Energy Transition and Geopolitics: Are Critical Minerals the New Oil?

WHITE PAPER

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Executive summary

The energy transition will cause big shifts in dependencies – away from oil and other fossil fuels, and towards a raft of critical minerals such as lithium and copper. Will this trading of places lead to politically and environmentally dangerous futures? This paper offers a broad framework for answering this question. It also suggests that most of the feared new dependencies on critical minerals can be managed.

Most of the policy concerns about critical minerals have been around fears that supplies won't keep pace with soaring demand and that raw and processed critical materials are overly concentrated in a few countries, notably China. For most critical minerals, however, there hasn't been much incentive to expand or diversify supplies radically. That is now changing, and adequate new supplies will plausibly appear, with the probable exception of copper, a mineral with a long history of supply struggles.

Critical minerals and oil have notably different demand factors. For oil, the global economy has little ability to temper demand quickly in response to shortages or manipulations in supply. Some big oil suppliers are responsive to state interests when they make investment and production decisions, which at times helps them manipulate supplies. By contrast, most critical minerals are used only when new projects are built. With the right policies in place, demand can be highly responsive. Suppliers, knowing this, are less likely and able to corner the market.

Moreover, most mineral suppliers respond principally to market conditions, rather than state interest. The risks to the global economy that the clean energy transition will create geopolitical tensions over critical minerals – as has happened thus far with oil – are not as great as feared so long as the market forces that govern supply and demand are properly harnessed. Innovation can also help temper demand, as has happened with cobalt where worries about dependence on slave labour have led innovators to find alternatives to the mineral and to identify new sources of supply.

This report identifies an array of "no regrets" policy initiatives that can help ensure that "trading places" does not have adverse economic and environmental consequences. Among these is helping markets operate more effectively, such as by creating more transparency of data about transactions and the encouragement of forward markets that will make it easier to signal scarcity and finance new supplies.

Introduction

How likely is it that the clean energy transition, advancing rapidly in much of the world, could replace dependence on oil and other hydrocarbons by dependencies on critical minerals? Analysts and pundits are debating this question – and are often coming up with answers that set alarm bells ringing.

This paper accepts as likely that dependencies on critical minerals will rise as the "energy transition" causes a big rise in the need for wiring, batteries, magnets and other key elements of cleaner energy systems. In tandem and with time, dependence on oil is likely to wane. But will this shift in dependencies be bad news for geopolitics, energy security or the environment?

This question has been hard to answer, partly because debates are advancing without much of a framework for analysis. Dire forecasts typically start with the expected surge in demand for critical minerals, with predictions often based on little more than the assumption of exponential growth. But a proper look at dependencies requires looking at how the whole system for supply and demand might respond, and how innovations in technologies, markets and governing institutions might alter those responses. The early days of the oil crisis in the 1970s saw similar errors in forecasting – with an obsession with supply, the assumption of exponential growth in demand and a failure to account for how the whole system might respond. These errors in forecasting can lead to grave mistakes in policy and investment.

This white paper is an effort to offer a preliminary framework for thinking about supply, demand and trade-offs as the dependence on critical materials increases.[1] It looks at supply and demand in turn, and argues that while most of the concerns about critical materials have focused on the level and concentration of supply, the most important factors driving potential scarcity in critical materials are actually found in the realm of demand. It then identifies an array of "no regrets" policy measures that can help make the inevitable shift towards more dependence on critical minerals less dangerous for the global economy, environment and political order.

