

The Role of Critical Minerals in Clean Energy Transitions Have Policy-Makers Given Investors a Secular Growth Story for Cyclical Stocks?

Our research is empirically based and tends towards places that are uncomfortable and out-of-favor. In 2020, as investors gorged on crypto, loss-making tech and growth stocks of dubious merit, we wrote a wall-of-work explaining the empirical case for the opportunities in energy and staples. One sector we purposefully avoided was the mining sector.

Our small and midcap model accumulated a mining weight roughly 3x the index by June 2020. Trying to pitch oil, gas, and grocery stocks amidst a speculative frenzy was a plenty-miserable affair. Miners struck us as a bridge-too-far. Interestingly, despite their explosive performance, the fundamentals have run even faster.

These commodity stocks face operating challenges that vary widely by geography, the resources they are extracting and relentless cost pressures from ruthless competition. Worse, a good deal of the long-term thesis for end-demand relies on the movement to a green electric grid and shift the world from internal combustion vehicles (ICE) to battery electric vehicles (BEV). That led to further hesitation. **Here's why:**

In 2021, Toyota explained that three hybrids (HEV) cut CO2 output by the same amount as one BEV. At the time of publication, Toyota had sold 18 million hybrids. Those 18 million HEVs cut CO2 output by the equivalent of nearly 6 million BEVs. **So, 18 million hybrids got us the benefit of ~6 million battery electric vehicles.**

The difference? The **batteries** used to make Toyota's 18 million hybrids would only make 260,000 battery electric vehicles. The importance of understanding this cannot be overstated.

Let's beat it to pieces using this very real-world example:

1. You are intent on reducing the world's CO2 emissions and you have some batteries
2. Those batteries can make either 18,000,000 hybrids **or** 260,000 battery electric vehicles
3. 18 million hybrids will reduce CO2 by the same amount as 6 million battery electric vehicles

Same number of batteries. You get the benefit of 6 million BEVs by building hybrids rather than actually building 260k BEVs. [20x the CO2 reduction by building hybrids.](#)

We thought facts like these would resonate with environmentalists looking for the most efficient method to cut CO2 output. **We were wrong.** To the degree society cares about the CO2 benefits, the limitations around mining supply and the impact of battery manufacturing, the appeal of hybrids and plug-in hybrids is obvious.

But that narrative is in the "middle," less prone to polarization, dogma and, apparently, policy adoption. To be clear, Toyota has long embraced a scientifically driven approach to CO2 reduction that included everything from hybrids to pure BEVs. As [Gill Pratt](#), the remarkable head of Toyota Research Institute explains, their diverse approach acknowledged the limitations in supply chains and the benefits of a **diverse** set of scientifically sound solutions to a complex problem.

For the open-minded, we highly recommend reading some of his work found [here](#), [here](#), [here](#) and [here](#). Reading his practical and evidence-based thoughts, it is difficult to believe the [press](#) has lambasted this company's environmental intentions and credentials.

Under relentless pressure from environmental [groups](#), Toyota appears to have recently caved. In October the press [reported](#) the company may be overhauling their approach to electrification. The world appears to be going "whole hog" on BEVs as **the** solution.

For fans of Tesla's stock and the green grid, we think this article may be of great interest to you. The electrification of transportation is going to require a massive amount of mining. The stocks are incredibly cheap. KCR's model portfolios are investing in these stocks and, if you are a believer, these stocks may offer tremendous leverage to a long-term secular story.

The Big Dig & the Quest for Minerals to Electrify Transportation

This research will focus on the IEA's remarkable report [The Role of Critical Minerals in Clean Energy Transitions](#).ⁱ We found the scope and depth of the IEA's research on the challenges facing the mining industry stunning. While the press regales us with stories about the waves of new BEVs coming to market, much less attention has been focused on the dirty business of mining.

Our comments on the report attempt to summarize and explain the yawning disparity between supply and demand. At over 280 pages, KCR most certainly failed to capture more than the broad strokes in what is a remarkably detailed piece of research. But the message is clear.

Supply shortages are meaningful and imminent. In the next seven years, many minerals will face tight market conditions. The "...supply from existing mines and projects under construction is estimated to meet only half of...lithium and cobalt requirements and 80% of copper needs by 2030."ⁱⁱ As the IEA's Executive Director put it:

There is a looming mismatch between the world's climate ambitions and the availability of critical minerals...this mismatch is something that worries us. Copper is the main ingredient for the electrification initiative. The world has enough deposits to meet demand but...the investors have not yet been convinced by governments' pledges to reduce emissions..." -Faith Birol, IEA Executive Directorⁱⁱⁱ

A recent cover-story by Automotive News lead with the startling image below. The cover asks "... where on earth are all the materials going to come from?" While that [article](#) is a quick and compelling summary of the problems in the US, let's dig in to the global challenges as explained by the IEA's terrific report.



