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Critical Condition: Mitigating Mineral Supply-Chain Risks

Energy Research Paper

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New energy systems use a wide variety of critical minerals, including lithium, rare earths, cobalt and others. However, concerns are growing over the economic, political, and environmental risks to reliable supplies of such minerals.

What are these risks? Which are real and which exaggerated? What are strategies to mitigate supply-chain risks in extraction and processing, for companies who use them as inputs, and for governments?

ENERGY RESEARCH PAPER

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EXECUTIVE SUMMARY

- Critical minerals include a wide variety of elements and some other substances, with important applications in energy (particularly new energy systems), military or the general economy.
- Critical minerals often highlighted include lithium, nickel, cobalt, rare earths, and copper.
- Major nations have lists of critical minerals, but these are very broad and vary significantly from each other, with limited consensus.
- Western concerns about critical minerals relate particularly to the dominant role of China, and to some extent Russia, in their mining and processing, both at home and in international supply chains.
- Secondarily, there are worries about over-dependence on a few countries for materials, where supply could be interrupted by political, environmental or security problems, for instance Chile and Peru for copper, and the Democratic Republic of Congo for cobalt.
- Chinese concerns relate more to interruptions of supply, particularly to traditional energy commodities, including oil, gas and coal, as well as bulk materials where China is not self-sufficient such as iron ore and copper.
- Governments have introduced or considered a wide range of policies to mitigate critical mineral risks, including subsidising or facilitating domestic or third-country mining and processing, and accumulating strategic stocks.
- Measures led more by the private sector, typically in response to price rises, include substitution with other materials, and development of alternative technologies or novel sources.
- Most critical minerals are geologically available in large quantities, and alternative supplies can be developed over time. Only a few are truly "rare", but extraction and processing may be economically or environmentally problematic.
- Governments' critical minerals policies are often not very clear about which exact risks they are intended to mitigate and focus more on "niche" but high-profile materials than less glamorous bulk commodities. Western, but not Chinese, policies also pay too much attention to mining, and not enough to the processing of minerals, which is often a more significant bottleneck.
- Policies of self-sufficiency, export bans or trading blocs raise prices, are negative for the adoption of low-carbon technologies, and can heighten international trade and political tensions, thus raising the likelihood of conflict.
- Specific policies to safeguard critical mineral supplies for military or national security uses may be justifiable.

Critical minerals are a variously-defined group of materials, crucial for new energy systems, the military, or the broad economy. They are mostly elements, usually metals, sometimes in a specific form (e.g. diamond, graphite), sometimes chemically combined (e.g. fluorspar, potash), although some complex substances (oil, natural rubber) may also be included.

Attention on critical minerals has risen because of dominance of their mining and processing by a few countries, notably China; the growing geopolitical tensions between China and Russia on the one hand, and the US, Europe and partners on the other; and the rising importance of some minerals in new energy technologies (for instance, silicon for solar panels, rare earths for electric car and wind turbine magnets, lithium for batteries).

Governments have devised a range of policies to safeguard access to critical minerals. In some cases, these may be excessively expensive or even counterproductive. These mechanisms have not really been tested in a situation of major stress.

The emerging low-carbon economy uses many materials that were previously not in major demand or adds substantially to the growth in demand for existing commodities.

For example, a conventional vehicle uses about 33.5 kg of critical metals (copper and manganese); an electric car uses 53.2 kg of copper, 24.5 kg of manganese, 8.9 kg of lithium, 39.9 kg of nickel, 13.3 kg of cobalt, 63.3 kg of graphite and 0.3 kg of other critical minerals[i]. The EV also uses 25-27% more aluminium, but less steel. Batteries, typically containing lithium, cobalt, nickel, and graphite, will be used in the future energy economy in much greater quantities for grid storage and EVs; permanent magnets in electric motors and wind turbines contain neodymium and other rare earths. A much more electrified economy