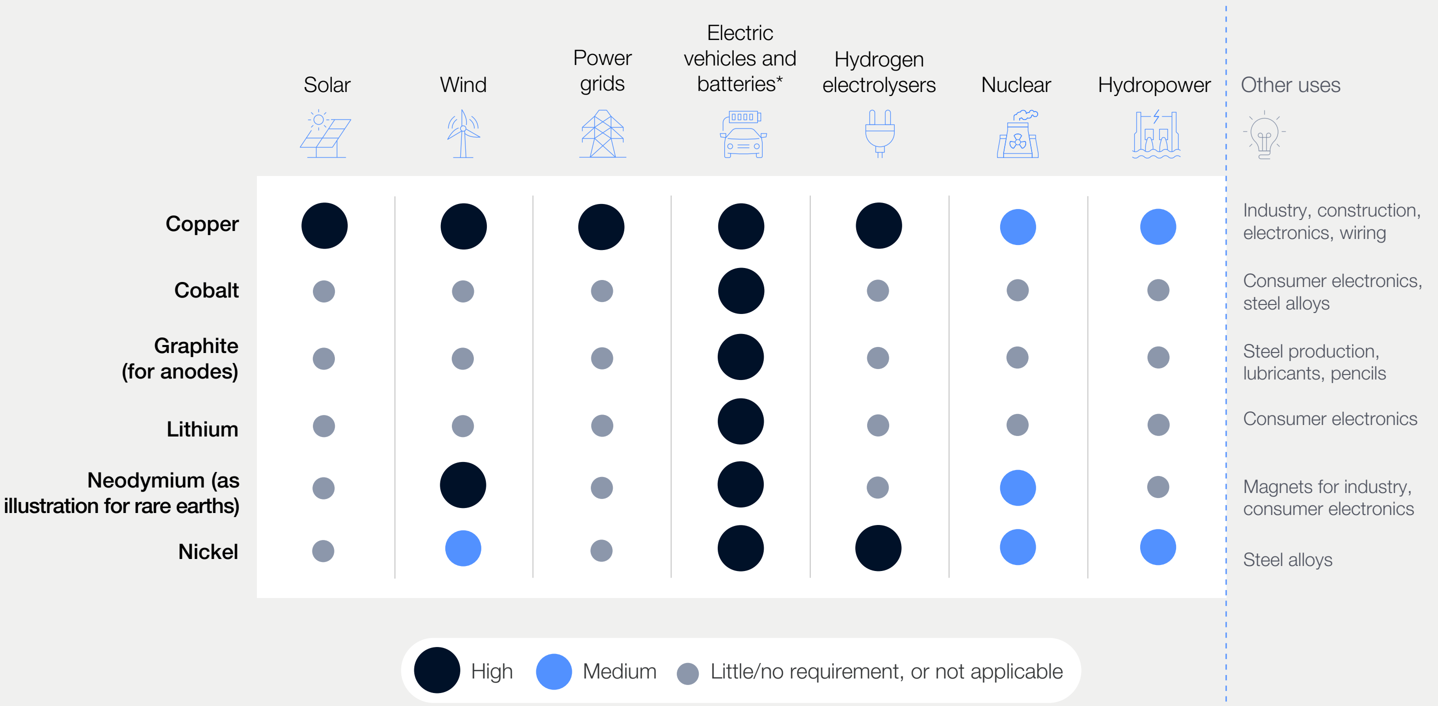
1 Supply

Alarm about rising dependence on critical minerals start with warnings about supply. Demand for these minerals will explode, it is assumed, and this animates two big *dependista* worries.

First, the supplies needed might not appear in time. Widely used projections see lithium demand increase ten-fold or more.[2] If that's the case, where will all these new supplies come from? For perspective, the demand for oil only doubled from 1970 to today – and meeting that rise in demand was challenging enough for the whole world's oil industry. How will lithium producers keep pace with a much bigger rate of expansion? Second, production is already highly concentrated in a few countries, especially China.

The analysis in this white paper focuses on the "big six" critical materials – copper, lithium, graphite, nickel, cobalt and rare earths.[3] Some of these are used almost exclusively in clean energy products (e.g. lithium in batteries) while others are used in lots of diverse applications (e.g. nickel in batteries and corrosion plating on metals).

FIGURE 1 **Importance of critical minerals in clean energy transition**



* Structural steel and aluminium for electric vehicles are not included as energy transition demand, as this is not "additional" demand – these materials would be used in similar amounts in internal combustion vehicles as well.

Source: ETC, *Material and Resource Requirements for the Energy Transition*, 2023.

1.1 Supply volumes

Will supply keep up with demand? Figure 2 shows current global supply of each of the big six in volumetric terms. Of these, copper is already supplied in a mature market (25 million tonnes of copper comprises the current annual supply). The long history of copper supply is why significant concerns exist about new supplies coming online to keep pace with expected demand – the world has for decades struggled to find and produce copper in large volumes, and this struggle will get harder.

For most of the others, current supplies are much smaller and no relevant historical experience exists to test whether, with the right incentives, new supplies could materialize. For example, graphite supply today is about 1.5 million tonnes for all purposes, of which only a small fraction gets used in clean energy systems like batteries for electric vehicles (EVs). Total global cobalt supply, about half of which ends up in batteries, is only about 200,000 tonnes.

