RECELL OVERVIEW AND UPDATE

Project ID: bat377

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Argonne National Laboratory

2020 DOE Vehicle Technologies Office
Annual Merit Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
VEHICLE TECHNOLOGIES OFFICE

PRESENTATION OVERVIEW

- Relevance (Why recycle lithium-ion batteries)
- ReCell's Approach
- Technical Accomplishments
- Summary

- Six poster presentations expand on each focus area
  - Direct Cathode Recycling: Material Separation and Preparation: bat464
  - Direct Cathode Recycling: Relithiation and Upcycling: bat465
  - Recycling of Non-Cathode Based Battery Materials: bat466
  - Battery Design for Recycle: bat467
  - Modeling and Analysis of Battery Recycling: bat468
  - Battery Recycling Crosscut Technologies: bat469

PROJECT OVERVIEW

Timeline

- Project start: October 2018
- Project end: September 2021
- Percent complete: ~50%

Budget

FY19	$4,615k
FY20	$5,150k

Barriers

- Recycling and Sustainability
  - Cost to recycle is currently 5-15% of battery cost
  - Material shortage (Li, Co, and Ni)
  - Varying chemistries result in variable backend value

Partners

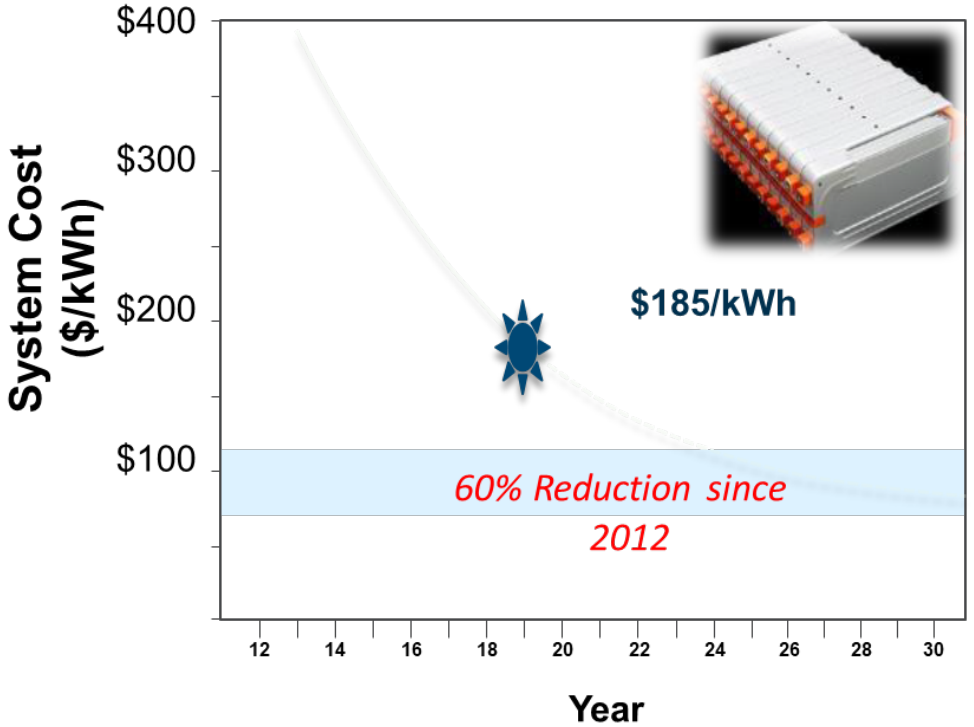
- Argonne National Laboratory
- National Renewable Energy Laboratory
- Oak Ridge National Laboratory
- University of California, San Diego
- Worcester Polytechnic Institute
- Michigan Technological University

RELEVANCE

By September 30, 2022, reduce the cost of electric vehicle battery packs to less than $150/kWh with technologies that significantly reduce or eliminate the dependency on critical materials (such as cobalt) and utilize recycled material feedstocks.