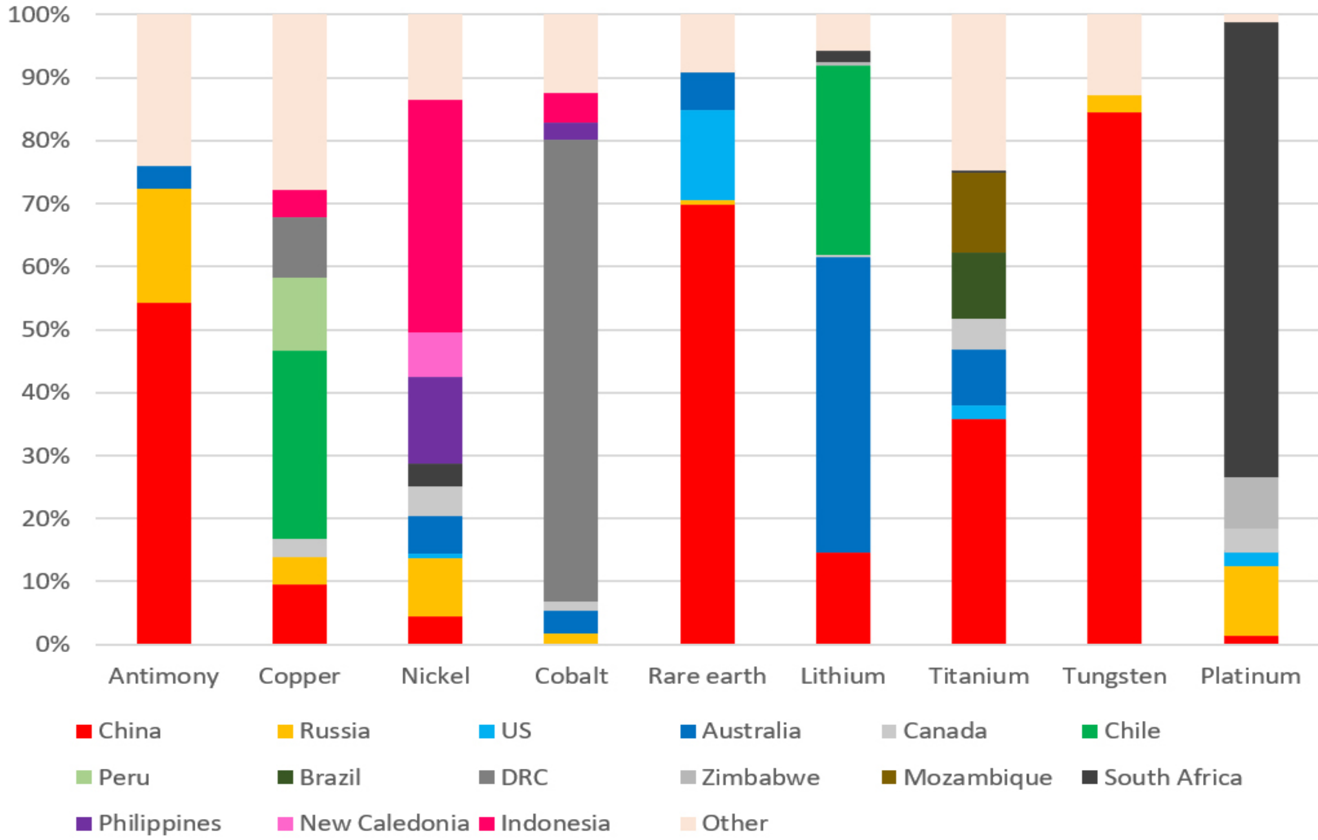
On the other hand, other commodities that were crucial in the past – notably oil, gas and coal – may lose importance. But, in the transitional period, their supply concentration may increase, and lack of investment could result in periods of shortage. Past attention on the security of traditional commodities may wane, as Europe's focus on gas did in the run-up to Russia's 2022 invasion of Ukraine.

For another group of critical minerals, their future importance is uncertain and depends on the take-up of technologies that employ them. For example, vanadium is used in redox flow batteries, which may or may not become widely used. Molten tin may be used in energy storage systems[ii]. Demand for uranium may increase, depending on the outlook for nuclear power, after agreement was reached at COP28 to triple its deployment by 2050[iii], while some proposed new reactor designs use thorium[iv], which has large global resources but is not employed today.

Production of critical minerals is indeed geographically concentrated, much more than for oil or gas (Figure 1). But no one country is dominant. China, for example, has more than half the market in rare earths, tungsten and antimony and is important in titanium, lithium, and copper. Russia features for several minerals but in a secondary role.

Several other countries dominate in one – but only one – commodity, such as Australia in lithium, the DRC in cobalt, South Africa in platinum and Indonesia in nickel. Chile is a leader in both copper and lithium, but with only 30% of the market in each case. Brazil and Canada, which are mining powerhouses in other materials, feature only in relatively minor roles.

Figure 1 Production of selected critical minerals, by country[v]



Various major countries define critical minerals differently.

Table 1 Official definition of critical minerals in various leading countries[vi]

	US	EU	UK	Japan	Canada	Australia	India	China	Total
Aluminium	●	●			●			●	4
Antimony	●	●	●	●	●	●	●	●	8
Arsenic	●								1
Barite	●	●							2
Beryllium	●	●		●		●	●		5
Bismuth	●	●	●		●	●	●		5
Borate		●							1
Cadmium							●		1
Caesium	●				●				2
Chromium	●			●	●	●		●	5
Coal								●	1
Coal-seam gas								●	1
Cobalt	●	●	●	●	●	●	●	●	8
Coking coal		●							1
Copper				●	●		●	●	4
Diamond				●					1
Fluorite	●	●		●	●			●	5
Gallium	●	●	●	●	●	●	●		7
Germanium	●	●		●	●	●	●		6
Gold				●				●	2
Graphite	●	●	●		●	●	●	●	7
Hafnium	●	●				●	●		4
Helium	●				●	●			3
Indium	●	●	●	●	●	●	●		7
Iron								●	1
Lead				●					1
Lithium	●	●	●	●	●	●	●	●	8
Magnesium	●	●	●	●	●	●			6
Manganese	●			●	●	●			5
Molybdenum				●	●		●	●	4
Natural gas								●	1
Natural rubber		●							1
Nickel				●	●		●	●	4
Niobium	●	●	●	●	●	●	●		7
Oil								●	1
Phosphorus		●		●			●	●	4
Platinum-group metals[1]	●	●	●	●	●	●	●		7
Potash	●				●		●	●	4
Rare earths[2]	●	●	●	●	●	●	●	●	8
Rhenium	●			●		●	●		4
Rubidium	●								1
Scandium	●	●			●	●			4
Selenium							●		1
Shale gas								●	1
Silicon		●	●				●		3
Silver				●					1
Strontium	●	●		●			●		4
Tantalum	●	●	●	●	●	●	●		7
Tellurium	●		●		●		●		4
Tin	●		●	●	●		●	●	6
Titanium	●	●		●	●	●	●		6
Tungsten	●	●	●	●	●	●	●	●	8
Uranium	●				●			●	3
Vanadium	●	●	●	●	●	●	●		7
Zinc				●	●				2
Zirconium	●			●		●	●	●	5
Total	35	28	17	31	31	24	30	24	

