

# Spring 2021 Industry Study

## Final Report

### *Securing Minerals Critical to National Security*

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## **1. Executive Summary**

The fragility of today's critical minerals global value chain poses an untenable risk to the national security and economic prosperity of the United States. With domestic supply lagging after decades of underinvestment and inattention, the United States relies heavily upon foreign sources for dozens of mineral products that form the fabric of the U.S. economy and defense industrial base. While some of these foreign sources are steadfast U.S. allies, other less dependable foreign suppliers like China or politically unstable states represent serious supply vulnerabilities and risks. Exacerbating the situation, global trends in manufacturing and green technology portend higher future demand and heated competition for these vital materials. On its current path, the United States is not well-positioned to compete successfully for these essential components.

Mineral extraction and processing is a notoriously expensive, complex, and risky industry subject to the vagaries of price swings. Such difficult market forces reinforced by unsupportive investment climates and weak social licenses to operate at home and abroad have led to an underdeveloped domestic minerals sector and serious challenges for U.S. mining companies overseas. This dynamic has led to a divergence between what the United States needs for its national security and what the free market is able to provide. By contrast, U.S. competitors, like China, eschew free market principles to successfully prop up domestic champions, manipulate minerals markets, and use political pressure to access minerals overseas.

To mitigate the risk of potentially catastrophic supply disruptions in critical minerals and their downstream products, the United States must take immediate, bold, and whole-of-government action in concert with global partners to correct its course. The United States should implement new minerals policies that prioritize and strengthen government coordination structures, form new international partnerships, improve foreign and domestic investment climates, enhance the sector's sustainability, and integrate supply stocks. This paper will provide tangible, interrelated policy recommendations within these key areas based on close examination and analysis of the critical mineral mining industry and its future challenges and opportunities. These policies adopted together will form a reinforcing set of coherent actions whose whole is greater than the sum of its parts. Like mining, these recommendations will require long-term, sustained commitments of political and financial resources but ultimately should strengthen U.S. national security and economic prosperity for decades to come.

The window of opportunity is now. Without action, the U.S. mineral dependence on unreliable sources will further constrain the U.S. strategic decision space. Adversaries will be able to exploit their dominance of mineral supply chains to coerce the United States and its allies into acting against their national security interests. The United States should harness and focus its resources, allies, and political will now to prevent this scenario and safeguard a prosperous and secure future.

## **2. Introduction**

**Purpose:** The Eisenhower School for National Security and Resource Strategy (ES) exists to prepare “select military officers and civilians for strategic leadership and success in developing national security strategy and in evaluating, marshaling, and managing resources in the execution of that strategy.”<sup>1</sup> A major component of the ES curriculum is the Industry Studies Program (IS), which provides students opportunities to analyze and assess the state and relevance of selected economic/industrial sectors to national security.

**Study Focus:** The Strategic Materials (StratMat) IS seminar focused its studies on all stages of the global supply chain of “critical minerals.” The U.S. Geological Survey (USGS) defines critical minerals as a “nonfuel mineral or mineral material that is essential to the economic and national security of the United States, is from a supply chain that is vulnerable to disruption, and that is an important component in the manufacturing of products, the absence of which would have substantial consequences for the U.S. economy or national security.”<sup>2</sup> Mining in this paper refers to the extraction of minerals and the initial upstream production stages of these minerals into refined mineral elements for onward sale as raw material. This research will concentrate, but not exclusively focus, on the 35 mineral commodities the USGS identified as critical to U.S. economic and national security.<sup>3</sup>

To investigate critical minerals, the StratMat IS met with U.S. stakeholders from government, industry, and academia along with international representatives from Australia, Brazil, Canada, Chile, the Democratic Republic of the Congo, Germany, Ghana, and South Africa. The IS explored the following significant issues and challenges:

- The high levels of risk (technical, market, regulatory, political) and boom/bust cycles;
- Difficulty attracting capital for long-term investments and before profits are realized;
- Strategic decisions regarding vertical integration vs. disintegration, scope, and globalization;
- Impact of state-owned or state-sponsored companies on market competition;
- Environmental protection concerns resulting from mining and beneficiating processes;
- Social license to operate mines and processing facilities in the United States and abroad;
- Identifying critical minerals that are strategic today and potentially strategic in the future;
- Dependence on foreign sources for the production and/or processing of critical minerals;
- Government’s role in innovation and reducing critical mineral supply-chain risk; and
- The pros/cons and complexities of subsidies, stockpiling, and ally agreements.<sup>4</sup>

**National Security Defined – Economic Security:** The new Biden Administration published an interim National Security Strategy in March 2021 identifying three key national security pillars: “Protect the security of the American people; Expand economic prosperity and opportunity; Realize and defend the democratic values at the heart of the American way of life.”<sup>5</sup> The Administration is prioritizing cooperation with allies and partners. The IS Seminar defines U.S. national security as extending beyond national defense to also include economic security.

**Distinction between China and the Chinese Communist Party (CCP):** The People’s Republic of China plays a significant global role in the critical minerals industry, both as a major supplier and consumer. While this research frequently references “China” as taking actions that are hostile, threatening, or manipulative of the critical minerals market, it is important to note that the real threat lies with the CCP and not the people of China.

### **3. Critical Minerals Importance to National Security**

Mineral resources are critical to preserve and strengthen U.S. national security. From advanced weapons systems to the latest healthcare technology, a broad range of U.S. industrial and consumer products depend on critical minerals as essential ingredients for their production.<sup>6</sup> As mining experts like to say, "If it's not grown, it's mined."<sup>7</sup> The United States relies on critical minerals to sustain its defense industrial base, power green energy initiatives, innovate in space exploration, ensure the nation's high-tech manufacturing sector remains globally competitive, and create and sustain jobs. In other words, secure and reliable access to critical minerals is a necessary condition for national security and economic prosperity.

The USGS has identified 35 minerals as critical to U.S. economic and national security. The United States is highly dependent on foreign sources to procure 24 of these critical minerals, however.<sup>8</sup> (See Appendix 3-1.) The United States is 100 percent import reliant on 14 critical minerals, aside from a small amount of recycling.<sup>9</sup> These minerals are difficult to substitute in most economic and national security applications.<sup>10</sup> Graphite, manganese, niobium, rare earths, and tantalum fall into this category. The United States is more than 75% import reliant on an additional 10 critical minerals, including rhenium, tin, titanium concentrate, and uranium.<sup>11</sup>

As a result, U.S. supply chains for many critical minerals are fragile and highly vulnerable to disruption. Risks include overseas export restrictions, political instability, and natural disasters. China's imposition of rare earth export restrictions against Japan in 2010 exemplifies the threat.<sup>12</sup> In another example, international mining companies Lynas and MP Materials both mine rare earth elements outside China, but each company relies on a single mine source: Mount Weld in Australia and Mountain Pass in California, respectively.<sup>13,14</sup> A flood or landslide, an environmental accident, or even a workers' strike at one of these locations would disrupt production for a significant part of the global non-Chinese supply of rare earths.

Many countries share the same sources for their minerals. For instance, the map for the European Union's (EU) sources of critical minerals is strikingly similar to the map of U.S. sources. (See Appendix 3-2.) Only a few countries supply critical minerals, and the consuming countries, including China, must compete to secure access to those resources. The growing demand for high-tech products and green technologies, both major applications for critical minerals, will only exacerbate the situation.<sup>15</sup>

A tool developed by the non-profit organization MITRE enabled the StratMat IS to summarize the problem facing the United States with the following framing question: How might we ensure a secure and reliable critical minerals supply chain for the United States, its allies, and partners, while considering global competition and unfair trade/business practices as we aim to promote economic prosperity and national security? (See Appendix 3-3.)

### **4. Current Conditions of the Overall Mining Sector**

#### **Structure: Economics of the Mining Industry**

The mining industry faces unique constraints that shape the industry's structure, such as extended lead times, high sunk costs, and depleting assets. The mining industry has to focus on long-term time horizons with the average lifespan of a typical mine spanning from 18 to 80 years, according to KPMG. (See Appendix 4-1.) In this life cycle, only the production phase generates revenues but simultaneously depletes the mine's assets. Mining firms are often subject to volatile price swings in commodity markets with little recourse to influence price levels.

Developing new mines is challenging, capital intensive, and time-consuming. Mining often requires complex technology, such as the complicated chain of extracting, separating, refining, and purifying rare earth ores into oxides. Additionally, various minerals have considerable differences in production scale. For instance, iron ore production is counted in millions of metric tons, while rare earths are in tens of thousands.<sup>16,17</sup> Some commodities, like gallium, are by-products of other minerals.<sup>18</sup> Their production depends on the main mineral's mining, possibly limiting supply. This disparity in scale and origin creates different dynamics for each commodity.

Mining companies vary widely in size, scope, and activities. Small companies, called junior mining companies, tend to specialize in earlier and riskier stages of mining projects.<sup>19</sup> However, Robin Adams in *Modern Management in the Global Mining Industry* explains that “[the] majority of junior mining companies will either fold or struggle to remain alive. A few will make a viable and major discovery and will be either bought out or financed by a major.”<sup>20</sup> The major companies are the most prominent in the mining industry. They are primarily Anglo-Australian, U.S., Canadian, South African, or Asian companies and often offer a diversified portfolio of mineral products. These major companies focus mainly on the development and exploitation phases of a mining project. Rio Tinto, Vale, Freeport McMoran, BHP, and Glencore are examples of major companies with diversified portfolios. Alternatively, some specialize in one commodity, especially gold, like AngloGold Ashanti.<sup>21</sup>

State-owned enterprises (SOE) are another category of mining companies. SOE's often exploit their home nation's natural resources, like Chile's major state-owned copper producer Codelco.<sup>22</sup> Chinese SOEs are different as they mine both in China and abroad.<sup>23</sup> The Chinese government also uses SOEs to promote its interests through export restrictions.<sup>24</sup> This diversity in mining companies creates unique behaviors, opportunities, and challenges for each of them.

A Porter's Five Forces analysis of mining reveals key features of the industry and how it relates to customers, suppliers, and governments.<sup>25</sup> (See Appendix 4-2.) The analysis shows that rivalry among competitors in mining depends on the mineral. For example, the rivalry is intense in gold production with many companies involved. In contrast, rare earths production is almost a monopoly with Chinese state-owned enterprises accounting for 90 percent of supply in 2019.<sup>26,27</sup>

Customer buying power is moderate. Whether customers use minerals to manufacture products or create new materials, miners' minerals are often irreplaceable inputs for their products. Therefore, some customers decide to vertically integrate with mining firms to ensure reliable and affordable access to these essential inputs.<sup>28</sup>

Nevertheless, due to its peculiar long-term, capital-intensive nature, and high entry costs, the mining industry experiences only a few new entrants. The industry expands typically when existing major companies diversify into new minerals or junior companies become majors. However, those companies originate from within the sector. MarketLine's *Global Metals & Mining* study asserts that new entrants sometimes originate from countries whose governments provide new financial support to mining firms as part of economic diversification plans.<sup>29</sup>

Suppliers are often influential players providing the skilled labor, chemical products, and heavy equipment essential to mining and processing.<sup>30</sup> Governments also serve as suppliers and exert strong power as they often own the land or the rights to mineral resources, provide patents and licenses to exploit a mine, build infrastructure, and help train workers. Governments also define and enforce the regulations with which mining companies must comply.<sup>31</sup>

Given the unique characteristics of critical minerals, the threat of substitutes is weak. Even when substitutes are possible, it might be that the substitute is just as critical. For instance, rubidium is a possible substitute for cesium, but both are on the U.S. list of critical minerals.<sup>32,33</sup>

### **Conduct: Firm Strategies in the Mining Industry**

An effective strategy is critical to a firm's success in the difficult mining industry. Given the diversity of the mining industry, no two firms respond in the same manner to every situation. However, two main approaches to strategic market positioning have emerged: diversify or find a niche. Rio Tinto pursues the diversification model and considers it elemental to its success because it reduces the company's exposure to fluctuating commodity prices.<sup>34</sup> On the opposite side of the spectrum, Lynas has found a niche position as the only significant rare earth producer outside China. Lynas also emphasizes its products' high quality and environmental standards to differentiate itself from Chinese rare earth products.<sup>35</sup>

Managing relationships with customers, local communities, and governments is also part of the mining industry's conduct. Mining operations can severely disrupt the surrounding environment; therefore, gaining local community support is crucial. In 2019, the Minerals Council in South Africa highlighted "re-establishing trust with global mining and investment community" as one of the "steps needed to restore the South African mining sector to the top quartile of the most competitive mining jurisdictions."<sup>36</sup> The mining industry must also maintain good relationships with governments as they are both suppliers and regulators.<sup>37</sup> Moreover, governments can make valuable investments in infrastructure to provide affordable water and energy to mining companies, as Australia has demonstrated.<sup>38</sup> Water, transportation, and energy often constitute high costs for firms, so government investments in these areas can create a competitive advantage for a country's mining companies.<sup>39</sup> Such investments are easier to secure if the company and the government enjoy collaborative relationships.

Mining companies must also strike a balance between exploitation and exploration when developing a strategy. Once exploiting a mine, mining companies have little direct influence on the orebody grade, composition, and labor cost. However, they may improve their processes, especially in how they process raw material to transform it into a sellable commodity. Freeport McMoRan follows this path by using artificial intelligence to "find new process changes that would increase Bagdad's [one of Freeport's copper-ore concentrating mills] copper output without a massive injection of capital."<sup>40</sup> Hence, investing in process improvements can help a mining company create or maintain a competitive advantage. Therefore, research and development should be part of a mining firm's strategy.

Exploitation (or production) is the only phase when a mine generates revenues while simultaneously depleting its assets. This phase can last decades. (See Appendix 4-1.) On the other hand, exploration and developing a new mine involve considerable investments. In *The Extractive Industries Sector*, Håvard Halland writes, "[the] costs of mine development can vary from around \$50 million to \$15 billion, according to the mine type and size, location, and infrastructure requirements."<sup>41</sup> Therefore, a mining firm cannot operate exclusively in the exploration or exploitation phase if it wants long-term survival. Thanks to its different business units, Albemarle can pursue both paths simultaneously: the bromine unit maximizes cash flow generation, while Albemarle keeps developing the lithium unit, with most activities aimed at reducing costs.<sup>42</sup> Diversified companies with multiple mines can more easily achieve this balance than specialized ones.

Innovation in mining is important to a firm's success in exploiting its resources. Given the economics of mining, however, when times are bad, businesses find it difficult to justify increasing capital investment in innovation to lower costs and improve efficiency.<sup>43</sup> Policies that promote innovation must address the core challenges which make mining unpredictable and keep commercial investment capital on the sidelines. Because the high uncertainty in sustained profitability of mining projects deters risky investments in innovation, government intervention is warranted. Politicians should act but must heed the warning by business strategist Michael Porter and avoid "the all-too-easy escape routes that appear to offer a path to competitive advantage but are actually shortcuts to failure."<sup>44</sup>

### **Performance: Financial Performance & Investment in the Mining Industry**

Mining companies invest substantial capital to explore and develop new mines. Therefore, they need to find ways to accumulate the required funds through retained earnings, debt and equity financing, and other non-traditional methods. After exploring the financing options, this paper will assess a few mining companies' financial performances to determine if they create or destroy value at an acceptable level of financial risk.

Mining companies can finance new mining projects using retained earnings. If retained earnings are insufficient, the firm can raise debt. In 2019, Rio Tinto used this method with a \$3.9 billion debt increase.<sup>45</sup> However, Rio Tinto's financial strategy is debt reduction, as shown in its *Annual Report 2020*.<sup>46</sup> Given the current record-low interest rates, debt financing allows mining companies to reduce their long-term financial risks (e.g., refinancing debt at lower rates). PwC also noted this trend in its *Mine 2019 Resourcing the Future* report.<sup>47</sup>

Another financing option is to raise equity. In 2020, Lynas followed this path to raise 425 million (AUD) to develop its plant in Malaysia and build a new processing plant in Australia.<sup>48</sup> Closely linked to raising equity, privately-owned companies can go public. In 2020, MP Materials combined an Initial Public Offering (IPO) with a merger.<sup>49</sup> Mergers & Acquisitions offer opportunities to diversify (CVRD and Inco in 2006), reinforce their position in a market (Barrick Gold and Randgold Resources in 2018), or vertically integrate (Rio Tinto and Alcan in 2007).<sup>50</sup> Finally, mining companies can rely on non-traditional methods to secure financing. Examples include governmental support through loans, tax reductions or exemptions, and direct subsidies.<sup>51,52,53</sup> Another non-traditional option proposed by McKinsey & Company recommends selling a portion of advance production.<sup>54</sup>

For mining companies to accumulate capital through raising equity or going public, investors must believe that the firm can create value at an acceptable level of financial risk. Computing the return on invested capital (ROIC) and comparing it to the weighted average cost of capital (WACC) determines whether a firm is creating or destroying value. Appendix 4-3 presents a table with the recent ROIC for select western companies. The table contains diversified companies (Rio Tinto, Freeport-McMoRan, Albemarle) and specialized companies (Lynas, MP Materials, AngloGold Ashanti, Materion).

The ROIC's are as diverse as the companies with Lynas, Freeport McMoRan, and MP materials enduring losses in either 2019 or 2020, or both, so they have a negative ROIC. A more in-depth review highlights that price volatility and production declines due to COVID-19 account for most of the loss. For example, AngloGold Ashanti had an ROIC of merely 0.1 percent in 2019 while recording 16.4 percent in 2020. However, the diversified companies had different outcomes with Freeport McMoRan suffering the weakest results among the diversified companies, while Rio Tinto fared very well. Though specific to each company, the mining

industry WACC ranges between 8-12 percent. Among the firms analyzed, only Rio Tinto and AngloGold Ashanti created value in 2020, with an ROIC superior to this industry average WACC. In the other companies, the capital is better invested elsewhere.

When an investor buys a company's shares or a bank loans money, they are taking the risk of a fall in the share price or never being repaid.<sup>55</sup> Appendix 4-3 exhibits the current ratio, long-term debt-to-equity ratio, and debt-to-equity ratio to determine the level of financial risk mining companies take. Most companies' current ratios were higher than one, denoting low short-term financial risk. Furthermore, with high long-term debt-to-equity ratios (higher than one), Albemarle, AngloGold Ashanti, and Freeport McMoRan have a potential financial risk in repaying long-term debt. However, the ratios have improved from 2019 to 2020, showing the companies' attempts to rectify the situation that is consistent with the mining industry's approach to reducing debt levels.

The previous data demonstrates the wide range of financial performances across the mining industry. As a general trend, value creation tends to be low or negative, making the investment unattractive. However, it is low risk with the potential for high reward for some companies like Rio Tinto, concluding that the more diversified portfolio mitigates some of the market's volatility. This attracts new investors trying to emulate the industry's top performers.

## **5. Mining in the United States - Conditions and Challenges**

### **National Competitiveness of the U.S. Mining Industry**

The national competitiveness of the U.S. mining and minerals industry is best examined through the context of a Porter's Diamond analysis. (See Appendix 5-1.) The United States possesses a vast natural endowment of critical minerals. (See Appendix 5-2.) Firms competing in the United States have high investor protections and face open and rigorous competition. Like the overall mining industry and as highlighted in the Porter Five Forces analysis in Section 4, a few large firms compete to differentiate their products, process, and services or exploit their mature minerals (e.g., copper, molybdenum) to extract the most profit through increasing operational efficiency and lowering costs. However, there are advantages that spur competition and disadvantages that dampen the nation's full potential.

The U.S. critical minerals sector enjoys many advantages that make it competitive on the international arena. Due to the intense domestic rivalry, U.S. companies must either create differentiated products, develop cost-saving processes, or locate lowest-cost/highest quality sources to be competitive. They bring these measures to their foreign investments and ventures. U.S. companies must meet demanding customer needs, such as high environmental standards, product quality, and purity of mineral requirements. U.S. mineral companies must also meet the demand for an expanding set of mineral applications in the U.S.'s cutting-edge technology fields.

The U.S. critical minerals sector has disadvantages that reduce U.S. competitiveness both domestically and internationally. The industry is congested with large multinational firms focused primarily on exploiting existing mines and processes versus exploring new minerals, so limited private capital is employed for exploration. U.S. companies also face continuing challenges for gaining licenses to operate on both public and private lands with lengthy permitting processes, layered federal, state, and local regulations, and robust conservation and environmental activist organizations who often oppose new projects. High barriers to entry still exist to realize traction on reviving domestic production - high capital costs, achieving economies of scale to lower per-unit cost, and competition with non-market economies. Finally,

the long-term decline and stagnation of the U.S. mining industry have made it challenging to attract and retain labor with the requisite knowledge and skills.

### **Bureau of Mines - An Opportunity Lost**

The mining sector has long played a critical role in the history of the United States going back to the Gold Rush of the 1800s. The mining sector provided critical minerals during wartime mobilizations and employed millions. In recent years, however, the mining industry has been associated with environmental degradation and has lost the attention of government leaders. This lost focus was due in part to the dissolution of the Bureau of Mines 25 years ago.

From its inception in 1910 until its dissolution in 1996, the Bureau of Mines was the primary federal agency for scientific research and credible information on extraction, processing, use, and conservation of mineral resources.<sup>56</sup> It is a logical starting place for a discussion on the U.S. mining sector due to its lasting legacy and prominent place in history. The presence of this organization was felt through the industry both domestically and internationally. Established within the Department of the Interior, the catalyst for its founding was a then-recent wave of catastrophic mine disasters that claimed the lives of many miners and earned the mining industry a reputation as being extremely hazardous. Over the years, this government entity built relationships with many mining companies and the overall industry by its intense focus on safety, health, environmental impacts, and the processing of minerals and materials. The Bureau of Mines quickly earned a solid reputation worldwide and was recognized as a focal point for new developments and the evolution of science and technology in the field of critical minerals.<sup>57</sup>

Aside from the Bureau's routine analysis of trends and needs in the industry, its customer-facing interactions with private and public mining companies helped guide research and ensured findings were distributed to those who needed and could benefit from the data. Among its many accomplishments, the Bureau is credited with research and technology that reduced mining fatalities by 97 percent (from ~3,000 recorded in 1907 to 98 recorded in 1993), created techniques to recover strategic and critical minerals to reduce U.S. vulnerability during crisis (Cold War), developed the use of bacteria to remove arsenic and cyanide from wastewater, and uncovered the world's largest deposits of lead and zinc at Alaska's Red Dog Creek, which led to hundreds of millions of dollars in capital investments for mine development.<sup>58</sup>

Because of its many impacts, the United States Bureau of Mines left behind a valuable legacy and is still highly regarded by experts today. So, this begs the question: if the Bureau of Mines was so impactful and successful, why was it dissolved? The answer to this question can be answered in one word – politics. The 104<sup>th</sup> Congress assembled in January of 1995. It was the first time in 40 years the Republicans had control of both the House and the Senate. Their goal was to reinvent the government through downsizing, and the Bureau was a relatively easy target.<sup>59</sup> Concerns over the adverse environmental effects of mining also existed in Congress. With the Bureau of Mines closure, almost \$100 million, or 66 percent of its programs ceased completely. Officials divided the Bureau's responsibilities among other government agencies.

Congress' decision to close the Bureau of Mines seemed rational at the time. It saved money, protected the environment, and posed little strategic risk. The United States was the dominant global superpower after the collapse of the Soviet Union a few years earlier. Russia was no longer a serious threat. China was still trying to transition from an agrarian economy and remained opened to Western economic influences. Many in America thought that the global free market would adequately address the supply and demand issues surrounding the mining of

critical minerals. Overall, there was a perceived minimal national security threat to the nation having adequate access to critical minerals.

Fast-forward 25 years, and America now finds itself in a different global environment. China and Russia are back as global competitors, with China dominating the critical mineral industry and affecting the critical mineral supply chain. The future of protecting the environment depends on mining critical minerals to supply new green energy technologies. The global open market does not always act in the interest of U.S. national security regarding critical mineral stockpiling and investing decisions. What the United States lost when the Bureau of Mines closed is exactly what it needs today – a single entity that can aggregate information about critical minerals, serve as a credible voice in the United States government with awareness of the criticality of mining and minerals, and represent the mining industry adequately through the lens of political aims and strategic policy.

## **U.S. Industrial Policy and Other Issues**

### ***United States Mineral Strategy and Policy***

The United States once played a dominant role in the global critical mineral supply chain. In 2010 China abruptly cut off supply to Japan, which prompted more U.S. government attention and focus to acknowledge U.S. supply chain vulnerabilities and the economic importance critical minerals play in new technology development. However, it was not until 2017 that the U.S. Government issued a clear policy with actionable policy measures. The need for a consistent policy apparatus is imperative to maintain a laser focus on overcoming challenges. The most recent executive orders from the current and previous Administrations demonstrate an inability to maintain that laser focus.

The 2017-2020 Trump Administration Executive Orders defined and narrowed the scope of critical minerals. It also laid out a strategy and an action plan to boost domestic production and develop close partnerships with allies.<sup>60</sup> The Trump Administration issued Executive Order 13817 in 2017 stating, “it shall be the policy of the Federal Government to reduce the Nation’s vulnerability to disruptions in the supply of critical minerals, which constitutes a strategic vulnerability for the security and prosperity of the United States.”<sup>61</sup> To address the inherent economic and security weaknesses, the Department of Commerce developed the “*Federal Strategy to Ensure Secure and Reliable Supplies of Critical Materials*” to reduce the nation’s vulnerabilities to disruptions in the supply of critical minerals through both a general policy and six specific Calls to Action: (1) Advance transformational research, development, and deployment across critical mineral supply chains, (2) Strengthen America’s critical mineral supply chains and defense industrial base, (3) Enhance international trade and cooperation related to critical minerals, (4) Improve understanding of domestic critical minerals resources, (5) Improve access to domestic critical mineral resources on federal lands and reduce federal permitting timeframes, and (6) Grow the American critical minerals workforce.<sup>62</sup>

Conversely, the Biden Administration’s executive order opened the scope of attention to more industries in addition to critical minerals. Although a sustained focus on critical minerals signals a continued commitment from the U.S. government across Presidential transitions, the recently broadened scope to pharmaceuticals and essentially all supply chains will spark a vigorous competition for already scarce U.S. government resources. The lack of a clear top-down prioritization or more narrowed focus on any one specific supply chain vulnerability will

lead to even longer delays to an already daunting task of securing a more resilient mineral supply chain.

