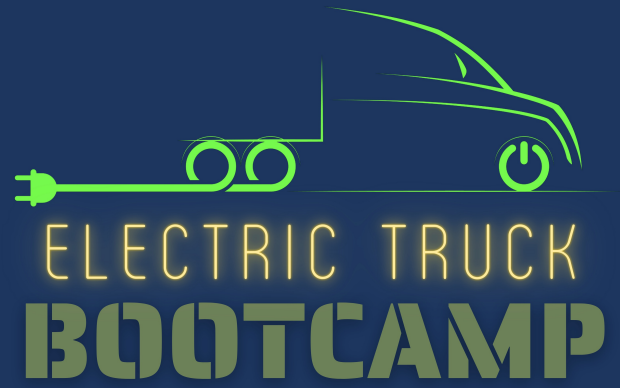
# Sustainable Supply Chains & End of Life

July 27, 2021

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NACFE NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY IN PARTNERSHIP WITH RMI ENERGY. TRANSFORMED.


# More info at www.runonless.com

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Join us for the 10th anniversary of the leading clean transportation event!

**August 30 to September 2, 2021**

Bootcamp Attendees Discount Code: **BOOTCAMP50**

Register at www.actexpo.com/register

# Electric Truck Bootcamp

- 4/20 – What's Driving e-Trucks
- 5/5 – Charging Planning & Buildout
- 5/18 – Charging Power Management
- 6/1 – Working with Your Utility
- 6/15 – Incentives for Electrification
- 6/29 – Maintenance, Training, Safety
- 7/13 – Financing the Transition
- **7/27 – Sustainable Value Chains**
- 8/10 – Global Perspectives
- 8/24 – Driver Behavior & Experience

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# Bootcamp Updates

# Before we get started:

## Q&A

Submit your questions to the host using the Q&A box in the upper right-hand corner.

## Presentations

A recording of today's webinar will be available on the ACT News website, and you will be emailed a link by early next week.

## Survey

There will be a 30-second survey shown at the end. We appreciate your feedback!

## Technical Issues

Contact Benjamin Chan at:
**stephane.babcock@gladstein.org**
or call 424-363-0341 for assistance.

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# Cradle-to-Grave Sustainability Considerations for Electric Trucks

Sustainable Supply Chains

Battery Recycling

Pollution

Ethical Mining Practices

Battery Second Life

Battery Life

Supply Chain Transparency

Vehicle Life

Corruption

Human Rights

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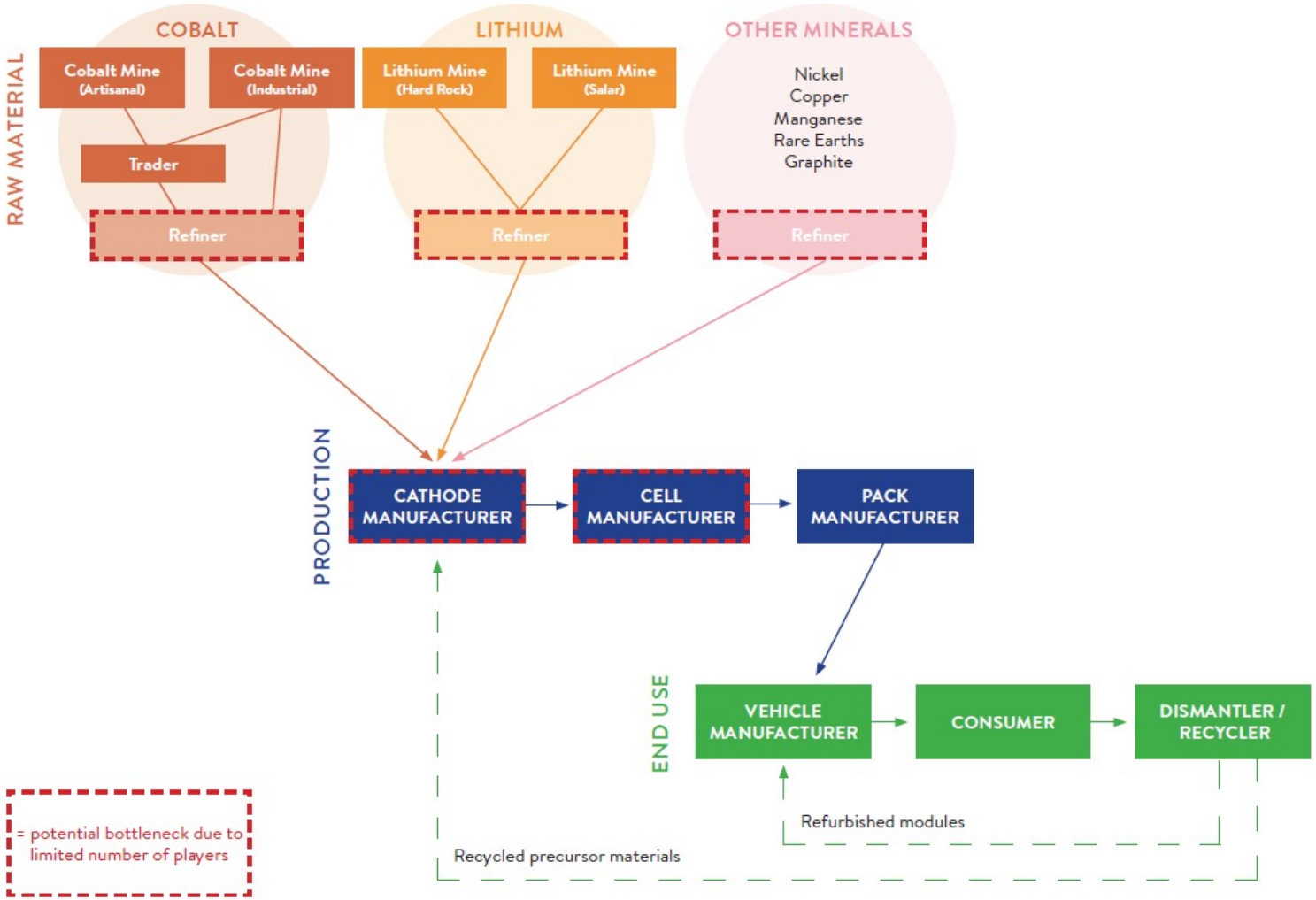
# Battery Supply Chain




Source: CLEE & NRGI

# DOE Lithium-Ion Battery Recycling Prize

## PHASE II
## Prototype and Partnering
## WINNERS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# Lithion Recycling Won the 2nd Annual Commercial Vehicle Cleantech Challenge

Commercial Vehicle Cleantech Challenge

A Product Innovation Showcase


Lithion

Lithium-ion battery recycling

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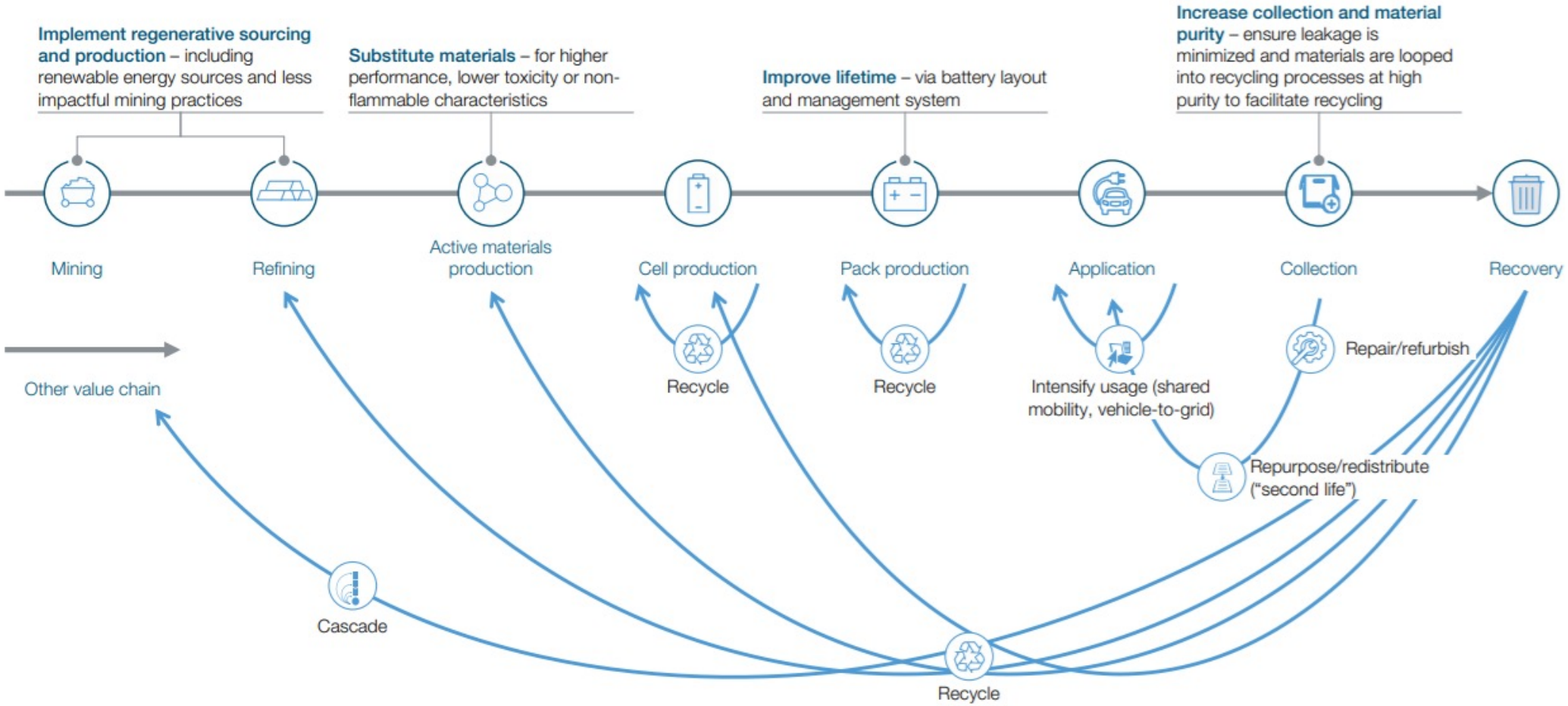
# Although myths persist, research shows:

