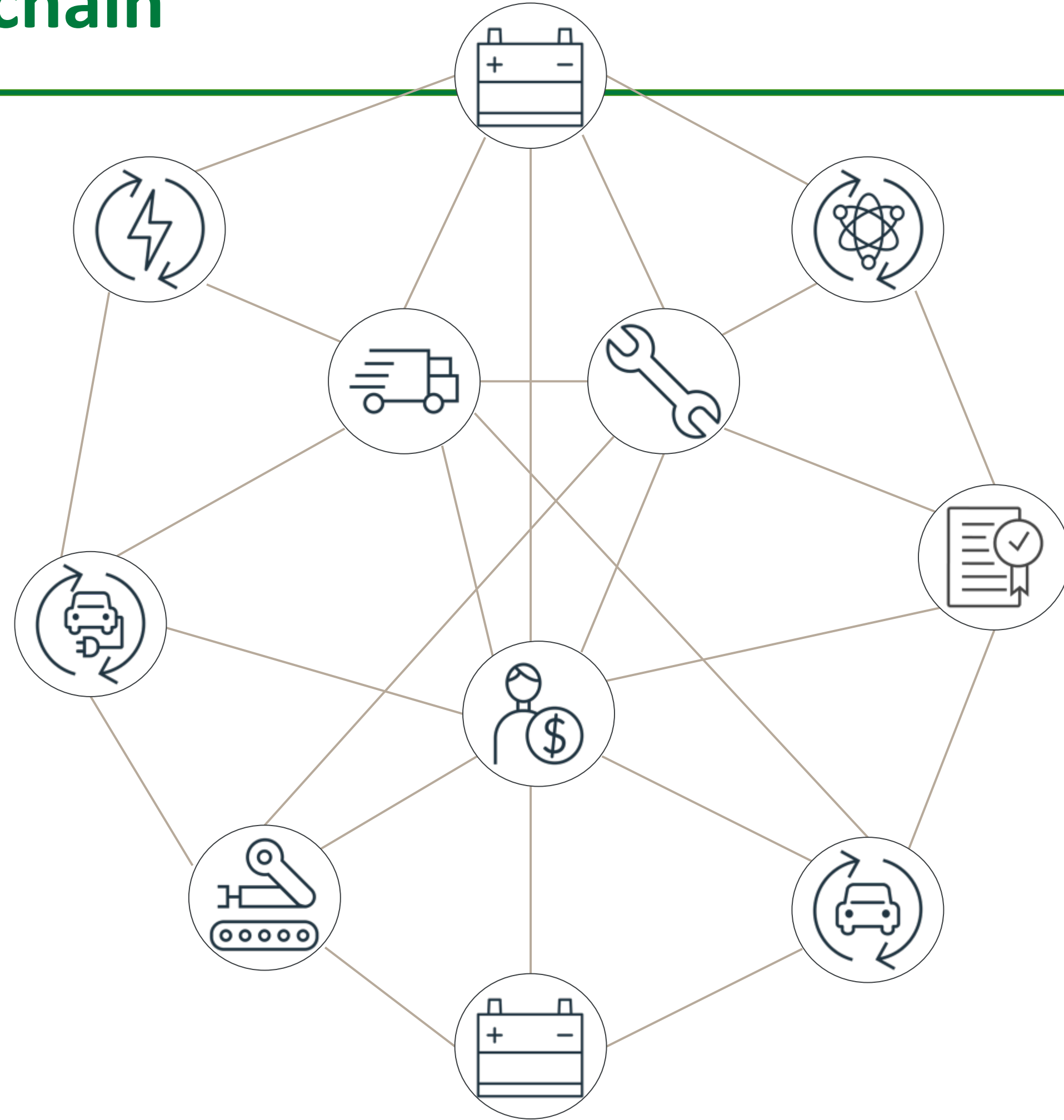


# Concept Overview - Uniting Stakeholders in the Lifecycle



# EVB Stakeholders on Blockchain

**Qualified  
stakeholders  
sharing  
permissioned  
data on a  
distributed  
ledger  
(blockchain)**

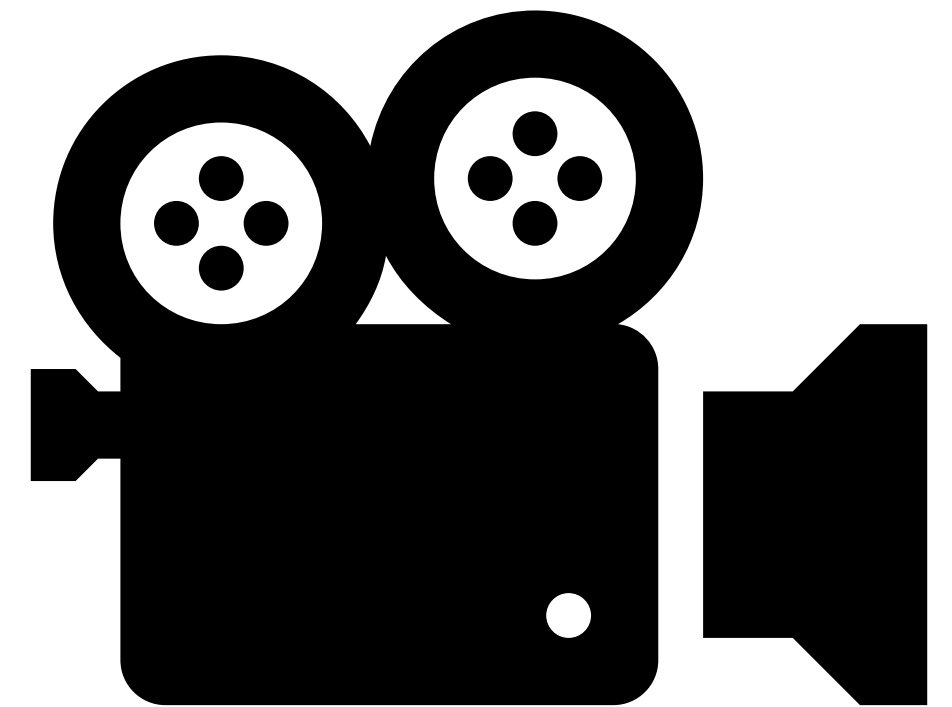




# Video Demonstration

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- **A video demonstration will play shortly.**
- **Check your audio settings on both your computer and your headset to hear the video**



# Potential Voucher Uses

---

## **American Made Network:**

Team EVB member Global Battery Solutions is also an American Made Network member. GBS can provide Team EVBs with a limited prototype license agreement to utilize their commercial-ready Application Specific Integrated Circuit (ASIC) with wireless communication. The ASIC is to be affixed to batteries and will securely transmit key information and characteristics about the battery. Voucher funds can be used to realize the necessary connectivity and interface for the battery data to the blockchain platform - establishing a direct IoT interface or hardware capture through a secure node in the blockchain network.

## **National Labs:**

Team EVBs hopes to engage a National Lab to establish battery health scoring formulas, based on chemistries, from actors and use cases. The objective would be to define boundaries for utilization of the aggregated data in modeling to support value chains and predict movements of materials to end of life processing.



# Get in touch

**Lauren Roman - Business Director Metals & Minerals**

**Ecosystems**

**Lauren@everledger.io**

**+1 973-224-7632**

**everledger.io**

# Admiral Instruments

- Battery Sorting With Voltammetry & Impedance Data
- Track 2 – Separation & Sorting





# Introduction to



**#1 Founded in February 2017**

**#2 Headquarters in Tempe, Arizona**

**#3 E-chem Instruments Manufacturer**

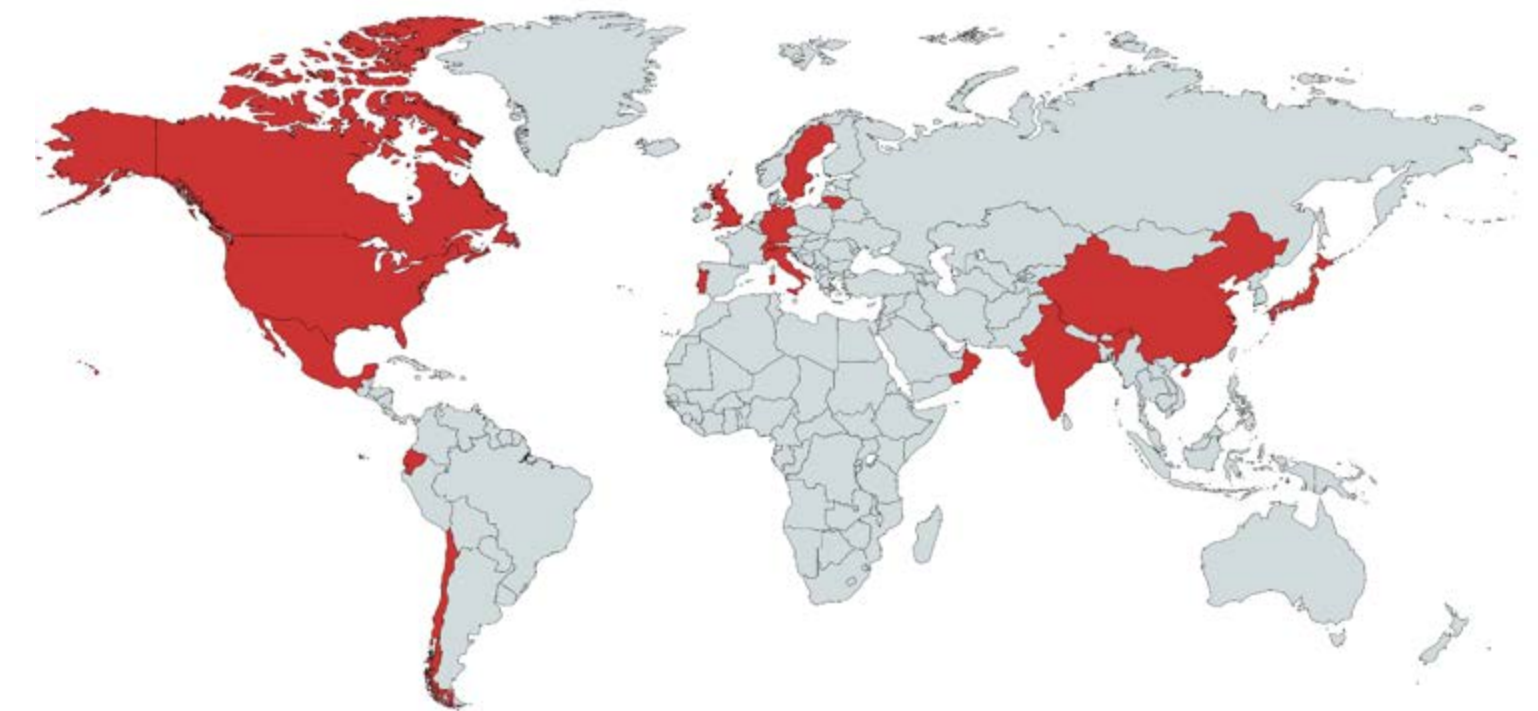
**#4 Eight Full-time Engineers On Team**

**#5 Applying our R&D talent to Li-ion battery sorting to boost recycling profitability**

Notable Company Awards



Squidstat™ Potentiostats Sold To Hundreds of Customers in 24 Countries



Our **proven ability to design & manufacture** research-grade electrochemical workstations lays a solid foundation to invent the...

## ***Electrochemical Battery Sorting System™ (EBSS)***

***Rapid throughput. Automated analysis.***

Our target... in under a second  
**recyclers will know**

**#1 Li-ion Cell Chemistry**

**#2 State of Health (SOH)**

**#3 State of Charge (SOC)**

### **Low Cost**

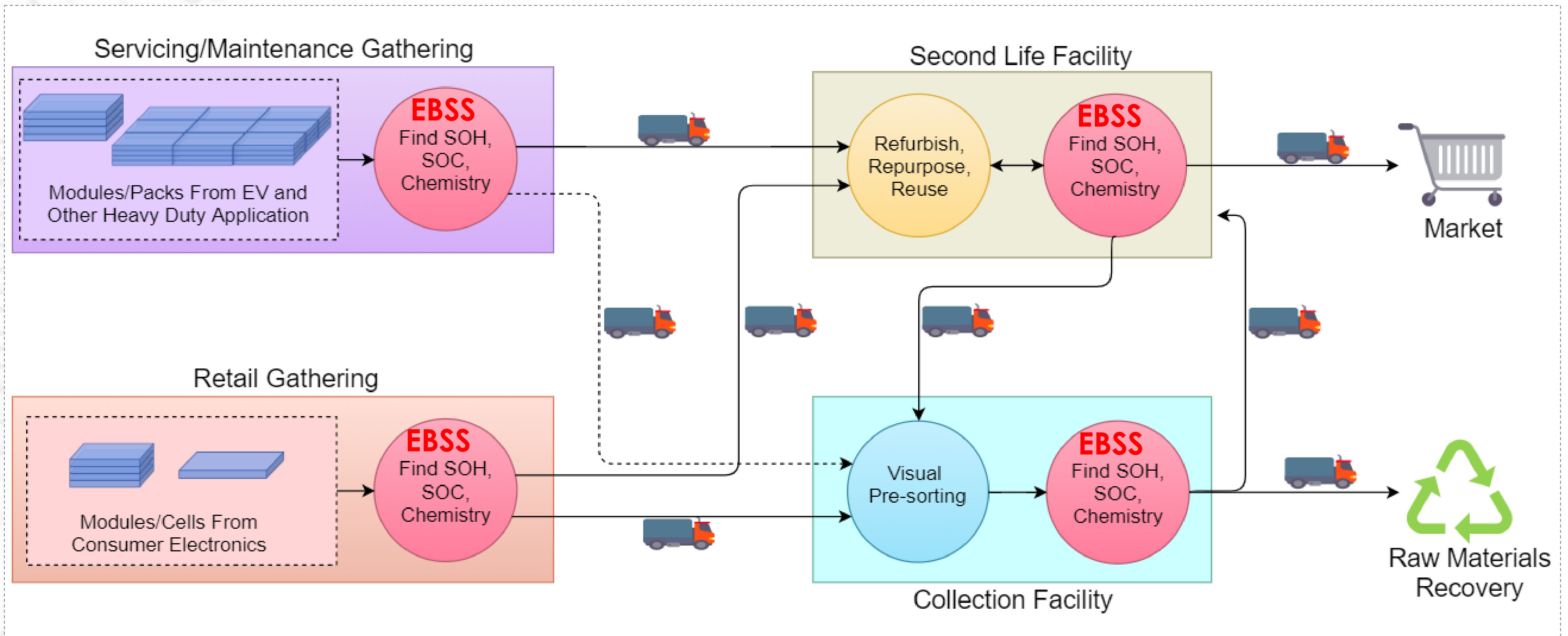
As low as  
\$0.003 per  
cell sorted

### **High Benefit**

+2x resale  
value of  
materials



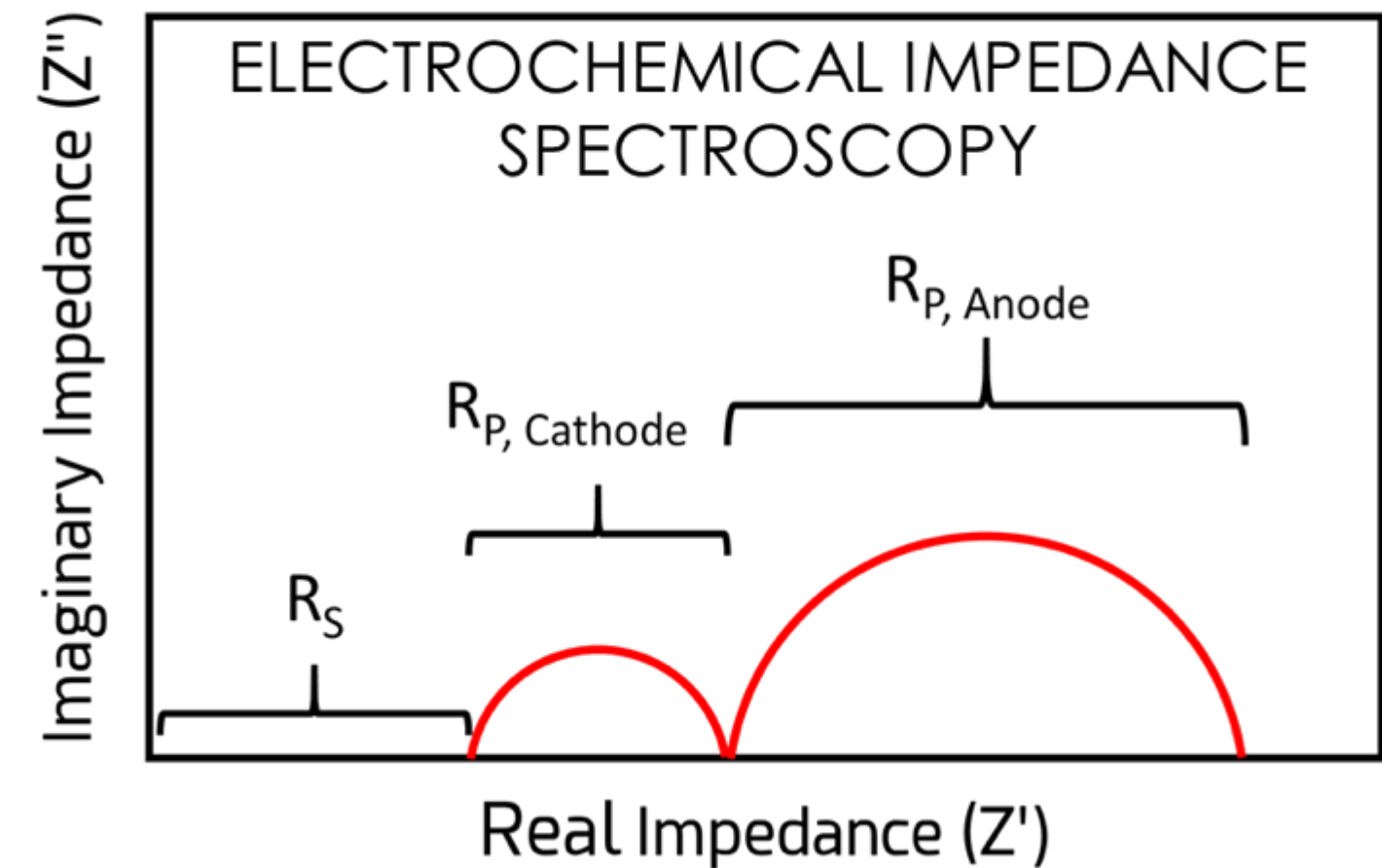
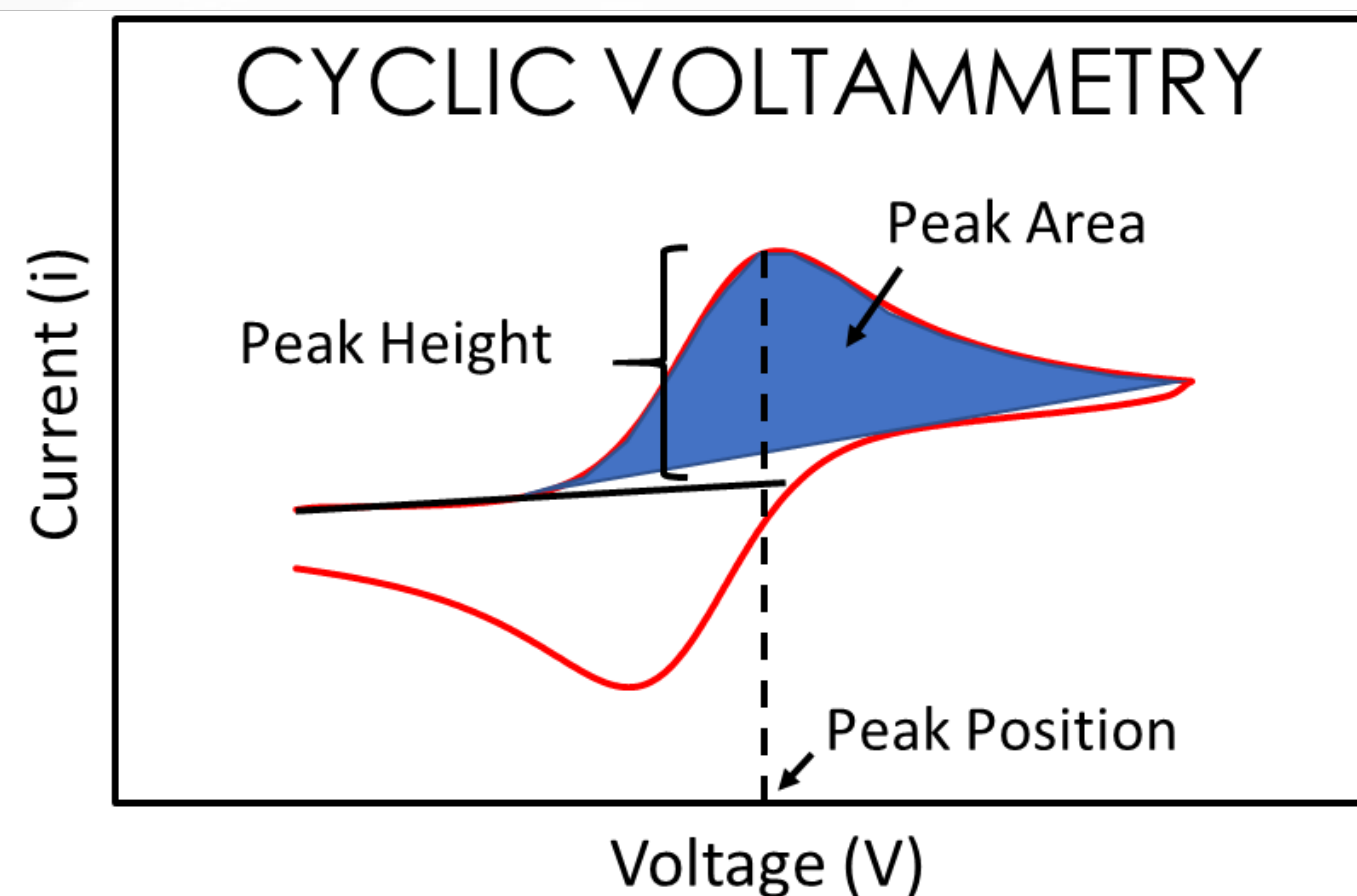
# End-to-End Solution Concept



