Unpacking Mineral Markets: Situating the Opportunities

By Jonah Allen[1] and Shane Sethi[2]

Overview

Decarbonization and development are driving up demand for critical minerals; the countries that produce these minerals have new opportunities to capture value both from mining and from more lucrative downstream activities. Yet mineral price volatility and overcapacity across the supply chain have put these ambitions to the test. The mix and scale of transition demand now and in the future, and the expectations behind them, will shape realized growth in market volumes, while prices, which are volatile and uncertain, will determine fiscal windfalls as well as the viability of projects both upstream and downstream. Sharper examination of mineral market dynamics, and clearer dissemination of their complexities are needed to ground more robust policy objectives aimed at lasting development outcomes.

The Promise of Electrification?

Global electrification driven by both decarbonization and development is expected to create unprecedented growth in the global mining sector and expand both the scope and scale of mineral demand. The International Energy Agency's Net Zero Emissions Scenario sees electricity's share of final energy consumption growing from about 20 percent today to more than 50 percent in 2050. Technologies to produce renewable electricity are more materially complex than fossil incumbents (Figure 1); the networks used to transport this electricity need to be established, expanded, and upgraded, and such infrastructure will require vast quantities of copper, aluminum, and steel. The batteries that will store much of this energy and power sustainable transport demand lithium, graphite, nickel, manganese, cobalt, iron, and other materials.

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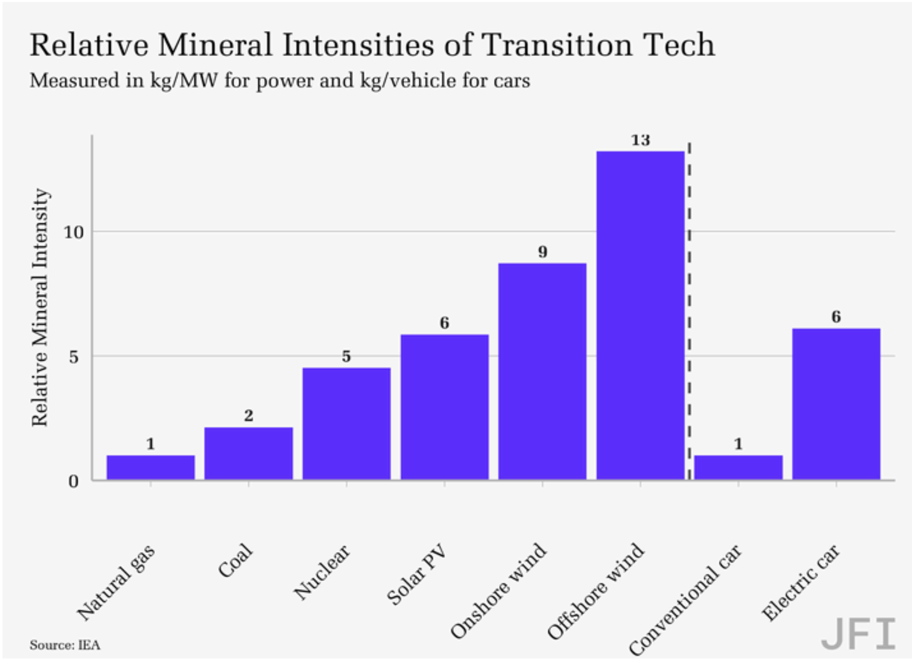


Figure 1 (above): Total mineral intensity of typical power generation and transport technologies, from IEA, 2021, benchmarked against the incumbent technology. Solar PV, for example, measured in kilograms of minerals per MegaWatt of power, requires six times as many minerals as natural gas. Measured in kg per vehicle, electric vehicles require six times as many minerals as conventional cars. IEA analysis excludes steel and aluminum demand.[3]

Transition-critical mineral demand has thus been expected to outpace our ability to bring production online, representing a clear opportunity for current and aspiring producer countries to capitalize on the opportunity, both from the mining of these minerals and more lucrative downstream activities, including processing, refining, and manufacturing, which have been concentrated in China and the Global North.

Battery minerals market volatility

In the past couple of years, market realities have put the ambitions of producer countries to the test. Other than copper,[4] major transition-critical mineral markets are currently experiencing supply gluts through 2030 at least.[5] The pace at which supply scaled to meet potential

[3] Method notes from IEA: "Steel and aluminum are not included [in either figure]. The values for offshore wind and onshore wind are based on the direct-drive permanent magnet synchronous generator system (including array cables) and the doubly-fed induction generator system respectively. The values for coal and natural gas are based on ultra-supercritical plants and combined-cycle gas turbines. Actual consumption can vary by project depending on technology choice, project size and installation environment. The values for vehicles are for the entire vehicle including batteries, motors and glider. The intensities for an electric car are based on a 75 kWh NMC (nickel manganese cobalt) 622 cathode and graphite-based anode. The values for offshore wind and onshore wind are based on the direct-drive permanent magnet synchronous generator system (including array cables) and the doubly-fed induction generator system respectively."
[4] Growth in data centers serving AI development, and their rising electricity needs, is expected to drive demand–supply imbalances for copper.
[5] BloombergNEF, *Transition Metals Outlook 2024*, October 3, 2024

demand—while demand did not scale accordingly—has caught market analysts, producers, and policymakers in both producer and consumer countries by surprise. The turbulence in battery metal markets, particularly lithium, nickel, and cobalt, exemplifies both the overoptimism about the transition and the complex challenges of generating lasting development outcomes in the context of commodity market volatility (highlighted in our last report).

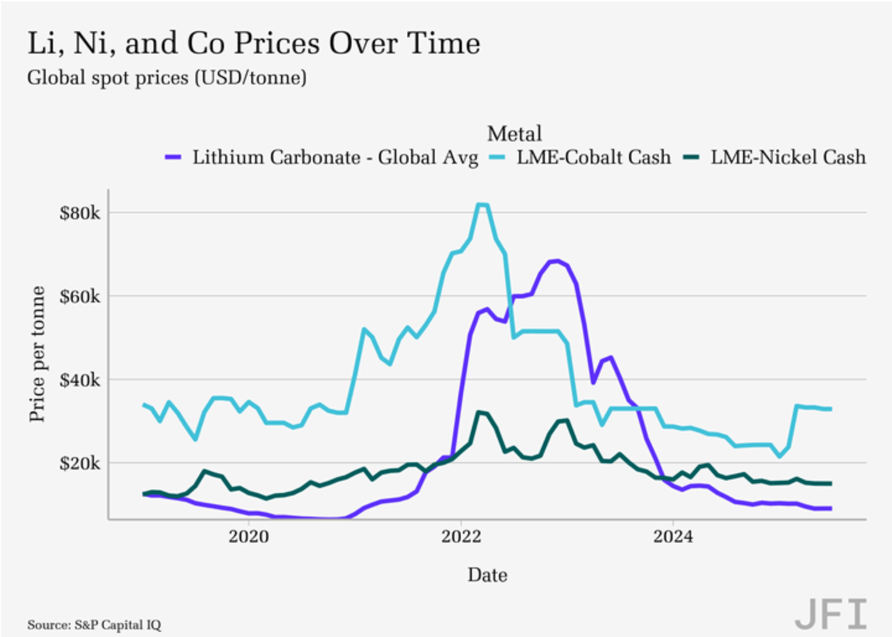


Figure 2 Lithium, nickel, and cobalt monthly prices, from S&P Cap IQ (Jan 2019 to July 2025)

The rise and crash in battery mineral prices has been most pronounced in the lithium market. The global average price for lithium carbonate peaked in December 2022 at $68,366/mt 2023 and has since crashed 87 percent to $9,050/mt as of July 2025., As electric vehicles and energy storage drove demand for lithium-ion batteries, producers across Australia, South America, China, Africa, and elsewhere foresaw supply deficits and raced to cash in (Figure 3). Because lithium occurs in many geological settings and across the world and, crucially, many hard-rock projects were partially built or mothballed and could be restarted quickly once prices spiked, Australian-led supply has scaled rapidly. Meanwhile, demand growth has been more modest than expected due to slower-than-anticipated adoption rates, rollbacks in EV subsidies, and broader economic headwinds.[6] As a result, the market has shifted into a long-term supply glut, putting downward pressure on prices and raising concerns about project viability and long-term investment discipline in the sector.

[6] Elevated and persistent interest rates have dampened consumer and corporate borrowing, raising the cost of car loans and credit, which in turn has slowed EV adoption and weakened broader demand growth. In the context of low prices, interest rates have placed additional pressure on miners by raising financing costs in a capital-intensive sector.

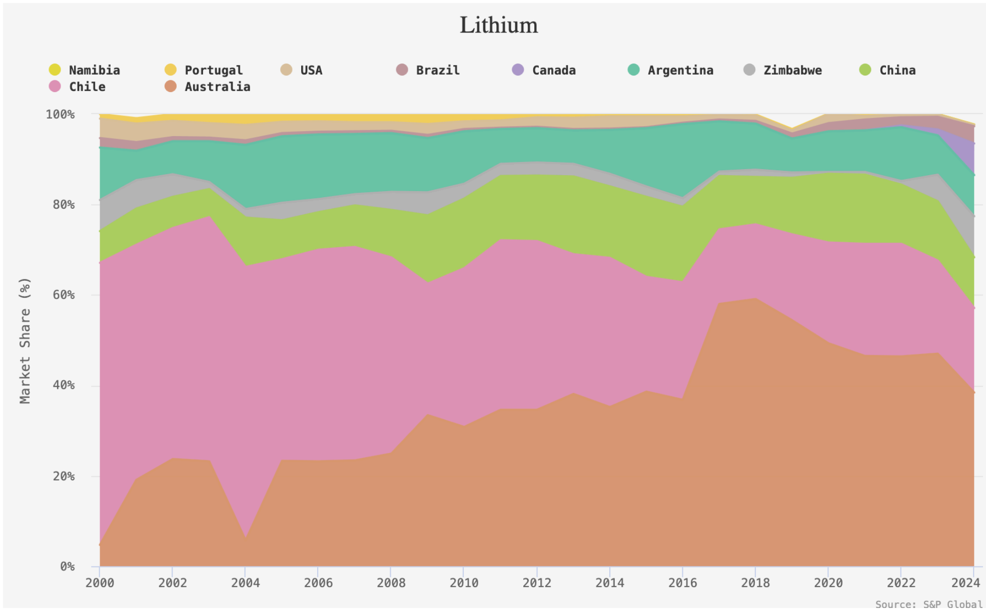
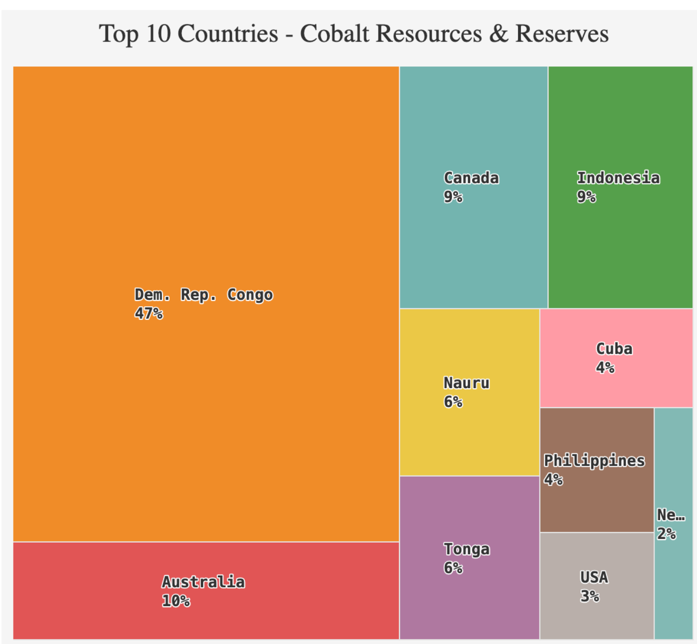


Figure 3: Historical Market Share of Production for Lithium from JFI's [Mineral Market Dashboard](). See the Appendix for historical production shares of other minerals.

Meanwhile, not only has expected overall battery demand growth slowed, but advances in battery technology have shifted the makeup of battery chemistries and reshaped associated demand expectations. Chemistries with reduced or no reliance on nickel and cobalt, such as lithium-iron-phosphate (LFP) batteries, have gained traction, particularly in mass-market electric vehicles. These alternatives, driven largely by Chinese manufacturers, have significantly downgraded forecasts for long-term nickel and cobalt demand.



