

What Makes a Mineral “Critical” for Defense Applications?

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When it comes to critical minerals used in defense applications—including dual-use technologies with both military and commercial functions—the prevailing narrative is clear: these minerals are essential to a range of military capabilities; China dominates many critical mineral supply chains; and, as a result, the U.S. faces vulnerabilities in its ability to sustain operations in defense of national security. Commentators often cite historical examples where restricted access to natural resources negatively impacted U.S. military efforts, such as copper and rubber shortages during WWII and more recent shortages of antimony linked to the war in Ukraine.¹

While it is plausible that over-reliance on Chinese-produced mineral inputs could degrade U.S. military capabilities—particularly in prolonged, large-scale operations—the conditions under which this would necessarily occur remain unclear.² To start, there is no consensus on which minerals are most critical to the defense sector. The table at the end of this document compares defense-critical minerals identified by several sources, including the Defense Logistics Agency (DLA), the European Commission’s Joint Research Centre, and two research and consulting firms. As the table shows, there is limited agreement across these sources.

These inconsistencies highlight several challenges in identifying which materials are most essential to military operations and present the highest risk under current sourcing conditions. First, many critical minerals are used across a wide range of military and dual-use applications, and it is often unclear which of these uses is most vital—or most likely to become a bottleneck during a prolonged conflict. Second, especially for advanced technologies, understanding exactly how and why a mineral is used, and the costs of substituting it, is not always straightforward. Moreover, in complex systems, tracing the origin of the minerals used is notoriously difficult. The default therefore is to assume minerals are being mined and processed by an adversary, which may not be the case. Lastly, disaggregating military from civilian consumption is a persistent challenge. This distinction is crucial for assessing whether commercial supplies could be redirected for military use during wartime, but data limitations make such analysis difficult. Even the DLA lacks sufficient data to model demand for many of the materials it stockpiles.³

In the sections that follow, I present four brief case studies of critical minerals identified as important to defense applications, to illustrate how these challenges affect assessments of mineral-related risks to U.S. defense capabilities.

¹ [Greg Wischer](#), “The U.S. Military and NATO Face Serious Risks of Mineral Shortages,” February 2024; [Bloomberg News](#), “Metal for bullets risks bigger shortage after near-300% surge,” March 2025; [Alexander Field](#), “The U.S. Synthetic Rubber Program and the Fall of Singapore,” February 2024.

² Other, more expansive definitions of national defense that go beyond the ability to carry out military operations have also been considered in the context of critical minerals (e.g. maintaining economic security or technical leadership). Here, I chose to focus on a much narrower definition of national defense.

³ [GAO](#), *National Defense Stockpile: Actions Needed to Improve DOD’s Efforts to Prepare for Emergencies*, September 2024.

Antimony

Antimony's applications are diffuse. On the military side, it acts as a hardener for lead-based small- and medium-caliber ammunition, including armor-piercing bullets.⁴ Antimonial lead is also used to manufacture shielding for mobile reactors in nuclear-powered submarines and aircraft carriers.⁵ Antimony trioxide is a key component in flame retardants used in military uniforms, equipment, and vehicles.⁶ When combined with indium, antimony forms a compound highly sensitive to infrared light, with applications in night vision goggles and infrared sensors.⁷ Antimony is also used as a primer in ammunition.⁸ On the commercial side, antimony is primarily used as a flame retardant and in lead-acid batteries.⁹ It also serves as a clarifying agent to improve solar panel efficiency and as a dopant in silicon to produce semiconductors for electrical components.¹⁰

Antimony's broad range of applications—spanning traditional military uses like munitions and dual-use products such as flame retardants—makes it difficult to assess military demand relative to total demand. According to the USGS, the primary U.S. uses are: (1) antimonial lead and ammunition, accounting for 40% of domestic apparent consumption, and (2) flame retardants, accounting for 39% of consumption.¹¹ In the first case, I was unable to determine from open-source information what proportion of antimonial lead is used specifically for ammunition. DoD demand for antimony trioxide-based flame retardants is also unclear. Given the compound's widespread use in consumer products such as textiles and plastics, however, it is likely that military demand constitutes a relatively small share of total consumption.

