U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Lithium Ion Battery Recycling and Material Sustainability

Vehicle Technologies Office

David Howell

March 14, 2019

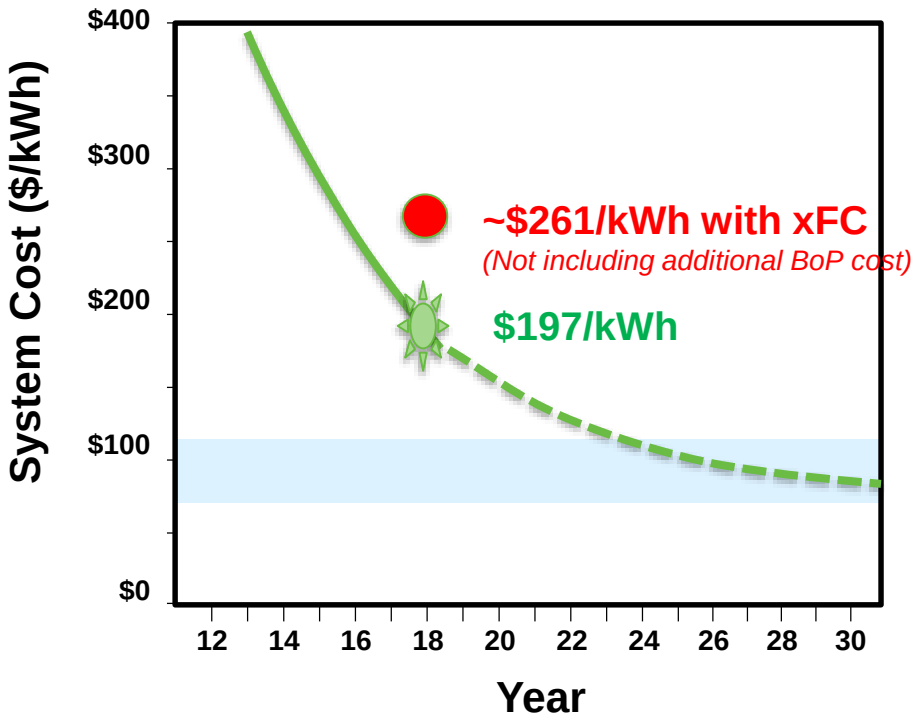
DOE Strategic Objective for Electric Vehicle Battery Storage

By September 30, 2022

- reduce the cost of EV battery packs to less than $150/kWh (Long term goal is $80/kWh)
- significantly reduce or eliminate the dependency on critical materials
- utilize recycled material feedstocks.

