U.S. DEPARTMENT OF
ENERGY
Office of Electricity

Supply Chain E.O. 14017 – Energy Storage and Electric Grid

Ben Shrager and Andre Pereira, Office of Electricity

10/20/21

E.O. 14017

Sec. 4.(a)(iv) The Secretary of Energy, in consultation with the heads of appropriate agencies, shall submit a report on supply chains for the energy sector industrial base *(as determined by the Secretary of Energy).*

Each report shall include a review of:

i. critical goods and materials underlying the supply chain;
ii. other essential goods and materials, including digital products;
iii. manufacturing or other capabilities necessary;
iv. defense, intelligence, cyber, homeland security, health, climate, environmental, natural, market, economic, geopolitical, human-rights or forced-labor risks or other contingencies that may disrupt, strain, compromise, or eliminate the supply chain;
v. the resilience and capacity of American manufacturing supply chains to support national and economic security and emergency preparedness;
vi. allied and partner actions
vii. primary causes of risks
viii. prioritization of critical goods and materials, including digital products
ix. specific policy recommendations for ensuring a resilient supply chain
x. executive, legislative, regulatory, and policy changes
xi. proposals for improving Government-wide effort to strengthen supply chains

Report Assignment

- DOE technology offices tasked with writing reports about technology supply chains: OE responsible for **Electric Grid (LPT & HVDC)** and **Energy Storage/ Batteries**
- Analysis needed to inform policy recommendations exploring the full manufacturing supply chain, including raw materials, processed materials, subcomponents, final products, and end-of-life material recovery.
  - Assessment of expected growth in energy demand and potential bottlenecks as the energy industrial base evolve to meet this rising demand.
  - Identifying risks caused by increased demand on existing supply chains.
  - Identifying what is required to develop a U.S. based supply chain capable of supporting decarbonization pathways set by the administration
- **Actionable policy recommendations geared towards addressing two main policy goals:**
  - Enabling the U.S to meet its domestic demand for critical technologies that supports decarbonization pathways.
  - Enabling the creation of an industrial base capable of exporting clean energy products.

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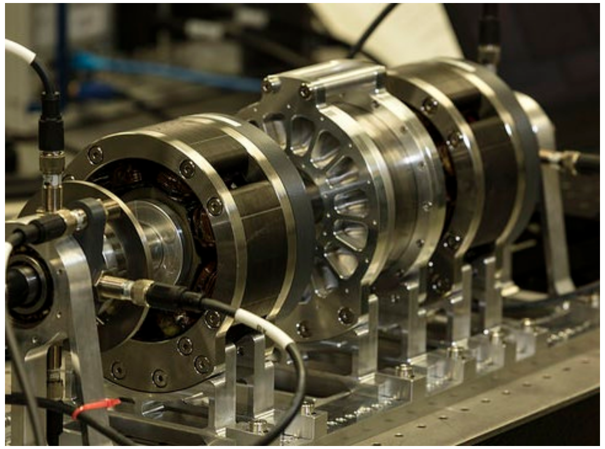

Electric Grid Supply Chain Vulnerabilities

Andre Pereira, Office of Electricity

10/20/21

Large Power Transformers (LPTs) - Vulnerabilities

Dependency on Foreign Markets

- No US manufacturer for extra high voltage transformers; and there is only one U.S. company manufacturing grain-oriented electrical steel (GOES). Domestic manufacturers of LPTs highly rely on the foreign suppliers of GOES, up to 100%
- Currently, there are only 17 U.S. suppliers of high voltage bushings, a critical component that connects an LPT to the transmission line. High voltage bushings are custom made and the lead times could extend up to 5 months.