- Electric trucks are **much cleaner** than internal combustion engine trucks **over their lifetime**.
- **Battery manufacturing** life-cycle emissions debt is **quickly paid off** (typically in <2 years).
- **Grid decarbonization** offers a **significant opportunity** to reduce the impact of battery manufacturing.

Source: ICCT

# Circular Economy Levers for Batteries




Source: World Economic Forum, Global Battery Alliance; McKinsey and SYSTEMIQ analysis

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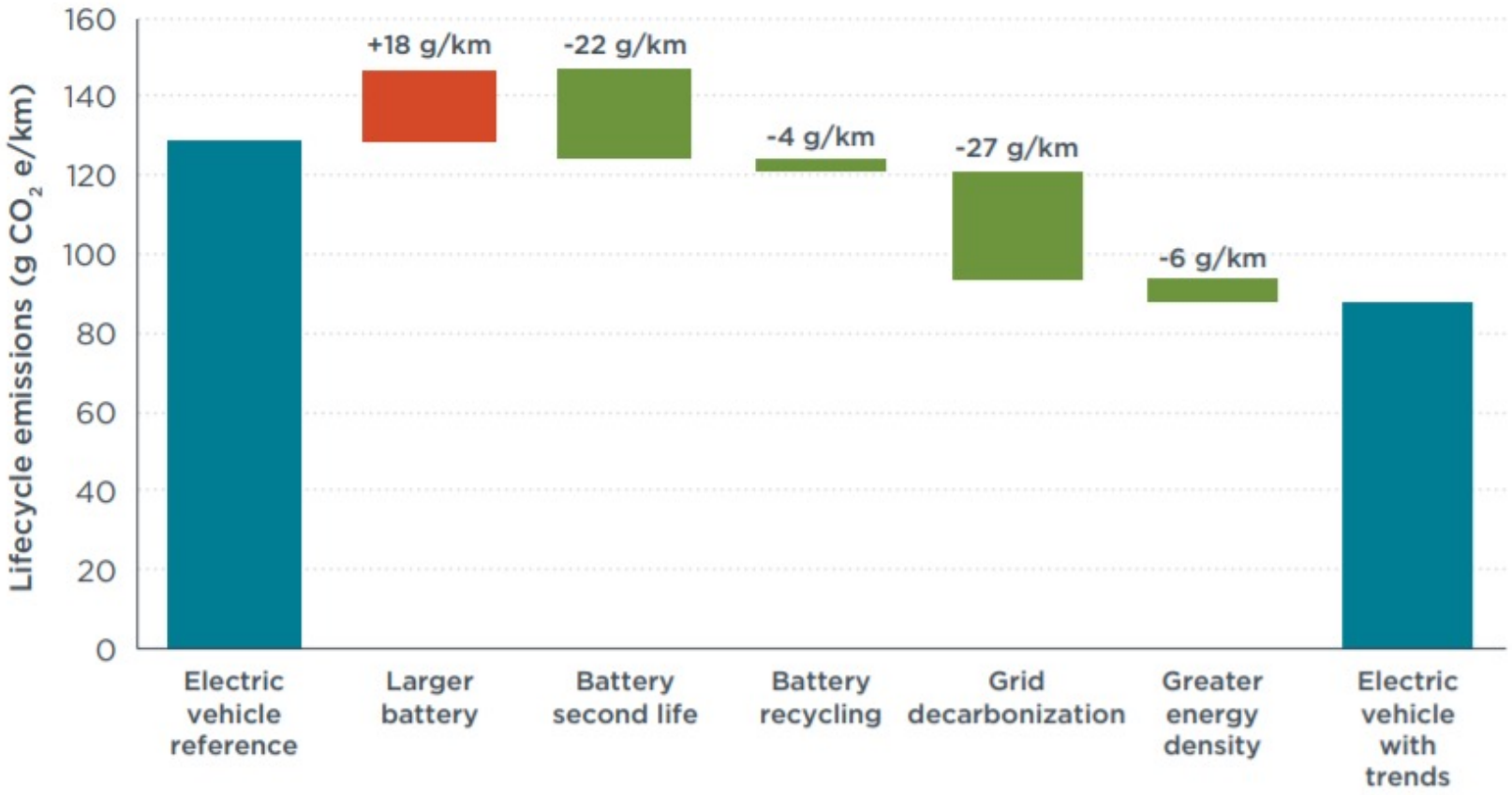
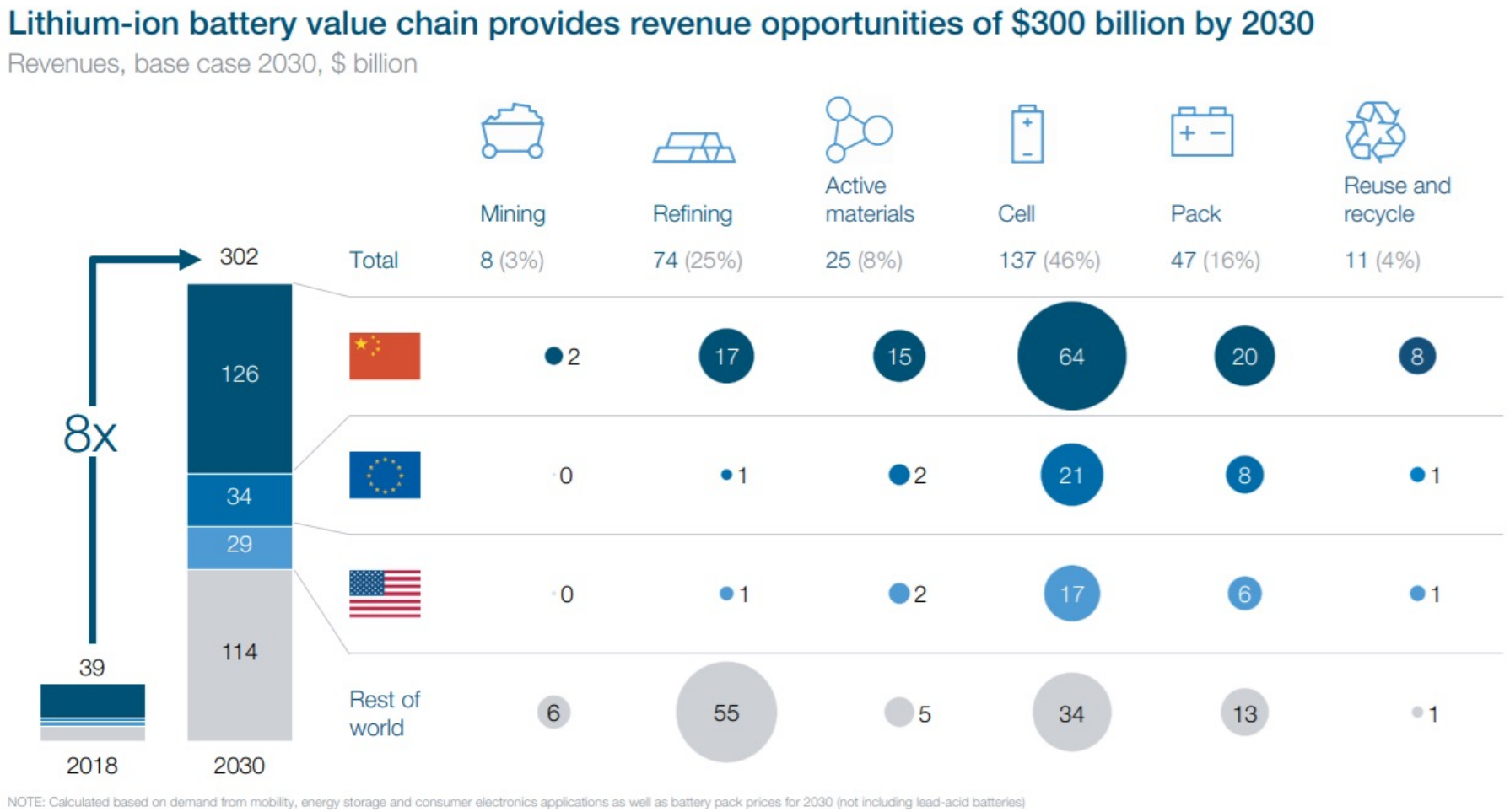
# Battery Trends' Combined Impact on Overall EV Life-Cycle Emissions




Source: ICCT

# Battery Value Chain Opportunities




Source: World Economic Forum, Global Battery Alliance; McKinsey analysis

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# Sustainable supply chains are about more than just batteries.

