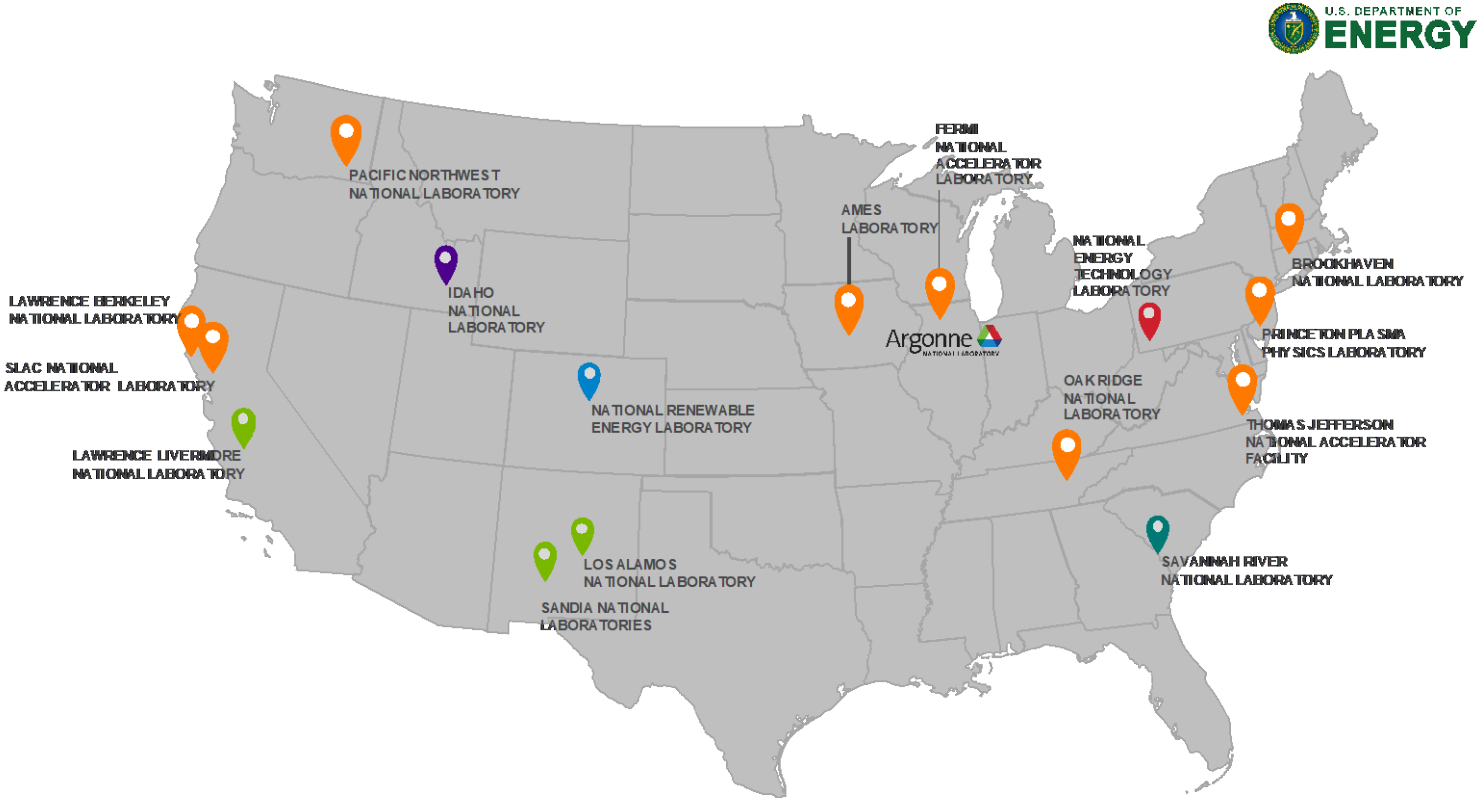
INTRODUCTION TO LITHIUM ION BATTERIES

JEFF SPANGENBERGER
Senior Engineering Specialist
jspangenberger@anl.gov

March 22nd, 2018