Process diagram for our End-to-End solution, with **red circles** where EBSS modules are deployed

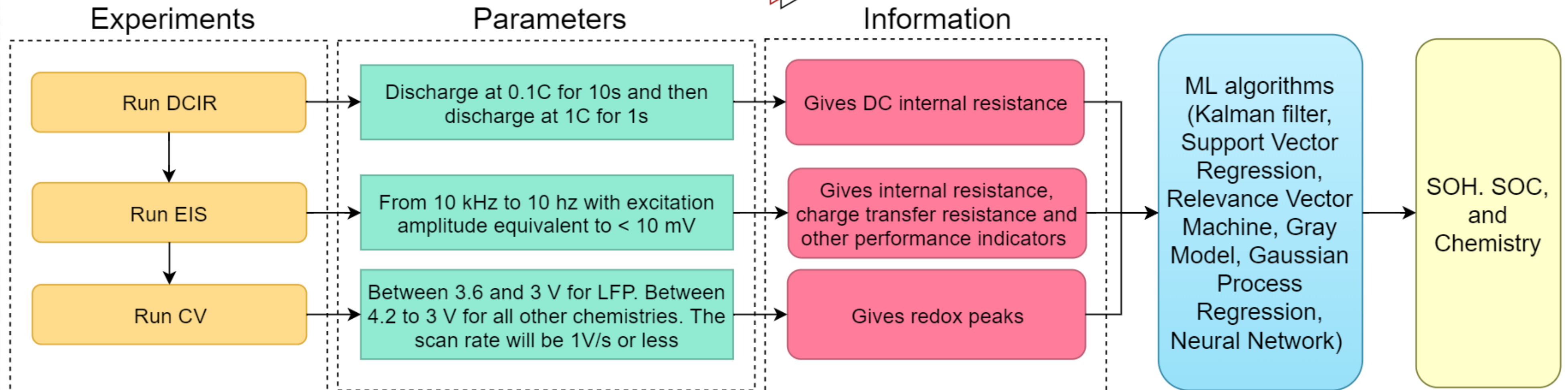
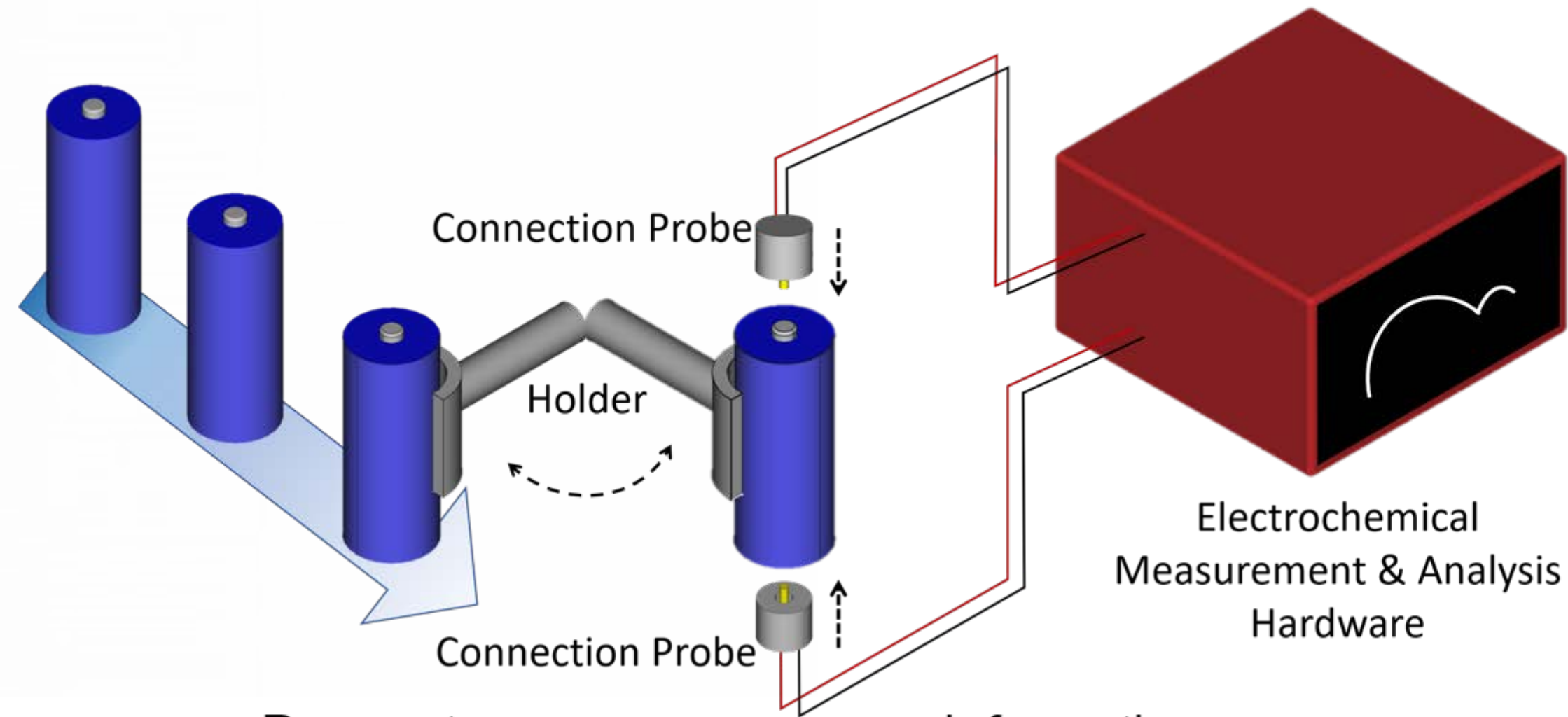
# Phase I Questions To Answer

1. How do peak positions and voltammetry profiles obtained with Cyclic Voltammetry (CV) differ as a function of cathode composition?
2. Do peak positions and profiles obtained during a CV depend on SOC?
3. How do peak positions and profiles obtained during a CV change as a function of battery degradation (SOH)?
4. Can information obtained from CV, combined with Electrochemical Impedance Spectroscopy (EIS), be used to develop models to predict SOC, SOH and cathode composition of Li-ion batteries?





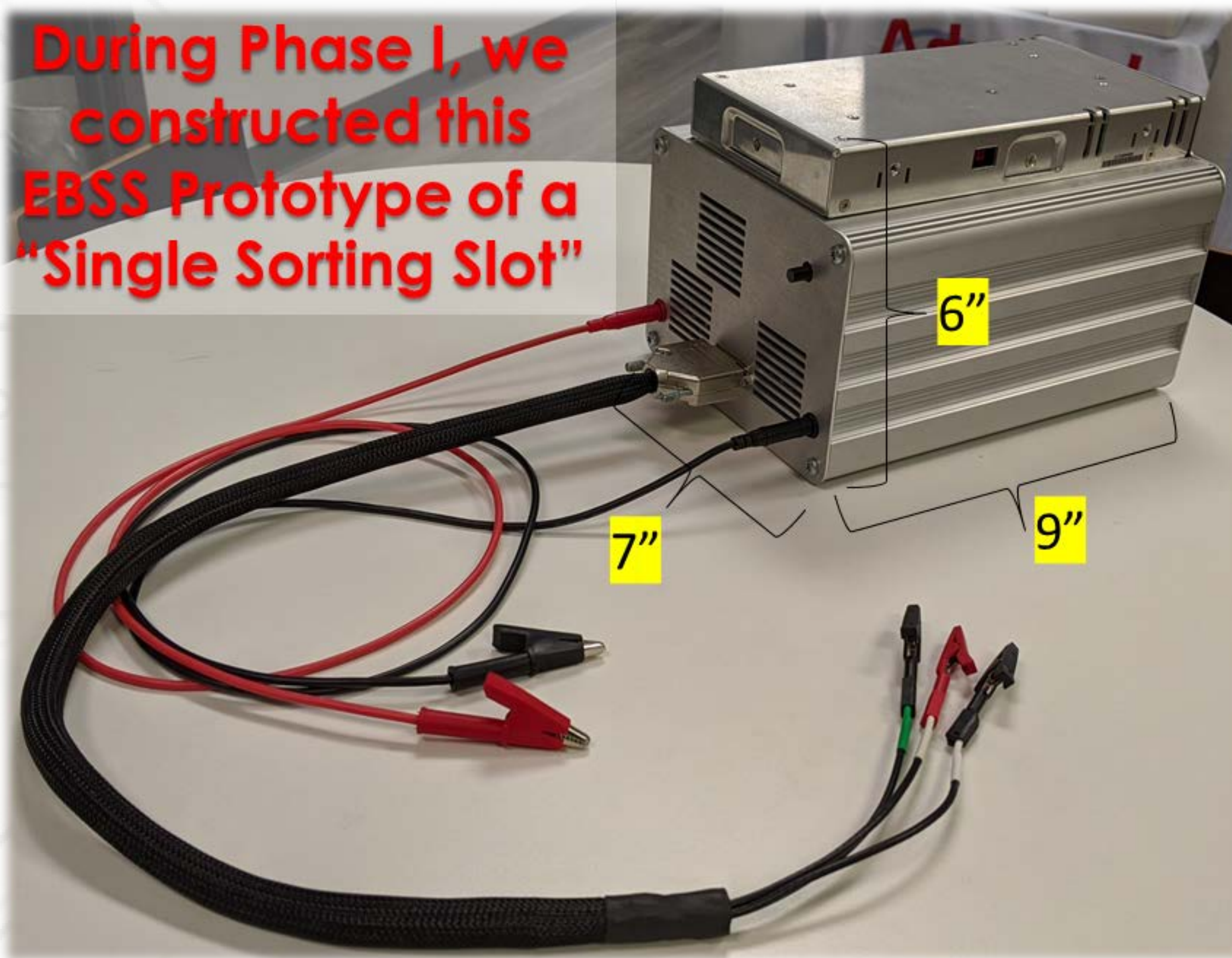
# EBSS Measurement Procedure





# EBSS Measurement Procedure

**During Phase I, we constructed this EBSS Prototype of a "Single Sorting Slot"**



Built Single Channel Prototype in Phase I

Automatic Battery Loading in Phase II



# Summary of Results

Battery Sorting Metric	Cyclic Voltammetry	Electrochemical Impedance Spectroscopy (EIS)
Li-ion Cell Chemistry	YES	NO
State of Health (SOH)	YES	YES
State of Charge (SOC)	NO	YES

## Cyclic Voltammetry

- Need to increase measurement speed
- Slow scan rates may damage cells
- Fast constant current charge-discharge & analyzing  $dQ/dV$  vs.  $V$  may be better
- Designing higher-power sorting channels in anticipation of Phase II

## EIS

- Fast scan (<1 second)
- Non-invasive and non-destructive
- Same hardware design can be used with large cells/packs
- In the EBSS, it needs to be run on each cell before CV

Phase II will focus on automating battery loading into the EBSS and data analysis with Machine Learning

**Phase III will scale to sorting at the scale of battery packs**

# Partners

**we** are seeking for Phase **II and III**

**Battery Recyclers**  
willing to pilot EBSS  
prototypes at their  
recycling facilities



Teams with proven  
**Pre-sorting**  
**Technologies** based  
on cell form factor



**National Labs** to  
help with cycling  
cells and taking  
measurements



# Potential Voucher Uses

- Procuring a wider variety of Li-ion cells, modules, and packs than we have access to by ourselves, and aging the cells in controlled conditions
- Collecting cycling, CV, and EIS data on additional battery chemistries beyond the 5 types tested in Phase I
- Operating EBSS prototypes in “real-world” sorting conditions
- Evaluating efficacy of “pre-sorting” technologies based on cell/module/pack form factors
- Assisting in the design of the automatic battery connector mechanism

# In CLOSING

## Vision Statement

*“Relentlessly invent electrochemical measurement systems to  
help solve the world’s most complex engineering challenges.”*

Proven  
ability to use  
CV and EIS  
together

Clear plan for  
involving  
voucher  
partners

Already  
designing  
Phase II  
hardware





**Mark Sholin**  
President and Co-Founder



**Sujan Shrestha, PhD**  
Applications Engineer

# Follow Us



@potentiostats



[AdmiralInstruments.com](http://AdmiralInstruments.com)

# Contact Us

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Sujan Shrestha, PhD  
*Technical Lead*

[sujan@admiralinstruments.com](mailto:sujan@admiralinstruments.com)  
+1 480 256 8706

# Team Portables

---

Reward to Recycle:  
Closing the loop on portable lithium ion batteries

*A demonstration whereby portable LIBs and the products they power are given a digital identity to engage consumers and support increased recycling*



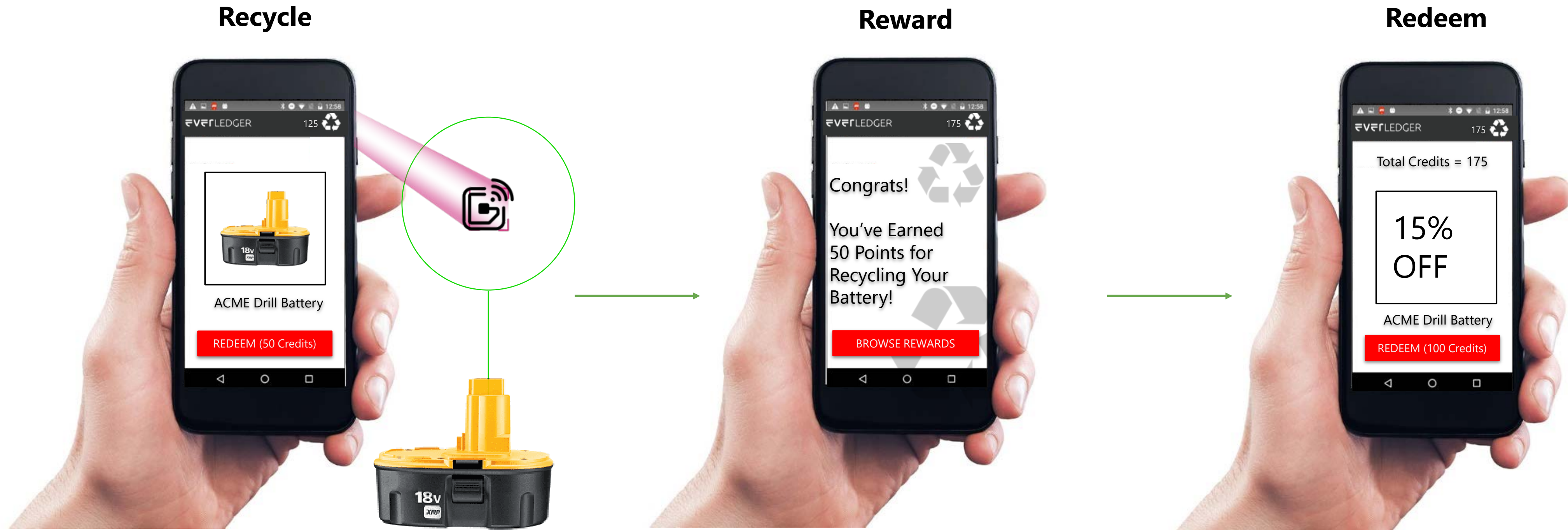


# Team Portables Introduction

## **Team Lead - Matt Davidson, Technical Business Analyst - Everledger**

- Mike Bax - VP Market Development, Call2Recycle
- Rohi Sukhia - President, Open Blockchain Asset Disposition Alliance; CEO; Tradeloop
- Joe Marion - President Association of Service & Computer Dealers/N American Association of
- Telecom Dealers (Ascdi/Natd)
- Jason Linnell - Executive Director, National Center for Electronics Recycling (NCER)
- Steve Christiansen - Executive Director, Responsible Battery Coalition
- Scott Wiggins, VP Environmental Health & Safety - Institute of Scrap Recycling Industries (ISRI)
- David Waggoner, Chief Scientist, Department of Environmental Management - ISRI
- Ron Lembke, Standards Committee Chair - Reverse Logistics Association (RLA)
- Mark Caffarey, President Umicore USA Inc.
- John Greaves, Chair - American National Standards Institute Materials Handling 10 Standards
- Yorke Rhodes, Principal Program Manager Blockchain Engineering - Microsoft Azure
- Carrie George, VP and Head of Sustainability – Everledger
- Lauren Roman, Business Development Director - Metals & Minerals Ecosystem - Everledger

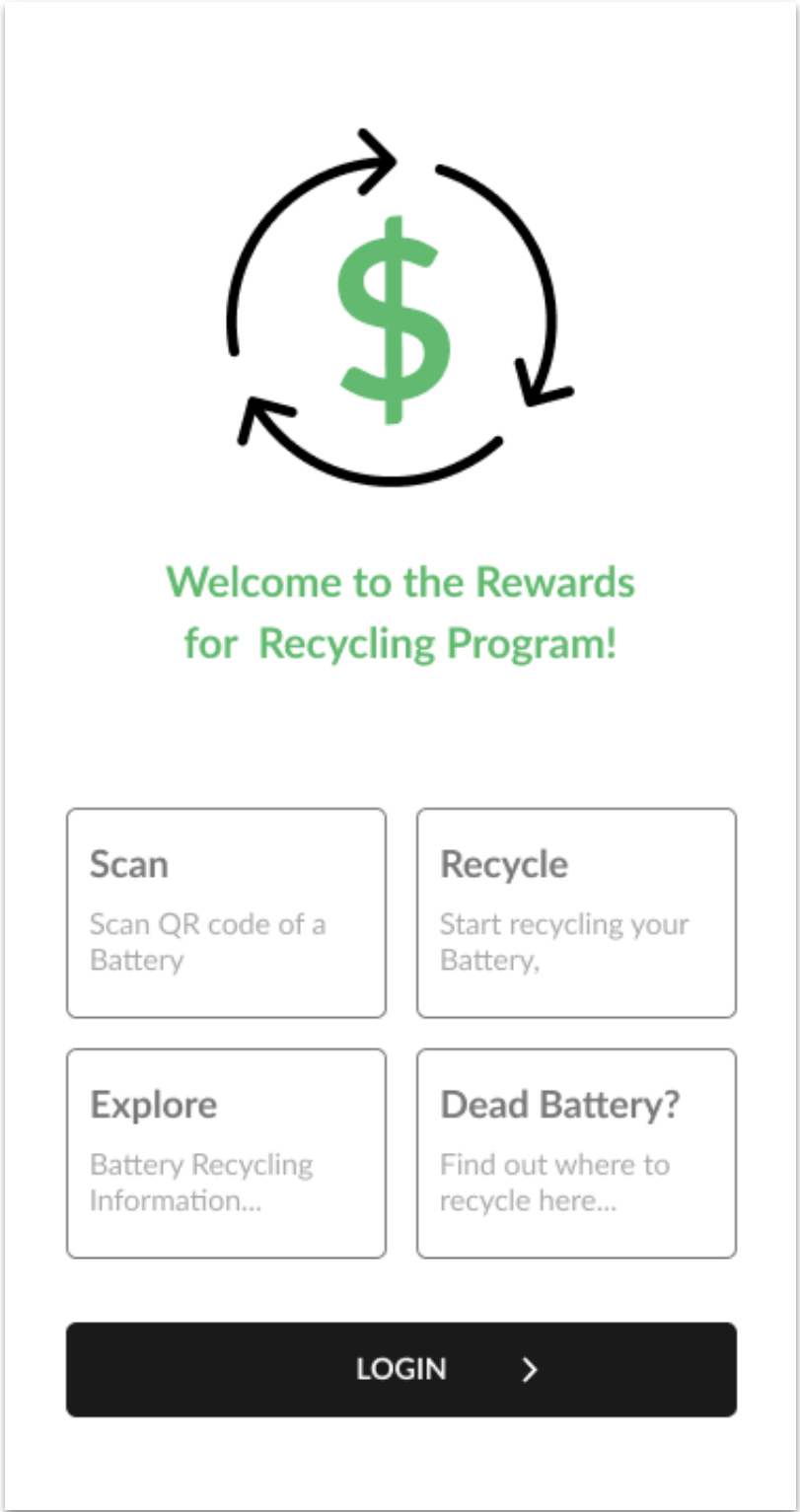
# Reward to Recycle



Consumers will be able to be rewarded at the point of collection through credits that accumulate to reflect their recycling success. Once enough rewards are earned, consumers can redeem these credits for coupons for new products. This can be funded by other mechanisms within the application itself, such as advertising.



# Discovering the Application



# Recycling the Battery

Welcome to the Rewards  
for Recycling Program!

Scan

Scan QR code of a  
Battery

Recycle

Start recycling your  
Battery,

Explore

Battery Recycling  
Information...

Dead Battery?

Find out where to  
recycle here...

My Rewards

Reward for your  
recycled batteries...

BACK

Select which battery to recycle

SCAN NEW

Model Number  
XX2019

OEM  
MFG Name

Serial  
XYZ - Serial

SOH  
XXX-XXX

Model Number  
XX2019

OEM  
Manu name

Serial  
XYZ - Serial

SOH  
XXX-XXX

Model Number  
XX2019

OEM  
Manu name

Serial  
XYZ - Serial

SOH  
XXX-XXX

BACK

Bin/Battery information

Bin Id  
XXX-XXX-XX

Bin Location  
New York

Battery Id  
XXX-XXX-XX

Battery Type  
New York

Recycle Now



# Earning a Reward

←

BACK

≡

Congratulations!

You have recycled your battery!

Bin Id

XXX-XXX-XX

Bin Location

New York

Battery Id

XXX-XXX-XX

Battery Type

New York

Your Reward Details

Coupon Code

XXX-XXX-XX

Reward

XX % OFF

Where to use?

Any ACME battery stores

←

BACK

≡

Your Rewards

Your Reward Details

Coupon Code

XXX-XXX-XX

Reward

XX % OFF

Where to use?

Any ACME battery stores

Your Reward Details

Coupon Code

XXX-XXX-XX

Reward

XX % OFF

Where to use?

Any ACME battery stores

Your Reward Details

Coupon Code

XXX-XXX-XX

Reward

XX % OFF

Where to use?

Any ACME battery stores

←

BACK

≡

Your Reward Details

Coupon Code

XXX-XXX-XX

Reward

XX % OFF

Where to use?

Any ACME battery stores

≡

Welcome to the Rewards  
for Recycling Program!

Scan

Scan QR code of a  
Battery

Recycle

Start recycling your  
Battery,

Explore

Battery Recycling  
Information...

Dead Battery?

Find out where to  
recycle here...

