THREAT OF LIMITED U.S. ACCESS TO CRITICAL RAW MINERALS

PUBLIC Sector Focus

Short-term election cycles
Policy optics
Geopolitical control
Foreign threat

Misalignment

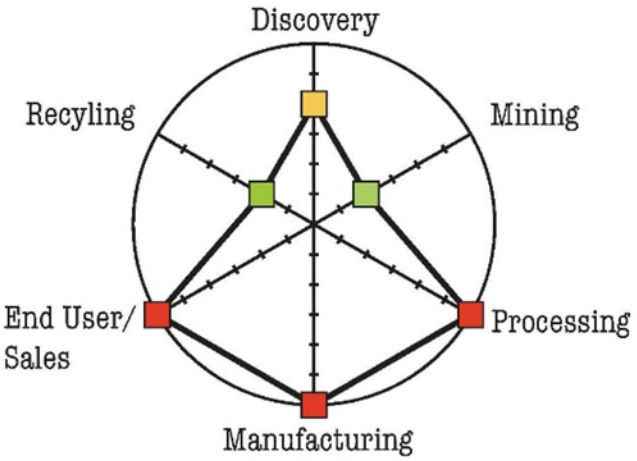
PRIVATE Sector Focus

International economic cooperation
Long-term ownership & profit
Scalability
Return on investment

Mitigation

Unified strategic vision
Technology development
Align regulation - federal, state, and local
Investment incentives
Stockpiling

Foreign Actor Threat Risk Ranking



Intent
Capability
Low
Medium
High

Discovery ≫ Mining ≫ Processing ≫ Manufacturing ≫ End User/Sales ≫ Recycling

2024 PUBLIC-PRIVATE ANALYTIC EXCHANGE PROGRAM

Homeland Security

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Executive Summary

This 2024 Public-Private Analytic Exchange Program team explored the implications of U.S. industry's inability to obtain or maintain access to supplies of critical raw materials (CRM). Despite some policy efforts by U.S. government and private industry alliances and working groups, CRM shortages are projected to escalate and become a critical challenge to the U.S. economy due to increasing demand, coupled with the outsized control that foreign adversaries exert over CRM supply chains.

The team's methodology focused on investigating misalignment at each stage of the life cycle for CRM supply chains—discovery, mining, processing, manufacturing, end user/sales, and recycling—and proposing potential mitigations to address the issues identified. For simplicity across disparate industries and actors, and as a reflection of the team's own varied backgrounds, key players involved in the CRM space have been divided into two broad categories: the public and private sectors.

The findings of this analysis indicate that there are major misalignments in U.S. public and private sector approaches to CRM supply chain challenges and their potential mitigations. These misalignments are hinged on disparities between short- and long-term goals in the public and private sectors, particularly those involving risk tolerance and return on investment (ROI).

Across all phases, geopolitical control goals and priorities driven by election cycles dominate the incentive space for policymakers. The private sector must focus on long-term strategies to achieve success, especially in the first three phases of CRM life cycle.

Beyond priorities and timelines, government actors and private entities have markedly different approaches to risk tolerance. The private sector is more comfortable weighing supply chain risk against a variety of factors that drive costs and profitability. Private entities, working individually, can be punished by the market for costly anticipatory mitigation to avoid shortages that would, if they occurred, raise prices—and margins—for producers. Meanwhile, governments are intolerant of supply chain risks at the system level and make calculations based on potential harms to the collective group of myriad end users and consumers, with particular concern for defense and critical infrastructure applications.

The ROI calculation that drives private sector business decisions is in many ways responsible for the overall lack of private initiative across the discovery, mining, processing, and recycling life cycle stages, and to some extent manufacturing and end user/sales. To the extent the economy needs it, the private sector does not find it economically feasible to invest or engage in discovery or mining projects which could take decades and still fail if prices fall, or processing and recycling which are not scalable, leaving few options to drive down costs. While the public sector does make ROI calculation for its activities, the government cannot 'fail' in the same way a business does and, therefore, does not experience the same incentives from a poor ROI.

In the end, this is a rather obvious case of under-provision by the markets of a good critical to national security. Given the current laws, geopolitics, geography of resources, and state of technology, private CRM provision is impossible to the required levels. Adversaries with different political and economic structures, like China, opt for subsidizing their industry to take advantage of the situation, for however long such subsidy may last. This is not a realistic or sustainable option for the U.S. society, but the U.S. has greater innovation potential.

This innovative potential, both in technology and industrial organization, could be one single advantage large enough to tip the scales, however, the misalignments identified in this paper may destroy this opportunity if not resolved. Overall, lack of unifying strategy on CRM and an ***effective*** forum for public and private sector to work out these misalignments must be addressed.

Both the public and private sectors must create opportunities for formal engagement to develop creative and feasible solutions to the challenges the U.S. faces regarding critical minerals.

The team's general recommendations are as follows:

- Streamlining regulatory requirements across U.S. jurisdictions and U.S. allies reduces uncertainty for the private sector actors in mining, processing, and manufacturing.
- Support for U.S. public-private coordination and innovation across industries can harness the unique advantages of U.S. systems better than attempts to emulate authoritarian and non-market adversaries.
- Efforts to bridge expertise gaps after decades of supply chain globalization are needed from the public and private sectors, in mining, processing, and manufacturing sectors.
- Prioritization of specific industries, supply chains, and vulnerabilities by the U.S. government reduces business uncertainty and allows stockpiling, subsidizing, trade controls, and other efforts to be focused on strategic necessities first while seeking systemic change to CRM supply chains.

Foreign actor threats to supply chains that could undermine U.S. economic and political power have also been assessed. For each stage, the potential foreign actor threat is ranked by overall capability and intent. The matrix below assesses each life cycle stage's risk of disruption by foreign threat actor probability and intent to determine that the processing, manufacturing, and end user/sales are in the highest risk category.

CRM Stage	Capability of a foreign actor to act	Intent of a foreign actor to act
Discovery	2	2
Mining	2	1
Processing	3	3
Manufacturing	3	3
End User/Sales	3	3
Recycling	2	1

Legend
Low
Medium
High

1. Overview

1.1. Key Intelligence Questions

What are the misalignments in public and private sector approaches to critical raw minerals supply chains and how could foreign threat actors take advantage of them?

What steps can be taken to align those priorities and secure domestic/allied supply chains?

1.2. Background

Common ground between the wide variety of stakeholders in the global critical raw materials (CRM) sector is rare. Within the U.S. and internationally, CRM stakeholders diverge on foundational matters—including the definition of CRM—as well as larger-scale policies, business and economic strategies, and appetite for international collaboration. While the European Union (EU) favors the term "critical raw materials," U.S. government policy focuses on "critical minerals," defined in Executive Order (EO) 13817 as: [1] [2]

- (i) a non-fuel mineral or mineral material essential to the economic and national security of the United States, (ii) the supply chain of which is vulnerable to disruption, and (iii) that serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for our economy or our national security.

Divergent interests and concerns of businesses operating with globalized supply chains and governments grappling with the localized nature of critical mineral deposits and rising geopolitical tensions fuels misalignments between the public and private sectors. In the U.S., although policy may shift between administrations, it is possible to find continuity and alignment; for example, the national laboratory system and federally funded research and development centers (FFRDCs) grew out of beneficial common interests.

Recent misalignment between the U.S. public and private sectors are evident in the tension between clean energy policy initiatives, national security concerns, and the prevailing operating models of the CRM business sector—as well as downstream manufacturers and consumers. Policy mandates for new energy technologies implemented at scale cut against national security concerns that discourage reliance on adversarial nations for manufacturing inputs, including CRM. The private sector's current raw materials sources, processing methods, and existing supply chains often deeply rely on cooperation with adversarial nations.

