RISKS TO SUPPLY-CHAIN RESILIENCE: CHINA'S POSITION IN THE ELECTRIC VEHICLE MARKET

BY SAM ASHWORTH-HAYES

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About the Author

Sam Ashworth-Hayes is a policy researcher and Associate Fellow at the Henry Jackson Society. He has previously worked as an economic consultant and journalist.

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1. Introduction

As the West moves to decarbonise transport, current policy goals and targets are set to drive a massive shift towards the use of electric vehicles over a very short timeframe. In Britain, Government policy states that all new cars sold after 2035 must be fully 'zero emission' at the tailpipe. This will require massive investment in domestic infrastructure, from charging points to electricity generation.

It will also require careful consideration of the potential geopolitical risks involved in the transition. At present, China occupies a central role in the electric vehicle supply chain. Beijing has previously used market dominance as a diplomatic tool to extract concessions from other nations, and there is a risk that it could do so again if the West becomes sufficiently dependent upon it during the transition to electric vehicles. In order to avoid such reliance, the West will need to make collective investments in the development of alternative battery supply chains, and may need to consider the speed of the eventual transition.

China's position in the electric vehicle market is frankly remarkable. Setting aside its position as the largest producer of electric vehicles, Beijing dominates multiple stages of the production process, including the refining of critical minerals, the production of cathodes and anodes, and the assembly of cells.

This dominance presents potential problems. China has previously demonstrated a willingness to use dominant market positions to extract concessions or make demands. As demand for its products surges over the next decade, driven by the global transition to electric vehicles, it will be in a position where it would be able to cause significant economic difficulties by disrupting the flow of materials, components, batteries and vehicles to countries it views as behaving in an antagonistic fashion. The British Government's new Critical Minerals Strategy recognises this potential disruption, highlighting the reliance on lithium, cobalt, graphite and rare earth elements for electric vehicle production, and China's role as a "dominant player". [1]

Similarly, the new Minerals Security Partnership – consisting of the United Kingdom, United States, European Union, Australia, Canada, Korea, Japan, and other wealthy aligned countries – has been established with the explicit intention of reinforcing "critical mineral supply chains essential for the clean energy transition". In addition to the core members, countries with large mineral resources also attended a meeting at the United Nations. [2]

In order to avoid being held to ransom in the longer term, Western countries have the option of working collaboratively to develop alternative sources of mineral supply and to develop refining capacity and the capability to build sufficient supplies of electric batteries such that reliance on China is minimised. In the short term, however, there are relatively few policy options available. The long lead times for mineral extraction projects and for building refining plants and battery factories, combined with the extremely tight timetables chosen by national leaders, mean that there is little scope for reducing reliance on Beijing's goodwill through the major 'pinch point'.

It is possible to reduce the strain on supplies and the extent of reliance on China by slowing the transition towards zero tailpipe emission vehicles. This could be worked to fit with net zero

[1] "Resilience for the Future: The UK's critical minerals strategy", Department for Business, Energy & Industrial Strategy, 22 July 2022, https://www.gov.uk/government/publications/uk-critical-mineral-strategy/resilience-for-the-future-the-uks-critical-minerals-strategy.

[2] "Minerals Security Partnership Convening Supports Robust Supply Chains for Clean Energy Technologies", U.S. Department of State, 22 September 2022, https://www.state.gov/minerals-security-partnership-convening-supports-robust-supply-chains-for-clean-energy-technologies/.

goals through the selection of appropriate biofuels – ensuring that transport is still carbon neutral (or negative) while also avoiding the temptation to put all the eggs in a single basket.

The remainder of this briefing proceeds as follows. The first section outlines current UK Government policy on road transportation and the progress so far towards the 'zero tailpipe emissions' standard. The second section briefly outlines the supply chain for British vehicles and the likely avenues through which Chinese components enter the country. The third section outlines the Chinese state's use of economic power as a tool for coercive diplomacy. The fourth analyses China's place in the global electric vehicle supply chain, from mineral extraction and refinement to battery, engine and vehicle manufacturing. The fifth section examines policy options for reducing reliance on Beijing, and the sixth looks at the UK's new Critical Minerals Strategy. Finally, a brief summary is presented in the conclusion.

2. The future of British road transport

The British Government intends to achieve a net zero economy by 2050. In the words of then-Prime Minister Boris Johnson: "In 2050, we will still be driving cars, flying planes and heating our homes, but our cars will be electric gliding silently around our cities"; the eventual aim is to "retire the internal combustion engine". [3]

To this end, the sale of new cars fully powered by petrol or diesel will be banned in Britain from 2030 onwards. The sale of hybrid vehicles will be permitted for a limited period, until 2035, after which, current policy states that all new cars will be required to be "fully zero emission at the tailpipe". [4]

This represents a truly massive shift in policy. In 2020, just 3.3% of cars on British roads would have qualified for sale under the hybrid policy, let alone the zero emissions standard. [5] By July 2022, 13.9% of new car registrations were for battery electric vehicles. Plug-in hybrids have accounted for another 6.3%, hybrid electric vehicles 11.5% and mild hybrid electric vehicles a combined 18.5%. Vehicles powered solely by diesel or petrol now account for under 50% of new car registrations. [6] If petrol prices remain high, then this could drive a lasting change in consumer behaviour. In case this doesn't happen, the Government intends to introduce mandates from 2024 onwards dictating what percentage of new cars and vans sold by manufacturers will be required to be zero emission. [7]

This policy will be supported by other measures, including the provision of charging facilities across the country; investment in power generation to ensure that increased demand for electricity is adequately met; and support for domestic research and manufacturing to ensure that the automotive industry keeps pace. These measures address risks to the successful implementation of the policy. They do not address the risks of unforeseen consequences.

