THE MOSAIC APPROACH:

a Multidimensional Strategy for Strengthening America's Critical Minerals Supply Chain

Report prepared by
Duncan Wood, Alexandra Helfgott,
Mary D'Amico, and Erik Romanin

Wilson Center | SUPPLY CHAIN INITIATIVE

Executive Summary

The United States faces a troubling scenario when it comes to the supply chain for critical minerals. Rapidly increasing demand, under-developed national resources, intense international competition, and years of neglect in this issue area place the U.S. at a distinct disadvantage vis-à-vis China in securing access to the metals and Rare Earth Elements that are vital for the energy transition and for geopolitical ambitions. This paper reflects the dialogue sustained by a high-level group of stakeholders in the summer of 2021 and argues that the United States must take a number of key steps to make the critical minerals supply chain more resilient.

Central among these steps are:

- **Government actions**
  - Explicitly recognize the link between critical minerals on the one hand and geopolitical and climate goals on the other
  - Prioritize the development of national resources and processing facilities in the United States, while also embracing new technological solutions
  - Focus on strengthening human capital in the critical minerals sector
  - Streamline the permitting process for opening new mines
  - Consider the stockpiling of critical minerals
- **Private sector actions**
  - Lower the risk profile of mining for investors to facilitate investment in the industry
  - Seek long-term, fixed price contracts to guarantee supply
  - Invest in new technologies to lower costs
  - Invest in human capital through universities and community colleges, as well as lifelong learning approaches
  - Highlight how mining contributes to a clean energy future
- **International actions**
  - The U.S. must work with international allies and partners to develop new resources
  - Leverage the USMCA and strong mining industries within North America
  - Work with international partners to create a global regime for critical minerals that emphasizes minimum standards for ESG

Introduction

In the summer of 2021, the Wilson Center convened a Critical Minerals Working Group, made up of stakeholders from industry, academia and civil society, to examine the vulnerabilities that exist in the supply chain, and to discuss how the private sector and government can address them. This report draws on the major insights and recommendations of the impressive knowledge and experience of the working group and offers an alternative channel that feeds into the stakeholder engagement process called for in President Biden's review of America's supply chains.

The working group identified three main vulnerabilities in the supply chain. First, the United States must face the ever-rising demand for critical minerals while constrained by chronic underinvestment in mining, processing, infrastructure, and human capital. Second, the United States must compete on a global basis against China and the European Union for access to critical minerals and must address the geographic concentration of both extractive and processing activities. To reference the most obvious example, China's dominant position in the supply chain stems not only from its ownership and control of critical minerals mines, but also processing facilities. Third, there is a governance challenge that impacts the first two vulnerabilities in which mining firms from the United States and other western countries must adhere to justifiably stringent compliance measures in the areas of environment, society and transparency/anti-corruption regulations, regardless of whether they are operating domestically or internationally. Permitting and legislative restrictions on U.S. mining firms place them at a competitive disadvantage compared to Chinese competitors and provide a strong disincentive for developing resources within the United States.

Our Working Group recognizes that there is no silver bullet to respond to these challenges, but rather the need for a "Mosaic Approach," involving action by both the private sector and the government at the national and international levels. In the private sector, there must be increased strategic investment in resource development and processing, technology, and human capital, which must accompany efforts to change the risk profile, real and perceived, of the mining sector. Furthermore, the industry must concretely improve relations with both decision-makers and the general public. For the government, one of the most important steps to be taken is perhaps the easiest: the explicit and repeated recognition that critical minerals are an essential component of both the United States' geopolitical competitiveness and its fight to mitigate climate change. This acknowledgement by U.S. political leaders that neither climate nor geopolitical goals can be reached without secure access to critical minerals will help to bring about a paradigm shift in thinking about the sector, and the required legislative and regulatory change needed to encourage investment in the extraction and processing, infrastructure, recycling, and human capital.

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Finally, the report examines international actions that must accompany these private and governmental ef-

forts. The United States and its allies must invest significant diplomatic and economic capital into building a more effective global regime for the governance of critical minerals extraction. The harmonization of standards at a global level will reduce the advantage currently held by Chinese firms and other geopolitical rivals. Of particular importance will be efforts to increase transparency and anti-corruption measures. The United States must look to its allies and friends to play a more important role in the supply chain, and the U.S. must be willing to work with them to develop resources and standardize practices. The U.S. must also be open to using ally standards as a starting point, rather than reinventing the wheel through the development of new standards which will not only cost time, but will also create discrepancies between standards across nations.

Another key step is to recognize the urgency of the situation and prioritize action. The moves taken by recent U.S. administrations provide some hope, but efforts must be sustained and strengthened. In that spirit, this report offers an optimistic perspective that focuses on solutions rather than obstacles.

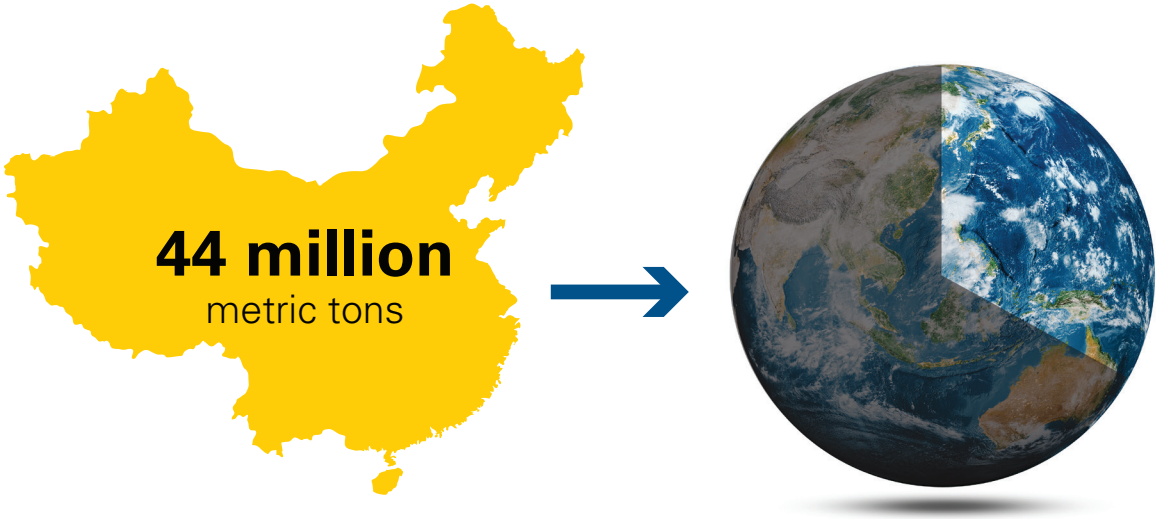
Veliki Krivelj mine of Zijin Bor Copper, one of the largest copper reserves in the world, owned by the Chinese mining company Zijin Mining Group in Bor, Serbia on May 2, 2021. Source: Mirko Kuzmanovic/shutterstock.com

An Uncertain Present and a Future Full of Concern: Mapping the Supply Chain

In its discussions, the Critical Minerals Working Group focused on some of the raw materials which are crucial for environmental sustainability goals, national security, and economic prosperity. These included lithium, nickel, cobalt, copper, and certain rare earth elements which are needed to manufacture lithium-ion batteries, motors of electric vehicles and windmills, as well as many other applications.[1] Governments and business leaders have set ambitious goals in hopes of mitigating the dramatic effects of global climate change. These involve technological responses that depend heavily on critical minerals.