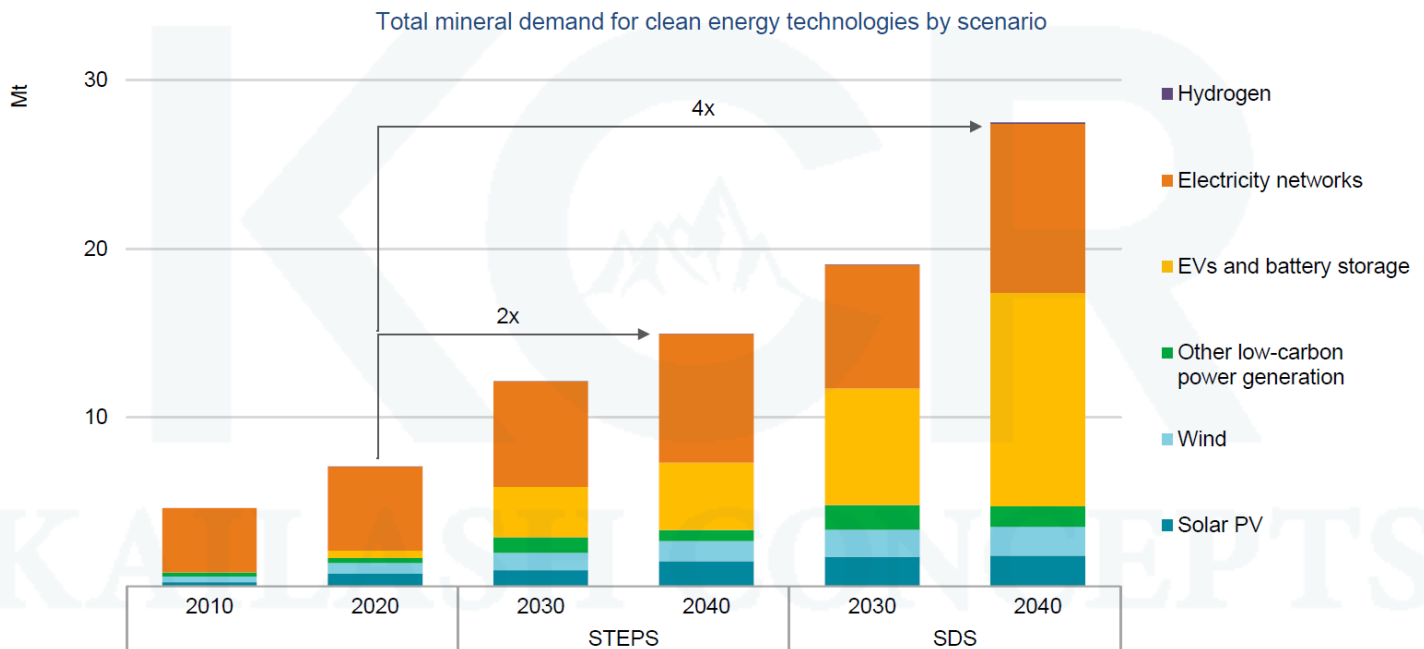
The Growth in Mineral Demand in One Chart

The IEA’s projections contemplate two future scenarios. The first is the “STEPS” which shows how demand will change based on **current policies**. The second scenario is the “SDS” which is how the demand function will change if the world’s member countries to the Paris Agreement hit their commitments. What’s remarkable about the SDS (Paris Agreement) goals is that these numbers are **not** the Net Zero 2050 numbers. The Net Zero 2050 numbers would be significantly **higher** than anything you will see in this piece.

The chart below shows the total change in annual mineral demand by these scenarios. Demand growth is enormous. Even more remarkable, these changes include efficiency gains based on technological improvements. Specifically, the IEA report contemplates 11 different cases under **both** scenarios to capture changes in technology where appropriate.^{iv}

Despite incorporating significant future efficiencies, the IEA predicts that mineral demand will grow 4x.

Total mineral demand from clean energy technologies is set to double in the STEPS and quadruple in the SDS by 2040



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Notes: Includes all minerals in the scope of this report, including chromium, copper, major battery metals (lithium, nickel, cobalt, manganese and graphite), molybdenum, platinum group metals, zinc, REEs and others, but does not include steel and aluminium (see Annex for a full list of minerals). Mt = million tonnes.

Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 46

Summarily: This forecast is not simple linear extrapolation of current technologies – it incorporates efficiencies and technologies yet to be deployed.^v

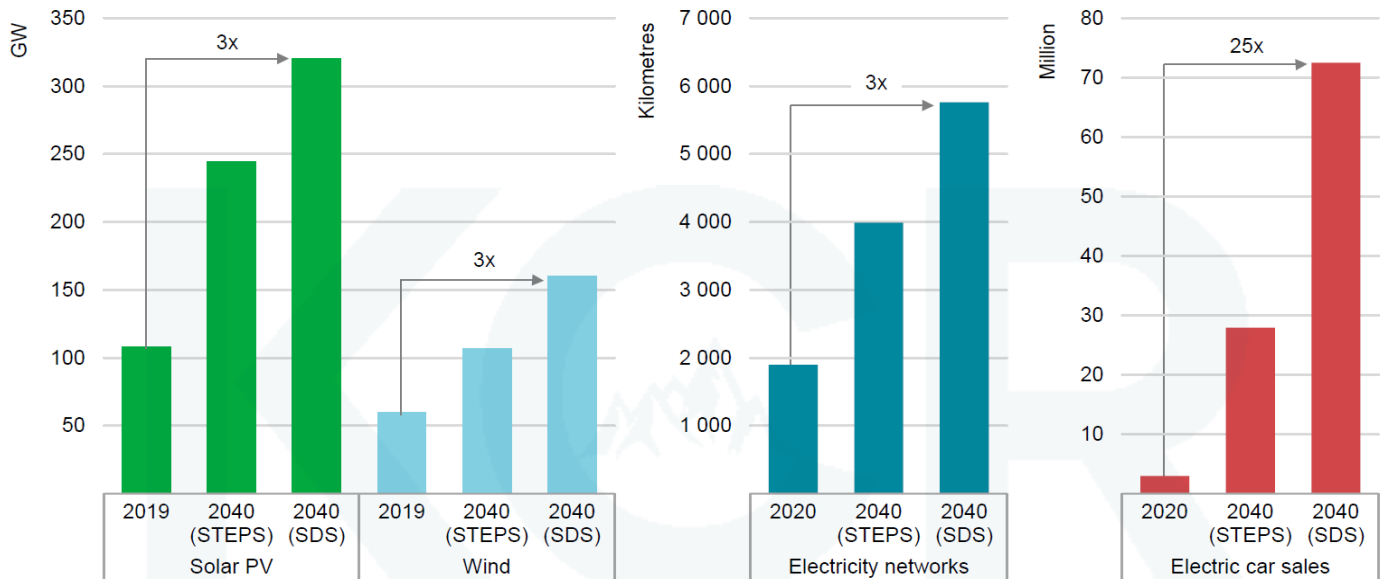
What are the Primary Drivers of Demand Growth?

