A Publication of The Council of State Governments **Southern Office**

Issue Brief

Mission Critical

The Vital Role of Rare Earth Elements to 21st Century Economies

CSG SOUTH

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Introduction

High-tech devices such as computers, smartphones, and tablets have become essential pieces of modern life, changing how we live and communicate. Critical minerals, such as nickel, cobalt, and lithium, and rare earth elements, such as europium, are crucial parts of many of these devices. This trend has led some energy experts to argue that while fossil fuels powered the global economy of the 19th and 20th centuries, **critical minerals will power the 21st century and beyond.**

In the United States, approximately 15,000 tons of critical minerals are consumed annually, with the vast majority sourced from other countries, including China and the Democratic Republic of the Congo.[i] China has become a significant player in the sector regarding the extraction and refining of critical minerals. **China's dominance of the critical minerals sector, which some have labeled a monopoly, creates vulnerabilities in the supply chain. In 2020, China produced 140,000 tons of rare earth elements, compared to 38,000 tons from the United States.**[ii] This dependence on China has inspired some countries and corporations to locate new sources of critical minerals or collaborate with other nations. Disruptions caused by the COVID-19 pandemic have further highlighted the fragility of global supply chains.

CHINA'S DOMINANCE OF THE CRITICAL MINERALS SECTOR, WHICH SOME HAVE LABELED A MONOPOLY, CREATES VULNERABILITIES IN THE SUPPLY CHAIN. IN 2020, CHINA PRODUCED 140,000 TONS OF RARE EARTH ELEMENTS, COMPARED TO 38,000 TONS FROM THE UNITED STATES.

The United States has worked to become more energy independent in recent years. Still, this move has largely ignored the role of critical minerals due to the environmental effects associated with their extraction. This ***CSG South Issue Brief*** discusses the history and importance of critical minerals and government actions to support and diversify the critical mineral supply chain.

Critical Minerals and Rare Earth Elements Basics

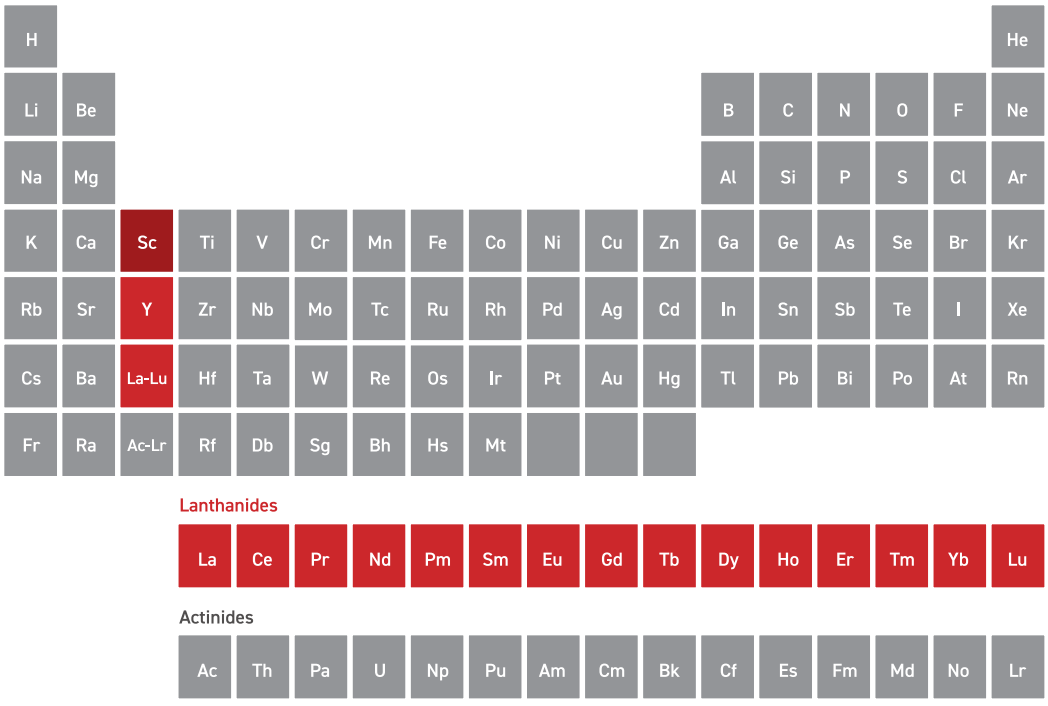
Critical minerals are a class of elements, substances, and materials essential to a nation. However, what qualifies as a critical mineral has changed over time. Recognizing their importance, the U.S. Department of the Interior (DOI) published the first official federal government list of critical minerals in 2018. The list featured 35 mineral commodities, including aluminum, cobalt, the rare earth elements group, titanium, uranium, and more.[iii]

In February 2022, the USGS released an update to the critical minerals list, adding nickel, zinc, and other minerals. The new draft contains 50 commodities, but most of the additions stem from listing rare earth elements individually instead of as a group. Nickel has become increasingly important due to its usage in EV batteries and stainless steel. Currently, the United States relies on foreign suppliers for approximately half of domestic nickel consumption. The only nickel mine presently operating in the United States, the Eagle Mine in Michigan, exports nickel concentrates for foreign refining.[iv,v]

The federal Energy Act of 2020 defined critical minerals as elements necessary to the economic or national security of the United States and have a supply chain vulnerable to disruption.[vi] Other countries and regions produce their own critical mineral lists, including Japan, the European Union, and Australia.[vii]

Rare earth elements (REEs), also known as rare earth metals, are a class of 17 elements[1] that are grouped together on the periodic table of elements. All 17 REEs are part of the DOI critical minerals list.[viii] Despite their name, REEs are not particularly rare. Thulium and lutetium, the rarest of the REEs, are nearly 200 times more abundant than gold. The name comes from the fact that REEs are usually not found grouped in high concentrations, which makes extracting and refining REEs more complex and less economical.[ix,x]

Figure 1. Rare Earth Elements



Source: Hobart King, Ph.D., "REE - Rare Earth Elements - Metals, Minerals, Mining, Uses," *Geology.Com*, accessed December 2, 2021, https://geology.com/articles/rare-earth-elements/.

[1] Yttrium, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium.

Critical Mineral Uses

Critical minerals and REEs are used in many products and devices, including airplanes, electricity generation and transmission systems, fluorescent lighting, catalytic converters, cell phones, nuclear reactor components, magnets, camera lenses, batteries, DVDs, computer disk drives, wind turbines, and solar panels.[xi,xii,xiii] Moreover, critical minerals are essential to the renewable energy sector. Since 2010, the average amount of minerals needed for a new unit of power generation has increased 50 percent as new energy sources, such as wind and solar, have become more prevalent.[xiv] An onshore wind farm uses eight times as many minerals as a gas-fired power plant with the same output.[xv]