Battery Cost Reduction

Based on Useable Energy and production of 100k EV Packs/year



ReCell ADVANCED BATTERY RECYCLING

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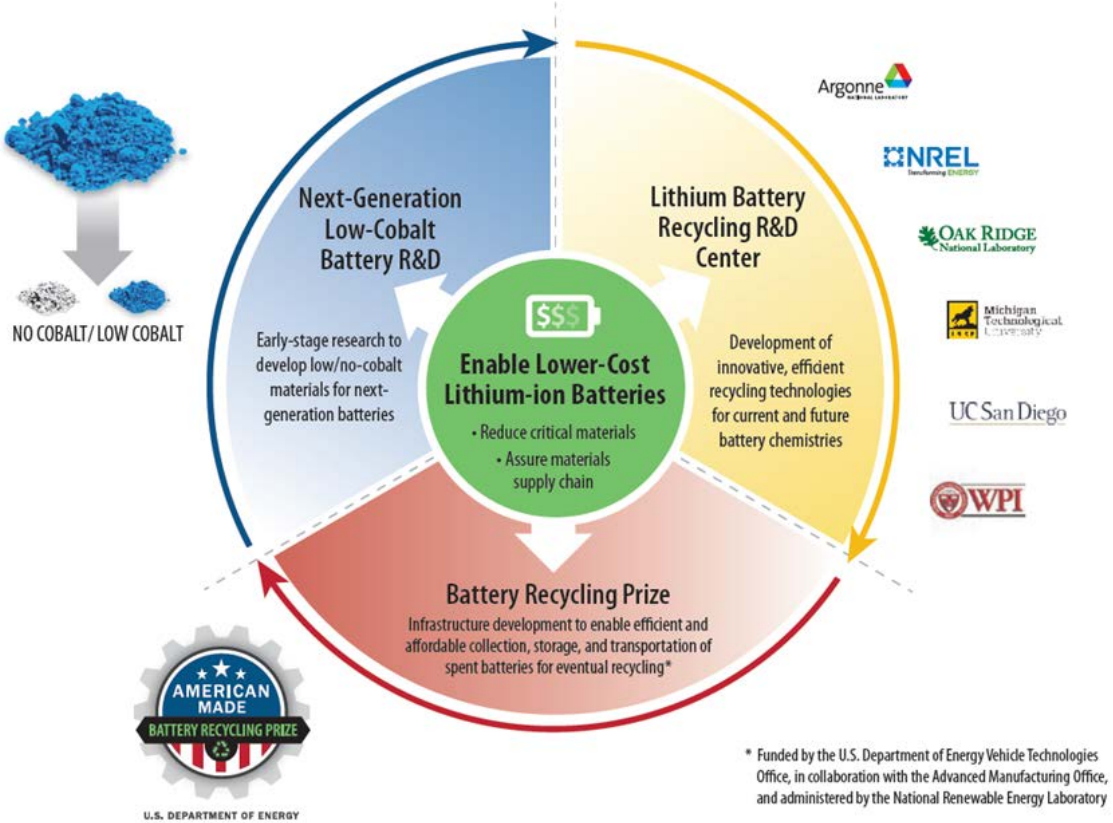
RELEVANCE

