OurEnergyPolicy

EARTHSHOT FOUNDATION

# Critical Mineral Supply Chains

TERRANAUT PROGRAMS

MINOLOGUES

Restoring Trust in Mining

August 2024

# Table of Contents

# Letters from Leadership

Earthshot Foundation hosted our first dialogues in 2008, declaring – we already know what we need to do – to protect and preserve our natural capital and livable planet. And how to do it – by accelerating the deployment of abundant, accessible, clean and affordable energy for all. A Terranaut® Dialogue begins with a Motive (why) and leads to a Mission (how). **Responsible, nature+ mining** is our motive as we explore the working definition for **true mining** and what it means to **restore trust in mining.** We are delighted to present the 2024 Minologues Series in collaboration with OurEnergyPolicy. The series convenes four cohorts of expert practitioners and stakeholders to discuss intelligent policy design across national security, supply chains, responsible mining and future-mining topics. The series finale will take place on October 7th in Washington, DC. This paper summarizes the consensus contributions from our second cohort. At Earthshot, we believe, "the aim of scientific work [and our work] is truth."

Chase Weir — Founder & Board Chair, the Earthshot Foundation

OurEnergyPolicy's mission is to bring experts together in civil, substantive dialogue to explore solutions to the energy challenges facing the United States. We have partnered with The Earthshot Foundation to explore the crucial questions regarding the availability of critical minerals for American energy needs in this Minologues Series. The Series is a nine-part program, and this paper contains the important insights and recommendations from a working session of leaders on critical mineral supply chains challenges. I want to thank our workshop participants and the staffs at OEP and Earthshot for their work on this document, and —consistent with OEP's non-partisan and open approach to addressing issues— I want to invite all energy stakeholders to read the paper carefully and contribute their views on this vitally important topic.

Bill Squadron — President, OurEnergyPolicy

# Executive Summary

What are critical mineral supply chains? They are the complex networks involved in the extraction, processing, manufacturing, and transportation of minerals essential for modern technologies, especially those required for batteries, renewable energy materials, electronics, defense, and other high-tech industries. Resilience in these supply chains is critical due to the integral role critical minerals play in strategic sectors, and the potential vulnerabilities associated with their supply.[1]

This is the second white paper from the 2024 Minologues, a Terranaut program dialogue series hosted by Earthshot Foundation and OurEnergyPolicy. Each workshop seeks to address challenges and opportunities from increasing demand for critical minerals – resources to produce the batteries, electric vehicles and new energy technology assets.

Many critical minerals face significant vulnerabilities in their supply chains. A highly concentrated supply chain that lacks diverse upstream and midstream sources is more susceptible to chokepoints that leave few, if any, alternatives. The level of influence over mineral extraction and processing by Foreign Entities of Concern (FEOCs) such as companies controlled by the People's Republic of China adds another layer of geopolitical vulnerability that makes critical mineral access a potential pawn in international conflicts.[2]

The lack of sufficient supply for many key minerals underscores the urgency for strategic investments in both mining and recycling. Economic viability for new mining projects is a serious challenge, however, with decreasing ore grades and regulatory hurdles making these projects often unappealing to financial markets. While supply chain diversification can increase the upfront costs of a project, it can enhance long-term resilience, which should make projects more attractive to investors.[3]

The constraints of existing transportation infrastructure – via water, rail and road – hinder efforts to enhance supply chain diversification with new mines and processing facilities.

Environmental and humanitarian concerns about mining practices in certain territories also are a factor; leading private sector companies are committing to sustainability goals, and they want to commit to ethical sourcing of their critical materials. To do so, these stakeholders require more reliable data and greater transparency in the supply chain of critical minerals. The scarcity of pricing and source transparency contributes to price instability and makes it difficult for downstream companies to ensure their components were produced with the ethical standards they seek.

To strengthen supply chain resilience and mitigate risks associated with mineral supply chains, the cohort recommends the following:

1. Implement Full-Value Mining To Maximize the Yield From Existing Mines
2. Expand the 45x Tax Credit To Apply to New Mining Projects
3. Increase Proactive, Cooperative Infrastructure Planning To Address the Transportation and Power Needs of Mineral-Related Facilities
4. Engage in Enhanced International Efforts to Provide More Reliable Data and Pricing Transparency, and Establish Trusted Supply Networks
5. Implement Material Standardization To Facilitate Qualification and Create Greater Market Reliability

By implementing these recommendations, governments and industry stakeholders can work together to address supply chain challenges and ensure a stable and sustainable supply of critical minerals.

