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9. Geopolitics of critical raw material supply constraints

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INTRODUCTION

Low carbon transitions impact which and how raw materials are utilised. Materials used for low carbon technologies are currently extracted and processed in only a handful of countries, prompting discussions on how geopolitics can threaten supply security and, at times, the viability of low carbon transitions. This chapter provides an overview and critique of how geopolitics is framed as a threat to critical raw materials (CRMs) that are vital for enabling low carbon transitions.

Mitigating climate change will change the use of natural resources. Consumption of fossil energy will have to decline to meet the Paris Agreement, even if carbon capture technologies are adopted. Fossil energy sources will have to be replaced by resources and technologies that emit fewer greenhouse gases. Variable renewables, such as solar PV and wind power, are often assumed to make up most of the supply growth (e.g. IEA, 2023a). These technologies harness natural flows that are less geographically concentrated than fossil energy. Emerging literature on the geopolitics of the energy transition (Scholten, 2023) has pointed out that this should, if not eliminate, at least reduce some of the main geopolitical issues associated with fossil fuels. However, low carbon technologies increase demand for raw materials and the variety of materials used (Watari et al., 2021). Examples of increased demand include rare earths used for electric vehicle (EV) motors and wind power generators, lithium, cobalt and graphite for EV batteries and silicon for solar PVs (Hu et al., 2024). The International Energy Agency estimates demand for energy materials to experience a sixfold increase by 2040 compared to 2020 in their low carbon scenarios (IEA, 2021).

Mining and reserves for many of the raw materials used in low carbon technologies are geographically concentrated in just a handful of countries, many identified as fragile states, for example having increased risk of internal conflicts (Månberger and Johansson, 2019). Most of these countries are not major exporters of fossil energy today. Replacing fossil energy with renewables will therefore shift trade flows and make importers dependent on new suppliers.

Politicians are increasingly aware of these new challenges. Although socio-environmental impacts are recognised, most of the focus is to avoid the new trade dependencies becoming vulnerabilities that can be exploited as leverage points by foreign states. For example, when launching the European Critical Raw Materials Act, European Commission President Ursula von der Leyen said: “Lithium and rare earths will soon be more important than oil and gas. Our demand for rare earths alone will increase fivefold by 2030. […] We must avoid becoming dependent again, as we did with oil and gas.”[1]

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[1] https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_22_5523.

This chapter focuses on raw materials classified as critical. Criticality scoring is based on perceptions, typically a combination of high risk of supply disruption and vulnerability to disruptions (Schrijvers et al., 2020). Most critical raw materials are metals but there are a few that are not, for example, graphite is sometimes included, and the EU also include noble gases in the screening of critical raw materials although these are not materials. This chapter use the term "(critical) raw material", indicating that the concept includes more than just metals. Natural resources are referred to when discussing geographies where raw materials and fossil fuels are extracted, for example "resource nationalism". Raw materials are often extracted as minerals, that is, substances composed of multiple elements. After extraction, these minerals undergo processing and purification before they can be used to produce goods.

This chapter proceeds by outlining the material basis of energy transitions. Based on previous literature, it then develops a framework of relationships between CRM supply security and geopolitics. The chapter ends by calling for more focus on developing capabilities to respond to disruptions than suppressing threats.

THE MATERIAL BASIS OF LOW CARBON TRANSITIONS AND ITS GEOGRAPHICAL DIMENSION

Demand for raw materials has increased over time and, without policy intervention, it is likely to continue to do so because of economic and population growth. An assessment of the seven most used metals (iron, manganese, aluminium, copper, nickel, zinc and lead) projected global demand to double or triple by 2050 compared to 2015 (Elshkaki et al., 2018). Although there is consensus in the literature that low carbon transitions increase material demand, the range of estimates varies widely due to differing underlying assumptions on future technological development, material substitution, recycling rates (Månberger and Stenqvist, 2018) and economic growth (Pulido-Sánchez et al., 2022).

