CHINA RESEARCH GROUP

POLICY BRIEF

The UK and China: Critical Minerals

NOVEMBER 2021

Executive Summary

- Critical minerals are minerals considered essential to the economic and national security of a country, where the supply chain is vulnerable to disruption and shortages would pose a serious risk to the economy. They are the building block of a transition to clean energy.

- The combination of decarbonising our energy sector with renewables, the shift to electric vehicles and the creation of a flexible energy storage system will substantially increase the UK's demand for critical minerals.

- Global demand for critical minerals is set to soar in the next two decades. As a result, a race to secure supplies of critical minerals is under way.

- One nation has a huge head start. China dominates the refining and processing of critical minerals, controlling up to 90% of this stage of the midstream of the supply chain. While its dominance was partly fuelled by Western offshoring, the Chinese government has systematically supported its rare earths industry with strategic industrial policy.

- This raises clear concerns of strategic dependence at a time when Beijing is deepening its state control of the rare earths industry. This is compounded by the ethical questions of opaque supply chains and environmental issues of high-carbon supply chains.

- China's strategy is evolving. In 2020, the country became the world's largest importer of seven types of rare earths, symbolising a shift to offshoring low-value mining and focusing on the higher-value midstream processing and downstream manufacturing.

- Reducing dependence on China will be tricky. Critical minerals are likely to play an increasingly important role in the Belt and Road, further complicating attempts to reduce dependence on China. Chinese state-backed companies have also taken stakes in leading Western rare earths mining companies, many of which sell their concentrate back to China for processing.

- The state model is here to stay. The bulk of actors are benefitting from significant state support, including our like-minded partners, such as the US and Australia. Most developed industrial economies are seeking to build regionalised or domestic sovereign supply chains as a matter of national security.

- In the face of China's dominance and rising state-backed competition for access to critical minerals, the UK needs a resilience-focused strategy in order to protect its manufacturing base and national security.

Introduction

Our Net Zero strategy will see the UK invest in a range of clean technologies to propel us towards a carbon neutral economy. This is a wholesale transition that will upheave the infrastructure on which our country is built, in turn generating new dependencies that could rewrite our geopolitical relationships.

The lesson from the past two years is that what underpins our economy must be resilient supply chains. A greener economy depends on a reliable supply of the building block of net zero: critical minerals. It is the lithium for batteries and neodymium for the magnets in wind turbines that will power our green industrial revolution.

Until now, the globalised market largely provided a steady supply of raw materials at low prices. But the increased focus on security of supply chains combined with rising demand from mass adoption of renewable technologies is upending those market dynamics.

The race to secure supply is heating up. We are beginning to see the effects of competition. Lithium prices are five times higher than this time last year. From Australia to Japan, countries are sinking in huge state investment into securing supply for domestic industry.

In this new resource race, one nation has an enormous head start. China controls a staggering proportion of the supply of many of these critical minerals. Decades of state support means that China controls 90% of the midstream processing of rare earths, creating one of the most striking examples of strategic dependency in any industry, anywhere.

This paper will look at the shifting sands of the China-dominated critical minerals industry, and how the UK's lack of strategy has created a situation of strategic dependency.

1. What are critical minerals?

Critical minerals are minerals considered essential to the economic and national security of a country, where the supply chain is vulnerable to disruption and shortages would pose a serious risk to the economy. They are key to manufacturing and agricultural supply chains, and to the successful deployment of modern technologies in a variety of industries, including telecommunications, national defence, and (renewable and non-renewable) energy.

This flexible definition of critical minerals means that countries periodically update their critical minerals lists to reflect changing technology and supply situations.

Within the broader definition of critical minerals, rare earth elements (REEs) are a group of 17 metallic elements. The "rare" in rare earth elements is a misnomer in that it reflects a historical unfamiliarity with the elements rather than true geological scarcity.[1]

The similarity of the chemical properties of REEs, evidenced by their proximity on the periodic table, makes many of them extremely difficult to separate. They are extracted through a range of capital and skill-intensive methods before being transported to facilities and refined for end-use products, in what is called the mine-to-magnet supply chain.

From bridges and fighter jets to solar panels and electric vehicles, almost every innovation of the 21st century relies upon critical minerals.