## DTNA Says Portland Plant Will Be First to Achieve Carbon-Neutral Production

*DTNA's truck manufacturing plant in Portland, Ore. The plant reduced its energy consumption from vehicle manufacturing with equipment replacement and facility upgrades. (Daimler Trucks North America)*

Sustainable Business

## Volvo, SSAB plan first fossil-free steel trucks on road to carbon neutrality

Department of Energy

## DOE Announces $162 Million to Decarbonize Cars and Trucks

APRIL 15, 2021

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*Senior Vehicles Analyst*
Union of Concerned Scientists

**Kunal Phalpher**
*Chief Commercial Officer*
Li-Cycle

**Jeff Spangenberger**
*Materials Recycling Group Lead,*
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*Jimmy O'Dea, Ph.D.*
*Senior Vehicles Analyst*

@jimmyodea

*Hanjiro Ambrose, Ph.D.*
*Hitz Family Climate Fellow*

Union of Concerned Scientists

FACT SHEET

# Electric Vehicle Batteries

## *Addressing Questions about Critical Materials and Recycling*

**HIGHLIGHTS**

*Electric vehicles are critical to reducing transportation pollution and solving the climate crisis, but manufacturing them at the necessary scale will require significantly increasing production of the batteries that power them. How batteries are made, what they are made of, and whether they are reused or recycled affect the sustainability of this crucial component. Even though batteries last many years, they eventually reach the end of their useful life for powering electric vehicles. Policies and incentives for recycling and reusing batteries, including strong health and labor standards, will further lessen the impacts of electric vehicles.*

Battery electric vehicles (BEVs) are a key strategy for reducing air pollution and global warming emissions. They have zero tailpipe emissions, and even when powered by today's sources of electricity, their life cycle global warming emissions are significantly lower than those for vehicles fueled with gasoline or diesel (O'Dea 2019; Reichmuth 2020). However, the increased adoption of BEVs raises important questions about the availability, recyclability, and sustainability of battery materials.

Scaling up BEV manufacturing will mean increasing the production and processing of several materials used in today's lithium-ion batteries. Fortunately, strategies for recycling lithium-ion batteries offer the possibility of a sustainable, long-term supply of such materials, supporting the continued deployment of electric vehicles (EVs). However, implementing those strategies will require addressing a number of technical, economic, logistic, and regulatory barriers.

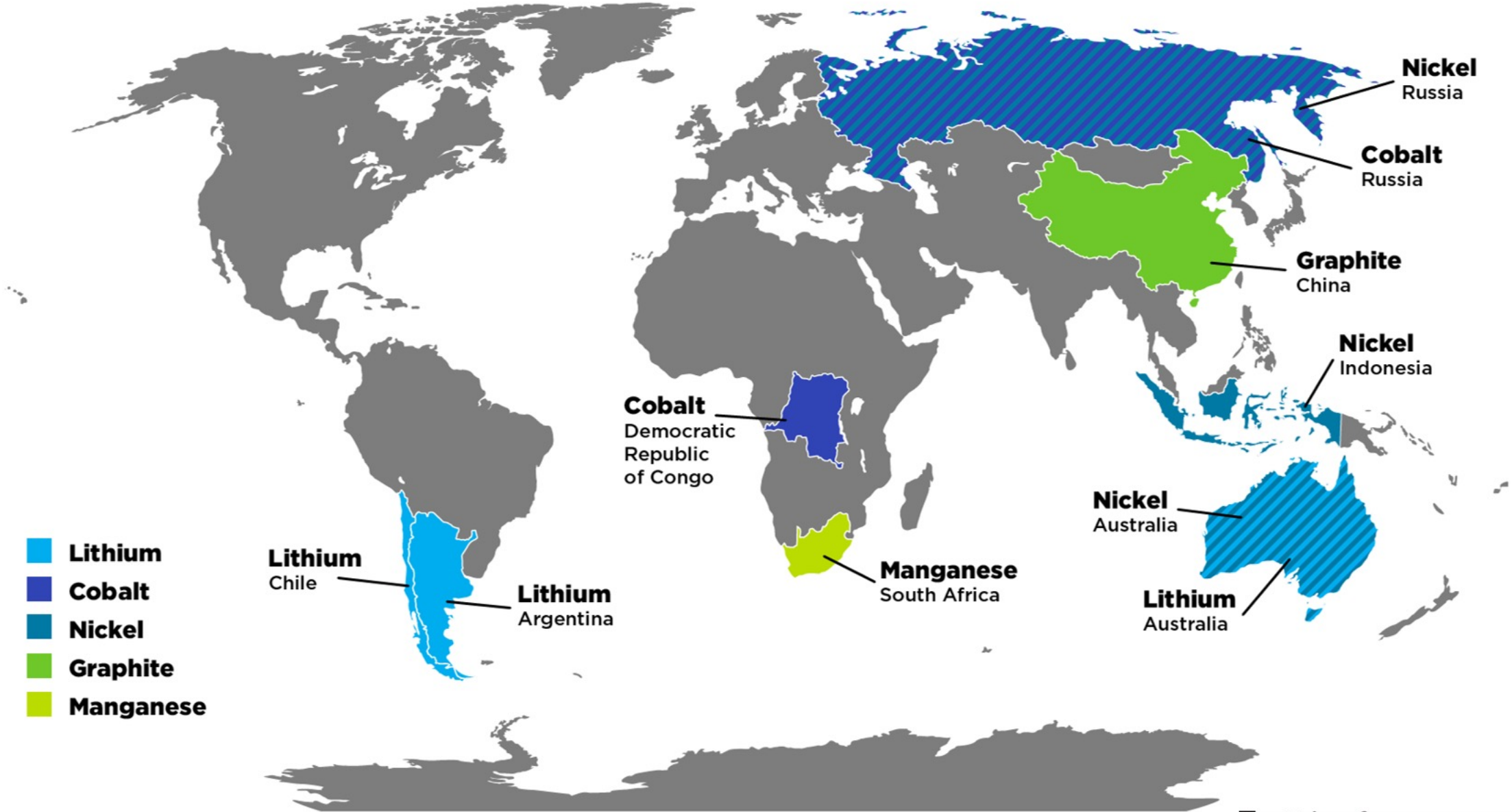
Courtesy of Li-Cycle

*Recycling the cobalt, lithium, and other critical materials in electric vehicle batteries will help meet increased demand for materials as vehicle sales grow in future years and reduce the need to mine new materials. Recycling facilities are currently few and far between—Li-Cycle (shown above) is one of just 10 or so in the world operating today—underscoring the need for policies to help promote increased recycling.*

***ucsusa.org/resources/ev-battery-recycling***

Union of Concerned Scientists

# Complex supply/manufacturing, e.g. mineral reserves

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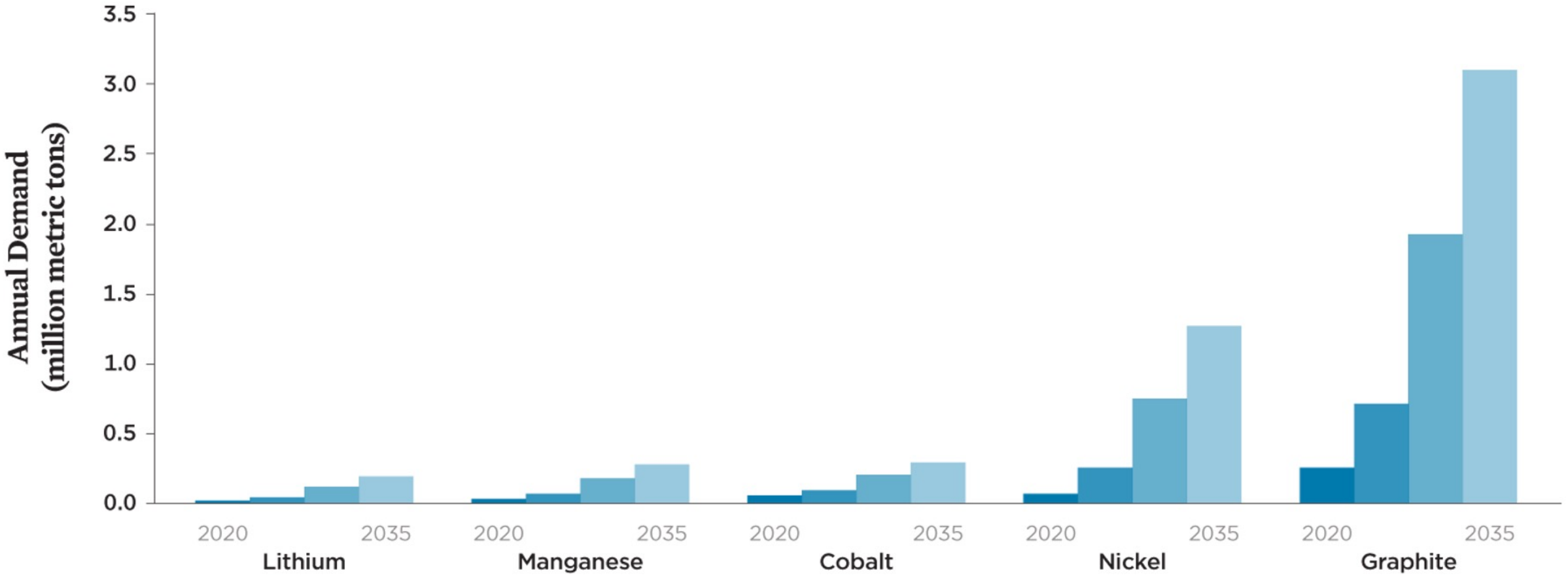
# Demand for battery materials will increase