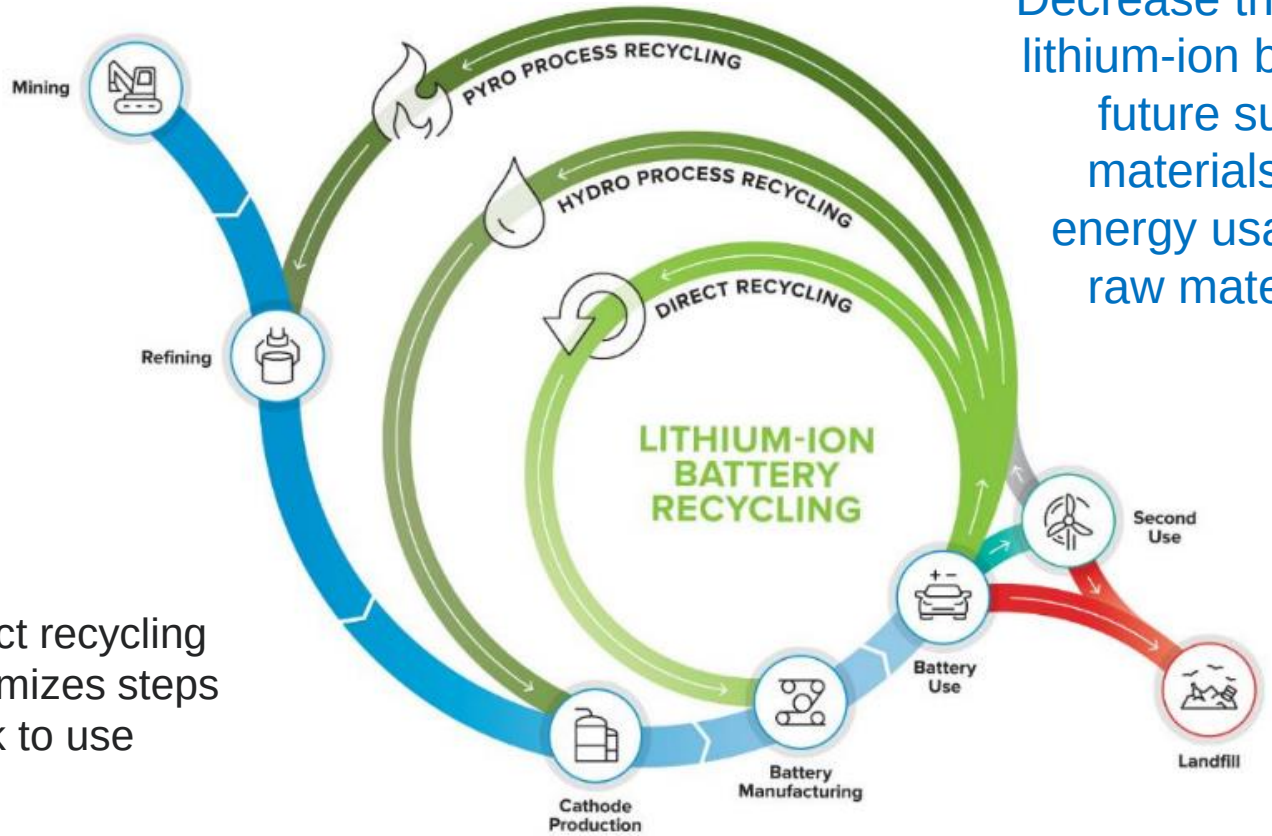
- Lower cost of batteries
- Enable lower environmental impacts
- Increase our country's energy security



APPROACH

ReCell's Mission:

Decrease the cost of recycling lithium-ion batteries to ensure future supply of critical materials and decrease energy usage compared to raw material production



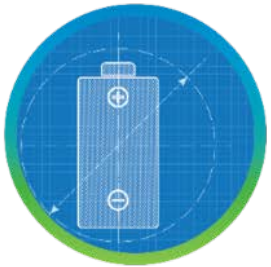
Direct recycling minimizes steps back to use

APPROACH

Year 1 – Bench scale testing: Powder-to-Cell → Year 2 – Start to scale up unit operations → Year 3 – Finish scale up and show cell-to-cell recycling

