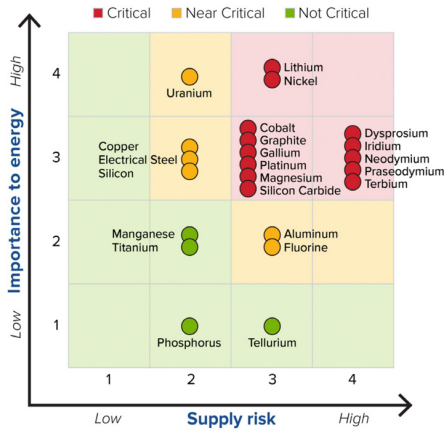
Critical Materials

Minerals are integral to modern society. They are found in alloys, magnets, batteries, catalysts, phosphors, and polishing compounds that are integrated into aircraft, communication systems, electric vehicles, lasers, naval vessels, electronics, and lighting.[1] However, some minerals have limited supply and incur high environmental and financial extraction costs. There is concern if supply of these necessary materials can meet future needs. Material criticality is assessed by supply risk, vulnerability to supply restrictions, and environmental implications.[2] One category of critical mineral is rare earth elements (REEs). There are 16 REEs designated as critical minerals. Many REEs are vital for renewable energy and energy storage.[1]

- Global demand for critical materials is expected to rise as the world shifts to clean energy. Demand for lithium and graphite used in EV batteries is forecast to increase by factors of 12.6 and 3.4, respectively, between 2021 and 2040.[3]
- Increasing offshore wind capacity creates demand for rare earth magnets, with installed global capacity expected to grow by a factor of 15 between 2018 and 2040.[4]
- The average amount of critical materials needed per new unit of power generation capacity increased by 50% since 2010.[5]
- Refining often occurs in a different location than mining. For 20 minerals analyzed by the IEA, an average of 70% of refining took place in China.[3]
- The U.S. produced an estimated 45 kt of rare-earth-oxide in mineral concentrates in 2025, valued at $240M.[6]

Materials Criticality Matrix, Medium Term (2025-35)[7]



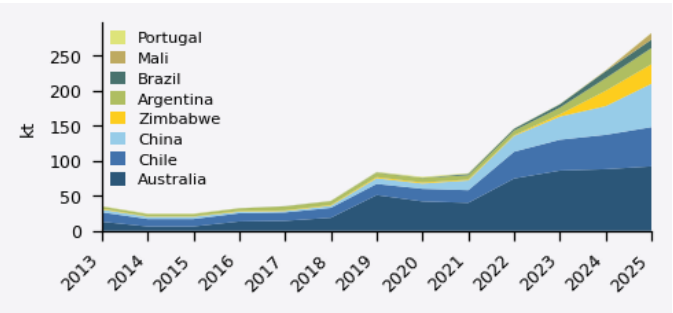
Critical Materials Definition

- The Energy Act of 2020 defines critical materials and minerals as those that serve an essential function in manufacturing and have high risk of supply disruption, with significant consequences for the U.S. economy or national security.[8]
- In 2022, USGS published a list of 50 critical minerals, expanding the list to 60 in 2025.[9] The U.S. is 100% import-reliant for 11 critical minerals and >75% import-reliant for another 10.[1]
- The 2023 critical materials list published by the U.S. DOE included 18 critical materials for energy, and 50 critical minerals determined by USGS. Among the DOE's critical materials for energy, one is not on the USGS list: electrical steel.[10] Metallurgical coal was added in 2025.[11]
- Critical materials for energy are determined based on short- and medium-term assessment[10] of supply risk and importance to the energy sector.[7]
- DOE identified that nickel, platinum, magnesium, SiC, and praseodymium become critical in 2025–2035, primarily for batteries and vehicle lightweighting.[7]
- The DOE's Critical Materials Innovation Hub focuses on increasing critical mineral supply, finding alternative materials, and enhancing recycling.[29]

Global Extraction

- Lithium is increasingly important for batteries in phones, laptops, and EVs.[13] The U.S., Argentina, Bolivia, and Chile hold 62.7% of global resources, while Australia, China, Chile, Zimbabwe, and Argentina produced 90% of world lithium in 2025.[1]
- China refines the majority of lithium: 70% of global supply whilst mining 22% of global supply in 2024.[3]
- Sodium-ion batteries are becoming an alternative to lithium-ion batteries in some applications. Sodium is not a critical material, and these batteries avoid lithium and graphite; however, they use other critical minerals such as nickel.[10,21]
- Sodium-ion batteries have 69-85% the energy density as lithium-ion batteries and perform better in colder environments.[21]
- Copper is key for electrical wiring and appliances.[14] At current production levels, existing resources may last 60 years. Extraction becomes more energy-intensive as ore quality decreases.[14]
- Top producers include Chile (23%), Congo (14%), Peru (11%),

World Lithium Production[1]



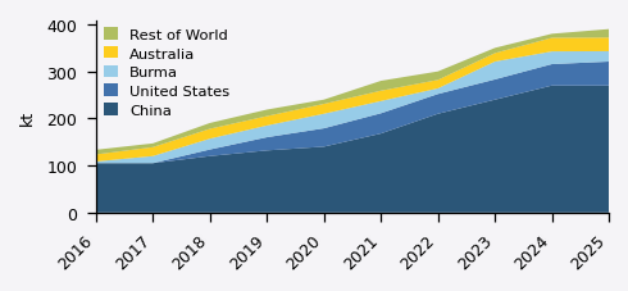
China (8%), Russia (6%), and the U.S. (4%).[1]

