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Task Force 2: Wellbeing, Environmental Sustainability, and Just Transition

Critical Minerals for Net-Zero Transition: How the G7 can Address Supply Chain Challenges and Socioenvironmental Spillovers*

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Abstract

As the world's most developed economies, the Group of Seven (G7) countries play a crucial role in leading the transition to net-zero, which necessitates the use of critical minerals (CMs) in various clean energy applications. However, the growing demand for CMs raises questions about the socioeconomic, environmental, and supply security implications, given their unequal distribution and the reliance on international supplies.

The challenges include potential supply disruptions and price volatility resulting from overseas dependency on CMs, significant environmental impacts throughout the lifecycle of CMs, the lack of alternatives intensifying the stress on the global minerals market, and insufficient investment in the entire CM value chain.

To tackle these challenges, the G7 should boost domestic production, promote public–private partnerships, foster cooperation for knowledge-sharing among members, and build stronger trade agreements with source countries. These steps can help strengthen the group's resilience to potential CM supply chain challenges. The G7 also needs to take concerted actions to minimize negative trade-offs that may arise from their actions to address supply chain vulnerabilities and account for the consequences beyond its member countries. Finally, developing a clean energy-critical mineral ecosystem among member countries will help the G7 reinforce circular economy practices and promote investment in research and development.

This policy brief highlights that the G7's challenges associated with the CM value chain are critical, and hence, innovative solutions are needed. In this regard, partnering with the Group of Twenty (G20) can be beneficial. The G7 and G20 summits may also consider aligning national and multilateral strategies as well as finance and investment policies to promote sustainable practices and ensure CM supply chain resilience.

Introduction

The transition to net-zero in the Group of Seven (G7) countries has gained significant momentum as governments are increasingly recognizing the urgency to achieve ambitious climate goals. This has led to a surge in demand for critical minerals (CMs), which play a key role in a wide range of clean energy technologies, such as wind turbines, solar panels, electric vehicles, and battery storage. While there is no consensus on the definition and the elements that constitute "critical minerals", this term, as used in this brief, refers to "all non-fuel mineral materials required for the energy transition, which have strategic and economic importance and are vulnerable to supply chain disruption".[1] Rare earth elements (REEs), comprising 17 elements including 15 of the lanthanide series (US Geological Survey 2018), are also considered CMs due to their demand in

[1] The definition used in this paper is indicative and is based on information from various sources, including European Commission (2023), Ministry of Natural Resources Canada (2022), and International Energy Agency (IEA) (2021).

several advanced technology-based applications. Several G7 members have published definitions and lists of CMs based on the criticality—economic importance and supply risks—they face, with a high degree of commonality among the identified lists. For example, the United States identifies 50 CMs, including minerals from REEs and platinum group metals (US Geological Survey 2022), while the European Union lists 34 individual materials, which are termed as critical raw materials, including REEs and platinum group metals (European Commission 2023). Canada has a shorter list of CMs, which includes only 31 minerals (Ministry of Natural Resources Canada 2022) (Table 1).

Table 1: List of Critical Minerals Identified by the United States, the European Union, and Canada

Countries	List of Critical Minerals
United States (50 critical minerals as per 2022 list)	Aluminum, antimony, arsenic, barite, beryllium, bismuth, cerium, cesium, chromium, cobalt, dysprosium, erbium, europium, fluorspar, gadolinium, gallium, germanium, graphite, hafnium, holmium, indium, iridium, lanthanum, lithium, lutetium, magnesium, manganese, neodymium, nickel, niobium, palladium, platinum, praseodymium, rhodium, rubidium, ruthenium, samarium, scandium, tantalum, tellurium, terbium, thulium, tin, titanium, tungsten, vanadium, ytterbium, yttrium, zinc, zirconium
European Union (34 critical raw materials as per 2023 list)	Aluminium/bauxite, coking coal, lithium, phosphorus, antimony, feldspar, light and heavy rare earth elements, scandium, arsenic, fluorspar, magnesium, silicon metal, baryte, gallium, manganese, strontium, beryllium, germanium, natural graphite, tantalum, bismuth, hafnium, niobium, titanium metal, boron/borate, helium, platinum group metals, tungsten, cobalt, phosphate rock, vanadium, copper, nickel
Canada (31 critical minerals as per 2022 list)	Aluminum, antimony, bismuth, cesium, chromite, cobalt, copper, fluorspar, gallium, germanium, graphite, helium, indium, lithium, magnesium, manganese, molybdenum, nickel, niobium, platinum group metals, potash, rare earth elements, scandium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium, zinc