Natural resources can only be extracted in places where they have been identified. Studying the spatial location of resources is therefore of interest to understand which places may become future extraction sites, anticipate conflicts that may emerge, and how these can be prevented or mitigated. Table 9.1 shows some of the connections between what resources are used for, the main reserve holders and the resources' criticality status according to the EU and the US. Both the EU and the US assess criticality based on a combination of supply risk (threat of import disruption) and vulnerability to disruptions. Their CRM-ratings largely overlap (Zhou and Månberger, 2024) with only minor differences that can, for example, be explained by the EU using both historic data and forward-looking forecast, while the US relies solely on historic numbers.

A handful of countries stand out as holding around half or more of the reserve for one or two resources: DRC for cobalt, Indonesia for nickel, South Africa for PGE, China for REE and silicon and Australia for vanadium. In addition to these, Brazil, Chile and Russia also hold large shares of reserves for several resources. The geographical concentration of reserves for many raw materials used in low carbon technologies is higher than for crude oil. The highest concentration is identified for platinum group metals and silicon, followed by cobalt.

The relatively high geographical concentration is one of the explanations for classifying a resource as critical. This can have implications for low carbon transitions and geopolitics. Import-dependent countries adopt policies to secure their own CRM supply. Their strategies

Table 9.1 *Overview of some resources used in low carbon energy systems, their criticality status and geographical concentration of the three major reserve holders in 2023 (oil is provided as a point of reference)*

Resource(s)	Low carbon application (examples)	Critical according to US[a]	Critical according to EU[b]	HHI	Largest holder of reserve (share)	Second largest holder of reserve (share)	Third largest holder of reserve (share)
Cobalt	Li-batteries	Yes	Yes	3608	DRC (55%)	Australia (15%)	Cuba (5%)
Copper	Electrification	No	Yes (added 2023)	733	Chile (19%)	Peru (12%)	Australia (10%)
Lithium	Li-batteries	Yes	Yes (added 2023)	1889	Chile (33%)	Australia (22%)	Argentina (13%)
Manganese	Li-batteries	Yes	Yes (added 2023)	2163	South Africa (32%)	Australia (26%)	China (15%)
Nickel	Li-batteries	Yes (added 2022)	Yes (added 2023)	2353	Indonesia (42%)	Australia (18%)	Brazil (12%)
PGE	Fuel cells	Yes	Yes	7938	South Africa (89%)	Russia (8%)	Zimbabwe (2%)
REE	Motors, Generators	Yes	Yes	2113	China (40%)	Brazil (19%)	Russia (9%)
Selenium	Solar PV	No	No	1351	Russia (26%)	Peru (20%)	United States (16%)
Silicon	Solar PV	No	Yes	6282	China (89%)	Brazil (5%)	Norway (4%)
Silver	Solar PV, Solar Thermal	No	No	1037	Peru (18%)	Australia (15%)	Russia (15%)
Tellurium	Solar PV	Yes	No	467	Russia (16%)	United States (11%)	China (9%)
Vanadium	Redox flow-batteries used for stationary storage	Yes	Yes	3246	Australia (45%)	Russia (26%)	China (23%)
Oil	N/A	N/A	N/A	1119	Venezuela (19%)	Saudi Arabia (17%)	Canada (11%)

Notes: PGE stands for Platinum group elements; REE stands for Rare earth elements; HHI stands for Herfindahl-Hirschman index and is calculated as the sum of squares of the individual countries' reserve shares. A high value corresponds to a high market concentration, with the maximum value of 10 000; below 1500 is low concentration; 1500–2500 moderate and above 2500 highly concentrated. [a] (US DoI, 2022) and [b] (EU, 2023)

Source: Adapted from Månberger and Johansson (2019) with updated data from USGS (2024).

to do so can conflict with other countries' interests in securing their supplies (Zhou and Månberger, 2024). Such state interventions motivated by national supply security can make interstate collaboration difficult. The criticality narrative can also be used by market actors to mobilise political commitment and investment in certain mining projects. However, the merits of framing natural resources as critical are subject to debate (Haddad et al., 2024). Criticality is frequently motivated by a desire to increase stability and supply security, but Wojewska et al. (2024) argue that a criticality framing contributes more to the opposite, adding speculation that magnifies commodity markets' cyclical boom–bust patterns.