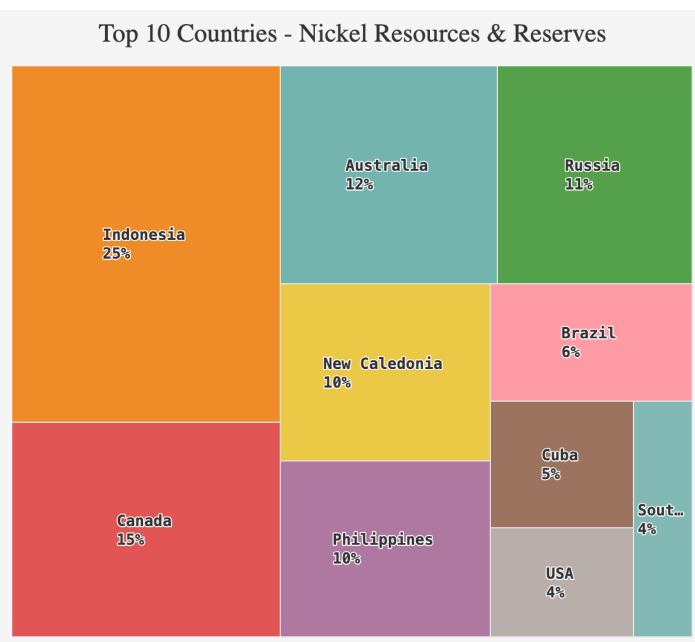
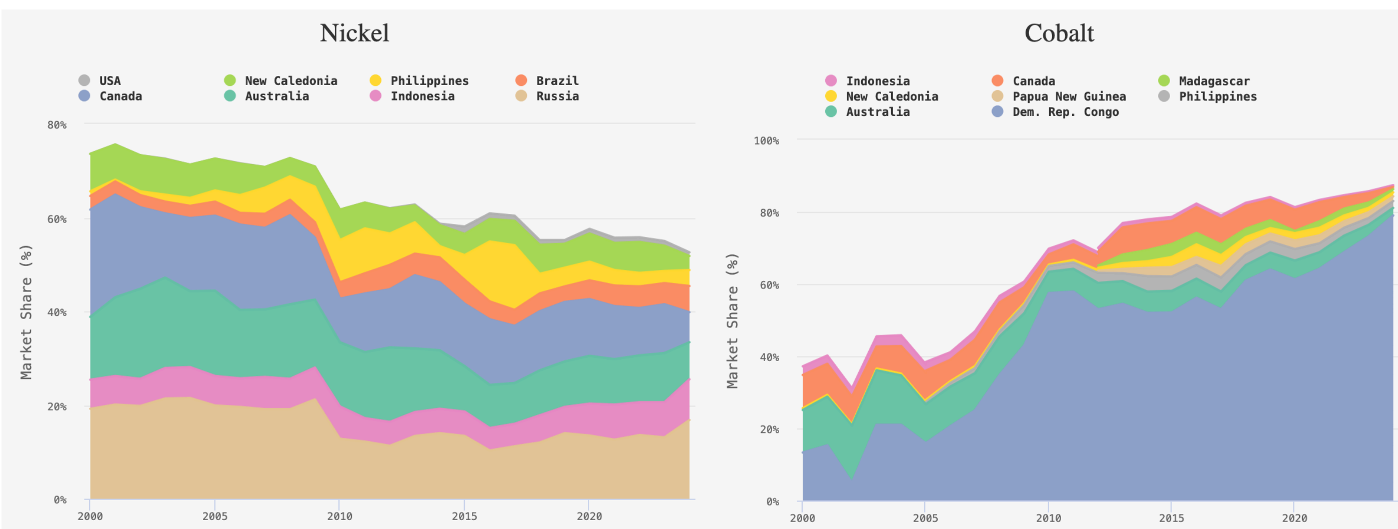


Figure 4: Share of nickel and cobalt reserves among the top 10 countries with reserves, from JFI's Mineral Market Dashboard with data from S&P Global. Note that this is the relative split of the top 10 countries only, so that both the names and resource estimates of other countries are excluded. See the Appendix for more minerals.

While nickel and cobalt are mined globally, their highest-quality and lowest-cost reserves are concentrated (Figure 4 above). Indonesia has emerged as the dominant producer of high-purity nickel, particularly through laterite ores processed into nickel pig iron and refined via energy- and carbon-intensive methods, often through Chinese-owned or -financed facilities.[7] Since the export ban in 2020, the island nation has prioritized an aggressive downstreaming policy—now reaching midstream NMC battery component manufacturing—that has relied on equally aggressive expansions in supply. Cobalt production, meanwhile, is heavily concentrated in the Democratic Republic of Congo (DRC), which accounts for more than 70 percent of global supply. While cobalt is typically produced as a by-product of copper or nickel mining, the DRC hosts some of the only deposits where cobalt concentrations are high enough for it to be considered a primary or economically coequal product. In a context of weak governance and widespread corruption, cobalt production in the DRC has scaled rapidly, driven in part by the expansion of artisanal mining, which often relies on child labor and exploitative working conditions. This surge in supply, much of it informal and poorly regulated, has flooded the market and contributed to the sharp decline in prices. At the same time, ethical and geopolitical concerns tied to DRC supply chains have accelerated the push to reduce or eliminate cobalt use entirely, as seen in the growing adoption of LFP batteries and other alternative chemistries.



[7] The structure and timing of Indonesia's 2020 nickel-ore export ban forced in-country processing just as Chinese investors were scaling capacity, and because their equipment depended on Indonesia's high-grade laterites, investment anchored quickly in dedicated industrial parks. This sequencing turned ore access into downstream build-out, rapidly lifting high-purity nickel supply. By contrast, the 2023 bauxite ban underperformed as buyers easily substituted with Guinean supply, and Indonesia's bauxite industry has not fully recovered.

Figure 5: Historical market shares of nickel and cobalt production, from JFI's Mineral Market Dashboard with data from S&P Global.

Recognizing their influence on global battery mineral markets and the consequences of oversupply, both Indonesia and the DRC have taken steps to rein in production growth and thereby global prices. In Indonesia, the government has begun tightening annual production quotas, shortening mining licences, and increasing environmental scrutiny, while the DRC recently imposed a temporary export ban on artisanal cobalt and is weighing implementing export quotas in partnership with Indonesia in the long term. The ability of these efforts to buoy global prices depends on their effectiveness (which is in question for both), as well as the broader market outlook, which is unfavorable. Tariff uncertainty, growing trade barriers, and persistent global economic headwinds continue to cloud demand forecasts. As previously noted, the outlook for lithium, nickel, and cobalt will remain closely tied to the electric vehicle market, which has continued to experience turbulence since 2021.

Downstream turbulence and feedback loops

This volatility in the upstream market has been mirrored and amplified by downstream dynamics in EV demand, corporate financing conditions, trade policy, and manufacturing overcapacity. While battery mineral prices were climbing in 2020 and 2021, there was a significant wave of electric vehicle (EV) initial public offerings (IPOs), particularly through special purpose acquisition company (SPAC) transactions. Nikola Motors, for example, went public in May 2020 via a SPAC merger, with its stock price surging from the initial $10 SPAC valuation to over $90 within days of the deal's completion. Many of the EV companies that entered public markets during this period, including Fisker, Hyliion, Lordstown Motors, Canoo, and Arrival, did so without generating revenue, primarily raising capital to fund the development and delivery of their first vehicle models.

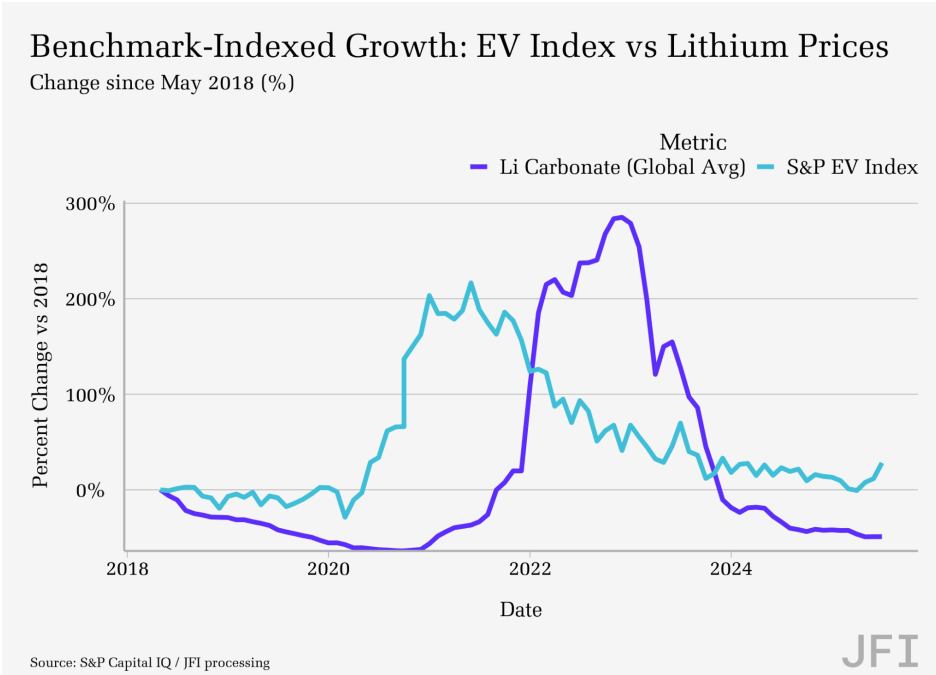


Figure 6: S&P EV Market Index (called "S&P Kenosha Electric Vehicle Index") and global average lithium carbonate prices, from S&P Global. Prices are benchmarked as a percentage movement against their starting value in May 2018 for comparability. The S&P Kensho Electric Vehicles Index is designed to measure the performance of companies involved in the electric vehicle sector and the ecosystems supporting it.

The sharp rise in interest rates beginning in 2022 had a significant impact on equity markets, particularly affecting high-growth sectors such as EVs, where companies tend to be capital-intensive and unprofitable in their early stages. For those that had already depleted much of the capital raised during their IPOs and were increasingly reliant on debt to finance operations, research and development, and production scale-up, the higher borrowing costs strained balance sheets. As a result, multiple EV companies have filed for bankruptcy or experienced steep declines in market value, with some losing 80 percent to 90 percent of their equity.

On the consumer demand side, the EU and the US have sought to spur domestic EV manufacture by limiting competition from Chinese imports; the EU introduced countervailing duties on EVs from China in 2024 to offset subsidies provided by the Chinese government to its value chain, and the US and Canada have imposed tariffs exceeding 100 percent on Chinese EV imports. These efforts are key in protecting the domestic industry, but imply higher costs for consumers, at least in the short term. Western consumer EV adoption rates, while still growing, are doing so at much slower rates.

These efforts have also increased pressure on a Chinese market already managing extreme supply gluts. Utilization rates across EV production facilities are averaging 50 percent, with several producers remaining open with less than 5 percent of capacity utilization; this situation is clearly unsustainable given the high fixed costs of these factories. Meanwhile, an aggressive price war has been unfolding between BYD and CATL, the top two producers, as they vie for market share. This is ironically great news for adoption—EV sales grew 40 percent year over year in 2024 in China—but not for battery mineral producers everywhere seeking to supply these producers.

Further, this story is not unique to EV production; China is also managing overcapacity in mineral refining and smelting. In copper markets, for instance, refiners generally apply treatment charges (TC) to process ore. However, due to refinery overcapacity (or mine undercapacity), market TC rates have been zero in some cases and may even go negative, such that refiners would *pay* producers to take ore. While this is positive for ore exporters, it creates a less-than-favorable environment for producer countries to invest in downstream capacity. Similarly, overcapacity in zinc, aluminum, and nickel refineries and smelters is eroding profitability across the sector and is pushing even established Western facilities such as Glencore to seek government support.

Transition-Critical Minerals Now and Tomorrow

In this context, transition-critical mineral markets need to be considered with more scrutiny; what minerals do energy transition technologies demand, and in what relative quantities? What is the current scale of opportunity in these markets, and how is that expected to change with the transition? How sensitive are these expectations, and the related potential for required minerals, to the pace of the transition and rapidly evolving technologies and material intensities?

Transition-critical minerals have a wide range of applications; some are critical to only one or a couple of key end-uses—such as molybdenum, zinc, or cobalt—while others are required more ubiquitously—such as copper or aluminum.

Table 1: Energy transition uses of selected commodities

Commodity	Key Energy Transition Uses
Aluminium	Solar PV, CSP, Electricity networks, EVs, Battery Storage
Chromium	CSP, Geothermal
Cobalt	EVs, Battery Storage
Copper	Solar PV, Wind, Bioenergy, Electricity networks, EVs, Battery Storage
Graphite[8]	EVs, Battery Storage
Iron	Electricity networks, EVs

[8] Both natural and synthetic graphite are used in battery production. Natural graphite deposits vary in quality; only high quality “flake” and “crystalline vein graphite” are used in lithium-ion batteries (along with synthetic graphite production).

Lithium	EVs, Battery Storage
Manganese	Wind, EVs, Battery Storage
Molybdenum	Wind
Neodymium	Wind, EVs, Battery Storage
Nickel	Geothermal, EVs, Battery Storage, Hydrogen
Platinum Group Metals (PGMs)	Hydrogen
Silicon	Solar PV, EVs, Battery Storage
Silver	Solar PV
Rare Earth Elements (REEs)	Wind, EVs, Battery Storage
Zinc	Wind

CSP = Concentrated solar power
EV = Electric vehicles
PV = Photovoltaic

From Geopolitics of the energy transition: Critical materials (IRENA, 2023) and others.

