Supply Chains and the Energy Transition

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Energy and the Economy: Reshuffling the Energy Deck
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1. What we do

2. Global Trade and value-add: LED case study

3. Beyond cost-Carbon now matters: Photovoltaics (PV) example

4. Rising demand and global trade: Electric Vehicle (EV) batteries illustration
Techno-economic, Manufacturing Decarbonization, and Supply Chain

Provide analysis to put research problems in context and analytically show technology potential. With early TRLs, in collaboration with researchers, put together models. The models serve three purposes:

1) Cost & Price
   i. Highlight manufacturing process/es that add the most cost
   ii. Predict the minimum sustainable price to compete with current state of art
   iii. Estimate effects of technical breakthroughs on entire systems costs

2) Demonstrate embodied carbon impact of grid mix and technology choices

3) Understand supply chain and trade flow implications
Global Trade and value-add: LED case study

- U.S. luminaire market-$17.3 billion
- US imported $3.9 billion
- Therefore US domestically manufactured ~$13 billion in lighting products
- 77% of total revenue sold

Beyond cost-Carbon now matters: Photovoltaics (PV) example
Commercially available PV Technologies

cadmium telluride (CdTe)  
crystalline silicon (Si)

• Silicon based solar cells are most dominant, 90%+ of global market
• Majority of entire Si value chain is manufactured in China
Major manufacturing of CdTe in USA and southeast Asia.

- Silicon based solar cells are most dominant, 90%+ of global market.
- CdTe is 40% of the U.S. axis-based tracking market, and ~25% of cumulative U.S. installations >1 MW.

PV Module Embodied Carbon

European Union (2020)

USA (2020)

China (2020)

India (2020)

Natural Gas
Coal
Nuclear
Hydro
Renewables

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Rising demand and global trade: Electric Vehicle (EV) batteries illustration
Projected Global Demand for Lithium-ion Batteries

Source: BNEF Electric Vehicle Outlook 2022

23% average annual growth rate
LIBRA – Lithium-Ion Battery Resource Assessment Model

LIBRA is a system-dynamics model that evaluates the macro-economic viability of the battery manufacturing, use, and recycling industries across the global supply chain under differing dynamic conditions.

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2021 Global Lithium Supply Chain Flows

Sources:
- NREL Analysis;

*Mining and Preprocessing products:
  - Lithium carbonate and hydroxide from brines, hard rock (e.g., spodumene) and other sources

Non-LIB EV battery related flow

ROAsia – Rest of Asia
ROW – Rest of World

33% of Global Lithium to EVs

19% of Global Lithium to Consumer and Stationary Storage

48% of Global Lithium to Chemical and Other Uses

100% of Global Lithium to EVs

Total 2.1 million tonnes Li reserves

2021 Estimated Global Li Reserves

Thousands of MT

Ores, mattes and intermediates

Refined compounds (carbonate and hydroxide)

LIB Cathodes

Battery Manufacturing

EV Manufacturing

EV Use

EVs

LIBs

Mining, Recycling And Preprocessing*

And Preprocessing*

Mining, Recycling And Preprocessing*
2021 Global Cobalt Supply Chain Flows

Ores, mattes and intermediates

- Mining, Recycling and Preprocessing*
  - Ores: naturally occurring solids containing cobalt
  - Mattes and Intermediates: (30-100% Co)

Refined compounds (oxides & hydroxides)

- Cathodes, Metals and Other Manufacturing
- Battery Manufacturing
- EV Manufacturing
- EV Use

LIB Cathodes

- 45% of Global Cobalt to Metallurgical, Ceramic and Other Uses

EV Use

- 23% of Global Cobalt to EVs


*Mining, Recycling and Preprocessing products:
- Ores: naturally occurring solids containing cobalt
- Mattes and Intermediates: (30-100% Co)
- ROAsia – Rest of Asia
- ROW – Rest of World
- DRC – Democratic Republic of the Congo
2021 Global Class 1* Nickel Supply Chain Flows

*Class 1 Ni is a refined product and in general has been obtained from sulfide deposits. The reserves shown are for all terrestrial nickel deposits (laterite and sulfide). Refining and flows are estimates based on reported refined products (i.e., Class 1 or 2.)

Recycling to meet demand

- There is a lower share of cobalt and nickel recovered for the Net Zero scenario because the growth in EV sales is so rapid the industry has trouble keeping up given the time required to build new plants.
- The share of demand met for nickel grows at a greater rate because of chemistry changes.
Conclusion
Thank You

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