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National Security Newsletter

March 2021

SOURCEREE

Over the past few years, the Sourceree Team has been closely monitoring the semiconductor industry, high-capacity battery supply chain, and rare earth elements (REEs) market, making the late February 2021 signing of the Biden Administration's Executive Order on America's Supply Chains very exciting for us. The EO included all three of those items as priorities for the Departments of Commerce, Energy, and Defense, and requested a report of the supply chain risks within the next 100 days. In March's SHIELD Newsletter, the Sourceree Team has compiled a Special Edition, flagging the highlights of in-depth articles on the challenges and opportunities in these three critical industries to protect America's supply chain. In this newsletter, we thought it best to let the EO set the tone, and we pinned the relevant excerpts above our article roundups for each industry. Now more than ever, our national security depends on developments in the CFIUS and Supply Chain Risk Management (SCRM) space.

--Adam Murphy, Sourceree President

EO 14017, America's Supply Chains

"More resilient supply chains are secure and diverse — facilitating greater domestic production, a range of supply, built-in redundancies, adequate stockpiles, safe and secure digital networks, and a world-class American manufacturing base and workforce. Moreover, close cooperation on resilient supply chains with allies and partners who share our values will foster collective economic and national security and strengthen the capacity to respond to international disasters and emergencies."

Department of Commerce – Semiconductors

Section 3. (b) i.
"The Secretary of Commerce, in consultation with the heads of appropriate agencies, shall submit a report identifying risks in the semiconductor manufacturing and advanced packaging supply chains and policy recommendations to address these risks."

The Semiconductor Supply Chain: Assessing National Competitiveness

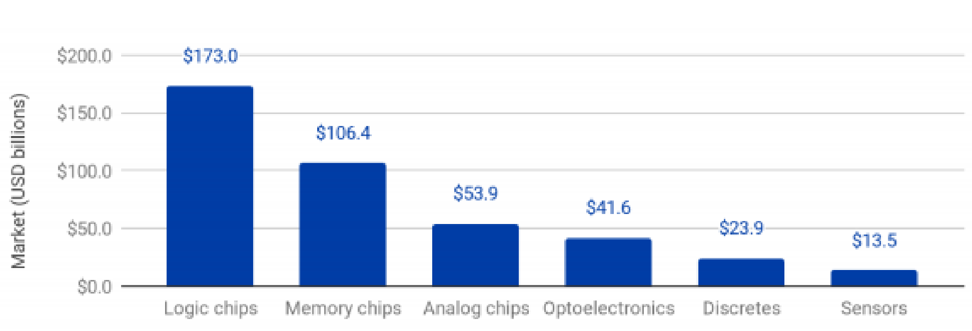
Georgetown Center for Security and Emerging Technology
Authors: Saif M. Khan; Alexander Mann; Dahlia Peterson
January 2021

The COVID-19 pandemic triggered a global semiconductor shortage, impacting automaker and consumer electronics industries for the foreseeable future. The following report from the Georgetown Center for Security and Emerging Technology (CSET) maps out supply chain and national competitiveness across each of the seven sectors of the semiconductor supply chain, providing insight into areas of concentration to reinforce the industry.

Select excerpts from the piece:

The half-trillion-dollar semiconductor supply chain is one of the world's most complex. The production of a single computer chip often requires more than 1,000 steps passing through international borders 70 or more times before reaching an end customer. However, the advancement of China's semiconductor industry could reconfigure these supply chains, affecting international security and the competitiveness of current incumbents. Policies that affect even a single firm or supply chain step can have global ripple effects with tens of billions of dollars of impact. To avoid unpredicted harms, policymakers must understand the supply chain and national competitiveness across each sector.

