CRITICAL MINERALS

GLOBAL SUPPLY CHAINS AND INDO-PACIFIC GEOPOLITICS

NBR
THE NATIONAL BUREAU *of* ASIAN RESEARCH

THE NATIONAL BUREAU *of* ASIAN RESEARCH
NBR SPECIAL REPORT #102 | DECEMBER 2022

CRITICAL MINERALS

Global Supply Chains and Indo-Pacific Geopolitics

Sharon E. Burke, Llewelyn Hughes, Phung Quoc Huy, Kristin Vekasi, and Yu-Hsuan Wu

THE NATIONAL BUREAU *of* ASIAN RESEARCH

The NBR Special Report provides access to current research on special topics conducted by the world's leading experts in Asian affairs. The views expressed in these reports are those of the authors and do not necessarily reflect the views of other NBR research associates or institutions that support NBR.

The National Bureau of Asian Research helps decision-makers better understand Asia and craft concrete, actionable policy. NBR is an independent research institution based in Seattle and Washington, D.C. We bring world-class scholarship to bear on the evolving strategic environment in Asia through original, policy-relevant research, and we invest in our future by training the next generation of Asia specialists.

Our research is conducted by a global network of specialists and tackles critical issues identified by stakeholders in anticipation of future challenges. The findings are a result of independent scholarship and do not reflect institutional perspectives. Our rigorous standards facilitate informed decision-making based on knowledge rather than ideology.

Established in 1989, NBR is a legacy organization of Senator Henry M. Jackson, who foresaw the national need for an institution to study and inform public policy on Asia in both the public and private sectors. Building on Senator Jackson's bipartisan approach, NBR engages policymakers looking for reliable Asia expertise through sustained interaction in high-trust, nonpartisan settings. Our experts and research have shaped congressional legislation and administration policies, brought issues to the top of the U.S. foreign policy agenda, and attracted worldwide media attention. We mobilize expertise on Asia for a more effective foreign policy.

NBR receives support from foundations, corporations, government (including foreign governments of allies and liberal democracies), and public agencies, and philanthropic individuals. NBR reserves the right to publish findings. We do not undertake classified or proprietary research work, and we observe policies to avoid conflicts of interest.

To download issues of the NBR Special Report, please visit the NBR website http://www.nbr.org.

This is the one-hundred-and-second NBR Special Report.

NBR is a tax-exempt, nonprofit corporation under I.R.C. Sec. 501(c)(3), qualified to receive tax-exempt contributions.

Cover design and illustration by Nate Christenson.

For further information about NBR, contact:

The National Bureau of Asian Research
One Union Square
600 University Street, Suite 1012
Seattle, Washington 98101

206-632-7370 Phone
nbr@nbr.org E-mail
http://www.nbr.org

NBR SPECIAL REPORT #102 | DECEMBER 2022

CRITICAL MINERALS

Global Supply Chains and Indo-Pacific Geopolitics

TABLE OF CONTENTS

v Foreword
Mikkal E. Herberg and Micah Sindelar

1 Geopolitics of Critical Minerals
Yu-Hsuan Wu and Phung Quoc Huy

13 Securing Critical Mineral Supply Chains in the Indo-Pacific: A Perspective from Australia
Llewelyn Hughes

23 Building Resilient Critical Mineral Supply Chains: Lessons from Japan and South Korea
Kristin Vekasi

35 Shiny Objects: Repositioning the United States for Critical Mineral Success
Sharon E. Burke

FOREWORD

As the global transition to a cleaner, more sustainable energy mix accelerates, demand is mushrooming for a wide range of critical minerals central to clean energy technologies. The world is transitioning from a fossil fuel–intensive to a minerals-intensive energy economy. These minerals include lithium, cobalt, nickel, graphite, rare earth elements, and a whole range of other more traditional minerals like copper and zinc. At the same time, the world energy system is also shifting toward an electricity-driven final energy use to broaden the availability of energy supplies and take advantage of cleaner sources of electricity generation.

The enormous expansion of the global electric vehicle (EV) market is a key driver in rising demand for minerals critical to battery production. Given that batteries make up roughly one-quarter of the cost of an EV, inexpensive and accessible supplies of these minerals are key to making EVs popular, affordable, and commercially viable to compete with the internal combustion engine. EV manufacturing requires enormous amounts of copper and zinc, which, in addition to aluminum, are used in the expansion of renewables like solar and wind power. Moreover, utility-scale battery storage technology, which is vital to addressing the intermittency challenge posed by renewable power generation, requires huge amounts of these critical minerals.

Hence, governments and companies are scrambling to mobilize the mining, transportation, processing, and manufacturing of products from critical minerals in order to meet ever-increasing global ambitions for reducing greenhouse gas emissions and addressing climate change. Countries that hold large reserves of these minerals are working to craft new investment and policy strategies to maximize the benefits of this potential source of wealth for their economies, people, and national security.

However, the scramble for new mineral supplies and processing capacity is not taking place in a geopolitical vacuum. The new geopolitics of clean energy is being shaped by intensifying strategic competition as well as powerful recent shocks to global supply chains that are fundamentally changing the way that countries and companies organize their supply systems and production chains.

Most importantly, control over critical mineral supply, processing, and clean technology manufacturing is becoming a significant new element in the widening strategic and economic competition between the United States and China. Since the outbreak of the U.S.-China trade war and implementation of tariffs in 2018, U.S. companies have begun to pursue, and the U.S. government has encouraged, the development of more diversified supply chains away from China. But China and its companies have more than a decade lead in accessing and mining critical mineral supplies around the world and developing a large critical mineral processing sector and possess world-leading EV, battery, and renewables manufacturing capacities. In this environment, U.S. clean energy policies incentivizing investments in critical minerals, processing, and manufacturing are now explicitly linked to developing supply chains excluding China. This will prove very challenging.

Another factor in heightened competition for critical minerals is the Covid-19 pandemic. Lockdowns to curb the spread of the virus hammered global supply chains for everything from food to semiconductors and further incentivized companies and countries to diversify and secure their supply chains. This continues to influence the pattern of investments in mining, processing, and manufacturing of critical minerals.

Finally, the Russian invasion of Ukraine has reinforced concerns over concentrated dependence on energy and mineral investments and supplies. In the aftermath of the invasion, Russia's decision to cut off most of its natural gas exports to Europe is further driving the impulse to diversify supply chains to reduce their vulnerability to geopolitical conflicts. Beyond oil and gas, Russia is a key global supplier of nickel, palladium, and other minerals vital to the clean energy revolution.

Consequently, the risk of geopolitical conflicts and "black swan" events is increasingly driving U.S., European, and Asian critical mineral policies, investments, and supply chain security decisions as the world transitions toward cleaner energy. Some experts see this trend leading to political regionalization of supply chains or potentially a "balkanization" of supply chains. Countries are increasingly focusing their critical mineral strategies on concepts like "nearshoring," "friendshoring," or "ally-shoring." "Just in time" supply chain management is shifting to "just in case" supply chain security. Beyond diversification, some countries are looking at building strategic stocks of minerals or investments to ensure "spare capacity" and redundancy in mineral or processing capacities.

In the Indo-Pacific region, this trend is playing out in national and corporate strategies to diversify critical mineral supplies and capacity away from China. It is showing up in the national strategies of the United States, Japan, South Korea, and other key states. It is also filtering into strategies involving multilateral forums such as the Quad grouping of the United States, Japan, Australia, and India as well as in bilateral agreements and investments. Key mineral supplier states like Australia and Indonesia are also shaping strategies to capitalize on the "gold rush" to access critical minerals. A new geopolitics of clean energy minerals and production power is thus emerging across the Indo-Pacific region.

To assess the implications of these developments, the National Bureau of Asian Research (NBR) commissioned four essays by scholars with expertise on these issues. The preliminary findings were discussed at a hybrid workshop in Washington, D.C., on July 28, 2022, which NBR was pleased to once again cohost with the Wilson Center. Participants included senior representatives from the U.S. government and foreign policymaking communities as well as leading industry and geopolitical experts. The authors have drawn on feedback they received at the workshop to strengthen their research and findings.

In the first essay, Yu-Hsuan Wu and Phung Quoc Huy from the Asia Pacific Energy Research Centre provide a crisp and clear analysis of the heavy geographic concentration and know-how led by a small group of countries, which raise serious concerns about the potential supply instability, pricing volatility, and geopolitical risks of the global critical mineral market. They call it an alarm bell "for nations that rely on critical mineral imports or the final products." For example, in each of the mining, processing, and manufacturing phases of six critical minerals globally, three countries account for at least one-half of global production, although the countries are not the same in each phase. In fact, these mineral supply chains are markedly more concentrated than global oil and natural gas supply chains, indicating the enormous potential for supply disruptions compared to the risks in the oil and gas markets. Wu and Phung's data also shows the scale of China's role, which suggests why access to critical minerals and processing capacity has become a key strategic concern in the context of intensifying geopolitical competition in the region.

In the second essay, Llewelyn Hughes from the Australian National University examines critical minerals from the perspective of Australia, a key future supplier of many critical minerals. The country faces a double challenge in moving away from a heavily fossil fuel–driven domestic economy and export sector to shift toward a clean energy future. Most importantly, the new government elected in May 2022 is weighing how to take advantage of the opportunity to become a major exporter of critical minerals. To do this, it is taking a more active approach to developing critical mineral supply chains and production. Australia already has a well-developed regime enabling investment in the extraction and export of natural resources. The government has launched a number of initiatives over the past several years and possesses the institutional capacity to support Australia's future growth as a critical minerals "powerhouse." The country is also looking at capturing more of the downstream value chain by building up its processing and manufacturing potential and competitiveness. Internationally, Australia is forging agreements with the United States, Japan, South Korea, and India to integrate itself into the "global value chains" involving low-carbon technologies.

In the third essay, Kristin Vekasi from the University of Maine considers the lessons from Japan's and South Korea's progress in building resilient critical mineral supply chains. Both countries' approaches include policies to diversify overseas critical mineral supply sources. They also have both developed institutions around the key economic ministries to provide funding, insurance, and direct support for overseas mining projects in public-private partnerships led by state-supported companies. The range of countries for projects is global and aimed at avoiding China. Bilateral agreements backstop many of these investments, and the stockpiling of critical minerals was started decades ago. While not all projects or initiatives have been successful, both Japan and South Korea have developed a much wider and more diversified critical mineral supply chain through deliberate state-led industrial policy. The question for the United States is whether it can develop the industrial policy capacity and institutions that have been reasonably effective for Japan and South Korea.

The final essay is by Sharon Burke, president of Ecospherics, and assesses the prospects for repositioning the United States for critical mineral success. The United States has only recently developed new policies focused on the clean energy and critical defense implications of heavy reliance on imported critical minerals. The Obama administration was spurred to action by China's withholding of rare earth minerals from Japan in 2010, which led to the new Critical Materials Strategy. The Pentagon, as a result, stopped the liquidation of the National Defense Stockpile and reassessed its contents. The Trump administration later accelerated the response to Chinese dominance of the high-tech critical mineral supply chain. The Biden administration has brought a sharper focus on production at home and diversification abroad that prioritizes "reshoring" and "friendshoring." Nonetheless, the United States still faces real challenges in advancing a more effective strategy. A deep-seated aversion to industrial policy remains a hindrance to mobilizing the coordinated government action needed to compete with China. Resistance from environmental groups to domestic mining or processing projects is a clear challenge. Internationally, the refusal to ratify the United Nations Convention on the Law of the Sea undermines U.S. influence on potential seabed critical mineral mining and resource access. Burke suggests that a more strategic approach is a matter of urgency.

Collectively, these four essays provide context for the new geopolitics and strategic competition emerging around controlling critical minerals and outline pathways for the United States and its partners in the Indo-Pacific to establish and improve upon resilient and secure supply chains. The analysis stresses the importance of public-private partnerships and bilateral relationships for the diversification of resource extraction and manufacturing. Additionally, sweeping industrial policy; implementation of environmental, social, and governance standards; and innovation in mining technology and recycling will be needed for the United States and its partners to catch up to China's head start. When considering the rising pressure and challenges posed by climate change, obtaining financing and investment to support secure supply chains with like-minded countries is imperative to realize a more sustainable energy future.

The 2022 Energy Security Program would not have been possible without the support, guidance, and dedication of a number of organizations and individuals whose efforts are particularly worthy of recognition. First, we are grateful to Chevron, ConocoPhillips, and Freeport-McMoRan for their sponsorship of NBR's energy programming. Their contributions are indispensable. Second, over the past several months we have received comments from numerous U.S. and East Asian scholars, representatives at international organizations and financial institutions such as the Asian Development Bank and Japan Bank for International Cooperation, and government officials on how the world has arrived at the geopolitical challenges surrounding critical minerals and what pathways exist going forward. While there are too many people and groups to list individually, the workshop and this report would not have been possible without their contributions.

Finally, working tirelessly behind the scenes to develop the program and refine the policy discussions were NBR's Audrey Mossberger, Ashley Johnson, Tom Lutken, Chihiro Aita, and Juliette Perrier (who also provided the concept for the cover illustration). We are also grateful to Michael Kugelman and his team at the Wilson Center for their support of the workshop. We hope that you enjoy reading this year's report.

Mikkal E. Herberg
Research Director of the Energy Security Program, NBR
Senior Lecturer, University of California San Diego

Micah Sindelar
Project Manager, Energy and Environmental Affairs, NBR

THE NATIONAL BUREAU *of* ASIAN RESEARCH

NBR SPECIAL REPORT #102 | DECEMBER 2022

Geopolitics of Critical Minerals

Yu-Hsuan Wu and Phung Quoc Huy

YU-HSUAN WU is a Researcher at the Asia Pacific Energy Research Centre (APERC). He is responsible for Chinese Taipei's energy outlook and overview and is involved in several energy security projects. He can be reached at <yuhsuan.wu@aperc.or.jp>.

PHUNG QUOC HUY is a Senior Researcher at the Asia Pacific Energy Research Centre (APERC). He is interested in the coal market; clean coal technologies; energy policies; carbon capture, utilization, and storage; critical minerals; renewable energy certificates; and low-carbon towns. He can be reached at <huy.phung@aperc.or.jp>.

EXECUTIVE SUMMARY

This essay finds that the supply chains of critical minerals are highly concentrated by a few countries, creating geopolitical issues amid global clean energy transitions.

MAIN ARGUMENT

Several minerals are indispensable to the production of clean energy equipment, such as solar photovoltaic modules, wind turbines, and batteries, and demand for these minerals is expected to increase substantially in the next few decades as many economies deploy clean energy technologies. A review of supply chains (mining, processing, manufacturing, and end use) of six critical minerals (cobalt, copper, lithium, nickel, rare earth elements, and silicon) suggests that the supply chains of critical minerals are highly concentrated, which creates potential economic, energy, and national security risks. Highly concentrated supply chains will also shape the related downstream industries and the future energy mix of many countries. Technological innovation could reduce this concentration and the associated risks, but game-changing innovation is likely several decades away from commercialization. Given the technological uncertainties, increased investment in diverse supply chains is required to ensure an adequate supply of critical minerals in the coming decades.