Advocates of policies to ban the sale of petrol and diesel vehicles argue that a major benefit of transitioning away from fossil fuels – combined with a transition to greener forms of electricity generation – is reduced exposure to variability in fossil fuel prices. The current war in Ukraine has highlighted the dangers of European reliance on autocratic regimes for energy security, and in turn Britain's indirect exposure through global markets. This benefit, however, will be significantly reduced if a new point of geopolitical risk is introduced during the transition.

China currently dominates multiple critical components of the electric vehicle supply chain, from the refinement of critical minerals to the production of battery components, cells and completed batteries. Beijing also enjoys a substantial advantage in the production of the rare earth elements that are necessary to produce electric vehicle motors, and indeed electric vehicles themselves. This dominance has already caused the Biden administration to publish a review of the risks in the electric vehicle supply chain. [8]

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[3] "Net Zero Strategy: Build Back Greener", HM Government, October 2021, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf.

[4] "Government takes historic step towards net-zero with end of sale of new petrol and diesel cars by 2030", Department for Transport, 18 November 2020, https://www.gov.uk/government/news/government-takes-historic-step-towards-net-zero-with-end-of-sale-of-new-petrol-and-diesel-cars-by-2030.

[5] Lewis Pickett, James Winnett, Dominic Carver and Paul Bolton, "Electric vehicles and infrastructure", House of Commons Library, 20 December 2021, https://researchbriefings.files.parliament.uk/documents/CBP-7480/CBP-7480.pdf.

[6] "Car Registrations", SMMT, July 2022, https://www.smmt.co.uk/vehicle-data/car-registrations/.

[7] "Net Zero Strategy".

[8] "Building resilient supply chains, revitalizing American manufacturing, and fostering broad-based growth", The White House, June 2021, https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf.

3. The current supply chain for British vehicles

China's role in the British market for electric vehicles is generally not as a supplier of finished goods. In 2019 – the last pre-pandemic year for which data is available – Britain imported some 2.05 million cars and light commercial vehicles in total. Some 78.1% of these came from the EU, with the second largest trading partner (Japan) accounting for 7%. China provided just 0.8% of imported vehicles. [9]

This is not cause for complacency. China exported half a million electric vehicles in 2021 – 60% of the worldwide total – and accounted for 15% of the EU's battery electric vehicle market. Over 57% of all electric vehicles manufactured in 2021 were made in China. Europe and America, in comparison, accounted for 22% and 12%. [10]

It is now the view of some experts that China's head start in the production of electric vehicles could see Europe become a net importer of Chinese vehicles, flipping a long-held pattern. [11] This is due to three factors: electric vehicles are relatively simple to build (requiring less in the way of high-skilled labour); synergies with China's dominance of battery production; and aggressive trade measures and policies enacted by the Chinese state.

There is little that Western policymakers can do about relative factor endowments or Chinese domestic policy, although responses to trade measures would be possible. The second factor, however, could be overcome with sufficient domestic investment. In addition to being the largest producer of electric vehicles, China's BYD is also the world's second largest producer of batteries. The number one spot belongs to Contemporary Amperex Technology (CATL), which is also based in China. In total, some 76% of worldwide electric vehicle battery cell manufacturing capability is based in the country. [12] Moreover – as discussed later – China occupies a dominant position throughout the input side of the supply chain, from mineral processing through to components assembly and battery production.

This not only presents another vector through which Chinese dominance of the electric vehicle supply chain could pose security threats, but feeds into Beijing's strength in vehicle manufacturing, from advantages in 'just-in-time' production through to creating a rich environment for knowledge exchange. [13]

9 "UK Automotive Trade Report 2020", SMMT, https://www.smmt.co.uk/wp-content/uploads/sites/2/SMMT-Automotive-Trade-Report-2020.pdf, p.10.

10 Juan Felipe Munoz, "Electric Cars Made In China Are Among The Most Popular EVs in Europe", *InsideEVs*, 14 May 2022, https://insideevs.com/news/585693/electric-cars-cmade-china-sell-europe/; "China's Electric Car Exports More Than Double, Mostly to Europe", *Bloomberg UK*, 21 June 2022, https://www.bloomberg.com/news/articles/2022-06-21/china-s-electric-car-exports-more-than-double-mostly-to-europe; Takashi Kawakami, Yohei Muramatsu and Saki Shirai, "China led world with 500,000 electric car exports in 2021", *Nikkei Asia*, 8 March 2022, https://asia.nikkei.com/Spotlight/Electric-cars-in-China/China-led-world-with-500-000-electric-car-exports-in-2021.

11 Gregor Sebastian and François Chimits, "'Made in China' electric vehicles could turn Sino-EU trade on its head", Mercator Institute for China Studies, 30 May 2022, https://merics.org/en/short-analysis/made-china-electric-vehicles-could-turn-sino-eu-trade-its-head.

12 "National Blueprint for Lithium Batteries", Federal Consortium For Advanced Batteries, June 2021, https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf.

13 "UK electric vehicle and battery production potential to 2040", The Faraday Institution, June 2022, https://www.faraday.ac.uk/wp-content/uploads/2022/06/2040-Gigafactory-Report_2022_Final_spreads.pdf.