The list of which materials are considered critical by different countries is itself instructive.

They could be divided into four groups:

- Common, used in major quantities, where large-scale interruption would be generally economically damaging and could not quickly be replaced (e.g. oil, coal, gas, iron)
- Relatively common, but some stress from new demand, and supply relatively concentrated and exposed to scale-up risks (e.g. copper, silver, tin)
- Not geologically scarce, but production or processing is highly concentrated and developing alternative supply or alternative materials would be lengthy (e.g. lithium, rare earths)
- Genuinely rare, used in small quantities, important in some applications but could be substituted (e.g. scandium, tellurium)

There is also a distinction between fuels, which are consumed in use (oil, gas, coal), and materials. An interruption in oil or gas supply rapidly causes an economy to stop working. A disruption in the supply of rare earths or silicon would stop factories using those materials from working, but existing systems (e.g. electric cars, solar panels) would continue to work for long periods. Uranium falls somewhere in the middle since reactors are only refuelled every few years.

In general, it could be observed that Western countries have over-focussed on some niche, specialist materials, typically with applications in defence or new energy systems. Amazingly, coal, oil, gas, and iron are only on China's list. Yet in 2022, following Russia's invasion of Ukraine, gas became the most critical commodity to Europe, with record-high prices and economic stress.

China, by contrast, focuses more on bulk materials, particularly energy commodities: coal, gas (including specifically coal-seam gas and shale gas), oil, iron, copper, and aluminium.

There is also a surprising lack of consensus on which minerals make the cut. Out of 90 naturally occurring elements, 69 are on someone's list[3]. But only antimony, cobalt, lithium, rare earths and tungsten are marked by everyone as critical. They are also not necessarily sorted by vulnerability: for example, Australia is the world's largest exporter of lithium, but has it on its list; Canada is a major potash producer and also lists it.

Finally, a distinction should be drawn between resources, reserves, production and processing. Many of these minerals exist around the world in large quantities but sub-economic concentrations or hard-to-extract situations. These resources could become economically viable if prices rise, technology improves, or national security considerations take priority.

1-Some countries separate these (platinum, palladium, iridium, osmium and rhodium) or name only some of them, usually platinum and palladium

2-Some countries name specific rare earths, or distinguish light (lanthanum to promethium) from heavy (europium to lutetium), the heavy REEs being rarer and usually more expensive.

3-Including 17 rare earth elements, 6 platinum-group elements, carbon (coal, diamond, graphite), and the key element in various minerals (e.g. fluorine in fluorspar, boron in borates). Additionally, three non-elemental substances: oil, natural gas, and natural rubber.

Several countries have large economically viable reserves of minerals, for instance lithium in Mexico and Bolivia, but little or no commercial extraction, because of political instability or hostility to foreign investment. Again, this situation can change, bringing new low-cost supply to the market, and undermining the economics of higher-cost competitors.

NATURE OF CRITICAL MATERIAL RISKS

Before considering mitigation measures, countries should consider exactly what risks they are seeking to guard against. This can be classified across two axes. Firstly, is the material applied in energy (e.g. silicon, lithium), in military (e.g. rare earths, titanium) or general for the broad economy (e.g. copper, aluminium)? Secondly, is the risk economic (prices may be high or volatile), geopolitical (major global blocs may compete or cut off supplies), or security (supplies or transit from a limited source may be interrupted, e.g. by labour unrest or terrorism)?

Table 2 can then help to consider the risks in each case, and how to mitigate them. For example, military use may be relatively unconcerned about economic risk (they can pay whatever price is required), but very concerned about geopolitical risk (the denial of critical materials by a potential or actual enemy). Conversely, apart from oil and gas, few commodities are used in sufficient quantity to have a serious general economic impact if their price rises.

