U.S. DEPARTMENT OF ENERGY

Bipartisan Infrastructure Law Electric Drive Vehicle Battery Recycling and Second Life Applications Funding Opportunity Announcement (DE-FOA-0002680) Selections

FACTSHEETS

Funded through $73.9 million from the Bipartisan Infrastructure Law, this portfolio of projects will support research and development projects to address: (1) Advanced Materials Separation, Scale-Up, and Reintegration for Lithium-Ion Battery Recycling for the Battery Supply Chain and (2) Second Life Scale-Up Demonstration Projects.

November ____, 2022

Battery Recycling and Technology Process Selections

NEVADA

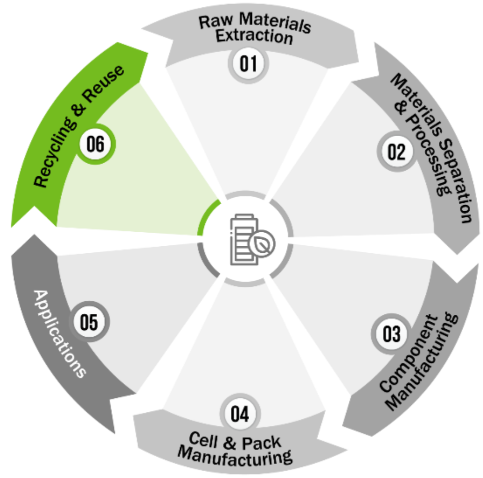
PROJECT NAME: Advanced Separation and Processing Technologies for Enhanced Product Recovery and Improved Water Utilization, Cost Reduction, and Environmental Impact of an Integrated Lithium-Ion Battery Recycling System

APPLICANT: American Battery Technology Company (Reno, NV)

Federal Cost Share: $9,999,378

Recipient Cost Share: $10,000,622

Supply Chain Segment: Recycling



Project Description:
American Battery Technology Company (ABTC) and its partners will validate, test, and deploy at pre-commercial scale three disruptive advanced separation and processing technologies to its existing lithium-ion battery recycling facility to further enhance economic competitiveness, reduce environmental impact, and re-integrate an even greater percentage of the constituent components to the domestic battery manufacturing market. ABTC will work in partnership with Novonix Group, University of Nevada, Reno (UNR), University of Utah (U of U), North Carolina State University (NCSU), National Renewable Energy Laboratory (NREL), Argonne National Laboratory (ANL), and Idaho National Laboratory (INL), and with downstream material validation and offtake by Dainen Material, Novonix Group, and iM3NY.

ABTC has developed and is constructing an integrated pre-commercial scale recycling facility that will operate with many of these baseline technologies, however it has also developed several enhanced separation and processing techniques that will allow for the recovery of additional products and further reduction of energy and water consumption and life cycle greenhouse gas emissions. Through this proposed project, ABTC and its partners will validate and optimize each of these advanced technologies at the bench scale, then manufacture qualification batches of these products for evaluation and testing by downstream partners, followed by the scale-up of these advanced systems for integration into ABTC's existing pre-commercial scale lithium-ion battery recycling facility.

American Battery Technology Company is currently building a battery recycling facility located in Fernley, Nevada. The initial plant capacity will be able to process 20,000 metric tons per year of end-of-life batteries and battery manufacturing waste, scaling up to 100,000 metric tons per year. ABTC's Lithium-Ion Battery Recycling Pilot Plant will be an entirely new construction consisting of three functional building areas totaling approximately 100,000 square feet of floor space with 60,000 square feet dedicated production space.