THREE MAJOR CHALLENGES

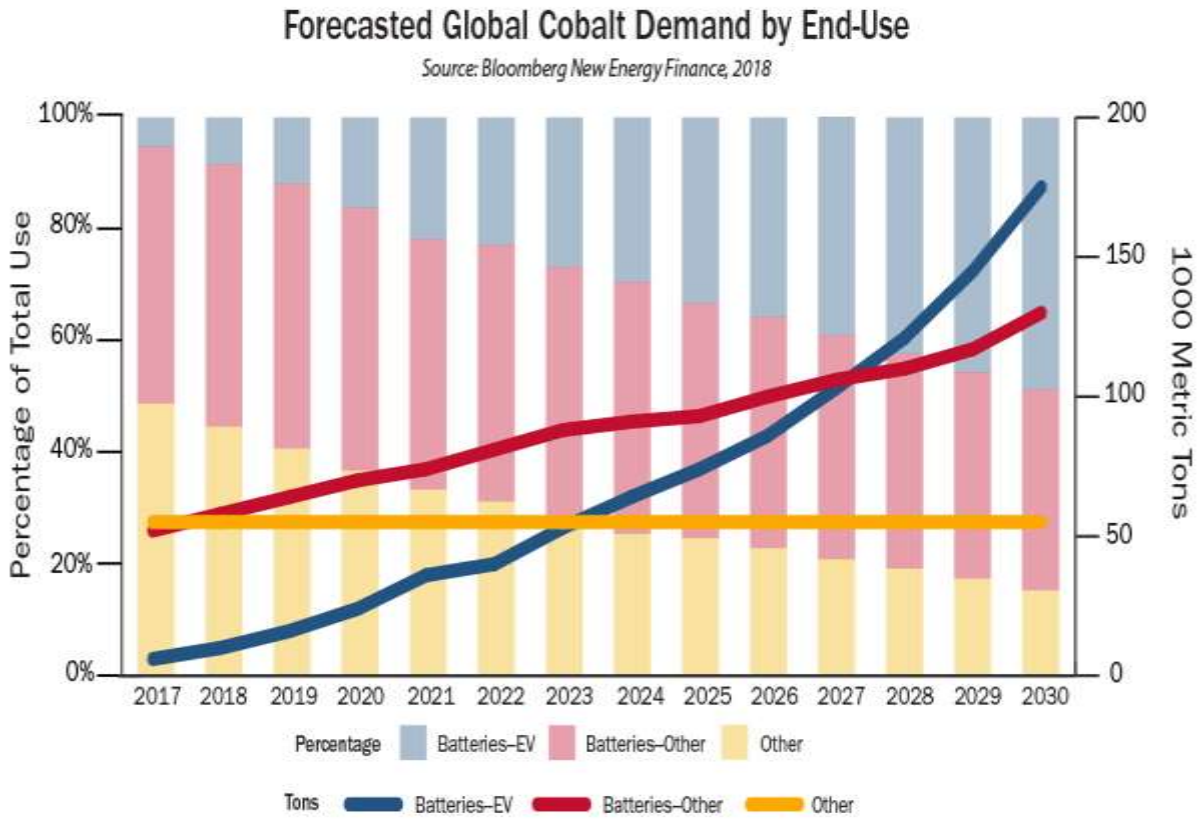
1. Further reduce battery costs (initial and life cycle)
2. Eliminate dependence on critical materials
3. Develop safe batteries that charge in <15 mins



Global Cobalt Demand Forecast

Cobalt is considered the highest material supply risk for EVs

Demand from EV market is projected to dominate as early as 2027



DOE VTO Critical Materials Research Plan for Batteries

NO COBALT/ LOW COBALT

Next-Generation Low-Cobalt Battery R&D

Early-stage research to develop low/no-cobalt materials for next-generation batteries

ReCell Lithium Battery Recycling R&D Center

Development of innovative, efficient recycling technologies for current and future battery chemistries

Enable Lower-Cost Lithium-ion Batteries

- Reduce critical materials
- Ensure materials supply chain

Battery Recycling Prize

Infrastructure development to enable efficient and affordable collection, storage, and transportation of spent batteries for eventual recycling*

AMERICAN MADE BATTERY RECYCLING PRIZE

U.S. DEPARTMENT OF ENERGY

Argonne NATIONAL LABORATORY

ReCell

NREL Transforming ENERGY

OAK RIDGE National Laboratory

Michigan Technological University

UC San Diego

WPI

* Funded by the U.S. Department of Energy Vehicle Technologies Office, within the Office of EERE, in collaboration with the Advanced Manufacturing Office, and administered by the National Renewable Energy Laboratory

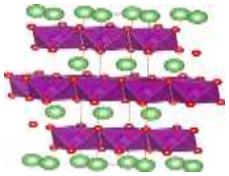
Potential Impact of Lo-No Cobalt Cathodes

Research focused on reduction or the elimination of cobalt within a LiB is essential for reducing the cost and assuring the sustainability of EVs.

Over $44M of R&D over Three Years

Reduced Cobalt

"substitution"

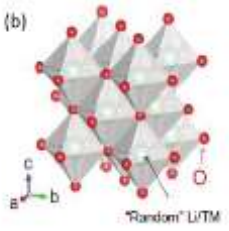


Argonne NATIONAL LABORATORY
NREL
OAK RIDGE National Laboratory
Pacific Northwest NATIONAL LABORATORY
BERKELEY LAB

CABOT
PENN STATE
UC IRVINE
THE UNIVERSITY OF TEXAS AT AUSTIN

No Cobalt

"new structure"



BERKELEY LAB
Pacific Northwest NATIONAL LABORATORY
UC Santa Barbara
OAK RIDGE National Laboratory