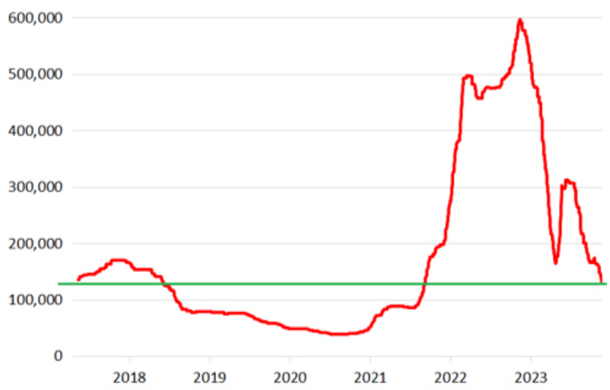
Table 2 Classification of critical material risks and level of concern

	Use of material		
Nature of risk	Energy	Military	General
Economic	✸✸	✸	✸
Geopolitical	✸✸✸	✸✸✸	✸✸
Security	✸✸	✸✸	✸✸

Economic risks are often understated but probably the most important. Demand surges, shortfalls in output and rising costs can lead to major economic problems for commodity-importing economies. Conversely, price slumps damage commodity exporters, and may make investments in alternative supplies or materials unviable. That has been the dominant theme of the oil industry for the last 150 years.

It may be less important for many critical minerals, which are used in smaller quantities. But lithium, for example, has been through a price surge and crash in 2022-23 even more extreme than past episodes in oil (Figure 2).

Figure 2 Lithium carbonate price, 99.5% battery grade, CNY per tonne[vii]



Critical minerals markets are often small, not very liquid, non-transparent, dominated by a few players on each side, and without well-developed futures markets, all of which encourages extreme price volatility.

That in turn makes some risk mitigation strategies risky, as, for example, investment in high-priced alternative supplies or competing technologies can be undermined by a price collapse.

Conversely, for minerals exporters, their market could be cut off by sanctions. This is illustrated by the case of Russia. In December 2023, the UK, a major centre for metals business, banned the trading of physical metals of Russian origin, including aluminium, copper, and nickel[viii]. The G7 also plans to ban the import of Russian diamonds[ix]. While Russia will probably find alternative markets, notably China, these sanctions could require it to offer substantial discounts to other buyers, as with oil.

The concentration of critical mineral mining and processing in China and, to a lesser extent, in Russia, raises obvious geopolitical concerns in Western countries. Supplies could be cut off entirely, for instance as in the shut-off of most Russian gas to Europe around the war in Ukraine, or lithium or rare earths from China in the event of a conflict over Taiwan. China may use its leverage over other countries, as for instance when it cut exports of rare earths to Japan because of a territorial dispute over the Senkaku (Diaoyu) islands[x], although it cited environmental reasons. In August 2023, China ceased exporting germanium and gallium, which have military applications, likely a reaction to the US ban on advanced semiconductor sales to China[xi]. Exposure could run the other way: China unofficially stopped importing Australian coal between late 2020 and early 2023, due to a deterioration in relations[xii].

Conversely, the West's leverage over China may appear to be less, but US oil and liquefied natural gas (LNG), and Australian LNG, are essential components of Chinese energy consumption. In the event of an outright conflict, Chinese maritime supply routes from the Middle East and south-east Asia could also be interrupted.

Other risks are more specific, and typically relate to local political, security or environmental problems. Several key minerals are concentrated in countries with significant political risks, notably cobalt and tantalum from the Democratic Republic of Congo. Labour disputes and community protests often interrupt output of platinum group elements in South Africa, and copper in Peru. Extreme weather, such as flooding of mines, or storms closing export ports, is likely to intensify with climate change.

Strategic reserves: Many of these minerals are used only in small quantities and values. It would be very feasible, for a cost of only a few billion dollars, to stockpile several years' worth of critical minerals. To take an extreme example, scandium, used in small quantities in high-performance aerospace and fuel cells, costs about $10 million per tonne, but at about 40 tonnes of global use per year, a stockpile would cost $400 million. Contrast this to the US's Strategic Petroleum Reserve, which has a maximum capacity of 714 million barrels, would cost about $55 billion to refill at current prices (not including maintenance), and which could meet all US oil demand only for about a month. Similarly, Europe's gas storage is at record highs, but would quickly be depleted in the event of a cold winter and any further significant supply disruption.

Self-sufficiency: countries can seek to install more minerals mining and processing at home. This is the best guarantee of supply security and has added advantages of winning domestic political support (through the promise of jobs and local economic activity). However, mining depends, of course, on possessing quantities of economically viable minerals. Developing new mines in most OECD countries takes many years and often encounters major environmental, legal and community obstacles. For example, a major copper-nickel mine in Michigan[xiii], a copper-gold mine in Alaska[xiv], and a lithium mine in Serbia, have all been blocked[xv]. Minerals processing facilities, particularly for rare earths and silicon, are often energy- and carbon-intensive and produce toxic waste.

Supply diversification: many critical minerals are not rare in geological terms, and further exploration and development would access new reserves. For example, Central Asia is not currently a major producer of rare earths, but it has significant resources (Figure 2)[xvi].

