

THE RECELL CENTER: ADVANCED BATTERY RECYCLING



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WHAT IS IN A BATTERY?

Parts of a 100kWh NMC622 Battery

(and how much is in
an electric vehicle)

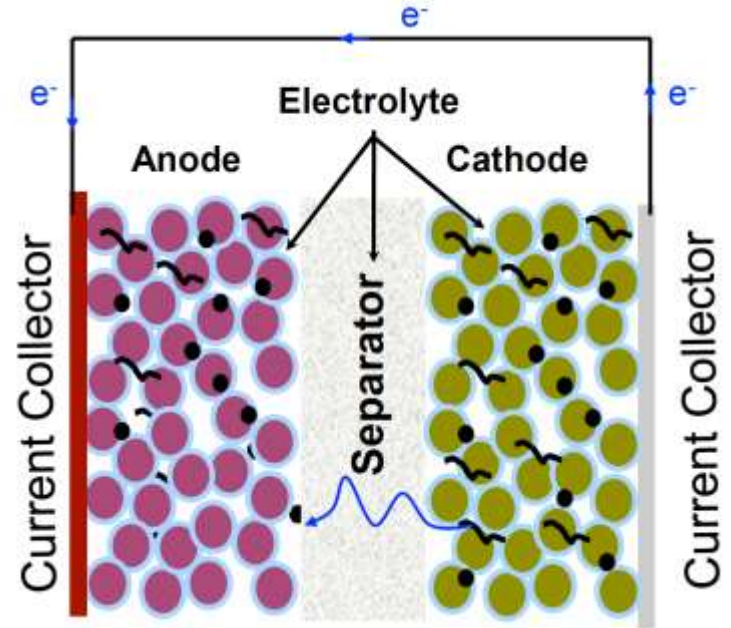
Cathode

Lithium	23 lbs
Nickel	115 lbs
Cobalt	38 lbs
Manganese	36 lbs
Copper foil	43 lbs

Anode

Graphite	189 lbs
Alum. Foil	19 lbs
Electrolyte	79 lbs
Separator	6 lbs
Bal. of pack	554 lbs