### ***Investment Climate***

To attract foreign investors, a nation must offer both economically viable mineral reserves and a favorable policy environment that minimizes risk and maximizes predictability for companies. A favorable investment climate in mining includes political stability, predictable and efficient policies and regulations, relevant infrastructure, tax stability, transparent governance, data availability, skilled labor, and an independent judiciary. These factors provide firms confidence that investments will provide sufficient and predictable ROIC that validates the large, long-term capital investments required in mining. Countries also use a broad range of fiscal instruments to attract investment, such as tax holidays, reduced royalties, and stabilized tax rates. (See Appendix 5-3.)

Because countries compete for foreign investment, a country's success in attracting investment depends less on the absolute attractiveness of its business climate than on its attractiveness relative to other nations. The ongoing competition between mining powerhouses Australia and Canada is illustrative. Both have attractive investment climates and well-developed mining sectors, but companies can still choose one over the other.

Including both geologic and policy attractiveness, the United States is the third most attractive region in the world for mining investment, according to the Fraser Institute's Annual Survey of Mining Companies 2020.<sup>63</sup> Australia earned the top spot, followed by Canada.<sup>64</sup> The Fraser Institute surveys mining companies on the investment attractiveness of 77 jurisdictions from geological potential and policy perspectives.<sup>65</sup> The United States was the top-ranked region on policy alone.<sup>66</sup> (See Appendix 5-4.)

As in other countries, foreign investment is important to the U.S. mining sector. Foreign Direct Investment (FDI) stock in the U.S. mining sector totaled \$37.8 billion in 2019, a rise of roughly 300 percent from the approximately \$10 billion in FDI stock in 2000, according to the U.S. Bureau of Economic Analysis.<sup>67</sup> (See Appendix 5-5.) Of this FDI stock, \$29.9 billion comprised foreign investment in metal ore mining. Top investors are companies based in Australia, Canada, the UK, and Mexico.<sup>68</sup>

The Behre Dolbear consultancy labels the U.S. mining sector a "paradox" in that its "experienced governmental and financial sectors contribute to high investor confidence," but public concern over environmental impacts "leads to an onerous permitting process that creates sufficient uncertainty to sometimes destroy the viability of new projects."<sup>69</sup> Foreign investors must navigate a complicated assortment of complex environmental rules and regulations administered by multiple agencies at the federal, state, and local levels. No centralized government actor has full ownership over coordinating U.S. mining policy.

Perhaps the most significant deterrent to mining investment in the United States is the lengthy, costly, and inefficient permitting process that can take upwards of 7 to 10 years.<sup>70</sup> (See Appendix 5-6.) In Canada and Australia, the permitting process with the same strict environmental standards only takes about two to three years. (See Appendix 5-7.) Poor agency coordination, insufficient resources, and long approval timeframes typically make the environmental permitting process the lengthiest step in receiving government approval for a mine's operation.<sup>71</sup> Over 36 federal environmental laws and regulations touch on aspects of the mining sector, layered on top of many state and local laws.<sup>72</sup> While permits serve to avoid, limit, control, and offset potential environmental damage, the uncertainties and complexities of

America's triple layer of politics, laws, and regulations can cause delays that tie up investor capital in stagnant, permit-pending projects and impose large opportunity costs for investors who could be investing elsewhere.<sup>73</sup>

In addition to permitting, prevalent legal action against mining projects by outside parties in the United States hurts its investment climate. These lawsuits can significantly delay a project and legal defenses can soak up private sector and government time and resources. For example, Rio Tinto (55 percent ownership) and BHP (45 percent) have spent \$2 billion in development costs of the Resolution Copper Mine in Arizona for over a decade but have not produced any copper because of pending legal action by Native American groups suing to stop the mine's operation to prevent the destruction of ancestral land they consider to be sacred.<sup>74</sup>

The investment climate is also not homogenous throughout the United States, and state-level policies affect investment decisions. Idaho, Wyoming, Nevada, Utah, Arizona, and New Mexico were ranked in the top ten of jurisdictions worldwide in the Fraser Institute Survey's Policy Perception Index.<sup>75</sup> California was in 62<sup>nd</sup> place, however, due to concerns over the enforcement of environmental regulations, labor regulations, and available labor skills.<sup>76</sup>

The United States has vast mineral resources but limited knowledge of the economic viability of significant portions of it, harming its investment climate. Less than 18 percent of U.S. land has been geologically mapped at a scale for mining decisions, however.<sup>77</sup> (See Appendix 5-8.) By providing geological data, governments address two market failures.<sup>78</sup> First, because early-stage geoscience is a public good, the private sector is disincentivized to supply the data as it must share the benefits. Second, the uncertainty of a successful prospect is so high without adequate data, and mining firms cannot properly value a prospect.<sup>79</sup> The World Bank states, "A well-funded geological survey can act as a tremendous stimulus to investor interest in geological potential."<sup>80</sup>

As the United States attracts foreign investment, especially in critical minerals, it must carefully balance the benefits of foreign investment with risks to national security. The U.S. government screens foreign investment for national security risks through the Committee on Foreign Investment in the United States (CFIUS). CFIUS' challenge is keeping vital U.S. companies out of the hands of adversaries but in a way that does not stifle legitimate FDI.

### ***Sustainability – An Expanded View***

A reinvigorated and sustainable, thriving mineral industry in the United States is largely dependent on an improved social license to operate (SLO). The challenge of SLO stems from fears that today's new mining operation is tomorrow's superfund site.<sup>81</sup> Counterintuitively, the U.S. mining industry's constraint of environmental regulations and the headwinds of a political confrontation is an opportunity for transformation into a sustainable advantage. The Ethics Center of Australia defines the SLO in its simplest form as "the acceptance granted to a company or organization by the community."<sup>82</sup> It further elaborates that the social license to operate consists of legitimacy, credibility, trust, the degree to which an organization follows established rules, providing accurate and precise information to the community while maintaining commitments. The following elements which contribute to SLO have been researched and lead to policy recommendations later in this paper: environmental issues, climate change concerns, recycling and reuse opportunities, as well as workforce, labor, and education factors.

Mining represents an inherently negative impact on the environment and risks significant damage if not designed and operated with appropriate care and responsibility, according to

Canadian mining expert Robin Adams.<sup>83</sup> Adams further clarified, however, that “the degree of disturbance can vary enormously” depending on the method, design, and operation of the mine.<sup>84</sup>

Mining companies have made significant efforts within the United States to improve environmental stewardship. As pointed out by the American Geosciences Institute, “Modern mining operations actively strive to mitigate potential environmental consequences of extracting metals, and such operations are strictly regulated in the United States.”<sup>85</sup> Many foreign and developing countries are experiencing more extreme environmental impacts. Illegal artisanal mines in Peru are transforming Amazon forests into disaster zones of sand and ponds. As reported by rare earths expert David Abraham, the Bayan Obo Mine in China turned the local village of Dalahai into “one of about 450 ‘cancer villages’ in the country after the improper lining of the tailings lake led to contamination of the surrounding soil, groundwater, and vegetation.”<sup>86</sup> The United States has a real opportunity to build upon its increasingly stringent environmental protection policies and become a global leader for best practices and environmental stewardship.<sup>87</sup>

Nations around the world are stepping up efforts to address climate change. The United States, Canada, the EU, and Australia all have made significant climate change commitments. President Biden committed the United States to achieve a 50-52 percent reduction of greenhouse gas emissions compared to 2005 levels by 2030.<sup>88</sup>

The desired rapid acceleration of renewable energy technology and manufacturing equipment that will harness wind, solar, and hydro sources to meet these commitments requires significantly increased mining. As David Abraham asserts, “Mining is not antithetical to a green economy; it’s a necessity.”<sup>89</sup> These renewable energy sources are highly dependent on critical mineral commodities. Photovoltaic cells in solar panels rely on important amounts of arsenic, gallium, germanium, indium, and tellurium.<sup>90</sup> Wind turbines that increasingly dot the American landscape rely on large amounts of aluminum and rare-earth elements.<sup>91</sup> Batteries, which play an important supporting role for renewable energy sources, rely on critical mineral commodities of cobalt, graphite, lithium, and manganese.<sup>92</sup> A focus on renewable energy sources is an opportunity to align both environmentalists’ and mineral producer interests through domestic and allied collaboration.

A circular economy where mine waste is transformed into useful products will become an essential component of the future sustainable mining and metals market.<sup>93</sup> (See Appendix 5-9.) According to the U.S. Environmental Protection Agency, the United States “discarded 75 percent of 2.4 million tons of electronics in 2009...without any recycling.”<sup>94</sup> Tokyo Foundation’s researcher, Hikaru Hiranuma, estimates that “Japan has more metals like silver, gold, and indium sitting in electronic gadgetry around the country than in the reserves at many mine sites globally.”<sup>95</sup> The reuse and recycling of these currently idle materials present an opportunity for the United States to exploit and show global leadership on sustainable mining. With proper policy governance, the United States is positioned to invest in recycling technology and collaborate with allies such as the EU, Canada, and Australia to create access to a large amount of material that would otherwise end up in landfill sites, while contributing to the long-term sustainability of mineral reserves and strengthening public trust.

Another concerning aspect of sustainability is the industry’s looming human capital dilemma, plagued by three severe challenges: an aging workforce, a lack of available skilled labor, and a lack of mining-related academic programs. The National Mining Association (using Bureau of Labor and Statistics data) reports that over half of the mining labor force could retire by 2029, and less than 27 percent of its labor is aged 34 and younger.<sup>96,97</sup> A 2018 Mercer North

American Mining Survey found 67 percent of respondents concerned with the aging workforce, and only 56 percent reported confidence in their talent pipeline.<sup>98</sup> The mining industry runs on skilled labor, and retiring Baby Boomers mark an exodus of that labor. Industrial Safety and Hygiene News (ISHN) reports that only one new skilled laborer enters for every five retirees.<sup>99</sup> Adecco reports 62 percent of all firms struggle to fill skilled labor positions, and 74 percent predict a shortfall of qualified, skilled trade workers.<sup>100</sup> Appendix 5-10 illustrates several vital segments of the workforce currently held by retiring Baby Boomers.

While only 3 percent of mining jobs require a college degree, experts in technical fields (e.g., geoscience and metallurgy) play vital roles, but mining-related academic disciplines are diminishing. Mining engineering ranked 277<sup>th</sup> in popularity out of 384 fields of study in 2019, with only 188 graduates nationwide.<sup>101</sup> Even the Colorado School of Mines had only 4% of its 2019 graduates earn a metallurgical engineering degree.<sup>102</sup> These numbers not only fail to meet the industry's needs, but also place the academic programs at risk of cancellation; the U.S. currently has only 18 institutions with mining engineering programs.<sup>103, 104</sup> In comparison, China reports more than 30 institutions offer academic mining programs.<sup>105</sup> As education programs dwindle, so does faculty, exacerbating the problem. Mining faculty shrank from around 120 in 1984 to only 70 in 2007, creating an average of only four faculty per program.<sup>106</sup> Appendix 5-11 presents a compelling faculty pipeline infographic produced by the Society for Mining, Metallurgy and Exploration (SME).

An aging, retiring workforce and academic faculty, both with scant replacements, threatens the talent pipeline for potentially a generation or more. Addressing the human capital pipeline deficiencies are critical to ensuring the sustainability of the industry for posterity.

## **6. Global Dynamics and Outlook**

Mining is truly a globally integrated industry with nations interdependent on each other for key minerals. Cooperation among countries and firms through trade and investment in minerals is necessary to power today's modern economies. In 2020, the minerals industry amounted to \$1.6 trillion or approximately 1.8 percent of global GDP.<sup>107</sup> The sector is projected to surpass \$2.4 trillion by 2025.<sup>108</sup> Australia, Canada, China, Russia, and the United States are the largest mining nations globally in terms of production.<sup>109,110</sup>

### **Competition for Resources**

With demand for critical minerals quickly rising, competition to secure their access has grown in importance and become part of today's great power competition. The United States has greater than a 50 percent import reliance on at least 24 of the 35 minerals it has deemed critical.<sup>111</sup> This leaves the United States vulnerable to export restrictions by other countries, most prominently China, which has imposed trade restrictions on 14 critical minerals.<sup>112</sup> China's restriction on rare earth exports to Japan in 2010 showcased China's ability to utilize trade restrictions as a weapon. For the United States and its allies, the security of supply will be especially contentious for the 11 nonfuel critical minerals for which the United States and China are both import reliant.<sup>113</sup> (See Appendix 6-1.) As Great Power Competition intensifies, the USGS predicts China could steer the supply of these minerals exclusively to China to satisfy its needs and disrupt supply to the United States.<sup>114</sup>

## **China**

China has emerged as a mining powerhouse in recent decades thanks to a series of interrelated competitive advantages. A Porter Diamond analysis of China's rare earth elements (REE) illustrates China's competitive advantages and disadvantages in China's mining sector. (See Appendix 6-2.) Effective long-term government industrial policies have been key for the success of China's main REE firms (all state-owned).<sup>115</sup> They benefit from the government's strategic interventions in global markets, financial support, and relatively low regulatory hurdles.<sup>116</sup> China's plentiful, low-wage labor force is also a significant advantage that keeps costs low for Chinese companies relative to other mining nations. A robust network of related and supported industries is another major advantage for China that allows companies easy access to suppliers and customers. These clusters enable the development of vertically integrated supply chains from mine to REE processing, to magnets, to finished products.<sup>117</sup>

The element of chance has a special application to China in its current dominant position in REE markets. Based on industry efforts to reduce costs in the late 1990s, companies in the United States and other countries processing REE chose to cease processing operations and capitalize on the low processing costs in China. The trend matched China's opening to the global economy and World Trade Organization (WTO) membership. Within a brief period, the overwhelming majority of global REE processing capability rested securely within China.<sup>118</sup>

China also has its share of disadvantages in its national competitiveness. Lax and sometimes ineffective government oversight has traditionally enabled illegal REE mining to flood the market with an oversupply of REE, sometimes driving REE prices down and reducing revenue for state-supported firms.<sup>119</sup> In addition, weakly controlled environmental degradation caused by mining is harming local communities and threatens the long-term sustainability of the REE mining industry in China by putting its social license to operate at risk.<sup>120</sup> Finally, heavy government support to state-owned REE enterprises can ultimately stifle innovation and productivity by reducing healthy competition.

To supplement its domestic mining production and feed its larger industrial needs, China is conducting a concerted campaign to secure access to mineral resources in nations worldwide, primarily through its Belt and Road Initiative (BRI). Since its unveiling over seven years ago, 140 countries and 29 international organizations have signed cooperation agreements for the BRI.<sup>121</sup> The BRI builds China's commercial ties abroad by financing, constructing, and developing major transport, energy, technology, and other infrastructure projects in the Indo-Pacific, Africa, the Middle East, Europe, and the Americas.<sup>122</sup> China is building roads, railways, shipping routes, ports, oil refineries, industrial parks, and power plants in at least 72 countries. China can ultimately use this infrastructure to move its mineral resources and maintain its competitive edge in markets.<sup>123</sup> While China presents the BRI as selfless assistance, it is one of its main instruments to exert global power and influence and grow its economy, all of which helps the Chinese Communist Party garner the legitimacy it needs to remain in power.<sup>124</sup>

## **Russia**

While China is the exceptionally dominant force in the global mineral supply chain, national security strategy also compels consideration of the policies and capabilities of the other great power competitor, Russia. From the perspective of resource economics, the Russian Federation would seem to have many advantages with respect to global competition in minerals and mining. In particular, the nation has an expansive landmass encompassing 21 percent of the world's mineral resources, leading positions in production and/or reserves of iron ore, aluminum,

gold, nickel, and platinum group metals (PGMs), as well as a historically strong standing in global export markets for metals and minerals.<sup>125</sup>

The Porter Diamond Model of national competitiveness, however, generates additional insights that bring to light several manifest and emergent disadvantages for Russia's competitive position in this sector.<sup>126</sup> (See Appendix 6-3.) For example, while the nation's vast mineral resources are a significant benefit in terms of factor conditions, the remote locations of many hard rock mining operations bring physical infrastructure challenges, the quality and depth of human capital in the Russian mining sector is eroding, and access to financial capital (especially from foreign sources) is severely constrained.<sup>127</sup> With respect to demand conditions, while a boom in construction has increased internal demand for some materials, most Russian metals and minerals are still produced primarily for export to distant consumers, as the domestic processing and manufacturing industries that would require these materials are still developing.<sup>128</sup>

In terms of related and supporting industries, although there are more than 40,000 Russian metallurgy enterprises to support the mining industries, the country remains dependent on imports for supplies of advanced (and even basic) mining machinery and equipment.<sup>129</sup> Finally, while the context for firm strategy and rivalry is bolstered by the presence of more than 18,000 mining enterprises, the vast majority of which are privately owned,<sup>130</sup> there remains a stark absence of open and vigorous local competition as many mineral sectors are dominated by a single firm (UC Rusal in aluminum, Norilsk Nickel in nickel, Alrosa in diamonds) or a handful of firms (iron ore and copper), and local players are insulated from foreign competition as a result of restrictive "strategic investments" laws and regulations.<sup>131</sup>

### **Developing Nations and Emerging Markets**

China is the top producer and supplier of many critical minerals. However, developing countries and emerging markets in Africa, Asia, and South America are home to significant reserves and mining operations of many as well. (See Appendix 6-4.) In fact, the United States is dependent upon developing nations and emerging markets to provide at least 30% of 14 critical minerals.<sup>132</sup> (See Appendix 6-5.) Southern Africa, for example, plays a dominant role in mining chromium, manganese, platinum group metals, tantalum, and cobalt. Brazil produces 88% of the world's niobium. USGS research indicates resource rivalry between the United States and China is likely to be most contentious in South America and South and Central Africa.<sup>133</sup>

The United States, and the world, depend upon these nations, but mineral mining in emerging economies presents challenges for international mining companies, governments, and local communities. Western firms can struggle when investing in countries with unwelcoming investment climates as they must navigate shifting political winds or massive policy changes.<sup>134</sup> Sixty-five percent of minerals mined in 2018 were produced in countries considered politically unstable.<sup>135</sup> The concept of "resource nationalism" is also gaining traction worldwide as governments seek to capture more of their resources' value for the state.<sup>136</sup> In this, governments must maintain an acceptable balance of value distribution and avoid deterring investments by making projects no longer economically viable.

Meanwhile, many nations that control access to valuable minerals and natural resources find themselves victims of "the resource curse." The resource curse is a paradoxical situation in which a nation with an abundance of natural resources suffers from poor economic growth, underdevelopment, and weak governance compared to countries with fewer natural resources. Economists from the World Bank and the French Development Agency explain the "resource

curse” in three broad ways: 1) a sudden growth in an extractive industry resulting in the crowding out of other industries, including manufacturing, that is more conducive to long-term economic growth, 2) a dependence on minerals and natural resources as a primary source of national income but which leaves the country vulnerable to global mineral commodity price shocks, 3) a situation in which the immediate wealth and attention of a mineral discovery can often exacerbate rent-seeking, corruption, and conflict in society.<sup>137</sup> Russia appears to have fallen into the resource trap caused by its reliance on natural resources for national income and an oligarchic system that stifles free and fair domestic competition. Developed nations in North America, Europe, Asia, and Australia can potentially use targeted diplomatic efforts and foreign assistance programs to help these emerging market mining countries overcome the resource curse through developing strong institutions, economies, and strategic infrastructure.

### **Current International Agreements with Established Partners**

The United States has historical trade relationships and established logistics chains with Canada and Australia. Working with them to develop their critical mineral deposits can help improve the security of the U.S. supply. For example, the United States, Australia, and Canada are working together in a geoscience collaboration partnership, the Critical Minerals Mapping Initiative, to support mineral discovery in all three countries.<sup>138</sup> (See Appendix 6-6).

In a clear effort to come closer together with the United States regarding critical minerals, the Australian government also published a report identifying 15 rare earth and critical minerals projects it aimed to highlight as part of joint U.S.-Australia efforts.<sup>139</sup> In October 2019, Australian Trade released a report entitled, “Critical Minerals Supply Chain in the United States: Mapping the Landscape for Australian Suppliers” to specifically “help Australian producers identify end-users in the United States and facilitate commercial offtake and investment agreements with them.”<sup>140</sup> Led by the Department of State, the U.S.-Australia Critical Minerals Working Group is another path for the U.S. government to coordinate and collaborate with an ally to address global supply chain challenges. The focus of the Biden Administration on climate and energy is likely to see a steady increase in demand for critical minerals mined in Australia.

As with Australia, the United States shares with Canada a mutual interest in improving critical mineral security and ensuring the future competitiveness of both countries’ mineral industries. The Canada–U.S. Joint Action Plan on Critical Minerals Collaboration, advances secure access to the critical minerals that are key to economic growth and security of both countries — including uranium and rare earth elements — while bolstering the competitiveness in global markets and creating jobs for Canadians and Americans.<sup>141</sup>

Although this is a great starting point, there are more allies and partners facing the same interdependence on non-market economies for critical minerals than just the United States, Canada, and Australia.

### **Comparison of Allied Nations Critical Mineral Lists and Learning from Close Allies**

The United States, EU, Japan, and South Korea have defined certain minerals as critical based on whether the mineral has a high degree of import reliance, few or no substitutes, geopolitical risks, and a high level of production concentration.<sup>142</sup> As an essential supplier of critical minerals, Canada has outlined its list as essential to economic security, required for the transition to a low-carbon economy, and a sustainable source for allies.<sup>143</sup> Australia and Canada produce several minerals the United States has identified as critical (see Appendix 6-7 for table

comparing critical minerals list). Canada currently produces 13 minerals on the U.S. critical minerals list, while Australia offers 8 of the 14 critical minerals the United States fully imports.

Increasing and diversifying Canadian and Australian production of critical minerals can enhance North American supply chain security and increase trade. The table in Appendix 6-7 reflects seven minerals where Canada and Australia can meet not only the U.S. critical mineral needs but also the needs of the EU, Japan, and South Korea. Although in several spaces the two countries are competitors, this healthy competition can spark innovation as a byproduct. Furthermore, neither country nor other allies possess alternatives to the hundreds of China processing patents dominating 90% of processing in the industry.<sup>144</sup> Therefore, more research and development collaboration and collective resources require each country to offer a portion(s) of the supply chain, starting with the most crucial processing stage. Finding the most economically and environmentally friendly approach faster requires more heads collaborating, not one.

As stated previously, the mining permitting process can take upwards of 7 to 10 years in the United States but only 2 to 3 years in Canada and Australia.<sup>145</sup> The permit process expediency in Canada and Australia is due mainly to the time-based schedule published in advance for the federal review process, which outlines upfront roles, responsibilities, and timeframes.<sup>146</sup> The United States has everything to gain from a strategic alliance that covers more than just geoscience and mineral exploration but extends into leveraging how the United States could adopt policies to remove one of the main barriers for investment. If not, the lengthy, costly, and inefficient U.S. permitting process will continue to drive business investments to countries with shorter permitting processes. Why spend time recreating the wheel when there are partners with the experience to share that can boost U.S. national competitiveness?

The United States can also learn from the communication narratives of its close allies and partners. The Australian government published a report on the outlook of critical minerals as a value proposition on what it has to offer to the world, including the United States.<sup>147</sup> The report outlines why critical minerals are essential, focuses on the top six minerals dominated by two or three countries, and highlights mostly nascent world markets for those minerals.<sup>148</sup> Australia demonstrates an effective way to attract attention and counter the Chinese narrative with a value proposition ready to accept and field potential suitors through a dedicated centralized government organization.

Canada is taking a similar approach to benefit from the increasing demand by highlighting its reputation as a reliable partner to build global supply chains. The Canadian Minerals and Metals Plan (CMMP) was developed in cooperation with federal and provincial governments and other stakeholders in academia and industry, serving as a global leadership lesson on building a coherent set of actions to mobilize all stakeholders.<sup>149</sup> According to the government's CMMP website, the plan aims to "raise Canadians' awareness of the importance of the minerals sector, respond to ongoing and emerging challenges, and help position Canada for opportunities offered by an evolving economy."<sup>150</sup>

These current international agreements set the foundation for sharing information, gaining knowledge, and forging new relationships with other countries that are just as concerned about China's chokehold on critical minerals. Each country brings its strengths and expertise and could be the missing puzzle piece for one another. Policymakers, industry, and other stakeholders must galvanize this information within the current window of opportunity to meet the needs of secure and stable supply chains. However, these partnerships are not insulated from the shifting policy priorities during political transitions.

## **7. Policy Recommendations:**

As this paper has highlighted, the U.S. supply chain for critical minerals is vulnerable and fragile. Mining is an expensive, complex, and risky endeavor subject to volatility. This difficult market environment reinforced by unsupportive investment climates and weak social licenses to operate at home and abroad has led to an underdeveloped domestic minerals sector and serious challenges for U.S. mining companies overseas. This dynamic has led to a divergence between what the United States needs for its national security and what the free market is able to provide. To correct this imbalance, more effective government interventions are required. IS StratMat proposes the following five policy recommendations:

### **Policy Recommendation 1: Re-fund the U.S. Bureau of Mines (Rebrand and Rename)**

**Summary:** The United States should take immediate, bold, and whole-of-government action in concert with global partners to correct its course. Reenergizing the United States Bureau of Mines (USBM) is a logical starting place for this policy recommendation due to its prominent role and impact in developing U.S. mining and national minerals security. During the Bureau's earlier existence, it built relationships with mining companies and the overall industry by its intense focus on safety, health, environmental impacts, and industrial practices of processing of minerals and materials. The USBM earned a foremost reputation globally and was recognized as a focal point for new developments regarding the evolution of science and technology in critical minerals. At the federal level, the United States needs a champion to implement new minerals policies that prioritize and strengthen government coordination structures, form new international partnerships, improve foreign and domestic investment climates, enhance the sector's sustainability, and integrate supply stocks. The USBM can serve as the lead advocate to implement and provide course corrections ensuring the United States remains competitive in the minerals mining exploration, extraction, and land reclamation space.

**Background:** From the Bureau of Mines (USBM) inception in 1910 until its dissolution in 1996, it was the premier federal agency for scientific research and credible information on extraction, processing, use, and conservation of mineral resources. The bureau was established and operated within the Department of the Interior until congressional actions closed and dispersed its functions to other federal agencies at lower levels of influence. The presence of the USBM was felt through the industry both domestically and internationally. The catalyst for its founding was in response to a series of catastrophic mine disasters that claimed the lives of numerous miners earning the mining industry a reputation as an extremely hazardous business. Aside from the Bureau's routine analysis to evaluate trends and needs in the industry, its customer-facing interactions with private and public mining companies helped focus research and ensure findings were distributed to those who needed and could benefit from the data.