Though geologic and market conditions prevent the threat from being entirely mitigated, there are options to partially mitigate U.S. exposure to foreign threat actors in this space by discovering and developing new sources, creating new alternatives and efficiencies through innovation, and building greater resilience into every stage of the CRM supply chains.

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[1] (U) | EUR-Lex | Document 32024R1252 | 11 APR 2024 | "REGULATION (EU) 2024/1252 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL" | eur-lex.europa.eu

[2] (U) | Federal Register | EO 13817 | 26 DEC 2017 | "A Federal Strategy To Ensure Secure and Reliable Supplies of Critical Minerals" | federalregister.gov

In addition to the expertise of individual team members and their colleagues, there was significant engagement and dialogue with subject matter experts from the Critical Materials Innovation Hub at Ames National Laboratory, Johns Hopkins University's Net Zero Industrial Policy Lab, technology policy and energy supply chain think tanks and working groups, and the Federal Bureau of Investigation (FBI). Members of this research team are presented below.

CRM Research Team

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1.3. Scope and Audience

This research paper considers any CRM as identified by the U.S. Geological Survey (USGS), but it does not focus on any specific mineral individually. Instead, the research is focused on the incentives and resulting actions of public and private sector entities, as they affect supply chain resilience. U.S. government policy, research, and analysis were incorporated to represent the views of the public sector, as well as industry statements, private sector research, and news media to represent the views of the private sector. The team's target audience comprises decision makers in

both the U.S. public and private sectors, including but not limited to government officials and business leaders.

1.4. Methodology

Access limitations to critical raw materials can disrupt the entirety of the downstream supply chain. Because so many end-use products contain CRM, an access disruption has the potential to impact every sector of the U.S. economy. Analyzing life cycle stages of CRM allows deeper insight into the threats and mitigation options available, which vary from stage to stage. Taken together, the recommendations across each stage also reveal key areas of overlapping opportunity for alignment across stages of the supply chain to ensure critical raw materials—and their end products—remain available at prices consumers are willing to accept.

1.4.1. Critical Raw Materials Life Cycle Stages

Critical raw materials take a lengthy journey from discovery to the end-use. Each stage has its unique challenges and players. This report organizes the research and analysis by the following six stages:

1.4.2. Public/Private Sector

There are numerous public and private sector entities with wide-ranging roles, responsibilities, and objectives in CRM supply chains. The public sector can influence the outcomes for availability of CRM to industry by domestic and international policy, subsidies (in research, education, mining, preferential tax treatment etc.), and other types of ‘soft’ strategies, like encouraging the public to recycle, encouraging interest in science and engineering professions related to developing alternatives to CRM, and spearheading a unified strategy to alleviate the CRM shortage. The private sector must adhere to public policy but can also influence and constrain the options available to policy makers.

It is important to recognize the third important player, the consumer, who interacts with both the government and private industry. The consumer demonstrates by their active choices in the market if they are willing to bear higher prices in the name of cleaner technology, for instance. They also give their vote of confidence to government officials who enact policy related to tariffs, trade agreements, mining laws, and other policies affecting the prices of products, which use CRM. The scope of this paper excludes consumer choice analysis due to its complexity.

The misalignments between the public and private sectors are apparent in law and regulation, risk assessment, investment in technology, and short vs. long-term goals. However, the scale and complexity of the threat underscores the necessity of public-private alignment; without that alignment, the problem has not been and will not be resolved.

1.4.3. Mitigations and Opportunities

After exploring the misalignments between public and private sector actors at each stage, the sub-teams proposed mitigation strategies and opportunities their research indicated would be most effective, most achievable, or a workable combination of the two.

1.4.4. Risk Assessment of Threat

Each sub-team working a CRM life cycle stage rated foreign actor threat using the following parameters: intent of a foreign actor to act and capability of a foreign actor to act on a scale of Low (1), Medium (2), High (3).

2. Findings

2.1. Discovery

2.1.1. Misalignment

Public organizations are focused on geopolitics and supply chain control, which discourages private industry from public partnerships as they must focus on balancing risk, cost, and other market factors. At the discovery stage, this means few effective, coordinated efforts between public and private entities to identify and explore new mineral sources.

2.1.2. Public

The U.S. government, at various levels, has led the effort to address the increased perception of risk from China's dominance of CRM, driven by rising trade tensions and the painful experience of the impacts of supply chain disruption during the global pandemic. Through EOs, mapping initiatives, and public-private partnerships like this one, the U.S. government has sent clear policy signals on the desirability of secure CRM supply.[3] [4] [5] However, progress has been slow in the discovery phase for a variety of reasons.

- Disjointed or nonexistent cooperation among U.S. government entities, state/local entities, and international allies makes the regulatory landscape more complex and less predictable, increasing the risk for companies engaged in CRM discovery efforts.
- The lack of an overarching strategy to preserve market incentives for investment in new discovery/mining (stable prices, certain demand) in the face of strategic Chinese control of

[3] (U) | USGS Geology, Geophysics, and Geochemistry Center | 31 AUG 2023 | "Critical Minerals Mapping Initiative (CMMI)" | usgs.gov

[4] (U) | Federal Register | EO 14017 | 24 FEB 2021 | "America's Supply Chains" | federalregister.gov

[5] (U) | Federal Register | EO 13817 | 26 DEC 2017 | "A Federal Strategy To Ensure Secure and Reliable Supplies of Critical Minerals" | federalregister.gov

many of critical raw minerals, means that Beijing can manipulate prices intentionally to knock out competitors.[6] [7] [8]

- Many critical mineral deposits are outside the West and require globalized engagement. Some areas are off-limits to U.S. development due to conflict and/or geopolitical issues disrupting trade (e.g., Afghanistan, Iran, Ukraine).

2.1.3. Private

Announcements that new (or at previously untested) sources of CRM have been discovered have accelerated in recent years as U.S. and EU leaders signaled their focus on the risk. Nevertheless, actual U.S. dependance on Chinese (or Chinese-owned) mining and processing has not substantially improved and is not fully reflected in trade statistics, which only indicate imports of the raw material itself, and do not reflect the import of the various raw materials incorporated into components or products, as with solar panels, semiconductors, machinery, batteries, etc.

- Large deposits and extraction at scale—the key to unlocking economies of scale—requires the involvement of mining's majors, but those companies have little incentive to act in advance to alleviate high prices that would benefit their margins.[9]
    - Many critical minerals, particularly rare earths, are not technically rare so much as dispersed. They appear in small quantities alongside larger deposits, but it is not economically feasible for most large mines to sort and refine those small amounts alongside the miner's targeted products. The critical minerals end up as waste, typically in tailings dams.
- The mining industry typically only engages with only a few subsequent links in the supply chain and is therefore unlikely to independently determine the full picture of sourcing desires of distant downstream manufacturers.
- Those distant downstream manufacturers are spread across disparate end user industries, and do not coordinate on any particular supply chain message to miners beyond price and legal compliance.

2.1.4. Mitigation/Opportunity

Given the level of disconnect between public and private in this space, there are significant opportunities to improve the situation. The recommendations below were considered by the team to be among the most feasible, the most impactful, or both.

- Streamline and prioritize U.S. permitting and reduce litigation risks and delays across jurisdictions to put a ceiling on the risk to miners and increase speed to market.