POLICY IMPLICATIONS

- The demand for critical minerals is expected to increase drastically in the next few decades to achieve the energy transition and the net-zero emission targets that many countries have already proposed. Under this projection, the highly concentrated critical mineral supply chains will increase the potential economic and security risks that should not be ignored.
- Historical events have shown that an economy with substantial market power in critical mineral supply chains has the potential and ability to shape downstream industries and use them as a political and economic weapon.
- Innovative technologies in the supply chains for critical minerals could mitigate the concentration and the associated risks. However, considering the uncertainty of innovation, investment in diverse supply chains is still indispensable to ensure adequate and affordable critical minerals.

As of June 2022, 137 countries have committed to achieving net zero or carbon neutrality by the middle of this century. The transitional period requires switching from fossil fuel to cleaner energy, in which renewable energy plays a crucial role. The International Energy Agency (IEA) estimates that the share of renewable energy is expected to account for two-thirds of the total energy supply by 2050 in its "net-zero emissions by 2050" scenario.[1] The Asia-Pacific Economic Cooperation (APEC) shows a similar trajectory out to 2050 in its "carbon neutrality" scenario.[2] To facilitate this transition to more sustainable energy systems, there is a correspondingly important role for clean energy technology and critical minerals.

This essay selects critical minerals based on three key criteria: demand growth, supplier concentration, and importance to clean energy technology.[3] Using these criteria, six critical minerals are selected for study: cobalt, copper, lithium, nickel, rare earth elements (REEs), and silicon. Clean energy technologies in this study include solar photovoltaic (PV) panels, wind turbines, electric vehicles (EVs), and electrical grids.[4]

Geographically, in each of the mining, processing, and manufacturing phases, there are three countries responsible for at least around half the global production of each critical material. Although the countries are not the same in each phase, there are notable similarities in the top three, which emphasizes supply limitations. Technologically, China is the global leader in mining REEs and silicon as well as in the processing, manufacturing, and end uses of all six critical minerals. While the Democratic Republic of Congo (DRC) dominates global cobalt ore production, Australia is the largest lithium ore producer in the world. Indonesia has the largest share of global nickel raw materials, and Chile is the largest copper ore producer worldwide. Thus, in the current context, heavy geographic concentration and know-how led by a small number of countries raise serious concerns about supply instability, pricing volatility, and geopolitical risks in the global critical mineral market. This should cause alarm for nations that rely on critical mineral imports or the final products.

This essay begins with an overview of critical minerals and supply chains, followed by a discussion of geopolitical issues. It concludes with an analysis of new technologies that may mitigate some of the geopolitical concerns.

Overview of Critical Minerals and Supply Chains

According to the IEA's "sustainable development" scenario, the consumption of lithium, nickel, and cobalt is expected to drastically rise by 42, 33, and 21 times, respectively, by 2040 compared to 2020, while REEs, copper, and silicon will have relatively less growth of 7, 3, and 2 times, respectively.[5] Based on various sources, shortages and higher prices are expected in almost

1 IEA, *World Energy Outlook 2021* (Paris: IEA, 2021), https://www.iea.org/reports/world-energy-outlook-2021.

2 Asia Pacific Energy Research Centre (APERC), *APEC Energy Demand and Supply Outlook*, 8th ed. (Tokyo: APERC, 2022), https://www.apec.org/publications/2022/09/apec-energy-demand-and-supply-outlook-%288th-edition%29---volume-i.

3 The authors are aware that the supply chain of "clean energy" may not be as clean as its name suggests. This is especially true in the mining, processing, and manufacturing stages, which can be energy-consuming processes. However, there seems to be no well-accepted term to replace "clean energy technology." Hence, in this essay, we use "clean energy technology" to refer to solar, wind, EV and battery storage, and electricity networks.

4 REEs are a family of seventeen elements (fifteen elements in the lanthanide group, along with scandium and yttrium). Neodymium is one of the most important elements for the clean energy transition and is a key ingredient in producing the powerful permanent magnets used for motors in EVs and wind turbines.

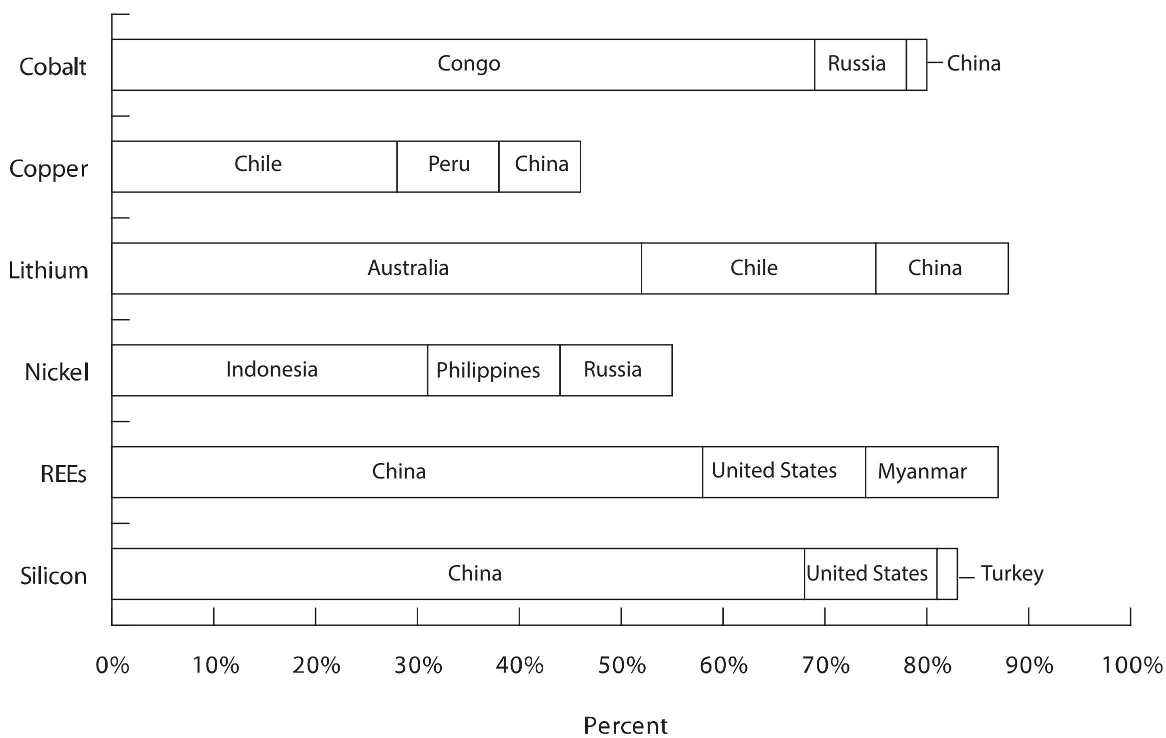
5 IEA, "The Role of Critical Minerals in Clean Energy Transitions," May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

all critical mineral markets.[6] In the following sections, the supply chain (mining, processing, manufacturing, and end uses) for six selected critical minerals is discussed to provide broad insights into the main countries with concentrated stakes in each phase.[7]

Mining

The top-three countries' total share of global mining production for each critical mineral is between 47% and 88%, suggesting a concentrated mining market (see **Figure 1**).[8] The DRC has an

FIGURE 1 Top-three producers in the critical mineral mining market



SOURCE U.S. Geological Survey (USGS), *Mineral Commodity Summaries 2022* (Reston: USGS, 2022), https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf; IEA, "The Role of Critical Minerals in Clean Energy Transitions," May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-inclean-energy-transitions.; and "World—Silica Sands (Quartz Sands or Industrial Sands)—Market Analysis, Forecast, Size, Trends and Insights," IndexBox, August 13, 2022, https://www.indexbox.io/store/world-silica-sands-quartz-sands-or-industrial-sands-market-analysis-forecast-size-trends-and-insights.

6 Silicon may be the only exception. An excess of the mineral in the markets is forecast by 2030, owing to an overcapacity issue in China's silicon industry, according to some sources. The capacity in China alone is expected to be large enough to cover the global demand for silicon metal. Although more studies are needed to understand this overcapacity issue, it may result from a shortage of energy and China's unique "market mechanism." See U.S. International Trade Commission, "Silicon Metal from China," May 2018, https://www.usitc.gov/publications/701_731/pub4783.pdf; and Liesbet Gregoir et al., "Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge," KU Leuven and Eurometaux, April 2022, https://eurometaux.eu/media/jmxf2qm0/metals-for-clean-energy.pdf.

7 Definitions for different stages of the supply chains are provided in the following sections. However, due to the limited availability of data, the definitions for different critical minerals in the same stage may not be identical.

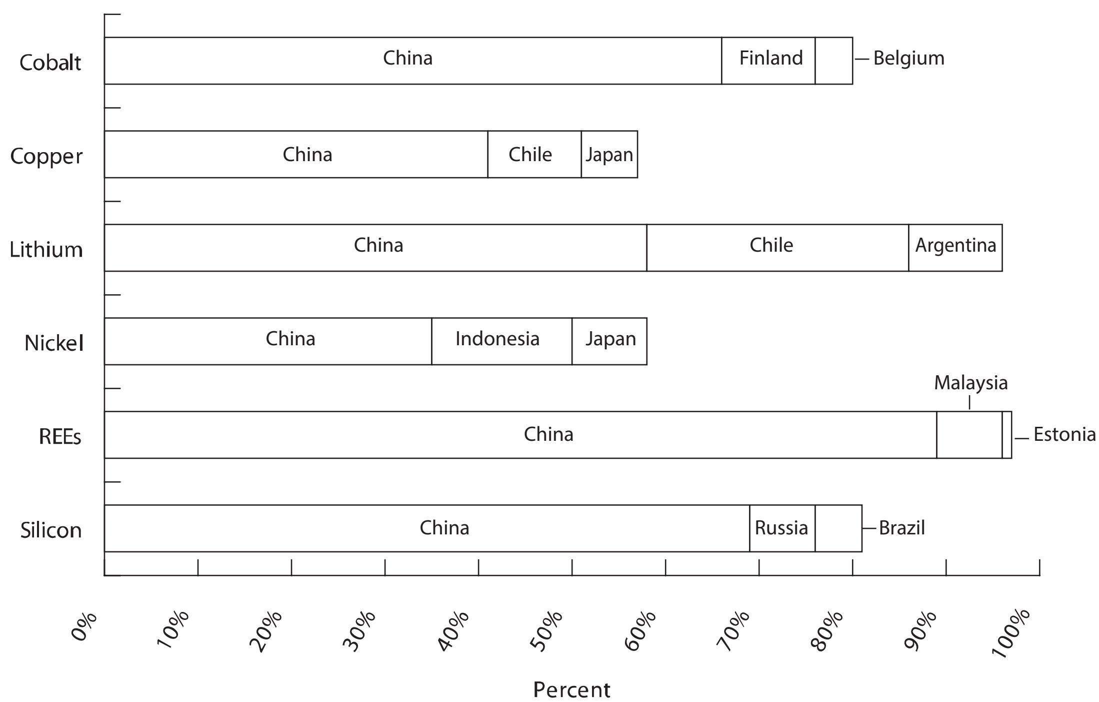
8 Mining is defined as the activity of extracting targeted raw ores (e.g., sulfide ore and oxide ore) from the Earth's crust, and mining production is defined as the production of the targeted raw ores. The production of silica is regarded as silicon mining production.

overwhelming share of cobalt extraction, accounting for approximately 70% of global production. Chile is the largest copper mine producer (28%) and the second-largest lithium mine producer (23%), while Australia is the principal producer of lithium mine products (52%). Indonesia is the largest nickel producer, accounting for 31% of the world's nickel mining. China dominates REE (58%) and silicon (68%) mining production and ranks third in global mining production of cobalt (2%), copper (8%), and lithium (13%).

Processing

The processing markets for the six critical minerals are also concentrated.[9] The total share of the top-three producers exceeds 50% of global processing of the selected critical minerals (see **Figure 2**). China owns the largest share of the processing of all selected critical minerals: cobalt

FIGURE 2 Top-three producers in the critical mineral processing market



SOURCE "Global Cobalt Supply Chain: Limited Number of Players, China and the DRC to Maintain Their Dominance," Fitch Solutions, September 22, 2021, https://www.fitchsolutions.com/mining/global-cobalt-supply-chain-limited-number-players-china-and-drc-maintain-their-dominance-22-09-2021; IEA, "The Role of Critical Minerals in Clean Energy Transitions"; U.S. Department of Energy, *Rare Earth Permanent Magnets: Supply Chain Deep Dive Assessment* (Washington, D.C., February 2022), https://www.energy.gov/sites/default/files/2022-02/Neodymium%20Magnets%20Supply%20Chain%20Report%20-%20Final.pdf; and USGS, *Mineral Commodity Summaries 2022*.

[9] Processing is defined as the activity of the preliminary separating of the targeted minerals from the raw ores (e.g., pyrometallurgy and hydrometallurgy). Metallurgical-grade silicon production is regarded as silicon processing production.

(66%), copper (41%), lithium (58%), nickel (35%), REEs (89%), and silicon (69%). Chile ranks second in copper and lithium processing, accounting for 10% and 28%, respectively. Indonesia, the largest nickel mining country, ranks second in the nickel processing market (15%). The rest of the countries in the top-three processing markets are not listed in the mining market, which implies that the processing stage does not depend on the origin of raw critical mineral resources.[10]

Manufacturing

The manufacturing markets for the six critical minerals also remain concentrated.[11] The total share of the top-three manufacturers accounts for over half the global manufacturing products (see **Figure 3**). China dominates all manufacturing markets, namely cobalt (67%), copper (41%), lithium (55%), nickel (25%), REEs (92%), and silicon (76%). Chile ranks second in copper (10%) and lithium (27%) manufacturing products. Chile seems to take advantage of mineral resources in the copper and lithium markets to develop the upstream and midstream mineral industries. Japan is listed in the top-three processing and manufacturing countries for copper and nickel as well as in the top-three cobalt and REE manufacturers. Finland ranks second in cobalt processing and manufacturing markets, while Argentina ranks third in lithium processing and manufacturing markets. The market shares for these two countries are around 10% in both the processing and manufacturing stages. Overall, the market shares and ranks suggest a close relationship between the processing and manufacturing markets.[12]

End Uses

The end-use markets for the selected critical minerals are concentrated much like the previous three steps in the supply chain.[13] The total share of the top-three producers exceeds 70% of the global end use of selected critical minerals (see **Figure 4**). There are, however, two caveats. First, except for silicon and lithium, the top-three end users of other critical minerals are aggregated partly by regions instead of countries. The different aggregation makes the comparison of concentration between end-use markets and other markets problematic. Second, the end-use data here refers to the shares of end-use products or the critical mineral consumption in the end-use sectors. However, China's dominance in all end-use markets is undisputed, with cobalt (32%), copper (54%), lithium (39%), nickel (59%), REEs (68%), and silicon (70%). South Korea ranks second in lithium (20%) and silicon (5%) end-use production, while Japan ranks third in lithium (18%) end-use production.