Whether antimony is truly indispensable to military applications is also debatable. Organic compounds and hydrated aluminum oxide can replace antimony trioxide in flame retardants.¹² Tungsten alloys can be used to manufacture armor-piercing projectiles.¹³ And some modern explosive primers are formulated without lead or antimony.¹⁴

The U.S. primarily imports antimony in oxide, unwrought, and powder forms. As shown in Figure 1, over the past decade, roughly half of U.S. antimony oxide imports came from China (53% in 2024). However, the other half came from a diverse group of countries, including long-standing allies such as Belgium, Canada, France, and Japan. A smaller proportion of unwrought antimony and powders—inputs for antimonial lead—was sourced from China (10% in 2024), and this share has been steadily declining over the past ten years. Countries like Thailand now make up an

⁴ [Luis Tercero](#), *Critical Raw Material Substitution Profiles*, April 2018; [David Blackmon](#), "Antimony: The Most Important Mineral You Never Heard Of," May 2021.

⁵ [Perpetua Resources](#), "Antimony: A Critical Metalloid for Manufacturing, National Defense and the Next Generation of Energy Generation and Storage Technologies," April 2021.

⁶ [Military Metals Corp.](#), November 2024.

⁷ [Antimony Resources Corp.](#)

⁸ [Yeter Makina](#).

⁹ [USGS](#), *Mineral Commodity Summaries*, January 2025; Tecero, 2018.

¹⁰ [Xiaoying Du](#), "Photovoltaics to become largest use of antimony, Twinkling Star chairman," November 2023.

¹¹ [USGS](#), 2025.

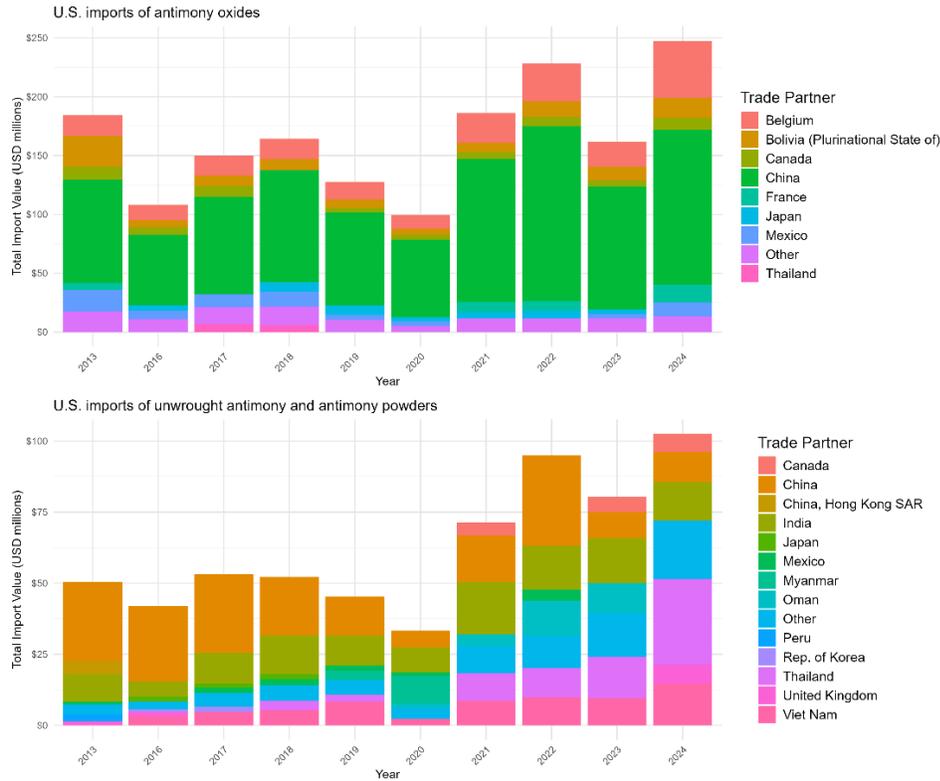
¹² [USGS](#), 2025.