Global demand

The World Bank estimates that global production of critical minerals may have to increase by nearly 500% by 2050 to meet the demand for clean energy technology required to limit global temperature increases to below 2°C. [2]

The inexorable rise of Tesla and lithium batteries have dominated the story so far. And the International Energy Agency (IEA) forecasts that batteries will account for 60% of the clean technology market in 2050, becoming the single largest source of demand for lithium, nickel and cobalt. Depending on which battery technologies predominate, the IEA forecasts global lithium demand increasing by anywhere from 13 times to 51 times by 2040.[3]

However, it is important to note that critical minerals are not just a battery story. They are essential for the wider clean energy transition; neodymium and praseodymium are necessary for offshore wind turbines; polysilicon for solar power and platinum for hydrogen fuel cells.

UK demand

There are three main ways that the UK's Net Zero strategy will increase our demand for critical minerals.

1. Our power supply will mainly be based on renewables, such as wind and solar. The UK has made a concrete pledge to quadruple existing offshore wind capacity to 40GW by 2030, backed by investing £160m into port infrastructure for installation.

2. Our pledge to end the sale of new petrol and diesel vehicles by 2030 and hybrid vehicles by 2035, and funding for up to 4,000 new zero emission buses. This will be accompanied by investment in at least two British gigafactories to support a domestic electric vehicle manufacturing industry.
3. The subsequent increase in charging demand for electricity, combined with a more variable energy supply from renewables, will require a flexible low carbon energy storage system and an uptick in electricity generation.

In 2019, a group of British scientists estimated that to make all cars and vans electric by 2050 and all sales to be purely battery-electric by 2035 in the UK would require just under two times the current total annual world cobalt production, nearly the entire world production of neodymium, three quarters the world's lithium production and at least half of the world's copper production. These numbers could be decreased by more efficient batteries, but the fundamental dynamics point to a steep increase in demand.

This paper will focus on critical minerals as a net zero story, but it is also worth noting that critical minerals are also essential to the components necessary in all things from surveillance systems, lasers and material coatings to improve battery technology, armour and night vision. Missile systems and other military equipment in the UK and US use rare earth magnets which are mostly sourced from China.

Spotlight on: neodymium

Offshore wind capacity will rely on neodymium, dysprosium and praseodymium (commonly referred to as NdpR) to make permanent magnets for wind turbines.[1] The magnets are essential to reducing the weight and increasing the efficiency of turbines. They are also used in a variety of other applications, including MRI scanners and speakers.

China dominates the production from 'mine to magnet'. At the moment, around 70% of neodymium is mined in China, followed by 11% from the USA (Mountain Pass), 9% from Australia (Mount Weld), and 6% from Myanmar.[1]

Adamas Intelligence reports that NdpR prices surpassed $100 per kilogram in 2021; the highest price for a decade. Production of NdpR is expected to increase by 50% in China by 2025 in order to meet market demand.[1]

2. China and critical minerals

A huge increase in demand for critical minerals is one half of the story. The second half of the story is China's dominance.

Figure 1 below outlines in red the stages of the rare earths supply chain (separation, processing, and magnet making) in which the West is particularly reliant upon China.

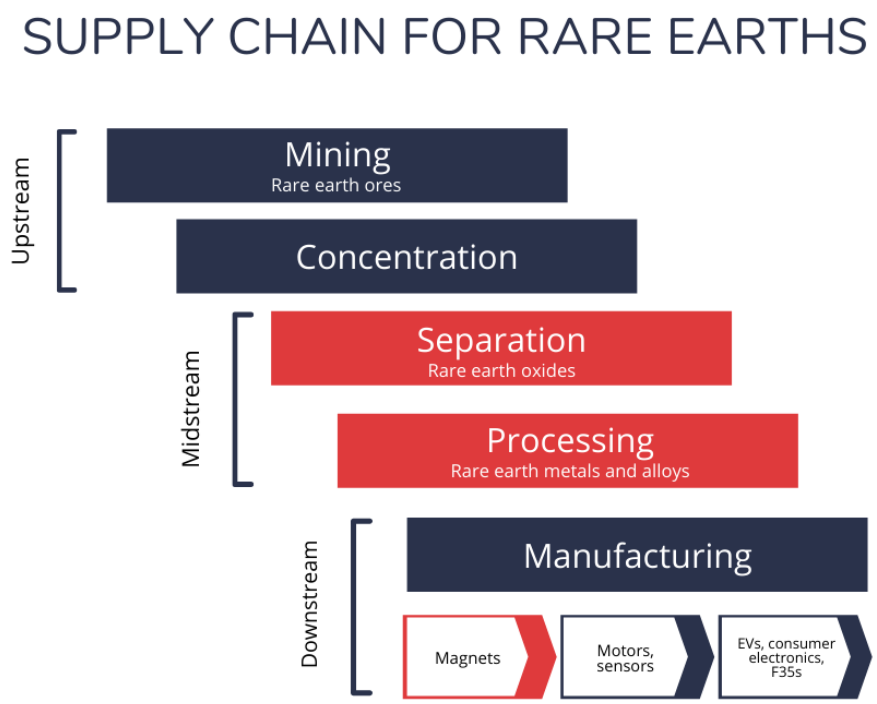

Figure 1 - Supply chain for rare earths metals[4]

This dominance has become more complex in the past few years, as countries have pursued fragmented strategies to onshore elements of the supply chain.