- Meeting increasing demand and electrifying vehicles would require mining 170% more copper from 2018 to 2050 than has been produced to date.[22] This would double the cost of copper.[26]
- Copper is unique in that it does not lose its physical and chemical properties when it is recycled;[15] in 2025, 30% came from recycled sources (17% post-consumer, 83% new manufacturing scrap).[1]
- REEs are an important group of critical minerals. Although moderately abundant in Earth's crust, they are distributed diffusely and difficult to extract in large quantities.[16]
- REEs are used in cell phones, energy-efficient lighting, magnets, EV batteries, and catalysts for automobiles and petroleum refining.[16]
- There are 17 REEs: the lanthanide elements (atomic numbers 57-71), scandium (Sc), and yttrium (Y).[17] The REEs neodymium (Nd), praseodymium (Pr), dysprosium (Dy) and terbium (Tb) are key components of the permanent magnets used in wind turbines and EV motors.[18] Substitutes for REEs are available but less effective.[13]
- Global mine production increased to an estimated 390 kt of REO equivalent in 2025, largely due to increased mining in the U.S., Thailand, Brazil, and Madagascar.[1]
- China produced 270 kt of REEs in 2025, 69% of global production, and holds reserves of 44 Mt.[1] The U.S. is the second-largest producer with 51 kt and reserves of 1.9 Mt.[1]
- The refining of REE is more concentrated than mining, with China refining 91% of all REE in 2025.[19]
- The U.S. used $613M of REEs in 2016, generating $496B in economic activity across other sectors, including oil refining, medical devices, and automotive manufacturing.[20]

Life Cycle Impacts

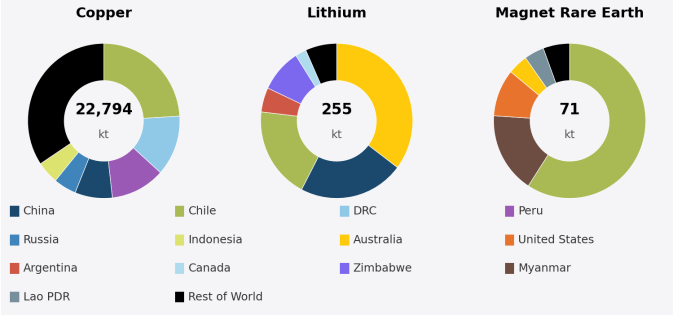
- Mining is a destructive process that disrupts the environment and widely disperses waste. Chemical compounds used in extraction can enter the air, surface water, and groundwater.[23]
- Grinding and crushing ore containing critical minerals often releases dust with carcinogenic and negative respiratory effects on exposed workers and neighbors.[23]

Rare Earth Oxide Production by Country[1]

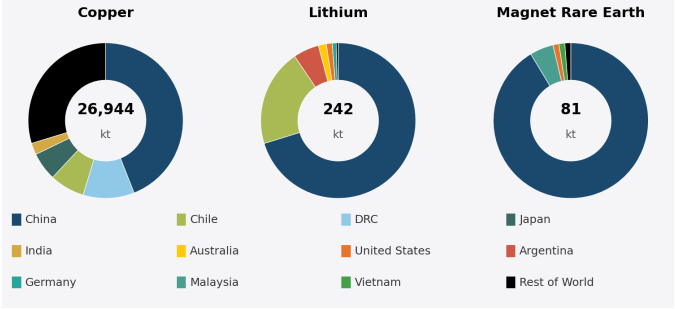


- Mining can negatively impact human rights. The Democratic Republic of Congo is the world's leading producer of cobalt, widely used in EV batteries, but child labor is routine due to lax regulation and oversight.[24]
- Many REE deposits contain thorium and uranium, which pose significant radiation hazards. While these elements can generate nuclear energy, they are rarely economically recoverable and remain in tailings, posing environmental and human health risks.[12]
- Recycling critical materials results in lower human health and environmental impacts than mining virgin material. However, improper recycling procedures in nations with lax or nonexistent worker protection regulations can lead to exposure to carcinogenic and toxic materials.[25]

Global Mining Rates in 2024[3]



Global Refining Rates in 2024[3]



Solutions and Sustainable Actions

- Recycle electronics. Metals recovered from cell phones, televisions, and computers can be effectively reused or recycled, though currently around 1% of REEs are recycled.[27]
- Buy refurbished rather than new products. Rent products from companies with take-back programs requiring material recycling.[12]
- Recent legislation expands federal support for domestic mineral extraction, appropriating $5B to the Department of Defense's Industrial Base Fund for critical mineral supply chain investment, plus $2B for strategic stockpiling.[28] However, it leaves some gaps unaddressed, repealing or phasing out measures that would increase processing and midstream capacity building while reducing electric vehicles and other technologies that support demand.[28]

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Sources for this factsheet are online, help with units and abbreviations is here. See css.umich.edu/publications/factsheets for other factsheets.