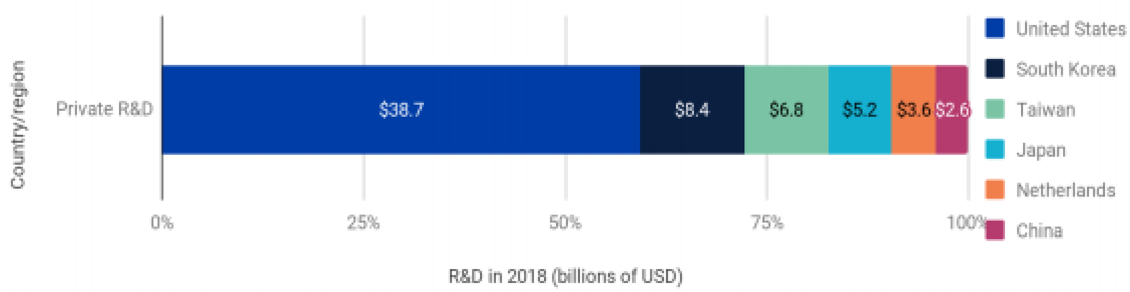
Figure 5: 2019 semiconductor market



Source: WSTS[30]
Note: Logic chips include microprocessors and microcontrollers.

The United States decisively leads all other countries—including China—in semiconductor R&D, which feeds into all other supply chain segments. The private sector performs most semiconductor R&D.

Figure 3: U.S. firms led semiconductor industry R&D in 2018



Source: SIA, SemiWiki[22]

Complex and globalized supply chains have driven rapid progress in semiconductors for decades—epitomized by Moore's Law. Today, semiconductors represent a critical strength for the United States, which remains the global leader across many parts of the supply chain. Together, the United States and its allies—especially Japan, the Netherlands, Taiwan, South Korea, the United Kingdom, and Germany—are technological and market leaders at virtually every step of the semiconductor supply chain.

Though still lagging behind, China increasingly challenges this leadership across several sectors. In particular, China is quickly expanding market share in chip design and manufacturing; and also plans to increase capabilities in production inputs: SME, EDA, core IP, and materials. If successful, China could reconfigure global supply chains, with critical impacts on U.S. national and international security. Companion CSET policy briefs titled "Securing Semiconductor Supply Chains" and "China's Progress in Semiconductor Manufacturing Equipment" offer recommendations to sustain U.S. and allied advantages—which will be at risk without concerted action.

Table 1: Semiconductor value add and market shares by segment and firm headquarters

	Segment Value add	Market shares						
		U.S.	S. Korea	Japan	Taiwan	Europe	China	Other
EDA	1.5%	96%	<1%	3%	0%	0%	<1%	0%
Core IP	0.9%	52%	0%	0%	1%	43%	2%	2%
Wafers	2.5%	0%	10%	56%	16%	14%	4%	0%
Fab tools	14.9%	44%	2%	29%	<1%	23%	1%	1%
ATP tools	2.4%	23%	9%	44%	3%	6%	9%	7%
Design	29.8%	47%	19%	10%	6%	10%	5%	3%
Fab	38.4%	33%	22%	10%	19%	8%	7%	1%
ATP	9.6%	28%	13%	7%	29%	5%	14%	4%
Total value add		39%	16%	14%	12%	11%	6%	2%

Sources: CSET calculations, financial statements, WSTS, SIA, SEMI, IC Insights, Yole, and VLSI Research[14]
Note: Color intensities are correlated with the magnitude of the values.

Department of Energy – High-Capacity Batteries, and Critical Mineral Supply Chains

