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# The IEA's Critical Minerals Report and its Implications for Japan

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## Abstract

In this paper, we analyze the International Energy Agency (IEA) report on *The Role of Critical Minerals in Clean Energy Transitions*. The document is one of 3 flagship special reports underpinning the IEA's aim to outline the material, financial and other requirements for a global roadmap to net-zero decarbonization by 2050. The report outlines myriad risks that can only be addressed through smart and global collaboration. It is a wake-up call to Japan, and all other countries committed to decarbonization, to undertake immediate and robust policy changes. In this paper, we discuss the report's findings and then turn to assess its implications for Japan.

## Introduction

On May 5, 2021 the International Energy Agency (IEA) launched its authoritative report on *The Role of Critical Minerals in Clean Energy Transitions* (hereafter, *Critical Minerals*). The 285-page document is one of 3 flagship special reports underpinning the IEA's aim to outline the material, financial and other requirements for a global roadmap to net-zero decarbonization by 2050. Thus *Critical Minerals* aggregates the best-available current evidence on the supply and demand for copper, nickel, lithium, rare earths, silicon, and other metals and minerals crucial to clean-energy technologies. Its compelling visual presentation and well-written analysis shows that the faster and deeper we pursue decarbonization, the more we need prodigious quantities of critical minerals. Yet current supply chains are simply inadequate to meet oncoming demand. The report outlines myriad risks that can only be addressed through smart and global collaboration. It is a wake-up call to Japan, and all other countries committed to decarbonization, to undertake immediate and robust policy

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## Energy Transition Materials

*Critical Minerals*<sup>1)</sup> emerged at a very important time. It follows a series of increasingly concerning studies on mineral demand for the energy transition. The report follows a decade of EU-funded scoping and other studies that increasingly assess global demand across power, mobility, communications, health tech, military, space, and other categories. To quote an editorial in the April, 2021 edition of the academic journal *Materials*, “The indisputable conclusion after about 10 years of finalized CRM projects research is that the most advanced technologies required for the green and digital transition will lead to a drastic increase in demand.”<sup>2)</sup>

In addition, it was published shortly after the March 2021 release of the International Renewable Energy Agency (IRENA) annual update to its Renewable Energy Statistics.<sup>3)</sup> The IRENA report highlights that in 2020, total global power capacity additions were 260 gigawatts (GW), of which over 80% was renewable, versus roughly only 20% in 2001. And the IRENA data show that among the renewable capacity additions, fully 91% were solar and wind.

The IEA's study helps greatly to understand the material implications of this striking trend towards increased renewables. *Critical Minerals* is not in the least opposed to renewable energy, but warns that failure to act now to secure adequate and environmentally-sustainable supplies of critical minerals threatens, in short order, to bring on price increases and other shocks that will likely delay decarbonization and increase its cost. The report is the most comprehensive study yet available, assessing 16 key clean-energy technologies and several critical minerals, including cobalt, copper, lithium, nickel and select rare earths. The sobering conclusions of *Critical Minerals* are, if anything conservative as it does not include

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1) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021 is accessible at the following URL: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

2) See Girtan, Mihaela, et al. “The Critical Raw Materials Issue between Scarcity, Supply Risk, and Unique Properties,” *Materials*, April, 2021: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8067847/>

3) See Renewable Energy Statistics 2021, International Renewable Energy Agency, March 2021: <https://irena.org/publications/2021/March/Renewable-Capacity-Statistics-2021>

the prodigious critical mineral demand in health care, space technologies, defence systems, and other very mineral-intensive areas.<sup>4)</sup> Nor does it analyze the full slate of 30-odd critical minerals in Japanese, EU, US, Canadian, Australian, and other countries' current lists.

The IEA work will guide discussion of decarbonization at the COP26 and other high-level talks scheduled for 2021 and afterwards. But there is a risk of its analysis being interpreted through partisan lenses. On the one hand fossil-fuel advocates were quick to declare that *Critical Minerals* shows the energy transition away from fossil fuels is emissions-intensive and otherwise compromised.<sup>5)</sup> And on the other hand, the pro-renewable Carbon Tracker think-tank's analysts were cited dismissing the findings with the assertion that "no amount of fancy footwork by apologists for the fossil fuel system should deflect us from the central point that we have the resources to make the energy transition a reality and to usher in a new age of growth and prosperity."<sup>6)</sup> *Critical Minerals* in fact supports neither extreme and hence deserves a detailed, dispassionate analysis.

So let us explore the highlights of the report. **Figure 1** outlines the range of energy technologies the IEA team assessed and their respective reliance on several focus critical minerals. The reliance is expressed in black, grey and white dots, indicating respectively high, medium and low reliance. As is evident, EVs and battery storage are particularly voracious in their need for critical minerals. Among power generation technologies, the critical mineral requirements for wind and solar variable renewable energy (VRE) are higher than hydro, geothermal and nuclear.

Detailed quantification of this material-intensity in transport is seen in **figure 2**, which outlines the general average of critical mineral density for electric vehicles and clean power generation. We see in the top section ("transport") of the figure that an electric vehicle is dramatically more material-intensive than a conventional, internal-combustion engine car. Electrification not only requires much more copper per vehicle, but also significant quantities of lithium, nickel, cobalt, graphite, and rare earths. Overall, an electric vehicle is 5 to 6 times as mineral-intensive than a conventional vehicle.

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4) On these broader uses for critical minerals, see "Securing Critical Materials for Critical Sectors: Policy options for the Netherlands and the European Union," Hague Centre for Strategic Studies, December 10, 2020: <https://hcass.nl/report/securing-critical-raw-materials>

5) For example, see Mark P. Mills, "Biden's NOT-So-Clean Energy Transition," *The Wall Street Journal*, May 11, 2021: <https://www.manhattan-institute.org/bidens-not-so-clean-energy-transition>

6) Cited in "Record metals boom may threaten transition to green energy," *The Guardian*, May 15, 2021: <https://www.theguardian.com/business/2021/may/15/record-metals-boom-may-threaten-transition-to-green-energy>

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

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.

\* In this report, aluminium demand is assessed for electricity networks only and is not included in the aggregate demand projections.

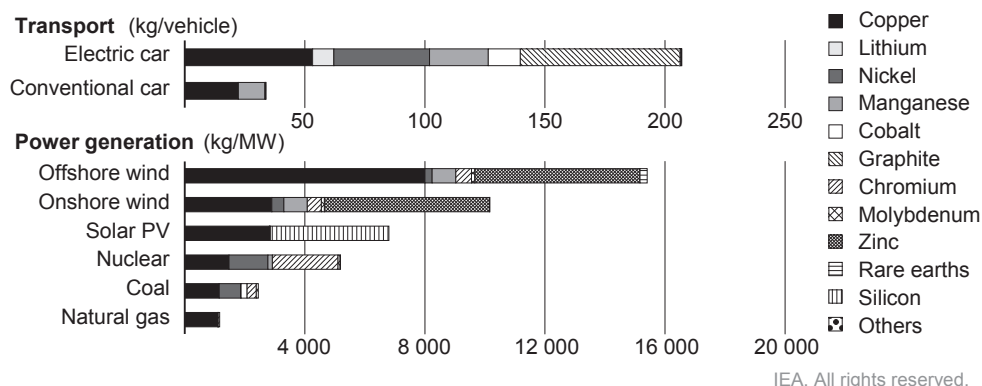
Source: IEA, 2021<sup>7)</sup>

Figure 1 Critical mineral needs for clean energy technologies

Similarly, figure 2 demonstrates that clean power generation technologies have significantly higher material-density, expressed as kilogrammes/megawatt (kg/MW) of generation capacity. Carbon-intensive natural gas and coal-fired generation require only moderate amounts of copper, nickel and other materials for the pipes and other infrastructure that compose their plant. By comparison, a nuclear plant has, per MW, more than double the material footprint of coal and triple that of natural gas, with an especially heavy reliance on chromium. But solar and wind generation have even heavier reliance on such base metals as copper in addition to rare earths for offshore wind and silicon for solar. Moreover, the aggregate per-MW amount of critical minerals balloons from a couple of metric tons for a natural gas plant to nearly 16 tons for offshore wind. Since wind and solar have considerably lower capacity factors – meaning percent of actual power generation versus rated generation capacity – than fossil-fuel and nuclear plant, their total volume of critical minerals required to produce a given amount of power is even higher than expressed in the figure.

Additionally, the IEA data suggest that distributed energy solutions may need

7) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.

Source: IEA, 2021<sup>8)</sup>

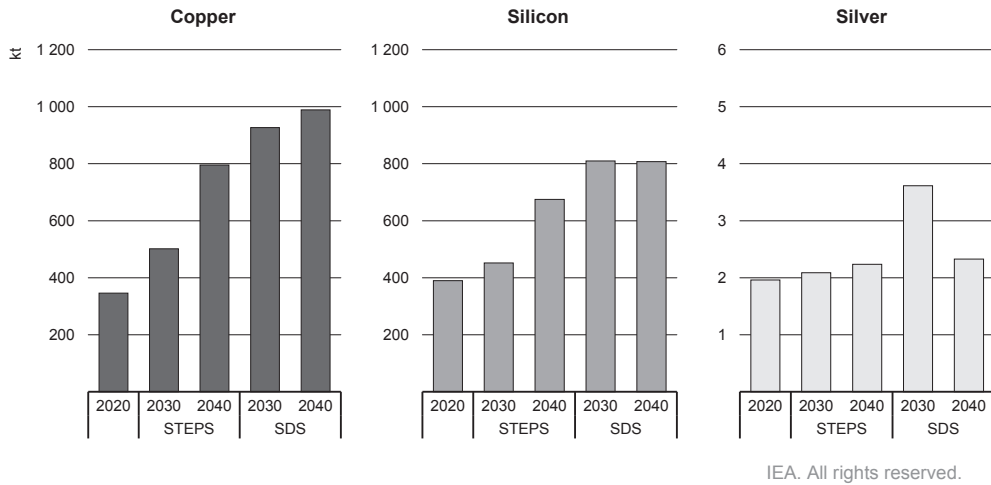
Figure 2 Minerals used in selected clean energy technologies

rethinking. This is because the more distributed the power generation the higher the material-intensity: “Distributed solar PV systems tend to have string inverters or microinverters, requiring about 40% more copper than utility-scale projects, which typically use central inverters. Other mineral intensities are similar between utility-scale and distributed applications.”<sup>9)</sup>

Figure 3 offers more data on key mineral demand for solar power. It enumerates the 2020 demand, in kilotons (kt), for copper, silicon and silver in global solar deployments. The figure then assesses the likely increased demand according to two scenarios: the Stated Policies Scenario (STEPS), which currently implies global warming of over 3 degrees Celsius, and Sustainable Development Scenario (SDS), which aims to limit global warming to well below 2 degrees Celsius, and ideally to 1.5 degrees. STEPS and SDS are used throughout the report. As we see in figure 3, the SDS and STEPS scenarios for solar vary greatly for the years 2030 and 2040. Copper demand more than doubles in SDS 2040, compared to 2020. Silicon, in turn, doubles, by SDS 2040, but then levels off through technological change and recycling. Silver in fact declines in the SDS scenario for 2040 compared to a large

8) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

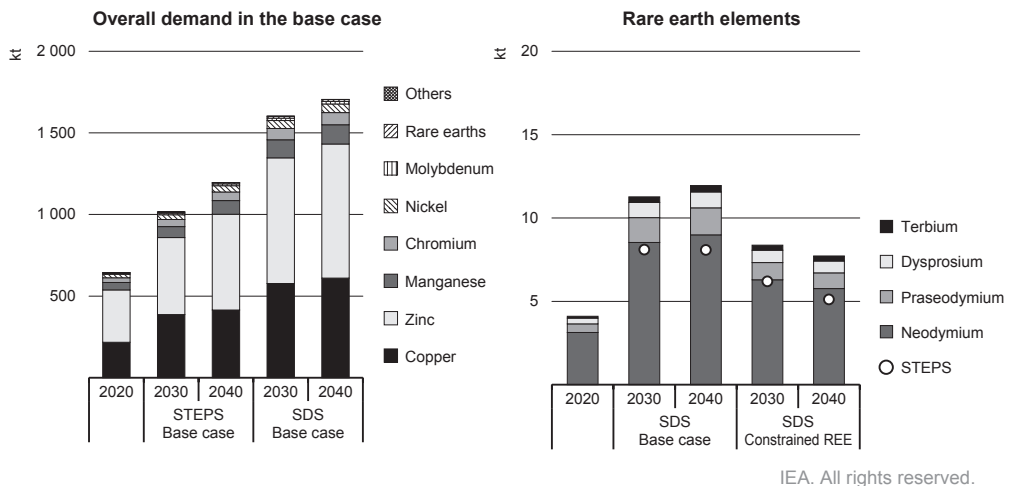
9) See p. 56, *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021 is accessible at the following URL: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



Note: kt = thousand tonnes.

Source: IEA, 2021<sup>10)</sup>

Figure 3 Demand for copper, silicon and silver for solar PV by scenario



Source: IEA, 2021<sup>11)</sup>

Figure 4 Mineral demand for wind by scenario

increase in SDS 2030.

Figure 4 then takes up the critical mineral requirement for wind power. It suggests that achieving SDS by 2040 requires a tripling of critical mineral demand. The rare earth de-

10), 11) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

mand is shown to be much more than double 2020 levels in the SDS base case for both 2030 and 2040, and roughly double even in a constrained scenario. This result highlights the challenges confronting substitution (or higher efficiency of use) for rare earths in the permanent magnets used in wind turbines.

**Figure 5** outlines the capacity additions and consequent material demand for concentrated solar power (CSP), geothermal, hydro, and bioenergy. We see that the greatest increase in capacity addition is expected from CSP, which in turn implies a dramatic increase in critical minerals. Geothermal power is not expected to contribute much new capacity, and in 2020 – the year of most recent comprehensive data<sup>12)</sup> – provided only 1 % of total global renewable power generation, but has a striking dependence on chromium and nickel. The least material-intensive renewables are hydro and bioenergy (such as solid biofuels, biogas, combustion of municipal waste, and liquid biofuel). In 2020, hydro represented 43% of total global renewable capacity and contributed about 58% (4,418 TWh) of total global renewable power generation of 7,660 TWh. For its part, bioenergy represented 9.3% of total global renewable power generation in 2020, and is expected to double in capacity in the IEA'S 2040 SDS scenario. The critical mineral cost of bioenergy is minimal, but the environmental cost is often questioned.<sup>13)</sup>

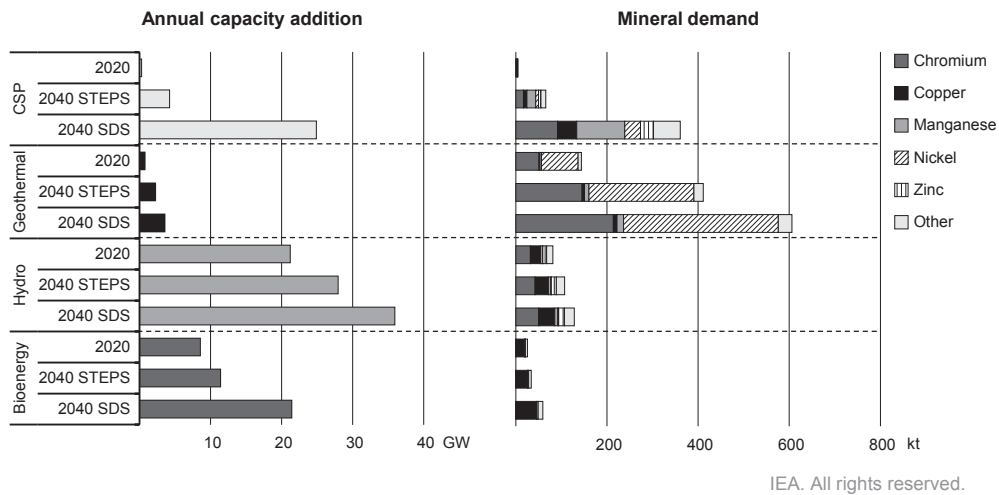
**Figure 6** from *Critical Minerals* also addresses the role of nuclear energy in decarbonizing scenarios. It shows that 2020 capacity additions for nuclear are quite significant in China, Russia and the Middle East. Its data for Japan reflect, of course, restarts of idled capacity rather than new build. The data also suggest that the 2040 SDS scenario requires about a doubling of average annual capacity additions, especially in China. The material costs of these capacity additions are considerably lower than for most renewables, requiring slightly more than 80 kt, mostly chromium, copper and nickel. As we saw in **figure 2**, this material density per MW of capacity is much less than what is required for solar and wind, even without adding the larger power networks (transmission, storage and other infrastructure) required for solar and wind. The network data are discussed in the next figure.

**Figure 7** presents the IEA's best guess on the power grid expansion required to

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12) The data are available at "Net Zero by 2050: a Roadmap for the Global Energy Sector," International Energy Agency, May 18, 2021: <https://www.iea.org/news/pathway-to-critical-and-formidable-goal-of-net-zero-emissions-by-2050-is-narrow-but-brings-huge-benefits-according-to-iea-special-report>

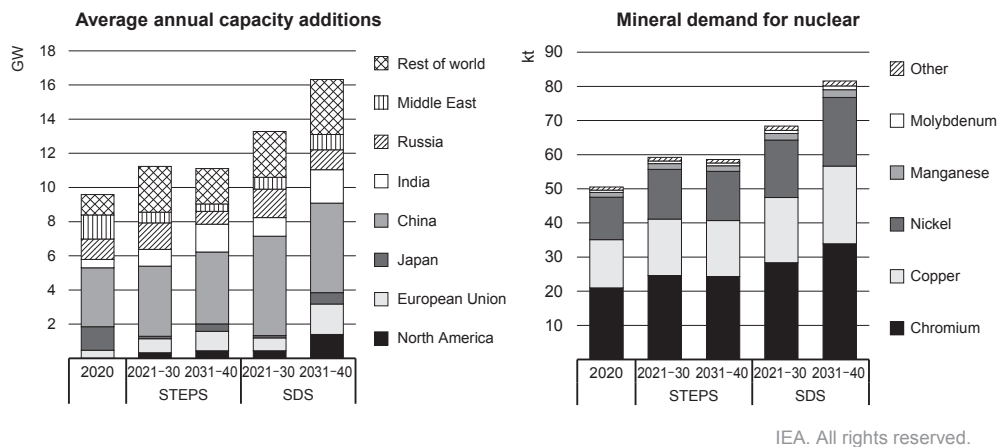
13) Thorough analyses of bioenergy can be found in the various publications of the IEA Bioenergy Technology Collaboration Programme: <https://www.ieabioenergy.com>



Note: CSP = concentrating solar power.

Source: IEA, 2021<sup>14)</sup>

Figure 5 Annual capacity addition and mineral demand from other renewable technologies by scenario



Note: Russia = Russian Federation.

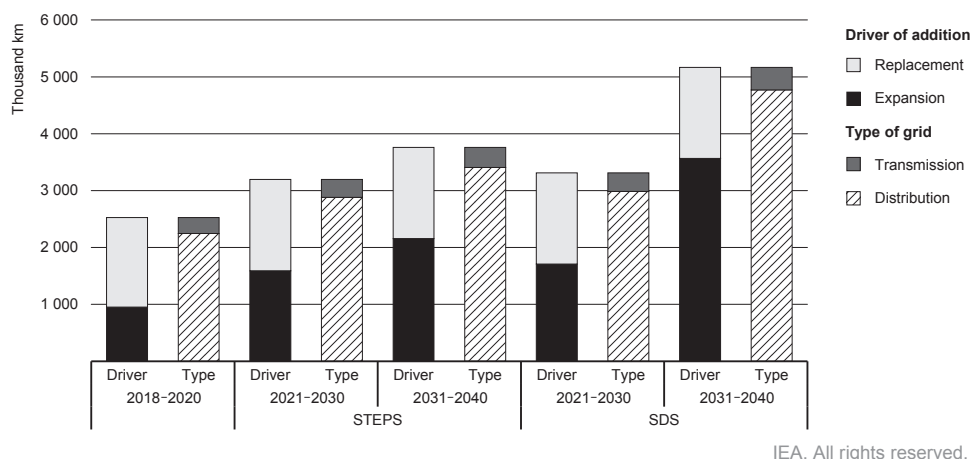
Source: IEA, 2021<sup>15)</sup>

Figure 6 Average annual capacity additions and mineral demand from nuclear power

achieve the STEPS and SDS scenarios, based on 2018–2020 drivers and type. The drivers are divided into replacement and expansion, whereas type is divided into transmission and distri-

14), 15) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



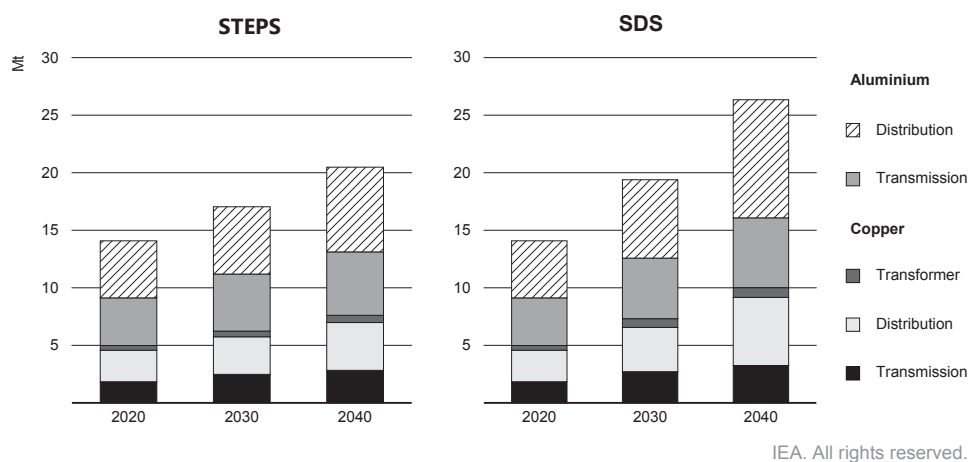


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Source: IEA (2020c).