**Recommendation:** Re-fund a lean United States Bureau of Mines (USBM) or another centralized federal organization with a focus on a whole-of-government minerals strategy. This recommendation's preferred course of action is to create a new organization called The Bureau of Mineral Resources versus the once known United States Bureau of Mines. The former title is outdated, and the name itself seems to limit the scope of its intent. The new name (The Bureau of Mineral Resources) is more representative of what this organization will be charged to own

and execute. It is clear the United States is missing a single entity that can aggregate critical information about mining and strategic materials. The unfortunate dissolution of the Bureau of Mines left the country without a credible voice in the Administration to propagate awareness of domestic criticality regarding mining and mineral vulnerabilities. Additionally, when the Bureau was closed, there was no single entity to represent the industry adequately and commensurately through the lens of political aims and strategic policy.

Refunding the USBM and changing the name to The Bureau of Mineral Resources will bring advocacy and awareness back to strategy and policy, enabling the United States to craft strategic material supply chains by synthesizing and distilling critical information for policy makers. Second, returning the Bureau under the new brand will also increase the relationship between the government and businesses to create the much-needed synergy in this space to underwrite the United States' overall competitiveness with China and other potential threats. Creating the Bureau of Mineral Resources will be the necessary organizational change in the government to provide focused awareness and advocacy at the appropriate dialogue levels with other nations and the domestic audience. While these recommendations do not necessarily need to be prioritized over each other, if the Bureau of Mineral Resources is created first, then it will be the best-informed entity to advocate for more thoughtful and deliberate allocation of resources, including funds from the Defense Production Act.

**Costs:** Re-funding the United States Bureau of Mines can be accomplished primarily with existing resources and through an appropriation language change to allow collections from permitting and other fees to offset priority requirements within the Bureau. The 1990s Bureau's budget averaged \$175 million per year in annual appropriations, which is approximately \$300 million in FY 2021 dollars. Existing resources are garnered by reconsolidating the functions and budgets that were dispersed to other agencies: Department of Agriculture, Department of Interior, Department of Commerce, and Department of Energy. Alternatively, the Secretary of Interior may use its authority and existing resources to establish a lean organization, leaving the missions where they are currently located throughout the federal departments.<sup>151</sup>

**Risks:** Pushback from strong politically aligned industry organizations may view the re-establishment of the USBM as government overreach and a potential prelude to follow-on regulations and more federal bureaucracy. Also select federal agencies that gained responsibilities from the 1996 USBM closure may not want to give up those functions nor the corresponding manpower and funding. These losing organizations may not support a forced reduction of these assets along with their perceived ability to impact and influence government policy. Overcoming these two major challenges will require a political overture that focuses on the national security implications of the entire value chain of commercial and defense related minerals resources from exploration, processing to end-product/goods. The last consideration under risk is that changing the name from the United States Bureau of Mines to the Bureau of Mineral Resources will require legislative action. Legislation does not move swiftly but could be expedited and facilitated by the Office of Management and Budget in preparing and coordinating the FY 2023 President's Budget and even sooner in final negotiations of the FY 2022 Budget. Sending through an established institutionalized process sends a strong signal on the President's priorities and the license for Congress to act with transferring resources and authorities to the Department of Interior.

## **Policy Recommendation 2: Establish a Critical Minerals Alliance**

**Summary:** The United States should establish a “Critical Minerals Alliance” (CMA) with its closest allies (Australia, Canada, South Korea, Japan, the European Union, and the United Kingdom), representing some of the world’s largest suppliers and consumers of critical minerals. These like-minded countries have shared interests of national security, economic prosperity, values and norms, and adequate joint strength in mining resources and capabilities to compete against China’s dominance in the global mining industry. A formal CMA can withstand political transitions, requiring considerable political capital to reverse.

**Background:** Rio Tinto chief executive officer J.S. Jacques states it best, "no single nation, no matter how resource-rich, possesses a mineral endowment that will completely meet the mineral and metals demands for this technology age."<sup>152</sup> The United States cannot tackle the problem of critical mineral access alone and must collaborate and coordinate efforts with our allies and partners, many of which face the same risks and have developed their own critical mineral strategies.

**Recommendation:** Establish a Critical Minerals Alliance based on four guiding principles:

1. Create member obligations to abide by high CMA standards on democratic principles, fair trade, transparency, human rights, and environmental protection.
2. Collaborate on accountability measures between CMA members. For example, failure to abide by the CMA standards may expose members to responses like limiting access to common research & development and funding initiatives.
3. Consult CMA members when facing critical minerals access challenges. For instance, if a non-member restricts its export of a critical mineral, CMA members may share stockpile resources and jointly work to increase mineral production within the alliance.
4. Promote the CMA standards in international institutions and forums like the WTO.

The initial CMA members will include the United States, Canada, and Australia due to the strong role that mining plays in each nation’s economy, and the three nations can easily leverage the existing geoscience partnership between them to mitigate barriers and reach quick consensus on CMA priorities, goals, and objectives. However, the trilateral CMA group should work in parallel with the other identified nations and extend CMA membership to them as soon as they are ready. The group may gather regularly, exchange ideas informally through normal diplomatic channels, or meet on the sidelines of other multilateral events.

The CMA will facilitate trade between critical mineral producers and consumers. Large critical mineral consumer nations (South Korea, Japan, UK, the United States, and the EU) will gain a secure and reliable source of critical minerals, while the producing countries (Australia, Canada, and the United States) can secure long-term sales and a diversified critical minerals supply chain without fearing Chinese nefarious trade practices. CMA “consuming nations” can provide strong support in the areas of mineral exploration, mining processing, R&D, and innovation systems to bypass China and ensure adequate critical mineral supplies. The CMA can facilitate access to financial capital for mining companies. Canada, Australia, the United States, and others should bring together government and non-government financing mechanisms, including U.S. EXIM Bank, the U.S. Development Finance Corporation, Export Development Canada, and Export Finance Australia, for critical minerals project financing.

Alliance “producing nations” should focus mining efforts primarily in the United States, Canada, Australia, and Europe, as well as in South America and Africa, where many nations are engaged in critical mineral mining (primarily the Democratic Republic of Congo, South Africa, Brazil, and Chile). As the alliance producing nations expand operations into these emerging markets, they should coordinate efforts to ensure no duplication of efforts and advance sound economic policies, democratic institutions, high environmental standards, and anti-corruption programs. Partnering with close allies on mining standards will ensure responsible sourcing, fair-trade practices, and resilient supply chain development. Partnering also counters China’s ambitions to dominate global mining technical standards, which threatens western economic competitiveness and technological leadership.

Any new alliance entrant must commit to the CMA membership high standards and abide by the principles outlined in the membership action plan (MAP), established by the original three members. In addition to a nation’s capacity to be a significant producer or supplier of critical minerals, the CMA will consider each nation applicant’s other unique potential contributions to the alliance. Additionally, the alliance will pursue relationships with “partner nations,” much like NATO “partner nations,” that may not yet meet full MAP criteria but that may offer other strategic benefits by giving them an observer seat at the table and a path forward to full membership. The alliance will engage in dialogue and practical cooperation with these “partner nations” in areas of mutual interest to include information sharing, training, and education.

**Costs:** Costs for establishing the CMA should be minimal. Initially, at least, the CMA will be a general forum of like-minded nations with no brick-and-mortar facilities or staff requiring new budgets to operate. Each country’s centralized mining organization (the U.S. Bureau of Mines for the United States – see previous recommendation) will ensure continuity between meetings, consistent messaging, and an agile iterative feedback mechanism among member nations.

**Risks:** There are some minimal risks involved with creating a Critical Minerals Alliance. For example, the alliance could morph into a less agile organization creating more bureaucracy with challenges in building consensus and moving at the speed of relevance. To prevent this, the core founding members (United States, Canada, and Australia) should establish themselves as “permanent members” (like the UN Security Council permanent members) capable of vetoing issues that could potentially slow down processes. It is also possible that China could develop a parallel organization in response to the CMA. However, Western nations, like the United States, Canada, and Australia, possess a strategic advantage over China in attracting other countries to enter partnerships based upon transparency and outcomes that are beneficial to all parties involved. China would have a challenging time competing against a CMA led by the United States, Canada, and Australia. CMA members must carefully craft the narrative around the alliance that does not alienate non-members and inadvertently push them into a partnership with China. Being transparent and engaging with potential members from the very beginning is a way to avoid such a risk.

### **Policy Recommendation 3: Improve the Investment Climate at Home and Abroad**

**Summary:** The United States should adopt new policies to promote favorable investment conditions for U.S. and allied mining companies domestically and in key mineral-rich countries by streamlining the U.S. permitting process, increasing geodata access, utilizing the Trusted

Capital Marketplace initiative, and conducting a sustained diplomatic, commercial, and development assistance campaign to boost foreign investment opportunities.

### **Attract Inward Foreign Investment**

**Background:** The U.S. investment climate in the mining sector is dampened by a lengthy, complex permitting process and a limited understanding of the economic value of the United States' immense geological endowment. While attracting investment is critical, the U.S. government must ensure foreign investment does not threaten U.S. national security interests.

### **Recommendations:**

**Streamline Permitting Process:** The U.S. government at the federal, state, and local levels should streamline the permitting process for new mining operations with more predictable and precise deadlines while reducing the number of redundant agency reviews. The government should continue to expand recent National Environmental Policy Act modifications that extend down to the state and local levels by encouraging the establishment of State Permitting Councils to align, complement, and inform Federal Permitting Improvement Steering Councils (FPISC) for authorization decisions.<sup>153</sup> Federal, state, and local entities should examine and adopt successful permitting practices developed by allies like Canada and Australia that aligns to standardized international best permitting practices. This effort should complement the creation of a fully digital process that allows for data transparency, greater deadline adherence, informed decision timelines, and data driven understanding of claims, requests, and decisions.

**Increase Data Availability:** The U.S. government should expand its knowledge of U.S. mineral reserves through increased geophysical, geological, and topographical mapping and surveying. The U.S. government should ensure all new and existing geodata is easily accessible on-line to the public and private companies in usable electronic formats. U.S. experts should also hold professional exchanges with counterparts in other mineral-rich countries to share best practices, database resources, and technological innovations. The Critical Minerals Mapping Initiative (CMMI) formed by the geoscience agencies of Australia, Canada, and the United States is a proof-of-concept for this initiative and can serve as a model.

**Establish Trusted Capital Marketplace for Minerals:** The U.S. government should include the mineral industry in the newly established Trusted Capital Marketplace to form a Mineral Investment Marketplace of vetted sources of strategic capital. The Trusted Capital Marketplace is a new pilot program authorized by the 2018 NDAA to attract safe investment in critical defense industries.<sup>154</sup> This new forum can strengthen domestic manufacturing in minerals production critical to defense through capital loans, guarantees, incentives, and investments. This marketplace will connect upstream and downstream companies across the CMA and other trusted partners. The marketplace will signal U.S. government support for the sector, increasing investment confidence in the policy environment and serving as an alternative to DPA funding. By requiring CFIUS screening, the marketplace will support vetted investments that crowd out capital investments by adversaries seeking to exploit vulnerabilities.

**Costs/Risks:** To fund a more streamlined permitting process, government agencies should consider developing new application fee schedules and gain authorities to apply this revenue to making the required changes. Agencies should develop this fee schedule in consultation with industry to avoid raising costs to levels that deter investment and highlight how fees will quicken

the approval process. The U.S. government also might not have sufficient resources or capacity to significantly increase its surveying and mapping programs at the breadth and depth required by industry. The government can work with industry and interest groups on a business model to raise the necessary revenue to fund it, however. Models could include public-private partnerships or subsidized private sector options.<sup>155</sup> The National Cooperative Geologic Mapping Program that cost-shares mapping between federal, state, and universities provides a model.<sup>156</sup> Implementing the Minerals Investment Marketplace will leverage the resources of the Trusted Capital Marketplace structure already in place to take advantage of this economies of scale. Marketplace firms will also pay a fee for participation to help off-set new program costs.

### ***Boost Foreign Investment Opportunities for U.S. and Allied Companies***

**Background:** Foreign investment by U.S. companies overseas can play a significant role in securing the supply of critical minerals for the United States. Control of these resources by U.S. or allied nations' companies ultimately increases the likelihood of reliable U.S. access.

**Recommendation:** The U.S. government should institute new policy initiatives to boost investment opportunities for U.S. and allied mining companies overseas. High-level, sustained diplomatic campaigns through bilateral talks, commercial advocacy, and public diplomacy can steer key critical mineral source countries toward more welcoming investment climates for U.S. and allied companies. The U.S. Development Finance Corporation (DFC) should prioritize investments in mineral sector projects as part of this initiative. Agencies like USAID could facilitate collaboration between governments, foreign firms, and local communities on social licenses to operate and the fair value distribution of a nation's mineral resources. This improved climate will help level the playing field for U.S. and Critical Minerals Alliance companies competing with opaque Chinese companies.

**Costs/Risks:** Implementing this recommendation will require moving mineral supply security to a top-tier priority policy issue for relevant U.S. Missions overseas, which will need to devote additional personnel time to covering the issue. DFC, which doubled its investment cap to 60 billion in 2019 and has new financial tools, can bring its resources to bear as well. U.S. industry and interest groups may object to U.S. government support for investments by U.S. allies overseas rather than advocacy for only U.S. companies. The U.S. government would advocate for only those non-U.S. companies based in the CMA and who receive a *trusted mining seal of approval* (See Sustainability Recommendation). Those alliance members would reciprocate with advocacy for U.S. companies. In addition, policymakers could emphasize how U.S. companies further down the value chain could benefit from this advocacy.

### **Policy Recommendation 4: Expand and Enhance Sustainability**

**Background:** The United States must elevate the priority and visibility of sustainable and ethical governance of mining. The increasing pressure by western democracies toward environmental responsibility means the SLO remains the number one issue for miners.<sup>157</sup> Global mining operations face the wrath of local communities which have rising expectations around how mining operations plan, design, operate and address environmental issues, climate change concerns, recycling and reuse opportunities, workforce, labor and education factors, and indigenous rights and native title.<sup>158</sup> Large portions of the public are mostly unaware of mining

operations or the extensive applications of extracted minerals, especially in technology and green energy applications. Consequently, young people discount mining employment opportunities, impeding the future of an industry that suffers an aging, retiring workforce. The lack of interest has also led to the decline of mining-related academic programs, limited funding, and a dwindling faculty rapidly retiring from universities with no replacements.

### **Recommendations:**

***Establish a “Trusted Mining Seal of Approval”:*** The U.S. Government should establish an acceptable minimum standard for ethical extraction of minerals which leads to a “sustainability” certification, that is, a “Trusted Mining Seal of Approval.” The United States has the technology, oversight, regulations, and willingness to be the world’s leader in responsible, ethical, and environmentally safe mining practices.

The U.S. government should begin by adopting, funding, and enforcing international collaboration efforts that have already begun. These attempts at self-regulation reveal the need for government intervention. The Equator Principles is “a risk management framework, adopted by financial institutions, for determining, assessing and managing environmental and social risk in projects.”<sup>159</sup> The International Council on Mining and Metals (ICMM) is “an international organization dedicated to a safe, fair and sustainable mining and metals industry.”<sup>160</sup> Ensuring the global minerals trade is fair and equitable, and aided by the transparency of information technology, a “Trusted Mining Seal of Approval” granted to compliant operators via the **re-funded Bureau of Mines** will raise the social and economic value of responsibly sourced strategic materials. Clearly outlining measures and specific criteria that protect the U.S. natural environment increases long-term confidence and reinforces the viability of mining projects required for sustained investment. Detailed coordination and oversight by the **Bureau of Mines** ensures the **Enhanced Investment Climate** can confidently accelerate permit processing without eroding standards of environmental protection and safety. The selective granting of licenses for mine development with detailed scrutiny of appropriate levels of design and environmental safeguards builds trust within local communities. Skipping steps, failures, and accidents lead to ecological damage and destroy trust rapidly.

By broadening the influence of a “Trusted Mining Seal of Approval” via the **Critical Minerals Alliance**, collaboration and alignment with allies and partners can help ensure responsible sourcing, fair-trade practices, and resilient supply chain development.<sup>161</sup> International adoption of sustainable mining practices brings collective diplomatic pressure to bear on non-compliant countries and creates accountability through exclusion from international markets or application of economic sanctions. This approach would be a bulwark against mineral-rich nations with low ethical, responsible, and sustainable sourcing standards from attempting to over-deplete reserves and manipulate markets with a flood of inexpensive minerals. Setting a global standard may seem complex and naively optimistic; however, examples of success already exist in managing conflict diamonds. The peer pressure of global standards could be the catalyst for improvement in countries struggling to contain or curtail illegal mining operations within their borders.

***Invest in a Circular Economy:*** The U.S. government should develop a strategy of investment in a circular economy. Led by the newly re-funded **Bureau of Mines**, the United States should invest in innovative technology to exploit recycling and mineral extraction from idle or discarded high technology gadgets that currently end up in landfill sites as well as mineral extraction

processes from current mine tailings. The government should also provide incentives or tax breaks for the use and development of green energy and low emission technology that will both reduce operating costs at mines and mineral processing plants as well as positively contribute to reducing carbon emissions and consequently the rate of climate change. In line with the policy recommendation on **CMA**, the United States should look for opportunities to collaborate with allies and partners to share technology and pool resources to aid in the development of green energy technologies and recycling processes. **The Bureau of Mines** should sponsor technology development challenges with industry and academia like the innovation challenges often issued by the Defense Advanced Research Projects Agency (DARPA).

***Launch a Public Relations Campaign:*** Industry leaders, academia, and most notably the government (at all levels) must wage a concerted public relations campaign to increase interest in young high school graduates to follow careers in the mining industry. Such a campaign must highlight the importance of the industry in everyday life and its benefit to the manufacturing value chain. Cooperating with environmental groups, particularly in advancing the **Trusted Mining Seal of Approval** concept, leaders must work to celebrate environmentally responsible mining operations and the multitude of extracted minerals' green energy applications. As the public becomes more informed, mining will become more socially accepted – even respected – gaining greater social license to operate.

The government should also partner with mining associations and coordinate with the Department of Education to shape K-12 instruction, especially earth and social science curricula. Young people need to gain an appreciation for mineral basics, the modern mining industry, and their role in essential issues and technological innovations. Correcting misperceptions and educating the public on mining's strategic impacts will serve the industry in perpetuity, inspiring young people to enter this dynamic, important field. Growing interest will also translate into increased demand for mining-related higher education programs, breathing life back into existing programs and encouraging new ones.

In addition to the information and education campaign, the sector would also benefit from public and private funding of mining-related academic research. Such funding will spur growth in those academic programs that feed the highly specialized mining talent pipeline. Funded research also encourages qualified individuals to pursue advanced degrees and remain in academia to feed the mining-related faculty pipeline. The investment also enables students and faculty to explore various aspects of mining and to lead mining innovation, which further advances the sustainability of this vital industry.

**Costs/Risks:** Funding for government oversight, intervention, and sponsoring of the “Trusted Mining Seal of Approval” should come from extraction taxes based on tonnage of material excavated. Given the existence of various forms of self-regulation are already creating value, mining companies should accept the adoption of additional marginal assessments.

Investment in the research and innovation necessary to succeed in new mineral extraction, recycling, and green energy represents very high upfront costs that will only pay dividends through reduced future operating costs. A more significant investment of patient capital by government should promote academia and small businesses to invent products and components that capitalize on reused and ethically sourced strategic materials.

An effective marketing campaign can be very costly and will not present an immediate, easily measured return on investment. The funding and messaging should result from a public,

private, and non-governmental partnership, led by the Department of the Interior (DoI) in concert with mining firms and associations. The DoI should work closely with the Department of Education to update K-12 curricula, exposing students to the importance of modern mining and its impacts on society, garnering interest and support for the next generation of mining.

### **Policy Recommendation 5: Create the National Security Stockpile**

**Background:** As laid out in recommendations 1-4, the United States can strengthen its domestic mineral production and team with partners and allies in order to enhance the United States' supply chain resiliency through diversity. However, mineral supply chains will remain vulnerable to disruption where there is little existing diversity and the existing supply chains concentrate risk. For example, there may be many rare earths separating and smelting companies, but if they are all located in China and can be manipulated by the CCP, the supply chain risk is concentrated. In these cases of low supply chain diversity and concentrated risk, stockpiles typically provide the ability recover from a supply chain disruption and continue production while another source is established. The National Defense Stockpile contains materials needed by the defense industrial base during potential wartime disruptions. Manufacturing companies often stockpile materials that are at risk for disruption.

#### **Recommendations:**

***Expand the National Defense Stockpile into the National Security Stockpile:*** This stockpile would include critical minerals that are essential to the U.S. economy, not just national defense. Because the competition with China is more geo-economic than geo-political in nature, the strength of the U.S. economy will play the larger role in great power competition. The Strategic and Critical Materials Stockpiling Act specifically states that the stockpile is for defense needs, so the Department of Defense would need to propose this change to legislation. The Defense Logistics Agency would continue to manage the National Defense Stockpile as a larger National Security Stockpile customer.

***Make the National Security Stockpile a public/private venture:*** The biggest impediment to a National Security Stockpile would be its size. The mineral needs of the U.S. industry as a nation dwarfs the needs of the defense industrial base needed for wartime sustainment. This would require a public-private venture that pools the inventory resources of U.S. industries, along with the National Defense Stockpile purchased minerals needed for wartime contingencies. Large U.S. companies could lower their costs of holding and managing expensive inventories, and smaller companies could insure themselves against supply chain disruptions at a much lower cost than maintaining their own inventory.

***Designate the re-funded Bureau of Mines as the National Security Stockpile manager:*** The national defense stockpile already has legislation that allows the President to designate the manager for the national defense stockpile, which is currently the Defense Logistics Agency (DLA). DLA uses the mineral use surveys provided by the USGS to form the basis for the stockpile needs. By expanding the stockpile's scope and public/private nature, the President should change the designated manager of the stockpile. The Bureau of Mines would be the best place for the manager, with close ties to the need surveys by USGS and knowledge of mineral sustainability efforts, domestic production, and alliance supply chain diversity. DLA would

continue to manage the National Defense Stockpile as a customer of the larger National Security Stockpile.

The National Security Stockpile could bring several assets to the table that could reduce inventory costs for U.S. companies. First, the stockpile could provide storage space, as the national defense stockpile has excess storage space throughout the country. Second, the stockpile could provide rotation management that is already used for the national defense stockpile. Third, like the Strategic Petroleum Reserve (SPR), the market stabilizing effect of having a mineral commodity “buffer” would stabilize prices. Fourth, assuming the stockpile would buy preferentially from U.S. suppliers, the larger stockpile would create a larger demand for U.S. sourced mineral mines and processors. This could create a steady demand that could eliminate the need to use the Defense Production Act to target specific mineral commodities, as was used for beryllium and rare earth elements.

Although the National Security Stockpile would be an asset for U.S. company use, the implications to recommendation 2 is the potential expansion of a multinational mineral alliance that includes multinational stockpiling. This global stabilizing effect would benefit multinational companies and provide more incentives for countries to join an open mineral market alliance.

**Costs:** The stockpile should be cost neutral. Industry partners would provide operating funds to manage their portion of the stockpile, and the stockpile would gain an economy of size and scope by combining the stockpiles of industry partners. Like the National Defense Stockpile, the National Security Stockpile would operate through the rotational sale of the stockpile. The stockpile could leverage existing, unused footprints.

The Federal Deposit Insurance Corporation (FDIC) illustrates one possible example. An independent agency created by congress in 1933 in response to thousands of bank failures, the FDIC receives no Congressional appropriations - it is funded by premiums that banks and savings associations pay for deposit insurance coverage. The FDIC insures trillions of dollars of deposits in U.S. banks and thrifts - deposits in virtually every bank and savings association in the country. Another example is the SPR. The SPR, managed by the Department of Energy, is the world's largest supply of emergency crude oil to reduce the impact of disruptions in supplies of petroleum products. The SPR is operated and managed by a private vendor and purchased and sold competitively on the market.

**Risks:** A counterargument to the National Security Stockpile is the failure of the Strategic National Stockpile (SNS) to function during the COVID-19 pandemic. The SNS was under-appropriated, and managers failed to properly rotate and replenish some of the SNS, leading to expired and broken equipment. The SNS was an emergency-use stockpile. Although it was privately managed, funding was completely dependent on appropriation. The National Security Stockpile would be different because its inventory would be rotated and used by the private industries that are using the inventory in their day-to-day operations. The physical stockpiles would be partially owned and operated by the private companies that are invested in the stockpile, not dependent on appropriations.

## **8. Conclusion**

To mitigate the risk of potentially catastrophic supply disruptions in critical minerals and their downstream products, the United States must take immediate, bold, and whole-of-

government action in concert with global partners to correct its course. The United States should implement new minerals policies that prioritize and strengthen government coordination structures, form new international partnerships, improve foreign and domestic investment climates, enhance the sector's sustainability, and integrate supply stocks. This paper provides tangible policy recommendations within these key areas based on close examination and analysis of the critical mineral mining industry and its future challenges and opportunities. Like mining, these recommendations will require long-term, sustained commitments of political and financial resources, but ultimately should strengthen U.S. national security and economic prosperity for decades to come.

Adopting all the policy recommendations will create a force multiplier as they form a supporting set of coherent actions and activity systems. While each of these five recommendations operates effectively on its own, the synergy of all recommendations working in concert will bring the full potential of the U.S. minerals industry to solve the U.S. mineral vulnerability. In particular, re-funding and rebranding the Bureau of Mines ensures that there is an integrator and coordinator for the entirety of the recommended actions.

The window of opportunity is now. Without action, the U.S. mineral dependence on unreliable sources will further constrain the U.S. strategic decision space. Adversaries will be able to exploit their dominance of mineral supply chains to coerce the United States and its allies into acting against their national security interests. The United States should harness and focus its resources, allies, and political will now to prevent this scenario and safeguard a prosperous and secure future.