¹³ [Stanford Advanced Materials](#).

¹⁴ [Yeter Makina](#).

increasing share of U.S. imports. Of course, it could be the case that China is exporting ore or intermediate antimony products to Thailand for processing and re-export. However, if we look more closely at Thailand’s imports of antimony ore and concentrates, these come primarily from Myanmar, a smaller but still significant global producer.

Figure 1: U.S. Antimony Imports By Country



Source: UN Comtrade Database.

Cobalt

Key military applications of cobalt include turbine engines for aircraft and high-capacity batteries. When alloyed with metals like nickel and iron, cobalt enhances high-temperature performance and corrosion resistance, making it ideal for use in jet aircraft engines.¹⁵ Cobalt is also critical to various lithium-ion battery chemistries—such as lithium nickel manganese cobalt (NMC), lithium nickel cobalt aluminum (NCA), and lithium cobalt oxide (LCO)—where it helps maintain battery longevity.¹⁶ Lithium-ion batteries are used across a range of military platforms, including drones, other unmanned systems, and portable devices like communication equipment for dismounted soldiers.¹⁷

Both cobalt-containing superalloys and lithium-ion batteries are dual-use technologies with broad civilian applications, particularly in the aerospace and EV industries. Additional civilian uses

¹⁵ CRM_InnoNet, “Critical Raw Materials Substitution Profiles,” September 2013.

¹⁶ Tecero, 2018.

¹⁷ Joseph Webster, “Batteries as a Military Enabler,” June 2024.

of cobalt include cemented carbides (for cutting tools), catalysts (e.g., for sulfur removal in oil and gas refining), and as a coloring agent.¹⁸

In the U.S., cobalt is primarily used in superalloys for aircraft engines, which accounted for over half (51%) of domestic consumption in 2024.¹⁹ Chemical applications, including battery precursor materials, made up another 25%. Globally, however, only 9% of cobalt is used in superalloys, while 45% goes to batteries—reflecting the U.S. manufacturing landscape, which is more heavily skewed toward aerospace than battery production.

As with other minerals, estimating the defense sector's share of cobalt demand is not straightforward. However, the military share or total aerospace industry sales (about 40%) can serve as a rough proxy for cobalt use in military-grade superalloys.²⁰ In contrast, the dominance of commercial EVs in the battery market suggests that DoD demand for cobalt from batteries is likely modest.

Substitutes for cobalt are limited. While materials such as carbon-carbon composites and titanium aluminides can replace cobalt-based alloys, they generally underperform at high temperatures and are not considered viable for jet engine applications.²¹ Likewise, cobalt-free high-capacity battery chemistries—most notably lithium iron phosphate (LFP)—exist, but their lower energy density may limit their utility in sensitive operational contexts.

As shown in Figure 2, the vast majority of U.S. cobalt imports are in matte, powder, or unwrought form, with cobalt powder being the preferred input for superalloys. In 2024, imports of this category had a total value of about \$300 million, compared to only \$37 million for cobalt oxides and hydroxides. The U.S. does not appear to import a large share of cobalt directly from China. Instead, Finland—home to several cobalt refining plants—is a major source of oxides and hydroxides.²² Imports of matte, powder, or unwrought cobalt have generally come from a diverse set of trade partners.

¹⁸ Tecero, 2018.