INDIANA

Battery Recycling and Technology Process Selections

Cirba Solutions
Battery Management & Materials

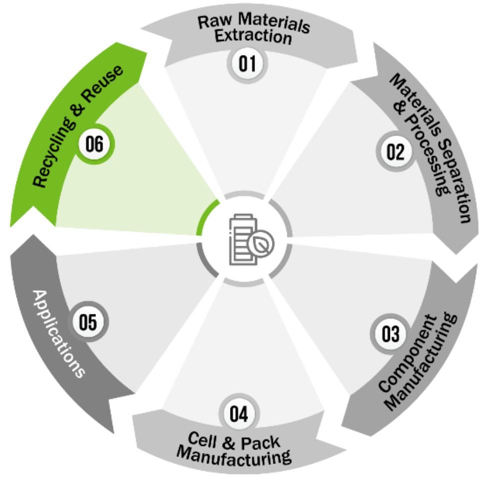
PROJECT NAME: Novel Integrated End-to-End Processing of End-of-Life EV Batteries for Remanufacturing of New EV Cells

APPLICANT: Cirba Solutions (Indianapolis, IN)

Federal Cost Share: $7,424,242

Recipient Cost Share: $10,878,427

Supply Chain Segment: Recycling



Project Description:
Cirba Solutions (formerly known as Retriev), will develop a process for recycling critical materials from end of life (EOL) EV batteries for use in the manufacture of new EV cells at its lithium-ion battery (LIB) recycling facility in Lancaster, Ohio.

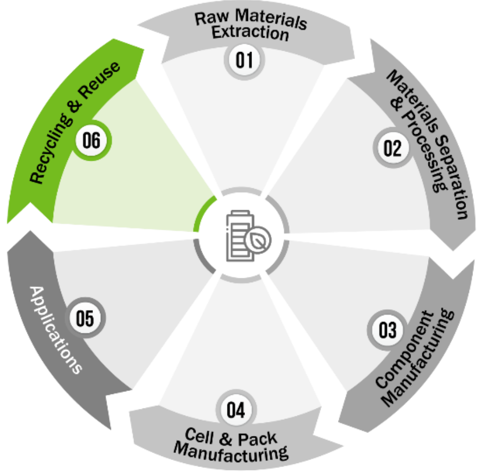
The project will support the demonstration of the scalability, reliability, and cost-effectiveness of advanced recycling technologies. Cirba plans to modify its current commercial hydrometallurgical line at its Lancaster facility to convert black mass from EOL LIBs to an intermediate mixed-metal sulfate solution and then to purified mixed-metal hydroxides. This conversion utilizes a new patented process for recovering purified mixed nickel, cobalt, and manganese hydroxides. Cirba has partnered with Momentum Technologies, the licensee of a scalable, energy-efficient, low-cost, and closed-loop Membrane Solvent Extraction (MSX) process developed by scientists at Oak Ridge National Laboratory (ORNL), to separate the intermediate mixed-metal sulfate solution into pure, battery-grade nitrate salts. Cirba is also partnering with 6K Inc., a leader in transforming engineered materials into products that advance industries across additive manufacturing, to produce virgin cathode active material (CAM) for LIBs. Lastly, Cirba will partner with a DOE National Laboratory such as ORNL to use these CAMs to manufacture and validate functional LIBs as efficient as those made from virgin materials.

The unique combination of these new, individually demonstrated technologies has the potential to reduce overall purification costs and eliminate complexity of EOL LIB recycling. A successful demonstration of this energy-efficient, cost-effective process will enable the recovery of high-purity products acceptable to OEMs. OEM acceptance of LIBs produced through the project will close the loop for maintaining critical battery materials within the U.S. LIB industry and retain these critical materials for expected LIB growth domestically. By weaving MSX technology into a closed-loop battery recycling and manufacturing process, Cirba is catalyzing a domestic supply chain for recycled critical materials that will help meet the expected increase in demand for LIBs and the elements critical to LIB manufacturing.

CALIFORNIA

<u>Second Life Demonstration</u>

PROJECT NAME: MW-Scale Swappable and Reusable Second-Use EV Battery Energy Storage Unit for Maximum Cost-Effectiveness



APPLICANT: Element Energy, Inc. (Menlo Park, CA)

Federal Cost Share: $7,888,476

Recipient Cost Share: $7,885,438

Supply Chain Segment: Recycling

Project Description:
Before EV batteries can be mass deployed as second-life energy storage systems (ESS), two key technical challenges must be overcome. The first is to provide enough performance and cycle life to make a second-life application economically viable. Over time during use (such as in EVs), the capacity and impedance of individual cells/modules within a larger battery pack begin to diverge. Since conventional batteries are made up of hundreds of cells hardwired in different series/parallel configurations, the capacity and degradation rate of the entire pack is tied to the worst-performing cell within.