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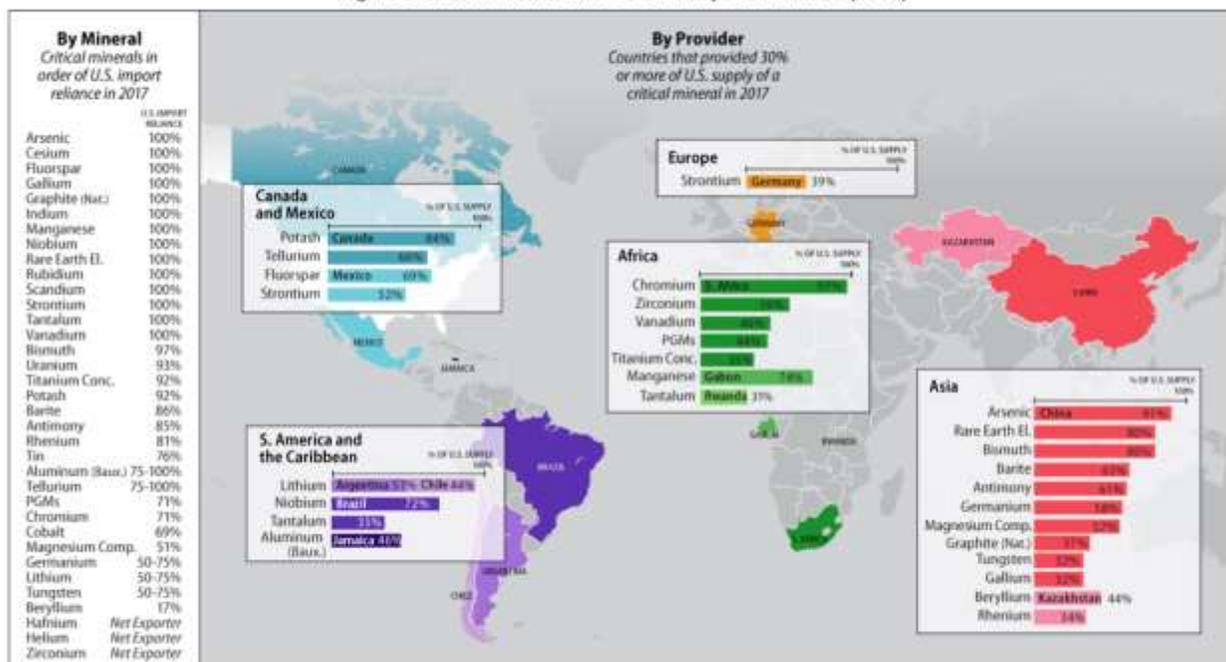
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**APPENDIX A**  
**Supporting Charts, Graphs, and Figures**

## Appendix 3-1

### Foreign Sources of U.S. Critical Minerals

**Figure 3. Critical Minerals: Net U.S. Import Reliance (2017)**

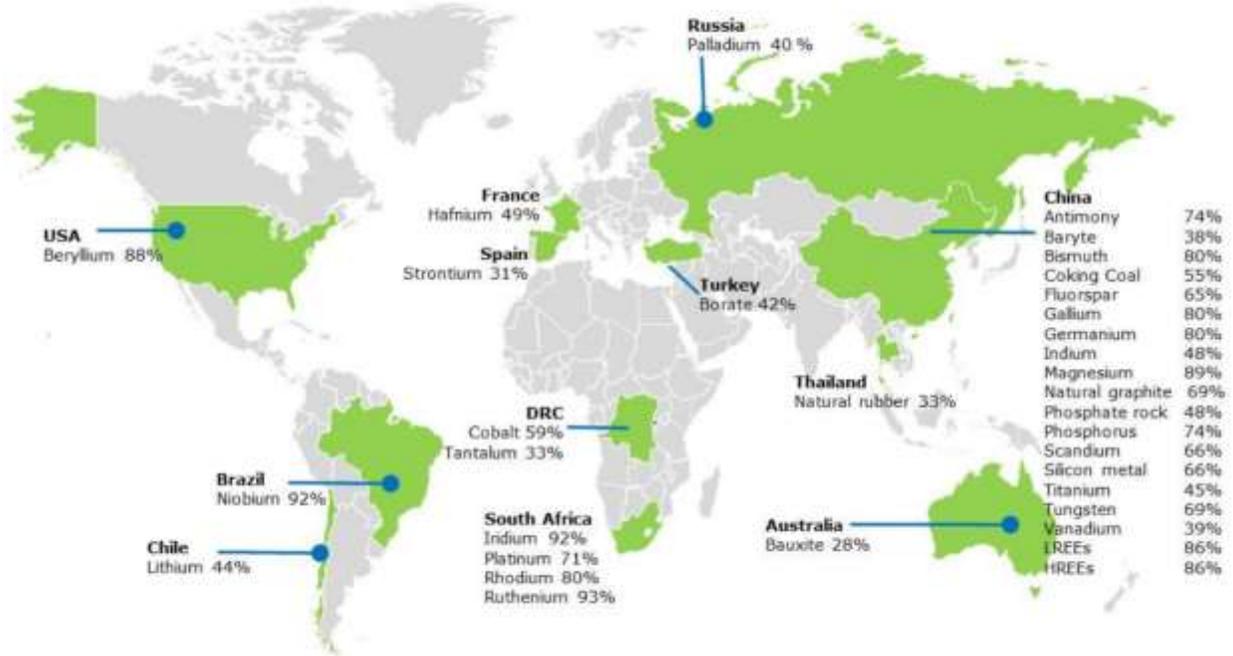


**Source:** Figure created by CRS based on USGS Minerals Commodities Summaries data, 2019.  
**Note:** Countries listed in the bar graph represent the leading supplier of U.S. imports.

Source: Marc Humphries, *Critical Minerals and U.S. Public Policy*, Congressional Research Service, June 28, 2019, 33, <https://crsreports.congress.gov/product/pdf/R/R45810/1>.

## Appendix 3-2

### Sources of European Union Critical Minerals<sup>162</sup>



Source: Gian Andrea Blengini, Cynthia EL Latunussa, Umberto Eynard, Cristina Torres de Matos, Dominic Wittmer, Konstantinos Georgitzikis, Claudiu Pavel, Samuel Carrara, Lucia Mancini, Manuela Unguru, Darina Blagoeva, Fabrice Mathieux, and David Pennington, *European Commission, Study on the EU's list of Critical Raw Materials – Final Report (2020)*, European Union, September 2020, 6, <https://ec.europa.eu/docsroom/documents/42883/attachments/1/translations/en/renditions/native>.

## Appendix 3-3

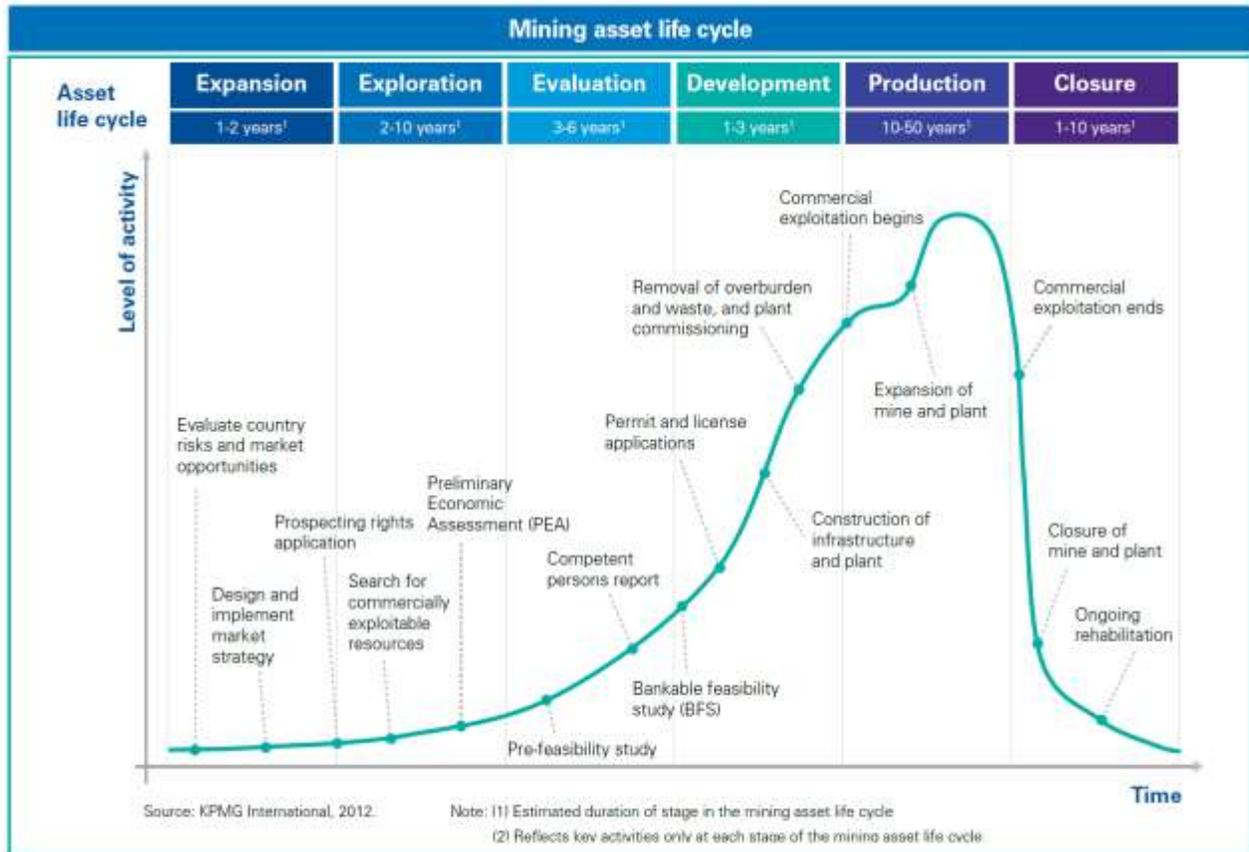
# MITRE Problem Framing Tool

Defining the Right Problem		
<p><b>What is the problem?</b></p> <ul style="list-style-type: none"> <li>•The US relies upon single sources for critical minerals</li> <li>•Fragile/vulnerable value chain</li> <li>•Domestic or allied supply of strategic materials is essential for national security</li> <li>•Need for a trusted, resilient supply chain</li> <li>•Prosperity – economic power</li> <li>•Value chain – supply chain</li> <li>•Lack of Awareness - "If it's not grown, it's mined"</li> <li>•Competitiveness between market vs. non-market economies (China has the capability of acting like a monopoly for multiple critical minerals)</li> <li>•Different Environmental rules</li> </ul>	<p><b>Who has the problem?</b></p> <p>The U.S., its industrial base</p> <p><b>When and Where do they experience it?</b></p> <ul style="list-style-type: none"> <li>•Feeder industry – equipment manufactures, Energy Companies (water, power), Exploration</li> <li>•Industry – mining, refining, processing</li> <li>•Downstream industry – Defense Industry, Construction, Vehicle Manufacturing, Consumer tech products, semi-conductors, etc...</li> <li>•Coconsumers (anybody using an iPhone, drives a E-Car)</li> </ul>	<p><b>What is the scope?</b></p> <div style="display: flex; align-items: center; gap: 10px;"> <div style="text-align: right;"> <p>Small ←</p> <p>Trivial ←</p> <p>Static ←</p> </div> <div style="text-align: center;"> </div> </div>
<p><b>Who else has it?</b></p> <p>Colleagues, competitors, other domains, etc.</p> <p>EU, Canada, Australia, Russia, China, producing countries → <b>Everybody</b></p> <p>How do they deal with it?</p> <p>Critical minerals strategies, trade agreements, domestic supply increase</p>	<p><b>What are the elements of the problem?</b></p> <p><i>Physical, social, emotional, professional, primary, secondary</i></p> <p>Location of minerals, Policies (government, industry), Social license to operate, Environmental impact, Advocacy, Scarcity of resources, Chinese world view vs. Western world view</p> <p><b>Why haven't we solved it?</b></p> <ul style="list-style-type: none"> <li><input type="checkbox"/> It's New</li> <li><input checked="" type="checkbox"/> It's Hard</li> <li><input type="checkbox"/> It's Low Priority</li> <li><input type="checkbox"/> Other</li> </ul> <p>•Lack of US Grand Strategy</p> <p>•Need of consensus government</p> <p>•Short-term investment at the expense of long-term sustainability (No patient capital)</p>	<p><b>Who does not have it?</b></p> <p>Colleagues, competitors, other domains, etc.</p> <p><b>Why not?</b></p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Avoided</li> <li><input type="checkbox"/> Mitigated</li> <li><input type="checkbox"/> Solved</li> <li><input checked="" type="checkbox"/> Other</li> </ul> <p>No one</p>
<p><b>Stated another way, the problem is:</b> The current vulnerabilities associated with global critical material markets put at risk the U.S. ability to defend and advance its national security and economic prosperity.</p>		
<p>How might we create ways to <span style="border: 1px solid black; padding: 2px;">Ensure a secured and reliable critical minerals' supply</span></p> <p style="text-align: center; font-size: small;">ACT ON PAIN/GAIN</p> <p>for <span style="border: 1px solid black; padding: 2px;">The U.S. (its allies and partners)</span></p> <p style="text-align: center; font-size: small;">PERSONA</p> <p>while considering <span style="border: 1px solid black; padding: 2px;">The global competition and unfair trade/business practices</span></p> <p style="text-align: center; font-size: small;">OTHER STAKEHOLDERS</p> <p>as we aim to <span style="border: 1px solid black; padding: 2px;">promote economic prosperity and national security</span> ?</p> <p style="text-align: center; font-size: small;">JOB TO BE DONE</p>		

Source: IS StratMat Seminar 9 Coursework

# Appendix 4-1

## Mining Asset Life Cycle



Source: KPMG Global Mining Institute, Peru country mining guide, KPMG, February 2016, 26, <https://assets.kpmg/content/dam/kpmg/pdf/2016/03/peru-mining-country-guide.pdf>.

## Appendix 4-2

### Porter's Five Forces Applied to the Mining Industry



Source: IS StratMat Seminar 9 Coursework

## Appendix 4-3

### Financial Ratios/ROIC for Select Western Mining Companies

Company	Rio Tinto <sup>1</sup>		Lynas <sup>2</sup>		MP material <sup>3</sup>		Albemarle Corporation <sup>4</sup>		Freeport McMoRan <sup>5</sup>		AngloGold Ashanti <sup>6</sup>		Materion <sup>7</sup>	
	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019
Year	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019
<b>Ratios</b>														
ROIC <sup>8</sup>	16.04%	10.17%	-2.31%	10.26%	-2.12%	-9.58%	5.29%	7.29%	2.86%	-0.64%	16.42%	0.14%	1.66%	6.88%
Current ratio	1.80	1.56	1.88	2.36	13.03	0.88	1.22	1.58	2.72	2.47	2.43	1.38	3.66	4.39
Long-term-debt-to-equity ratio	0.72	0.78	0.62	0.51	0.21	-4.91	0.98	1.11	1.97	2.17	0.80	0.94	0.42	0.20
Debt-to-equity ratio	0.97	1.05	0.81	0.64	0.26	-6.65	1.40	1.47	2.31	2.51	1.06	1.48	0.61	0.39
<b>Data (in thousands)</b>														
Net income	12,984,000	7,318,000	-19,395	83,079	-21,825	-6,755	446,615	604,357	865,000	-189,000	1,095,000	7,000	15,462	53,394
Current assets	20,855,000	17,303,000	179,062	162,891	561,047	27,409	2,206,184	2,225,109	9,303,000	7,915,000	2,334,000	1,982,000	463,999	537,747
Shareholders' equity	47,054,000	40,532,000	518,381	535,397	853,877	-18,022	4,268,227	3,932,250	10,174,000	9,298,000	3,695,000	2,640,000	655,630	645,743
Non-controlling equity	4,849,000	4,710,000	0	0	0	0	200,367	161,330	8,494,000	8,150,000	45,000	36,000	0	0
Current liabilities	11,607,000	11,125,000	95,098	68,932	43,061	31,315	1,801,849	1,408,996	3,417,000	3,209,000	959,000	1,437,000	126,884	122,440
Long-Term liabilities	33,880,000	31,435,000	322,646	274,476	177,350	88,501	4,180,503	4,358,287	20,059,000	20,152,000	2,973,000	2,478,000	275,346	130,247
Total liabilities	45,487,000	42,560,000	417,744	343,408	220,411	119,816	5,982,352	5,767,283	23,476,000	23,361,000	3,932,000	3,915,000	402,230	252,687
Firm invested capital	80,934,000	71,967,000	841,027	809,873	1,031,227	70,479	8,448,730	8,290,537	30,233,000	29,450,000	6,668,000	5,118,000	930,976	775,990

<sup>1</sup> Annual Report 2020, Rio Tinto, February 22, 2021, 199-203, <https://www.riotinto.com/-/media/Content/Documents/Invest/Reports/Annual-reports/RT-Annual-report-2020.pdf?rev=6df52113b92840648d05a4ac9e4cc1d8>.

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<sup>2</sup> 2020 Annual Report, Lynas, October 6, 2020, 40-41, [https://lynasrareearths.com/wp-content/uploads/2020/10/LYC\\_AR20-30Sep20-LODGE-2122450-1.pdf](https://lynasrareearths.com/wp-content/uploads/2020/10/LYC_AR20-30Sep20-LODGE-2122450-1.pdf).

<sup>3</sup> MP Materials Financial Statements (Form 10-K) FY 2020, MP Materials, March 22, 2021, 51 - 62, <https://d18rn0p25nwr6d.cloudfront.net/CIK-0001801368/7c83b453-4580-4c19-935a-5d198af27e58.pdf>.

<sup>4</sup> Albemarle Financial Statements (Form 10-K) FY 2020, Albemarle Corporation, February 19, 2021, 65-66, <https://investors.albemarle.com/static-files/079a93de-6a90-4057-92da-9ab7cf9b2c3b>.

<sup>5</sup> Freeport McMoRan Financial Statements (Form 10-K) FY 2020, Freeport McMoRan, February 16, 2021, 112-113, [https://s22.q4cdn.com/529358580/files/doc\\_financials/10-K/10\\_k2020.pdf](https://s22.q4cdn.com/529358580/files/doc_financials/10-K/10_k2020.pdf).

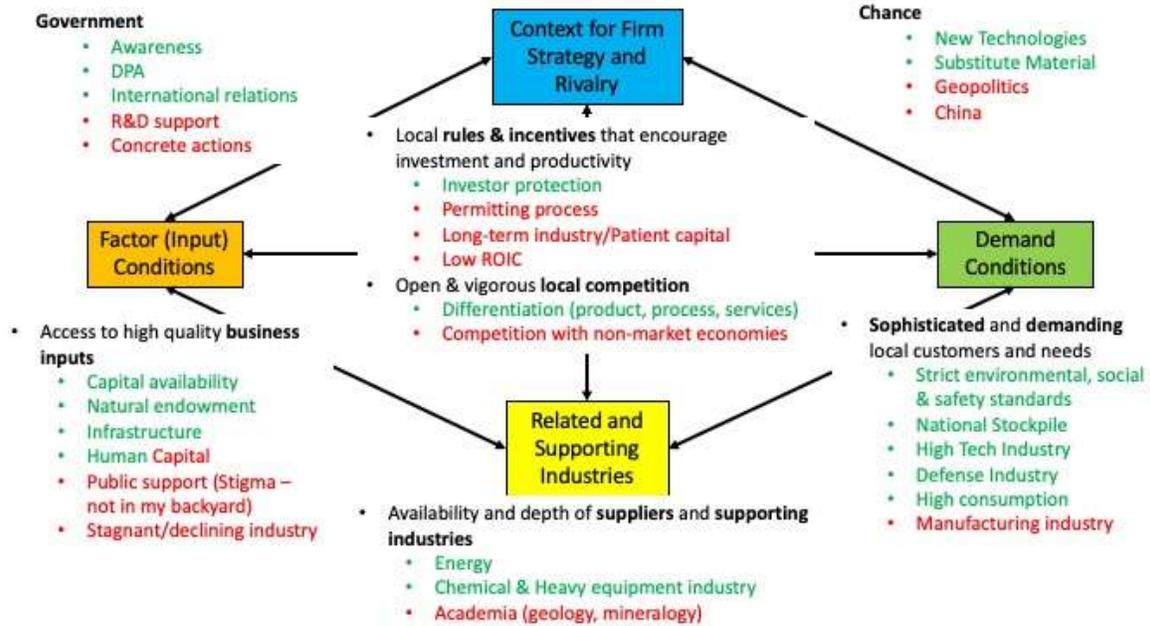
<sup>6</sup> AngloGold Ashanti Annual Financial Statements 2020, AngloGold Ashanti Limited, March 26, 2021, 34-35 <https://www.anglogoldashanti.com/investors/annual-reports/>.

<sup>7</sup> Materion 2020 Annual Report, Materion, February 18, 2021, 42-43, [https://s24.q4cdn.com/750845857/files/doc\\_financials/2020/ar/2020-Annual-Report.pdf](https://s24.q4cdn.com/750845857/files/doc_financials/2020/ar/2020-Annual-Report.pdf).

<sup>8</sup> The ROIC is computed according to the following formula:  $ROIC = \frac{Net\ income}{Long\ term\ liabilities + Shareholders' equity}$ . Using the total equity (shareholders' and non-controlling equities) does not change the comments in section 4.

## Appendix 5-1

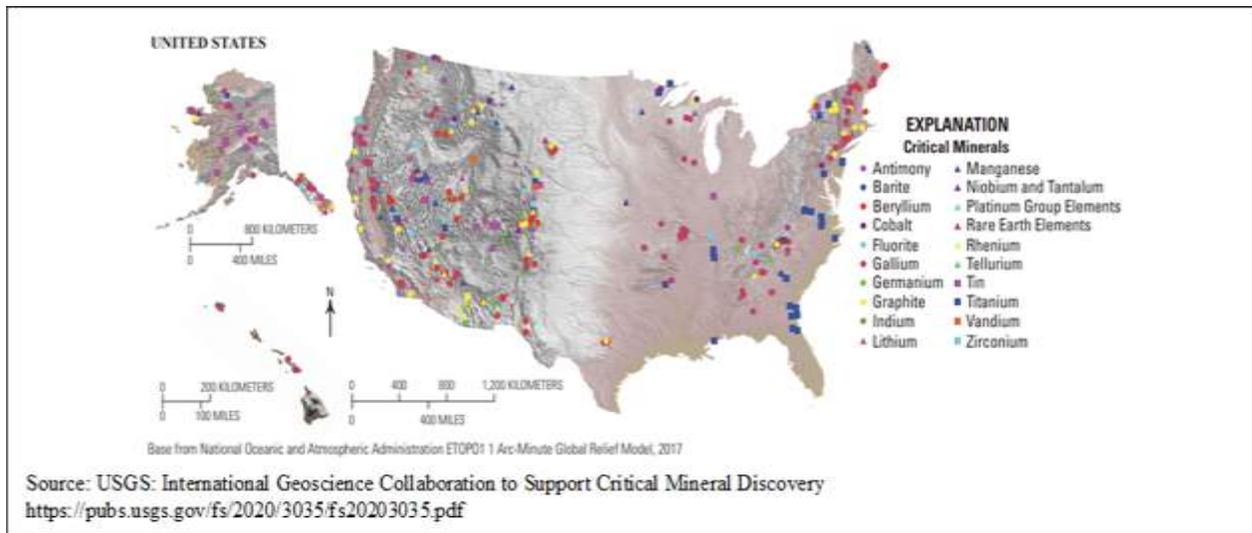
### Porter Diamond for U.S. Mining Industry



Source: IS StratMat Seminar 9 Coursework

## Appendix 5-2

### U.S. Critical Mineral Discovery to Date



## Appendix 5-3

# Mining Fiscal Instruments and Corresponding Investment Tax Incentives

Table 1. Typical mining tax incentives

Mining fiscal instruments	Corresponding tax incentives
<b>Taxes on income</b> (e.g., corporate income tax, resource rent taxes, withholding taxes)	<ul style="list-style-type: none"><li>• Income tax holiday</li><li>• Accelerated depreciation</li><li>• Investment allowance/tax credit</li><li>• Longer loss carry forward</li><li>• Withholding tax relief on interest expense dividends, services (e.g., management fees)</li></ul>
<b>Taxes on production</b> (e.g., mineral royalties)	<ul style="list-style-type: none"><li>• Reduced royalties</li><li>• Royalty holidays</li><li>• Sliding-scale royalties</li></ul>
<b>Tariffs on imports and exports</b> (e.g., tariffs on import of capital inputs)	<ul style="list-style-type: none"><li>• Import duty relief</li></ul>
<b>Others</b>	<ul style="list-style-type: none"><li>• Stabilization of fiscal terms</li><li>• Property tax</li><li>• VAT</li></ul>

Source: Alexandra Readhead, “Insights on Incentives: Tax Competition in Mining,” OECD - The International Institute for Sustainable Development, 2018, 7, <https://www.oecd.org/tax/beps/tax-incentives-in-mining-minimising-risks-to-revenue-oecd-igf.pdf>.

## **Appendix 5-4**

### **Fraser Institute's Annual Survey of Mining Companies 2020 Policy Perception Index Questionnaire**

The Fraser survey is designed to capture the opinions of managers and executives about the level of investment barriers in jurisdictions with which their companies are familiar. Respondents are asked to indicate how each of the 15 policy factors below influenced company decisions to invest in various jurisdictions.

1. Uncertainty concerning the administration, interpretation, or enforcement of existing regulations;
2. Uncertainty concerning environmental regulations (stability of regulations, consistency and timeliness of regulatory process, regulations not based on science);
3. Regulatory duplication and inconsistencies (includes federal/provincial, federal/state, inter-departmental overlap, etc.);
4. Legal system (legal processes that are fair, transparent, non-corrupt, timely, efficiently administered, etc.)
5. Taxation regime (includes personal, corporate, payroll, capital, and other taxes, and complexity of tax compliance);
6. Uncertainty concerning disputed land claims;
7. Uncertainty concerning what areas will be protected as wilderness, parks, or archeological sites, etc.;
8. Infrastructure (includes access to roads, power availability, etc.);
9. Socioeconomic agreements/community development conditions (includes local purchasing or processing requirements, or supplying social infrastructure such as schools or hospitals, etc.);
10. Trade barriers (tariff and non-tariff barriers, restrictions on profit repatriation, currency restrictions, etc.);
11. Political stability;
12. Labor regulations/employment agreements and labor militancy/work disruptions;
13. Quality of the geological database (includes quality and scale of maps, ease of access to information, etc.);
14. Level of security (includes physical security due to the threat of attack by terrorists, criminals, guerrilla groups, etc.);
15. Availability of labor/skills.

Source: Fraser Institute Annual Survey Of Mining Of Mining Companies 2020, pages 6-7,  
<https://www.fraserinstitute.org/sites/default/files/annual-survey-of-mining-companies-2020.pdf>.