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[6] (U) | Australian Strategic Policy Institute (ASPI) The Strategist | Gregory D. Wischer | 06 MAR 2024 | "China shows how Western governments should stockpile minerals" | aspistrategist.org.au

[7] (U) | Oil Price | Charles Kennedy | 06 APR 2023 | "Lithium Expert Says China Manipulating Prices Downward" | oilprice.com

[8] (U) | Cowboy State Daily | 07 JUL 2023 | "China Plays Dirty To Keep Mineral Prices Low And Hamstring US Companies, Critics Say" | cowboystatedaily.com

[9] (U) | Johns Hopkins University Net Zero Industrial Policy Lab | Bentley Allan | 20 JUN 2024 | Interview with Dr. Bentley Allan, Founder and Co-Director of the Net Zero Industrial Policy Lab

- "Rediscover" CRM by reassessing existing deposits and tailings in the U.S. for critical minerals to act as an unprocessed stockpiling system that can hasten response times in the event of a crisis.
- Pursue strategic public/private technology development for the discovery, extraction, and processing of new deposits on earth (including deep mining, and undersea mining), in space, or via the creation of synthetic minerals as an alternative.
    - The push for synthetics has attracted the most funding thus far, primarily from technology companies experimenting with AI and quantum computing to extrapolate probable atomic compositions, rather than from public funds or mining industry investment.
- Continue and expand efforts to bring public and private entities and experts together in order to build awareness of the full scope of the issue across the supply chain, improve cooperation across industries and fields, and generate workable and durable solutions.

2.1.5. Foreign Actor Threat

Global powers adversarial to the U.S., such as Russia and China, have extensively invested in domestic mining and processing of CRM, and dominate many of those markets as a result. China leverages a whole-of-government, whole-of-society strategy, including strategic overproduction and other price manipulation practices, to ensure continued dominance. That control allows for:

- Price manipulation to undercut U.S. and allied competitors and render subsidies either insufficient or too costly for elected governments to maintain over time.
- Export controls to restrict U.S. companies and U.S. supply chains from accessing CRM directly, while also encouraging downstream supply chains to remain in China to ensure continued access despite export controls.
    - China has implemented export controls on gallium, germanium, and natural graphite since 2023, which have had price impacts but have not resulted in acute shortages while export licenses continue to be granted.[10]
    - Export controls are more effective over the long term as a threat than in actual implementation, though in the short-term impacts can be severe. Once controls are enforced, price signals and continuity of supply demands create fertile conditions for rapid diversification of supply.[11] [12]

Moreover, Russia and China have utilized soft power toward other mineral-rich nations, particularly in Africa. Their influences hinders both U.S. public and private sector organizations

[10] (U) | FTI Consulting | Christopher R. LeWand et al. | 19 JUL 2023 | "China's Export Controls on Critical Minerals – Gallium, Germanium and Graphite" | fticonsulting.com

[11] (U) | Foreign Policy | Joseph Rachman | 15 AUG 2023 | "Japan might have an answer to Chinese rare earth threats" | foreignpolicy.com | In a 2010 dispute with Japan, China declared a halt to rare earth exports, which led to a political backlash and WTO ruling against China, spurred illegal mining when prices spiked, and destroyed some demand for Chinese minerals in the long term by encouraging development of alternative supplies and strategies, particularly by Japan.

[12] (U) | Reuters | Andy Home | 10 JUL 2023 | "China flexes critical metals muscles with export curbs" | reuters.com

from conducting business in those nations. A key Russian strategy is weighing minerals as a currency to encourage a 'no debt' fallacy.[13] In addition, Russia has provided paramilitary security in exchange for mining agreements for lithium and cobalt.[14]

2.2. Mining

2.2.1. Misalignment

After discovery of a deposit comes the decision by the mining company or consortium on whether to develop the site—what technologies and investments would need to be made over what timeline, balanced against the anticipated price for that material.

Foreign threat actors are pursuing a broader strategy to control mines outside their territory by purchasing mines directly, or indirectly through offtake agreements and joint ventures that muddy clarity of ownership. Meanwhile, the U.S. government lacks a coherent strategic focus, often focused on ownership and potential misuse instead.

Separately, the U.S. public sector and private sector have differing timescales in mind, with government focused on shorter cycles (elections, international politics, and control) while private mining companies must consider long term trajectories of ownership and access as the life cycle of a mine spans decades.

Against this backdrop, the most effective solutions are assessed to be derived from technology changes rather than attempts to alter structural misalignments that are both vast and persistent.

2.2.2. Public

As indicated above, U.S. public strategy is operating on shorted term cycles of elections, international relations, and economic conditions—consider the shift in U.S. government risk perceptions and rhetoric regarding China from 2014 to 2024 for example. Without a longer-term strategic vision that carries through the decades that it will take to shift CRM supply chains from the mine onward, U.S. public officials will continue to struggle to shift the mining industry at scale.

2.2.3. Private

In an inversion of many industries, the mining industry—similar to oil and gas—must plan on significantly longer timescales than U.S. government administrations. It commonly takes 20 years to advance from discovery through production, and decades more before production ceases and restoration of the landscape is complete. Private mining entities are therefore approaching a mining operation with different goals, including community outreach, people relations, and long-term trajectories of ownership and access.

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[13] (U) | Carbon Credits | Saptakee S | 07 MAY 2024 | "Russian Power Plays: Deploys Military Might over Africa's Critical Minerals" | carboncredits.com

[14] (U) | Strategic Review for Southern Africa | Theo Neethling | Vol. 42 No. 2 | 18 DEC 2020 | "Assessing Russia's New Interaction with Africa: Energy Diplomacy, Arms Exports and Mineral Resource Markets" | pp 15–36 | upjournals.up.ac.za

2.2.4. Mitigation/Opportunity

At present, extraction of CRM from existing mines at scale is not economically viable, as evinced by the fact the majors aren't pursuing it. The U.S. could impose regulations requiring companies to mine incidental CRM—which is how China achieved its current production levels—the U.S. government is not politically prepared to offer subsidies of the size and duration needed to keep them globally competitive despite that regulatory burden. subsidize its companies as Beijing did, and they would not remain globally competitive.

Instead, the U.S. system is better suited to innovating a way out of the economic viability problem. Core mining technology has not experienced innovative technological or social change to improve mining capabilities and efficiencies in decades. Current investments in innovation and technology in the mining industry focus on near-term change or maturing components trialed in other industries rather than transformative change necessary to make CRM extraction viable at scale.

On the other side of the industry spectrum, small miners can and do take risks, but often struggle to attract sufficient funding or access to tools necessary to extract more than their target minerals.