My Rewards

Reward for your  
recycled batteries...

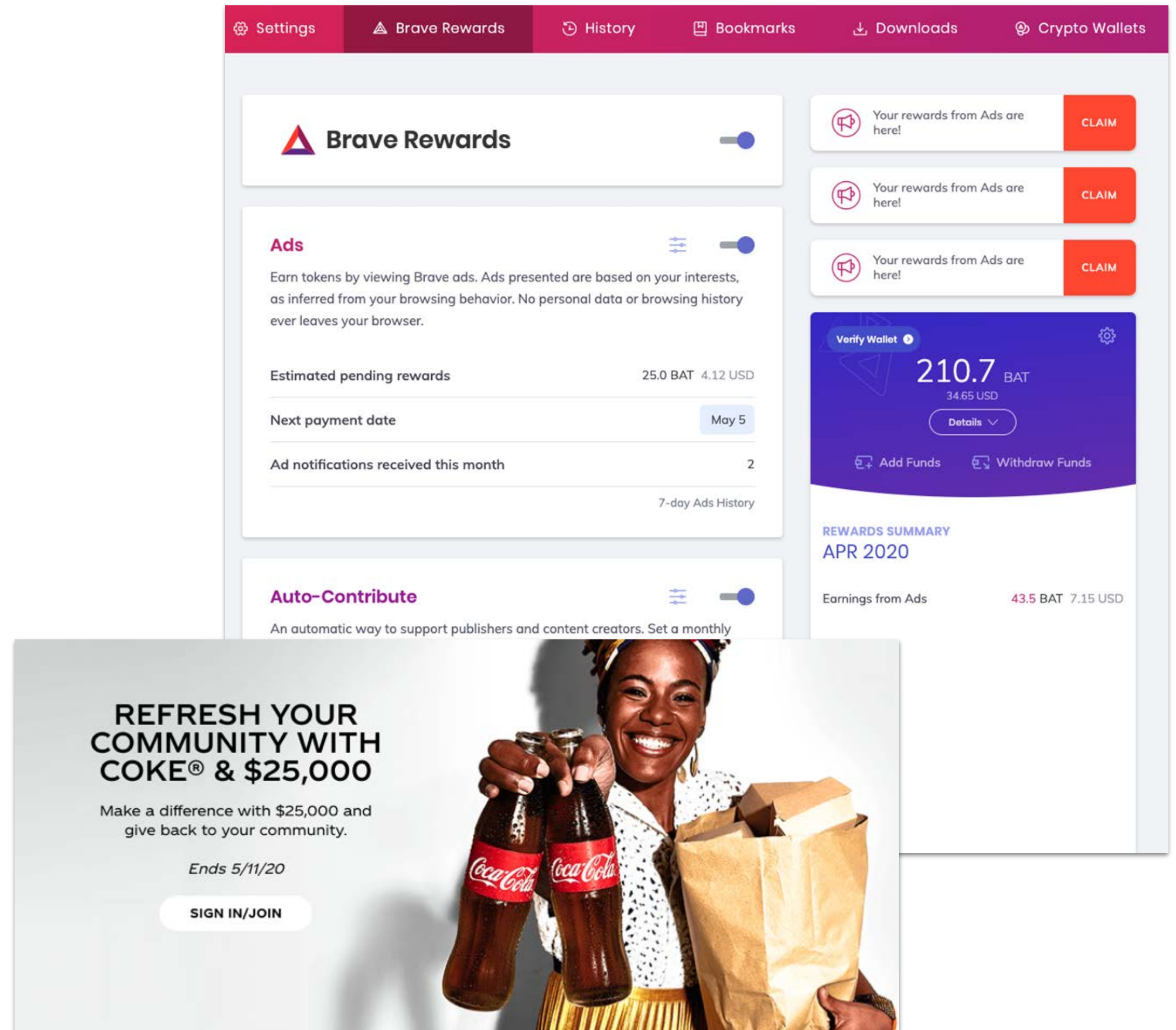
# Points for Rewards Program

Users can accumulate Points that can be redeemed for physical and digital rewards:

- **Vouchers for participating stores, brands**
- **Discounts towards new products**
- Carbon offset purchases
- Sweepstakes
- Altruism
  - Charitable donations
  - Peer to peer donations to support sustainability projects
    - Brave Browser/Patreon mirror
  - Link to give backs

These rewards would be contributed by an ecosystem of platform members. In return, they will be able to promote products and draw from analytics regarding user activity on the platform.

Users can be targeted while in-store recycling old batteries.





# Potential Voucher Uses

- **50% will be used to engage a university** for controlled market research using a validated approach. Market research will test consumers engagement and use of the app that informs, supports and rewards portable LIB recycling.
- Approach will:
  - Specify the information required to answer whether the pilot is successful
  - Design the method for collecting information
  - Manage and implement the data collection process, in a statistically-relevant way
  - Analyze the results
  - Communicate the findings and their implications to the DoE
  - If needed, adjust the pilot according to the findings for a successful wider implementation

The research will consist of four major phases:

1. Determine the research problem
  2. Select the appropriate research design
  3. Execute the research design
  4. Communicate the results
- Prepare and present the final report

**50% will be used to engage a National Laboratory.** Possible project: To evaluate and test options for auto ID (QR code, NFC, other) for identifying and tracking batteries.

# Break

Please return at 3:30 p.m. ET for presentations from VSP Organizations.

Coming up next...

3:30 – Global Battery Solutions

3:40 – Larta

3:50 – EPICenter

4:00 – Energsoft

4:10 – ARKASA

4:20 – Xometry

4:30 – Coulometrics LLC







# Lithium-Ion Battery Recycling Prize

Voucher Service Providers – Organization Presentations



U.S. DEPARTMENT OF ENERGY



# Next Gen Battery Life Cycle Management

Lithium-Ion Battery Recycling Prize Demo Day





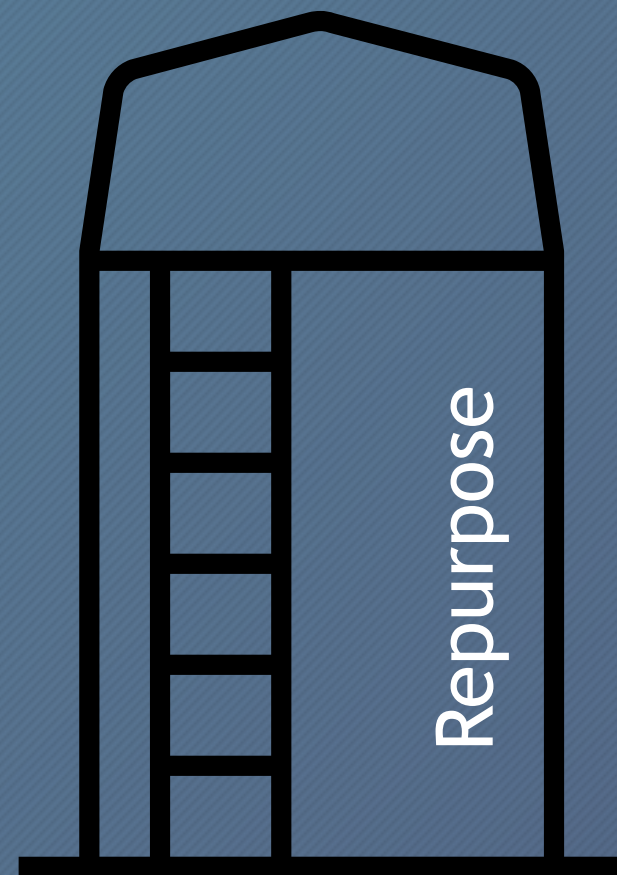
# Global Battery Solutions



- Capabilities
  - Battery life cycle management services
  - Electronics support
  - Solar+ ESS provider
- Automotive OEM supplier
  - Tier 1 and Tier 2
- Engaged in product development and consulting
- Culture of innovation with a focus on quality and sustainability



# Traditional Battery Life Cycle Management

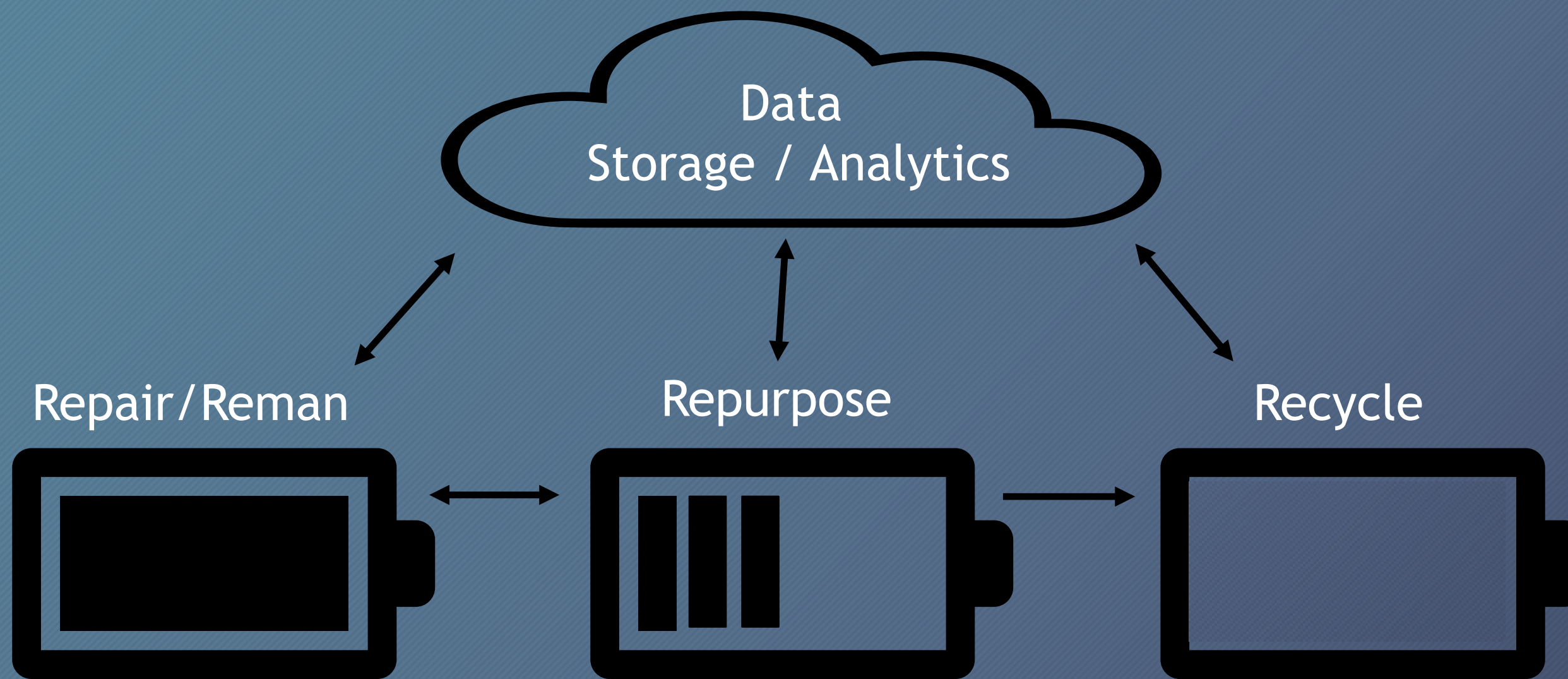


## Silo Effect:

1. Specialize equipment
2. Unknown history of performance
3. Missing/limited incident reporting
4. Grading/Sorting/Balancing challenges
5. Safety concerns



# Next Gen Battery Life Cycle Management



## Potential Benefits of Data Sharing:

1. Active flow and visibility
2. Universal testing equipment
3. Shared history of performance and key events
4. Warranty support and predictive analytics
5. Ease of sorting and grading
6. Potential for standardization, aftermarket confidence and more accurate pricing



# Next Gen Battery Life Cycle Management



- 💡 Cell level and wireless solution to maximize benefits
- 💡 IoT support for digitization of manufacturing
- 💡 Traceability of key material flows
- 💡 Alerts and geographic mapping for first responders
- 💡 Active monitoring for errant behavior in transit



# GBS Affiliations, Awards & Certifications



Michigan Celebrates  
Small Business

2020 Michigan Top 50 Companies  
2020 SmartZone Best Small Business

**NAATBatt**  
INTERNATIONAL



**SBA**  
**WOSB**  
Woman Owned Small Business

**ISO**  
9001:2015



  
**LG PRO**  
SILVER







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## Commercialization Services for BRP Phase III Awardees July 22, 2020



# PANELISTS



ROHIT SHUKLA

*Founder and CEO*

*Larta Institute*



DAVID BEROKOFF

*Program Director*

*Larta Energy Practice*

# AGENDA

**1**

**About Larta**

**3**

**Next Steps**

**2**

**Commercialization Assistance**

**4**

**Contact Information**





# ABOUT LARTA

# LARTA ENERGIZES THE DEVELOPMENT OF NEW TECHNOLOGIES THAT PROMOTE A SUSTAINABLE PLANET.

Our proven model enables entrepreneurs to transform their ideas  
solutions that  
*feed, **fuel**, and heal the world.*

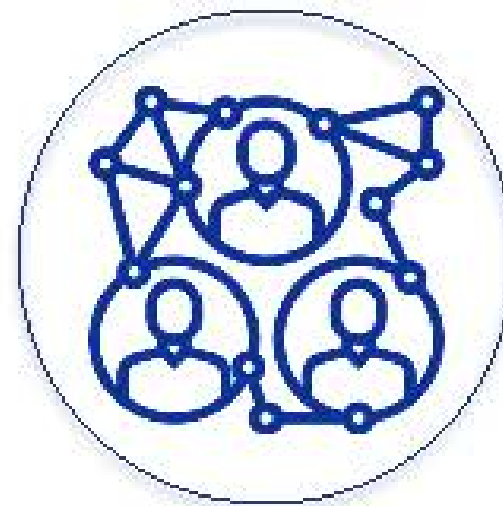
## STAKEHOLDERS



ENTREPRENEURS



GOVERNMENTS



BUYERS &  
ADOPTERS



INVESTORS

# OUR MISSION



# LARTA'S MODEL FOR SUCCESS

Optimize your new technology's marketplace success with our system of commercialization programs and services.



Expert Advisors



Commercialization Plan



Valuable Resources



Strategic Connections

# ENGAGING WITH SBIR/STTR AWARDDEES



**NIST**





# LARTA'S ROSTER OF PRINCIPAL ADVISORS (PAs)

## PERSONALIZED GUIDANCE FROM A NETWORK OF EXPERTS AND SUCCESSFUL ENTREPRENEURS

Each Larta client company is matched with a hand-picked Principal Advisor with experience in the client's sub-sector. The PA, who is selected from our bench of 100+ seasoned experts, becomes the company's advocate, guide and curator, guiding each company one-on-one to build and execute a roadmap for success

# PA & INDUSTRY BENCH STRENGTH

A profile of Larta's bench of Principal Advisors:

13 years average of business consulting experience

18 years average of commercialization experience

98% Have startup experience

35% Have VC experience

50% Have incubator experience

Many have worked for or with industry leaders such as organizations shown at right:

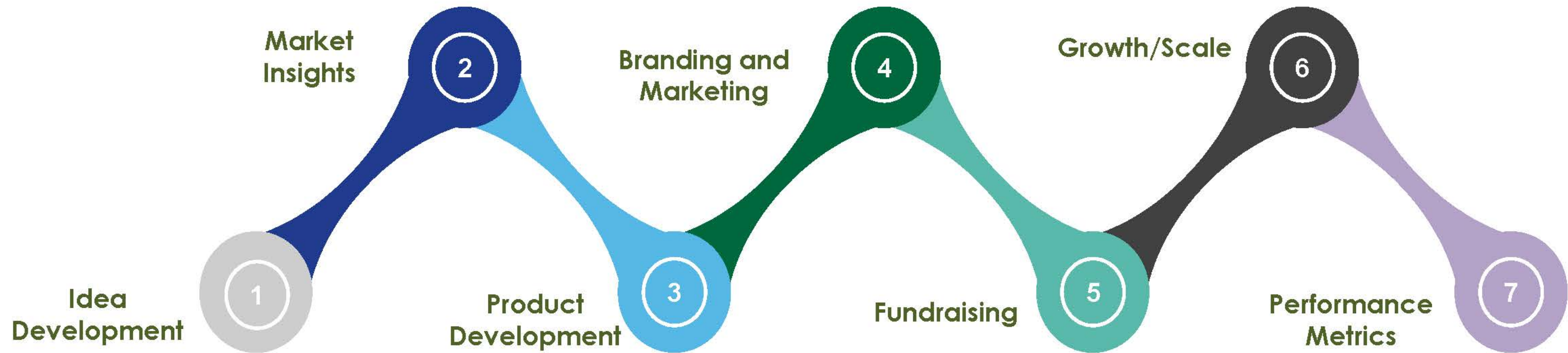






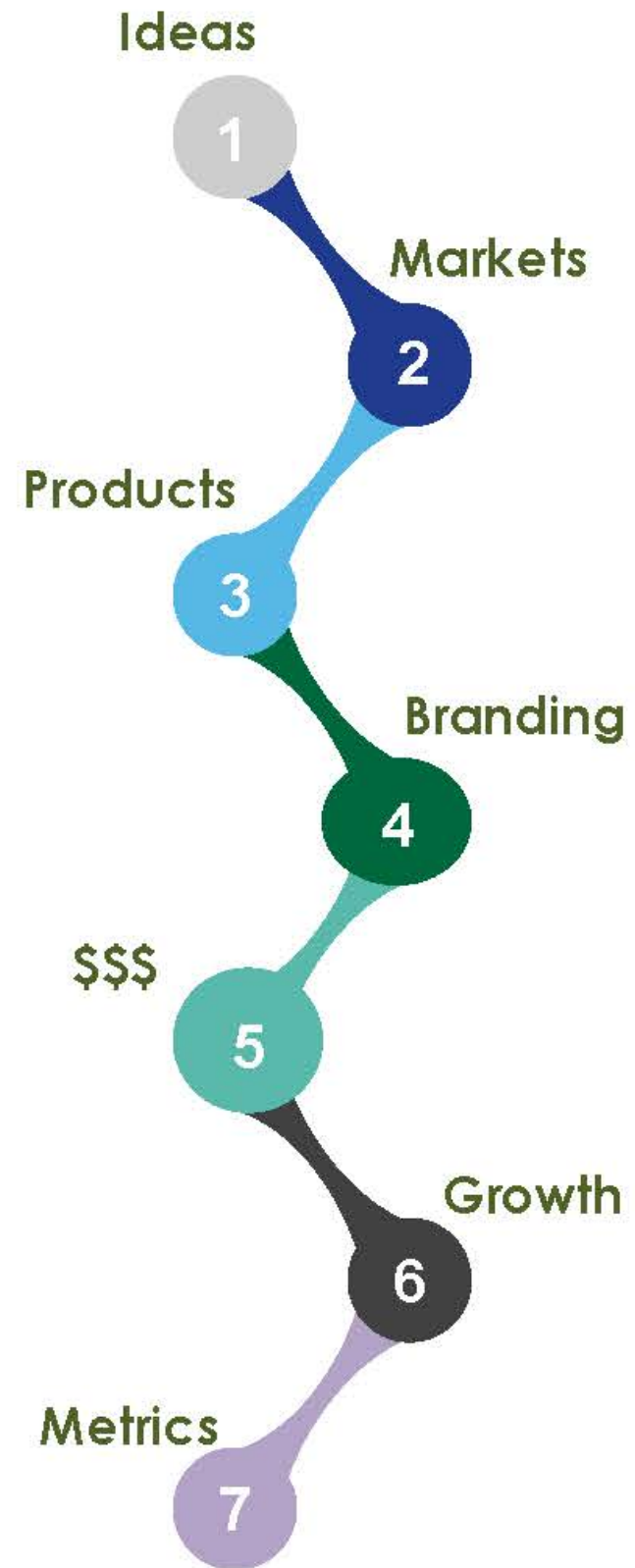
# COMMERCIALIZATION ASSISTANCE

# LARTA'S 'MENU' SERVICES





# LARTA'S MENU SERVICES

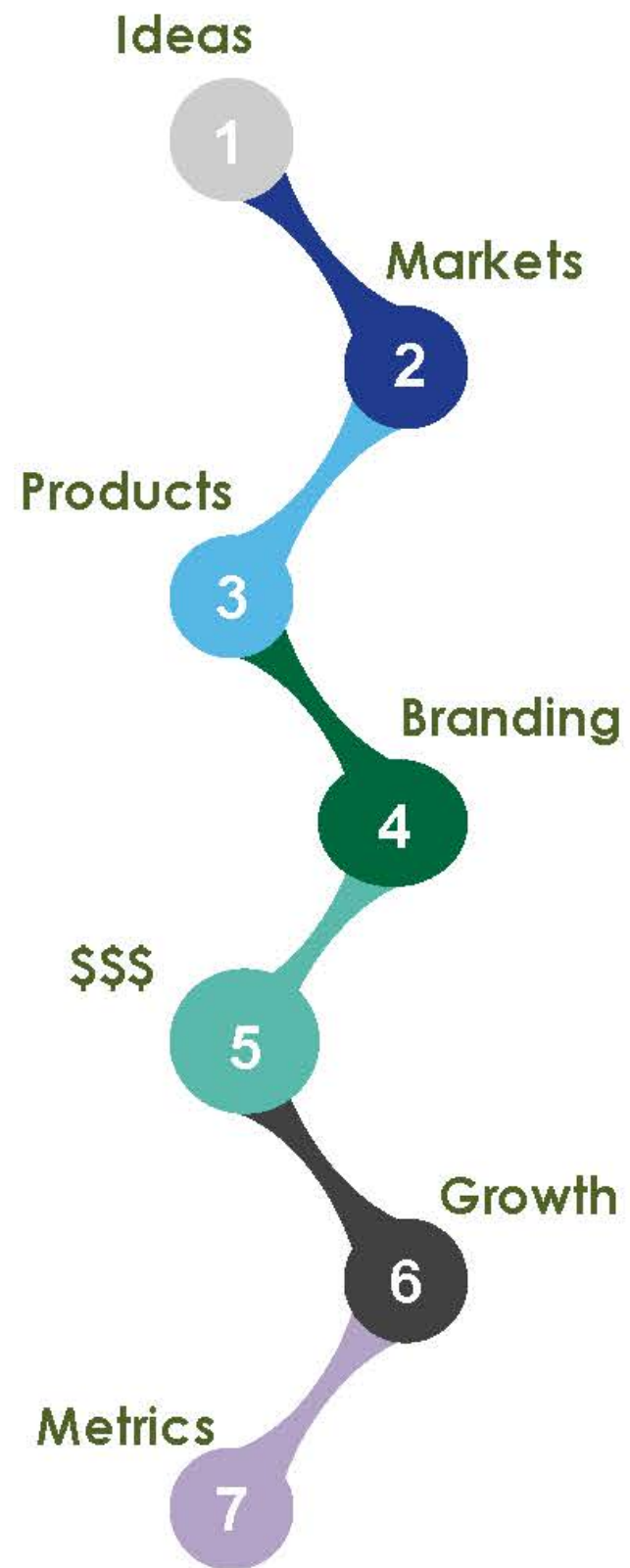


## IDEA DEVELOPMENT:

*critical T2M building blocks and roadmaps.*

- Customer Value Proposition
- Business Plan Development
- Technology Assessment
- IP Assessment
- Licensing Strategy