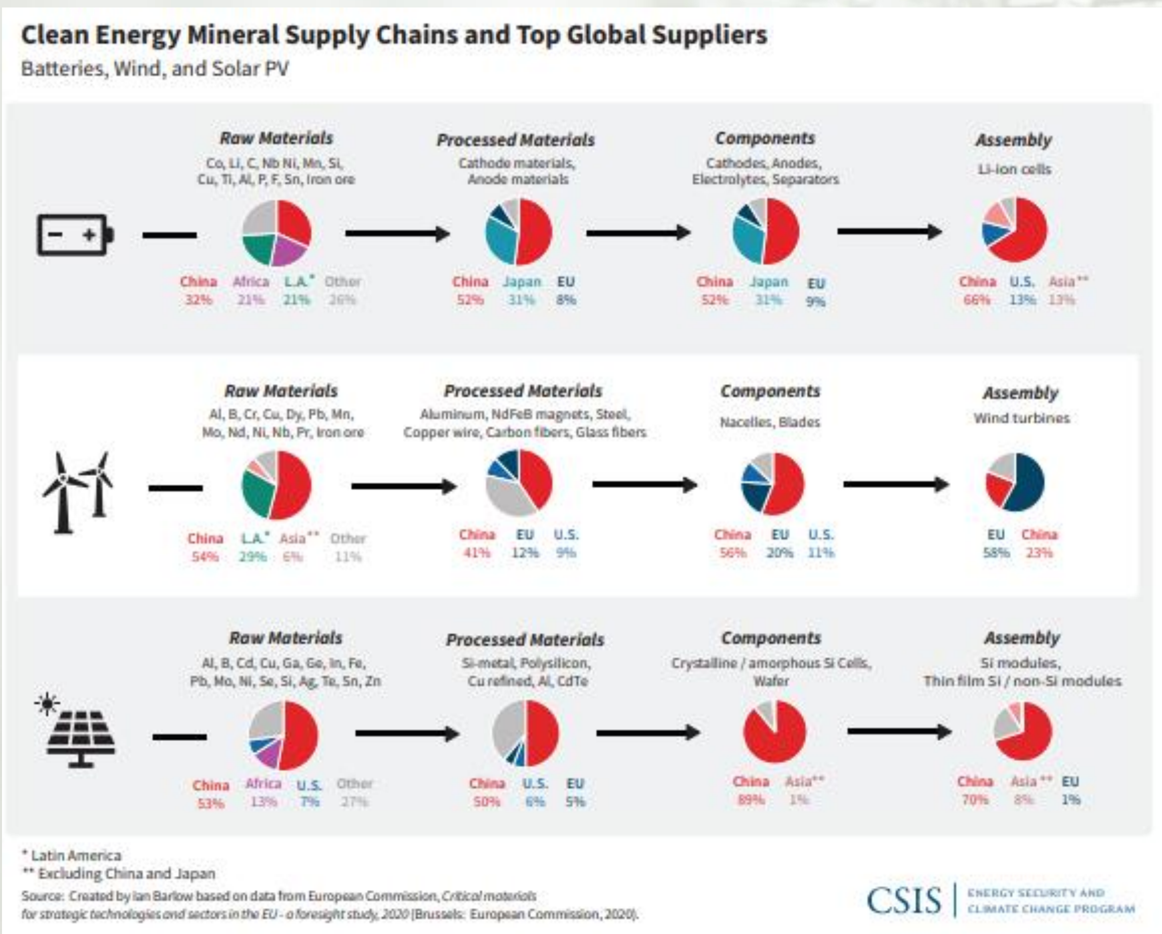
Section 3. (b) ii.
"The Secretary of Energy, in consultation with the heads of appropriate agencies, shall submit a report identifying risks in the supply chain for high-capacity batteries, including electric-vehicle batteries, and policy recommendations to address these risks."

The Geopolitics of Critical Minerals Supply Chains

Center for Strategic and International Studies (CSIS)
Author: Joy Nakano
11 March 2021

Among the minerals identified as the key to advancing clean energy technology are those necessary for energy storage and the critical minerals necessary to manufacture high-capacity batteries. With demand expected to increase 450 percent over the next 30 years, this CSIS report lays out market leaders for critical mineral supply and processing and examines each country's primary interests to identify areas of competition and cooperation across the global chain.