In assessing the scale of opportunity that transition-related demand growth may offer to producer countries across each of these minerals, three factors need to be considered for a given commodity: i) its current market size, ii) how the *overall* energy transition will affect demand growth (i.e. the share of transition tech demand across all its end uses), and iii) how *concentrated* its future demand is expected to be in *particular* transition-relevant technologies (i.e. the diversity of transition use). Each of these factors is essential information for producer countries: the first two, because they speak to the total future market size; the last, because it informs both the robustness of the market to different technological pathways the energy transition might take and the potential routes for downstream value capture. And each of these factors varies considerably across transition minerals.

Transition-critical commodity markets are a fraction of the size of primary fossil fuel markets. According to the Observatory of Economic Complexity, mineral fuels, oils, and products generated a global trade value of $3.16 trillion in 2023 and represented 14 percent of world trade. In the same year, *all* ores, slags, and ash products combined represent only 1.5 percent of world trade, generating $348 billion in value—about 10 percent of fossil fuels' value. Further, iron ore alone accounts for 47 percent of this value, and copper ore accounts for another 27 percent—together these two products, which are essential across infrastructure applications, represent about three-quarters of global primary mineral markets.[9]

[9] Of course, not all transition-critical "minerals" are ore products—lithium is a salt, and in most forms it is considered a "chemical product."

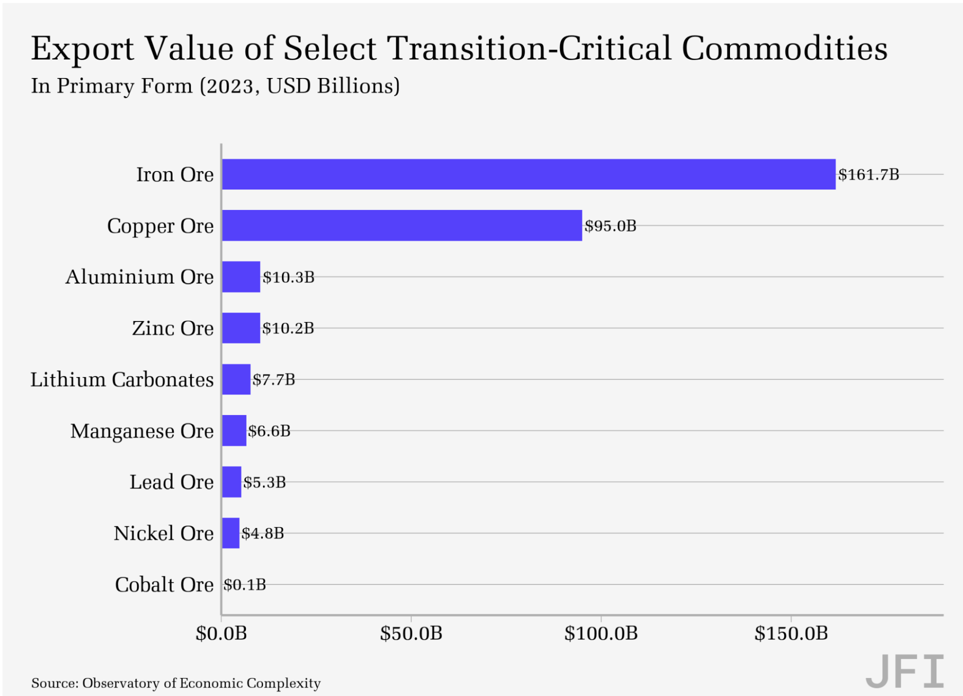


Figure 7: Global trade value of selected transition minerals in 2023 according to the Observatory of Economic Complexity. These figures correspond to the primary forms of the commodity—cobalt ores only generated $0.10 billion in trade value in 2023, but refined forms of cobalt generated $5.27 billion.

However, while fossil fuel supply chains are relatively short—94 percent of fossil fuels are burned for energy consumption—mineral value chains are longer and more complex, accumulating value along the way, to be manufactured into products that last 10–30 years, with potential for recycling and reuse. The motivation for primary commodity exporters to develop even initial processing and refining capabilities (and recycling of scrap) is clear: higher-complexity metal products had a global trade value of $1.54 trillion in 2023, more than four times the value of their primary products. For some commodities, the comparison is even more stark. Finished aluminum products (including scrap) generated $232 billion in global trade value, compared to $10.3 billion for aluminum ore (bauxite). In the case of cobalt, refined forms and scrap generated more than 50 times as much trade value compared to trade in its primary form.

In grounding the expectations of transition demand growth, it's essential to recognize that these mineral products have varying dependence on—and sensitivity to—transition technology requirements. While lithium markets have been strongly impacted by EV market uncertainty, nickel prices have been far less volatile in response (see Fig. 2). This is in part because battery-grade nickel represents a smaller share of total demand: currently, EV battery demand accounts for less than a fifth of nickel's end use (nickel is primarily used in stainless steel, also an essential infrastructure material), whereas the majority of lithium demand is already linked to the energy transition and is expected to grow significantly in that context.

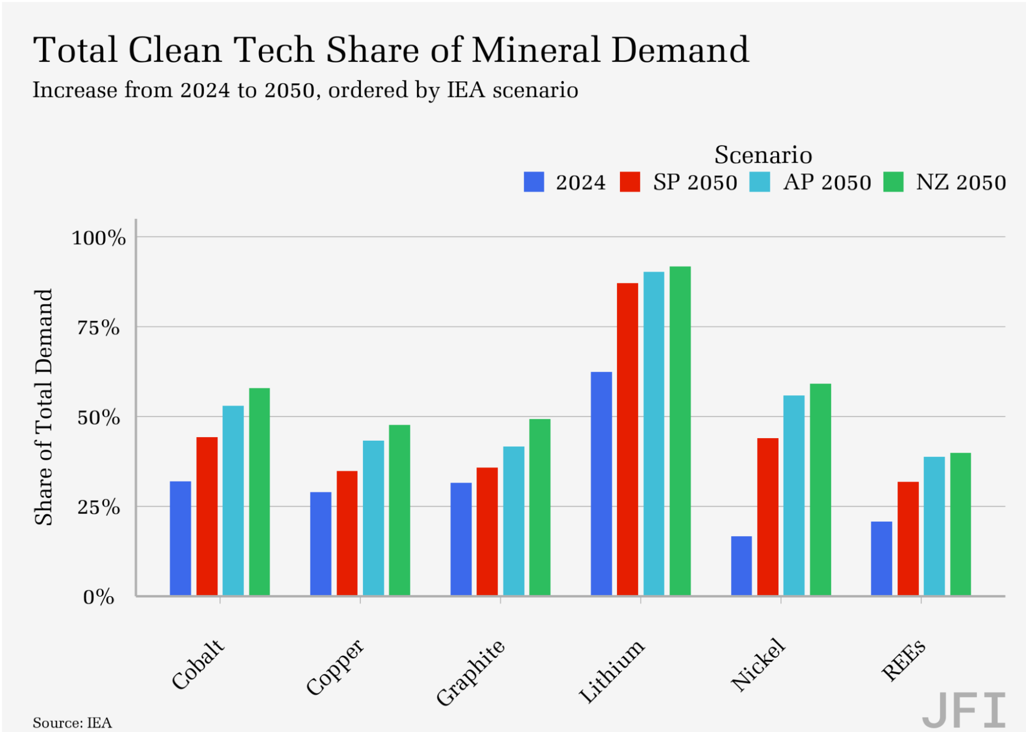


Figure 8: The current share of total transition demand for selected minerals now and in 2050 according to IEA's three scenarios: Stated Policies (SP), Announced Pledges (AP), and Net Zero (NZ).

Further, the growth expectations above are driven not only by assumptions of the pace of the transition, but also by the mix of technologies adopted and the material intensity of these products. Aggressive nickel demand growth projections linked to the transition (Figure 8) are expected to be driven largely by lithium-ion batteries in vehicles and energy storage systems (Figure 9). These expectations, however, depend on the continued dominance of nickel-based cathode technologies, which are currently being challenged by lower-cost lithium-iron phosphate batteries, especially for passenger vehicles. Contrast this with copper, which has more moderate growth expectations across scenarios (Figure 8), but far more diverse end uses (Figure 9), and a much larger global market, as discussed above.

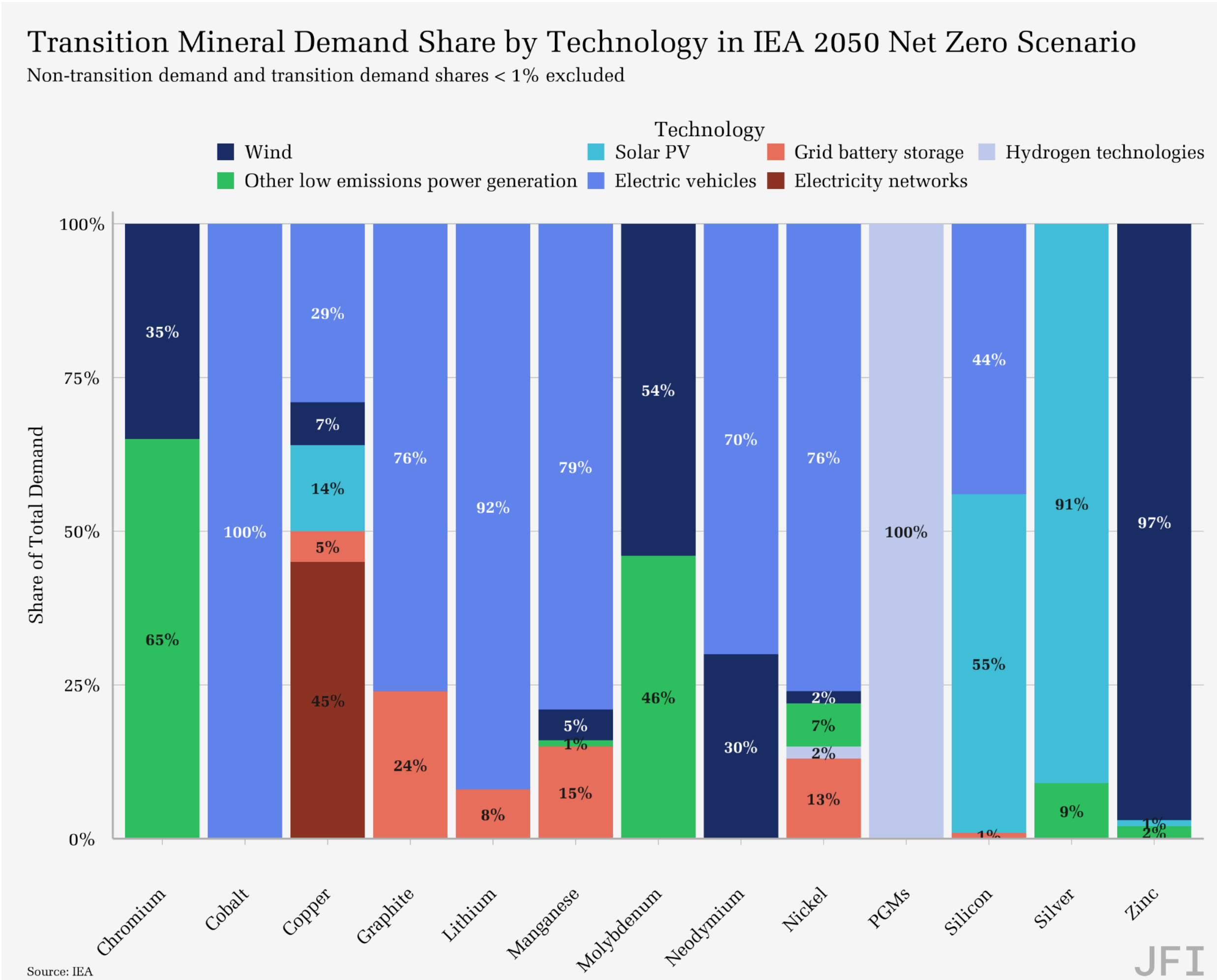


Figure 9: The mix of transition end uses by mineral in the IEA Net Zero 2050 Scenario. Demand shares that represent less than 1 percent are dropped from the figure for legibility. **Non-transition demand is excluded.**

Finally, the growth of mineral markets and the overall opportunity that they may present to producer countries in the future depends on the interaction of two key factors: market volume (quantity) and value (price). As discussed in our last report, scenario-modeling-driven expectations for demand growth and supply forecasts are often disjointed, meaning they do not allow for feedback between these two layers, which is usually signaled through market prices. It is likewise very difficult to capture that the mineral intensities of technologies, and the type of technologies being adopted for decarbonization solutions, are extremely dynamic and mutable in practice (though there are robust solutions to mitigate some of these shortcomings in scenario modeling).