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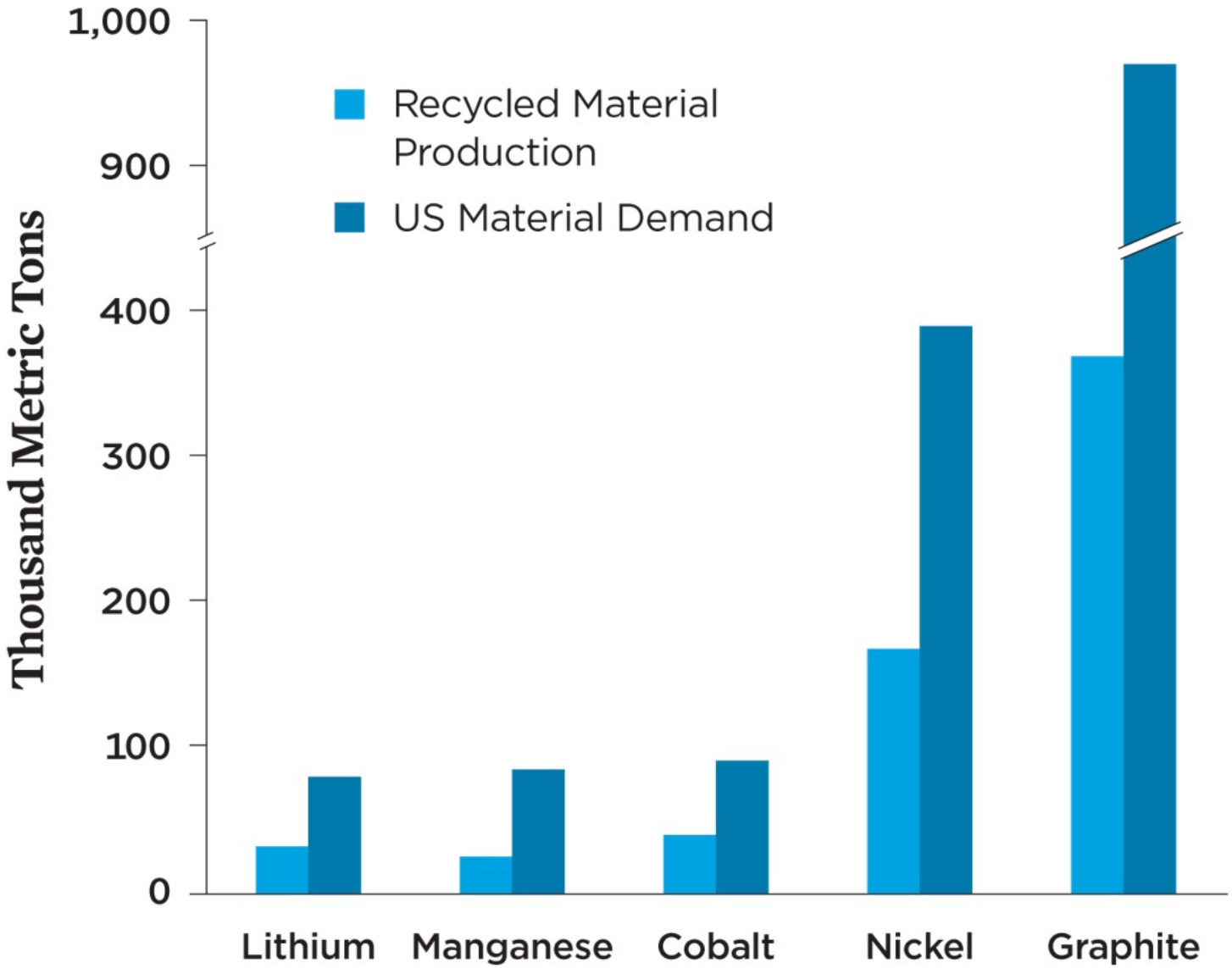
# Recycling can meet a measurable amount of demand




**…e.g., 30% of US demand in 2035**

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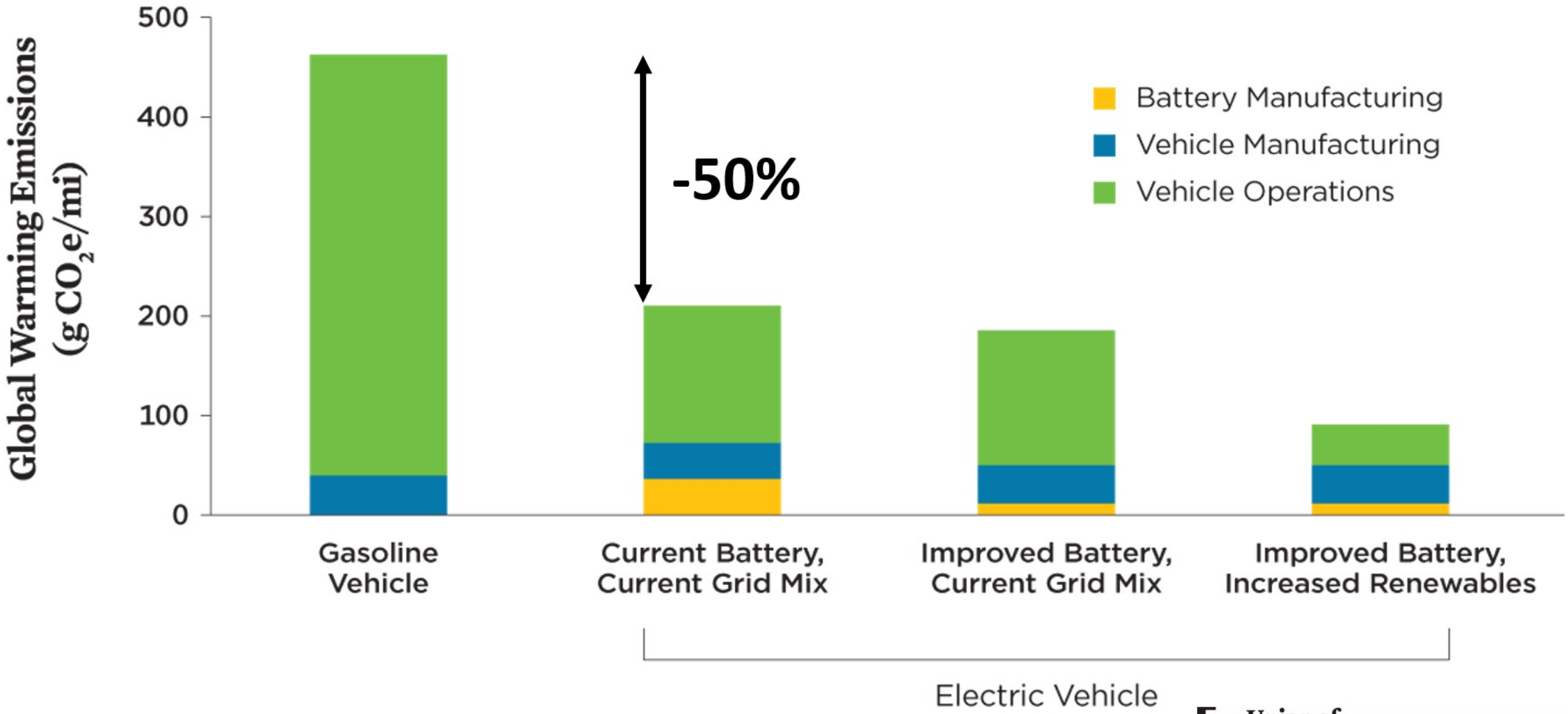
# EVs have lower GHG emissions, even w/battery manufacturing