Raw material supply chains post-extraction also demonstrate geographical concentration and bottlenecks. Less accessible data make comparisons difficult, but it is well known that China has a central position in trade networks for several CRMs; it imports mineral concentrates and exports refined metals and higher value goods (Xia et al., 2024). For lithium, cobalt and rare earths, China holds more than half of the global refining capacity, and for copper and nickel, this figure is between 30 and 45 per cent (IEA, 2021). Chinese firms also own capacity in other countries to mine, process and manufacture products using CRMs (see for example Prina Cerai, 2024). Chinese foreign direct investments have increased in recent years, but it remains debated to what extent the Chinese government is involved and able to coordinate and utilise Chinese ownership in other countries for political power purposes (Holslag, 2022).

RELATIONSHIPS BETWEEN CRM SUPPLY SECURITY AND GEOPOLITICS

Recent years have seen an emergent body of literature exploring connections between geopolitics and CRM supply threats (IRENA, 2023; Wang et al., 2025). Below follows an overview of three root causes of CRM supply disruptions related to geopolitics: (1) local events that impact global commodity markets; (2) resource nationalism; and (3) weaponising supply. The last two typically result in export controls but the underlying motivations differ: increasing resource rents domestically (see e.g. Xu et al., 2024) or using exports as a foreign policy tool.

Local Events with Global Impact

Due to geographical resource concentration, local events that cause supply disturbances can spread through the supply chain network and impact remote importers. These events can have various origins, such as mine accidents, labour strikes, social instability, antagonistic (terrorist) attacks, natural disasters and severe weather leading to flooding, droughts and heatwaves that restrict mining operations. Local events with global impacts can be seen as a "source risk". There are examples of local events that have reduced global supply. For example, oil supply disturbances are well documented in the literature (cause, duration, volume, etc.). Critical raw materials are less well documented (Wang et al., 2025). Examples also exist of *anticipated* disturbances that did not materialise but still triggered price spikes and responses (see Box 9.1).

Several publications have indicated that measures to strengthen local sustainability can compromise resource extraction by restricting future production capacity (Jowitt et al., 2020). For example, it can be challenging for mines in arid regions to co-exist with other water-intensive sectors, such as agriculture. The impact of climate change on CRM mining is underexplored, but it is more likely to negatively impact production than enable it (Odell et al., 2018; Savige et al., 2025). The negative impact can, for example, result from direct weather-related impacts, making it (temporarily) difficult to operate the mine. Climate change is expected to increase the severity of droughts and heat stress, and some CRMs, such as lithium, have been identified as highly exposed (PWC, 2024). Climate change can also have indirect effects, such as increased social instability that impacts mining (Lèbre et al., 2019).

Indicators for countries' general socio-political stability and level of good governance are frequently adopted as proxies for geopolitical source risk (see for example Althaf and Babbitt, 2021). However, concerns have been raised that these are poor proxies for supply risk as no correlation exists between these indicators and actual supply disruptions (Kühnel et al., 2023). Social instability can indeed cause disruptions, but current methods are inadequate, and more granular approaches need to be developed if the risk of social instability is to be meaningful to include in assessments.

BOX 9.1 THE 1970S COBALT CRISES: ORIGIN, IMPACT AND LESSONS (NOT) LEARNED?

The southern Katanga region in the Democratic Republic of the Congo (DRC) has a copper-rich mineralisation belt that also contain cobalt. The DRC holds more than half of the known global cobalt reserves and is also the largest producer, accounting for more than 70 per cent of global output in 2023, a share that has increased in the last few years (USGS, 2024). It was one of the most important mining countries for cobalt in the 1900s (Gulley, 2022). In the 1970s, DRC's cobalt output constituted around half of the global output (Ericsson et al., 2024). At the time, cobalt had two major industrial uses: as an alloy to produce high-strength steel and in high-performance permanent magnets (SmCo-magnets). Cobalt was also used for its traditional colouring purposes.