Select excerpts from the piece:



Confronted with the rising threat of climate change, many governments around the world have launched efforts to electrify their energy system while decarbonizing their electric power supply. This trend has led to an increased demand for non-carbon-emitting sources of electricity and energy storage technologies, and in turn has grown the demand for these technologies' component minerals and materials. According to a World Bank study, the demand for component minerals for electric storage batteries—such as aluminum, cobalt, lithium, manganese, and nickel—could rise by more than 450 percent by 2050 if clean energy technology is deployed at a level consistent with the Paris Climate Agreement goal of keeping the rise in atmospheric temperature to no more than 2 degrees Celsius.

Supply chain security for the minerals and materials needed in clean energy technologies has become a strategic issue, not only because it could affect the pace of clean energy technology deployment around the world but also because clean energy technology has become the latest frontier for the geoeconomic rivalries sparked by China's competitive manufacturing sector. No longer a simple mineral producer or component assembler, China is emerging as a higher-value manufacturer that requires a growing volume of the minerals and metals that are considered key to clean energy technology manufacturing. This development has increased the pressure for other major economies dependent on mineral imports to secure their critical minerals supply chains.

Key observations include:

- The security of critical minerals supply chains is a strategic issue, in light of the expected exponential demand growth led by clean energy technology deployment around the world.
- Sustained political commitment to technological innovation is essential to managing the growing competition over resources and clean energy manufacturing value chains.
- China's development of midstream and downstream capacities has turned it from a supplier of raw minerals and materials to a key consumer of them. China's commanding position along critical minerals supply chains is a key factor that shapes other economies' strategic responses.
- Different economies are motivated by different concerns reflecting the heterogeneity in their resource endowment profiles and industrial structures. The United States appears most concerned about import dependence that can be exploited geopolitically, while the European Union and Japan appear primarily concerned with the effects of supply disruptions on their industrial competitiveness.
- Recent efforts to strengthen critical minerals supply chains include the United States' development of midstream capacities, the European Union's orchestrated support for its battery sector, and Japan's stockpile modernization and resource development abroad.
- Competition over critical minerals supplies is also rising between import-dependent economies. Such competition could hinder effective international partnerships that might otherwise mitigate existing risks to supply chains.

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Supply Chain for EV Batteries: 2020 Trade and Value-added Update

United States International Trade Commission
Authors: Jeff Horowitz; David Coffin; Brennan Taylor
January 2021

Electric vehicle (EV) batteries are a named component of the EO's direction for the Department of Energy to examine the high-capacity battery supply chain. In previous newsletters, we have provided some background on EV batteries' potential to enhance the energy grid, dependent on production capacity improvements to meet demand, which the US International Trade Commission's article we are not on pace to do. The article further identifies imports and exports at each juncture of the EV battery supply chain, including competitive advantage across the globe, and identifies improvements made in trade classification standards that will help to track production and supply trends in the future.

Select excerpts from the piece:

The electric vehicle (EV) battery supply chain is a relatively new area of global competition in the passenger vehicle industry, and EVs make up an increasingly significant share of passenger vehicle sales. Globally, the top three markets for EV sales are China, the United States and the EU. However, starting in 2017, EV-specific trade data became available internationally, so we are now able to better track the import and export of EVs, in addition to sales. Moreover, the increase in EV sales has led to an increase in demand for the batteries needed to power these vehicles. The EV battery supply chain is an area that is particularly competitive because of a lack of established suppliers, and projected future demand outstrips current supply, both at the cell level and at the material level. Thus, the makeup of this supply chain is very much in flux.

Since 2017, the quantity and variety of EVs produced and sold has expanded rapidly. Global EV sales increased 78 percent from over 754,000 in 2017 to over 1.5 million in 2019. U.S. EV sales more than doubled from 104,490 in 2017 to nearly 245,000 in 2019. With Tesla's Model 3 selling at such high volumes, U.S. production makes up a higher share of U.S. EV sales than in previous years. In 2017 13 different EV models were offered in the United States, but in 2019 that had expanded to 18.