An assessment of supply requires looking at lots of factors – source rocks, the ease of siting new mines, availability of skilled labour and a wide array of "above ground" risks (e.g. political instability) that might impede investment. That kind of detailed spadework, done widely in the industry, is beyond the scope of this paper. But what's clear from looking across all these minerals is that only one of them – copper – has the kind of large, mature market where it is possible to draw any robust conclusions about the difficulty of bringing substantial new supplies online. Volumetrically, the problem of copper supply is a genuine concern.[4] For all the rest, it is hard to assess whether there will be challenges in supply because the industries occupy relatively small niches in global mining. Lithium demand might rise 10-fold or more (depending on forecasts), but from a base of less than 1 million tonnes today. In 2023, the whole world's lithium market was worth only $5.7 billion,[5] out of a global mining industry that is worth about $2 trillion.[6]

Just because market projections for non-copper minerals are small doesn't make them automatically scalable. But most signs suggest that scalability has just begun. In 2022 alone, there was a one-fifth expansion in global supplies of lithium – essentially all of it outside China – as suppliers saw a credible market signal to expand.[7] In other critical materials as well, supplies are witnessing a big expansion away from today's dominant market suppliers – such as large new cobalt finds in Australia and expansion of rare earth production in California. The world is just beginning to see signals for the need to expand supplies and many of the responses are encouraging.

1.2 Concentration of supply

What about the other supply worry: concentration? The data available today suggests that this is a big concern (Figure 2) and that a few suppliers and processors control most of the market.

The top three producers account for between 50% and 90% of mining and processing.

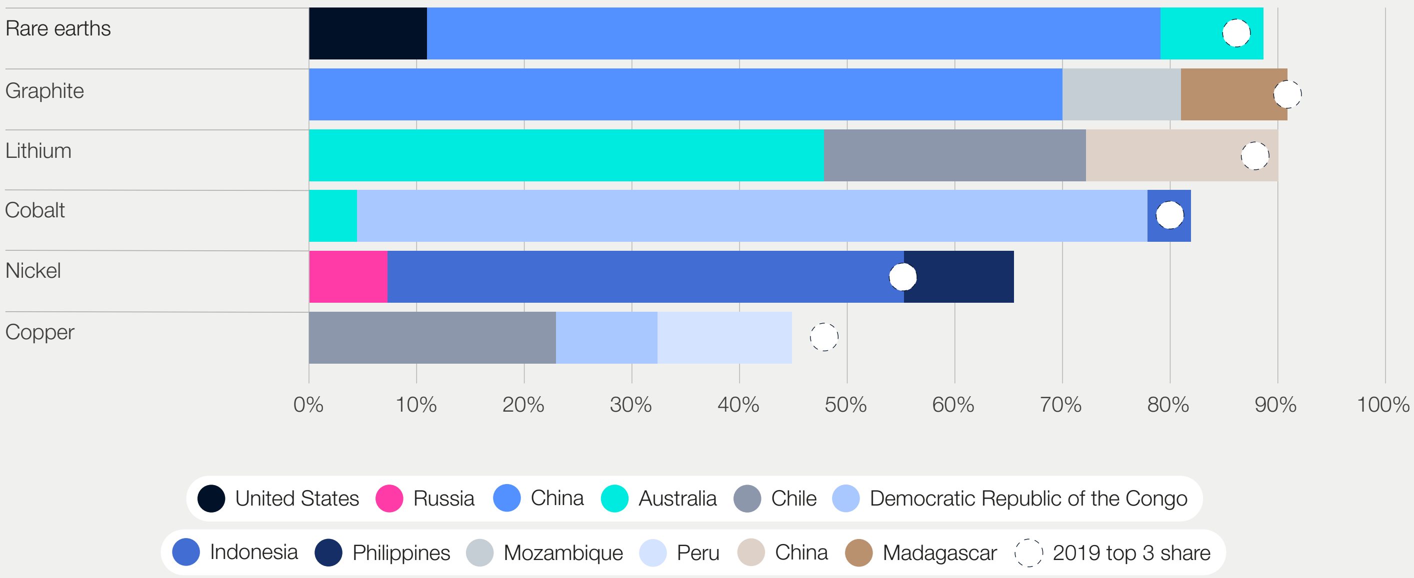
For comparison, the share of the Organization of the Petroleum Exporting Countries (OPEC) in world oil production is just 40%,[8] and this smaller concentration has inspired endless worries about the producer cartel's control over global oil supplies and prices. But the comparison with OPEC can be highly misleading. Without much cartel-like behaviour in critical minerals, governments and buyers have not had much incentive to diversify supplies. Instead, the global market has optimized around costs of production and ease of access to source materials such as in Chile for copper, Australia for lithium and the Democratic Republic of the Congo (DRC) for cobalt.

