

INTRODUCTION TO LITHIUM ION BATTERIES



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THE NATIONAL LAB SYSTEM



KEY FACTS ABOUT ARGONNE



3,300 employees

1,600 scientists and engineers

300 postdoctoral researchers

7,100 facility users

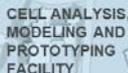
\$780M operating budget



ARGONNE LEADERSHIP
COMPUTING FACILITY



MATERIALS
ENGINEERING
RESEARCH
FACILITY



CELL ANALYSIS,
MODELING AND
PROTOTYPING
FACILITY



ADVANCED PHOTON SOURCE



ELECTROCHEMICAL
ANALYSIS AND
DIAGNOSTICS
LABORATORY



CENTER FOR NANOSCALE
MATERIALS

- High-performance Computing
- Computational Science
- Artificial intelligence
- Urban and building technologies
- Resiliency / Cyber Security
- Energy Storage

- Connected and autonomous vehicles and e-mobility
- Electric vehicles
- Engines, fuels, emissions
- Smart manufacturing

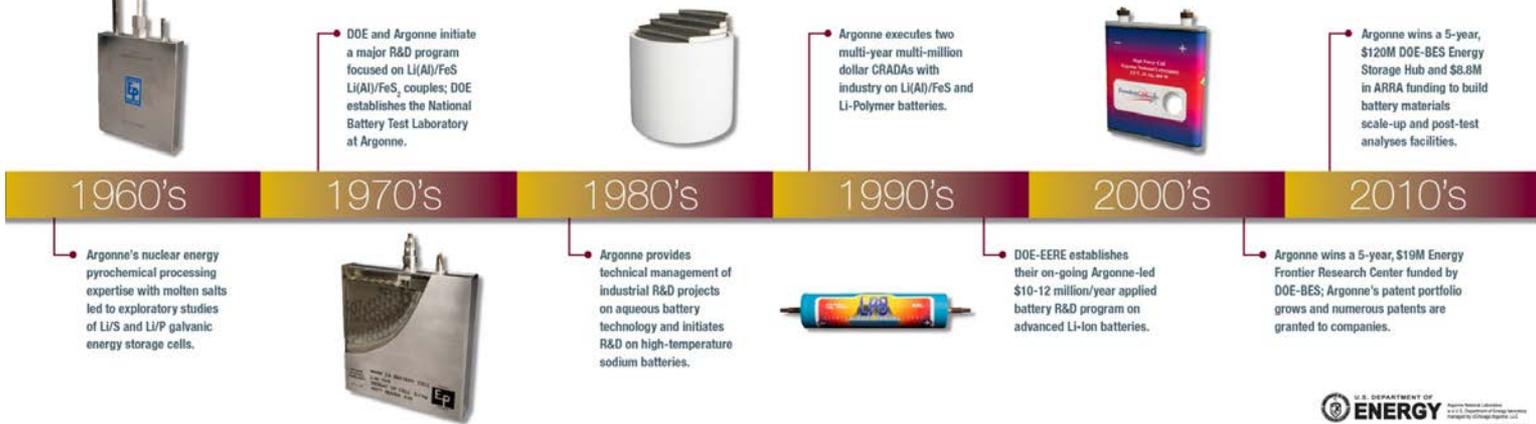
- Materials characterization
- Nanomaterials

ANL BATTERY PROGRAM: 50 YEARS OF R&D

History of the BATTERY PROGRAM at Argonne National Laboratory



The Argonne battery program grew out of the laboratory's nuclear R&D program. Researchers were studying alternative methods for converting the heat generated in controlled nuclear reactions to electricity while searching for a better path than steam generation. One of the early approaches studied was "thermally regenerative galvanic cells."