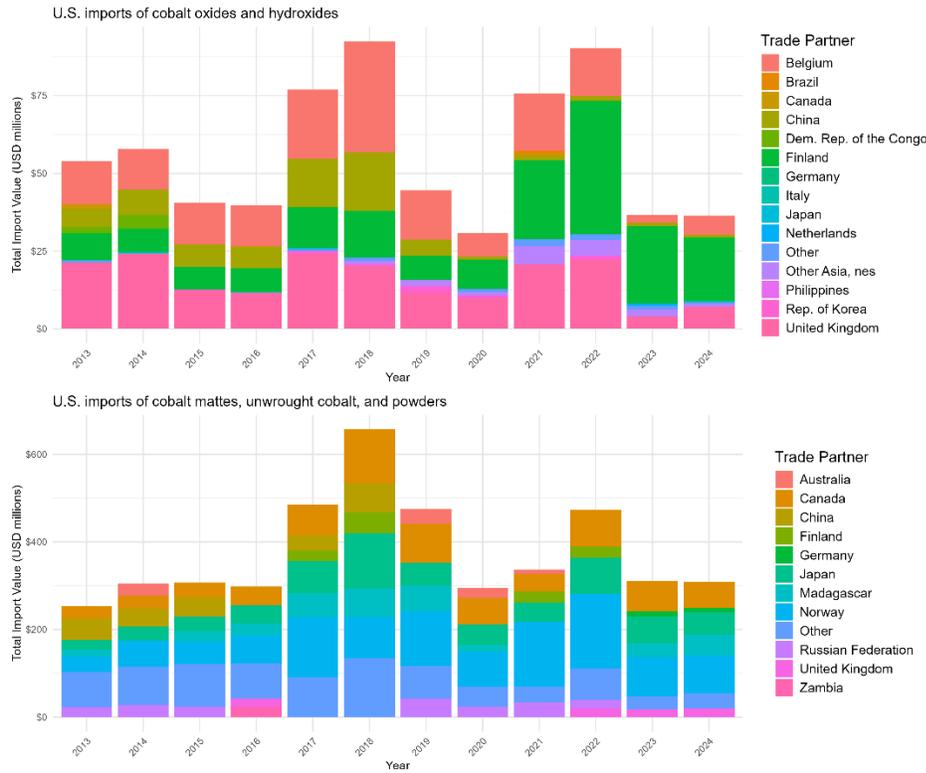
¹⁹ USGS, 2025.

²⁰ [Aerospace Industries Association](#), “2024 Facts & Figures: U.S. Aerospace & Defense.”

²¹ Tecero, 2018.

²² [Jukka Konnunaho et al.](#), “A mining industry overview of cobalt in Finland: exploration, deposits and utilization,” November 2023.

Figure 2: U.S. Cobalt Imports By Country



Source: UN Comtrade Database.

Beryllium

Beryllium is primarily used in alloyed form with copper (CuBe), and sometimes with aluminum (AlBe) or nickel (NiBe), with broad applications across industries.²³ In the military, these alloys are used in the frames of tanks, infantry vehicles, artillery, and military aircraft.²⁴ Beryllium alloys offer a unique advantage for aircraft in particular: they are stronger than steel and six times lighter.²⁵ AlBe and CuBe alloys are also used in various electronic subsystems integrated into ground and air vehicles.²⁶ Pure beryllium metal is used in critical military optics and sensors, including casings for targeting cameras on helicopters and drones, as well as high-precision mirrors in tanks and missile systems—where they help stabilize and maintain accuracy under intense motion or vibration.²⁷ Beryllium oxide ceramics are used in missile guidance and radar systems, where their high thermal conductivity supports heat dispersion and electrical insulation.²⁸

²³ Tecero, 2018; CRM_InnoNet, 2013.

²⁴ Tecero, 2018.

²⁵ USGS, “Beryllium—Important for National Defense,” May 2012.

²⁶ Claudiu C. Pavel and Evangelos Tzimas, “Raw materials in the European defence industry,” November 2016, <https://publications.jrc.ec.europa.eu/repository/handle/JRC98333>.

²⁷ USGS, “Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply,” 2017.

²⁸ USGS, 2012; Chin Trento, “The Application of Beryllium in Missiles,” April 2024.