# LARTA'S MENU SERVICES



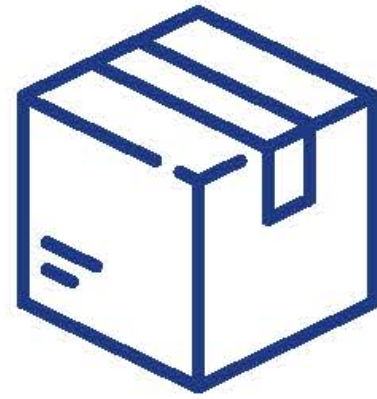
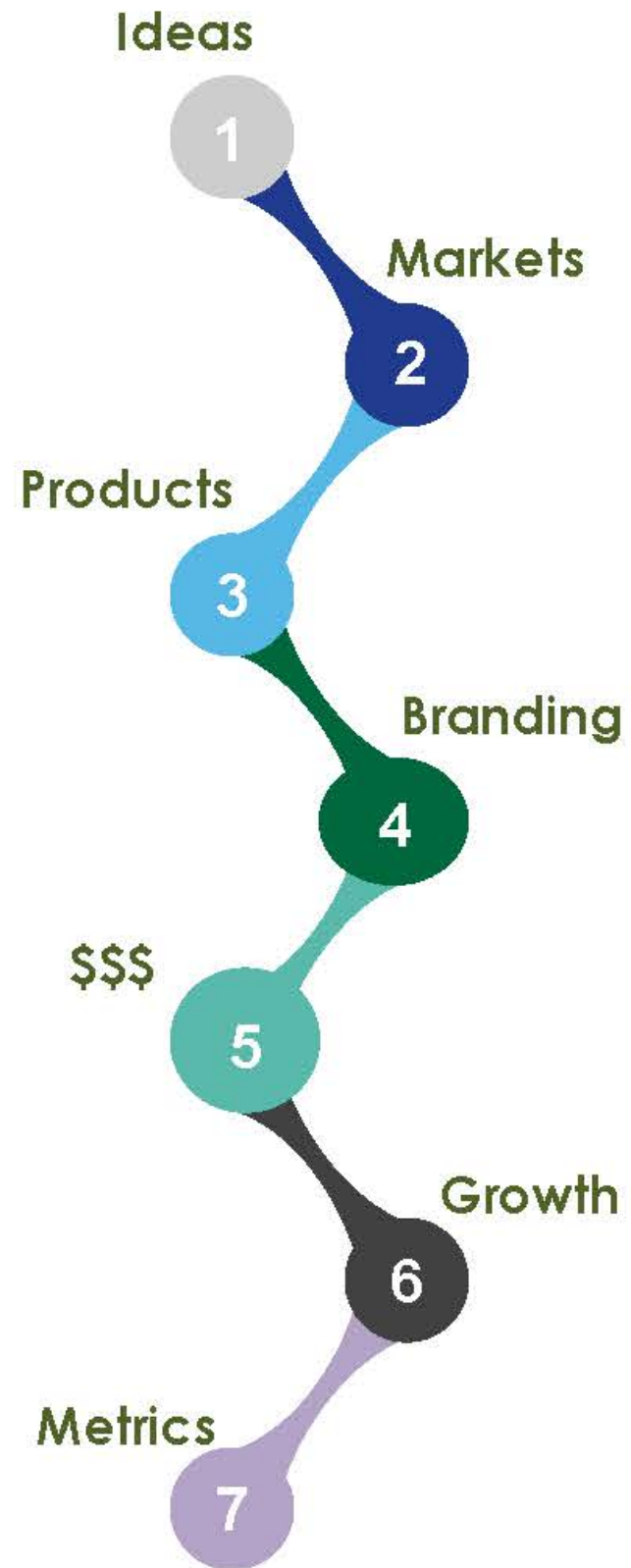
## MARKET INSIGHTS:

*market research, pricing, key industry stakeholders*

- Go-To-Market Strategy
- Customer Discovery
- Primary Market Research
- Secondary Market Research
- Customized Market Research
- Pricing Strategy
- Key Industry Points of Contact



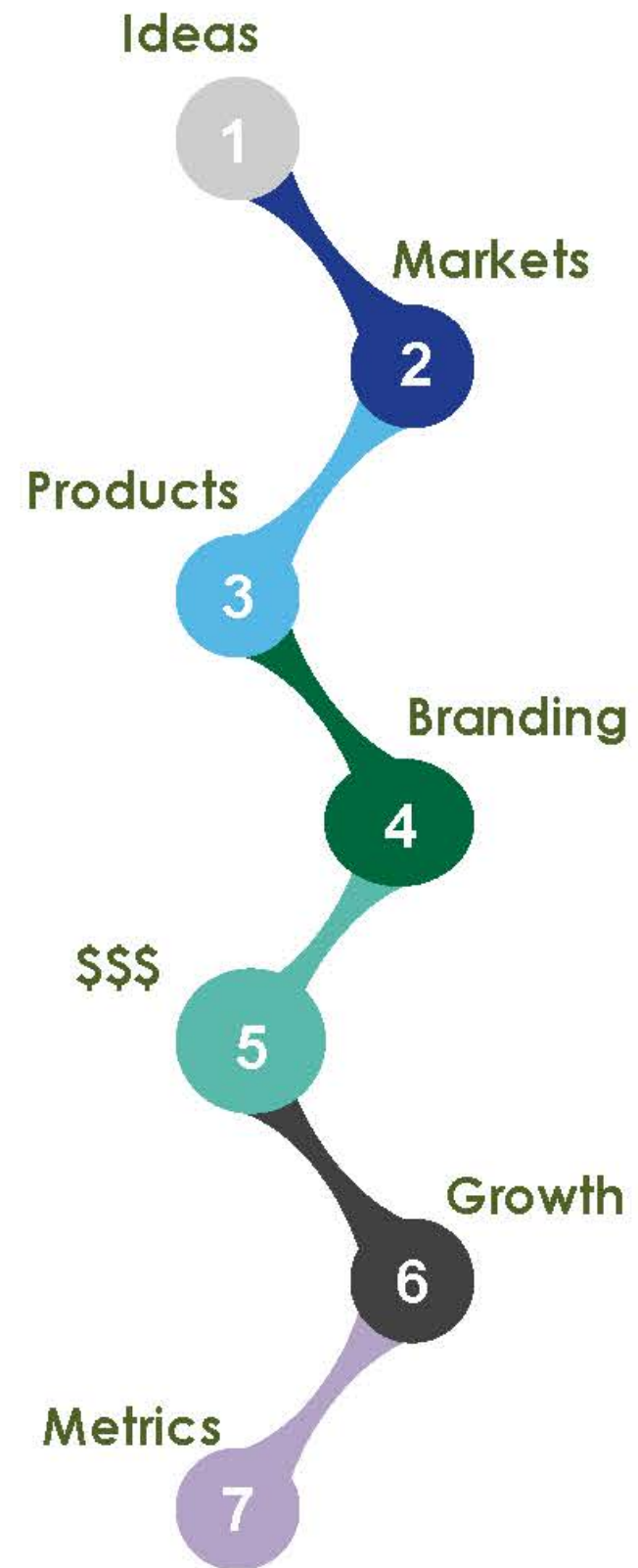
# LARTA'S MENU SERVICES



**PRODUCT DEVELOPMENT:**  
*transforming concept to production to  
scale.*

- Product and Market Roadmap
- Testing and Validation Plan
- Prototype Refinement and Optimization
- System Integration Analysis
- Field Demonstration Support
- Manufacturing Feasibility Assessment

# LARTA'S MENU SERVICES

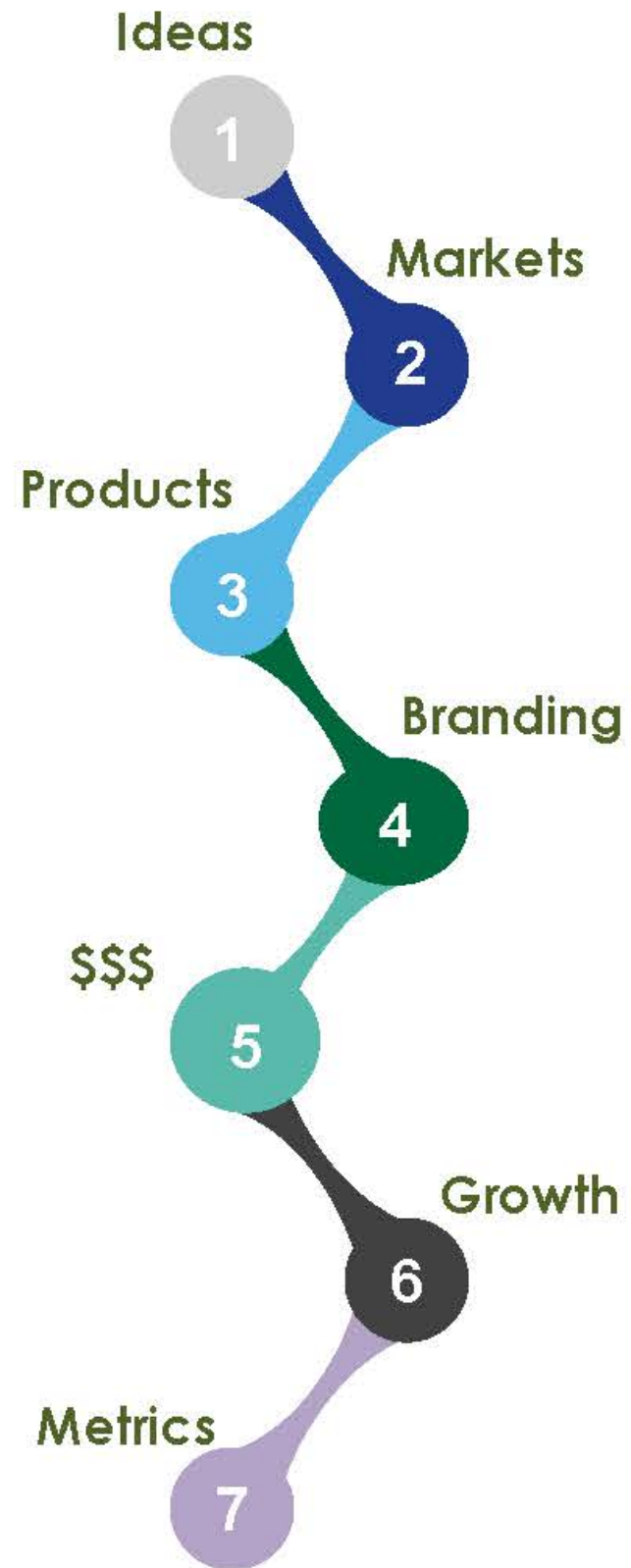


**BRANDING & MARKETING:**  
*sales and marketing, branding, website*

- Marketing and Promotional Strategy
- Branding Strategy
- Website Development
- Sales/Marketing Materials



# LARTA'S MENU SERVICES

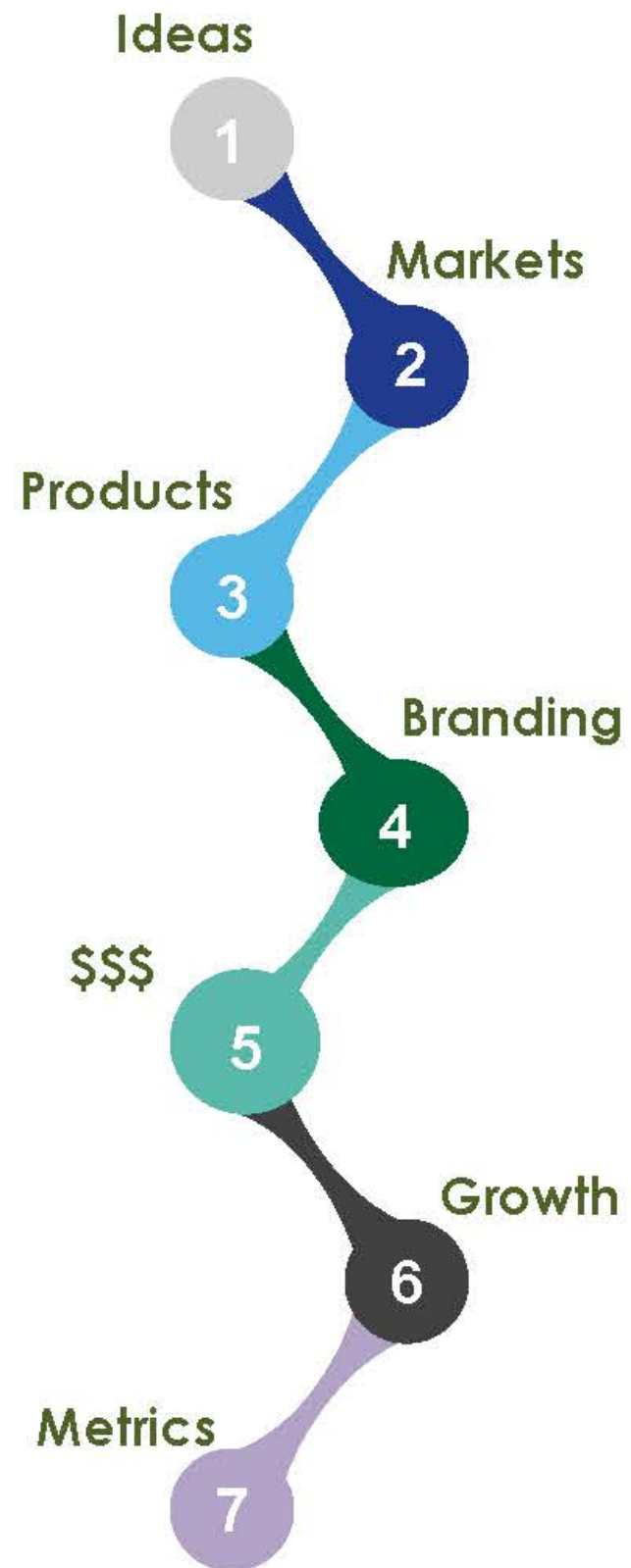


## FUNDRAISING:

*prepare for licensing/fundraising*

- Fundraising Strategy
- Pitch Deck
- Business and Financial Modeling
- Licensing Fees Negotiations
- Investment Term Sheet

# LARTA'S MENU SERVICES



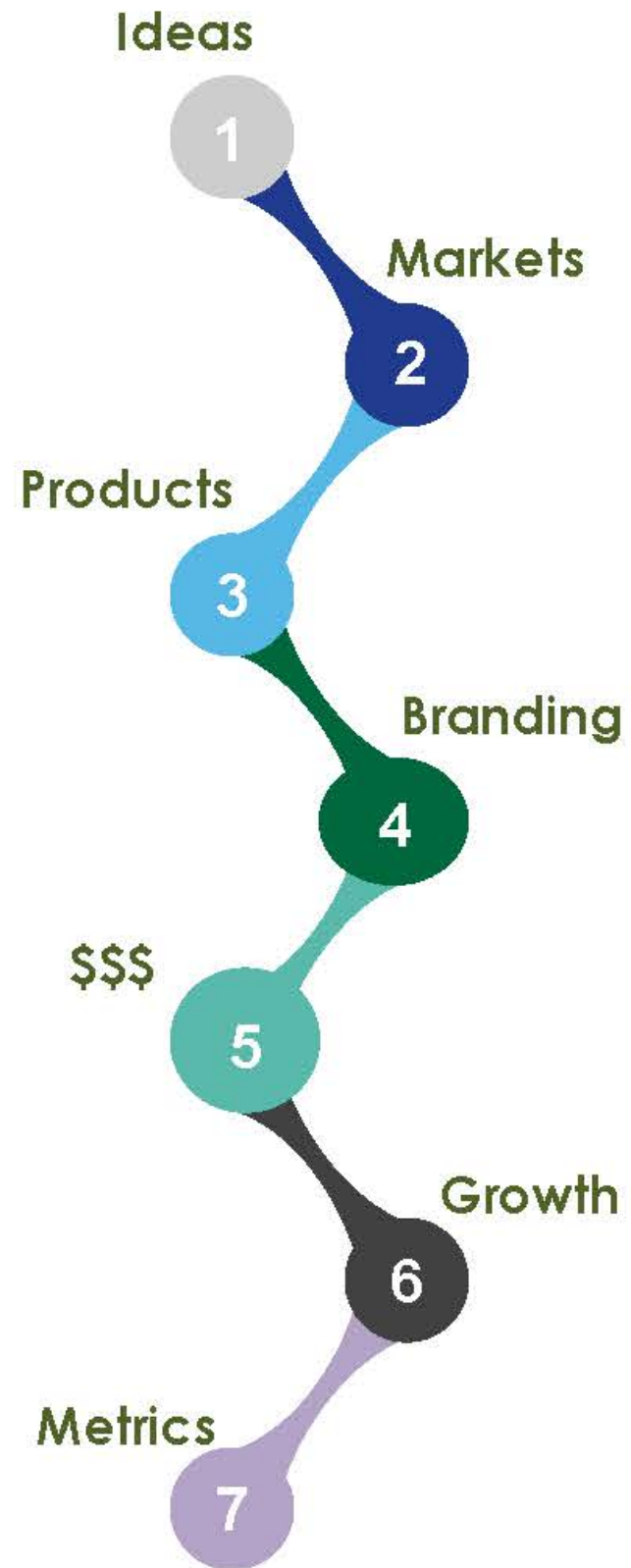
## GROWTH/SCALE:

*business, production and revenue growth*

- Growth Financing
- Business Workflow Processes/Systems
- Manufacturing and Production
- Business and Financial Modeling
- Staffing
- Partners



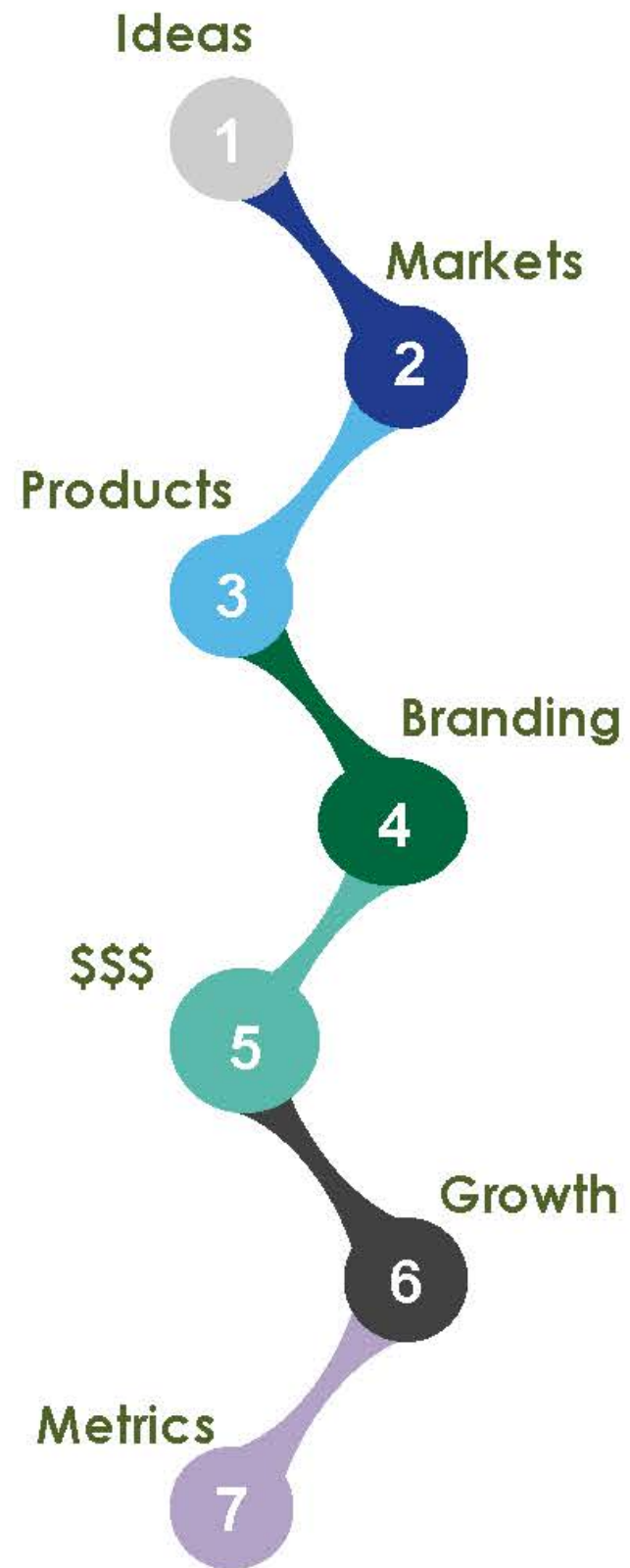
# LARTA'S MENU SERVICES



**PERFORMANCE METRICS:**  
*Tracking commercialization milestones*

- License Deals
- M&A Events
- Fundraising
- Product Launches
- Partnerships
- Government Awards/Grants

# LARTA'S MENU SERVICES



## GROWTH/SCALE:

*business, production and revenue growth*

- Growth Financing
- Business Workflow Processes/Systems
- Manufacturing and Production
- Business and Financial Modeling
- Staffing
- Partners





# NEXT STEPS

# NEXT STEPS

*Connect with us to:*

- **Complete** “needs assessment”.
- **Recognize** where you stand in reference to a subject market.
- **Understand** how we can help fill critical gaps/needs.
- **Launch** engagement.
- **Deliver** outstanding value with completed outcomes.