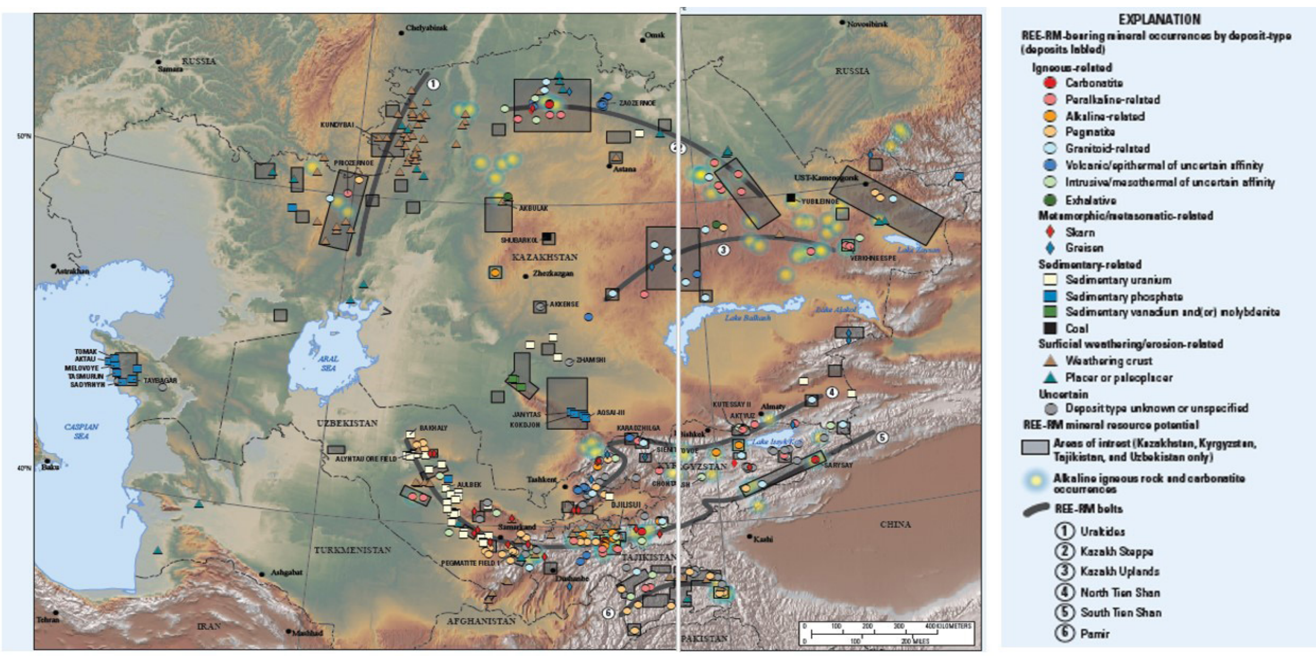
Setting up mines and processing facilities in other countries has some of the benefits of self-sufficiency. It may be more effective in that mineral deposits in these countries may be of higher quality, and projects may proceed more quickly. Even if the country has political or security challenges, adding to supply diversity still diminishes the overall portfolio risk. This diversification can include methods such as simply instructing state-controlled companies to invest, applying tax credits or export credits to supply from certain countries, concluding free-trade agreements, or sponsoring studies and mineral exploration in promising areas. It could also include providing funding for infrastructure that helps minerals production and export, for example railways, roads, ports, and electricity grids.

Technology access: for several of these minerals, the key bottleneck is not access to the raw material, but to the skills to process it. Chinese firms have become dominant in areas such as refining rare earths, lithium and nickel. Other nations concerned about dependency can ensure that they retain access to cutting-edge technology, for example through joint ventures, or retaining a small (possibly government-subsidised) processing capacity that can be scaled up if required.

Developing more environmentally friendly extraction and processing technologies would also be very helpful for countries such as the US and Europe, where environmentalist opposition often holds back new projects.

Supply-chain ownership: China is particularly known for taking stakes in overseas mineral projects to gain control of the supply chain, introduce and improve its technologies, protect itself against adverse price movements, and build political relations with important mineral suppliers.

Figure 3 Rare Earth Resources of Central Asia



Chinese companies dominate nickel mining and processing in Indonesia, for example, and have developed expertise in processing its unique deposits[xvii]. India has also established a state-owned company to acquire overseas mineral assets[xviii], while Saudi Arabia's Manara Minerals, a joint venture between the Public Investment Fund and state-owned miner Ma'aden, has taken a 10% stake in the base metals unit of Brazilian miner Vale, which produces copper and nickel[xix]. This approach is more difficult for OECD countries, who rarely have state-owned or state-controlled mining companies. Instead of direct ownership, companies could also enter long-term contracts for minerals supply.

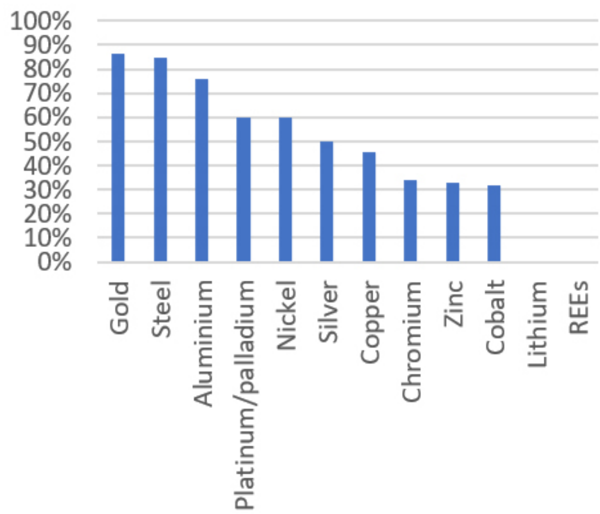
Alternative sources – some minerals can be produced from sources other than traditional mines. For example:

- reprocessing spoil heaps can yield rare earths, cobalt, nickel, and copper[xx]
- old coal mines may contain rare earths in associated deposits[xxi]
- brine from desalination contains potentially economic quantities of some critical minerals (notably, magnesium, rubidium, borate and possibly lithium, strontium, caesium, and uranium[xxii])
- oilfield, magmatic and geothermal brines may be enriched in critical minerals, notably lithium[xxiii], copper and silver[xxiv]
- direct lithium extraction (DLE) is technically complicated, but may be a less energy- and water-intensive method of extracting lithium
- deep-sea mining is attracting growing interest, particularly for copper, nickel and manganese, but also raises substantial environmental concerns.

Recycling: metals in particular are usually almost infinitely recyclable. Aluminium (76%), steel (85%) and gold are already recycled to high levels (Figure 3). Recycling can be promoted by government mandates, promoting proper sorting of waste, or initiatives such as carbon pricing. Better design of products such as batteries can make them easier to disassemble and recycle. Used electric vehicle batteries can also be re-used for less demanding applications, such as stationary electricity storage.

Rates of recycling of lithium and rare earths are very low. But, given the projected major scale-up of demand for some materials, and the early stage of deployment, recycling will not make a major contribution to supply for a long time.

Figure 4 End-of-life recycling rates for selected metals [xxv]



Partnerships: countries can work together to recognise critical minerals supply from those considered "friendly". An obvious grouping would be the US, Canada, EU, UK, Norway, Australia, Japan and South Korea. Similarly, China and Russia may work together.

Other major producers such as South Africa and Brazil will probably not align with any bloc. This concept of "friendshoring" (as distinct from onshoring, itself the inverse of offshoring) applies to supply chains more generally.

However, mutual recognition is not always easy, particularly when countries – in particular the US – offer subsidies for domestic sourcing that they do not wish to be available to companies from other countries. The former administration of Donald Trump imposed tariffs even on US imports of EU aluminium on supposed "national security" grounds. "Friendshoring" is also risky if it divides the world into competing geopolitical blocs, as discussed below.

Development of alternatives – many "critical minerals" are in fact not so critical. For example, in many uses, copper can be replaced with aluminium; copper and aluminium cables could be replaced by carbon nanotubes; aluminium car bodies with carbon fibre; natural with synthetic graphite; nickel and cobalt in batteries with iron and phosphate; lithium in Li-ion batteries with sodium; neodymium in magnets with cerium (also a rare earth, but more common), iron nitride, or other materials[xxvi]. If the use of a material cannot be avoided entirely, the quantity required can be reduced, as with the use of silver in solar panels[xxvii]. Or, technologies can be employed that avoid the demand entirely, for example induction motors that do not require permanent magnets. Sometimes, performance of the alternatives may not be as good, but still acceptable in many uses.

Political and investment stability: major minerals-using countries can invest diplomatic and financial resources to improve stability and investment conditions, and build political links, with key minerals producers and processors. Security forces, early warning systems and emergency responders can reduce exposure to insecurity and natural disasters, particularly in lower-income countries. However, it is important to avoid militarising the minerals industry or prioritising interests of the extractive company or country over those of the host nation and residents.

Institutions and alliances: the International Energy Agency (IEA), International Renewable Energy Agency (IRENA) and Organisation of Petroleum Exporting Countries (OPEC) are examples of bodies that help coordinate energy policy between members. The Energy Charter Treaty improves the security of cross-border energy investments, while the World Trade Organisation is intended to promote global free trade. Some of these bodies could or do take on tasks of securing mineral security. The IEA runs a cooperative programme of sharing emergency oil stocks; a similar approach could be taken for critical minerals. Member countries could also commit not to use "beggar-my-neighbour" policies such as export bans in times of emergency.

Financial markets have an important role to play in limiting risk and price volatility through promoting price transparency and offering options and futures contracts. Only a few critical minerals markets have liquidity and transparency comparable to that of the oil and gas markets. Many minerals are not freely traded. Quality standards and benchmarks are not always compatible, and prices can vary widely between high-grade material and that for ordinary industrial use. Sanctions on Russia also affect trading, notably aluminium and copper on the London Metals Exchange[xxviii].

Policies on critical minerals have several potential negative consequences.

Higher costs – almost by definition, new sources of minerals will be more costly, or they would be developed already. For example, the US Treasury's and Department of Energy's interpretations of the Inflation Reduction Act will limit tax credits for electric vehicles using Chinese materials[xxix]. That will require makers to use other sources, raising the overall cost of mineral inputs. The requirement for certification of origin along the value chain also introduces additional costs, encourages rent-seeking lobbying, and invites evasion.

Reducing economic competitiveness – higher costs for inputs in turn make products less competitive. The result could be, for example, that EVs made in the US or batteries made in Europe compete in their domestic markets, because of protectionism, but are uncompetitive internationally. That could lead to the reverse of what is intended, i.e. to the even greater dominance of Chinese-made products outside the US and Europe.