On the commercial side, beryllium alloys are primarily used in electronics and telecommunications equipment. Beryllium foils—uniquely transparent to x-rays—are used in medical imaging devices.²⁹ Beryllium metal and beryllium oxide also serve as moderators and reflectors in nuclear reactors to help control fission reactions.³⁰ According to the USGS, in 2024, approximately 19% of beryllium products in the U.S. were used in aerospace and defense applications.³¹

Due to its high cost, beryllium is typically reserved for specialized uses where its unique properties are essential, which limits its substitutability. For CuBe alloys, some alternatives include copper alloys mixed with nickel and silicon, tin, or titanium.³² Aluminum nitride or boron nitride can substitute for beryllium oxide in certain applications.³³ While these substitutes may be less expensive, they are often not viable for military systems that have strict performance and reliability requirements.

The U.S. is the largest global producer of beryllium, accounting for roughly half of global production in 2024.³⁴ The leading U.S. mining and refining company, Materion, produces beryllium in multiple forms, including beryllium metal and CuBe alloys.³⁵ While the U.S. has significant beryllium resources, these resources are in the form of bertrandite ore and not beryl ore, which is the sole input for high purity beryllium metal.³⁶

Yttrium

Yttrium is one of nine heavy rare earth elements. In military applications, a key use is in yttrium aluminum garnet (YAG), one of the most widely used laser materials, which enables targeting, range-finding, and laser-guided weaponry.³⁷ Yttrium compounds are also used in thermal barrier coatings that protect aircraft turbine blades from extreme heat and corrosion, and yttrium-based phosphors are used in military display screens.³⁸ Its durable and heat-resistant properties also make yttrium valuable for weapon mounting systems on military vehicles and tanks.³⁹

On the civilian side, similar applications include YAG lasers used in industrial and medical settings; phosphors for color televisions and LED displays; yttrium-stabilized zirconia (YSZ), which serves as an electrolyte in solid oxide fuel cells; and as an additive in aluminum and magnesium alloys, among other uses.⁴⁰

²⁹ USGS, 2012.

³⁰ USGS, 2012.

³¹ USGS, 2025.

³² USGS, 2025.

³³ USGS, 2025.

³⁴ USGS, 2025.

³⁵ [Fabian Villalobos et al.](#), “From Mines to Markets in the Middle East and Central Asia,” September 2024.

³⁶ USGS, 2017.

³⁷ [SFA Oxford](#), “Critical Minerals in Defence Sector Applications.”

³⁸ SFA Oxford; Pavel and Tzimas, 2016.

³⁹ SFA Oxford.

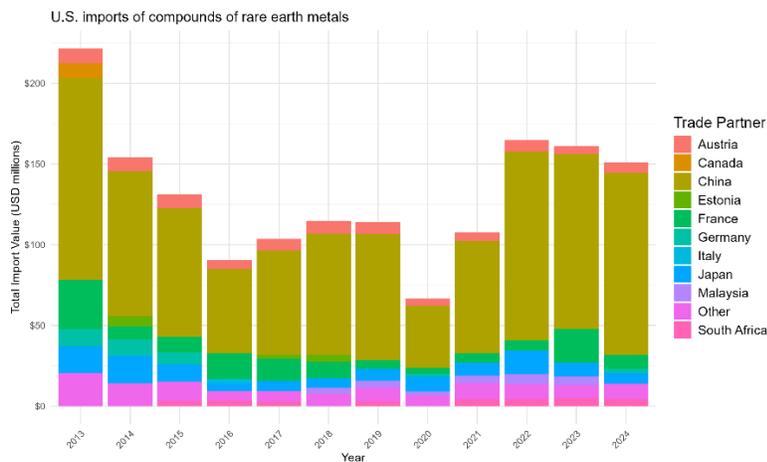
⁴⁰ SFA Oxford.

Substitutability for yttrium is generally low, particularly in lasers and phosphors.⁴¹ While calcium oxide or magnesium oxide can replace yttrium in thermal barrier coatings, they are typically less effective in terms of strength and durability.⁴²

Although specific data on the distribution of yttrium across different applications—and particularly within the defense sector—are not readily available, it is likely that military demand represents a small share of total consumption given yttrium’s widespread use in popular commercial technologies like LED displays.

