Introduction

On October 27, 2020 Japanese Prime Minister Suga Yoshihide announced that his administration would set national policy on course to aim at net-zero in greenhouse gas (GHG) emissions by 2050. Japan is now one of over 100 countries committed to achieving net-zero by 2050. 2) Japan’s decarbonization pledge is backed up by ambitions for a vast rollout of offshore wind, millions of tonnes of “green hydrogen,” and assertions that domestic automakers can achieve net-zero emissions from the entire life cycle 3) of a vehicle. 4)

Japan’s commitment was strongly welcomed by an international climate-policy community shocked by the impact of the COVID-19 pandemic and seeking roadmaps for build-
ing back better on all fronts.\textsuperscript{5)} Perhaps Japan possesses the innovative capacity to realize its decarbonization goals. But one pressing question is whether resource-scarce Japan has sufficient access to the voluminous critical raw materials required to pursue its emergent plan for decarbonization. Equally important is asking whether Japan has a robust strategy to secure critical raw materials that also conform to rapidly strengthening sustainability rules.

\textbf{It’s a material world}

The imperative of rapid decarbonization is a global consensus. But it is important to note that no country’s net-zero commitments are backed up by detailed and credible planning. Even the much-lauded EU goals for a green recovery and decarbonization by 2050 lack clarity. The EU goals remain largely a vision rather than a roadmap. The hard work of land-use changes, lifestyle shifts, the relative proportion of decarbonizing energy technologies, and other fundamental issues remain to be decided. Yet what is clear is that decarbonization will require a lot of new mining for copper, cobalt, lithium, and other critical raw materials (also referred to as “critical minerals” and “critical and strategic minerals”\textsuperscript{6}). These materials are used in especially high densities in variable renewable energy (VRE) and electrified mobility, especially electric vehicles (EVs).

Specialists have debated for several years whether there are adequate supplies of critical raw materials to meet the projected demand for significantly increased renewable energy, let alone scenarios of global decarbonization.\textsuperscript{7)} But concerns about decarbonization’s material demand went mainstream at the start of 2021. On January 11, 2021, the International Energy Agency (IEA) announced a series of special projects for 2021, leading up to the May 18 release of \textit{The World’s Roadmap to Net Zero by 2050}.\textsuperscript{8)} Key among the IEA special re-

\textsuperscript{5)} One example is Japan NRG founder Yuriy Humber’s article “There are good reasons to celebrate Japan’s decarbonization pledge,” \textit{Nikkei Asia}, December 12, 2020: https://asia.nikkei.com/Opinion/There-are-good-reasons-to-celebrate-Japan-s-decarbonization-pledge

\textsuperscript{6)} Other terms include “green energy metals,” “energy transition metals,” “battery metals,” and the like. These terms generally delineate subset groups of minerals and metals used in renewable energy, battery storage, and more specific applications.

\textsuperscript{7)} One example of the debate is seen in Peter Viebahn, et al., “Assessing the need for critical minerals to shift the German energy system towards a high proportion of renewables,” \textit{Renewable and Sustainable Energy Reviews}, Vol. 49, September 2015: https://www.sciencedirect.com/science/article/pii/S1364032115003408

\textsuperscript{8)} The IEA announcement is summarized at “IEA to produce world’s first comprehensive roadmap to net-zero emissions by 2050,” International Energy Agency, January 11, 2021: https://www.
ports will be what IEA director Fatih Birol correctly described as the first comprehensive and global study of the supply constraints, lifecycle costs, environmental justice, and related challenges confronting the critical minerals used in electric vehicles, renewable energy equipment, and the myriad other elements of the clean energy transition. This IEA special report is to be titled The Role of Critical Minerals in Clean Energy Transitions, and is slated for publication in April.