Union of Concerned Scientists

# Need policies to achieve sustainable batteries

Local impacts

Battery chemistry

Collection

Disassembly

Transportation

Economics

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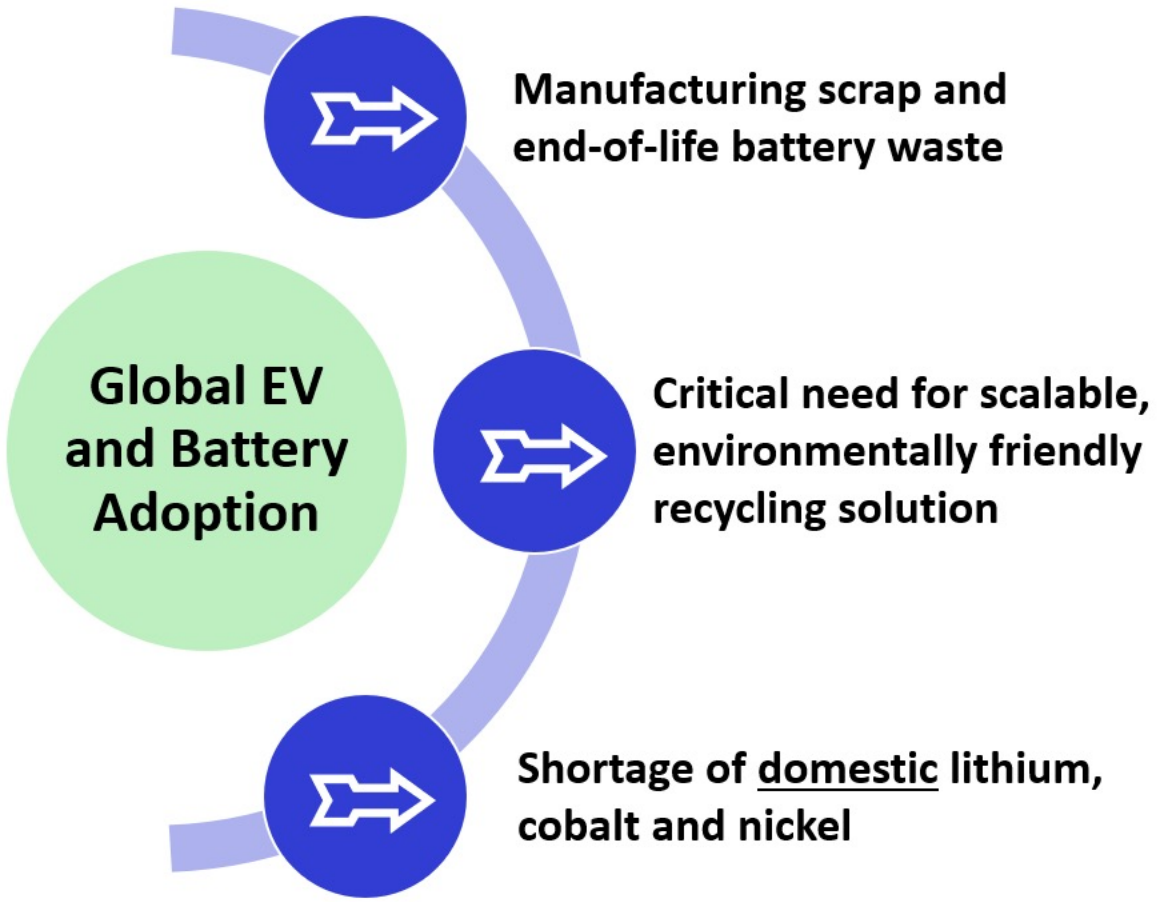
# Sustainable Supply Chains & End of Life

July 27th, 2021

NACFE Electric Bootcamp

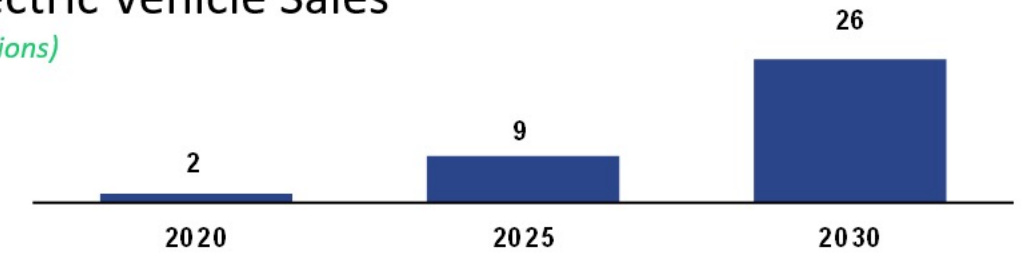
# RECYCLING IMPERATIVE WITH MASSIVE ELECTRIFICATION RAMP




Source: Benchmark Mineral Intelligence, BloombergNEF Electric Vehicle Outlook 2020.