TOTAL **1102 lbs**



WE NEED TO MINE A LOT OF MINERALS

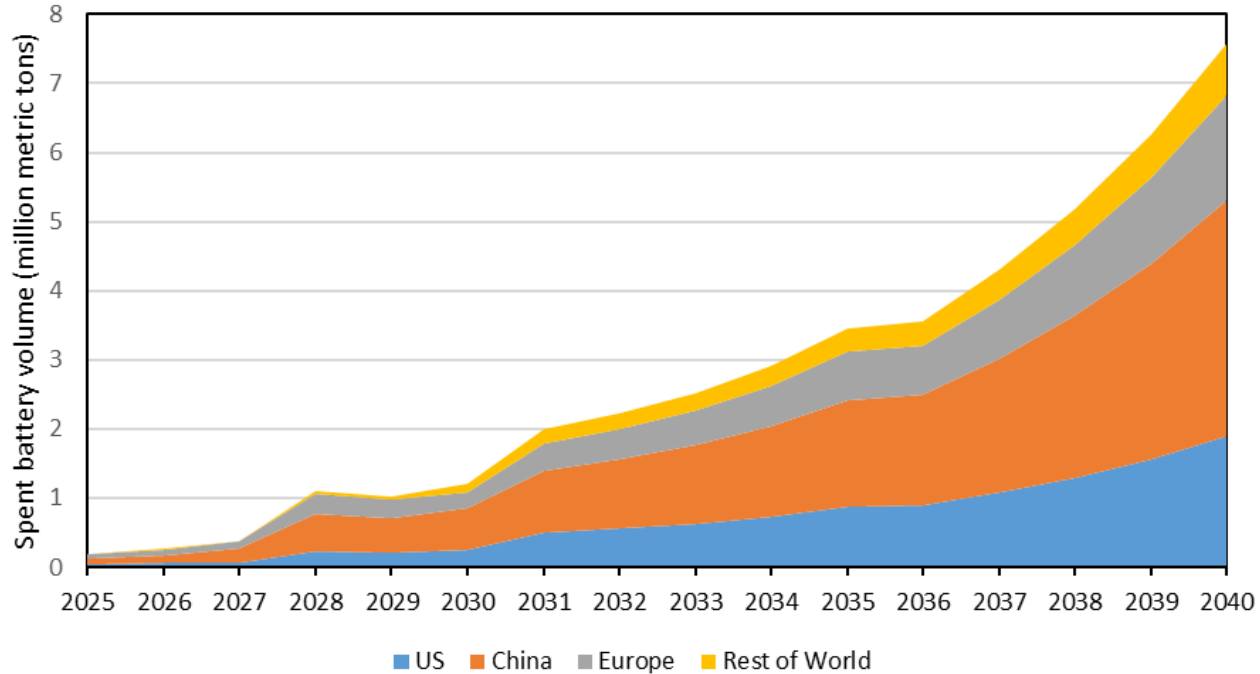


	Li	Ni	Co
For global adoption (kt) ^{1,2}	10,500	52,000	17,400
US reserve (kt) ³	750	340	69
World reserve (kt) ³	22,000	95,000	7,600

1. Based on 100kWh NMC622 battery from BatPaC 5.0 8March2022
2. Assuming 1 billion electric vehicles worldwide
3. USGS Mineral Commodity Summaries 2022

SETTING THE STAGE

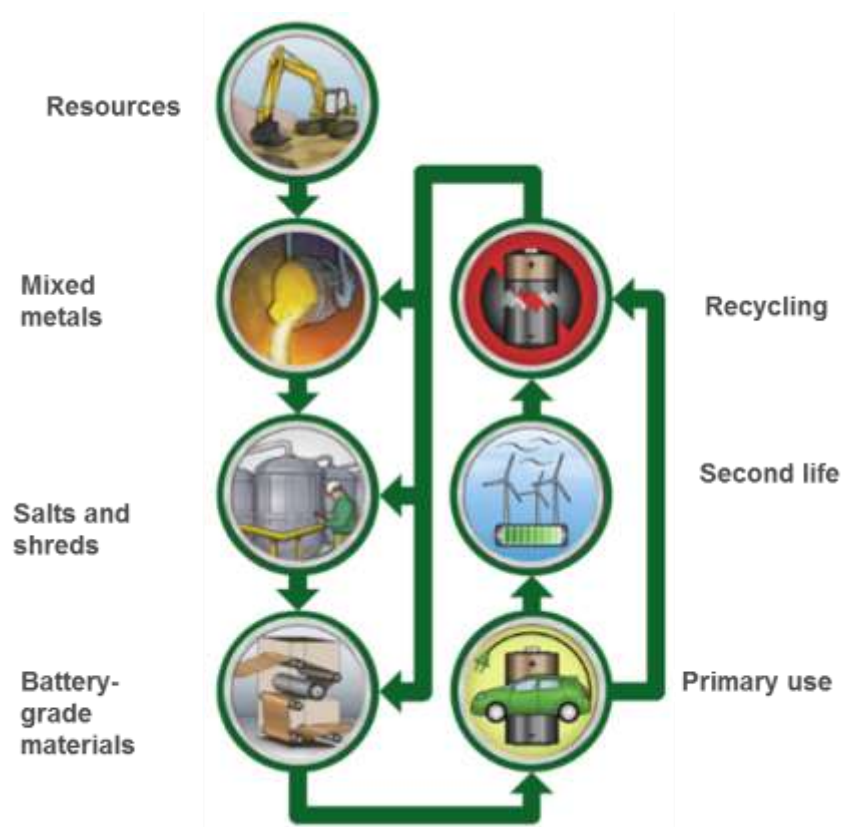
Projected Global Spent EV Battery Volume



(ANL projection based on IEA global PEV projection)

CURRENT PROCESSING

- Recycling lithium-ion batteries is possible today
- The process technologies are mature
 - Hydro
 - Pyro
- There are pros and cons to all process types, but they are all better than landfilling



Courtesy Argonne

THE RECELL CENTER



Purpose

- Foster the continued improvement of cost-effective, environmentally sound processes to recycle lithium-ion batteries
- Bring together experts from all battery recycling areas and bridge the gaps
- Efficiently address the many challenges that face a successful advanced battery recycling infrastructure

Outcome

- Minimize use of the earth's limited resources, reduce energy consumption and increase our national security
- Provide stability to the battery supply chain
- Drive battery pack costs down to DOE's \$80/kWh usable energy goal