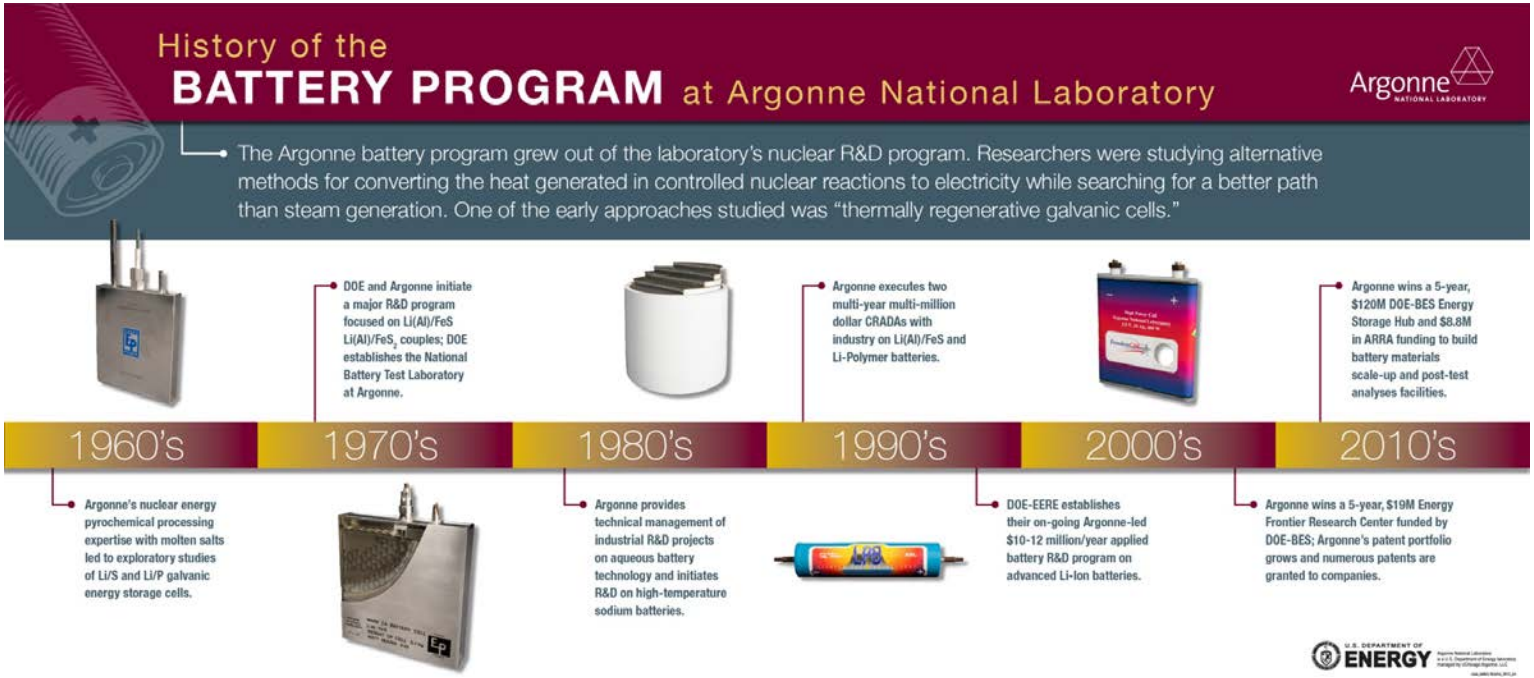
THE NATIONAL LAB SYSTEM



Argonne NATIONAL LABORATORY

KEY FACTS ABOUT ARGONNE

ANL BATTERY PROGRAM: 50 YEARS OF R&D



R&D focus:

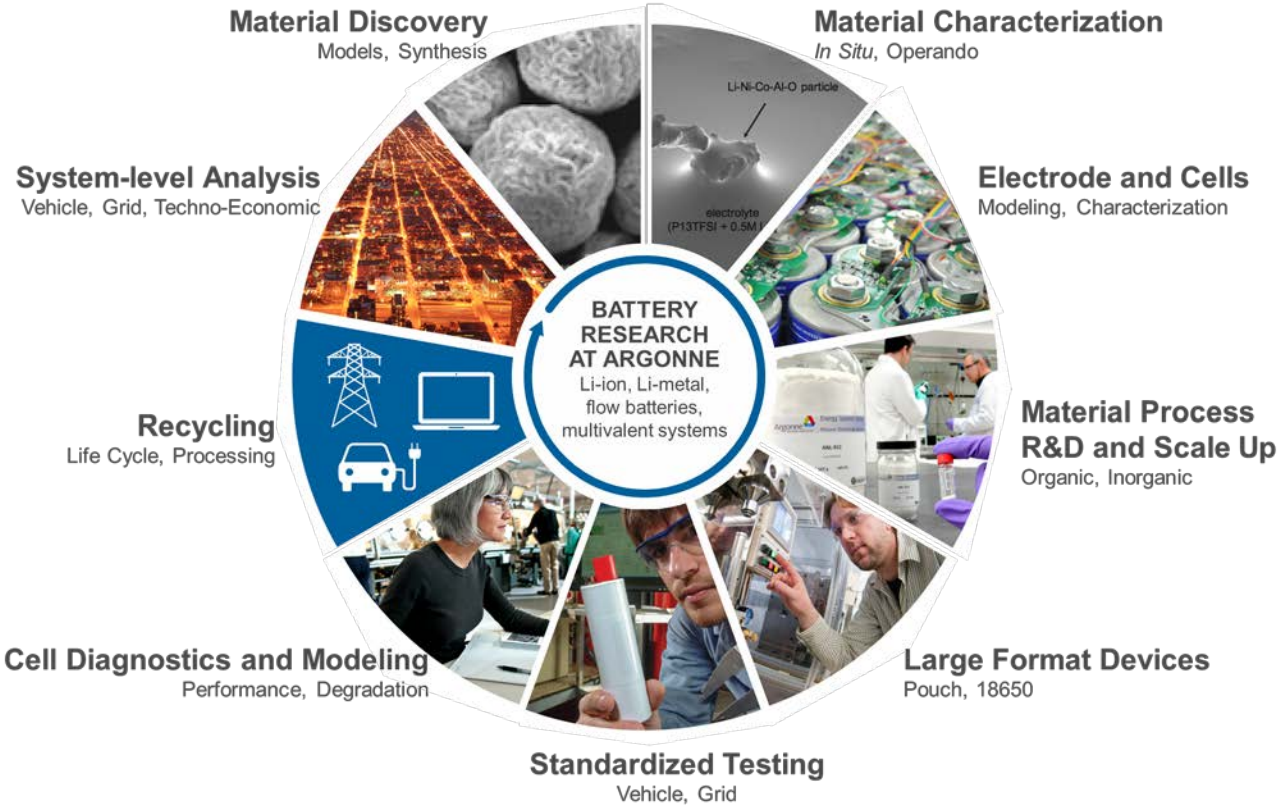
1964 - 1998: High/Moderate temperature Li batteries