Sources: US Geological Survey (2022), European Commission (2023), Ministry of Natural Resources Canada (2022).

Challenges

The demand for various types of CMs is growing and is expected to increase significantly by 2030, with estimates ranging from two to four times current levels (IEA 2022b). Estimates (IEA 2022b) indicate that the cost of minerals used in clean energy technologies is projected to increase more than fivefold by the mid-21st century. Demand for some CMs, such as graphite, is expected to increase more than fivefold by mid-21st century. Although technology is constantly evolving and the number of critical minerals required per application may decrease in the future, the surge in demand could eventually lead to a price hike, which in turn can make the transition to low-carbon energy alternatives unaffordable or cause unexpected delays for countries. Some of the main challenges that remain to be tackled include supply concerns, geopolitical volatilities, environmental and social impacts of mining and processing, insufficient investment in diversifying to new production locations and alternative sources, and lack of efficient industrial practices for recycling and recovery of CMs.

Challenges to Critical Mineral Supply Lines

The report of the G7 Panel on Economic Resilience (Pánel del G7 en resiliencia económica 2021) stressed the importance of mapping CM stocks and flows to anticipate supply-related bottlenecks. A major concern is that the much of the production and processing of CMs is based in a small number of non-G7 countries. This market concentration (Pánel del G7 en resiliencia económica 2021) of extraction, production, processing, and refining CMs and REEs has resulted in concerns about the predictability of supply.

Countries like the Democratic Republic of the Congo and Australia possess 70% of the global share of cobalt and 55% of lithium, while the People's Republic of China (PRC) remains the top producer of about 18 specific CMs. The PRC also accounts for over 60% of the world's REE production (IEA 2021) and dominates processing operations, along with the manufacturing and assembly of solar photovoltaic modules and electric vehicle batteries, accounting for 75% of the global industry (IEA 2022b). Despite new mineral finds and other exploration projects in progress in many parts of the world, the geographical concentration of production is not expected to change significantly in the near future (IEA 2021).

The high geographical concentration also implies higher geopolitical risks due to state-led nonmarket interventions, such as trade restrictions or capitalizing on the economic vulnerability of countries to meet geopolitical goals. It is often noted that state-owned enterprises' ownership can worsen the vulnerability of CM supplies when political differences between countries begin to reflect in trade engagements. For instance, in the past, geopolitical issues in northeast Asia (Bradsher 2010; US Government 2011) led to disruptions in the supply of REEs from the PRC to Japan (Chadha 2020). Similarly, trade disputes between the US and the PRC in 2018 culminated in the PRC imposing a ban on CM trade with the US (Schmid 2019).

Rising demand and supply chain disruptions cause CM price hikes (Chadha 2020; The White House 2022). In 2021, global lithium and cobalt prices doubled, while copper, nickel, and aluminum rose by 25%–40%, adversely impacting dependent industries in several importing countries. A lack of transparency in individual CM markets, asymmetric information between market participants and market observers, and supply chain disruptions together exacerbate price volatility concerns. Unless supply chain resilience is strengthened, the increasing demand for CMs may become a bottleneck for the deployment of clean energy technologies (IEA 2021).