The chart below helps us understand the primary drivers of the aggregate changes in demand seen above.

- First Chart: annual increase in solar power & wind power installations triples
- Second Chart: the new kilometers of installed electricity networks also triples
- Third Chart: the world will be selling over 70 million battery electric vehicles per year by 2040, a 25x increase over current levels

But achieving climate goals requires a further rapid acceleration in clean energy deployment

Annual deployment of clean energy technologies by scenario



IEA. All rights reserved.

Notes: PV = Photovoltaic; STEPS = Stated Policies Scenario; SDS = Sustainable Development Scenario.

Sources: IEA (2021a); IEA (2020a).

Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 25

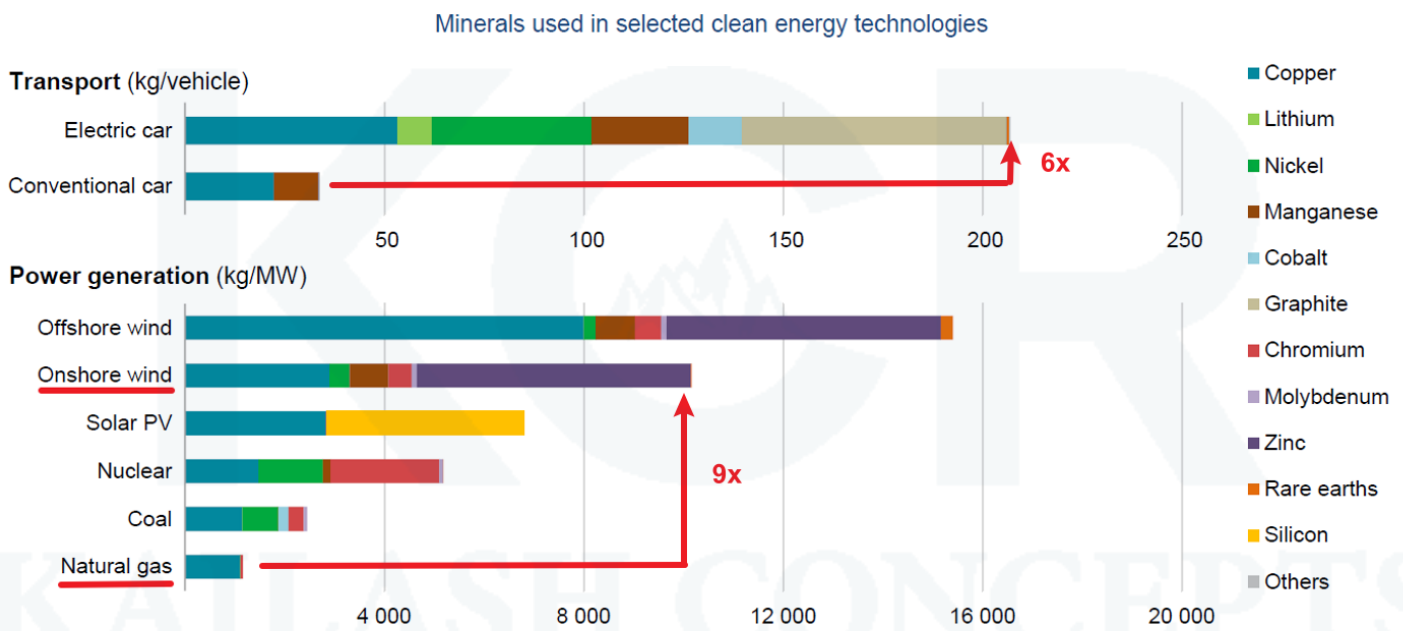
Mineral Intensity: How do BEVs, Wind & Solar Compare to Nuclear, Coal & Gas?

The changes contemplated in the chart above lead to exponential growth in demand compared to the technologies they seek to replace.

The chart below shows the amounts of various minerals green technologies consume relative to traditional technologies. The contrasts are eye-opening for the uninitiated. Look at the top two bars comparing an Electric car to a Conventional car.

Tough to see, but as the IEA explains, the electric car requires at staggering 6x the mineral inputs of a conventional car. Remember, current EV sales are 3.5 million and under this plan we are ramping that to 70 million units a year. And each unit needs 6x the mined material to make.^{vi}

An even more dramatic change is in store for **power generation**. The “**Onshore wind**” installations require 9x the minerals of a gas-fired plant of equivalent output.^{vii} Again, we can see the exponential nature of mineral demand as we ramp sales and installations of far more mining-intensive technologies.



IEA. All rights reserved.

Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 26

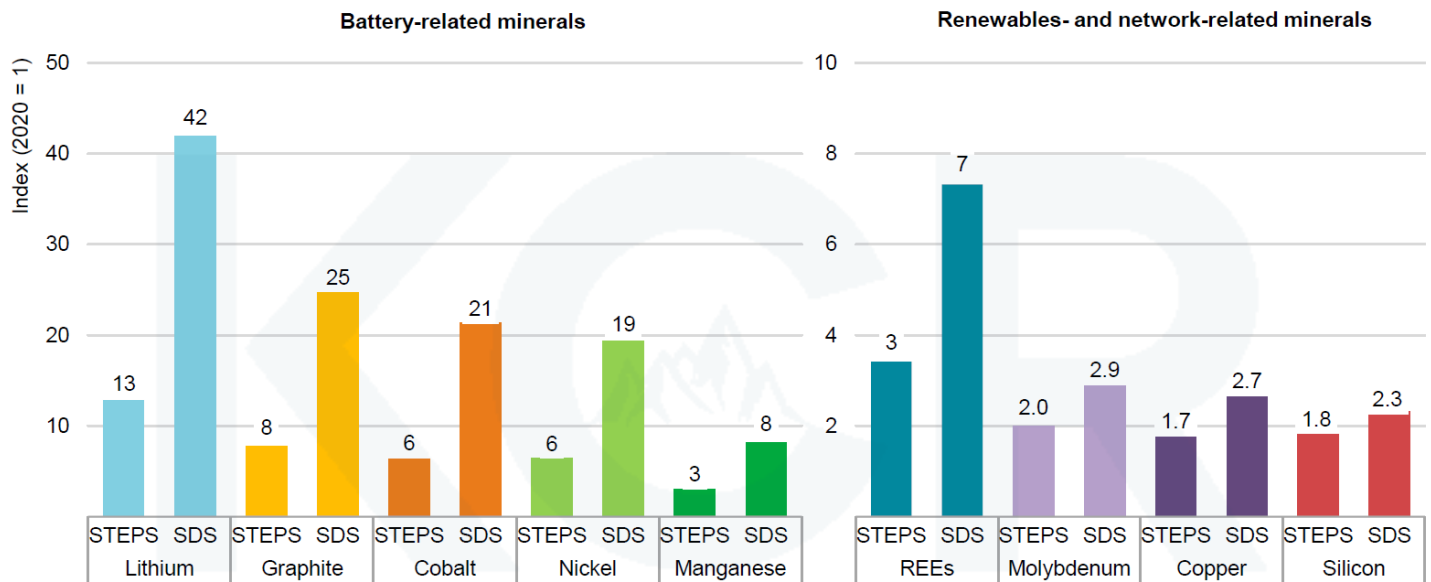
Mineral Intensity: How Would these Changes Impact Mineral Demand?

The chart below shows the change in demand across the many categories of minerals required to shift the economy green. The numbers on the left are difficult to process. Lithium up 42x, graphite up 25x, cobalt 21x, nickel 19x and manganese 8x.

Yet the numbers on the right are no less compelling. Unlike the metals on the left where starting levels of production are relatively muted, metals like copper are rising off an already massive base. By weight, copper, graphite and nickel dominate the change in absolute incremental mined materials.^{viii}

The relative demand growth is particularly high for battery-related minerals

Growth in demand for selected minerals from clean energy technologies in 2040 relative to 2020 levels



Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 47



Mineral Supply: Where do We Stand & Where are We Going?

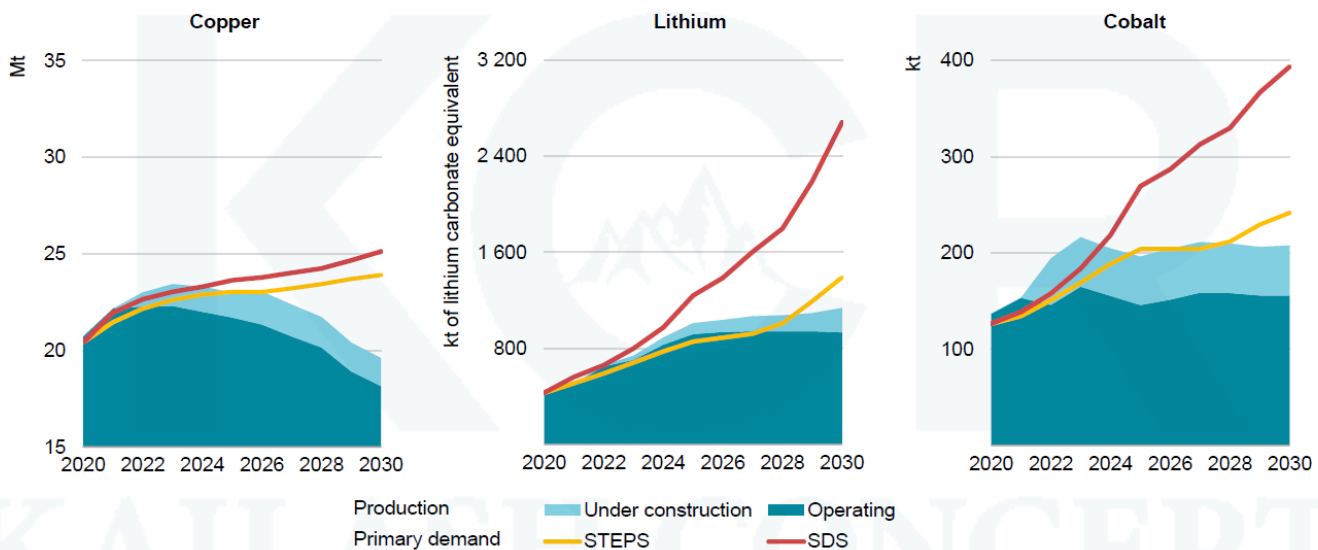
On this topic the IEA does not mince words. In a bold header they warn “**Current supply and investment plans are not yet ready for accelerated energy transitions.**” The charts below show the operating supply and supply that is under construction as well as demand net of recycling for copper, lithium and cobalt.