The battery manufacturing supply chain has three main parts: cell manufacturing, module manufacturing, and pack assembly. These three stages can be conducted in the same place or broken up into two or (theoretically) three locations. For example, the Envision AESC plant in Sunderland, England, produces battery cells and modules, and assembles packs for the Nissan Leaf. However, Envision AESC also sends modules to Spain, where they are put into packs for electric vans. Additionally, Tesla produces modules and packs at its Gigafactory, which opened in 2017 in Nevada, using cells produced by Panasonic at the Gigafactory. However Tesla also produces modules and packs at its Fremont location using cells produced both internally and by Panasonic in Japan. Pack assembly tends to occur near the vehicle assembly location because of the cost of transporting battery packs, which are larger and heavier than cells or modules.

For lithium-ion battery trade, the United States and Germany are beginning to import almost as much as China in recent years, but China still holds a large share of the world's exports. The situation regarding the Harmonized Commodity Description and Coding System (HS) classification remains unchanged over the last few years; HS subheading 8507.60 is where lithium-ion batteries for all uses are categorized for purposes of tracking international trade. However, the U.S. Harmonized Tariff System (HTS) has additional 10-digit statistical reporting numbers for imports that separate EV batteries from other lithium-ion batteries which makes it possible to analyze U.S. trade in EV batteries at a more precise level. As mentioned previously, battery cells are traded under a broader statistical reporting number for battery parts, which makes it difficult to track imports and exports of battery cells at a global level, since that trade data includes a lot of other products as well.

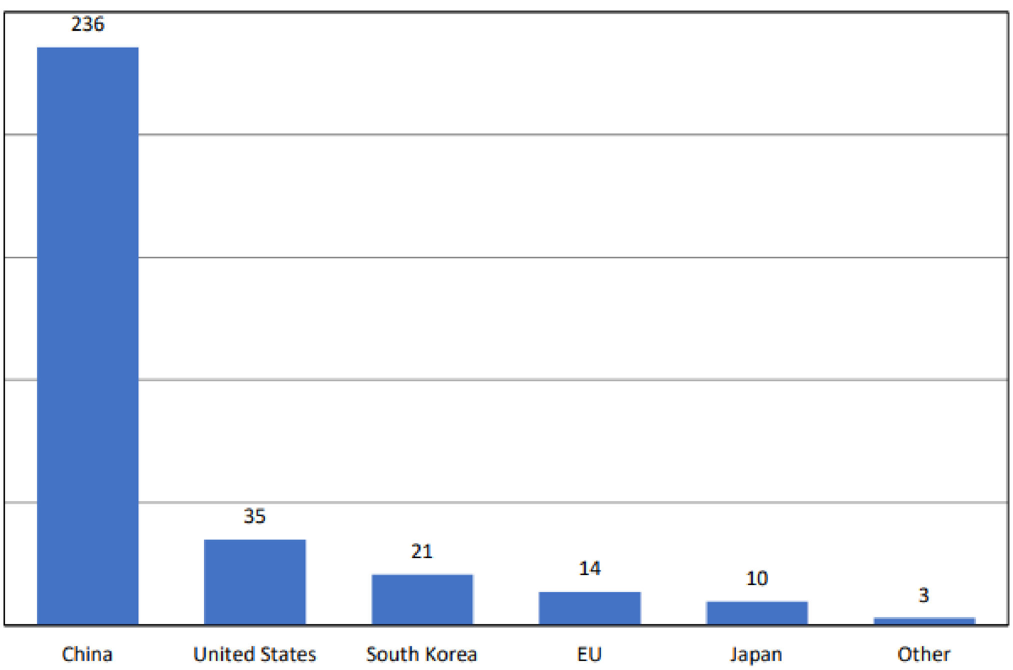
Table 6 Exports of lithium-ion batteries by country, 2017–19 (million $)

Exporter	2017	2018	2019	% growth
China	8,048	10,825	13,031	62
South Korea	3,518	4,388	4,678	33
Hong Kong	2,174	2,877	3,099	43
Japan	2,572	2,580	2,054	-20
Poland	269	821	2,030	656
United States	1,292	1,396	1,499	16
Rest of World	3,242	5,222	6,760	108
Total	22,077	29,438	35,134	59

Source: IHS Markit, Global Trade Atlas (HS 8507.60; accessed December 9, 2020).