Moreover, even as the influence of OPEC on oil prices has been prone to exaggeration, the ability to exert pricing power by controlling spare capacity is much greater in oil than for all the critical minerals. Short-run elasticity of demand for oil is very low and thus modest shifts in the volume of supply leave oil users with few choices, at least in the short term, but to pay higher prices.

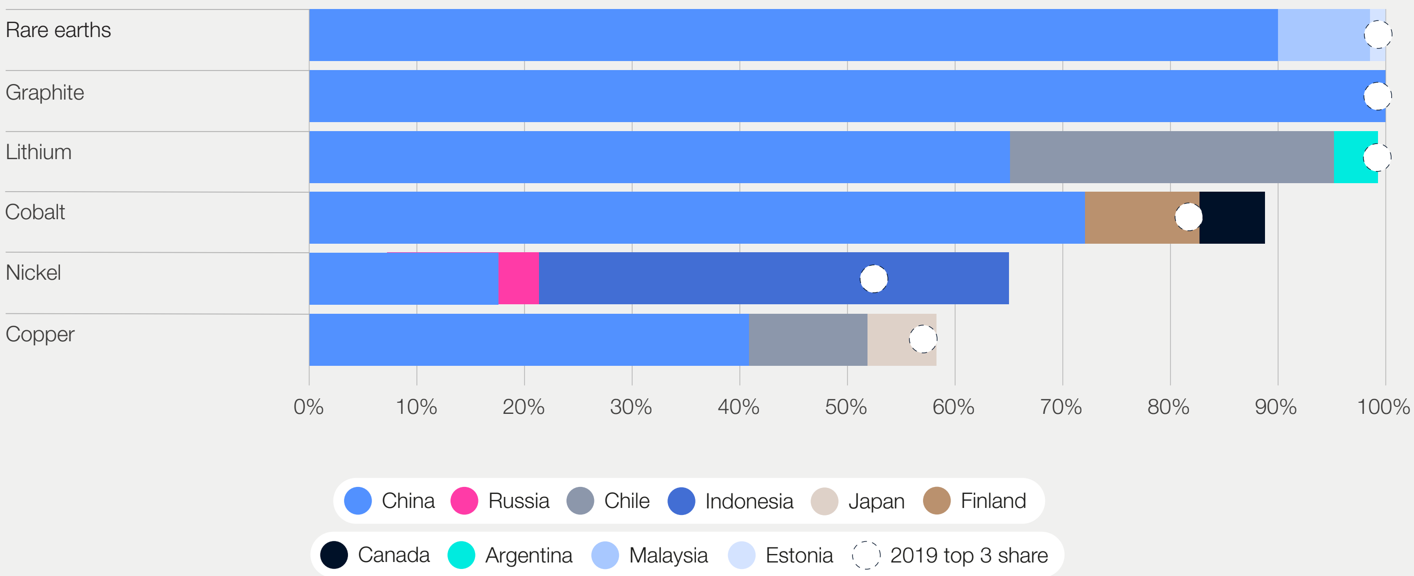
The only country that has, for a sustained period of time, cared much about control over supplies of critical minerals is the country that has been their biggest user: China. Not surprisingly, China has created powerful policies, including vital financing, that have cemented its dominant position – especially in processing, which is much easier to control because it does not require physical control over source rocks. Most of these policies are aimed inward, to ensure supply for Chinese industry.[9] However, could China cut off the rest of the world by blocking access to critical minerals – in raw or processed forms?

FIGURE 2 | **Top 3 countries for mining and processing of critical minerals**

Share of top three producing countries in mining of select minerals, 2022



Share of top three producing countries in processing of select minerals, 2022



Source: IEA (2023), *Critical Minerals Market Review*, 2023.