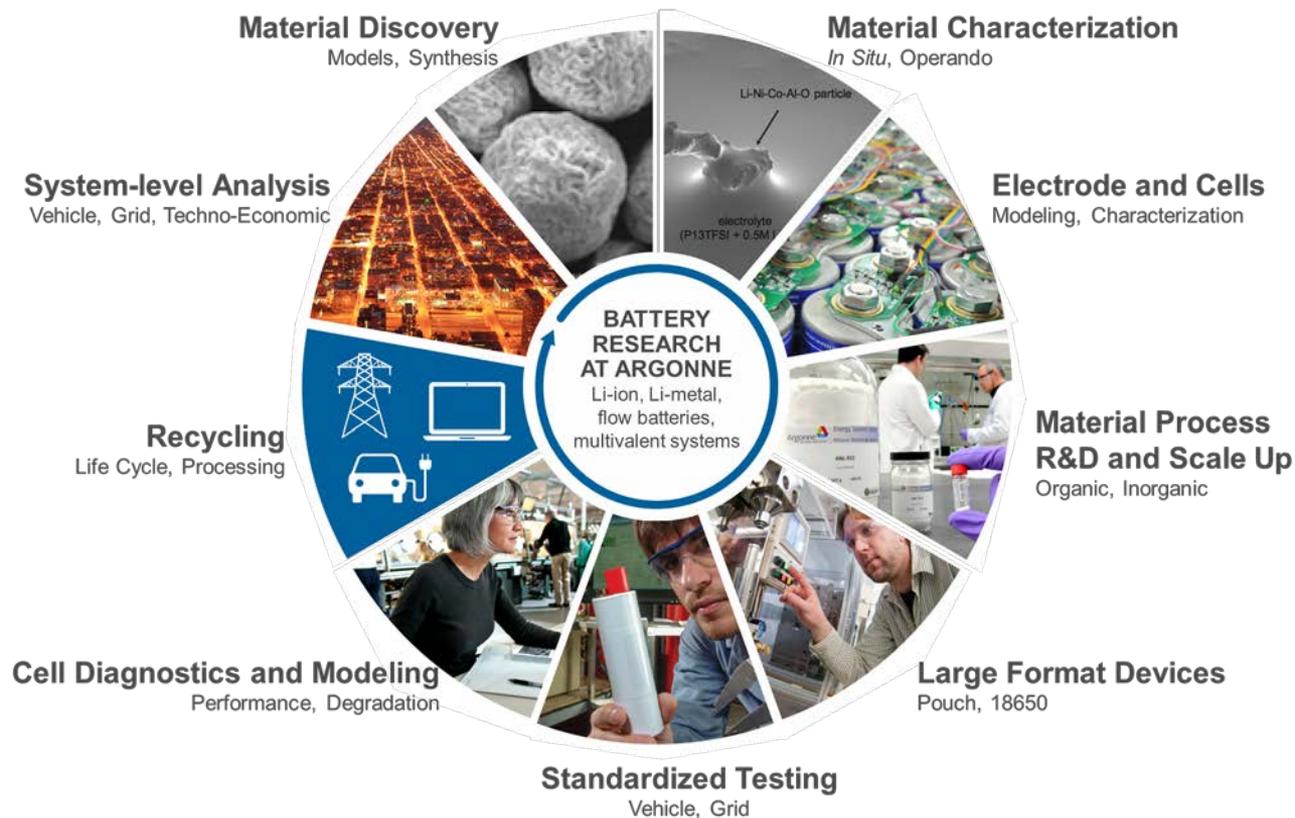
R&D focus:

1964 - 1998: High/Moderate temperature Li batteries

1998: Room-temperature Li-ion batteries

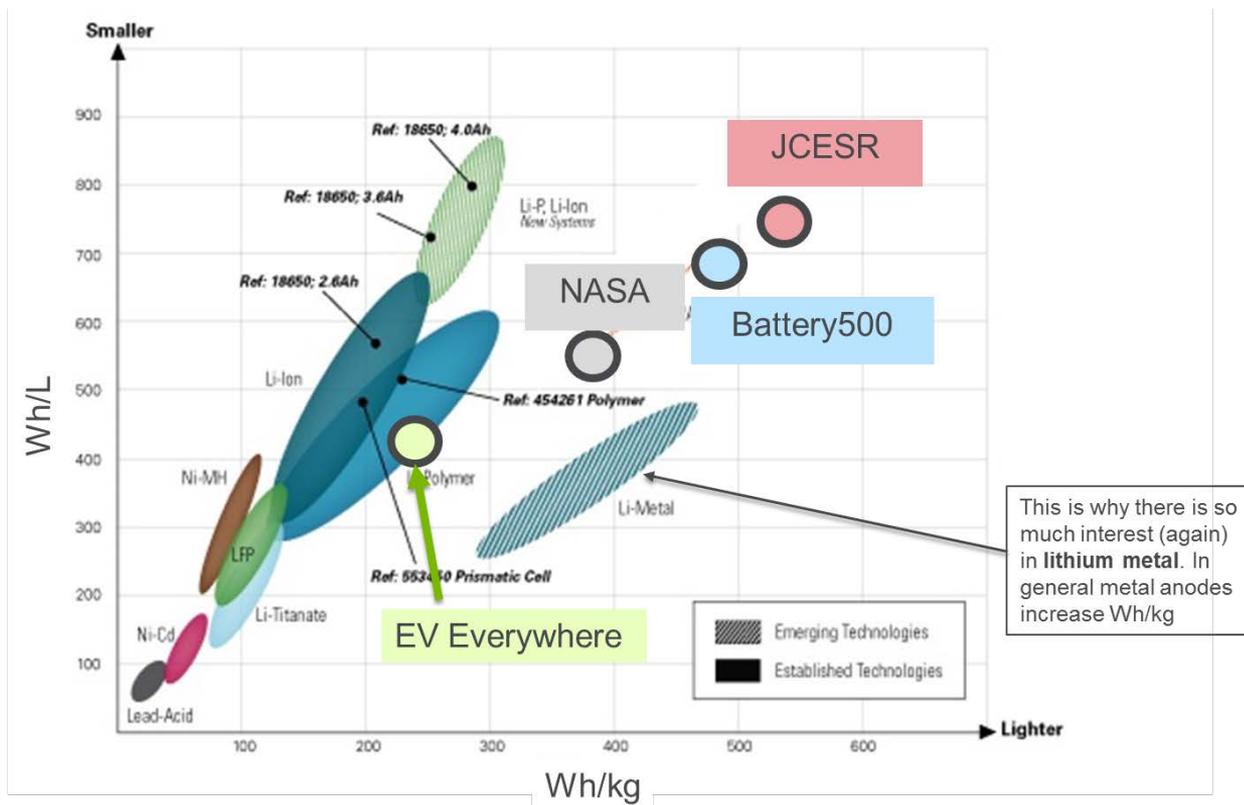
2012: Li metal, oxygen, sulfur, flow, Mg