The growth in copper demand represents a herculean undertaking. The metal plays a role in virtually every clean source of power generation [see appendix, Fig 1].^{ix} When you look at the charts below, note the difference in **scale** between the vertical axes on copper (left chart), lithium (middle), and cobalt (right chart).

Annual copper demand is measured in **millions of tons per year** while lithium and cobalt are measured in kilotonnes, or 1,000s of tons per year. We do not say this to diminish the challenges faced by metals like cobalt and lithium. Merely to highlight just how massive the mining demands will be in the copper space.

Meeting primary demand in the SDS requires strong growth in investment to bring forward new supply sources over the next decade

Committed mine production and primary demand for selected minerals



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Notes: Primary demand is total demand net of recycled volume (also called primary supply requirements). Projected production profiles are sourced from the S&P Global Market Intelligence database with adjustments to unspecified volumes. Operating projects include the expansion of existing mines. Under-construction projects include those for which the development stage is indicated as commissioning, construction planned, construction started or preproduction. Mt = million tonnes.

Source: IEA analysis based on S&P Global (2021).

Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 119

Already precariously tight, the IEA goes on to warn that these estimates suffer from a collection of other risks.^x

Each of the specific points below has a compelling set of associated charts in the appendix:

- Higher geographical concentration of production and processing [**Appendix Fig. 2 & Fig 3**]
- Very slow discovery and development timelines make it difficult to bring on supply [**Appendix Fig. 4**]
- Mining is an energy intensive sector and brings its own raft of serious ESG concerns; as ore qualities decline the energy intensity escalates [**Appendix Fig. 5**]
- These ESG concerns create a circular problem as mining companies attempt to remediate their consumption of diesel, electricity and other resources, cause extraction costs to rise [**Appendix Fig. 5**]
- Water shortages are now common with lithium and copper facing acute headwinds [**Appendix Fig. 6**]

Conclusion:

- The IEA report is clear that green energy goals are well-ahead of the current and planned supply of materials
- A lack of policy clarity has left the green transition vulnerable to mining supply shortages as investors and mining companies are reticent to sink money into incremental capacity
- The complexity of solving for the mineral shortage creates a potential opportunity for investors, as the movement to electrify transportation with green energy would create a massive secular demand cycle for commodities

Our follow-on piece will explain the opportunity we see in a select group of US listed mining companies.

Note:

We have seen many folks attack the IEA as if they were conspiring to lead us to ruin. Like so much in America, the politics of these topics are unfortunately ferocious. You can probably surmise from our introduction that some of us at KCR believe there are aspects of this path that are suboptimal.

That some on the KCR team may disagree with the environmental merits of the proposed green transition does not, however, suggest we have anything but respect for the massive amount of research, organization and work that went into this remarkable piece.

In our view, the piece is a healthy dose of clarity, transparency and honesty for both advocates and critics of the green energy transition. From page 191 – 245 is an entire section titled “Sustainable and responsible development” that reads like an intensely researched piece on the **risks** from this endeavor. Considering the IEA is advocating **for** the green transition, we applaud them for putting the dirt, as it were, out there in gory detail.

To our friends who are pro-BEV-let’s-go-green and our friends who believe the undertaking to be an epic folly, we cannot recommend this report strongly enough. As the writer of this report ([Matt](#)) I can say that it reads **to me** like a strong endorsement for more open communication between both sides. I felt that the lack of organization around supply coupled with the severe environmental, social and policy risks in trying to ramp mining up to this scale has been woefully underappreciated by advocates of BEVs.

To circle back to where we began....it makes me wonder if we should all have listened a bit more closely to the folks at Toyota. More on that another day....

Thank you as always.

Appendix:

Figure 1: The table below shows the intensity of various primary minerals in the different sources of electricity. Per the IEA’s notes under the table, black circles indicate “high” demand, grey circles “moderate” and white circles “low,”. Looking at the matrix, what stands out to us is that, aside from being essential to building the grid, copper is also critical to virtually every clean technology out there excluding geothermal and hydrogen.

Critical mineral needs for clean energy technologies

	Copper	Cobalt	Nickel	Lithium	REEs	Chromium	Zinc	PGMs	Aluminium*
Solar PV	●	○	○	○	○	○	○	○	●
Wind	●	○	●	○	●	●	●	○	●
Hydro	●	○	○	○	○	●	●	○	●
CSP	●	○	●	○	○	●	●	○	●
Bioenergy	●	○	○	○	○	○	●	○	●
Geothermal	○	○	●	○	○	●	○	○	○
Nuclear	●	○	●	○	○	●	○	○	○
Electricity networks	●	○	○	○	○	○	○	○	●
EVs and battery storage	●	●	●	●	●	○	○	○	●
Hydrogen	○	○	●	○	●	○	○	●	●