Large Power Transformers (LPTs) - Vulnerabilities

Raw Materials Price Volatility

- Historical price volatility of raw materials such as GOES and copper makes the LPT supply chain vulnerable

LPT production

- Lack of transformer modularity and automation in the manufacturing process, and lead times (6-18 months) associated with production

General Business Considerations

- Low flexibility in a low volume competitive market
- Prone to monopolies
- Questionable profit margins

High Voltage Direct Current (HVDC) - Vulnerabilities

Limited Number of Suppliers

- ABB, Siemens, and GE supply nearly all North America's HVDC equipment
- No US based DC cable, circuit breaker, or converter suppliers

Limited HVDC system build capacity

- Design and construction skills to build HVDC systems are limited
- Risky as demand grows to meet emission goals there may noy be enough supply resulting in cost increases and failed projects

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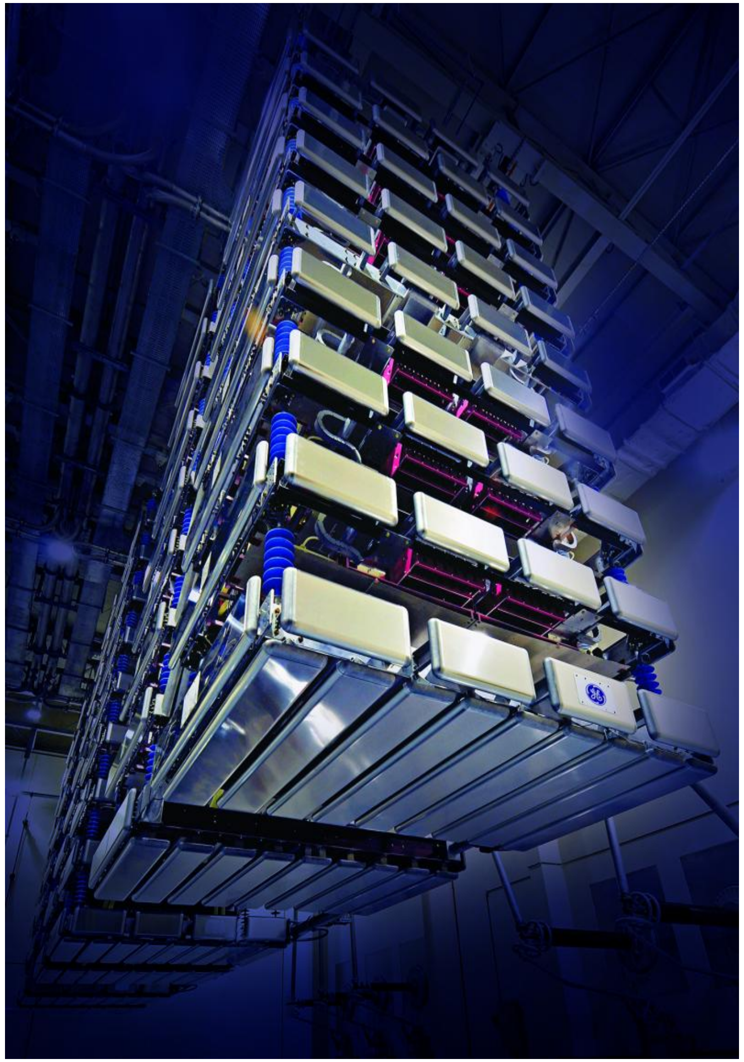
High Voltage Direct Current (HVDC) - Vulnerabilities

Material Availability

– The USGS identified 23 mineral commodities, including **aluminum and tantalum**, among others as posing the greatest supply risk for the U.S. manufacturing sector.



Policy Options – Current Policies

U.S. policies related to the Electric Grid

- Bipartisan infrastructure Bill/Infrastructure investment and Jobs Act
- American Recovery and Reinvestment Act (ARRTA)
- Trade Adjustment Assistance (TAA) Program established under the Trade Adjustment Assistance Reauthorization Act of 2015
- United States Innovation and Competition Act
- Energy policy Act of 2005
- Trade Act of 1974
- The Advanced Manufacturing Jobs in America Act
- Energy Act of 2020
- The Economic Development Administration Reauthorization Act of 2004
- The Emergency Steel Loan Guarantee and Emergency Oil and Gas Guaranteed Loan Act of 1999