# Introduction

In the quest for sustainable energy solutions to combat climate change and meet growing energy demands, the role of critical minerals cannot be overstated. From lithium for batteries to cobalt for electric vehicle motors, these minerals are essential for a low-carbon future.

As battery development, energy storage and vehicle electrification efforts intensify, understanding the challenges and opportunities inherent in these supply chains is paramount. By shining a light on the complexities of mineral sourcing, processing, and distribution, Earthshot Foundation and OurEnergyPolicy seek to inform decision-makers with empowering insights as they navigate this intersection of energy and minerals.

This report reflects the views of an expert working group on critical mineral supply chains. The working group members include experts from government, industry, think tanks, and academic institutions brought together to address the most prominent challenges in critical mineral supply chains and the opportunities available for their improvement.

This working group is the second installment of the 2024 Minologues, an in-depth series dedicated to addressing U.S. concerns over critical mineral accessibility for the energy transition. Hosted by the Earthshot Foundation and OurEnergyPolicy, the Minologues are supported with a generous grant from the Terranaut Dialogues program.

In this second chapter of the Minologues, the Supply Chains working group explores factors that contribute to supply chain vulnerabilities and ways to alleviate these risks through strategic planning and incentivization. It will build upon the foundation laid by the first chapter: "Critical Minerals & National Security," which discussed the convergence between energy security and national security. This chapter will focus on supply chain diversification and transparency; and the recommendations center on how to improve supply chain resilience.

# Supply Chain Challenges

## *Definition of Criticality*

Designation as a "critical" mineral facilitates access to certain government funding and expedited project permitting. The United States Geological Survey defines 50 minerals as "critical" based on their concentration risks, supply sufficiency and demand for their utilization in key technologies.[4] Its list is attached as Appendix A.

The OEP/Earthshot expert participants identified six principal areas of concern for critical mineral supply chains:

- Risks of Undue Concentration
- Available Supply
- Transportation Pathways
- Mineral Source Visibility and Data Transparency
- Investment Risk and Economic Viability of Projects
- Environmental and Humanitarian Concerns

Each of these concerns is discussed further throughout this document.