- U.S. government actions to encourage mining majors to innovate, through tax benefits, regulatory fast-tracks, or other methods, would help de-risk investment in more impactful (though less certain) technologies like evolving quantum sensors for atomic-level mapping of ore bodies, scaling up and commercializing photonic tractor beams, etc.[15] [16] [17]
- A U.S. government-led mechanism for strategically bringing together small miners to add efficiencies and diversify the minerals they are collectively able to mine could create opportunities at the other end of the industrial scale.
- Technological advancements and innovation in entirely new mining disciplines are likely to emerge as deep-sea mining begins and accelerates globally, but the U.S. is currently excluded from the International Seabed Authority's licensing because it is not a party to the UN Law of the Sea. A change in that policy stance or at least a concerted effort to support and partner with allies leading deep-sea mining efforts, such as Norway and Japan, may offer additional paths for mining innovation.
- The number of students enrolled in mining engineering programs in the U.S. is approximately 600, compared to a peak of 1,500 in 2014 and more than 12,000 enrolled in China.[18] Without sufficient expertise, the U.S. must rely on foreign mining engineers, cutting against self-sufficiency goals and hampering innovation in the private sector. Joint

[15] (U) | AZO Materials | G. P. Thomas | 26 FEB 2013 | "Functional Tractor Beams" | azom.com

[16] (U) | AZO Quantum | Taha Khan | 13 FEB 2024 | "Leveraging Quantum Sensors for Advanced Geological Surveying Techniques" | azoquantum.com

[17] (U) | Deloitte/NORCAT | Andrew Swart et al. | 2024 | "The future of mining with AI" | deloitte.com

[18] (U) | Ames National Laboratory Critical Materials Innovation Hub | Kwame Awuah-Offei and Elizabeth Holley | 28 MAY 2024 | Interview of Dr. Kwame Awuah-Offei, Union Pacific/Rocky Mountain Professor of Mining Engineering and Chair of the Department of Mining & Explosives Engineering at Missouri University of Science & Technology, and Dr. Elizabeth Holley, Associate Professor of Mining Engineering at Colorado School of Mines, in Coordination with the Critical Materials Innovation Hub

public-private efforts to expand mining engineering program enrollment would be beneficial.

2.2.5. Foreign Actor Threat

The relative regional isolation of the mining technology development, with regional variations in mining methodologies even within global companies, means that countries investing heavily in mining-specific technology and technology innovation in general can leave others lagging behind.

However, while mining technological developments remain isolated, developments in cyber capabilities aimed at global mines steadily increase. Outdated and dispersed mining IT systems and endpoints are startlingly vulnerable to cyberattack, resulting in stolen intellectual property/trade secrets like maps and surveys, geological data, and potential mining locations or acquisitions or even shutting down production. A 2022 cyberattack of Canadian Copper Mountain Mining Corporation (CMMC) in British Columbia, Canada, took down an operation producing nearly 65 million pounds of copper equivalent per year for a week.[19] [20]

In addition, China has taken steps to duplicate and extend the social value concept that can make Western mining companies more attractive for locals at foreign mine sites, undercutting that advantage. Russia, meanwhile, is willing to offer paramilitary support to African governments in exchange for access to resources.[21] [22]

2.3. Processing

2.3.1. Misalignment

Mineral processing is often outsourced to countries other than where the minerals are mined. Infrastructure requirements and local environmental impacts outweighed the costs of shipping raw ore abroad for processing in recent decades. CRM practices consider inelastic relationships between supply and price and seek to overcome the geopolitical realities of localized mineral deposits through secondary production, but both geopolitical tensions and public-private misalignment impede cohesive practices across the industry.

[19] (U) | Hudbay Minerals | Accessed 10 JUL 2024 | “Copper Mountain” | hudbayminerals.com

[20] (U) | Mining.com | 06 JAN 2023 | “Copper Mountain reopens mine after ransomware attack” | mining.com

[21] (U) | CNBC | Elliot Smith | 27 FEB 2024 | “Russia offering African governments ‘regime survival package’ in exchange for resources, research says” | cnbc.com

[22] (U) | Royal United Services Institute (RUSI) | Jack Watling et al. | FEB 2024 | “The Threat from Russia’s Unconventional Warfare Beyond Ukraine, 2022–24” | static.rusi.org

The global aluminum supply chain illustrates discrepancies between production and processing. Between 2000 and 2017, China's primary aluminum production capacity grew by over 1400%, representing 83% of total global production capacity and unseating the U.S. as the world's largest primary producer.[23] [24] By 2021, the U.S. produced less than 2% of primary aluminum globally, while secondary smelters accounted for over 75% of U.S. domestic supply.[25] However, China's surge in aluminum production is built on imports of bauxite from Guinea, Australia, and Indonesia rather than increased mining.[26]

The advantages of secondary smelting include cost savings on transportation, overhead, and energy expenditure, as well as incentivizing recycling by creating demand for new and old scrap. Although the rise of secondary smelting in the U.S. accounted for over 75% of the domestic aluminum industry's earnings in 2020, it is not a feasible solution for all CRM.[27] Metal companionality (fig. 1[28]), or the "degree to which a metal is obtained largely or entirely as a by-product of one or more host metals from geologic ores," means that the global availability of critical raw minerals is often determined during the processing stage of their "host" metals.[29] Commercial processing techniques, in turn, seek to optimize yield of the host metals. A 2015 study found that, for the 62 most commonly used metals and metalloids in modern technology, over 50% of their global supply was obtained as companion metals.[30]

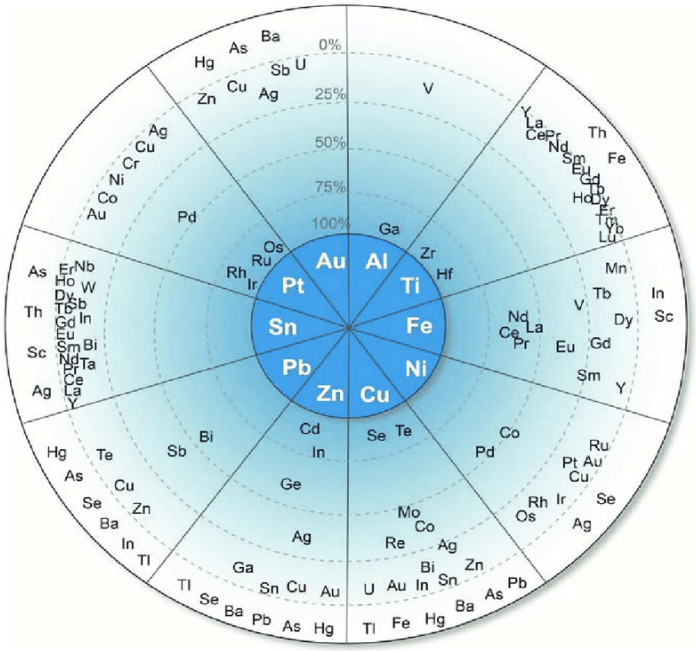

Figure 1: Wheel of Metal Companionality

[23] (U) | Economic Policy Institute | Adam S. Hersh and Robert E. Scott | 25 MAY 2021 | "Aluminum producing and consuming industries have thrived under U.S. Section 232 import measures" | epi.org

[24] (U) | Congressional Research Service (CRS) | Christopher D. Watson | R47294 | 26 OCT 2022 | "U.S. Aluminum Manufacturing: Industry Trends and Sustainability" | crsreports.congress.gov

[25] Ibid.

[26] (U) | Reuters | 20 APR 2023 | "China needs to mine more bauxite at home, industry official says" | reuters.com

[27] Ibid.

[28] (U) Nordic Innovation Report | Pasi Eilu et al. | SEP 2021 | "The Nordic supply potential of critical metals and minerals for a Green Energy Transition" | researchgate.net

[29] (U) | Science Advances | N. T. Nassar et al. | 03 APR 2015 | "By-Product Metals Are Technically Essential but Have Problematic Supply" | science.org

[30] Ibid.

2.3.2. Public

Public sector policy toward mineral processing focuses on environmental factors, which is one reason why mining companies outsource processing to other nations with less restrictive environmental regulations. Other factors include more processing capacity (i.e., facilities and skillsets) and/or cheaper labor. While other areas of technology are beginning to receive more attention on local capability and skill development (e.g., Chips and Science Act), metallurgical processing has yet to receive similar focus.