Socioenvironmental Spillovers of the Critical Mineral Value Chain

The G7's growing demand for CMs to meet low carbon transition goals can result in negative environmental and social impacts in producing or supplying countries. These impacts can be termed as negative international spillovers.[2] To tackle the challenges related to the unequal distribution of CMs, their environmental impacts, and insufficient investment in the CM value chain, it is essential

2 "International spillover effects occur when one country's actions generate benefits or impose costs on another country that are not reflected in market prices, and therefore are not "internalized" by the actions of consumers and producers. Such spillover effects can undermine other countries' efforts to achieve the SDGs." (SDSN 2023)

to minimize negative trade-offs and adopt a just transition perspective that prioritizes fairness and equity to ensure effective and equitable solutions.

The environmental impacts of the CM value chain are wide-ranging, including water pollution from cyanide and sulfuric acid used in refining (IEA 2021; Egidi 2022). Production processes, such as those used in lithium processing facilities in Chile, Argentina, Bolivia, and elsewhere, impact the quality and quantity of available water resources (Wanger 2011), while copper extraction has led to water scarcity in Chile and Peru (Northey et al. 2017). As a result, mining activities often compete with water required for agricultural irrigation (Urkidi 2010), leading to loss of forest cover (Bebbington et al. 2018), biodiversity (Sonter, Ali, and Watson 2018), and other important ecosystems, illustrating the wide-ranging effects of CM mining (Durán, Rauch, and Gaston 2013; Murguía, Bringezu, and Schaldach 2016).

In some producing countries, the lack of adequate governance and capacity to put in place and effectively enforce environmental and labor regulations and standards is a major concern (Goh and Effendi 2017; Schoderer, Dell'Angelo, and Huitema 2020). This can lead to unchecked environmental damage, human rights abuses, and unsafe labor practices, as seen in the Democratic Republic of Congo, which is responsible for 60% of global cobalt production and has been subject to concerns about these issues (European Commission 2018; Elbel, Bose O'Reilly, and Hrzic 2023). Environmental, social, and governance impacts of mining projects are also a major concern. As mining firms monopolize lands for exploration and extraction, it can cause social disruption and conflicts with local communities. Governance issues arise in terms of transparency, corruption, and the inequitable distribution of costs and benefits. The ethical dimension of these impacts notwithstanding, they can also adversely affect the industry, increase costs, and potentially lead to legal action or regulatory intervention that jeopardizes stable supply. Such impacts of production raise concerns about the fair distribution of benefits as we move toward zero-carbon societies.

Lack of Investment, Alternatives, and Recycling

Previous sections have demonstrated that CM supply is fragile due to issues related to distribution and geopolitics. These uncertainties have prompted discussions on alternative options, including finding substitute materials that offer similar performance, diversifying the source regions of CM production, reducing the material intensity, and promoting the recycling and recovery of CMs. In the past, REE exports to Japan were disrupted due to geopolitical tensions in the northeast Asian region, causing many importing nations to increase their efforts to find alternative supply sources.

At present, the rate of CM recycling and recovery through urban mining[3] are low due to high costs and other technical complexities. Finding substitutes for CMs has proven extremely challenging. While REEs have limited or no direct replacements, some alternatives are available for a few CMs. In a few instances, substitutes are cheaper and more efficient than the original CMs (Zhao, Wang and Negnevitsky 2022). There is also visible progress in finding alternatives to silicon, platinum, and graphite. However, most of the substitute materials at present are in the research and development (R&D) stage, and it can take 5 to 15 years for substitutes to become market ready.

[3] Urban mining involves the extraction of valuable raw materials, particularly metals and minerals, from electronic waste.

Past experiences suggest that minerals supply crises can encourage investments to mitigate the problem, often with substitute minerals. Even with substitutes, some minerals will always remain critical since different types of CMs are needed for different technologies. This dynamic process calls for continuous innovation efforts to stay abreast of changing demands (Tsafos 2022). However, investments in CM mining and development are far below the requirements for accelerating the clean energy transition. The International Energy Agency (IEA) estimates that the total global anticipated investment in CM mining until 2030 under a net-zero energy scenario is between $180 billion and $220 billion against a required investment of $360 billion–$450 billion (IEA 2023). Investments in minerals development often come with a delay—something that can be an issue given the exigency of the energy demand. Therefore, mining and construction of processing facilities for CMs will remain crucial for the next 3 to 4 decades to support the energy transition.