Price volatility – if government policies subsidise development of new mineral sources, that could lead to over-supply and eventual price collapse. Or, if government support is withdrawn abruptly because of a change of policy or administration, anticipated mineral supply could suddenly be removed.

Fiscal burden – if diversification policies are paid for by government, that imposes a burden of higher taxation and/or higher debt.

Lack of supply chain integration – in the case of many minerals, control of both supply and processing is concentrated. For example, MP Materials has restarted the Mountain Pass mine in California, the US's main supplier, provides about 15 per cent of global rare earths, but it has to ship concentrate to China for processing, and only recently started up its own refining operation[xxx]. Conversely, a country establishing its own processing capacity would have to be sure that it could obtain inputs.

Environmental and social damage – if diversification policies drive mineral development into new areas, that might lead to negative consequences if those areas are not adequately prepared for mining operations or are environmentally sensitive. At the same time, if investment in existing mining areas dries up, they could be left with an unfunded legacy of environmental damage and unemployment.

Deterring alternatives – if government policies to boost critical mineral supply succeed, including by subsidising supply, that would deter alternatives – for example, reducing the amount of critical minerals used in systems, or replacing them with cheaper materials, as in substituting copper with aluminium.

Slowing decarbonisation – the combination of higher and/or more volatile prices for key inputs, described above, would raise the cost of new energy systems and so slow their adoption, leading to higher emissions.

Damaging political relations – increased trade is generally thought to promote peace[xxxi]. Moves for greater self-sufficiency are, therefore, potentially dangerous in lowering barriers to conflict. This is particularly so for countries where relations are already poor, for example China-US, Japan-China or Russia-EU. The development of blocs which largely trade within themselves and deny critical minerals to others would be particularly dangerous for raising the risk of a major multilateral conflict.

Weakening lower-income countries – commodity exports form a large part of the exports of numerous developing countries. Diversification could bring new earnings for some countries. But an attempt to boost mining in "safe" jurisdictions such as the US, Canada, Australia and EU could limit investment into countries such as the DRC, Zambia and Peru.

Critical minerals have emerged as a major area of concern in recent years, because of the combination of rising geopolitical tensions and the emergence of demand from the new energy industry.

Critical mineral embargoes are likely to be ineffective over the longer term, since alternative sources or substitutes will be developed. With the partial exception of China, no country is dominant across the board, therefore cutting off a supply of one critical mineral would risk retaliation by suppliers of others.

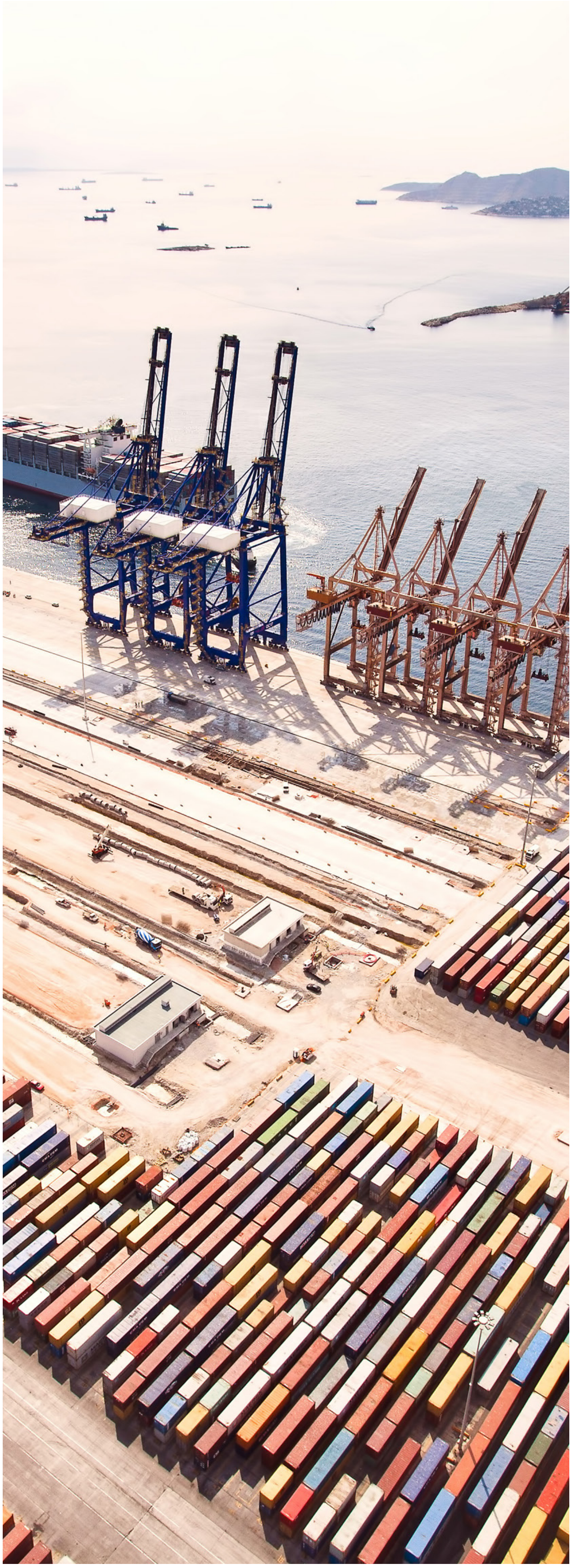
Temporary interruptions of supply from accidents, security problems, political insecurity or natural disasters can, similarly, be compensated, or offset by strategic storage. The major risk is likely not from the niche materials used in small quantities, but from the more bulk commodities which are not easily replaced quickly, notably copper.

