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Final Report

Toward an Industrial Security Strategy to Safeguard Access to Critical Minerals

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1. Executive Summary

Access to minerals is critical to U.S. economic and national security. However, in recent years, China and Russia have gained strategic advantages in critical mineral global supply chains, introducing unacceptable risks to the U.S. industrial base. In response, the United States must develop and execute a comprehensive, long-term industrial security strategy with its allies and partners to expand reliable and assured access to critical minerals.

An assessment of the national competitive advantages of four states provides valuable context to the problem and underpins this report's recommendations. China is an influential leader in the global mining industry, creating value across the entire mineral supply chain and holding significant power over supplies. Russia possesses abundant natural resources and skilled human capital, but poor governance challenges its global market access. Canada recognizes critical and strategic minerals are necessary for future economic growth and is taking proactive steps to develop its mining capacity. Australia is a dominant presence in the mining industry, benefiting from strong domestic rivals, aggressive home-based suppliers, and demanding local customers. Compared to the international community, the United States hosts an economic environment that encourages competition and innovation, but its mining industry struggles to compete with foreign competition.

This report provides eight policy recommendations for orienting the ways and means needed to expand domestic mining, maintain access to supply chains, and reduce U.S. economic and national security risks. The following is a summary list of recommendations:

1. Innovation: Foster mining innovation ecosystems for greater industry collaboration
2. National Defense Stockpile (NDS): Regularly audit and appropriately fund the NDS
3. Human Capital: Increase stakeholder collaboration to expand the mining workforce
4. Industry Policy: Incentivize domestic mining exploration, development, and production
5. Supply chains: Action recommendations contained within the "*100-Day Supply Chain Review under Executive Order 14017 "Securing America's Supply Chains*"
6. Environment, Social, Governance (ESG): Develop international ESG standards
7. Permitting: Increase permitting efficiencies to increase mining competitiveness
8. Coalition Criticality: Develop an international critical materials list with allies and partners for increased risk awareness and mitigation planning

2. Introduction

For nearly a century, unfettered access to minerals and metals empowered the innovation that made the U.S. economy and national security strong. Unfortunately, over the last two decades, the United States has witnessed a decline in many of its domestic mining and mineral processing capabilities. Conversely, competitors, such as China and Russia, have invested in and gained advantages in those same capabilities. This outcome now bears unacceptable risk to the global industrial base upon which U.S. national security depends. In response, the United States must develop and execute a comprehensive, long-term industrial security strategy with its allies and partners to expand reliable and assured access to critical minerals. The following pages contribute to the development of such a strategy by describing the situation and challenges of the critical minerals dilemma, the national competitiveness of select critical mineral supply chain stakeholders, and policy recommendations for orienting the ways and means needed to expand access to reliable supply chains.

3. Situation and Challenges

Economics and Security

The global demand for technology is driving exponential demand growth for minerals.[1] A recent International Energy Agency study asserted U.S. demand alone will grow by approximately 30 times between 2020 and 2040, as measured by commodity mass.[2] Correspondingly, a University of Birmingham study demonstrated that growth is also taking place in the breadth of minerals demanded, which is currently measured in the dozens (See Figure 1).[3] As demand grows, the requirement to secure supply chains will also grow.[4]

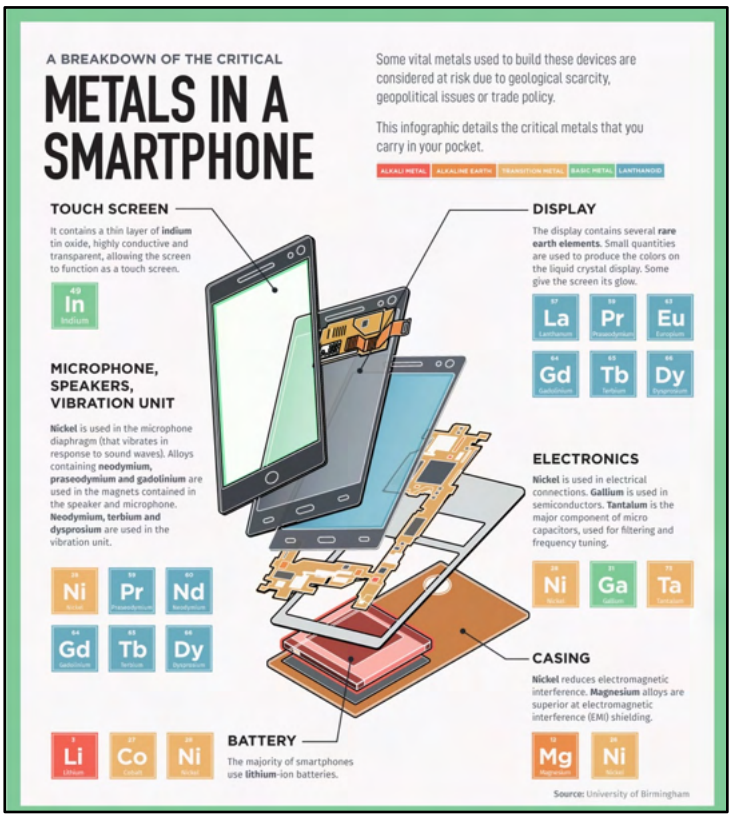

Figure 1. Breadth of Critical Minerals in Demand[5]

In general, the supply of minerals extends worldwide, but certain conditions in any one country affect its ability to develop its mineral potential fully. By their market share, four countries operate over 50 percent of all mining globally: The People's Republic of China, the United States, Russia, and Australia (See Figure 2).[6] These countries have been successful at developing their mineral potential because they have substantial mineral resources, the political will to facilitate mining, and the technology and expertise to explore, extract, and process the minerals. In some cases, these countries expanded their ability to supply minerals by establishing governance institutions that advance the skills and technology to extract and process minerals and worked with allies and partners to regionally broaden the political and economic conditions favorable to mining and processing. While these conditions resulted in a net worldwide supply growth of minerals and metals, they have also generated localized supply concentrations that become a source of power for those that control them and a critical vulnerability to those that rely upon them.

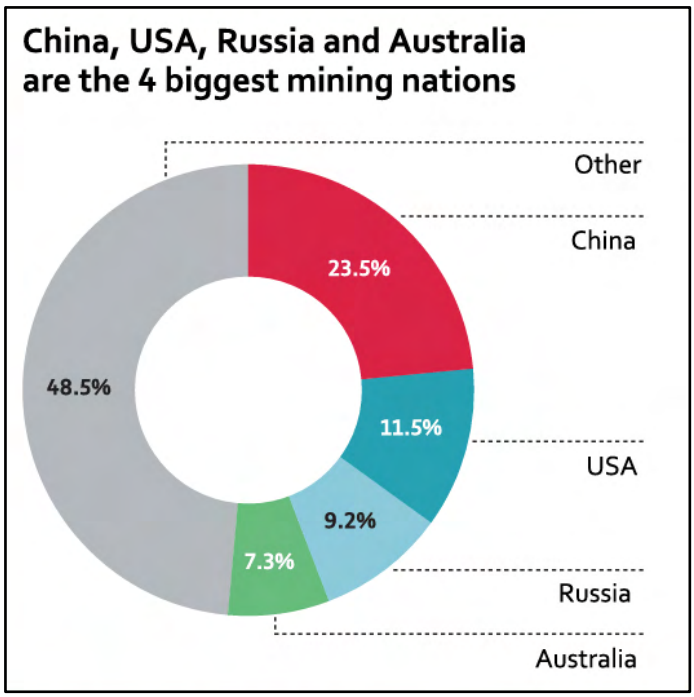

Figure 2. Distribution of Global Mining[7]

A PRC-Japan disagreement illustrates the potential vulnerability should a competitor chooses to weaponize its control over the supply chain. In 2010, Japanese Coast Guardsmen arrested the captain of a Chinese fishing vessel for violating Japanese fishing laws in its territorial waters around the Senkaku Islands. The Chinese government responded by "refusing to fill Japanese companies' orders for rare earth elements, including neodymium and dysprosium."[8] With no other access or ability to process the required elements, the Japanese government acquiesced and released the Chinese captain. The economic fallout of this political skirmish cascaded across the rare earth minerals market, where prices climbed as much as 2,000% over the next year and a half due to commodities brokers' fears of decreased access and market volatility.[9] Since 2010, the worldwide strategic environment grew even more tense due to China's growing economic influence and Russia's aggressive behavior, both of which appear to have elevated mineral supply chain risks.

Defining Criticality and Risk

Since 2017, the U.S. government has recognized the need to develop and update a Critical Mineral List (CML) as a basis for U.S. policy on critical minerals. However, the

challenge of defining and measuring mineral criticality and risk has proven complex as there are no universally agreed-upon methodologies. In the words of Alex King, former director of the Department of Energy's Critical Materials Institute, "[w]hat is critical depends on who you are, where you are, and when you ask."[10]

Despite the challenges, Congress and the U.S. Geological Survey have (USGS) developed two essential definitions that have begun to shape U.S. policy. First, in the Energy Act of 2020, Congress defined *critical minerals* as: "the minerals, elements, substances, or materials that [a] are essential to the economic or national security of the United States; [b] the supply chain of which is vulnerable to disruptions […]; and [c] serve an essential function in the manufacturing of a product […], the absence of which would have significant consequences for the economic or national security of the United States."[11] This definition provided the basis for further interagency efforts to identify the critical mineral supply chains of greatest U.S. risk. Second, in February 2022, the USGS issued the Mineral Commodities Summaries 2022 with an updated CML containing 50 minerals based on the new USGS definition of *supply risk* as "the confluence of the following three factors: the likelihood of a foreign supply disruption, the dependency of the U.S. manufacturing sector on foreign supplies, and the vulnerability of the U.S. manufacturing sector to a supply disruption" (see Appendix B).[12] With established definitions for *critical minerals* and *supply risk*, the U.S. government is poised to develop policy and strategy to safeguard its economy and national security.

Another challenge in defining U.S. *criticality* and *risk* is describing their practical economic and security boundaries. For example, the United States currently assesses mineral criticality at the U.S. national level while effectively recognizing allies as diversified supply sources. However, the U.S. economy and industrial base are closely linked to the allied industrial bases of Australia, Canada, and the United Kingdom through the National

Technology and Industrial Base (NTIB). Additionally, the U.S. economy is interdependent with the European Union and its Defense Technological and Industrial Base (EDTIB), a major base of trading partners and allies that defend the Western values of liberal democracy and the free market.[13] Similarly, U.S. security also depends on North Atlantic Treaty Organization (NATO) allies and their industrial capabilities. Thus, exposure to the critical mineral supply vulnerabilities of individual allies in each entity affects the U.S. economy, national security, and vulnerability to critical mineral supply risks.

4. Structure – Conduct - Performance

Structure

Mining firms face several unique circumstances that shape their industry's structure and challenges, including long time-frames, high capital requirements, significant community expectations, and volatile markets. A mining project's lifespan can last generations and the initial phases of exploration, feasibility determination, and construction can last more than a decade, and require millions of dollars in investments (see Appendix C). Furthermore, a mine depletes its commodity assets as its operations progress, and as the mine matures and advances toward closure, mining companies are increasingly exposed to costly environmental, social, and corporate governance (ESG) factors. Finally, many firms have little-to-no control over commodity prices and global mineral markets can be volatile, rendering revenues unpredictable over the lifespan of the mining operation.

Geology and geography add additional sources of risk to the mining industry. At the mining site, firms face challenges predicting the performance of mines prior to extraction and estimating construction costs. In mining regions, firms often endure harsh physical environments, geopolitical instability, and a lack of infrastructure or human capital. Finally, ore concentrate is frequently shipped to countries far from its origin for processing, and products are sold to diverse buyers located worldwide, adding shipping risks and costs.

The combination of these challenges creates a high-risk industry with high entry and exit costs. As a result, the mining industry has many companies that specialize in the phases of exploration through feasibility, but fewer that engage in higher-risk and capital-intensive mining operations. In this mining ecosystem, junior mining firms play an important role in identifying reserves that mining operations firms can acquire when market conditions allow.[14] Ultimately, these factors create an industry structure that is dominated by oligopolies, monopolies, and state-owned enterprises, with the profitable mining firms tending to pursue common business strategies aimed at maximizing shareholder value.

Conduct

Mining firms employ several strategies to remain viable among industry challenges:

Niche Focus. Mining firms that specialize in niche commodity markets often find it difficult to differentiate their products. As a result, firms may try to differentiate products by using unique processing techniques that offer higher-grade concentrates or invest in research and development to identify new commercial uses for its product.

Diversification. Mining firms may diversify their commodity offerings to offset risk. For example, Glencore has balanced its product supplies between current and emerging energy markets including in oil, natural gas, cobalt, and nickel. This strategy is rare as it requires managerial expertise in unrelated business units, which carries competitive risks.[15]

Operations. Firms must find a balance between creating value with existing assets and investing in new operations. Within existing operations, they may streamline processes, modify management, upgrade technology, develop economies of scale, or alter the production of certain commodities within their ore bodies. Alternatively, firms may also invest in capital-intensive exploration and brownfield or greenfield development. As firms assess these options, they may discover that investing in innovations for active mines creates less value than pursuing the comparative cost advantages of mining ventures in other regions.

Integration. Many mining firms seek vertical and horizontal integration. Vertical integration captures added value at multiple stages of a product's value chain. Horizontal integration captures value across several products at the same level of the value chain and mitigates competition. The 2012 Glencore Xstrata merger exemplified vertical integration by integrating commodities trading and mining in one firm.[16] Glencore later demonstrated horizontal integration by partnering with Managem to acquire cobalt from recycled batteries while it was also extracting cobalt from mines in the Democratic Republic of Congo.[17]

Relationships. Mining firms must employ legal, technical, and public affairs expertise to navigate many relationships. In the developing world, firms often navigate export tariffs, inconsistent royalty rates, corruption, and myriad dangers to their mining operations or ownership claims. In the developed world, firms often face permitting delays or "not in my back yard" resistance. In the United States, firms face regulatory requirements at federal, state, and local levels and may require years to satisfy permitting requirements.

Performance

Creating value in the mining industry is challenging (see Appendix D). The lengthy-time horizons, high capital requirements, and volatile commodity markets make investing in mining less appealing relative to other higher-profit industries such as software development. However, several large mining firms (e.g., Glencore and Rio Tinto) have succeeded at creating value and attracting investors.