In IEA director Birol's January 11 press conference, he pointed to lithium, nickel, cobalt and rare earths as among the critical minerals under the IEA's review. That brief itemization is not exhaustive. What constitutes a “critical raw material” (CRM) – to use the European Commission’s abbreviation – varies by country and is based on each jurisdiction's assessment of dozens of materials’ specific domestic economic importance, supply risk and related factors. China's most recent CRM list, which is not publicly available, dates back to 2016 and delineates 24 “strategic minerals.” This number is the same as Australia’s list, though the two lists differ greatly in composition and purpose. As of 2018, the U.S. identifies 35 CRMs. This number is the same as South Korea’s list of 35 CRMs, though their specific content varies. And Japan’s CRM list comprises 34 materials, up from 30 in 2012.

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9) The IEA press conference, titled “IEA key priorities and special projects for 2021,” is available at the following URL: https://www.youtube.com/watch?v=ZZNEFn5UfrQ
For their part, India’s specialists often use “new-age metals,” “Technology Metals and Energy-Critical Metals,” and “Energy Critical Elements” to delineate CRM critical raw materials.\(^{17}\) India’s first study of critical minerals was undertaken in 2016. It assessed 49 non-fuel minerals, and determined that 12 confronted serious supply constraints by 2030.\(^{18}\) India’s list is virtually certain to increase, in line with those of Japan, the EU, and other examples. The same is true of Germany’s raw materials strategy, which is surprisingly limited in spite of the country’s lofty ambitions for VRE, EVs and other elements of decarbonization.\(^{19}\)

Interestingly, what is deemed a critical resource has largely evolved and expanded in line with the expansion of digital technology, clean energy and decarbonization goals.\(^{20}\) The EU is a notable example of this phenomenon. Its first triennial review of CRMs identified 14 materials in 2011, and the second review in 2014 expanded that to 20 CRMs. As investments in renewable energy and other green tech sectors have soared, the EU’s CRM list has ballooned. By 2017, it contained 27 materials. As of September 2020, the number had grown to 30.\(^{21}\)

Another factor that drives CRM lists is technological innovation. Increasingly sophisticated devices – whether in consumer electronics, renewable energy, or military hardware – require ever more types of CRM. Hence, for example, the “fabrication of high-speed, high-capacity integrated circuits required only 12 minerals in the 1980s but more than 60 by the 2000s. Building a modern cell phone now requires materials containing 75 minerals, compris-

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\(^{17}\) One example is seen in S. Vijay Kumar, “We Need to Mine in India to Make in India,” Presentation to India Mining Summit 2018, July, 2018: https://www.teriin.org/sites/default/files/2018-08/mining-recommendation-paper.pdf


\(^{21}\) The EU list separates the rare earths into two categories of heavy and light elements. On the EU list and its evolution, see “Critical raw materials,” European Commission, nd: https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en
ing elements covering about two thirds of the periodic table.”22) And as the required number
of CRMs increase in these devices, the market for the devices is increasingly global.

At present, all publicly available national lists include the 17 rare earth metals, gener-
ally grouping them as a single item, reflecting their outsized importance relative to their
small quantities.23) In 2019, global mined production of rare earths was just 210,000 tons with
a market value of about USD 8 billion. That latter figure belies their importance, as rare
earths were essential to many multiples of that value in VRE, EVs, electronics, and other ap-
plications.24)

While most CRM lists converge on rare earths, cobalt, graphite, indium, and lithium,
the view on other materials differs. For example, Japan has long determined copper to be
critical, whereas the EU, US, and other countries do not. Yet the global assessments of cop-
per appear to be rapidly moving towards Japan’s position. One reason is that copper is used
in more applications, in addition to clean energy, than any other CRM.25) Copper is also the
“gateway” to many other CRMs because they are byproducts of copper production.26) At the
same time, ramping up copper mining is fraught with environmental impacts, governance
challenges, human rights implications, and other issues. Thus, copper is increasingly central
to assessments of critical raw materials.27) Many experts and analysts are re-evaluating cop-
er’s core contribution in the renewables space and – as Wood Mackenzie does – ranking it