Minerals such as lithium, nickel, and rare earth elements already play an important role in the global economy, yet demand for these raw materials is predicted to increase exponentially. To understand the critical minerals supply chain (CMSC), it is important to detail the scope of the demand of these minerals, their uses, and where they are located, extracted, and processed. The U.S. and many international partners face an inherent disadvantage due to the geographical concentration of these minerals.

Rare earth elements (REEs) are abundant throughout the earth's crust,but only sufficiently concentrated to be mined and processed economically in certain locations. China is one of such locations, possessing one of the largest known REE reserves in the world. The country constitutes about 44 million[2]. The majority of this ore is located in the Chinese autonomous region of Inner Mongolia. China mines the most REEs of any nation on earth and is responsible for nearly 65% of all extraction. This number is likely higher if we include black-market and unofficial REE mining in the People's Republic of China. Not only does China mine the most REEs, the majority of REE separation and processing also occurs in



China has over 1/3 of all REE Reserves

Source: https://investingnews.com/daily/resource-investing/critical-metals-investing/rare-earth-investing/rare-earth-reserves-country/

China, with around 85% of all processing taking place in the country. In terms of REE mining, the United States is a distant second, extracting only about a quarter of the amount mined in China. The sole mine in the United States extracting REEs is the Mountain Pass mine operated by MP Materials Corp. in California which in 2020 contributed 16% of global supply of REEs, according to USGS[3]. Other notable miners of REEs are Myanmar and Australia.

The lithium supply chain presents a different picture as it is dominated to a lesser extent by one country. The largest proven reserves are in Chile, Australia, Argentina, China and the U.S. Lithium typically comes from rich underground brine deposits or hard-rock spodumene deposits. Australia is the lead producing nation, contributing about 46% of global mine production, predominantly from its hard-rock lithium deposits in Western Australia. China is in third place mining about 17% of lithium in 2019, although they are responsible for nearly 60% of global lithium processing. The U.S. has one smaller lithium mine, contributing 5,000 metric tons to the 350,000 metric tons of global supply[4].

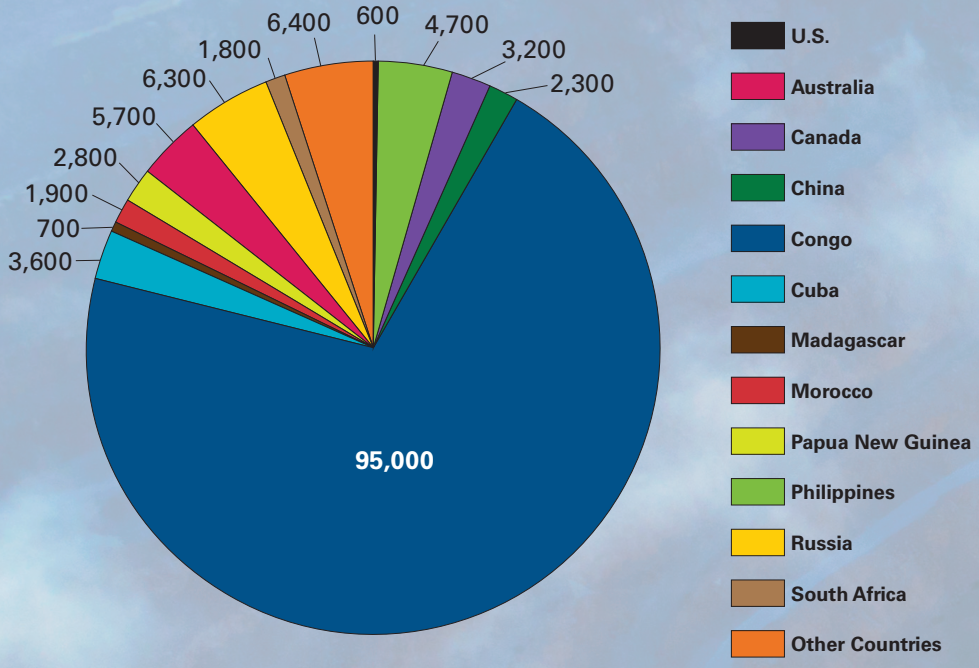
Cobalt is integral to the manufacturing of lithium-ion batteries and other advanced technologies. While there are a number of uses for cobalt, most cobalt that is mined is used to make lithium ion batteries (around 57% according to the Cobalt Institute[5]).

The Democratic Republic of Congo (DRC) is the world's largest producer of cobalt, producing roughly 90,000 metric tons of the world's 140,000 metric tons in 2019[6]. The Copper Belt in Central Africa contains the world's largest proven cobalt deposits with other significant deposits also located in Australia, Cuba, the Philippines, and Canada. In the U.S., cobalt resources are primarily located in Minnesota and Idaho. Michigan is home to one cobalt-producing mine, but this mine only contributes one percentage of global cobalt supply. While most of the world's cobalt is mined in the DRC, many mines are owned by multinational mining companies and investors. Chinese-owned mining companies, including China Molybdenum, control about 70% cobalt mining and also refine 70% to 80% of the world's cobalt. While less than 20% of DRC cobalt comes from 'artisanal' and small scale mines, the unfair labor practices associated with these operations has tarnished the reputation of cobalt and led to many Western OEMs seeking to reduce or even eliminate cobalt from their batteries.[7] As many entities search for alternative sources of cobalt, some have looked to the ocean floor. It is estimated that over 120 million tons of cobalt can be found in manganese nodules and crusts on the floor of the Atlantic, Indian, and Pacific Oceans. These resources will require time and large-scale investments to develop.

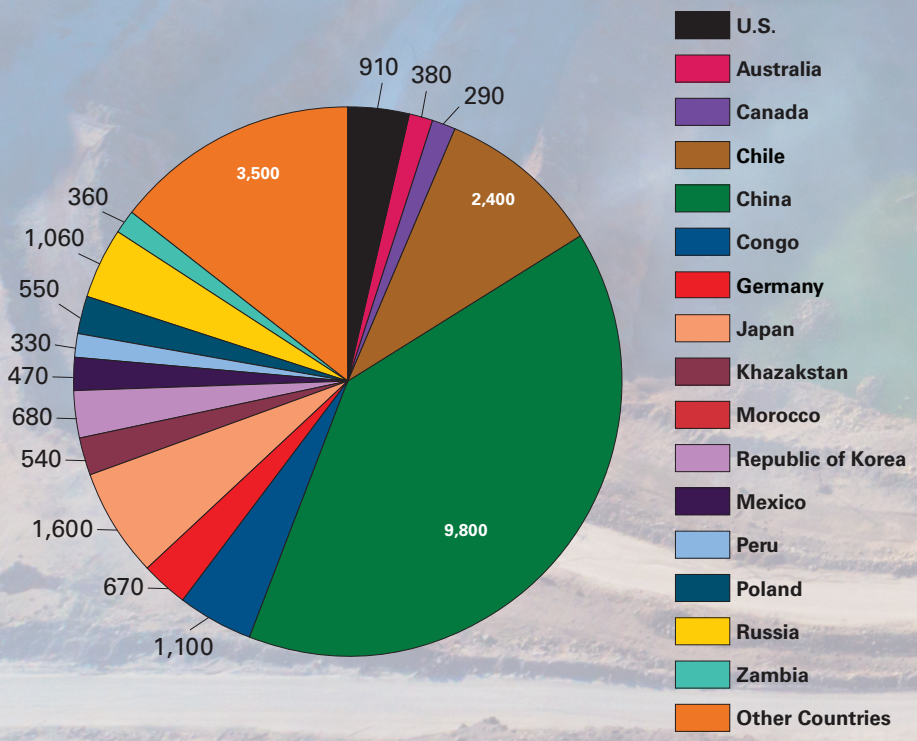
Not only does China mine the most REEs, the majority of REE separation and processing also occurs in China