For the United States, the majority of assembled EV battery imports continue to be imported from South Korea and the majority of battery parts are imported from Japan, while the majority of exports of lithium-ion batteries from the United States are destined for the Netherlands, Mexico and the United Kingdom.

Figure 2 Global EV battery manufacturing capacity (GWh), 2019



Source: BNEF, "Battery Manufacturing," May 30, 2019.

Department of Defense – Rare Earth Elements (REEs)

Section 3. (b) iii

"The Secretary of Defense (as the National Defense Stockpile Manager), in consultation with the heads of appropriate agencies, shall submit a report identifying risks in the supply chain for critical minerals and other identified strategic materials, including rare earth elements (as determined by the Secretary of Defense), and policy recommendations to address these risks. The report shall also describe and update work done pursuant to Executive Order 13953 of September 30, 2020 (Addressing the Threat to the Domestic Supply Chain From Reliance on Critical Minerals From Foreign Adversaries and Supporting the Domestic Mining and Processing Industries)."

An Overview of Rare Earth Elements and Related Issues for Congress

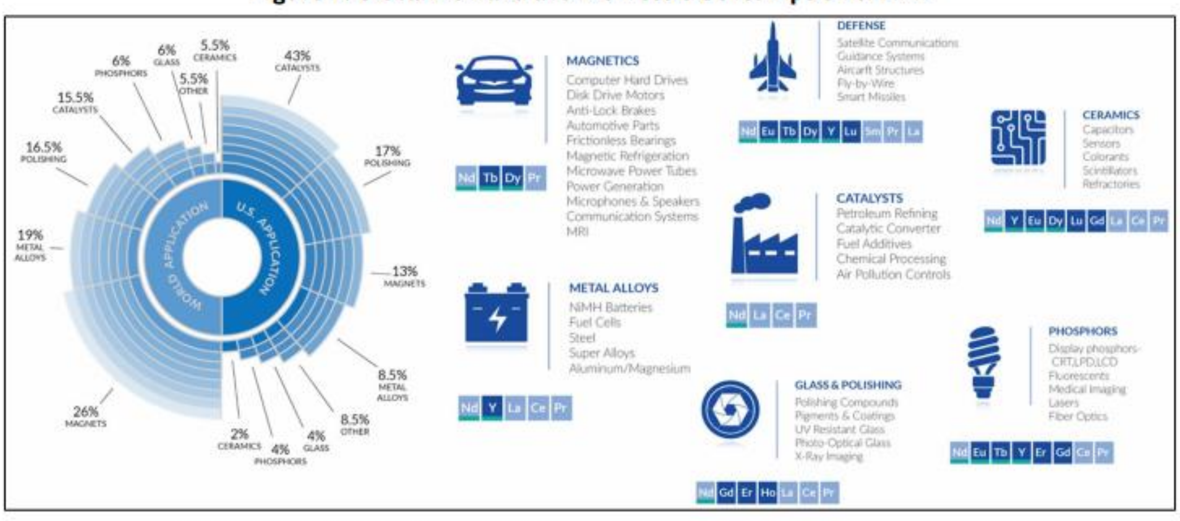
Congressional Research Service
24 November 2020

In a piece in the January newsletter, we laid the foundation for the importance of rare earth elements (REEs), with their diverse applications including defense and energy technologies, and the fact that we are 100% reliant on imports of 14 out of the 17 REEs. The Congressional Research Service provided the following overview which goes deeper into the uses for REEs as well as REE mining locations across the globe.

Select excerpts from the piece:

Although domestic resources exist for some REE, the United States is currently reliant on imports. In 2019, the United States imported 100% of rare earth metals and compounds it consumed, even though it exported some domestically mined rare earth element concentrate for further processing (due in part to a lack of domestic processing facilities).