News, February 5, 2021: https://eos.org/science-updates/geological-surveys-unite-to-improve-
critical-mineral-security
23) A summary of the rare earth elements can be found at “Rare earth elements facts,” Natural Re-
sources Canada, November 27, 2019: https://www.nrcan.gc.ca/science-data/science-research/earth-
sciences/earth-sciences-resources/earth-sciences-federal-programs/rare-earth-elements-facts/20522
24) The global data on rare earths are summarized in “Mineral Commodity Summaries, 2020” United
25) One good visual portrayal of copper’s role – too detailed for reproduction in the present paper – is
available on the title page of “Critical materials for strategic technologies and sectors in the EU – a
Strategic_Technologies_and_Sectors_in_the_EU_2020.pdf
26) For this reason, many American experts argued their own country’s CRM list should include cop-
er. See Veronica Tuazon, “Critical Minerals’ list snubs copper, sparks discussion of criticality,” Earth
Magazine, December 20, 2018: https://www.earthmagazine.org/article/critical-minerals-list-
snubs-copper-sparks-discussion-criticality
27) See Dieuwertje Schrivers, et al., “A review of methods and data to determine raw material critical-
science/article/pii/S0921344919305233
alongside aluminum, nickel, cobalt and lithium as an "energy transition metal." 28)

**Driving concerns**

As alluded to in the above, there are several drivers for this deepening convergence of concern regarding CRMs. One is the rapidly increasing global commitment to “green deal,” “green recovery,” and similarly named transformative policies. These GHG-reduction policies predate COVID-19. But during the pandemic, a consensus emerged to “build back better” from the ravages of COVID-19 and cope with climate change.

These GHG-reduction initiatives are also imperative lest China’s GHG-intensive recovery from COVID-19 become the norm for much of the planet. The authoritative Carbon Monitor’s January 22, 2021 calculations show that China’s emissions from January 1, 2020 to December 31, 2021 exceeded the previous year’s total by 0.5%. During the same period, total global emissions declined by 4.4%, dropping 8.1% in India, 5.0% in Japan, 12.5% in the US, and 7.5% in the EU 29).

However, decarbonized power, housing, mobility, communications, and other industries are not built with intangible technologies and innovation. Greening requires prodigious amounts of very tangible CRMs whose environmental costs and geopolitical implications are increasingly huge. To be sure, the CRMs used in decarbonizing green technologies are a dramatically different mix of materials than the fossil-fuels that distinguish the grey, or carbon-intensive economy and society. Put simply, solar panels and wind farms – the poster kids of green – do not burn any of the 7 billions tonnes of thermal coal forecast to be produced in 2020.30) But on the other hand, the CRM-intensity of green technology is impressive. Hence, the more solar, wind and battery storage there is in the decarbonizing power mix, the higher the CRM intensity of installed generating capacity and the CRM intensity of generated power.

For example, as seen in figure 1, data from a March 2020 IEA report indicate that

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29) The regularly updated data are available at Carbon Monitor: https://carbonmonitor.org

30) Renewable do of course dirty energy and a lot of metallurgical coal in their manufacture, but we do not address those issues here. On the coal data for 2020, see “Global coal production will grow this year despite covid-19,” Mining.com, April 9, 2020: https://www.mining.com/global-coal-production-to-grow-by-0-5-in-2020/
building offshore wind capacity is well over ten times more copper-intensive than natural gas- and coal-fired fossil fuel plant. The figure summarizes the kilogrammes of copper, lithium, nickel, and other CRMs required to build a megawatt (MW) of generation capacity for the different technologies. It shows that building a MW of intermittent wind and solar generating capacity requires many more multiples of CRMs than a MW of gas and coal plant. The expression of CRM-intensity is kgs/MW.