Mindful of the comparisons with oil, it would seem irrational for China to manipulate the critical materials it supplies to the rest of the world – because the rest of the world will react. Yet there are experiences that give cause for worry. In 2010, China stopped the export of rare earths to Japan,[10] following Japan's arrest of the captain of a Chinese vessel that had collided with Japanese coast guards' boats. In the eyes of many observers, China continues to use these threats. In 2019, in the midst of severe US-China trade tensions, Chinese President Xi Jinping visited a rare earth mine, reminding importers that China remains the dominant supplier of these materials.[11] Indeed, in 2023 the country also strengthened its export control over gallium, germanium and graphite.[12]

While China attracts a lot of attention today, the dangers of excessive dependence on any single supplier or processor are more generic. Reflecting on the challenge of security in 1913, the early days of the global oil market, Churchill implored that security came "from variety and variety alone". The supply chains of some minerals have many non-Chinese concentrations of concern. For instance, Indonesia has quickly increased its market share for nickel (about 40% now) at the expense of other suppliers (notably Australia), thanks to technology, policy and foreign investment.

Periodic stocktaking, discussed in more detail below, would be able to identify these trends and also the kinds of policy and market arrangements that could encourage private investment to sustain higher levels of diversity – as is done in many markets where there are fears of excessive dependence on single suppliers and concerns about competition.

While these political acts create some risk, for the most part they are political stunts and experts in all these governments know the risks not just to users but also suppliers. Too much actual manipulation in supply will create responses by other suppliers and users.

Consider lithium: most production today and into the near future is from hard rock mining – a process of moving and processing large amounts of material and water, and it is often difficult to gain permission to build new mines fast enough to meet rising demand.[13] But lithium can also be extracted from brines, a process that could be made radically more efficient, requiring less land and also allowing for the use of lower grade lithium deposits, through processes known as direct lithium extraction (DLE).

The logic of DLE has been known for a long time, and is not without trade-offs, such as possibly much larger water inputs, but the incentive to test and deploy it hasn't existed. Now a diverse array of DLE projects is taking shape, especially in places where there are new, strong policy incentives to diversify supply – involving startups with innovative technology along with large incumbents such as mining and oil and gas firms that have skills in extraction, processing and systems engineering.[14]

The same logics of innovation apply for most of the rest of the critical minerals. It is true that traditional hard rock mining is taking greater efforts and yielding lower quality ores. But innovation is also providing new methods of supply, including supplies created by re-processing waste tailings from earlier mining efforts.

2 Demand

Dependency is a function of demand as well as supply. As with oil, it is relatively easy to worry that supplies could falter, and their concentration could create risks of interruption. But as with oil, some of the biggest surprises come from shifts in demand and how supply and demand interact. When costs rise or supplies seem insecure, the market and policy-makers in government create strong incentives to make do with less. When the market can send reliable forward signals of scarcity and risk, the incentives to be more frugal are even more powerful.

Most projections for soaring demand are based on static or simple assumptions about the relationship between deploying lots of new devices (e.g. batteries, motors, generators and inverters) and current material needs for each device. If materials are scarce and there are incentives to do more with less, those static or simple assumptions won't hold.

Estimating future demand requires looking not just at the sheer number of devices but also three other factors: efficiency in the use of critical materials, recycling and substitution.

By helping to reduce cumulative primary materials requirements, and increasing the share of demand which is met by secondary supply, efficiency and recycling become credible avenues to close supply gaps. For instance, the ETC estimates that a 30% fall in cumulative demand for copper could result from a combination of reduced use in grids, a reduced build-out of wind and solar installations, as well as from lesser copper use in EVs.[15] These estimates are hard to pin down and could well be quite conservative because experience with these technologies at scale is at a very early stage. In recycling, for example, there isn't yet much real-world experience – nor yet opportunities for real-world innovation and system optimization – because large numbers of devices bearing critical materials have not yet been removed from service.

The story with recycling aligns with that of supply and demand. With incentives, markets can respond – at least to a point. The potentials are large because, unlike oil, most uses of critical minerals are non-destructive – the mineral plays chemical roles such as through catalysis. It is not consumed in the process. (By contrast, with oil, destruction by burning is the main application.) In principle, large portions of the critical materials in the devices of the clean energy revolution – such as solar cells, wind turbine hubs, electric vehicles and batteries – can be recycled.