The second challenge to the widespread adoption of used batteries is safety and the need to improve thermal runaway prevention (e.g., off-gas detection and embedded fire sprinklers). Although not specifically related to second-life batteries, operating batteries off-specification (ESS instead of EV use) and beyond their design lifetime (below 80% state-of-health) imposes a significant burden to ensure the system is operated safely throughout the second-life period.

Element's unique hardware and software approach to battery management can help overcome the challenges in scaling the second-life battery market. Proprietary technology replaces a traditional power conversion system with a distributed power conversion approach for a more granular level of control. Instead of controlling a Megawatt hour- (MWh) scale battery as a single element with thousands of cells all subjected to the same use profile, Element's technology independently controls the power flowing in and out of each module (tens of cells).

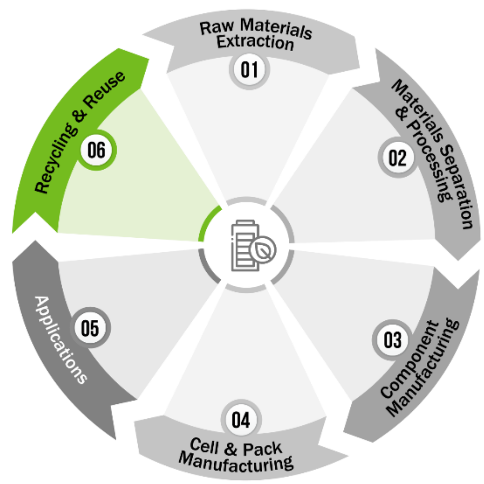
Element Energy and NextEra Energy Resources (NEER) are jointly pursuing a commercial scale pilot facility at one of NEER's wind generating facilities in West Texas. This provides an opportunity for Element's technology to be deployed in a real-world application on the grid, which is key to validating the viability and value proposition provided by Element's unique technology.

Battery Recycling and Technology Process Selections

MICHIGAN

PROJECT NAME: Supplying Refined Battery Materials into the United States Electric Vehicle Battery Supply Chain by Synergizing Lithium-ion Battery Recycling with Mine Waste Reclamation

Michigan Technological University



APPLICANT: Michigan Technological University (Houghton, MI)

Federal Cost Share: $8,137,783

Recipient Cost Share: $2,034,483

Supply Chain Segment: Recycling

Project Description:
This project addresses several economic and technical challenges in the lithium-ion battery recycling industry, including, 1) low payable metals, 2) difficulty in achieving specifications for battery-grade lithium from mixed secondary feedstock, 3) high operational costs and environmental impact of the state-of-the-art recycling practices. The project will develop and demonstrate an innovative synergized battery recycling and metal refining technology and accelerate its commercialization to achieve product demonstration and process validation. The pilot-scale facility (Q3 2023 start) aims to process 5-20 kilowatt hour (kWh) of battery cells and modules per day, producing both intermediate lithium and nickel products as well as battery-grade lithium carbonate (Li_2CO_3) and nickel sulfate ($NiSO_4$).

The project team consists of engineers and experts in subject matter, commercialization, permitting, and investor/community engagement to ensure the success of this project with the end goal of enabling commercialization of these technologies to the benefit of the electric vehicle Li-ion battery supply chain in the United States. Potential project impacts include:

- Reducing total energy use and total greenhouse gas (GHG) emission by at least 25% per nickel unit produced compared to the state-of-the-art recycling practice.
- Establishing a profitable U.S. battery recycling business regardless of the types of cathode chemistry.
- Supplying additional nickel and cobalt minerals from unconventional resources. If further successful, an additional 56 million lbs. of nickel and 2 million lbs. of cobalt from Eagle's Humboldt Tailing Disposal Facility (HTDF) will be recoverable.