Summary

The market shares of various critical minerals in different stages of the supply chain suggest that the supply chains are highly concentrated and shaped by many factors, including

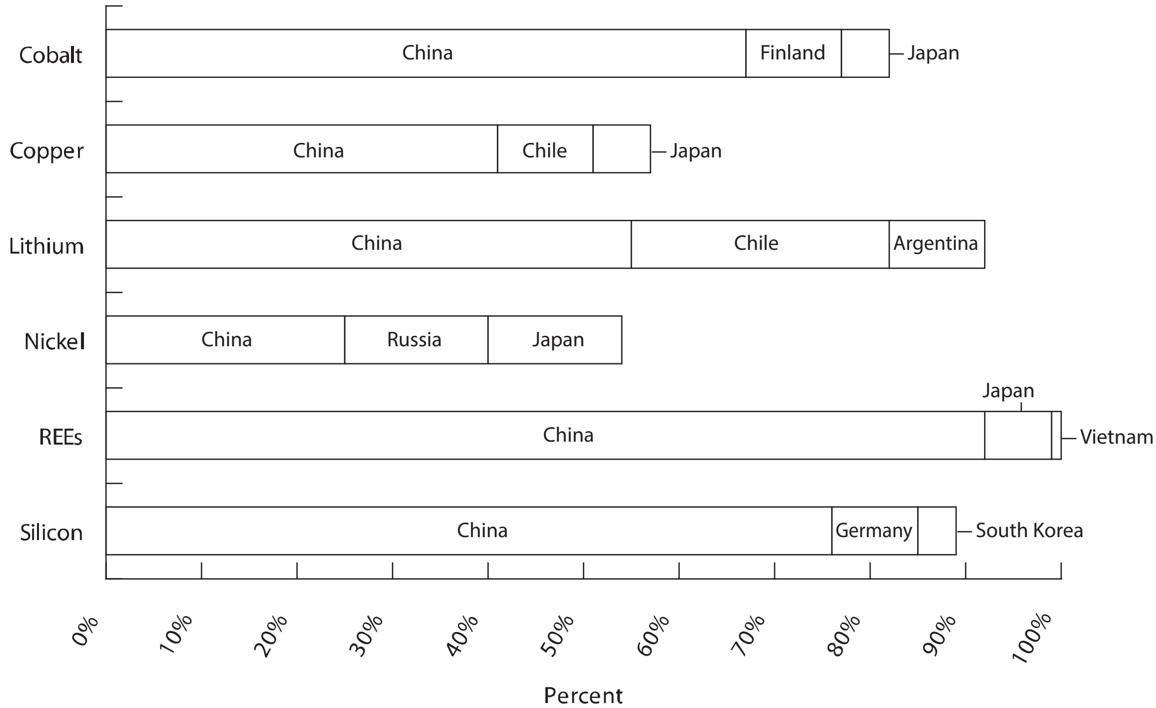
[10] The development of processing industries in countries without raw resources may result from their comparative advantages in separation or refinery technology and the investment needed. The cooperation of China and Myanmar in REEs is one example: the former possessed the needed capital and technological know-how, and the latter offered the raw materials.

[11] Manufacturing is defined as the activity of further refining the targeted minerals from the processed products. Lithium chemical production, Class 1 nickel production, sintered neodymium magnet production, and polysilicon production are regarded as manufacturing productions.

[12] The relationships may result from the similar definitions we made for the stages and critical minerals. The close relationships between processing and manufacturing may imply that economies with a comparative advantage in one stage can naturally have a comparative advantage in the other. However, further studies are needed to understand the relationships between these two stages.

[13] End uses are defined as the amounts of critical minerals consumed to produce the final product. Solar PV module production is regarded as a silicon end-use product.

FIGURE 3 Top-three producers in the critical mineral manufacturing market

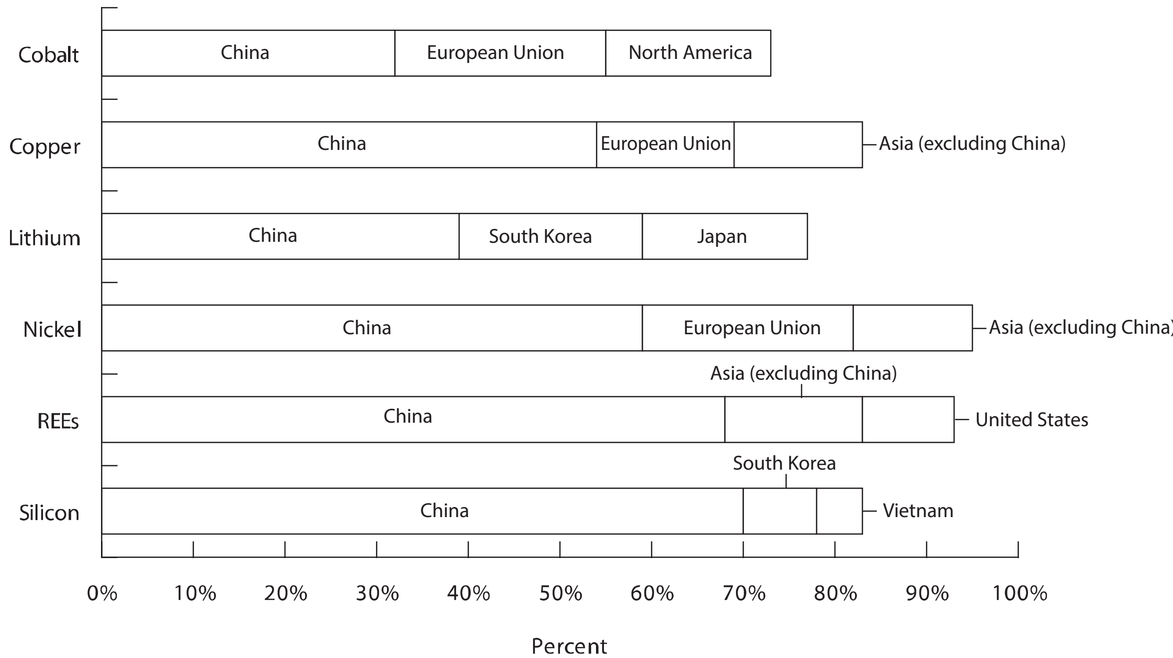


SOURCE: "'State of the Cobalt Market' Report," Cobalt Institute, May 17, 2021, https://www.cobaltinstitute.org/wp-content/uploads/2021/05/CobaltInstitute_Market_Report_2020_1.pdf; International Copper Study Group, *The World Copper Factbook 2021* (Lisbon: International Copper Study Group, 2021), https://icsg.org/wp-content/uploads/2021/11/ICSG-Factbook-2021.pdf; "Europe's Lithium Challenge on the Road to Electrification," Rock Tech Lithium, June 4, 2021, available at https://elements.visualcapitalist.com/europes-lithium-supply-challenge-on-the-road-to-electrification; Marcelo Azevedo, Nicolas Goffaux, and Ken Hoffman, "How Clean Can the Nickel Industry Become?" McKinsey & Company, September 11, 2020, https://www.mckinsey.com/industries/metals-and-mining/our-insights/how-clean-can-the-nickel-industry-become; U.S. Department of Energy, *Rare Earth Permanent Magnets*; Johannes Bernreuter, "Background and Ranking of the Top Ten Polysilicon Producers," Bernreuter Research, June 29, 2020, https://www.bernreuter.com/polysilicon/manufacturers; and Kelly Pickerel, "China's Share of World's Polysilicon Production Grows from 30% to 80% in Just One Decade," Solar Power World, April 27, 2022, https://www.solarpowerworldonline.com/2022/04/chinas-share-of-worlds-polysilicon-production-grows-from-30-to-80-in-just-one-decade.

endowments (e.g., distribution of mineral reserve and labor cost), economic structure, energy policy, technology, and environmental regulations of each country. An abundant mineral reserve alone does not necessarily imply dominance of the entire supply chain. The best example of this is in the world's largest cobalt miner, the DRC, which does not play any significant role in the processing, manufacturing, or end-use stage. In addition, China dominates the entire supply chain of REEs and silicon and ranks first in the processing, manufacturing, and end use of the other critical minerals discussed in this section. China's leadership might result from its early and abundant investment in the critical mineral supply chain.

The following section discusses the geopolitical aspects of highly concentrated supply chains.

FIGURE 4 Top-three users (producers) in the critical mineral end-use market



SOURCE "Global Cobalt Supply Chain"; IEA, "The Role of Critical Minerals in Clean Energy Transitions"; U.S. Department of Energy, *Rare Earth Permanent Magnets*; and USGS, *Mineral Commodity Summaries 2022*.

Geopolitical Aspects

The critical mineral market is expected to be more complicated and volatile than the oil market given its highly concentrated supply chains. Under the global energy transition trend, it will be essential to pay equal or even greater attention to supply chains. The concentrated supply chains in critical minerals could be problematic or trigger disputes because intentional disruptions could affect a country's industrial competitiveness and provide economic and political leverage to suppliers with market power.

For the industry's competitiveness, a country that dominates upstream production may enjoy ease of access to the feedstock. For example, China dominates the entire supply chain of solar PV modules. Its cost advantage is generally recognized as the result of cheap labor, an economy of scale, and ease of access to the feedstocks. It is also worth noting that economies of scale in solar PV module production further reinforce the profitability of those with market power in upstream production. China's solar PV supply chain dominance has raised concerns in several countries, including the United States. According to the U.S. Department of Energy, it would be risky for the United States to continue to rely on China's silicon production, and it would be beneficial for the U.S. economy to develop and secure its own solar PV supply chain.[14]

[14] U.S. Department of Energy, "Rare Earth Permanent Magnets: Supply Chain Deep Dive Assessment," February 2022, https://www.energy.gov/sites/default/files/2022-02/Neodymium%20Magnets%20Supply%20Chain%20Report%20-%20Final.pdf.

Consequently, the United States has implemented several policies to encourage domestic solar PV and the upstream industries and imposed restrictions on specific solar PV products or feedstocks from China.

Some countries with abundant critical mineral resources have imposed restrictions on the export of raw materials to stimulate domestic investment and production of higher value-added products. Indonesia, the world's largest nickel miner and second-largest nickel processor, started restricting raw nickel exports in 2014. According to the Indonesian government, the restriction stimulated investment in nickel refineries and nickel-based products.[15] This case shows a country's attempt to develop an entire supply chain, increase economic profits, and improve economic structures. Not surprisingly, the restrictions on exports resulted in complaints from other economies. The European Union, for example, claimed that the restrictions were illegal and harmful to its stainless steel producers.[16]

The security risks involved with critical mineral supply disruption are more disquieting. A supply disruption can be caused by natural disasters, political turmoil, international conflicts, or anything that can affect the production and export of critical minerals. One well-known example is the export restrictions on REEs that China imposed on Japan in 2010 after Japan seized a trawler it said was fishing illegally in its waters. The effectiveness of these restrictions was demonstrated by the speed with which Japan released the boat captain without receiving any concessions. This example highlights how market power in the supply chains of critical materials can be used as both a political and an economic weapon.[17]

A more recent example of a critical mineral supply disruption occurred in Myanmar. In 2021, REE exports from Myanmar to China were affected by the military coup and the border closure to limit the spread of Covid-19. Although China is the world's leading REE producer and consumer, it relies on the (heavy) REE feedstock from Myanmar. The disruption is believed to be one of the reasons that the price of REEs rose significantly in 2021.[18] This example shows that domestic political turmoil or a natural disaster can cause a global supply issue if it happens in a country that dominates, or partially dominates, certain critical minerals.

These economic and security aspects of geopolitical issues suggest that participants in a supply chain should pay attention to the movements of major suppliers of critical minerals because of their potential ability to reshape the related industries. The following section discusses the potential of innovative technologies along with their uncertainties.

Innovative Technologies

The foregoing analysis of the geographic concentration of critical minerals and the resulting geopolitical issues has revealed the fragility of global supply chains. This situation underscores

15 Krisna Gupta, "Indonesia's Claim That Banning Nickel Exports Spurs Downstreaming Is Questionable," Conversation, March 30, 2022, https://theconversation.com/indonesias-claim-that-banning-nickel-exports-spurs-downstreaming-is-questionable-180229.

16 "Indonesia Says 'Ready to Fight' EU at WTO over Nickel Export Curbs," Reuters, February 26, 2021, https://www.reuters.com/article/us-eu-indonesia-trade-idUSKBN2AQ0GO.

17 Under China's REE export restrictions in 2010, Japan used its REE stockpile to fill the gap, sought different REE sources, and invested in related technologies (e.g., seabed mining and recycling). There were short-term shocks resulting from China's restrictions on Japan, but the restrictions did not tremendously harm the Japanese economy. Instead, the restrictions raised Japan's awareness of its import dependency on critical minerals.

18 The strong demand for wind power and electric vehicles is another reason for the increasing price of REEs.

the need for innovative technologies at all stages in the supply chain to provide more stable and affordable mineral sources for future clean energy development.

In mining, deep-seabed mineral extraction is one potentially innovative technology that several countries are interested in exploring—particularly countries located in the Pacific Ocean's Ring of Fire. Japan, for example, plans to create mining technology and select a mining location in its exclusive economic zone by the end of 2028.[19] In Europe, Norway plans to start seabed mining exploration on its continental shelf as early as 2023. However, deep-seabed mining still carries uncertainties due to technological and marine environmental hurdles. First, a pilot project on deep-sea mining was conducted by the Japan Oil, Gas and Metals National Corporation in 2017, but it still needs further technical investigations to become commercially feasible. Second, impacts on ecosystems and biodiversity remain poorly understood, despite several rigorous studies. The International Seabed Authority, a UN body, is drawing up regulatory frameworks for the international seabed—areas outside any national jurisdiction—aiming to promote deep-sea mining while minimizing damage to the marine environment.[20]

In processing, various research projects have been conducted in the United States, including several pilot-scale tests and demonstrations. The West Virginia University Research Corporation has implemented a project called "Development and Testing of an Integrated Acid Mine Drainage (AMD) Treatment and Rare Earth/Critical Mineral Plant." If successful, the plant will generate around one thousand tons per year of REE and critical material oxides from coal and other ore bodies, with an estimated contained value of $237 per kilogram.[21] Additionally, the United States is conducting a feasibility study to assess the potential of REE recovery from coal, coal byproducts, and waste materials to support the U.S. domestic supply of REEs for clean energy. The target is to produce one to three tons of REEs per day by 2026.

In manufacturing and end use, innovative technologies in efficiency and design are vital to reduce material intensity. In the case of wind turbines, a larger size contributes to higher capacity, leading to a reduction in the material intensity of minerals. For instance, on a kilogram per megawatt (MW) basis, a 3.45 MW turbine contains around 50% less copper than a 2 MW turbine.[22]

Although innovative technologies are being developed at various stages of critical mineral supply chains to reduce dependency on primary supply, these innovations reveal uncertainties due to technological and environmental obstacles. Therefore, investment in mineral production is imperative to ensure a supply of critical minerals for clean energy technologies in the coming decades.[23]

---

19 "JOGMEC Conducts World's First Successful Excavation of Cobalt-Rich Seabed in the Deep Ocean; Excavation Test Seeks to Identify Best Practices to Access Essential Green Technology Ingredients While Minimizing Environmental Impact," Japan Oil, Gas and Metals National Corporation, August 21, 2020, https://www.jogmec.go.jp/english/news/release/news_01_000033.html; "Japan to Commercialize Mining of Rare Metals on Seabed," Eleven Media Group, January 19, 2021, https://elevenmyanmar.com/news/japan-to-commercialize-mining-of-rare-metals-on-seabed; and IEA, "The Role of Critical Minerals in Clean Energy Transitions."