Recent developments show that the plans and strategies of certain G7 members, such as the United States, with regard to CMs emphasize the importance of securing and developing CM mines through investment in R&D, as well as trade with friendly nations. However, due to geopolitical and security concerns, foreign investments in CMs are now subject to heightened scrutiny.

Underinvestment in the CM value chain can prevent the speed of energy transition needed to limit global warming to below 1.5°C. The IEA has observed that the current supply and investment strategies for several essential minerals are insufficient to meet the requirements for the rapid adoption of electric vehicles, wind turbines, and solar panels (IEA 2021). The situation is compounded by structural underinvestment in new supply capacity between 2018 and 2021, as well as COVID-19 related disruptions, causing several players to pause production projects, including those related to strategic battery minerals.

While more downstream facilities, such as battery cell manufacturing infrastructure, can be operational within a few years, mines have a longer lead time (around 10–20 years). Mineral processing facilities also take more time, around 3–8 years (IEA 2022a). As a result, it is of the highest urgency to understand and mitigate some of the risks inherent to upstream projects so that more investment can flow into production to meet projected demand.

Recommendations

The following recommendations offer solutions to challenges related to supplies, environmental impacts, and investment needs. The section also emphasizes the potential for collaboration with G20 member countries.

Secure Adequate Supplies of CMs

The growing importance of minerals needed for a decarbonized energy system presents unique challenges for the G7. To meet these challenges, actions should be taken domestically and regionally within the G7 and beyond.

- First, countries need to strengthen domestic industries, scientific expertise, and human resource capabilities. Strengthening domestic production of CMs within the G7 countries should also be prioritized. It can help to reduce reliance on foreign sources and create domestic economic opportunities (US Department of Commerce 2019). To achieve this, the G7 should provide incentives to mineral producers, encourage exploration and resource development, and invest in research and development of new technologies to reduce CM demand. Additionally, the G7 countries should strive to engage in joint ventures with other producers, as well as pursue multilateral and bilateral agreements with other countries.

- Moreover, the production and use of CMs require diverse skills and knowledge. The growing demand for CMs must be supported by the G7 governments dedicating adequate financial support for innovation and R&D. The United Kingdom's plans to promote skills in CM industries and encourage educational establishments (UK Government 2022) could be replicated in other member countries.
- Fostering cooperation and knowledge-sharing among G7 members could also help boost the group's ability to address CM supply challenges. Creating databases on the geological occurrence and distribution of CMs and sharing research and development of innovative new technologies relevant to CMs will strengthen the G7's resilience in that aspect. The G7 countries may need to build stronger trade agreements with source countries supported by international regulations to ensure the reliability of the supplies.

Strengthen Circular Economy, Address Environmental and Social Concerns

'The G7' countries need to play an important role in minimizing the environmental and social impacts of CM extraction and use. Building sustainability throughout the entire CM value chain is crucial.

- To achieve this goal, the G7 countries should implement sustainable sourcing practices, which include environmental and social impact assessments, engagement with local communities, responsible sourcing policies, and promoting good practices in CM extraction and use. Environmental and social impact assessments can identify and mitigate potential environmental and social risks while engaging with local communities and implementing responsible sourcing policies that ensure equitable sharing of benefits and reduce human rights abuses.
- The G7 must address the negative international spillovers associated with CM extraction as part of their transition away from fossil fuel-generated energy. They should also take the lead in establishing systems that can properly account for and share the burdens of such impacts between producing and consuming countries and work to reduce negative impacts. The G7 countries should prioritize good governance in the CM sector moving beyond environmental, social, and governance reporting toward public disclosure, transparent supply chain tracking, and international certification of CMs. In this regard, the use of advanced technology such as enterprise blockchain may help strengthen transparency in information tracking and sharing. They should also focus on governance problems that otherwise threaten stable supply and work to advance anti-corruption and governance standards throughout the CM supply chain. These standards should feature prominently in guidance from organizations like the Organisation for Economic Co-operation and Development (OECD), legislation in the European Union and G7 members, new systems in producer countries, and the policies of mining and battery companies and sector investors.
- Furthermore, it is important to keep in mind that environmental and social impacts are caused not only during the production stage of CMs but also during the processing and consumption stages. These impacts include the associated energy consumption, water stress, and carbon