ANL BATTERY PROGRAM: ACROSS THE VALUE CHAIN



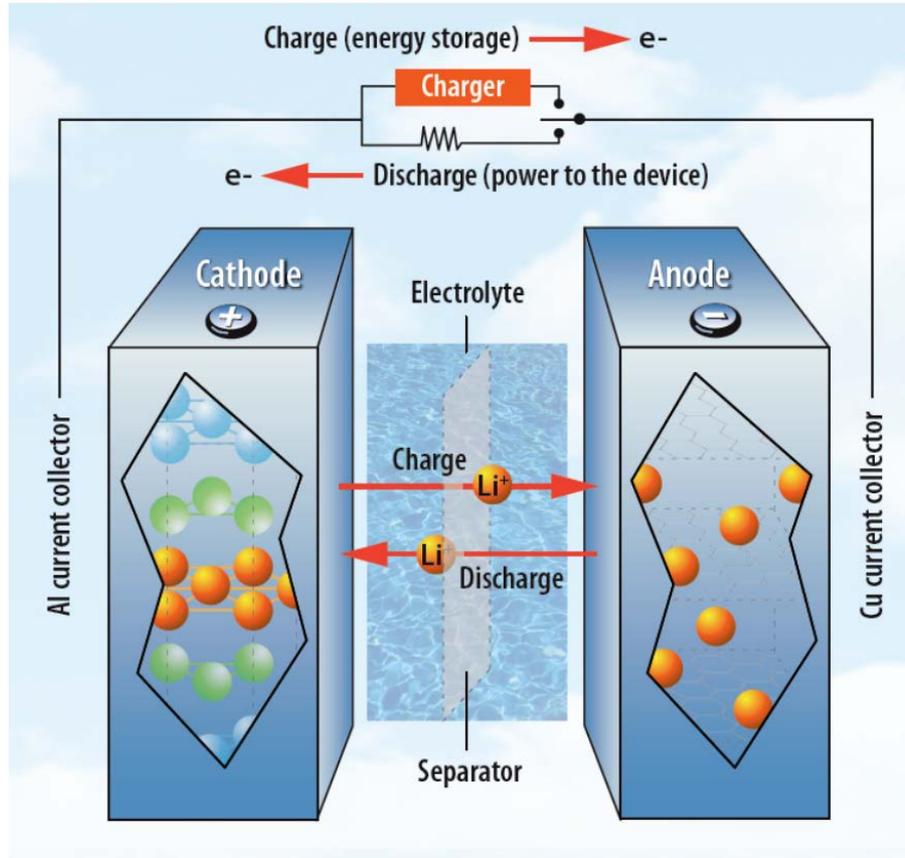
COMPARISON OF OTHER CHEMISTRIES

Energy density has increased through time with different chemistries



This is why there is so much interest (again) in lithium metal. In general metal anodes increase Wh/kg

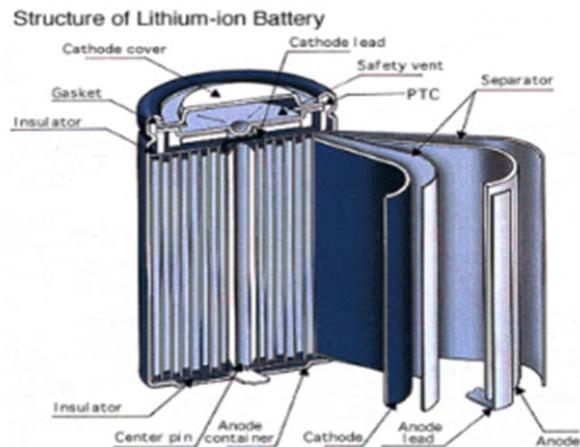
HOW LITHIUM ION BATTERIES WORK



- All batteries use this same basic configuration
 - Anode, cathode and electrolyte
- Lithium batteries and lithium ion batteries are different
 - Lithium batteries use lithium metal anodes (usually non-rechargeable)
 - Lithium ion batteries use graphite or other material

LITHIUM ION CHEMISTRIES

Cathodes

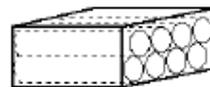


Anodes

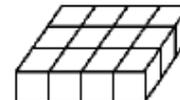
Graphite



Cell



Module



Pack

Source: L. Gaines and R. Cuenca, *Costs of Lithium-Ion Batteries for Vehicles*, Report ANL/ESD-42 (2000)

CHEMISTRY vs USE

- Different chemistries are used for different applications
- Consumer electronics use the most energy dense
- Vehicles use other chemistries