20 "G-7 Countries Say Strict Environmental Rules Needed for Deep-sea Mining," Reuters, May 27, 2022, https://www.reuters.com/world/g7-countries-say-strict-environmental-rules-needed-deep-sea-mining-2022-05-27.

21 U.S. National Energy Technology Laboratory, "2020–2021 Critical Minerals Sustainability Program Project Portfolio," May 2021, 18, https://www.netl.doe.gov/sites/default/files/2021-05/2020-2021-REE-Portfolio.pdf.

22 Alessia Elia et al., "Wind Turbine Cost Reduction: A Detailed Bottom-Up Analysis of Innovation Drivers," *Energy Policy*, no. 147 (2020).

23 IEA, "The Role of Critical Minerals in Clean Energy Transitions."

Conclusion

Demand for critical minerals is expected to rise rapidly in the coming decades, given their significant role in the manufacture of clean energy equipment. The geopolitics of critical mineral supply chains have become an issue for many governments, particularly in import-dependent countries. The following are the main takeaways from this study:

- The demand for six materials critical to the manufacture of clean energy equipment is expected to triple by 2030 and quadruple by 2040 as the world transitions toward clean energy technologies. By 2040, lithium has the highest expected growth in demand relative to 2020 levels (42-fold), followed by nickel (33-fold) and cobalt (21-fold), while demand for REEs, copper, and silicon will grow at a slower pace.
- Processing and manufacturing are mostly concentrated in the top-three countries, accounting for over half of the global production of each critical mineral (although the top three are different for different materials). China is the global leader in mining REEs and silicon and currently dominates the processing to end-use segments for all six critical minerals.
- Critical mineral supply chains are much more concentrated than the oil and gas supply chains on which the world currently relies. Geopolitical issues suggest that participants should pay attention to the potential economic, energy, and national security risks associated with critical mineral supply chains to ensure affordable and available critical minerals for economic development and decarbonization.
- In the long term, technological innovations, such as deep-seabed mining, provide potential solutions to reduce dependency on concentrated supplies and secure material supply in several countries. However, various uncertainties exist due to technological constraints and environmental impacts. As a result, increased investment in diverse supply chains is required to ensure an adequate supply of critical minerals in the coming decades.

THE NATIONAL BUREAU *of* ASIAN RESEARCH

NBR SPECIAL REPORT #102 | DECEMBER 2022

Securing Critical Mineral Supply Chains in the Indo-Pacific: A Perspective from Australia

Llewelyn Hughes

LLEWELYN HUGHES is an Associate Professor in the Crawford School of Public Policy at the Australian National University. He can be reached at <llewelyn.hughes@anu.edu.au>.

EXECUTIVE SUMMARY

This essay examines the relationship between critical minerals and resource security and then considers Australia's current strategy toward the critical minerals sector as well as its emerging international strategy.

MAIN ARGUMENT

For decades Australia has been a major exporter of energy commodities to countries in the Indo-Pacific. The shift toward decarbonization regionally is thus of crucial importance to Australia economically and geopolitically. The country has large deposits of minerals and base metals that are important in the low-carbon energy transition, and both the federal and state governments are moving to further develop Australia's innovation system to target critical mineral resources. This includes focusing on opportunities to increasingly participate in high value–added downstream processes and developing a number of international partnerships. Australia's critical mineral strategy will continue to develop with an export orientation and a focus on downstream value-adding capabilities.

POLICY IMPLICATIONS

- Governments and companies should monitor ongoing developments in critical mineral policy in Australia.
- Australia's open investment regime and mature mining sector mean that there are ample opportunities to invest and partner in critical minerals in Australia, including in downstream processing.
- It is crucial that governments work together to develop effective environmental, social, and governance and traceability standards in support of critical mineral development.

Security risks for fuels that supply energy products and services are a long-standing concern of governments in the Indo-Pacific region. These concerns have historically focused on a limited number of fossil fuels—in particular, crude oil, gas, and to a lesser extent coal. Concerns are now expanding to incorporate a broader range of commodities that are crucial to the global low-carbon energy transition.

The "net-zero emissions by 2050" scenario released by the International Energy Agency (IEA) illustrates the pace and scale with which countries will need to reconfigure industries and supply chains to ensure consistency with a 50% chance of limiting the global temperature increase to 1.5 degree Celsius, without a temperature overshoot. Under this scenario, CO_2 emissions related to energy use and industrial processes fall almost 40% globally between 2020 and 2030 and to net zero by 2050. Methane emissions from fossil fuel use also fall by 75% by 2030, while demand for coal falls by 90%, oil by 75%, and natural gas by 55%. Remaining fossil fuel use is dedicated to products with embodied carbon, and where carbon capture and sequestration technologies are in place.

Even under the IEA's less ambitious "announced pledges case," which assumes that announced net-zero emissions pledges made by governments globally are met, global CO_2 emissions from electricity fall by 60% between 2020 and 2050. Coal and oil use drop rapidly, while natural gas use increases to 2025 and is then flat until 2050. Along with electrification of transportation and across other sectors, the share of renewables in the global electricity sector increases from 29% in 2020 to almost 70% in 2050, led by solar photovoltaics and wind power, which represent 50% of total global electricity supply by 2050.[1]

The implications of these changes for countries in the Indo-Pacific are profound. Rapid economic growth in the region has been underpinned by carbon-intensive fuels. The region is home to a large fleet of relatively young thermal coal plants, many of which have benefited in part from bilateral financial organizations in Japan, China, and South Korea. In addition, the energy transition requires enormous investments in low-carbon technologies, which increases demand for minerals and base metals.

For Australia, the economic opportunity from the energy transition comes not only from replacing carbon-intensive infrastructure domestically, but from the opportunity to export critical minerals used in the production of low-carbon technologies. There is also the potential to move down the value chain to process a greater share of value-added products domestically.

To assess these opportunities, this essay begins with an analysis of the relationship between critical minerals and resource security. It then outlines Australia's strategy toward the critical mineral sector and concludes with some remarks about the country's emerging international strategy in critical minerals.

Resource Risks and Rising Global Demand for Critical Minerals

The transition to a low-carbon economy fundamentally alters the structure of energy security risks. An assessment of the energy security implications of deep decarbonization across six integrated assessment models shows decarbonization will lead to lower global energy trade and

1 IEA, "Net Zero by 2050: A Roadmap for the Global Energy Sector," May 2021, https://www.iea.org/reports/net-zero-by-2050.

reduce the energy imports of China, India, the European Union, and the United States.[2] The current crisis in energy markets underscores that energy import dependence alone is inadequate as a measure of energy security. Nevertheless, lower reliance on energy imports increases the physical security of supplies, not least because it means a reduced reliance on the maritime domain in which power is contested.[3]

Aside from a projected reduction in trade, the decarbonization of energy systems requires an enormous increase in the production of key minerals used in products substituting for fossil fuels in power generation, transportation, and industry. The volume of minerals used to provide an additional unit of power-generation capacity has already grown by 50% since 2010 as the share of renewable electricity has increased globally.[4] The IEA estimates that lithium demand will grow more than 40 times by 2040 if governments follow through on their stated policy commitments. Demand for graphite, cobalt, and nickel will increase around 20 to 25 times over the same period, and demand for copper will more than double.

Thus, while energy security concerns historically have focused on crude oil, and more recently on natural gas, the low-carbon energy transition requires governments to focus on a broader array of products when identifying and managing risks associated with a decarbonized global energy system. **Table 1** provides an overview of the critical minerals needed for various clean energy technologies. Detailed analysis will be required on a commodity basis given differences in the market structure for minerals, while risks will be determined by the potential rate of growth in mining and processing capabilities, the overall availability of resources, and the potential presence of geographic and geopolitical risks.[5]

A key risk is the potential for market concentration to reduce supply chain resilience. Security risks in supply chains emerge from market concentration among suppliers in the presence of a lack of substitutes.[6] The IEA notes the high levels of potential market concentration in some minerals and in mineral processing. Recent policy announced by the European Commission likewise identifies supply risk as an important factor in determining which minerals are designated as critical.[7]

Australia's Approach to Critical Minerals

The low-carbon energy transition has important implications for Australia's position as an exporter of energy-related commodities. The development of supply chains for critical minerals is not only about managing supply chain risk. In addition, the Australian federal government has implemented measures that position the country as a key supplier of minerals.

Australia already supplies large volumes of carbon-intensive fuels, notably thermal coal and liquefied natural gas (LNG), much of which is exported to the major economies of the Indo-Pacific.

2 Jessica Jewell, Aleh Cherp, and Keywan Riahi, "Energy Security under De-carbonization Scenarios: An Assessment Framework and Evaluation under Different Technology and Policy Choices," *Energy Policy* 65 (2014): 743–60.

3 Llewelyn Hughes and Austin Long, "Is There an Oil Weapon? Security Implications of Changes in the Structure of the International Oil Market," *International Security* 39, no. 3 (2014/2015): 152–89.

4 IEA, "The Role of Critical Minerals in Clean Energy Transitions," May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

5 Dolf Gielen, *Critical Minerals for the Energy Transition* (Abu Dhabi: International Renewable Energy Agency, 2021).

6 Eugene Gholz and Llewelyn Hughes, "Market Structure and Economic Sanctions: The 2010 Rare Earth Elements Episode as a Pathway Case of Market Adjustment," *Review of International Political Economy* 28, no. 3 (2021): 611–34.

7 European Commission, "Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability," September 2020.

TABLE 1 Critical mineral needs by technology

	Copper	Cobalt	Nickel	Lithium	REEs	Chromium	Zinc	Platinum group metals	Aluminum
Solar PV	●	○	○	○	○	○	○	○	●
Wind	●	○	◎	○	●	◎	●	○	◎
Hydro	◎	○	○	○	○	●	◎	○	◎
Concentrating solar power	◎	○	◎	○	○	●	◎	○	●
Bioenergy	●	○	○	○	○	○	◎	○	◎
Geothermal	○	○	●	○	○	●	○	○	○
Nuclear	◎	○	◎	○	○	◎	○	○	○
Electricity networks	●	○	○	○	○	○	○	○	●
EVs and battery storage	●	●	●	●	●	○	○	○	●
Hydrogen	○	○	●	○	◎	○	○	●	◎

SOURCE: IEA, "The Role of Critical Minerals in Clean Energy Transitions," May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

NOTE: Shading indicates the relative importance of minerals for a particular clean energy technology: ● indicates high, ◎ indicates medium, and ○ indicates low.

In 2020, Australia was the second-largest exporter of thermal coal globally, accounting for 21% of all exports by value, after only Indonesia with 23%. Exports to Japan were valued at AU$12.8 billion, exports to South Korea at AU$4.4 billion, exports to Taiwan at AU$3.6 billion, and exports to India at AU$1.6 billion. Australia is also a major trading partner of LNG with countries in the region, exporting AU$17.2 billion in LNG to Japan, AU$7.1 billion to South Korea, AU$17.7 billion to China, and AU$2.7 billion to Taiwan. Overall, Australia exports 21% of total LNG traded globally by value. Australia is also a major exporter of iron ore and metallurgical coal, which are used in steel manufacturing.

Australia's long-standing position as an exporter of carbon-intensive fuels also means that the country has a well-developed regime enabling investment in resource extraction. The country's mining equipment, technology, and services sector incorporates firms working across the mineral value chain from exploration to operations, maintenance, and remediation. The sector as a whole is oriented toward exports.[8] The policy framework for critical minerals development is also consistent with the International Renewable Energy Agency's recommendation that a diversified market is best provided through growth in demand through open trade and investment.[9] The combination

[8] CSIRO Futures, "Mining Equipment, Technology and Services: A Roadmap for Unlocking Future Growth Opportunities for Australia," 2017.

[9] Gielen, *Critical Minerals for the Energy Transition*.

of an export orientation and an open regulatory framework for investment puts Australia in a good position to take advantage of the growth in demand for critical minerals required in support of the low-carbon energy transition, both as a commodities exporter and as an exporter of higher-value products.

The new government that took office in May 2022 has submitted a revised nationally determined contribution, establishing an economy-wide target of a 43% reduction in greenhouse gas emissions by 2030 relative to 2005. Responding more effectively to climate change is a key message that Prime Minister Anthony Albanese and Foreign Minister Penny Wong have underscored during meetings with Australia's Pacific neighbors, given that climate change represents an existential threat to these small island states.

Australia has a large resource base of a number of base metals and critical minerals important to the low-carbon energy transition.[10] The former and current governments both have recognized the economic opportunity from critical minerals. Prior to the election, the government under former prime minister Scott Morrison released the Critical Minerals Strategy. The document sought to position Australia as a supplier of "reliable, secure and resilient supplies" of critical minerals to other countries and laid out the vision that by 2030 Australia would establish itself as "a global critical minerals powerhouse" that is "integral to international critical mineral supply chains and technologies crucial to the global economy."[11] The strategy identified 26 minerals as critical and provided an assessment of Australia's geological potential.[12] This document was preceded by analysis released in 2021 by the Commonwealth Scientific and Industrial Research Organisation identifying opportunities in mining and manufacturing emerging from Australia's role as a supplier of critical minerals in the energy transition.

The Morrison government also integrated capabilities in critical minerals through the creation of the Critical Minerals Facilitation Office in January 2020. In addition, the Major Projects Facilitation Agency assists in commonwealth government approval processes for projects valued at AU$20 million or more, providing a one-stop-shop approach to investment. Projects valued at AU$50 million or more can be given "major project status," which unlocks additional support from the agency to enable investment.

In October 2022 the new government announced that it will revise the Critical Minerals Strategy.[13] In its first budget, announced that same month, the Albanese administration allocated AU$99.8 million over three years for the Strategic Critical Minerals Development Program designed to help critical mineral producers overcome market and technical barriers. The program enables industry, as well as state and territory governments, to apply for grants of up to AU$50 million, covering up to 50% of total costs, to conduct feasibility studies, develop engineering designs, or build pilot or demonstration projects. In addition, AU$50.5 million was allocated over four years to establish the Australian Critical Minerals Research and Development Hub to coordinate government, industry, and the research sector, as well as support international research and development collaboration. These initiatives build on, and partially replace, work by

---

10 Mike Sandiford, "The Net-Zero Opportunity for Australian Minerals," in *The Superpower Transformation: Building Australia's Zero-Carbon Future*, ed. Ross Garnaut (Collingwood: La Trobe University Press, 2022).

11 Department of Industry, Science, Energy and Resources (Australia), *2022 Critical Minerals Strategy* (Canberra, March 2022), https://www.industry.gov.au/sites/default/files/2022-09/2022-critical-minerals-strategy_0.pdf.