In 2015, China accounted for some 90 percent of rare earth mining, but this is now down to around 58 percent in 2020. The US and Australia have gradually boosted production, while China has increasingly offshored production as its economy develops: in 2019, China accounted for 80% of global rare earth concentrates imports.[5] For other critical minerals, such as lithium, cobalt and nickel, the vast majority of mining takes place in countries such as South Africa and Australia.

The midstream - refining and processing - remains a major chokepoint. Chinese firms account for 89% of midstream rare earth processing by revenues, and its dominance extends down the value chain into magnet manufacturing. Out of 190,000 tonnes of rare earth magnets that are produced annually, 175,000 are made in China.[6] The dominance also extends beyond rare earths; China is also a 'near-monopolist' in graphite, vanadium and cobalt processing[7], and continues to account for around 80% of all lithium battery cell manufacturing capacity today.[8]

At the downstream level, manufacturing once again becomes more globalised. China has little presence in the battery assembly phase of the lithium supply chain, and end-use components are often manufactured in the West.

How did we get to this situation? China's dominance in rare earths is a story that broadly fits the conventional tale of China's industrial development. From the 1980s to the 2010s, the industry grew exponentially - at great environmental cost. From the 2010s, Beijing sought to consolidate a sprawling industry into six firms in order to increase control and oversight. And since 2016, Chinese firms have leveraged the international market in order to supplement domestic production.

Rare earths as a strategic industry in China

Until the 1970s, the US was the world leader in rare earths manufacturing. But between 1978 and 1989, Chinese rare earth production increased by an average of 40 per cent a year.[9] This rapid commercial development came at a time when the West was looking to offshore environmentally damaging manufacturing.

In 1990, the Chinese government labelled rare earths as a strategic industry, at a time when the US and China each accounted for about a third of rare earths processing. Foreign entities were only able to invest in Chinese rare earth mining and separation companies as part of a joint venture, which had to be approved by the Chinese State Department and Planning Commission and the Ministry of Commerce.[10]

From 2000 onwards, China became the world's leading producer and exporter of rare earths, and quickly achieved near-monopoly control over the supply chain. The risks of supply concentration cropped up in 2010, when the Chinese government reduced its export quotas by 40%. Prices quadrupled.

This culminated in an unfair trade practices case successfully brought against China at the WTO in 2013. Chuin-Wei Yap of *The Wall Street Journal* argues that Beijing employed quotas to artificially push rare earth prices sharply higher, despite continually claiming that quotas were merely an attempt to clean up its highly polluting domestic mining industry.[11]

Consolidation era

A desire to tackle pollution, the onset of the US-China trade war, and a new industrial policy saw China's rare earths policy evolve from around 2015.[12] The opaque nature of both rare earth flows and Chinese open source documentation means limited information is available on the minutiae of Chinese rare earths policy, but there is evidence that increased bandwidth has been designated to rare earths by the relevant ministries since the launch of *Made in China* 2025 in 2015.

Yang Danhui of the Chinese Academy of Social Sciences summarised the CCP's overall approach as: "the use of the rare earths national strategy to support the industrial strategy."[13] The central government, as announced in its 13th Five-Year Plan in 2016, placed priority on three domestic objectives with regards to REEs[14]:

1. Establishing industrial order for critical minerals through state direction
2. Treating environmental problems
3. Encouraging the domestic downstream use of rare earths

Increased level of state involvement is evident in the 'Consolidation Plan', which was drawn up in 2015 to amalgamate China's slew of rare earth mining and processing firms[15], and intended to crackdown on illegal mining and pollution.