THE UNIVERSITY OF TEXAS AT AUSTIN
NEXTECH MATERIALS
UC San Diego
OAK RIDGE National Laboratory

Cobalt Content (kg) *per 100 kWh Battery Pack*	NMC622	19
	Lo-No CO target	< 5 or Zero

Current Recycling R&D

- **Farasis Recycling (USABC: 2018 - Present)**
  - Direct recycling of cathode material
  - Cell fabrication with mixed virgin and recycled material
  - Potential 60% cathode cost reduction compared to control

- **WPI Recycling (USABC: 2016 – Present)**
  - Hydrometallurgical separation with direct synthesis to NMC111 with mixed battery chemistries
  - Recovered 3kg NMC111 powder from 30kg of Volt batteries
  - Focus on Scale-up and recycling NMC622 cells

- **OnTo Technologies (SBIR: 2012-2016, VTO FOA Award 2018)**
  - Hydrometallurgical direct recycling process
  - Cathode achieved full capacity retention for 2500 cycles
  - 2018: Process controls for deactivating and transporting spent batteries

Lithium Ion Battery Recycling R&D Center

MISSION

- Decrease the cost of recycling lithium ion batteries
- Recover critical materials and high value materials
- Develop cost effective methods to reintroduce recovered materials into the battery material supply stream

Argonne NATIONAL LABORATORY

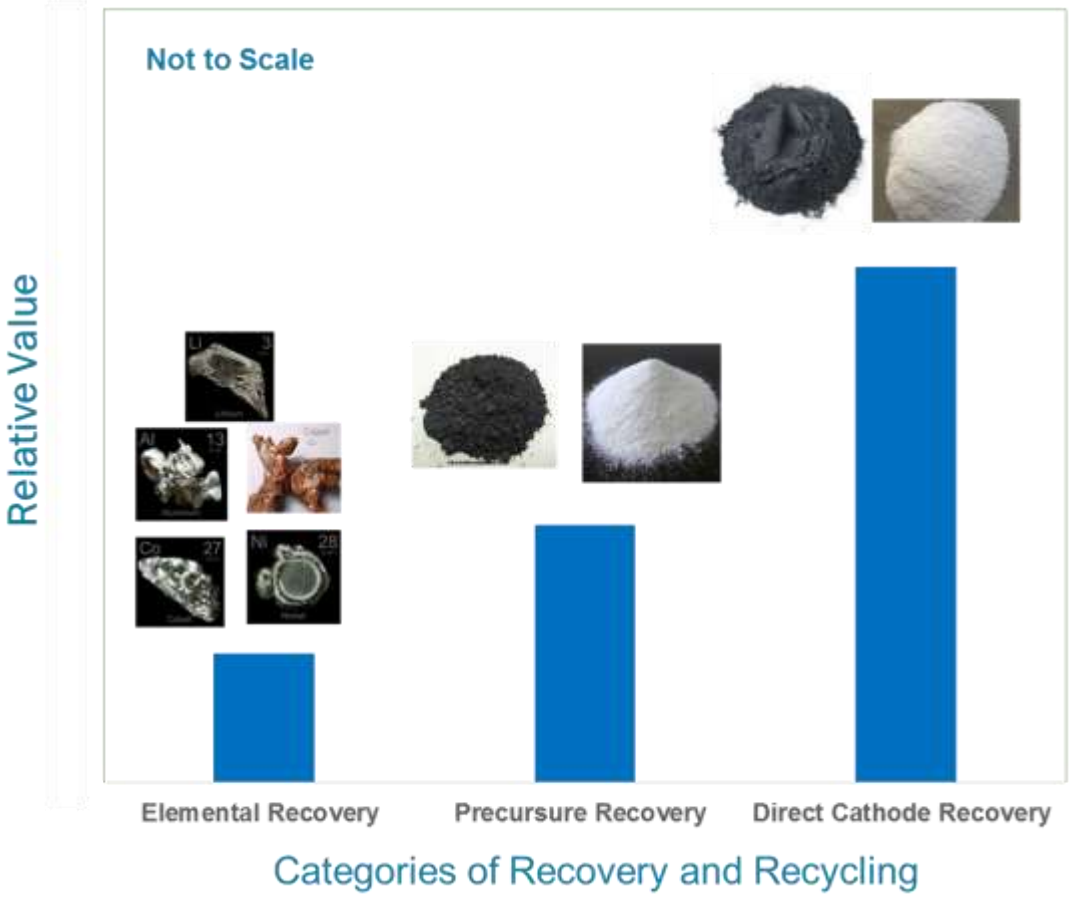
NREL

OAK RIDGE National Laboratory

Michigan Technological University

UC San Diego

WPI



“Battery Recycling Prize”

