May 2023

Critical Minerals and Energy Transition Technologies

Critical minerals are essential to advancing energy transition technologies in the United States (U.S.). Manufacturing products that generate, store, and release alternative clean and renewable energy, such as electric car batteries, wind turbines, and solar panels, rely on the availability of critical minerals.

Issue

Manufacturing in the U.S. will rely on securing access to critical minerals to meet society's increasing demand for alternative clean and renewable energy transition technologies. Critical minerals are defined as non-fuel minerals or mineral materials that are essential to the U.S. economy and national security, and are susceptible to supply chain disruption (USDOE 2020, USGS 2022). Since mineral market and supply chain analyses are regularly updated as new information becomes available, and society's demand for raw materials used to manufacture products and drive technological innovation can change, The Energy Act of 2020 (USDOE 2020) requires a review, and update if needed, of the identified critical minerals at least once every three years.

Not all critical minerals are readily available (e.g., currently discovered, mined, or processed) in the U.S, to support manufacturing the products needed in energy transition technologies. When a sufficient domestic supply of critical minerals is unavailable, the U.S. relies on foreign imports to secure minerals required for manufacturing renewable energy and other products. Identifying and developing domestic sources of critical minerals will assist in meeting the demand and strengthening domestic supply chains for alternative and energy transition technologies in the U.S.

Background

The U.S. began identifying critical minerals during World War I, when nickel, nitrates, platinum, potash, and tin were among those recognized to be important to the war effort but limited in domestic supply. In 1917, *Mineral Resources in War and Their Bearing on Preparedness* (Pogue 1917) was published and presented ongoing research in mineral commodity availability and demand. The first modern U.S. list of critical minerals was drafted by the United States Geological Survey (USGS) for the United States Department of the Interior (USDOI) in 2018 and included 35 mineral commodities (USGS 2018, USDOI 2018).

In 2022, the USGS released an updated list of critical minerals that included 50 mineral commodities (USGS 2022). The increase in 15 total critical minerals reported included minerals both added to and removed from the previous list based on current supply, demand, and production data, and applicable U.S. policy. The International Energy Agency (IEA) identified additional minerals as "important" for clean energy technologies (e.g., electric cars, wind turbines, solar panels) that were not included in the USGS 2022 update, such as copper, molybdenum, and silicon (IEA 2021).

The USGS publishes information for a number of mineral commodities including but not limited to those the U.S. currently considers critical. Information such as import and export statistics, commodity trends, and world production and reserve estimates, is updated on an annual basis and published in individual *Mineral Commodity Summaries*. These publications (USGS 2023) were used to illustrate critical and "important" minerals for manufacturing electric vehicles, wind turbines, and solar panels in Figures 1, 2, and 3, respectively.

Electric Vehicle Batteries

Use: rechargeable battery cathode. In 2022, the U.S. mined and exported cobalt but was 76% reliant on foreign sources to meet domestic demand.

Top 5 Countries for Production (2022): Democratic Republic of the Congo, Indonesia, Russia, Australia, Canada

Top 5 Countries with Reserves (2022): Democratic Republic of the Congo, Australia, Indonesia, Cuba, Philippines

Top U.S. Import Sources (2018-2021): Norway, Canada, Finland, Japan

Use: anode in many lithium batteries and motors. In 2022, the U.S. was 100% reliant on foreign sources of graphite to meet domestic demand.

Top 5 Countries for Production (2022): China, Mozambique, Madagascar, Brazil, Republic of Korea

Top 5 Countries with Reserves (2022): Turkey, Brazil, China, Madagascar, Mozambique

Top U.S. Import Sources (2018-2021): China, Mexico, Canada, Madagascar

Use: rechargeable battery anode. In 2022, the U.S. mined and exported rare earth minerals but was more than 95% reliant on foreign sources to meet domestic demand.

Top 5 Countries for Production (2022): China, United States, Australia, Burma, Vietnam

Top 5 Countries with Reserves (2022): China, Vietnam, Brazil, Russia, India

Top U.S. Import Sources (2018-2021): China, Malaysia, Estonia, Japan

Use: common battery material. In 2022, the U.S. mined and exported lithium but was more than 25% reliant on foreign sources to meet domestic demand.