As an example, average silver intensity per installed solar module has halved over the past decade, with potential for further innovation. This economizing is a direct response to silver's high cost: though it makes up less than 0.1 percent of module weight, it accounts for around 10 percent of manufacturing cost. There are limits to these efficiency changes, since silver is essential for conductivity and producers cannot completely substitute it away. However, even this limit does not apply to other contexts; lithium-iron-phosphate batteries are an example of manufacturers innovating away entirely through substitution to lower both costs and social risks of their production.

Thus, the assumptions that scenario models make—both macro-level and technology-level—determine the outcomes. Our analysis shows that projections from leading expert groups, including IEA, BNEF, and S&P, vary considerably across groups and within scenarios, demonstrating both how sensitive projections are to their assumptions and how uncertain the future market volumes pathways are:

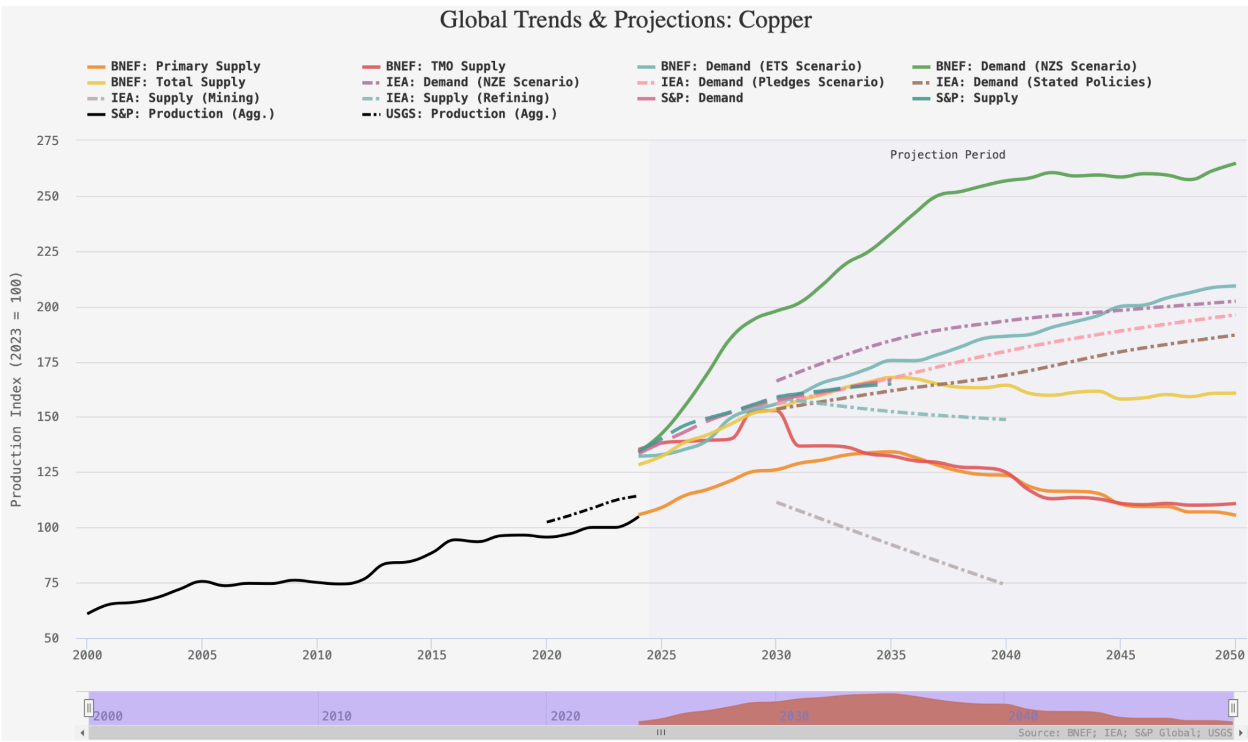


Figure 10: Varying projections of copper market growth across demand and supply scenarios, benchmarked to S&P's estimation of aggregate market volume in 2024. From JFI's Mineral Market Dashboard with data from S&P Global, BloombergNEF, and the IEA. See the Appendix for other mineral market comparisons.

The other key element, market value, is even more challenging to account for. The scale of opportunity is measured in potential revenues, not volume, and revenues depend on commodity price movements. To highlight an example explored in our last report, Sigma Lithium's Grota Do Cirilo mine has consistently hit production targets presented in its January 2023 feasibility study (when lithium prices were at peak), but with lithium concentrate prices falling rapidly and consistently since then, the project has likely been achieving gross revenues at just 35 percent of projections in year one and 14 percent of expectations in year two, with harsh implications for local royalty revenues.

Though this represents an extreme example, it highlights the broader truth: commodity prices are volatile, cyclical, and uncertain. They are sensitive to a suite of risks and uncertainties that range from the natural (geological variability, extreme weather), to project-level (spikes in water or energy costs, social resistance), to domestic and international policy (interest or exchange rate changes, fiscal regime changes, trade policies, political instability), to name a few. Smooth-line scenario projections of market size out to 2030 or 2050 (like the ones above) can be quite misleading, and producer countries' abilities to capitalize on the potential that transition-mineral market growth represents will depend on their ability to navigate volatility in practice.

As an example, consider the 2022 and 2050 market size comparisons in BloombergNEF's 2023 *Transition Metals Outlook*. The report publishes two scenarios of market volume growth based on an *Economic Transition Scenario* and *Net Zero Scenario* (Figure 10 above includes copper estimates for the 2024 edition). Interacting these volumes with prices is key to demonstrating how the relative opportunity in value terms can look very different. For example, compare steel and copper's relative importance in volume terms on the left to value terms on the right.

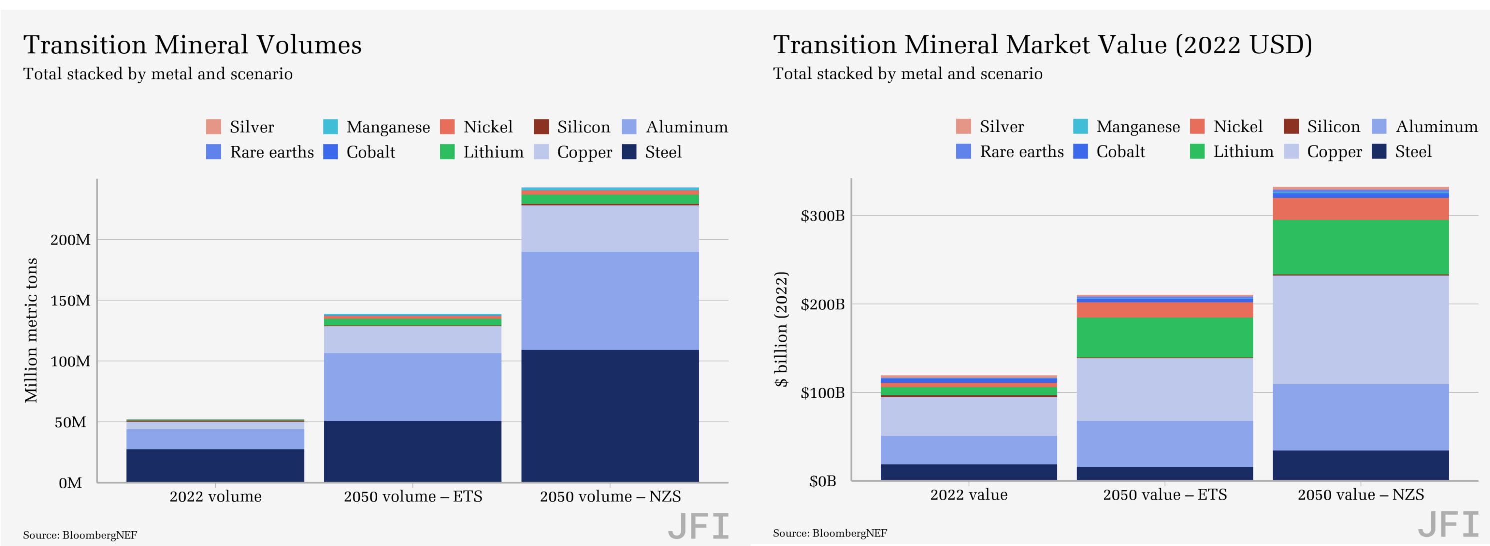


Figure 11: Transition mineral volumes vs. value in 2022 and in 2050 according to the *Economic Transition Scenario* and *Net Zero Scenario* in BloombergNEF's *2023 Transition Metals Outlook.*

While the chart is useful for understanding the volume vs. value nuance, in reality, what this comparison will look like in 2050 is far less straightforward. Utilizing market volume projections from the demand outlook scenarios, the BNEF illustration has three steps: i) use (nominal) average annual prices from 2012 to 2022 to determine a historical average price, ii) multiply these prices by market volume in both 2050 scenarios, and iii) discount 2050 market values to 2022 for comparability, using a 2.75 percent annual inflation rate (which is "in line with the average rates for major economies where demand is concentrated").

To consider more critically the scale of opportunity that transition-critical minerals may offer, however, it's useful to unpack two key shortcomings. The first, comparatively minor, is that the existing baseline computation does not adjust historical values for inflation. The second, far more substantial, is that this illustrative forecasting method such as these risks misleading the broader audience about the extreme uncertainty these markets face.

To highlight the long-term uncertainty in transition-critical mineral markets and the sensitivity of outcomes to modeling assumptions, consider instead a rolling 36-month average of five key commodities (copper, aluminum, nickel, cobalt, and lithium) using observations from January 2009 through July 2025 (about the same period as BNEF analysis, but with more recent data). As is clear in Figure 12, *when and how* an average price is taken has key implications for analysis. For example, BNEF executed this analysis in 2022, the year when battery mineral prices—particularly lithium—were at peak.

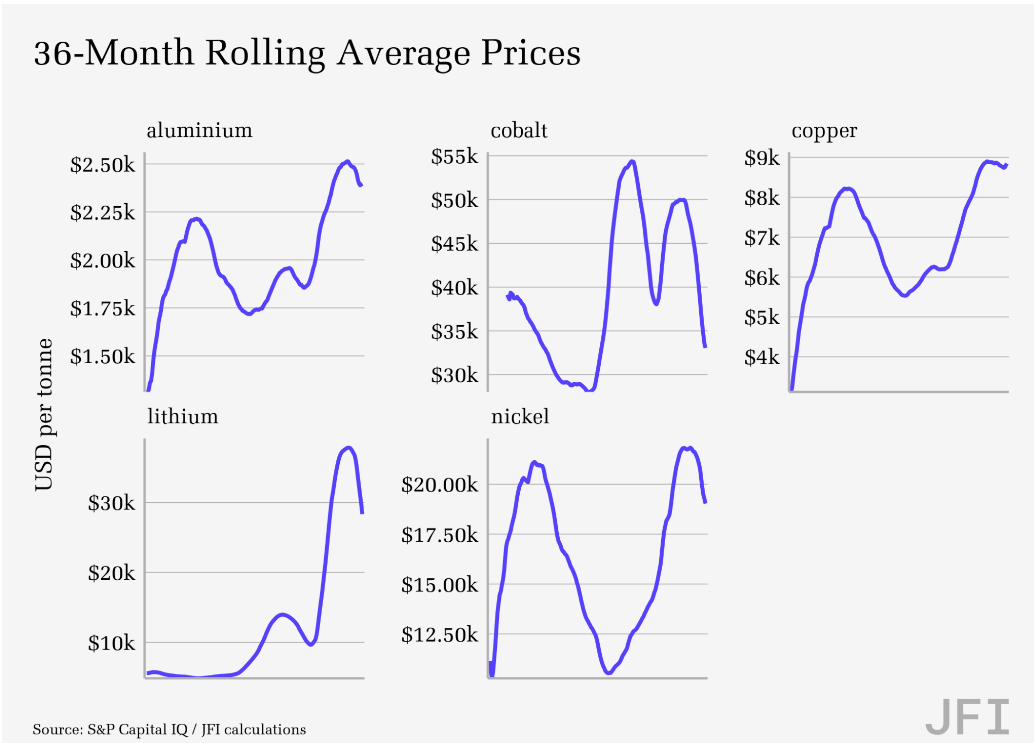


Figure 12: The rolling 36-month average price of aluminum, cobalt, copper, lithium, and nickel from January 2009 to July 2025. The second month averages across only the first and second months; the 36th month averages across all months in the data, and then the following months drop the first month of data from the average, and so on. This approach captures market volatility while also dampening the price swings.

In some cases, price volatility can have an even greater impact on projections for future market size than scenario modeling results of future market volumes. To illustrate this, we take the highest and lowest 36-month average of these commodities and interact them with the market volume estimate in the *Economic Transition Scenario* (the more conservative scenario projection), similar to BNEF's approach but without the *Net Zero Scenario* outlook.[10] For consistency and comparability, we inflate the BNEF values into nominal terms using the 2.75 percent annual rate, and plot them alongside the potential "range" between the high/low price interactions.