In the case of the aluminum industry, the U.S. public sector intertwined policy changes with economic and employment development initiatives to increase national production. In a 2024 economic impact study, the Aluminum Association found that the industry supports 700,000 U.S. jobs and generates $228 billion annually, roughly 1% of the U.S. GDP.[31] Job creation in the secondary processing market, including mid-and-downstream production, account for employment growth, while primary processing jobs decreased.[32]

Congress acknowledged the climate impact of increased aluminum production in the U.S. in its 2022 report *U.S. Aluminum Manufacturing: Industry Trends and Sustainability,* writing that the energy-intensive process contributes roughly 2% of global greenhouse gases.[33] Over half of these emissions come from electricity required for primary aluminum smelting; recent legislation therefore seeks to incentivize carbon-neutral aluminum production and secondary production techniques.[34] Through the Inflation Reduction Act of 2022, the Department of Energy established the Advanced Industrial Facilities Deployment Program, which provides financial assistance to producers and manufacturers that use technologies to reduce greenhouse gas emissions.[35]

2.3.3. Private

Private companies are creating coalitions to fund new processing facilities in nations that previously outsourced their processing. An example is Australia's new ore processing facilities. However, such facilities are causing geopolitical schisms and hurting other trade negotiations. Australia and China's longstanding economic ties are strained due to Australia's emerging processing industry, among other tensions.

Private companies have also come together to urge public policy changes that would favorably affect their industries by increasing supply, optimizing manufacturing and processing practices, and improving public sentiment. In 2023, U.S. companies like Ball Corporation, Ford Motor Company, GM, PepsiCo, and others signed an open letter to U.S. Energy Secretary Jennifer Granholm, advocating for federal investments in domestic aluminum production.[36] They cited

[31] (U) | The Aluminum Association | 23 APR 2024 | "Record Recycling Jobs and Economic Output for U.S. Aluminum as Investment Continues" | aluminum.org

[32] Ibid.

[33] (U) | CRS | Christopher D. Watson | R47294 | 26 OCT 2022 | "US Aluminum Manufacturing: Industry Trends and Sustainability" | crsreports.congress.gov

[34] Ibid.

[35] Ibid.

[36] (U) | Buy Clean Aluminum | 28 SEP 2023 | "Business Leaders Call for U.S. Department of Energy Investment in Clean Primary Aluminum" | buycleanaluminum.com

"spiking electricity prices, lack of access to low-cost renewable energy, and insufficient federal investment" as threats to the U.S.' primary aluminum smelters continuing operations.[37]

While the Inflation Reduction Act (IRA) included investment in carbon-neutral processing of aluminum, the open letter argues that the IRA's mandate for increased wind and solar energy development will exceed current domestic aluminum consumption, requiring greater investment in aluminum production for full implementation of the law. The role of CRM in clean energy solutions presents common ground for the investment interests of the public and private sector, but producing and deploying clean energy solutions at scale will require collaboration between public and private stakeholders.

2.3.4. Mitigation/Opportunity

For U.S. mineral supply chains to become more self-sufficient, processing capacity must be considered in addition to mining.

- Public and private partnerships will need to co-fund the expensive infrastructure components to process different types of ore and upskill their national workforces by creating education opportunities.
- The latter is arguably the more difficult challenge. Despite mining's importance to modern civilization, younger generations' interest in mining engineering and metallurgy has been declining for decades. This is in part due to negative reputational concerns informed by historical and modern events.
- The industry needs to creatively retell its story to attract and keep new talent in new places. This is especially true for areas like the U.S., where global market share of processing has declined in recent decades.

2.3.5. Foreign Actor Threat

China has been the primary beneficiary of outsourced mineral processing, both in economic and expertise terms. The Chinese government uses national dominance in the processing field to attempt to influence other nations, particularly Australia, vis-à-vis their relationship with the U.S.[38]

- Regional shifts in expertise cause downstream effects on national health, productivity, and spending, which differentiate foreign nations with more efficient raw material processing from nations that outsource processing. In the U.S., for example, older aluminum processing plants produce some of the highest perfluorocarbon emissions in the world (fig. 2, below[39]), requiring a larger national lift to not only modernize the industry, but negate its negative climate effects.[40]

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[37] Ibid.

[38] (U) | RUSI | Alexander Korolev and Fengshi Wu | 22 APR 2024 | "Australia's Critical Minerals Strategy amid US–China Geopolitical Rivalry" | rusi.org

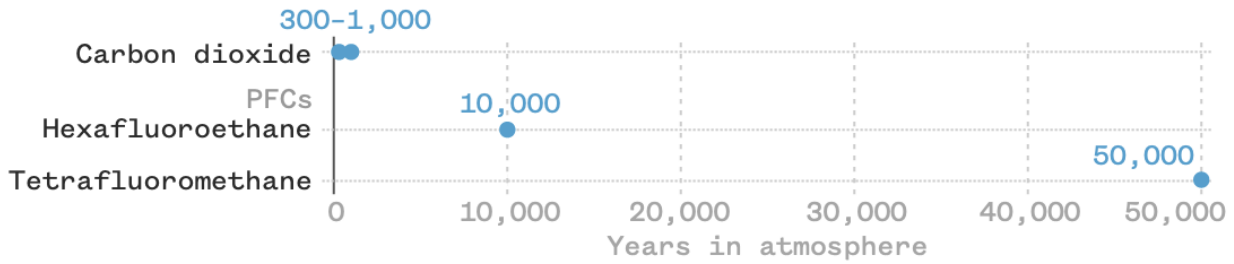
[39] (U) | NBC News | Phil McKenna | 06 DEC 2022 | "Aluminum plants in the U.S. are releasing tons of highly potent greenhouse gas, unlike their counterparts abroad" | nbcnews.com

[40] Ibid.

- National security implications of the energy consumption required for critical raw material processing run concurrent with the global clean energy transition. Strain on power infrastructure, shortages of metals for new construction, and suboptimal processing sectors create vulnerabilities that may be exploited by foreign threat actors.

Figure 2: Emissions related to aluminum processing

Perfluorocarbons (PFCs) and carbon dioxide are both released during aluminum smelting, but PFCs remain in the atmosphere much longer.



Source: Intergovernmental Panel on Climate Change, NASA

Graphic: Paul Horn / Inside Climate News and JoElla Carman / NBC News

2.4. Manufacturing

2.4.1. Misalignment

Divergent interests between the public and private sectors, as well as the lack of long-term strategic policy goals contribute to a dynamic that potentially inhibits future innovation, manufacturing capabilities, and security to the benefit of rivals who can more easily manipulate supply chains.

2.4.2. Public

The public sector lacks detailed expertise in manufacturing supply chains, as well as clear prioritization of what is necessary versus desirable to national and economic security. These factors hinder the government's ability to craft effective policies.

One area where this is evident is the lack of overarching strategy for green manufacturing capabilities. Studies of U.S. needs to meet green energy goals are plentiful, but the lack of a public intermediary entity to effectively bring diverse industries together to pool demand and draw on industry expertise to inform policy hamstrings attempts to develop an overarching strategy.[41]

2.4.3. Private

Disparate end user industries have widely varying, and sometimes competing, critical mineral needs connected by complex, global supply chains. Private entities must also navigate different

[41] (U) Johns Hopkins University Net Zero Industrial Policy Lab | Bentley Allan | 20 JUN 2024 | Interview with Dr. Bentley Allan, Founder and Co-Director of the Net Zero Industrial Policy Lab

regulations depending on country, industry, and customer. These challenges are especially acute in smaller businesses and startups that may not have the resources to mitigate risks or separate themselves from questionable sources in their supply chains.