2020 Estimated Production

COBALT MINING PRODUCTION (data in metric tons)

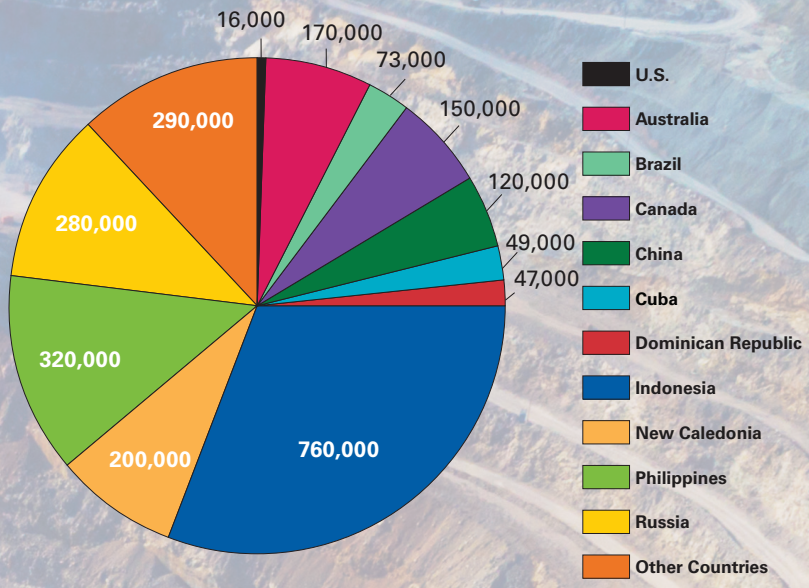


COPPER REFINERY PRODUCTION (data in thousand metric tons)

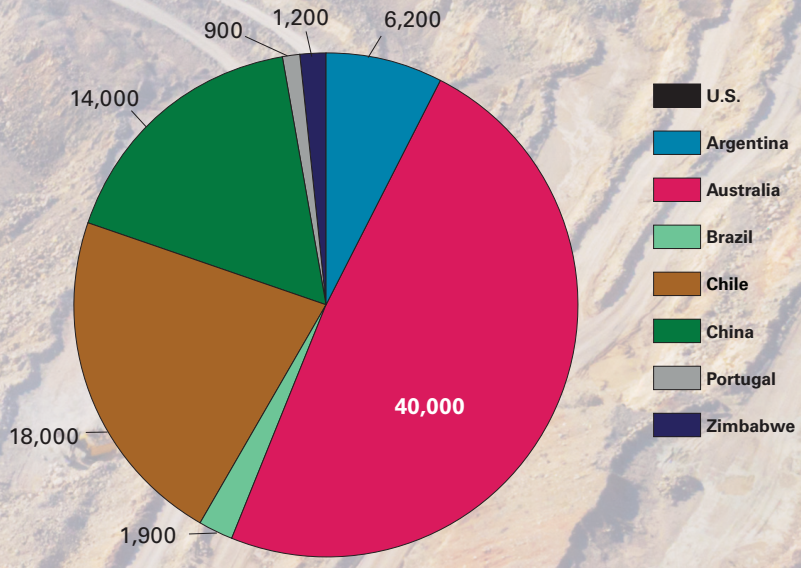


Source for all pie charts on these 2 pages: USGS, Critical Minerals Yearbook (pg 8)
*(*https://pubs.usgs.gov/periodicals/mcs2021/mcs2021.pdf*)*

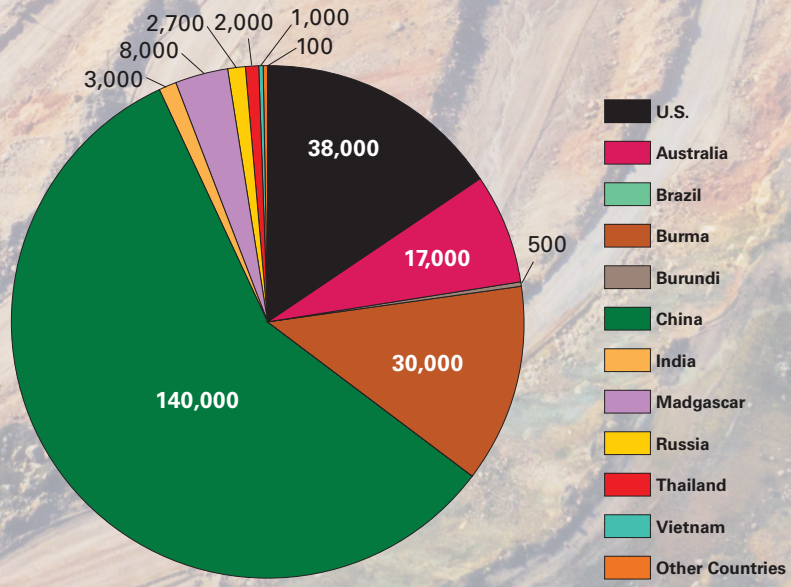
NICKEL MINING PRODUCTION (data in metric tons)



LITHIUM MINING PRODUCTION (data in metric tons)



RARE EARTH MINING PRODUCTION (data in metric tons)



It is vital here to emphasize that cobalt demand is growing significantly. While the amount of cobalt per vehicle is indeed reducing as battery chemistries shift, overall demand is multiplying so rapidly with the rise in demand for battery capacity that the DRC remains vitally important. Ocean floor and non-DRC supply provide alternative sources in the longer term, and recycling too, but during this decade the DRC is pivotal, which means that the U.S. government and private firms have little choice but to build ties with the country.

Nickel and copper are two other metals integral to the global energy transition and national security. Copper production is dominated by Chile followed by Peru, China, the United States, and the DRC[8]. Copper and copper alloys are utilized in building and infrastructure projects. Additionally, copper's conductivity makes it a key mineral for electrical and electronic products. Copper is essential for anode current collection, cell wiring, and for EV charging infrastructure. Due to the importance of electrification to meet global environmental sustainability goals, copper is a strategic and important resource.

Nearly 80% of global nickel is used to produce super alloys and strong materials, such as stainless steel. The amount of nickel used for battery manufacturing is quickly increasing. The largest nickel producing countries in the world are Indonesia, the Philippines, Russia, New Caledonia, a French territory in the South Pacific, and Canada. The U.S. is home to only one nickel-producing mine, located in Michigan. Nearly all of U.S. produced nickel is exported abroad for further processing and refinement. Polymetallic nodules on the ocean floor represent a significant domestic opportunity for increasing U.S. supplies of nickel, with the added bonus that they also contain cobalt and manganese.

It is clear that the United States does not hold an advantage in geographic concentration of critical minerals, which is a key factor in the CMSC and compounds the vulnerabilities identified by this Working Group.

Know thyself: identifying the weaknesses in the CMSC

The Working Group has identified three distinct, yet intertwined, vulnerabilities in the critical minerals supply chain: the challenge of meeting rising demand, global competition with China and beyond, and governance challenges.