What matters for recycling are economic benefits and costs – and thus incentives and technology.[16] Today, about half of lithium batteries are recycled after removal from service, and global trade in recycling (focused on China) is important.[17] Studies of rare earths point to similar observations – valuable materials can be recovered through recycling but there often hasn't been much incentive to take recycling very far.[18] In principle, most of the critical materials can be recycled to very high degrees, approaching 100% in some cases.

The overall picture for recycling hinges on the difference between the supplies of recycled materials (as earlier generations of clean devices are retired from service) and the total demand for critical minerals (with expanding demand for new clean devices). Recycling can play a significant role, but if total demand for minerals is rising steeply, then recycling from devices that accounted for demand in years past can never be the decisive source of total supply. Even with bullish estimates for recovery rates, recycling could account for only about 10% of the global lithium supply needed in 2030.[19]

Substitution is also a powerful force that can be felt quickly in the markets. A shift to sodium-ion batteries beyond 2030, combined with faster battery energy density improvements and slower growth in battery pack sizes, is estimated to lead to a 40% reduction in lithium demand by 2050.[20]

The common thread in the stories about efficiency, recycling and substitution is the interaction between incentives and technological change. The cobalt story is instructive here. Until concerns about the DRC's dominance in cobalt became widespread, there were few concerns about the methods used to produce cobalt. The shifting focus from small batteries in consumer electronics to large ones in EVs brought about new concerns about the scalability of supply. With new incentives, innovation has focused on shifting battery chemistries to make it possible to reduce or even eliminate the use of cobalt in cathodes. Today, a surge in the use of technologies such as lithium iron phosphate (LFP) batteries is already displacing demand for cobalt and nickel significantly.[21]

The contrast with oil is quite striking. For example: there has been, for decades, a search for alternatives to petroleum for powering automobiles. That search has led to interest in hydrogen, biofuels and electricity. Electricity has been thought to be a winner at least three times over the last 120 years; today, that winning position seems to be firmly established. Yet the rates of change remain sluggish. Despite strong interest in switching away from oil and aggressive policies to achieve that outcome, the use of EVs displaced only around 0.7 million barrels per day or 1.3 exajoule (Mb/d or 1.3 EJ) of oil in 2022.[22]

Examining every use for critical materials and the respective potential for technological substitution is beyond the scope of this paper and, to some degree, unknowable because the evolution of technology is unclear. However, what is clear is that many specialized applications of critical materials are amenable to substitution when an incentive to find alternatives exists.

These solutions do not come into being automatically. They depend, in part, on reliable market signals for scarcity – in the case of cobalt, those came a bit from price and a lot from fear of regulation and loss of reputation (and other costs) for western cobalt users. They depend on the incentives for production of knowledge – fundamental new ideas about battery chemistry are, in part, global public goods and won't be supplied adequately without funding programmes designed for public benefit.

At the same time, this prospect of substitution may discourage investment in the expansion of supply of critical minerals. All these factors require policy signals.

3 Unavoidable "unknowables"

While the world of analysts agrees on a wide range of issues related to assessing supply and demand, agreement is impossible in many places from today's vantage point.

It is possible, today, to be nonchalant about most critical minerals because markets will respond – new supplies will emerge, and demand will respond when prices rise. It is possible, as well, to be alarmed – at least about some parts of the market, such as copper, where supply and demand seem poised to misalign and the market, on its own, won't fix problems.

The correct answers, if they will ever be known, are unknowable today because real market behaviour depends on so many factors and interactions that are impossible to predict accurately. Such uncertainties are intrinsic to a fast-moving and rapidly changing industry and they affect policy strategy, which must be designed for experimentation, learning and adaptation.[23]

The list of unknowns is long. Below are the two most important categories.

3.1 Industrial policy and managed trade

Should countries treat critical minerals as a matter of critical national policy and rely on government to organize the means of production and control? Many governments are now doing this. China, as mentioned above, has already achieved a dominant position in mining and especially processing through active industrial policy. Programmes such as those for diversification of cobalt supplies, and especially those for diversification of production methods and supplies of lithium, are matters of national policy in western countries.

It's not clear whether this national strategic approach works better than relying entirely on market forces – or whether, perhaps, for particular critical minerals and jurisdictions, a more active, interventionist approach might be best. Once governments intervene, can there be any proper mix of market forces and interventions, or does policy quickly supplant markets?