DIRECT CATHODE RECYCLING

OTHER MATERIAL RECOVERY



DESIGN FOR RECYCLING

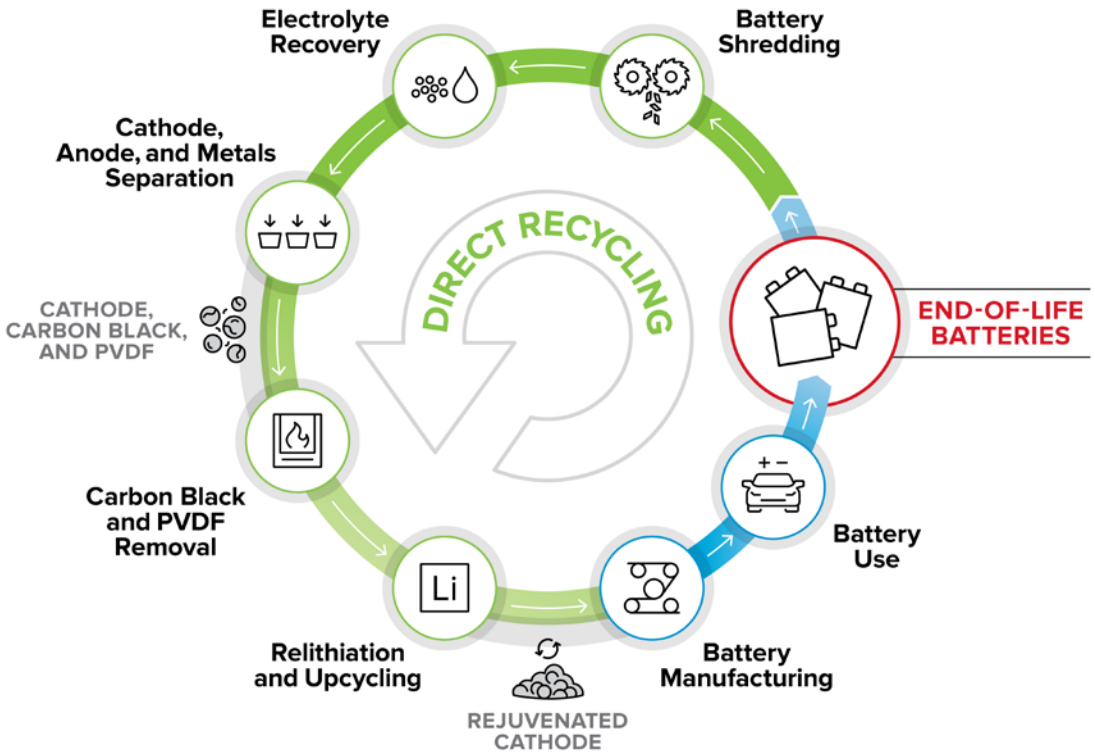
MODELING AND ANALYSIS

Program does not include battery dismantling, transportation, or 2nd use

APPROACH

- Multiple processes investigated to mitigate risk
- Continual review of new project ideas
- End projects that are not showing promise in cost and performance
- These processes can benefit other recycling processes

Typical Direct Recycling Process Flow

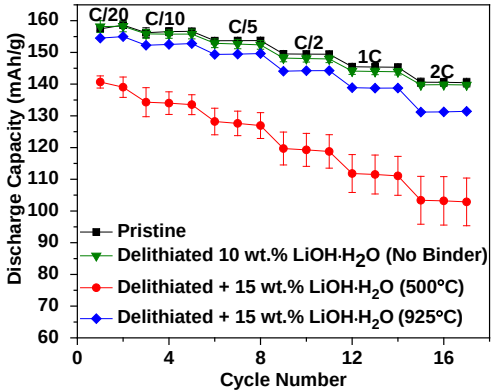


TECHNICAL ACCOMPLISHMENTS

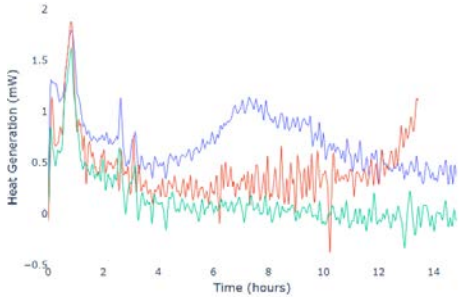
Focus area and crosscutting accomplishment examples

- Direct – Binder burnout and relithiation, single step, Hazen test
- Other Materials – Robust, very efficient solvent-based delamination of electrodes has been developed.
- Design for Recycle - Estimated penalty in energy density with the new cell design using BatPac
- Modeling and analysis – EverBatt 2019 made available for download
- Crosscut – Contaminant microcalorimetic signatures identified

- Add number of Inventions
- Everbatt received 2019 R&D100 award



Cathode performance after simultaneous binder burnout and relithiation



When atypical materials (contaminants) are introduced to the cathode, the heat signature during formation can be used to identify the contaminant. This technology can be used to assess the efficacy of the recycling processes under ReCell.

TECHNICAL ACCOMPLISHMENTS

ReCell Industry Collaboration Meeting; November 7-8, 2019

Provided an opportunity for ReCell and industry stakeholders to exchange challenges and ideas.