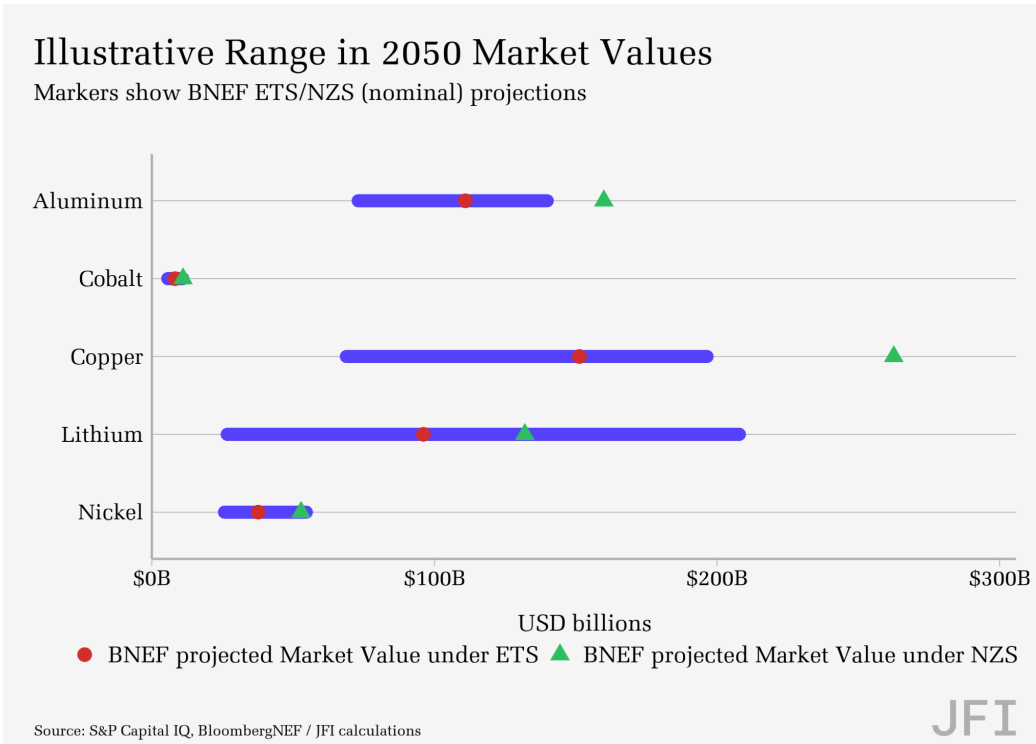


Figure 13: An illustrative range of future market values using the more conservative *Economic Transition Scenario* volumes and the highest/lowest values of the rolling 36-month average price of aluminum, cobalt, copper, lithium, and nickel from January 2009 to July 2025. The markers show BNEF's approach with the 10-year average price against the *Net Zero Transition Scenario* and the *Economic Transition Scenario*. Cobalt is a small market, so the distribution is less obvious than the other four minerals; the low-price case estimate for cobalt is $5.6 billion and the high-price case estimate is $10.9 billion, a 94 percent difference.

Other than copper and aluminum (which are larger markets in volume terms), price has a greater (or equal) impact on total value estimates than the demand scenario. On the low end, the percent difference between the two extreme values in 2050 ranges from about 46 percent for aluminum to as high as 680 percent for lithium, a difference of about $44 billion and $181 billion, respectively.

This is about much more than back-of-the-envelope modeling decisions: the reality that unfolds for transition-critical mineral markets has key implications for the sector and the countries that rely on it. Answering the question of which lithium projects are viable, and where, in the $181 billion world looks very different than it does for the $44 billion world. So too does the amount of potential tax revenues available (and scale of economic spillovers) to host countries for

[10] Thus the sample begins in January 2012, the first average with 36 months of data.

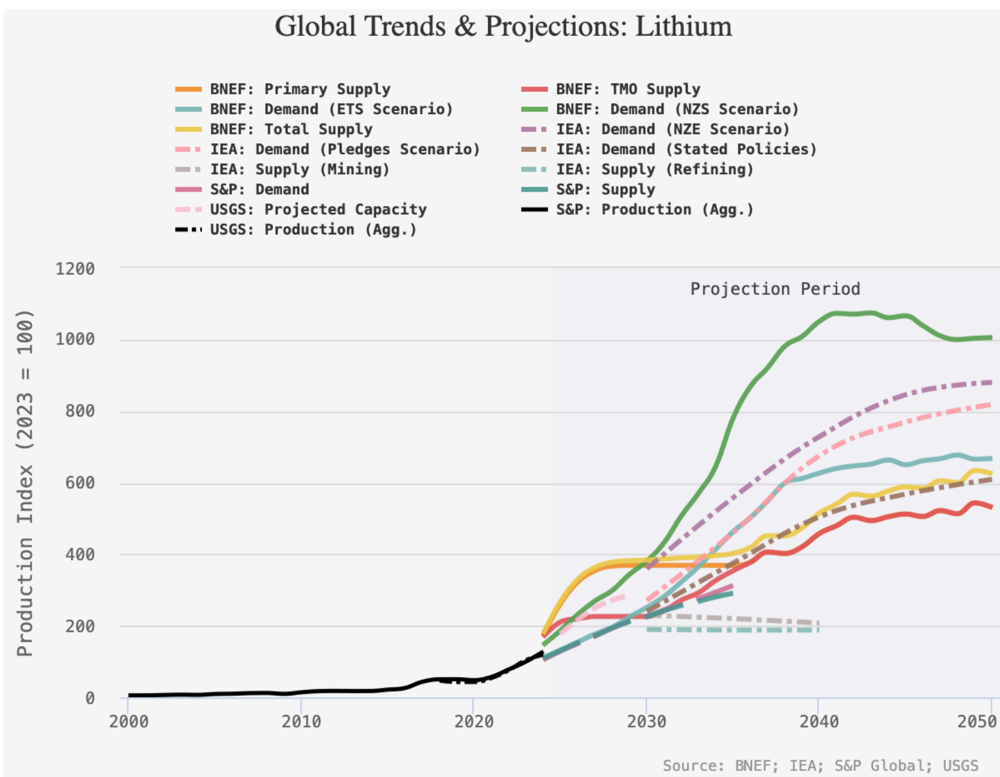
domestic resource mobilization; a gross revenue royalty rate of 2–5 percent (which is standard) implies a difference of $2.74–$6.85 billion in overall potential royalty revenues.

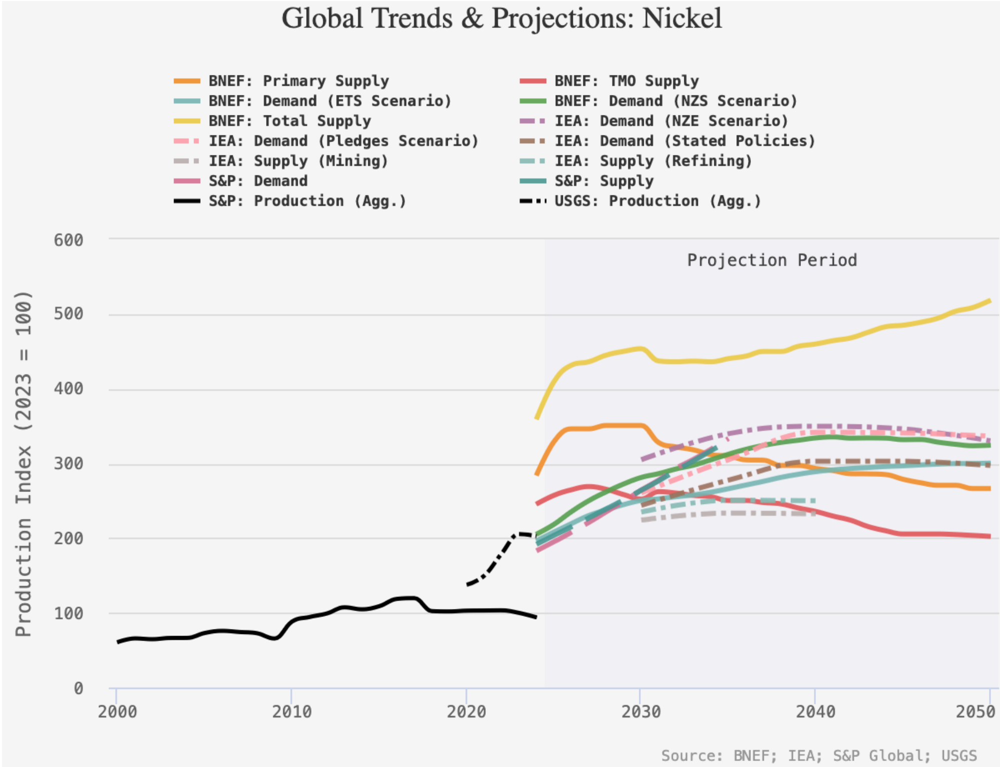
The future of mineral markets is promising, but deeply uncertain; it is essential to ground expectations for value capture and downstreaming policies within this volatility and develop policy objectives that can navigate it robustly. Without more grounded discussion and analysis, policymakers risk pursuing opportunities presented in illustrative and static views of the future, which may or may not transpire for a host of reasons, and risk being unprepared for other possible outcomes. In this context, there is an urgent need for a more critical examination of mineral market dynamics and implications for producer countries seeking to utilize the minerals sector as a springboard for development. In particular, research should focus on strategies for producer countries, especially LMICs, to navigate mineral market dynamics while attracting investment for development around the extractive sector; the role of stockpiling, strategic intervention, and trade partnerships in achieving both development and security objectives; the challenges and opportunities presented by market fragmentation arising from geopolitical tensions; the complexities of responding to price changes in both primary and co-product minerals; and deeper analysis of the conditions under which mineral market formalization delivers intended benefits.

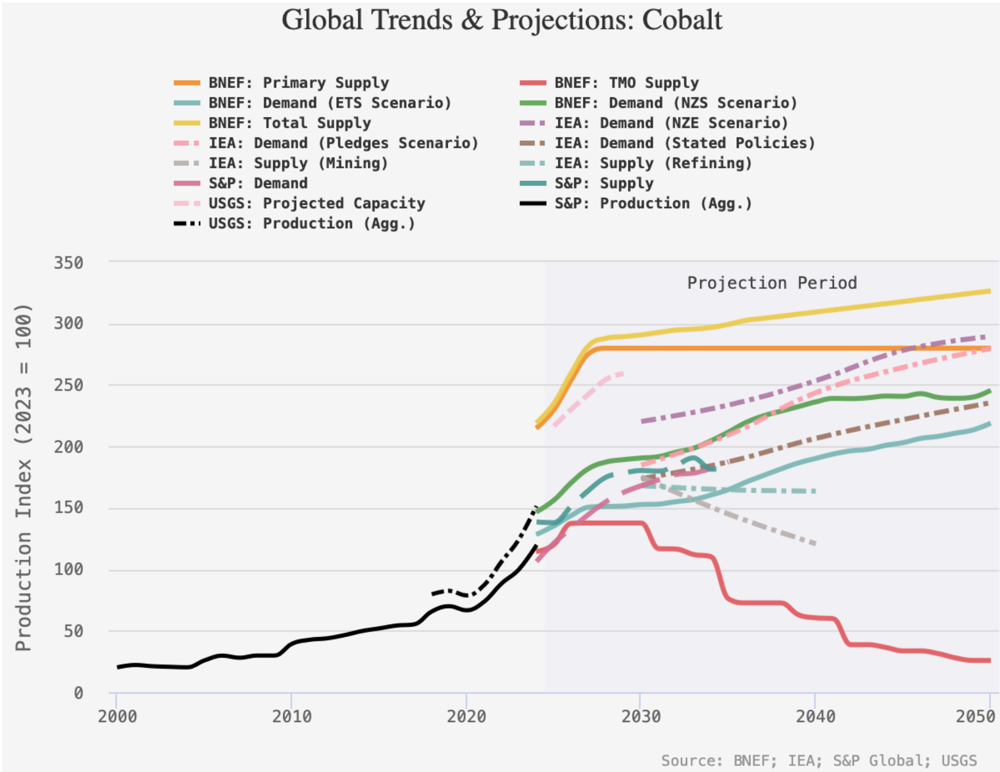
Appendix - Accompanying Figures from JFI's Mineral Market Dashboard