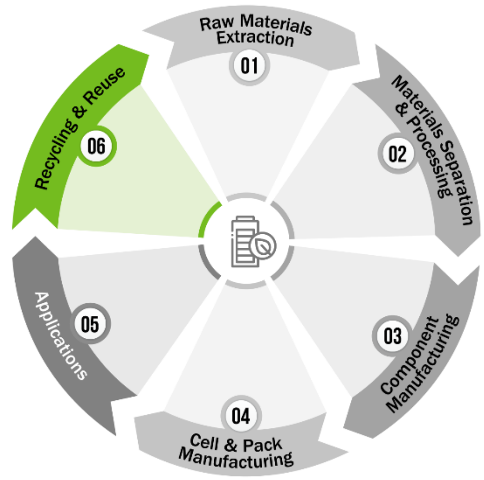
Support from DOE will directly impact the Upper Peninsula of Michigan, primarily (but not limited to) the counties of Houghton and Marquette. The support from DOE is critical to help MTU move from lab to pilot-scale and result in regional workforce and job creation through Nion Metals, a MTU spin-off. MTU will be working with our partner, Michigan Works, to help identify, recruit and train new employees.

<u>Battery Recycling and Technology Process Selections</u>

NEW JERSEY

PROJECT NAME: An Environmentally Sustainable Solution to Completely Recycle and Upcycle Lithium-Ion Battery Components

PRINCETON NUENERGY



APPLICANT: Princeton NuEnergy Inc. (Bordentown, NJ)

Federal Cost Share: $10,000,000

Recipient Cost Share: $2,000,000

Supply Chain Segment: Recycling

Project Description:
End-of-life (EOL) lithium-ion (LIB) batteries will become important secondary sources for materials used in the production of new batteries. Decreasing the cost of recycling and improving the recycling rate could thus significantly reduce the life cycle cost of LIBs, alleviate material shortages, lessen the environmental impact of new material production, and provide low-cost active materials for the manufacturing of new LIBs. With the large increase in cell production expected in the next decade, primary scrap from production is another key source for global recycling efforts. The LIB recycling methods currently used are hydrometallurgical and pyrometallurgical processes. Though effective, these processes only enable the recovery of specific metals and in material forms that are of low value to LIB manufacturers. To make LIB recycling profitable and to encourage industry growth without charging disposal fees to consumers, new recycling methods such as direct recycling need to be developed. Direct recycling is the recovery, regeneration, and reuse of LIB components directly without breaking down the chemical structure.

Princeton NuEnergy, Inc. (PNE), Argonne National Laboratory (ANL), National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL) and University of California, Irvine (UCI) will team together to develop an environmentally sustainable solution to recycle EOL LIBs from automated LIB pack disassembly to complete component recycling/upcycling, which includes cathode-to-cathode upcycling, anode-to-anode recycling/upcycling, electrolyte component recovery, and polyvinylidene fluoride (PVDF) binder recovery to boost the total recycling efficiency of LIBs. The proposed approach will significantly lower costs in LIB materials fabrication, increase material performance, reduce chemical waste compared to existing industrial production methods, and reduce geopolitical risk from the materials supply chain

The project provides an opportunity to advance recycling technology by leveraging the team members' unique capabilities, including (1) battery pack safe discharge and automated disassembly, (2) efficient battery component separation, (3) cathode and anode material upcycling, (4) electrolyte component and PVDF recovery and purification, and (5) system-level scale-up and integration. The funding will also enable a manufacturing-centric and systematic investigation of complete recycling/upcycling of spent LIB components and create technologically relevant IPs and a knowledge base for high throughput and low-cost LIB recycling.

