

Biotechnology to Secure Critical Mineral Supply Chains

A Case Study on Copper

The United States depends on China for the majority of its supply of dozens of critical minerals including copper, one of the newest additions to the U.S. Geological Service (USGS) Critical Minerals List.¹ Without a reliable supply of these minerals, the United States risks ceding leadership in industries that will define its economic and strategic future. One promising avenue to address this gap is biomining, a process that uses microorganisms to extract minerals from ore and waste streams. In January 2026, the National Security Commission on Emerging Biotechnology (NSCEB) convened leading experts across industry, academia, and government to identify key obstacles to using biotechnology to extract and process critical minerals—including copper—and to evaluate solutions to those challenges.²

1.2

million — the number of 155 mm artillery shells the U.S. Army aims to produce annually, each one made with copper.³

~9%

of globally refined copper was used for military applications worldwide in 2021, projected to grow 14% annually to 4.22 million tons by 2026.⁴

50%

of global copper smelting capacity is controlled by a single foreign producer.⁵

~20%

of the world's copper is already recovered via biotechnology, yet the United States is not leading in scaling this technology.⁶

Copper's Role In The U.S. Defense Industrial Base

The USGS added copper to the Critical Minerals List on November 7, 2025.⁷ The USGS Critical Minerals List recognizes minerals subject to domestic supply gaps and foreign processing chokepoints.⁸ The United States relies on copper to build its infrastructure, run its communications, and power its defense systems. Naval vessels, radar systems, satellite terminals, and radiation-hardened chips all depend on copper that meets defense-grade specifications.⁹ As the U.S. military continues to expand its munitions industrial base, the demand for copper will only intensify, and the industrial base supplying it must be able to keep pace.¹⁰

How China Built The Chokepoint

Like many of the minerals on the USGS Critical Mineral List, China controls much of the copper supply chain. The Chinese Communist Party (CCP) built its position in the copper supply chain deliberately over decades.¹¹ State enterprises such as China Minmetals Corporation, CMOC Group Limited, and China Nonferrous Metal Mining (Group) Corporation, Limited acquired upstream mining rights across multiple countries, including Zambia and Peru. This access came at below-market financing terms that competitors in the United States cannot match.¹² Alongside these acquisitions, China built the domestic capacity for smelting, the high-heat process that extracts metal from concentrated ore, as well as refining to process that output.¹³ Chinese firms now control roughly 50% of global copper smelting, giving China significant leverage over copper prices, supply, and processing access for the United States and its allies and partners.¹⁴

The Copper Value Chain: Defense Vulnerability & Biomining Solution

Stage in the Copper Value Chain	China's Current Leverage Point	Potential Biomining Disruption	Resulting Defense and Technology Implications
Ore Extraction	State-backed Chinese firms hold upstream mining rights in many of the world's key copper producing nations, outpacing the United States.	The United States has significant domestic copper resources, including substantial deposits of lower-grade ore. ¹⁵ Bioleaching is particularly suited to lower-grade ores, which can be too costly to extract using conventional methods. ¹⁶	Increased domestic biomining would help enable copper recovery from domestic deposits in states like in Arizona, Nevada, and New Mexico, reducing import exposure for munitions-grade copper. ¹⁷
Processing	China absorbs roughly 18% of copper concentrate exports, meaning a significant share of American-mined copper flows directly to Chinese smelters. ¹⁸	Bioleaching produces copper bearing solution directly. The process requires no flotation concentrate and no Chinese smelter. ^{19, 20}	Onshored bioleaching would lessen the processing chokepoint that China controls. As a result, Department of Defense's (DOD) copper supply chain would become more secure. ²¹
Smelting / Refining	U.S. domestic smelting capacity covers only half of what American mines produce. ²² China controls roughly 50% of global smelting, and with only two U.S. copper smelters running — both already at capacity — the United States remains exposed to potential export restrictions. ²³	Synthetic biology-enhanced bioleaching can extract copper from ore into solution, which is then converted to industry-standard copper cathode, requiring no smelter and no Chinese processing. ²⁴	Onshoring copper processing would minimize one of the most weaponizable dependencies in the supply chain. With domestic processing in place, the DOD could establish a stronger chain-of-custody over the copper it uses. ²⁵
End-Use Manufacturing	Chip fabricator companies depend on Chinese-dominated refining for many of the critical minerals used in semiconductor manufacturing, including copper, exposing the U.S. defense supply chain to vulnerabilities. ²⁶	Biomining paired with advanced refining could eventually supply domestically-sourced copper for U.S. electronics — from laptops to cell phones — with synthetic biology research exploring ways to improve extraction efficiency, though that application has yet to reach commercial scale. ²⁷	Biomining would help secure the domestic supply that defense electronics depend on — from the heavy-copper circuit boards used in radar and satellite systems to the hardware built for space. ²⁸
Waste & Tailings	China has already begun formalizing standards and technical capacity to recover critical minerals from its own tailings. The United States has no comparable framework, leaving domestic resources untapped while China grows its lead in the underlying technology and market. ²⁹	Bioremediation would disrupt this gap by recovering residual copper from mine tailings. ³⁰	Bioremediation would help convert legacy mine sites into strategic reserves, reducing the DOD's long-term exposure to supply disruptions. ³¹

The risks posed by U.S. supply chain dependence on China are no longer abstract. In 2023, the CCP began imposing global licensing controls on gallium, germanium, and graphite exports. By December 2024, the CCP specifically targeted the United States by banning exports of gallium, germanium, and antimony.³² In April 2025, China extended export controls to seven rare earth elements, targeted at minerals essential to U.S. defense and semiconductor production.³³ A 2024 USGS assessment found that a complete restriction of just gallium and germanium could reduce U.S. GDP by \$3.4 billion.³⁴ Copper processing faces many of the same supply chain risks as other critical minerals, creating similar vulnerabilities for the United States.