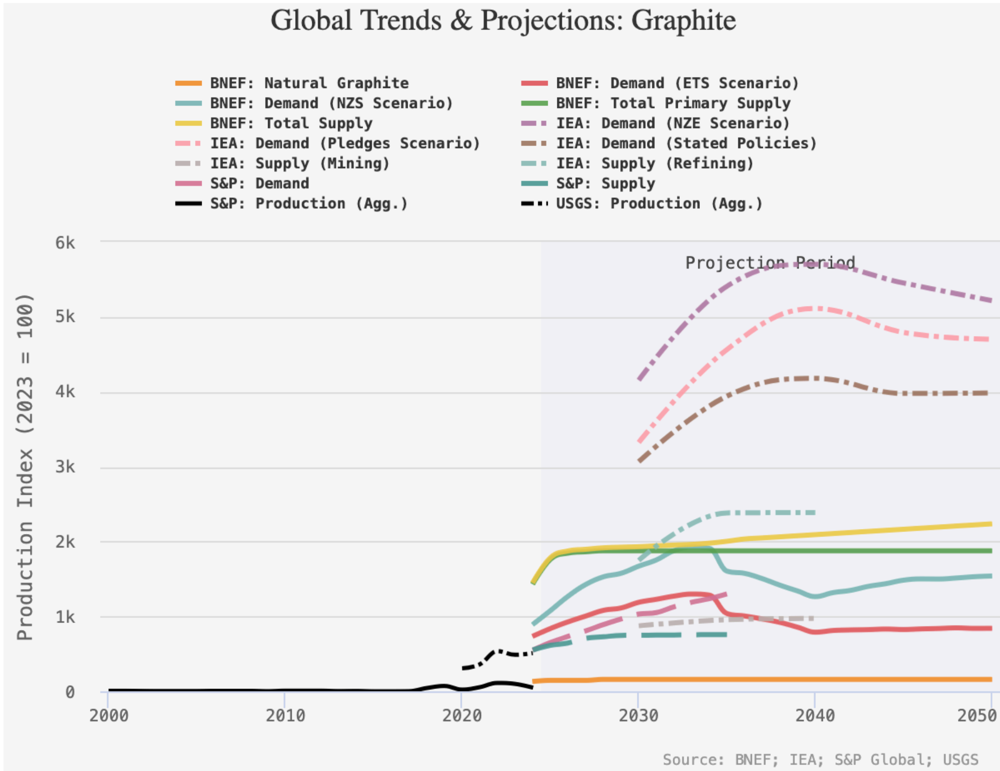
I. Scenario projections of other transition-critical minerals (excludes copper, featured above)

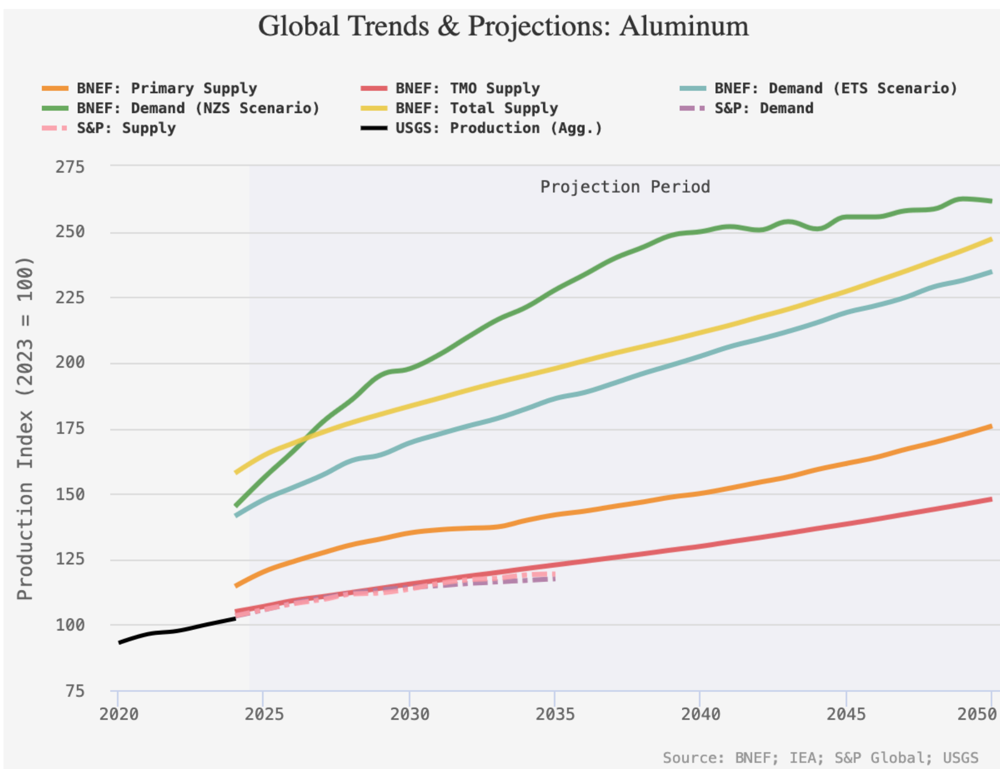
Note: Values are shown as an index to allow comparison across different data sources and various projection scenarios and forecasts. For all commodities except Aluminum, which references USGS 2023 Production, series are indexed relative to a common baseline derived from the values of the S&P 2023 aggregate production estimate. An index near 100 represents this approximate baseline level. This method shows relative trends and scale but prevents the calculation of precise raw data values.



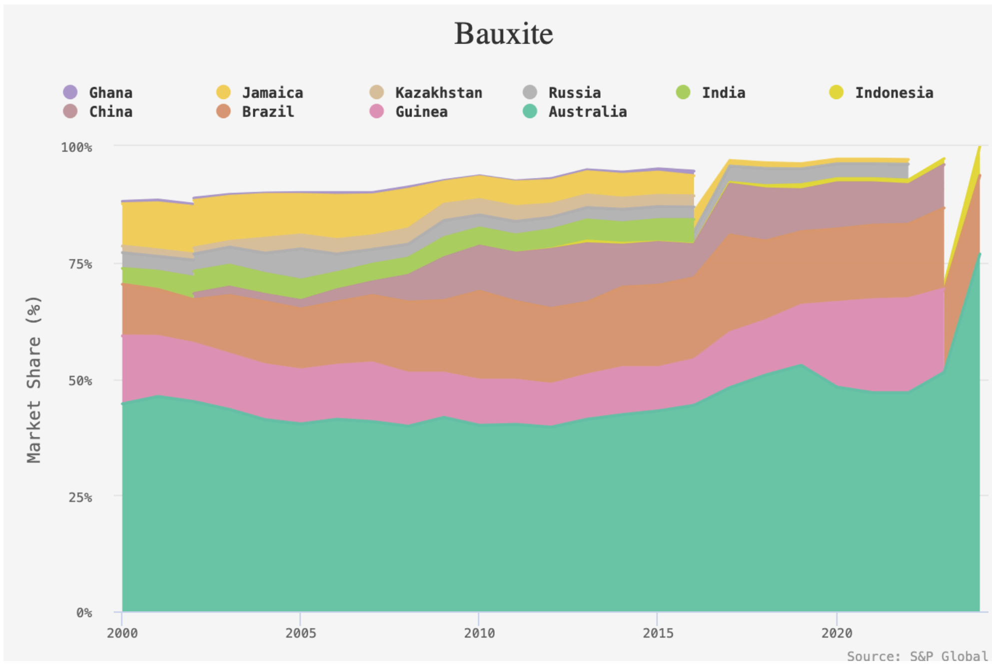

Global Trends & Projections: Nickel
BNEF: Primary Supply
BNEF: Demand (ETS Scenario)
BNEF: Total Supply
IEA: Demand (Pledges Scenario)
IEA: Supply (Mining)
S&P: Demand
S&P: Production (Agg.)
BNEF: TMO Supply
BNEF: Demand (NZS Scenario)
IEA: Demand (NZE Scenario)
IEA: Demand (Stated Policies)
IEA: Supply (Refining)
S&P: Supply
USGS: Production (Agg.)
Projection Period
Production Index (2023 = 100)
0
100
200
300
400
500
600
2000
2010
2020
2030
2040
2050
Source: BNEF; IEA; S&P Global; USGS

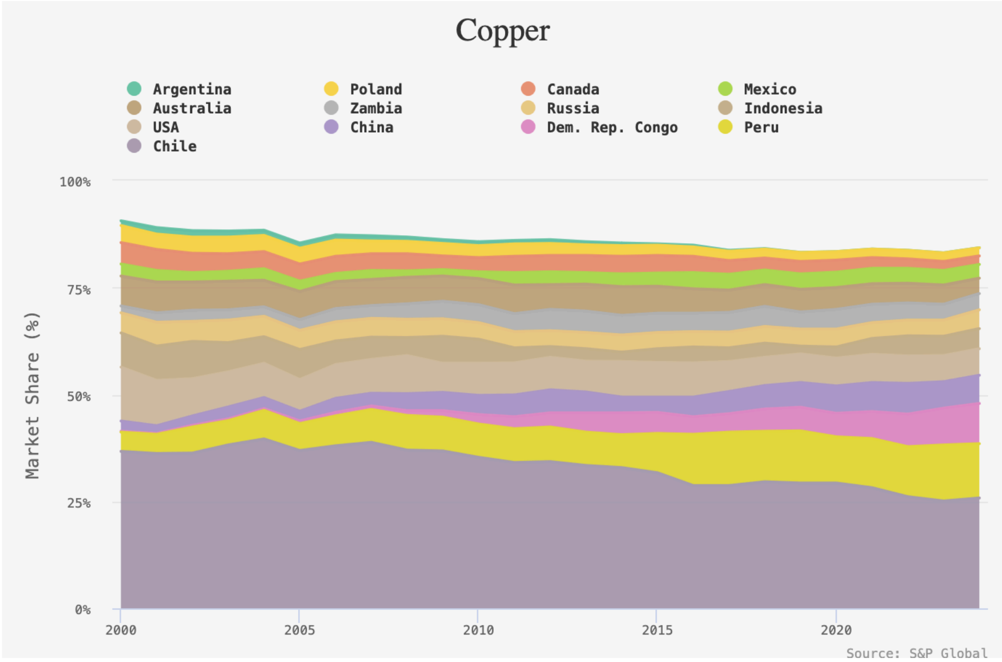

Global Trends & Projections: Cobalt
BNEF: Primary Supply
BNEF: Demand (ETS Scenario)
BNEF: Total Supply
IEA: Demand (Pledges Scenario)
IEA: Supply (Mining)
S&P: Demand
USGS: Projected Capacity
USGS: Production (Agg.)
BNEF: TMO Supply
BNEF: Demand (NZS Scenario)
IEA: Demand (NZE Scenario)
IEA: Demand (Stated Policies)
IEA: Supply (Refining)
S&P: Supply
S&P: Production (Agg.)
Projection Period
Production Index (2023 = 100)
0
50
100
150
200
250
300
350
2000
2010
2020
2030
2040
2050
Source: BNEF; IEA; S&P Global; USGS

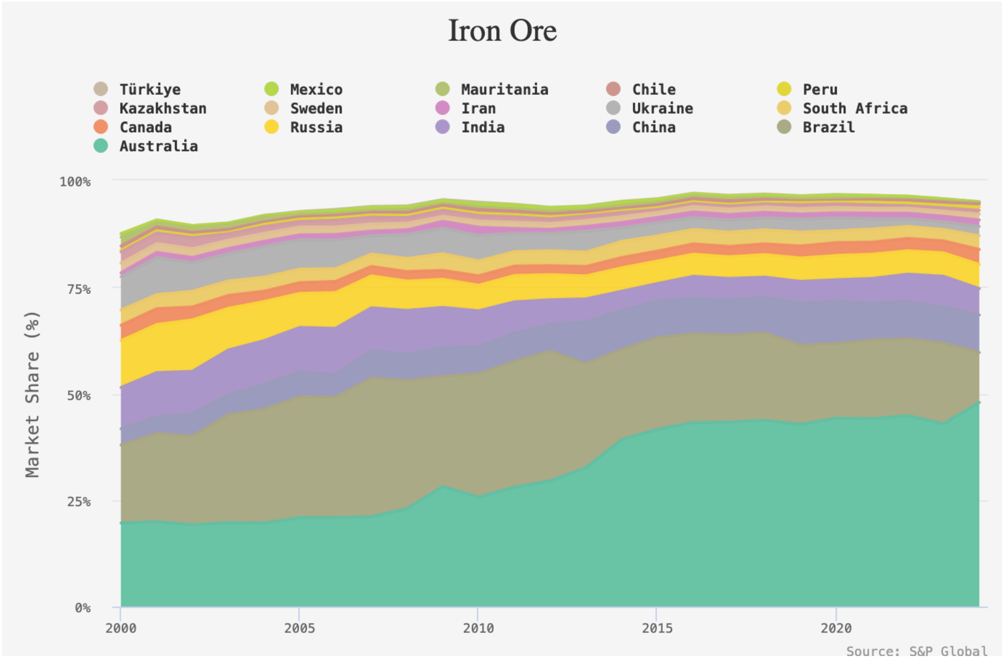

Global Trends & Projections: Graphite
BNEF: Natural Graphite
BNEF: Demand (ETS Scenario)
BNEF: Demand (NZS Scenario)
BNEF: Total Primary Supply
BNEF: Total Supply
IEA: Demand (NZE Scenario)
IEA: Demand (Pledges Scenario)
IEA: Demand (Stated Policies)
IEA: Supply (Mining)
IEA: Supply (Refining)
S&P: Demand
S&P: Supply
S&P: Production (Agg.)
USGS: Production (Agg.)
Production Index (2023 = 100)
6k
5k
4k
3k
2k
1k
0
Projection Period
2000
2010
2020
2030
2040
2050
Source: BNEF; IEA; S&P Global; USGS