Source: IEA, 2021<sup>16)</sup>

Figure 7 Annual average grid expansion and replacement needs by scenario



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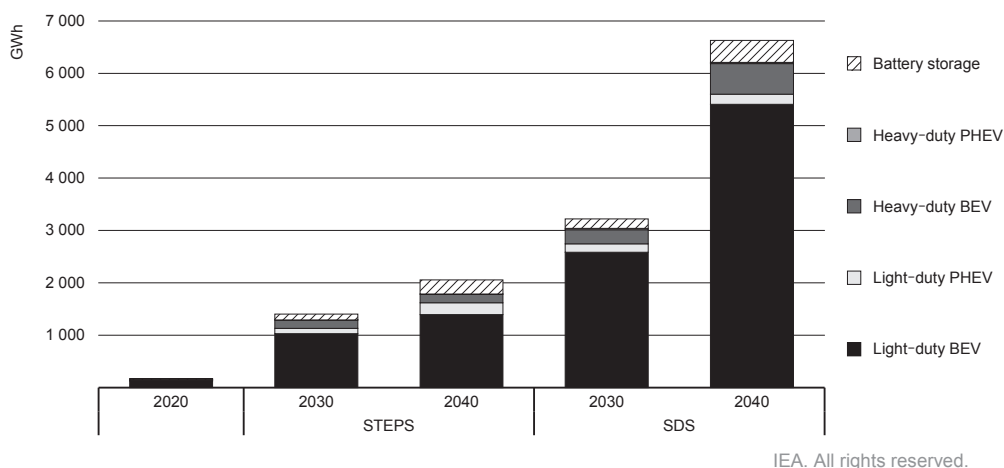
Note: Includes demand for grid expansion and replacement.

Source: IEA, 2021<sup>17)</sup>

Figure 8 Demand for copper and aluminium for electricity grids by scenario

bution. We see that both the STEPS and SDS scenarios imply a significant shift in the character of annual grid demand. Both see annual expansion of the global grids increase significantly from under 1,000 kilometers to (in SDS 2031-2040) over 5,000 kilometers. That is a

16), 17) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



Notes: Light-duty includes passenger light-duty vehicles, light commercial vehicles, and two- and three-wheelers. Heavy-duty vehicles include medium-sized freight trucks, heavy freight trucks and buses. BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle; GWh = gigawatt hour.

Source: IEA (2020c).

Source: IEA, 2021<sup>18)</sup>

Figure 9 Global battery capacity additions

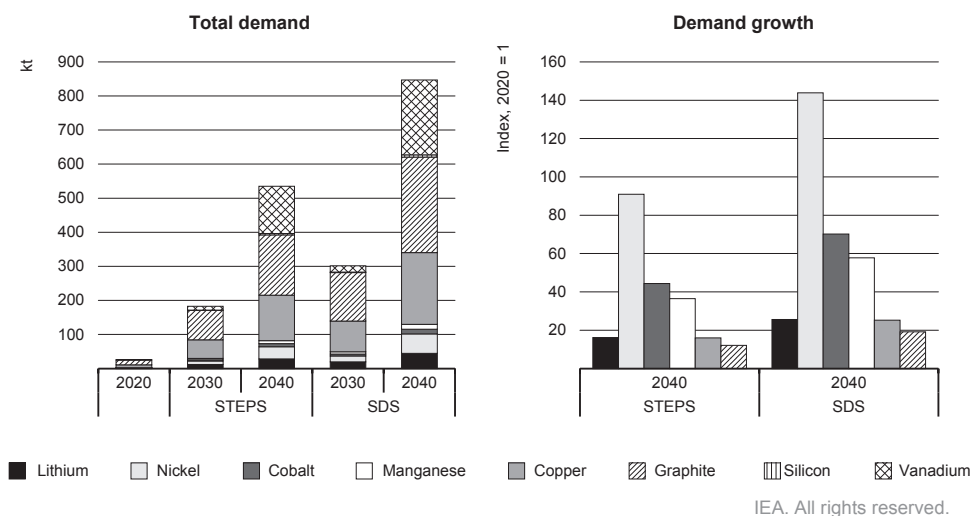
very material-intensive endeavour, as we see in figure 8.

Figure 8 provides a summary of the megatons (Mt) of copper and aluminum needed for the STEPS and SDS scenarios, for 2020, 2030 and 2040. The overall difference between the two scenarios in 2040 is over 5 Mt of copper and aluminum.

Figure 9 turns to examine the demand for battery storage in the STEPS and SDS scenarios. It shows that the 2020 levels of battery storage additions were minimal, but multiply significantly under any scenario. Yet the SDS 2040 projection is especially huge, with well over 6,000 gigawatt-hours (GWh) of battery storage. The lion's share is for battery-electric vehicles (BEV in the figure).

Figure 10 follows up on the above with an analysis of the material implications of the storage scenarios. The 2020 levels of demand are negligible, but rapidly mushroom. In the SDS 2040 scenario, over 800 kt of materials is required, centred on copper, graphite and vanadium. The rates of demand growth are also stupendous in the case of lithium, with two-digit increases being the norm, and a startling 140 times increase for lithium in the SDS 2040 scenario.

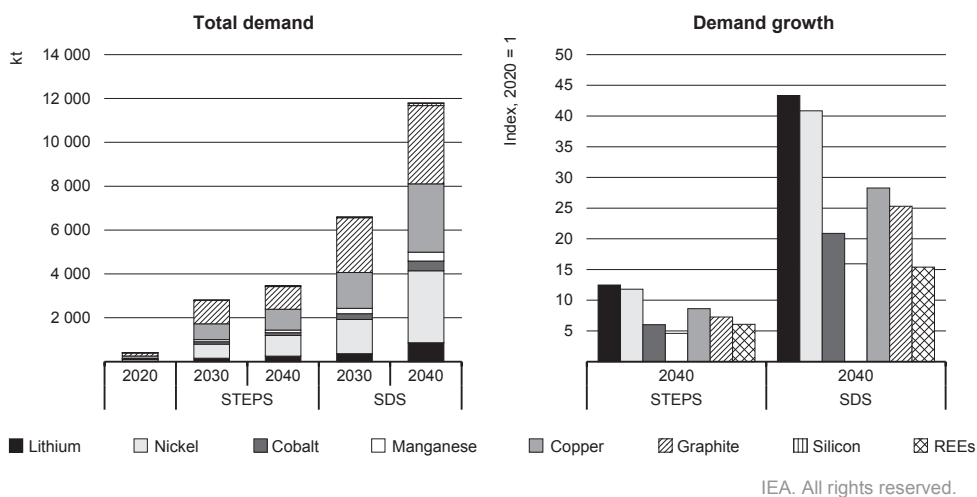
18) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



Note: Silicon and vanadium are excluded from the demand growth graph.

Source: IEA, 2021<sup>19)</sup>

Figure 10 Mineral demand from battery storage additions in the SDS

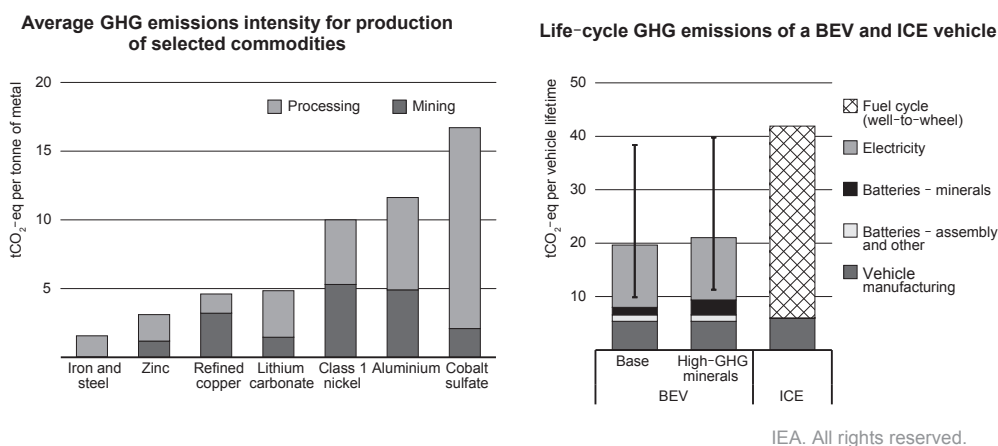


Note: Silicon is excluded from the demand growth graph due to its very high growth (over 500-fold increase), starting from a low base.

Source: IEA, 2021<sup>20)</sup>

Figure 11 Mineral demand from new EV sales

19), 20) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



Notes: BEV = battery electric vehicle; ICE = internal combustion engine. The "High-GHG minerals" case assumes double the GHG emissions intensity for battery minerals. Includes both Scope 1 and 2 emissions of all GHG from primary production. See Chapter 4 for more detailed assumptions.

Source: IEA analysis based on IEA (2020a); IEA (2020b); Kelly et al. (2020); Argonne National Laboratory (2020); Argonne National Laboratory (2019); Rio Tinto (2020); S&P Global (2021); Skarn Associates (2021); Marx et al. (2018).

Source: IEA, 2021<sup>21)</sup>

Figure 12 Life-cycle GHG emissions, electric and conventional vehicles

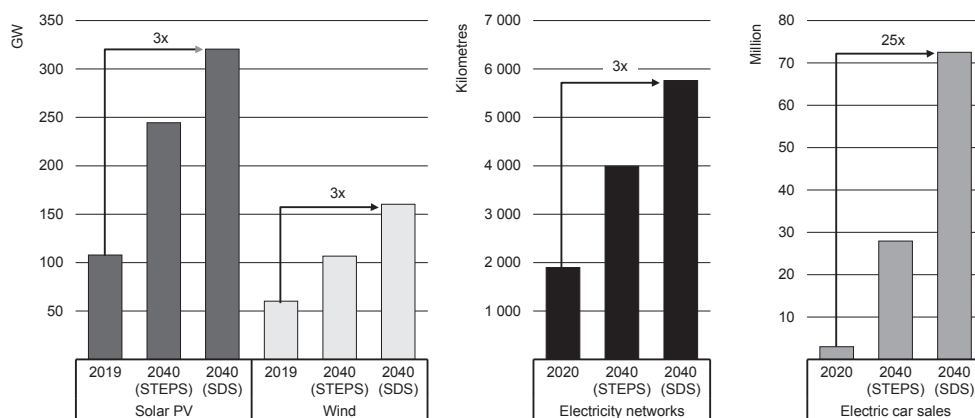
Figure 11 continues with an analysis of the material implications of the battery-electric vehicle scenarios. The volumes dramatically exceed those required for storage batteries, such that the SDS 2040 scenario for new EVs is just under 12,000 kt. And here too the growth rates of demand are double-digit.

Yet quite unlike recent literature from fossil-fuel advocates, *Critical Minerals* does not in the least argue that this higher material footprint negates the decarbonizing effect of electric vehicles and renewable energy. Its detailed assessments include, as seen in figure 12, the comparative lifecycles emissions for an electric and conventional vehicle. The IEA data show that even assuming GHG-intensive materials and electricity, the electric vehicle's lifecycle emission are less than half its conventional counterpart.