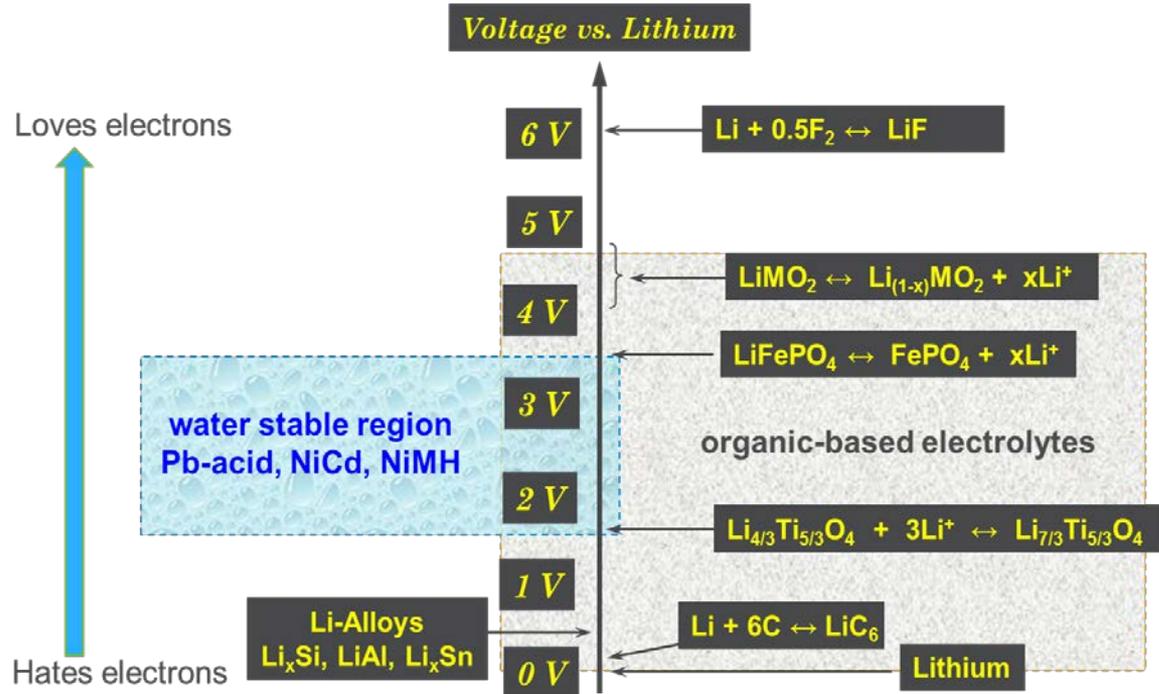
Chemistry	Nominal (V)	Charge (V) limit	Charge & Discharge C-rates	Energy Density Wh/kg	Applications	Note
Cobalt	3.60V	4.20V	1C limit	110-190	Cell Phone, cameras, laptops	Since 1990s, most commonly used for portable devices, has highest energy density.
Manganese (spiral)	3.7-3.80V	4.20V	10C cont. 40C pulse	110-120	Power tools, medical equipment	Low internal resistance: offers high current rate and fast charging but lower energy density.
NCM (Nickel-Cobalt-Manganese)	3.70V	4.10V*	~5C cont. 30C pulse	140-160	Power tools, medical equipment	Nickel, Cobalt, Manganese mix; provides compromise between high current rate and high capacity.
Phosphate	3.2-3.30V	3.60V*	35C cont.	95-140	Power tools, medical equipment	New, high current rate, long cycle life.

* Higher voltages provide more capacity but reduce cycle life.

www.powerportstore.com/lithium_cell_chemistries.htm

CHEMISTRIES AND VOLTAGE

- Organic electrolytes are needed for higher voltage chemistries
- Organic electrolytes are flammable



STARTER BATTERIES REPLACING LEAD ACID

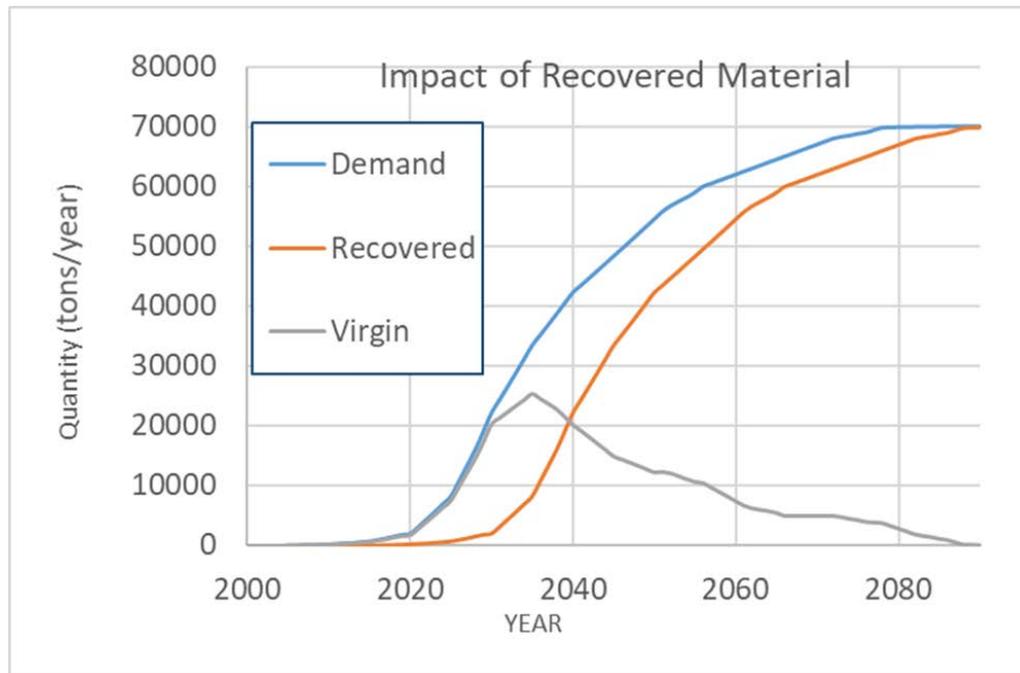
Considerations are being made to ban lead acid