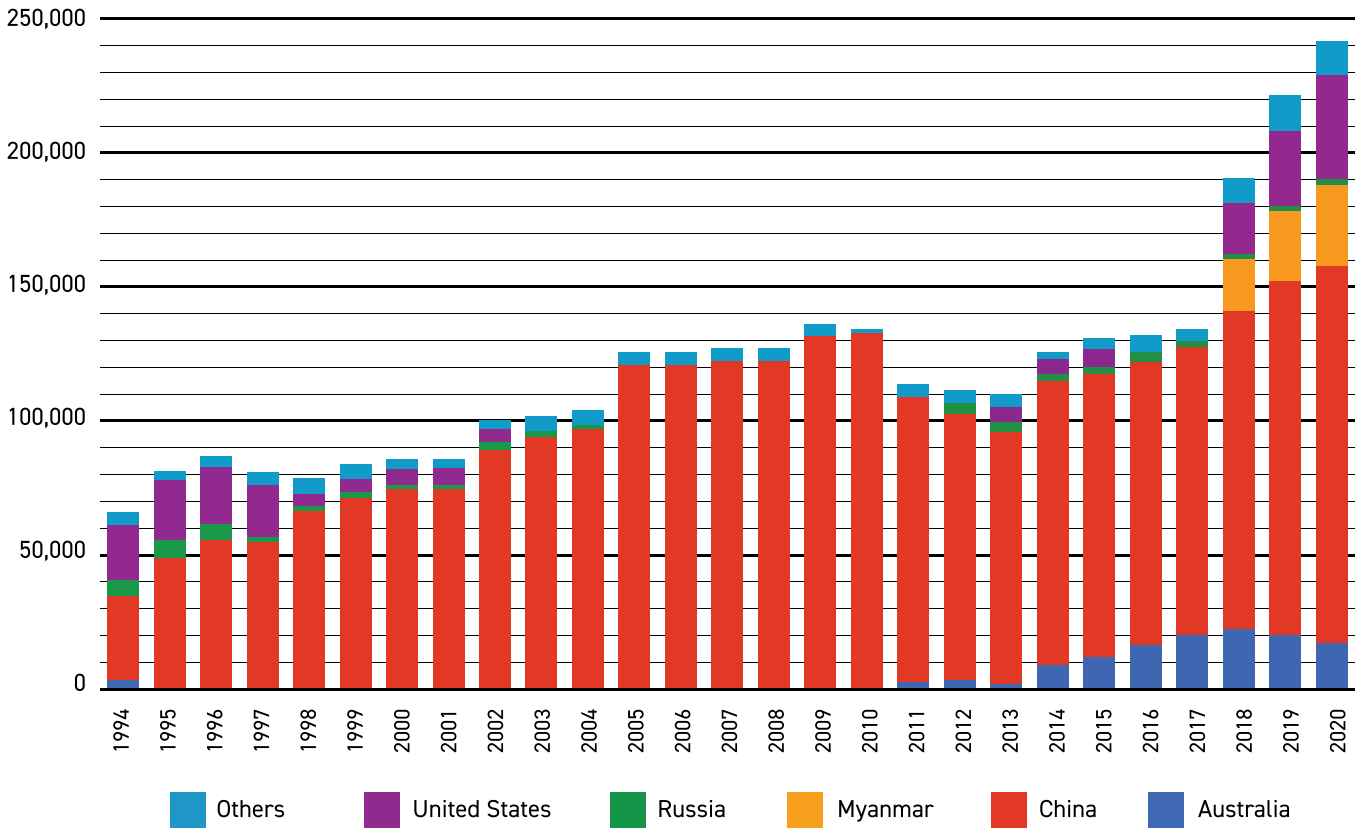
Critical minerals also are vital to electric vehicles (EVs). The average EV has five times as many minerals as an internal combustion vehicle.[xvi] EV batteries containing cobalt have a longer driving distance and a lower chance of overheating than batteries without cobalt.[xvii] This demand has caused the price of cobalt to increase dramatically, rising 500 percent between 2016 and 2018.[xviii] As sales of EVs and the use of renewable energy expands, analysts project that demand and prices for critical minerals will continue to increase. The annual global market for REEs is projected to rise 45 percent from 2019 to 2025.[xix] Furthermore, the International Energy Agency projects that demand for cobalt will exceed currently known supplies by 2030. [xx] Meanwhile, industry experts project that by 2030, auto manufacturers will spend $50 billion on lithium alone.[xxi]
In June 2021, the Biden administration warned that China might use its dominance over the critical minerals sector to prevent American companies from gaining ground in EV production. The White House claimed that most of the $100 billion in critical mineral subsidies administered by the Chinese government in the past 10 years were given to Chinese-based or state-owned companies. **These subsidies have allowed Chinese companies to dominate the production of critical minerals and thus outcompete domestic firms by offering critical minerals at lower prices to manufacturers.**[xxii] To combat this, the administration is advocating for American companies

to have greater access to cobalt reserves held by Australia, Canada, and other allies through increased trade.[xxiii] In the meantime, American auto manufacturers are building domestic EV battery factories. Kentucky, Tennessee, and Georgia will all open new manufacturing facilities for EV batteries in the next few years. At the same time, instability in cobalt supplies and rising prices have inspired some EV manufacturers to use recycled critical minerals or develop alternatives to cobalt, such as lithium iron phosphate substitutes.[xxiv]

Most importantly, rare earth elements are crucial to national security. The U.S. Department of Defense uses REEs for lasers, precision-guided munitions, communications and radar systems, avionics, night-vision equipment, satellites, range finders, and armored vehicles. Because of these uses and limited domestic supply, the United States is currently dependent on foreign sources of critical minerals to produce crucial military equipment.[xxv] This dependence on foreign sources comes with risks. In October 2020, China announced unspecified sanctions against Lockheed Martin, Boeing Defense, and other U.S. defense manufacturers after these companies agreed to sell defense equipment to Taiwan. This incident demonstrated the delicate balance between nations at the intersection of international trade and diplomacy.[xxvi] If the United States were to engage in conflict with a critical mineral-producing nation, this dependency could have disastrous consequences. To hedge against this, the United States has increased production of REEs since 2018, when the Trump administration began prioritizing domestic manufacturing, as seen in **Figure 2**. However, China still dominates the refining process.

Figure 2. Rare Earth Element Production

(Metric tons - rare earth oxide equivalent)



Source: Hobart King, Ph.D., "REE - Rare Earth Elements - Metals, Minerals, Mining, Uses," Geology.Com, accessed December 2, 2021, https://geology.com/articles/rare-earth-elements/.

History of Critical Minerals

The U.S. government has monitored supplies of critical minerals since at least World War II. In 1939, Albert Einstein urged President Roosevelt to secure more significant amounts of uranium from Belgian Congo, now the Democratic Republic of the Congo (Congo), for use in atomic bombs. In the years since, Congo has become one of the world's top suppliers of uranium, cobalt, copper, and other critical minerals. These minerals are so abundant in Congo that waste piles from abandoned mines there sometimes contain more cobalt and copper than active mines in other parts of the world.[xxvii]

During the 1950s and 60s, REEs were primarily used in medications and nuclear weapons.[xxviii] **In the 1960s, the demand for REEs grew with the invention of color television. Europium became a necessity due to its ability to produce color images.** The Mountain Pass Mine in California, a significant europium source, was the largest global REE mine throughout this period. From the 1950s to 1980s, the Carolina Tin-Spodumene Belt[2] in Gaston County, North Carolina, was the top global source of lithium, although significantly less lithium was mined then compared to today.[xxix] During this time, the United States was the leading producer of critical minerals, with europium as the driving factor.[xxx]

China entered the market in the 1980s and began selling REEs for less than the cost of production. American producers couldn't compete with lower Chinese prices spurred by cheap Chinese labor, leading many American companies to close sites[3] or shift their focus away from REEs. Some American communities were opposed to the environmental costs associated with critical mineral mining, including the high amounts of water consumed and the wastewater produced in the process.[xxxi,xxxii,xxxiii] **In 1986, China surpassed the United States as the top global producer of REEs, a position it has held ever since.**

By 2010, China dominated REE production, controlling nearly 95 percent of the global market. That same year, China suspended REE exports to Japan after Japan detained a Chinese fishing boat captain in a fishing dispute. China also restricted exports to other nations and raised prices for some minerals. Price increases ranged from 60 to 350 percent compared to a few years earlier. Some experts worry that the United States is ill-prepared if China were to suspend critical mineral exports like the Organization of Petroleum Exporting Countries' oil embargo of the 1970s.[xxxiv,xxxv]

BY 2010, CHINA DOMINATED REE PRODUCTION, CONTROLLING NEARLY 95 PERCENT OF THE GLOBAL MARKET.