The Consolidation Plan marked a new era of aligning rare earth policy with China's broader industrial goals, and resulted in the creation of a "big six" of rare earth SOE conglomerates that are now responsible for 80% of the country's REE capacity.[16] Three of the groups are controlled by the central government, whilst the other three have provincial or city governments as their dominant stakeholders.[17] Each of the six conglomerates covers various parts of the REE supply chains, with particular emphasis placed on the upstream and midstream of production.[18]

Reports in 2021 suggest that the Chinese government will look to consolidate further, merging the six rare earth companies into two rare earth majors. Beijing also announced a new package of subsidies in July 2021, including cash subsidies, government support for R&D and tailor-made subsidies and specific preferential policies for major projects worth at least 1 billion yuan ($154 million). [19]

Belt and Road

In 2018, Beijing became a net importer of several rare earth elements for the first time since 1985.[20] recognised its need to develop its "base" of critical mineral production overseas as well as at home. For example, China only mines 1% of the world's reserves of cobalt and yet controls a significant proportion of its global supply chains.[21]

To mitigate the risks presented by a potential decoupling and the reshoring of full critical mineral supply chains by China's competitors, Chinese rare earth giants have taken steps to embed themselves more deeply into global supply chains and adhere to the concept of dual circulation espoused by Xi Jinping, which aims to increase self-sufficiency at home while increasing reliance on China abroad. Analysts also believe that these relationships present longer-term attempts to offshore mining and processing, which add the least value and can be the most environmentally damaging.[22]

China has employed a strategy titled "Two Resources, Two Markets" with the goal of supplementing domestic production with imported earth to strengthen its commercial position.[23] China is now the top critical mineral export market for 13 African countries; part of a pattern of China's role as the driver of economic activity in the region.[24]

Notable recent moves include:

- A $20 billion loan from China to Guinea, agreed in 2017 in exchange for bauxite concessions.[25] China agreed to loan Guinea the funds in exchange for access to bauxite. It guaranteed the development of three projects, including a China Aluminum Corp-backed mine that opened in 2020.
- In 2020, Chinese state-owned China Nonferrous Metal Mining Group (CNMC) and DRC state-owned miner Gécamines struck a "mega deal" to give the Chinese giant access to a series of huge copper and cobalt mines.[26] In return, China wrote off $28million worth of DRC debt and signed a memorandum of understanding to make the DRC the 45th country on the BRI this year.[27]
- Chinese companies recently acquired the rights to develop three of Argentina's lithium mines, paying over $1 billion.[28]

The drive to secure critical minerals is likely to play an increasingly important role in the Belt and Road in the next decade. The deployment of 5G networks, for example, will support a number of industries that will become voracious consumers of critical minerals.

Hedging in the developed world

China's critical minerals companies are also active global investors. So far this year, Chinese companies have spent $1.58 billion on acquiring lithium mining rights.[29]

Mary Hui of *Quartz* has led the reporting on Chinese critical minerals giant Shenghe Resources[30] Shenghe describes its ownership as "mixed" but its largest shareholder is a research institute within the state-owned China Geological Survey.[31] Shenghe holds an 8% stake in American firm MP Materials, which secured its access to rare earth output from its MountainPass mine[32] and has signed a memorandum of understanding with Australian critical minerals firm RareX for a majority owned joint-venture in a novel rare earths mining and refining project in Western Australia.[33]

Shenghe also signed a joint venture agreement with China National Nuclear Corporation (CNNC) to facilitate the trading and processing of rare earth minerals at the Kvanefjeld mine in Greenland. But the deal was later derailed when Greenland elected a governing party which pledged to ban the mine's development.[34]

There are very few rare earths or critical minerals projects without any links to China, thus significantly complicating any attempt to reduce dependence.

The next frontier

In line with its status as the dominant minerals nation, Beijing is also seeking to influence the policies to shape the architecture on which the industry is built. Open-source analysts have flagged the rise of China's state-funded LOGINK network as one way in which Beijing can wield its influence. LOGINK can be thought of as a "super app" for international logistics: it is a digital logging system to simplify and standardise logistics visibility.[35]

Since LOGINK's inception, China's government has sought to promote the platform as a global technical standard for information logistics. But one byproduct of LOGINK's widespread adoption at ports is that the transportation of raw materials is dependent on Chinese standards, and information on mining and critical mineral flows are relayed through a system controlled by China's Ministry of Transport.

Whilst it's difficult to categorise China's approach to ports and logistics as either purely commercial or purely strategic, a by-product of its maritime interests is unrivalled intelligence on the flow of critical minerals.

3. The UK's situation

The UK government has placed a strong emphasis on the EV industry, backing several domestic battery-related initiatives through the Automotive Transformation Fund. This includes subsidies for the new Nissan-Envision AESC gigafactory in Sunderland and £4m for the UK's first recycling plant for high-performance rare earth magnets. This activity has largely focused on the downstream, with the bulk of investment going into gigafactories.