China and Burma (Myanmar) account for the majority of global yttrium production. In 2024, major importers of Chinese-produced yttrium oxide—the key input for lasers, phosphors, and thermal barrier coatings—included Japan, Italy, the U.S., and South Korea.⁴³ Due to limitations in UN Comtrade data, yttrium imports cannot be disaggregated from other rare earth elements; however, the figure below still illustrates the U.S.’s broader dependence on Chinese-sourced rare earths, including yttrium.

Figure 3: U.S. Rare Earth Compound Imports By Country



Source: UN Comtrade Database.

Factors to Consider in Assessing Risks to Defense Critical Minerals

The cases above highlight a number of questions that may help to provide a more nuanced picture of the risks associated with critical minerals used in defense applications:

What are the use cases for military applications? In wartime, the priority will likely be on consumable items rather than non-consumables with a longer lifespan—items that have to be continually re-supplied in order to sustain operations. Some of the items described above—like munitions or spare parts for military vehicles or aircraft—clearly fall into this category. Others—like lasers or display screens—are more difficult to assess in terms of how quickly they will need to be replaced.

⁴¹ USGS, 2025.

⁴² USGS, 2025.

⁴³ USGS, 2025.

Another consideration is how widely a mineral is used outside of defense. If a particular mineral input has a broad range of commercial applications—used across industries and exported to many different countries—the supplier (particularly one that dominates global supply, like China) may be less incentivized to cut off access to it. Doing so could have wider economic consequences, potentially disrupting exports to multiple trading partners and harming downstream manufacturing sectors. In contrast, a mineral input that is niche or tightly linked to military end uses may be easier to target and restrict.

How close is the application to the upstream mineral and what is the current U.S. role in manufacturing? This is somewhat related to the first question. The closer the mineral input is to the final military application, the easier it is to make a case for securing supply—especially if current sources are considered risky (e.g., dominated by China). For example, if U.S. manufacturers are importing an antimony alloy specifically to produce bullets, the connection between the mineral and the defense application is clear, and the argument for supply security is straightforward.

In contrast, when the mineral is buried several layers deep in the supply chain—like cobalt used in electric vehicle batteries—it becomes much harder to trace where the material is coming from and who is refining or assembling it. These downstream products are often made up of multiple subcomponents, each with their own complex inputs. If the U.S. is importing the finished product or even the component, we may not have the domestic capability to produce it ourselves—at least not without rebuilding or expanding manufacturing capacity.

How substitutable are the critical mineral inputs for a given application? Assessing criticality also requires evaluating how easily a mineral input can be replaced with an alternative. In some cases, like antimony, there are known substitutes that may be appropriate in military contexts where performance thresholds are lower. Other minerals, like beryllium, are much harder to replace.

Importantly, in a national emergency, technical substitutability alone may not be enough. Even if a substitute exists on paper, transitioning to it in practice can take time—time the defense industrial base may not have. The feasibility of substitution depends not only on material properties, but also on how closely the replacement aligns with existing production methods, equipment, and supply chains.

What proportion of consumption is driven by military demand? For minerals like antimony and beryllium, which are used extensively in defense and aerospace—ranging from munitions and flame retardants to precision components and optical systems—DoD demand likely accounts for a significant share of total U.S. consumption. In these cases, the military may have greater influence over supply chains, and securing access becomes more strategically important.

In contrast, for minerals like cobalt, where the vast majority of demand comes from the commercial sector—particularly for electric vehicle batteries—the military likely accounts for only a small share of overall consumption. This doesn't necessarily make cobalt less critical, but it does shift the calculus. In such cases, the Department of Defense may have less direct leverage, but there may be more opportunities to divert commercially earmarked supply in a national emergency. Understanding the balance between military and civilian demand helps clarify when the U.S.

government should act as a direct market participant versus when it should rely more on other policy levers.

Who supplies the mineral? Some materials, like yttrium, are produced almost exclusively in one country—China—making them especially vulnerable to geopolitical disruptions. In contrast, the U.S. is a leading producer of beryllium, giving it a more secure position in that supply chain and more direct control over production, refinement, and end-use integration.