In 2012, the United States, European Union, and Japan filed a complaint against China at the World Trade Organization (WTO), alleging unfair trade practices. The WTO sided with the United States and its allies, forcing China to alter its policies[xxxvi] Although costs eventually returned to pre-2010 levels, this near-monopolistic control inspired the United States and other nations to develop domestic mineral reserves and diversify their foreign sources. Today, California's Mountain Pass Mine is the only critical minerals site currently being mined in the United States.[xxxvii,xxxviii]

[2] Spodumene is a mineral composed of lithium aluminum inosilicate.
[3] A site is a location from which minerals are currently, or soon will be, extracted. These can be at surface level or underground.

How Are They Mined?

Critical minerals and REEs are found in low concentrations, usually a few hundred parts per million by weight, and must be separated from the surrounding materials. Because of this, the mining process can be messy, costly, and time-intensive. First, the rocks are mined and crushed into powder. Next, the powder passes through a series of water tanks where minerals rise to the top and waste sinks to the bottom. After this, the minerals are dried in a kiln and dissolved in acid. Finally, the hazardous wastewater is sent to evaporation ponds.[4] A single critical mineral mine can produce millions of gallons of wastewater annually. When the Mountain Pass Mine in California is operating at full capacity, it generates 850 gallons of salty wastewater per minute. Hazardous materials, such as thorium and uranium, can accrue in the pipes used to transport wastewater, posing potential leakage risks. In the 1990s, pipes used to transport wastewater from the Mountain Pass Mine burst, spilling hazardous materials in the area.[xxxix]

Brine pools for lithium mining

In the United States, a complex permitting process and other barriers often hinder the extraction of critical minerals. A new mining project may require multiple permits depending on the location, climatic conditions, and proximity to existing infrastructure. A new project must also align with applicable local, state, federal, and tribal regulations. Because of this complexity, applicants may mistakenly omit relevant information from their application, forcing them to apply multiple times before being approved. For sites covered by a federal land-use planning document,[5] a mineral assessment may be required to determine the presence and quantity of minerals in a location. A mineral assessment on federally owned lands can take two to three years to complete.[xl] One analysis found that it takes an average of 16.5 years from discovering a new deposit until the first minerals are extracted. On average, developers spend 12 years completing exploration and feasibility studies and four to five years constructing the mine.[xli] Domestically, at least four critical mineral facilities are currently under consideration in Minnesota, North Carolina, Georgia, and Texas.

In 2005, PolyMet Mining began the environmental review and permitting process for a new mine near Babbitt, Minnesota, that would extract copper, nickel, cobalt, palladium, platinum, and gold. PolyMet estimates that the mine would have a $1 billion economic impact and create 360 direct jobs and 600 indirect jobs in the area. The company claims that its work will be completed by 2072, and the site would need to be maintained for at least 200 years afterward to prevent environmental damage. By 2019, the site had received the relevant state and federal permits to operate for 20 years. However, several permits have been suspended or revoked due to legal challenges from a nearby Native American tribe and environmental groups. The start of mining operations is on hold until the cases are resolved.[xlii]

In North Carolina, Piedmont Lithium is seeking to resume lithium mining at the aforementioned Carolina Tin-Spodumene Belt. The company currently owns, leases, or holds options on approximately 1,500 acres in and around Gaston County. The site could potentially create 500 jobs but faces opposition from environmental groups, some community members, and County Commission members who worry that the site would cause ecological damage, noise, and increased traffic. The project would remove 800,000 to 1.3 million gallons of groundwater a

[4] An evaporation pond is a manmade pond designed to collect and evaporate water through sunlight and ambient temperatures.
[5] Examples of a land-use planning document include a comprehensive plan, general plan, or master plan created by a local, state, federal, or tribal government.

day from the local water table to reach the buried lithium, then deposit the water into local waterways, utilizing a new process that does not use sulfates or acid to extract the minerals. Due to local opposition, the company's deal to provide lithium to Tesla for use in their electric vehicle batteries is currently on hold.[xliii]

In 2019, Alabama-based mining company Twin Pines Minerals applied for state and federal permits to mine titanium at a site in Charlton County, Georgia. The project has faced fierce opposition from environmental groups due to its proximity to the Okefenokee National Wildlife Refuge and Swamp, the most significant blackwater wetlands in North America. The proposed site is 2.9 miles from the edge of the refuge. In 2020, the U.S. Army Corps of Engineers determined that the project did not require federal approval under the new Navigable Waters Protection Rule, which replaced the much stricter 2015 Waters of the United States Rule. As of this writing, the project is under review by the Georgia Environmental Protection Division. Government officials have received more than 100,000 public comments in opposition to the project. In response to public outcry, chemical company Chemours announced in February 2022 that it would not purchase titanium mined from the proposed Charlton County site or any other future project near the swamp.[xliv,xlv,xlvi,xlvii,xlviii]

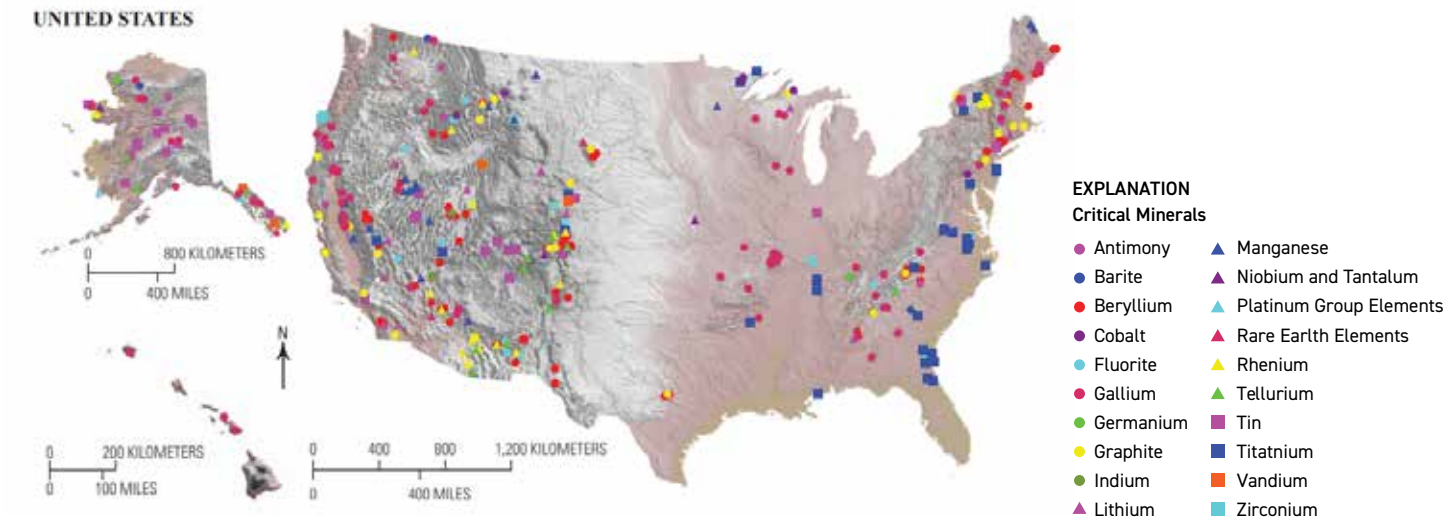
In February 2021, the U.S. Department of Defense awarded a $30 million grant to Lynas Rare Earths, Inc. to build two REE refinement facilities near Hondo, Texas. The new facilities, one for heavy elements and one for light, would be the first U.S. facilities to import REEs for refinement and could chip away at China's dominance of the REE refining sector.[xlix] The grant is part of the Defense Production Act (DPA) Title III technology investment agreement, which ensures the availability of essential domestic industrial resources to support defense and homeland security needs. Lynas hopes to process up to 25 percent of the world's REE oxides at the facility.[l]