### The Need for Unprecedented Volumes

But as we see in figure 13, the urgent challenge is in meeting the oncoming tsunami of demand for critical minerals used in clean generation, electrical networks, and electric vehi-

21) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



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

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

Source: IEA, 2021<sup>22)</sup>

Figure 13 Annual deployment of clean energy technologies by scenario

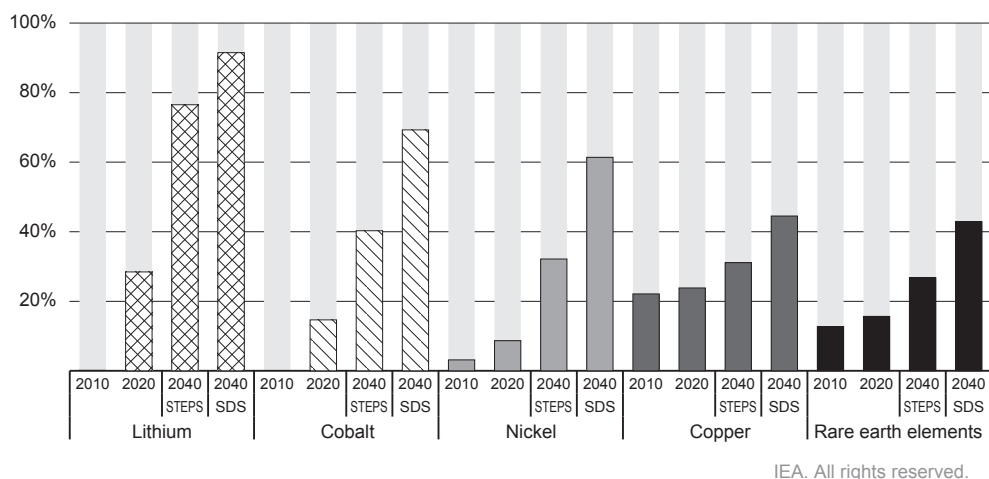
cles. The figure shows us that even under STEPS, solar deployment more than doubles between 2019 and 2040, with corresponding increases in wind, electricity networks and electric vehicles. But under the ideal of SDS (if not even more aggressive decarbonization), solar, wind, and power networks triple, while electric vehicles increase an astounding 25 times.

The IEA concludes that the aggregate demand for the 30-odd critical minerals used in clean-energy technologies may increase by six-fold or more. Within that increase, depending on the 11 technological pathways used by Critical Minerals, individual materials confront varying demand profiles. For example, in utility scale storage under the SDS, between 2020 and 2040 nickel demand is projected to grow 140 times, cobalt by 70 times, and manganese by 58 times.

Figure 14 suggests the significance of pathways with respect to critical mineral demand. The figure portrays the 2010 percent share of total demand by energy for lithium, cobalt, nickel, copper and rare earths. We see that energy demand for lithium, cobalt and nickel were minimal in 2010 as a share of demand elsewhere (for example, about 70% of nickel is used in stainless steel).<sup>23)</sup> In 2010, energy demand for copper was already over 20% of all

22) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

23) Nickel's uses are described at "End use of nickel," Nickel Institute, 2021: <https://nickelinstitute.org/about-nickel/#05-end-use-nickel>



Notes: Demand from other sectors was assessed using historical consumption, relevant activity drivers and the derived material intensity. Neodymium demand is used as indicative for rare earth elements. STEPS = Stated Policies Scenario, an indication of where the energy system is heading based on a sector-by-sector analysis of today's policies and policy announcements; SDS = Sustainable Development Scenario, indicating what would be required in a trajectory consistent with meeting the Paris Agreement goals.

Source: IEA, 2021<sup>24)</sup>

Figure 14 Share of clean energy technologies in total demand for selected minerals

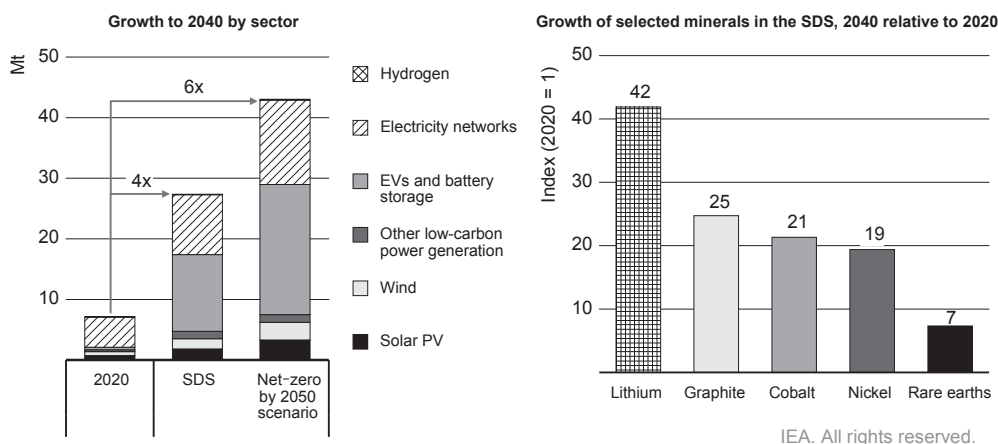
uses, with rare earths just over 15%. But under the SDS 2040 scenario, the energy share of demand for all these materials is expected to increase, with the most striking numbers seen in lithium, cobalt and nickel.

## Markets and Mining

The right-hand side of **figure 15** focuses in on the demand growth numbers for lithium, cobalt, nickel, copper and rare earths in the SDS 2040 scenario. The demand for each in 2020 is indexed as 1, and the growth in demand for SDS 2040 expressed as a multiple of that. Hence we see that SDS 2040 implies 42 times more lithium must be produced over the next two decades, followed by 25 times more graphite, 21 times more cobalt, 19 times more nickel, and 7 times more rare earths.

The left-hand side of **figure 15** shows that the growth in demand does not stop at 2040, but continues to 2050, with especially large increases in electricity networks and EVs/

24) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



Notes: Mt = million tonnes. Includes all minerals in the scope of this report, but does not include steel and aluminium.

See Annex for a full list of minerals.

Source: IEA, 2021<sup>25)</sup>

Figure 15 Mineral demand for clean energy technologies by scenario

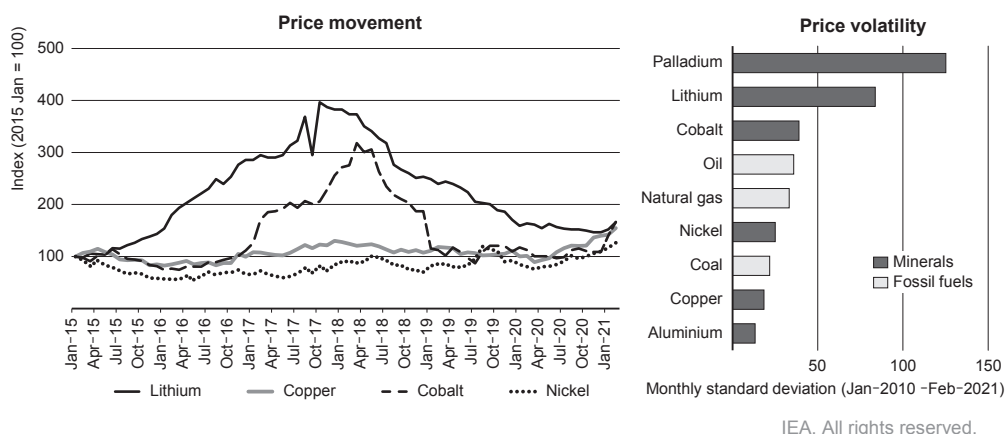
battery storage.

One might be inclined to argue – like an economist – that the prospect of such massive demand will see market mechanisms deftly respond by investing in more mining, greater efficiency, and substitution. *Critical Materials* concedes that history shows these market-driven responses do indeed happen, but adds that they are “typically accompanied by price volatility, considerable times lags or some loss of performance or efficiency.”

As to price volatility, the left-hand side of **figure 16** provides some exemplary evidence. It shows that between January 2015 and January 2021, the volatility in lithium prices reached 400% followed by cobalt at over 300%. On the figure's right-hand side, we see that the volatility of mineral prices is generally much higher than for fossil fuels (oil, natural gas and coal), between January 2010 and February 2021. One of the implications of volatility is serious investment risk, as miners and other upstream actors have little certainty that they can recover their costs for developing critical mineral resources.

In consequence, waiting for market mechanisms to kick in risks raising the cost of decarbonization while also slowing its pace and reducing its depth in difficult areas. If one accepts that decarbonization is urgent, perhaps on par with producing vaccines against COVID, then it is imperative for robust policy to drive markets and other institutions towards the

25) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



Notes: Assessment based on Lithium Carbonate CIF Asia, LME Copper Grade A Cash, LME Cobalt Cash and LME Nickel Cash prices.

Source: IEA (2020a), S&P Global (2021).

Source: IEA, 2021<sup>26)</sup>

Figure 16 Price movement and volatility of selected minerals

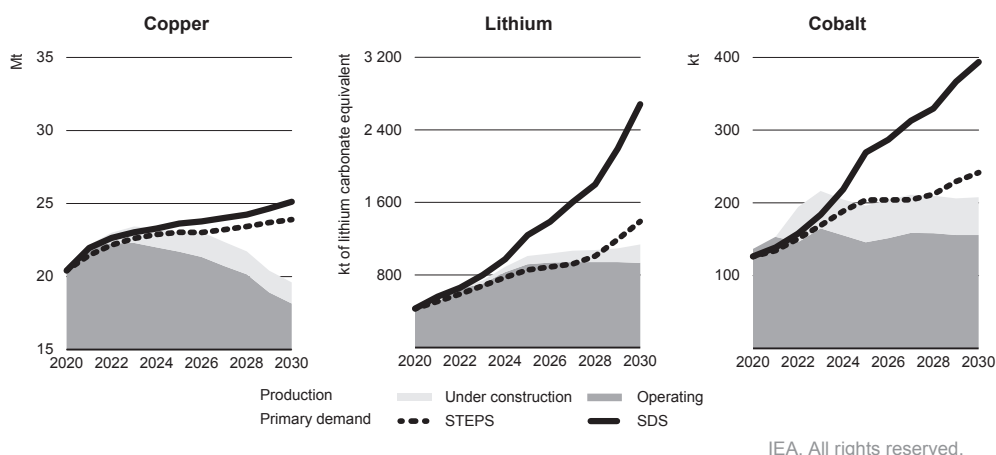
collective goal.

One additional proof of the IEA's argument is seen in the data in **figure 17**. The figure shows the 2020–2030 clean-energy demand profiles for copper, lithium and cobalt under STEPS and SDS. Current and planned mining projects are clearly inadequate for these three materials alone, notwithstanding the enormous amount of attention they have received in recent years. Similar charts could be generated for graphite, nickel, rare earths, and the other critical minerals essential to energy transition.