Beyond these projects, a disparate set of critical minerals mining initiatives are springing up, which are generally relying on freeport status, encompassing favourable tariffs or tax breaks:

- Cornish Lithium's plans to to produce lithium from geothermal waters and mining in Cornwall
- Pensana's planned $125m rare earths separation facility in Yorkshire, shipping ore from Angola
- Peak Resources' $165m plan for a NdPr refinery in the Tees Valley, shipping ore from Tanzania

A lack of strategy

Three broad sets of concerns were raised in interviews. The first was scepticism around the commercial viability of rare earth facilities in the UK: high upfront costs, technical challenges and competition with subsidised Chinese suppliers means that such facilities will only be viable if prices remain at record 2021 highs for the mine lifecycle. The second concern was that we lack the data to assess which initiatives and investments would most effectively improve supply chain resilience.[36] And the third was that UK government support pales in comparison to the substantive strategies and schemes in place in other countries (see the next section for more detail).

Less Common Metals, one of the UK's leading rare earths companies, recently published a UK government-funded feasibility study into building a UK rare earths magnet base. LCM concludes that developing a UK sovereign supply chain would require either an integrated mine-to-magnet company, or a profit-sharing agreement between participants.

This would require a policy shift in the UK's inaugural Critical Minerals Strategy, set to be published in 2022. The Net Zero strategy reiterates that the UK's approach to resilience is based on the principle that "openness [to free markets] confers resilience".

However, continuing to adopt a fully market-based approach would be a risky strategy. By and large, it is true that Western firms and governments have had few complaints to date about a largely reliable supply of high-quality, low-cost rare earth magnets from China. But this situation is precarious.

The first is the situation of dependency. Further geopolitical tension with China renders the midstream chokepoint a strategic vulnerability. And geopolitical tensions aside, the combination of increasing demand (with a large number of state-backed players) combined with an increased risk of accidental supply disruption are likely to create a more volatile market.

But the second is increasingly relevant: reliance on China raises significant environmental and ethical challenges. Net zero should mean net zero supply chains, not offshoring environmental costs elsewhere. Current critical minerals supply chains lack transparency.

Increasing state-backed competition

Industry experts believe there will be a degree of regionalisation in supply chains, shortening the distance between midstream and downstream production to reduce carbon footprints.

But if the UK wants to build a sovereign supply chain, it will face an increasingly competitive international environment - and one where almost all participants are benefitting from significant state backing. As discussed above, China has a whole-of-government strategy and its rare earth firms benefit from significant financial support. In response, other countries are pursuing state-backed strategies.

- In the US, the Pentagon has awarded tens of millions of dollars of grants to domestic rare earth magnet companies.[37] Congress is currently debating a Rare Earth Magnet Act which would offer subsidies equal to $20 per kilogram of rare earth magnets manufactured in the United States. The tax credit would increase to $30 per kilogram if all of the component rare earth material of these magnets is produced within the United States.[38] President Biden's review of the critical minerals supply chain is still under way.

- Japan's raw materials strategy, borne out of China's export ban in 2010, is overseen by the Japan Oil, Gas and Metals National Corporation (JOGMEC), a state-backed company governed by the Ministry of Economy, Trade and Industry. It has overseen its REE imports from China fall 91% to 58% in the ensuing period. For example, Jogmec and Japanese trading firm Sojitz invested $250 million in Lynas in 2011.

- The Australian Government established an Australian Critical Minerals Facilitation Office in 2019. Its initiatives include $300million on bringing industry, government and research organisations to increase the scope of rare earths exploration, and a $1.45bn loan facility to help finance critical mineral facilities.

- The European Raw Materials Alliance is driving the debate in the EU. An EU-wide Critical Minerals Strategy is under consideration, but the European Battery Alliance has set the goal of sourcing 80% of Europe's lithium demand from European sources by 2025.

Geopolitical threats

Much of the debate so far has focused on the risks of deliberate disruption. As geopolitical tensions have risen in the past two years, China's leadership has exhibited a propensity to threaten and implement policies of economic coercion. Deliberate supply disruption is improbable, but constitutes a significant strategic vulnerability.

Spotlight on: New dependencies

The UK is providing significant state backing to its electric vehicle supply chain. But, so far, this investment does not seem to be focused on decreasing dependence.

UK government subsidising Chinese battery company

Nissan's new battery factory in Sunderland is being built with around £85m of government support, in order to safeguard the future of the Sunderland plant. Envision AESC, which is Nissan's battery supplier, is expected to spend £450m building the factory. While this will support the UK's electric vehicles industry, it does mean that the UK government is subsidising a Chinese battery firm.