4. Beijing's use of economic power in coercive diplomacy

China's approach to geopolitics involves heavy use of economic power as a tool to sway governments towards Beijing's position. This can come in the form of investment – as with the Belt and Road Initiative – or coercion. As the UK Government's Critical Minerals Strategy document notes, "foreign actors may use control of resources as leverage on other issues". [14]

A very clear-cut example occurred in September 2010, when a Chinese fishing boat operating near the Senkaku Islands collided with two Japanese Coast Guard vessels over a 40-minute period, leading to the detention of the boat's captain. [15] The arrest led to protests outside the Japanese embassy in Beijing, and a spokeswoman for the Chinese foreign ministry issued a "demand" that "Japanese patrol boats refrain from so-called law enforcement activities in waters off the Diaoyu islands". [16]

Two weeks later, Chinese customs officials began to block shipments of rare earth elements to Japan. [17] No official embargo was issued, although the blockage followed a non-specified threat of action from the Chinese Prime Minister should the captain fail to be released. China's position in the rare earths market gave it enormous leverage in 2010. It retains this position today, producing over 55% of the world's rare earths output in 2020, and controlling 85% of refining capacity. [18] It has also achieved dominant positioning throughout the electric vehicle supply chain.

The consequences of Russia's invasion of Ukraine should serve to focus attention on the fundamental strategic contradiction of deep economic reliance alongside highly adversarial relationships. Germany is currently in the position of drawing up plans for surviving a winter without Russian gas, where measures proposed range from the minor (shutting down swimming pools and turning off streetlights) to the extreme (industrial dormitories for citizens). [19] This reliance was a clear and obvious weakness ahead of time; repeated warnings following military action in 2014 went unheeded and indeed German policy over the ensuing period if anything served to heighten existing dependencies.

This experience should be learned from. China has repeatedly shown its willingness to deploy restrictions on trade to pressure countries to fall into line. The 2016 deployment of a US anti-missile system in South Korea resulted in a yearlong reduction in Chinese tourism and damage to South Korean firms operating in China, knocking a substantial sum off the Korean economy in punishment. [20] In 2019, meanwhile, Chinese officials responded to escalating trade tensions with Washington – and in particular President Trump's blacklisting of Huawei – by suggesting that the state could use rare earths as "China's counter-weapon against the US's unwarranted suppression". This statement did not result in hard action but did at least signal awareness that such measures could be in the toolkit for dispute resolution in the future. [21]

14 "Resilience for the Future".

15 Mure Dickie and Kathrin Hille, "Japan's arrest of captain angers Beijing", *Financial Times*, 8 September 2010, https://www.ft.com/content/a09e651a-bb04-11df-9e1d-00144feab49a.

16 Ibid.

17 Keith Bradsher, "Amid Tension, China Blocks Vital Exports to Japan", *The New York Times*, 22 September 2010, https://www.nytimes.com/2010/09/23/business/global/23rare.html.

18 Carl A. Williams, "China continues dominance of rare earths markets to 2030, says Roskill", *Mining[dot]Com*, 26 February 2021, https://www.mining.com/china-continues-dominance-of-rare-earths-markets-to-2030-says-roskill/.

19 Kate Connolly, "Germany braces for 'nightmare' of Russia turning off gas for good", *The Guardian*, 10 July 2022, https://www.theguardian.com/world/2022/jul/10/germany-russia-gas-flow-permanent-halt-nord-stream-1-maintenance.

20 Christine Kim and Ben Blanchard, "China, South Korea agree to mend ties after THAAD standoff", *Reuters*, 31 October 2017, https://www.reuters.com/article/us-northkorea-missiles-idUSKBN1D003G.

21 Lucy Hornby and Archie Zhang, "China's state planner suggests using rare earths in US trade war", *Financial Times*, 29 May 2019, https://www.ft.com/content/a0125e6a-8168-11e9-b592-5fe435b57a3b.

In October 2020, China's official Xinhua News Agency reported that the Chinese legislature had passed a law enabling the state to "take countermeasures against any country or region that abuses export-control measures and poses a threat to China's national security and interests". This was seen as a direct continuation of the 'rare earths' threats relating to the US action against Huawei. [22]

Geopolitical tensions may also lead to difficulties doing business. The Chinese battery manufacturer CATL has recently paused the announcement of a major investment in a North American plant following the visit of House Speaker Nancy Pelosi to Taiwan, with Bloomberg reporting that any announcement could be seen to "stoke tensions". [23]

Any disruption caused by China restricting the flow of materials, components or indeed completed electric vehicles would be costly to domestic industries that make large contributions to the British economy; if continued over a long period, it would also prove disruptive to the transport sector generally by reducing the ability to replace those elements lost naturally to depreciation over time.

A more pressing threat is the risk that China simply prioritises domestic consumption and its own energy transition, potentially leaving the West high and dry, with investments made under the assumption of bountiful electric vehicle availability stranded and insufficient provision for alternative fuel sources available.

This has already proved a problem for US producers of electric vehicle battery cells, who have stated that Chinese suppliers have provided "previous generation" material, reserving "their most recent, and best, material for their larger volume Chinese cell making clients". [24]

22 Iori Kawate, "China passes export control law with potential for rare-earths ban", *Nikkei Asia*, 19 October 2020, https://asia.nikkei.com/Politics/International-relations/US-China-tensions/China-passes-export-control-law-with-potential-for-rare-earths-ban.

23 Eric Martin, Edward Ludlow and Gabrielle Coppola, "Pelosi's Taiwan Trip Spurs Chinese Battery Giant to Pause Plant Debut", *Bloomberg UK*, 2 August 2022, https://www.bloomberg.com/news/articles/2022-08-02/pelosi-trip-spurs-china-battery-giant-to-pause-plant-unveiling.