Biotechnology Offers A Path Forward

Bioleaching is the most mature form of copper biomining.³⁵ Microorganisms break down copper ore, releasing copper ions into a solution that can then be extracted and purified without a smelter.³⁶ This process already produces around 20% of the world's copper.³⁷ The same biology also works on waste discarded as tailings, recovering up to 90% of residual copper and turning legacy waste piles into a resource rather than a liability.³⁸

The United States has what it needs to lead in copper biomining, but it has not scaled the technology at home. American researchers identified the science behind bioleaching in 1947, and by the 1960s and 1970s, the United States led the world in industrial-scale bioleaching. At one point, the United States recovered a quarter of its copper utilizing this method.³⁹ The lead did not hold. In other countries, such as Chile, the technology scaled into standard industrial practice, while most U.S. copper mines stayed anchored to conventional smelting.⁴⁰

Meanwhile, China is moving to close its own gap, committing roughly \$10 billion through 2030 to bioleaching capacity. Furthermore, China already runs the technology at industrial scale.⁴¹ Without action, the United States will fall behind in a technology it pioneered.

The limiting factor is not the science, but the scale-up. Regulatory hurdles compound the problem: the NSCEB discussion paper, *Modernizing Microbial Biotechnology Regulation*, identifies that genetically engineered microorganisms used to recover critical minerals from mining waste face unclear commercialization pathways, pushing biotechnology developers to move projects

offshore instead of scaling domestically.⁴² Biomining technologies at domestic mines could help the United States meet its copper demand, including for national defense, while reducing the economic and national security risk of overreliance on China.

There are myriad other ways that biotechnology can advance critical mineral extraction, processing, and refining. Synthetic-biology-based bioleaching can recover rare earth elements — many of which the United States imports almost entirely from China — from electronic waste, including magnets, batteries, and circuit boards.⁴³ Engineered processes can also selectively recover critical minerals that would otherwise go unrecovered in acid mine drainage and industrial wastewater.⁴⁴

Federal agencies, including the Department of Energy (DOE) and the Defense Advanced Research Projects Agency (DARPA), have begun funding early biomining efforts. DOE is investing in commercial-scale critical minerals initiatives, and DARPA's Environmental Microbes as a BioEngineering Resource (EMBER) program supports earlier-stage research into engineered microbes that recover rare earth elements from mine waste and electronics.⁴⁵ However, these applications face many of the same barriers as copper biomining.

Policymakers can take concrete steps to address the abovementioned challenges and ensure U.S. leadership in critical minerals. The following recommendations are derived from the NSCEB's April 2025 Report, *Charting the Future of Biotechnology*.⁴⁶

April 2025 Report Recommendations

Recommendation 2.2a

Congress must establish and fund an Independence Investment Fund, led by a non-governmental manager, that would invest in technology startups that strengthen U.S. national and economic security

Government can provide a powerful signal to private investors about the importance and viability of a company or technology. The Independence Investment Fund could invest in sourcing capabilities for defense-critical inputs such as copper biomining, a proven scientific process, that needs capital to scale. An early investment from the Fund could help crowd in the private capital necessary to build sufficient domestic biomining capacity here in the United States. Investments could also support less proven, but promising, technologies in areas like e-waste extraction and refining.

Recommendation 3.2a

Congress must direct the Department of Defense (DOD) to work with private companies to build commercial facilities across the country to biomanufacture products that are critical for DOD needs.

Congress should support the commercialization of national-security-relevant biotechnologies, appropriating at least \$762 million over five years for the Distributed Bioindustrial Manufacturing Program (DBIMP) — a DOD program that strengthens defense supply chains by helping private companies build commercial-scale biomanufacturing facilities.⁴⁷ DBIMP has already awarded over \$60 million to 34 companies to plan bioindustrial facilities, with follow-on funding planned to build full-scale commercial capacity.⁴⁸ Biomining companies are strong candidates for subsequent DBIMP funding rounds: the underlying technology is well established, and the domestic ore and tailings base is large enough to support commercial-scale production.⁴⁹

Recommendation 2.3a

Congress must authorize and fund the Department of Energy (DOE) and the Department of Commerce (DOC) to develop a network of manufacturing facilities across the country for precommercial bioindustrial product scale-up.

These facilities would allow companies to test and prove that their technology works at pilot and demonstration scale before moving to full commercial production. For biomining companies, these facilities would ease the transition from the lab to mines and tailings sites.

Recommendation 3.2d

Congress should require the Department of Defense (DOD) to enter into advance market commitments (AMCs) and offtake agreements for biotechnology products that are needed for defense.

These agreements would help biomining companies secure an early buyer before they scale, reducing the investment risk that has largely kept the technology in the lab. For copper biomining companies, this could mean a DOD customer for domestically produced copper from the outset.

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