Alexander Dennis and BYD

In 2015, the UK's largest bus manufacturer, Alexander Dennis (ADL), signed a partnership agreement with BYD (Build Your Dreams), which is China's largest battery and car manufacturer. Under the agreement, Alexander Dennis and BYD have electrified more than 1,000 buses. The UK government is providing up to £120m to support the roll-out of zero-emission buses. Since 2015 over 70% of the electric buses on UK roads use BYD's battery technology.[1]

In 2010, a dispute between Japan and China over the Senkaku Islands saw China withhold supply of rare earths, jolting countries into taking steps to diversify supply chains. And in the midst of the then escalating trade war between the US and China in 2018, a visit to Chinese rare earth magnet producer JL Mag Rare-Earth by Chinese president Xi Jinping was covered extensively by Chinese state-run media in a clear warning to the international community that China holds the cards if relations were to deteriorate.[39]

This perspective should be balanced against Xi's desire to cultivate China's image as a global player, and the knowledge that such a move could backfire. When China reduced its export quotas by 37% in 2010, the increases in prices led to an influx in capital throughout global rare earth supply chains, financing more than 200 mining and processing projects outside of China.[40]

Fragile supply chains

This year has highlighted the fragility of global supply chains, often for reasons out of our control. In the next decade, increasing demand, the risks of geopolitics and the possibility of extreme weather events could all pose a risk to reliability of supply at a time when it is already tight due to rising demand.

For example, China relied on Myanmar for about half its heavy rare earth concentrates in 2020. But the effects of the political coup have seen the prices of dysprosium and terbium rise by 60% and 90% compared to last year.[41] Or extreme weather events can hamper production. In 2020, 'once-in-a-lifetime' floods shut down Shenghe's plants in Sichuan, destroying tens of millions of rare earth stocks.

The general point is that domestic disruption can have a disproportionate international effect in a highly concentrated market. China accounts for 85% of the world's magnesium supply, most of which is smelted in one city in Shaanxi - Yulin. In September this year, Yulin's local government ordered its magnesium smelters to cut production in order to meet central government energy consumption targets. By October, European carmarkers were warning of a major magnesium shortage that threatened millions of jobs.

Ethical and environmental risks

The environmental and ethical risks in rare earth mining, and mining in general, are well-documented. Rare earth ores tend to be mixed with radioactive materials, and processing and refinement often

requires chemicals such as ammonia and hydrochloric acid. It is estimated that processing one ton of rare earths generates 2000 tonnes of toxic byproducts.[42]

The Chinese government has sanctioned the construction of a number of factories within close proximity of rare earth mines in its north western provinces of Inner Mongolia, Xinjiang and Sichuan provinces to increase efficiency in refinement and lower production costs. These are often close to a cheap supply of coal. For example, electricity is 40% of the cost of operating costs when producing polysilicon, and Xinjiang has the cheapest electricity prices in China.[43]

This also raises important ethical questions. The *Helena Kennedy Centre* at Sheffield Hallam University in the UK has produced ground-breaking reports identifying polysilicon companies in the Uyghur region using coercive labour practices, including labour transfer.[44]

The UK and other countries have an opportunity to demand more ethically and environmentally transparent supply chains for critical minerals and rare earths.

4. Policy options

As things stand, the UK would be highly exposed to supply disruption. Ramping up domestic production is unfeasible on a short time scale. While the UK was able to develop domestic manufacturing capacity for 70% of our PPE requirements in one year, a similar reshoring would be impossible to replicate with rare earths. It takes around 7-10 years to set up one part of the critical minerals supply chain.

The UK's strategy so far has revolved around research, with UK Research and Innovation funds provided to centres such as the Birmingham Centre for Strategic Elements & Critical Minerals (BCSECM), the British Geological Survey's Critical Metals Alliance, and the Camborne Schools of Mines. These groups are a knowledge base and innovation hub which the UK can draw on in creating a national rare earths strategy.

Moving forward, the UK needs to debate the level of state support it is willing to provide in order to increase resilience. There is no single solution, but the debate around policy responses is likely to centre around a mix of the following options:

1. Recycling magnets could provide a viable alternative to mining. At present, the recycling rate for rare earth magnets, such as those produced by LCM, is extremely low at around 3%.[45] The EU has mandated a series of recycling targets, including to recycle 70% of lithium batteries by 2030.[46]
2. Creating a stable pricing environment to allow processing to develop in the UK. There is a growing domestic critical mineral mining sector, but without government support to harmonise the stages of production in the UK, it will be a tall ask to persuade investors to invest in the UK's relatively small domestic market.
3. The UK is a global hub for mining finance, consultancy and research. This knowledge base should enable the UK to become a key player in developing global ESG standards in the critical minerals market and improving the data on the environmental footprint of mining.
4. Countries such as the US and Japan have signed bilateral agreements on critical minerals, while the Quad and EU have formed working groups. Forging international partnerships in industry engagement, securing supply chains for strategic industries and defence, and information sharing on resources and new technologies.
5. Increasing the role of hydrogen in our energy mix, given it is substantially less mineral-intensive than lithium and batteries.
6. Exploring the potential of using development financing to build low-carbon mining and production capacity in developing regions.[47]