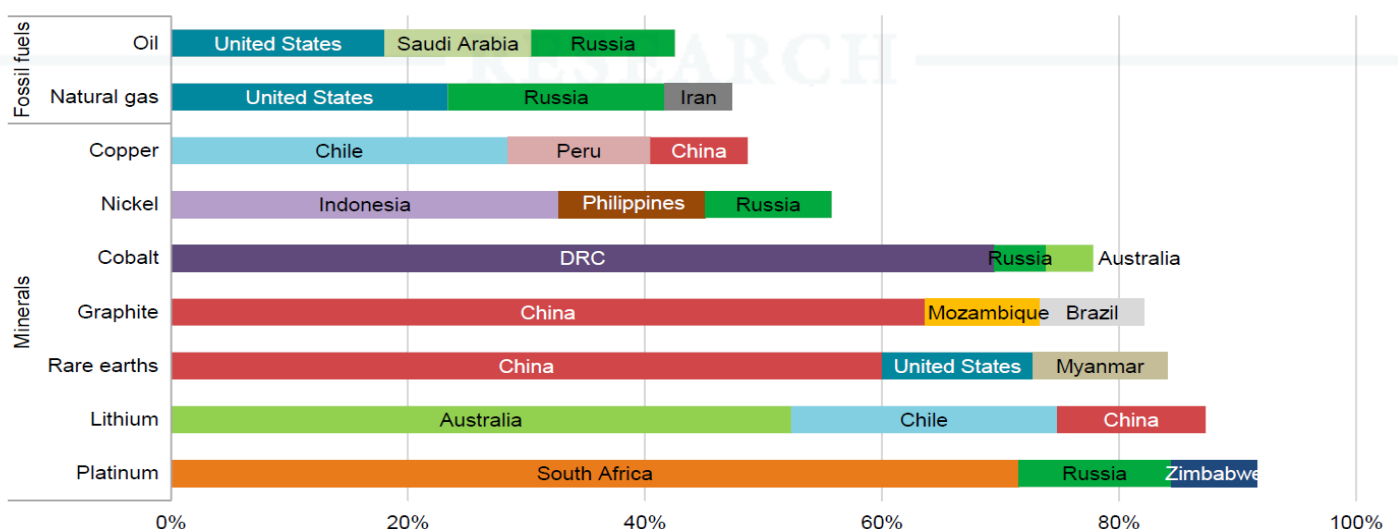
Notes: Shading indicates the relative importance of minerals for a particular clean energy technology (● = high; ● = moderate; ○ = low), which are discussed in their respective sections in this chapter. CSP = concentrating solar power; PGM = platinum group metals.

Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 45

Figure 2: Production and supply is highly concentrated...

Current production of many energy transition minerals is more geographically concentrated than that of oil or natural gas

Share of top three producing countries in total production for selected minerals and fossil fuels, 2019

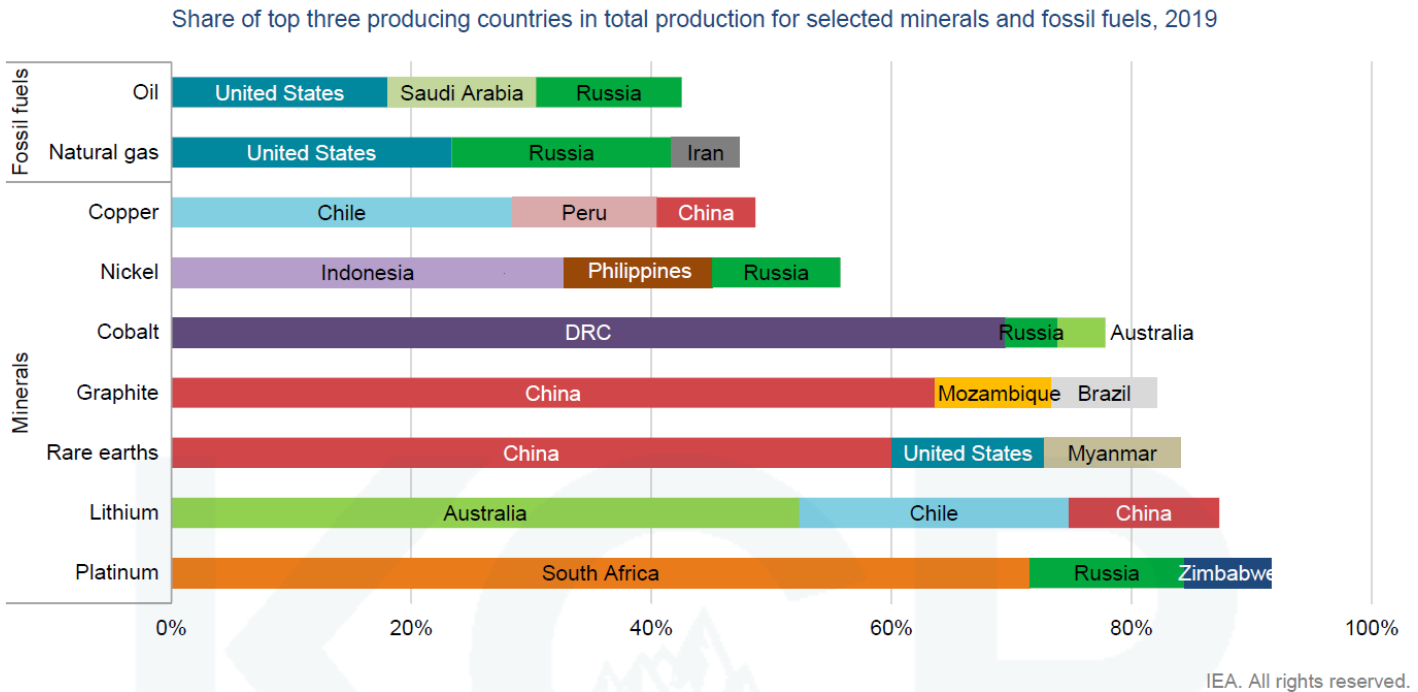


Sources: IEA (2020b); USGS (2021).

Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 30

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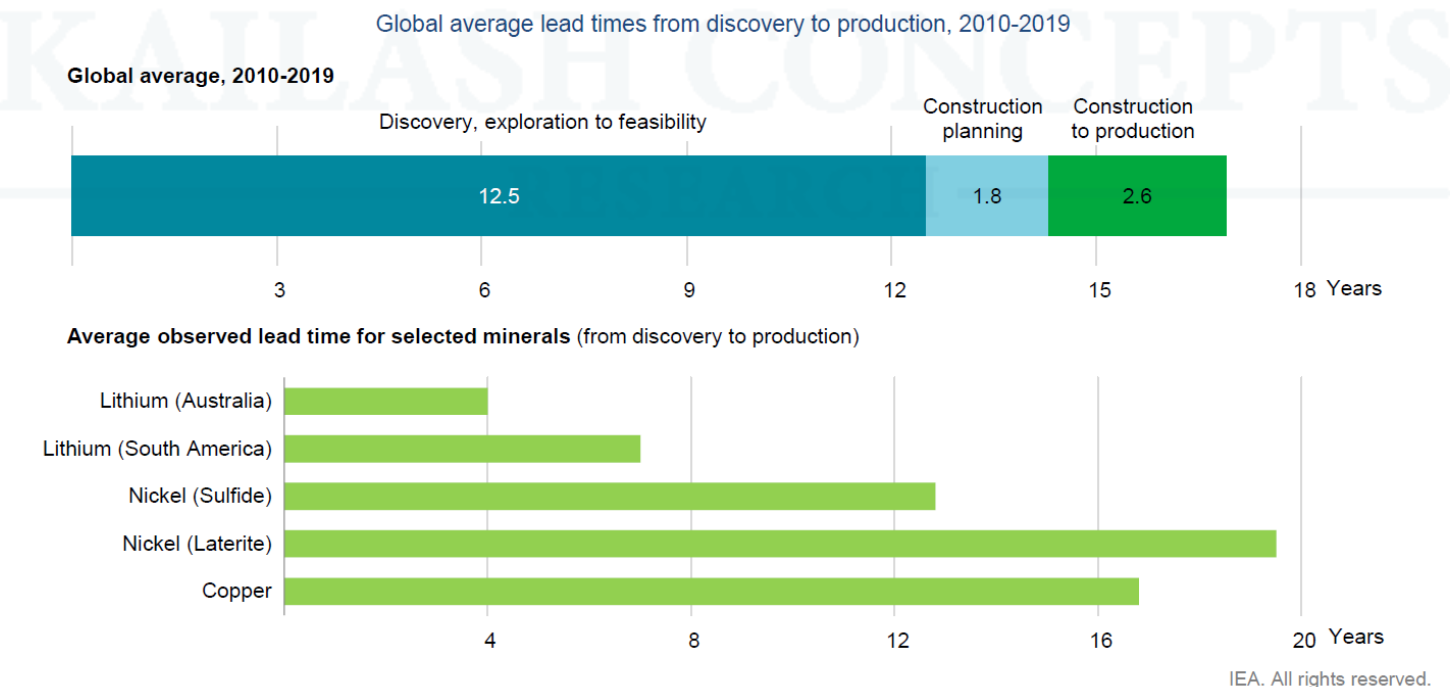
Figure 3: ...the location of supply is exacerbated by the concentrated location of mineral processing
Current production of many energy transition minerals is more geographically concentrated than that of oil or natural gas



Sources: IEA (2020b); USGS (2021).
 Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 30

Figure 4: Supply is difficult to bring on quickly

Project development lead times: Market tightness can appear much more quickly than new projects