## CONTACT US



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*Larta Energy Practice*  
*Associate Director*  
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vpaliwal@larta.org



David Berokoff  
*Larta Energy Practice*  
*Director*  
213 262-1638  
dberokoff@larta.org

**Ideas, energized.**





# Creating a Energy Innovation Hub

- Founded in 2015



- Separate 501(c)(3) organization with board members from each founding organization
- Vision for an **energy innovation hub** with a global impact
- “EPI” stands for:
  - Energy
  - Partnerships
  - Innovation

# Mission and Vision

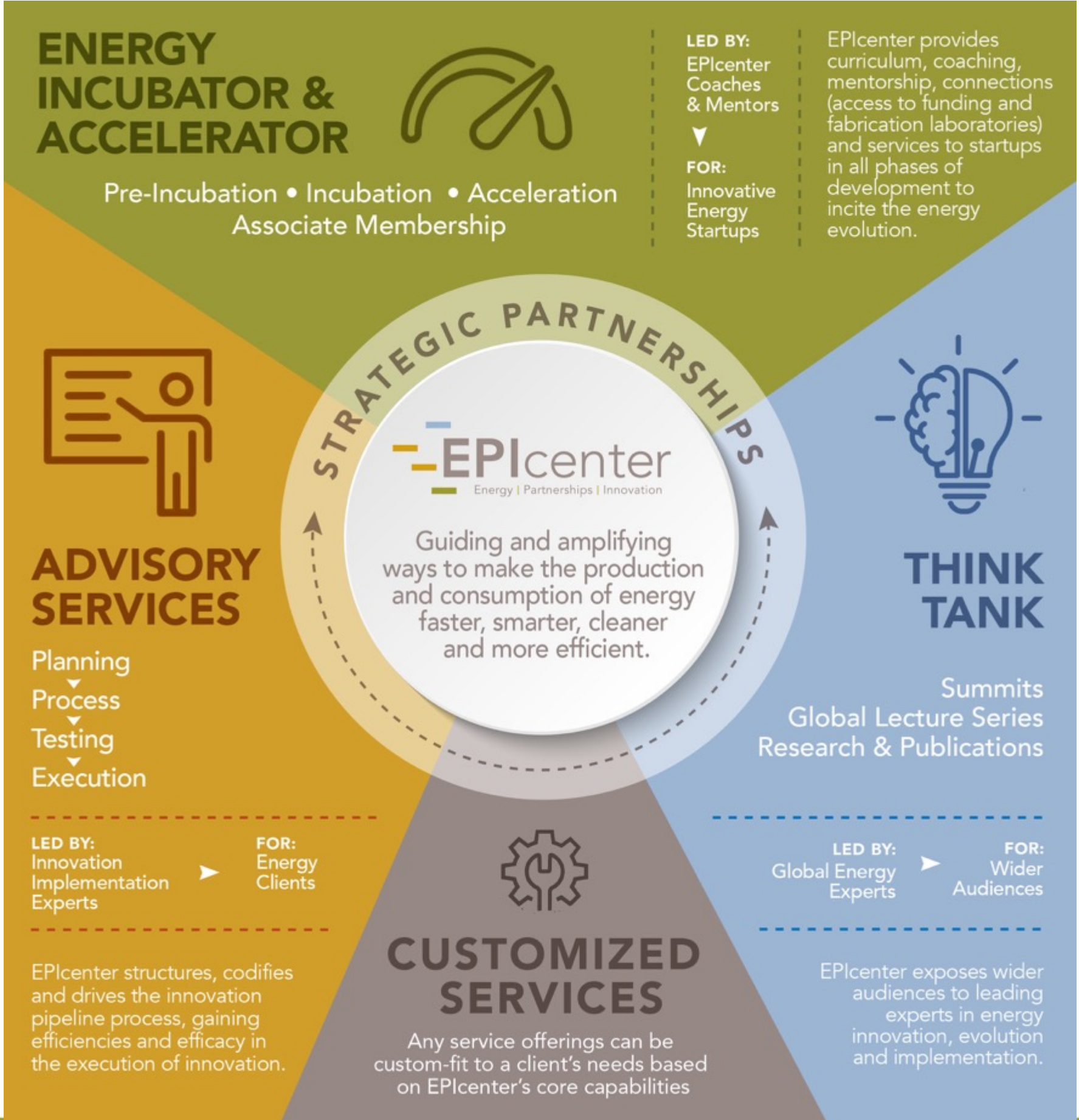
**EPIcenter** propels energy innovation and thought for our global future with a think tank, incubator and accelerator, strategic partnerships, and critical conversations around energy.

Its vision is to be the hub for energy innovation and thought leadership driving profound global impact.





# Energy Innovation and Thought Leadership Hub



For mature startups with energy-related innovations, there are two ways to engage with Advisory Services:

- If you are interested in being considered by one of our utility clients for their innovation pipelines (pilot opportunities, demonstrations, etc.) EPIcenter can review your product or service and determine potential fit.
- If you are interested in business development and partnership support, EPIcenter can contract directly with a startup to facilitate introductions to potential key partners and assist with your business development efforts.



## EPIcenter Energy Incubator and Accelerator (EEIA)

- 4 distinct programs that serve energy startups at various stages of development
- Focus on innovations that have the potential to impact advancement of energy
- Services include:
  - One-on-one coaching with a Certified Business Coach
  - Access to mentors and subject matter experts from various industries
  - Access to technical and fabrication resources
  - Access to proven curricula
  - Access to funding, potential pilot partners, channel partners, etc.



# Strategic Partners

EPIcenter has a strong network of 80+ strategic partners





# *Contact Us*

*Andi Littlejohn*

*Director of the EPIcenter Energy Incubator and Accelerator*

[\*alittlejohn@epicenterus.org\*](mailto:alittlejohn@epicenterus.org)

*(210)904-2625*

*epicenterus.org*

# Energsoft – Battery Analytics Platform

Lithium Battery Recycling Prize 2020

Slava Agafonov – CEO

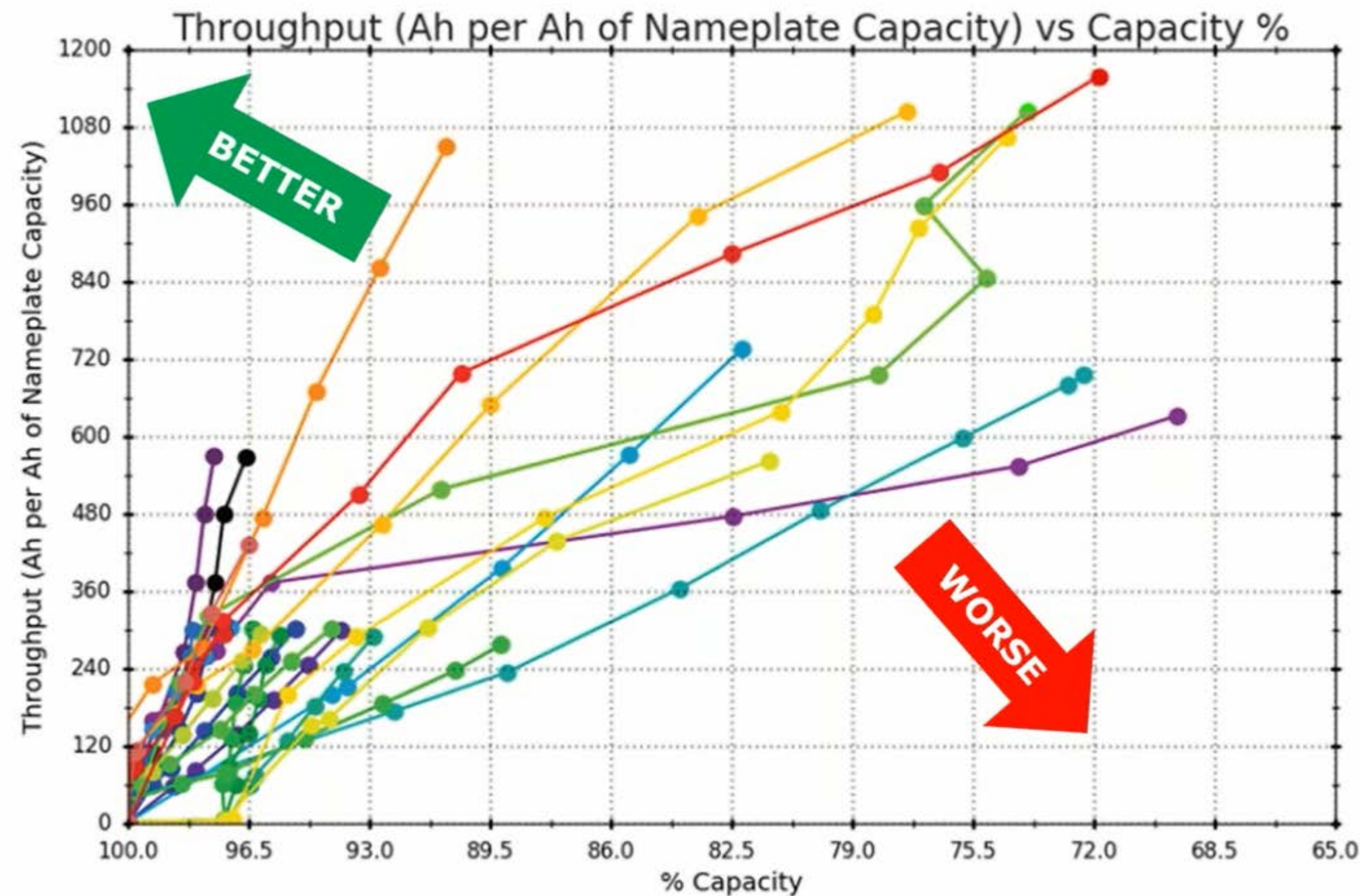
[slava@energsoft.com](mailto:slava@energsoft.com)

<https://energsoft.com>





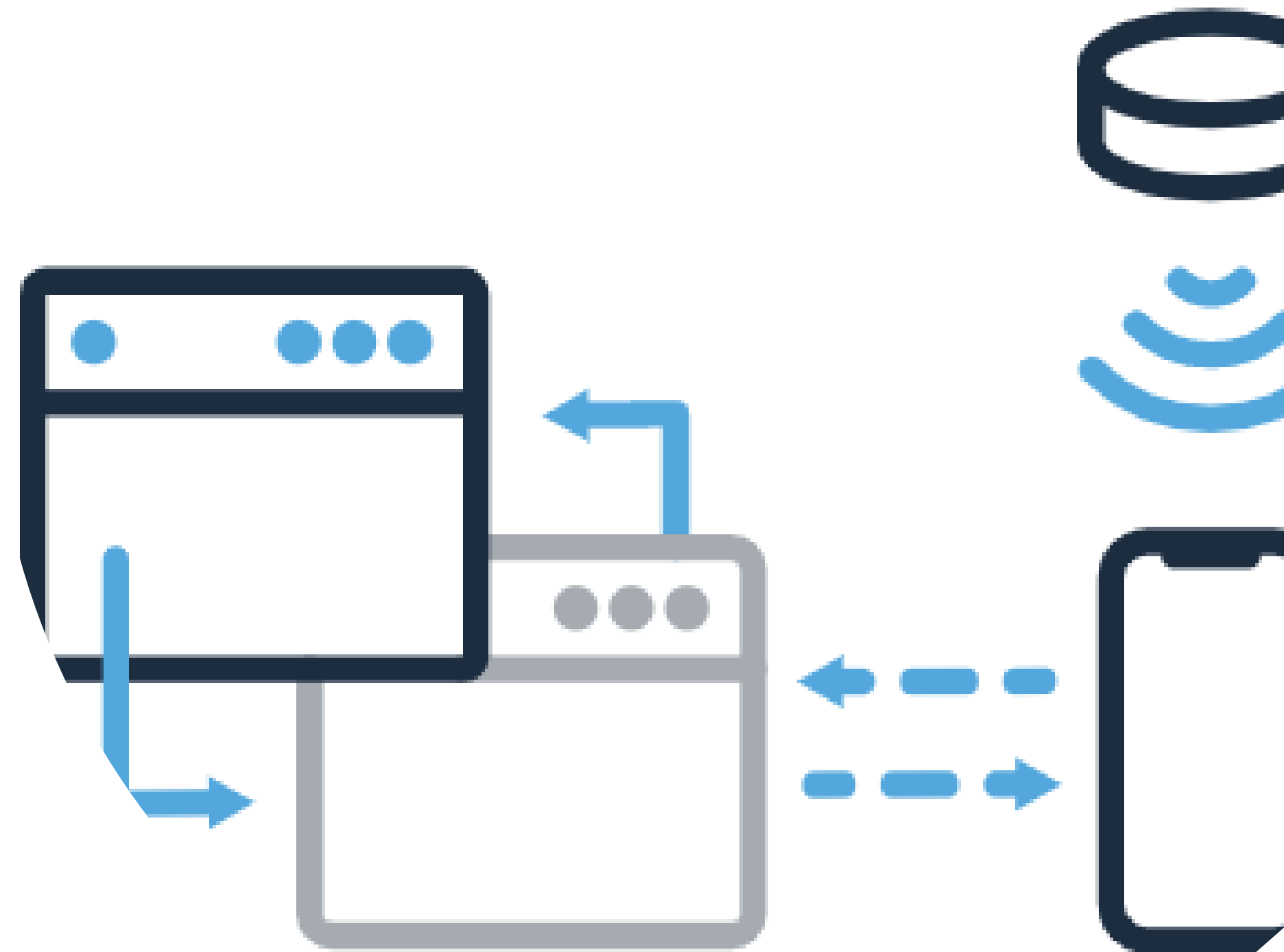
# Battery recycling supply chain challenges



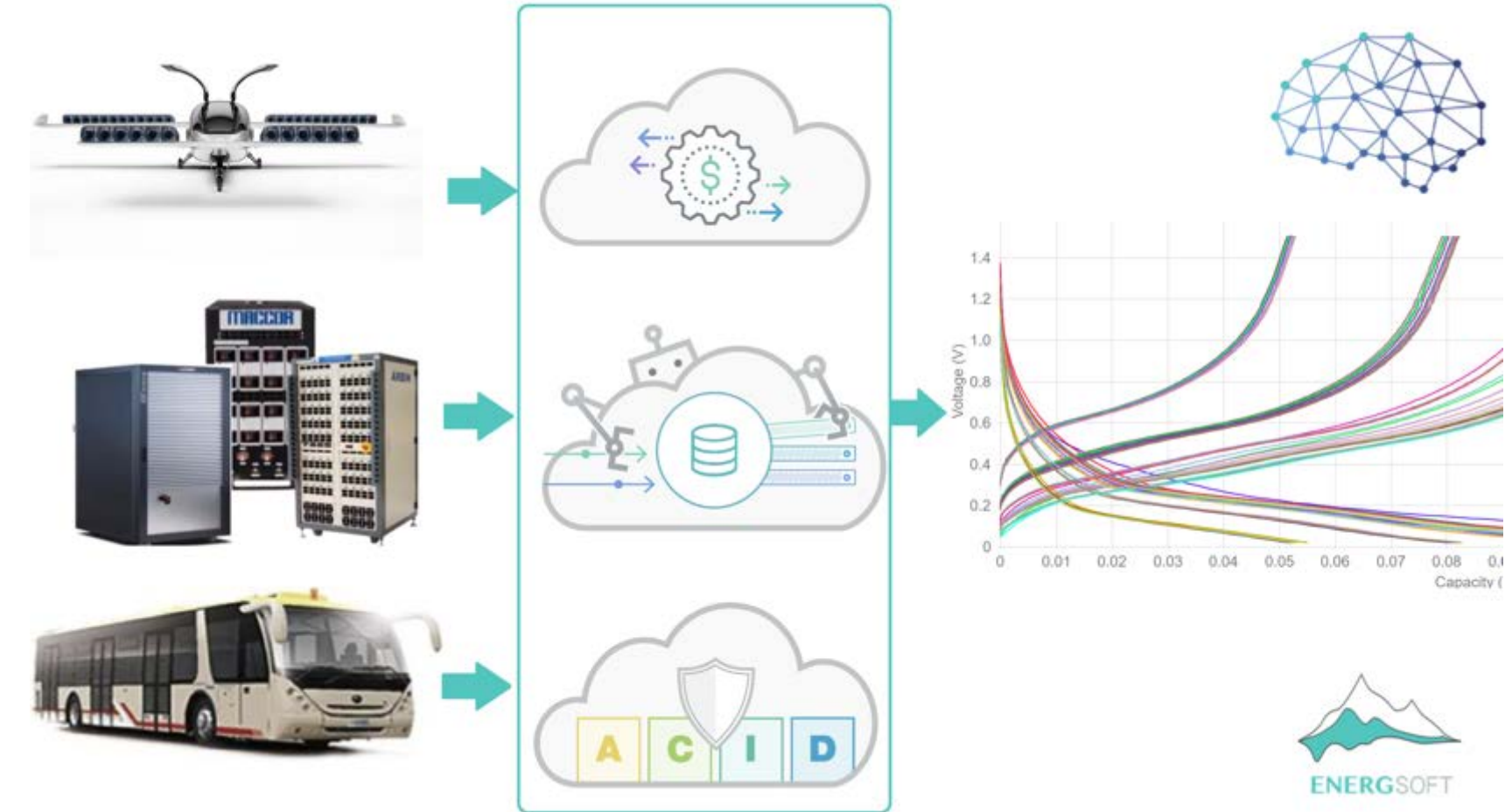
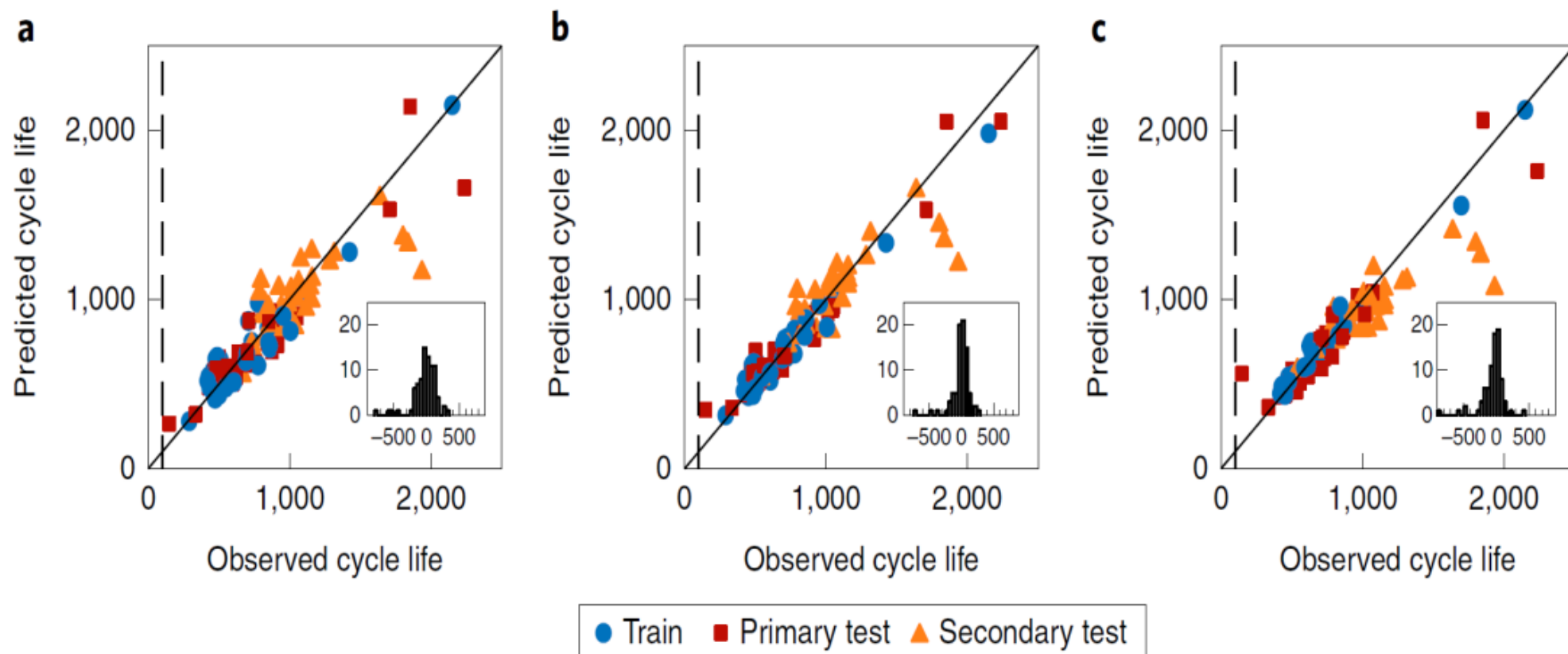
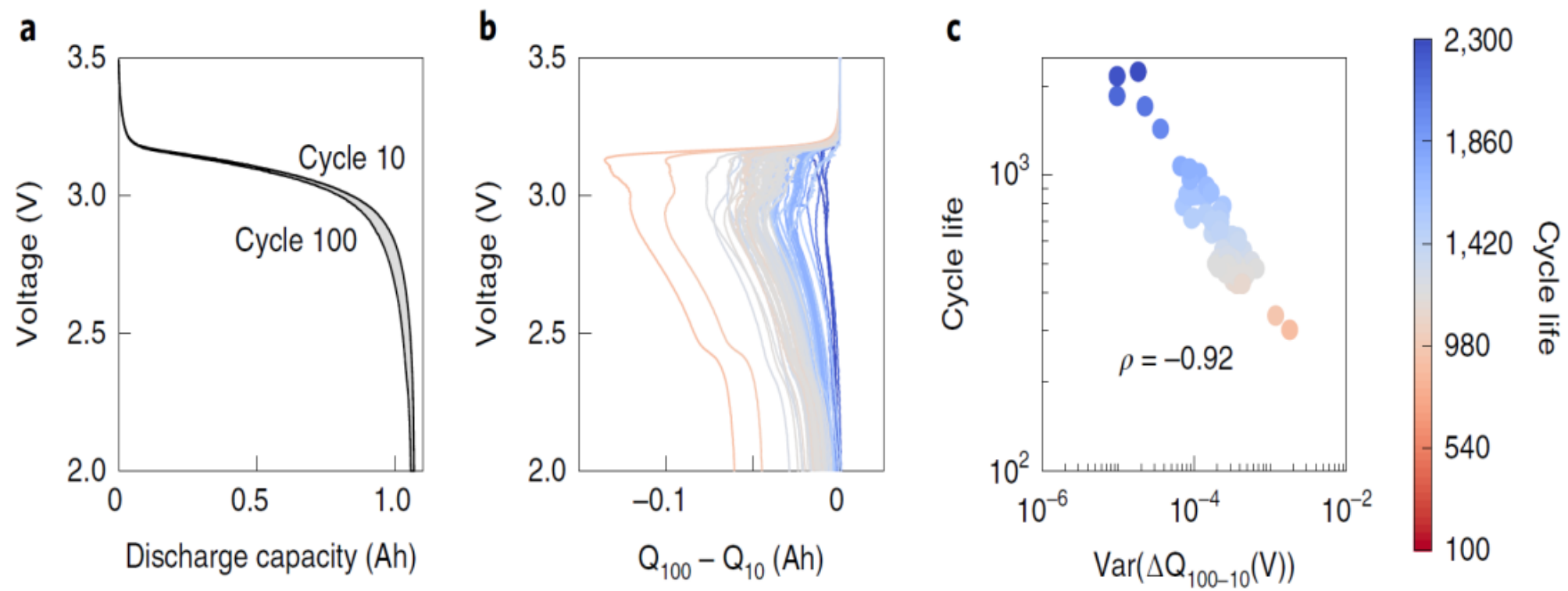
- Time-Consuming Evaluations - Enable U.S.-based recyclers to reach economies of scale
- Without Data and Metrics Collection the recycling on discarded lithium-ion batteries is slow
- Distributed Teams, Decision makers and Devices
- Measuring Performance and Reliability to Make Confident Calls
- Safety certification need more comprehensive solution to the challenges facing

# Prototyping

- Receive faster market feedback to quickly test your ideas thanks to proved prototyping techniques and proof of concept in 2 weeks
- Collect valuable feedback based on high-quality prototypes to test your hypothesis and iterate rapidly
- **Agile:** Helps us optimize operations, lower issue rate by reducing inefficiencies, improve the development process
- **Delivery:** Continuous and transparent, which allows you to be in control and feel a full-fledged member of a development process







Materials & Production (Battery R&D)



Certification & Benchmarking (Historical and Statistical)



Field operation & Primary Usage (System Integration)



End-of-life & Second Life (Warranty Returns)



Prognostics & Prescriptive Analytics (ML & Artificial Intelligence)



# Research & Customizations

1. Find the most suitable technologies to your needs and make a solid foundation for your product relying on our 90 years combined R&D expertise
2. Research, technology consulting and software product development customization services for our platform to deliver your battery and energy storage product on time and within the budget.
3. Mining and Cleaning the data.
4. Get access to a perfect blend of modern solutions including IoT, hardware integration, artificial intelligence and everything in between to build the product you need.
5. Big Data Processing and Predictive Analytics, Real Time Measuring, Automatic Gathering, Aggregation and Analysis of distributed streaming data.