12 For a table listing these critical minerals, along with Australian geological potential, see Department of Industry, Science, Energy and Resources (Australia), *2022 Critical Minerals Strategy*, 26–27.

13 "Support for Critical Minerals Breakthroughs," Department of Industry, Science and Resources (Australia), Press Release, October 21, 2022, https://www.minister.industry.gov.au/ministers/king/media-releases/support-critical-minerals-breakthroughs.

the previous government designed to support Australia's role as a supplier of critical minerals (see **Table 2**).

TABLE 2 Selected Australian government initiatives on critical minerals

Initiative	Organization	Date
Initiatives under former government		
Outlook for Selected Critical Minerals: Australia 2019	Department of Industry, Science, Energy and Resources	2019
Australian Global Resources Statement	Department of Industry, Science, Energy and Resources	2020
Resources Technology and Critical Minerals Processing National Manufacturing Priority Road Map	Department of Industry, Science, Energy and Resources	2021
Australian Critical Minerals Prospectus 2021	Australian Trade and Investment Commission (Austrade)	2021
Critical Energy Minerals Roadmap	Commonwealth Scientific and Industrial Research Organisation	2021
Critical Minerals Strategy	Department of Industry, Science, Energy and Resources	2022
Initiatives under new government		
Critical Minerals Development Program	Department of Industry, Science, Energy and Resources	2022
Australian Critical Minerals Research and Development Hub	Geoscience Australia; Commonwealth Scientific and Industrial Research Organisation; Australian Nuclear Science and Technology Organisation	2022

SOURCE: Compiled by the author.

Capturing More of the Value Chain

A priority of Australia's Critical Minerals Strategy is to explore moving into downstream processing of critical minerals in order to capture more of the value associated with processing and manufacturing of intermediate and final products. The goal of adding more processing capabilities within Australia is underpinned by the "Resources Technology and Critical Minerals Processing National Manufacturing Priority Road Map," released by the Morrison government in 2021. While Australia has a significant resource base in critical minerals, downstream processing capabilities are limited. Through a process of industry engagement, the document identified the following challenges that must be overcome:

- *Developing technologies that increase competitiveness*. Examples include the development of ore body mapping technologies, geophysical tools and drilling technologies, greater automation, and improved grinding and processing technologies.

- *Supporting sustainability and productivity*. Examples include the development of technologies to decrease the use of environmentally sensitive chemicals in processing, increase efficient water use, improve monitoring and remediation capabilities, and improve the ratio of ore to waste.
- *Recovering value from waste*. Examples include innovation to enable better capture of resources from tailings and equipment that has reached the end of its life.
- *Improving horizontal and vertical diversification*. Examples include using the existing technology base to expand horizontally or vertically, thereby providing companies with an opportunity to further scale operations.[14]

To explore these opportunities the Australian government under both Morrison and Albanese has supported the creation of a number of cooperative research centres (CRCs). The CRC program is a federal grant program that provides support for medium- to long-term research partnerships with problems identified by industry needs. Proposed partnerships are assessed through competitive funding rounds.[15] In the area of critical minerals, the following CRCs are in operation:

- *Future Battery Industries CRC*. Examines innovative pathways to mine, extract, refine, and recycle battery minerals, metals, and materials to produce battery products.
- *CRC for Optimising Resource Extraction*. Develops energy-saving and resource-expanding technologies in support of the domestic mining and minerals industry.
- *MinEx CRC*. Creates new opportunities for mineral discovery by delivering more productive, safer, and environmentally friendly drilling methods; developing new technologies for collecting data while drilling; and collecting exploration data on never before sampled rocks that are hidden but prospective for minerals.

In addition, there are a number of CRC projects, which fund joint industry-research partnerships for up to three years, capped at AU$3 million with public investment of up to 50% of the total grant value. Recent CRC projects have supported industry-led research focused on extracting critical minerals and rare earths from bauxite residue, improving the processing of critical raw materials into platinum group metals, and supporting development of battery-grade materials from low-grade nickel laterite. See **Table 3** for an overview of federal initiatives relevant to critical minerals.

Developing an International Strategy

In addition to supporting R&D and early-stage project development, the government can also support developing new supply chains for critical minerals through international engagement. Accordingly, the Australian government is developing international partnerships in critical minerals to complement domestic measures supporting investment in mining and exploring opportunities to move down the value chain into mineral processing. Global value chains are commonly characterized by the geographic dispersion and de-verticalization of productive activities across multiple firms.[16] This is also the case for key low-carbon technologies such as solar photovoltaics and wind turbines. Global value chains differ depending on technology

14 Government of Australia, "Resources Technology and Critical Minerals Processing National Manufacturing Priority Road Map," 2022.

15 A full list of currently funded CRCs is available at https://business.gov.au/grants-and-programs/cooperative-research-centres-crc-grants/current-cooperative-research-centres-crcs.

16 Richard Baldwin, "Global Supply Chains: Why They Emerged, Why They Matter, and Where They Are Going," Centre for Trade and Economic Integration, CTEI Papers, 2012.

TABLE 3 Recent federal initiatives relevant to critical minerals

	Fundamental research → Proof of concept →	Demonstration →	Early adoption → Large-scale development
Mining	**Optimising Resource Extraction CRC (2010–21)** • improving feed quality • enabling mass separation • increasing extraction efficiency **MinEx CRC (2018–)** • New exploration tools to collect subsurface data	**Critical Minerals Accelerator Initiative (2022–)** • AU$200 million over five years • Department of Industry, Science, Energy and Resources –feasibility studies –engineering design work –pilot testing –building demonstration plants	**Critical Minerals Facility (2021–)** • up to AU$2 billion • Export Finance Australia –complements commercial finance –extraction/processing for export –completed feasibility studies –buyer commitment –use of proven technology –financial, technical, and commercial cap
Processing	**Future Battery Industries CRC (2019–)** • battery market and value chain development • battery chain supply chain integrity • energy grid optimization (with batteries) • transitional impact of batteries on society and the economy • optimize battery industry ecosystem **National Critical Mineral Research and Development Centre (2022)** • AU$50 million over three years • tax offset on top of the applicable corporate tax rate for R&D –intellectual property in critical mineral processing –technical bottlenecks in strategic supply chains –collaborative research **Modern Manufacturing Initiative (2022–)** • AU$1.3 billion • pilot, demonstrate, or scale up techniques and processes • AU$274 million to critical minerals related to products in 2020 and 2021 –Pure Battery Technologies: AU$119.6 million for nickel and cobalt battery material refinery –Australian Vanadium: AU$49 million for vanadium battery industry powered by green hydrogen –Arafura Resources: AU$30 million for Nolans Project Rare Earth Separation Plant	**Clean Energy Finance Corporation** • projects that develop, commercialize, or use renewable energy, low emissions, or energy efficiency • debt and equity offerings: aim to deliver a positive return across portfolio –US$52 million in Pilbara Minerals to mine and process raw material for lithium hydroxide –US$1.5 million through Clean Energy Innovation Fund in Novalith for low-carbon lithium production	

SOURCE: Compiled by the author from government documents.

characteristics as well as due to the specific capabilities and strategies adopted by firms.[17] Their structures are poorly captured by the national data collected on trade and investment and are highly dynamic. Industrial indices also commonly involve a high level of aggregation and thus do not provide sufficient resolution to understand the structure of global value chains for key technologies of interest.[18]

Given these challenges, a priority of the federal government is to identify the structure of global value chains involving low-carbon technologies. In addition to participation by international firms in industry-led CRCs, Australia has signed memoranda of understanding with South Korea, India, and Japan. A delegation from India visited Australia under their critical minerals partnership in July 2022 to support Indian investment in Australia's critical mineral sector. The United States and Australia are also implementing a critical minerals plan of action, which includes the convening of a working group to explore opportunities for cooperation in financing, extracting, and processing critical minerals and in developing environmental, social, and governance standards as well as traceability standards. Like domestic industry strategy toward mining and processing, international partnerships remain a work in progress, and there is still potential to further develop them in order to unlock investment in Australia's critical mineral sector.

Conclusion

Australia's long-standing role as an exporter of resource commodities, coupled with large deposits of a number of base metals and critical minerals, means that the country is well positioned to benefit from the economic opportunities of the low-carbon energy transition, even as its exports of traditional emissions-intensive commodities fall. Recognizing this, governments are developing a mix of domestic and international measures to support critical mineral industry growth, including considering policy settings that support the potential for increasing value-adding downstream activities in Australia.

The review of the Critical Minerals Strategy being carried out by the Albanese government has placed a renewed emphasis on achieving net-zero emissions, developing manufacturing capabilities, and supporting reconciliation with Aboriginal and Torres Strait Islander people. There are likely to be substantial additional and new policy initiatives aligned with these principles, which is a positive signal for Australia's ability to support supply chain diversification in critical mineral mining and processing. Together with Australia's open inward investment regime, this means that there will be numerous investment and partnership opportunities for companies and governments seeking to diversify supply chains in the mining and processing of critical minerals.

---

17 Jonas Nahm, *Collaborative Advantage: Forging Green Industries in the New Global Economy* (New York: Oxford University Press, 2021).

18 Jorrit Gosens, "The Greening of South-South Trade: Levels, Growth, and Specialization of Trade in Clean Energy Technologies between Countries in the Global South," *Renewable Energy* 160 (2020): 931–43.

THE NATIONAL BUREAU *of* ASIAN RESEARCH

NBR SPECIAL REPORT #102 | DECEMBER 2022

Building Resilient Critical Mineral Supply Chains: Lessons from Japan and South Korea

Kristin Vekasi

KRISTIN VEKASI is Associate Professor in the Department of Political Science and the School of Policy and International Affairs at the University of Maine. She can be reached at <kristin.vekasi@maine.edu>.

EXECUTIVE SUMMARY

This essay considers Japanese and South Korean critical mineral policies and assesses how they may be appropriate or adaptable for the U.S.

MAIN ARGUMENT

The world needs more resilient critical mineral supply chains. One shared risk to resilience for many critical minerals is geographic concentration in the mining or midstream processing of materials. Japan and South Korea are both early and proactive movers to diversify and expand their critical mineral supply chains. Under the guidance of government ministries and active financial, technical, and logistical support from specialized government organizations, Japanese and South Korean firms have formed private-public partnerships to expand critical mineral supply chains around the world, decreasing their vulnerability to manufacturing chokepoints.

POLICY IMPLICATIONS

Given profound differences in the political institutional context, there are three policy lessons that the U.S. can learn from the experience of Japan's and South Korea's more state-led approach:

- Australia is a key partner, with rich resource endowments, technical expertise, and transparent and reliable governance. The U.S. should proactively expand existing partnerships and seek new ones.
- Buy-in from and cooperation with the private sector are key to the success of government-led ventures, and any U.S. administration must be sure to consult with the private sector as well as other key stakeholders in local communities.
- Critical mineral projects have high rates of failure and a lengthy time horizon before success. The U.S. must be prepared to follow through on long-term projects even in the face of challenges.

There is broad agreement that the world needs more critical minerals and that a full supply chain approach is necessary to meet demand.[1] Critical minerals share at least two qualities: they are necessary inputs for national economic goals and have serious risks that threaten the resilience of the supply chain. The first criterion—importance to the national economy—is ultimately a political question for each country. However, policies typically target minerals needed for green technologies, permanent magnets, batteries, and of course inputs necessary for defense readiness. While the second criterion differs based on the specific geological and industrial profile of each mineral, there are some shared characteristics in supply risks. The clearest risk arises from chokepoints created by severe geographic concentration in the mining or midstream processing of the minerals. Supply risk also arises from a lack of broad technical expertise outside countries where chokepoints already exist, trade or other regulatory barriers, and the opacity of markets that introduces challenges to new entrants. All these risks introduce the possibility of economic coercion, a weapon more readily utilized in recent decades.

The United States officially recognized the strategic nature of some minerals over a decade ago, at least with respect to defense applications.[2] However, concrete policy initiatives to increase supply as well as the resilience of the supply have been halting. Without sustained action now, supply will simply not meet future demand. Japan and the Republic of Korea (hereafter South Korea), like the United States, face similar supply chain challenges in the critical mineral space, not least difficulties in developing supply chains without a key chokepoint in China.

This essay considers the Japanese and South Korean critical mineral policies and assesses how they may be appropriate or adaptable for the United States. It will walk through the similarities and differences in Japanese and South Korean approaches, from coordinated industrial policy to financing overseas projects to international cooperation. In Japan's case, we have over a decade of evidence of coordinated industrial policy, leading to successes in a vertically integrated non-Chinese supply of rare earths. South Korea has been financing overseas research and initial exploration for decades, and in recent years has also started to incentivize diversification projects as well.

Mitigating Risk to Build Resilience: Japanese and South Korean Overseas Diversification Efforts

Supply resilience entails a critical mineral value chain where states or market actors have mitigated risks like the geographic concentration of minerals, lack of technical expertise, and trade barriers, and that is more responsive to sudden shocks or crises. Resilience also entails meeting demand, which is increasingly a challenge as new technologies and markets require more critical minerals. One key element in building a resilient supply chain is investing in mining operations and processing plants to separate and purify elements into the necessary metals, oxides, or alloys.

1 Mori Hamada and Matsumoto Shintaro Okawa, "The Overview of the Economic Security Promotion Bill and Its Impact on Business," Center for Information on Security Trade Control, February 28, 2022, 53; "The Biden-Harris Plan to Revitalize American Manufacturing and Secure Critical Supply Chains in 2022," White House, February 24, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/24/the-biden-harris-plan-to-revitalize-american-manufacturing-and-secure-critical-supply-chains-in-2022; and "S. Korea to Closely Review Supply Chain of Key Materials," Yonhap, November 17, 2021, https://en.yna.co.kr/view/AEN20211117008300320.

2 U.S. Department of Defense, "Strategic and Critical Materials 2013 Report on Stockpile Requirements," January 2013; and Valerie Bailey Grasso, "Rare Earth Elements in National Defense: Background, Oversight Issues, and Options for Congress," Congressional Research Service, CRS Report to Congress, R41744, December 23, 2013, https://sgp.fas.org/crs/natsec/R41744.pdf.

The lead time for a new mining venture is long, typically taking at least a decade. Building capacity in cutting-edge midstream processing facilities can take even longer.

The focus is primarily on mitigating the risks of geographic concentration with financial support measures for the private sector to diversify along the supply chain. Investments in basic research and recycling innovations and public policy to increase the transparency of critical mineral markets are also crucial steps toward a resilient supply chain. Yet, though important, these measures sidestep the key issue of diversifying and expanding supply at both the mining and processing stages in the short term. As just one concrete example, the 2022 Inflation Reduction Act provides incentives for consumers to purchase electric vehicles but includes restrictions based on domestic or partner-country manufacturing. This legislation means that the United States and countries with which it has free trade agreements need to dramatically increase the supply of magnet and battery materials so consumers will be eligible for the bill's incentives. Without increasing capacity for minerals such as lithium, cobalt, and rare earths in this set of countries, incentive-eligible electric vehicles will be scarce.[3]

A key lesson from the Japanese and South Korean approaches is that the U.S. government could do more to directly alleviate the initial risks of new critical mineral ventures both in the United States and abroad, more rapidly increasing capacity along the supply chain. Both Japan and South Korea have public agencies with options for equity funding or liability guarantees that can mitigate risks, mostly at the early stages but in some cases for more mature projects. They not only fund domestic projects but also provide assistance for projects abroad involving Japanese or Korean companies.