Policy Options – Lessons Learned

Lessons learned from past policies

- Tariffs applied to GOES reduced U.S. consumption and did not improve domestic manufacturing competitiveness
- Tariffs on GOES and core laminates were found to negatively impact the domestic transformer industry and have not achieved any short term or longer-term goals related to improving global competitiveness

Policy Options - GOES

GOES

- GOES domestic demand stimulation is important. Part of demand stimulation is to make U.S. products cost competitive to GOES provided by Asian countries. This would require government support in various forms such as **subsidies**, **joint research to reduce costs**, and **training the future manufacturing workforce**.

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Policy Options - LPT

LPT

- Domestic manufactures have under 40% capacity utilization suggesting weak demand for domestic LPT. The high import rate suggests that LPTs produced domestically are not cost-competitive and/or lower quality.
- To solve this issue, demand stimulation may be necessary. This could be done through a combination of methods such as **short-term subsidies, more research into cost cutting options, more training to improve worker efficiency, and increased automation and modularization to reduce labor costs.**

Policy Options - HVDC

HVDC

- Converter is a weak link in the HVDC supply chain with an insignificant domestic market, and the inability to compete with the global market. HVDC breaker (switchgear) is another weak link due to lack of domestic manufacturing capacity.
- To stimulate HVDC demand, the U.S. needs to accelerate national renewable energy to grid integration and **encourage domestic HVDC projects**
- The U.S should **increase HVDC related R&D investment**. R&D areas include grid interconnection, cost feasibility, grid stability, harmonics, power quality, grid control and residence, HVDV grid maintenance, and life cycle management.

Questions for the EAC

1. What manufacturing capabilities are currently in the U.S. related to LPT and HVDC components/systems?
2. How competitive is the U.S compared to global markets for LPT/ HVDC?
3. What is your impression on the future U.S. and global demand of LPT and HVDC?
4. What are your perceived supply chain risks/bottlenecks/vulnerabilities regarding raw materials or sub-component supply?
5. What are your suggested policy actions to incentivize domestic manufacturing of LPT and HVDC components?
6. What policy actions do you suggest to solve LPT/HVDC supply chain challenges?