The United States had built up strategic stockpiles of cobalt and many other raw materials after the Second World War, but these stocks were drawn down in the 1970s. After the stock draw down ended, the market was short on supply, and a series of events unfolded in the DRC that triggered the price of cobalt to increase seven-fold from 1978 to 1982. These market events are known as the 1970s cobalt crises. The DRC had previously sought to nationalise part of the cobalt mining industry. Infrastructure for providing electricity and transporting cobalt was mismanaged, causing the output to fall somewhat. In 1978, a rebellion erupted, involving soldiers from Angola and supported by the Soviet Union. The rebellion was quickly defeated without severely damaging the mines – in fact, output was stable during the turmoil. The price increase has been explained by market speculation and fear of the Soviets gaining control of the cobalt mines,which could constrain the West's access in the future (Gulley, 2022).

Market actors responded to the cobalt crises in several ways: recycling increased, mining expanded in other countries, its use was replaced by substitutes in several applications, such as some ceramics, and new permanent magnets were developed that use neodymium instead of cobalt (Alonso et al., 2007). The responses turned the market balance into a surplus and a price crash soon followed.

Resource Nationalism

Reserves that can be extracted at a low cost are geographically concentrated, as outlined in the previous section. Low-cost producers therefore have an incentive to maximise resource rents and retain a larger share of the producer surplus, that is, the difference between the market price and the production cost. Commonly adopted regulations include taxes on mining and exports (Kowalski and Legendre, 2023).

Mining is capital-intensive and generates fewer jobs compared to later steps in the value chain. Some mining countries aim to integrate downstream in the supply chain to attain a larger share of the value-adding activities within their own borders. Prohibiting the export of unrefined mineral concentrates, while allowing the export of refined metal, is one such strategy. A recent example is Indonesia's decision to restrict the export of unrefined nickel while continuing to export refined nickel metal (see Box 9.2). Free-trade proponents have argued that producers are generally better off by not following Indonesia's example because they lack the necessary infrastructure and institutions to attract investors (Fliess et al., 2017).

High geographic reserve concentration can enable market power. Table 9.1 indicates that market concentration for many critical raw materials is high. However, it is difficult for single suppliers to successfully manipulate prices to their favour as other suppliers often exist and would increase their output. Successful price management requires several producers to collaborate and collude. It remains disputed to what extent this is possible and likely for critical raw materials. Few producers and strong demand growth are examples of arguments used to support the viability of producer cartels (Ghorbani et al., 2024). Difficulties in collaboration, the risk of cheating, and the existence of substitutes are common arguments raised by those who downplay the prospects for future CRM cartels to thrive (Mares, 2022).

Assuming CRM-producer cartels developed, the impact would likely be somewhat higher prices but not necessarily physical unavailability of supply. Price cartels can even reduce the risk of supply disruptions as producers will withhold supplies, and the higher price incentivises high-cost producers to extract more, which diversifies supply. An analogy is the market for crude oil, the behaviour of the Organisation for Petroleum Exporting Countries (OPEC) and its impact on prices and availability.

BOX 9.2 INDONESIA'S EXPORT BAN OF UNREFINED NICKEL: UNFAIR COMPETITION OR RECLAIMING RIGHTS TO DEVELOP?

The Indonesian mining law introduced in 2009 requires mining companies to refine the mineral domestically before it is exported (IEA, 2023b). One of its aims is to increase domestic jobs and economic development in Indonesia. The law was implemented in several steps beginning in 2014 by restricting mineral exports. Initially, it was still possible to export nickel contained as a co-product if the exporter paid an export fee. In August 2019, the government announced that the export ban would be stricter by 1 January 2020, requiring companies to construct smelters in Indonesia.

The export ban resulted in an inflow of foreign direct investments in metal smelting industries, predominantly owned and operated by Chinese firms (Guberman et al., 2024). Indonesia's long-term plan is to bring in more value-adding processes to the country and become a world-leading manufacturer of batteries and stainless steel, two products that use nickel.

The EU, supported by the USA, appealed to the World Trade Organization (WTO) against Indonesia's export ban. On 30 November 2022, the WTO recommended Indonesia change its export regulation to conform with GATT 1994 (WTO, 2022). Indonesia has so far (2025) not done so. China chose a different stance from that of Western countries, increasing investments in the Indonesian metal refining sector, finding mutual benefits that strengthened the bilateral relations between the two countries (Mandavia, 2022).