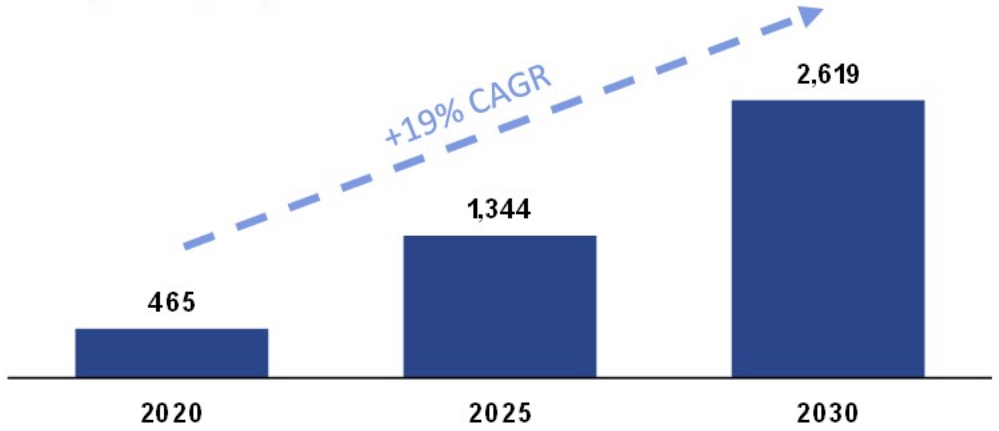
## Electric Vehicle Sales

*(millions)*




## Lithium-Ion Batteries for Recycling

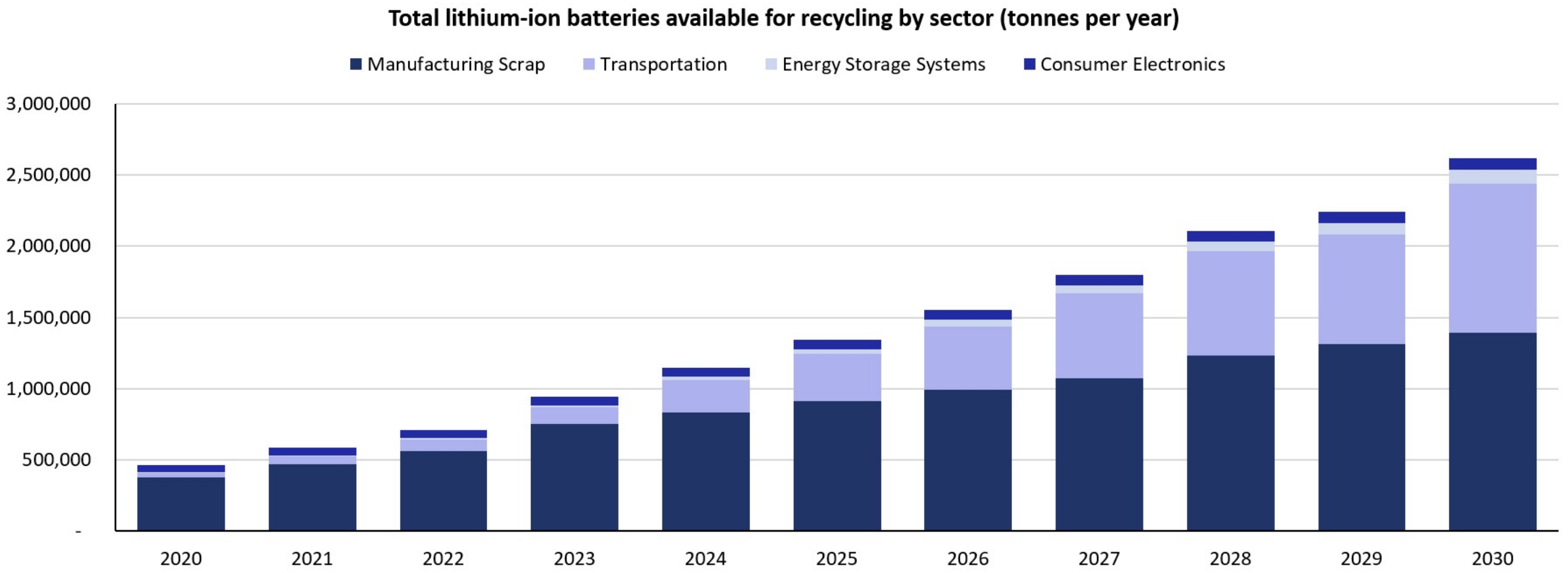
*(Thousands of tonnes/year)*



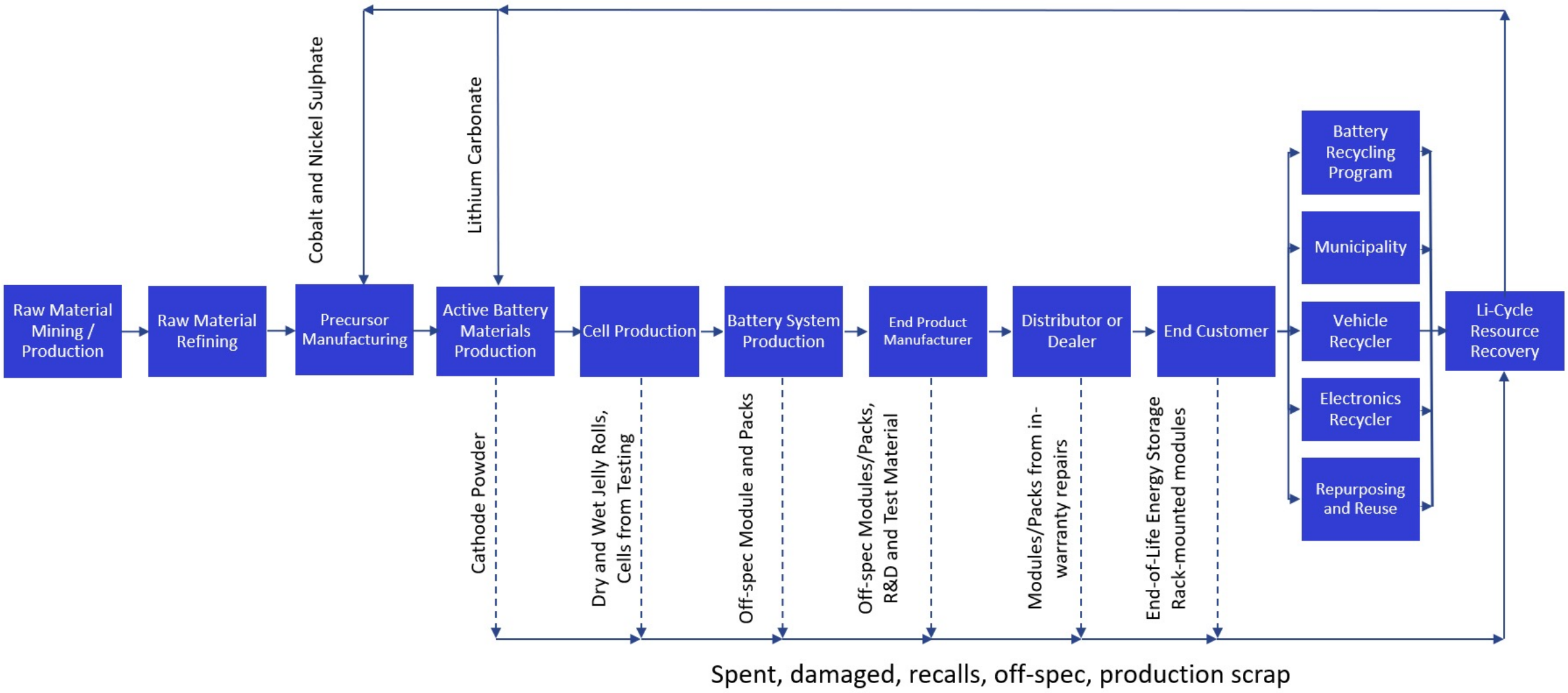

**5% - 10% of battery production is typically rejected as waste during the manufacturing process, creating significant recycling needs during EV ramp-up, in addition to building end-of-lifecycle supply**

# EXPONENTIAL LI-ION BATTERY DEMAND GROWTH

## The global lithium-ion battery recycling industry could have >2.5 million tonnes available for recycling by 2030



# RECYCLING IN THE LITHIUM-ION SUPPLY CHAIN



# RECYCLING SUPPLY CHAIN: INCUMBENT PROCESS

## Incumbent recycling chain/processes

*Disaggregated, inefficient, low recoveries, waste-oriented*

***≤50% recovery rate***

Batteries received, discharged, dismantled heavily, potentially shredded

High temperature processing, calcining / roasted, burning off electrolyte, plastics, and other volatile components

Smelter – electric furnace process, processes black mass from the preceding step

Traditional hydromet refinery; processes the matte containing Ni, Co, Cu from the electric furnace; produces Ni, Co, Cu metal

Re-dissolve metals to produce Co & Ni chemicals (sulphates) that can be utilized by typical cathode precursor manufacturers

## What's being lost:

| | | | | |
|---|---|---|---|---|
| *Possibly the electrolyte; partially the plastics* | *Electrolyte lost; fluorine emitted; potentially plastics; potentially graphite* | *Lithium goes into slag (uneconomic to recover thereafter); graphite, aluminum, and other light components – all directed to the slag and off-gas* | *Losing any residual manganese and other minor components in the matte from the smelter* | *N/A* |

# RECYCLING SUPPLY CHAIN: LI-CYCLE

## Li-Cycle process overview

*Streamlined, efficient, high recoveries*

***Up to 95% recovery rate***

### Spoke

Batteries received; no sorting, no discharge, minimal dismantling; automated process; mechanical only, no thermal, shredded

### Hub

Directly treat hydrometallurgically to recover battery grade chemicals inclusive of lithium; no thermal processing or loss of components

*All materials and end-products redirected to the lithium-ion battery supply chain and broader economy*


Li-Cycle®

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*Senior Vehicles Analyst*
Union of Concerned Scientists

**Kunal Phalpher**
*Chief Commercial Officer*
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(Electric Truck Bootcamp)

ReCell
ADVANCED BATTERY RECYCLING

# THE RECELL CENTER:

## MAKING LITHIUM-ION BATTERY RECYCLING PROFITABLE

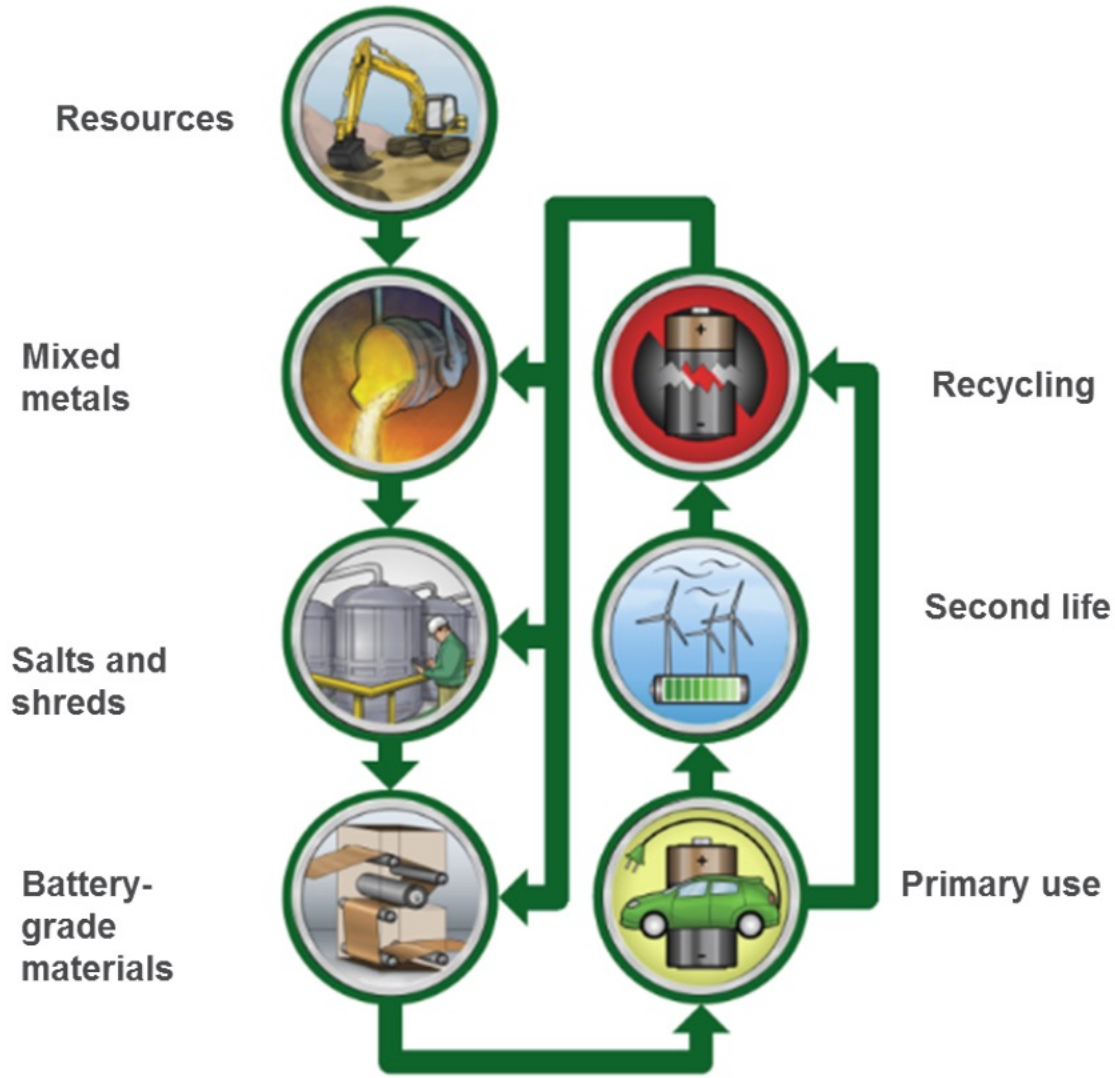
**Jeff Spangenberger**
Argonne National Laboratory
Director, ReCell Center
Materials Recycling R&D Program Lead