1998: Room-temperature Li-ion batteries

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

Argonne NATIONAL LABORATORY

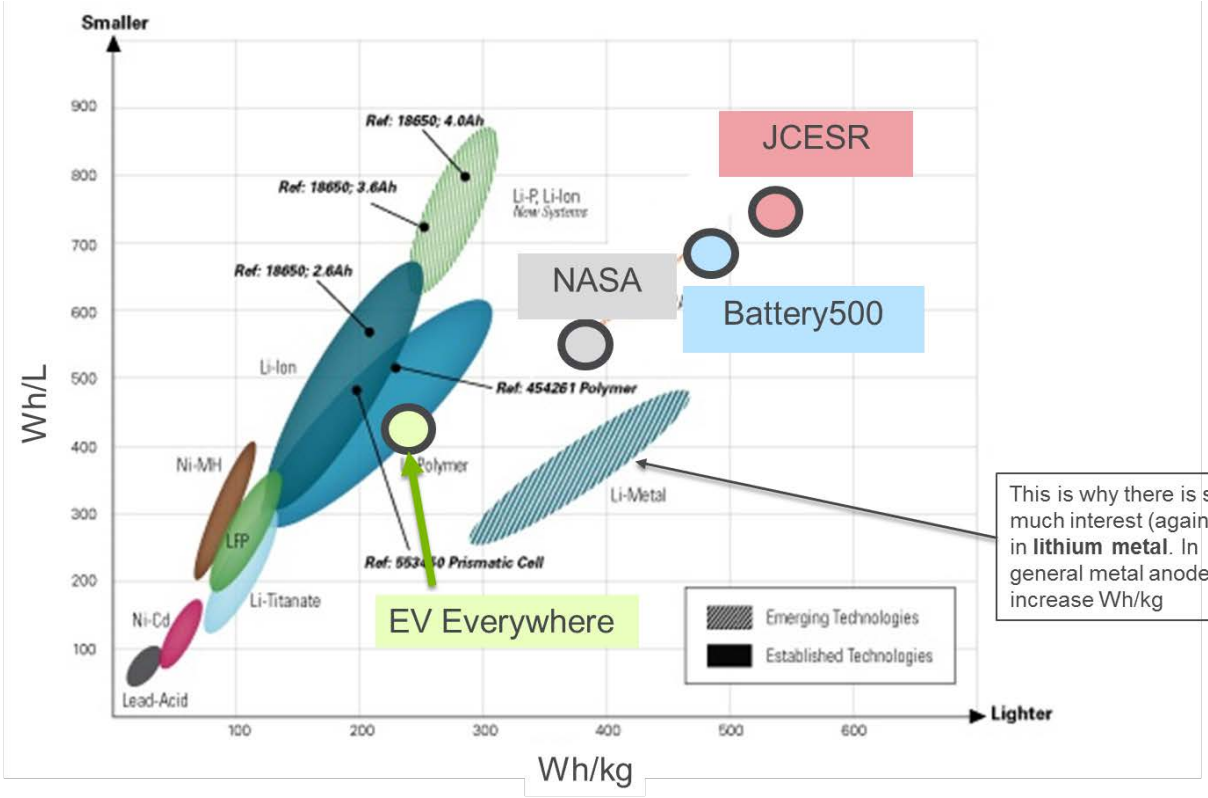
ANL BATTERY PROGRAM: ACROSS THE VALUE CHAIN



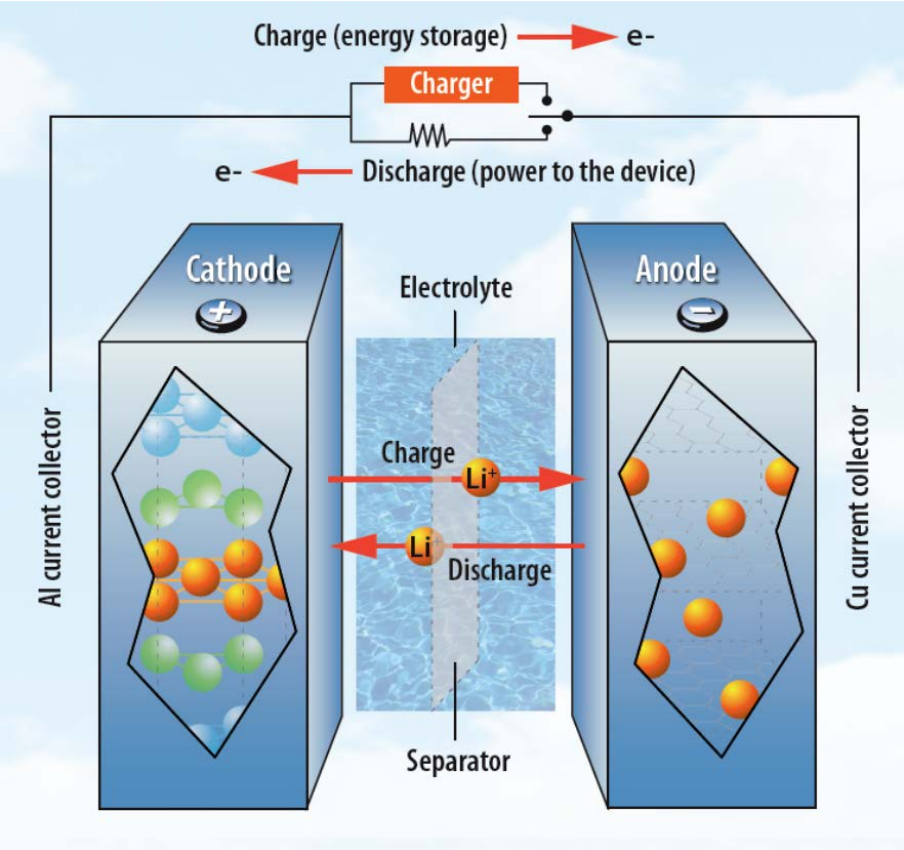
Argonne NATIONAL LABORATORY

COMPARISON OF OTHER CHEMISTRIES

Energy density has increased through time with different chemistries



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

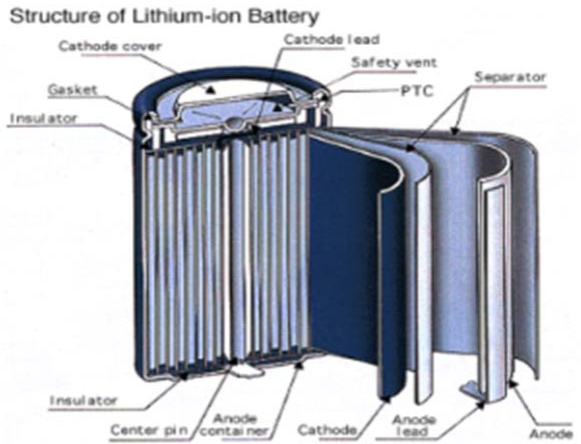
$LiCoO_2$ (LCO)

$Li(NiMnCo)O_2$ (NMC)

$Li(NiCoAl)O_2$ (NCA)

$LiFePO_4$ (LFP)

$LiMn_2O_4$ (LMO)