The meeting included stakeholders from every corner of the vehicle battery value chain

XX people
from YY companies

Feedback from participants has lead to a second meeting to take place in fall of 2020

TECHNICAL ACCOMPLISHMENTS

Manufacturing Scrap Recycling

Cathode manufacturing scrap is an entry point with less materials barriers while validating a partial list of unit operations being developed within ReCell

Unit Operations

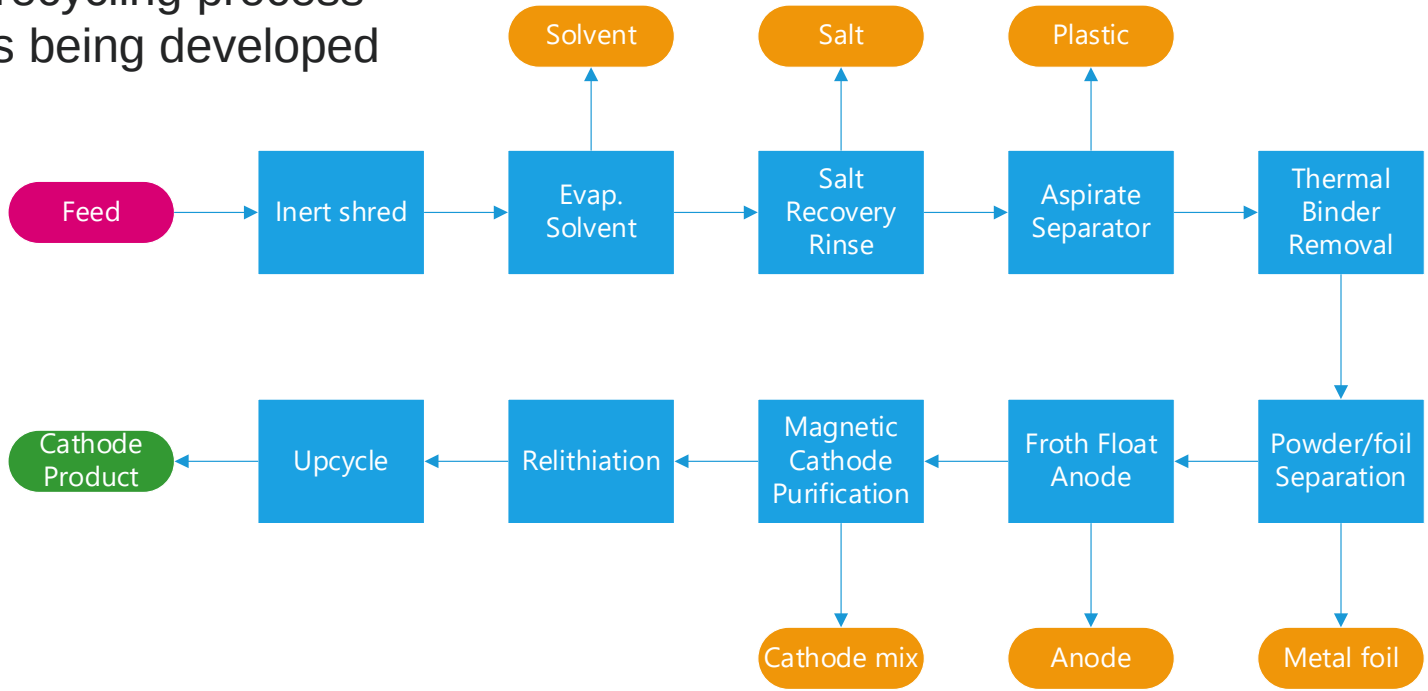
Shredding
Delamination
Binder Removal
Relithiation

Demonstration from this point

TECHNICAL ACCOMPLISHMENTS

A Complete Direct Recycling Process

Putting the pieces together: One example direct recycling process using processes being developed



TECHNICAL ACCOMPLISHMENTS

Center accomplishments – cont'd

- ReCell Laboratory Space
- Equipment
  - Screener
  - Magnet
  - Froth column
  - Calciners
  - Powders hood
  - Sink/float separation
  - Aspirator
  - CSTR