# Appendix 5-5

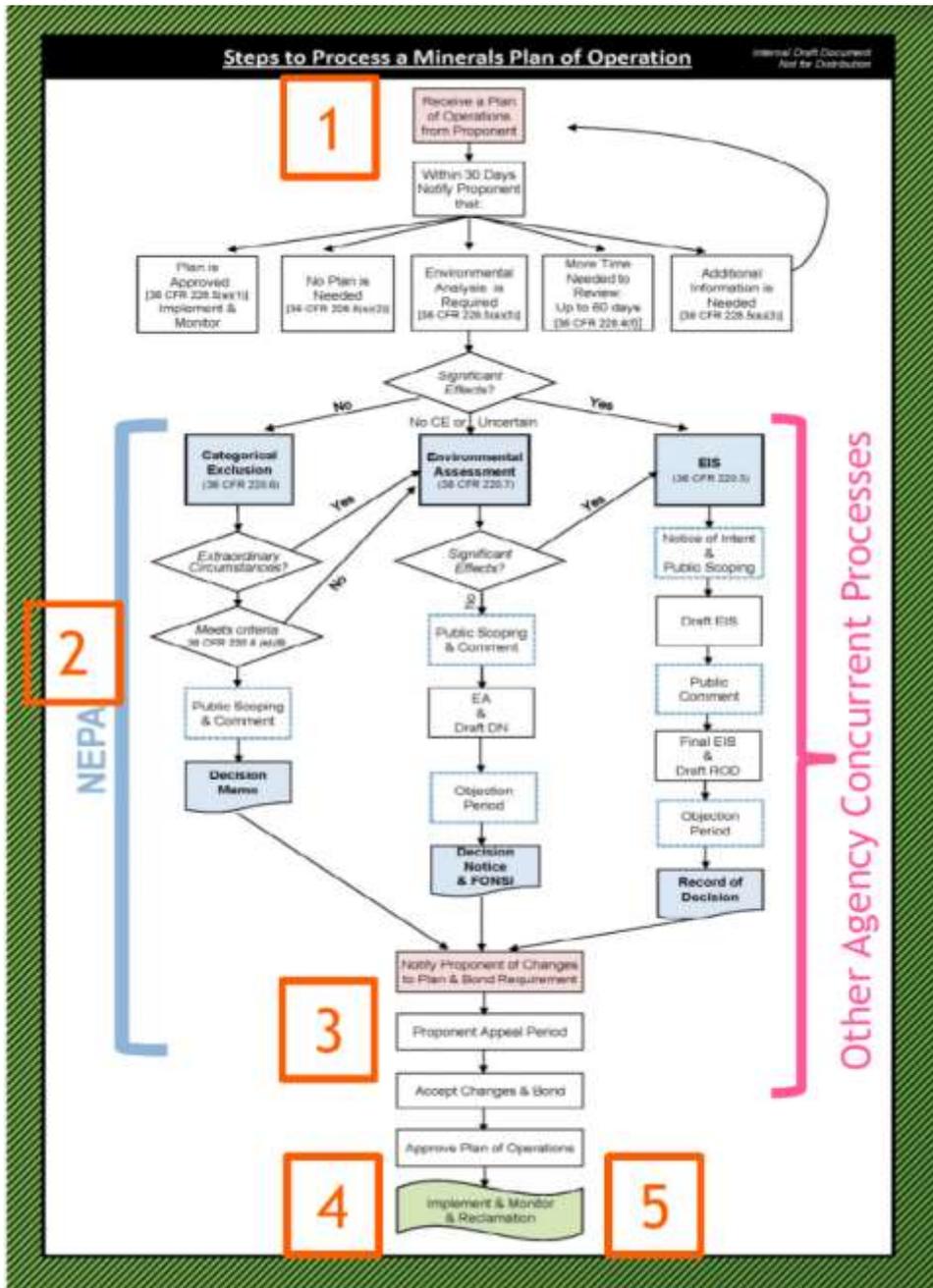
## FDI Stock in the U.S. Mining Sector (1997-2019)



Source: U.S. Bureau of Economic Analysis via Select USA, [https://www.selectusa.gov/fdi\\_stock\\_in\\_the\\_us\\_by\\_detailed\\_industry](https://www.selectusa.gov/fdi_stock_in_the_us_by_detailed_industry).

## Appendix 5-6

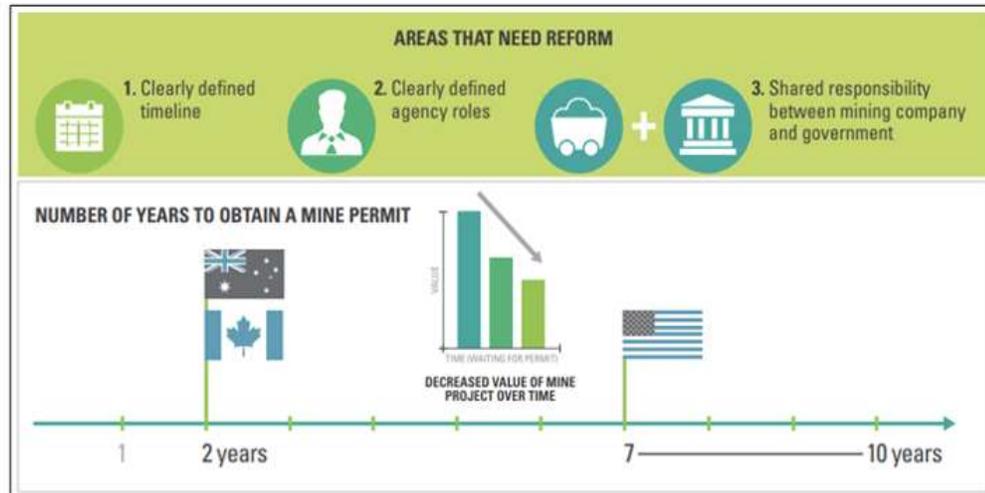
### Steps to Process a Forest Service Permit for Locatable Resources



Source: U.S. Forest Service, IS Lecture Presentation

## Appendix 5-7

### U.S. Permitting Timeline Compared to Other Nations

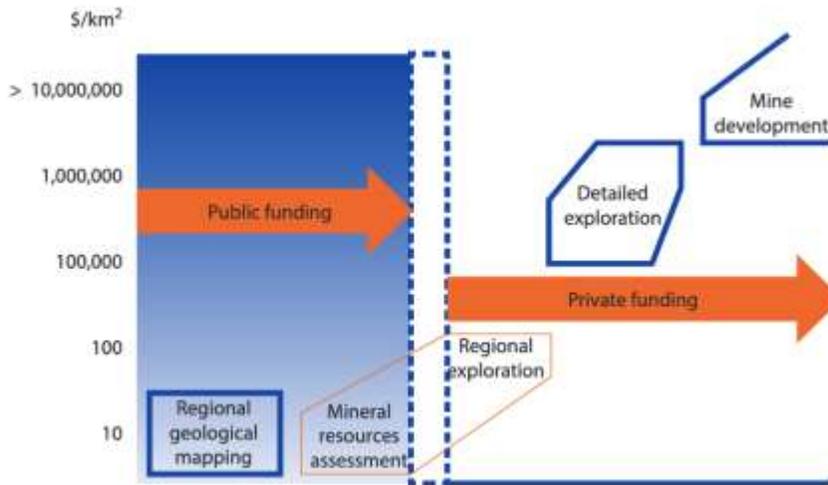


Source: National Mining Association Fact Sheet Delays In The U.S. Mine Permitting Process Impair And Discourage Mining At Home  
[https://nma.org/wp-content/uploads/2016/09/Infographic\\_SNL\\_minerals\\_permitting.pdf](https://nma.org/wp-content/uploads/2016/09/Infographic_SNL_minerals_permitting.pdf)

## Appendix 5-8

### Typical Public-Private Cost Sharing for GeoData

Figure 5.1 Sharing Costs of Geodata between the Private and Public Sectors

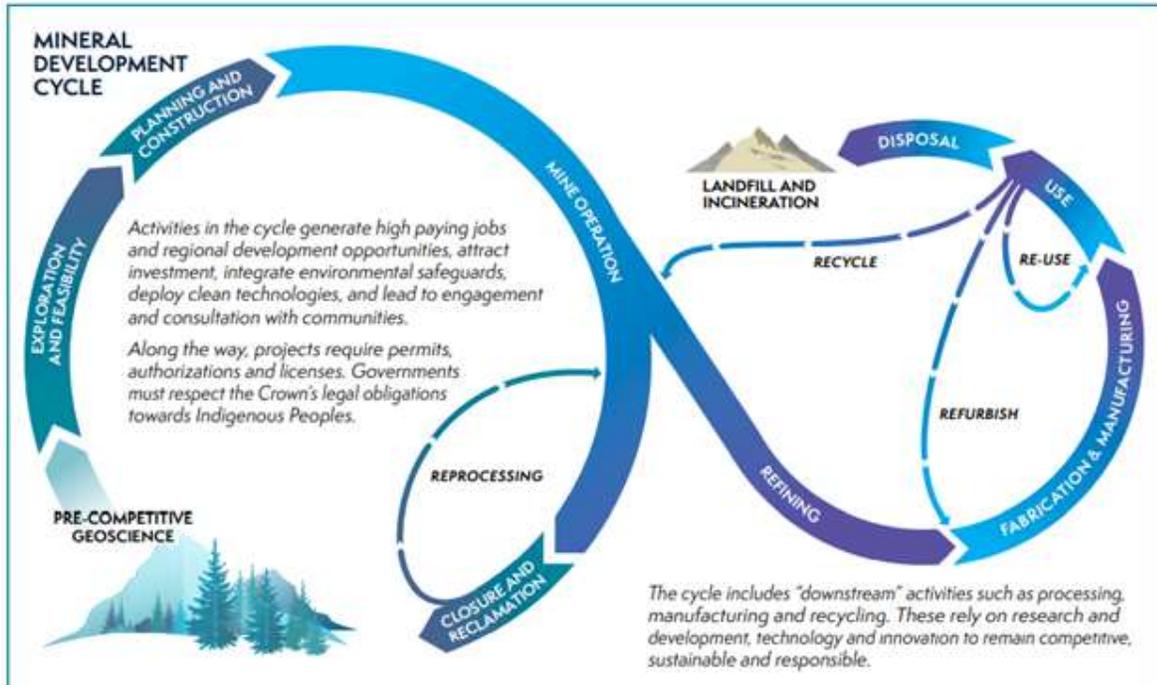


Source: World Bank Oil, Gas, and Mining Policy Division.  
Note: km<sup>2</sup> = square kilometers.

Source: Håvard Halland, Martin Lokanc, and Arvind Nair, *Extractive Industries Sector: Essentials for Economists, Public Finance Professionals, and Policy Makers* (Herndon: World Bank Publications, 2015), 60.

## Appendix 5-9

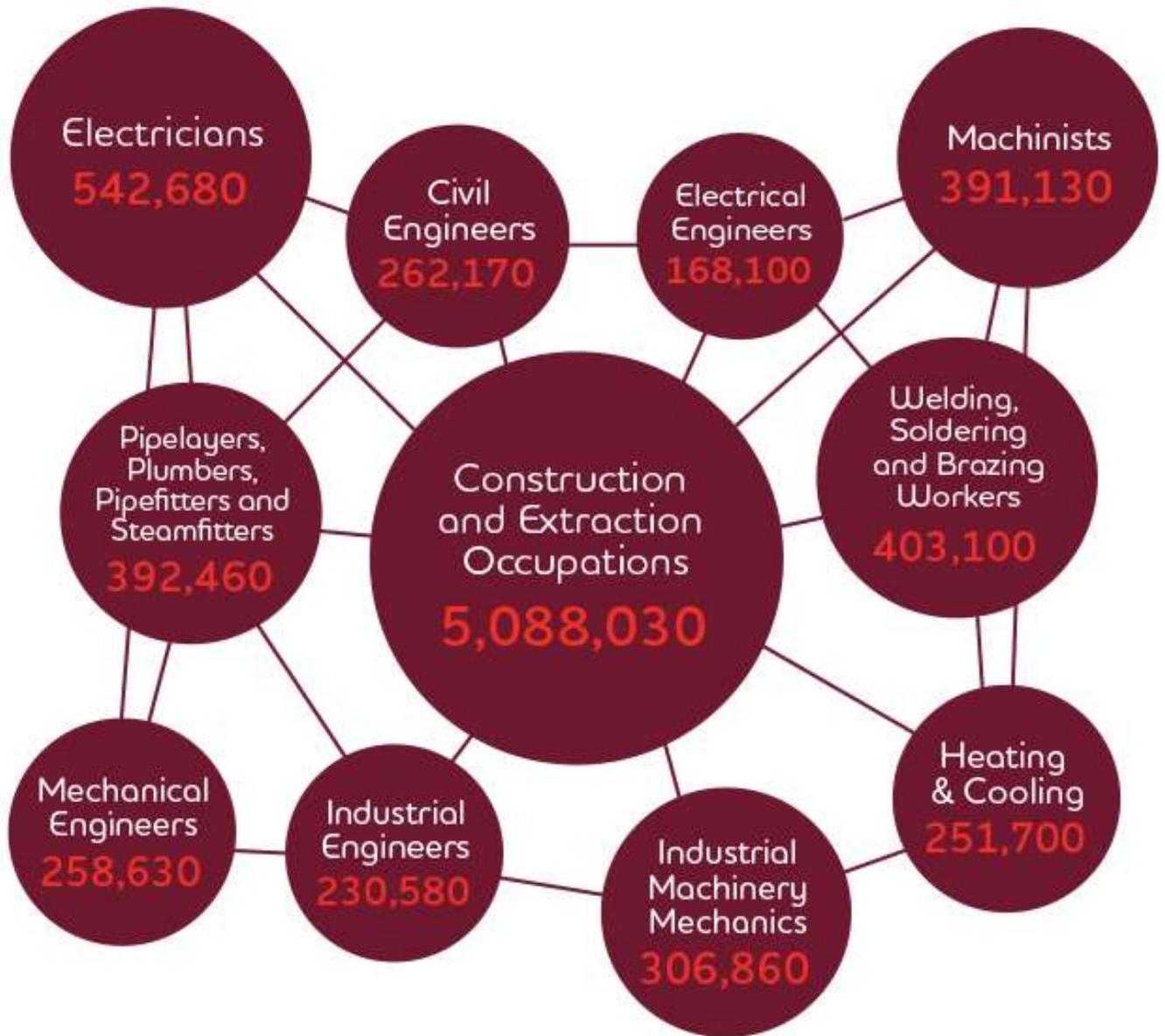
### Circular Economy of the Mineral Development Cycle



Source: Natural Resources Canada, "The Canadian Minerals and Metals Plan," March 2019.

## Appendix 5-10

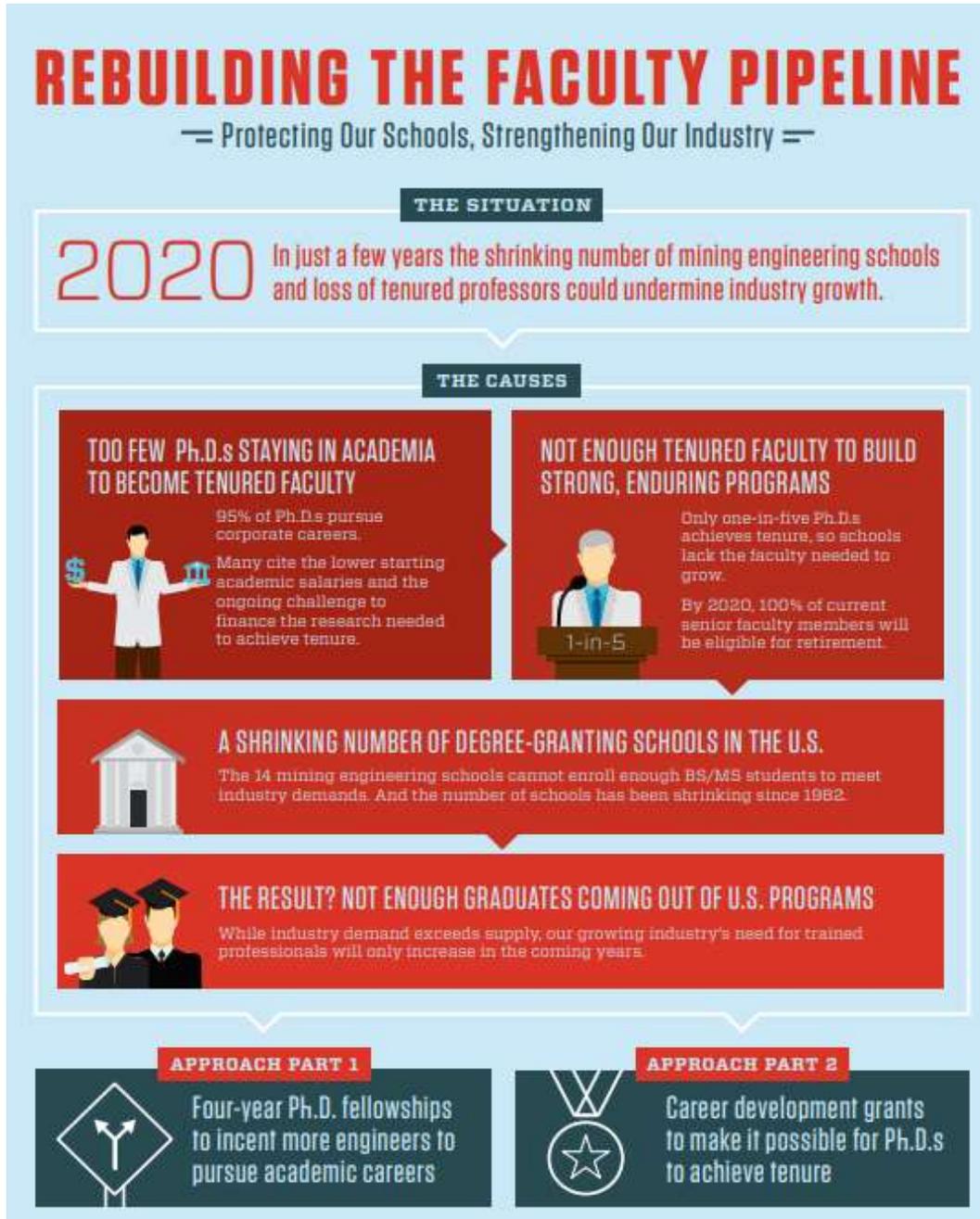
### Baby Boomers in Skilled Trades



Source: Adecco USA (<https://www.adeccousa.com/employers/resources/skilled-trades-in-demand/>)

# Appendix 5-11

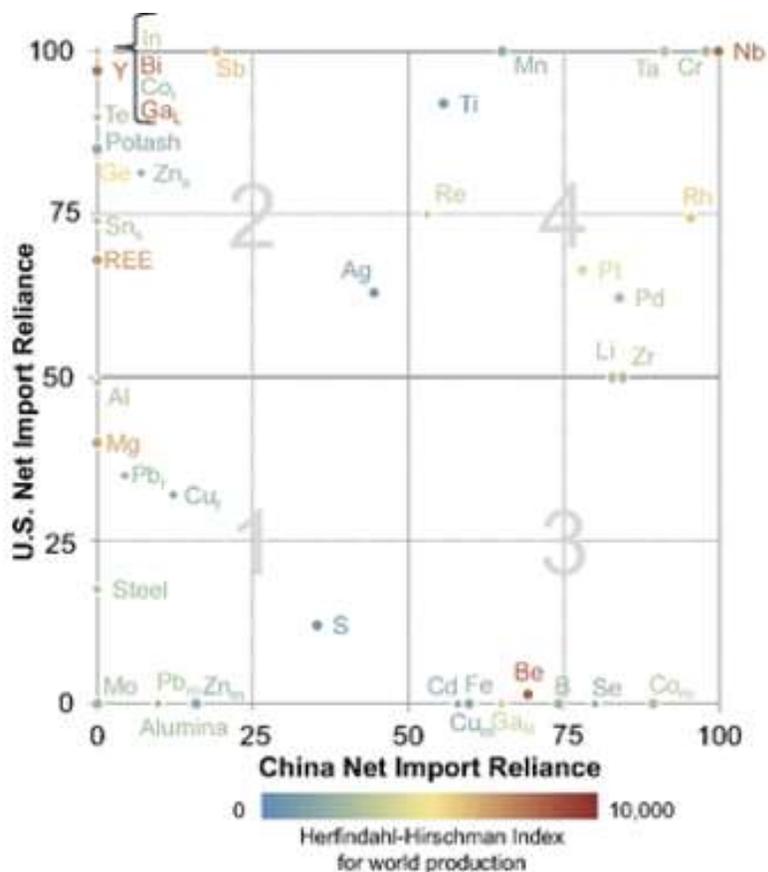
## SME Faculty Challenge Infographic



Source: Society for Mining, Metallurgy, and Exploration,  
<https://smenet.blob.core.windows.net/smecms/sme/media/smeazurestorage/professional%20development/pdf%20files/rebuildingfacultypipeline.pdf>.

## Appendix 6-1

### Net Import Reliance of the United States and China as a Percentage of Domestic Consumption for 42 Minerals for the Year 2014



**Explanation:** Net import reliance of the United States (vertical axis) and China (horizontal axis) as a percentage of domestic consumption for 42 minerals for the year 2014. Data denoted by element abbreviation. Circles indicate mine production. Rhombuses indicate refinery or smelter production. Subscripts differentiate between multiple production stages (H, high-purity production; L, low-purity production; m, mine production; r, refinery production; s, smelter production). Each point is colored according to the concentration of that mineral’s world production as measured by the HHI at the country level.

Source: National Minerals Information Center, US Geological Survey. Andrew L. Gulley, Nedal T. Nassar, and Sean Xun, “China, the United States, and Competition for Resources That Enable Emerging Technologies,” *Proceedings of the National Academy of Sciences* 115, no. 16 (April 17, 2018): 4111–15, <https://doi.org/10.1073/pnas.1717152115>.

## Appendix 6-2

# China Rare Earth Industry - Porter Diamond of National Competitiveness



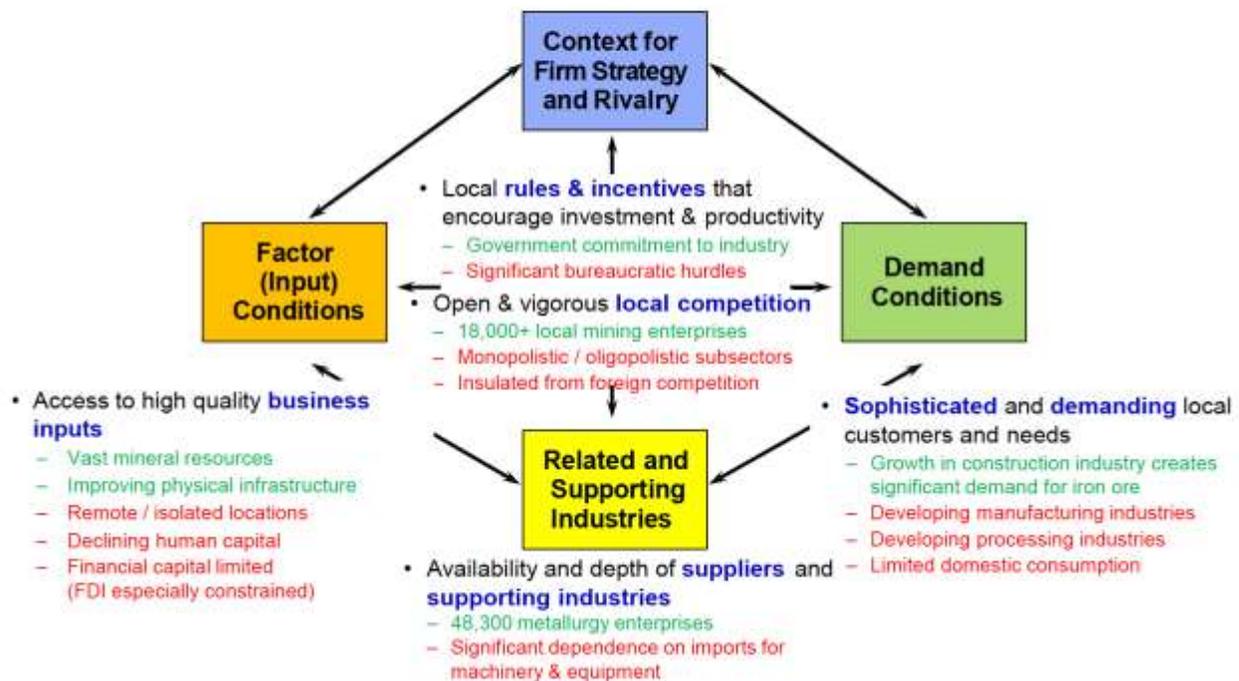
Source: IS StratMat Seminar 9 Coursework

## Appendix 6-3

### Russia - Porter Diamond of National Competitiveness

# Russia Mineral Industry & Policy

## *Porter Diamond of National Competitiveness*



Source: IS StratMat Seminar 9 Coursework

## Appendix 6-4

### Map of Critical Minerals Produced in the Developing World

Most nations are located in Africa, South America, and Asia and are home to significant strategic/critical mineral reserves and mining operations.