RISING DEMAND

The first challenge is the scale and pace of rising demand. As mentioned, demand for critical minerals outpaces that of supply, and will continue to rise, particularly considering the key role that critical minerals will play in the clean energy transition. An International Energy Agency (IEA) assessment found that to reach the Paris Agreement goals of a less than 2° Celcius rise in global temperature, clean energy technologies would demand four times the current mineral input by the year 2040[9]. The IEA foresees mineral demand specifically for electric vehicles and grid storage for EV batteries to increase at least 30 times by 2040 and estimates a tripling of mineral demand by 2040 for low-carbon power generation[10]. While these predictions take place over the course of decades, exponential increases in demand for lithium are already happening. In a 2021 quarterly earnings report SQM, the second largest lithium producing company in the world, predicted global lithium demand to increase by nearly 50% in 2021[11]. Already unable to keep pace, considering lag time, permitting challenges and underinvestment in infrastructure, technological innovation, and human capital, this issue will continue to compound[12].

The critical minerals and rare earths industries face this challenge of limited supply and rising demand, which is complicated by underinvestment, mining's long-term orientation and associated high risk profile, and questions of human capital and R&D. Despite best efforts to synchronize supply and demand, discrepancies remain. One reason for the mismatch relates to investors' preference for shorter-term horizons than what is possible in the long-term oriented mining industry. From the exploration and discovery phases, to permitting, and then to extraction and processing, mining is profoundly complex and nuanced which makes investment difficult and at times, risky. Long lead times for critical minerals and REEs, often due to extensive processes and highly bureaucratic policies, significantly impact supply chains, but are often overlooked in conversations about the mining supply chain's vulnerabilities which tend to focus on the extractive and processing portions of the supply chain. Extensive permitting processes result in long lead times to bring mines online, which in turn delays production and impedes the overall supply chain. In addition, legal challenges to the permitting process often extend lead times beyond the 10 year mark. The 100-Day review concluded: "For the second supply chain step of refining and processing, the U.S. has an even more significant deficit than in raw production capacity as critical minerals

The IEA foresees mineral demand specifically for electric vehicles and grid storage for EV batteries to increase at least 30 times by 2040.

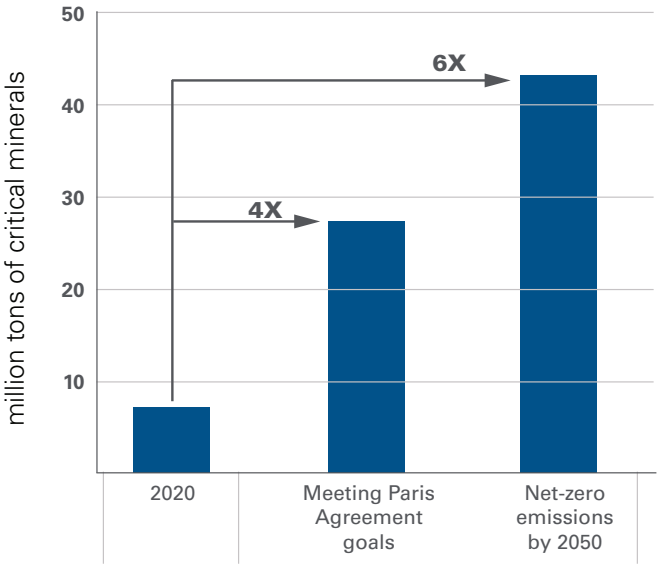
mined in the U.S. are often exported for processing. Increasing U.S. processing capacity alone would bolster the supply chain … Currently, the U.S. has limited raw material production capacity and virtually no processing capacity."[13]

The perceived high-risk profile of mining is a deterrent for investment. Exploration and assay risks, feasibility concerns, pricing risks, and potential political challenges all pose significant risk to the mining industry and have resulted in chronic underinvestment. This underinvestment results in a lost opportunity for U.S. competitiveness. The United States is on the brink of a huge opportunity within the REE production space - mining and producing more rare earths in 2020 than ever, and still, estimates show that the U.S. and Canada combined have a surplus of 17.7 million tons of rare earth resources[14]. Despite this, the U.S. remains heavily reliant on China for rare earth compounds and metals, with China providing to the U.S. an estimated 80% of imported rare earth elements between 2016 and 2019[15]. This U.S. reliance upon Chinese REEs is partially attributable to insufficient domestic processing abilities. Investment in production facilities can align U.S. supply with demand and remain globally competitive where REEs are readily available. Without a high concentration of REEs, investment in innovation and other solutions can bring competitive advantage.

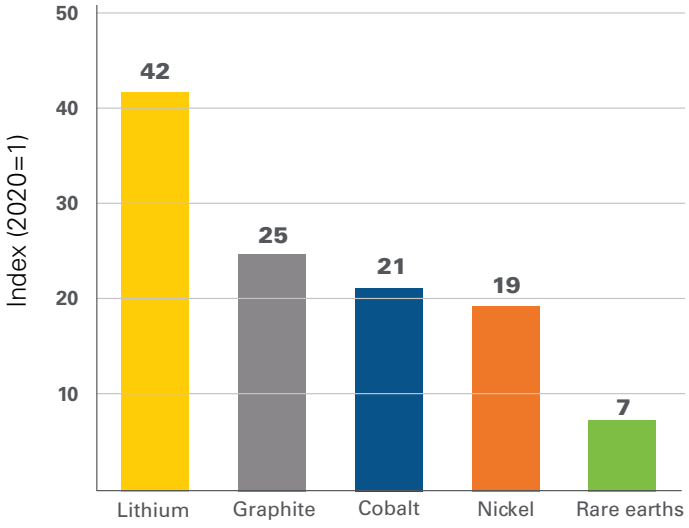
Finding and developing national resources is easier said than done. The U.S. has only mapped approximately 12% of its land in terms of metal reserves: the USGS estimates it would take 10+ years to find and map all U.S. resources, with another 7-10 years to get those resources to market, completely missing the window within which the U.S. requires critical minerals. While new discovery projects are important for the long term, the U.S. will need to address known resources for its short and mid-term strategy.

Human capital is another crucial element of the critical minerals supply chain. Resiliency and competitiveness rely on availability and quality of both talent and expertise. An obstacle facing many companies is the trend in declining enrollment in mining programs among young people. According to a 2019 report produced by the Mining Industry Human Resources Council (MiHR), enrollment rates in undergraduate mining engineering

As Demand for Clean Energy Technologies Grows, So Does Demand for Critical Minerals



Predicted Growth of Selected Minerals According to the IEA



*Source: IEA report (*https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions*)*

programs declined by 12% from 2015 to 2016 across Canadian universities[16]. Scott Dunbar, associate professor at the Norman B. Keevil Institute of Mining Engineering at the University of British Columbia (UBC), argues that a possible cause of decreased enrollment is[17]:

> "...is that the industry has not shed the perception that it is 'dirty.' Sustainability and long-term job prospects must be at the core of all the technological advancements if there is going to be an adequate number of new entrants to the industry, he said."

Technological advances in the mining industry must begin with significant and consistent investments in employee education, training, and development. The 2021 MiHR Council report predicts the need for between 29,000 and 48,000 new hires in a five-year, post-COVID-19 scenario[18]. Further investment for R&D and human capital is crucial to lower costs, increase efficiencies, address differences in quality. This will strengthen critical minerals supply chains, while also aligning mineral industry positions with sustainability and clean energy, both of which are attractive growth industries in the U.S. industries in the U.S.