Figure 1. Global Demand and Domestic Consumption of REE



Source: National Energy Technology Laboratory (NETL), "REE-CM Program," https://www.netl.doe.gov/coal/rare-earth-elements/program-overview/background.

From the 1960s until around 1985, the United States was the world's largest producer of REE, with all production originating from the Mountain Pass mine in California. Starting in the mid11980s, China began REE mining and extraction operations and became the largest contributor to global REE production. By the 2010s, China was producing nearly 85% of the world's supply of REE and supplying 95% of processed REE.9 China imposed export restrictions on REE between 2010 and 2014, resulting in dramatic increases in REE prices during those years. 10 These high prices led to increased global exploration for REE deposits. The 40 largest exploration projects indicate over 3,000 million metric tons (Mt) of inferred resources (at various grades) in more than 15 countries.

Table 1. Active REE Mines in 2017

Deposit Name	Location	Resource (Mt)	Grade (REO, %)
Mount Weld	Australia	23.9	7.9
Buena Norte	Brazil	na	na
Bayan Obo	China	800	6
Daluxiang (Dalucao)	China	15.2	5
Maoniuping	China	50.2	2.89
South China clay deposits	China	na	0.05 – 0.4
Weishan	China	na	na
Karnasurt Mountain	Russia	na	na
Mountain Pass	United States	16.7	7.98
Dong Pao	Vietnam	na	na

Source: Bradley S. Van Gosen, Philip L. Verplanck, Robert R. Seal II, Keith R. Long, and Joseph Gambogi, *Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply*, ed. Klaus J. Schulz, John H. DeYoung, Jr., Robert R. Seal II, Dwight C. Bradley (Reston, VA: U.S. Geological Survey, 2017), Table O3, p. O12, https://doi.org/10.3133/pp1802O.

In addition to new deposits of REE, changes to existing extraction and recycling technologies could increase the secondary supply of REE by allowing the use of otherwise unusable sources of REE. New extraction technologies or lower cost extraction technologies can allow lower-grade deposits to be mined economically (i.e., lower a mine's cut-off grade). Such technologies can also potentially be applied to new sources of REE, such as wastewater or recycled waste.

[Critical Materials Rare Earths Supply Chain: A Situational White Paper](#)

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy
April 2020

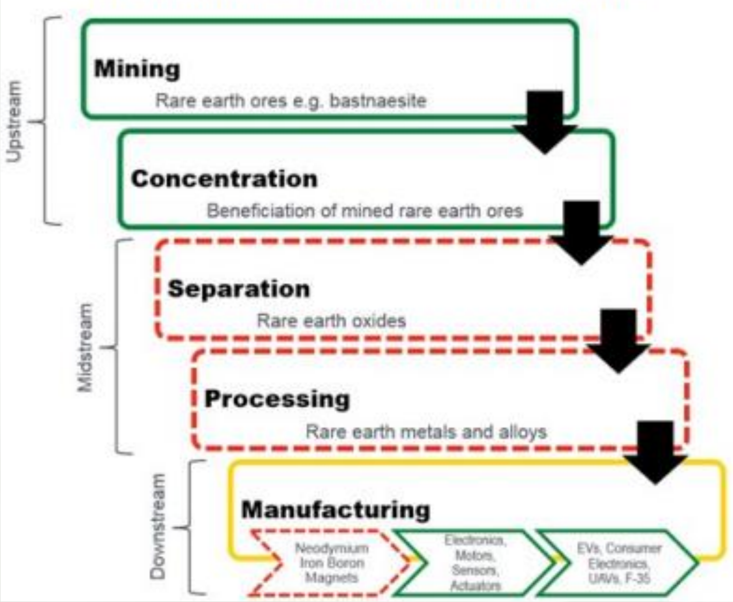
In this Department of Energy white paper, the authors break down challenges and opportunities to enhancing the nearly entirely dependent supply chain for the United States' acquisition of REEs. This includes recycling, research and development, and the full spectrum of processing necessary to use these minerals. The full article identifies the broader challenge of technology transfer among academia, government, and industry to exchange scientific and technical data that would improve the supply chain.