24 "Building resilient supply chains".

5. China's place in the electric vehicle supply chain

The extent of China's position throughout the electric vehicle supply chain is cause for concern, and in particular its dominance of battery production. The majority of batteries used in battery electric vehicles for the foreseeable future are likely to be lithium-ion designs, barring breakthroughs with next generation technologies such as solid-state batteries.

Lithium-ion batteries used in electric vehicles come in a range of designs designated by the materials used in their cathode. Nickel-Cobalt-Manganese batteries account for the largest share of global output, followed by Lithium-Iron-Phosphate and Nickel-Cobalt-Aluminium. [25] The anode for these batteries typically consists of a graphite derivative, and is separated from the cathode by an electrolyte solution. [26]

The lithium-ion supply chain can be broken down into five stages: the extraction of raw materials, their subsequent processing, the manufacturing of battery cell components, the assembly of battery cells, and the assembly of the completed battery pack. [27] China has managed to achieve a dominant position at several of these stages.

The degree to which these trends can be reversed or overcome varies at different stages of the manufacturing process, and policy suggestions for limiting reliance on Beijing vary accordingly.

5.1. Raw material extraction and processing

One of the most fundamental limits on electrification is the abundance and location of mineral deposits. It is not possible to 'onshore' extraction of a mineral when it isn't present in a country in viable concentrations. Where these resources are available, it may not be possible to extract them.

To take one example, China's dominance of rare earths production is not based on geography alone. Rare earths (other than promethium) are "abundant in the earth's crust", but "mostly found in dilute concentrations". [28] This factor makes their extraction economically and ecologically costly, factors that have played into China's low-cost, low-environmental regulation approach to doing business. Indeed, one US administration paper accused Beijing of having "strategically flooded the global market with rare earths at subsidized prices, driven out competitors, and deterred new market entrants", enabling it to better "flex its soft power muscles by embargoing rare earths". [29] The United States – which used to have its own indigenous rare earths industry – is now attempting to rebuild this capability from scratch.

The UK does not possess known rare earths deposits which could be extracted in an economically viable fashion. [30] If it is to avoid dependence on Beijing, it will have to hope for an increase in production in allied countries such as the United States or Australia.

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[25] Benjamin Ballinger, Martin Stringer, Diego R. Schmeda-Lopez, Benjamin Kefford, Brett Parkinson, Chris Greig and Simon Smart, "The vulnerability of electric vehicle deployment to critical mineral supply", *Applied Energy* 255 (2019).

[26] Elsa A. Olivetti, Gerbrand Ceder, Gabrielle G. Gaustad and Xinkai Fu, "Lithium-Ion Battery Supply Chain Considerations: Analysis of Potential Bottlenecks in Critical Metals", *Joule* 1, no. 2 (2017).

[27] Bruno Jetin, "Who will control the electric vehicle market", 27th International GERPISA Conference, June 2019, https://halshs.archives-ouvertes.fr/halshs-03193666/document.

[28] Indra Overland, "The geopolitics of renewable energy: Debunking four emerging myths", *Energy Research & Social Science* 49 (March 2019), https://www.sciencedirect.com/science/article/pii/S2214629618308636?via%3Dihub.

[29] "Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States, Report to President Donald J. Trump by the Interagency Task Force in Fulfillment of Executive Order 13806", September 2018, https://media.defense.gov/2018/Oct/05/2002048904/-1/-1/1/ASSESSING-AND-STRENGTHENING-THE-MANUFACTURING-AND-DEFENSE-INDUSTRIAL-BASE-AND-SUPPLY-CHAIN-RESILIENCY.PDF.

[30] "The potential for rare earth elements in the UK", British Geological Survey, May 2020, https://www2.bgs.ac.uk/mineralsuk/download/cmp/REE.pdf.

In this, the rare earths example is illustrative of the general state of play. China is not particularly geographically fortunate, but has invested heavily in extraction and processing, giving it a considerable lead over other countries. The question generally is whether the West, collectively, has the will and capability to develop new sources of supply at a pace sufficient to meet rising demand.

And demand is rising. The decarbonisation of global road transport through electricity is set to send demand for critical mineral inputs surging. Some 100 million plug-in electric vehicles are set to be brought into service by 2030, with an associated surge in input use.[31] Many of the materials used in these batteries are abundant relative to predicted demand – production in 2017 of inputs such as fluorine, aluminium, manganese and phosphorus was at least ten times greater than the anticipated demand in 2030.[32] Other minerals used in battery production are in scarcer supply – in particular, graphite, lithium, cobalt and high-quality nickel.

Graphite in particular presents a clear strategic risk. China accounted for some 68% of world graphite production in 2019, with Brazil a distant runner up at 10% of output.[33] By 2021, China's market share had reached 82%.[34] While only 2% of 2016 output was dedicated to the production of batteries, it has been suggested that the availability of graphite at a sufficient purity for battery manufacture may be relatively constrained.[35] Beyond the provision of the raw material, some 95% of the processing of graphite for batteries is undertaken by Chinese firms.[36]

Lithium mining is also highly concentrated, with a clear majority of world production taking place in Australia and Chile.[37] These countries are unlikely to pose significant geopolitical risks, and Australia is a member of the 'Five Eyes' group of anglosphere countries, enjoying deep political and security links with the US and UK. Unfortunately, Australia's role in lithium production ends at extraction: it exports the lion's share of its ore to China, which refines it into the form suitable for use in lithium-ion batteries.[38] In 2019, China accounted for approximately 60% of all lithium processing worldwide.[39] As with graphite, this represents a recurring theme: where China does not directly own materials on its own territory, it has tended to invest in global extraction. Australia's lithium industry has benefited from Beijing's largesse, as have mines across Argentina and Chile, and one Chinese firm alone – Tianqi Lithium – is believed to control "almost half of the world's lithium production".[40]

The supply of cobalt is more tightly constrained. Almost 70% of global output in 2017 came from the Democratic Republic of the Congo.[41] While China has limited reserves of its own, it

31 Ballinger, et al., "The vulnerability of electric vehicle deployment to critical mineral supply".

32 Ibid.

33 "Building resilient supply chains", p.121.