GLOBAL COMPETITION AND THE CHINA CHALLENGE

A second challenge for U.S. supply chains is global competition. The United States, European Union, and China compete for resources, intellectual property, and talent in the mining sector. The playing field is not level, however, as producers in dominant supplier countries (which, in many cases, means China) face lower ESG standards and more favorable financing terms. Because the U.S., EU, and others cannot compete with China solely on price, other factors must be taken into consideration.

Trendlines show that the United States has fallen far behind China in the area of critical minerals production and processing. China's dominance here is a direct threat to U.S. supply chains, competitiveness, and geopolitical ambitions, but reveals many learning and development opportunities for the U.S. in terms of extraction, processing, and manufacturing.

There is an urgent need for public and policy-maker education about China's dominance of critical minerals and a pressing necessity to identify alternatives to China for U.S. procurement of critical minerals. Though China maintains relatively high standards for mining activities within its borders, the same cannot be said for that of Chinese companies' foreign operations, where ESG standards may not be in place and local governments and corporations do not have alternatives to Chinese operations. China's dominance makes it exceedingly difficult to incentivize cleaner, more sustainable, and more equitable practices in both extraction and processing of critical minerals.

Where China lacks geological advantages, it compensates by establishing value-added advantages. For example, while the majority of global cobalt is sourced in the DRC, China is the world's largest consumer of cobalt and also produces the most cobalt, most of which is imported from the DRC, according to USGS[19]. Western firms cannot reasonably compete with China when it comes to price, particularly in circumstances where subsidies and poor labor practices are common. Most importantly, however, China has been enacting its own strategic vision for critical minerals by pouring billions of dollars into production assets. The United States has fallen gravely behind in investing in resource-rich emerging countries, putting itself at a disadvantage and allowing further opportunities for China and other competitors to exert their dominance.

Chinese risk reduction efforts have helped the country to dominate and maintain control over the critical minerals industry. China's drive for self-sufficiency and its dominance of emerging technologies,

such as electric vehicle battery production, has been made possible by collaborations between the public and private sectors, with substantial R&D funding from the government. In both Russia and China, government subsidies put competing U.S. firms at a huge disadvantage, which reduces the viability of the domestic industrial base and ultimately creates a dangerous foreign reliance that can undermine U.S. commercial and national security interests. One of the most essential roles of government is to provide for the common defense, and as such, the U.S. government has a responsibility to secure supply chains critical to national security. Enacting policies, such as production tax credits, that would level the playing field between suppliers in the global REE supply chain would promote a vibrant domestic industrial base capable of mining and processing REE materials necessary for U.S. defense and commercial interests. For America to successfully embrace viable REE mining and processing, the U.S. government must play an active role in ensuring that its domestic companies remain in business.

The biggest takeaway here is that the United States, if it truly wants to compete, must invest in the development of critical minerals extraction and processing. The investment must be financial, of course, but must also involve diplomatic efforts to build better ties with resource-rich countries.

GOVERNANCE CHALLENGES

Governance has a key role in the CMSC to create a more equitable playing field that rewards virtue and punishes transgression. Critical minerals and REEs are viewed as commodities, with price as the determining factor for firms in choosing a supplier. For meaningful change to come about, they must be de-commoditized, and values must be integrated into the commodities themselves. To allow U.S. firms to compete, we must cultivate a mining and processing environment that is stable and that encourages investment supportive of ESG. Of course, there are myriad issues around ESG, including political will, processing, and above-ground conditions. The current opacity of the CMSC has created a significant need for new international agreements on tracking, transparency, and disclosure, especially given the dominance of countries where transparency is far from a priority.

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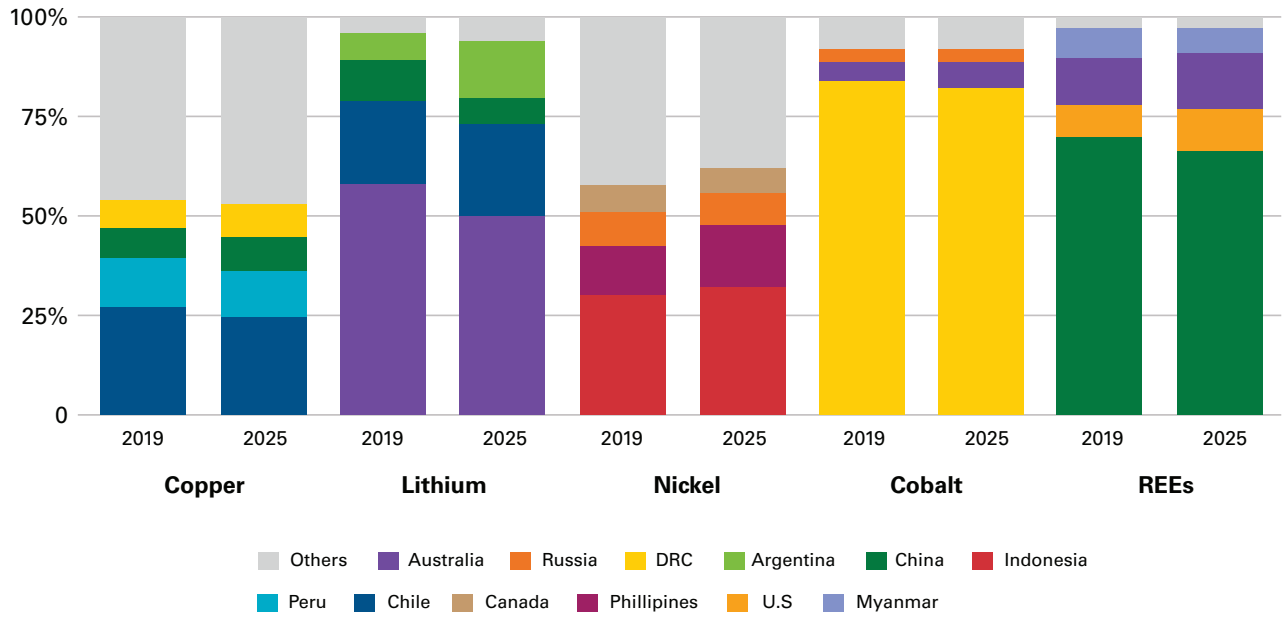
Permitting policies play a significant role in the global competition for critical minerals, oftentimes in the context of time frame challenges. There is clear crossover between permitting and social license challenges; the extensive nature of permitting regimes in the U.S. makes them comprehensive and thorough, but also difficult, timely, and costly, thus putting the U.S. and allies at a distinct disadvantage as compared to competitors with less extensive permitting policies. From start to finish, including development to construction, start-up, operations, and reclamation, U.S.-based projects are required to obtain various permits, such as environmental permits, developmental and operational permits, reclamation bonding and related activities, and permits from authorizing agencies. A major mining project on federal lands may be subject to 30 or more local, state, and federal regulations and programs[20]. U.S. permitting regimes' multiple stage processes, involvement of various agencies at all levels of government, and lack of basic, cross-agency coordination has resulted in a seven-10 year permit timeframe for U.S. based mining projects. This marks a stark contrast to that of Canada and Australia where the average permitting period is two years and envi-

ronmental standards are equally thorough[21].