leakage stemming from the production, transportation, processing, consumption, and disposal of CMs. As major consumers, the G7 consumers need to better understand and account for these issues throughout the life cycle of CMs, and G7 countries can consider instituting policies to help manage demand and reduce wastage.

- G7 countries need to take a comprehensive approach to address the environmental challenges by fostering innovation and R&D in alternative CMs and promoting recycling, recovery, and resource conservation, thus reducing their dependence on overseas supplies.

Encourage Investment in the CM Sector and Promote Research and Development

- The G7 countries should encourage research and development into new technologies and substitute materials that can reduce CM demand. The focus should be on identifying other alternative minerals or technologies that can be used in the important clean energy transitions. Investment efforts into R&D and technology should take a broad-based strategy for fostering technology innovation, developing supply chain resilience, enhancing recycling and introducing sustainability standards (IEA 2021).
- Public–private partnerships may be encouraged in the CM sector for financing large-scale projects. The European Union's Global Gateway initiative is an example of a financing mechanism that encourages private sector investment in a safe, secure, and environmentally sustainable manner. Similar schemes can motivate investment in the CM sector too.

Addressing Challenges to Critical Minerals Supply Chain: Synergies with G20

The challenges and issues associated with CMs needed for the clean energy transition are not restricted to G7 nations but are relevant worldwide. Hence, it is necessary to coordinate efforts to promote sustainable practices, foster innovation, and address environmental and supply-related concerns.

- To achieve this, a joint platform with the G20 that also includes the important national and non-state stakeholders may be planned. Similar interests are already driving strategic partnerships like the 11-country Minerals Security Partnership [4] for building CM supply chains, the Critical Minerals Mapping Initiative, [5] and the Energy Resource Governance Initiative.[6] The platform should prioritize principles of fairness and equity and use the Sustainable Development Goals as an overarching framework to ensure social and environmental concerns are addressed in addition to economic concerns.
- This platform could facilitate collaboration and sharing of good practices to enhance countries' capacity to address challenges posed by CM demand in the energy transition. It could also

[4] Australia, Canada, Finland, France, Germany, Japan, the Republic of Korea, Sweden, the United Kingdom, the United States, and the European Commission are founding members

[5] The geoscience organizations of Geoscience Australia, the Geological Survey of Canada, and the US Geological Survey.

[6] This US-led initiative was started in 2019 with four other founder countries—Australia, Botswana, Canada, Peru. Argentina, Brazil, Democratic Republic of the Congo, Namibia, the Philippines, and Zambia joined later.

facilitate transparent reporting of mineral production and reserves using open databases. Moreover, it could assist countries in developing sustainable domestic extraction, refining production, recovery, and recycling capacity to enhance the supply chain resilience of CMs and thus restrict price volatilities.

- To further promote responsible sourcing of CMs, the G7 with the larger group of the G20 can support transparency and accountability measures in the supply chain. One way to do this is by implementing existing standards and guidelines such as Responsible Mining Assurance and the OECD's Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas. They can also promote co-innovation (Janardhanan et al. 2021) by establishing collaborative platforms for stakeholders from various sectors to jointly innovate, develop, and implement solutions—especially in the case of research and development—for finding alternatives and developing sustainable practices.
- Future G7 and G20 summits should consider aligning national and multilateral strategies to address CM concerns. This could include how finance and investment policies support sustainable mining and processing practices and align with the long-term climate mitigation goals and just transition. By taking such steps, the G7 and G20 can play a leading role in promoting sustainable practices and addressing environmental concerns related to the energy transition while also ensuring the supply chain resilience of critical minerals.

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