Top 5 Countries for Production (2022): Australia, Chile, China, Argentina, Brazil

Top 5 Countries with Reserves (2022): Chile, Australia, Argentina, China, United States

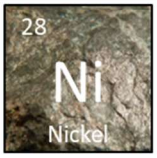
Top U.S. Import Sources (2018-2021): Argentina, Chile, China, Russia

Use: cathode in many lithium batteries. In 2022, the U.S. was 100% reliant on foreign sources of manganese to meet domestic demand.

Top 5 Countries for Production (2022): South Africa, Gabon, Australia, China, Ghana

Top 5 Countries with Reserves (2022): South Africa, China, Brazil, Australia, Ukraine

Top U.S. Import Sources (2018-2021): Gabon, Georgia, South Africa, Australia



Use: cathode in lithium batteries. In 2022, the U.S. mined and exported nickel but was 56% reliant on foreign sources to meet domestic demand.

Top 5 Countries for Production (2022): Indonesia, Philippines, Russia, New Caledonia, Australia

Top 5 Countries with Reserves (2022): Indonesia, Brazil, Australia, Russia, New Caledonia

Top U.S. Import Sources (2018-2021): Canada, Norway, Australia, Finland

Use: increase lifespan of batteries. In 2022, the U.S. mined and exported vanadium but was 54% reliant on foreign sources to meet domestic demand.

Top Countries for Production (2022): China, Russia, South Africa, Brazil

Top 5 Countries with Reserves (2022): China, Australia, Russia, South Africa, Brazil

Top U.S. Import Sources (2018-2021): Brazil, Austria, Canada, South Africa

Figure 1. Critical minerals for electric vehicle batteries (USGS 2023).

Frame, Batteries, and Magnets
Bauxite (aluminum)
Cobalt (see Figure 1)
Manganese (see Figure 1)
Molybdenum
Rare Earths (see Figure 1)
Vanadium (see Figure 1)
Zinc

Wiring and Circuitry
Copper
Tungsten

Wind Turbines

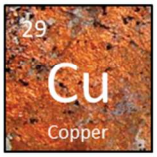
	**Use:** nearly all components, including nacelle where transfer of wind power to electricity occurs. In 2022, the U.S. mined and exported bauxite but was 54% reliant on foreign sources to meet domestic demand. **Top 5 Countries for Production (2022):** China, India, Russia, Canada, United Arab Emirates **Top 5 Countries with Capacity (2022):** China, India, Russia, Canada, United Arab Emirates **Top U.S. Import Sources (2018-2021):** Canada, United Arab Emirates, Russia, China
	**Use:** grounding and carrying electrical current. In 2022, the U.S. mined and exported copper but was 41% reliant on foreign sources to meet domestic demand. **Top 5 Countries for Production (2022):** China, Chile, Democratic Republic of the Congo, Peru, United States **Top 5 Countries with Capacity (2022):** Chile, Australia, Peru, Russia, Mexico **Top U.S. Import Sources (2018-2021):** Finland, Mexico, Chile, Canada
	**Use:** alloying element. In 2022, the U.S. mined and exported molybdenum and is considered a net exporter. **Top 5 Countries for Production (2022):** China, Chile, United States, Peru, Mexico **Top 5 Countries with Reserves (2022):** China, United States, Peru, Chile, Russia **Top U.S. Import Sources (2018-2021):** Peru, Chile, Mexico, Canada
	**Use:** conductor. In 2022, the U.S. mined and exported tungsten but was more than 50% reliant on foreign sources to meet domestic demand. **Top 5 Countries for Production (2022):** China, Vietnam, Russia, Bolivia, Rwanda **Top 5 Countries with Reserves (2022):** China, Russia, Vietnam, Spain, Austria **Top U.S. Import Sources (2018-2021):** China, Germany, Bolivia, Vietnam
	**Use:** galvanizing to prevent corrosion. In 2022, the U.S. mined and exported zinc and is considered a net exporter of ores and concentrates. **Top 5 Countries for Production (2022):** China, Peru, Australia, India, United States **Top 5 Countries with Reserves (2022):** Australia, China, Russia, Peru, Mexico **Top U.S. Import Sources (2018-2021):** Peru, Canada, Mexico, China

Figure 2. Critical minerals for wind turbines (USGS 2023).