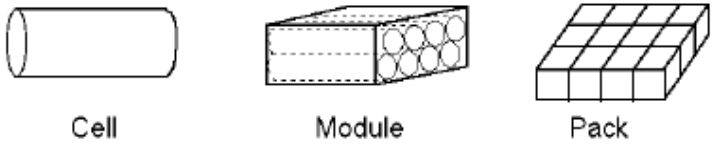


Anodes

Graphite

$Li_4Ti_5O_{12}$

Li_xSi_y



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

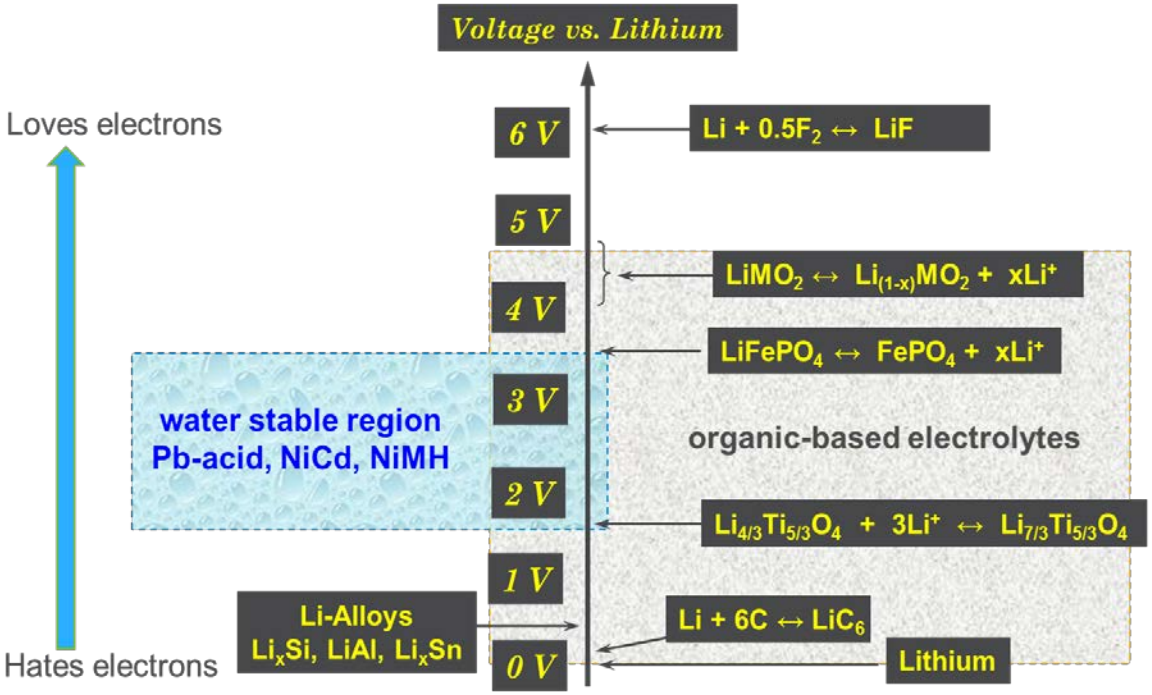
Chemistry	Nominal (V)	Charge (V) limit	Charge & Discharge C-rates	Energy Density Wh/kg	Applications	Note
Cobalt	3.60V	4.20V	1C limit	110-190	Cell Phone, cameras, laptops	Since 1990s, most commonly used for portable devices, has highest energy density.
Manganese (spiral)	3.7-3.80V	4.20V	10C cont. 40C 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

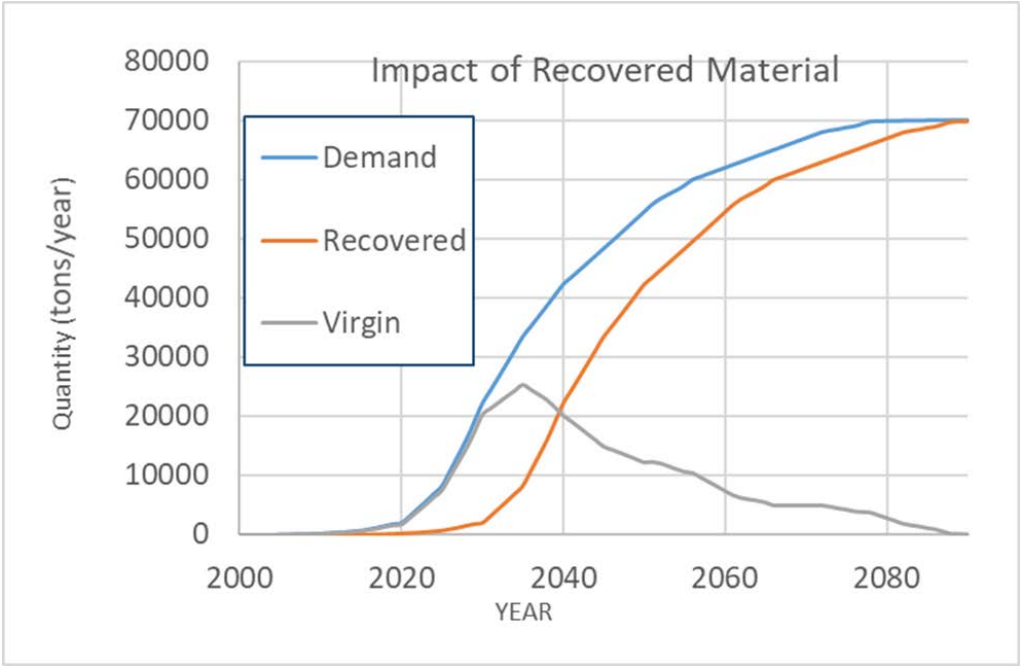
Considerations are being made to ban lead acid