Second Life Demonstration

CALIFORNIA

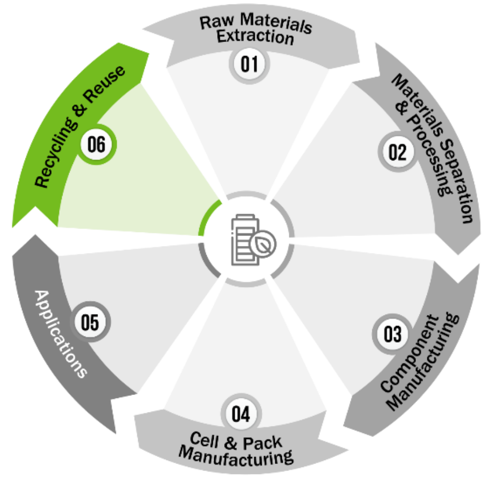
PROJECT NAME: Second Life Battery Microgrid Demonstration Enabled by Advanced State of Health Tracking

APPLICANT: RePurpose Energy, Inc. (Fairfield, CA)

Federal Cost Share: $6,000,000

Recipient Cost Share: $6,000,000

Supply Chain Segment: Recycling



Project Description:
A firm understanding of battery state of health (SoH) is critical to several steps in the electric vehicle (EV) battery repurposing process, including battery screening, battery reassembly, and second-life operation. An EV battery's SoH is defined as its remaining energy storage capacity as a percentage of its original capacity at the time of manufacturing.

This project involves the development, third-party validation, and high-impact demonstration of technology to cost-effectively estimate and monitor the SoH of used EV batteries. Using this technology. the initial SoH of used EV batteries will be estimated in less than two minutes using electrical pulse testing and artificial intelligence. This initial SoH information will be used to optimize reassembly of the batteries and as an input to an equivalent circuit model embedded in a battery management system to track battery SoH throughout second life.

The efficacy of the technology will be validated via evaluation by Idaho National Laboratory (INL). Finally, the technology will be demonstrated via the fabrication, installation, and operation of a microgrid consisting of a second-life battery energy storage system and solar photovoltaics.

The microgrid will be located at a critical facility in a disadvantaged community, reduce energy cost, improve energy resilience, and stimulate the creation of good-paying jobs in the community. Project partners include GE Research, San Jose State University, and Idaho National Laboratory.

Bipartisan Infrastructure Law: *Electric Drive Vehicle Battery Recycling and Second Life Applications*

U.S. DEPARTMENT OF ENERGY

<u>**Second Life Demonstration**</u>

CALIFORNIA

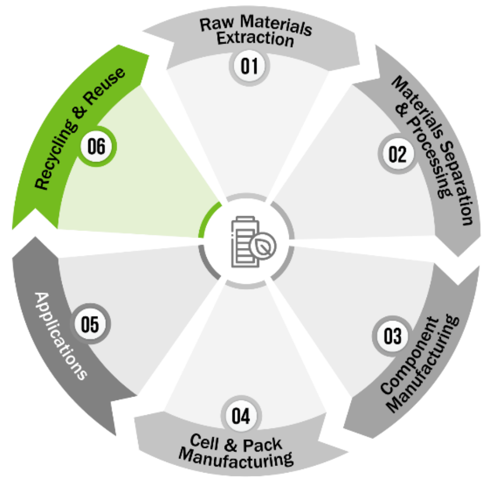
PROJECT NAME: Low-Cost and Scalable Second Use Battery Demonstration in Central California for Equitable Domestic Manufacturing and Job Growth

APPLICANT: Smartville Inc (Carlsbad, CA)

Federal Cost Share: $5,999,525

Recipient Cost Share: $6,019,955

Supply Chain Segment: Recycling



Project Description:
Smartville Inc., teaming with the National Renewable Energy Laboratory (NREL), Wellhead Electric, Spiers New Technology, Utah State University, Colorado State University, and Rhombus Energy Solutions, will develop and demonstrate its unique and innovative second-life battery life-balancing and unifying technology to accelerate real-world deployment of systems to fulfill utility customer and system-level needs for stationary energy storage.