5. The National Competitive Advantages of Key States

National competitiveness within the mining industry depends on a nation's capacity to innovate and upgrade, ultimately succeeding if the domestic political and economic environment is forward-looking, dynamic, and challenging. The four attributes of the Porter Diamond outlining the national competitiveness of an industry are *factor conditions, demand conditions, related and supporting industries,* and *firm strategy, structure, and rivalry*.[18] The

below paragraphs use the Porter Diamond framework to examine the PRC, Russia, Canada, Australia, and the United States, and provide policy recommendations to strengthen U.S. critical mineral sourcing and supply chains.

China's National Competitive Advantage

China is a significant leader in the global mining industry, creating value across the entire mineral supply chain. In 2013, President Xi Jinping announced the Belt and Road Initiative (BRI) and began to prioritize relationships and engage with countries abundant in resources needed to further the PRC's self-reliance plan.[19] China's demand for mineral commodities boosted regional economic growth, with many countries compromising their ESG standards to attract Chinese investments.[20] An analysis of China's mining describes competitive advantages and disadvantages in the mining industry.

Factors Conditions: According to the USGS, China possesses 21 mineral commodities within its borders.[21] Moreover, China owns roughly one-third of the global rare earth elements (REE) reserves and leads the world in REE mining and processing. While its domestic REE consumption accounts for approximately 80 percent of its domestic REE production, China's total output in combination with its cheap labor provide it with an unmatched competitive advantage.[22] Nevertheless, China's disregard for environmental concerns could threaten its mineral sustainability in the future.

Demand Conditions: China leads the global downstream production of several minerals, and plans to further expand downstream operations through BRI and *Made in China 2025* investments. For example, its relationship with the Democratic of Republic of Congo (DRC) offers China a competitive advantage in the cobalt market and stable access to the processing of cobalt to support domestic demand. Cobalt is key to lithium battery manufacturing, and China accounts for 72 percent of cobalt refining capacity, a significant advantage in meeting the global electric vehicle (EV) demand.[23]

Related and Supported Industries: China recognized the importance of non-fuel minerals early, researching REE applications as early as 1985 and investing in production via the 1986-1990 *National Five-Year Plan for Rare Earth Industry*. China also targeted permanent magnets as one of the ten focus industries in its *Made in China 2025* initiative. The combination of these investments allows China to dominate clean energy supply chains in raw materials, processed materials, and in the manufacture of components, batteries, windmills, and solar panels. Technology transfers from foreign firms also provide China with advantages in downstream manufacturing capacity. Additionally, the PRC plans to use beneficial regulations, tax incentives, and financing to entice foreign direct investment to increase manufacturing capacity by 2025.[24] While these efforts allow China to secure supply chains, they also risk suppressing innovation.

Firm Strategy, Structure, and Rivalry: China maintains its REE market advantage by suppressing global prices. This business strategy sacrifices short-term profits, but in doing so, eliminates China's global competition and enables the country to maintain a dominant market position.[25] Additionally, its BRI implementation positively benefits China by increasing its global access and efficiency in downstream expansion. However, one disadvantage is China's high financial debt, which adds risk to its future sustainability.

Insights and Recommendations: While China's mineral exports remain essential to the U.S. economy and defense industry, its influence over supply chains presents risk. In 2020, China passed an export-control law that restricted the export of controlled items to protect its security and to domestic supply.[26] The United States must therefore reduce its reliance on China by developing a long-term strategy with allies and partners to increase domestic mining and processing while diversifying global supply chains. See Appendix E.

Russia's National Competitive Advantage

Russia is blessed with abundant natural resources and skilled human capital, but cursed with poor governance. Despite its critical place in the clean energy, semiconductor, automotive, defense, and aerospace industries, Russia's 2022 invasion of Ukraine triggered crippling international sanctions that are likely to result in a 10 percent contraction of real GDP in 2022.[27] These emerging effects will likely affect its mining and mineral industry.

Factor Conditions: Russia has mineral wealth and a highly competitive workforce. It accounts for an estimated 14 percent of total global mineral extraction.[28] Russia's Ministry of Natural Resources and Environment estimated the value of its mineral reserves in 2017 to be $910 billion.[29] Additionally, Russia possesses one of the most educated populations in the world with approximately 53 percent of Russians achieving a tertiary education compared to 26 percent of G20 country populations.[30] Furthermore, the USGS estimated that in 2011 the Russian mining industry employed over one million people, or 1.6 percent of its working population, which gives Russian a relatively high degree of familiarity with the industry.[31]

Demand Conditions: Trade is an essential aspect of the Russian economy with imports and exports averaging 40 percent of its GDP, compared to 20 percent for the United States. Minerals, including oil and gas, account for almost 45 percent of its exports.[32] While the EU plans to reduce its dependence on Russian hydrocarbons, the transition to clean energy will increase the demand for Russian minerals such as cobalt and nickel, for which Russia is the second- and third-largest producer in the world, respectively. Finally, the on-going Russia-Ukraine war reveals Russia's impact on global base-metal supplies like aluminum and nickel, as well as strategic minerals such as palladium, scandium, and titanium, all five of which are on the 2022 U.S. Critical Minerals List.[33]

Related and Supported Industries: The Russian economy is reliant on mineral extraction and oriented toward foreign demand. In 2021, Russia recorded a $197B trade

surplus. The three biggest commodities, as a percentage of total Russia exports, were minerals (44.7 percent), base metals (10.4 percent), and chemicals and plastics (7.3 percent).[34] However, recent sanctions make it difficult and costly to deliver goods to Russia, especially with maritime transport companies such as Maersk and the Mediterranean Shipping Company discontinuing container deliveries to the country. [35]

Firm Strategy, Structure, and Rivalry: At the end of 2017, Russia had 17,600 enterprises engaged in mining and quarrying. Of these, 3,000 were involved in mining metal ores; 1,700, in the production of petroleum and natural gas; 900, in mining coal; and the remaining 12,600 in other mineral mining ventures.. Additionally, across all mining enterprises, Russian citizens own approximately 16,300 businesses, foreign or joint domestic-and-foreign owned entities own 200 businesses, and central and municipal governments own the remaining 100.[36] Private ownership in Russia may not result in market competition, however, as business interests seem be in the hands of a select few oligarchs. As such, Russia's mining industry is not globally competitive and only three firms (Nornickel, Euraz, and Mechel PAO) value among the world's 100 largest mining firms by market capitalization. In contrast, Canada and the United States count 35 and 21 firms, respectively, among the largest mining firms.[37]

Insights and Recommendations: Many countries have levied sanctions on Russia in response to Russia's invasion of Ukraine, but such an approach may be short-sighted due to western-economic dependence on Russia's minerals. Before expanding Russian sanctions further, U.S. policy-makers should review the concentration of critical and strategic minerals in Russia and the limited options for acquiring them elsewhere.[38] See Appendix F.

Canada's National Competitive Advantage

Canada assesses that access to critical and strategic minerals is necessary for the current, upcoming technologies, and future economic growth.[39] Since 2019, the country has

developed a critical mineral list, a robust Canada Minerals and Metals Plan, and a Critical Mineral Strategy, which will be published in 2022.[40] The Canadian Government fully supports its mining industry via a collaborative, focused, and aligned pan-governmental environment between federal, provincial, territorial, communities, association, and firms. The 2022 federal budget is proof of its strategic messaging and investment promises to the mining industry as it aligns clean energy to Canada's economic goals.

Factor Conditions: Canada's competitive advantage stems from several factors. First, it has three key endowments: vast resources and reserves, a long historical relationship with mining, and broad political support for the free market, democracy, and social support.[41] Additionally, Canada has a well-regulated financial system, including the Toronto Stock Exchange (TSX) and TSX Venture Capital, which handle 42 percent of the world's mining companies. Another factor is the government's efficient permitting, financing, and innovation systems, tax-like *flow-through shares* mechanisms, exploration incentives, royalties options, and different project generation options. Lastly, Canada maintains world-class energy infrastructure, water accessibility, academic eco-systems, governmental research and development (R&D) institutions, and federal and provincial mining standards.[42]

Demand Conditions: Canada's shift toward clean energy is adding to global demand for associated minerals.[43] Firms have increased incentives to invest in vertical integration with downstream products due to the changing Canadian economic landscape. Although many downstream integrations are limited, there are signs of investments by potential new-entrant firms such as LG, BASF, and Stellantis. In addition, the federal budget has programmed over $23.3B (C$30B) to encourage innovation in disruptive technologies, supply chain resiliency, and critical minerals mining to maintain Canada's long-term competitiveness.[44] It is also widely acknowledged that Canada's REE are of lower grade and require more complex mineralogical extraction, thereby incentivizing firm-level innovation

and long-term investment. Finally, legislation for health and safety, water, environment, and government incentives such as "*green mining*" innovation may create fear or perfect for incremental innovation in processes.[45]

Related and Supported Industries: Canada is a high-end technology economy. Its modern supporting market segments and industries, such as aerospace and mining supply and services, enable its competitive advantage. Furthermore, to bolster downstream manufacturing and research and offset diminishing federal R&D investments, Canada reversed its previous position and provided $780M (C$1B) over five years to invest in five super-clusters.[46] Notably, Canada holds smaller clusters including one for additive manufacturing in Montreal that could bolster innovative technologies if connected with the critical mineral mining industry. Finally, many Canadian defense firms are closely tied to the U.S. domestic industrial base, which requires access to Canada's critical mineral products.

Firm Strategy, Structure, and Rivalry: Canada firm structures and rivalry stems from the overarching mining industry structure.[47] Based on a multi-tiered approach, the industry ensures more than a thousand junior mining companies can compete for exploration and development of deposits, while also hosting over 160 senior, public, and international companies competing to extract critical mineral ores. This rivalry eco-system is further accentuated by the fact that at least three provinces and one territory are highly prized for investment on the global stage.[48] Finally, some critical minerals are derived from the tailings of existing mining operations, permitting these secondary producers to capitalize on prior investments.

Insights and Recommendations: Canada's many positive attributes enable a robust competitive advantage for its mining industry. Building on the enhanced cooperation announcement between the United States and Canada in 2020 and 2021, the two countries should further expand their industrial cooperation by drafting a combined National Security

Resource Strategy.[49] This could also be the perfect opportunity to create an NTIB-like board for critical minerals.[50] See Appendix G.

Australia's National Competitive Advantage

As Australia looks to continue its dominant presence within the mining industry, it benefits from having strong domestic rivals, aggressive home-based suppliers, and demanding local customers. Australia's national competitiveness is underpinned by its capacity to innovate and upgrade, succeeding in an environment characterized as forward-looking, dynamic, and challenging.[51] Each factor examined below presents the case of an Australian national competitive advantage in the mining and metals industry.

Factor Conditions: Australia possesses substantial physical, knowledge, capital resources, and infrastructure advantages. The country hosts the world's most advanced pre-competitive geological intelligence detailing both proven and unexplored mineral systems within its borders. Over 70 types of mineral deposits of economic significance have been identified, and over 350 mines are producing 23 mineral commodities in significant amounts globally.[52] The nation's vast industry knowledge and experience was developed over the course of several decades through universities, research institutes (e.g., Commonwealth Scientific and Industrial Research Organization), and trade associations (e.g., Minerals Council of Australia). Australia's capital resources have strengthened the mining industry through targeted funding and projects, evidenced by the Australian government's recent award of over $6.4B (A$9B) toward infrastructure to support critical mineral production. The country's recently announced *Roads of Strategic Importance* and *Northern Australia Infrastructure Facility* commitments are just a few of the many programs designed to support the infrastructure development of roads, rail, ports, and electricity generation facilities to enhance the widespread distribution of critical minerals.[53] Finally, funding for Cooperative

Research Centers (CRCs), mineral exploration, and R&D programs also support Australia's competitive advantage in the mining industry.

Demand Conditions: Australia's domestic demand for minerals is strong, with increased dependency on critical minerals for computing, manufacturing, green energy, medical, defense, and other technology forecasted into the future. International demand is also driving economies of scale and innovation that allows Australia to preserve its competitive edge in the global mining industry.

Related and Supporting Industries: Australia maintains an expansive mining services sector. Mining Equipment, Technology, and Services Ignited (METS Ignited) works with Australian mining industry suppliers, global miners, research organizations, and capital providers to improve the competitiveness and productivity of the Australian METS sector. Additionally, an initiative to identify and promote key clusters and collaboration networks within the mining industry is designed to maintain Australia's national competitiveness. Recent projects are expected to add $52B (A$74B) in value to the national economy by 2030 and create more than 80,000 new jobs within the mining services industry.[54] Lastly, advances in information technology are improving the ability of the services sector to reap considerable cost advantages from specialization.[55] Overall, advances in the mining services sector benefit Australia's national competitiveness within the industry.

Firm Strategy, Structure, and Rivalry: Australia is home to some of the largest mining companies in the world, including BHP Group, Rio Tinto, Fortescue Metals, Newcrest Mining, and South 32, firms that account for $104B in revenue in 2020.[56] Additionally, other top global mining companies, such as Glencore and Anglo American, operate mines as part of multiple joint-venture mining operations in Australia. These senior companies continue to drive competitiveness in the industry, focusing on "cutting costs sustainably by improving productivity through investments in new technology, such as

automation, drones, and big data analytics."[57] Australia also hosts several junior mining companies in the sector, mainly in exploration and promotion of new projects.[58] These smaller companies play a positive role in stimulating domestic competition, but are vulnerable and lack resilience to survive amidst price fluctuations in turbulent markets.[59] The structure of mining companies and competitiveness among rivals cements Australia's strong position in the mining industry.

Insights and Recommendations: As demand for critical minerals grows, there are significant opportunities for both the United States and Australia to develop and fortify sources and supply chains. Fostering the relationship between the U.S. and Australian mining industries is a critical step towards addressing the critical mineral challenges today and in the future. The U.S. and Australian governments should create a bi- or multi-lateral CRC to research and engage critical mineral supply chain risks and opportunities among allies. Australian CRCs have reached marked achievements in adoption, commercialization, and innovation in the mining industry. Expanding this effort to allies and partner countries would allow them to work together to ensure safe, ethical, and reliable sources of critical minerals for the future. See Appendix H.