- In industries with shared mineral needs, volumes, and purities, competing companies struggle to effectively cooperate to push for supply chain change at the raw minerals level.
- Even when industry groups manage to advocate for raw minerals sourcing shifts, they are often too far removed from raw minerals markets by multiple layers of the supply chain to have any impact on mineral producers.
- Manufacturing companies may take limited mitigation actions, such as increasing days of supply by weeks or months in various stages of the value chain but cannot sustain expansive mitigation measures—such as stockpiling all needed minerals against long-term disruption—as it makes them uncompetitive.

2.4.4. Mitigation/Opportunity

Foreign allies are adapting to supply chain challenges by formalizing collaboration between the public and private sectors. Although these measures are not fully replicable in the U.S., they can provide frameworks for developing cooperation.

- Japanese-style stockpiling[42] of critical minerals by manufacturers is coordinated and supported by government. To manage the stockpile, Japan subsidizes the interest required to borrow funds for the purchase of rare metals and the costs required to maintain and manage stockpile warehouses.
- Development of formal mechanisms for cooperation between industry and government can improve understanding of CRM needs and guide policy proposals to address challenges from adversaries. Germany provides possible models for cooperation.[43]
- Identification of specific minerals, parts, or components higher in the value chain that address the most pressing security or economic concerns of the U.S. government.
    - Clear priorities can illuminate optimal solutions for mitigating the most acute risks in the most efficient way.
        - Example 1: Reshoring the entire semiconductor value chain will take decades, but stockpiling silicon wafers instead of raw silicon ore helps address potential disruptions in the interim.
        - Example 2: Incentives to re-shore or friend-shore all manufacturing necessarily includes low-strategic-value goods like toys, which represents inefficiencies for the U.S. government and U.S. consumers vs. incentivizing a focused basket of strategic goods.

[42] (U) | International Energy Agency | Last Updated 26 OCT 2023 | "International Resource Strategy - National stockpiling system" | iea.org

[43] (U) | German Federal Ministry for Economic Affairs and Climate Action (BMWK) | Accessed 20 JUL 2024 | "Joining forces to strengthen German industry" | bmwk.de

- Coordination with allies to defend diversification initiatives across the value chain and preserve fair market and trade conditions in the face of emergent market manipulation efforts.

2.4.5. Foreign Actor Threat

As part of its self-sufficiency drive in technology and other industries deemed critical by the Chinese Communist Party (CCP), Beijing is attempting to cease its reliance on Western companies, expertise, and technologies. If that goal is met, it permits China broader leeway in limiting Western access to the raw material inputs, reducing the CCP's fear of retaliation by Western governments.

- China's control of critical raw minerals markets allows Beijing to interrupt continuity of supply for U.S. manufacturers directly, to undermine diversification efforts indirectly, or to manipulate availability and pricing to disadvantage U.S. manufacturers vis-à-vis Chinese manufacturers competing in global markets.
    - **Directly**: As discussed above, China has placed export controls on gallium, germanium, and natural graphite in the last year,[44] and banned exports of rare earth extraction and separation technology.[45] China may at any time deny exports of raw material—or the components that utilize them—to disrupt production by U.S. manufacturers and/or purchase by U.S. consumers, causing potentially serious economic harm and military readiness. U.S. manufacturing supply chain executives currently consider this a critical risk.
    - **Indirectly**: China may leverage export controls or threat thereof to prevent manufacturers further up the value chain from moving operations out of China. Despite pressure from their customers eager to diversify from China, mid-stream suppliers utilizing critical raw minerals may decline to move operations out of China, because doing so would leave them more vulnerable to export controls on the raw material, while also potentially provoking Chinese authorities or customers.[46] [47]
    - **Tilting the field**: China could selectively limit mineral exports to undermine U.S. manufacturers by creating uncertainty or disruptions in their supply chains while

[44] (U) | Nikkei Asia | Shunsuke Tabeta | 07 NOV 2023 | "China tightens rare-earth export curbs amid tensions with U.S." | asia.nikkei.com | Gallium and Germanium announced 03 JUL 2023, effective 01 AUG 2023. Rare earth metals and oxide exporters were asked to begin reporting transactions—thought to be data collection to determine how to implement controls in the future. Chinese export controls on natural graphite were announced 20 OCT 2023, effective 01 DEC 2023.

[45] (U) | Center for Strategic and International Studies (CSIS) | Gracelin Baskaran | 08 JAN 2024 | "What China's Ban on Rare Earths Processing Technology Exports Means" | csis.org

[46] (U) | Reuters | 29 AUG 2023 | "US companies in China struggle with raids, slow deal approvals, anti-espionage law" | reuters.com | Last year, U.S. memory chip manufacturer Micron and due diligence/consulting firms Mintz, Bain & Co. and Capvision were subject to retaliation by Chinese officials for U.S. government actions and activities related to topics Beijing deems sensitive.

[47] (U) CSIS | Matthew Reynolds | 22 JUN 2023 | "Micron Aggression: The Right Response to Beijing's Ban on the U.S. Chipmaker" | csis.org

protecting China's domestic manufacturers. As the costs for U.S. manufacturers rise, they become less competitive globally.

2.5. End User/Sales

2.5.1. Misalignment

Diverging interests between public and private sectors creates disparate risk tolerances to cost, lead times, and end users of critical raw material (CRM) products. These disparate risk tolerances introduce vulnerabilities to existing critical infrastructure supply chains and could hinder future supply chains to the benefit of adversarial nations looking to undermine America's economy and national security.

2.5.2. Public

The public sector maintains a low risk tolerance with national security as its main priority. Most public sector agencies have a pre-established list of acceptable suppliers that adhere to the Buy American Act, which limits purchasing through cleared, domestic manufacturers.[48] However, the public sector is still susceptible to domestic supply and demand fluctuations.

- This low risk tolerance enables the public sector to enact tariffs and create import restrictions without much disruption to supply chains but can adversely impact public sector supply chains.[49] [50]
- Domestically procured supply items reduces potential disruption from foreign adversaries, long lead times and invests in the U.S. economy.
- The public sector has not created an environment that incentivizes public industries; however, revisions to Section 301 tariffs announced in May 2024 by the U.S. Trade Representative and White House, are aimed at incentivizing industrial partners with the procurement of critical minerals.[51]

2.5.3. Private

The risk tolerance of private sector end-users is generally higher than the public sector. The private sector's focus on profitability drives their risk tolerance, which varies by industry, company, and project. This influences the private sector's decisions when securing supply chains and can introduce vulnerabilities into supply chains.

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[48] (U) | U.S. Government Accountability Office (GAO) | 05 APR 1978 | "The Buy American Act" | gao.gov

[49] (U) | The White House | 16 MAY 2024 | "FACT SHEET: Biden-Harris Administration Takes Action to Strengthen American Solar Manufacturing and Protect Manufacturers and Workers from China's Unfair Trade Practices" | whitehouse.gov

[50] (U) | U.S. Customs and Border Protection (CBP) | "Uyghur Forced Labor Prevention Act" | Last Updated 01 JUL 2024 | cbp.gov

[51] (U) | The White House | 14 MAY 2024 | "FACT SHEET: President Biden Takes Action to Protect American Workers and Businesses from China's Unfair Trade Practices" | whitehouse.gov

- The competitive nature of the private sector, and the variety of the type of sectors, creates fluctuating risk tolerances and limits the level of engagement with public sector entities to help secure private sector supply chain gaps.
- The private sector's cash flow considerations and focus on profitability creates an environment to engage manufacturers who deliver on time and budget, regardless of sourcing country. This approach risks intellectual property theft and localized economies of scale[52] that can contribute to longer term market control and manipulation.
- Many private sector companies do not have the resources to track, manage, and forecast the CRM required for their products (e.g., lithium for electric vehicle batteries, gallium used in solar panels, etc.) potentially creating future shortages with competing industries. This increases the risk of purchasing compromised products from rival nations, such as purchasing products with cyber vulnerabilities, those manufactured through forced labor, or engaging with companies avoiding import tariffs; all of which could compromise private sector controlled critical infrastructure through future import restrictions.[53] [54]
- The private sector cannot take cash intensive mitigation measures such as stockpiling products against long-term supply chain disruptions or public sector policy changes as advances in technology, bids for projects, and a business' cash flow make these measures unprofitable.