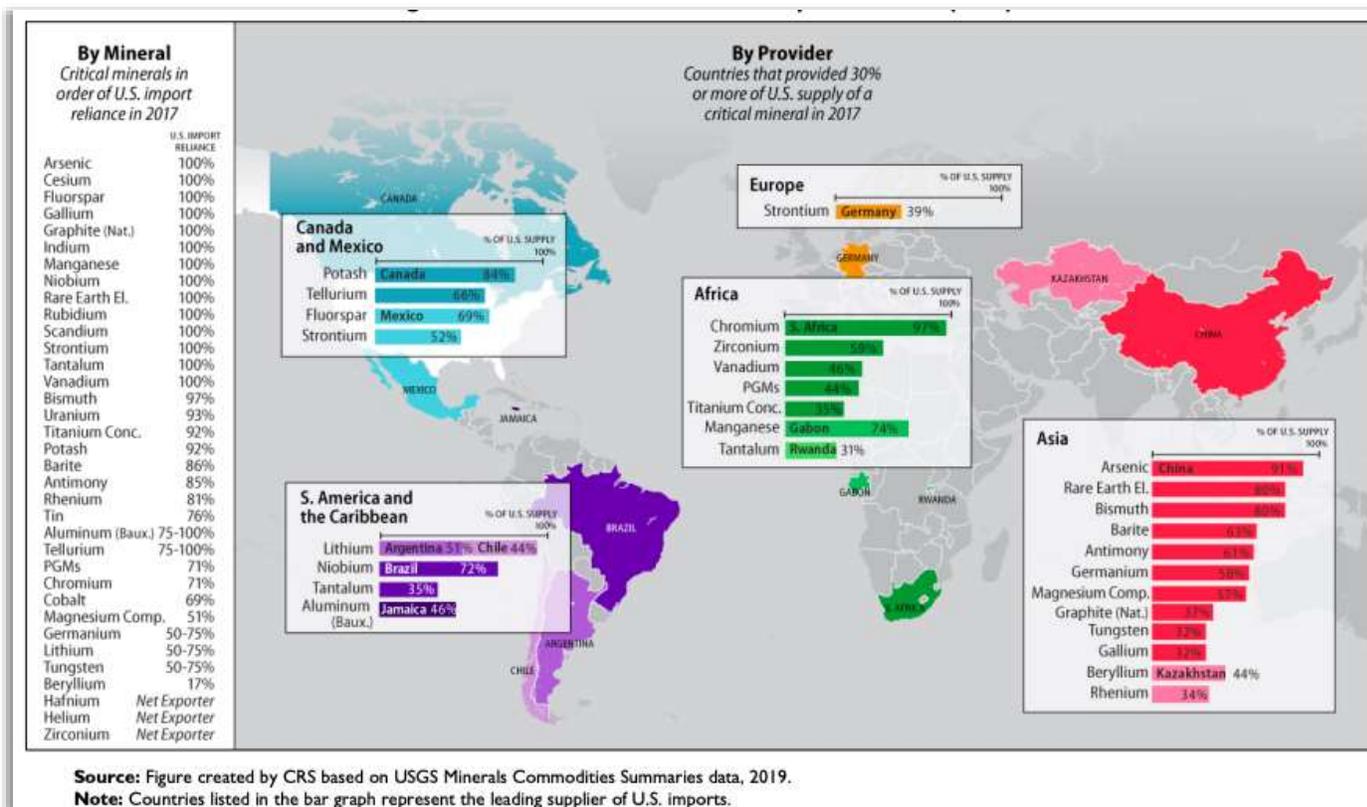


Source: World Economic Forum, <https://www.weforum.org/agenda/2015/11/is-the-term-developing-world-outdated/>.

## Appendix 6-5

### Nations that Provide 30% or More of U.S. Supply of a Critical Mineral

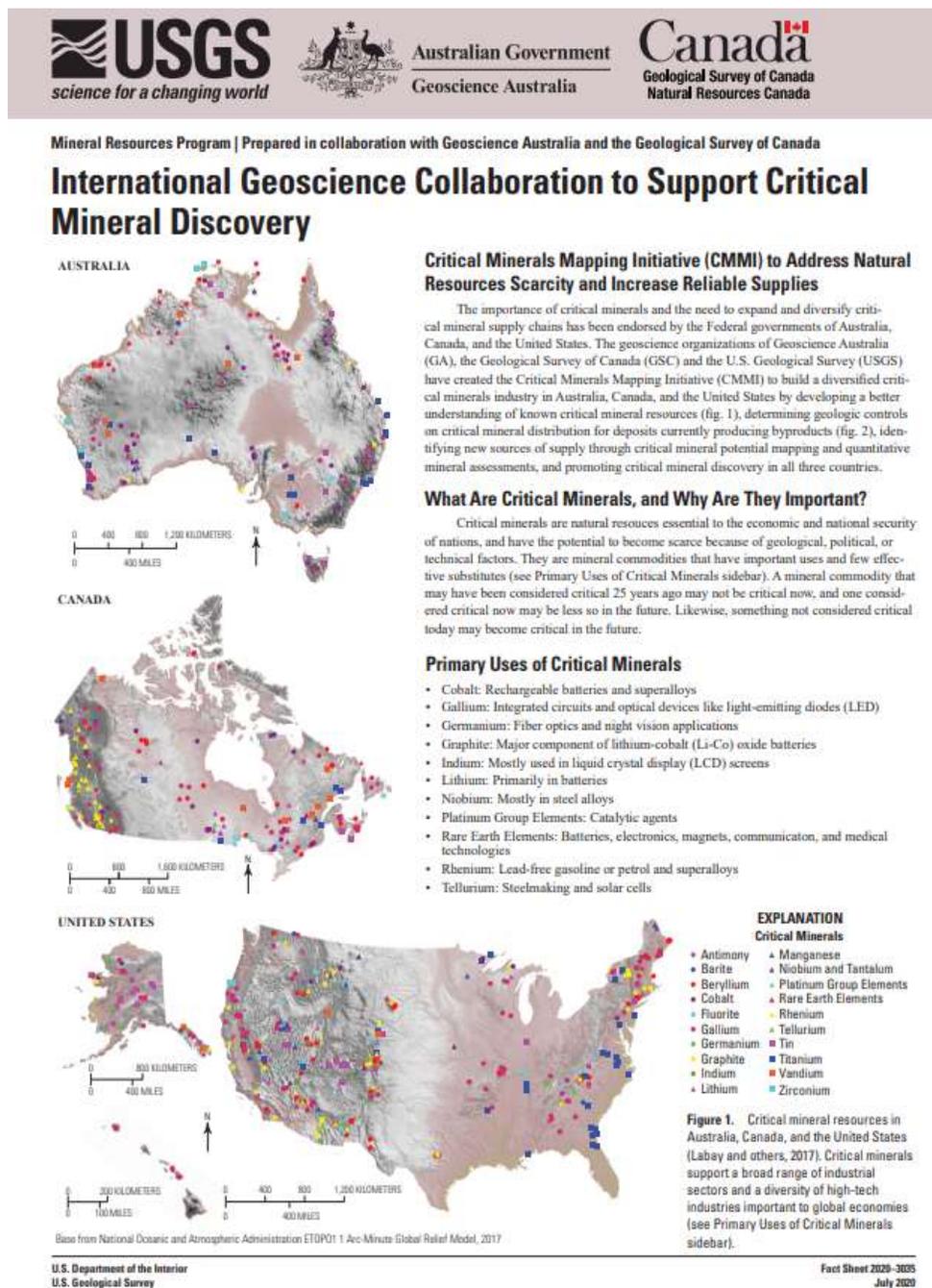
Many critical minerals come from the developing world in Africa and South America.



Source: Marc Humphries, *Critical Minerals and U.S. Public Policy*, Congressional Research Service, June 28, 2019, 33, <https://crsreports.congress.gov/product/pdf/R/R45810/1>.

# Appendix 6-6

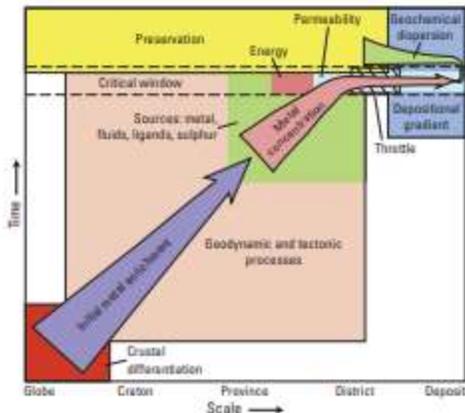
## Critical Minerals Mapping Initiative (CMMI)



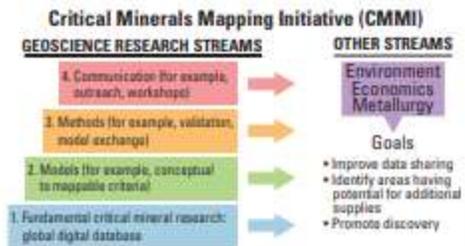
Source: U.S. Geological Survey prepared in collaboration with Geoscience Australia and the Geological Survey of Canada, "Fact Sheet 2020: International Geoscience Collaboration to Support Critical Mineral Discovery," (Department of Interior, July 2020), <https://pubs.usgs.gov/fs/2020/3035/fs20203035.pdf>.



**Figure 2.** Raglan nickel-copper mine site in northern Québec, Canada, produces byproduct cobalt and platinum group elements, which are considered critical minerals. Photograph used with permission from Raglan Mine.



**Figure 3.** Spatial and temporal scales of mineral systems and their key geologic processes (modified from Huston and others, 2016).



**Figure 4.** Geoscience streams of CMMI.

## Global Digital Database

The distribution of critical minerals in ore deposits is poorly understood. Geochemical analyses of archived collections are designed to inventory critical minerals (Granitto and others, 2020). Integration of the Ore Samples Normalized to Average Crustal Abundance database (OSNACA, <http://www.cet.edu.au/research-projects/special-projects/projects/osnaca-ore-samples-normalised-to-average-crustal-abundance>) and other GA, GSC, and USGS databases will form the beginnings of a global database necessary to understand the controls on critical mineral distribution and to increase accuracy in mineral resource assessments.

## What Will Be Gained Through Collaboration?

Together GA, the GSC, and the USGS will:

- promote a collective understanding of critical minerals science;
- share data;
- identify knowledge gaps;
- unify critical minerals analyses from all three countries;
- build upon existing datasets for use in critical mineral assessments;
- improve the knowledge base of critical mineral concentrations in different deposit types; and
- leverage strengths to enhance working relationships and share expertise.

## Mineral Systems Approach

The mineral systems approach to mineral deposit genesis provides a framework that considers geologic processes that control the formation and preservation of mineral deposits (fig. 3). Placing critical minerals into a mineral system framework represents one of the most important outcomes of knowledge and data sharing between the three geological survey organizations.

## Progress

Workshops in July 2018 (Denver, Colorado, United States) and December 2019 (Ottawa, Canada) identified four geoscience streams of study as part of the CMMI (fig. 4); future workshops are proposed to advance this work.

## References Cited

- Granitto, M., Emsbo, P., Hofstra, A.H., Orkild-Norton, A.R., Bennett, M.M., Azain, J.S., Koenig, A.E., and Karl, N.A., 2020, Global geochemical database of critical minerals in archived mine samples: U.S. Geological Survey data release, <https://doi.org/10.5066/P9Z3XL6D>.
- Huston, D.L., Mernagh, T.P., Hagemann, S.G., Doublier, M.P., Fiorentini, M., Champion, D.C., Jaques, A.L., Czarnota, K., Cayley, R., Skirrow, R., and Bastrakov, E., 2016, Tectono-metallogenic systems—The place of mineral systems within tectonic evolution, with an emphasis on Australian examples: *Ore Geology Reviews*, v. 76, p. 168–210, accessed April 2020, at <https://doi.org/10.1016/j.oregeorev.2015.09.005>.
- Labay, K., Burger, M.H., Bellora, J.D., Schultz, K.J., DeYoung, J.H., Seal, R.R., II, Bradley, D.C., Mauk, J.L., and San Juan, C.A., 2017, Global distribution of selected mines, deposits, and districts of critical minerals: U.S. Geological Survey data release, <https://doi.org/10.5066/F7GH9GQR>.

## For More Information Contact

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## Appendix 6-7

### Comparison of Critical Minerals List of Select U.S. Allies

Comparison of Critical <sup>1</sup> Minerals List of Select U.S. Allies						
Mineral or Metal	Country					
	USA	Australia <sup>2</sup>	EU	Japan	South Korea	Canada
Aluminum	✓					✓
Antimony	✓	✓	✓	✓	✓	✓
Arseni	✓					
Barite/Barium	✓		✓	✓		
Beryllium	✓	✓				
Bismuth	✓	✓	✓			✓
Cesium	✓					✓
Chromium	✓	✓		✓	✓	✓
Coal				✓		
Cobalt	✓	✓	✓	✓	✓	✓
Coking Coal			✓			
Copper				✓		✓
Flourspar	✓		✓			✓
Gallium	✓	✓	✓	✓	✓	✓
Germanium	✓	✓	✓			✓
Graphite	✓	✓	✓	✓		✓
Hafnium	✓	✓	✓			
Helium	✓	✓				✓
Indium	✓	✓	✓	✓	✓	✓
Lithium	✓	✓	✓	✓	✓	✓
Magnesium	✓	✓	✓		✓	✓
Maganese	✓	✓		✓	✓	✓
Molybdenum				✓	✓	✓
Nickel				✓	✓	✓
Niobium	✓	✓	✓	✓	✓	✓
Phosphate Rock			✓			
Platinum Groups Metals/Elements	✓	✓	✓	✓	✓	✓
Potash	✓					
Rare Earth Elements	✓	✓	✓	✓		✓
Rhenium	✓	✓		✓		
Rubidium	✓					
Scandium	✓	✓				✓
Selenium					✓	
Strontium	✓					
Tantalum	✓	✓	✓	✓		✓
Tellurium	✓				✓	✓
Tin	✓					✓
Titanium	✓	✓		✓	✓	✓
Tungsten	✓	✓	✓	✓	✓	✓
Uranium	✓			✓		✓
Vandium	✓	✓	✓	✓	✓	✓
Zinc				✓		✓
Zirconium	✓	✓			✓	

<sup>1</sup> The term "critical" is different for every country and for the U.S. signifies where it needs more secure access. In Canada and Australia, signals what critical materials the country can provide to others.

<sup>2</sup> Australia's critical mineral list is a communication tool on what Australia can provide to other countries. Signifies where Australia and Canada could help the U.S.

Signifies areas where all six countries overlap.

Table modified from the Canadian Minerals and Metals Plan to include Australia.

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**APPENDIX B**  
**Essays on Select Topics**

## **National Innovation Policy for Strategic Materials**

By: Mr. Robert Finley

### **Introduction**

Michael Porter teaches the response of nations to increasing competition should be through innovation. “National prosperity is created, not inherited. A nation's competitiveness depends on the capacity of its industry to innovate and upgrade.”<sup>1</sup> However, Robert Atkinson points out that “the unquestioned position of the United States as the world’s leading economy over the past half century has led too many U.S. policymakers to falsely believe that America is immune from such ferocious global competition.”<sup>2</sup> Despite the U.S. being a resource-rich country, U.S. miners face increasing risks to profitability in the strategic minerals value chain.<sup>3</sup>

Minerals are basic to our way of living and essentially everything we use in modern society is a product of the mining, agriculture, or oil and gas industries.<sup>4</sup> Miners must be more productive by tightly managing cash, prioritizing the operation of core assets, and reducing or cutting nonessential or non-core capital expenditures.<sup>5</sup> Emerging nations exhibit a trend toward economic protectionism to favor domestic producers and ensure host countries receive their fair share of resource wealth and impedes U.S. access to global resource deposits.<sup>6</sup> Moreover, increasing pressure by western democracies toward environmental responsibility means the Social License to Operate (SLO) remains the number one issue for miners.<sup>7</sup>

The sustained profitability of mining is highly uncertain and warrants government intervention. However, politicians should act but must avoid “the all-too-easy escape routes that appear to offer a path to competitive advantage, but are a shortcut to failure.”<sup>8</sup> This paper asserts that the challenges to mining profitability requires the U.S. create a National Innovation Policy for strategic materials that open pathways to new resources and diversify value chains.

### **Characteristics of Innovation in Strategic Materials**

Clay Christensen observes “the capitalist's dilemma,” where “doing the right thing for long-term prosperity is the wrong thing for most investors.”<sup>9</sup> In no business is the capitalist’s dilemma truer than in mining and processing strategic materials. The adoption of industry upgrades is slow, and research shows it has “far more in common with mature manufacturing industries than it does with the high-tech sector.”<sup>10</sup> As Porter notes, “strong pressures leading to underinvestment, however, plague more mature industries.”<sup>11</sup> Policies that promote innovation must address the core challenges which make mining unpredictable and keep commercial investment capital on the sidelines, namely, the SLO, Project Viability, Price Volatility, and the Mine Improvement Paradox.

SLO. The highest risk faced by the mining industry is a SLO, which exacerbates the capitalist’s dilemma. The slightest uncertainty that local or federal governments might seize expected profits without warning scares away long-term capital. Global mining operations face the wrath of local communities with “greater expectations around how miners respect indigenous rights and native title.”<sup>12</sup> When resource-rich nations fall on hard times, the probability increases for “a return to resource nationalism, with increased debate around who miners sell to and for what purpose.”<sup>13</sup> Sustainably sourcing strategic materials requires organizational and regulatory innovation.

**Project Viability.** When considering new projects, the “return on investment for each product or service a company makes is measured individually,”<sup>14</sup> and with a “lack of conventional equity and debt capital many investors shy away from investing in mining projects.”<sup>15</sup> Investors in new mining projects, such as purchasing additional or upgraded excavating equipment, want confidence in sustained customer demand that will secure monetary returns. Meanwhile, mineral customers desire confidence in a steady source of raw materials that depend on stable operations using tangible and reliable equipment. Bridging the confidence gap between extraction potential and extraction reality for a mining project requires innovations in information, exploration, extraction, and refining technologies.

**Price Volatility.** Fluctuating commodity prices mean that, during boom years, mining and exploration companies must battle to raise capital. “Miners need to be able to make sustainable, long-term decisions as they deal with the return of severe commodity price volatility, the threat of substitution and changing customer demand.”<sup>16</sup> Stabilizing commodity prices require innovations that create sustained and diversified downstream market demand.

**Mine Improvement Paradox.** Known as the “Mine Improvement Paradox,” the mining industry is its own worst enemy at securing innovations. The old saying “if it ain’t broke, don’t fix it” might have been coined by a miner. Successfully and profitably operating mines with tried and true equipment quell the motivation for technological change.<sup>17</sup> Miners are keen to avoid unnecessary technical risks, which leads to a ‘fast follower’ culture. Companies proudly admit to being the ‘first to be second’ in deployment of new technologies.<sup>18</sup> However, when times are bad, the economics of mining prevent businesses from justifying the increasing capital investments required to reduce operating costs and improve productivity.<sup>19</sup> A bottoms-up reinvention of mining is also painful because new mines are particularly bad places to try out new and unproven technologies.<sup>20</sup> Braking the Mine Improvement Paradox requires rapid adoption of Radical and Disruptive innovations.

## **U.S. National Innovation Policy in Strategic Materials**

During the 1849 California Gold Rush, no miners ever made real fortunes mining gold. Instead, entrepreneurs like Levi Strauss and Samuel Brennan made their fortunes ‘mining the miners,’<sup>21</sup> that is, selling tools and supplies to the miners in exchange for their gold. While the characteristics of mining are now highly mechanized, the nature and economics of mining remain unchanged. The adoption of industry upgrades is slow, and critics characterize it an industry resistant to innovation and technological changes.<sup>22</sup> Research shows it has “far more in common with mature manufacturing industries than it does with the high-tech sector.”<sup>23</sup> The fact is that mining is not a high-tech industry.<sup>24</sup> This is a huge barrier to innovation in mining because, as Porter notes, “strong pressures leading to underinvestment, however, plague more mature industries.”<sup>25</sup> The mining industry’s present productivity advances originate outside the industry, specifically with equipment manufacturers and suppliers.<sup>26</sup>

A National Innovation Policy for strategic materials must address the unique nature and challenges of the mining industry consistent with the four core areas of the Porter Diamond, which are Factor Conditions, Demand Conditions, Supporting and Related Industries, and Firm, Structure, and Rivalry.

### ***Factor Conditions:***

Factor Conditions characterize those things that make conducting business favorable, like skilled labor, scientific education, and intellectual property protections. Porter notes, “The stock of factors that a nation enjoys at a particular time is less important than the rate and efficiency

with which it creates, upgrades, and deploys them in particular industries.”<sup>27</sup> Therefore, the more specialized and concentrated the Factor Condition, the more likely industry innovation will occur. The U.S. enjoys several factor conditions that provide a competitive advantage such as an Information Technology (IT) skills base and broad Secondary Education.

**Adoption of Smart Mines.** Leaning on existing U.S. Factor Conditions, Silicon Valley is a world leader in the deployment of Big Data,<sup>28</sup> Artificial Intelligence, and Agile Methods. “Much like urban planning, a mining site requires intelligent movement of workers, equipment, and excavated materials to maximize efficiency while cutting down on waste.”<sup>29</sup> Providing U.S. and partner firms with tax credits or other incentives for adopting Smart Mining technologies supports Sustaining and Incremental Innovations and breaks the Mine Improvement Paradox.

**Targeted Education Grants.** Expansion of education grants targeted on Materials Science, Geology, and Mining Technology will reap long-term benefits. Specifically, grants should target community college and trade school programs focused on mining skills. There is a nationwide skilled workforce shortage where “over the next decade we will see a wave of 3½ million skilled workers retiring, with very few skilled workers ready to take their place.”<sup>30</sup> A more knowledgeable workforce can effectively exploit Agile methods that reduce Project Volatility and inject the Incremental Innovations of Smart Mine technology.

### ***Demand Conditions:***

Demand Conditions characterize the quality of customers buying an industries’ goods and services. Porter observes, that “[nations] gain competitive advantage in industries where the home demand gives their companies a clearer or earlier picture of emerging buyers needs, and where demanding buyers pressure companies to innovate faster and achieve more sophisticated competitive advantages than their foreign rivals.”<sup>31</sup> Localized and refined demands incite innovation. The U.S. economy sets high demand conditions across several industry areas and is an opportunity for the competition over strategic materials to pull innovations through the value chain.

**Material Science Research Grants.** Research into exotic materials with novel uses sparks the Radical and Disruptive innovation of new products. There is a widening “valley of death”<sup>32</sup> where innovations are stuck in academia and do not result in practical solutions. Commercial sector innovation and large corporate labs are falling out of favor with investors and instead rely on outside inventions to fuel their growth.<sup>33</sup> A more significant investment of patient capital by government should promote academia and small businesses to invent products and components that capitalize on strategic materials.

**Environmental Regulations.** The challenge of the Social LTO stems from fears that today’s new mining operation is tomorrow’s superfund site.<sup>34</sup> However, the constraint of “right-sized” environmental regulations can transform a political confrontation into a sustainable industry advantage that incentivizes innovation. Aided by the transparency offered by Smart Mines, instituting a national agency that audits and grants a “Trusted Mining Seal of Approval” to compliant operators will raise the social and economic value of responsibly sourced strategic materials. As a point of comparison, “Denmark’s environmentalism has led to success for companies in water-pollution control equipment and windmills.”<sup>35</sup> The policy must cut through the rancor of false choices and binary thinking inculcating the public discourse and instead “right-size” environmental regulations.

**Electric Cars.** The pervasive car culture of the U.S. is kindling for igniting the Demand Conditions required for stoking Sustaining and Incremental Innovations. Increasing the production of electric cars will send new demand signals through the value chain for large

quantities of strategic materials, improving Project Viability and Price Volatility of materials like Neodymium for electric motors and Lithium for high performance batteries. Policies that energize the demand for electric cars should focus on influencing customer choices, such as tax rebates for gas-powered vehicle trade-ins. Government purchases of electric-powered Post Office vehicles or Military utility vehicles send a strong demand signal.

**Build a Nationwide Smart Grid.** A distributed, resilient, networked, and democratized grid where electricity can efficiently be produced, used, bought, or sold from anywhere, will electrify the economy, support energy independence, and improve national security.<sup>36</sup> A Smart Grid provokes new demand for the nation to innovate and upgrade how it lives and works. Strategic materials, such as copper, lithium, and neodymium will be front and center in the nationwide production and deployment of batteries, solar panels, wind turbines, and electric motors. A Smart Grid forces wide-ranging innovations of all types, improve Social LTO and Project Viability, and reduces Price Volatility.

**Exotic Exploration Projects.** Innovations occur where customers are the most demanding. Government backing for ambitious mining projects in the most environmentally hostile locations will spark Radical Innovations in mining technology. Exotic areas such as Greenland, Antarctica, or the ocean floor offer uncompromising obstacles across multiple dimensions. The requirements to minimize environmental impact, maximize safety, and reliably operate with remote access and extreme weather are catalysts for mining innovations. Exotic location projects can be prototypes for the most exotic mining environment of all, asteroids, where the proto-planet 16 Psyche has an estimated value of \$10,000 quadrillion.<sup>37</sup> In November 2015, President Obama signed the Space Resource Exploration and Utilization Act of 2015, which entitles U.S. citizens, including commercial entities, “the explicit right to own resources extracted from space, including asteroids.”<sup>38</sup> Leveraging the U.S. competitive advantage of space exploration, a government led mission to explore, sample, and evaluate the mineral potential of an asteroid could spark Radical and Disruptive innovations across the mining industry in areas of sensing, robotics, and in-stream refining.

### ***Related and Supporting Industries:***

When considering improvements to mining productivity, government policies should also target the Related and Supporting industries. Related industries, like the energy extraction of coal, oil, and gas, and Supporting Industries, like earth moving equipment and mineral geology, not only provide the most cost-effective inputs, but working relationships among local suppliers are also the connective tissue for an industry and a conduit for information exchange. Porter says that “[far] more significant than mere access to components and machinery, however, is the advantage that home-based related and supporting industries provide innovation and upgrading.”<sup>39</sup> As suppliers capture additional value for themselves, the benefits accrue down the value chain.

**Create an Exploration Cooperative.** A particular market failure of the mining sector is inefficient resource exploration. Project Viability concerns and Price Volatility risk disincentivizes the accumulation and sharing of information about new resource deposits among competitors. The government should create and support an openly available mineral resource information repository which should open pathways to more stable and sustained investments across the industry. Counterintuitively, public information sharing will make mineral claims more marketable and valuable. Publicly accessible information promotes more informed speculation and more efficient exploitation by the best owner. For example, the discovery of excess copper by a firm looking for cobalt might motivate a firm specializing in copper

extraction to invest in the cobalt project. The government should invest in populating the database with government-owned information, such as Satellite Hyperspectral Surveys.<sup>40</sup> Combined with the Targeted Education Grants, geologic research and field study could add to the richness of the shared information. Small firms with grants to enhance technologies like Acoustic Signal Processing or remote sensors and drones could monetize potentially valuable mineral claims.

**Promote Exploration Mines.** In cooperation with Targeted Education Grants, the Exploration Cooperative, and “right-sized” Environmental Regulations, the government should streamline the approval process and co-sponsor the operation of small exploration mines that experiment with new mining technologies. Government partnerships with small exploration mines could bridge the gap from discovering a deposit to significant project development. By limiting the size and environmental impact of the project, small exploration mines can prove reserves earlier, illuminate ore bodies more clearly, solicit appreciable investments sooner, and generate marginal returns that underwrite the long waiting periods that typically accompany large projects. Simultaneously, suppliers looking to test and improve mining equipment could start exploration mines as proving grounds for potentially Disruptive Innovations in extraction and refining technologies, such as robotics or Photo-remediation.<sup>41</sup>

**The Thorium Problem.** Nuclear Thorium Molten Salt Reactors (TMSR) represent a tremendous opportunity for the U.S. Commonly found in mineral deposits with valuable REE, radioactive Thorium poisons the viability of new mine projects. In cooperation with the Department of Energy, a shift in focus to processing Thorium as a nuclear fuel can have spillover effects for REE. Because a TMSR completely consumes all nuclear reactants, Thorium extracted from REE mines (and the lingering burden of 300,000 tons of existing U.S. atomic waste) becomes a strategic U.S. advantage.<sup>42</sup> A TMSR is environmentally safe enough to use inside a city, as the potential for a Chernobyl-style meltdown is non-existent. It is small enough to relocate by truck, train, or plane and secure enough that the creation of weapons-grade fissile materials is impossible. While commercial initiatives face existing regulatory requirements and public scrutiny, public investment in a TMSR could be the catalyst to solving several strategic U.S. National Security interests.