CRITICAL MINERALS AND REES ARE FOUND IN LOW CONCENTRATIONS, USUALLY A FEW HUNDRED PARTS PER MILLION BY WEIGHT, AND MUST BE SEPARATED FROM THE SURROUNDING MATERIALS. BECAUSE OF THIS, THE MINING PROCESS CAN BE MESSY, COSTLY, AND TIME-INTENSIVE.

Processing plant at a lithium mine in Western Australia

Where are They Found?

Figure 3. Known U.S. Deposits of Critical Minerals



Base from National Oceanic and Atmospheric Administration ETOPO1 1 Arc-Minute Global Relief Model, 2017

Source: "Critical Minerals Mapping Initiative (CMMI)," U.S. Geological Survey, August 4, 2021, https://www.usgs.gov/centers/gggsc/science/critical-minerals-mazpping-initiative-cmmi.

As seen in **Figures 3 and 4**, critical minerals are found worldwide, including locations in the United States. Because of the aforementioned dangers, some Americans are hesitant to support a new mine in their community. Consequently, **China and other countries with lax labor laws and limited environmental regulations have been the top producers in the 21st century.** In some cases, three or four nations account for more than 75 percent of a mineral's global production (see **Figure 5**).[li]

China is the world's leading producer of many critical minerals and is the largest source for 10 of the 35 critical minerals identified by the U.S. Department of the Interior. In 2019, China produced 62 percent of global REE raw materials; that same year, the United States produced 12.2 percent. While Beijing has prioritized locating domestic critical mineral deposits, U.S. efforts have been hampered by a lengthy review and permitting process not present in China. China also has greater refining capabilities than the United States, with numerous Chinese facilities processing foreign and domestic minerals. Because of these factors, in 2018, the United States imported 98 percent of processed REEs from China.[lii,liii,liv,lv]

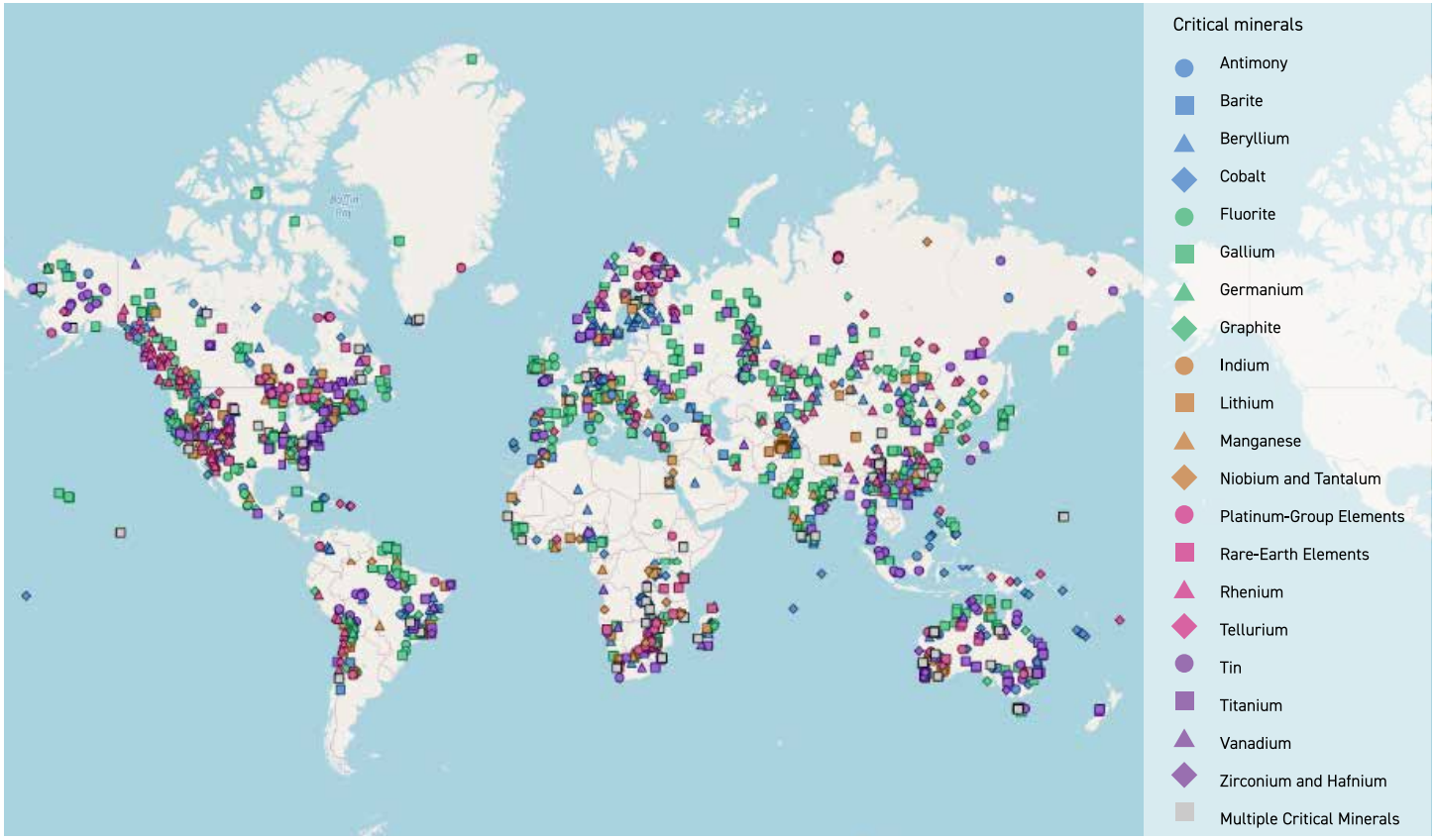
The Democratic Republic of the Congo, known for its human rights abuses and corruption, accounts for 70 percent of the world's cobalt production. In Congo, dangerous working conditions, including child labor, have inspired some observers to refer to cobalt as the "blood diamond of batteries."[lvi] The demand for cobalt is so great that "artisanal miners," those not employed by a mining company, who use simple tools and have no formal training, account for one-fifth of Congolese cobalt extraction.[lvii] Congo has been a top source of cobalt for many Chinese companies—15 of the 19 working cobalt mines in Congo are owned or financed by Chinese companies.[lviii]

Finely ground coltan ore, widely used in most modern technology

CHINA AND OTHER COUNTRIES WITH LAX LABOR LAWS AND LIMITED ENVIRONMENTAL REGULATIONS HAVE BEEN THE TOP PRODUCERS IN THE 21ST CENTURY. IN SOME CASES, THREE OR FOUR NATIONS ACCOUNT FOR MORE THAN 75 PERCENT OF A MINERAL'S GLOBAL PRODUCTION.