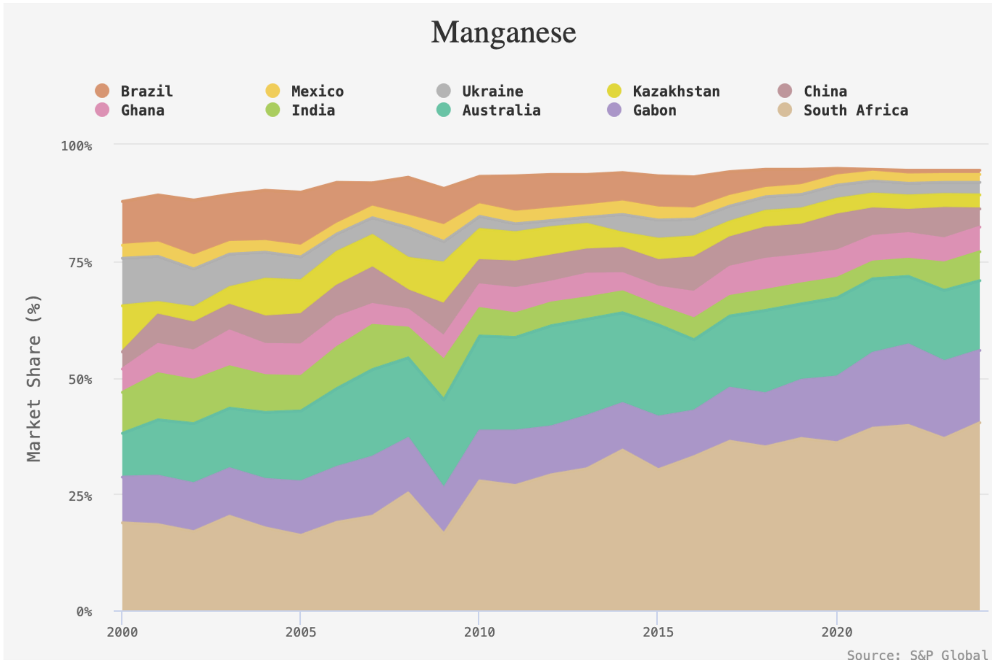

Global Trends & Projections: Aluminum
BNEF: Primary Supply
BNEF: TMO Supply
BNEF: Demand (ETS Scenario)
BNEF: Demand (NZS Scenario)
BNEF: Total Supply
S&P: Demand
S&P: Supply
USGS: Production (Agg.)
Production Index (2023 = 100)
275
250
225
200
175
150
125
100
75
Projection Period
2020
2025
2030
2035
2040
2045
2050
Source: BNEF; IEA; S&P Global; USGS

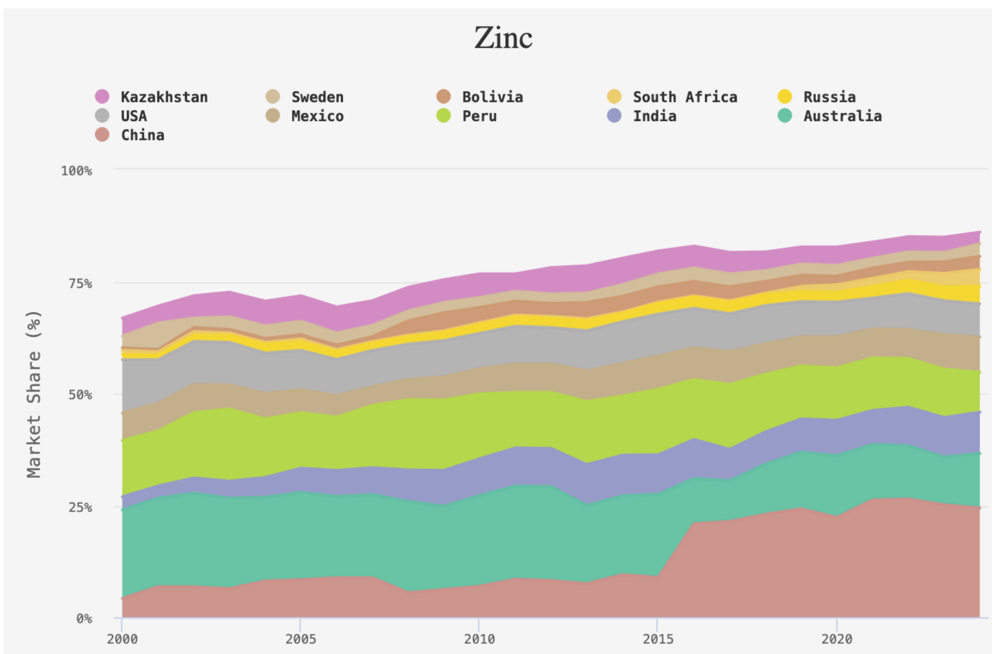
II. Leading producers of other transition-critical minerals (excludes lithium, nickel, and cobalt, featured above).




Copper
Argentina
Australia
USA
Chile
Poland
Zambia
China
Canada
Russia
Dem. Rep. Congo
Mexico
Indonesia
Peru
Market Share (%)
100%
75%
50%
25%
0%
2000
2005
2010
2015
2020
Source: S&P Global

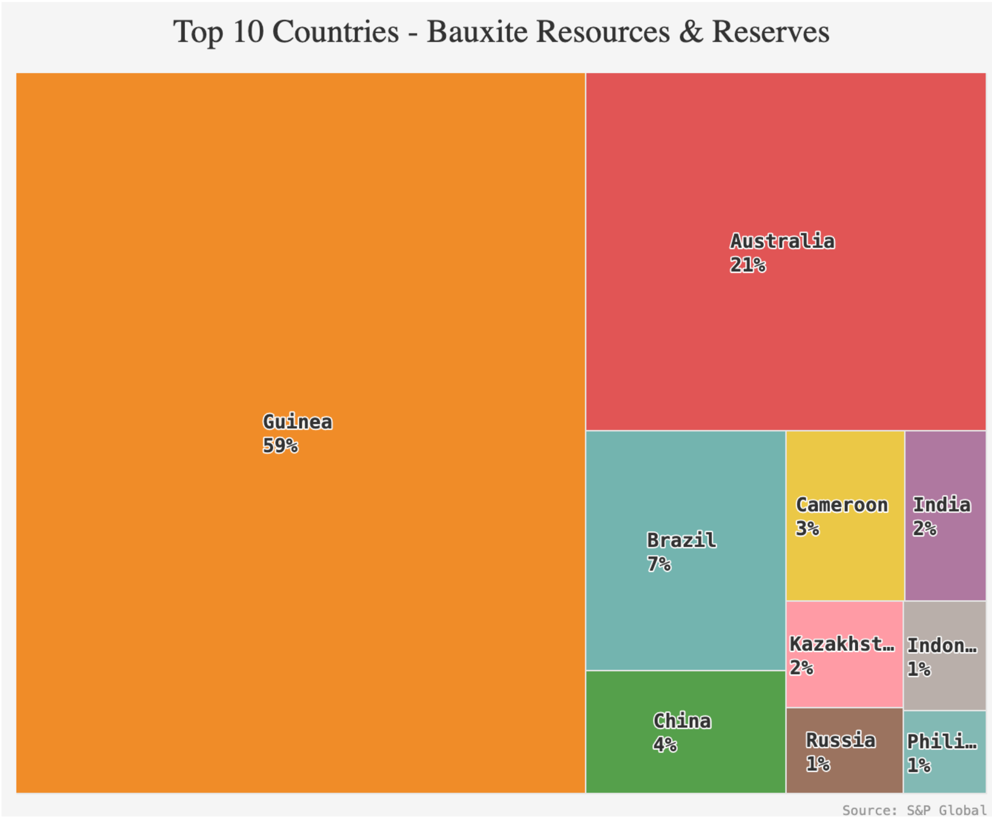

Iron Ore
Türkiye
Kazakhstan
Canada
Australia
Mexico
Sweden
Russia
Mauritania
Iran
India
Chile
Ukraine
China
Peru
South Africa
Brazil
Market Share (%)
100%
75%
50%
25%
0%
2000
2005
2010
2015
2020
Source: S&P Global

