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Supply-Chain Analysis of Li-Ion Battery Material and Impact of Recycling

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RELEVANCE

Lithium-ion batteries (LIBs) have emerged as the battery of choice for rapidly growing markets in electric vehicles and grid electricity storage.

Challenges in the supply chain of raw materials include:

- Possibility of demand for lithium, graphite, cobalt, and nickel could outstripping supply of virgin material
- Concentration of mining in only a few countries
- Supply risk due to government instability in origin countries
- Risk of price increases.

Recycling of LIBs would ease supply shortages allowing continued growth of beneficial markets.

OBJECTIVE: Define the future economic role of recycling of LIBs.

SUMMARY

This project provides a comprehensive view of global trends in supply and demand for materials critical for LIBs and the processes needed for recycling to contribute to the circular economy of these materials. To date, we have:

- Quantified the current state of global supply of raw materials
- Elucidated the global manufacturing and trade flows associated with LIBs
- Analyzed the LIB manufacturing value chain
- Benchmarked the current state of LIB recycling.

These analyses provide the basis for modeling the potential for LIB recycling to provide critical materials for continuing manufacturing of new batteries in the future.

FUTURE WORK/ CHALLENGES & BARRIERS

Tasks 2 and 3 of this project—quantifying the economics of battery recycling and modeling LIB recycled material supply curves—will be completed in Fiscal Year (FY) 2018 and FY 2019.

Future initiatives include a more comprehensive analysis of the "reverse supply chain" for LIBs, including analysis of policies and programs for recovering materials from end-of-life vehicles, vehicle disassembly, and geographic considerations for battery recycling operations.

Environmental and energy impacts of LIB recycling versus use of virgin materials will also be a focus of future research.

COLLABORATION AND ACKNOWLEDGEMENTS

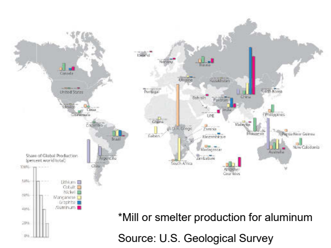
We are partnering with Argonne National Laboratory

APPROACH

Task 1. Quantify global trends in supply and demand for materials critical for LIBs

- Milestone: Update the LIB critical material supply chain and trade flows maps
- Understand trends in vehicle sales, and stationary battery deployment to estimate future battery materials demand
- Quantify trends in battery capacity, material use, and battery manufacturing technologies
- Quantify the time-dependent supply of spent LIB battery materials

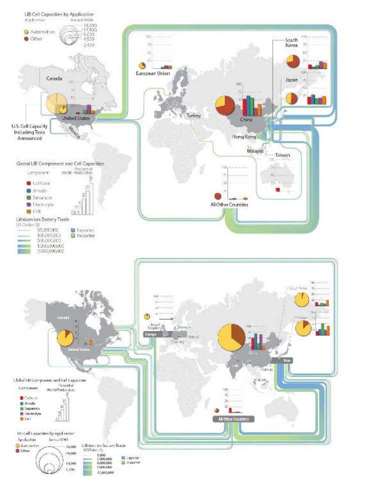
2017 Global Mine Production of LIB Materials*



*Mill or smelter production for aluminum

Source: U.S. Geological Survey

2014 (top) and 2017 (bottom) Regional LIB Supply Chains and Trade Flows.



2014 Sources: Corporate reporting; Bloomberg New Energy Finance BNEF 2015; 2013 International Trade Centre www.trademap.org accessed January 2015. 2017 Sources: BNEF 2017; Avicenne 2017; NREL analysis 2018

Task 2. Quantify the economics of battery recycling accounting for regional differences

- Milestone: Time and location dependent cost for recycled LIB materials – June 30, 2018
- Working in concert with the Argonne ReCell team, develop cost parameters for the three most common recycling processes

Employ NREL's unique CEMAC international manufacturing cost models to estimate recycling process costs accounting for regional differences in labor, energy, transport, regulatory compliance, and other costs.