2.5.4. Mitigation/Opportunity

Increased Private-Public sector cooperation could limit future supply chain shortages, including cross-industry domestic competition for end users of privately controlled critical infrastructure.

- Li-Bridge is an example of a wholistic public-private approach to ensure all stakeholders (e.g., private industry, national laboratories, and the federal government) develop and execute a national strategy to create an accelerated and secure supply chain for lithium-based batteries.[55] Creating additional private-public cross-industry partnerships could enable the public sector in forecasting, stockpiling, and adequately incentivizing purchase of more secure supply chains. This type of partnership could also influence the private sector's risk tolerance and priorities to focus on longer-term security issues and invest in more secure supply chains from non-rival nations.
- Japanese-style industry-academia-government collaboration to secure appropriate forecasting and stockpiling of CRM to achieve energy security, economic efficiency, and

[52] (U) | Bloomberg | Colin McKerracher | 12 APR 2024 | "China already makes as many batteries as the entire world wants" | bloomberg.com

[53] (U) | Solar Energy Industries Association (SEIA) | DEC 2019 | "The High Cost of Tariffs" | seia.org

[54] (U) | Foreign Policy | Lili Pike | 21 AUG 2023 | "Has the U.S. Campaign Against Uyghur Forced Labor Been Successful?" | foreignpolicy.com

[55] (U) | Lawrence Berkeley National Laboratory Energy Storage Center | Accessed 20 JUL 2024 | "What is Li-Bridge?" | energystorage.lbl.gov

environmental stability could be used a model to achieve the same level of U.S. private-public collaboration to align interests and risk tolerances.[56]

- Stockpiles of critical minerals are managed through the Department of Energy, federally regulated emergency agencies, and the National Defense Authorization Act (NDAA). These partnerships should be expanded to include cross-industry private sector end users.
- Increased cooperation with allies and partners through "friend-shoring" procurement agreements can limit adversarial nation-state price fixing while securing U.S. supply chains for both public and private sectors.

2.5.5. Foreign Actor Threat

As part of its self-sufficiency drive in technology and other industries deemed critical by the Chinese Communist Party (CCP), Beijing is attempting to cease its reliance on Western companies, expertise, and technologies. If that goal is met, it permits China broader leeway in limiting Western access to the raw material inputs, reducing the CCP's fear of retaliation by Western governments.

- In a NDAA mandated study, RAND concluded eighteen of the thirty-seven critical minerals relevant to defense applications are concentrated in China with fourteen more concentrated in countries that have strong diplomatic and economic relationships with China.[57]
- **Indirectly**: China has created legal frameworks to become a manufacturing epicenter to secure intellectual property and production; thereby controlling market prices and influencing U.S. private-sector-controlled critical infrastructure.[58] [59]
- **Indirectly**: China continues end user dominance through control of rare earth metal imports and refining. The U.S. imports 76% of rare earth metals from China and relies on China to refine domestically mined rare earth metals, ensuring U.S. supply chain reliance on adversarial nations. [60]
- **Directly**: The 2017 Cybersecurity and 2021 Cyber Vulnerability Reporting Laws enables the CCP to control cyber environments to discover, exploit, and maintain backdoor access

[56] (U) | Japanese Ministry of Economy, Trade and Industry (METI) Agency for Natural Resources and Energy | 31 JUL 2020 | "Japan's new international resource strategy to secure rare metals" | enecho.meti.go.jp

[57] (U) | RAND Corporation | Cortney Weinbaum et al. | 11 FEB 2022 | "Assessing Systemic Strengths and Vulnerabilities of China's Defense Industrial Base" | rand.org

[58] (U) | National Counterintelligence and Security Center (NCSC) | 20 JUN 2023 | "SAFEGUARDING OUR FUTURE: U.S. Business Risk: People's Republic of China (PRC) Laws Expand Beijing's Oversight of Foreign and Domestic Companies" | dni.gov

[59] (U) | CSIS | Gracelin Baskaran | 12 JUN 2024 | "Digging Deeper: Building Our Critical Minerals Workforce" | csis.org

[60] Ibid.

in technology through end user products, compromising private sector controlled critical infrastructure.[61]

- **Directly**: China-based cybergroup DragonBridge previously created disinformation campaigns aimed toward stopping domestic production which would keep the private sector dependent on adversarial nations.[62]

2.6. Recycling/End-of-Life

2.6.1. Misalignment

While there are a multitude of challenges affecting critical minerals recovery and substitution at home and abroad, differing perspectives and priorities are key drivers of public-private misalignment on domestic critical minerals recycling programs. Several concerns centered on existing recycling **laws** and economics of **scalability** in recycling CRM were identified:

- Recycling is not federally mandated in the U.S.
- State and local recycling laws are often inconsistent and contradictory.
- Recycled minerals are shipped outside of U.S.
- Lack of technology to recycle at scale and make a positive ROI.
- Product design prevents cost-effective recycling.
- Processing locations are not optimal to transport recycled minerals.

2.6.2. Public

The public sector recognizes the strategic importance of critical minerals recycling, but viable, large-scale domestic projects remain limited due to significant economic, infrastructural, and technical barriers faced by the private sector. Federal, state, and local level efforts are uncoordinated, despite—or perhaps because of—multiple initiatives by departments, agencies, and local authorities. Conflicting recycling laws across the country increase the costs of other factors, including transportation.

Therefore, while the public sector may have a long-term expectation for private industry to improve recycling efforts, it does not provide any short-term incentive for companies to do so, either by mandates or adequate financial assistance.

2.6.3. Private

The complexities of the recycling process are one hindrance to private sector recycling efforts. In order to effectively recycle, the appropriate entities must reseparate all components. Each

[61] (U) | NCSC | 20 JUN 2023 | "SAFEGUARDING OUR FUTURE: U.S. Business Risk: People's Republic of China (PRC) Laws Expand Beijing's Oversight of Foreign and Domestic Companies" | dni.gov

[62] (U) | RAND Corporation | Marta Kepe and Fabian Villalobos | 03 NOV 2022 | "Enhance U.S. Rare Earth Security Through International Cooperation" | rand.org

component must be treated somewhat differently to extract and purify the critical minerals. This causes the extraction process to be technologically and financially cost-ineffective. [63]

A profit-seeking business will not engage in a money-losing venture. Since it is often more expensive to recycle old equipment, companies simply purchase new hardware. Although U.S. government entities, such as the Department of Energy and the Department of State, are collaborating to fund some private companies' recycling projects, such efforts are relatively narrow ventures, and are unlikely to mitigate the currents gaps and foreign dependence issues affecting critical raw minerals supply chains.