The United States' National Competitive Advantage

The United States hosts an economic environment that encourages competition and innovation, but its mining industry struggles to compete with foreign competition. For example, the breadth and depth of U.S. industrial demand for minerals requires the United States to be a strong competitor in the mining and mineral processing industries. However, the U.S. mining industry's ability to extract and process REE lags well behind China's, which is expected to control over 55 percent of the global REE capacity by 2040.[60]

Factor Conditions: The U.S. economy features specialized and sophisticated industries and strong growth. Industries such as space exploration, defense, medical

research, advanced computing, transportation, and clean energy are world-class innovators, adding value in global markets and driving supporting industries to develop advanced technologies. Their advancements set a high demand for processed minerals used in critical components that enable further innovation. In 2019, for example, the estimated total value of nonfuel mineral production in the United States was $86.3B, an increase of three percent over 2018. Likewise, the total value of industrial mineral production in 2019 was $58.2B, also a three percent increase over 2018.[61] Yet, while the United States dominates many commercial industries, it is deficient in its ability to manufacture components from critical minerals.

Demand Conditions: Generally, U.S. private and public demand for many products remains strong, contributing to a highly competitive economy. However, the economy's relative low capacity for mineral extraction and processing strain industry's ability to meet demand in extraordinary circumstances such as pandemics and wars. Additionally, federal action to prioritize critical minerals to meet manufacturing needs may have detrimental effects in other industries. Environmental regulations also challenge mineral supplier's demands as federal, state, and local regulations conflict or confuse domestic mining firms, ultimately stymieing extraction and processing.

Related and Supporting Industries: Executive Order 14017 actions seek to leverage mining firms, including MP Materials, Berkshire Hathaway Energy, and Redwood Materials, to invest in production and recycling facilities to attract specific mineral commodity suppliers to the domestic market.[62] Additionally, commercial firms, such as Tesla, Intel, and Samsung, are investing in U.S. facilities to develop and manufacture semiconductors, lithium battery, and other critical mineral-based components. With federal funding, the U.S. mining industry is developing partnerships to fill critical supply chain manufacturing gaps.

Firm Strategy, Structure, and Rivalry: The United States is home to several mining firms, many of which employ niche and vertical integration strategies to remain

profitable. Notably, the mining firm Materion holds a near-monopoly on beryllium and focuses its development on manufacturing components made with beryllium. While the mining firm MP Materials also has a near-monopoly on cesium and is investing in U.S.-based REE processing as it is currently reliant on overseas processing. Freeport McMoRan's molybdenum mine in Colorado, in use for decades, is only streamlining operations to mine their product more efficiently; they are not seeking new mining operations.

Insights and Recommendations: The United States cannot tackle the critical mineral supply chain problem alone; it must work with allies and partners to further develop critical mineral processing capacity. The United States should reform mining regulations, examining the best practices of Australia and Canada for empowering industry with minimum bureaucracy. Collective efforts with Canada and Australia will create a better environment in which to increase supply chain resiliency and minimize overreliance on foreign sources of supply. Meanwhile, the United States must maintain an amicable trade relationship with China due to its reliance on Chinese minerals and processing capacity; policies to "cut China out" are not economically viable.

Strengthening Ally and Partner National Competitive Advantage Relationships

Through collaboration with industry and allies and partners, the U.S. government must revise domestic and international policy to increase its competitive advantage and capitalize on allied and partner competitive advantages to secure the supply of critical minerals for economic and national security needs. See Appendix I.

6. Policy Recommendations

Innovation

The metals and mining industry can no longer adopt the laggard mantra of "first to be second," and instead, must evolve through innovation. Mineral mining, unlike other commodity-producing industries, does not offer highly differentiated products. Therefore,

innovation within the metals and mining sector primarily occurs when a firm adopts a new or improved business process, promotes greater economies of scale, or implements new technologies that increase productivity and efficiency.[63]

The Opportunity: As demand for critical minerals is expected to increase, the mining industry must seize opportunities to develop and implement cutting-edge innovations faster. Environmental, social, and governance risks were cited as the top risk for mining in 2022. For a nine-year period ending in 2025, mining innovation is forecasted to create $319B of value while also creating an additional $107B for direct support the ESG opportunities. [64]

The Problem: Worldwide, mining is a $656B industry.[65] Despite high revenues, mining firms fail to invest in innovation comparable to other industries. When mining companies choose to invest in innovation, nearly all research and development funding is targeted toward advancements in the exploration phase. Metals and mining innovation investment represents approximately one-half percent of overall revenue.[66] In contrast, manufacturing firms invest about two to three percent of overall revenue, and the gas and oil industry invests three to five percent.

The Recommendation: Two policies are recommended for consideration at the federal level. First, mining innovation would benefit from many aspects inherent in *Right to Repair* legislation. *Right to Repair* was conceived to enable third-party vehicle repair to reduce sustainment. Since R&D funding in mining is increasingly applied to equipment manufacturers and suppliers of mining operations equipment, equipment manufacturers are not incentivized to share software or design information across the industry.[67] Manufacturers can be incentivized to make their code available through open source either by licensing sales or through voluntary participation in design consortiums. This action would create data-rich environment wherein advanced software and smart sensors for state-of-the-art mining may flourish across equipment from different manufacturers.

Secondly, the federal government must foster the growth of mining innovation ecosystems that connect equipment manufacturers, mining universities, major and minor metals, and miners allowing for greater industry collaboration. The innovation ecosystems could be funded as an additional percentage of mining royalties from industrial manufacturers looking to participate and even DoD program offices to reduce their program's risk profile tied to critical minerals.

National Defense Stockpile

Shortly after World War I, geologist Charles Leith led a movement to create national stockpiles of several critical raw materials necessary for industrial production.[68] Leith's efforts led Congress to pass the Strategic and Critical Materials Stockpiling Act of 1939, which created the National Defense Stockpile. Originally designed to deal with potential mineral market uncertainties caused by World War II, several pieces of follow-on legislation affected National Defense Stockpile (NDS) operations. In 1951, the President's Material Policy Commission recognized the importance of a national stockpile for military emergencies, but endorsed purchasing minerals at the lowest cost rather than develop self-sufficiency.[69] Throughout the next decade, the stockpile value rose from 54 million dollars in 1941 to just over four billion dollars in 1952 and to 9.6 billion dollars in 1989.[70]

The Opportunity: The Strategic and Critical Materials Stockpiling Act of 1979 broadened the scope of the original 1939 act and included measures to mitigate risks associated with foreign dependence of critical materials during national emergencies. Notably, the 1979 version required that the national stockpile house materials needed for no less than a three-year military operation.[71] However, despite world events such as the oil crisis of the 1970s, which raised early concerns about U.S. vulnerability to mineral imports, few NDS purchases were made during this period. As a result, the NDS was ill-maintained

and deficient in several critical minerals at the start of the 1980s and would remain in this lackluster condition for nearly two decades.

The Problem: The NDS was originally created to ensure the availability of strategic and critical mineral inputs to support United States defense needs. Since the creation of the NDS, global supply chains have increasingly crossed international borders and, as a result, become increasingly vulnerable to unforeseen world events. As analysts in many fields correctly recognize, one country cannot control the entire supply chain of critical minerals.[72] The United States will never control the whole supply chain to meet its critical materials needs. While stockpiling critical materials for use during a crisis remains necessary, working with allies and partners to secure reliable and diversified access to alternate mineral sources provides enhanced flexibility.[73]

The Recommendation: The NDS must be audited regularly for relevance and funded to appropriate levels to ensure stocks are sufficient to meet demands. Furthermore, regular audits of the NDS must ensure that holdings correlate to the materials used by the defense industry to manufacture its most critical goods. This ensures the NDS maintains the materials on-hand the sector needs today, not what the sector required decades prior. Secondly, the government must provide adequate funding to the NDS.[74] Currently, new material purchases for the NDS are made from the sale of excess NDS materials. This cyclical process is unsustainable, and at this point, the NDS lacks the resources to sell in order to purchase new stocks of materials at current market prices.

Human Capital

The mining industry requires human capital investments focused on increased educational and professional opportunities, and partnerships with academia and industry to ensure the industry's domestic survival and mitigate supply risks.

The Opportunity: Several recent executive orders and government strategy documents present the mining industry's human capital concerns when highlighting the need for resilient supply chains and reduced reliance on foreign suppliers of critical minerals.[75] Momentum in the U.S. government is building to support the interagency cooperation required to impact the mining industry's human capital needs, but resources must accompany executive orders and strategies.

The Problem: Increased domestic production of critical minerals is essential to mitigate national security concerns and increase supply chain resilience, but the labor force required to support U.S. mining growth does not exist.[76] The availability of well-paying mining jobs, workers with the necessary technical skills, and the infrastructure near mining operations is lagging or non-existent. The current domestic mining labor market fails to send adequate demand signals to a future workforce, resulting in relatively few active mines in the United States. Domestic mining jobs are stagnant, and young talented graduates with mining-related degrees, lacking employment opportunities in the mining sciences here, pursue work outside of the United States.[77]

The Recommendation: The U.S. Department of Commerce's *Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals* provides six separate calls to action accompanied by 24 goals and 61 recommendations on policies the federal government should pursue to meet the demands outlined in Executive Order 13817.[78] The report's *Call to Action 6*, titled "Grow the American Critical Minerals Workforce," lists four concrete goals for positive change in the domestic mining workforce to meet future domestic needs. The first goal is titled, "Bolster Education in Mining Engineering, Geology, and Other Fields Related to Critical Minerals Mining and Manufacturing," and specifically addresses the mining industry's education challenges by promoting future efforts to expand the collaboration between academia and industry to create expanded opportunities for education, training and

credentialing of critical mining-related skills.[79] Continued focus and cooperation between government, industry, and academia is needed to mitigate current mining human capital challenges, and promote workforce growth through programs that are relevant, interesting, and attract the best and brightest."[80]

Industry Policy

The Opportunity: Mining industry firms and potential new entrants make investment decisions largely based commodity prices and estimates of future demand.[81] Government policy should aim to improve industry confidence by signaling that the U.S. government and manufacturers are committed to strengthening domestic and allied mineral supply chains.

The Problem: Long-lead times, high capital requirements, volatile commodity pricing, and PRC state-funded price manipulation make success difficult for firms in the mining industry. Policymakers need to balance national security requirements, ESG goals, and commercial viability as they implement actions to bolster critical mineral supply chains.

The Recommendation: The U.S. government should commit capital to advancing domestic mining exploration, development, and production. The DoD's recent award of DPA Title III funding to MP Materials is an example of an effective public-private effort to increase domestic production of REE. The DoD also sponsored Materion's beryllium facilities to ensure a secure supply of its products. These funding measures, along the executive orders and critical mineral strategies published over the past decade, are a necessary start and provide reassuring signals to potential investors.[82] Additionally, Congress should provide tax incentives, appropriate grant funds, and update trade policy to strengthen the business case for expanding domestic mineral extraction and diversifying supply chains across allied nations, while avoiding the marginalization of existing suppliers.

Supply Chains

Critical minerals provide the building blocks for modern technologies and are essential to our economic prosperity and national security. Minerals such as REE, lithium, and cobalt are especially vital to clean-energy technologies including batteries, electric vehicles, wind turbines, and solar panels; however, China controls much or all of their extraction and processing.[83]

The Opportunity: The U.S. government and the private sector are taking steps to restore and secure the strategic materials supply chain. The Biden Administration's initial commitment to *Securing a Made in America Supply Chain for Critical Minerals* establishes important initiatives pertaining to materials required for EV battery production. Furthermore, the Department of Defense's Industrial Base Analysis and Sustainment program recently awarded MP Materials $35M to expand its Mountain Pass, California facilities to support enhanced operations across the heavy REE value chain. If successful, MP Materials will establish a complete end-to-end domestic permanent magnet supply chain located here in the United States. Finally, the Bipartisan Infrastructure Law provides $140M in funding for research and development into recovering REE and other critical minerals from coal, ash and other mine waste, thereby reducing the need for new mining and providing additional resilience to already fragile supply chains.[84]

The Problem: The United States assumes high critical mineral supply chain risk due to a lack of domestic mining and processing capability and capacity, and overreliance on foreign sources. This dire situation began at the end of the Cold War when economic efficiencies created by globalization left critical mineral markets highly concentrated and subject to supply disruption. Today, a lack of supply chain resilience in critical materials is deemed a national security threat, and swift mitigation actions are required.

The Recommendation: To reestablish secure supply chains, the White House needs to lead a task force that implements the recommendations in the 100-Day Reviews under Executive Order 14017: (1) Developing and fostering new sustainability standards for strategic and critical material-intensive industries; (2) Expanding sustainable domestic production and processing capacity, including recovery from secondary and unconventional sources and recycling; (3) Deploy the DPA and other programs; (4) Convene industry stakeholders to expand production; (5) Promote interagency R&D to support sustainable production and a technically skilled workforce; (6) Strengthen U.S. stockpiles; and (7) Work with allies and partners and strengthen global supply chain transparency.[85]

Environment, Social, and Governance

Environmental, Social, and Governance policy practitioners primarily consist of environmental advocates, mining operators, and oversight bodies from federal, state, and municipal structures through industrial third-party organizations. As with many policy arenas, advocacy for varied domestic and global stakeholders often results in gridlock. Fortunately, the current policy environment offers opportunities as ESG and sustainability strategies are widely accepted as essential to successful operations.

The Opportunity: The emergence of strategic minerals to support the growth of green and advanced technology places hard rock mining in the debate surrounding the environment, responsible business practices, and secure supply chains.[86] At the same time, transnational mining corporations are acknowledging the mandate to engage responsibly with diverse stakeholders, including local communities, water and power providers, and local workforce participants.[87]

The Problem: Since mining regulations vary by country and region, an overall lack of internationally-accepted ESG standards creates unique challenges. Lack of consensus on ESG standards contributes to child labor in the Democratic Republic of Congo, the

unchecked dumping of contaminated waste in China, and the continued pollution of downstream lands from inactive mines in the United States.[88]

The Recommendation: The U.S. government should sponsor third-party standards for international acceptance of ESG. As an example, the Initiative for Responsible Mining Assurance (IRMA) offers standards that "define good practices for what responsible mining should look like at the industrial scale." Endorsed by mining corporations and environmental advocacy groups alike, IRMA Standards adopt metrics that track a corporation's business integrity, planning for positive legacies, social responsibility, and environmental responsibility to assess ESG and sustainability progress.[89] Advancing ESG efforts across the industry is necessary towards protecting the environment, and the people that both work and consume the earth's critical mineral resources.

Permitting

For decades, U.S. mining corporations and federal agencies have warned of inefficient permitting processes for mineral exploration, extraction, processing, and mine site remediation that result in costly delays, declining global competitiveness of the U.S. mining industry, and vulnerable critical mineral supply chains.