Conclusion

China has pursued a systematic state-led approach to its rare earths industry. Now, the rest of the world is catching up, and exploring ways to build sovereign supply chains to protect their industry. The knock-on effect is rising international competition, from upstream access to raw materials to the downstream cost of rare earth magnets.

The UK's lack of clear strategy has created a situation of high dependence. This strategy looks increasingly out of kilter with almost every major industrial economy, exposing us to a high level of risk of supply disruption. This is compounded by poor supply chain transparency.

A more resilient critical minerals strategy would build a stronger base for a net zero transition. Any strategy will have to be dual-pronged, encompassing both support for domestic production and stronger international partnerships.

The question of supply chain dependency is complex, time-consuming, and bereft of quick fixes. But in the case of critical minerals - where strategic dependence represents a genuine risk to national security – resilience should play a bigger part in the debate.

About the authors

This paper was authored by Julia Pamilih and Chris Cash, with additional research by Joe Tyler-Todd. It was based on a review of publicly available literature, including UK government and Chinese language sources, academic and third sector research, and journalistic material. This was supplemented by interviews with 17 leading UK-based critical minerals experts from the public, private sector and academia from November 2020 to March 2021.

Endnotes

[1]Russell Parman. 'An elemental issue'. *U.S. Army Aviation and Missile Command*. 26 September 2019. Retrieved from: https://www.army.mil/article/227715/an_elemental_issue

[2] World Bank. Mineral Production to Soar as Demand for Clean Energy Increases. 11 May 2020. Retrieved from: https://www.worldbank.org/en/news/press-release/2020/05/11/mineral-production-to-soar-as-demand-for-clean-energy-increases

[3] International Energy Agency. *World Energy Outlook 2021.* October 2021.

[4] Cabe Atwell. Rare earth metal supply chain is caught in global politics. *EET Asia.* 5 March 2021. Retrieved from: https://www.eetasia.com/rare-earth-metals-supply-chain-caught-global-politics/

[5] Reuters. China becomes world's biggest importer of rare earths – analysts. 14 March 2019. https://www.mining.com/web/china-becomes-worlds-biggest-importer-rare-earths-analysts/

[6]Interview with industry experts, January 2021.

[7] Jeffrey Wilson. A Quad Partnership to Secure Battery Value Chains. *National Security College, Australian National University.* October 2021.

[8] Andy Colthorpe. 'China continues to dominate lithium battery supply chains but policy support gives US new hope'. *Energy Storage News.* 8 October 2021. Retrieved from: https://www.energy-storage.news/china-continues-to-dominate-lithium-battery-supply-chains-but-policy-support-gives-us-new-hope/

[9] Sophia Kalantzakos. *China and the Geopolitics of Rare Earths.* Oxford University Press. November 2017.

[10] Pui-Kwan Tse, "China's Rare-Earth Industry: Open-File Report 2011-2042," *U.S. Geological Survey*. 2011.

[11] Chuin-Wei Yap, 'China Ends Rare-Earth Minerals Export Quotas', *The Wall Street Journal.* 2015.

[12]Anna Holzmann and Nis Grunberg. "Greening" China: An analysis of Beijing's sustainable development strategies. MERICS. January 2021.

[13] Yang Danhui, 'National Strategy for Resource Safety, Competition among Major Powers, and Development and Utilization of Rare Mineral Resources' (资源安全、大国竞争与稀有矿产资源开发利用的国家战略), *Study and Exploration*, 2018.