34 "Global Graphite Market: China's Share Reaches 82% - IndexBox", *IndexBox*, 1 March 2022, https://www.globenewswire.com/news-release/2022/03/01/2394028/0/en/Global-Graphite-Market-China-s-Share-Reaches-82-IndexBox.html.

35 Ahmad Mayyas, Darlene Steward and Margaret Mann, "The case for recycling: Overview and challenges in the material supply chain for automotive li-ion batteries", *Sustainable Materials and Technologies* 19 (2019); Ashutosh Pandey, "Chinese graphite dominance threatens electric car ambitions", DW, 14 March 2022, https://www.dw.com/en/chinese-graphite-dominance-threatens-electric-car-ambitions/a-60888876.

36 Ballinger, et al., "The vulnerability of electric vehicle deployment to critical mineral supply".

37 Marcelo Azevedo, Nicolò Campagnol, Toralf Hagenbruch, Ken Hoffman, Ajay Lala and Oliver Ramsbottom, "Lithium and cobalt – a tale of two commodities", McKinsey & Company, June 2018, https://www.mckinsey.com/~/media/mckinsey/industries/metals%20and%20mining/our%20insights/lithium%20and%20cobalt%20a%20tale%20of%20two%20commodities/lithium-and-cobalt-a-tale-of-two-commodities.pdf.

38 Tsisilile Igogo, Debra Sandor, Ahmad Mayyas and Jill Engel-Cox, "Supply chain of raw materials used in the manufacturing of light-duty vehicle lithium-ion batteries", Clean Energy Manufacturing Analysis Center, August 2019, https://www.nrel.gov/docs/fy19osti/73374.pdf.

39 "Building resilient supply chains".

40 Amit Katwala, "The World Can't Wean Itself Off Chinese Lithium", *Wired*, 30 June 2022, https://www.wired.co.uk/article/china-lithium-mining-production.

41 Azevedo, et al., "Lithium and Cobalt".

has invested significantly in the Congo, with the result that some 14% of the world's cobalt mine production is estimated to fall under Chinese control or ownership. [42] High levels of investment in domestic refining capacity have given Beijing a dominant position downstream of raw materials output, with 50% of global refinery capacity under Chinese control. [43] By 2030, the equivalent of 81% of 2017's cobalt production could be required to meet electric vehicle production targets. [44]

The example of cobalt illustrates that there are risks extant in the supply chain beyond geopolitical tensions. The Democratic Republic of Congo is not a highly stable country, and its mining industry is not marked by an excessive respect for human rights. It is not impossible to imagine a scenario whereby conflict within the country contributes further to spiralling prices. As a McKinsey report has noted, supply disruptions have not been unknown historically, and we are currently in a period during which changing mining laws and ownership disputes are combining to create greater uncertainty over future supply. [45]

Equally, some 90% of cobalt production occurs as a by-product of mining for nickel or copper. [46] As it is not the primary purpose for extraction, its production is less price sensitive than would otherwise be the case. This means that for a given level of demand, significant price rises could be required in order to incentivise production increases.

Even relatively abundant resources can run into issues. Global reserves of nickel are large, but only very high purity material can be used in battery cell cathodes. Some 1 million tonnes of Class 1 nickel were mined in 2019. In order to fully replace US annual vehicle sales with their electric equivalents, a little under 1.3 million tonnes would be required. [47] Given demand outside of the US, this represents a substantial mismatch in supply and demand, and there are "market indications that there could be a large shortage of Class 1 nickel in the next 3-7 years". [48] Approximately a quarter of global nickel reserves are found in Indonesia. Again, signalling a degree of planning not quite as present in Western countries, China has already invested heavily in Indonesian production and processing. One report suggests that Chinese firms will attempt to "wield influence over global mineral flows… threatening the growth of the home-grown battery/EV sector" in the West. [49]

5.2. Engine designs

Permanent magnet motors account for 86% of electric vehicle sales and are heavily reliant on the use of the rare earth elements dysprosium, terbium, praseodymium and neodymium, all of which are in scarce supply relative to predicted demand. [50] Alternative designs which do not use these elements – induction motors – are relatively lacking in efficiency.

Unfortunately, China's dominance of the rare earth market is such that "permanent magnets cannot be produced without passing through China". [51] One 2010 estimate from the US

[42] Andrew L. Gulley, Erin A. McCullough and Kim B. Shedd, "China's domestic and foreign influence in the global cobalt supply chain", *Resources Policy* 62 (2019).

[43] Ibid.

[44] Ballinger, et al., "The vulnerability of electric vehicle deployment to critical mineral supply".

[45] Azevedo, et al., "Lithium and Cobalt".

[46] Ibid.

[47] "Building resilient supply chains".

[48] Ibid.

[49] Michelle Michot Foss and Jacob Koelsch, "Need Nickel? How electrifying transport and Chinese investment are playing out in the Indonesian archipelago", Center for Energy Studies, April 2022, https://www.bakerinstitute.org/research/need-nickel-how-electrifying-transport-and-chinese-investment-are-playing-out-indonesian-archipelago.