Select excerpts from the piece:

The assured supply of critical materials and the resiliency of their supply chains are essential to the economic prosperity and national defense of the United States. The manufacturing and deployment of these goods provides employment for American workers and contributes to U.S. economic growth. The United States is dependent on foreign sources of critical materials. Many foreign sources of critical materials are concentrated in just one or two countries. For example, 60% of the world's cobalt is mined in the Democratic of Congo, and 80% of that supply is processed in China. The dependency of the nation on foreign sources of critical materials creates a strategic vulnerability for both our economy and our military with respect to adverse foreign government actions, natural disasters, and other events that could disrupt supply.

Figure 4. Rare Earth Element Supply Chain for Neodymium Iron Boron Magnets

Gaps in the domestic supply chain are shown in red.



Recycling
Currently, end-of-life products that contain REEs, including magnets, batteries and fluorescent light bulbs, are recycled in limited quantities.25 Urban Mining Company has built its business

model on magnet-to-magnet recycling. The Rare Earth Salts pilot plant processes fluorescent light bulbs. Momentum Technologies has licensed patented technology developed by the Critical Materials Institute, a DOE Energy Innovation Hub, to recovery REOs from magnet waste streams.

Opportunities

Innovation Ecosystem Criticality applies not just to materials, but also to broader systems they are a part of. To address strategic vulnerabilities, the entire supply chain needs to be considered. For example, increasing the rate of mining without increasing corresponding processing and manufacturing capabilities will simply move the source of economic and national security risk further down the supply chain and create dependence on foreign sources for these capabilities. An innovation ecosystem should be built around a supply chain framework that emphasizes the integrated, interconnected nature of the problem.

Key areas for development include:

- Understanding the systems, networks, and evolution of materials flow to identify opportunities, including co-production and unconventional resources
- Strengthening and extending relationships to match producers and customers
- Sustained engagement with OEMs, labs, and academia throughout the process to scale up new technologies
- Establishing a pipeline of projects for private investment
- Establishing an advisory group or community that identifies challenges and opportunities on an ongoing basis, including bridging domestic and international FOCI
- Pursuing a multidisciplinary workforce including AI, automation, rapid prototyping

R&D Solutions

R&D is well-positioned to address long-term solutions to the supply chain. Transformational innovation can be used to shift the paradigm in the industry. DOE and DOD, including the Defense Advanced Research Projects Agency (DARPA) and the Air Force Research Lab, are all investing in developing technologies that have the potential to innovate the supply chain and reduce dependence on rare earths by substantially reducing or even eliminating their use in end-use technologies. In order to reduce costs and maintain responsible environment stewardship, connectivity is needed across the supply chain. For example, modular process intensification can link feedstocks with processing by co-locating multiple stages of the supply chain. Modeling and analysis play an important role in validating such ideas. Techno-economic analysis (TEA), life-cycle analysis (LCA) and agent-based modeling were discussed as vital steps in the scale-up of new technologies. Cooperation through public-private partnerships is needed for such validation and verification, with test-beds and pilot-scale facilities as one avenue to demonstrate new technologies. For development of new processes, certification is needed.

Supply Chain Development

Moving beyond R&D, commercial stockpiles and regulatory incentives were suggested as one possible way to stabilize the industry, although there was not consensus about whether either approach would be effective. Leveraging international collaboration with allied nations, such as members of the North Atlantic Treaty Organization (NATO), was suggested as a means to stand up an assured rare earth supply chain to reduce market uncertainty and volatility.

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Sourceree's SHIELD program is a comprehensive supply chain risk management (SCRM) solution designed to help answer questions about supply chain disruptions and risks, particularly foreign investment.

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