Worse yet, massively increased mining of critical minerals is not simply a matter of throwing more money at producers. One major problem in this respect is the lead times for mining projects. In **figure 18**, *Critical Minerals* highlights the bracing fact that, between 2010–2019, the global average lead time – from discovery to production – for the world's top 35 critical minerals mining projects was well over 15 years. The fastest average projects the IEA team identify in their report is 4 years for mining lithium in Australia. But finding and developing nickel and copper mines take well over a decade, and often closer to 2 decades. Even halving these lead times does little to address the demand gaps seen in **figure 17**.

26) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>





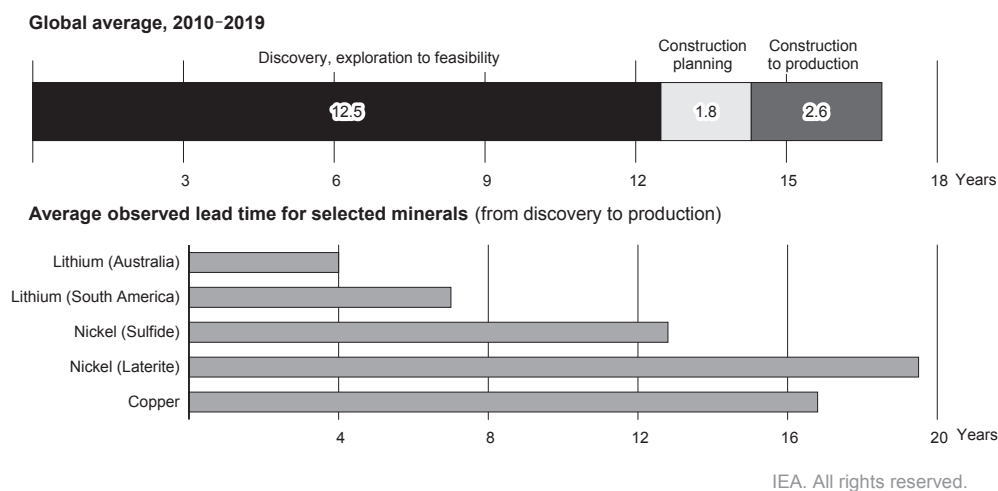
Notes: Primary demand is total demand net of recycled volume (also called primary supply requirements).

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: IEA, 2021<sup>27)</sup>

Figure 17 Committed mine production and primary demand for selected minerals



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: IEA, 2021<sup>28)</sup>

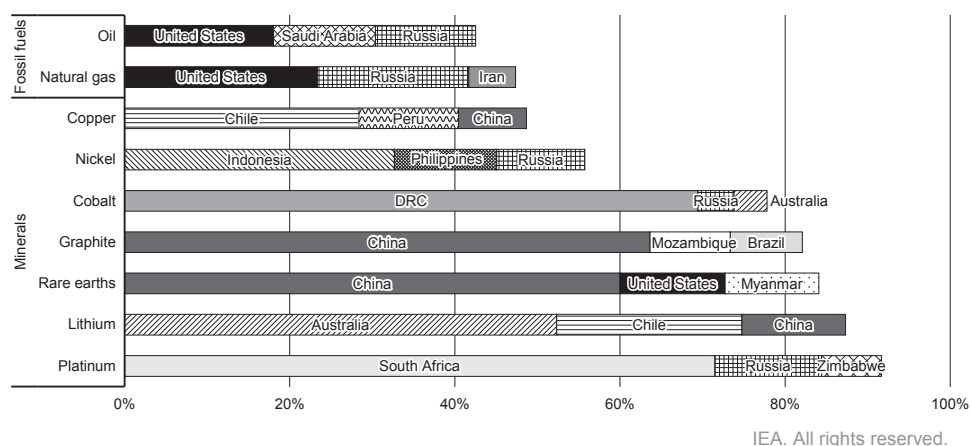
Figure 18 Global average lead times from discovery to production, 2010-2019

27), 28) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

## The Geopolitical and ESG Issues

*Critical Minerals* also aggregated the data on comparative geographical concentration of fossil fuel and critical mineral production. We see a summary of their data in **figure 19**. The key point is that the three major fossil fuel producing countries have relatively small market shares of oil and natural gas (coal is even more distributed) compared to the top three producers of critical minerals. Indeed, just the Democratic Republic of the Congo alone is the site of roughly 70% of cobalt production, while China is home to 60% or more of rare earths and graphite. The higher the market dominance of the top three, the greater the geopolitical risks for consumer countries. These risks include not only incentives to form cartels, but also supply-chain risks stemming from increasingly frequent natural disasters, strikes in mining, and related phenomena.

In addition, **figure 20** shows that there is a much higher dependence on exports among critical mineral producers. The left-hand side of the figure highlights the significant number of African and Central and South American (C & S America) countries that relied on critical minerals for over 50% of their exports in 2019. The right-hand side of the figure further

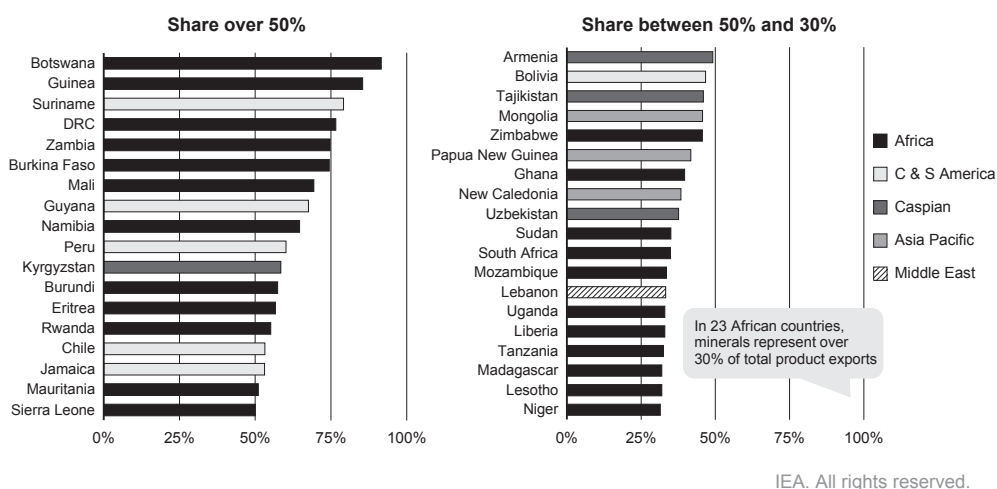


Sources: IEA (2020b); USGS (2021).

Source: IEA, 2021<sup>29)</sup>

**Figure 19** Share of top three producing countries in total production for selected minerals and fossil fuels, 2019

29) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



Notes: The chart shows countries whose share (based on monetary value) is above 30%. Standard international trade classification codes 27, 28, 68, 667 and 971 were included in the minerals and metals category. C & S America = Central and South America.

Source: IEA analysis based on UNCTAD (2021).

Source: IEA, 2021<sup>30)</sup>

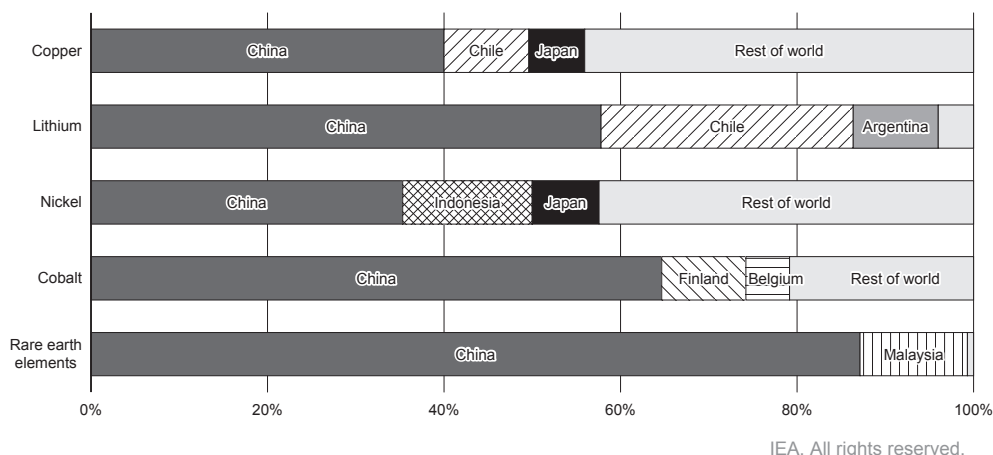
Figure 20 Share of minerals and metals in total product exports for mineral producing countries, 2019

breaks down the data to shares of 30% to 50%, and makes the important point that 23 African countries rely on critical minerals for over 30% of their exports.

The IEA's analyses of projects in the pipeline also suggests that this concentration is very unlikely to change much, at least over the next 5 to 10 years, even though many of the production sites have poor performance on governance, human rights, and other indicators. That means the complication of long lead times is compounded by ESG challenges. The severe human rights concerns surrounding cobalt – 70% of which is mined in the Democratic Republic of the Congo – have led to efforts to substitute for it. But as we saw in figure 15, the IEA anticipates demand for the mineral to increase 21 times between 2020 and 2040, under an SDS scenario.

We must also not forget that processing of critical minerals is also geographically concentrated, as portrayed in figure 21. The very high volatility of demand, the environmental costs of refining, and other drivers underlie this concentration. The figure shows that China is the dominant player in processing in 2019. While there is significant talk of relocating pro-

30) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

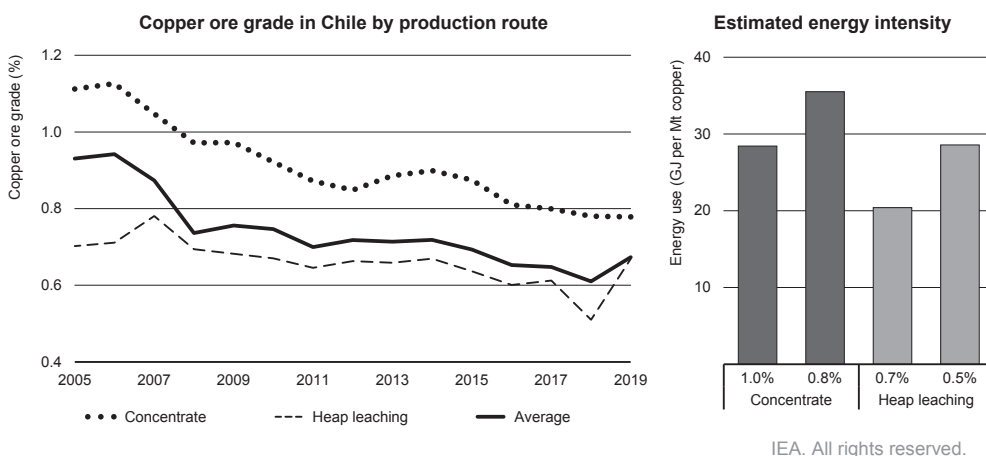


Note: The values for copper are for refining operations.

Sources: World Bureau of Metal Statistics (2020); Adamas Intelligence (2020) for rare earth elements.