[14] 'China's rare earth policy in recent years and its impact - analysis', *Geological Review* (**中国近年稀土政策及其影响分析**, ***地质论评***), 2021. Retrieved from ;http://www.geojournals.cn/georev/ch/reader/view_abstract.aspx?file_no=dzlp2013z10025

[15] D Yang 'Research on China's rare earth industry development and policy' (**中国稀土**产业发展与政策研究), 2015

[16] *Ibid.*

[17] Yuzhou Shen, Ruthann Moomy, Roderick G. Eggert, 'China's public policy towards rare earths, 1975-2018', *Mineral Economics,* 2020

[18] *Ibid.*

[19] Mary Hui. China's rare earth hub is rolling out massive subsidies to fix the industry's Achilles hill. *Quartz*. July 2021. Retrieved from: https://qz.com/2031940/chinas-rare-earth-hub-baotou-introduces-massive-subsidies/

[20] Li Liuxi and Denise Jia. China Became Net Importer of Rare Earths in 2018. *Caixin.* March 2019. Retrieved from: https://www.caixinglobal.com/2019-03-16/china-became-net-importer-of-rare-earths-in-2018-101393333.html

[21] Jack Farchy and Hayley Warren, 'China has a Secret Weapon in the Race to Dominate Critical Minerals', *Bloomberg,* 2018

[22] *Ibid.*

[23] 'Insights into China's Recent Investments in Mineral Resources Globally', *Sai Industrial,* 2017

[24] Magnus Ericsson, 'Chinese control over African and global mining - past, present and future', *Mineral Economics,* 2020

[25] Saliou Samb. China to loan Guinea $20 billion to secure aluminum ore. *Reuters.* September 2017. Retrieved from:https://www.reuters.com/article/us-guinea-mining-china-idUSKCN1BH1YT

[26] 'Mega deal between Gécamines and Chinese state-owned company CNMC for one of DRC's flagship copper mines could be leaving the country short-changed', *Global Witness, 2019*

[27] 'What China's increasing control over cobalt resources in the DRC means for the West – report', *Mining Dot Com,* 2021

[28] Kenji Kawase. Chinese investors jostle over Argentina lithium mines. *Nikkei Asia.* October 2021. Retrieved from: https://asia.nikkei.com/Business/Materials/Chinese-investors-jostle-over-Argentine-lithium-mines

[29] S&P Global Market Intelligence*. China mining, battery companies sweep up lithium supplies in acquisition blitz.* November 2021. Retrieved from: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/china-mining-battery-companies-sweep-up-lithium-supplies-in-acquisition-blitz-67205411

[30] Mary Hui, 2021

[31] 'Shenghe Resources - about us' http://en.shengheholding.com/aboutMake

[32] Mary Hui, 2021

[33] Green Car Congress. 'RareX executes MoU with global rare earths producer Shenghe Resources'. February 2021. Retrieved from: https://www.greencarcongress.com/2021/02/20210213-rarex.html

[34] World Nuclear News. New Chinese JV for rare earth minerals from Greenland. January 2019. https://www.world-nuclear-news.org/Articles/New-Chinese-JV-for-rare-earth-minerals-from

[35] Emily de la Bruyere and Nathan Picarsic, 2020

[36] Interview with industry experts, 2021

[37] Reuters. *Pentagon awards $13m in rare earths funding to US projects.* November 2020. Retrieved from: https://www.reuters.com/article/usa-rareearths-idINKBN27Y2F0

[38] Greg Matlock. Proposed US Legislation Could Encourage Mining of Rare Earth Metals. *Mayer Brown.* September 2021. Retrieved from: https://www.mayerbrown.com/en/perspectives-events/publications/2021/09/proposed-us-legislation-could-encourage-mining-of-rare-earth-metals

[39] 'Lucy Hornby and Henry Sanderson. 'Xi highlights China's dominance of rare earths market', *Financial Times.* May 2019. Retrieved from: https://www.ft.com/content/48398c92-7b5d-11e9-81d2-f785092ab560

[40] *Visual Capitalist,* 2021

[41] Shunsuke Tabeta. China to create rare earths giant by joining three state companies. *Nikkei Asia.* October 2021. Retrieved from: https://asia.nikkei.com/Economy/China-to-create-rare-earths-giant-by-joining-three-state-companies

[42] Jonathan Kaiman. Rare earth mining in China: the bleak social and environmental costs. *The* Guardian. March 2014. Retrieved from: https://www.theguardian.com/sustainable-business/rare-earth-mining-china-social-environmental-costs

[43] Dan Murtagh. Why It's So Hard for the Solar Industry to Quit Xinjiang. Bloomberg. *February 2021*. Retrieved from: https://www.bloomberg.com/news/articles/2021-02-10/why-it-s-so-hard-for-the-solar-industry-to-quit-xinjiang

[44] Helena Kennedy Centre. *In Broad Daylight: Uyghur Forced Labour and Global Solar Supply Chains*. 2021.

[45] 'Recycled permanent magnets provide a source for rare earth elements', *European Commission,* 2019

[46] Ibid.

[47] CrEAM Commission. 'Securing Technology-Critical Minerals for Britain', *University of Birmingham*. March 2021.