[50] "The vulnerability of electric vehicle deployment".

[51] Ibid.

Government Accountability Office suggested that rebuilding the US rare earth supply chain would take "up to 15 years". [52] As noted above, efforts are only now commencing, and not necessarily with the sort of intensity that would ensure a degree of success. For the foreseeable future, China's dominance of the production of permanent magnets will remain an issue.

5.3. Battery manufacturing

While China's share of global mining activity related to the production of materials used in batteries is relatively low (23%), it is substantially higher for certain critical elements, particularly when Chinese ownership of overseas resources is accounted for. Some 80% of worldwide chemical refinement for these resources took place in China in 2019, as did 65% of anode manufacturing, 42% of cathode manufacturing, and 65% of the production of the electrolyte solution. [53] In that year, 73% of lithium-ion battery cell manufacturing capacity was based in China. The trend with updates to these figures is not cause for optimism. More recent sources have estimated that 80% of all battery cell manufacturing capacity is currently located in China or suggested that China's share of the anode market will exceed 80% by 2023. [54]

The UK lags significantly in the manufacturing of batteries, both relative to competing nations and to its own projected demand. The Faraday Institution has stated that demand for electric vehicle battery manufacturing in the UK will reach 100 GWh per annum by 2030 and 200 GWh by 2040 as a result of the switch over to zero emission vehicles. [55] It estimates that this will require five and ten large battery factories respectively, and notes also that these facilities take time to reach full production: "Gigafactories take at least five years to reach operational capacity". With just two large British factories currently in the pipeline, investments will need to be made in the next two years in order to have a reasonable chance of meeting demand through domestic production.

And Britain probably will want to do that. The synergies between battery production – some 40% of the value of an electric vehicle – and the manufacturing of the vehicle itself tend to favour colocation. This is particularly true considering the rules of origin for trade between Britain and the EU, which may well make the use of non-British or European batteries in cars destined for export to the bloc uneconomic. The current proportion of a vehicle which can originate outside of Europe is 60%; by 2027, this will have fallen to 45%. [56]

As illustrated above, however, simply having the capacity to assemble batteries is not sufficient to mitigate supply chain risk. China still has a dominant position in the assembly of battery components and cells, and moving dependency back a stage does not alleviate the risk. Ultimately, until China's grip on the refinement of raw materials is broken, there will be strategic risks to the UK's battery supply chain.

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52 "Rare Earth Materials in the Defense Supply Chain", United States Government Accountability Office, 14 April 2010, https://www.gao.gov/assets/gao-10-617r.pdf.

53 "Building resilient supply chains".

54 "U.S. Narrows Gap With China In Race To Dominate Battery Value Chain", *BloombergNEF*, 7 October 2021, https://about.bnef.com/blog/u-s-narrows-gap-with-china-in-race-to-dominate-battery-value-chain/; "Global Market of Major Four Li-ion Battery Components: Key Research Findings 2021", Yano Research Institute, 14 June 2021, https://www.yanoresearch.com/en/press-release/show/press_id/2728.

55 "UK electric vehicle and battery production potential to 2040".

56 Graham Lanktree, "Can Britain really be an electric vehicle powerhouse?", *Politico*, 30 June 2022, https://www.politico.eu/article/britain-become-electric-vehicle-export-powerhouse-nissan-tesla/.

6. Reducing reliance on China

China has attained a dominant position in the manufacturing of electric vehicle batteries, from the refinement of materials through to the development of components and ultimately completed batteries.

This dominance is reason for both caution and optimism. Caution is needed because, in the medium term, there is a real risk that the West will find itself once again too reliant on the goodwill of undemocratic states for the functioning of critical parts of the economy. At the same time, the only fixed factor – the geographical distribution of mineral inputs – is no more in China's favour than the West's. Through careful strategic investment and partnership building, it should be possible to weaken China's stranglehold on the refinement of raw materials, and with that the production of battery cell components.

The primary difficulty in securing the electric vehicle supply chain is the speed of the proposed transition. Today, 2030 is a little under eight years away. The process of identifying a site, developing it, beginning operations, and scaling up to full production introduces significant lags in the matching of mineral supply to mineral demand, with response times measured in years rather than months. Given the tightness with which global demand is expected to push against global supply, bringing new sources online in time is likely to prove extremely challenging.

This does not mean it is not worth trying. Certainly, over the medium to long term, as non-internal combustion engine powertrain technologies continue to mature, we should look to diversify critical supplies away from China. Investing in the economic and political development and stability of the Democratic Republic of Congo could be one step towards stabilising supplies of cobalt, for instance. More broadly, Western countries should look to mimic China's strategy of building direct commercial ties with countries with reserves of critical minerals, investing in mining capacity and political ties. This approach would allow greater certainty of supply of raw inputs.

The new Minerals Security Partnership is a good step in this direction, with wealthy democracies planning to work with minerals-rich nations including the Democratic Republic of Congo, Tanzania, Argentina, and Brazil in developing critical minerals projects which will secure supplies. [57]

Alongside this measure, developing the capability to refine minerals outside the borders of China will also be critical. This is likely to be a pan-Western effort, with both the EU and US showing concern over the supply chain for electric vehicles. To reverse an earlier statement, as the case of Australia currently demonstrates, it's no good holding the critical mineral inputs if you can't actually process them: the chokepoint is shifted downstream, but still exists. Europe's first lithium refinery – announced in February this year – is currently scheduled to begin operations in 2024. [58] While this sort of lead time may make it possible to reduce reliance on China by 2030, total elimination is unlikely.