Source: IEA, 2021<sup>31)</sup>

Figure 21 Share of processing volume by country for selected minerals, 2019



Notes: Energy use for concentrate covers mine, concentrating plant, smelter, refinery and services. For heap leaching, energy use covers mine, leaching, solvent extraction, electro-winning processes and services. GJ = gigajoule.

Source: IEA analysis based on COCHILCO (2019) and Rötzer and Schmidt (2020).

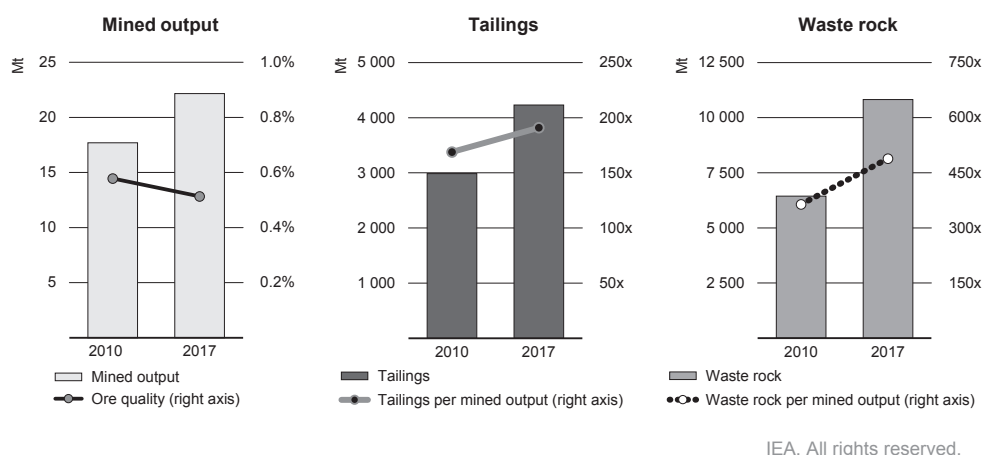
Source: IEA, 2021<sup>32)</sup>

Figure 22 Average ore grade in Chile and estimated energy intensity by quality

cessing and related supply chains, that is a lot easier said than actually done.

An additional matter of concern is declining ore grades and their impact on mining's

31), 32) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



Source: IEA analysis based on data updated and expanded from Mudd and Jowitt (2016).

Source: IEA, 2021<sup>33)</sup>

Figure 23 Waste generation from copper and nickel mining

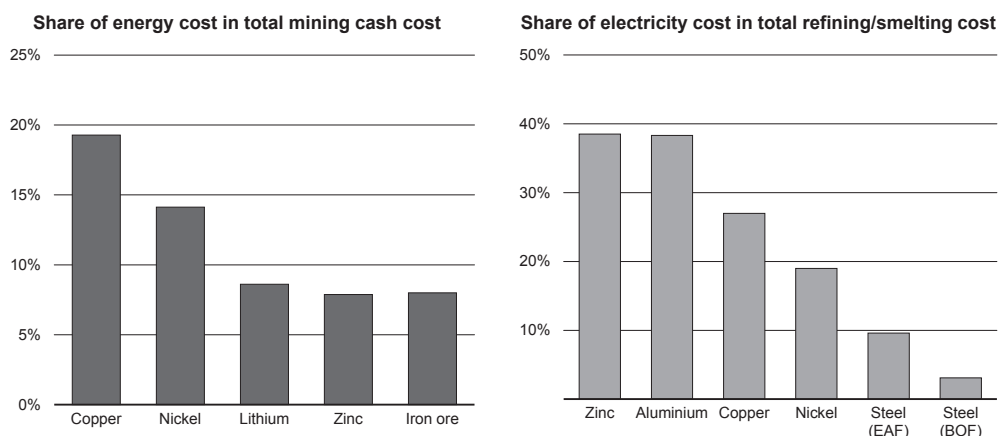
pecuniary and environmental costs. Figure 22 portrays the state of copper ore-grades in Chile between 2005 and 2019. The data show that average ore grades declined significantly over the period, raising the energy intensity measured in gigajoules (GJ) of energy use per Mt of copper. A similar trend is event in other materials.

The upshot of these trends is further explored in figure 23. It shows that declining ore grades in copper and nickel – between 2010 and 2017 – leads to higher tailing and waste rocks for a unit volume of ore extraction. Tailings and waste rock volumes are measured in the billions of tons (1,000 Mt), and include significant quantities of radioactive materials and other impurities.

Figure 24 also shows that energy costs are already relatively high for critical minerals, at both the mining and refining areas of the upstream. Indeed, the energy costs for copper are just under 20% of total mining cash cost, but as we saw in earlier data are expected to increase due to declining ore grades.

These cost and related issues bear on the ESG performance of critical minerals. But the IEA data in figure 25 show that a significant share of copper, lithium, nickel and cobalt production takes place in areas with poor governance and high emissions-intensity of electricity. Even where governance is good, as in Austrian lithium, the emissions intensity is

33) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



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Notes: ESG = environmental, social and governance; EAF = electric arc furnace; BOF = basic oxygen furnace.

Energy and electricity costs show global average values, and can vary by region and operational practice.

Source: IEA analysis based on S&P Global (2021) for mining, BHP (2011) for iron ore and Eurometaux (2020) for refining/smeltering.

Source: IEA, 2021<sup>34)</sup>

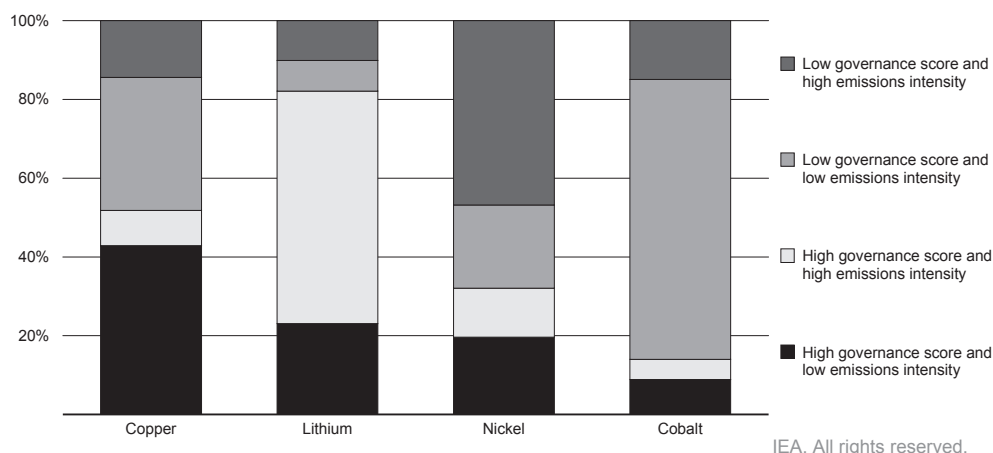
Figure 24 Share of energy cost in total mining cash cost and electricity intensity for selected materials

poor.

And human rights are hardly the only ESG conundrum. An additional matter of grave concern is that many critical minerals – particularly copper and lithium – are mined in areas with high water stress. **Figure 26** shows this with data on copper, lithium, zinc, nickel, bauxite (the raw material for aluminum) and cobalt. Climate impacts are generally worsening water stress in these areas, but mining the minerals requires large volumes of water that it often ruins. In consequence, increased mining risks exacerbating water stress in the absence of robust and perhaps costly countermeasures such as water recycling and desalinization.

The importance of water is further illustrated in **figure 27**. The data show that most critical minerals require a lot of water per unit of output, and have significant water pollution impacts. The fact of generally declining ore-grades suggests coping with these problems is an uphill battle.

34) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

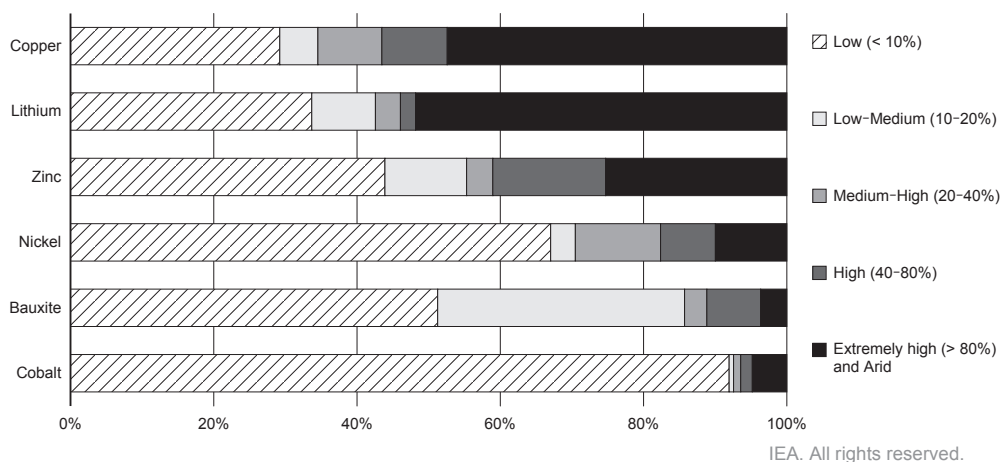


Notes: Analysis using the World Bank Worldwide Governance Indicator (as a proxy for governance) and electricity CO<sub>2</sub> intensity (as a proxy for emissions performance). Composite governance rank scores below 50 were classified as low governance; electricity CO<sub>2</sub> emissions intensity above 463 g CO<sub>2</sub>/kWh (global average value in 2019) was classified as high emissions intensity.

Source: World Bank (2020), IEA (2020).

Source: IEA, 2021<sup>35)</sup>

Figure 25 Distribution of production of selected minerals by governance and emissions performance, 2019



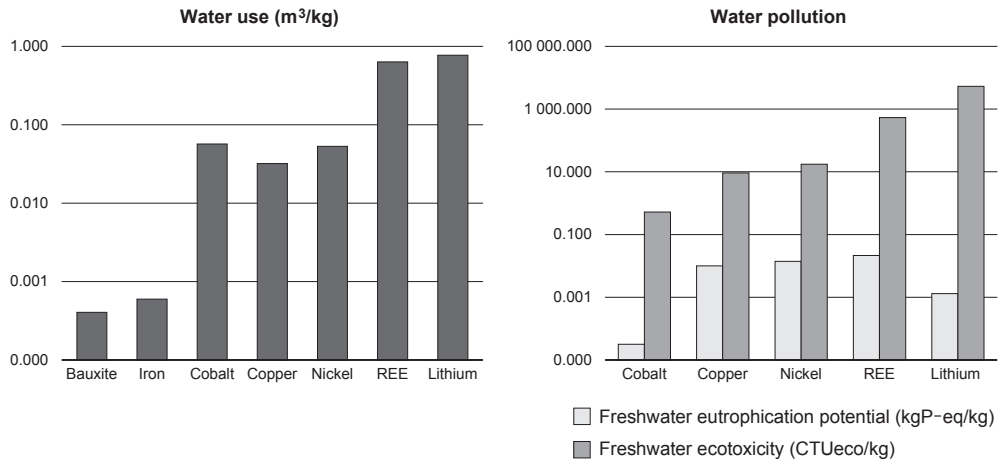
Note: Water stress levels are as defined in the Aqueduct 3.0 dataset according to the ratio of total water withdrawals over the total available surface and groundwater supplies.