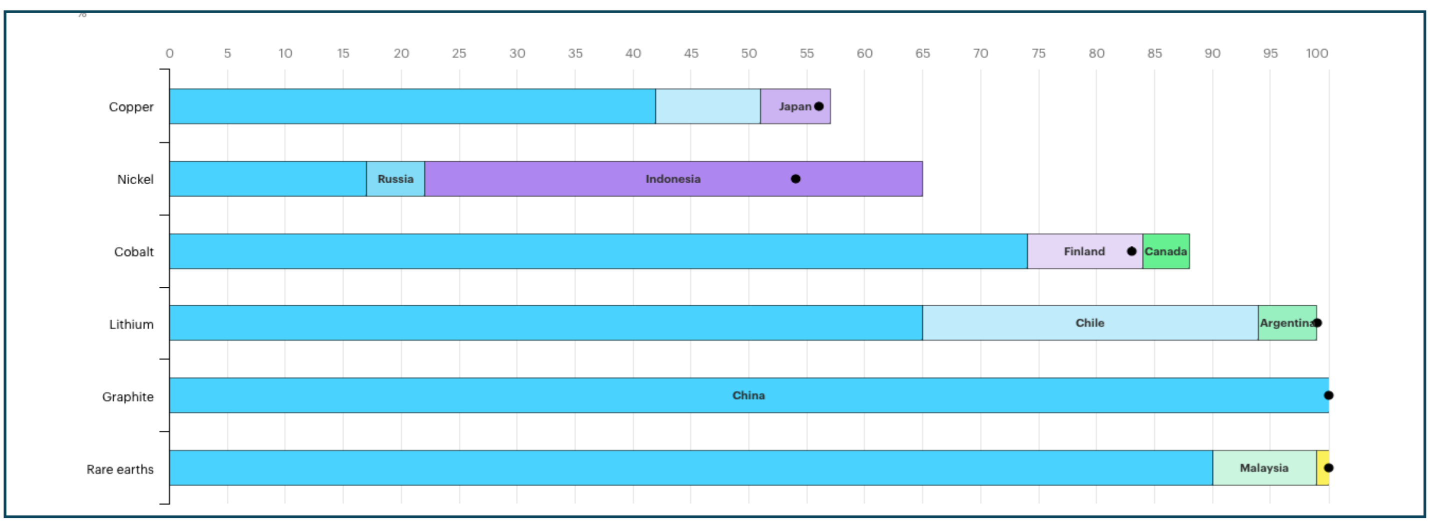
## *Concentration Risks*

While minerals essential to batteries and to wind and solar equipment – such as lithium, copper, cobalt and nickel – are widely distributed throughout the earth's crust, they are disproportionately extracted and processed in just a few countries, particularly the Republic of China. Reliance on such limited sources creates an unhealthy vulnerability.[5]

The 2022 Bipartisan Infrastructure Law establishes tax and other incentives not to obtain source materials that are provided by so-called "Foreign Entities of Concern," which are organizations that are controlled by nations such as China, Russia, Iran and North Korea. The law reflects the broader objective of promoting diversification of extraction and processing options and reducing the current reliance on these undependable sources.[6]

The cohort felt strongly that efforts to expand the range of sources – both through additional domestic projects and collaboration with friendly foreign nations – are extremely important. While these

*Share of top three producing countries in processing of selected minerals, 2022*[16]




Source: IEA, Critical Minerals Market Review 2023 efforts may prove more costly in the short term, mining and processing diversification is vital for long-term resilience and economic security.[7]

## *Supply Tightness*

Projections indicate that the U.S. and the world face a significant shortage of many minerals that the energy transition will require. To illustrate, producing the amount of copper for anticipated renewable energy electrification by 2050 would necessitate six new copper mines annually for the next three decades.[8]

There is, therefore, a monumental need to increase mineral production, especially challenging since new mines can take as much as 20 years from initial exploration to production. In short, more mines for numerous elements are essential. This need will require policies that incentivize financing, streamline permitting, maximize recycling and spur innovative technologies.

## *Transportation Infrastructure*

Transporting minerals and heavy industrial materials from the mine to processing facilities and from there to manufacturing sites is a major challenge. While such transport today relies heavily on maritime and port infrastructure,[9] movement by rail and road also must factor into planning for the diversification and expansion noted above.

The lack of sufficient transportation infrastructure can restrict midstream companies in their project siting, often requiring locations close to mines or ports. Indeed, in the U.S., it is often more cost-effective to import materials from Asia through existing ports rather than develop inland possibilities where the sufficient rail and road infrastructure does not exist.[10] This paradox is not sustainable if the U.S. is to establish more robust mining and processing capability.

Moreover, the existing electric grid infrastructure can be a factor in siting new processing facilities. These energy-intensive operations may require enhancements to the power framework in the applicable region, which also requires significant advanced planning.[11]

The cohort emphasized that strategic planning for global diversification and enhanced supply include both the transport element and the grid infrastructure associated with new projects.

## *Source Tracing and Transparency*

Minerals and their derivatives often cross multiple borders and involve numerous intermediaries – traders, brokers and suppliers – before becoming a final product. The information regarding the path taken and the applicable prices is largely unavailable or unreliable.[12]