The Opportunity: Competition between countries for relative permitting efficiency is critical to attracting supply chains to their territories and must be central to any U.S. critical minerals strategy. The United States already ranks highly among global jurisdictions for mining due to the efficacy its political system, economic system, currency, social license, taxation, and low levels of corruption.[90] Additionally, its rich mineral endowment and the federal ownership of over 28 percent of the country's landmass, uniquely positions the federal government to compete globally for mining development.[91] However, U.S. permitting processes consistently garner widespread accusations of inefficiency that limit U.S. mining attractiveness.[92] Consequently, with policy action focused on improving

permitting efficiency, the United States could mitigate its most significant competitive disadvantage.

The Problem: Permitting in the United States is plagued by uncertainty, delay, financial risk, corporate confusion, and stark state-to-state disparities. The general regulatory uncertainty and permitting delays emerged with mine waste and reclamation statutes in the 1970s.[93] And, a recent Bureau of Land Management and the Forest Service study found that permitting processes now require between one month and 11 years, with an average of two years.[94] By comparison, Canada's permitting processes appear to be the fastest in the world and average less than six months.[95] The long U.S. permitting delays create unforeseen costs and damage mining corporations' cumulative cash flows, driving up their costs of capital.[96] While the quality of firm's mine plan is the best determinant of the time it will require to earn its permits, there exists wide disparities between states' permitting implementation, with Nevada outcompeting most global jurisdictions while California ranks among the worst.[97]

The Recommendation: Using Canada as the pacing global competitor for permitting timelines, the federal government should set the simple and ambitious goal of reducing the average mineral exploration and mine operations permitting timelines to six months or below across all states. To accomplish this, the federal government should first align standards with states by publishing permitting guides, imposing conditions on federal infrastructure grants to prompt state follow-through, and offer tax breaks for corporate expenses for environmental law and engineering services. Second, agencies should share responsibilities by allowing firms to submit their own environmental assessments and impact statements for federal agency review, as Canada and Australia do.[98] Finally, federal agencies should measure their performance and engage regularly with industry to address bottlenecks.

Coalition Criticality

The Opportunity: Developing an alliance-level CML would provide additional early warning signals and sharpen U.S. awareness of the true criticality of individual minerals. Key allies within the NTIB have already developed their own CMLs as has the EU with its EDTIB CML.[99] Thus, data is already available and only requires consolidation and collaboration over methodology to produce an alliance-level CML.

The Problem: Relying solely on a U.S. national CML fails to fully portray U.S. mineral criticality and risks, because the U.S. economy and national security increasingly depend on a global industrial base, especially in times of conflict. Thus, assessing the shared and diverging mineral supply vulnerabilities of allied industrial bases including the NTIB, NATO, or the EDTIB provides an prudent starting point for policy development and prioritizing U.S. actions to secure critical supply chains.

The Recommendation: Develop an NTIB-level CML, with possible later expansion to NATO- or NTIB-EDTIB-levels, to determine criticality and risk across the entire industrial base upon which the interdependent U.S. and allied economies and security rely.

7. Conclusion

Global demand for critical minerals is growing rapidly while several critical supply chains are gradually concentrating in risky areas. The United States and its allies must rebalance their economic and security policies to assure access to the critical mineral supply chains that underpin economic and national security. In doing so, the United States must aim to improve the national competitiveness of its mineral exploration and mining sector through domestic policy updates and international collaboration with allies and partners. Recent legislation, national strategies, and international engagements regarding critical minerals have provided paths toward assured critical mineral supplies, but it is now time to unify and expand upon those efforts in a comprehensive and long-term industrial security strategy.

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Based on a federal, provincial, and territorial governments' collaboration, the list is based on three core fundamentals: (1) Essential to Canada's economic security; (2) Required for Canada's transition to a low-carbon economy; (3) A sustainable source of critical minerals for our partners. Unfortunately, it has very limited ties with national defense or national security. Furthermore, Canada's list of critical minerals is different than that of the United States. It comprises of 31 minerals, many of which are the same, but it does not it does not separate the Rare Essential Elements as USGS does in the U.S. Critical Mineral List. In accordance with the Canadian Minerals and Metals Plan (CMMP), the Minister of Natural Resources Canada is mandated to create and implement a critical mineral strategy in the near-term.

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[46] John Knubley. *Building Superclusters for Canada.* https://brookfieldinstitute.ca/wp-content/uploads/Superclusters_Final2.pdf, Ottawa: Brookfield Institute, April 2021. 4-5. It is important to note that Canada's innovation program has been eroding for the last two decades. However, Knubley highlights the importance adjusting course and focusing not only on innovation, but creating superclusters. An idea already well-known in Canada since the 1980s, and instrumental for some provinces (e.g., Quebec and Ontario) to bolster their economies, the 2018 initiative was to create an environment supported by federal and provincial governments to enter joint ventures with firms and create superclusters. The five superclusters that Knubley highlights as having received federal financing are: (1) Digital Technology Supercluster (B.C.); (2) Protein Industries in the Canadian prairies (e.g., Alberta and Saskatchewan), (3) Next

Generation Manufacturing supercluster (Ontario); (4) Scale AI supercluster (Quebec); and (5) Ocean Supercluster (Atlantic Canada).

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[49] U.S. Department of State. *United States and Canada Forge Ahead on Critical Minerals Cooperation.* July 31, 2021. https://www.state.gov/united-states-and-canada-forge-ahead-on-critical-minerals-cooperation/ (accessed May 04, 2020). Connect2Canada. *U.S.-Canada Collaboration on Critical Minerals.* August 21, 2019. https://connect2canada.com/2019/08/u-s-canada-collaboration-on-critical-minerals/. (accessed May 04, 2022).

[50] The White House. "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth." https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf, Washington D.C., June 2021. 162. In this report, the White House stated that these synergies permit an excellent environment for critical mineral-related collaboration, cooperation, and joint ventures. For example, on the United States could seek collaboration with Canada on topics under its Canada Minerals and Mining Plan (CMMP) to see if certain strategies and areas of action are advisable in a future U.S. minerals and mining plan. Because of the collaborative nature of CMMP, understanding the roadmap to its creation could also promulgate ideas for federal, state, indigenous inclusion, and private synergies. Another area worth investigating for lessons is the Mining Association of Canada (MAC) Towards Sustainable Mining (TSM) Initiative. TSM is sort of an informal ISO contract for mining firms to abide by. It is an excellent model for U.S. mining associations and government entities to review as it ties all angles of what a mine needs to do for its social, environmental, and economical contracts. Another example of practical synergy could be to have Canada create a National Defense Stockpile where a percentile would be held on behalf of the U.S. Department of Defense (DoD).

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- *Critical Minerals Rare Earths Supply Chain: A Situational White Paper*, U.S. Department of Energy, 2020
- *Executive Order 13953: Addressing the Threat to the Domestic Supply Chain from Reliance on Critical Minerals from Foreign Adversaries and Supporting the Domestic Mining and Processing Industries*, 2020
- *Critical Minerals and Materials*, U.S. Department of Energy, 2020
- *Executive Order 14017: Executive Order on America's Supply Chains*, 2021

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Appendix A – Ukraine and Russia

Question: Given that U.S. policy is to support Ukraine in this war instigated by Russia, what options are available within the context of each Industry Study to do so? Include recommendations to support broader U.S. policy.

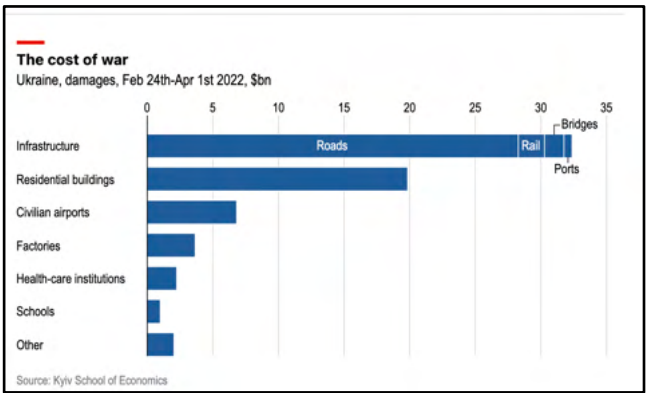
BLUF: The Strategic Materials Seminar recommends that the United States establish a joint executive and legislative commission regarding a post-war Ukraine Reconstruction Program to:

(1) Determine U.S. foreign aid objectives
(2) Generate actionable macroeconomic policy recommendations to foster competitive microeconomic conditions in Ukraine
(3) Identify industries (e.g., mining, agricultural, steel manufacturing) that can be leveraged to catalyze economic growth in Ukraine

The international community's overarching goal for Ukrainian reconstruction should be to realize Ukraine's full economic potential. .

Situation:

- According to the World Bank, Ukraine's economy is expected to contract by 45 percent in 2022.[1]
- An early analysis by the Kyiv School of Economics, estimates the physical damage exceeded $68B as of 01 April 2022, equivalent to more than a third of Ukraine's 2021 GDP.[2]



Source: The Economist's Graphic Detail (April 5, 2022)[3]

[1] Office of the Chief Economist and Demirgüç-Kunt Demirgüç-Kunt, "War in the Region," Europe and Central Asia Economic Update (Washington, D.C.: World Bank Group, Spring 2022), 99.
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[3] "Russia's War in Ukraine Has Caused at Least $68bn in Physical Damage."

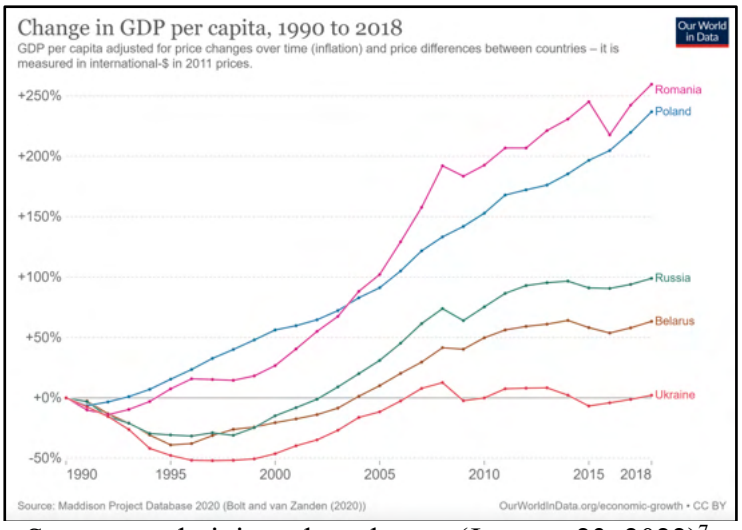
- The estimated cost of Ukrainian Economic Recovery: Ukraine's Ministry of Economy and KSE estimate that all losses combined could range from $564B to $600B, or 2.8 to 3 times its 2021 GDP.[4]

International Response to Assisting Ukraine in the Long-Term:

- Growing global support for a Marshall Plan, formally known as European Recovery Plan, which can be replicated and tailored for a post-war Ukraine.
- On 10 May 2022, Charles Michel, president of the European Council urged Japan to contribute to a Marshall Plan-style trust fund, which has already accumulated $6.3B (€6B) in commitments.[5]
- On 03 May 2022, Speaker Nancy Pelosi advocated for the Ukraine Democracy Defense Lend-Lease Act of 2022: "And I hope that when this conflict is over, we can play another historic role with a Marshall Plan to help Ukraine rebuild."[6]

Concerns about Ukrainian Reconstruction:

- Prior to the war, the Ukrainian economy was a laggard.



Source: noahpinionsubstack.com (January 23, 2022)[7]

- The Ukrainian bureaucracy is plagued with corruption.[8]
- An oligarch class has disproportional influence in the Ukrainian economy.[9]

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[4] "Russia's War in Ukraine Has Caused at Least $68bn in Physical Damage."
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[8] Ibid.
[9] Ibid.

- The Ukrainian economy is dependent on the Russian energy industry despite possessing the second largest natural gas reserves in Europe.[10]
- Some industrialists are forecasting a global recession beginning in 2022.[11]

Ukrainian Endowments:

- Ukraine has a world-class agriculture industry and provides the world with a substantial amount of wheat, corn, and additional products.
- Ukraine has a significant manufacturing industry, which can be modernized and leveraged. Of note, Ukraine has a modern defense and aerospace industry, which recently employed one million people (e.g.. Antonov and Yuzhmash corporations).[12]
- Ukraine has considerable mineral resources, as described in the below table.

World Rank	Mineral	Percentage of World Output
3rd	Gallium	1.3%
	Rutile	12.3%
5th	Titanium Sponge	4.4%
	Graphite	2.2%
	Bromine	1.3%
7th	Iron Ore	2.5%
	Manganese Ore	4.2%
8th	Kaolin	4.9%
	Magnesium	0.8%
9th	Ilmenite	4.2%
	Pig Iron	1.7%
11th	Bentonite	1.0%
	Peat	2.1%
	Raw Steel	1.2%

Source: USGS 2017-2018 Mineral Yearbook Ukraine[13]

Policy Recommendations:

The United States should establish a joint executive and legislative commission regarding a post-war Ukraine Reconstruction Program (URP) to:

1. **Determine U.S. foreign aid objectives**.

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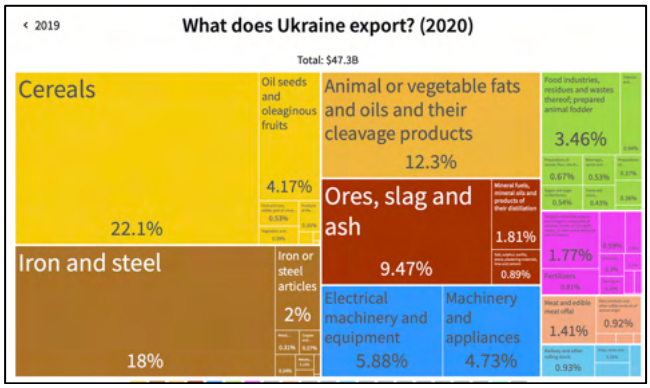
[12] Noah Smith, "Ukraine's Economic Future," Substack newsletter, *Noahpinion* (blog), March 23, 2022, https://noahpinion.substack.com/p/ukraines-economic-future.
[13] Elena Safirova, "Ukraine [Advance Release]," 2017-2018 Minerals Yearbook (Reston, VA: U.S. Geological Survey (USGS), January 2022), 49.1.

a. **Action #1**: Commission a study of the pre- and post-war Ukrainian economy and its potential for implementing foreign assistance.
b. **Action #2**: Assess aspects of the European Recovery Plan that can be replicated in Ukraine.
c. **Action #3**: Design U.S. foreign aid objectives agreeable to European Union and Ukrainian leaders.
d. **Action #4**: Determine the forms and levels of U.S. aid, including grant-to-loan ratios.
e. **Action #5**: Designate a U.S. agency to lead the implementation of U.S. aid to Ukrainian reconstruction, or whether implementation would require an independent agency such as the European Recovery Program's Economic Cooperation Administration (ECA).[14]

2. **Generate actionable macroeconomic policy recommendations to foster competitive microeconomic conditions in Ukraine.**
a. **Action #1**: Examine recent developmental successes (e.g., South Korea, Poland) for lessons on beneficial macroeconomic policies to apply in Ukraine.[15]
b. **Action #2**: Develop p macroeconomic policies that address the following for Ukraine (inspired by European Recovery Plan):[16]
    i. The expansion of Ukraine's agriculture, manufacturing, and mineral extraction industries.
    ii. The eradicating corruption, marginalizing the influence of oligarchs, and establishing effective legal systems and governance.
    iii. The restoration of stable currency, budget, and finances in Ukraine.
    iv. The stimulation of international trade between Ukraine and the European Union.