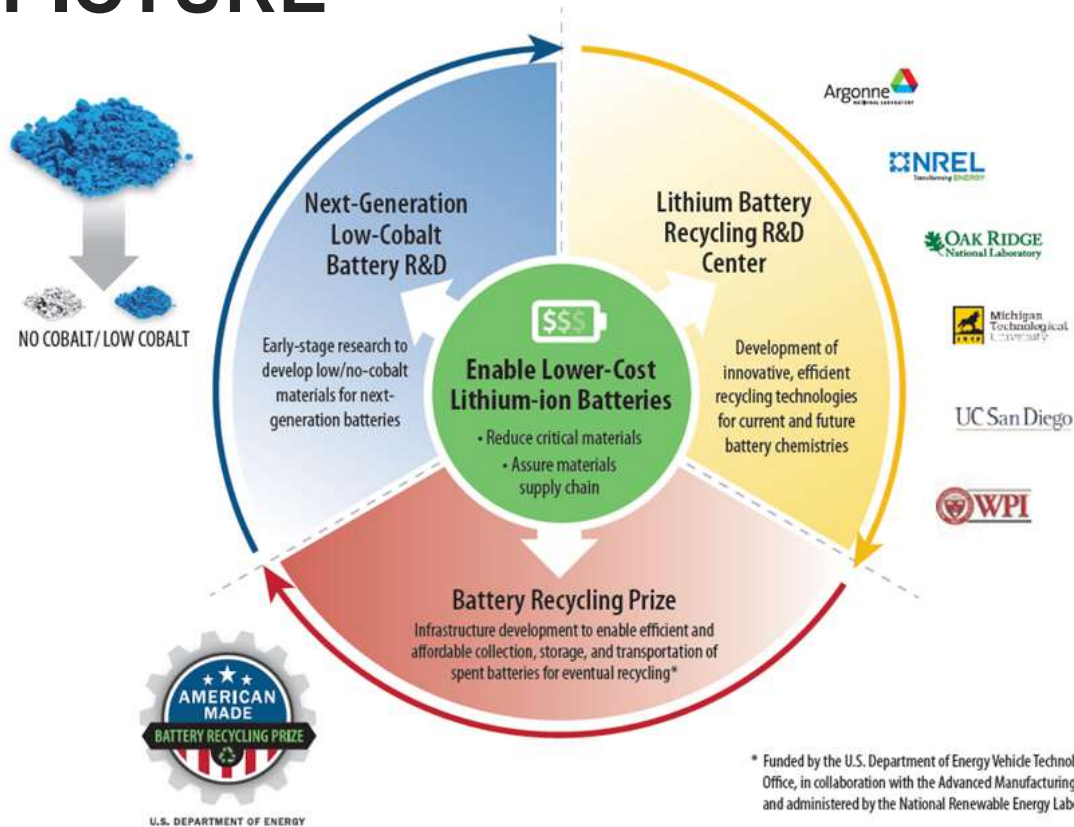
THE RECELL CENTER'S MISSION

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



Courtesy Argonne

DOE VEHICLE TECHNOLOGIES OFFICE BIGGER PICTURE



RECELL HAS FOUR FOCUS AREAS

- Binder Removal
- Cathode/ Cathode Separation
- Relithiation
- Cathode Upcycling
- Impurity Impact



**DIRECT
CATHODE
RECYCLING**

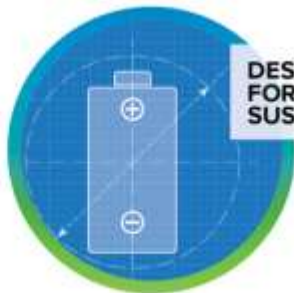
**OTHER
MATERIAL
RECOVERY**



- Cell Shredding
- Electrode Delamination
- Anode/ Cathode Separation
- Electrolyte Component Recovery

Cross Cutting Projects

- Cell Design for Rejuvenation



**DESIGN
FOR
SUSTAINABILITY**

**MODELING
AND
ANALYSIS**



- EverBatt (TEA/LCA)
- LIBRA (Supply Chain Modeling)

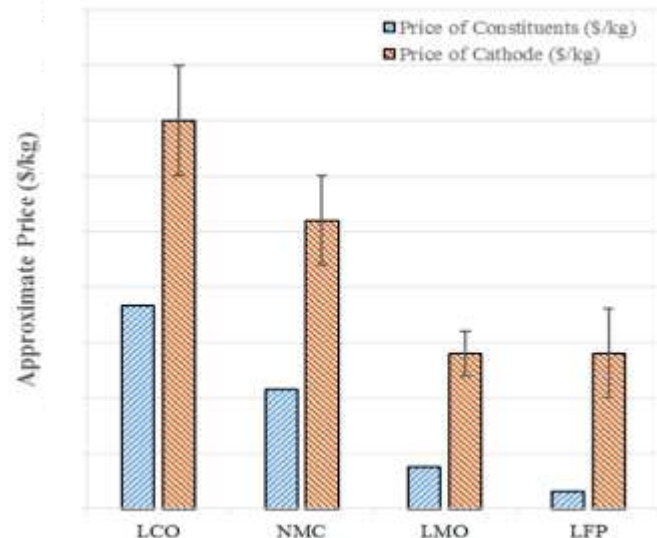
Courtesy Argonne

DIRECT RECYCLING



Direct recycling recovers cathode material instead of metal salts, offering the most potential for cost effectiveness