Russia, another geopolitical rival of the United States, holds approximately 10 percent of global untapped REE deposits and is home to roughly 13 million tons of REEs. The Russian government wants to access these deposits to decrease the country's dependence on Chinese exports. To do this, Russia is reducing mining taxes and offering low-interest loans to investors for select projects. If successful, Russia could increase REE production from approximately 3,000 tons per year to 7,700 tons annually and could become self-sufficient by 2025.[lix,lx]

Figure 4. Global Distribution of Critical Minerals



Source: "Mineral Resources Online Spatial Data," Mineral Resources Data, U.S. Geological Survey, accessed December 20, 2021, https://mrdata.usgs.gov/general/map-global.html#home.

North America, China, and Australia are home to some of the world's largest known REE deposits, with India, Brazil, Malaysia, and South Africa having smaller reserves. China has the largest known supply and is the world's top producer of REEs. According to current estimates, China possesses approximately 36 percent of the global supply of REEs, while the United States has roughly 13 percent. **Domestically, REEs exist in California, Nebraska, Colorado, New Mexico, Texas, New York, Alaska, and Wyoming, although geologists believe other states may have unknown reserves.**[lxi]

DOMESTICALLY, REES EXIST IN CALIFORNIA, NEBRASKA, COLORADO, NEW MEXICO, TEXAS, NEW YORK, ALASKA, AND WYOMING, ALTHOUGH GEOLOGISTS BELIEVE OTHER STATES MAY HAVE UNKNOWN RESERVES.

Figure 5. Top Producers of Key Critical Minerals

Top Producers of Cobalt, 2020

Nation	Thousands of Tons Extracted	Market Share
Democratic Republic of the Congo	94.6	67.3%
Australia	6.2	4.4%
Zambia	4.7	3.3%

Top Producers of Lithium, 2020

Nation	Thousands of Tons Extracted	Market Share
Australia	44.0	46.4%
Chile	22.7	23.9%
China	15.4	16.2%

Top Producers of Natural Graphite, 2020

Nation	Thousands of Tons Extracted	Market Share
China	715.5	71.7%
Brazil	104.7	10.5%
India	37.5	3.7%

Top Producers of Rare Earth Elements, 2020

Nation	Thousands of Tons Extracted	Market Share
China	154.3	52.3%
Australia	45.6	15.5%
United States	41.9	14.2%

Source: "BP Statistical Review of World Energy 2021," BP, accessed January 25, 2022, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf.

Pandemic Supply Chain Interruptions

In January 2020, the World Health Organization identified the first cases of COVID-19 in Wuhan, China. In addition to the millions of deaths and illnesses caused by COVID-19, the pandemic disrupted the global supply chain, including the critical minerals sector. Many countries and companies stopped operating as COVID-19 spread across the globe. These disruptions exposed the weaknesses of the "just in time" production model that dominates the global supply chain. Under a "just in time" production model, manufacturers, wholesalers, and other suppliers order materials only when needed and keep only limited inventories. With this approach, companies reduce the need for warehouses to store goods and supplies, thus saving money.[lxii] **A global slowdown of computer microchip production in 2020 delayed the production of vehicles, computers, household appliances, and other devices. A similar downturn in critical mineral production could have disastrous consequences.**

Federal Government Actions

While the federal government has taken numerous actions related to critical minerals dating back to at least World War II, this report focuses on federal activities in the past six years. The Trump administration was particularly active on critical mineral policy, issuing several executive orders and reports and highlighting the issue's importance in public speeches. The Biden administration has continued many of these efforts during its tenure in the White House.

Executive Orders and Federal Reports

Issued by President Trump in December 2017, Executive Order 13817 (E.O. 13817) outlined potential approaches to make the United States less reliant on foreign sources of critical minerals. According to the order, a lack of reliable data, coupled with challenges securing mining permits, makes the extraction of domestic minerals difficult or cost-prohibitive. Because of these challenges, domestic critical mineral reserves remain untapped. Additionally, the order instructed the federal government to reduce dependence on foreign sources by identifying new domestic sources; increasing exploration, mining, recycling, and reprocessing; ensuring that mining companies have access to comprehensive geological data; and simplifying the permitting process for new mines. The order required the U.S. Department of the Interior (DOI) to publish a list of critical minerals in the Federal Register; directed the federal government to promote the domestic extraction of these minerals; and ordered the U.S. Department of Commerce to create a national strategy working toward these goals.[lxiii]

Following the order, the DOI released a draft list of critical minerals and sought public comment in February 2018. After receiving 435 public comments, the Secretary of the Interior released the final list of critical minerals in May 2018. The list includes aluminum, cobalt, lithium, the rare earth elements group, uranium, and 30 other minerals.[lxiv] See the **Appendix** for the complete list.

In June 2019, the Department of Commerce published A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals (Federal Strategy). The report issues several calls to action for the federal government regarding

critical minerals: expand the research and development strategy; diversify sources; encourage their recycling; develop substitutes; strengthen the supply chain and defense industrial base; enhance mineral trade and cooperation; improve access to domestic minerals on federal lands; reduce federal permitting timeframes; and grow the domestic critical minerals workforce.[lxv] The report notes that the United States is import-reliant for 31 critical minerals[6] and highlights 14 minerals with no domestic source.[7] According to the report, if China or Russia halted critical mineral exports, the U.S. would experience significant shortages.[lxvi]

Issued in September 2020, Executive Order 13953 (E.O. 13953) declared a national emergency regarding critical mineral import reliance. The Trump administration found that the United States relies on imports for more than 75 percent of barite, 100 percent of gallium, and 100 percent of graphite consumed domestically. Barite is critical to the hydraulic fracturing industry. Light-emitting diodes (LEDs), diode lasers, and 5G telecommunications equipment use gallium. Graphite is crucial to cellphone batteries, laptop computers, and hybrid and electric vehicles.[lxvii] The order instructs various executive branch agencies to recommend potential solutions to the United States' critical mineral import reliance. Additionally, the order directs several executive branch agencies to expedite critical minerals mining permits and reuse historic and abandoned mining sites to expand access to domestic critical minerals.[lxviii]

The U.S. Department of Energy's (DOE) Strategy to Support Domestic Critical Mineral and Material Supply Chains (January 2021) highlights three overarching objectives: diversifying supply, developing substitutes, and improving the reuse and recycling of critical minerals. Goals related to these objectives include: developing a supply chain that is sustainable and not dependent on foreign adversaries; improving the mapping of mineral deposits; increasing the domestic mineral workforce; and partnering with international allies and other federal agencies to promote the use of best practices for sustainable mining and refining.[lxix] **The DOE is working to accomplish these goals by producing critical minerals from alternative sources such as coal and coal byproducts; creating new rare earth separation methods; developing new magnet alloys and components to limit the need for critical minerals; recovering rare earth magnets from hard disk drives; and developing new techniques to reuse recycled magnets.**[lxx]

In February 2022, the Biden administration announced the formation of a study committee to recommend updates to the General Mining Law of 1872 that governs mining on federal public domain lands to promote greater domestic mining. The administration also awarded a $35 million grant to MP Materials, the owners of the Mountain Pass Mine, to process REEs in the United States. MP Materials plans to invest $700 million of its funds to build a new facility that they hope will begin refining REEs in California by the end of 2022. The company says that the new facility will create more than 350 jobs and refine enough REEs to build 500,000 electric vehicles by 2025. Additionally, the administration ordered the Pentagon to increase its reserves of critical minerals and issued a Request for Information for the design, construction, and operation of a new facility to extract critical minerals from coal waste and ash.[lxxi]

Continuing its work on the issue, the Biden administration approved the use of the Defense Production Act (DPA) regarding at least five critical minerals in March 2022. The White House instructed the U.S. Department of Defense to consider lithium, cobalt, graphite, nickel, and manganese as crucial to national security under the DPA. The order directs the Department of Defense to prioritize new projects related to the discovery, extraction, and processing of domestic critical minerals. No new funding was announced with the order. The Department is allowed to keep as much as $750 million in its Defense Production Act Fund.