### ***Firm Strategy, Structure and Rivalry:***

As noted earlier, a domestic rivalry is the most powerful of all the forces stimulating innovation. Structure and rivalry are where good government policy has the least control but is often where politicians first seek to interfere. Porter warns that “only companies themselves can achieve and sustain competitive advantage,” and they must “recognize the uncomfortable truth that innovation grows out of pressure and challenge.”<sup>43</sup> Rather than mineral resource nationalization or protectionist policies, which might shield U.S. companies from foreign competition, government initiatives should stoke Rivalry in the downstream value chain.

**Energy Independence.** One real risk of failure in the Great Power Competition is losing U.S. energy independence. Producing renewable energy is not an end unto itself but rather a means to power the economy. Just as the 1970’s oil crisis left the U.S. embroiled in Middle Eastern Politics for decades, the quest for renewable wind and solar energy currently depends on strategic materials from China. However, the affinity of politicians to raise fossil fuel prices, believing it will stimulate the adoption of green energy production and Electric Cars, is counterproductive. U.S. petroleum independence keeps energy costs low and encourages competition among green products, which prompts innovation. Competition among petroleum

and renewable energy sources is a bulwark against failing companies like Solyndra from becoming State sponsored “zombie-companies.”<sup>44</sup>

Electric Power Deregulation. Implementing a Smart Grid, replete with the demand for strategic materials such as Lithium, Cobalt, Neodymium, and Copper, requires innovative and structural changes to financing the electric power generation industry. Electric power deregulation is inevitable and could be a real opportunity to boost the green economy. A Smart Grid enables the highly competitive democratization of electricity into a “produce anywhere, consume anywhere” model. Solar Panels and Wind Turbines deployed on houses, shopping malls, and parking lots should capture optimal value for their landowners. However, as demonstrated by the California-Enron debacle, cronyism and energy market manipulation is a real danger.<sup>45</sup> Cutting through the stagnation of over-regulation and preventing black-outs and market meltdowns via under-regulation requires apolitical management of the green energy transition.

## Conclusion

As strictly defined, mining is not a high-tech industry<sup>46</sup> and criticisms are likely to remain that miners resist and implement innovation and technological changes slowly.<sup>47</sup> Still, policies that enhance the Factor Conditions, Demand Conditions, Supplier Conditions, and Industry Rivalry represent the best opportunity to stimulate innovation for strategic materials and influence national prosperity. Using the recommendations above, a National Innovation Policy for strategic materials focused on developing diversified and interdependent value chains and aligned with the Porter Diamond principles is the best response to the challenges in the mining industry.

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# Foreign Investment Critical to Mining Industry's Success

By: Mr. Doug O'Neill

## I. Introduction

The United States faces a monumental challenge in securing the supply of minerals critical to national security in the face of an aggressive China pursuing market dominance. To ensure reliable access to these minerals, the United States must cooperate with foreign nations through trade and investment. Foreign direct investment (FDI) plays a vital role in the mining sector worldwide by providing essential financial capital and technology in this notoriously difficult and complex industry. The U.S. mining sector is poised to benefit greatly from FDI given the country's positive investment climate, but complicated regulatory and legal hurdles cast a shadow over the sector's attractiveness. Meanwhile, U.S. and allied nations' mining companies investing overseas often operate in shifting policy landscapes that belie the predictability they cherish. To compete with China for minerals that form the elemental foundation of the U.S. economy and national security, the U.S. government will need new policy actions to attract additional foreign investment in the U.S. mining sector and facilitate the success of U.S. and other western companies' investments in key mineral-rich countries overseas.

## II. Foreign Investment Important to Mining Industry's Success

Two main activities firms undertake to access foreign markets and resources are trade and investment. While trade entails an exchange of goods and services across borders, foreign investment is broadly defined as capital flows from one country into another that grants the foreign investors extensive and lasting ownership stakes in domestic companies and assets.<sup>1</sup> Firms often use FDI to diversify their market exposure, lower operating costs, or enjoy preferential tariffs, among other reasons. Companies structure overseas investments in various ways. Examples include forming joint ventures, creating overseas subsidiaries, acquiring voting stock in a foreign firm, or pursuing mergers and acquisitions.<sup>2</sup> Two main types of FDI are horizontal and vertical.<sup>3</sup> Horizontal is when a company simply expands its operations and activities to a foreign country. Vertical occurs when firms invest overseas to move to a new supply chain level. Countries benefit from foreign investment by gaining new financial capital, technology, innovation, training, management, marketing, and corporate governance practices.

Due to the challenging nature of mining, foreign investment is often critical to the sector's success in many countries. Mining in this paper refers to the extraction of minerals and the initial upstream production stages of these minerals into refined mineral elements for onward sale as a raw material commodity. The essay will concentrate but not exclusively focus on the 35 mineral commodities the U.S. Geological Survey (USGS) identified as critical to U.S. economic and national security in 2018.<sup>4</sup>

Mining requires significant upfront capital investment, often in the billions of dollars. This capital becomes sunk costs until production occurs. Mining also requires a long-term commitment; mines can take up to a decade or more to move from discovery to production.<sup>5</sup> Investment horizons last 30 years or more.<sup>6</sup> Mining often requires complex technology, such as the complicated chain of extracting, separating, refining, and purifying rare earth ores into oxides. High levels of commodity price uncertainty and discrepancies between actual versus

estimated values of reserves make it difficult for companies to assess whether their return on invested capital (ROIC) will surpass the weighted average cost of capital for a project.

These factors create significant risks that many investors are unwilling to take. These headwinds make it difficult for mining companies to “achieve the level of return required to compete with alternative asset classes for investment,” according to the consultancy Behre Dolbear.<sup>7</sup> For example, despite a surge in expected demand for clean energy, many small mining companies are struggling to secure sufficient investment capital to mine the metals required for green technologies.<sup>8</sup> Australia-based Jervois Mining is fighting to attract the \$100 million it needs to develop a cobalt mine in Idaho.<sup>9</sup> Cobalt is critical to building batteries for electric vehicles.<sup>10</sup> The company claims the mine could produce more than 15% of annual U.S. cobalt consumption.

Tapping into the resources of foreign firms can help countries overcome these obstacles and develop their mining sectors. Indian economist Dr. K.K. Chatterjee summarizes:

Capital mobility in the business of exploration and mining has become common in the globalized economy mainly because, in many countries which are rich in mineral resources, there is acute dearth of both capital and sophisticated technology for (i) exploring and exploiting the resources—particularly the deep-seated low-grade ones located in difficult and complex geological conditions and (ii) processing and recovering mineral and metal values—particularly those of high-value associated minerals present in minuscule quantities of parts-per-million or even parts-per-billion.<sup>11</sup>

### **III. Keys to Attracting Foreign Investment**

To attract foreign investors, a nation or sub-national jurisdiction must offer both economically viable mineral reserves and a favorable policy environment that minimizes risk and maximizes predictability for foreign companies.<sup>12</sup> When deciding where to invest, mining companies assess not only a project’s expected rate of return but the level of political and business risk.<sup>13</sup> A favorable investment climate in mining includes political stability, predictable and efficient policies and regulations, relevant infrastructure, tax stability, transparent governance, data availability, skilled labor, and an independent judiciary. These factors provide firms confidence that their foreign investments will provide sufficient and predictable ROIC that validates the large, long-term capital investments required in mining.

Because countries compete for foreign investment, however, a country’s success in attracting investment depends less on the absolute attractiveness of its business climate than on its attractiveness relative to other nations, an essential concept for governments seeking to attract investment.<sup>14</sup> The ongoing competition between mining powerhouses Australia and Canada to attract mining FDI illustrates this concept of relativeness. Both have attractive investment climates and well-developed mining sectors, but companies can still choose one over the other.

Countries also use a broad range of fiscal instruments to attract investment, such as tax holidays, reduced royalties, import duty relief, stabilized tax rates, and tax credits. OECD research indicates tax incentives alone do not attract investment, however. Mining companies typically consider other policy factors more critical to investment decisions because the mining sector revolves around unmovable location-specific resources, making investment less mobile and less responsive to tax incentives.”<sup>15</sup> World Bank experts contend the impact of royalty rates on foreign investment rates can be very minimal or dramatic, depending on the circumstances and the type of royalty.<sup>16</sup>

#### **IV. United States is an Attractive FDI Destination but Hurdles Remain**

Thanks to its overall welcoming investment climate, the United States is a leading destination for FDI globally, attracting \$246 billion in economy-wide FDI inflows in 2019.<sup>17</sup> As in other countries, foreign investment is important to the U.S. mining sector. FDI stock in the U.S. mining sector totaled \$37.8 billion in 2019, a rise of roughly 300 percent from the approximately \$10 billion in FDI stock in 2000, according to the U.S. Bureau of Economic Analysis.<sup>18</sup> Of this FDI stock, \$29.9 billion comprised foreign investment in metal ore mining, including \$22 billion in gold and silver and \$5.8 billion in copper, nickel, lead, and zinc ores. Top investors are companies based in Australia, Canada, and the UK.<sup>19</sup> Mexico's Grupo Mexico SA de CV is also a major player in copper mining.<sup>20</sup>

Including both geologic and policy attractiveness, the United States is the third most attractive region in the world for mining investment, according to the Fraser Institute's Annual Survey of Mining Companies 2020.<sup>21</sup> Australia earned the top spot, followed by Canada.<sup>22</sup> The Fraser Institute surveys mining companies on the investment attractiveness of 77 jurisdictions from geological potential and policy perspectives.<sup>23</sup> The United States was the top-ranked region on policy alone.<sup>24</sup> Respondents indicated approximately 40 percent of their investment decisions were determined by policy factors and 60 percent on mineral potential.<sup>25</sup>

The Fraser Survey results on the U.S. investment climate match the assessment of many consultancy groups. The Behre Dolbear consultancy labels the U.S. mining sector a "paradox" in that its "experienced governmental and financial sectors contribute to high investor confidence," but public concern over environmental impacts "leads to an onerous permitting process that creates sufficient uncertainty to sometimes destroy the viability of new projects."<sup>26</sup> Foreign investors must navigate a complicated assortment of complex environmental regulations, such as time-intensive environmental impact statements required under the Federal National Environmental Policy Act.<sup>27</sup> Multiple agencies at the federal, state, and local levels administer an array of rules while outside parties may legally challenge government permitting decisions.

The investment experience of Anglo-Australian giants Rio Tinto and BHP in Arizona's Resolution Copper Mine exemplifies the complexity of the permitting process. The companies first explored and began developing more than 17 years ago but are yet to secure the requisite permits. Economic impact assessments estimate the mine could supply up to one-quarter of U.S. copper demand over 60 years.<sup>28</sup> The permitting process has been underway since 2013. The project came close to acquiring its permits in early 2021, but the new Biden Administration put the project on hold in March 2021 amid opposition from environmental and Native American groups.<sup>29</sup> The San Carlos Apache Tribe had filed a lawsuit in January 2021 to stop the transfer of their sacred tribal land from public ownership into private ownership to prevent the destruction and desecration of their land.<sup>30</sup>

Many local political leaders support the mine for its economic benefits, including Arizona Governor Doug Ducey.<sup>31</sup> He said, "Undoing lengthy, comprehensive, and already-completed federal environmental studies on a whim with the changing of federal administrations doesn't work. This type of activity threatens an untold number of major projects in Arizona and around the country."<sup>32</sup> Rio Tinto (55 percent ownership) and BHP (45 percent) have spent \$2 billion in development costs but have not produced any copper, an experience that could deter other FDI into the United States.<sup>33</sup>

The Fraser Survey reveals the investment climate is not homogenous throughout the United States, and state-level policies affect the U.S. investment climate. Idaho and Wyoming were ranked as the top two jurisdictions worldwide in the 2020 Annual Survey's Policy

Perception Index.<sup>34</sup> Nevada, Utah, Arizona, and New Mexico also made the top 10.<sup>35</sup> California sits much further down the list at 62<sup>nd</sup> place, however. Mining firms gave Idaho and Nevada positive marks for political stability, infrastructure, and socioeconomic agreements.<sup>36</sup> Significant concerns over the enforcement of environmental regulations, the state's labor regulations, and labor skills availability helped dragged down California's ranking to the bottom third.<sup>37</sup>

## **V. Balancing Attracting FDI with National Security Risks**

As the United States attracts investment in mining, especially in critical minerals, it has to carefully balance the benefits of foreign investment with its risks to national security. The U.S. government screens foreign investment for national security risks through the Committee on Foreign Investment in the United States (CFIUS), an interagency body chaired by the U.S. Department. CFIUS reviews, investigates, monitors, conditions, and prohibits foreign investments into the United States on national security grounds. Prompted by growing fear of Chinese investments, the 2018 Foreign Investment Risk Review Modernization Act (FIRRMA) significantly expanded the authority of CFIUS to include reviews of minority share investments in key strategic sectors. CFIUS is not required to review mining investments, but it can review any transaction it deems a national security risk.<sup>38</sup> Canada recently tightened its screening guidelines for proposed foreign investments in companies specializing in 31 critical minerals.<sup>39</sup> CFIUS' challenge is keeping vital U.S. companies out of the hands of adversaries but in a way that does not stifle legitimate FDI. If CFIUS overuses its tools to block investments, it could prompt foreign nations to stop U.S. companies from investing in critical minerals projects.<sup>40</sup>

While the threat of Chinese investment compromising U.S. companies is real, not all Chinese investment is necessarily a threat. Many experts appropriately cite the Chinese acquisition and closure of U.S. rare earth magnet maker Magnequench's U.S. plant two decades ago as indicative of China's threat, but Chinese investment in the only active U.S. rare earth mine offers a different lesson today.<sup>41</sup> The Chinese rare earths company Shenghe Resources Holding has an approximately 9 percent stake in MP Materials, a U.S. company that operates a rare earth mine in Mountain Pass, California. MP Materials executives assert that Shenghe's investment in 2018 brought much-needed financial capital and critical technical knowledge of the company's dormant rare earths processing system, such as the chemical mixtures needed to refine the ore.<sup>42</sup> Shenghe's stake also helped MP Materials secure Chinese market access to sell its raw material to processors who are located almost exclusively in China. MP's CEO James Litinsky repeatedly makes assurances China does not control his firm. Litinsky said, "If the (U.S.) Department of Defense came to us and said, 'We need product, we'll sell there first.'"<sup>43</sup>

## **VI. Outward Foreign Investment Also Critical to Securing Mineral Supply**

Along with inward investment, foreign investment by U.S. companies overseas can play a significant role in securing the supply of critical minerals for the United States. Control of these resources by U.S. or allied nations' companies ultimately increases the likelihood the United States will have reliable access to critical minerals. In a crisis, the U.S. government could invoke the Defense Production Act to compel or incentivize U.S. mining companies overseas to prioritize meeting U.S. industrial needs.<sup>44</sup> Overseas investments by U.S. and allied nations' companies can prevent China from dominating mineral markets and obstructing U.S. supply.

Some of the largest mining companies in the world are headquartered in the United States, Australia, Canada, and the UK.<sup>45</sup> These companies compete worldwide with new Chinese giants such as Zijin Mining and state-owned China MinMetals Corporation. While

investing in each other's countries has its challenges, western firms face more difficulties when investing in developing countries and emerging markets with unwelcoming investment climates. Western firms are subject to the political whims or policy changes of governments, such as when Tanzania changed its mining code to one "completely hostile to foreign investment," as one mining executive told the Fraser Institute.<sup>46</sup> Sixty-five percent of minerals mined in 2018 were produced in countries considered politically unstable, according to an Austrian government report.<sup>47</sup>

The challenges U.S.-based mining company Freeport McMoRan has faced in its Grasberg gold and copper mine operation in Indonesia illustrate the difficulties western firms experience overseas. Grasberg holds the single largest known gold reserve and the second largest copper reserves in the world.<sup>48</sup> Indonesia is rich in minerals but a difficult place to invest. The country ranks third in geological potential but 69 of 77 in the Fraser Policy Perception Index.<sup>49</sup> The low-ranking stems from the Indonesian government's persistent changes to mining regulations since passing a new Mining Law in 2009. The changes have generated significant uncertainty for foreign investors as Indonesia struggles to balance the rights of foreign firms with state interests. The changes included forced renegotiations of contracts for higher royalties, divestment to local partners, additional local content, and domestic value-add processing of mineral ore prior to export.<sup>50</sup> Foreign companies have found complying with the requirements difficult.<sup>51</sup> Increased royalty rates represent a global challenge to companies. The World Bank says, "The regressive nature of royalties (that is, the effective tax rate decreases as operational profitability increases) has prompted the renegotiation of contracts during resource booms, as governments have felt entitled to a share of the windfall profits."<sup>52</sup>

In enforcing these new rules, the Indonesian government required Freeport to divest its 90 percent share in the Grasberg mine. Freeport now holds a 48.8% share, and state-owned mining company PT Inalum owns the remaining 51.2%.<sup>53</sup> The forced divestiture of its majority share came after Freeport spent 50 years investing in Indonesia. The company built up infrastructure, power plants, skilled labor, and housing in the remote jungles of Papua for mining operations.<sup>54</sup> Political analysts assessed the Freeport divestment would give Indonesian President Joko Widodo a political bump for his 2018 election campaign.<sup>55</sup> The move also matched growing "resource nationalism" worldwide as governments seek to capture more value for the state.<sup>56</sup> In this, governments must be careful to maintain an acceptable balance of value distribution for all parties and avoid deterring investment by making projects no longer economically viable.

For the United States and its allies, security of supply will be especially contentious for the 11 nonfuel critical minerals for which the United States and China are both import reliant.<sup>57</sup> As Great Power Competition intensifies, the USGS predicts China could steer the supply of these minerals exclusively to China to satisfy their needs and disrupt supply to the United States.<sup>58</sup> An example of China's use of foreign investment to secure the supply of one of these 11 shared import reliant minerals is niobium. This element serves as an alloying agent in high-strength steel. Approximately 85% of world niobium production comes from a single mine in Brazil owned by the firm CBBM. In 2011, a consortium of five Chinese State-owned enterprises (SOEs) paid \$1.95 billion for a 15% equity share in CBBM.<sup>59</sup> In 2016, the Chinese SOE China Molybdenum Company acquired 100% of a second Brazilian niobium mine.<sup>60</sup> These China investments did not grow the global niobium supply but likely diminished the niobium supply risk for China.<sup>61</sup> Chinese firms have also acquired equity stakes in lithium firms in Australia and Chile, a rare earth deposit in Greenland, and cobalt operations in the Democratic Republic of

Congo, Papua New Guinea, and Zambia.<sup>62</sup> USGS research indicates resource rivalry between the United States and China is likely to be most contentious in South America and South and Central Africa.<sup>63</sup>

## **VII. Policy Discussion on Promoting Inward and Outward Investment to Secure Supply**

To more effectively tap into its vast mineral resources and mitigate foreign dependence, the United States should undertake new policy measures to attract foreign investment. First, the U.S. government could establish a “Minerals Policy Unit” within the Executive Office of the President to analyze the maze of U.S. mineral policy, formulate recommendations, and drive policy reform. Policy reforms should focus on rationalizing and streamlining the regulatory and permitting processes divided between multiple agencies, including the Bureau of Land Management, U.S. Forest Service, U.S. Geological Survey, and state and local-level agencies.<sup>64</sup>

Second, the government should more aggressively market and promote the U.S. mining sector internationally. The Department of Commerce is the primary agency responsible for promoting foreign investment, yet its premier investment facilitation website, SelectUSA, does not feature the mining sector.<sup>65</sup> The U.S. government, led by the Commerce Department working with domestic industry groups, should ramp up marketing efforts to promote the U.S. mining sector overseas. The U.S. government could sponsor foreign mining delegations to the United States, fund annual mining expos, and facilitate connections between foreign and domestic companies through diplomatic missions. The United States should learn from Australia and Canada’s assertive and savvy marketing and promotion strategies.

Third, the U.S. government should increase access to data on U.S. reserves through improved mapping and surveying. The World Bank states, “A well-funded geological survey can act as a tremendous stimulus to investor interest in geological potential.”<sup>66</sup> Less than 18 percent of U.S. land has been geologically mapped at a scale for mining decisions.<sup>67</sup> The government’s data provision addresses two market failures from an economics perspective.<sup>68</sup> First, because early-stage geoscience is a public good, the private sector is disincentivized to supply the data as it must share the benefits. Second, the uncertainty of a successful prospect is so high without adequate data, mining firms cannot properly value a prospect.<sup>69</sup>

The U.S. government should also institute new policy initiatives to significantly boost mining investment opportunities for U.S. and allied companies overseas. High-level, sustained diplomatic campaigns through bilateral talks, industry coordination, commercial advocacy, and public diplomacy could help companies by steering key source countries toward greater governance predictability and transparency in the mining sector. This improved investment climate should help level the playing field for U.S. companies competing with opaque state-owned Chinese companies and decrease risks and uncertainty for U.S. investors.

The United States through agencies like USAID should also support and facilitate cooperation between governments, foreign firms, and local communities to promote sustainable operations by foreign mining companies. Such collaboration can help U.S. and western companies earn social acceptance from local communities for their projects or their social license to operate. Such consultations can help stakeholders reach consensus on how a nation divides its mining income between local communities, national governments, and the private sector.<sup>70</sup> One example is the Peruvian Canon Minero law that mandates 50 percent of mining taxes paid to the national government be funneled back to regional (25 percent) and municipal governments (75 percent).<sup>71</sup> This consultative process must be continuous. The concept of fair value distribution changes over time as expected production levels become actual levels, and price shifts change a

mine's profitability.<sup>72</sup> Continuous consultations can lead communities to view U.S. and allied firms as responsible actors in direct contrast to non-transparent Chinese firms. These steps should increase the likelihood that governments and communities will welcome U.S. and allied companies and avoid pendulum-like changes to policy like Freeport experienced in Indonesia.

### VIII. Conclusion

Countries around the world depend on foreign capital and technology to access their valuable mineral resources. The United States must recognize the benefits of foreign investment as it strengthens its supply chain for the critical minerals that are the atoms of the nation's economic dynamism and defense industrial base. U.S. competition with China for access to these minerals promises to be intense in the coming decades, especially minerals for which both countries are import reliant. If it is to compete successfully, the U.S. government must develop and implement new policies to attract foreign investment into the United States and better facilitate U.S. and allied companies' investments overseas. Similar to investing in a mining project, solving this complex problem will be a long-term endeavor requiring commitment, patience, and foresight. The time is now for the government to start this important undertaking and make a clear investment in the future of the U.S. economy and its national security.

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<sup>72</sup> Ibid, 13.

# HUMAN CAPITAL IN STRATEGIC MATERIALS

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## Introduction

The strategic materials industry has garnered much attention in recent years, given the depth, breadth, and exponential growth of extracted mineral applications, particularly in the context of great power competition with concerns over supply chain vulnerabilities. This is rightfully so, given the United States' (and other nations') staggering dependence on the People's Republic of China (PRC) for most of those minerals. While the nation enjoys vast natural resources and hosts a stable government and economic system (though both have considerable room for improvement), the US lacks a sufficient talent pipeline. The nation requires such a workforce to lead and operate throughout the materials cycle of exploring, extracting, beneficiating, smelting, fabricating, and producing.<sup>1</sup> Consequently, as government, industry, and academic leaders consider the challenges involved in the strategic materials sector, the importance of human capital quickly becomes apparent.

The strategic materials industry – and especially the mining industry responsible for much of the materials cycle – is vast and diverse. Its labor demands are equally extensive, ranging from unskilled labor to skilled technicians to highly specialized, advanced degree experts. Despite its strategic importance, increased attention, and very favorable financial incentives (i.e., compensation), the future of the mining workforce remains a major risk. There are four severe, yet addressable, challenges creating this human capital dilemma: an aging workforce, a lack of skilled labor, a lack of mining-related STEM programs, and a grievous image problem.

## Mining Industry Labor Statistics

The US Bureau of Labor and Statistics (BLS) estimates that the mining industry (excluding the oil & gas segments) employs 182,270 people or roughly 0.1% of the US workforce.<sup>2</sup> According to BLS, the mining subsector is broadly defined to include “ore extraction, quarrying, and beneficiating (e.g., crushing, screening, washing, sizing, concentrating, and flotation), customarily done at the mine site.”<sup>3</sup> The strategic materials sector includes more, ranging from minerals identification and exploration, through mining, to metals production (processing and refining). Unfortunately, these subsectors (some cross-functional, some unique) make accurate statistics difficult to aggregate.

Compensation in the mining industry is remarkably high and distributed. Using the Census Bureau's American Community Survey data, Data USA estimates the nonmetallic mining & quarrying industry average salary is \$65,838, making it 76 out of the 269 reported industry groups.<sup>4</sup> Metal Ore Mining rates are even better at \$84,419/year, placing it 36 out 269.<sup>5</sup> Even more impressive, the industry has a Gini coefficient of 0.299 – national average is 0.478 – which means wages are distributed relatively equally across the industry workforce.<sup>6</sup>

The Society for Mining, Metallurgy & Exploration (SME) estimates the mining industry will add 11,000 to 13,000 jobs per year over the next 20 years, driven by retirement and departure of the current aging workforce and the increase in demand for resource production.<sup>7</sup> Despite strategic importance, impressive compensation, and projected growth, the industry wrestles with labor shortfalls most experts predict will intensify. SME asserts that the US suffers a lack of skilled labor and an inadequate educational base to meet the current demand.<sup>8</sup>

## An Aging Workforce – Baby Boomers Forming a Silver Tsunami

Experts have provided considerable literature dedicated to the notion of a “Silver Tsunami” of Baby Boomers departing the workforce. According to AARP (formerly the American Association of Retired Persons), citing BLS numbers, 13 million workers will be 65 or older by 2024.<sup>9</sup> In the same timeframe, the workforce will increase about 5%, but the 65 and over demographic will increase 55%.<sup>10</sup> The National Mining Association (also using BLS data) reports the median age in the mining industry is 46 – two years older than the national average – with a median of 16 years’ experience. These staggering numbers translate into more than half of the current mining labor force likely being retired by 2029.<sup>11</sup> Even more pointed, BLS reports the “nonmetallic mineral mining and quarrying” sector median age is 48, and the mining sector overall touts less than 27% of the workforce being aged 34 and younger.<sup>12</sup>

Not surprisingly, a 2018 Mercer North American Mining Survey found 67% of respondents concerned about the aging workforce, and only 56% reported confidence in their talent pipeline.<sup>13</sup> The most common talent pipeline gaps reported were in technical professionals (100% respondents), followed by gaps in leadership pipelines (75% reported site managers, forepersons, or superintendents).<sup>14</sup> The older workforce poses a talent pipeline risk and presents added health and safety risks, particularly in such a physically demanding, dangerous sector. In addition, while older employees are generally more dependable, according to AARP (citing OSHA and BLS data), workers aged 55 and older experience twice as many days away from work due to nonfatal occupational injuries and illnesses, with substantially higher restricted activity and bed days.<sup>15</sup> These factors combined present a staggering problem for the mining industry, most notably a precipitous loss of leadership and skilled labor and increasing health and safety concerns. Most impactful, though, is the drain of skilled labor that the mining industry relies upon so heavily.