- 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

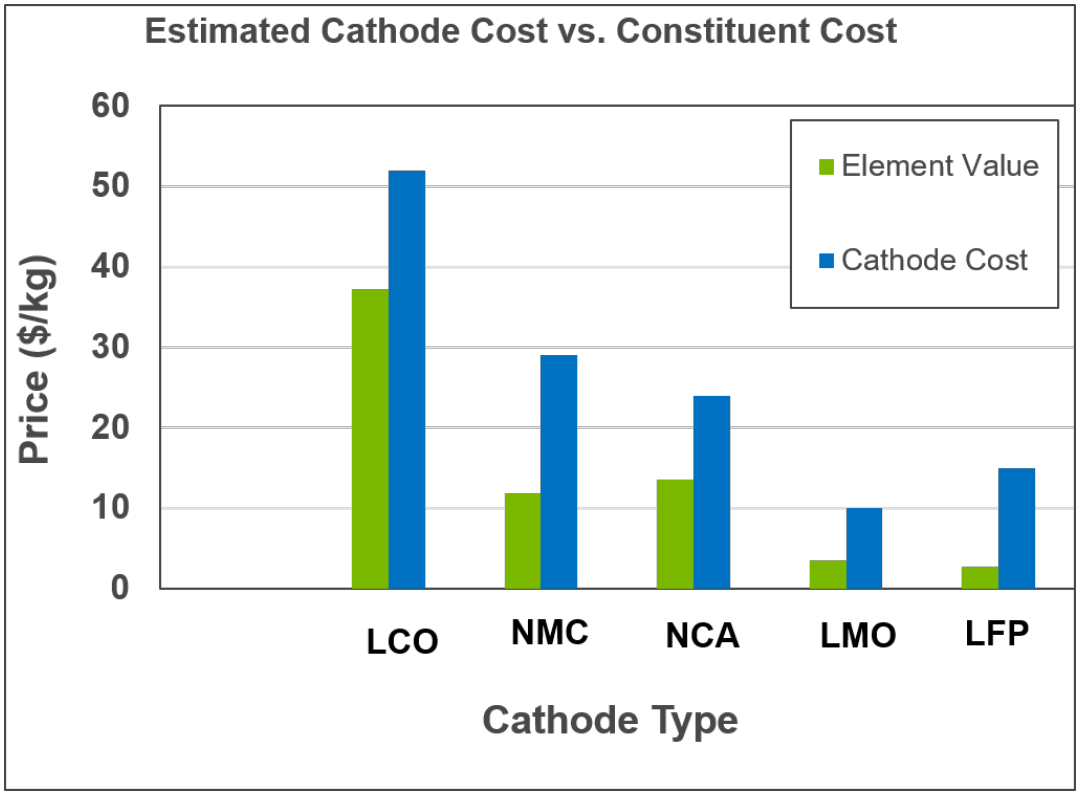
- Recycling batteries can minimize the use of our natural resources
- Long battery lifetime delays material return



RECYCLING TECHNOLOGY

	Pyrometallurgical	Hydrometallurgical	Direct
Temperature	High	Low	Low
Materials recovered	Co, Ni, Cu (**Li and Al to slag**)	Metals or salts, Li_2CO_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