Given the many stakeholders and the multilevel permitting process in the U.S., permitting delays pose a significant threat to mining projects in the U.S., even in states that have more generous mining policies, such as Nevada, West Virginia, and Arizona. In fact, a 2012 report published by Behre Dolbear found that the U.S. is tied with Papua New Guinea for most significant delays in mining permitting[22]. SNL Mining estimates that extensive permitting regimes decrease the expected value of a mine by half as a direct result of increased costs and risks directly associated with prolonged permitting requirements. Additionally, SNL Mining found that delays associated with permitting result in the loss of one third or more of the mining project[23]. The impact of U.S. bureaucratic hurdles in the permitting process is best illustrated by the fact that the U.S. comprises only 11% of global spending on global mining exploration, meaning that the majority of U.S. investment goes toward existing mines and mining projects, thus making it exceedingly difficult for the U.S. to compete on the global scale against formidable competitors such as China[24]. Attempts to reform permitting in the U.S. have been met with significant challenges, particularly as permitting becomes increasingly politicized and subject to multiple levels of legal challenges.

We must cultivate a mining and processing environment that is stable and that encourages investment supportive of ESG.

Projected Production of Critical Minerals (by country)



*Source: IEA report (*https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions*)*

A comprehensive approach to strengthening the critical minerals supply chain

Perhaps the single most important observation from the Critical Minerals Working Group is that there is no single, silver bullet that will solve the vulnerabilities in the U.S. supply chain. Instead of seeking simplistic, unidimensional approaches, the Working Group emphasized the need for a multi-faceted approach that pieces together actions by the private sector and government at both national and international levels.

"THIS IS NOT JUST ABOUT ROCKS"

As was outlined in an earlier section, the CMSC is multidimensional, involving not only the extractive process, but processing, primary use, and end use phases. In addition, there are "pre-extractive" factors that must be included in any meaningful discussion of this area, including the investment process, technology, permitting, the social license, and human capital availability.

Although government is not the only actor in this complex equation, its key role must be recognized. From strategic planning to education and R&D support, from procurement for public sector activities to pricing mechanisms, governments can play a guiding, driving, and limiting function. Their success or failure in this endeavor will, in large part, determine the ability of the private sector to ramp up production, secure access to critical minerals, and invest in the long-term future of the supply chain.

But, it is worth repeating that governments are not solely responsible for addressing the challenge. The actual investment, extraction, processing, end use, and logistics are overwhelmingly handled by private enterprises. To perform these functions well, companies must take more responsibility for their relations with government and key decision-makers, invest morein public and in particular, civil society relations, in technology, and workforce development, and must work to improve the investment profile of the mining

It takes nearly 17 years to bring a resource to production

*Source: IEA report (*https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions*)*

sector to secure adequate capitalization. Above all, the public image of mining and processing firms must be strengthened by real advances in environmental, social, and governance measures.

These public and private sector actions must be coordinated internationally. No one country, and certainly not the United States, has sufficient resources within its territory to satisfy the critical minerals requirements of the modern economy. Cooperation with foreign partners and allies, global investment strategies, and international supply chain integration will be essential components. It will be crucially important to identify where it makes economic sense for the U.S. to strengthen domestic capacity, where to rely on our international partners, and where we simply cannot compete.

Efforts to level the global playing field in the mining sector by establishing minimum environmental, social and governance (ESG) standards for the sector throughout the world will be of central importance. The United States government must continue to play a leading role in this in collaboration with private mining companies to ensure fair criteria and outcomes and also to ensure alternatives to Chinese supply; if ESG standards are improved but there are no alternative providers, the standards will not be effective. A focus on transparency and disclosure by firms will be central to this effort, with meaningful consequences for those firms that do not comply.

It is vital to recognize that none of these steps will be effective if we ignore economic imperatives. Better strategy, investment, cooperation, and application of standards will be undermined if the minerals themselves are not competitively priced when they reach consumers. Technological advances, human capital development, and regulatory compliance costs will all feature heavily in this calculation, but governments must also think about how they will factor in these elements when looking at imports. Competitiveness is undermined when minerals that are produced in parts of the world with less stringent standards are allowed to compete equally with those produced under more restrictive regulatory regimes.

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When all of these factors are pulled together, it becomes clear that a "mosaic approach" must be taken to address America's CMSC vulnerabilities. From the investment climate to the end use considerations, the U.S. government and private companies must adopt comprehensive and holistic strategies, embracing relations with financial actors, local communities and civil society, public decision-makers at local, state and federal levels of government, regulators, and with America's partners and allies overseas. There is an urgent need to focus on not just the security of the critical minerals supply, but also on its quality and price. Given ever rising demand, it will be necessary to "grow the critical minerals pie", rather than merely moving slices around. It is not a question of foreign or domestic solutions to the critical minerals equation. We can no longer think of the critical minerals equation as a question of either national or foreign options, recent experience has shown us that we must look to both domestic AND foreign solutions.

LEADING FROM THE TOP: GOVERNMENT ACTIONS

The U.S. government must play a central role in the design and implementation of any strategy involving the critical minerals supply chain and thus far, the actions taken by the Biden administration to do this are encouraging. By working with different government agencies and engaging in stakeholder dialogue to define the problem and seek solutions, the government has set an early precedent that offers hope. The 100-day review, "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth,"[25] published in June 2021, provided an excellent starting point, but it is vital that the U.S. government continues to engage in a meaningful fashion with a wide array of stakeholders. A coordinated strategy will be essential for long-term success, and the government must keep open channels for two-way communication with investors and producers.

Though none of the following suggestions from the Wilson Center's Critical Minerals Working Group is sufficient on its own, there are some that are absolutely necessary. First and foremost, the government and Congress must recognize the vital importance of the extractive and processing sectors for achieving broader geopolitical goals. If the United States cannot secure access to the minerals it needs, national defense, industry, and innovation will fall behind competitors and rivals who can. Second, the government must publicly recognize this fact and offer public policy solutions that will strengthen the critical minerals sector. For the Biden administration, there must also be an explicit recognition that achieving its climate goals will depend upon secure access to a number of critical minerals that are essential for battery storage, electrification, and energy efficiency.

The Biden Administration has recognized that recycling will play an important role in increasing the supply of critical minerals to both government and industry, but significant investment and tighter regula-

Region del Maule, Chile - Miner inside the access tunnel of an underground gold and copper mine. Source: Shutterstock.com

tions on recycling will be needed. Given the expected rapidly rising demand for critical minerals, however, recycling will only ever be able to cover a modest percentage of all demand for critical minerals, and the development of new sources must be a priority.

The U.S. government must also look at the entire value chain for the critical minerals industry, from extraction through to end use products. To do this effectively, the federal government must engage in strategic investment collaboration with the private sector and state governments to develop indigenous resources here in the U.S. This collaboration must focus on creating the right climate for investment, which means providing a stable and streamlined regulatory environment, as well as looking at incentives to bring other parts of the value chain (including refining, processing and the manufacture of primary use products) to the United States and allied countries (such as Canada, for example). A strategic consideration for American critical minerals in government procurement practices would greatly assist the strengthening of the industry and encourage higher levels of investment in domestic resource extraction.

Long-established mining methods are certainly part of the solution, but the U.S. government should not shy away from new and unorthodox sources of battery metals, rare earths, and other critical minerals, particularly if they offer a faster and more direct path to resource development, while respecting the highest environmental, social and governance standards. This includes an open-minded approach to new methods and new technologies for resource extraction.