Through the project, Smartville will execute technology iterations, achieve key performance objectives in accurate battery prognostics and life-balancing controls, and establish Low-Rate Initial Production (LRIP) of its Modular Assembly Battery (MOAB) second-life battery energy storage product that maximizes the compatibility and serviceability of repurposed EV batteries sourced from a diverse set automotive makes, models, and form factors. Additionally, Smartville will implement two large-scale second-life battery energy system demonstrations: (1) a 3,000 kWh system in San Joaquin, CA, located within a designated Disadvantaged Community (DAC) and operated in partnership with Wellhead Electric, the largest privately-owned Independent Power Producer (IPP) in California, and (2) a 500 kWh system to be installed and operated at NREL's Advanced Research on Integrated Energy Systems (ARIES) facility, with a focus on performance validation and data-backed battery management and prognostics research.

Smartville's EV battery repurposing technology will bring lasting contributions to the nation's energy infrastructure while supporting the growth of a more sustainable, resilient, and equitable energy sector. Smartville's scaled solution will help capture a growing percentage of the estimated 100 GWh/year of used EV batteries by 2030 by maximizing their remaining useful life while lowering the overall greenhouse gas emissions associated with both energy storage deployment and end-of-life battery recycling. Smartville's battery repurposing facilities will improve efficiencies and generate much needed added-value to the lithium-ion battery industry, support U.S. strategic interests and battery material supply chain security, and spur job creation in the power and manufacturing sectors. This proposal is also matched by the State of California with a guaranteed $1.5M in cost share funding through the California Energy Commission's EPIC program.

TENNESSEE

Second Life Demonstration

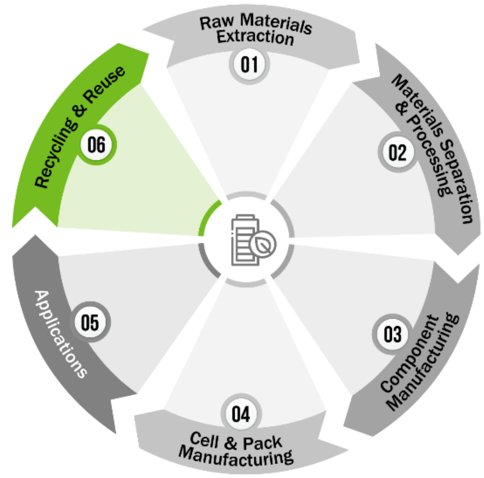
PROJECT NAME: Second-life Battery in Mobile EV Charging Application for Rural Transportation (SMART)

APPLICANT: Tennessee Technological University (Cookeville, TN)

Federal Cost Share: $4,531,642

Recipient Cost Share: $4,532,323

Supply Chain Segment: Recycling



Project Description:
Mobile charging stations (MCSs) play a critical role in removing the charging deserts in rural areas and alleviating range anxiety, as they can be transported to desired locations for EV charging with fewer concerns about power infrastructure and locational constraints. While rural America will potentially need many MCSs to eliminate charging deserts, the high investment cost due to large and new battery energy storage systems (BESS) and low utilization rate are barriers to adoption at a large scale. The requirement of large and new BESS in MCSs also burdens the U.S. battery supply chain.

This project aims to address the urgent need to develop affordable MCSs that can be deployed in rural America on a large scale by utilizing second-life batteries retired from EVs. The project objectives are to 1) design, develop, demonstrate, and validate four types of cost-effective MCSs to reduce upfront investment costs; 2) create and demonstrate first-of-the-kind affordable, resilient, and sustainable rural EV infrastructure in a multi-state region (TN, OH, VA, KY, WV, KS, and TX) by seamlessly integrating affordable MCSs into the existing charging network to support electrification in underserved rural communities; 3) collect and analyze the first-hand data of second-life-battery-integrated MCSs to assess the potential market and benefits; 4) create outreach, training, and education opportunities to help a broad range of EV stakeholders make informed decisions in adopting second-life-battery-powered MCSs and develop economically viable charging stations.