Frame
Bauxite (aluminum, see Figure 2)

Semiconductor
Arsenic

Solar Cells
Copper (see Figure 2)
Gallium
Germanium
Indium
Molybdenum (see Figure 2)
Tellurium

Solar Panels

Use: semiconductors for solar cells. In 2022, the U.S. was 100% reliant on foreign sources of arsenic to meet domestic demand.

Top 5 Countries for Production (2022): Peru, China, Morocco, Russia, Belgium

Top 5 Countries with Capacity (2022): China, Peru, Philippines, Chile, Canada

Top U.S. Import Sources (2018-2021): Malaysia, China, Morocco, Belgium

Use: thin-film solar cells. In 2022, the U.S. was 100% reliant on foreign sources of gallium to meet domestic demand.

Top 5 Countries for Production (2022): China, Russia, Japan, Republic of Korea, Ukraine

Top 5 Countries with Capacity (2022): China, Republic of Korea, Ukraine, Japan, Russia

Top U.S. Import Sources (2018-2021): China, Germany, Japan, Ukraine

Use: solar cells commonly used in satellites. In 2022, the U.S. mined and exported germanium but was more than 50% reliant on foreign sources to meet domestic demand.

Top 5 Countries for Production (2022): China

Top 5 Countries with Reserves (2022): data not available

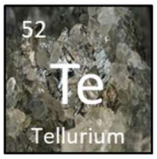
Top U.S. Import Sources (2018-2021): China, Belgium, Germany, Russia

Use: thin-film solar cells. In 2022, the U.S. was 100% reliant on foreign sources of indium to meet domestic demand.

Top 5 Countries for Production (2022): China, Republic of Korea, Japan, Canada, France

Top 5 Countries with Reserves (2022): data not available

Top U.S. Import Sources (2018-2021): Republic of Korea, Canada, China, France



Use: thin-film solar cells. In 2022, the U.S. mined and exported tellurium but was more than 75% reliant on foreign sources to meet domestic demand.

Top 5 Countries for Production (2022): China, Russia, Japan, Canada, Uzbekistan

Top 5 Countries with Reserves (2022): Russia, United States, China, Canada, South Africa

Top U.S. Import Sources (2018-2021): Canada, Germany, China, Philippines

Figure 3. Critical minerals for solar panels (USGS 2023).

SME Statement of Technical Position

SME supports the following goals to improve the reliable sourcing of critical minerals and advancing renewable and energy transition technologies, specifically the manufacturing of electric car batteries, wind turbines, and solar panels:

- Identifying and developing domestic sources of critical minerals and securing reliable sources of foreign imports where a domestic source is not identified.
- Quantifying U.S. critical mineral demand relative to availability.
- Maintaining U.S. global technical and economic competitiveness.

These goals can be achieved by:

- Facilitating domestic research, publication, education, and training in approaches to exploration, mining and processing critical minerals through collaboration between government, industry, and academia.
- Developing reprocessing and recycling technologies to recover critical minerals from mine waste materials (e.g., tailings, waste rock, products at end of life).
- Increasing domestic mining and processing capacity for critical minerals to meet increasing societal demand for energy transition and renewable energy technologies.
- Adopting safe, reliable, and secure policies that encourage development of technologies to support alternative energy transition and renewable energy, including streamlining permitting approvals for projects that will increase discovery and development of domestic critical minerals.
- Effectively engaging the public through outreach to convey the importance of critical minerals in the U.S. energy transition and development of renewable energy technologies, meeting the U.S. carbon emission reduction goals, and maintaining U.S. national security.

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