# Development

- Let's start with research - our experienced R&D department will offer the most suitable technology stack to shape your product.
- Be flexible to iterate while staying in control of building the launch-ready product with regular sprint and budget reports.
- Control the development process using flexible system of communications, receive constant updates and evaluate weekly demos.
- At this stage, we will create the project plan, specification document, and determine a required time and cost estimation

# Integration

- Get on-going post release support to keep your products' efficiency at maximum like our partner is having for over years
- Take your business to the smart level with credible insights, significant savings on maintenance and operations.
- Build complex IoT solutions, like remote grid monitoring, notifications and reporting.
- Multiple battery lab or field battery locations relying on our advanced, cross-domain expertise in Internet of Things/Intelligent Devices Development

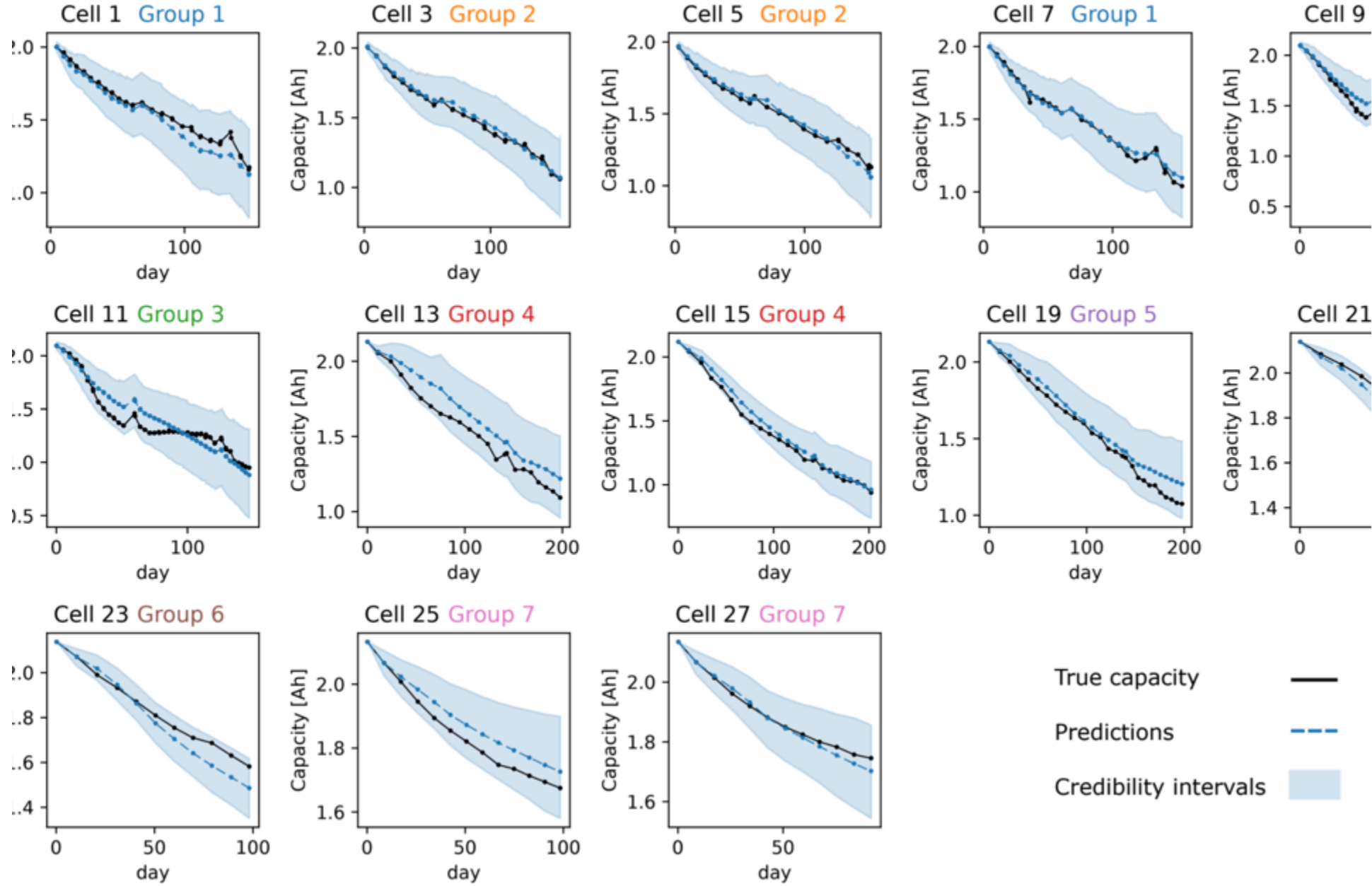
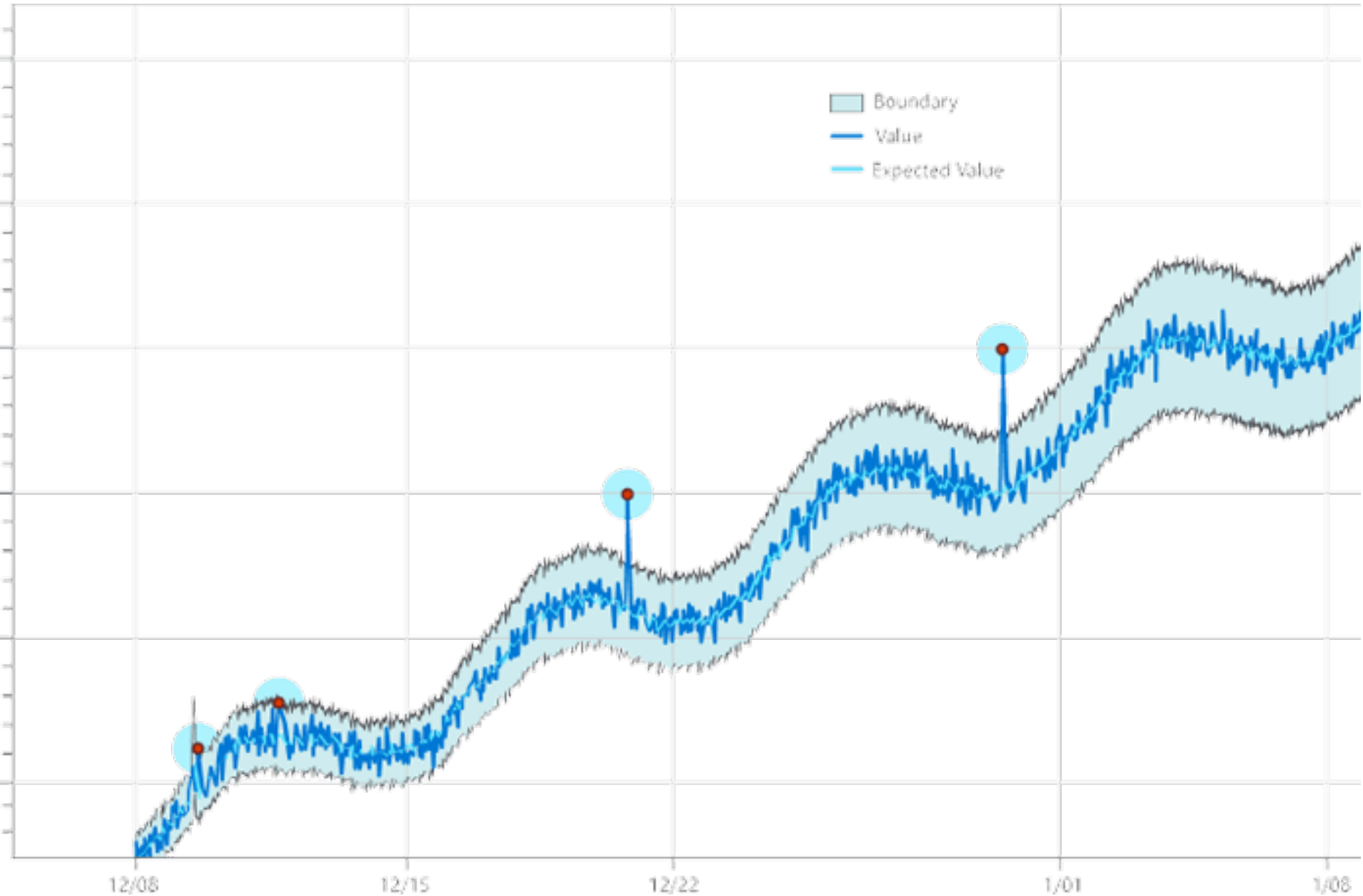






- Interactive Dashboards
  - Alerts and Notifications
  - AI and Predictive Analytics
  - Automated Reporting
  - State of the Art Algorithms
- 
- Track and Audit Metadata

Anomaly Finder Result (90 Sensitivity)



# Customer Testimonials

- **CEO of Battery Company** - "We were in a hurry because we needed to impress our customers by writing proposals to those customers to expand the projects. We are to a large extent using the results of the analysis we produced by using Enersoft analysis platform."
- **Manufacturer Battery Scientist, PhD** : "By combining state of the art prognostics tools and software systems, Enersoft enhances your operations by highlighting the information you need to focus on. We are able to analyze, track, and even predict, what is going to happen and when."
- **OEMs Director** in S&P 500: "Enersoft Insight+ takes the mystery out of our critical infrastructure's status by providing visibility into performance, allowing us to extend battery life, pick the best supplier and take action before issues occur."





**As we bring people of all lifestyles together, we keep on looking for the best and the brightest, capable of sharing the same vision. Everyone's opinion and perspective are welcomed, creating the result-oriented process.**

**Email US:** [sales@energsoft.com](mailto:sales@energsoft.com)

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# ARKASA

AMERICAN-MADE CHALLENGES

LITHIUM-ION BATTERY RECYCLING PRIZE | PHASE II

JULY 2020





# PASSION

HELPING MISSION-DRIVEN ORGANIZATIONS DELIVER RESULTS THAT ACCELERATE ENVIRONMENTAL SUSTAINABILITY.

# APPROACH

## For Phase II, We Will Help Teams With Prototyping and Partnering To

1. Prepare concepts into [market-ready solutions](#)
2. [Establish partnerships](#) to design, iterate and deploy these solutions
3. [Evaluate and verify](#) the proposed business and technology approach

## We Do This By Leveraging

- Personalized [1-on-1 coaching](#) for product and business development
- Direct experience in [battery technology commercialization](#)
- Several years having worked with [successful startups](#)
- Energy and automotive [industry relationships](#) and ecosystem access





## SERVICES

### Business Model Development

- **Product Strategy:** Segments, Competition, Positioning
- **Customer Acquisition:** Targeting, Approach, Outreach
- **Partnership Development:** Assessment, Strategy, Engagement

### Guidance on Second-Use Applications

- **Stationary Storage:** Residential, Commercial & Industrial, Utility-Scale
- **Mobile Storage:** Residential, Commercial & Industrial
- **Sector Needs:** Utilities, Automotive, Municipal, Commercial

---

## Outside Of Expertise

- DOT universal waste permit testing
- Battery abuse testing\*
- Thermal characterization\*
- Performance validation testing\*
- 2<sup>nd</sup> life battery grading and profiling\*
- Duty-cycle modeling and assessment\*
- Regulation advising

*\*Note: We have partners who may be able to support.*

---

---

# NOT SERVICES





# PROCESS

01

Demo Day (July)

- Connect
- Discuss
- Match

02

Submit (October)

- Ideate
- Refine
- Propose

03

WIN (November)

- SOW
- Contract
- Collaborate



PORTFOLIO  
+  
PARTNERS



# ABOUT US

- Founded 2016
- Minority-owned, based in southern California
- Experience:
  - Battery systems for commercial & industrial ESS, utility-scale ESS
  - Battery systems for electric vehicles
  - Electric vehicle charging, stationary and mobile
  - Solar for residential, commercial & industrial, utility-scale
  - Onshore wind and offshore wind, utility-scale

NEW: Get quotes straight from 2D mechanical drawings. [Click to try now!](#)

# Custom Manufacturing at Your Fingertips

With over 4,000 partners, our network is **always open for business.**



Parts in as Fast as 1 Day



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CNC Machining

3D Printing

Injection Molding

Sheet Metal

Buy Materials



Greg Paulsen  
Dir., Application Engineering,  
Xometry  
[gpaulsen@xometry.com](mailto:gpaulsen@xometry.com)  
[@XometryGreg](#)  
[www.xometry.com](http://www.xometry.com)



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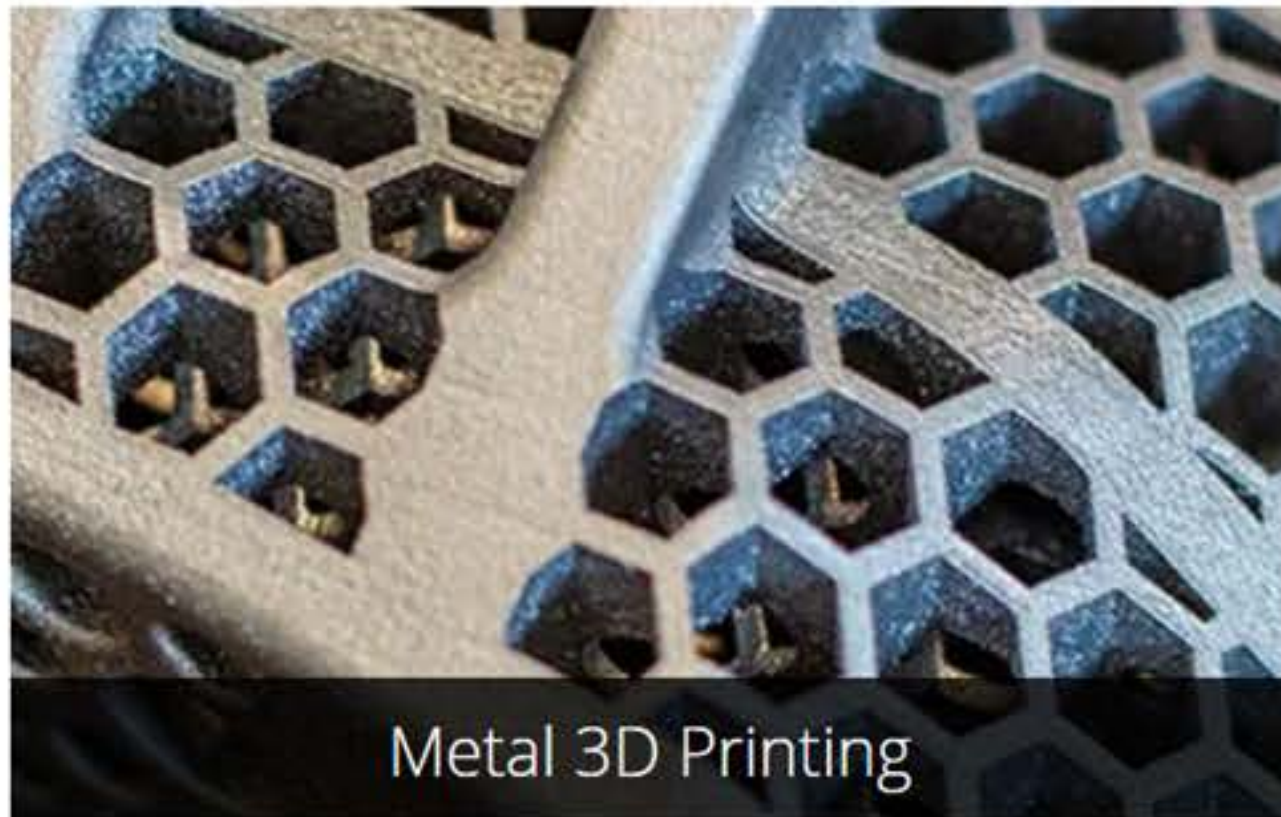
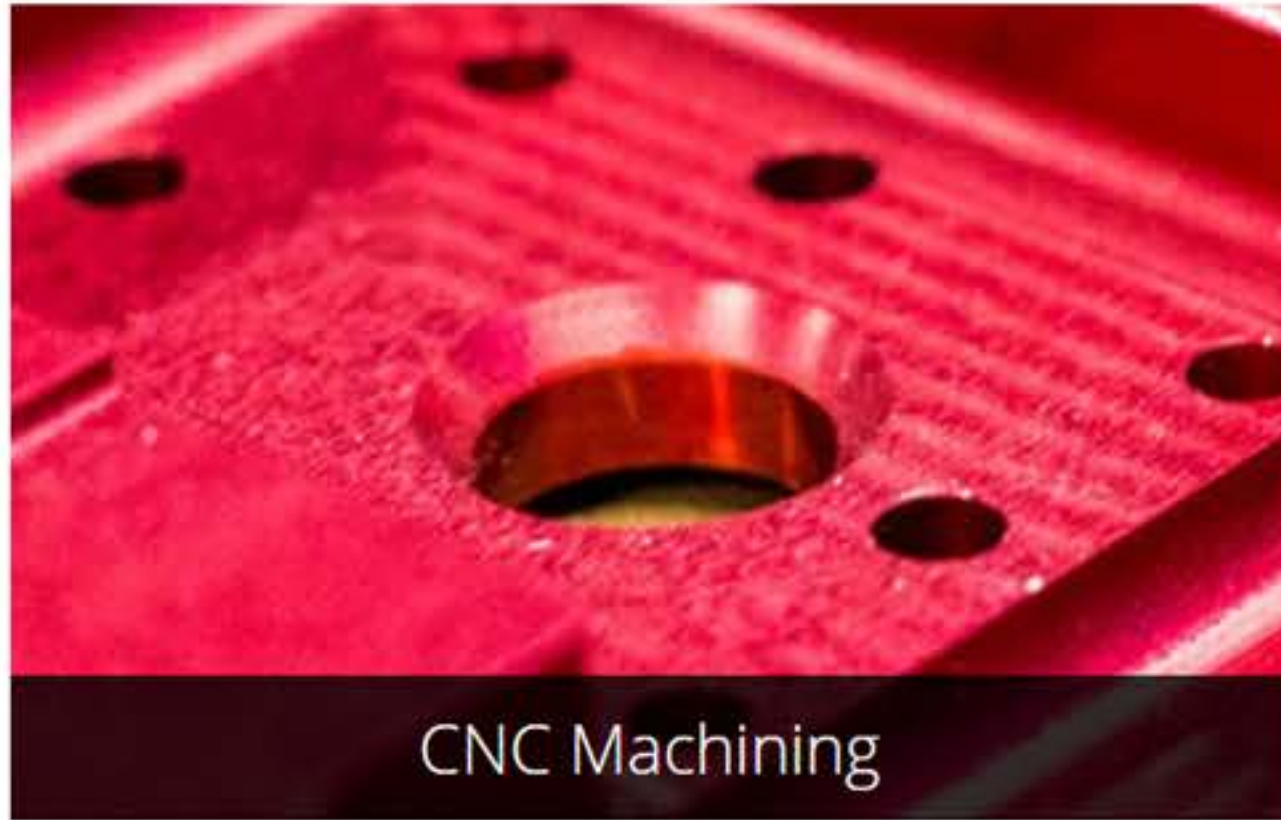
Turbocharge the way you make custom parts



[illegible]