Federal Legislation and Initiatives

In 2019, Australia, Botswana, Canada, Peru, and the United States signed on to the U.S.-led Energy Resource Governance Initiative (ERGI) to create and share best practices for the international mining sector.[lxxii] The ERGI's three primary objectives are promoting responsible and sustainable minerals governance among resource-rich nations, supporting integrated and resilient supply chains, and meeting increased demand for renewable energy technologies.[lxxiii]

[7] Arsenic, cesium, fluorspar, gallium, graphite, indium, manganese, niobium, rare earths group, rubidium, scandium, strontium, tantalum, and vanadium.

Growing out of the ERGI, the United States and Canada finalized the U.S.-Canada Joint Action Plan on Critical Minerals Collaboration in January 2020. Under the agreement, the United States and Canada will develop secure supply chains; improve information sharing; work more closely with the private sector; collaborate with other nations; develop supply chain models; and increase support for the mining industry.[lxxiv] Canada supplies the United States with 13 critical minerals and is the largest source of four. Although Canada does not currently produce rare earth elements, it plans to utilize its national reserves in the future.

The U.S. Geological Survey (USGS) is working with states to discover new domestic critical mineral reserves. In September 2020, the USGS announced projects that received grant funding under the Earth Mapping Resources Initiative (Earth MRI), a partnership between the USGS, state Geological Surveys, and the private sector. Under this grant, projects in 33 states received funding to improve shallow and deep geology mapping: $2.3 million went to state Geological Surveys for new mapping; $3.1 million for new aerial geophysical survey projects[8] in nine states; and 27 state Geological Surveys received a total of $762,000 to map critical mineral resources. This data helps geologists discover locations likely to have other minerals. Additionally, Earth MRI allocated $2.7 million for geophysical surveys conducted by private sector companies in Alaska, Colorado, Illinois, Kentucky, Minnesota, Missouri, New Mexico, North Carolina, Texas, and Virginia.[lxxv] **Figure 6** displays Earth MRI funding to Southern states.

The federal government's second COVID-19 pandemic relief bill, passed in December 2020, codified many of the Trump administration's executive orders related to critical minerals and allocated $800 million to fund minerals research. The legislation also directs the USGS to forecast demand for critical minerals and requires more geological surveys on federally owned lands.[lxxvi]

Figure 6. U.S. Geological Survey Earth Mapping Resources Initiative Funds to Southern States

State	FY 2019 MRI Funds	FY 2020 MRI Funds	Receiving Agency/Agencies
Alabama	$133,160	$0	Geological Survey of Alabama
Arkansas	$135,000	$0	Arkansas Geological Survey
Florida	$710	$100,000	Florida Dept. of Environmental Protection, Florida Geological Survey
Kentucky	$109,630	$75,000	University of Kentucky, Kentucky Geological Survey
Missouri	$34,973	$135,000	Missouri Dept. of Natural Resources
North Carolina	$159,928	$23,000	North Carolina Dept. of Environmental Quality, North Carolina Geological Survey
South Carolina	$146,161	$0	South Carolina Dept. of Natural Resources, South Carolina Geological Survey
Texas	$35,000	$134,453	University of Texas at Austin, Texas Geological Survey
Virginia	$159,931	$20,350	Virginia Dept. of Mines, Minerals, and Energy
West Virginia	$9,301	$125,000	West Virginia Geological & Economic Survey
Total	**$923,794**	**$612,803**	

Source: "USGS Earth Mapping Resources Initiative (Earth MRI) Funding to State Geological Surveys (FY2019 - FY2020)," U.S. Geological Survey, email communication from Alex Demas, January 31, 2022.

[8] Aerial geophysical surveys collect magnetic data to locate magnetic materials and gather radiometric data to find potassium, uranium, and thorium.

In November 2021, Congress passed the $1.2 trillion Infrastructure Investment and Jobs Act (IIJA) which provides funding for traditional infrastructure items, such as roads and bridges, and for areas such as the electric grid, electric vehicle charging stations, and fossil fuel projects. The legislation allocates $7 billion for improving the battery supply chain through increased critical mineral production and recycling and $3 billion for a new Battery Material Processing Grant to be awarded by the U.S. Department of Energy (DOE). Additionally, the IIJA instructs the DOE's Loan Program Office to invest in projects to increase the domestic supply of critical minerals.[lxxvii, lxxviii]

Pending Federal Legislation

In April 2021, Representative Lance Gooden of Texas sponsored H.R. 2688 to promote the extraction and use of domestic critical minerals. The bill would allow a new tax deduction for 200 percent of the cost of purchasing critical minerals mined in the United States and require the Department of the Interior to establish a grant program to develop critical mineral resources in the United States. The bill is pending before the House Ways and Means, Natural Resources Committee.[lxxix]

The American Critical Mineral Independence Act of 2021, sponsored by Representative Michael Waltz of Florida, would provide support for the U.S. supply of critical minerals, establish deadlines to complete environmental reviews of critical mineral projects on federal lands, and create requirements to expedite the review of these projects. The legislation is pending before the House Subcommittee on Antitrust, Commercial, and Administrative Law, under the purview of the House Judiciary Committee.[lxxx]

Also in 2021, Senator Lisa Murkowski of Alaska sponsored S. 1352 to expedite the federal permitting and review process for critical mineral reserves on federal lands. The bill would establish deadlines for the Bureau of Land Management and the Forest Service to complete these processes. The bill is pending before the Senate Energy and Natural Resources Committee.[lxxxi]

Several similar bills also are pending before the 2021-2022 Congress.

Ascend Elements battery recycling facility in Covington, GA

Innovation Spotlight

In January 2022, technology firm Ascend Elements, formerly known as Battery Resources, announced plans to open its first commercial-scale lithium-ion battery recycling facility in Covington, Georgia. The facility will open in August 2022 and is expected to be the largest of its kind in North America. The company was founded in Massachusetts in 2015 to turn all active battery materials into new batteries. The new facility will handle 30,000 metric tons of used lithium-ion batteries and scrap annually. The firm has also created a process to turn spent batteries into nickel-manganese-cobalt cathodes, used in electric vehicle batteries. The site location was unveiled weeks after electric vehicle manufacturer Rivian announced the opening of its new factory a few miles away in Social Circle, Georgia.[lxxxii,lxxxiii]

State Government Actions

To date, the federal government has been more active regarding critical minerals policy. However, a few states have considered mineral extraction and recycling laws. The limited state action provides an opportunity for legislatures to promote the extraction, processing, and use of critical minerals with or without assistance from the federal government. This section reviews recently enacted and introduced legislation from select states as of February 1, 2022.