Times of conflict are a different case. In a short conflict, stocks of critical materials and the equipment made from them would not be exhausted. In a long conflict, there would be time to build up minerals extraction and processing, and the sense of emergency would allow over-riding environmental, community or budgetary opposition. A medium length of high-intensity conflict is therefore the riskiest situation. There is a case for government-led measures to ensure a supply of critical minerals for military and crucial civilian industries in such a situation.

Western critical minerals lists arguably focus too much on niche substances, and do not distinguish sufficiently clearly which risks they are intended to guard against. Policies of subsidy and self-sufficiency, particularly in mining as distinct from processing, arguably do not guard fully against risks, and raise wider political and economic problems.

China's critical minerals list appears more realistic, and includes crucial fossil fuels. Its investment in processing, developing technological expertise, and taking stakes along the value chain, are notable elements of its strategy. It also has large stocks of raw materials, such as copper, held for mixed commercial and strategic reasons. Due to the likely US control of international sea-lanes in the event of conflict, and the US's ability to wield sanctions against important suppliers such as Russia, China faces vulnerabilities that the US does not. However, China's attempts to use boycotts of critical minerals, formal or informal, have been clumsy and have backfired.

In general, policies of autarky and subsidy are negative and should be avoided, except in very clearly defined cases of national security or military applications. It is much better to rely on market mechanisms, wide international collaboration, and development of improved technology. There is a role for strategic stocks of some critical materials, but, as with the IEA's oil requirement, it would be helpful to coordinate these internationally and avoid hoarding.



i- https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary
ii- https://cleantechnica.com/2023/12/13/molten-tin-lithium-free-energy-storage-long-duration-thermophotovoltaic/
iii- https://www.iaea.org/newscenter/news/nuclear-energy-makes-history-as-final-cop28-agreement-calls-for-faster-deployment
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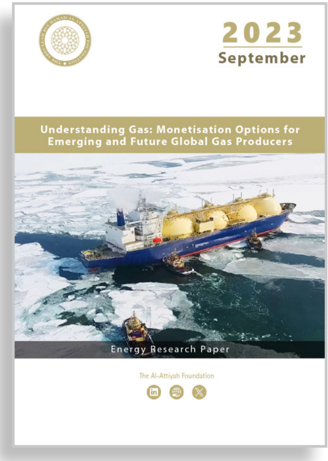
21 PAST ISSUES

Have you missed a previous issue? All past issues of The Al-Attiyah Foundation's Research Series, both Energy and Sustainability Development, can be found on the Foundation's website at www.abhafoundation.org/publications



September - 2023

Understanding Gas: Monetisation Options for Emerging and Future Global Gas Producers

Developing and bringing challenging gas resources to market has historically been a formidable endeavour. Commercial and technical advances have notably facilitated this process over the past two ecades, and the loss of legacy supply creates the opportunity for new sales.

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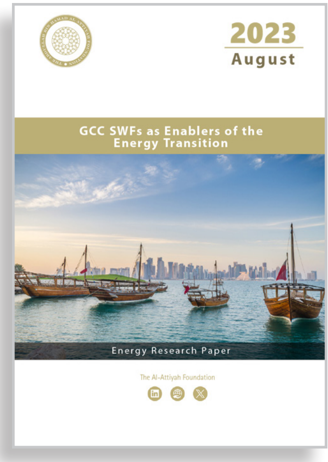

August - 2023

GCC SWFs as Enablers of the Energy Transition

The last decade has a seen sharp rise in GCC SWFs' investments in developed countries, as a result of which their accumulated assets have dramatically increased. Although investments in large, advanced economies and prominent emerging markets are likely to continue in the next few years, GCC SWFs are now increasingly recycling part of their petrodollar inflows into developing economies in the Middle East.

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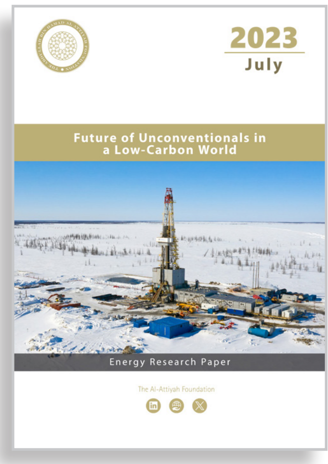

July - 2023

Future of Unconventionals in a Low-Carbon World

Over the past 20 years, unconventional resources have become a significant part of the global energy mix, accounting for onethird of the world's total oil & gas supplies. However, to achieve net-zero goals by 2050-2070 and the Paris Agreement's target of keeping global temperature increases below 1.5°C, a significant transition is required in the next 30 years.

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OUR PARTNERS

Our partners collaborate with The Al-Attiyah Foundation on various projects and research within the themes of energy and sustainable development.

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