Today's concentration of supplies in a few countries and use of abhorrent mining methods is the result of markets not seeing the right price signals. Fixing that could be a task for industrial policy, with all its potential flaws such as the proclivity of governments to identify and back the "right" solutions. Or it could be fixed through market reforms. If the latter approach is taken, then the reforms adopted will need to be designed and implemented in a multilateral context since the supplies and demands for these materials are global.

A lot of today's concerns revolve around China, in part because of brewing tensions between many Western nations and China, and in part due to actual concentrations.

Because so much of the managed trade debate focuses on China, it is important to deal with the reality that most nations are in no position to isolate China – their home supplies and demand are much too small, and thus any strategy that involves diversification away from China must be either multilateral (benefitting the global market) or hegemonic and implemented just in the biggest markets (e.g. the United States and the European Union, and possibly, Japan).

An area of emerging consensus is the importance of distinguishing between onshoring, which could create more brittle markets, and diversification. Even the aggressive onshoring activities by China have occurred within a global market, and no other country has the size of national supplies and demand that could facilitate a highly autarkic national market.

Diversification, by contrast, is much easier to implement in ways that don't undermine the value of market signals. As a practical matter, many nearshoring or friendshoring policies – if implemented in the context of continued open global markets – will have the effect of creating diversification.

3.2 The value of reliability

The other area of major disagreement concerns whether the future behaviour of critical minerals markets is possible to predict. All of the variables that affect supply and demand – discussed above – are hard to assess. The big picture is harder to decipher because those variables interact in ways that are so complex that no forecasting system can plausibly predict them. (All the excitement about the use of artificial intelligence (AI) to improve forecasting is largely irrelevant to such concerns since there is no system on which AI can be trained to predict how the supply and demand for critical materials could evolve.)

In all this uncertainty, different variables can plausibly have different emphasis. Within the Global Future Council on Energy Transition, some experts focus more on supply while others are more interested in the potential of altering demand trajectories.

Perhaps the greatest uncertainties here, however, lie with the preferences of governments. Should governments treat supply chains for critical materials as sacrosanct because constant, rising supply at reasonable cost is essential for an accelerating shift to clean energy? By that logic, most critical materials might be squarely inside the "small yard, high fence" approach to national security – a domain where big governments should be sure to control supply and demand. Or if these supplies prove unreliable or demand proves higher than expected, should governments be willing to relax their commitments to the energy transition so that demand for critical minerals relaxes in line with markets tightening? If a major producer or processor of critical materials withholds supplies, should big users be able to pause their demand?

What is clear is that with the right market and policy arrangements, a shift to greater dependence on critical materials can be compatible with the goal of a rapid shift to a clean energy future.

4 Roles of markets and policy

Most discussions of policy focus on things that analysts "know". Their approach to policy starts with the fact that some of the most important factors for policy are, today, unknowable. Policy strategies for managing dependence on critical minerals must acknowledge the unknowns, such as those outlined in the previous section. Mindful of these unknowns, "no regrets" policy strategies are vital – these are policy actions that are sensible almost regardless of how the uncertainties turn out. At least three such clusters of policies can be categorized.

4.1 Markets

First, it is important to let markets work where they can – especially when it comes to capital-intensive investment in new supplies and in demand response. Recognizing that markets do not automatically "work" on their own, policy action can address several areas of market failures:

– **Gathering and making available data** on supply, demand and market functioning such as production, demand, stockpiling and pricing. An equivalent in the oil market is the Joint Oil Data Initiative (JODI), a major initiative that linked users of oil (long organized, notably through the IEA) with suppliers.[24] Today, by contrast, information on most key minerals markets is quite thin.

– As minerals become truly critical, **creating forward markets** so that future supplies and demand can be linked more squarely to forward expectations. Today, most minerals don't have much of a forward market (copper being a notable exception).

– **Fuller pricing of externalities**, such as pollution impacts and water consumption. Depending on the mineral, a large fraction of world supply comes from places that don't have strong local environmental and labour standards.

Two additional complementary actions have value, though these will be harder to design and gain agreement on:

– As pollution externalities are priced and differences in prices grow, there may be a role for **border measures** to address these externalities where they have international impacts.