Source: IEA analysis based on WRI Aqueduct 3.0 dataset.

Source: IEA, 2021<sup>36)</sup>

Figure 26 Share of production volume by water stress level for selected minerals, 2020

35), 36) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



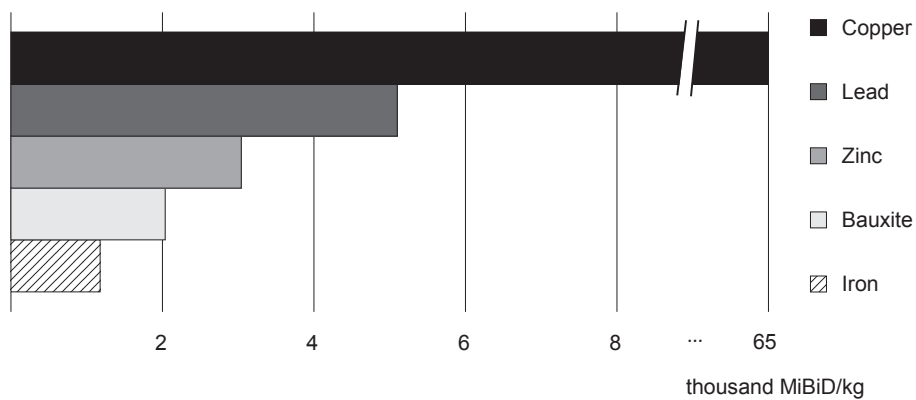
IEA. All rights reserved.

Notes: REE = rare earth element; CTUeco = comparative toxic unit for ecosystems; kgP-eq/kg = kilogramme of phosphorous-equivalent per kilogramme; m³/kg = cubic metres per kilogramme. Lithium data is for brine-based resources. REE refers to neodymium iron boron (NdFeB) magnet.

Source: IEA analysis based on Farjana, Huda and Mahmud (2019) (cobalt, copper, nickel) ; Jiang et al. (2020) (lithium) ; Marx et al. (2018) (REE) ; Tost et al. (2018) (bauxite and iron).

Source: IEA, 2021<sup>37)</sup>

Figure 27 Indicators for water use and water pollution for selected minerals



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Note: MiBiD is a non-dimensional index based on data regarding land cover, protected areas and mining operations.

Source: Kobayashi, Watando and Kakimoto, 2014.

Source: IEA, 2021<sup>38)</sup>

Figure 28 Intensity of mining pressure on biodiversity for selected minerals

37), 38) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

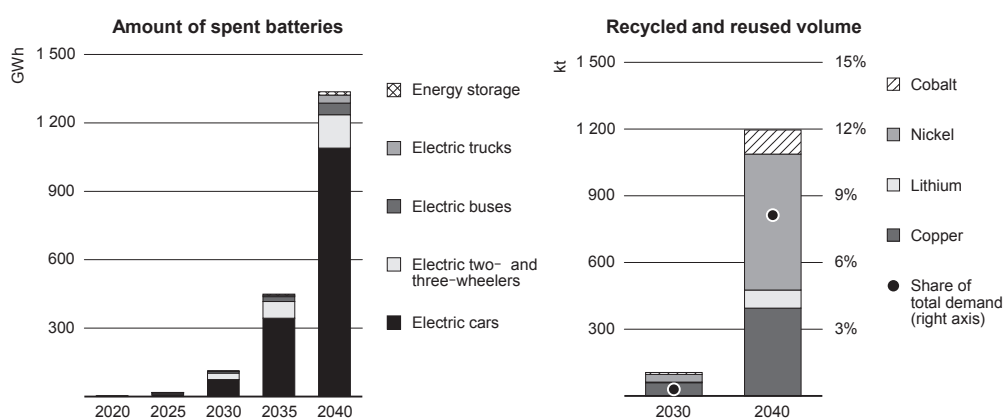


Figure 28 provides an additional measure of environmental impacts, measured as the pressure on biodiversity. The IEA data suggest that the per kg impact of copper is about 65 times more than iron.

## Recycling and Substitution

Perhaps the most startling finding from *Critical Minerals* is the limits of recycling and substitution. Most work on energy transitions looks to recycling in “circular economy” strategies as one key means to reduce the need for newly mined copper, cobalt, rare earths and other metals and minerals. Substitutions strategies complement this approach, by seeking new materials to replace the role of supply-constrained minerals used in batteries, solar panels, and the like. For example, recycling and substitution are key elements of Japan’s approach, with Panasonic’s 2170 lithium-ion batteries for Tesla reducing the share of problematic cobalt with increased nickel.

But as we see in figure 29, *Critical Minerals* does not expect recycling to become a significant source of supply for at least a couple of decades. The left-hand side of the figure



IEA. All rights reserved.

Note: GWh = gigawatt hour.

Source: IEA, 2021<sup>39)</sup>

Figure 29 Amount of spent lithium-ion batteries from EVs and storage and recycled and reused minerals from batteries in the SDS

39) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

shows that the 2020 stock of spent batteries is negligible, meaning their recycling cannot meet any of the escalating demand for battery storage. The right-hand side of the figure suggests that by 2030, recycled battery materials are at best a source of 1 % of demand, and even as late as 2040, recycling provides only about 8 % of demand.

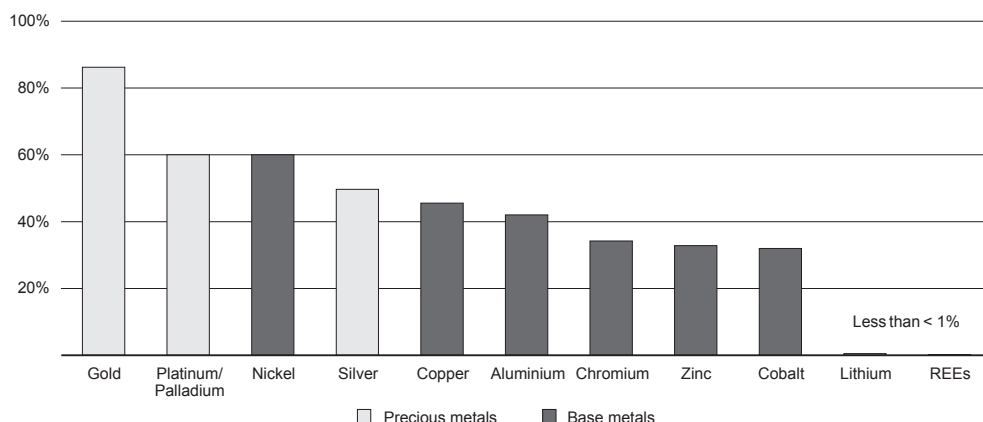
These results confirm earlier concerns about over-reliance on the circular economy. The IEA's findings on this point are consistent with other recent empirical work, such as the German Fraunhofer Institute's November 2020 study on "The Promise and Limits of Urban Mining."<sup>40)</sup> Another example is the December 10, 2020 survey from the Hague Centre for Strategic Studies (HCSS). The HCSS released a very detailed, book-length report on "Securing Critical Materials for Critical Sectors: Policy options for the Netherlands and the European Union," which examined the critical mineral implications of the Dutch and EU commitments to decarbonization. Their broad-based analysis included critical mineral demand for renewable energy (wind, solar, geothermal), energy grid infrastructure, carbon-capture and storage, electric vehicles, and semiconductors. The HCSS warned that recycling and other "circular economy" policies would quite inadequate to address the massive increase in required critical minerals volumes implied by decarbonization. They pointed out one cannot simply recycle critical minerals that are being dug up and processed for use in a massive rollout of energy, EVs, and other systems that will be in use for one or a few decades.

To be sure, *Critical Minerals* does not deny the importance of recycling and substitution. In fact, the report emphasizes recycling and substitution's importance in a broad strategy of investment, innovation, recycling, supply chain resilience and sustainability standards. Figure 30 from the report suggests that there is significant room to raise end-of-life recycling rates for many critical minerals. At the same time, achieving these increased rates confronts constraints due to the role of amalgams, which make critical minerals difficult to separate.

Figure 31 also shows that between 2010 and 2019 the recycled rates (as a fraction of inputs) remained relatively stable for aluminum, copper, lead and cobalt. As the tsunami of demand gathers pace from decarbonization, it is difficult to envision an increase in the recycled rate of inputs. In all likelihood, these rates will fall in the short and medium term until a sufficiently massive stock of new infrastructure is in place and reaching its end-use phase.

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40) See some of the data in Luis Tercero Espinoza, et al., "The promise and limits of Urban Mining: Potentials, Trade-Offs and Supporting Factors for the Recovery of Raw Materials from the Anthroposphere," Fraunhofer ISI, November, 2020: [https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccn/2020/Fraunhofer\\_ISI\\_Urban\\_Mining.pdf](https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccn/2020/Fraunhofer_ISI_Urban_Mining.pdf)

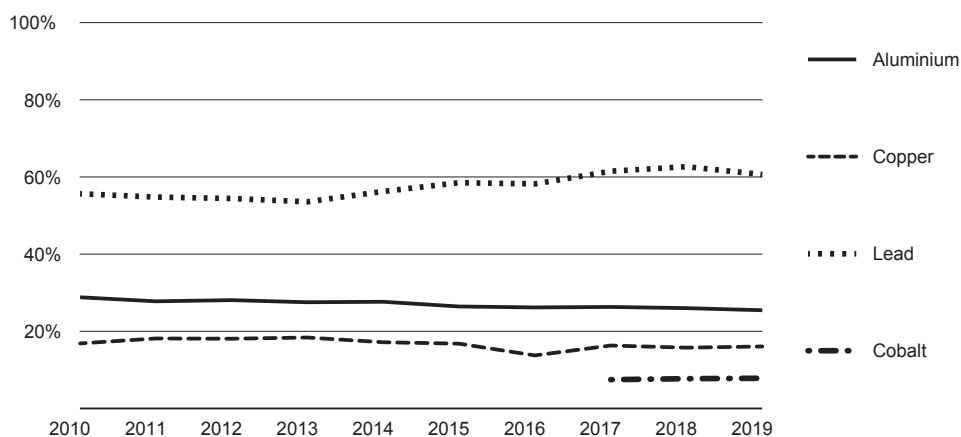


IEA. All rights reserved.

Sources: Henckens (2021); UNEP (2011) for aluminium; Sverdrup and Ragnarsdottir (2016) for platinum and palladium; OECD (2019) for nickel and cobalt.

Source: IEA, 2021<sup>41)</sup>

Figure 30 End-of-life recycling rates for selected metals



IEA. All rights reserved.

Notes: Share of secondary production in total refined product consumption. Does not include scrap volumes that are reused in end-use applications.

Source: World Bureau of Metal Statistics (2020).