99.9% fine titanium

Georgia

House Bill 1289, introduced in February 2022, would prevent the state's Environmental Protection Division (EPD) from issuing, modifying, or renewing any mining permit on the "geological feature known as Trail Ridge." HB 1289 is in direct response to the proposed titanium mine in Charlton County, Georgia. The bill has Republican and Democratic sponsors and has been referred to the Natural Resources and Environment committee. Should the bill pass, the project could still proceed if EPD approves the permit application before the bill takes effect on July 1, 2022.[lxxxiv] The Office of Governor Brian Kemp declined to comment on HB 1289 but declared February 8 as Okefenokee Swamp Day.[lxxxv]

Missouri

In November 2021, the Missouri Department of Natural Resources requested $134,000 in funding for fiscal year 2023 to help locate potential critical mineral deposits in the state.[lxxxvi] The allocation is included in Governor Parson's fiscal year 2023 proposed budget, which is under review by the General Assembly. These funds would supplement a $135,000 federal grant that the state received in September 2020 under the U.S. Geological Survey's Earth Mapping Resources Initiative. The grant funds were awarded to conduct an aerial survey of potential deposits in eastern Missouri.[lxxxviii] To date, geologists have located deposits of 14 critical minerals in the state.[lxxxix]

99.9% fine cerium

Photovoltaic modules in solar panels

Washington

The Washington State Legislature enacted House Bill 2645 (2020) to create a Photovoltaic (PV) Module Stewardship and Takeback Program, which would recycle and reuse photovoltaic modules that contain critical minerals. The program will be financed by companies that manufacture PV modules and was initially scheduled to start in 2022. In 2023, companies that manufacture, distribute, sell, and install modules would be required to submit a stewardship plan and receive approval from the Department of Ecology before selling PV modules.[xc] However, in 2021, House Bill 1393 delayed the start of important dates for the Takeback Program. Under the new law, manufacturers are required to submit their stewardship plan by July 1, 2024; submit an annual report to the Department of Ecology by April 1, 2026; and receive approval from the Department before selling PV modules starting on July 1, 2025.[xci]

West Virginia

Researchers at West Virginia University (WVU) are converting acid mine drainage, a pollutant associated with mining, into critical minerals. Acid mine drainage is created when surface and subsurface water interacts with rocks containing sulfur-bearing minerals. This toxic drainage can be harmful to humans, animals, and plants.[xcii] WVU's Water Research Institute is working with the state Department of Environmental Protection (DEP) to build a facility that will treat the acidic water and harvest critical minerals in the process. Once operational, the new facility will produce clean water and one ton of rare earth element and critical mineral concentrate each year. The facility is tentatively scheduled to open in May 2022. If successful, this model could be followed in other states.[xciii,xciv]

West Virginia legislators have introduced several bills in the 2022 legislative session related to critical minerals and WVU's work. House Bill 4003 would allow the DEP or its designee to sell all chemical compounds stemming from acid mine drainage in the state to offset the costs to maintain the state's water quality. Revenue received from these sales would be deposited in the state's Special Reclamation Water Trust Fund or the Acid Mine Drainage Set-Aside Fund.[xcv] House Bill 4025 would exempt the extraction, production, and sale of rare earth elements from property and severance taxation in the state for a maximum of five years.[xcvi] House Bill 4075 would make rare earth elements and other critical minerals subject to salvage value valuation—assessed at 5 percent of the original cost—for tax purposes.[xcvii] The Rare Earth Element and Critical Mineral Investment Tax Credit Act of 2022 (H.B. 4088) would create a 10-year tax credit offsetting personal income and corporation net income taxes for qualified rare earth element and critical mineral investments. The bill also would give rulemaking authority to the DEP regarding REEs extracted from acid mine drainage. These bills have been referred to the relevant House committees.[xcviii,xcix]

Acid mine drainage

Wyoming

Wyoming's 2020 to 2022 biennial state budget appropriated $80,000 to the state Geological Survey to identify critical mineral deposits. Of this funding, $50,000 is allocated for the use of an aeronautical magnetometer,[9] earth magnetic resonance imaging, and light detection evaluation to locate minerals. This amount is conditioned upon the availability of federal matching funds.[c]

In 2021, Senate File Number 0043[10] amended the duties of the Wyoming Energy Authority to include supporting efforts to expand the extraction of critical minerals—including REEs – and work with the private sector to boost the production of devices containing critical minerals. The legislation also codified official definitions for critical minerals and REEs. It authorized the state Energy Authority to issue bonds to finance facilities and projects related to the production and utilization of critical minerals.[ci]

Natural vanadium

[9] An aeronautical magnetometer is a sensor that measures magnetic induction (magnetic field intensity).
[10] Bills in the Wyoming Senate are called "Senate Files."

Conclusion/The Road Ahead

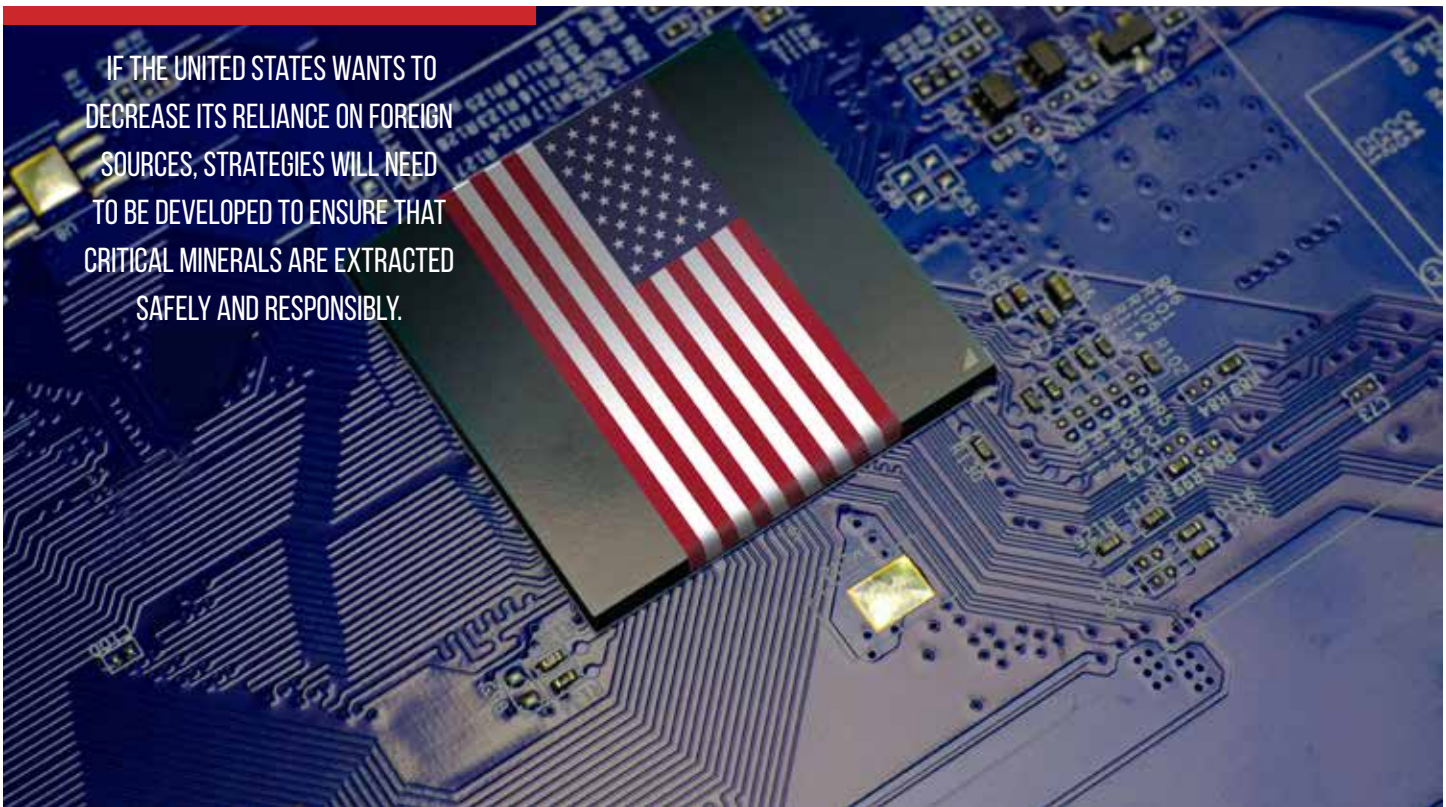
Critical minerals are vital components of the high-tech devices that have become a staple of modern life. **As consumers have become more reliant on smartphones and computers, demand for critical minerals has skyrocketed. Unfortunately, U.S. production of critical minerals has been minimal in the past 30 years.** This has fostered a dependence on foreign sources of minerals, such as China and the Congo. The need for critical minerals will remain until replacements emerge, which could be years away. Increased domestic mining could boost employment and reduce dependency on foreign sources. However, there are environmental risks associated with mining. **If the United States wants to decrease its reliance on foreign sources, strategies will need to be developed to ensure that critical minerals are extracted safely and responsibly.** The private sector will need guidance from the public sector to achieve this.