July 27, 2021

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

# CURRENT PROCESSING

- Recycling lithium-ion batteries is possible today
- These processes are mature
- Produce lower value products and are not revenue positive without tipping fees for many chemistries
- The U.S. is trailing other countries in battery recycling




Courtesy Argonne

# THE RECELL CENTER

Argonne NATIONAL LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

OAK RIDGE National Laboratory

UC San Diego

WPI

Michigan Technological University 1885

## Purpose

- Foster the development of cost-effective, environmentally sound processes to recycle lithium-ion batteries
- Bring together experts from various 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 in about 10 years (currently $185/kWh)

ReCell ADVANCED BATTERY RECYCLING

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# THE RECELL CENTER'S FOCUS AREAS

## The ReCell Center is a collaboration of three National Laboratories and three Universities

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

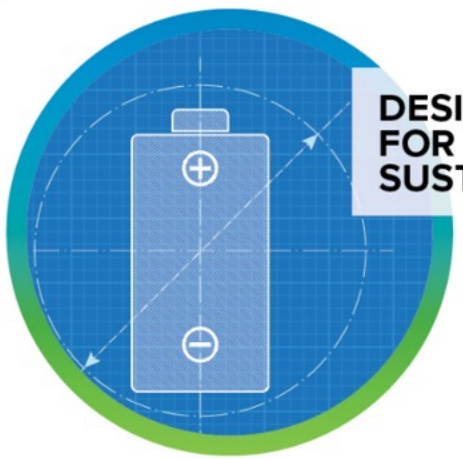
**DIRECT CATHODE RECYCLING**

**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)

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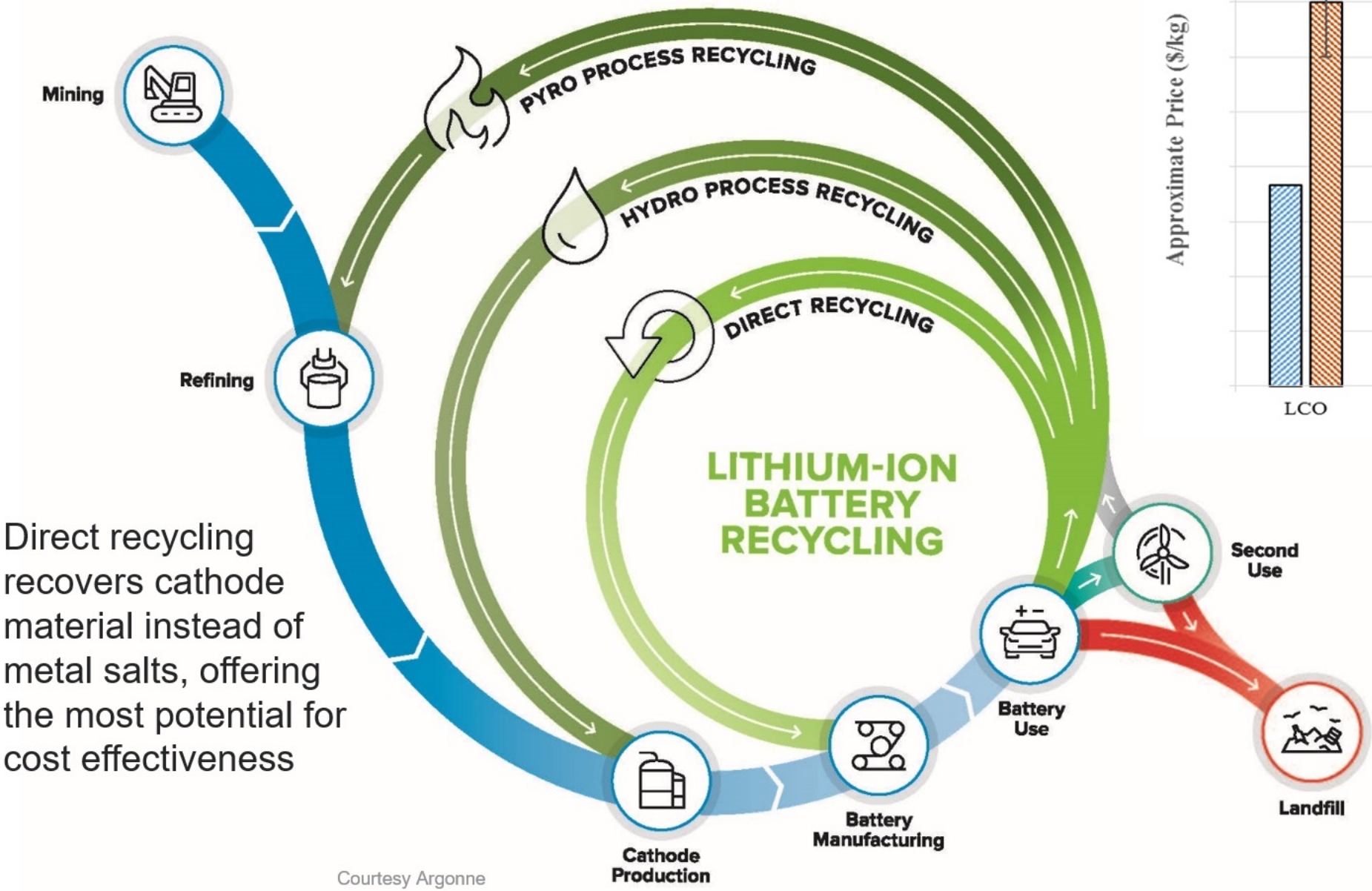
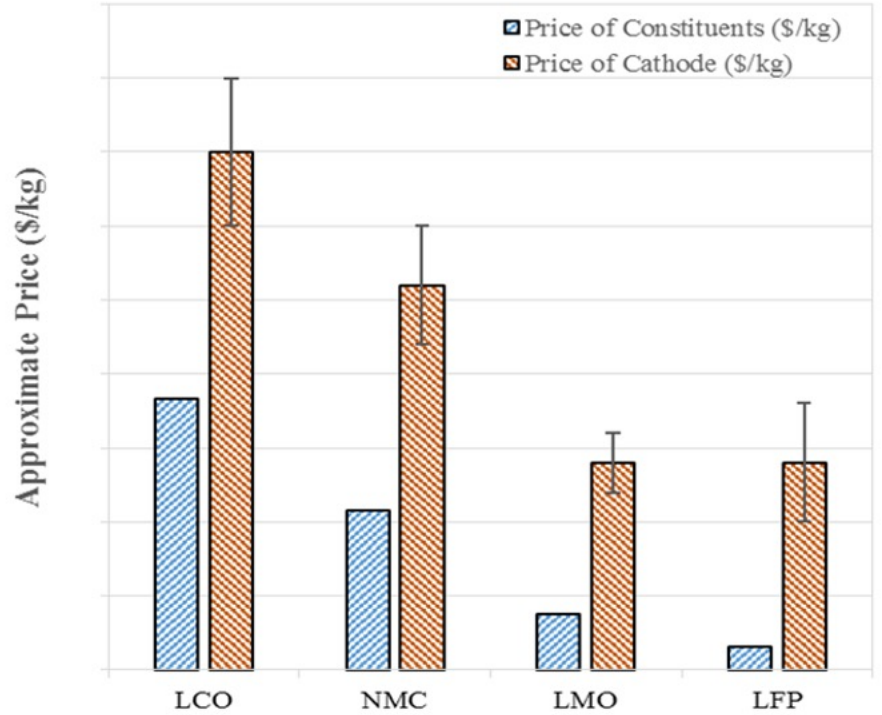
# DIRECT RECYCLING