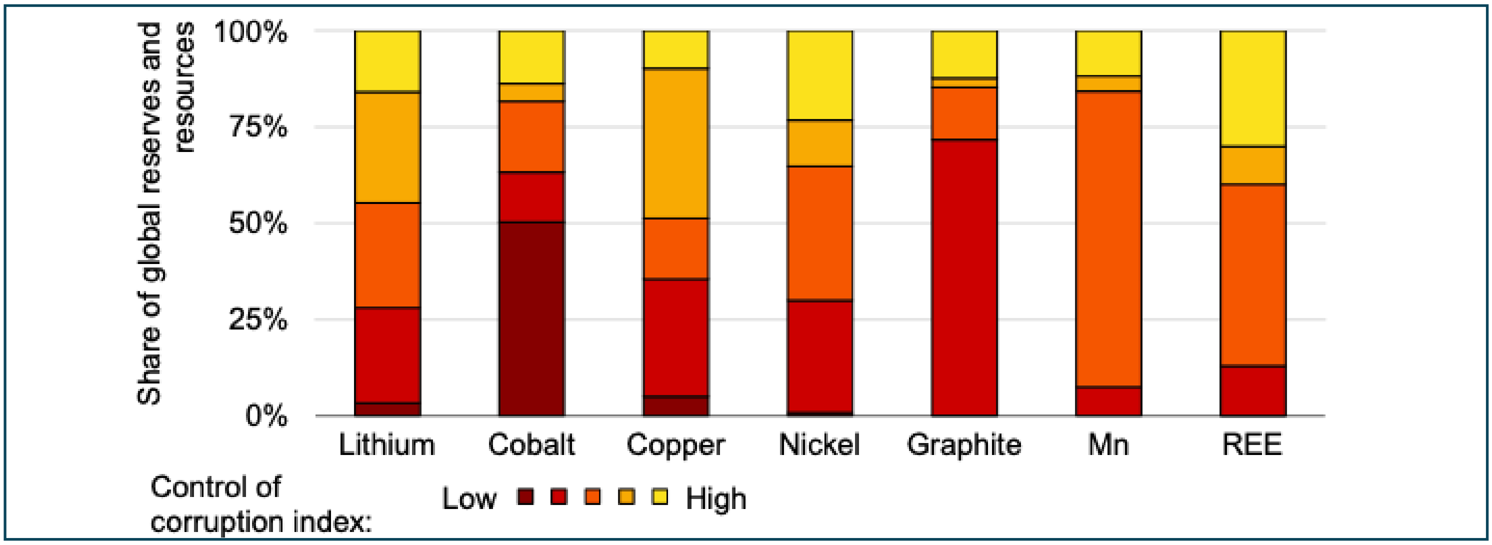
This lack of data and transparency leads to several significant supply chain problems. Policymakers require comprehensive and accurate data to make sound decisions. Financial firms require cost and pricing information to assess the risk associated with investing in a mining project. The many companies that wish to support secure and environmentally responsible sources for their materials and electricity require transparency in the multi-layered chain that ends at their facility; some of these companies are even willing to pay above-market pricing to encourage ethical sources.[13]

While some reasons for this opacity are understandable – such as companies not wishing to divulge competitively sensitive information – it is crucial to increase visibility into the entire chain of movement and to make available more accurate sourcing and pricing data. This will require diplomatic efforts and public-private cooperation, but the current uncertainties discourage sound decision-making (public and private) as well as project financing.

## *Project Financing*

To expand and diversify sources, new mines and processing facilities must be able to attract very sizable investments. This has become more challenging as exploration success has declined in recent years, while government-mandated permitting and mineral qualification processes are often lengthy, complex and daunting. In addition, price instability for numerous minerals, along with the lack of reliable data noted above, have created further deterrents for projects to secure financing.[14]

*Control of corruption index for global critical minerals reserves and resources*[17]




Source: IEA, Sustainable and Responsbile Critical Mineral Supply Chains

Government policies should seek to address this understandable risk-aversion regarding new mining projects. Some federal funding for supply chain-related efforts already exists, such as the grant program from the Department of Energy's Office of Manufacturing and Energy Supply Chains (MESC). Section 45x of the Inflation Reduction Act (IRA) provides a tax credit to promote the domestic production of clean energy components, but it does not currently apply to the mining activities that produce the minerals needed for these components; the cohort participants felt that extending the 45x credit to mining would be a very worthwhile step.[15]

In addition, government actions can improve data availability and transparency and streamline existing permitting and qualifications processes. Another aspect of mitigating financial risk is to assume some of the burden of the offtake agreements (pre-contracted buyers) often required by investors but which are not always possible for long-term projects.

## *Environmental and Humanitarian Concerns*

To meet projected demand, and enhance resiliency and economic security, more mines and processing facilities in the U.S. and allied countries are essential. These so-called Tier 1 jurisdictions recognize that local communities must be involved in the development of new sites, and that social and environmental impacts on those communities must be addressed.

The cohort observed that the government should provide more information about these projects to community leaders and must educate the public about the indisputable need for these minerals to support battery capability, vehicle electrification and the energy transition. The approval of or breaking ground on a mining project should receive positive recognition of its contribution to society in the same way that the opening of a battery or electric vehicle manufacturing plant is celebrated.