- It is a difficult decision
 - Lead is a concern
 - But 99% of lead acid batteries are recycled
 - Lithium-ion collection isn't established

MATERIAL RESOURCES AND RECYCLING

Lithium with and without recycle

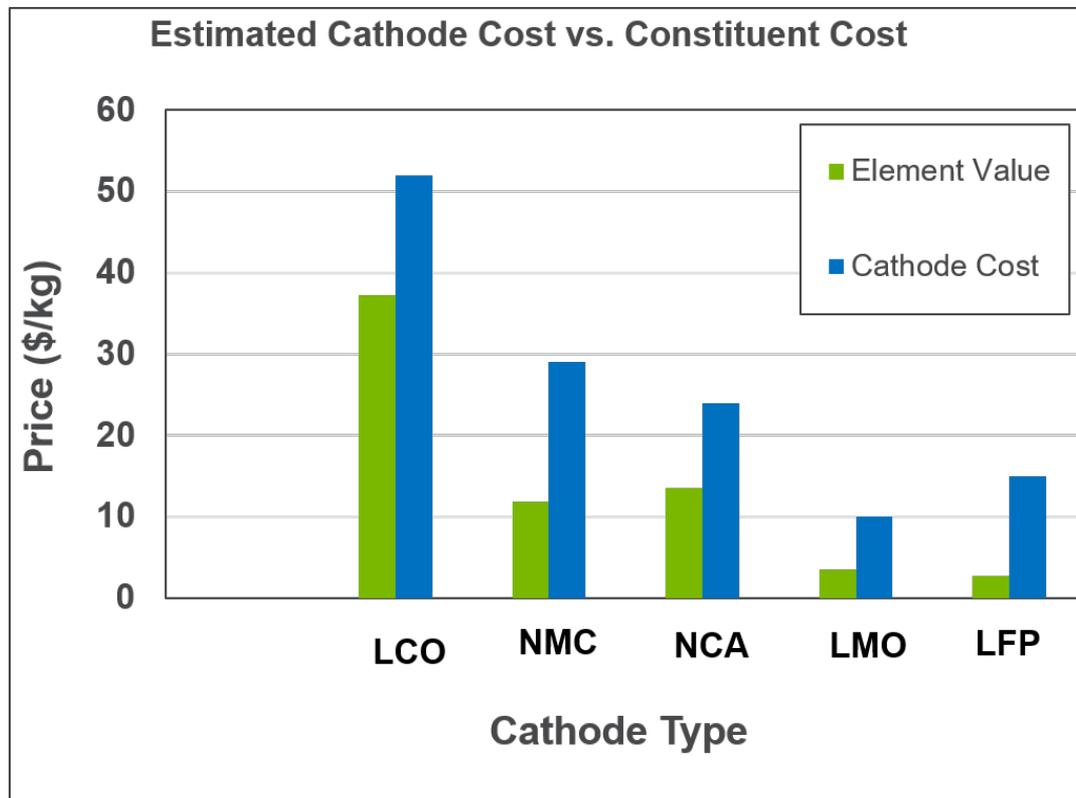
- Recycling batteries can minimize the use of our natural resources
- Long battery lifetime delays material return



RECYCLING TECHNOLOGY

	Pyrometallurgical	Hydrometallurgical	Direct
Temperature	High	Low	Low
Materials recovered	Co, Ni, Cu (Li and Al to slag)	Metals or salts, Li ₂ CO ₃ or LiOH	Cathode , anode, electrolyte, metals
Feed requirements	None	Separation desirable	Single chemistry required
Comments	New chemistries yield reduced product value	New chemistries yield reduced product value	Recovers high- value materials