The project team consists of one major EV original equipment manufacturer (Nissan North America), two MCS suppliers (BoxPower and FreeWire), one second-life BESS diagnostic company (ReJoule), one battery material recycling company (Princeton NuEnergy), four academic institutions (Tennessee Technological University, University of Texas-Austin, University of Kansas, and University of Memphis), Pacific Northwest National Laboratory, and two DOE Clean Cities coalitions (East Tennessee Clean Fuels Coalition and Virginia Clean Cities), three State Energy Offices (Tennessee Department of Environment and Conservation, Kentucky Office of Energy Policy, Texas State Energy Conservation Office), a top-ranked engineering, procurement, construction provider (Black & Veatch), and Twinify Technologies.

Bipartisan Infrastructure Law: Electric Drive Vehicle Battery Recycling and Second Life Applications

U.S. DEPARTMENT OF ENERGY

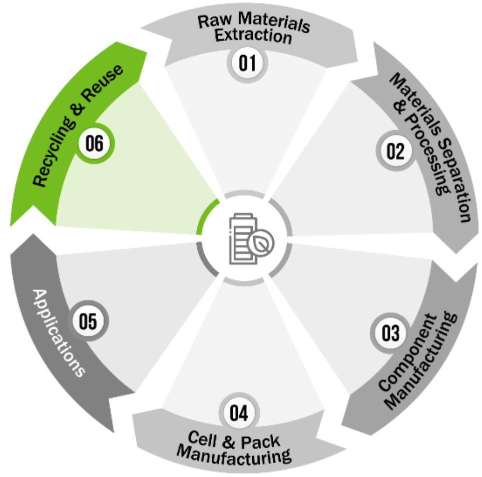
Battery Recycling and Technology Process Selections

CALIFORNIA

PROJECT NAME: Development and Scaling Up of the Purification and Regeneration Integrated Materials Engineering ("PRIME") Process for Cathodes Direct Recycling and Upcycling

UC San Diego

APPLICANT: The Regents of the Univ. of Calif., U.C. San Diego (La Jolla, CA)



Federal Cost Share: $10,000,000

Recipient Cost Share: $2,500,000

Supply Chain Segment: Recycling

Project Description:
Lithium-ion batteries (LIBs) prosper with the rapid emergence of electrification of the whole world. The increased adoption of Electric vehicles (EV), energy storage stations (ESS), and Internet of Things (IoT) devices will require a vast quantity of LIBs with disparate metrics within ten years. Ensuring a domestic supply of lithium batteries and accelerating the development of a robust and secure domestic industrial base become a critical need for the U.S. EV and energy industry (*U.S. National Blueprint Lithium Batteries 2021*).

Recycling LIBs not only reduces constraints imposed by materials scarcity and enhances environmental sustainability, but also supports a more secure and resilient domestic supply chain that is circular in nature. Currently, pyrometallurgy and hydrometallurgy methods dominate the industrial level battery recycling, mainly focused on cobalt (Co) and nickel (Ni) recovery, which suffer low yield, low profit, high environmental impact, and high energy consumption.

In this project, the team will develop and scale up a novel technology for recycling lithium-based batteries by implementing a Purification-Regeneration Integrated Materials Engineering ("***PRIME***") process for recycling and upcycling, which can more effectively regenerate critical cathode materials from both manufacturing scraps and spent batteries.

The energy consumption and the cost of the whole process are expected to be only 20% of traditional recycling methods due to successful integration of several key processing steps. The PRIME process merges the advantages of direct cathode recycling techniques with the novel purification strategy to improve the quality of recovered cathode materials with significantly reduced unit operation steps, which can be scaled up to an industrial level and solve the issue of limited domestic cathode supply. In this project, the team will fully develop this technology and build a working pilot to demonstrate a ton-level high-quality cathode production.