Australia is home to almost 20% of the world's cobalt reserves and "an abundance of key commodities… such as lithium, nickel… graphite, manganese, and alumina". [59] Investing in Australia's capacity to extract minerals, and to process them, would seem to be a win-win

[57] "Minerals Security Partnership Convening Supports Robust Supply Chains for Clean Energy Technologies".

[58] Cecilia Jamasmie, "Rock Tech, Bilfinger to build Europe's first lithium refinery", *Mining[Dot]Com*, 2 February 2022, https://www.mining.com/rock-tech-bilfinger-to-build-europes-first-lithium-refinery/.

[59] "Building resilient supply chains".

proposition for both Britain and Australia. The close economic, cultural and political ties between the nations provide a stable and profitable environment for this sort of private and public investment, as does its status as a member of the 'Five Eyes' and AUKUS security pacts. Attitudes in Canberra have recently hardened against Beijing, particularly following the imposition of sanctions on Australian exports in response to the Morrison Government's call for an investigation into the origins of COVID-19. However, there is still a substantial pro-China contingent in Australian politics, and the potential for future leaders to seek closer relations should be taken into account.

The degree to which global production of key minerals is concentrated in a handful of countries does present a degree of risk even when those countries are relatively stable. For this reason, if no other, developing better capabilities for the recycling of lithium-ion batteries would seem a sensible step in alleviating medium to long term potential for supply constraints to bind. The recycling of lithium-ion batteries is not yet believed to be economically viable. [60] Rising input prices may address this in part. It is worth noting that the Faraday Institution believes that investment in British recycling capabilities would not just reduce supply chain strain but would also help to attract investment in battery production. [61]

Investment in alternative battery designs is a sensible step in reducing reliance on scarce minerals, or those where supplies are concentrated in unstable countries with unethical extraction processes. A White House assessment notes the "potential for the use of novel higher capacity" designs using "abundant and inexpensive elements such as sulfur, iron, manganese, or even air-based cathodes", but notes also that they are "far from commercial realization". [62] In the near future, in other words, we are likely stuck with what we already have. Current designs making use of alternative elements have been rejected for a reason – alternatives tend to be heavier, reducing range and performance. While reducing the quantity of minerals required is possible, battery improvements seem unlikely to solve all issues by 2030.

In a similar vein, switching to the use of induction motors to avoid the reliance on the rare earth materials required for permanent magnet designs would require massive alterations in business plans from automotive manufacturers. Not only would the designs of engines, vehicles and batteries have to be altered, but substantial changes would need to be made to existing manufacturing facilities in order to accommodate these alterations. Without addressing the fundamental issue of battery reliance on China, the net effect would be to introduce a new source of uncertainty, cost and inefficiency into the transition without actually improving supply chain security.

It is worth emphasising that the fundamental issue with the increased uptake of electric vehicles appears to be navigating the initial period of higher demand. Supply of various minerals is expected to be tight even without any active malignity on the part of Beijing. Lithium, for instance, while relatively abundant in terms of current reserves, will require a scale-up in extraction and processing to meet demand. This will lead to short-term variation in prices, but in the longer term, as Haresh Kamath of the Electric Power Research Institute puts it, "As more processing capacity is built, these shortages are likely to work themselves out". [63]

A major point is that making investments which rely on a smooth transition could prove problematic, given a plausible expectation of short-term disruption even under assumptions

60 Mayyas, Steward and Mann, "The case for recycling".

61 "UK electric vehicle and battery production potential to 2040".

62 "Building resilient supply chains".

63 Davide Castelvecchi, "Electric cars and batteries: how will the world produce enough?", *Nature*, 17 August 2021, https://www.nature.com/articles/d41586-021-02222-1.

of benign behaviour. Investments into making electric vehicles viable are necessary for the transition to succeed – without a network of charging points, sufficient generating capacity on the national grid and so on, there is little point in making the transition.

However, these investments can be made as part of a technology neutral approach to decarbonisation. Permitting the use of zero net emission fuels such as biofuels – in contrast to zero tailpipe emissions – alongside electric- and hydrogen-fuelled vehicles would provide the system with a degree of 'slack' and allow for disruption in the UK's attempts to expand the power supply sufficiently, in trade with China or in global commodity prices. The primary risk to net zero from the use of biofuels would be the potential displacement of food production, resulting in land being converted to agricultural use with an associated rise in emissions. [64]

Ensuring net zero status would require not only an analysis of the original land site, but also the knock-on effects through the price mechanism, both within the affected country and connected markets. On the upside, biofuels have the benefit of using crops and waste materials which can be sourced from a wide range of countries, limiting exposure to single source of origin risks. One barrier would be scale; significant production of biofuels for transport energy could compete with calorie production for food. [65] The use of second-generation waste biofuels would alleviate this concern. As an option for alleviating some pressure rather than a complete replacement for fossil fuels, however, they could play a useful role.

Again, so long as production was carbon neutral, this use of biofuels could be achieved without risking the UK's climate change targets. Their use would also allow for the transition to take place at a steadier pace, with the UK benefitting from investment in mineral supply during this period.