The Japanese and South Korean political economies both have long histories of industrial policy: deliberate intervention in the market by state actors to promote national goals.[4] As such, they have bureaucratic capacity to plan and implement critical mineral policies. This experience does not necessarily translate into success for specific companies or sectors. Many industrial policy efforts in the periods of Japanese and South Korean high-speed growth in fact failed. But it does imply that the financial and economic personnel are in place to facilitate programs.

Critical mineral policy is formulated by Japan's Ministry of Economy, Trade and Industry (METI) and South Korea's Ministry of Trade, Industry and Energy (MOTIE). When international initiatives or projects receive direct state support, they are typically led by the state-owned agency Japan Oil, Gas and Metals National Corporation (JOGMEC) and Korea Mine Rehabilitation and Mineral Resources Corporation (KOMIR), although other organizations such as the Japan External Trade Organization (JETRO) have provided some funding. These public corporations are also responsible for the stockpiling of critical minerals, which Japan started in 1983 and South Korea in 2007. Development organizations like the Japan Bank for International Cooperation or Korea International Cooperation Agency also assist with overseas mining projects in the form of development aid. However, the efforts to build resilience along the supply chain largely arise from the public-private partnerships formulated by METI and MOTIE and implemented by JOGMEC and KOMIR.

Japanese and South Korean public policy mechanisms include direct funding of projects to promote critical mineral diversification. Japan's vigorous critical mineral policies were launched

[3] Reed Blakemore and Paddy Ryan, "The Inflation Reduction Act Places a Big Bet on Alternative Mineral Supply Chains," Atlantic Council, EnergySource, August 8, 2022, https://www.atlanticcouncil.org/blogs/energysource/the-inflation-reduction-act-places-a-big-bet-on-alternative-mineral-supply-chains.

[4] Steven K. Vogel, *Marketcraft: How Governments Make Markets Work* (New York: Oxford University Press, 2018).

after the supply risks were vividly revealed during the diplomatic crisis with China in 2010. Today they are reflected in Japan's broader "economic security" approach evident in the cabinet-level economic security post created in 2021 and the 2022 legislation.[5] Similarly, in South Korea critical mineral policy is connected to broader supply chain resilience policies, including the "Renewable Energy 3020 Plan" and an economic security team introduced in 2022 to provide an early-warning system for supply chain chokepoints.[6]

Japan

Japan's activities are notable for the number and breadth of funding agencies. The country's earliest efforts at critical mineral industrial policy were funded through a competitive process at METI in 2010.[7] At this point, overseas diversification efforts were smaller: of the 160 funded projects, only 7 were for diversification, 65 for reduction, 62 for recycling, and 26 for additional end-user research. After observing the supply chain issues during the Covid-19 pandemic, both METI and JETRO introduced support for Japanese companies through either reshoring key strategic industries or diversifying their supply chains outside China. METI's policies were largely geared toward reshoring and included two domestic rare earth projects for recycling and magnets. In 2021, JETRO launched an ongoing program to support supply chain diversification that largely targets the biomedical and semiconductor industries but also includes five projects for rare earths and other critical minerals.[8]

JOGMEC is the key player in Japanese critical mineral diversification, with offices around the world and a dedicated staff of over six hundred people. Like METI, JOGMEC increased assistance for mineral exploration in 2010 through equity support, participation, or loans to "enhance and expedite high-risk mineral exploration."[9] In particular, JOGMEC tries to mitigate difficulties private companies might face in situations with high country risk. It provides "liability guarantees for development funds loaned by private financial institutions to Japanese companies, in order to ensure the smooth procurement of development funds and to reduce the business risks and country risks associated with each project."[10] Private companies approach JOGMEC with a development plan that is carefully vetted by the organization before receiving funding. These projects then follow a public-private partnership model, where the public finance portion is focused on the viability of the project rather than the solvency of the individual company. JOGMEC is prepared to offer substantial funding over a long term, which is particularly important at the initial mining stages. It also funds other high-risk projects, such as the ongoing deep-sea mining and mineral development research.[11]

---

5 Akira Igata and Brad Glosserman, "Japan's New Economic Statecraft," *Washington Quarterly* 44, no. 3 (2021): 25–42.

6 "S. Korean Gov't Bolsters Supply Crunch Early Warning System Abroad," Yonhap, January 16, 2022, https://en.yna.co.kr/view/AEN20220116000800325.

7 METI (Japan), "Heisei 22 nendo rea aasu nado riyou Sangyou nado setsubi dounyuu hojokin (ichiji koubo): Saitaku jigyou ichiran" [Industries and Facilities That Use Rare Earths (Public Appeal): List of Selected Companies], 2010.

8 Mireya Solis, "The Big Squeeze: Japanese Supply Chains and Great Power Competition," Korea Economic Institute, July 30, 2021; and JETRO, "Kaigai sapuraichen tagen-ka-to shien jigyo daiichikai kobo (setsubi donyu hojo-gata (ippan-waku tokubetsu-waku) ni okeru saitaku jigyo-sha ni tsuite" [Overseas Supply Chain Diversification Project Support: Companies Selected in the First Public Offering (Specialized and General Equipment)], July 17, 2020, https://www.jetro.go.jp/services/supplychain/kekka-1.html.

9 "Financial Support for Japanese Companies: Metals," JOGMEC, 2022, https://www.jogmec.go.jp/english/stockpiling/metal_10_000003.html.

10 Ibid.

11 Hiroyuki Katayama, "JOGMEC's Role in Securing the Supply of Critical Minerals," 2012.

South Korea

With respect to critical mineral industrial policy, South Korea does not have as long a history as Japan, but its policy interventions are increasing in scope. Japan was an early mover in part due to its early experience of political coercion with rare earths. South Korean industrial policy is motivated by the securitization of minerals and supply chains, the experience of the Covid-19 pandemic, and the restrictions on semiconductor materials by Japan, which starkly revealed the vulnerability of a supply chain chokepoint.[12]

Like Japan, South Korea has a state-owned enterprise that directly aids critical mineral supply chain resilience: KOMIR. This organization evolved out of previous support measures for domestic mining and overseas resource exploration. The Korea Mining Promotion Corporation was launched in 1967 to support domestic mining in service to the resource needs of South Korea's rapidly growing economy. By 1978, it was clear that additional resources would be needed beyond the domestic mining capacity, and the organization began funding overseas resource development. In 1987 the Mine Industry Promotion Board was established, and in 2021 the two groups merged into KOMIR with a broader mandate that addresses expanding critical mineral needs in addition to supporting domestic mining and processing capacity.

KOMIR has four main support roles: stockpiling, informational support, technical support, and equity investment in both domestic and international projects. Laboratory-based technical support began in 2004. A state lab (Korea Laboratory Accreditation Scheme) runs analysis for resource development and offers professional training, particularly in developing countries where the potential mining projects may be connected with overseas development aid.[13] For example, KOMIR has major projects in Indonesia, Zambia (with the World Bank), Mongolia, Pakistan, and Peru. These projects, however, do not directly address supply risks for critical minerals but are focused on broader environmental risks and mining infrastructure, such as environmental cleanup and engineering rather than the development of new mines.[14] Yet they do aim to build robust relationships with "mineral-rich countries" in the process. This could lead to new suppliers, but it is an indirect path.

International diversification is another key role for KOMIR, particularly through providing overseas capital management support for the private sector to secure mineral resources. KOMIR opened offices in China, Chile, and Canada in 2001 and launched subsidiaries in Australia in 1997 and Mongolia in 2010. The early date in Australia is one indication of the country's importance for South Korea's supply chain resilience. Direct equity investment in overseas resource development began in 1990 with a chromium mine in Orhaneli, Turkey.

According to the analysis of all KOMIR projects, however, most of the organization's overseas funding is for initial exploration.[15] KOMIR will fund up to 80% of overseas research projects by resource development companies and has funded almost 1,200 exploration projects since 1978. In the 1970s and 1980s, funding was primarily focused on the Americas (largely copper mining in South America). From the 1990s on, efforts shifted to Asia, with over 80% of funded projects

12 Kyounga Lee and Jongmun Cha, "Towards Improved Circular Economy and Resource Security in South Korea," *Sustainability* 13, no. 1 (2020): 17; and Kristin Vekasi, "Trade Wars at the Intersection of Memory and Industrial Policy in Japan and South Korea," in *Research Handbook on Trade Wars*, ed. Ka Zeng and Wei Liang (Cheltenham: Edward Elgar, 2022), 381–97.

13 KOMIR, "Test Analysis Evaluation," 2022, https://www.komir.or.kr/eng/contents/185.

14 KOMIR, "Overseas Cooperation," 2022, https://www.komir.or.kr/eng/contents/186.

15 KOMIR, "Gwanghae Gwangeop Gongdan: Haeoe gwangsan josa hyunhwang" [Korea Mine Rehabilitation and Mineral Resources Corporation: Overseas Mining Survey Status], June 30, 2022, https://www.data.go.kr/data/15025211/fileData.do?recommendDataYn=Y.

in the last decade in the region. The bulk of these projects (62%) have been for coal, copper, and gold. Over the past decade, however, the focus on minerals for permanent magnets, batteries, and green technologies has increased tenfold, and these minerals now make up 15% of the total surveys after 2010.

Overseas Critical Mineral Projects

To compare Japanese and South Korean approaches, 90 critical mineral projects from 2009 to 2022 were analyzed for this essay.[16] The projects were compiled from JOGMEC, KOMIR, and METI reports in addition to news media articles. They include projects for cobalt, rare earths, molybdenum, nickel, tungsten, lithium, graphite, manganese, and silica and are distributed throughout North and South America, Africa, Asia, Oceania, and Europe. Of the 90 projects, 70% are KOMIR-funded overseas initial exploration projects. The global reach of these projects is notable. While most are in the Indo-Pacific region, there is significant technical assistance and funding for initial exploration in Africa and Central Asia, particularly mineral-rich Kazakhstan and Mongolia.

A key similarity in the Japanese and South Korean approaches is that private companies take the lead, with the public money provided either through competitive grants and loans or through vetted requests. None of the projects are specifically state-directed or purely state-financed; instead, they are either completely private ventures or public-private partnerships. While Japanese industrial policy started investing in post-mining supply chain projects over a decade ago, most South Korean projects have been at the earlier mining exploration stage. Recent movements from South Korea into the midstream and downstream have been pursued by the private sector, largely with support from Australia.[17]

Not all of the projects started during this time period resulted in a new supply: most of them did not. For example, early diversification efforts of Japanese private companies at the Mountain Pass mine in California did not result in a Japanese-U.S. joint venture. Similarly, partially JOGMEC-funded exploration projects in Canada have not produced a new Canada-based supply chain for rare earths. Toshiba's attempts at a joint venture with the state-owned Kazatomprom in Kazakhstan also failed. The reasons for the failure of these projects vary. Under its previous ownership, the Mountain Pass project had financial struggles and failed to build a vertically integrated business model. The extreme price increases of some rare earths in 2010, followed by the collapse in 2012 to 2009 levels, also sent projects that had seemed viable swiftly toward bankruptcy. In other cases, the institutional context of a partnership with a state-owned industry or environmental concerns about rare earth stalled or halted projects.

One notable success of supply chain diversification is the partnership between the Australian company Lynas and the Japanese general trading company Sojitz, started with support from JOGMEC during the rare earth crisis of 2009–11. Lynas now mines rare earths in Australia and then ships them to Malaysia for processing and eventual sale, mostly to Japanese companies. In

16 A color-coded map of the projects selected is available from the NBR website at https://www.nbr.org/wp-content/uploads/pdfs/publications/japanese-and-korean-critical-mineral-projects-2009-2022.pdf. The colors represent the sources of funding, which are both public (JOGMEC, METI, and JETRO in Japan and KOMIR in South Korea) and private. The map also includes the stage of the supply chain. Both countries pursue overseas projects along the supply chain from mining to processing to recycling.

17 Jeffrey Wilson, "The Prospects for Quad–South Korea Cooperation on Critical Minerals," German Marshall Fund of the United States, February 23, 2022, https://www.gmfus.org/news/prospects-quad-south-korea-cooperation-critical-minerals.

September 2022, JOGMEC and Sojitz made a new investment in Lynas for an expansion project at the Mount Weld mine.[18] The substantial and long-term funding provided through this public-private partnership facilitated success where others failed.

Many projects are still new. South Korea and Australia, for example, have recently launched new rare earth and tungsten projects, bolstered by the 2021 Korea-Australia Critical Mineral Agreement, to mine rare earths in Australia and process them in South Korea. Diversification efforts assisted by JETRO or JOGMEC in Vietnam or Malaysia may still bear fruit as well. Given the long time horizon of mining and post-processing, it is too soon to declare success or failure.

International Initiatives

A final element of Japanese and South Korean critical mineral initiatives is cooperation and participation in international activities, which range from joint action at the World Trade Organization against Chinese mineral export restrictions to multilateral organizations and summits.[19] Over the past five years, there have been at least seven different multilateral initiatives in the Indo-Pacific involving Japan, South Korea, or both that have cited cooperation on critical minerals as a core goal. **Table 1** lists these initiatives and their participants. The oldest initiative—the Conference on Critical Materials and Minerals—was catalyzed by the 2010 rare

TABLE 1 International initiatives related to critical mineral supply chain resilience in the Indo-Pacific

Initiative	Year	Members
Conference on Critical Materials and Minerals	2011	Australia, Canada, Japan, European Union, United States
U.S.-Japan Competitiveness and Resilience (CoRe) Partnership	2021	Japan, United States
Japan-Australia-India Supply Chain Resilience Initiative	2021	Australia, India, Japan
Korea-Australia Critical Mineral Agreement	2021	Australia, South Korea
G-7 Partnership for Global Infrastructure and Investment	2022	Canada, France, Germany, Italy, Japan, United Kingdom, United States
Indo-Pacific Economic Framework	2022	Australia, Brunei, India, Indonesia, Japan, Malaysia, New Zealand, the Philippines, Singapore, South Korea, Thailand, United States, Vietnam
Minerals Security Partnership	2022	Australia, Canada, Finland, France, Germany, Japan, South Korea, Sweden, United Kingdom, United States, European Commission

18 "Japan's JOGMEC, Sojitz Invest $9 Million in Rare-Earths Miner Lynas," Reuters, September 20, 2022, https://www.reuters.com/markets/commodities/japans-jogmec-sojitz-invest-9-mln-rare-earths-miner-lynas-2022-09-20.

19 World Trade Organization, "DS431: China—Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum," May 20, 2015, https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds431_e.htm.

earth crisis and was initially only an annual meeting between Japan and the United States. Canada subsequently joined, and the initiative has expanded in recent years to include Australia and the European Union. This meeting largely functions to share policy and governance expertise.