Traditional areas of government action, such as infrastructure and human capital development, remain key. Ensuring that transportation and energy infrastructure are available for both extractive and processing functions is critical to assisting private firms in their investment decisions. Furthermore, the U.S. government must take steps, alongside the private sector,

Indian Environment Minister Bhupender Yadav, left and U.S. Special Presidential Envoy for Climate John Kerry talk during the launch of Climate Action and Finance Mobilisation Dialogue

to encourage more young people to enter mining, geology, and engineering programs to guarantee a pipeline of talent for the future. New scholarships, as well as internships in the U.S. and abroad, will help to develop the future workforce, and there is ample room here for cooperation between the U.S. and state governments and the private sector.

At a basic level, the U.S. government and Congress, in particular should consider new legislation to provide a more encouraging investment climate for U.S. mining. The 1872 General Mining Law encouraged the extractive industries in an America that was growing rapidly and desperately needed sources of minerals, employment, and wealth creation to fulfil its ambitions. Since then, dozens of new laws have been applied to the mining industry to control its environmental and social impact. Simplifying this legislative framework by reducing regulatory burden would be a major step

Given ever rising demand, it will be necessary to "grow the critical minerals pie," rather than merely moving slices around.

towards improving the competitiveness of the U.S. mining industry.

To help reduce the exceedingly long lead times for mining projects mentioned earlier in this paper, the U.S. government should look again at international best practice for regulation and permitting. This lengthy process costs billions of dollars and impedes competitiveness of U.S.-based mining projects. As Canada's Fraser Institute argues,

> "The permitting process is costly for firms, as they must invest time and resources to comply with the permit's requirements. These costs can rise when the process lacks transparency or is uncertain, adding additional risk to firms and reducing a jurisdiction's competitiveness."[26]

Regulatory innovation that takes firm that takes firm competitiveness and national, geopolitical, and climate objectives into consideration into consideration is desperately needed to provide more transparent timelines for permitting, clearly define the roles of different agencies to avoid regulatory duplication, and to allow for shared responsibility between regulators and the firms they regulate. Again, looking to Canada, the province of Alberta has adopted what amounts to an honor system for hydrocarbons regulation, with heavy penalties for those that break the rules. Combining this approach with robust oversight would allow for speedier permitting, while providing strong incentives to respect ESG rules.

Secondary recovery of critical minerals is an important factor in satisfying demand. The USGS reported in 2021, that recycling in the U.S. is currently equivalent to 29% of cobalt consumption, 38% of all U.S. copper supply, and 50% of consumption of nickel.[27] Limited quantities of rare earths are recycled from batteries, permanent magnets, and fluorescent lamps, partially as a result of economic and/or technical viability according to USGS[28]. In terms of lithium, there are eight companies in the U.S. and Canada that have begun or plan to begin recycling lithium and lithium-ion batteries[29]. Given dramatically expanding demand, the U.S. will need to invest heavily in infrastructure for secondary recovery of critical minerals and metals. Moreover, the combination of a lack of a national mandate, plus absence of clear recycling policies and programs at all levels of government is a clear hindrance for advancement of critical minerals recycling in the U.S.[30].

It's about more than just price.

Even if there are substantial efforts to upscale recycling and implement national mandates, the process is inherently limited by rate of availability and secondary recovery of critical minerals will likely only partially meet rising demand. Despite this, countries such as Japan and South Korea have grown their secondary recovery efforts in direct response to competitors' (China and India, for example) attempts to secure increased access to primary materials - a valuable lesson and potential opportunity for the United States[31].

Lastly, the U.S. government should think carefully about the issues of stockpiling, strategic reserves, and recycling. Since the Strategic and Critical Materials Stock Piling Act of 1939, the U.S. government has sought to overcome import dependence by building stores of critical minerals. The strategic petroleum reserve is an example that was used to differing levels of success during times of high oil prices and supply challenges. However, that reserve has been steadily reduced in recent years as the U.S. has boosted domestic production through innovation and the discovery of new, hitherto commercially nonviable sources. Likewise, for some critical minerals, there may be a role for a strategic stockpiling, but securing reliable access to new sources would be a wiser and more flexible solution. Additionally, there must be

renewed focus on recycling and its potential benefits to the critical minerals industry.

CRITICAL INPUTS: THE ROLE OF THE PRIVATE SECTOR

While the government must work hand in hand with the private sector and will play a central role in securing the CMSC, it is the private sector that will be responsible for mining, importing, refining, processing and ultimately the end uses of critical minerals. With that in mind, the Critical Minerals Working Group called on industry to work closely with government in the design of supply chain policy, and to enact a number of strategies to help resolve current vulnerabilities.

Starting with mining financing, the private sector must work harder to improve its perceived risk profile in the eyes of investors. The heavily capital-intensive nature of mining, long-term debt burdens, and volatile prices for raw materials are the factors most commonly recognized as creating uncertainty among investors. To overcome this, mining firms must work, alone and in conjunction with government, to change this risk profile.

However, capital expenditure (CAPEX) is only part of the equation. Operating expenditure (OPEX) is often just as, or more, important for determining the viability of projects, and that depends heavily on price fluctuations on international markets. Long-term fixed price contracts would be one way to overcome these fluctuations, much as they have done for the liquefied natural gas (LNG) market globally.[32] Although this may not give the optimal price at any given moment in the life of a contract, price is often only one (albeit important) concern for consumers. Long-term contracts provide security for both the producer and the consumer of critical minerals and given the expected impressive jump in future demand and current supply chain concerns, should be welcomed by both government and private sector actors. What's more, securing long-term supply contracts from firms that respect best practice on ESG issues is compatible with contemporary life-cycle analysis strategies being employed by firms in the auto-sector. Ensuring that precursor materials, as well as primary products, parts, and components are compatible with environmental, human rights and anti-corruption concerns is becoming more and more common and is increasingly being given a central role alongside price considerations. In short, *it's about more than just price*. Government and the private sector need to move away from a unidimensional approach to supply; alongside price, ESG considerations must be given priority.

There are other ways to mitigate risk. Investing in new technologies that lower costs and provide the ability to respond rapidly to price changes in the market are an important step in the right direction. Again, the example that has been set by the oil and gas industry in recent years is indicative. The fracking revolution that has given back America its oil and gas independence should be seen as a model for the mining sector. The compulsive drive to cut costs has brought stunning technological innovations and advances that have completely changed the cost structure of the industry, allowing for shale oil and gas reserves to be turned on and off depending on the price cycle, and converting America's in ground reserves into the equivalent of a strategic petroleum reserve.

The mining sector is already looking at such new technologies, both on land and on the ocean floor, as a way to secure access to new resources and to drastically alter the cost structure of mining. There is significant potential to develop nickel, cobalt, copper, and manganese through the extraction of polymetallic nodules in the Pacific Ocean off the coast of the western United States. Government, universities, and industry must work together to bring these technological advances to market, and it is vitally import-

ant that the mining industry maintains control of these innovations, as they are a crucial factor in improving both business and national competitiveness. Innovation will also be critical in the battery sector, with low-cobalt technologies reducing dependence on the DRC as a mineral supplier and subsequently on China as a processing center. The potential for this, however, will not prevent overall demand for cobalt from growing massively in the next few years. Other solutions to this challenge will be needed.