More importantly, by avoiding total lock-in to a path of action, Britain would be better able to respond to any hostile signals from China, retaining a degree of strategic independence not available under the scenario where a full commitment to electric vehicles is made. This path would also fit relatively well with current policy – while the transition takes place, the Government is increasing the use of low carbon fuels through the Renewable Transport Fuels Obligation and by boosting the ethanol content of standard petrol. [66]

With that said, this policy would clearly not be without costs. If there is a significant 'first mover advantage' in the switch to electric vehicles in the West, then developing industrial capacity geared towards the production of batteries and vehicles early on is likely to pay dividends. There is some suggestion that this is indeed the case; the Faraday Institution has argued that without battery manufacturing capabilities the British automotive manufacturing is likely to become uncompetitive relative to its European peers. [67] However, in hard-to-abate sectors – maritime and aviation fuels and heavy road transport – alternative fuel sources are likely to be used. An excessive emphasis on one technology for decarbonising road transport could make the retention of strategic domestic capabilities for supporting these uses uneconomic.

This loss of industrial capacity could be viewed as a trade-off – the very likely price of slowing and smoothing the transition to electric vehicles, paid in order to avoid a situation where Beijing attempts to use its position in the supply chain to press its interests in a dispute over Taiwan, trade rules or other issues of consequence.

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64 "Greenhouse gas emission intensity of fuels and biofuels for road transport in Europe", European Environment Agency, 18 November 2021, https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of.

65 Tim Searchinger and Ralph Heimlich, "Avoiding bioenergy competition for food crops and land", World Resources Institute, January 2015, https://files.wri.org/d8/s3fs-public/avoiding_bioenergy_competition_food_crops_land.pdf.

66 "Decarbonising Transport: A Better, Greener Britain", Department for Transport, July 2021, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009448/decarbonising-transport-a-better-greener-britain.pdf.

67 "UK electric vehicle and battery production potential to 2040".

7. The new Critical Minerals Strategy

To its credit, the British Government has considered some of these risks and options in its Critical Minerals Strategy. [68] Increasing the recovery and recycling rates of minerals will not be sufficient to fully remove China's grip but will loosen it. However, recycling technologies are still at a relatively early stage of development and, by definition, a transition to electric vehicles will require a massive increase in the quantity of minerals in circulation. Improving domestic production capabilities will assist where Britain has supplies of key minerals; where it does not, no amount of domestic investment will manifest new sources of supply.

More interesting is the approach set out to securing international supply. As the Strategy notes, the UK has tended to rely on "market forces to deliver a secure supply of minerals". This approach does not work so well where supply is dominated by a single actor who may have strategic interests at odds with the UK's own. Some of the Strategy's recommended approaches (such as "support efforts to diversify international critical mineral supply chains" and "support UK companies to participate in building responsible, diversified supply chains overseas") chime with the recommendations of this report. Others (including "Boost global environmental, social and governance performance" or "Champion London as the world's capital of responsible finance for critical minerals") are more marginal in terms of security of supply, laudable as they may be from a social perspective.

Disappointingly for a lengthy document, specific recommendations on country-by-country engagement or technical approaches are notable largely by their absence. It's one thing to highlight the benefits of these approaches in a short briefing note setting out an issue and directions for its solution; it's another to repeat very high-level ideas in an official strategy document. A considerable degree of work will be needed to operationalise these concepts.

Similarly, while the strategy recognises "rapid demand growth and long lead times" as a risk for global supply failing to match demand, resulting in soaring prices and challenges to transition, no comparison is drawn between forecast supply and demand, or the speed with which efforts could expand the former or reduce the latter. This is a potential cause for concern; if the assumption is made that transition can happen smoothly without sufficient investigation into actual supply chain capacity, the UK could lock itself into a path with insufficient resources to actually back its strategy.

[68] "Resilience for the Future".

8. Conclusion

China occupies a central position in the electric vehicle supply chain, one that will not be easily circumvented in the near future. By capturing huge market shares at each stage – including the refinement of minerals, the manufacturing of battery and engine components, the assembly of cells and even the manufacturing of vehicles – Beijing has ensured that it will maintain its grip on the market. And the extent of its ongoing investment in electric vehicles and the upstream manufacturing processes associated with them leaves us little doubt that China has no intention of losing this grip without a fight.

This is deeply unfortunate given the very rapid rises in demand likely to take place over the coming decade. Beijing's history of threats – and sometimes actions – indicates a willingness to make use of this position when seeking to advance what it perceives to be core national interests, whether angling for the reinstatement of Huawei's ability to function fully in the US, the lifting of other trade measures or more aggressive goals in the South China Sea.

Over the medium to long term, the West should invest in refining capacity and the infrastructure needed for component manufacture, and should attempt to secure supply from third countries, developing extraction where necessary. However, these measures are unlikely to be of much use in reducing reliance on China over the next decade. In the short term, there is relatively little which can be done within the electric vehicle supply chain to elide Beijing.

This suggests two options. The first is simply to accept Chinese dominance of the electric vehicle supply chain as a necessary evil in the push to meet net zero goals. The case could be made that any conflict with China which crossed the boundary necessary for a large-scale denial of supply would lead to major reductions in trade in any case, which in turn would indicate that the marginal damage of transport reliance could be relatively low over a short horizon. That does not mean the case can be convincing to all.

The second major option would be to invest significantly in attempting to diversify supply chains over a medium- to long-term horizon. This is the option that the Government appears to have chosen. However, it is likely that supply will not be able to be increased sufficiently rapidly to avoid something of a supply crunch. Making use of other fuels during this period may provide some breathing space.

Title: “RISKS TO SUPPLY-CHAIN RESILIENCE: CHINA’S POSITION IN THE ELECTRIC VEHICLE MARKET”
By Sam Ashworth-Hayes

The Henry Jackson Society
Millbank Tower, 21-24 Millbank
London SW1P 4QP, UK

www.henryjacksonsociety.org

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