Later initiatives were all launched in 2021–22 and are connected to broader goals of supply chain resilience. Membership in these initiatives overlaps significantly, as do their purposes. They include aspirations for high environmental, social, and governance (ESG) standards and a full supply chain approach. For example, the U.S.-Japan partnership seeks "resilient and diverse supply chains of critical minerals to support energy security and the clean energy transition."[20] The G-7 Partnership for Global Infrastructure and Investment aims to develop "clean energy supply chains across the full integrated lifecycle, from the responsible mining of metals and critical minerals…to investing in new global refining, processing, and battery manufacturing sites."[21] The Minerals Security Partnership, the most recent initiative, seeks to "ensure that critical minerals are produced, processed, and recycled in a manner that supports the ability of countries to realize the full economic development benefit of their geological endowments." The partnership will "help catalyze investment from governments and the private sector for strategic opportunities—across the full value chain—that adhere to the highest environmental, social, and governance standards."[22] Member countries hope to expand mining of critical minerals to resource-rich developing countries using high ESG standards. This approach will appeal to multiple stakeholders: companies with high ESG reporting requirements in their home country, local communities at the site of the mine or processing plant, and consumers with concerns about the environmental sustainability of otherwise "green" technology. This approach is also about providing a cleaner, more sustainable alternative to Chinese projects, much like Japan's Quality Infrastructure approach.[23] The projects may initially be more expensive, but the long-term sustainability is more robust, with fewer negative externalities.

These initiatives are focused on building shared standards and rules to enable new mining entrants to compete on a level playing field, minimize the impact on local communities around a mine, and of course diversify the supply chain internationally by bringing in more players. Formal international cooperation, particularly with Australia but also with other countries in the Indo-Pacific region, has been key to the success of the financial mechanisms pursued by both Japan and South Korea. The initiatives and summits have either facilitated new corporate relationships or used economic partnerships or memoranda of understanding to lower barriers for new market entrants. Both countries have used state visits connecting private mining companies with international counterparts, formal economic partnership agreements, and memoranda of understanding to encourage new mining ventures. The multilateral groups, particularly the Indo-Pacific Economic Framework and the Minerals Security Partnership, seek to formalize and broaden this approach. Japan and the United States are the cornerstones of most of these initiatives, but Australia is the key corporate and mining partner. As a resource-rich country with deep expertise in mining

[20] "U.S.-Japan Competitiveness and Resilience (CoRe) Partnership," White House, Fact Sheet, April 17, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/16/fact-sheet-u-s-japan-competitiveness-and-resilience-core-partnership.

[21] "President Biden and G7 Leaders Formally Launch the Partnership for Global Infrastructure and Investment," White House, June 26, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/26/fact-sheet-president-biden-and-g7-leaders-formally-launch-the-partnership-for-global-infrastructure-and-investment.

[22] "Minerals Security Partnership," U.S. Department of State, Press Release, June 14, 2022, https://www.state.gov/minerals-security-partnership.

[23] Saori N. Katada and Jessica Liao, "China and Japan in Pursuit of Infrastructure Investment Leadership in Asia Competition or Convergence?" *Global Governance* 26, no. 3 (2020): 449–72.

technology, as well as being deeply integrated with regional free trade agreements, Australia is a linchpin in the critical mineral strategies of both Japan and South Korea.

Conclusion

Japanese and South Korean approaches have numerous similarities, most notably their inclusion of public corporations that facilitate overseas diversification and domestic mining of critical minerals. The organizations provide technical and informational assistance as well as supporting related research to increase efficiency along the value chain. Beyond the existence of these public agencies empowered to mitigate initial diversification risks through direct financial mechanisms, there is a specific ministry in each country that coordinates natural resource policies. Both countries also participate in multiple international initiatives that support the efforts of the private sector. Japan—likely because of its experience with economic coercion in 2010—was an earlier mover in both critical mineral industrial policy and international cooperation. South Korean participation has come later, but with great possibility for developing capacity to weaken midstream chokepoints in the supply chains.

An important point is that overseas investment efforts in locations with weaker rule of law and political institutions, such as Kazakhstan, often falter and fail. Although projects in locations with more robust legal systems, such as Australia, have also failed, the success rate is higher.

There are also important differences with respect to funding mechanisms and the existence of domestic geological deposits. While both countries focus on funding initial exploration, Japan has gone further than South Korea in equity funding and liability guarantees for overseas mining. South Korea, on the other hand, has more domestic alternatives than Japan for some materials (for example, rare earths and tungsten). It has a heavier focus on domestic participation in various stages of the supply chain, whereas Japan largely seeks international locations for mining and midstream processing, with only high-quality downstream precision work located domestically. The different relationships with Australia are informative. For rare earths, Korean and Australian firms are in the early stages of expanding a partnership with earth mining in Australia, with the midstream processing facility to be opened in South Korea. Japanese and Australian firms, in contrast, have located rare earth mining in Australia and midstream processing in Malaysia. Downstream precision industries such as high-quality permanent magnet production are located in Japan.

The United States to some extent has been pursuing both approaches—direct financing and international initiatives—but without the same speed or long-term commitment. Recent legislative and executive efforts in the United States show more appetite for industrial policy. However, a key policy lesson from Japan and South Korea—that direct financial support for private overseas mining efforts can increase resilience through diversification—will be politically challenging to implement.

As the United States moves to increase its resilience, there are a range of lessons to learn from the Japanese and Korean experiences. The governments of Japan and South Korea both implemented direct support programs. Even though the institutional and political context is different enough in the United States that direct emulation of these policies is not practical and likely not possible, three key lessons are still instructive. First, Australia has been crucial as a transparent and reliable partner. It is a mineral-rich country with strong infrastructure and existing trade agreements and participation in multilateral initiatives with the United States. Some ventures with Australian partners are already advancing, and the United States should proactively encourage more. Second, buy-in from and cooperation with the private sector have been essential for the success of Japanese and South Korean efforts, and any U.S. administration must be sure to consult with the private sector as well as other key stakeholders in local communities. Finally, in a sector with high rates of failure and a lengthy time horizon before success, the United States must be prepared to follow through on long-term projects.

Shiny Objects: Repositioning the United States for Critical Mineral Success

Sharon E. Burke

SHARON E. BURKE is the Founder and President of Ecospherics. She can be reached at <info@ecospherics.org> or on Twitter <@burkese>.

EXECUTIVE SUMMARY

This essay examines the path that led to the current bottlenecks in supply chains for critical minerals, what the U.S. government has done to chart a new way forward, and possible next steps.

MAIN ARGUMENT

One of the building blocks of the modern global economy is a class of minerals for which there was not much demand just a few decades ago. These minerals are essential for meeting the challenge of climate change through a transition to cleaner energy, which is driving demand even higher. The U.S. does not now have a sufficient and sustainable supply of these critical minerals, which is an increasingly significant environmental, economic, and geopolitical vulnerability. Although the Biden administration is harnessing a bipartisan consensus to take steps to improve the U.S. position on critical minerals, these efforts will not be enough without a more strategic approach. The future of U.S. economic and geostrategic competitiveness, especially with China, hangs in the balance.

POLICY IMPLICATIONS

The U.S. needs a comprehensive critical mineral strategy that ties together all the various existing and emerging policy and statutory initiatives and aspirations in a purposeful, coherent, and mutually reinforcing approach. Key elements of that strategy should include the following:

- domestic investments and international cooperation and investment
- analysis of the demand growth for critical minerals
- comprehensive environmental, social, and governance standards, not only for U.S. companies but also for allies and partners as part of a shared commitment and comparative advantage
- innovation in mining, processing, recycling, and end use of critical minerals
- modernization of U.S. policy, legal, and institutional infrastructure for critical minerals

Crime rates in the United States have been on a pandemic roller coaster of late,[1] but even so, one trend stands out: the steep rise in thefts of catalytic converters. Around 1,300 of these devices were torn off vehicles across the country in 2018 and more than 65,000 in 2021.[2] This surge in thefts has less to do with Covid-19, though, than with the fast-changing global market for minerals and the slow U.S. government response. Fortunately, the United States is now repositioning to set the country on a better path. At the same time, while the new policies, investments, and programs are significant, the U.S. government could still stand to have a clearer and more comprehensive strategy for improving mineral security in a way that better protects environmental quality, community rights, good governance, and the common interests of allies and partners in Asia and around the world.

In the case of catalytic converters, just a few grams of durable, lightweight rhodium, palladium, and platinum help limit the harmful pollution from a vehicle's exhaust—and at today's prices, that one small piece of equipment is worth hundreds or even thousands of dollars. The value goes beyond just the dollar cost, though: all three metals are on the U.S. list of critical minerals, which the Energy Act of 2020 defines as non-fuel minerals that are essential to the economic or national security of the United States and are vulnerable to supply-chain disruption.[3]

Critical minerals are a cornerstone of the digital economy and an essential building block for everything from MRI scanners, fiber-optic cables, smartphones, and guided munitions to renewable energy. Unfortunately, the United States has multiple chokepoints in its critical mineral supply chains. For example, it was 100% net-reliant on imports for 14 of the 35 minerals on the critical minerals list in 2021, while China was the lead global producer for 16 of them.[4] The United States is 70% reliant on Russia for the palladium that goes into catalytic converters.[5] More broadly, Russia is a major supplier not only of palladium but also of other metals and minerals to the global market. As a result, Western sanctions and Russia's war in Ukraine have dramatically affected the price and supply, exacerbating volatility in the plummeting and surging markets of the Covid-19 pandemic.[6] Nickel, for example, skyrocketed from $16,000 per tonne on March 10, 2021, to $48,241 per tonne on March 10, 2022.[7]

The United States is in a supply chain predicament that has been decades in the making. This essay examines the path that led to this point, what the U.S. government has done to chart a new way forward, and the next steps it should consider taking.

---

1 Richard Rosenfeld, Bobby Boxerman, and Ernesto Lopez Jr., "Pandemic, Social Unrest, and Crime in U.S. Cities: Mid-Year 2022 Update," Council on Criminal Justice, July 22, 2022, https://counciloncj.org/mid-year-2022-crime-trends.

2 "Catalytic Converter Thefts Triple 2020 Numbers in Seven Months," BeenVerified, September 7, 2022, https://www.beenverified.com/data-analysis/catalytic-converter-theft-state-rankings.

3 For the official list of critical minerals, see U.S. Geological Survey, "2022 Final List of Critical Minerals," February 24, 2022, available at https://www.federalregister.gov/documents/2022/02/24/2022-04027/2022-final-list-of-critical-minerals. The full text of the Energy Act of 2020 is available at https://www.govinfo.gov/content/pkg/BILLS-109hr6enr/pdf/BILLS-109hr6enr.pdf.

4 U.S. Geological Survey, "Mineral Commodity Summaries 2022," January 31, 2022, https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf. The list expanded to 50 critical minerals in 2022.

5 Ibid.

6 Ben Aris, "Commodity Prices Fall across the Board as the Market Adjusts to the Sanctions Realities," bne IntelliNews, September 14, 2022, https://www.intellinews.com/commodity-prices-fall-across-the-board-as-the-market-adjusts-to-the-sanctions-realities-256384.

7 Jason Sappor, "Commodity Briefing Service: Nickel March 2022," S&P Global, March 2022.

How Did the United States Get into This Predicament?

The strategic nature of minerals is nothing new, for both economic and national security. After all, whole eras of human history are named for metals, and the Bronze Age and Iron Age were as much about new weapons as they were about new tools. The dual-use nature of key minerals pertains to modern history, too. During World War II, for example, the United States conducted scrap-metal drives as part of the war effort, and a national stockpile of critical materials played an important part in economic security and the defense industrial base throughout the Cold War.[8] One 1985 report sounds decidedly modern, stating that the "dependence of the United States on a few nations of uncertain reliability for materials that are essential to many industrial and defense uses has heightened concern over materials and minerals policy in recent years."[9] The recommendations—to increase domestic exploration and processing, diversify global suppliers, and invest in innovation and recycling—could have come straight out of President Joe Biden's "100-Day Review" supply chain report.[10]

The geostrategic context for critical minerals may have clear antecedents, but there are ways in which the present situation is distinct, where the U.S. position is weaker and more consequential for the foreseeable future. The first major difference is demand growth. A combination of global population growth and economic development has shaped the escalating demand for materials, trends driven by China's rise and the improving well-being of millions of people.[11] The other major trend is technological innovation, particularly when it comes to critical minerals that were not in such high demand before the digital age, such as cobalt, indium, lithium, nickel, niobium, rare earth elements, and tantalum.[12] Their lightweight, corrosion-resistant, nonreactive, and conductive properties make them uniquely well-suited to high-tech applications. Climate change is further accelerating demand for these materials with the transition to renewable energy. In 2021, for example, electric vehicles became the top destination for cobalt, accounting for 34% of the total demand of 175,000 tonnes, compared to 15% for mobile phones.[13] Even with a pandemic-related dip, the electric vehicle industry grew by 43% between 2019 and 2020, according to the International Energy Agency, which predicts another 2,000% growth by 2030.[14] These trends, plus growth in utility-scale energy storage, solar, wind, and other renewable energy sources, could mean a quadrupling of demand for minerals and metals by 2040 in a best-case scenario.[15] Advocates for continued fossil-fuel development sometimes contend that sharply

---

8 Hugh Rockoff, "Keep on Scrapping: The Salvage Drives of World War II," National Bureau of Economic Research, Working Paper, no. 13148, September 2007, https://www.nber.org/system/files/working_papers/w13418/w13418.pdf; and National Academies, *Managing Materials for a Twenty-First Century Military* (Washington, D.C.: National Academies Press, 2008).

9 U.S. Office of Technology Assessment, "Strategic Materials: Technologies to Reduce U.S. Import Vulnerability," May 1985, available at https://www.princeton.edu/~ota/disk2/1985/8525/8525.PDF.

10 White House, *Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth* (Washington, D.C., June 2021), https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf.

11 Nedal T. Nassar et al., "Evaluating the Mineral Commodity Supply Risk of the U.S. Manufacturing Sector," *Science Advances* 6, no. 8 (2020).

12 Note that these are minerals designated by the U.S. government as "critical," but that does not mean that they are the only indispensable minerals or metals. Copper, for example, has been crucial to human civilization for thousands of years and is no less important for digital age economies. Moreover, while copper is not currently considered supply-constrained, its status could change in the future.

13 Neil Hume, "Electric Vehicles Overtake Phones as Top Source of Cobalt Demand," *Financial Times*, May 17, 2022, https://www.ft.com/content/2095ee9b-1426-48ca-9fae-cd79730e23b3.

14 "Trends and Developments in Electric Vehicle Markets," International Energy Agency (IEA), April 2021, https://www.iea.org/reports/global-ev-outlook-2021/trends-and-developments-in-electric-vehicle-markets.

15 IEA, "The Role of Critical Minerals in Clean Energy Transitions," May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

escalating critical mineral demand means that the energy transition is untenable.[16] Yet this somewhat specious argument assumes that curtailing climate change is somehow optional. It is not, if human societies are to survive.