3. **Identify industries (e.g., mining, agricultural, steel manufacturing) to be leveraged to catalyze economic growth in Ukraine.**
a. **Action #1**: The U.S. and European partners' funding priorities should target three industries within Ukraine to act as a catalyst for long-term economic growth:
    i. Agriculture (i.e., cereals, oil seeds, animal, or vegetable fats, etc.)
    ii. Mining and Quarrying (ores, slag, ash, etc.)
    iii. Iron and Steel Production (i.e., iron, steel, and products therefrom, etc.)

[14] Curt Tarnoff, "The Marshall Plan: Design, Accomplishments, and Significance," Prepared for Members and Committees of COngress (Washington, D.C.: Congressional Research Service, January 18, 2018), 9.
[15] Smith, "Ukraine's Economic Future."
[16] Tarnoff, "The Marshall Plan: Design, Accomplishments, and Significance," 1.



Source: Observatory of Economic Complexity (OEC)[17]

b. **<u>Action #2</u>**: The United States, European Union, and Ukraine need to establish an infrastructure repair prioritization list. The list should include at a minimum, power plants, electric grids, ports, roads, and rails.

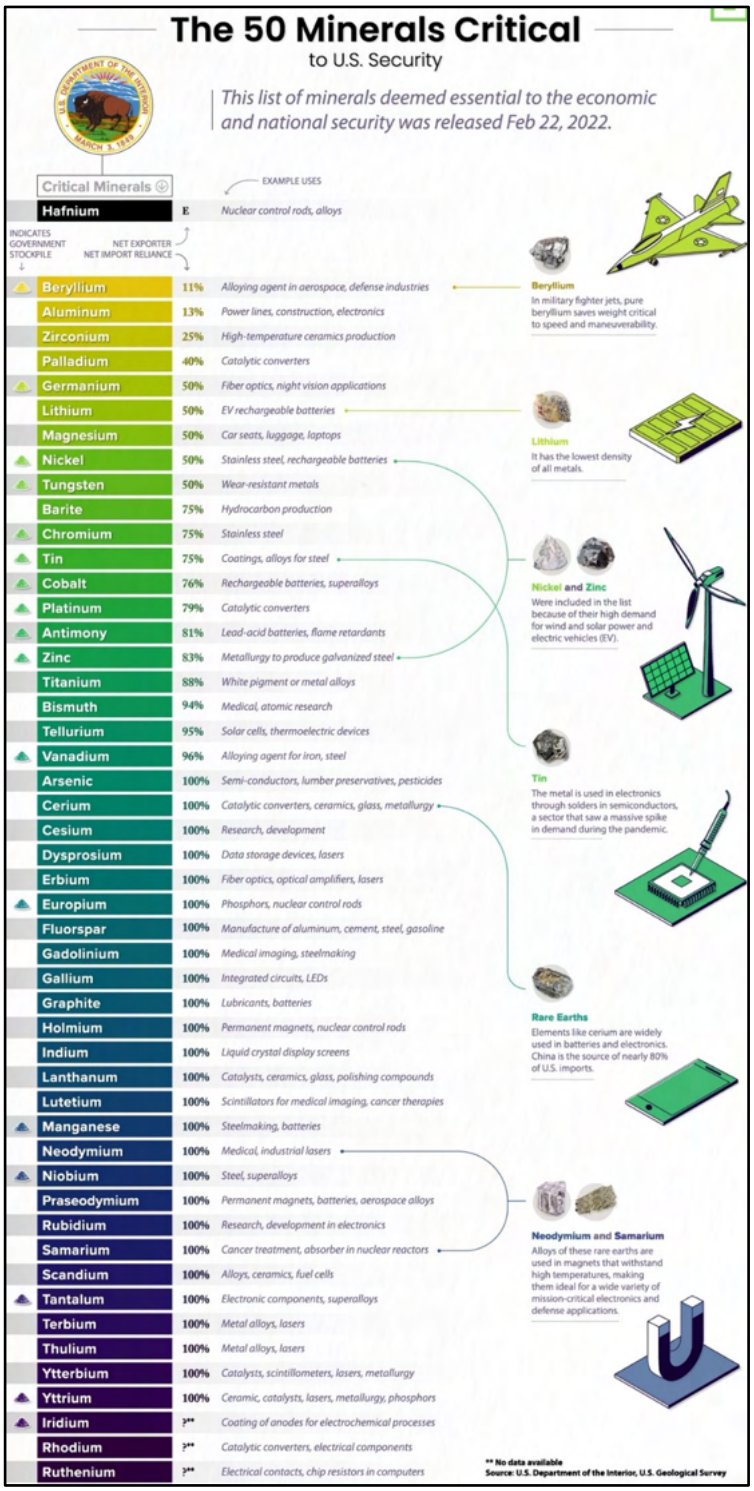
c. **<u>Action #3</u>:** Because it is likely that the first couple years of a recovering Ukrainian economy will be heavily dependent on agriculture and mineral extraction, the United States, European Union, and Ukraine must develop economic policies to alleviate the possibility of Dutch Disease and falling into a middle-income trap.[18] To do this, the United States, European Union, and Ukraine will need to invest in modernizing and expanding a broad portfolio of industries.

<u>Action #4</u>: The United States, European Union, and Ukraine must incentivize the development of Ukraine's energy industry (oil and natural gas) to create energy independence from Russia.

[17] "What Does Ukraine Export? (2020) | OEC," OEC - The Observatory of Economic Complexity, accessed May 12, 2022, https://oec.world/en/visualize/tree_map/hs92/export/ukr/all/show/2020/.
[18] Smith, "Ukraine's Economic Future."

Appendix B – USGS 2022 Critical Minerals List

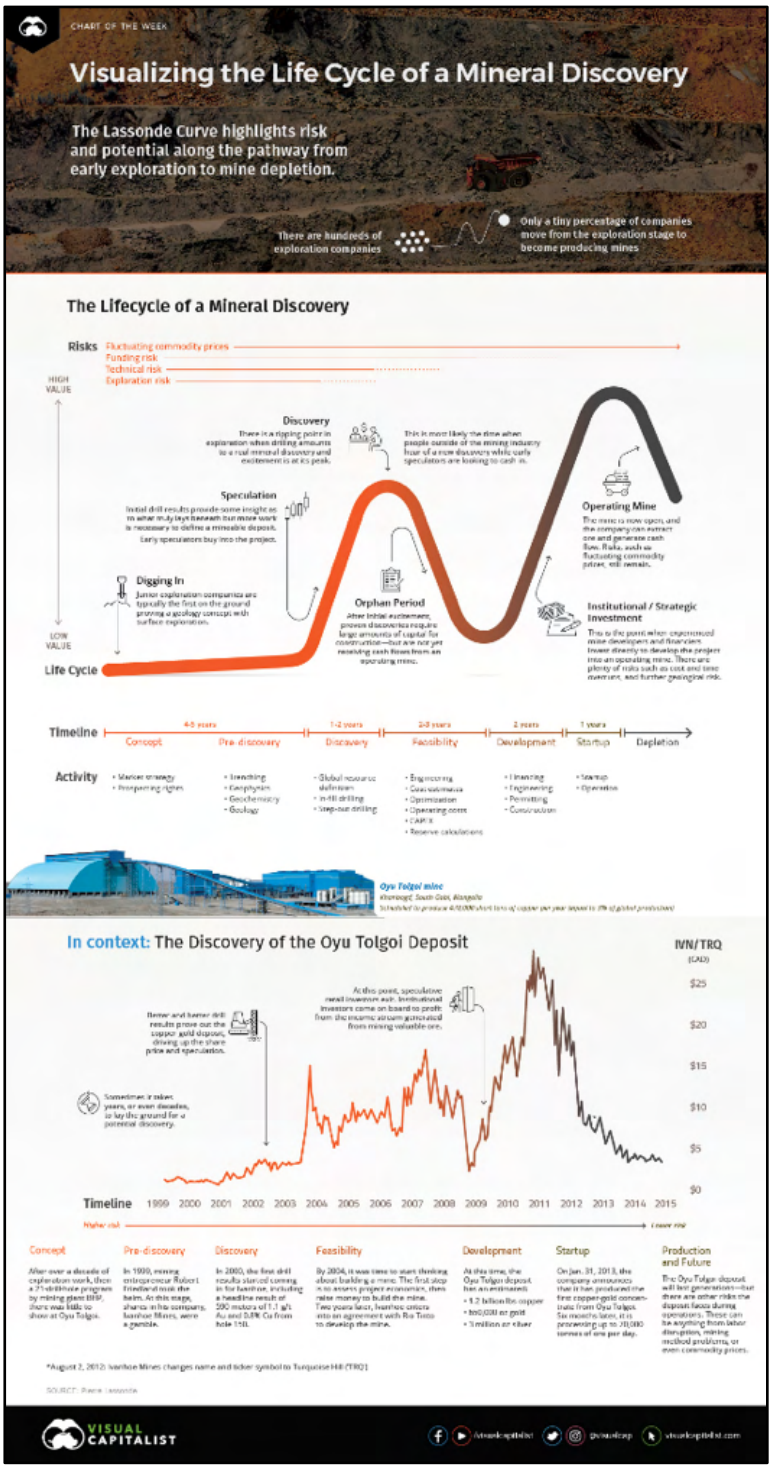
The following graphic lists and describes the USGS 2022 critical minerals.[19]



[19] Bruno Veditti, Visual Capitalist. *The 50 Minerals Critical to U.S. Security.* March 01, 2022. https://elements.visualcapitalist.com/the-50-minerals-critical-to-u-s-security/ (accessed May 07, 2022).

Appendix C – Mineral Discovery

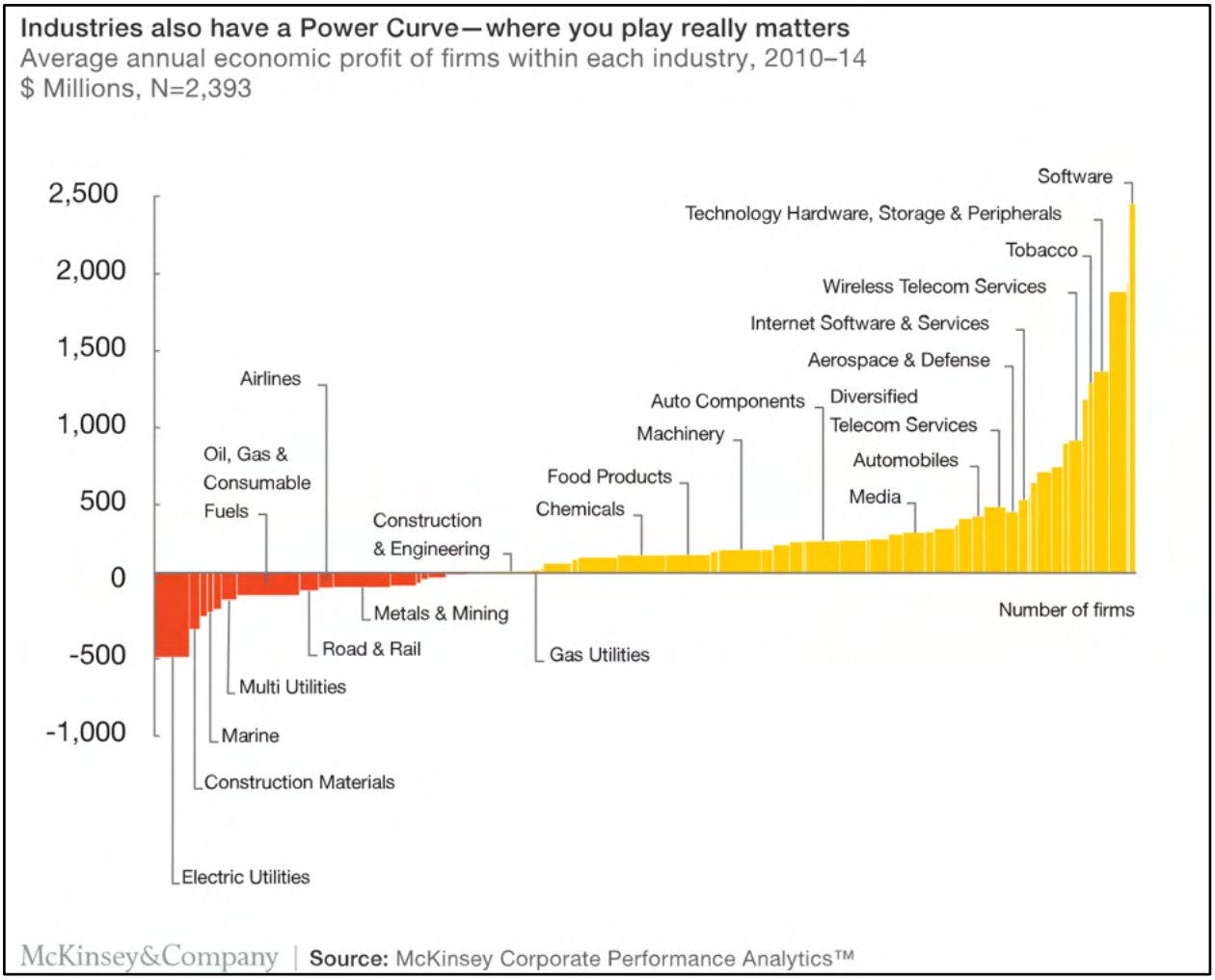
The following graphic illustrates the lengthy timespans associated with hardrock mining.[20]



[20] Nicholas LePan, Visual Capitalist. *Visualizing the Life Cycle of a Mineral Discovery.* September 12, 2019. https://www.visualcapitalist.com/visualizing-the-life-cycle-of-a-mineral-discovery/ (accessed April 25, 2022).