<u>**Second Life Demonstration**</u>

ALABAMA

PROJECT NAME: Adaptive Second-Use Battery Utilization with Different Degradation Levels for EV Charging Stations and Power Grid Support and Resiliency

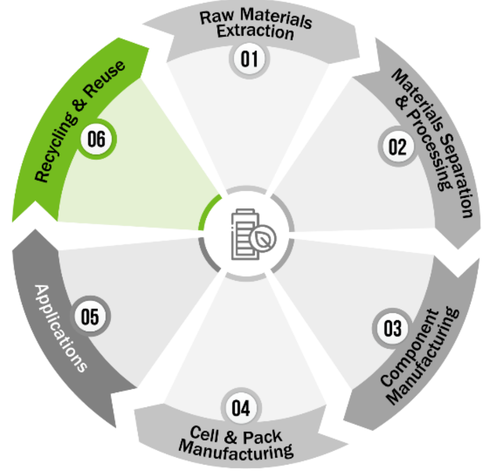
THE UNIVERSITY OF ALABAMA®

APPLICANT: The University of Alabama (Tuscaloosa, AL)

Federal Cost Share: $4,000,000

Recipient Cost Share: $4,000,000

Supply Chain Segment: Recycling



Project Description:
The objective of this project is to develop and demonstrate an economically viable end-of-life advanced lithium-ion battery (LIB) system to enable second uses for batteries in stationary electric vehicle (EV) charging stations, which reduces power grid demands, provides environmental benefits, and serves as a backup power source for EV charging when grid power is not available. Such as system also provides potential for energy reduction and cost savings in the lifecycle of EV batteries. Additionally, the utilization of the second-use batteries in EV charger applications makes EV chargers ready for the integration of renewable energy sources in EV charging stations. Second-use batteries that are retired from use in EVs can continue to serve EVs in stationary applications.

The proposed technology development and demonstration project, which involves both a multi-state utility power company (Southern Company Services) and EV manufacturer (Mercedes Benz US International Inc.,) in addition to the academic institution (UA), will demonstrate a module-level adaptive system architecture and health-aware control technology in which retired EV batteries support EV chargers at adaptive rates/magnitudes that are a function of their varying state-of-health values (during both charging and discharging), temperature values, and capacity values. The system is scalable, adaptable, and will be able to operate with battery modules with different chemistries, capacities, and voltage ranges.

The number of chargers and their use in the U.S. and around the world continues to increase. The power availability from these chargers is expected to become increasingly critical for EV customers with increased load impact on the power grid, especially during peak power demand hours. It is estimated that there will be more than 460,000 public EV charging stations in the U.S. by 2027. This rapid growth will undoubtedly bring the proposed technology to scale, which will further enhance the potential positive environmental impacts and improve quality of life.

LIST OF ACRONYMS

ABTC	American Battery Technology Company
ANL	Argonne National Laboratory
ARIES	Advanced Research on Integrated Energy Systems (NREL)
BESS	Battery Energy Storage Systems
BMS	Battery management system
CAM	Cathode active material
Co	Cobalt
CSU	Colorado State University
DAC	Disadvantaged community
DC-DC converter	Direct current to direct current converter
DOE	Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EOL	End of Life
EPIC	Electric Program Investment Charge (California Energy)
ESS	Energy Storage systems
EV(s)	Electric Vehicle(s)
GHG	Greenhouse gas emission
GWh	Gigawatt hour
INL	Idaho National Laboratory
IoT	Internet of things
IPP	Independent Power Producer
kWh	Kilowatt hour
Lbs	Pounds
Li2CO3	Lithium carbonate
LIB	Lithium-ion battery
Li-ion	Lithium-ion
LRIP	Low-Rate Initial Production
MCSs	Mobile charging stations
MSX	Membrane Solvent Extraction
MTU	Michigan Technological University
MWh	Mega-watt hour
NCSU	North Carolina State University
NEER	NextEra Energy Resources
Ni	Nickel
NiSO4	nickel sulfate
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturers
ORNL	Oak Ridge National Laboratory
PNE	Princeton NuEnergy
PVDF	Polyvinylidene fluoride
Q	Quarter
SLB	Second life batteries
SOH	State of health
U of U	University of Utah

UCI	University of California – Irvine
UNR	University of Nevada, Reno
USU	Utah State University