Finally, a big reason today is different is because most of these critical minerals have a range of supply constraints. That was not much of a problem in the past, when the demand for these niche materials was much lower, but it is a growing challenge now that demand is high. These minerals tend to be concentrated in a few geographies; are byproducts of other ores, such as copper or zinc; and require extensive, toxic processing to achieve a usable state. Although new discoveries are always possible and may be even likely, right now just a handful of countries are major suppliers of critical minerals to the global economy. These include industrialized nations such as Australia, Canada, the United States, and Russia, but by far the biggest supplier and processor of critical minerals is China. Beyond China's dominance, especially in rare earths, there are a number of other industrializing and developing economies with a significant advantage in specific critical mineral markets, such as the Democratic Republic of the Congo in cobalt, Indonesia in nickel and tin, Brazil in niobium, Chile in lithium, and South Africa in platinum group metals. The largest consumers of these minerals, beyond China and its environs (i.e., Macao and Hong Kong), are more or less regional blocs: Canada, Mexico, and the United States; the European Union and the United Kingdom; and Australia, Japan, South Korea, and Taiwan.

In the past, the U.S. government more or less assumed that open competition in mining is healthy for the industry. While that may be true, it has given nonmarket countries an advantage. Indeed, the Trump administration emphasized increasing domestic mining and U.S. energy nationalism and actually put trade sanctions on major producers and consumers, such as Canada, Japan, and the EU.[17]

What Steps Has the United States Taken So Far?

Given how fast the demand for cobalt, lithium, and other critical minerals has ballooned, the U.S. government, perhaps understandably, has not kept pace with its policies and investments. China, however, has been thinking ahead for some time—at least since 2003, and arguably back to the presidency of Deng Xiaoping, who allegedly noted in 1992 that "as there is oil in the Middle East, there is rare earth in China."[18] As China's demand for raw materials has grown, the government has used a combination of subsidies, state-owned enterprises, low labor costs, and lenient environmental standards to grow domestic mining and processing, including for export markets. In addition, China has pursued a globally diversified strategy that includes stockpiling, foreign direct investment, ownership stakes in mines and processing worldwide, and a collection

16 Dan Eberhart, "It's Harder Than You Think to Stop Using Fossil Fuels," *Forbes*, August 3, 2020, https://www.forbes.com/sites/daneberhart/2020/08/03/its-harder-than-you-think-to-stop-using-fossil-fuels/?sh=23828fb202ca.

17 See, for example, "President Donald J. Trump Is Protecting Our Domestic Mining Industry and Critical Minerals Supply Chains," White House, Fact Sheet, September 30, 2020, https://trumpwhitehouse.archives.gov/briefings-statements/president-donald-j-trump-protecting-domestic-mining-industry-critical-minerals-supply-chains; and "President Donald J. Trump Has Unleashed American Producers and Restored Our Energy Dominance," White House, Fact Sheet, July 29, 2020, https://trumpwhitehouse.archives.gov/briefings-statements/president-donald-j-trump-unleashed-american-producers-restored-energy-dominance.

18 W. David Menzie, "China's Global Quest for Resources and Implications for the United States," testimony before the U.S.-China Economic and Security Review Commission, Washington, D.C., January 26, 2012. For the quote from Deng Xiaoping, see Daniela Lackner and Susan McEwan-Fial, "From Resource Advantage to Economic Superiority: Development and Implications of China's Rare Earth Policy," Goethe University, Interdisciplinary Centre for East Asian Studies, Frankfurt Working Papers on East Asia, no. 6, October 2011, https://www.uni-frankfurt.de/50568316/WP_6-2011_Lackner_and_McEwen_Rare_earth_China.pdf.

of nonmarket incentives for producer countries. The result has been global mineral dominance, exemplified by China's position on rare earth elements. Between 1990 and 2000, China's production of rare earths grew by more than 450%, while production in the rest of the world fell by almost 60%, in no small measure because of the difficulty of competing with China.[19] In 2008, China began signaling that it would use its dominance both as a comparative advantage for domestic manufacturing and as a geostrategic tool. After a fishing boat fracas with Japan in 2010, for example, Beijing retaliated by cutting off rare earth exports to the country.

Chinese assertiveness on rare earth elements prodded the Obama administration to start adjusting U.S. critical minerals policies. The Critical Materials Strategy released by the Department of Energy in 2010 focused on mineral demand in the clean energy sector and advocated for a globally diversified strategy, substitution for scarce minerals, and recycling, reuse, and efficiency.[20] The Department of Defense also conducted a study of rare earths, which reached a somewhat different conclusion that market forces would ultimately correct any supply imbalances for critical minerals.[21] The Pentagon also stopped the liquidation of the National Defense Stockpile and reassessed its contents. By the beginning of the Trump administration, there was a growing urgency about Chinese dominance of the supply chain for high-tech critical minerals. President Donald Trump released two executive orders about supply chain security and critical minerals, declaring reliance on foreign suppliers an "unusual and extraordinary threat."[22] As directed by the first executive order, the Department of the Interior released a list of 35 critical minerals, and the Department of Commerce produced a comprehensive critical mineral strategy.[23]

President Biden's commitment to aggressive climate change policies focused even more attention on critical minerals, with a flurry of executive orders, reports, reviews, policies, and investments, including a comprehensive report reviewing supply chain vulnerabilities. While there is no overarching strategy tying these disparate pieces together, the "100-Day Review" makes it clear that the goal is to achieve a stable, sustainable supply of minerals for a clean energy U.S. economy in the digital age. The two most obvious objectives for achieving this goal, articulated as U.S. priorities for decades, are to increase production at home and diversify global suppliers—or "reshoring" and "friendshoring," as the current administration puts it.

The Biden administration and Congress have already taken concrete steps to achieve both core objectives, including the provision of significant funding and other incentives such as tax credits, in both the Bipartisan Infrastructure Act and the Inflation Reduction Act. Other core initiatives include the following:

- a new U.S. Geological Survey effort to better map reserves and resources
- the Department of Energy–led Federal Consortium for Advanced Batteries

---

19 Pui-Kwan Tse, "China's Rare Earth Industry," U.S. Geological Survey, February 22, 2011, https://pubs.usgs.gov/of/2011/1042/of2011-1042.pdf.

20 U.S. Department of Energy, *Critical Materials Strategy* (Washington, D.C., December 2010), https://www.energy.gov/sites/prod/files/edg/news/documents/criticalmaterialsstrategy.pdf.

21 U.S. Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, "Report to Congress: Rare Earth Materials in Defense Applications," March 2012, https://www.hsdl.org/?abstract&did=704803.

22 Donald J. Trump, "Executive Order on Addressing the Threat to the Domestic Supply Chain from Reliance on Critical Minerals from Foreign Adversaries," September 30, 2020, https://trumpwhitehouse.archives.gov/presidential-actions/executive-order-addressing-threat-domestic-supply-chain-reliance-critical-minerals-foreign-adversaries.

23 U.S. Department of the Interior, "Final List of Critical Minerals 2018," May 18, 2018, available at https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018; and U.S. Department of Commerce, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals* (Washington, D.C., June 2019), https://www.commerce.gov/data-and-reports/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals.

- the State Department's minerals diplomacy with close partners Canada and Australia, as well as a new minerals security partnership for coordinating investment and best practices
- the Department of the Interior's interagency working group on mining reform
- investments in developing-country producers through the U.S. Agency for International Development, Development Finance Corporation, and Millennium Challenge Corporation

Moreover, the Department of Defense is playing a crucial role in promoting domestic production through a range of programs, including strategic management of the Defense National Stockpile and oversight of the Defense Production Act Title III, which allows the U.S. government to catalyze domestic industries critical to national security and the defense industrial base. In addition to granting more than $60 million in commitments for rare earth mining and processing in 2021 and 2022 under the Defense Production Act, President Biden authorized in February 2022 the use of funds to improve the production of five minerals crucial for large-capacity batteries. The Inflation Reduction Act identified another $500 million for critical mineral initiatives.

How Does the United States Get Out of This Predicament?

The plethora of new initiatives is changing the direction of the U.S. critical mineral supply, but it is not enough. Consider, for example, that $500 million in funds, though a great deal of money, is roughly equivalent to the estimated capital cost of a single lithium mine in Nevada.[24] To enact significant change in U.S. policy toward critical minerals, Congress and the administration need to work together to coordinate all the incentives and government policies in a mutually reinforcing strategy that promotes cooperation with allies, partners, the private sector, and key community and environmental stakeholders. A more strategic approach includes several objectives.

Understanding demand growth. While the Biden administration and Congress have increased funding for resource mapping of critical mineral supplies, there is insufficient data and analysis on the competing, growing demands for critical minerals and other indispensable metals, such as copper. A comprehensive picture of the U.S. mineral economy that matches technology shifts and mineral demands with potential sources of supply could better guide purposeful, coordinated investments in everything from new mining technologies to focal points for U.S. resource diplomacy. In the Inflation Reduction Act, Congress provided funding to the U.S. Geological Survey to perform additional analysis. This is a good first step that should enable the agency to add the capacity it needs to extend its work.

Improving measures to protect environmental and social impact, as well as to promote good governance. The United States and its global partners need a clearer articulation of what sustainability really means in the mining sector and in a globally competitive environment. This involves identifying and consistently applying best practices and environmental, social, and governance (ESG) standards, likely differentiated by supply chains, since the details of mineral production can vary significantly between metals. The Biden administration has recognized the importance of these standards in key reports, but it has not necessarily incorporated those policies and principles across all government initiatives. While there are no internationally accepted ESG

24 "Clayton Valley Lithium Project, Nevada," Cypress Development Corp., https://cypressdevelopmentcorp.com/projects/nevada/clayton-valley-lithium-project-nevada.

standards at this time, there are promising efforts to establish them, such as the independent, nongovernmental Initiative for Responsible Mining Assurance.[25]

Promoting innovation in mining, processing, recycling, substitution, and demand reduction, both in the United States and around the world. Given that mining is not typically an industry that invests significantly in R&D, government funding and incentives can make a difference. For example, the U.S. company IperionX developed a new process for refining titanium, which is timely given the disruption of titanium exports from Russia and Ukraine. IperionX received an early boost in 2014 through a grant from the Advanced Research Projects Agency-Energy (ARPA-E) and is now scaling up through partnerships with Oak Ridge National Laboratory and the U.S. Navy.[26] A concerted strategy within a strategy for how to systematically promote innovation, perhaps generated by the Office of Science and Technology Policy, would help match demand, supply, and overarching goals. These goals include expanding U.S. government efforts to develop less toxic and destructive approaches to mining and processing and promoting demand reduction, substitution, and recycling, including the reuse and development of tailings and wastewater.

Reforming governing institutions. Institutional reform of federal agencies is a recommendation that tends to prompt eyerolls from experienced observers as something that is easy to propose but nearly impossible to achieve. Nonetheless, in the case of critical minerals, policy is scattered across a dozen federal agencies and organizations and at least four offices within the Executive Office of the President, as well as the offices of the nonstatutory, politically powerful national climate advisor and the special presidential coordinator for global infrastructure and energy security. The proliferation of offices and agencies reflects the genuine complexities of mineral concerns, but the lack of clear leadership or effective coordinating bodies hampers efficiency, adding drag to the system. The number of players also masks a lack of capacity in most agencies on these issues. Although it may be sufficient for the president to designate a lead coordinating agency and office within the White House, bolder action could be needed, such as reformulating the Department of Energy to be the Department of Energy and Industry. Several reform bills to improve the mine-permitting process are also under consideration in Congress and have the potential to streamline the process for responsible domestic mining. Shortcuts around key stakeholders will almost always come back to haunt future mining projects.

Letting go of counterproductive policies. The United States has a number of self-imposed burdens that constrain efforts to adopt a more strategic and nimble approach. One challenge is a long-standing aversion to industrial policy. From one perspective, this distaste is practical, given that a vibrant private sector is a comparative advantage for the United States. There is no reason, however, why U.S. government policies, programs, investments, and incentives cannot better support the competitiveness and sustainability of mining in the United States and partner countries. After all, it will be difficult to compete with China without a purposeful use of such governing tools.

Another challenge is the opposition of environmental groups to mining and, conversely, opposition of mining companies to environmental groups. There can be no clean energy transition or critical mineral growth without better cooperation between these parties, which is by no means impossible. There is, for example, a platinum and palladium mine in Stillwater, Montana,

---

[25] See the Initiative for Responsible Mining Assurance's website at https://responsiblemining.net.

[26] Willy Shih, "Manufacturing Process Innovations: A 'Bessemer Moment' for Titanium?" *Forbes*, July 10, 2022, https://www.forbes.com/sites/willyshih/2022/07/10/manufacturing-process-innovations-a-bessemer-moment-for-titanium; and "IperionX and Oak Ridge National Laboratory Technical Collaboration," Business Wire, July 25, 2022, https://www.businesswire.com/news/home/20220725005312/en/IperionX-and-Oak-Ridge-National-Laboratory-Technical-Collaboration.

that is governed by a twenty-year "good neighbor agreement" between the community, a local environmental group, and the mining company. There is also the Initiative for Responsible Mining Assurance, a cooperative effort to promote ESG standards that includes mining companies, such as Anglo American, and environmental advocacy groups, such as Earthworks.

Another counterproductive policy is the United States' failure to ratify the United Nations Convention on the Law of the Sea, which governs access to potential mineral reserves on the international seabed. The United States cannot be an effective voice for environmentally responsible exploitation of deep-sea minerals, nor can U.S. companies compete with China for access to those resources, until the U.S. Senate ratifies the treaty.

Finally, while economic and strategic competition with China will continue to be an important factor in 21st-century geopolitics, the United States must find a way to cooperate with China. The alternative of armed conflict benefits no one. Humanity will fail to overcome some of its biggest present and future challenges, such as climate change, without Sino-U.S. cooperation. Working together on critical minerals is a necessity, as well as a potential confidence-building measure, and a solid U.S. strategy would allow cooperation from a position of strength.

Conclusion

A more strategic U.S. approach to critical minerals is a matter of environmental, economic, and geopolitical urgency. In a dangerously politically fractious time for the United States, critical minerals are a rare point of bipartisan consensus. This is especially encouraging because a comprehensive national strategy cannot be a static, one-time event. Given the shifting currents of global power, rapidly changing market dynamics, and technological developments for these materials, any strategy will require frequent updates.

Finally, U.S. allies and partners around the world have proved to be responsive to better cooperation with the United States on critical minerals. This includes bilateral cooperation, such as the Supply Chain Working Group with Canada or the Net Zero Technology Acceleration Partnership with Australia, and new multilateral efforts, such as the Minerals Security Partnership. A common commitment will ultimately improve humanity's chance of sustaining a modern economy while meeting the challenges of climate change.

NBR THE NATIONAL BUREAU *of* ASIAN RESEARCH

Seattle and Washington, D.C.

600 UNIVERSITY STREET, SUITE 1012
SEATTLE, WASHINGTON 98101 USA
PHONE 206-632-7370, FAX 206-632-7487

1819 L STREET NW, NINTH FLOOR
WASHINGTON, D.C. 20036 USA
PHONE 202-347-9767, FAX 202-347-9766

NBR@NBR.ORG, WWW.NBR.ORG