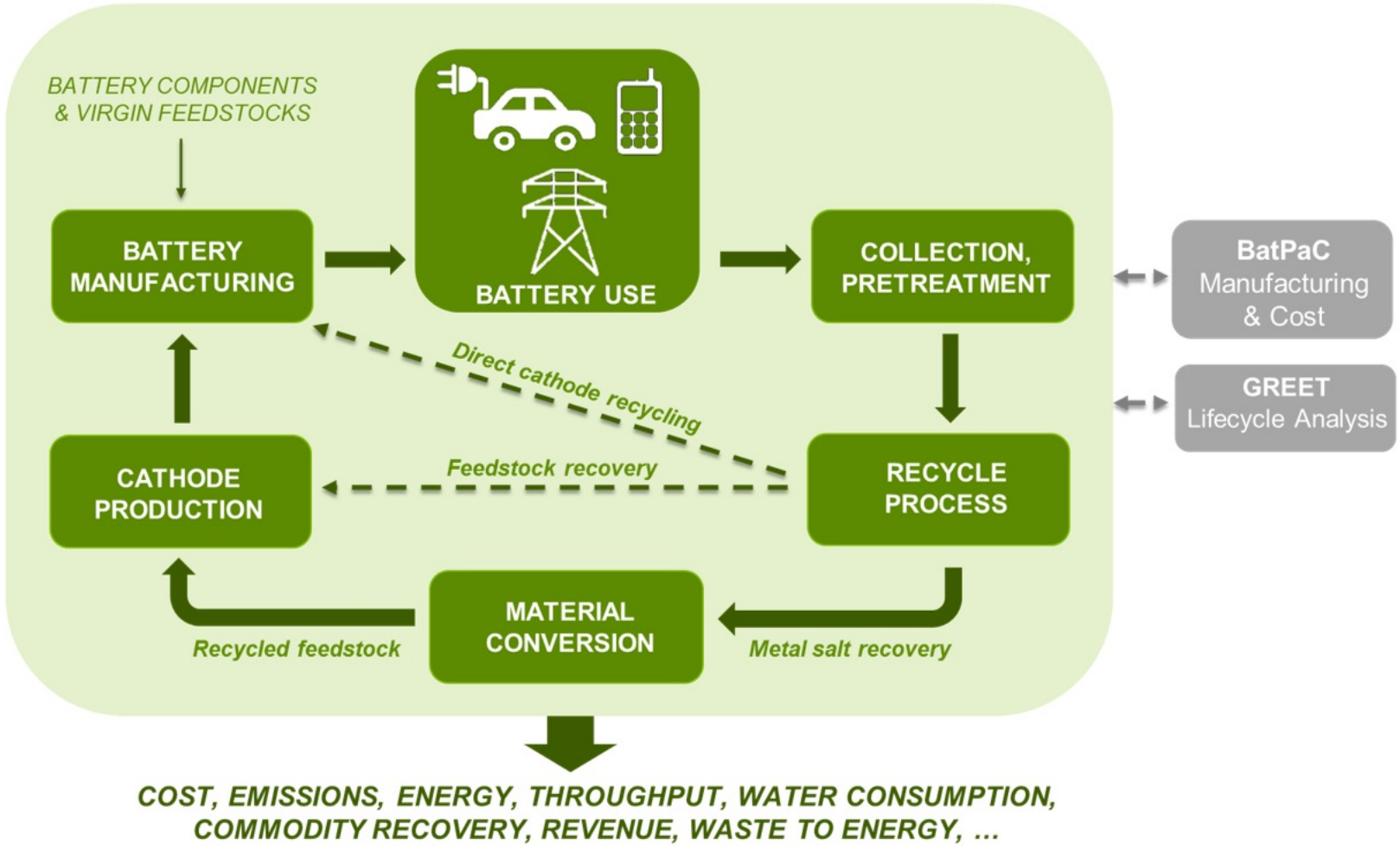

Courtesy Argonne




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

# EVERBATT MODEL FLOW

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




Courtesy Argonne

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ADVANCED
BATTERY RECYCLING

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

VEHICLE TECHNOLOGIES OFFICE

E-Mail: jspangenberger@anl.gov
Website: www.recellcenter.org

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# *Electric Truck Bootcamp*

## *Sustainable Supply Chains & End of Life*

*July 2021*



CLEARED FOR EXPORT

BAE SYSTEMS

# >20 yrs. of electrification innovation… and still learning

★ Industry-first innovations

**1998**
First of 1,677 NYC MTA hybrid fleet; world's largest

1

**2005**
San Francisco & TTC order 1st Gen hybrids

**2007** ★
Lithium-ion energy storage unveiled

1,000

**2011**
King County Metro opts for BAE Systems; fleet today is 869 buses

**2011** ★
FTA's American Fuel Cell Bus arrives at SunLine Transit

**2017** ★
LA Metro orders electrified accessories systems for CNG fleet

**2017**
Awarded industry leadership award for Transit Electrification

7,000

**2016**
SARTA becomes largest fuel cell bus fleet outside of CA


**2015**
First battery electric buses w/ Iveco enter service in Paris

5,000


**2013** ★
MN Metro – 1st engine stop/start, fully electric accessories in North America

**2018**
Westchester 60' hybrid fleet in to service

8,000

**2018** ★
Next-gen energy storage systems released

**2018**
Montreal/Quebec add 500 hybrids to Canada's largest hybrid fleet

**2018** ★
Champ-Urbana fields 1st 1K ultracapacitor ESS in North America

10,000

**2019**
MBTA orders 194 hybrids; total fleet > 450

**2019** ★
Gen3 product line launch at APTA NYC

**2019** ★
SFMTA deploys zero emission "Green Zones"

13,000

**2020**
BAE Systems wins NYC contracts to refresh hybrid fleet w/435 buses

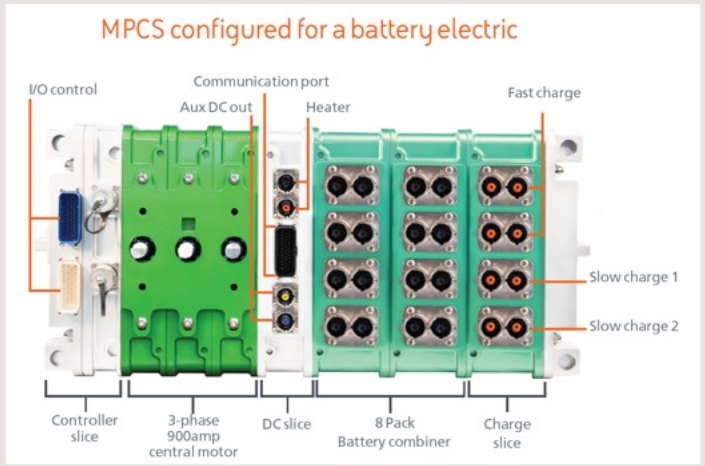
# Look for flexibility

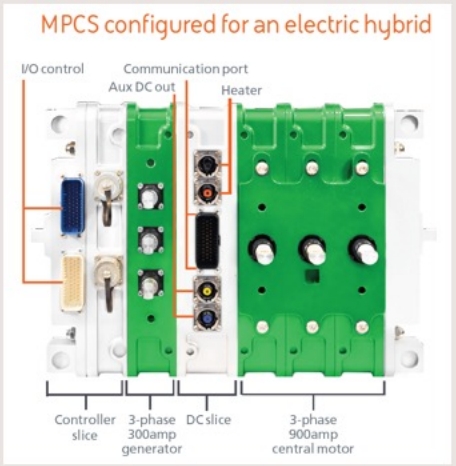
Solutions and platform architecture are becoming more varied

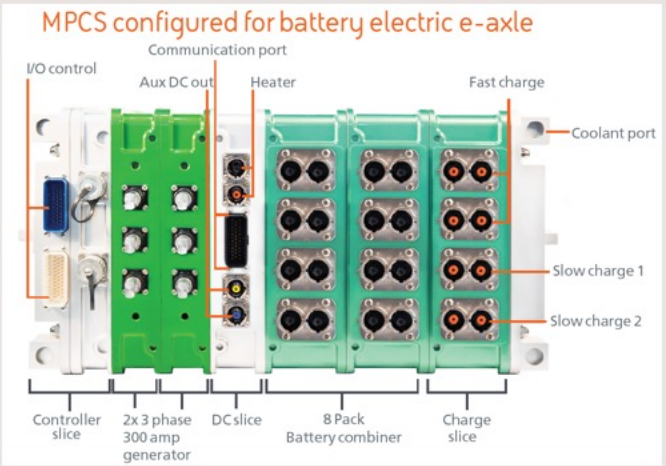
Diesel, CNG, H2, Gasoline, ICE Hybrid, Battery Electric, Fuel Cell Electric…

To reduce NRE costs and simplify supply chain look for suppliers able to support variants, using a ‘common core’

Look for suppliers, like BAE, who have figured out how to both modularize and commonize the power solution



# Design for life

Limited number of supply choices understand and design for the demands of HD commercial market

In transit BAE has always set a goal of 'lifetime' products
Was: 12yrs, 500,000mi., 52,000 hrs.
Now: 14yrs, 620,000mi. 60,000 hrs.

Leading with new technology to increase life with fewer components and higher efficiency (less heat)
eg. Silicon Carbide and Gallium Nitride switch modules

End of life and recyclability is a focus, and relies on partners and identifying and supporting new market opportunities

OEMs need to push end of life requirements to their supply partners
they are in the best position, already engaged with alternate markets, and should have larger volume potential

Ideally you want a partner with proven long life aftermarket support, as this technology is a challenge to maintain.

Your supply chain should be active in helping build the case for residual value.

# Partnership approach to supply chain, playing the 'long game'

BAE has witnessed, from the front lines, the market expectations and supply chain changes

The supply chain is maturing, leaders are emerging with experience, expertise and most importantly commitment

Systems are becoming more complicated and interconnected with the need for highly integrated solutions

Benefits are smaller, more optimized systems with fewer interfaces, lower cost, better operation

Challenge is the need to collaborate and share experience (IP) to truly excel

This has driven to a more strategic and relational, Win/Win supply chain, and less 'lowest cost today' approach

Makes for a stronger, committed supply chain where both the customer and supplier grow in capabilities

Changes some of the questions:

What is the compatibility of corporate structure and approach to product development?

Do we compliment each other and can we see our teams working well together?

Are we committed to the same goals?

How can we have a differentiated product?

**Strategic relationships will be key in this new electrified paradigm**

# Q&A:

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# Thank you!

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Our next training is **August 10** on **Global Perspectives**

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