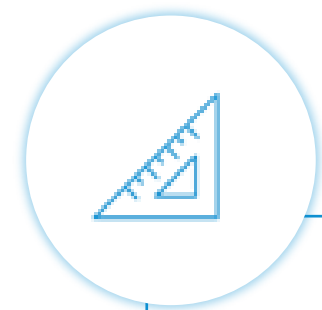
# Industrial Manufacturing Capabilities



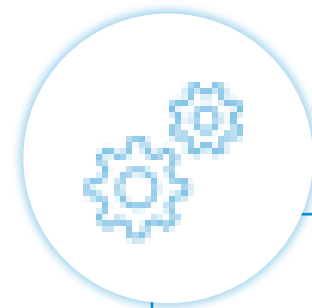


# Xometry for Engineering and Sourcing Professionals

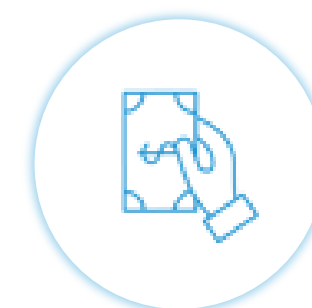
## A Simple Elegant Experience



**Design  
Part**



**Instant Online  
Quote**

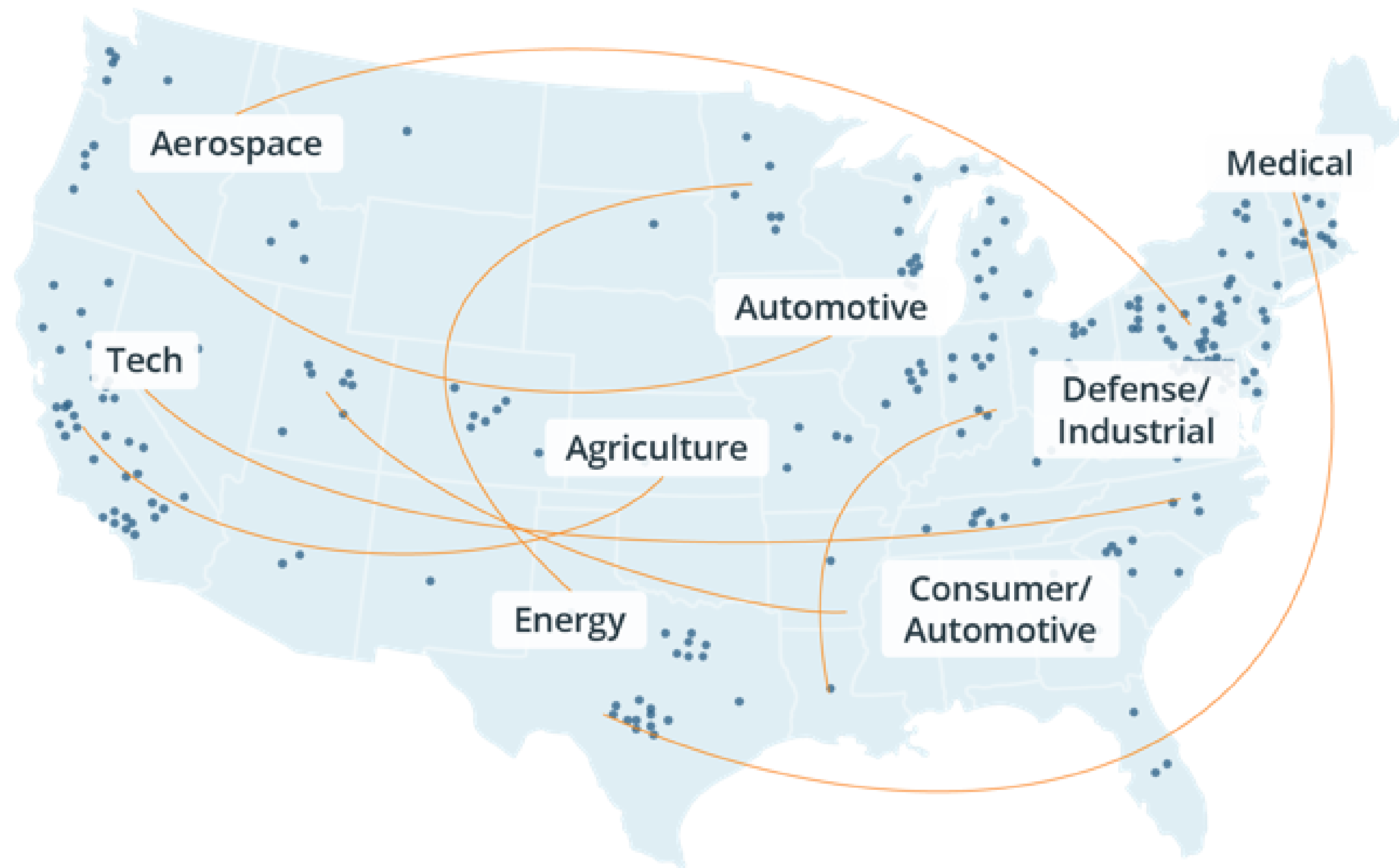


**Buy**

- Automated RFQ
- Expert Engineering Support Team
- Best Pricing Quality and Lead Times

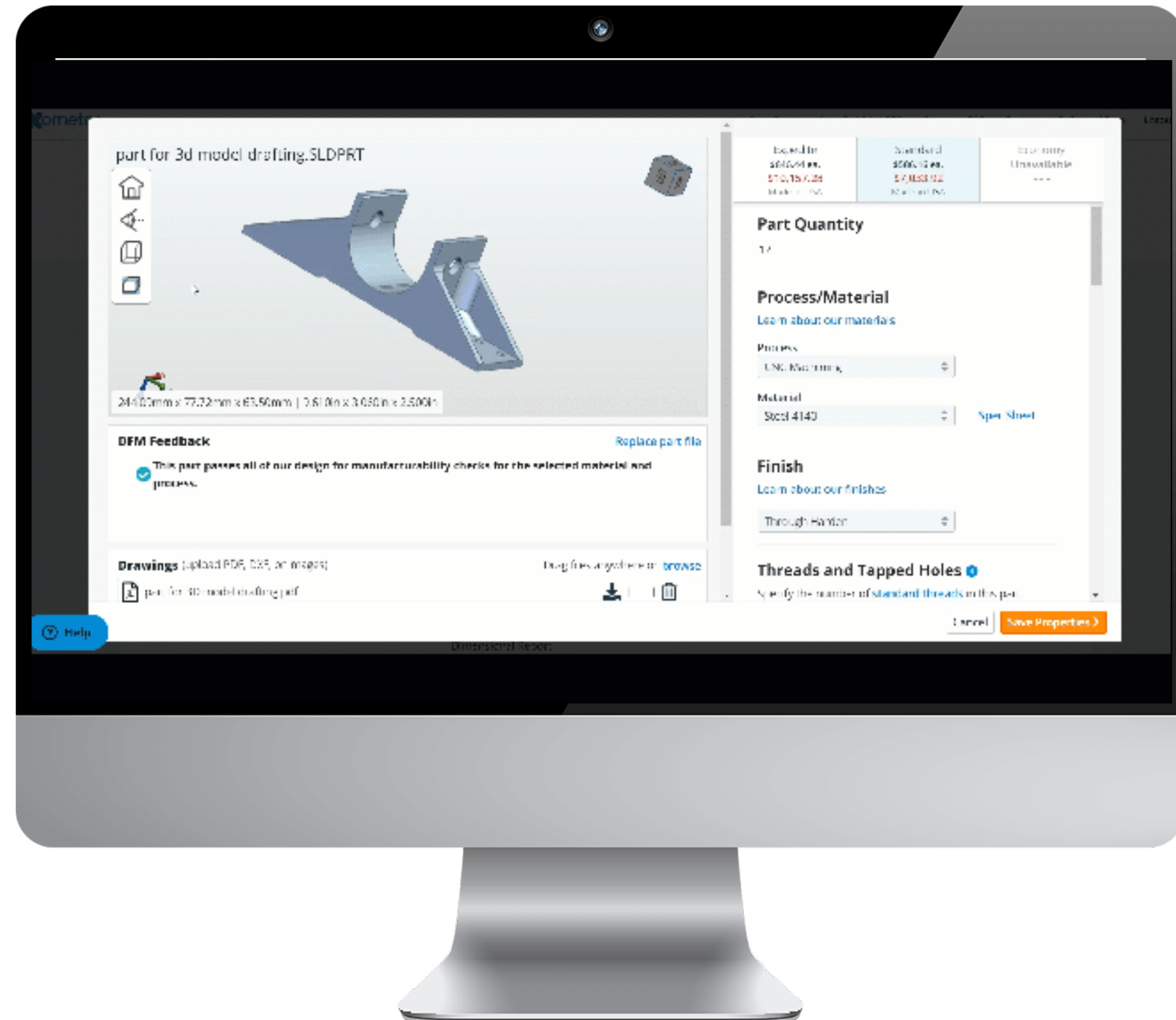
# XOMETRY PARTNER NETWORK BENEFITS FOR ENGINEERING AND SOURCING PROFESSIONALS

- Over 3,000 Manufacturing Partners across the U.S.
- Access to new capabilities & capacity (AS9100, NADCAP, ISO 9001, ETC...)
- “Should-Cost” pricing model
- Quality is ensured through Xometry directly
- All Partners are vetted through Xometry’s Partner Onboarding Program





# Xometry.com Platform

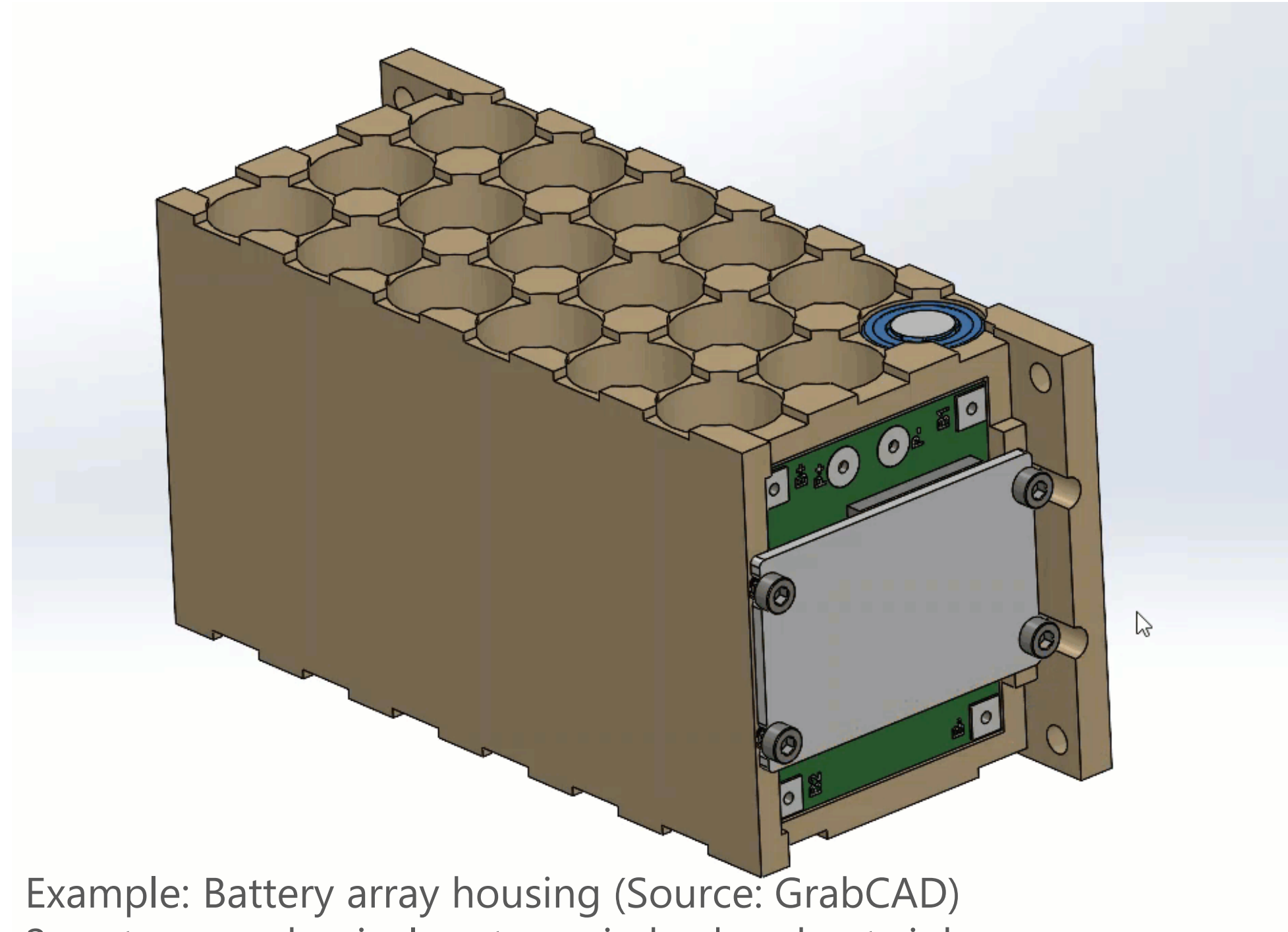


## Xometry's Proprietary AI-Powered Manufacturing Platform

- Instant pricing and quoting
- Free Design Guides and Resources
- Access to Application Engineers
- Dynamic pricing & lead times
- Guaranteed high-quality parts

# Your 3D Files & Drawings

- Accepted file types:
  - **STEP** (.step, .stp),
  - **SOLIDWORKS** (.sldprt),
  - **Mesh** (.stl),
  - **Parasolid** (.x\_t, .x\_b),
  - **DXF** (.dxf),
  - **Autodesk Inventor** (.ipt),
  - **Dassault Systems** (.3dxml, .catpart),
  - **PTC, Siemens** (.prt),
  - **ACIS** (.sat)



Example: Battery array housing (Source: GrabCAD)  
2 custom mechanical parts: main body + heat sink



# Upload to Xometry.com

- Instant Pricing and Lead Times
- 11 Different Manufacturing Technologies
  - 7 Types of 3D Printing
  - CNC
  - Sheet Metal
  - Urethane Casting
  - Injection Molding
- To-spec configuration and customization
- No Minimum Order

The screenshot displays the Xometry.com dashboard. At the top, the navigation bar includes a menu icon, the Xometry logo, and links for Dashboard, Xometry, FAQ, Contact, Refer and Earn, and Logout. The main content area is divided into two columns. The left column, titled 'Welcome back, Xometry!', features a file upload interface with a dashed blue border. It contains two file entries: '3S6P.SLDPR' and 'BMS\_heatsink.SLDPR', each with a blue 'X' icon for removal. Below the files is a 'Click to Upload Additional 3D Models' link. A progress bar at the bottom of this section shows 'Upload Files' as the current step and 'Select Process' as the next step, with a blue 'Next' button. The right column, titled 'Special Offers + News', contains three promotional cards. The first card, 'New Get Quotes on 2D Technical Drawings', offers quotes in as fast as 24 hours. The second card, 'Quote with a 2D Drawing', shows a technical drawing of a mechanical part. The third card, 'Save Big on 3D Printing', offers savings up to \$200 a month. Below the upload interface, there are links for 'Pick Up Where You Left Off', 'View All Quotes', and 'View Active Orders'. Two quote cards are displayed: 'Quote 08D31-15332' with a price of \$0.00 and a lead time of 0 business days, and 'Quote 08D31-15331' with a price of \$143.47 and a lead time of 5 business days. Both quotes show a production speed of 'Standard' and were last updated in July 2020.

Dashboard Xometry FAQ Contact Refer and Earn Logout

Welcome back, Xometry!

3S6P.SLDPR X

BMS\_heatsink.SLDPR X

Click to Upload Additional 3D Models

Upload Files Select Process Next

Pick Up Where You Left Off View All Quotes View Active Orders

Quote 08D31-15332

**\$0.00**

Lead Time: 0 Business Days

► Production Speed: Standard

Last Updated: Jul 14, 2020

Quote 08D31-15331

**\$143.47**

Lead Time: 5 Business Days

Production Speed: Standard

Last Updated: Jul

Special Offers + News

New

Get Quotes on 2D Technical Drawings

Don't have a 3D CAD file? No problem. Send your 2D files directly to Xometry Manufacturing Partners and get quotes in as fast as 24 hours.

Quote with a 2D Drawing

Save Big on 3D Printing

Save up to \$200 a month across 7 unique 3D Printing technologies. Sign up once and



Thank you!



Greg Paulsen  
Dir., Application Engineering,  
Xometry  
gpaulsen@xometry.com  
@XometryGreg  
www.xometry.com



# Coulometrics Services and Capabilities Overview

Prepared by: Dr. Edward R. Buie,  
Joe Turner, Shawn McMahon  
Coulometrics, LLC.

Date: July 14, 2020

# Company Overview

- Advanced Energy Storage Consulting and Toll Manufacturing located in Chattanooga, TN
  - + Started in 2011
    - 18 Employees
    - 30,000ft<sup>2</sup>
    - Basic materials R&D
    - Manufacturing / scale-up and state-of-the-art testing for batteries
    - Systems integration





# All of the critical core competencies for success...





# Cell Testing

- 1000+ channels of standard cell cyclers
- 250+ channels of **High Precision Coulometry**
- Temperature chambers controlled to  $\pm 0.1^{\circ}\text{C}$





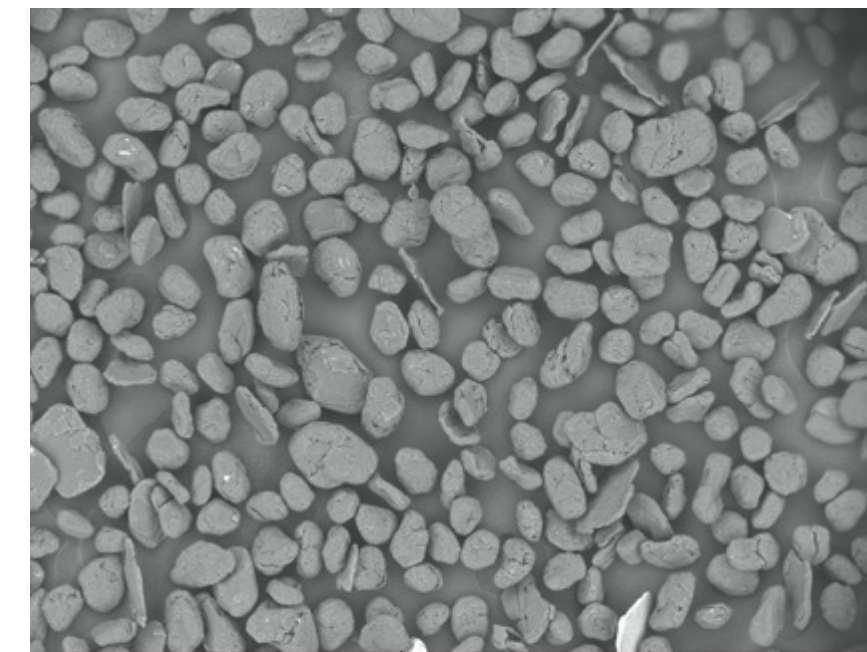
# Safety Testing

- Safety testing equipment capabilities including:
  - + Nail penetration
  - + Hot box testing
  - + Over-charge
  - + Thermal shock



# Materials Development

- Powder Analysis
  - + Particle size
  - + Tap Density
  - + BET Surface area
  - + SEM/EDS
  - + XRD
- Powder Processing
  - + Calcination tube furnace
  - + Coating processes
  - + Size classification
  - + Size reduction
- Electrochemical Characterization
  - + Coin cell assembly
  - + Material Specific capacity
  - + Cycling efficiency



G16-0213P-0011 2016/12/09 12:25 D4.6 x150 500 um  
Coulometrics, LLC



# Cell Design and Assembly



- Multiple format types
  - + Pouch
  - + Cylindrical
- Multiple sizes within the formats
  - + Small to large
    - 20mAh to nearly 100Ah
- Experience designing both high power and high energy cells
- Experienced with a wide variety of anodes and cathode materials
  - + Anode: Graphite (natural and artificial), LTO, Si, SiO<sub>x</sub>
  - + Cathode: NMC, LFP, NCA, LCO, LMO