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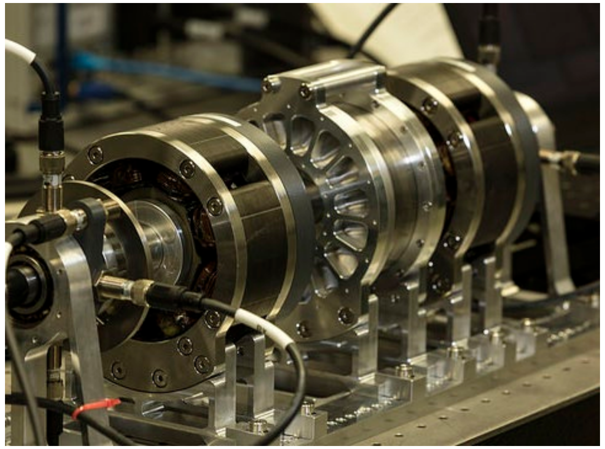
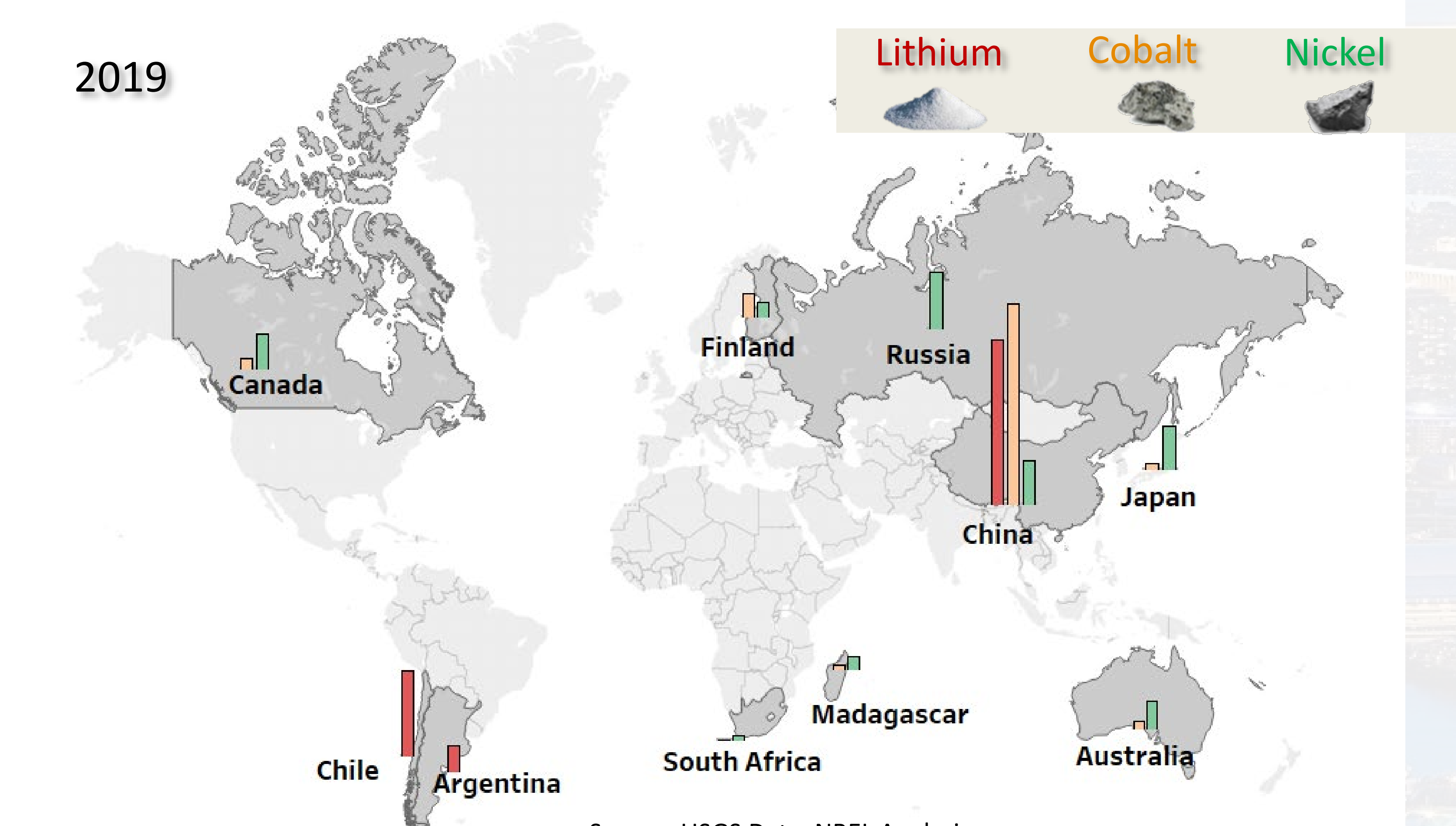


Energy Storage Supply Chain – Vulnerabilities and Policy Options

Ben Shrager, Office of Electricity

10/20/21

U.S. is Dependent on Other Countries for Li-ion Battery Refined Materials



Source: USGS Data, NREL Analysis

Percent of Global Refining Capacity			Total Metric Tons (2019)
Lithium			
1st	60%	China	66,100
2nd	30%	Chile	
3rd	10%	Argentina	
Cobalt			
1st	72%	China	162,900
2nd	9%	Finland	
3rd	4%	Canada	
4th	4%	Norway	
C1 Nickel			
1st	21%	Russia	1,171,300
2nd	16%	China	
3rd	15%	Japan	
4th	13%	Canada	