## An Exodus of Critical Skilled Labor

The mining industry, like many other industries, runs on skilled labor. From heavy equipment operators to plumbers and electricians, the complex nature of mining operations cannot function without tradespeople. Data USA (a Deloitte, Datawheel, and others' collaborative effort) is a "comprehensive website and visualization engine of public US Government data."<sup>16</sup> Data USA separates mining industry information into coal mining, metal ore mining, support activities for mining, and nonmetallic mineral mining and quarrying. As there is no clear industry group for strategic materials, metal ore mining and nonmetallic mining provide practical comparative data sets that provide a workforce composition illustrated in figures one and two.<sup>17</sup>

Figure 1: Nonmetallic Mineral Mining Occupations



Source: <https://datausa.io/profile/naics/nonmetallic-mineral-mining-quarrying>



Industrial Safety and Hygiene News (ISHN) reports that only one new employee enters for every five skilled laborers retiring out of the sector.<sup>19</sup> As much as Baby Boomers were drawn to skilled trades, younger generations generally are not. The Department of Defense's Industrial Capabilities Report to Congress for the fiscal year 2020 states, "adverse demographics and persistent biases against industrial trades careers among parents and educators," along with "educational policies that steer students toward four-year college programs," have severely stifled the skilled trades sector.<sup>20</sup> Patricia Hsieh, President of a San Diego-area community college, put it another way in her speech at the 2017 American Association of Community Colleges conference: "Negative attitudes and misconceptions persist even in the face of the positive statistical outlook for the job market for these middle-skill careers... It is considered a second choice, second-class. We really need to change how people see vocational and technical education."<sup>21</sup>

While the US education system emphasizes post-secondary education and four-year degrees (for good reasons), the trade skills offer tremendous, high-demand career opportunities that frequently go unfilled. Sadly, the DoD Industrial Capabilities Report describes a dire lack of available training and education programs for skilled labor. It gauges the vocational training network (including dedicated career training and education schools) have experienced "decades of neglect" and are severely limited in their capacity to impart relevant skills.<sup>22</sup> The US must reinvest in these skilled labor training programs and make a concerted effort to change the narrative in American high schools regarding the value and opportunities of these career paths. Not just the mining or strategic materials sector, but all US industries depend upon it.

## **STEM Dilemma – Foundations and Degrees**

In addition to the skilled labor shortage, the strategic materials workforce also suffers from a general deficiency of science, technology, engineering, and math (STEM) education in America. While only 3% of the mining industry jobs require a degree, employees with a foundation in STEM (i.e., provided through K-12 education) are most successful and best serve the strategic materials sector.<sup>23</sup> The diverse nature of the sector, with its complex technical processes and operations, all but demand some basic understanding of STEM principles. That demand for a STEM foundation will undoubtedly increase based on current trends in innovation and technology integration.

Even though most mining jobs do not require a four-year degree, many of this sector's jobs require some education beyond high school.<sup>24</sup> The additional education is typically filled by community colleges that provide a "direct alignment among their programs of study, the credentials they bestow, and industry education and skill requirements."<sup>25</sup> These post-secondary schools generally offer certificates, credentials, and associates degrees and provide an economical alternative to the first two years of a four-year degree program.<sup>26</sup> They also tend to be more flexible and responsive to align their academic programs to local industry needs, mainly through very effective industry-college partnerships.<sup>27</sup> Moreover, certification programs provide an essential mechanism for developing and sustaining a technical workforce, which improves the mining industry and serves to address the exodus of skilled labor overall.

Improvements to K-12 STEM foundations, community, and technical colleges meet most of the mining industry's workforce needs but specialized higher education (bachelor's and master's degrees) remains indispensable. Mining-related degrees cover such critical areas as geoscience (e.g., geochemistry, geophysics, mineralogy, hydrogeology); mechanics (e.g., geomechanics,

fracture mechanics, and fluid mechanics); thermodynamics; spatial analysis; control engineering (e.g., systems engineering, control theory); chemistry and metallurgy (particularly in the separation and refinement processes for certain minerals).<sup>28</sup>

There is considerable literature on how the US suffers from a shortage of post-secondary STEM students and fails to adequately compete with its Asian counterparts to produce scientists and engineers. The mining-related disciplines of scientific study are no different. For example, mining engineering degrees ranked 277 in popularity out of 384 fields of study in 2019 with only 188 graduates.<sup>29</sup> Mining & mineral engineering programs (a broader category available at 19 institutions in the US) awarded only 340 degrees in 2019, marking a decrease of 22% from 2018.<sup>30</sup> Figure 4 depicts the 15 academic institutions that awarded those degrees.

Figure 4: 2019 Mining and Mineral Engineering Degree-Producing US Programs

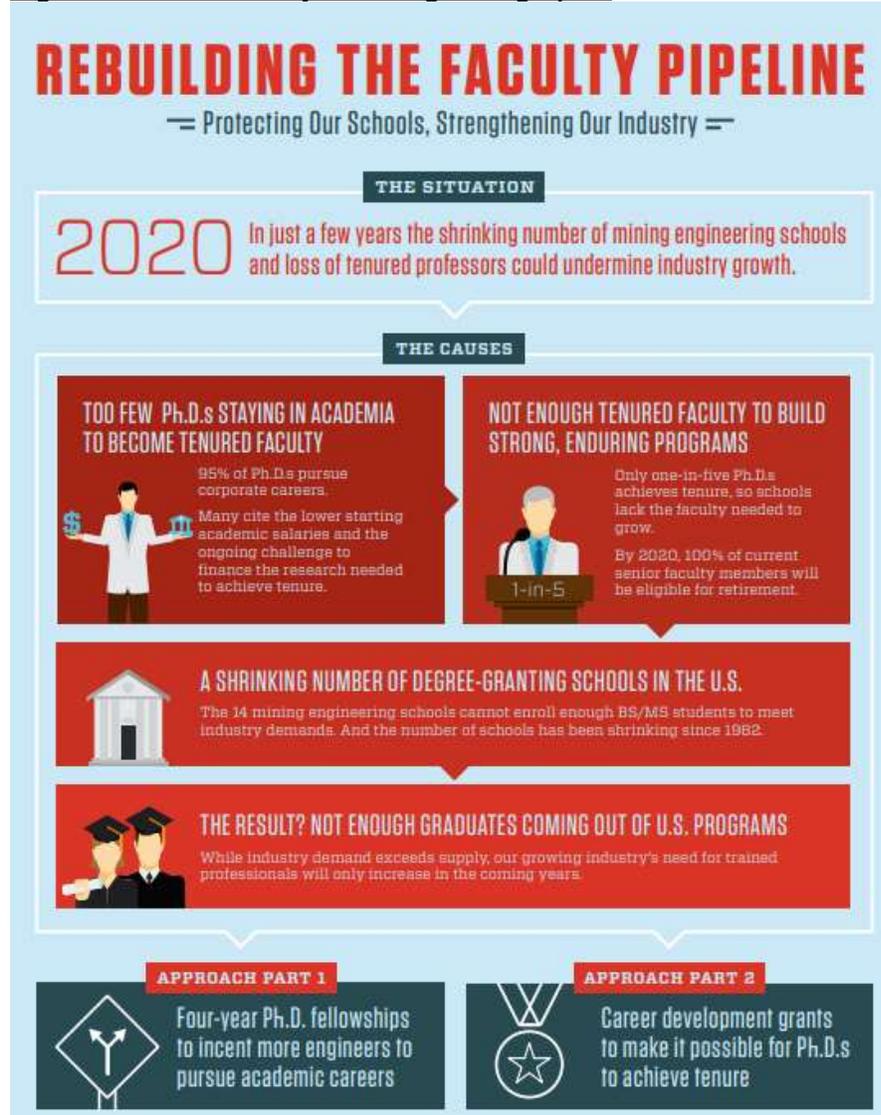


Source: <https://datausa.io/profile/cip/mining-mineral-engineering>

Other mining-related degrees include metallurgical engineering (235 degrees conferred in 2019, at an increase of 8%) and geochemistry degrees (40 degrees conferred, up 8%).<sup>31,32</sup> Even the Colorado School of Mines – arguably America’s premier mining institution – had only 4% of its 2019 alumni graduate with a metallurgical engineering degree and only 6% with a geological and geophysical engineering degree.<sup>33</sup> These small numbers not only fail to meet the industry’s needs, but they also place the academic programs at risk of cancellation by universities facing tough fiscal decisions. The US has experienced a high of 25 institutions with mining engineering programs in 1982 and a low of only 14 in 2009, with a current number of 18.<sup>34,35</sup> In comparison, China reports more than 30 institutions offering academic mining programs, while there are seven in Australia and six in Canada.<sup>36,37,38</sup>

As programs dwindle, so does the faculty, which compounds and protracts the problem. Mining-specific faculty numbers declined from around 120 in 1984 to only 70 in 2007. These numbers create an average of only five faculty at the 14 programs in existence at the time of the report.<sup>39</sup> This presents a staggering net loss, compromising the nation’s ability to educate mining industry professionals for years.<sup>40</sup> Moreover, the last 30 years have seen a drastic reduction in federal funding of mining studies and research, and the “dissolution of the former federal Bureau of Mines removed all funding for mining schools under the Mining and Mineral Resource Institutes Act of 1984.”<sup>41</sup> Figure 5 presents a compelling infographic produced by the Society for Mining, Metallurgy and Exploration (SME) on the mining faculty pipeline.

Figure 5 – SME Faculty Challenge Infographic



Source: <https://smenet.blob.core.windows.net/smecms/sme/media/smeazurestorage/professional%20development/pdf%20files/rebuildingfacultypipeline.pdf>

These challenges manifest in America’s global standing, also. While the US typically leads the world in academic institutional rankings, this is not precisely the case with mining and mineral engineering programs. Quacquarelli Symonds, Limited (QS), a British company specializing in analyzing higher education institutions, identified the Colorado School of Mines as the top school for mining and mineral engineering, however this is the only US university in the top ten.<sup>42</sup> Only six more make it into the top 50 (Pennsylvania State at #13; University of Arizona at #20; Virginia Polytechnic Institute & State University at #22; University of Colorado Boulder at #28; University of Utah at #32; Missouri University of Science & Technology at #43).<sup>43</sup> Australia touts five of the top ten, Canada comes in with three, and Chile’s Universidad de Chile rounds out the top ten.<sup>44</sup>

Sadly (but perhaps not surprisingly), the US failed to make Shanghai’s top 10 at all. The University of Pennsylvania and the Colorado School of Mines ranked #24 and #26 respectively,

according to the Shanghai Ranking Consultancy, an independent organization ranking world universities since 2009.<sup>45</sup> Their top 10 consists of 7 Chinese universities (Central South University #1) and 3 Australian universities (University of Western Australia #4).<sup>46</sup> Figure 6 portrays the QS rankings, and Figure 7 depicts Shanghai’s rankings.

**Figure 6: TopUniversities.com’s Mineral Mining Engineering Rankings**

↑ Rank	↓ University	↓ Overall Score
1	 Colorado School of Mines 📍 Golden, United States	93.5
2	 Curtin University 📍 Perth, Australia	85.2
3	 The University of Western Australia 📍 Perth, Australia	80
4	 The University of New South Wales (UNSW Sydney) 📍 Sydney, Australia	79.6
5	 The University of Queensland 📍 Brisbane, Australia	79.3
6	 McGill University 📍 Montreal, Canada	78.1
7	 Monash University 📍 Melbourne, Australia	76.6
8	 Queen's University at Kingston 📍 Kingston, Canada	75.7
9	 Universidad de Chile 📍 Santiago, Chile	75.1
9	 University of British Columbia 📍 Vancouver, Canada	75.1

Source: <https://www.topuniversities.com/university-rankings/university-subject-rankings/2020/engineering-mineral-mining>

Figure 7: Shanghai’s Mineral Mining Engineering Rankings

World Rank	Institution*	Country/Region	National/Regional Rank	Total Score
1	Central South University		1	262.2
2	China University of Mining and Technology - Xuzhou		2	259.3
3	China University of Geosciences (Beijing)		3	226.4
4	The University of Western Australia		1	225.1
5	China University of Mining and Technology - Beijing		4	214.2
6	Sichuan University		5	207.0
7	The University of Adelaide		2	205.0
8	China University of Geosciences (Wuhan)		6	204.2
9	Monash University		3	203.0
10	Shandong University of Science and Technology		7	196.0
11	University of Lorraine		1	193.2
12	The University of Queensland		4	192.0
13	The University of New South Wales		5	189.4
14	Northeastern University (Shenyang)		8	184.5
15	Kyushu University		1	178.0
16	The University of Hong Kong		1	177.7
17	Chongqing University		9	177.6
18	McGill University		1	177.4
19	Curtin University		6	174.8
20	University of Toronto		2	174.7
21	Nanjing University		10	174.6
22	University of Alberta		3	169.4
23	Imperial College London		1	169.2
24	Pennsylvania State University - University Park		1	167.7
25	University of Tasmania		7	166.6
26	Colorado School of Mines		2	166.5

Source: <http://www.shanghairanking.com/shanghairanking-subject-rankings/mining-mineral-engineering.html>

There is no shortage of literature on the need for (and mechanisms to leverage) improving US post-secondary institutions. The most common theme is to increase funding for research. Many experts and agencies, including a report from the National Research Council, offer that funded research attracts faculty and students, builds the faculty’s expertise, and improves the academic institution’s standing.<sup>47</sup> The US Department of Energy makes roughly the same assertion in its “Critical Minerals and Materials” report:

“DOE can play a central role in training the next generation of scientists and engineers needed to address critical mineral and material challenges. For example, the National Laboratories leverage the DOE Science Undergraduate Laboratory Internships (SULI) program and the NSF Research Experiences for Undergraduates (REU) programs to engage undergraduates in research and establish a pipeline for future graduate students.”<sup>48</sup>

Increased funding for research will also inevitably lead to more significant innovation. An industry wrought with human capital shortfalls desperately needs innovation to compensate. In turn, innovation will increase productivity, shift the demands for skilled labor, and improve working conditions. These factors combine to help draw more workers into the industry, relieving the pressure of the currently dwindling workforce.

### **Image Matters – a LOT**

An aging workforce, an already critical shortage of skilled labor, and systemic challenges of inadequate STEM education are problems enough, but they are really symptoms of a more endemic problem. While large portions of the industry’s operations occur in austere locations, conducted under often harsh environmental conditions, several very popular professions do, too. The *real* problems plaguing the strategic materials sector, especially the mining industry, are negative public image and lack of public awareness. The common (and largely inaccurate) image of mining is a dangerous, dirty, archaic industry that requires extensive regulation to ensure the safety of its employees, let alone the environment.<sup>49</sup> Large portions of the American public are mostly unaware of the far-reaching applications of extracted minerals, particularly in technology applications (like smartphones and clean energy).<sup>50</sup> They also commonly fail to realize there are no adequate substitutes or alternatives for the minerals (unlike some fossil-fuel applications), and few Americans appreciate the vulnerability of the current supply chain for most of those minerals.<sup>51</sup> Chris Hindle, Chief Commentator of *Mining Beacon*, put it very plainly when he wrote, “Amongst myriad concerns, including permitting, financing, and safety, miners need to wake up to the industry’s much larger problem, namely that we are not trusted and suffer from a dreadful image.”<sup>52</sup> The 2020 Global Mining Survey Report, produced by the global audit, tax, and advisory firm KPMG, noted that “social license to operate” is the fourth most critical concern of the 16 countries surveyed.<sup>53</sup>

To combat this image problem, industry leaders, academia, and most notably, the government (at all levels) must wage a concerted public relations campaign to educate the public. This campaign should include the importance of the industry and its benefit to the manufacturing value chain (including defense industry implications and especially “green” industry applications) and should partner with environmental groups to celebrate the clean-energy uses of extracted minerals and recognize the US as an industry leader in environmentally responsible mining practices.<sup>54</sup> The campaign should also include engagement through the Department of Education as well as state and local school boards to modify earth science and social science curricula. Classroom instruction needs to better educate young Americans on mineral basics (including their typical applications) and the *modern* mining industry (including its role in timely, essential issues and technological innovation).<sup>55</sup> An aggressive information campaign will also improve the workforce's current lack of diversity as more people (of more varied demographics) become interested and move to join the industry.

### **Conclusion**

The strategic materials sector suffers crippling human capital challenges that will derail any efforts to reduce critical mineral supply chain vulnerability if left unchecked. An aging, retiring workforce and academic faculty, both with scant replacements, threatens the talent pipeline for potentially a generation or more. The lack of research, academic pursuits, or even a general understanding or interest in mineral extraction undermines the domestic mining innovation base, which erodes the nation’s role as a technology and innovation global leader. Moreover, the lack

of skilled labor threatens the *entire* American industrial base, not just strategic materials. These issues, coupled with a severe image problem, require immediate action to secure the strategic materials sector and enable the US to face (and lead through) the challenges and opportunities of tomorrow.

## End Notes:

<sup>1</sup> Adopted from US Geological Survey, *Minerals, National Security, Foreign Affairs*, 17 September 2014.

<sup>2</sup> “Industries at a Glance,” Bureau of Labor Statistics, accessed April 20, 2021, <https://data.bls.gov/oes/#/indOcc/Multiple%20occupations%20for%20one%20industry>.

<sup>3</sup> “Industries at a Glance,” Bureau of Labor Statistics, accessed April 20, 2021, <https://www.bls.gov/iag/tgs/iag212.htm>.

<sup>4</sup> “Nonmetallic Mineral Mining & Quarrying,” DATA USA, accessed April 21, 2021, <https://datausa.io/profile/naics/nonmetallic-mineral-mining-quarrying>.

<sup>5</sup> “Metal Ore Mining,” DATA USA, accessed April 21, 2021, <https://datausa.io/profile/naics/metal-ore-mining>.

<sup>6</sup> Ibid.

<sup>7</sup> “Workforce Trends in the U.S. Mining Industry,” Society for Mining, Metallurgy & Exploration, accessed April 23, 2021, <https://www.smenet.org/What-We-Do/Technical-Briefings/Workforce-Trends-in-the-US-Mining-Industry>.

<sup>8</sup> Ibid.

<sup>9</sup> Kenneth Terrell, “Who’s Working More? People Age 65 and Older,” AARP, November 22, 2019, accessed April 21, 2021, <https://www.aarp.org/work/working-at-50-plus/info-2019/surging-older-workforce.html>.

<sup>10</sup> Ibid.

<sup>11</sup> “Statistics,” National Mining Association, accessed April 21, 2021, <https://nma.org/category/statistics/>.

<sup>12</sup> “Labor Force Statistics from the Current Population Survey,” Bureau of Labor Statistics, accessed April 21, 2021, <https://www.bls.gov/cps/cpsaat18b.htm>.

<sup>13</sup> “American Mining Companies and the Aging Workforce,” January 11, 2019, Mercer, accessed April 21, 2021, <https://www.imercer.com/articleinsights/american-mining-companies-and-the-aging-workforce>.

<sup>14</sup> Ibid.

<sup>15</sup> “Health and Safety Issues In An Aging Workforce,” AARP Public Policy Institute, accessed April 21, 2021, [https://assets.aarp.org/rgcenter/econ/ib49\\_health.pdf](https://assets.aarp.org/rgcenter/econ/ib49_health.pdf).

<sup>16</sup> “Background,” DATA USA, accessed April 20, 2021, <https://datausa.io/about/background>.

<sup>17</sup> “Mining Industries” DATA USA, accessed April 20, 2021, <https://datausa.io/search/?q=mining&dimension=PUMS%20Industry>.

<sup>18</sup> “Vocational Skills – Skilled Trades Are In Demand As Boomers Retire,” Adecco, July 7, 2016, accessed April 22, 2021, <https://www.adeccousa.com/employers/resources/skilled-trades-in-demand>.

<sup>19</sup> Taryn Netzer, “Baby Boomers retiring, leaving many open trades positions,” *Industrial Safety & Hygiene News*, June 11, 2019, <https://www.ishn.com/articles/110888-baby-boomers-retiring-leaving-many-open-trades-positions>.

<sup>20</sup> Office of Industrial Policy, Department of Defense, *Fiscal Year 2020 Industrial Capabilities Report to Congress* (Washington, DC: GPO, January 2021), 112.

<sup>21</sup> “The Stigma of Choosing Trade School Over College,” *The Atlantic*, March 6, 2019, accessed April 26, 2021, <https://www.theatlantic.com/education/archive/2019/03/choosing-trade-school-over-college/584275/>.

<sup>22</sup> Office of Industrial Policy, Department of Defense, *Fiscal Year 2020 Industrial Capabilities Report to Congress* (Washington, DC: GPO, January 2021), 112.

<sup>23</sup> “Statistics,” National Mining Association, accessed April 21, 2021, <https://nma.org/category/statistics/>.

- <sup>24</sup> National Research Council, *Emerging Workforce Trends in the U.S. Energy and Mining Industries: A Call to Action* (Washington, DC: National Academies Press, 2013), 216.
- <sup>25</sup> Ibid. 10.
- <sup>26</sup> Ibid. 224.
- <sup>27</sup> Ibid. 224.
- <sup>28</sup> “Mining Engineering,” Colorado School of Mines, accessed May 1, 2021, <https://www.mines.edu/academics/mining-engineering/>.
- <sup>29</sup> “Mining Engineering,” College Factual, accessed May 1, 2021, <https://www.collegefactual.com/majors/engineering/mining-engineering/rankings/most-popular/>.
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- <sup>32</sup> “Geochemistry,” DATA USA, accessed May 1, 2021, <https://datausa.io/profile/cip/geochemistry>.
- <sup>33</sup> “Colorado School of Mines,” DATA USA, accessed May 1, 2021, <https://datausa.io/profile/university/colorado-school-of-mines>.
- <sup>34</sup> National Research Council, *Emerging Workforce Trends in the U.S. Energy and Mining Industries: A Call to Action* (Washington, DC: National Academies Press, 2013), 85.
- <sup>35</sup> “Mining Mineral Engineering,” DATA USA, accessed May 1, 2021, <https://datausa.io/profile/cip/mining-mineral-engineering>.
- <sup>36</sup> “Shanghai Ranking’s Global Ranking of Academic Subjects 2020 – Mining & Mineral Engineering,” Shanghai Ranking, accessed May 1, 2021, <http://www.shanghairanking.com/shanghairanking-subject-rankings/mining-mineral-engineering.html>.
- <sup>37</sup> Scarlett Evans, “Australia’s Great Mining Universities,” Mining Technology, August 6, 2020, accessed May 1, 2021, <https://www.mining-technology.com/features/australias-great-mining-universities/>.
- <sup>38</sup> “Canadian Mining Engineering University Programs,” Canadian-Universities.net, accessed May 1, 2021, [http://www.canadian-universities.net/Universities/Programs/Mining\\_Engineering.html](http://www.canadian-universities.net/Universities/Programs/Mining_Engineering.html).
- <sup>39</sup> National Research Council, *Emerging Workforce Trends in the U.S. Energy and Mining Industries: A Call to Action* (Washington, DC: National Academies Press, 2013), 85.
- <sup>40</sup> Ibid. 83.
- <sup>41</sup> “Workforce Trends in the U.S. Mining Industry,” Society for Mining, Metallurgy & Exploration, accessed April 23, 2021, <https://www.smenet.org/What-We-Do/Technical-Briefings/Workforce-Trends-in-the-US-Mining-Industry>.
- <sup>42</sup> “Mineral & Mining Engineering,” QS Top Universities, accessed May 2, 2021, <https://www.topuniversities.com/university-rankings/university-subject-rankings/2020/engineering-mineral-mining>.
- <sup>43</sup> Ibid.
- <sup>44</sup> Ibid.
- <sup>45</sup> “Shanghai Ranking’s Global Ranking of Academic Subjects 2020 – Mining & Mineral Engineering,” Shanghai Ranking, accessed May 1, 2021, <http://www.shanghairanking.com/shanghairanking-subject-rankings/mining-mineral-engineering.html>.
- <sup>46</sup> Ibid.
- <sup>47</sup> National Research Council, *Emerging Workforce Trends in the U.S. Energy and Mining Industries: A Call to Action* (Washington, DC: National Academies Press, 2013), 7.
- <sup>48</sup> Department of Energy, *Critical Minerals and Materials, U.S. Department of Energy’s Strategy to Support Domestic Critical Mineral and Material Supply Chains* (Washington, DC: GPO, 2021), 22.
- <sup>49</sup> National Research Council, *Emerging Workforce Trends in the U.S. Energy and Mining Industries: A Call to Action* (Washington, DC: National Academies Press, 2013), 235.
- <sup>50</sup> Ibid. 235.
- <sup>51</sup> Ibid. 235

<sup>52</sup> Chris Hindle, “Mining’s Brand Problem,” *Mining Beacon*, April 11, 2019, <https://www.miningbeacon.com/posts/47846-mining-s-brand-problem>.

<sup>53</sup> 2020 KPMG Global Mining Survey, <https://home.kpmg/xx/en/home/insights/2020/02/2020-mining-risk-survey-report.html>, accessed May 14, 2021.

<sup>54</sup> Ned Mamula and Ann Bridges, *Ground Breaking! America’s New Quest for Mineral Independence* (Middletown, Delaware: TERRADYNAMICS Corporation, 2018), 235.

<sup>55</sup> *Ibid.*