Figure 1 actually understates the CRM-intensity of solar and wind. Wind and solar are intermittent, and produce only a fraction of their rated capacity, giving the installed plant a comparatively lower efficiency in using CRMs. So in actual generated power output – or megawatt-hours (MWh) of electricity – solar and wind have an even greater CRM-intensity than other technologies. We see this in figure 2, which displays one of the leading assess-

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ments\(^{33}\) of the total density of copper per kWh of power generated across a variety of technologies.

The research shows that wind has the highest density of copper for installed capacity but that solar has the highest density in actual use. The reason is that, with solar,

“utilization is significantly lower than that of wind applications due to the fact that solar PVs’ hours of generation are roughly limited to 3 hours either side of midday — i.e. 6 hours per 24, whereas wind farms could in theory run 24/7 depending on wind strength. The result is that on a g/kWh basis, copper intensity for solar PVs come in higher than that of wind technologies, but on an installed capacity basis (MW), copper intensity for wind (both onshore and offshore) applications come in higher.”\(^{34}\)

As for mobility, figure 3 shows us that the same IEA publication reveals electric vehicles require roughly five times as much CRM as a conventional car. Similar to power gen-

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eration via wind and solar, electric mobility has profound implications for required volumes of CRMs. Some of the best work on this has been done by Dutch researchers at Metabolic, Copper 8, and other cutting-edge consultancies. Their collaborative work is supported by the Dutch Ministry of Infrastructure and Water Management in addition to other stakeholders. Their analyses of the CRM implications of 30% EV by 2030 in the Netherlands, the EU, and the world warn that even with advanced battery chemistries, demand for cobalt, lithium and select rate earths outstrips global supply.35)

Another driver of growing concern over CRMs supply is dangerous uncertainty. Though CRM lists are being compiled and updated, the policy environment is opaque, the knowledge base concerning CRMs mining and processing is poor, and there are wildly optimistic assumptions regarding substitutability and recycling.

![Diagram showing minerals used in selected transport technologies](https://www.iea.org/data-and-statistics/charts/minerals-used-in-selected-power-generation-technologies)
We have already seen that decarbonization policies and projects are rapidly increasing, driving CRM demand well beyond sustainability. Concerning knowledge erosion and recycling, on December 10, 2020, the Hague Centre for Strategic Studies (HCSS) released a very detailed, book-length report on “Securing Critical Materials for Critical Sectors: Policy options for the Netherlands and the European Union.” The HCSS analysis first examined the CRM implications of the Dutch and EU commitments to decarbonization. Their broad-based analysis included CRM demand for renewable energy (wind, solar, geothermal), energy grid infrastructure, carbon-capture and storage, electric vehicles, and semiconductors. The HCSS warn that recycling and other “circular economy” policies are quite inadequate to address the massive increase in required CRM volumes implied by decarbonization. One cannot recycle CRMs that are being dug up and processed for use in a massive rollout of VRE, EVs, and other systems that will be in use for one or a few decades. One can perhaps reduce CRM demand by many informed and strategic choices about where to use them (e.g., materially-efficient public transit vs EVs), but that kind of thinking is not in evidence. Even the literature on “smart cities,” which are ipso facto a locus of CRM demand, does not address the CRM implications of smart grids, advanced communications, data centres, and other core technologies. Thus the HCSS report highlights the current magical thinking about CRM supply chains, not simply among policymakers but also industry participants, academics, and other stakeholders. The HCSS authors depict it as “knowledge erosion” and their arguments merit quotation in detail:

“Market actors are responsible for ensuring resilient supply chains for themselves, while the role of the government has been marginalized. A lack of long-term strategic direction and a phenomenon of knowledge erosion have resulted from reduced government involvement...

The phenomenon of knowledge erosion did not occur solely on the governmental level, but also on the industrial and academic levels. Due to heavy reliance on global value chains for imports of materials, intermediate and end products, the EU and the


Netherlands currently lack the industrial knowledge and facilities to become self-sufficient. There is a lack of academic and professional focus on developing industrial expertise for mining, refining and other supply chain stages."