The Trump and Biden administrations have prioritized developing the domestic critical mineral sector. Given the speed at which the federal government sometimes moves, state legislatures may wish to play a more active role in encouraging the identification, extraction, and processing of critical minerals.

There are steps that state governments can take to promote a stable supply:

- offering tax incentives to encourage new critical mineral mining ventures;
- simplifying the permitting process for new mines;
- making it easier for consumers to recycle devices containing critical minerals;
- encouraging the use of recycled critical minerals in state-funded projects;
- working with higher education institutions to provide scholarships to students majoring in geology or similar fields; and
- ensuring that state Geological Surveys have sufficient funding to identify existing critical minerals;

The federal COVID-19 relief bills and the recently passed $1.2 trillion Infrastructure Investment and Jobs Act have sent billions to state governments. The legislation prioritizes improving the battery supply chain and instructs the DOE's Loan Program Office to invest in projects to increase the domestic supply of critical minerals.[cii,ciii] These funds offer a potential opportunity for states to take on new projects. Now may be the perfect time to invest in critical minerals.



Appendix

Department of the Interior's 2018 Final List of Critical Minerals

"The United States is heavily reliant on imports of certain mineral commodities that are vital to the Nation's security and economic prosperity. This dependency of the United States on foreign sources creates a strategic vulnerability for both its economy and military to adverse foreign government action, natural disaster, and other events that can disrupt supply of these key minerals. Pursuant to Executive Order 13817 of December 20, 2017, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals," the Secretary of the Interior on February 16, 2018, presented a draft list of 35 mineral commodities deemed critical under the definition provided in the Executive Order. After considering the 453 public comments received, the Department of the Interior believes that the methodology used to draft the list remains valid and hereby finalizes the draft list of 35 critical minerals. The final list includes: Aluminum (bauxite), antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluorspar, gallium, germanium, graphite (natural), hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum group metals, potash, the rare earth elements group, rhenium, rubidium, scandium, strontium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium, and zirconium. This list of critical minerals, while "final," is not a permanent list, but will be dynamic and updated periodically to reflect current data on supply, demand, and concentration of production, as well as current policy priorities. This final list will serve as the Department of Commerce's initial focus as it develops its report to comply with Section 4 of Executive Order 13817."[civ]

Department of the Interior's 2022 Final List of Critical Minerals

"The Energy Act of 2020 directed the USGS to update the list of critical minerals, and the list is timely to provide guidance for use of the Bipartisan Infrastructure Law funds, both for the USGS and other agencies. The 2022 list of critical minerals includes the following:

- Aluminum, used in almost all sectors of the economy
- Antimony, used in lead-acid batteries and flame retardants
- Arsenic, used in semi-conductors
- Barite, used in hydrocarbon production.
- Beryllium, used as an alloying agent in aerospace and defense industries
- Bismuth, used in medical and atomic research
- Cerium, used in catalytic converters, ceramics, glass, metallurgy, and polishing compounds
- Cesium, used in research and development
- Chromium, used primarily in stainless steel and other alloys
- Cobalt, used in rechargeable batteries and superalloys
- Dysprosium, used in permanent magnets, data storage devices, and lasers
- Erbium, used in fiber optics, optical amplifiers, lasers, and glass colorants
- Europium, used in phosphors and nuclear control rods
- Fluorspar, used in the manufacture of aluminum, cement, steel, gasoline, and fluorine chemicals
- Gadolinium, used in medical imaging, permanent magnets, and steelmaking
- Gallium, used for integrated circuits and optical devices like LEDs
- Germanium, used for fiber optics and night vision applications

- Graphite, used for lubricants, batteries, and fuel cells
- Hafnium, used for nuclear control rods, alloys, and high-temperature ceramics
- Holmium, used in permanent magnets, nuclear control rods, and lasers
- Indium, used in liquid crystal display screens
- Iridium, used as coating of anodes for electrochemical processes and as a chemical catalyst
- Lanthanum, used to produce catalysts, ceramics, glass, polishing compounds, metallurgy, and batteries
- Lithium, used for rechargeable batteries
- Lutetium, used in scintillators for medical imaging, electronics, and some cancer therapies
- Magnesium, used as an alloy and for reducing metals
- Manganese, used in steelmaking and batteries
- Neodymium, used in permanent magnets, rubber catalysts, and in medical and industrial lasers
- Nickel, used to make stainless steel, superalloys, and rechargeable batteries
- Niobium, used mostly in steel and superalloys
- Palladium, used in catalytic converters and as a catalyst agent
- Platinum, used in catalytic converters
- Praseodymium, used in permanent magnets, batteries, aerospace alloys, ceramics, and colorants
- Rhodium, used in catalytic converters, electrical components, and as a catalyst
- Rubidium, used for research and development in electronics
- Ruthenium, used as catalysts, as well as electrical contacts and chip resistors in computers
- Samarium, used in permanent magnets, as an absorber in nuclear reactors, and in cancer treatments
- Scandium, used for alloys, ceramics, and fuel cells
- Tantalum, used in electronic components, mostly capacitors and in superalloys
- Tellurium, used in solar cells, thermoelectric devices, and as alloying additive
- Terbium, used in permanent magnets, fiber optics, lasers, and solid-state devices
- Thulium, used in various metal alloys and in lasers
- Tin, used as protective coatings and alloys for steel
- Titanium, used as a white pigment or metal alloys
- Tungsten, primarily used to make wear-resistant metals
- Vanadium, primarily used as alloying agent for iron and steel
- Ytterbium, used for catalysts, scintillometers, lasers, and metallurgy
- Yttrium, used for ceramic, catalysts, lasers, metallurgy, and phosphors
- Zinc, primarily used in metallurgy to produce galvanized steel
- Zirconium, used in the high-temperature ceramics and corrosion-resistant alloys."[cv]

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