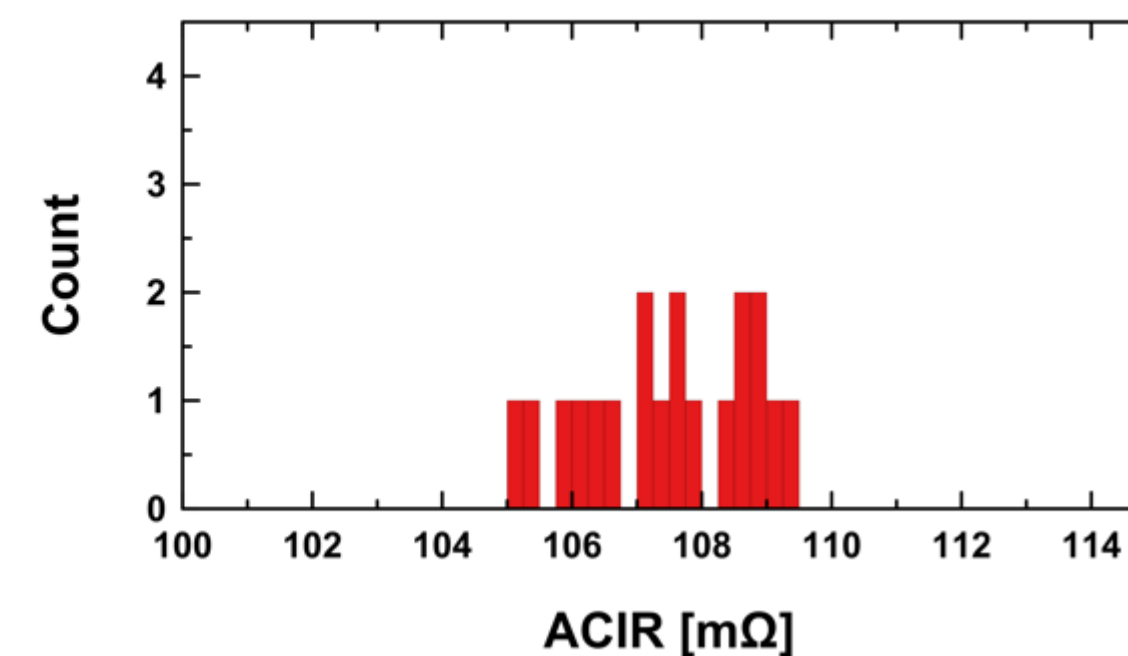
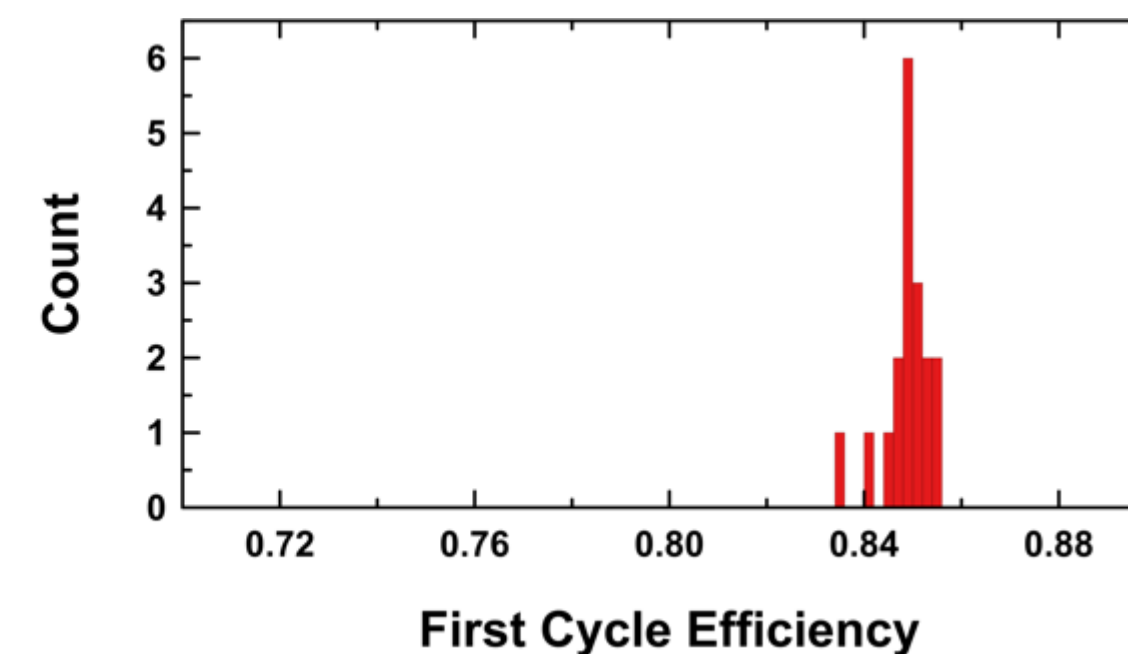
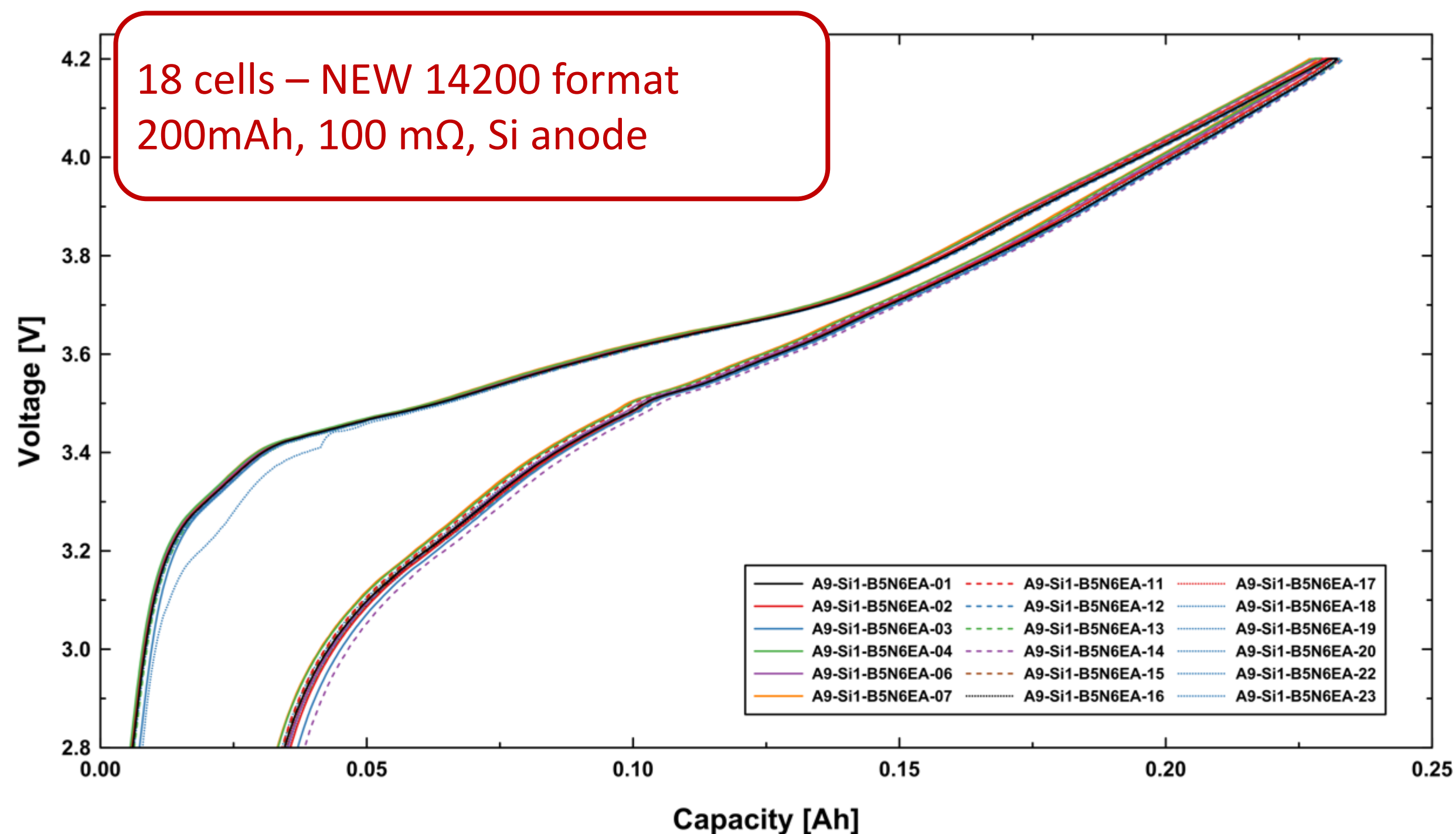
# Cell Design and Assembly

- Small Button Cells
- 14200
- 14500
  - + Double “A” size
- 18650
  - + As low as 5mΩ in power versions
- Can easily make
  - + 26650
    - 100% capacity of the 18650
  - + 21700
    - 50% more capacity than an 18650





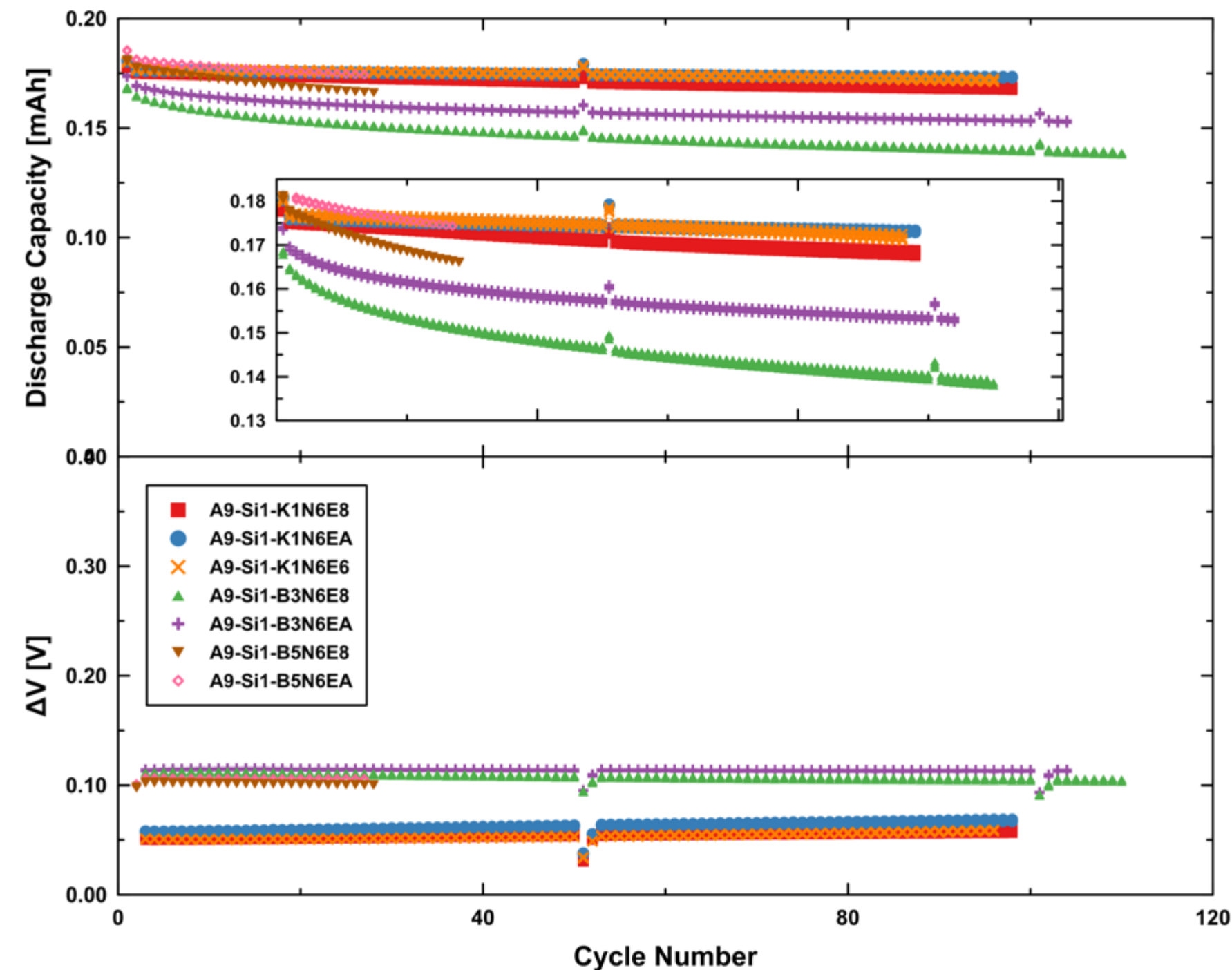
# New 14200 Cell Development – QC Data



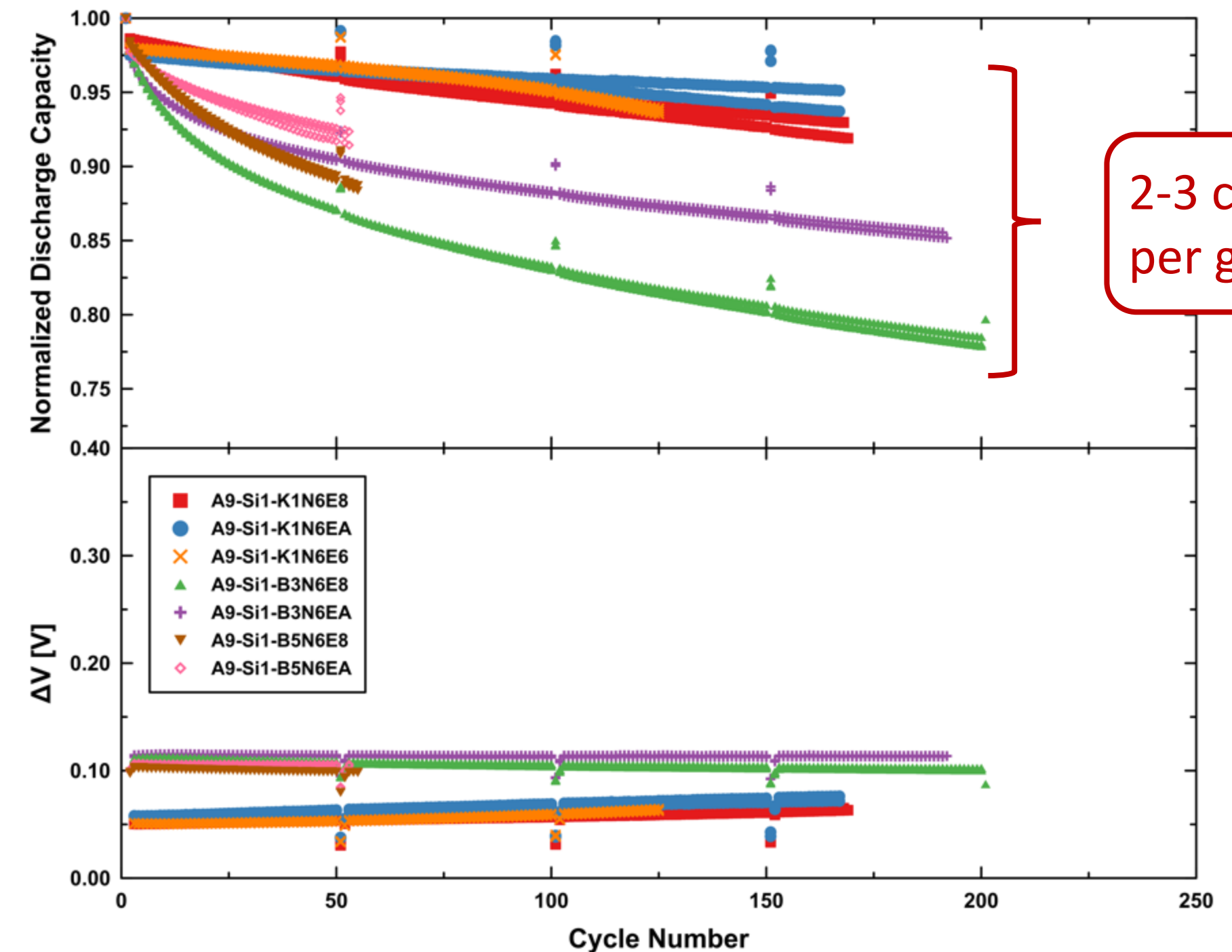
# Electrolyte Study

## Si anode - Cycling Data

Long-Term Cycling of 14200 DOE Si Project Cells  
C/3 Charge/Discharge, 3.0 to 4.2V, Temperature = 40°C



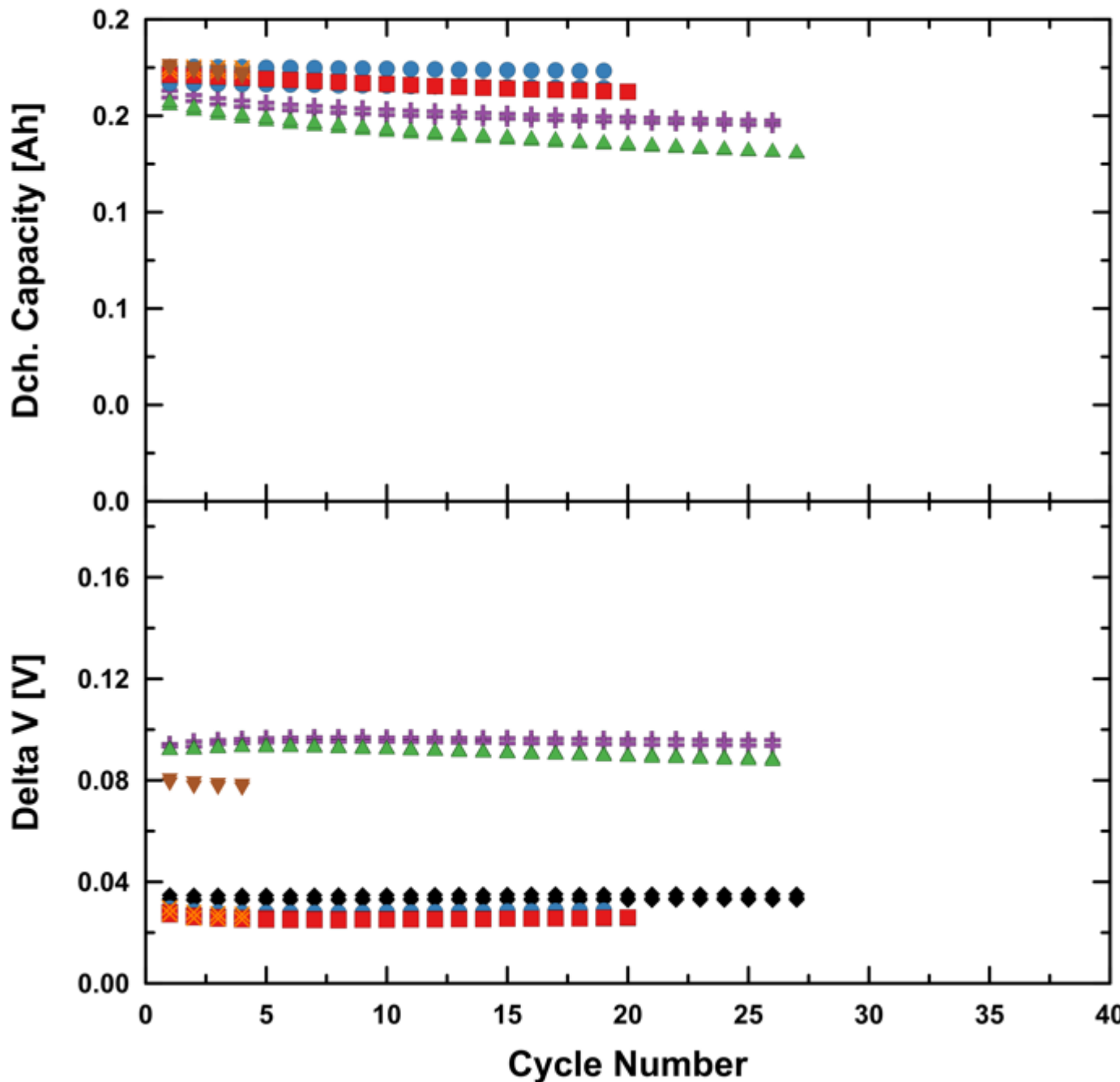
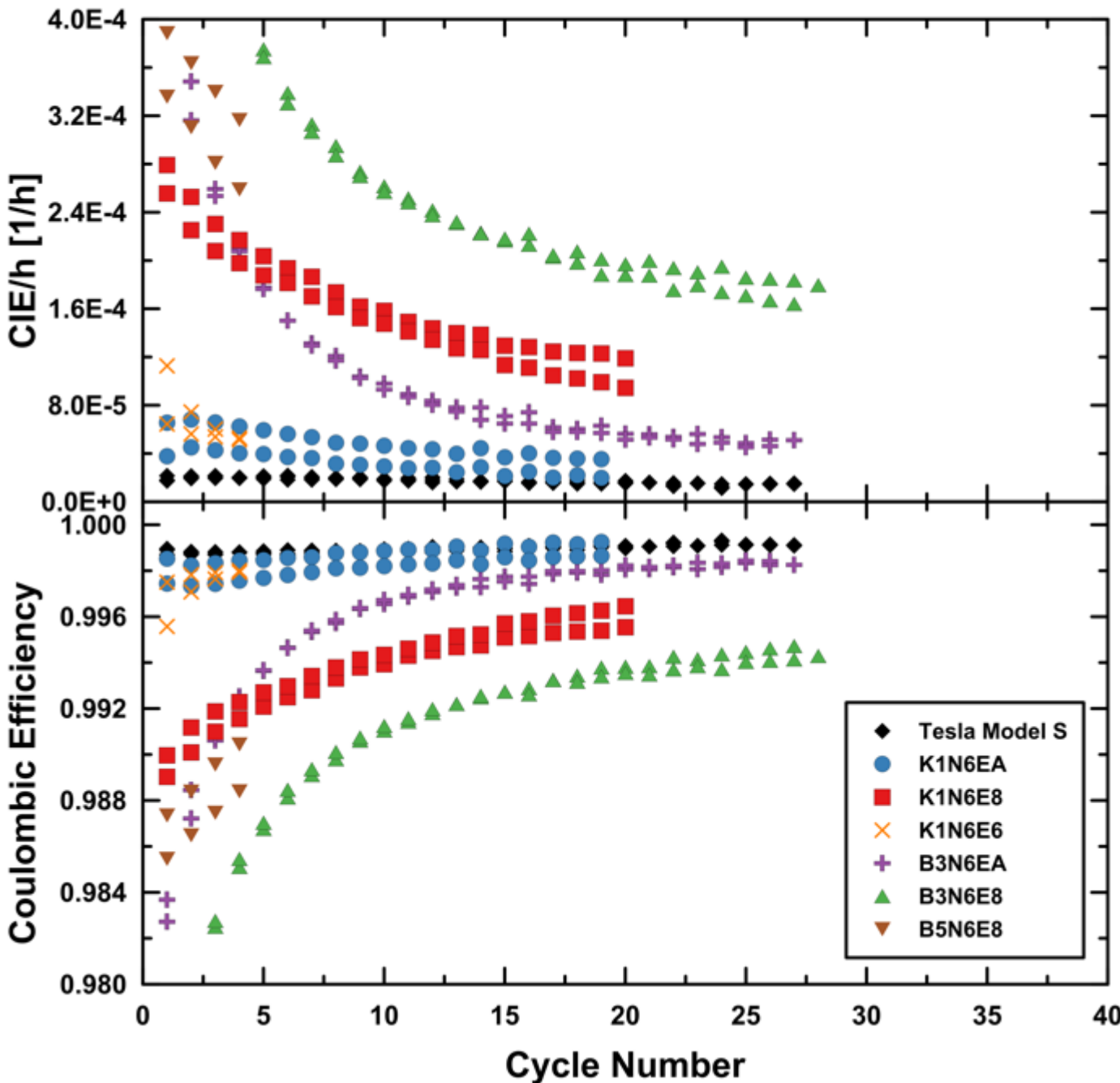
Long-Term Cycling of 14200 DOE Si Project Cells  
C/3 Charge/Discharge, 3.0 to 4.2V, Temperature = 40°C





# HPC Data

HPC<sub>B</sub> Cycling of DOE Silicon 14200 Cells  
Cycling to 4.2V, Temperature = 40°C



# One-on-One Meetings

Participants, please email  
[BatteryRecyclingPrize@nrel.gov](mailto:BatteryRecyclingPrize@nrel.gov) **by 7 p.m. ET**  
with a complete list of the VSPs you would  
like to meet with tomorrow.

You will receive a schedule for your one-on-one meetings by 8 a.m.  
ET tomorrow morning. Meetings will take place between  
10 a.m.—12 p.m. (Labs) and 2—4 p.m. (Organizations) ET. Please  
be available during the entire time slot.





U.S. Department of Energy  
LITHIUM-ION BATTERY RECYCLING PRIZE

# THANK YOU!