Of note, trade data alone may not always provide a full picture. Because of the complexity of global supply chains, where minerals are often mined in one country, processed in another, and exported in yet another form, or imported as part of other commodities, country-of-origin data can be misleading. In some cases, further investigation of trade flows may demonstrate that reliance on an adversary’s production is higher than suggested by import statistics. In other cases, like U.S. imports of antimony from Thailand, the opposite may be true.

It’s important to consider these factors holistically. If we consider each of these dimensions in isolation or in stove-piped manner, we risk developing an overly simplistic view of critical mineral vulnerabilities in defense supply chains. This can make coordinated, targeted action difficult and lead to investments that fall short of meeting national defense objectives. A more integrated approach can help prioritize resources where they’re most needed and ensure that supply chain resilience efforts actually align with operational requirements.

Table: Critical Minerals Important to National Defense

| Mineral (USGS Critical Minerals List) | Silverado Policy Accelerator | SFA Oxford | DLA Strategic Materials | EU Defense Materials |
|---------------------------------------|------------------------------|------------|-------------------------|----------------------|
| Aluminum | | ✓ | ✓ | ✓ |
| Antimony | ✓ | | ✓ | |
| Arsenic | ✓ | | ✓ | |
| Barite | | | | |
| Beryllium | | ✓ | ✓ | ✓ |
| Bismuth | ✓ | | ✓ | |
| Cerium | | | ✓ | ✓ |
| Cesium | | | | |
| Chromium | | | ✓ | ✓ |
| Cobalt | | ✓ | ✓ | ✓ |
| Dysprosium | | ✓ | ✓ | ✓ |
| Erbium | | ✓ | ✓ | ✓ |
| Europium | | ✓ | ✓ | ✓ |
| Fluorspar | | | | |
| Gadolinium | | ✓ | ✓ | ✓ |
| Gallium | ✓ | ✓ | ✓ | ✓ |

| | | | | |
|--------------|---|---|---|---|
| Germanium | ✓ | ✓ | ✓ | ✓ |
| Graphite | ✓ | ✓ | ✓ | |
| Hafnium | | | ✓ | ✓ |
| Holmium | | | ✓ | ✓ |
| Indium | ✓ | | ✓ | ✓ |
| Iridium | | | | |
| Lanthanum | | ✓ | ✓ | ✓ |
| Lithium | | ✓ | ✓ | ✓ |
| Lutetium | | ✓ | ✓ | ✓ |
| Magnesium | | | ✓ | ✓ |
| Manganese | | | ✓ | ✓ |
| Neodymium | | ✓ | ✓ | ✓ |
| Nickel | | | ✓ | ✓ |
| Niobium | | ✓ | ✓ | ✓ |
| Palladium | | | | |
| Platinum | | ✓ | | ✓ |
| Praseodymium | | ✓ | ✓ | ✓ |
| Rhodium | | | | |
| Rubidium | | | | |
| Ruthenium | | | | |
| Samarium | | ✓ | ✓ | ✓ |
| Scandium | ✓ | | ✓ | ✓ |
| Tantalum | ✓ | ✓ | ✓ | ✓ |
| Tellurium | | | ✓ | |
| Terbium | | ✓ | ✓ | ✓ |
| Thulium | | | ✓ | ✓ |
| Tin | | | ✓ | ✓ |
| Titanium | | ✓ | ✓ | ✓ |
| Tungsten | ✓ | ✓ | ✓ | ✓ |
| Vanadium | | | ✓ | ✓ |
| Ytterbium | | | ✓ | ✓ |
| Yttrium | ✓ | ✓ | ✓ | ✓ |
| Zinc | | | ✓ | ✓ |
| Zirconium | | | ✓ | ✓ |

Source: [Silverado Policy Accelerator](#); [SFA Oxford](#); [DLA Strategic Materials](#); European Commission's [Joint Research Centre](#).