Appendix D – Industries Power Curve

Capital investors often view mining firms as unattractive investments relative to firms operating in industries that produce positive average annual economic profits.[21]



[21] Martin Hirt, McKinsey & Company. *Is your strategy good enough to move you up on the power curve?* January 30, 2018. https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/the-strategy-and-corporate-finance-blog/is-your-strategy-good-enough-to-move-you-up-on-the-power-curve (accessed May 04, 2022).

Appendix E – China's National Competitive Advantage

This appendix reinforces Section 5's analysis of China's national competitive advantage. First, figure 1 provides visualization and amplification of key facts and figures related to the Chinese mining industry. Figure 2 provides a visualization of China's overall share of critical minerals on the global market, and figure 3 provides information on rare earth elements (REE) and the long-term implications of China REE downstream expansion. Finally, figure 4 provides a visualization and additional insights on China's competitive advantages and disadvantages using the Porter's Diamond tool.

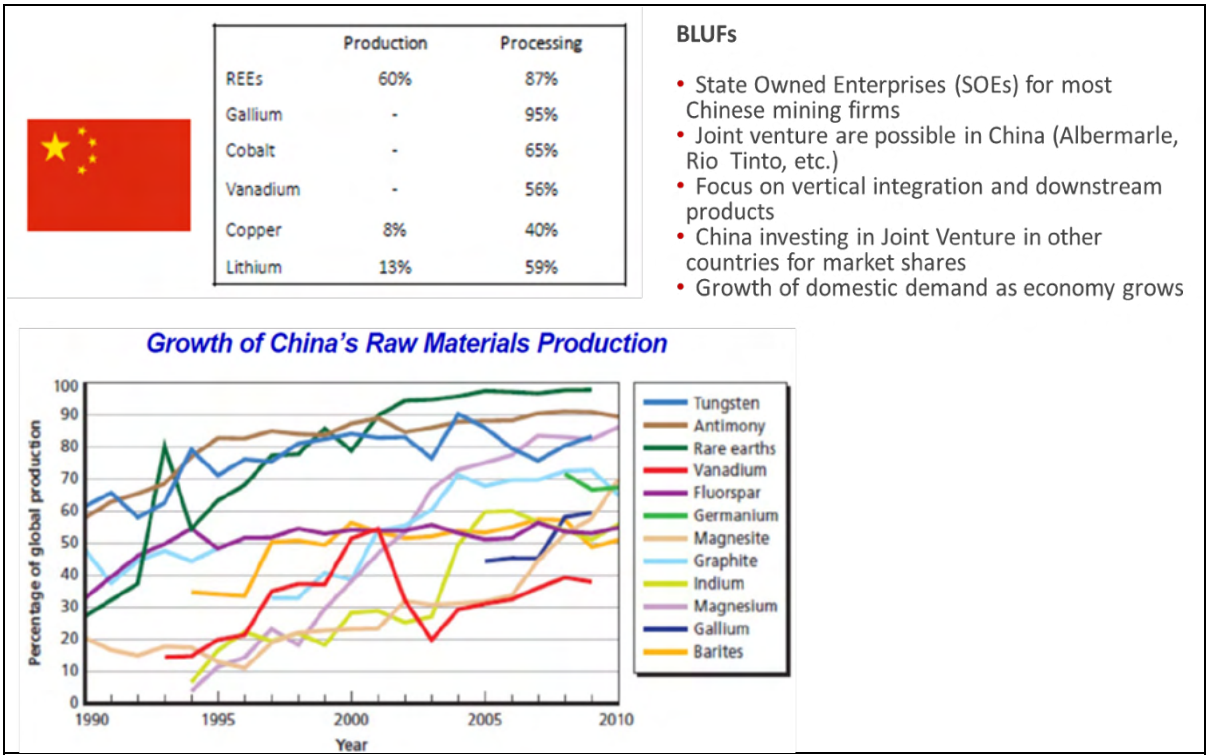


Figure 1: China's Mining Industry – Key Facts

Sources: Adjustments to 1- Eisenhower School AY 22, Strategic material -Dr P Coughlan presentation slides and 2- NRCan presentation to Eisenhower School – April 22.

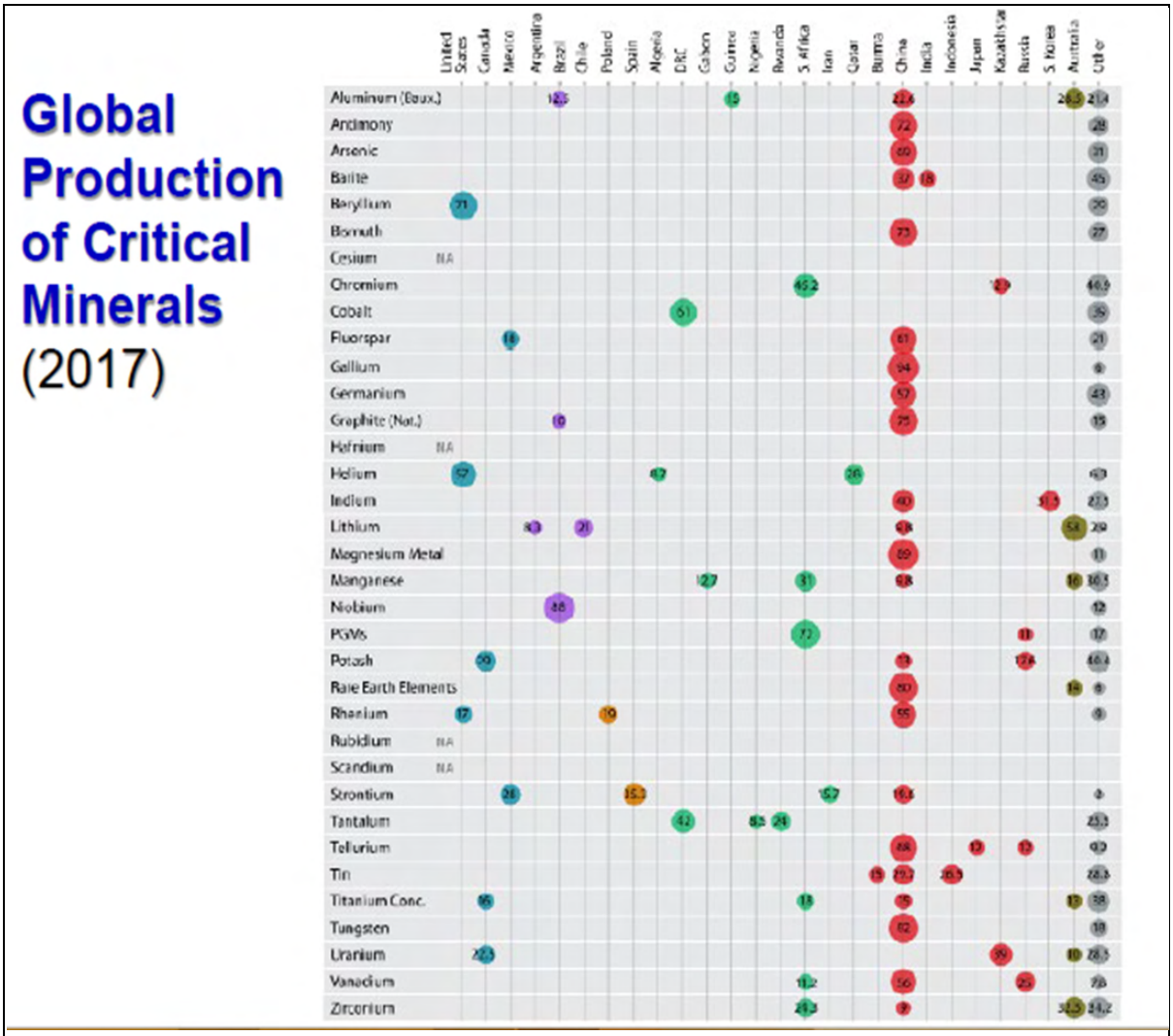


Figure 2: Global Production of Critical Minerals – China's Overall Share

Source: Eisenhower School AY 22, Strategic material -Dr P Coughlan presentation slides

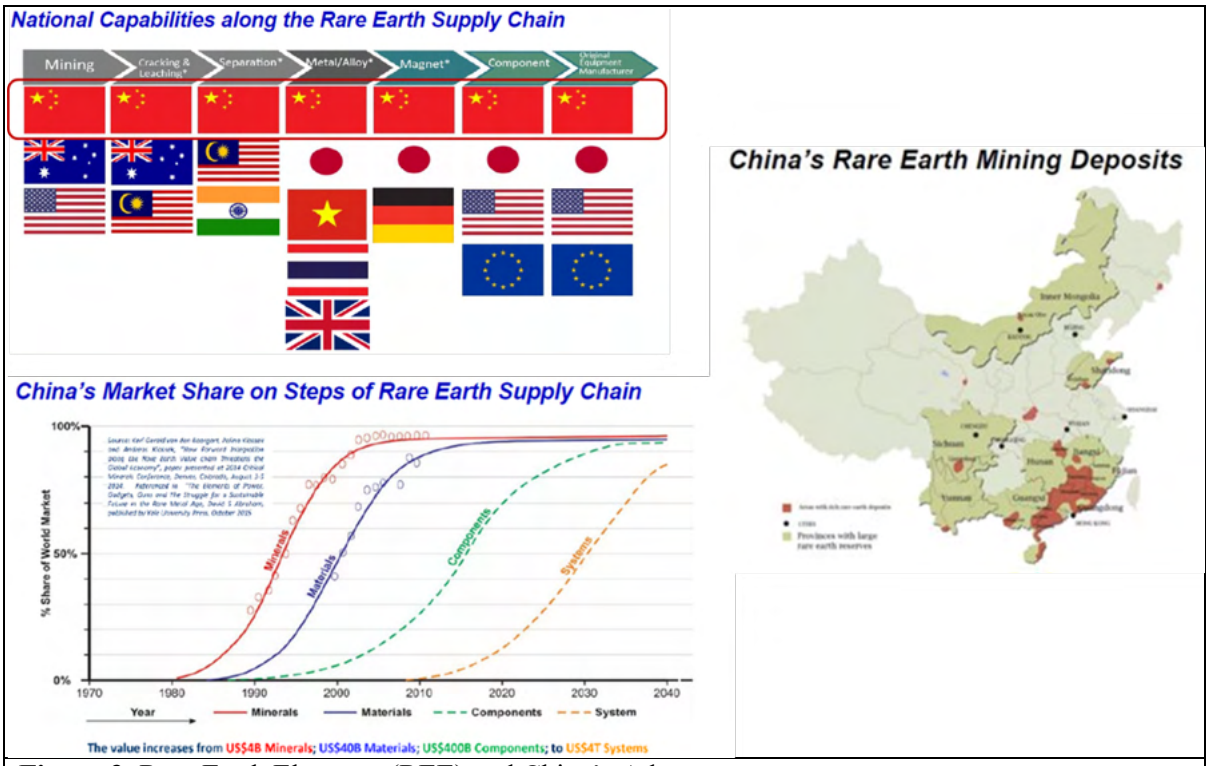


Figure 3: Rare Earth Elements (REE) and China's Advantage

Source: Eisenhower School AY 22, Strategic material -Dr P Coughlan presentation slides

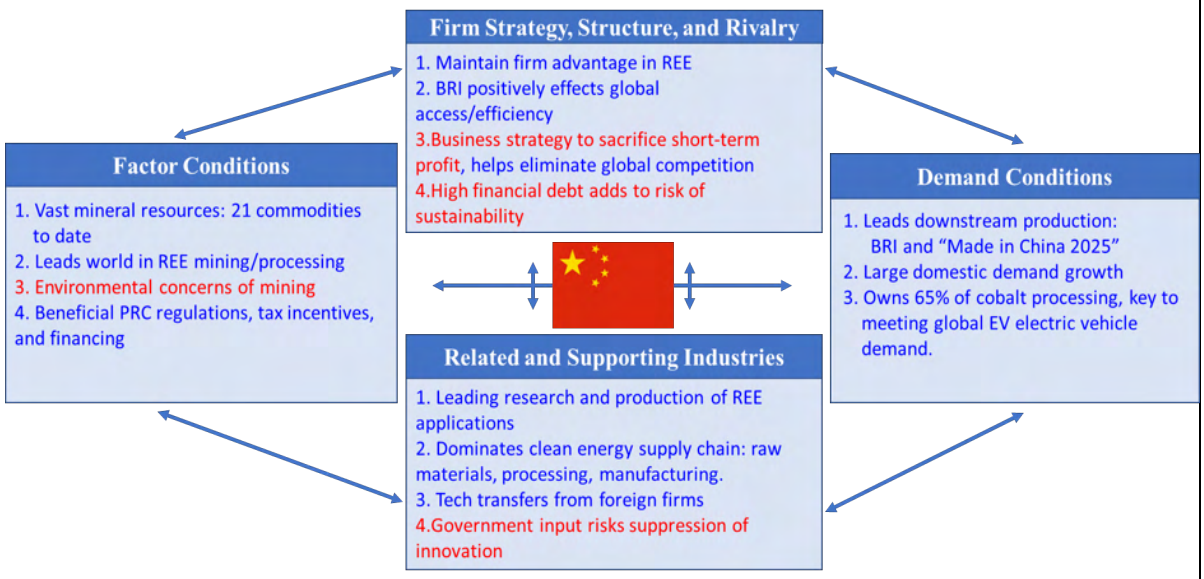


Figure 4: Porter's Diamond: China's Mining Industry

Appendix F – Russia's National Competitive Advantage

This appendix reinforces Section 5's analysis of Russia's national competitive advantage. Figure 1 provides a visualization and amplification of key facts and figures related to the Russian mining industry. Figure 2 provides a visualization and additional insights of Russia's competitive advantages and disadvantages using the Porter's Diamond tool.