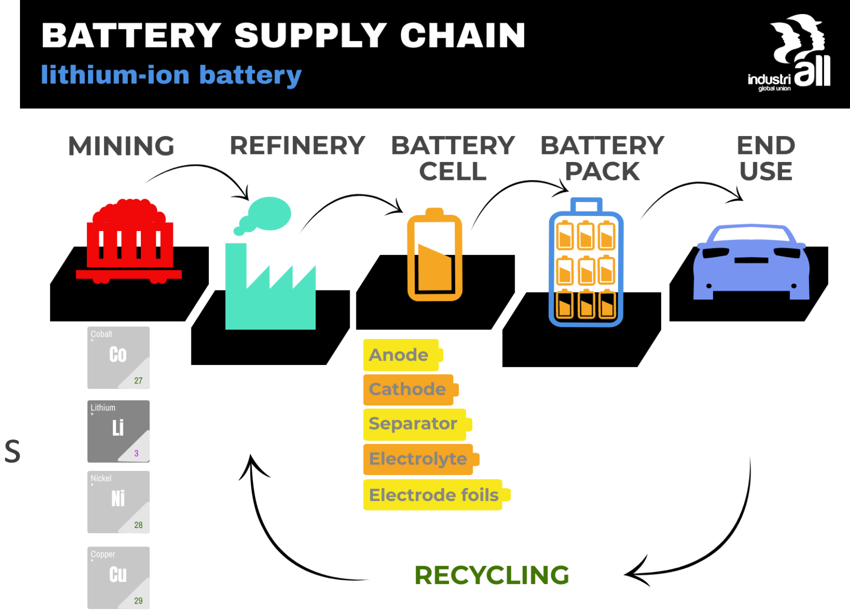
The U.S. currently depends on other countries for mining and production of most of materials used in Li-ion batteries. These countries often have sensitive U.S. relations or volatile political leadership.

Major Supply Chain Vulnerabilities in Energy Storage

1. Reliance on Other Countries for Critical Materials, Components and Products
2. Difficulty in Siting, Permitting, Environmental Emissions and Community Acceptance of Heavy Industries
3. Broad application requirements (performance, environmental, etc.) within energy storage with limited alternatives
4. Difficulty in Accessing Financing for ESS Projects, especially stand-alone

Expanding scope of 100-day report on policy recommendations for lithium batteries for transportation

Highlighted General Vulnerabilities



Raw Materials

- ❑ Lack of domestic reserves

Refined Materials

- ❑ Export restrictions, environmental, and human rights concerns
- ❑ Foreign dependence on a few nations for raw materials, refining, and manufacturing
- ❑ Disruptions from markets, economics, climate

Manufacturing (Electrodes, Electrolytes, Separators)

- ❑ Weak Domestic Production

Battery cells and pack

- ❑ High barriers to entry in this market (due to high capital and workforce requirements, need for R&D expenditures)

End-use

- ❑ Lack of standardization of ESS
- ❑ Limited substitutes for LIBs
- ❑ Difficulty in financing standalone energy storage projects due to lack of long-term off-take contracts

Recycling

- ❑ Non-profitable large-scale recycling solutions

Technology-Specific Vulnerabilities

Lithium-Ion Batteries

- Material availability
  - Cobalt, Lithium, Manganese, Class 1 Nickel, Graphite
- US has very limited refining, cathode or cell production
  - Dominance of China in refining and manufacturing is continuing to increase
- Operating costs are higher than others
- Environmental, siting, and safety concerns
- Recycling industry is in its infancy

Lead Acid Batteries

Lead acid supply chains are far less volatile than LIB, but have other issues that limit deployment:

- Limited energy density, lower energy content, lower cycle life, lower power density, and lower total cost of ownership than LIBs
- Systems-level integration barriers
- Other technical issues that limit application (e.g., Damage from cycling without coming to full state-of-charge)

Redox Flow (V, ZnBr, ZnFe) Batteries

- Worse economy of scale than LIBs
- Material availability
  - Vanadium, Zinc, Graphite
- Vanadium-based RFBs are highly dependent upon volatile vanadium prices
- Less established supply chain so loss of a single supplier could have significant impacts

Other Storage Technologies

- Newer technologies with lower TRL (Such as NaS, Zn-Air batteries) may have not deeply established supply chain, so loss of a single supplier could have significant impacts
- Hydrogen for grid storage requires energy- and emissions-intensive production. Cost-effective LH2 storage and transport technologies are lacking.
- Technologies like CAES and PSH depend on geology or otherwise are prohibitively expensive.