For instance, the Department of Defense's Industrial Base Analysis and Sustainment Program awarded Mountain Pass Materials Corp $35 million to separate and process heavy rare earth elements. Through this investment, Mountain Pass Materials will be able to recycle all recoverable rare earths from end-of-life magnets and magnet production scrap to increase resilience and environmental sustainability of the domestic supply.[64] [65]

There are some attempts to recycle in novel, cost-effective ways; sensor-based waste sorting technologies being developed by companies like STEINERT, Redwood Materials, and Li-Cycle are receiving billions in public funding in the U.S. to innovate in the batteries recycling space.[66] However, these types of enterprises require investments magnitudes beyond the aforementioned public funding.

In addition, smaller magnets and electronics are generally not available in quantities large enough to make recycling scalable earn an ROI. Meanwhile, larger magnets (MRI machines) are recycled typically through third parties in the People's Republic of China (PRC).

Another challenge is product designs that are difficult to maintain and recycle. Although some companies are attempting to build products with easily interchangeable parts, such as Dell's Concept Luna,[67] it is not clear that these efforts will factor into consumers' purchasing decisions.

2.6.4. Mitigation/Opportunity

Developing feasible, scaled-up recycling process is key to producing a positive ROI, which also reduces reliance on foreign CRM sources. Although critics of recycling programs may argue that even if everything is recycled in the U.S., projections state that CRM shortages will persist.[68]

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[63] (U) | Armed Forces Communications & Electronics Association (AFCEA) International | Diego Laje | 01 APR 2024 | "From Trash to Treasure: Critical Minerals Recycling" | afcea.org

[64] (U) | MP Materials | 22 FEB 2022 | "MP Materials Awarded Department of Defense Heavy Rare Earth Processing Contract" | investors.mpmaterials.com

[65] (U) | The White House | 22 FEB 2022 | "FACT SHEET: Securing a Made in America Supply Chain for Critical Minerals" | whitehouse.gov

[66] (U) | Energy Monitor | Nick Ferris | 24 MAR 2023 | "Why recycling is no golden ticket to endless critical minerals" | energymonitor.ai

[67] (U) | Dell Blog | Glen Robson | 15 DEC 2022 | "Data-Driven Innovation Meets Sustainable PC Design: Concept Luna's Evolution" | dell.com

[68] (U) | Energy Monitor | Nick Ferris | 24 MAR 2023 | "Why recycling is no golden ticket to endless critical minerals" | energymonitor.ai | The short-term problem is that there is not enough material to recycle from until at least 2030s.

However, recycling should be a component of a wholistic strategy in conjunction with mitigation efforts outlined above to combat CRM shortage. Improvements in recycling law and technology can help.

True public-private alignment requires a transition to a more circular economy for critical minerals and related finished products. Supporting such an effort necessitates strategic shifts in government and industry to create market demand for recycling services, while also further incentivizing and/or funding recycling projects and research.

Recycling CRM is currently not economically viable in the U.S., which inhibits attempts to secure future critical mineral supplies.[69] America's recycling infrastructure has not kept pace with today's waste stream. Communication between the manufacturers and the recycling industry needs to be enhanced to prepare for, and optimally manage, the recycling of future products.

Domestic markets for recycled minerals need to be strengthened. Some recycled minerals generated in the U.S. are exported internationally. However, changing international policies limit minerals exports. Public-private alignment should better integrate recycled minerals and end-of-life management into product and packaging designs.[70] The two need to improve communication among the different sectors of the recycling system to strengthen existing minerals markets and to develop new innovative markets.

2.6.5. Foreign Actor Threat

Foreign actors are unlikely to target recycling infrastructure at its current level of development. Although foreign actors have the capability for nefarious acts, such as using disinformation to disincentivize recycling in the U.S. and extend U.S. reliance on foreign countries for recycling, their intent remains a low probability. If future recycling processes produce large quantities of minerals in unsecure locations, theft is a concern. However, it is unlikely that the benefit of such efforts will outweigh the costs.

3. Conclusions and Recommendations

Both the public and private sectors must create opportunities for formal engagement to develop creative and feasible solutions to the challenges the U.S. faces regarding critical minerals. The matrix below assesses each life cycle stage's risk of disruption by foreign threat actor probability and intent to determine that the processing, manufacturing, and end user/sales are in the highest risk category. Based on current geopolitical relationships, critical mineral sources, and the forecast increase in critical mineral usage globally, foreign adversaries have several advantages over the U.S. in the critical mineral space. However, the U.S. still maintains advantages in technological innovation and resources to invest in addressing challenges.

The recommendations below are not exhaustive but represent feasible ideas to address current and future challenges.

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[69] (U) | AFCEA International | Diego Laje | 01 APR 2024 | "From Trash to Treasure: Critical Minerals Recycling" | afcea.org

[70] (U) | U.S. Environmental Protection Agency (EPA) | Last Updated 21 FEB 2024 | "The U.S. Recycling System" | epa.gov

- Increased partnerships with allies through engagement with the World Trade Organization and "friend-shoring agreements" to ensure continued access to fairly priced supply chains.
- Supply chain diversification through expanding the list of "friendly" countries that the Department of Defense can source from provides incentives for the private sector by knowing which countries are less likely to face import restrictions and tariffs.
- A coalition of private-public representatives, similar to the Li-Bridge group, is needed to forecast current and future critical raw minerals based on universal supply across industries to reduce competition and ensure emergency reserves. This would ensure clean, safe, long-term reliability of supply chains and help create a risk tolerance to better align the public and private sector.
- Regular review of programs such as the Customs-Trade Partnership Against Terrorism (C-TPAT) and assess the costs versus benefits to members when adding Minimum Security Criteria. A study from the University of Houston's Border, Trade, and Immigration Institute found that 25% of surveyed members indicated that implementing security improvements represents a "substantial cost."[71]
- Consolidate elements of the public sector that address critical minerals such as USGS, the Department of Energy, intelligence community, and others to provide policy makers and business leaders with accurate and actionable insights into the opportunities and challenges facing the U.S. in the critical mineral environment.
- The intelligence community and federal law enforcement should improve engagement with small startups and local economic development offices, particularly those involved in critical minerals. Foreign threat actors are actively exploiting these entities' desire for investment and lack of resources for mitigating threats to gain access to intellectual property and critical minerals through opaque investments and land purchases.
- Increase enrollment in mining and metallurgy programs. The private sector, particularly mining companies, can increase the funding for scholarships. The public sector can increase the number of international students in U.S. mining programs, particularly those from partner nations with growing mining industries.

[71] (U) | The Borders, Trade, and Immigration (BTI) Institute | Allen Gina et al. | MAY 2021 | "Assessment of Customs-Trade Partnership Against Terrorism (CTPAT) Program" | uh.edu/bti

CRM Stage	Capability of a foreign actor to act	Intent of a foreign actor to act
Discovery	2	2
Mining	2	1
Processing	3	3
Manufacturing	3	3
End User/Sales	3	3
Recycling	2	1

Legend
Low
Medium
High

4. Acknowledgements

This paper would not have been possible without the insights of the subject matter experts at the Ames National Laboratory, Johns Hopkins University's Net Zero Industrial Policy Lab, the FBI, RAND, and the Office of the Secretary of Defense who generously contributed their time and knowledge to guide the team's research. Special thanks go to Dr. Thomas Lograsso and Jennifer Brockpahler of the Ames National Laboratory Critical Materials Innovation Hub for arranging subject matter experts to speak during the team's research trip. The Critical Materials Innovation, or CMI, Hub is supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Advanced Materials and Manufacturing Technologies Office.