World Rank	Mineral	Percentage of World Production
1st	Absestos	59%
	Diamonds	30%
2nd	Aluminum	6.0%
	Antimony	11%
	Cobalt	4.9%
	Gallium	2.2%
	Germanium	5.7%
	Nitrogen	9.9%
	Palladium	38%
	Platinum	11%
	Potash	18%
	Silicon	10%
	Vanadium	25%
3rd	Gold	8.4%
	Rare Earths	2.0%
	Sulfur	8.8%
	Tellurium	9.4%
	Titanium Sponge	22%
	Tungsten	2.5%

	Production	Global Rank
Nickel	5%	3
Titanium	13%	3
Vanadium	17%	2
Aluminum	6%	3
Copper	4% (refined)	8
Potash	20%	2
Palladium	35%	2
Platinum	10%	2

Sources: 1 - USGS 2017-2018 Mineral Yearbook Russia; 2- NRCan presentation to Eisenhower School AY 22, Apr 22.

Source: CRS Analysis – Russia's Trade with the World in 2021.

Domestic Facts:

- Russia economy mainly extraction and some midstream manufacturing (metals)
- Value of all mineral reserves approximately valued at $910 billion USD (~60% GDP (2017)).
- Russia's mining industry mostly privately owned (most Russian)
- 17,600 enterprises engaged in mining (3,000 in mining metal ores)
- Fairly opaque market

International Facts:

- RUS invasion of UKR & current sanctions affects global base-metal markets (aluminum, cobalt, nickel, palladium (automotive industry), scandium (rare earth metal) and titanium (aerospace industry))
- Minimal qty of major Mining Firms (3x)

Figure 1: Russia's Mining Industry – Key Facts

Sources: 1 - USGS 2017-2018 Mineral Yearbook Russia; 2- NRCan presentation to Eisenhower School AY 22, Apr 22; and 3- : CRS Analysis – Russia's Trade with the World in 2021.

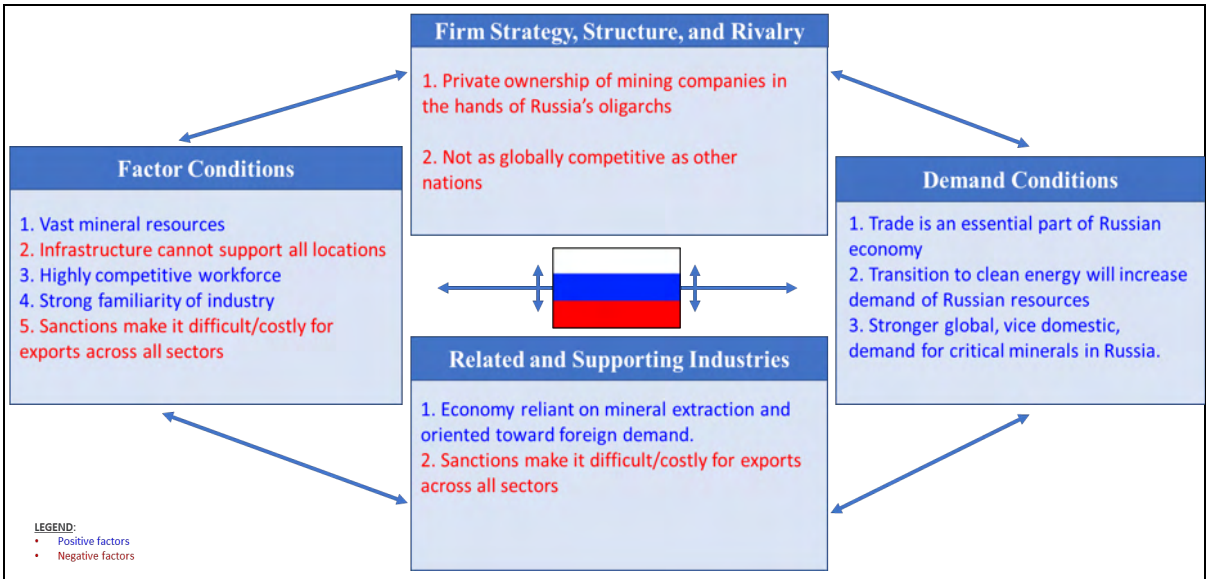


Figure 2 - Porter's Diamond: Russia's Mining Industry

Appendix G – Canada's National Competitive Advantage

This appendix reinforces Section 5's analysis of Canada's national competitive advantage. Figure 1 provides a visualization and amplification of key facts related to the Canada mining industry, and, figure 2 provides a visualization of Canada's current and emerging industrial clusters, innovation, and mining exploration. Finally, figure 3 provides a visualization and additional insights of Canada's competitive advantages and disadvantages using the Porter's Diamond tool.

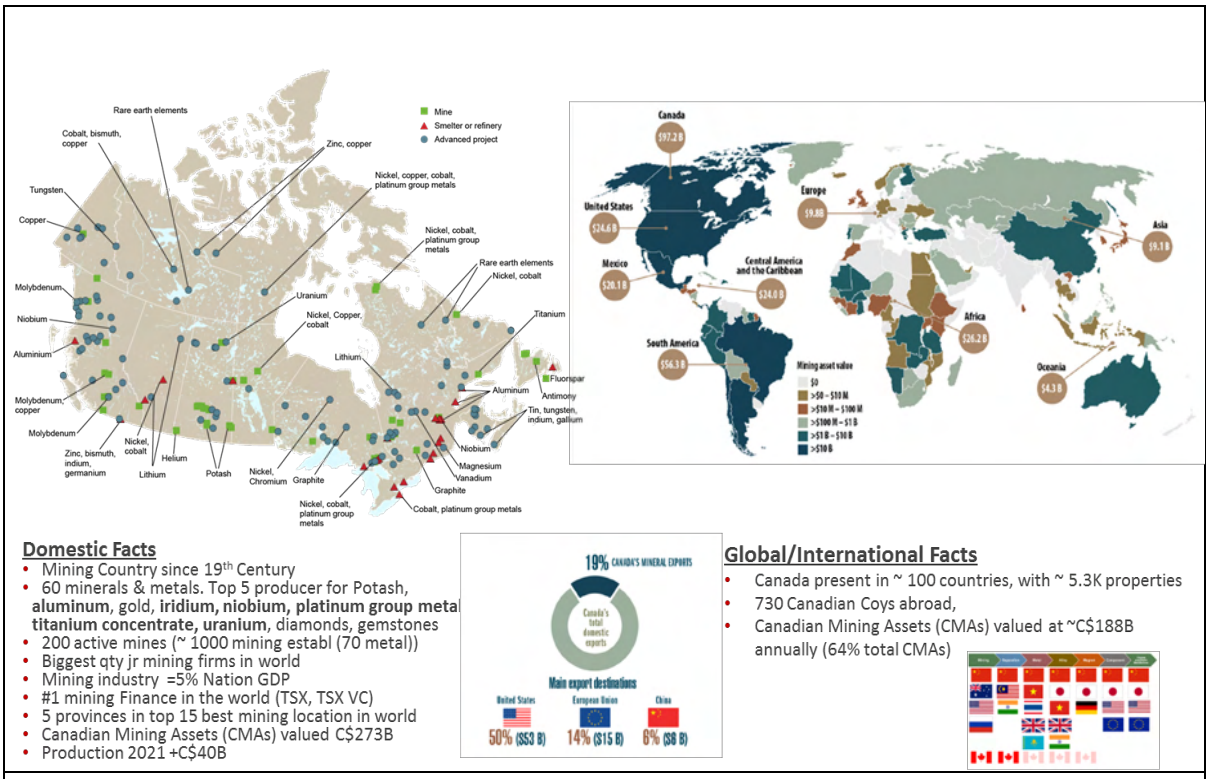


Figure 1: Canada's Mining Industry – Key Facts

Sources: : 1- https://www.canada.ca/en/campaign/critical-minerals-in-canada/critical-minerals-an-opportunity-for-canada.html , 2- Marketline Canada Mining Industry, 3- www.NrCan.gc.ca

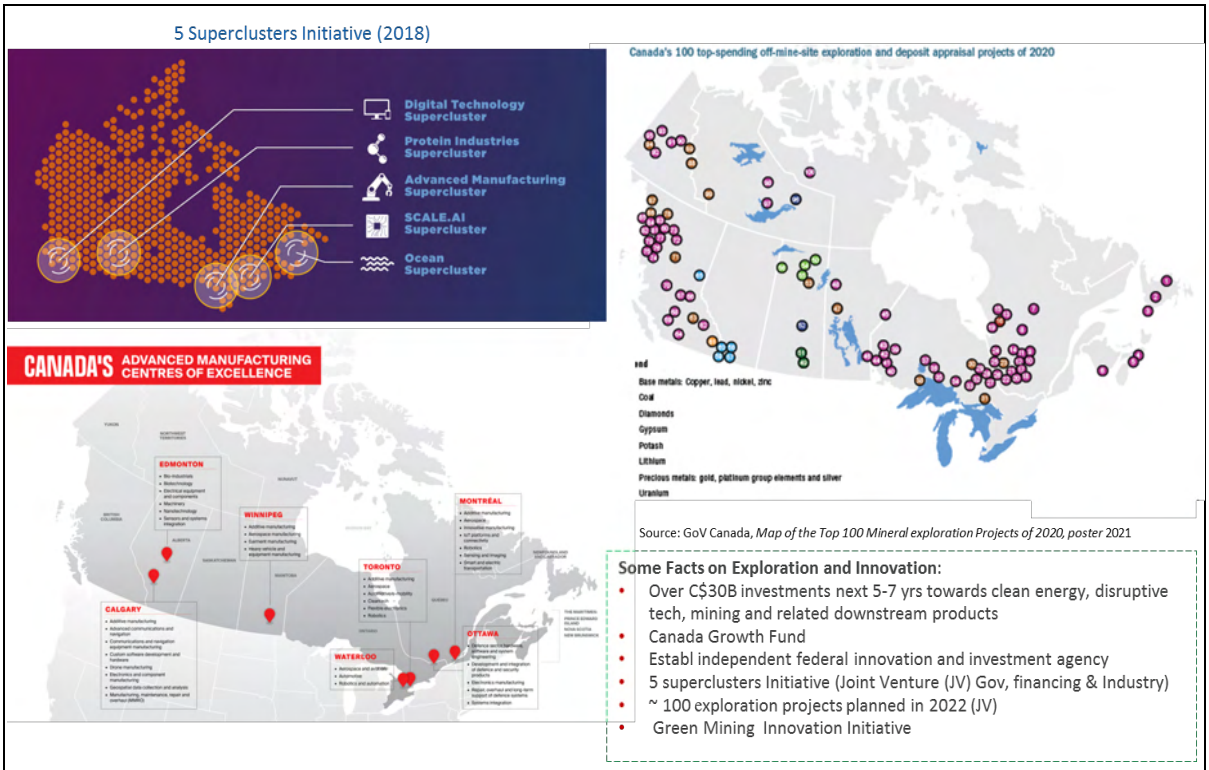


Figure 2: Cluster & Innovation Insights – Canadian Critical Mineral Industries

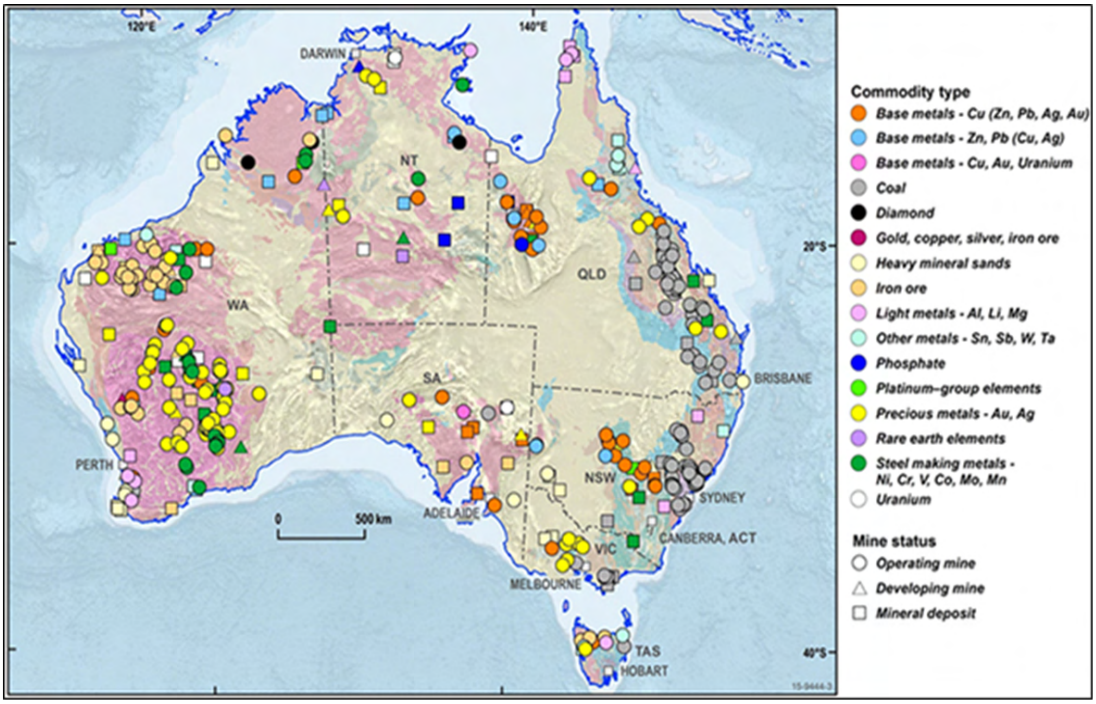
Source: : https://businessevents.destinationcanada.com/en-CA/economic-sectors/advanced-manufacturing.

Figure 3: Porter's Diamond: Canada's Mining Industry

Sources: 1- Porter, Competitive Advantage of Nations, 1990, ebook123, 2- Coughlan, ES IA 10-1 .ppt, Business Environment: Diamond, slide 39, NRCan Information April 22.

Appendix H – Australia's National Competitive Advantage

This appendix reinforces Section 5's analysis of Australia's national competitive advantage. Figure 1 provides visualization of Australia's mines and commodities, and, figure 2 amplifies Australia's commodity information with domestic and global comparisons. Finally, figure 3 provides a visualization and additional insights of Australia's competitive advantages and disadvantages using the Porter's Diamond tool.