Task 3. Model the dynamic relationships between demand, supply, and economics to quantify the potential contribution of LIB recycling

Milestone: Integration of global supply chain values from Tasks 1 and 2 with Argonne ReCell model – September 30, 2018

Model dynamic material supply and demand curves based on the cost and supply chain values developed in Tasks 1 and 2.

ACCOMPLISHMENTS

Task 1 – Updates to LIB Supply Chain Data and Maps

In 2017, 32 countries accounted for all production of the raw materials needed for nickel manganese cobalt (NMC) batteries. Supply risk is high for some raw materials:

- Cobalt: In 2016, 54% of the supply was mined in the Democratic Republic of the Congo; the U.S. Department of Energy has deemed cobalt near-critical supply risk.
- Natural Graphite: Deemed a critical supply risk by the Joint Research Centre in the European Commission, and the Royal Society of Chemistry primarily because of the very high concentration of both production and reserves in China
- Lithium: Potential short-term supply risk because of a long development lag for production from new mines

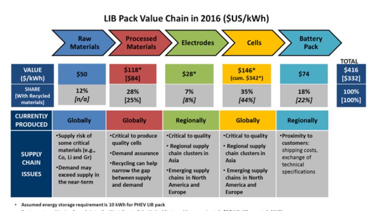
An update of regional LIB supply chain and trade flow maps highlights the rapid evolution in global LIB manufacturing.

- Global LIB manufacturing capacity grew from 76,255 megawatt-hours (MWh) to 189,762 MWh between 2014 and 2017.
- LIB manufacturing capacity is rapidly shifting from consumer electronics to vehicles. In 2014, 36% of global capacity was devoted to vehicles. In 2017 it rose to 60%.

Task 2 – Analysis of LIB Material Demand and Recycling Potential

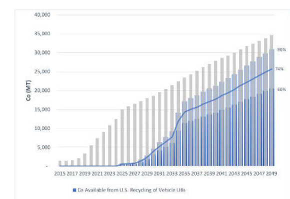
Value chain for plug-in hybrid electric vehicle battery with virgin and recycled materials

(cost in dollars of LIB pack with recycled materials is shown in the brackets)



Sources: NREL analysis 2018; BNEF 2017; Avicenne 2017

Projections of Co Demand and Potential Availability of Recycled Co for Vehicles Sold in the U.S.



Spent batteries from vehicles sold in the U.S. could supply U.S-based recycling operations. The amount of material recovered depends on:

- Battery chemistry at the time the batteries were manufactured
- The number of batteries manufactured
- Battery collection efficiency
- Recovery of material from recycling processes

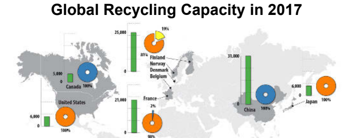
Sources: EIA 2017 AEO Reference Case; Avicenne 2017; BNEF 2017; Lebedeva et al. 2016; Argonne BatPac Model v3.1 18OCT2017; NREL analysis 2018

Task 3 – Modeling of Economic Potential for LIB Recycling

Existing LIB recycling facilities predominantly use pyrometallurgy and hydrometallurgy processes

- Facilities are not exclusively recycling LIBs (also nickel-metal hydride and nickel-cadmium batteries); mixed battery types are acceptable because materials are recovered as elemental metals
- Hydrometallurgy: Li_2CO_3, Al, Co, and Ni are recovered. Anode is destroyed.
- Pyrometallurgy: only Co and Ni are recovered

Global Recycling Capacity in 2017



Recycled materials are mainly cathode powders from different battery types (LIB, NiMH, NiCd)

LIB is the primary type of battery recycled

Sources: Lv et al., 2018; Heelan et al. 2016; Siret 2012, JRC 2016, NREL Analysis 2018

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