# Recommendations

The cohort's recommendations focused on supply chain diversification, stressing a strategic approach to reduce dependency on any single source or pathway, thereby minimizing risks associated with disruptions, enhancing flexibility, and improving overall resilience. The following recommendations will support diversification efforts.

## *1. Implement Full-Value Mining*

Many critical minerals are obtained as co-products and byproducts of mining operations targeting other minerals. Full-value mining is an extraction methodology that aims to extract the greatest value possible from orebodies by mining all potential minerals and reprocessing mining waste to recover as many valuable metals as possible. Given that a new mine takes decades to begin operations, transitioning currently active mining operations to full-value mining can help alleviate the pressure on new mining operations to meet rapidly increasing demand for critical minerals. Encouraging the comprehensive extraction of these materials will bolster supply chain diversification, security, and resilience.

## *2. Expand the 45x Tax Credit*

There is a need to provide additional incentives for capital sources to foster the construction of new mines and midstream businesses. Preferential tax provisions offer a more sustainable approach compared to direct government intervention in project financing. Expanding the IRA's Section 45x tax credit to cover extraction activities could significantly enhance the availability of capital for the upstream sector. This amendment to the 45x tax credit should also be crafted to apply to deployment of full-value mining, in addition to new mines.

## *3. Increase Proactive Infrastructure Planning*

Since building new midstream facilities becomes increasingly costly the further they are from established transportation hubs, expanding infrastructure for industrial transportation of high-density raw materials would expand opportunities for land-locked communities to participate in critical mineral supply chain diversification. These energy-intensive facilities also require proactive efforts to assure that the capacity of the regional electric grids can support the new processing and manufacturing activities.

This key action depends on cooperative efforts among federal, state and local government officials, as well as with the private developers of new projects. Whether applying for grants, loans, or other forms of assistance, companies introducing critical mineral-related initiatives must demonstrate a robust plan for transportation and power infrastructure and for sustainable integration. This comprehensive, collaborative and proactive approach is critical to the development of expanded domestic capabilities.

## 4. *Improve Data Availability and Establish Trusted Supply Networks*

Mineral provenance and pricing transparency are integral to the establishment of robust, reliable supply chains. These improvements can facilitate the ability of all stakeholders to make informed decisions, support responsible mining and unlock capital for the development of new mines and processing facilities around the globe.

As private industry attempts to comply with federal FEOC regulations and sourcing standards, supply chain traceability in the market is necessary. This will require increased efforts on international agreements with friendly nations and non-profit organizations to build accurate information frameworks and to induce, or require, companies to provide greater transparency.

In conjunction with this effort, establishing a trusted-supplier network could incentivize companies to buy from approved suppliers, reshaping purchasing behavior significantly. A comprehensive Defense Federal Acquisition Regulation Supplement (DFARS) list of secure suppliers would partially shift the burden of source tracing from private industry and support U.S. goals to reduce reliance on FEOCs in the U.S. economy.

## 5. *Adopt Material Standardization*

Satisfying material qualification requirements in the absence of standardization across product slates is a serious challenge to supply chain reliability, particularly when dealing with substituted materials. Government intervention can play a pivotal role in harmonizing qualification standards for critical minerals. By convening industry stakeholders, agreement on parameters for manufacturing inputs can be reached. This standardized approach would create guideline certainty, thus accelerating the qualification processes and expanding market opportunities by enabling broader acceptance of products. Enhancing alignment on qualification standards would also derisk projects and foster innovation.

# Signatories Page

This document represents the collective effort of the working group, reflecting a range of perspectives and contributions. Each participant retains the right to their own opinions and reservations regarding specific aspects of the white paper. Endorsement of this document does not imply unanimous agreement with all content but rather signifies support for the overall objectives of the working group.