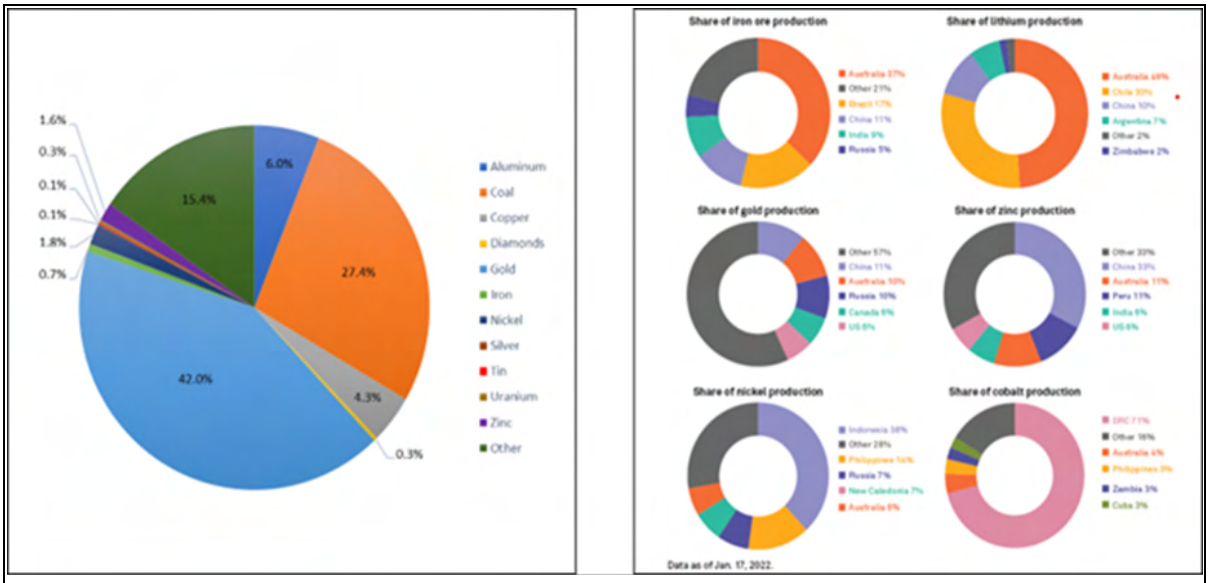


- Mining Country since 1800s
- 70 types of mineral deposits of economic significance
- 350 mines producing 23 mineral commodities

- #1 global producer for lithium and iron ore
- Mining industry =10% Nation GDP
- Mining industry production valued at over A$200 B for 2021

Figure 1: Australia's Mining Industry – Key Facts

Source: : https://www.ga.gov.au/education/classroom-resources/minerals-energy/australian-mineral-facts



Percentage of Total Australian Mineral Various Production of Export Earnings (2019)

Countries Global Share of Commodity Production (2022)

Figure 2: Australia's Mining Industry – Domestic and Global Shares

Sources: 1- https://www.ga.gov.au/digital-publication/aimr2020/value-of-australian-mineral-export ; 2- https://www.spglobal.com/marketintelligence/en/news-insights/research/australia-mining-by-the-numbers-2021

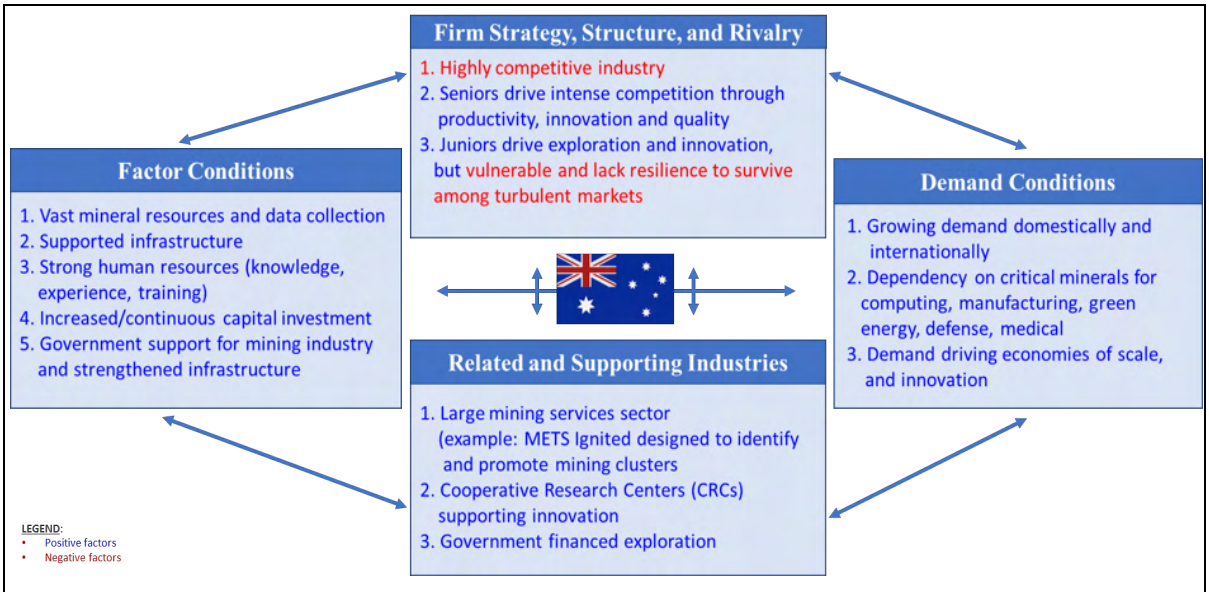


Figure 3 - Porter's Diamond: Australia's Mining Industry

Appendix I – United States' National Competitive Advantage

This appendix reinforces Section 5's analysis of the U.S. national competitive advantage. Figure 1 provides facts related to the United States mining industry and comparative data on other with other countries and regions, and figure 2 provides information on U.S. mining commodities and innovation clusters. Finally, figure 3 provides a visualization and additional insights of the U.S. competitive advantages and disadvantages using the Porter's Diamond tool.

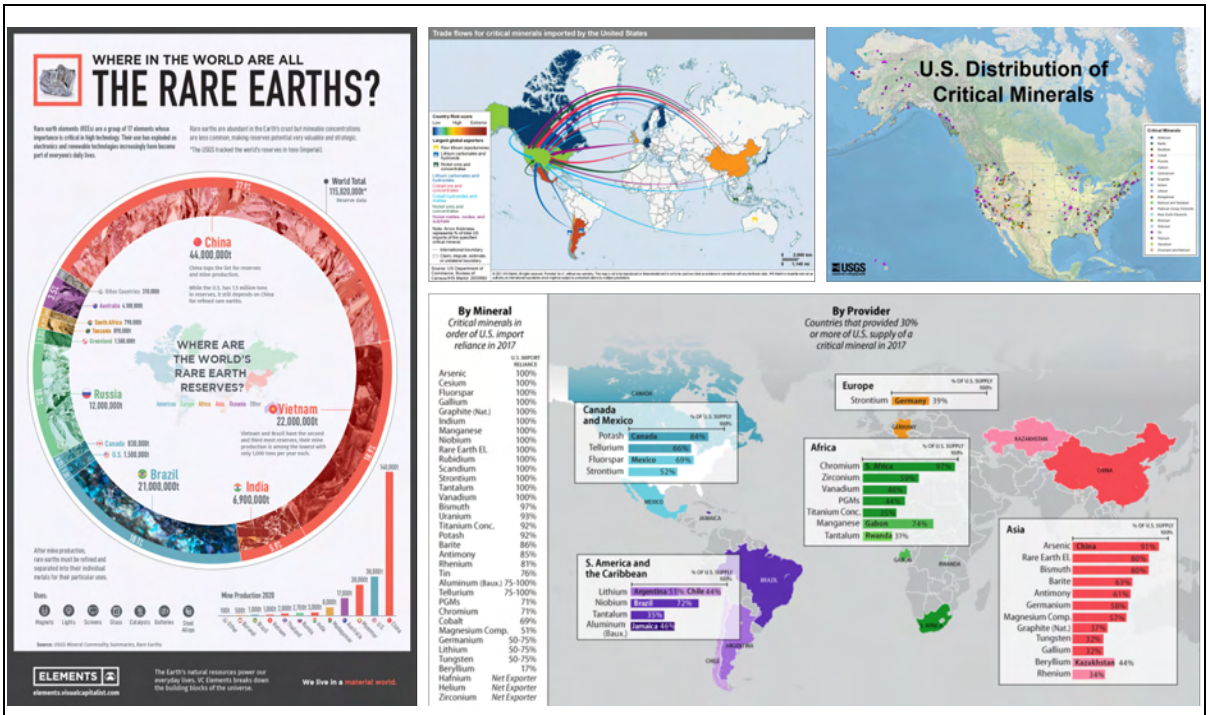


Figure 1: United States' Mining Industry – Key Facts

Sources: 1-Eisenhower School AY 22, Strategic material -Dr P Coughlan presentation slides; 2- USGS reference material

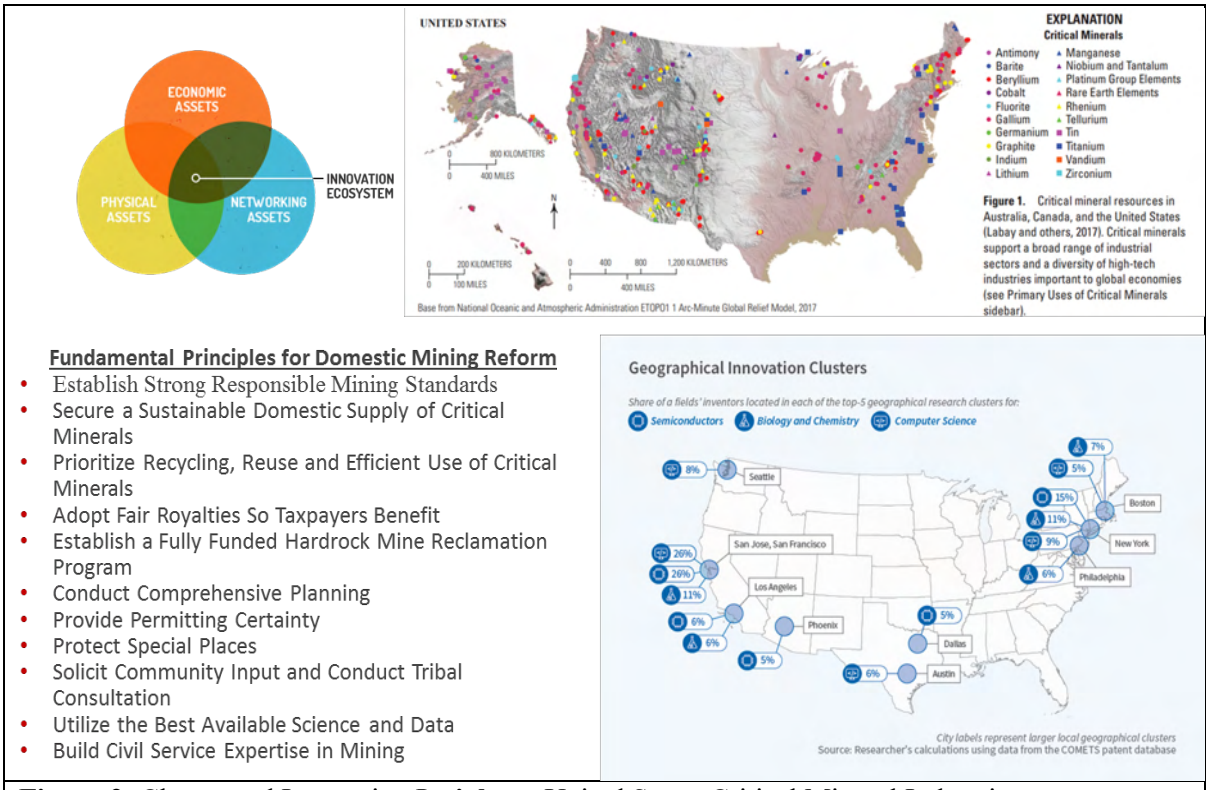


Figure 2: Cluster and Innovation **Insights** – United States Critical Mineral Industries

Source: https://www.nber.org/digest/nov19/most-us-high-tech-inventors-live-just-few-urban-clusters, https://www.brookings.edu/wp-content/uploads/2017/12/es_20171208_bailyclustersandinnovation.pdf, https://www.usgs.gov/media/images/united-states-critical-minerals-locations

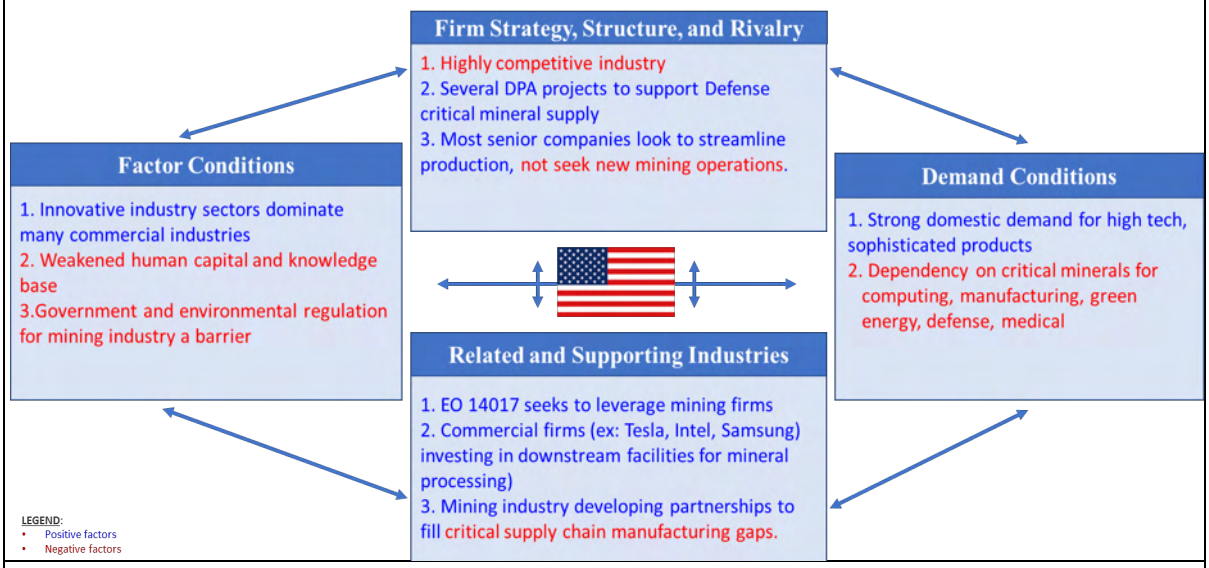


Figure 3 - Porter's Diamond: US's Mining Industry