MILESTONES

FY19 Q1	Complete	Establish the battery recycling center's mission and include its targets and goals
FY19 Q2	Complete	Provide an initial progress report on roll-to-roll relithiation
FY19 Q3	Complete	Provide an initial progress report on design for recycle initiative
FY19 Q4	Complete	Establish the ReCell Center's Battery Recycling Laboratory and Scale-up Facility
FY20 Q1	Complete	Electron Backscatter Diffraction data comparison of various chemically delithiated NMC-111 versus pristine NMC-111
FY20 Q2	Complete	All five relithiation processes added to EverBatt at lab scale and production scale
FY20 Q3	Ongoing	Down-select solvent(s) to separate black mass from current collector and optimize the process conditions to achieve >90% recovery of black mass
FY20 Q4	Ongoing	Demonstrate recovery of anode and cathode powders using the new pilot scale froth column

Each Individual project has its own milestones. Though not listed here.

COVID-19 has reduced lab time and may cause delays in completing FY20 milestones

REMAINING CHALLENGES AND BARRIERS

- Recovering materials that are just as pure as virgin
- What value does a 10 year old battery chemistry have?
- Detailed process information needed for accurate evaluation of technical and economic viability and a down-select process.
- Industry buy-in for commercialization is needed
- The use of lithium metal anodes and solid state electrolytes will require new recycling processes.
- Future battery chemistries (sulfur, sodium, magnesium, etc.) may introduce even more recycling challenges.

PROPOSED FUTURE WORK

- Research using new technologies that become available
- Expand work to upcycle obsolete cathode chemistries
- Demonstration of batteries made with recycled content in real applications
- Demonstration of a continuous battery recycling pilot line to prove feasibility to industry
- Joint projects with industry to ensure relevant work scope and commercialization
  - Start with manufacturing scrap
  - Move to end of life batteries
- Collaborative work with the Recycling Prize to close the gap of collection, transport and battery dismantling

Any proposed future work is subject to change based on funding levels

SUMMARY

- In year 2 of ReCell the objective is to start scaling up the most promising technologies
- Economic and environmental evaluations are performed for all processes using EverBatt
- EverBatt output being used to aid in down-selection process
- Direct recycling process flow options are being optimized
- New ideas are always considered and tested when deemed appropriate
- Cell shredding/processing has been added to the program scope
- Working to demonstrate processing of manufacturing scrap
- Industry involvement continues to grow, CRADAs and SPPs starting to form
- Facility space is now in place and scale-up equipment is being procured

RESPONSE TO REVIEWERS

"Projects need to be evaluated for technical and economic viability and a down-select process is needed. Many ongoing processes are clearly not cost effective."

The reviewer is correct that the projects need to be evaluated for both technical and economic viability in order to perform the most comprehensive downselect. Each project is reviewed for technical performance specific to its part in the overall recycling system while using EverBatt to evaluate the economic viability. So far several projects have been removed from the portfolio.

"The reviewer remarked it is good to perform quantitative analysis of the costs for recycling, elaborating that the costs of recycling should be compared with those of raw materials and the recycling percentage of materials should be provided."

EverBatt allows ReCell to put the individual unit operations together in many different configurations and to simply switch out one unit operation for another or reorder the operations. With that information EverBatt can easily compare recycled cathode product to raw material costs, or more specifically, cathode materials. Additionally it can compare costs with hydro- and pyrometallurgical models. We are currently in the process of modeling a complete direct recycling system scenario using ReCell-developed technologies that will be used to compare with raw materials and virgin cathode costs. We will also compare environmental impacts using EverBatt.

COLLABORATION AND ACKNOWLEDGEMENTS

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Michigan Technological University

NREL NATIONAL RENEWABLE ENERGY LABORATORY

WPI

OAK RIDGE National Laboratory

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POSTER PRESENTATIONS AND TOWN HALL

FRIDAY, JUNE 5, 2020 FROM X:00 TO X:00 (CENTRAL)

To continue the discussion the ReCell team will hold an interactive town hall meeting.

Please join us at the BlueJeans session shown below and ask questions through Slido

Take a picture of this slide

For Information about ReCell

BlueJeans Meeting Access information

Computer
https://bluejeans.com/749203749/9534?src=htmlEmail

Phone
(866) 226-4650
Meeting ID: 749 203 749

Slido Q/A website

Computer or Smart Phone
www.Slido.com

Event Code
“recell”

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