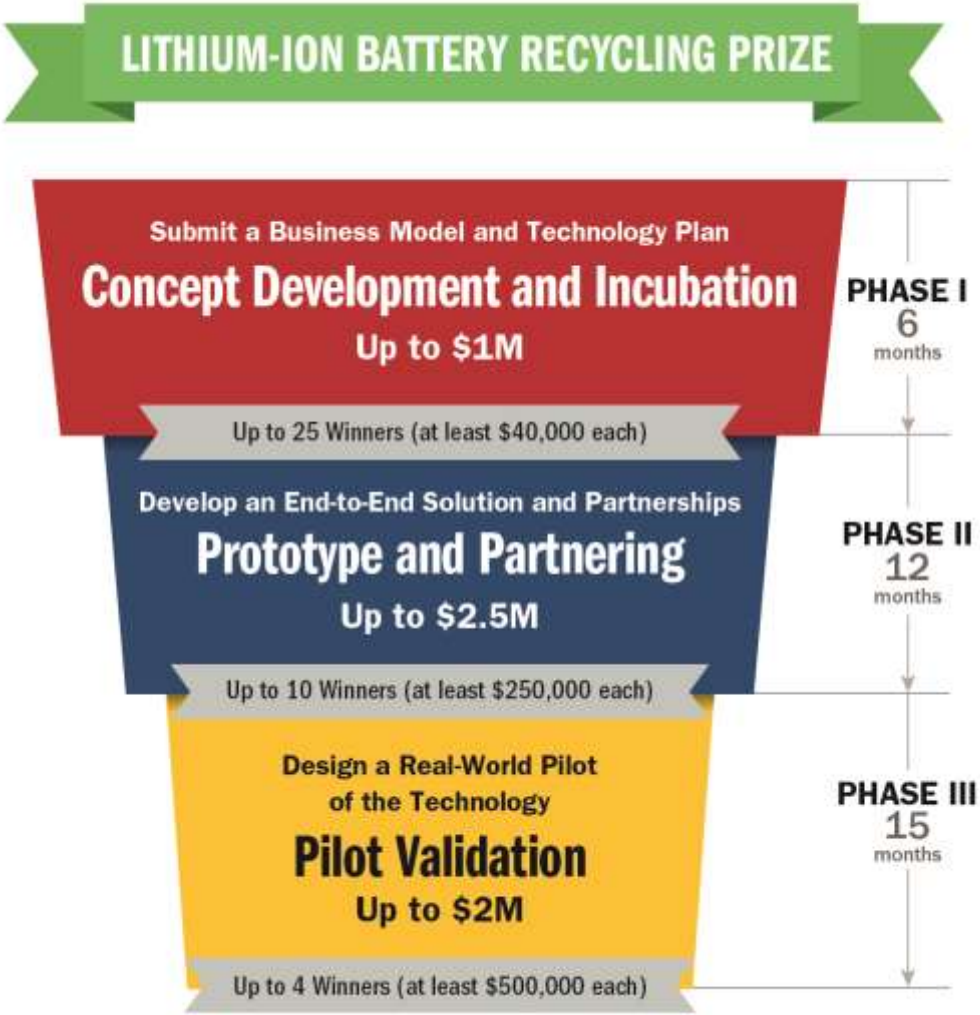
Innovative Business Models for Collection, Storing, and Transporting Discarded Li-Ion Batteries

PRIZE GOAL

Demonstrate a process that, has the potential to capture 90% of ALL lithium based battery technology in the U.S. when scaled.

Covers consumer electronics, stationary, and transportation applications.

The best entry will be based on the feasibility of the collection and storage process, cost to implement, and potential impact!



Thank You