---

Bill Squadron, President of OurEnergyPolicy

Chase Weir, Founder and Board Chair of the Earthshot Foundation

---

**Elisa Alonso**
U.S. Geological Survey

**Boris Chumack**
BHP

**Ruth Demeter**
U.S. Chamber of Commerce – GEI

**Kristen Hund**
The World Bank

**Abigail Hunter**
SAFE

**Todd Malan**
Talon Metals

**Travis Miller**
Google

**Matt Ross**
Roc Global

**Adam Simon**
Univeristy of Michigan

**Lauren Stowe**
U.S. Department of Energy

**Michael Toman**
Resources for the Future

**Karthik Valluru**
Boston Consulting Group

# Acknowledgements

We want to thank our working group participants for a dynamic, insightful discussion. This white paper reflects your expert contributions.

Our sincere appreciation goes to Jordan Crowe, Julia Saffer-D'Anna, Ina Gjika, Elizabeth Scarborough, Jenna Soroka, and Payton Corlew for their invaluable contributions to the working session and white paper.

Special thanks to the Earthshot Foundation for both sponsoring and conceptualizing this series.

# Notes

[1] Sun, Xiaoqi. "Supply Chain Risks of Critical Metals: Sources, Propagation, and Responses." Frontiers in Energy Research 10 (August 11, 2022). https://doi.org/10.3389/fenrg.2022.957884.

[2] IRENA (2023), Geopolitics of the energy transition: Critical materials, International Renewable Energy Agency, Abu Dhabi.

[3] Magdalena, Ricardo, Alicia Valero, and Guiomar Calvo. "Limit of Recovery: How Future Evolution of Ore Grades Could Influence Energy Consumption and Prices for Nickel, Cobalt, and Pgms." Minerals Engineering 200 (September 2023). https://doi.org/10.1016/j.mineng.2023.108150.

[4] Rowan, Linda. "Critical Mineral Resources: National Policy and Critical Minerals List." Washington: Congressional Research Service, April 8, 2024.

[5] Sun, Xiaoqi. "Supply Chain Risks of Critical Metals: Sources, Propagation, and Responses." Frontiers in Energy Research 10 (August 11, 2022). https://doi.org/10.3389/fenrg.2022.957884.

[6] Inflation Reduction Act: Pub. L. No. 117–58, 135 Stat. 429 (2021)

[7] "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals." Washington: U.S. Department of Commerce, 2021.

[8] Simon, Adam C., and Lawrence M. Cathles. "Copper Mining and Vehicle Electrification." Ann Arbor: International Energy Forum, May 2024.

[9] Verschuur, J., Koks, E.E. & Hall, J.W. Ports' criticality in international trade and global sup ply-chains. Nat Commun 13, 4351 (2022). https://doi.org/10.1038/s41467-022-32070-0

[10] Han, Zheng, and Hongtao Li. "Transportation Infrastructure and Trade." Japan and the World Economy 64 (2022). https://www.sciencedirect.com/science/article/pii/S0922142522000470.

[11] Aramendia, Emmanuel, Paul E. Brockway, Peter G. Taylor, and Jonathan Norman. "Global Energy Consumption of the Mineral Mining Industry: Exploring the Historical Perspective and Future Pathways to 2060." Global Environmental Change 83 (December 2023): 102745. https://doi.org/10.1016/j.gloenvcha.2023.102745.

[12] Schöneich, Svenja, Christina Saulich, and Melanie Müller. "Traceability and Foreign Corporate Accountability in Mineral Supply Chains." Regulation & Governance 17, no. 4 (May 19, 2023): 954–69. https://doi.org/10.1111/rego.12527.

[13] Schöneich, Svenja, Christina Saulich, and Melanie Müller. "Traceability and Foreign Corporate Accountability in Mineral Supply Chains." Regulation & Governance 17, no. 4 (May 19, 2023): 954–69. https://doi.org/10.1111/rego.12527.

[14] Jacobs, John. "Resilient Resource Reserve." Washington: Bipartisan Policy Center, July 2024.

[15] Inflation Reduction Act: Pub. L. No. 117–169, 136 Stat. 1818 (2022)

[16] IEA (2023), Critical Minerals Market Review 2023, IEA, Paris https://www.iea.org/reports/critical-minerals-market-review-2023, Licence: CC BY 4.0

[17] International Energy Agency (IEA) Office of Legal Counsel (OLC). "Sustainable and Responsible Critical Mineral Supply Chains: Guidance for Policy Makers." Washington: International Energy Agency, 2024.

# Appendix

**The 2022 list of critical minerals and their uses 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.

**Source: U.S. Geological Survey**