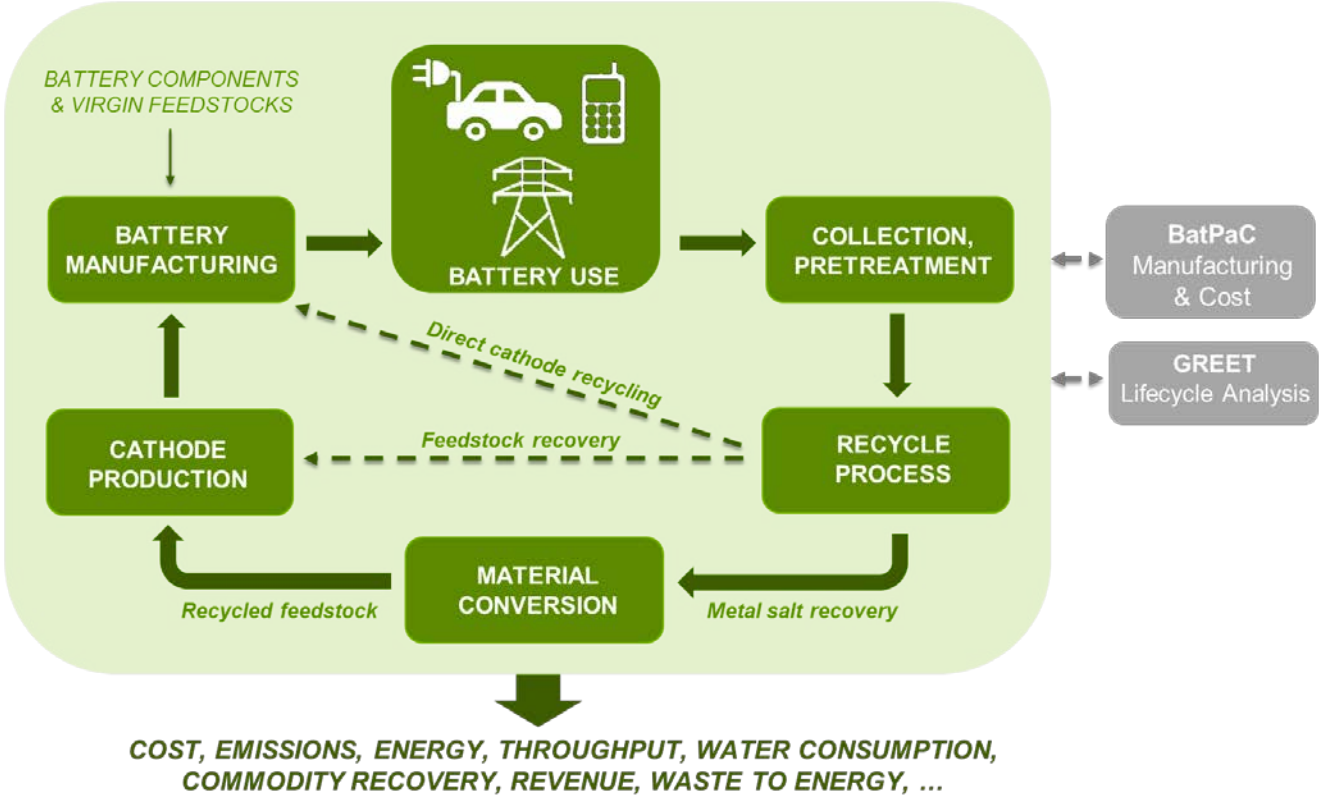
- The cathode is the most valuable
- Material value is cheap
- Cathode materials is expensive

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



Argonne NATIONAL LABORATORY

THANK YOU

ACCESS
Energy Storage at Argonne

https://access.anl.gov/

CONTRIBUTIONS FROM:

LINDA GAINES

ANDREW JANSEN

SUPPORT FROM DAVE HOWELL AND SAMM GILLARD; DOE-VTO