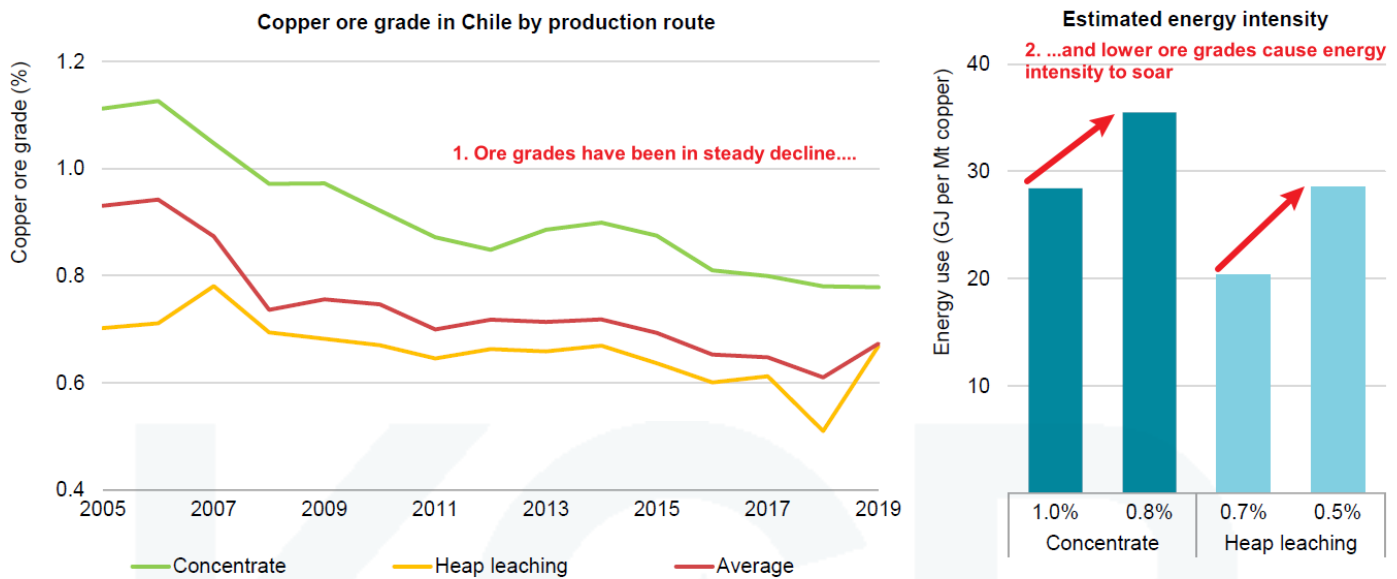


Note: Global average values are based on the top 35 mining projects that came online between 2010 and 2019.
 Source: IEA analysis based on S&P Global (2020), S&P Global (2019a) and Schodde (2017).
 Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 122

Figure 5: Declining ore grades (1) causes energy intensity to gap higher (2) (red annotations ours)

Resources: However, declining ore quality poses multiple challenges for extraction and processing costs, emissions and waste volumes

Average ore grade in Chile and estimated energy intensity by quality



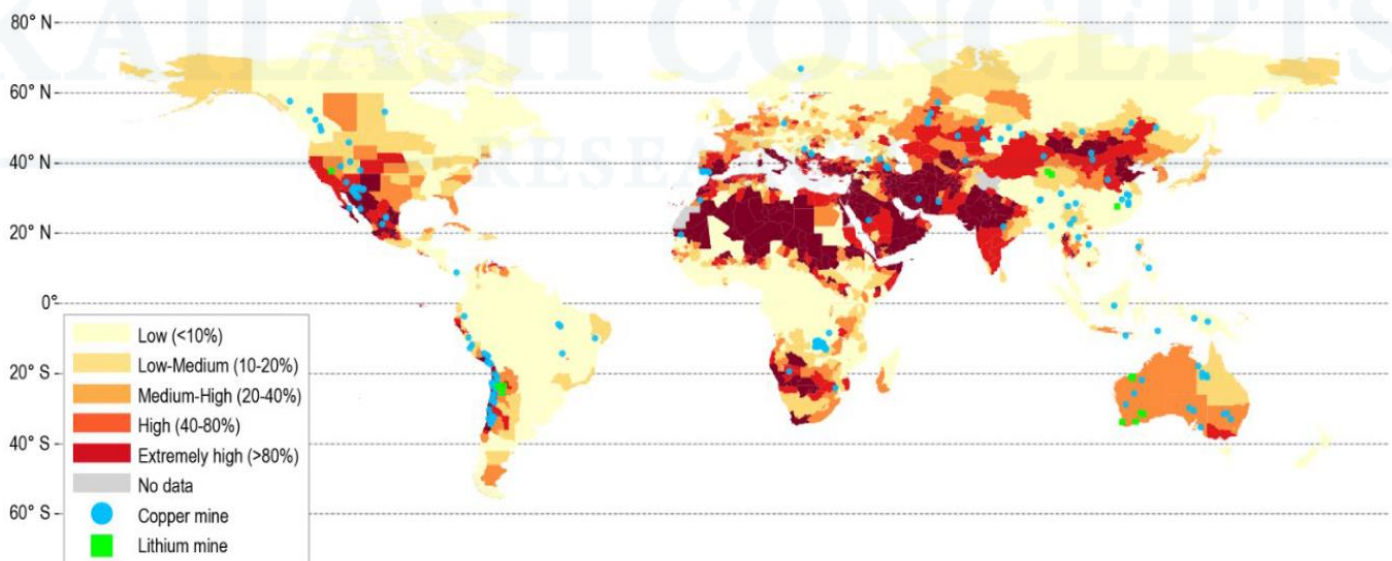
IEA. All rights reserved.

Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 124

Figure 6:

Climate risk: Mining assets are exposed to growing climate risks and water stress

Location of copper and lithium mines and water stress levels, 2020



IEA. All rights reserved.

Note: The exact water stress levels vary by location. While we assessed the share of mines located in water stress areas according to granular regional representations (shown on the following page), we aggregated them at the sub-national level on the map for the sake of simplification. Water stress levels are as defined in the Aqueduct 3.0 dataset according to the ratio of total water withdrawals over the total available surface and groundwater supplies.
Source: IEA analysis based on WRI Aqueduct 3.0 dataset.

Source: [The Role of Critical Minerals in Clean Energy Transitions](#), IEA, Page 127

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ⁱ “Revised Version, March 2022,” annotation is on the second page of the report, after the cover page, before the executive summary in bold red

ⁱⁱ Executive Summary, page 11

ⁱⁱⁱ <https://www.iea.org/news/clean-energy-demand-for-critical-minerals-set-to-soar-as-the-world-pursues-net-zero-goals> video, between minutes 6 and 12

^{iv} IEA, Page 44

^v IEA, Page 44

^{vi} IEA, Page 28

^{vii} IEA, Page 5

^{viii} IEA, Page 50

^{ix} IEA, pages 135 – 138, page 190

^x IEA, pages 120, 130, 125,