The future success of Indonesia's export ban is far from given. Assessments of the economic impact indicate that Indonesia would benefit from further downstream integration (Pirmana et al., 2023). However, market analysts have pointed towards a surplus nickel market with lower prices because of commissioning new mining projects in other countries (Daga, 2024) and that lithium batteries not containing nickel will gain in market share (Pandyaswargo et al., 2021).

OPEC is a producer cartel that allocates production quotas for each member. OPEC's behaviour does not follow the textbook theories for how a cartel should behave (Okullo and Reynès, 2016). Small high-cost producers are assigned larger quotas than would be desirable for the larger members, and the cartel produces too much in total due to over-allocation and cheating. The cartel's existence motivates non-member states to extract more, framing domestic extraction as a national security interest.

Weaponising Supply

The "energy weapon" refers to a situation where resource exporters utilise their exports as a foreign policy tool to persuade or force a targeted state to change their policies. OPEC's oil embargo, which sparked the first oil crises in the 1970s, is well known and had a lasting impact on energy policies and governance, including the foundation of the International Energy Agency (IEA) (Van de Graaf and Lesage, 2009). A later example is Russia's natural gas export strategy (Richter and Holz, 2015). Incentives to weaponise cross-border renewable energy trade seem to be lower than for fossil energy, but research on this topic is limited (Downie, 2022).

Emerging literature has begun to analyse if and how non-fuel mineral exports can be successfully weaponised. The 2010 rare earth crisis has been studied in-depth (Gholz and Hughes, 2021) (see Box 9.3 for a brief description of the event). Non-fuel minerals differ from energy in several ways, making import-dependent states less vulnerable to supply disruptions and hence reducing incentives for exporters to weaponise CRM supply. Supply disruptions for non-fuel minerals impact the manufacturing of new technologies, while as technologies that are already in use continue to function. Energy disruptions, on the other hand, directly reduce economic activity. Non-fuel minerals also have a smaller cost share compared to energy. It is therefore easier for societies to endure raw material price spikes than energy price spikes.

Studies on energy and non-fuel minerals have found that both supply- and demand-side factors influence the likelihood of managing exports for political purposes and its success if done so. Exporters need to have sufficient capabilities, such as state control or at least the ability to coordinate resource extraction and export. The exporter also needs to have a dominant market position, for example a limited number of competitors that restricts the number of alternative suppliers to turn to.

Several similarities exist between the literature on the energy weapon and the CRM weapon. First, actual physical disruptions appear to be few, but those that have occurred received headline attention. Secondly, the potency is questionable as the targeted states seldom give in and change their policies. Thirdly, utilising the weapon can backfire in the longer term as the targeted state develops contingency measures to become more autonomous. For non-fuel minerals, there is an even wider palette of alternatives available, such as recycling spent products, developing substitutes, and improving material efficiency.

Research on global markets and interdependence has argued that control of trade networks can be weaponised and used for sanctions by restricting targeted states' access (Farrell and Newman, 2019). For crude oil, controlling the global market structure has been argued as crucial for explaining US foreign and military policy (Stokes and Raphael, 2010). Payment in US currency and the financial system enables the US to sanction exporters by denying market access (e.g. Iran and Venezuela). For CRMs, China is the dominant actor, but research on its capabilities and motivations to influence the global CRM supply chains is scant.

BOX 9.3 THE 2010 RARE EARTH CRISIS: DID ENVIRONMENTAL CONCERNS OR A TERRITORIAL DISPUTE CONSTRAIN OUTPUT AND WAS THE IMPACT MATERIAL?

The Senkaku Islands in the East China Sea are under the administrative control of Japan but also claimed by China and Taiwan. They are uninhabited but hold economic and military value; fishers trawl the waters, and there might be oil, gas and other mineral deposits on the sea floor. On 7 September 2010, the Japanese coastguard requested a civilian Chinese fishing boat to leave the waters near the islands. The Chinese fishing boat refused and rammed a Japanese coastguard ship. The Japanese coastguard boarded the fishing boat and arrested the captain and his crew. China requested Japan to release the captain immediately, but Japan refused. A high-level diplomatic dispute ensued, which was only partly resolved after two and a half months of negotiations. This chain of events ignited the 2010 rare earths crisis.