Courtesy Argonne



DIRECT RECYCLING

Typical Direct Recycling Process Flow

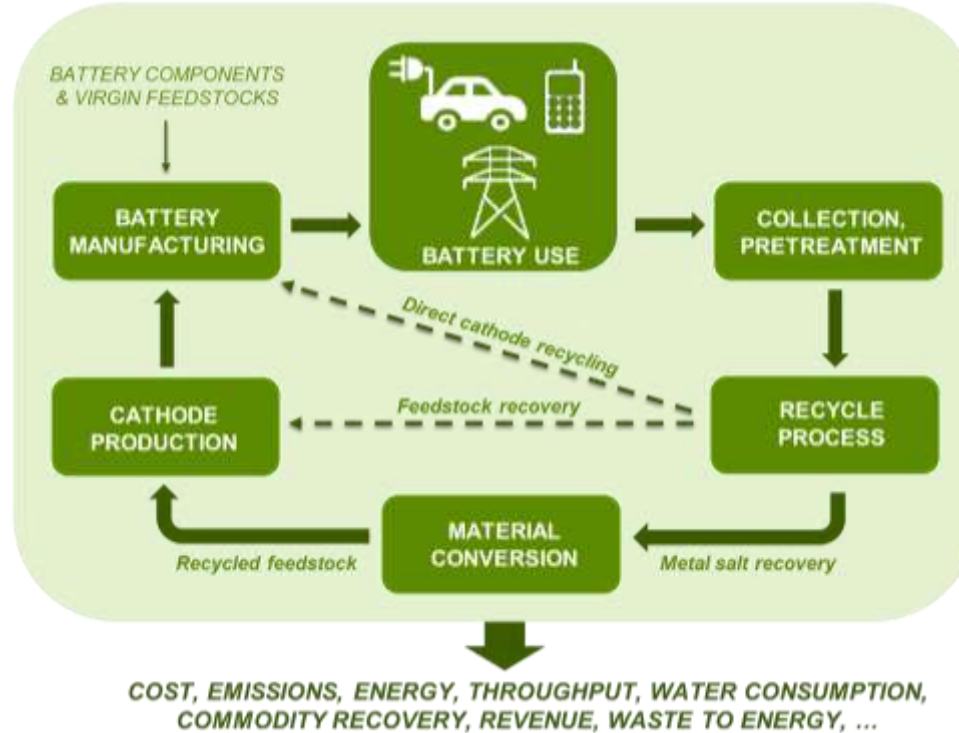
- Multiple processes investigated to mitigate risk
- Continual review of new project ideas
- End projects that are not showing promise in cost and performance
- These unit operations can benefit other recycling processes



Courtesy Argonne

EVERBATT MODEL FLOW

EverBatt breaks down and evaluates each stage of the battery's lifecycle providing the opportunity to compare each stage's cost and environmental impact to the overall impacts



Courtesy Argonne

EVERBATT DATA OUTPUT

Model output is consistent between lifecycle stages

Recycle				
	Pyro	Hydro	Direct	Custom
Cost per kg cell recycled	\$	\$	\$	
Energy use in MJ per kg cell recycled				
Total Energy	15.959	20.987	6.494	
Water use in gallon	5.3	0.5	1.5	
Total Emissions in g per kg cell recycled				
VOC	0.342	0.333	0.098	
CO	1.688	1.439	0.421	
NOx	5.478	2.700	0.789	
PM10	0.248	0.228	0.107	
PM2.5	0.208	0.207	0.076	
SOx	17.297	22.332	0.765	

Other outputs include:

Energy from fossil fuels, coal, natural gas and petroleum

Total emissions from BC, OC, CH₄, N₂O, CO₂, CO₂ (w/C in VOC & CO), and GHGs

* Example data is from hypothetical processes and will vary depending on process specifics

FACILITIES

Center accomplishments – cont'd

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



Courtesy Argonne

RECELL INDUSTRY COLLABORATION MEETING

November 2019

*134 people
from 76 organizations*

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

Potential for November 2022 meeting



Courtesy Argonne



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Energy Efficiency &
Renewable Energy

VEHICLE TECHNOLOGIES OFFICE

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