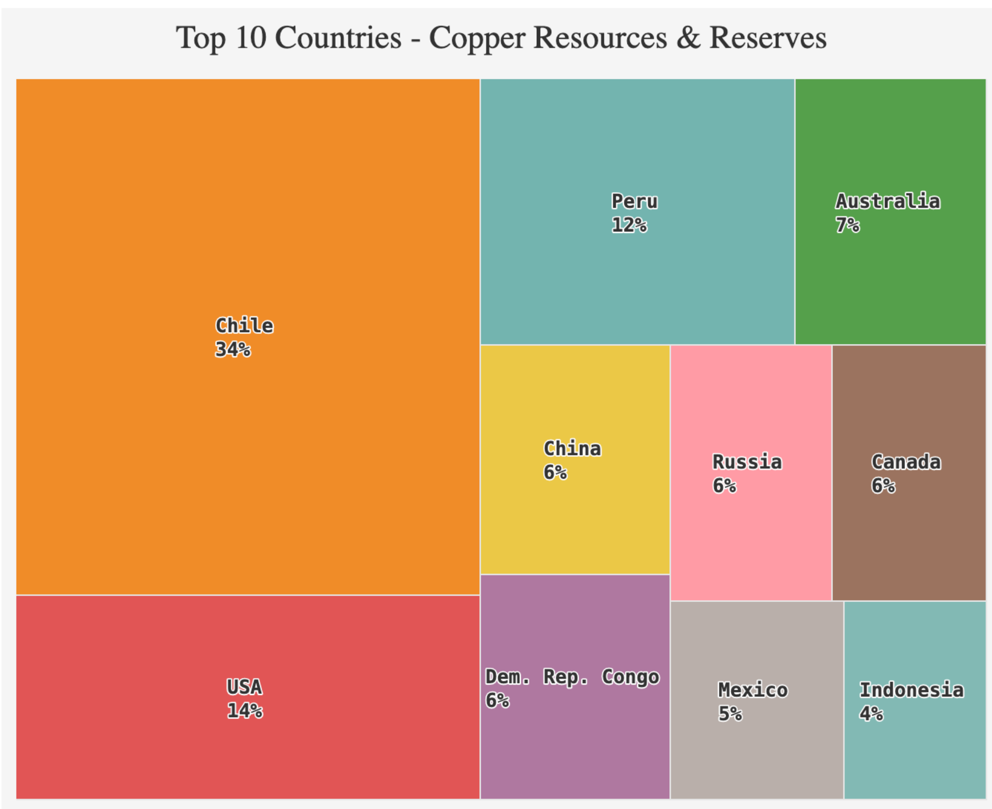


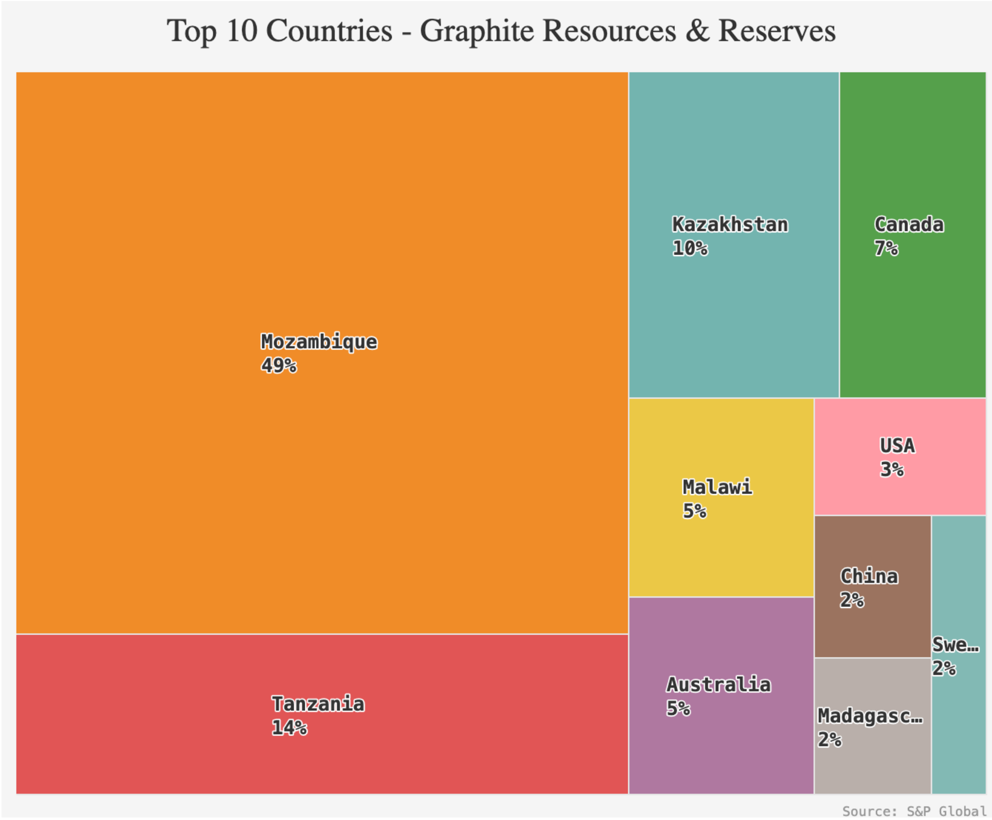


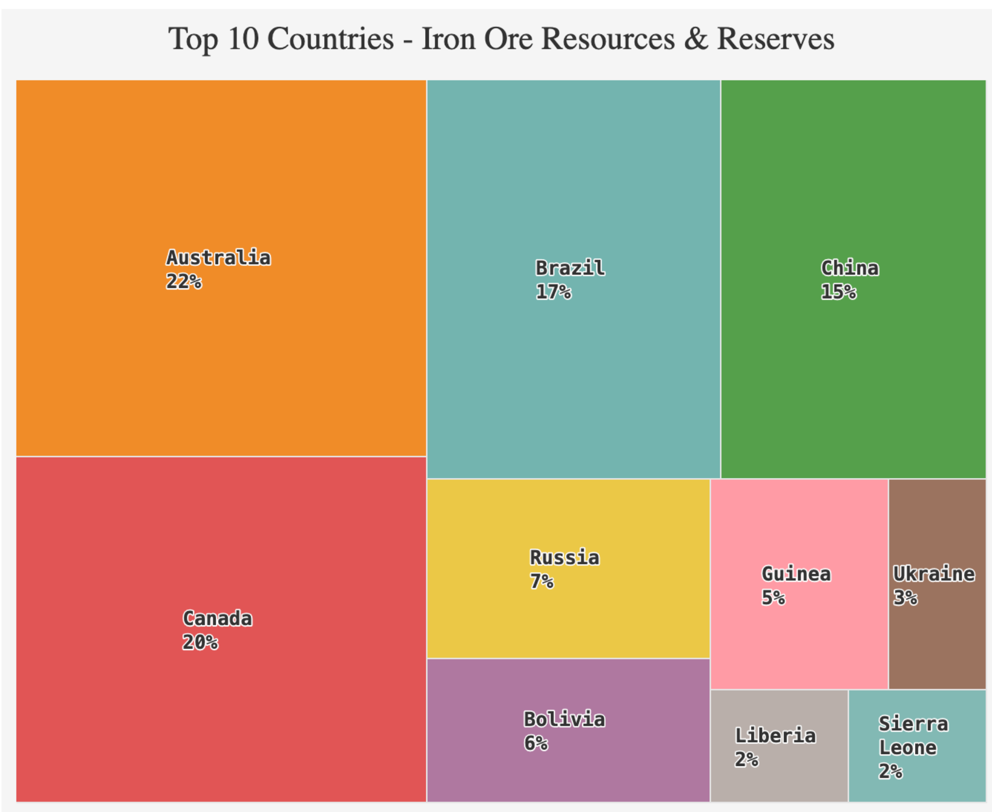
III. Countries with the largest resources and reserves of other transition minerals (excludes nickel and cobalt, featured above).

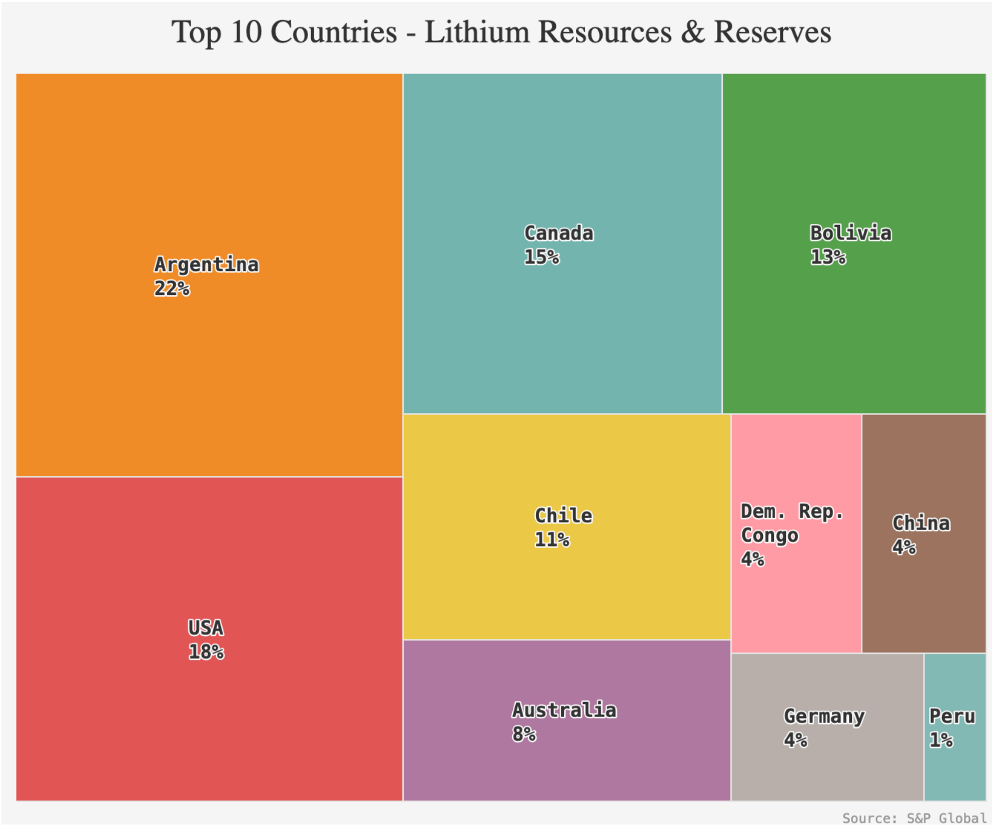
Note: These figures show the relative split of the top 10 countries only, so that both the names and resource estimates of other countries are excluded.

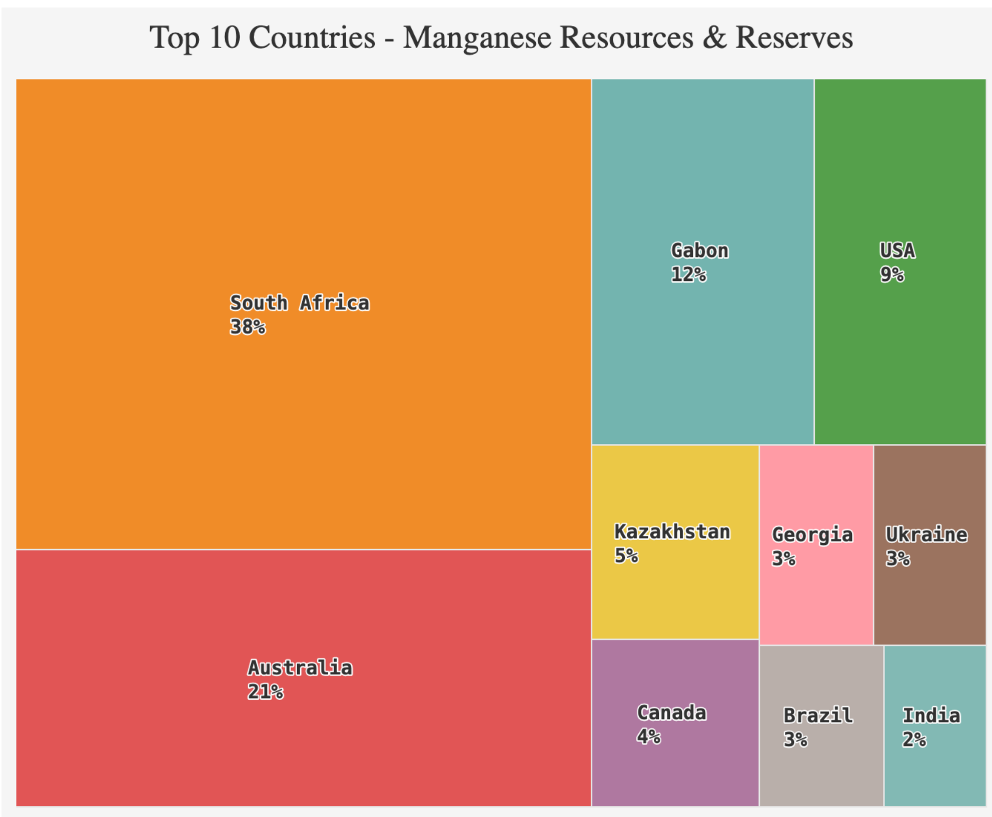

Top 10 Countries - Bauxite Resources & Reserves
Guinea 59%
Australia 21%
Brazil 7%
Cameroon 3%
India 2%
Kazakhst… 2%
Indon… 1%
China 4%
Russia 1%
Phili… 1%
Source: S&P Global


Top 10 Countries - Copper Resources & Reserves
Chile 34%
Peru 12%
Australia 7%
China 6%
Russia 6%
Canada 6%
USA 14%
Dem. Rep. Congo 6%
Mexico 5%
Indonesia 4%
Source: S&P Global

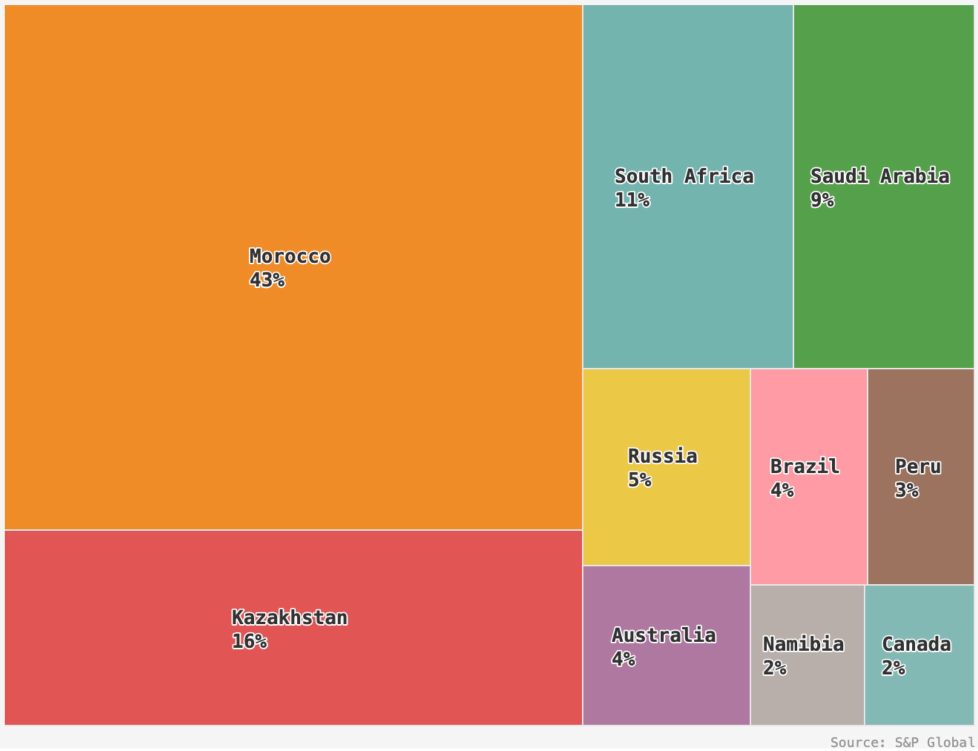

Top 10 Countries - Graphite Resources & Reserves
Mozambique 49%
Tanzania 14%
Kazakhstan 10%
Canada 7%
Malawi 5%
Australia 5%
USA 3%
China 2%
Swe… 2%
Madagasc… 2%
Source: S&P Global


Top 10 Countries - Iron Ore Resources & Reserves
Australia 22%
Canada 20%
Brazil 17%
China 15%
Russia 7%
Bolivia 6%
Guinea 5%
Ukraine 3%
Liberia 2%
Sierra Leone 2%
Source: S&P Global


Top 10 Countries - Lithium Resources & Reserves
Argentina 22%
Canada 15%
Bolivia 13%
USA 18%
Chile 11%
Dem. Rep. Congo 4%
China 4%
Australia 8%
Germany 4%
Peru 1%
Source: S&P Global


Top 10 Countries - Manganese Resources & Reserves
South Africa 38%
Gabon 12%
USA 9%
Australia 21%
Kazakhstan 5%
Georgia 3%
Ukraine 3%
Canada 4%
Brazil 3%
India 2%
Source: S&P Global

Top 10 Countries - Phosphate Resources & Reserves



Top 10 Countries - Zinc Resources & Reserves