China's response to the Japanese arrest and its aftermath remains debated to this day. Japan depended on Chinese exports of rare earths for manufacturing high-tech goods. At the time, China mined almost all the global output. According to Japan and Western allies, notably the USA and the EU, China reduced its exports of rare earths to Japan during the crisis to put pressure on Japan (StratCom COE, 2019). China, on the other hand, claims that they did not reduce exports to penalise Japan. The country did implement some measures that reduced mining, but the main reason was to reduce mines' environmental impact (Wilson, 2018).

The price of rare earths increased during the crisis, some up to tenfold. However, the price spike was short-lived, and a price collapse followed the year after. Some of the explanations proposed in the literature include Japan holding strategic CRM stocks, technological developments enabling the replacement of REEs, and illegal Chinese mining and smuggling that limited the restriction's enforcement (Gholz and Hughes, 2021).

The elevated price, regardless of the cause, increased interest in extraction elsewhere too. China's share of extraction dropped by a third to between 60 and 70 per cent in the following decade (USGS, 2024).

CONCLUDING THOUGHTS: A CRITICAL VIEW ON CRITICAL RAW MATERIALS

This chapter categorised perceptions of how geopolitics compromises supply security into three categories: (1) local events with global impact; (2) resource nationalism; and (3) weaponising supply. There are examples of threats that have materialised and triggered disturbances, both physical disruptions and price increases. Thus, "geopolitical risks" in a wider sense can indeed be a real supply security threat. However, the materiality of geopolitical risks is debatable as disturbances tend to be short-lived and have limited impact for societies. In addition to restoring and expanding supply, there are numerous other adaptation measures. Focusing on perceived supply threats narrows responses to protection, while many adaptation and resilience options are overlooked (see for example Chapter 27 by Logan et al. in this volume). For example, options for strengthening capacities could include assigning more weight to the role of material efficiency, substitution, recycling and diversification.

More research is needed to understand which materials and volumes are needed for different transition pathways to be feasible. This knowledge can serve the basis for developing criticality assessments based on resources *essential* for enabling certain functions that societies value, such as food, shelter and mobility, rather than the raw materials' share of *current* economic value. Such an approach would open up possibilities for identifying measures to mitigate criticality based on strengthening capabilities (i.e. positive security) rather than suppressing threats (i.e. negative security). For an overview of how these security conceptualisations relates to sustainability transitions, see Kivimaa (2024). This can serve as a starting point for integrating knowledge on material efficiency, focusing mainly on techno-economic factors and material sufficiency, and focusing more on societal factors such as lifestyles. For an overview of what the latter can imply for raw material use, see Bihouix (2021).

The EU's latest edition of the critical raw materials list is the fifth, and was released in 2023 (EU, 2023). One major change is that the methodology used to screen criticality was expanded to include a prediction of future shortage and supply-demand imbalances. Previous editions only used historic data. The prediction dimension could make the criticality assessment more relevant for policymakers as many responses take time to implement. For example, the EU added lithium to its list of critical raw materials for the first time in 2020, a metal for which demand has increased rapidly due to the adoption of electric vehicles. Opening new mines takes time. However, for a longer time-perspective to be a useful tool to guide policymakers, it needs to assess capabilities too, both for supply- and demand-side measures. Currently, this is not the case, since CRM lists only provide snapshots in time (Ku et al., 2018; 2024) and tend to focus more on threats than capabilities. This runs the risk of experts misguiding policymakers to prioritise materials that turn out to be less critical in the future than anticipated.

The science–policy interface may thus require more attention from scholars and reflections on what is communicated and how. Andersson (2020) found that discussions among Chinese experts on critical and strategic raw materials had preceded the discussions among policymakers. Experts and bureaucrats have key roles as they are responsible for developing the methods used for defining, operationalising and assessing raw material criticality (Machacek, 2017). Transferring problems and solutions from the expert community to the policymaking community may undermine transparency and legitimacy as it bypasses democratic processes when values and perceptions are defined by experts. This chapter has identified that some commonly perceived threats may be overstated, and calls for more attention on how capabilities and resilience can be developed.

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