Policy Options → Critical Vulnerability 1

Reliance on Other Countries for Critical Materials, Components and Products and Equipment

- Work with Allies and Partners to Expand Global Production and Ensure Access to Raw Materials and Equipment
- Increase resilience by strengthening US Recycling and Reuse
    - Targeted Incentives for Recycling
    - Battery Recovery and Recycling Task Force
    - Ensure Recycling and Processing Meet Highest Environmental Standards
    - *Conduct RD&D on economical lithium recovery*
    - *Conduct analysis and RD&D on battery reuse, including standards development*
- Increase Funding for R&D to Expand Uptake and Reduce Supply Chain Vulnerabilities
    - Include development of competing technologies (e.g., redox flow batteries)
    - Create a Manufacturing USA Institute for Storage Technologies
    - Increase funding for improving safety of energy storage technologies
- Support current energy storage industries with a stronger domestic presence
    - Lead-acid
    - CAES, PSH, hydrogen

Address environmental and other siting concerns with heavy industry

- Strengthen Responsibly-Sourced Supplies for Key Raw Materials focusing on lithium-ion materials initially by:
  - Supporting sustainable domestic extraction, refining, recycling and recovery from unconventional sources of key raw materials and sustainable domestic production of product components such as battery cells
  - Where these raw materials are not domestically available, partner with allies for responsible extraction and refining
- Invest in RD&D on improving production technologies' environmental impacts to not only meet the law, but significantly exceed it
- Harmonize environmental, health and safety regulations across nations
- Strong focus on "soft fixes" – community engagement, education

Policy Options → Critical Vulnerability 3

Broad application requirements (performance, environmental, etc.) within energy storage with limited technology alternatives

- Invest in R&D for ES technology development, especially stationary
  - 4-h lithium ion “sweet spot” does not address many grid and other applications
- Provide financial, technical and business assistance for deployment of new technologies

Difficulty in Accessing Financing for ESS Projects, especially stand-alone

- Support Energy Storage Demand in Public and Private Sectors
- Provide financing and regulatory support for ESS projects, especially stand-alone
- Develop ESS standards for components, contracts and compliance to assist integrators and utilities in developing consistent packages

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Key Policy Options

- **Short-term**
  - Strengthen Responsibly-Sourced Supplies for Key Raw Materials focusing on lithium-ion materials initially
  - Work with Allies and Partners to Expand Global Production and Ensure Access to Raw Materials and Equipment
  - Increase resilience by strengthening US Recycling and Reuse
- **Long-term**
  - Increase Funding for R&D to Expand Uptake and Reduce Supply Chain Vulnerabilities
  - Increase investment in alternative ESS technologies
- **Existing (Enacted/ Proposed) Legislation and Mechanisms**
  - Energy Act of 2020
  - Bipartisan Infrastructure or Build Back Better Act
  - Energy Storage Tax Incentive and Deployment Act of 2021
  - Bipartisan Infrastructure or Build Back Better Act has several R&D components that will address this: Title II has $60M for battery recycling grants
  - Increase investment through grants and funding of national labs for increased research, development and deployment of storage technologies across applications, similar to what is being done at the Joint Center for Energy Research, an Energy Innovation Hub (Trahey et al. 2020)

Questions for the EAC

1. Are we missing any storage technologies? Which should we emphasize?
2. What other vulnerabilities are present in the battery supply chain?
3. Any additional policy mechanisms to address vulnerabilities?
4. What other grid-specific storage considerations should be represented?

Questions?

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