MATERIAL VS CATHODE COST



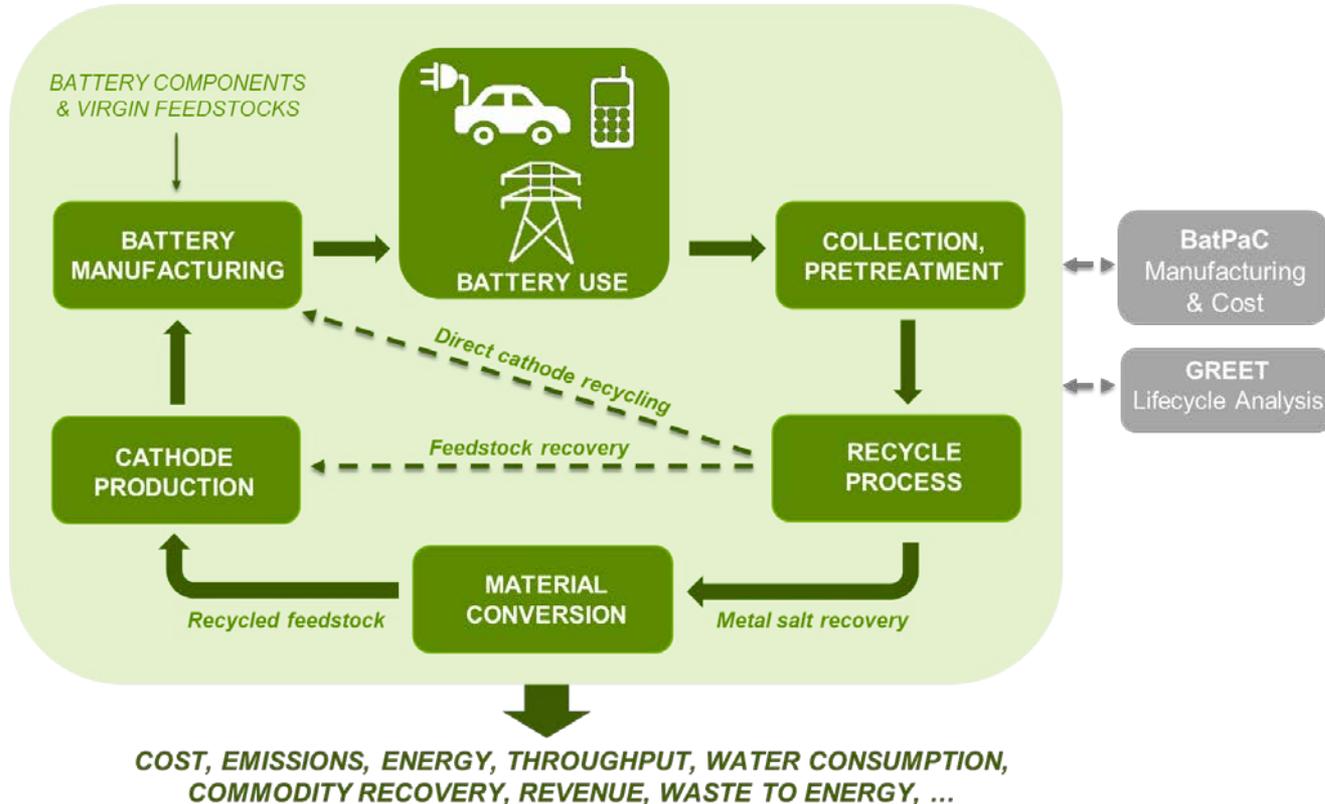
- The cathode is the most valuable
- Material value is cheap
- Cathode materials is expensive

ELECTRONICS AND VEHICLE BATTERIES

- Electronics' batteries have a collection challenge
- Electric vehicle batteries have a cost challenge

ARGONNE'S ReCell CLOSES THE LOOP

Quantitative model evaluates cost and environmental impact



THANK YOU



<https://access.anl.gov/>

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