– **Long-term commitments by governments** to reduce dependence and diversify supplies. It is not sustainable – politically or economically – to allow highly concentrated dependence on single suppliers or processors. Great care is needed in designing the policies aimed at promoting diversity because this is one of the areas where policies can easily backfire. Policies that seek diversity through onshoring, for example, can fragment supply chains and drive up costs, thereby undermining security and affordability. Similarly, policies aimed at boosting supplies from overseas producers should be made available to the largest number of candidates, rather than picking winner countries or projects.

Both additional actions implicate international trade. As a general rule, well-functioning global markets should be tapped as a source of diversity and reliability – not fragmented and balkanized.

4.2 Innovation

Second, huge value lies in ongoing investment in innovation – probably with a large degree of international coordination since new ideas that affect supply, demand and recycling technologies quickly become widely available in the global market. They are global public goods.

The innovation agenda is diverse. It includes innovations that diversify and expand supplies, such as DLE. And it includes a wide array of innovations that affect demand – notably innovations around efficiency, recycling and substitution. In a few areas, innovation is likely to have particularly high value. Those include cathodes, parts of battery systems (as currently conceived) that have posed the greatest challenges, such as for the use of cobalt and nickel.

If fears about lithium supplies rise, there are substantial opportunities, through innovation, to move away from lithium.[25] Given the robust concerns about copper, innovations that enable greater efficiency and substitution of copper seem, in particular, to offer high value.

The big question with innovation is how to get started. There is little capacity in global committees of governments for pushing this agenda. Instead, the most highly motivated governments – probably led by the large western users, ideally in collaboration with China – should set an innovation agenda.

4.3 Periodic stocktaking

Third, in writing this paper, the team have been struck by how little is known – and knowable – about the future supply and demand for all the critical minerals. Into this vacuum of information, a wide array of ideas flood – some scary and alarmist, others calming. But the reality is: nobody really knows.

There lies huge value in periodic, collective assessments of supply and demand. Such assessments should not just focus on central estimates but also outliers, with the goal not just of developing centrist scenarios but also a wider range of views about what could happen in the future. This periodic stocktaking is probably best led, as with investments in innovation, by the governments that are most highly motivated. It could usefully be linked to an innovation strategy since stress-test assessments of supply and demand can help identify areas of greatest value for innovation.

Conclusion

It is all but certain that the energy transition will create rising dependence on critical minerals. Whether that dependence will be problematic is hard to pin down today. Both supply and demand could be highly responsive to market conditions and innovation – much more responsive, in fact, than the supply and demand for oil and other hydrocarbons.

The authors of this paper see few causes for alarm but many reasons for diligence. Policy will play an essential role because market forces, on their own, seem unlikely to address all the key challenges of dependence on critical minerals. Policy should aim to help those market forces work more effectively – in particular by allowing market forces to send price signals about long-term scarcity – which can reinforce incentives for innovation, reduction in demand and expansion of supply. Too much of the policy debate is focused on supply and not enough on demand.

Creating an effective policy response will require careful political attention. The bigger the group of governments implicated the less likely that effective solutions will emerge – because, given deep uncertainties, gaining agreement and cooperating on policy will be challenging and will require approaches, such as experimentation and learning, that are adaptive. A coalition of motivated governments can lead this effort; with success, others can join.

Just as the oil age is not ending for lack of oil, the clean energy era need not falter for lack of lithium or nickel.

Contributors

Lead author

David G. Victor
Professor, University of California, San Diego (UCSD), USA; Co-chair of the 2023-2024 World Economic Forum Global Future Council on Energy Transition

Authors

Justine Roche
Lead, Energy Initiatives, World Economic Forum, Switzerland; Manager of the 2023-2024 World Economic Forum Global Future Council on Energy Transition

Joisa Saraiva
Professor, Fundação Getulio Vargas, Brazil

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Endnotes

1. Building on a recent report from the World Economic Forum that presents a group of risks emerging from a potential gap between the demand and supply of critical minerals and prioritizes management strategies. See: World Economic Forum, Securing Minerals for the Energy Transition, https://www.weforum.org/publications/securing-minerals-for-the-energy-transition/.
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World Economic Forum
91–93 route de la Capite
CH-1223 Cologny/Geneva
Switzerland

Tel.: +41 (0) 22 869 1212
Fax: +41 (0) 22 786 2744
contact@weforum.org
www.weforum.org