Source: IEA, 2021<sup>42)</sup>

Figure 31 Recycled input rates for selected metals and minerals

41), 42) *The Role of Critical Minerals in Clean Energy Transitions*, International Renewable Energy Agency, May 2021: <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

The upshot of the IEA analysis confounds the oft-repeated insistence that decarbonization can avoid hard choices by simply fostering the circular economy and harvesting the “urban mine” of discarded smart phones, appliances, and conventional cars. To take a recent example, Japan recycled about 80,000 tons of mobile phones and other e-waste to get about 2 tons of copper for Olympic medals.<sup>43)</sup> But in energy-transition terms, that nationwide project secured only 1/4 of the 8 tons of copper needed for a single MW of offshore wind capacity.

To reiterate, the IEA data persuasively show that the global community is only beginning to build a stock of energy-transition infrastructure, including long-distance networks, distributed grids, battery storage, electric vehicles, and offshore turbines. Once that huge stock is in place and portions of it have reached the end of their useful life, then one can expect substantial critical mineral flows from recycling. So while we certainly need to adopt much stronger policies right now on recycling and substitution, we should not expect them to bear ample fruit for decades.

### What is to be Done?

As alluded to earlier, *Critical Minerals* emphasizes the urgency of comprehensive policy, including an intensive effort at recycling, substitution, and innovation that helps increase the efficient use of critical minerals. *Critical Minerals* also underscores the need for clear policy goals within decarbonization, so as to reduce the risks of critical minerals price volatility and other impediments to expanded supply via mining and processing. In addition, the report stresses the need for a regime of ESG-compliant critical minerals, both to protect the environment and human wellbeing as well as to foster new supply. The latter aspect is a subtle way of saying that more diversified supply may be achieved by reducing the dominance of producers whose ability to downplay ESG-related issues impedes the opportunity for cleaner, more community-engaged producers to enter the market.

A further recommendation is much stronger and integrated international governance. At present, there is a patchwork of international institutions and initiatives that address various aspects of critical mineral mining and processing. But these efforts are poorly coordinated and often lack adequate transparency. The IEA rightly suggests that its energy security framework could be of service in this regard, by facilitation the collection and dissemination of credible data, regularly assessing the vulnerabilities of supply chains, enhancing flows of

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43) On this project, see “Tokyo 2020 Medal Project: Towards an Innovative Future for All,” Tokyo 2020: <https://olympics.com/tokyo-2020/en/games/medals-project/>

knowledge and sharing of best-practices, and raising ESG-type standards “to ensure a level playing field.”

## And What About Japan?

To its credit, Japan is already doing a few of the items that the IEA points to, and receives a degree of acknowledgement in the report. Japan has long been a leading manufacturer of high-tech, critical mineral-intensive goods. So since the early 1980s, Japan has been assessing its critical material vulnerabilities.

Japan initially undertook stockpiling of 7 key minerals including cobalt. But as we entered the new millenium, with the globalization of ICT and other technologies, this approach was deemed insufficient to address the country's increased critical mineral demand. So since the mid-2000s Japan has undertaken an explicit and increasingly robust strategy for designating critical minerals, and addressing supply risks by emphasizing overseas projects, advanced recycling, substitution and stockpiling.

In tandem, Japan's list of critical minerals has increased to a few dozen from the original 7. Japan has also built good clusters of expertise and initiatives in recycling and substitution, linking those with US and other centres of excellence. One example from October 2011 is the US-Japan-EU Trilateral Workshop on Critical Raw Materials. Also, since 2013 Japanese specialists have been working with the US Department of Energy's Ames Institute on the “effective use of critical materials.”

As to advanced recycling, that is a major priority. Japan seeks to expand collection of recyclable materials domestically and from overseas. Japan does have comparatively good initiatives on recycling and substitution. There is also a new effort to drill-down on tungsten, cobalt and 3 select rare earths. And as of March 2020, Japan instituted a New International Resource Strategy.<sup>44)</sup> This policy covers 34 critical minerals – referred to as “rare metals” – and includes increased and fine-tuned goals for stockpiling of emergency reserves and a greater ability for the Japan Oil, Gas and Metals National Corporation (JOGMEC) to support private-sector mining and smelting initiatives. JOGMEC is also empowered to work with foreign firms in exploration activities. The country also officially aims at 80% self-sufficiency by 2030 in base metals such as copper and nickel, and is aiming to undertake commercial exploi-

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44) While the strategy per se is in Japanese, a brief outline in English is available at “New International Resource Strategy Formulated,” Ministry of Economy, Trade and Industry, March 30, 2020: [https://www.meti.go.jp/english/press/2020/0330\\_005.html](https://www.meti.go.jp/english/press/2020/0330_005.html)

tation of its Exclusive Economic Zone seabed critical minerals from 2028.<sup>45)</sup>

Japan may be moving towards quantifying the enormous scale of its own critical mineral challenge. A report to the Ministry of Economy and Industry (METI) deliberation committee on energy on February 15, 2021 pointed out that installing just 10GW of offshore wind – about 3 nuclear reactors' worth of power generation – by 2030 would require about 10% of Japan's 2018 copper consumption and 20% of its niobium rare earth consumption.<sup>46)</sup> The METI is mooting 45 GW of offshore wind by 2040, which implies a lot of critical mineral demand that will not be met by recycling and substitution.

And that critical mineral demand is on top of critical mineral requirements for other clean energy generation, transmission and storage, electrified mobility, 5 G communications, data centres, and other elements of Japan's critical material-intensive Society 5.0, decarbonization, smart city, and related industrial policy ambitions.

Yet it is striking that Japan has yet to ballpark the overall critical mineral requirements for its goals. There are no comprehensive critical minerals assessments from within Japan, in spite of its lack of terrestrial critical mineral endowments. Indeed, the METI calculation of copper and niobium requirements for offshore wind is based on IEA data. But Japan's offshore wind may be more material-intensive, due to greater oceanic depths, project distance from the shore, and distance from centres of power consumption.

Moreover, on May 13, 2021 Japan's respected Research Institute of Innovative Technology for the Earth released a multi-scenario study on energy options. In its 100% renewable energy scenario, power prices quadrupled by 2050 because of intensive deployment of solar and wind coupled with electricity networks.<sup>47)</sup> So one would expect Japanese policy-makers to undertake detailed analyses – to the extent possible – of Japan-specific critical mineral requirements.

New critical mineral mining and processing infrastructure generally take many years

45) Japan's policies are put in a comparative context by Jane Nakano in "The Geopolitics of Critical Minerals Supply Chains," Center for Strategic and International Studies, March 11, 2021: <https://www.csis.org/analysis/geopolitics-critical-minerals-supply-chains>

46) See (in Japanese) p 21, "The Metal and Mineral Policies Towards Realizing Carbon Neutrality by 2050," February 15, 2021: [https://www.meti.go.jp/shingikai/enecho/shigen\\_nenryo/kogyo/pdf/007\\_03\\_00.pdf](https://www.meti.go.jp/shingikai/enecho/shigen_nenryo/kogyo/pdf/007_03_00.pdf)

47) See (in Japanese) "Scenario analyses of 2050 carbon neutrality (mid-term report)," Research Institute of Innovative Technology for the Earth, report to basic policy subcommittee, May 13, 2021: [https://www.enecho.meti.go.jp/committee/council/basic\\_policy\\_subcommittee/2021/043/043\\_005.pdf](https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/2021/043/043_005.pdf)

to put in place. So in the short run Japanese policy might be important to watch for potentially innovative approaches to coping with critical mineral supply and price risks by for example:

1 ) If possible, Japan should work with new US-Canada-Australia “Earth MRI” (Critical Minerals Mapping Initiative),<sup>48)</sup> which deploys the most advanced 3 D mapping technologies to identify CRM deposits in addition to natural disaster risks, and renewable energy resource potential. Japan has developed and diffused a lot of advanced mapping technology through its Society 5.0, National Resilience, and other initiatives, and could conceivably bring much to the table.

2 ) Japan could be working with India on exploring CRM (while also mapping disaster risks, RE potential), as only 10% of India has been explored and both countries need CRM.<sup>49)</sup>

3 ) Japan's seafloor mining of CRM is expected to start in 2028, but that could be accelerated in tandem with Japanese collaboration on work suggesting deepsea mining is potentially more ESG-compliant than terrestrial.<sup>50)</sup>

4 ) Japan's JOGMEC and other agencies could work with Canadian and other projects on mineralization (mining with CO2 sequestration via mine tailings) and reap opportunities for green critical minerals plus more options in the Joint Crediting Mechanism.<sup>51)</sup>

5 ) Japan's decarbonization goals are curiously uninformed by its significant climate adapta-

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48) See “Critical Cooperation: How Australia, Canada and the United States are Working Together to Support Critical Mineral Discovery,” USGS, October 16, 2020: <https://www.usgs.gov/news/critical-cooperation-how-australia-canada-and-united-states-are-working-together-support>

49) The details are at Biplop Chatterjee and Rayesh Chadha, “Non-Fuel Minerals and Mining: Enhancing Mineral Exploration in India,” Brookings India Discussion Note, April, 2020: <https://www.brookings.edu/wp-content/uploads/2020/04/Enhancing-Mineral-Exploration-in-India.pdf>

50) See Paulika, Daina, et al. “Life cycle climate change impacts of producing battery metals from land ores versus deep-sea polymetallic nodules,” *Journal of Cleaner Production*, December 2020: <https://www.sciencedirect.com/science/article/pii/S0959652620338671>

51) On mineralization see, “Giga Metals launches nickel CO2 capture project,” Craig Guthrie, August 10, 2020: <https://www.miningmagazine.com/sustainability/news/1392750/giga-metals-launches-nickel-co2-capture-project>

tion strategy,<sup>52)</sup> even though the IPCC and other global agencies highlight the synergies of mitigation and adaptation. Japan might consider the critical mineral implications of these synergies.

## Conclusion

We have seen that the critical mineral challenge is enormous globally and within Japan. Japan is conspicuously lacking in the think tanks and comprehensive public-policy schools that could build on the IEA's work, and assess Japan's myriad smart city, decarbonization and other targets in terms of Japan-specific critical mineral requirements.

Absent sudden substitution, recycling and other silver-bullet breakthroughs, it would appear that strategic prioritizing of the use of scarce critical minerals will be necessary. But there is limited evidence that this kind of thinking is – for example – animating discussion among the myriad stakeholders involved in ongoing deliberations on Japan's strategic energy policy.

Even so, as it considers the sobering critical mineral implications of accelerated decarbonization, Japan may be able to get more traction in these areas. One reason for cautious optimism is that because of ageing, depopulation, and other challenges, Japan is getting increasingly good at focusing scarce human, fiscal, material and other resources by addressing multiple problems simultaneously. Japan has a lot of Society 5.0, smart city, and other decarbonization industrial policies, and could use the looming crisis in critical minerals to gain more pragmatic, multi-stakeholder agreement. But at present, it remains to be seen if critical minerals emerge as a major, rather than minor, item in Japan's upcoming revision of its energy strategy, slated for the summer or fall of 2021.

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52) On this, see "Japan and Singapore Submit 2020 NDCs," SDG Knowledge Hub, April 2, 2020: <https://sdg.iisd.org/news/japan-and-singapore-submit-2020-ndcs/>