Alongside technological innovation, industry must also take its fair share of the burden of investment in human capital. Developing the mining workforce of the future requires not only the creation and financing of new undergraduate, graduate, and professional education programs, but also greater efforts to change the image of the mining sector among young people. Initial education and training is only one part of this equation however: on-the-job professional development programs need to be improved to ensure that workers in the extractive industry keep up to date with new technologies, can build a lifelong career path in mining, and increase their productivity.

Beyond cost cutting, technological advances, and workforce development, however, the Critical Minerals Working Group recognized that the mining sector urgently requires rebranding in the eyes of both government and the public. More and better outreach is essential to changing public perception, with an emphasis on the central role played by minerals in the fight against climate change. Explaining that the green revolution cannot happen without mining will be a key message. Providing better information pathways to decision-makers on advances in mining will also be important in improving understanding of the reality of the extractive industries, especially as it pertains to the differences between North American, European, and Australian mining firms on the one hand, and Chinese firms on the other.

It is vitally important that the focus does not fall solely on mining. The Working Group emphasized that ensuring that processing and primary production are vitally important parts of the supply chain that must also be re-shored or ally-shored if America's supply chains are to be made more resilient. This means working with federal, state and local governments to emphasize the economic, investment and employment advantages that can be derived from bringing processing and primary production. Explaining the positive spillovers from the entire minerals value chain will help to change perceptions and alter public policy.

One actor that cannot be ignored by the extractive industries is civil society. Non-governmental organizations (NGOs) at the local, national and international levels have provided a serious check on the ability of the mining industry to move rapidly on new (and existing) project development in the United States and other allied countries. The denial of the "social license" is one the most important obstacles for mining firms today. Engaging in effective and meaningful dialogue with moderate NGOs that can help to find a path forward on local community relations and must be a core element of future ESG strategies.

LEVELING THE PLAYING FIELD: ACTIONS ON THE GLOBAL STAGE

The preceding actions by the U.S. government and the private sector will be essential steps towards improving the CMSC, however, it is clear that the U.S. cannot act alone. The Biden administration has already recognized the central role that can be played by allied nations working together to strengthen the supply chain. Resource access will always be key; and while there is great potential within the borders of the United States of America, firms and government dependencies will still need to source their minerals from overseas. This means working with

friendly countries to ensure dependable supplies of critical minerals. In recent years the term "ally-shoring" has entered the policy lexicon, and nowhere will it be more important than in critical minerals. The United States enjoys such dependable friends and allies as Canada, Australia, Japan, the European Union, and South Korea, and it will be important to work alongside these allies to both boost production and avoid a "devil take the hindmost" race for supplies. The same applies to processing: investing in capacity at home and in friendly countries will help to decrease dependency on China and countries that may be less reliable in times of crisis.

One country that has not been mentioned, but warrants attention, is Mexico. With a sophisticated mining industry, significant reserves of copper and lithium, a heavy presence of foreign (mostly Canadian) mining firms, a manufacturing platform that is deeply integrated with that of the United States and a 21st century free trade agreement (FTA) with Canada and the United States in the form of USMCA, Mexico should be considered in any U.S. supply chain strategy. At present, the Mexican government is pursuing a nationalist, anti-private sector approach to natural resource extraction, but in the long-term the country should be viewed as an integral member of the North American mining and resource platform.

But simply working with allies will not be enough. Take the example of cobalt. With such a high concentration of the mineral in the DRC, the United States and its firms have little choice but to work with the country. As mentioned earlier, low-cobalt battery technologies hold potential, but overall demand for cobalt will rise significantly. This means a diplomatic strategy that opens opportunities for western firms at the same time as government and business strive to raise standards within the DRC. Additionally, cobalt processing capacity must be built outside of China to provide greater diversity in the supply chain.

Beyond questions of supply itself, the U.S. government must work with industry and with its allies overseas to develop binding international standards to level the playing field in environmental, social governance. These standards should be applied to both extractive industries and to the processing plants that transform the raw materials. Of particular importance is the issue of transparency and disclosure. This means both improving minimum standards for disclosure and developing a life-cycle approach to climate disclosure for products.

the U.S. must take the lead in encouraging other nations to raise their standards

As such, there must be a concerted global, cross-industry effort from the highest-level producers and suppliers all the way to consumers. Compliance with ESG standards is costly, but rather than pursuing a race to the bottom in terms of cost, the U.S. must take the lead in encouraging other nations to raise their standards while also bearing some of the additional costs. The Energy Resource Governance Initiative (ERGI) has been a centerpiece of the Trump and Biden administrations' approach to "sound mining governance and resilient energy mineral supply chains." ERGI has expanded since its launch in 2019 and is facilitating safer investment climates for western countries to invest in countries that wouldn't otherwise see investment. The initiative has made it incumbent upon government officials to seek out reformers in the mining industry and give them the tools and opportunities to succeed and effect reforms. Now, the U.S. government must work to harmonize its achievements with those of the EITI (Extractive Industries Transparency Initiative) and at the same time seek meaningful ways of ensuring compliance.

Short-term actions	Long-term actions
Streamlining regulatory & permitting processes	Human capital investment
Working with allies to develop resources & processing	Developing & negotiating global governance structures
Accepting the geopolitical & climate implications of the critical minerals industry	Building critical minerals stockpiles
Improving the image & reality of the mining industry	Developing new technologies

Concluding thoughts

America is currently poorly prepared to face the challenge of securing its critical minerals supply chain. China has already moved a long way ahead of the U.S., and this will compromise America's attempts to compete internationally, while also meeting climate change goals. To overcome this poor preparation, the U.S. government must work hand in hand with business and with overseas allies to build its own capacity in both mining and processing, and to collaborate in resource development in friendly countries. Furthermore, the U.S. must work with allies and partners to develop a global regime to improve environmental, social, and governance standards by establishing and enforcing rules that will level a playing field that is currently tilted heavily in the favor of Chinese firms.

Central to all of these endeavors will be the ongoing cooperation between the U.S. government and the private sector. Stakeholder dialogue is an absolute necessity if the attempts to make America's critical minerals supply chains more resilient are to be effective. Working with the market rather than against it, harnessing the potential of American enterprise and innovation, and joining with our allies around the world will provide the U.S. with the tools it needs to address the China challenge and to meet its climate ambitions.

Endnotes

1 There are a number of other critical minerals that were not considered in the dialogues but which present similarly urgent supply issues. Consider manganese, for example: the U.S. has zero domestic resources and imports 100% of its supply (used in steel industry and batteries). Of the dominant Nickel-Manganese-Cobalt (NMC) chemistries and particularly for some low-cobalt batteries, manganese is a crucial ingredient. It is already on the critical mineral list and by and large is sourced from Africa, and with processing concentrated in China.

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32 This is not to suggest that this is a simple option to adopt. Take or pay contracts pass significant risk to the consumer, and will have to be incentivized.

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EXPERTISE PROVIDED BY:

Morgan Bazilian, Colorado School of Mines

Robert Daly, Wilson Center

Elaine Dezenski, LumiRisk

Shihoko Goto, Wilson Center

Cordell Hull, Wilson Center

Ian Lange, Colorado School of Mines

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Wilson Center

Woodrow Wilson International Center for Scholars
One Woodrow Wilson Plaza
1300 Pennsylvania Avenue NW
Washington, DC 20004-3027

www.wilsoncenter.org
wwics@wilsoncenter.org
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@thewilsoncenter
202.691.4000