One consequence of "knowledge erosion" is that CRM-intensive "green recovery" decarbonization scenarios unfold in a blissful state of logistical ignorance. Few scenarios pay any heed to CRM-intensity, let alone the fact that scaling up any CRM mining and processing requires many years and a lot of money. And note, for example, that current copper projects are 33% smaller than the average project was in 2012; and these new projects are being undertaken by smaller firms with less experience.39) On top of these issues, the depletion of existing copper mining projects is striking. One recent assessment indicates that "without new capital investments...global copper mined production will drop from the current 20 million tonnes [Mt] to below 12Mt by 2034, leading to a supply shortfall of more than 15Mt. Over 200 copper mines are expected to run out of ore before 2035, with not enough new mines in the pipeline to take their place."40) In tandem, experts on the realities of lithium mining warn that battery-maker and other firms’ current planning for 2023 implies seven times more demand than any conceivable scenario for global supply.41)

Another driver of concern over CRMs is the implications of these trends for human rights. Supply constraints are likely to increase the pressure to relax worker and environmental safeguards in order to maximize extraction from existing mines. The Industriall Global Union – representing 50 million workers in 140 countries – warned about these challenges in a November 20, 2020 report. They examined the global battery supply chain’s reliance on copper, cobalt, nickel and lithium, together with the implied acceleration of electric vehicle sales. Their expert consultation cautioned that:

"The demand for critical raw materials for the low carbon energy transition batter-

39) On these data, see the summary of comments by Saad Rahim, Chief Economist and Global Head of Research, Trafigura, in “JEF U: Commodity Market Perspectives from Trafigura’s Chief Economist,” Jefferies University, December 16, 2020.

40) Rick Mills, “Copper, the most critical metal,” Mining.com, December 6, 2020: https://www.mining.com/web/copper-the-most-critical-metal/

ies, cobalt, lithium, copper and nickel, etc. will likely follow the same upstream demand side (mining) narrative of human rights’ violations and unacceptable environmental consequences: child labour, destruction of the living environment of indigenous peoples, ecological destruction, water shortage etc.”

One of the experts Industriall Global Union consulted with was Andy Leyland, head of Supply Chain Strategy at Benchmark Mineral Intelligence. Leyland noted that battery makers and electric vehicle manufacturers are pressing for cost reductions, at all points of the supply chain, including mining. For this reason, he warned that working conditions and other factors at existing mines are likely to degrade significantly in a “race to the bottom.” The result would be worsening environmental injustice at the point of production – i.e., generally the global south – while developed-country “green recovery” scenarios seek to implement environmental justice on the home front.

Prices are also a driver of concern. Benchmark Mineral Intelligence’s Andy Leyland forecast that prices for batteries will increase, even though virtually all expectations are for declining prices. Nearly every “green recovery” and 100% renewable energy scenario rests on the assumption of continued price declines in generation, transmission, storage (including batteries) and other aspects of power systems. These scenarios have even increased the call on CRMs by simplistic modeling of the economics of scaling “green hydrogen” to 100 GW in a decade. They assume that learning-curve dynamics will drive the price of renewable-produced hydrogen below the “blue hydrogen” produced by fossil fuels by 2030. Yet as Leyland highlighted above, the patent fact is that “demand for the required raw materials will grow faster than new mining capacities can be created.” Clearly, some hard, strategic choices have to be made on maximizing the efficient use of CRMs, lest the cost of decarbonization be worsened inequality and energy poverty.

The general response to this kind of evidence is to argue for substitution of the supply-constrained CRM. But there are limits to that approach. One example of limits is seen in the effort to use nickel to reduce reliance on cobalt in electric vehicle batteries. In collabora-

44) Ibid.
tion with Panasonic, the US automaker Tesla has been at the forefront of this initiative. Indeed, Tesla’s goal is to entirely eliminate the role of cobalt in electric-vehicle (EV) batteries, and it is achieving notable success in this objective. However, the initiative has encountered something of a “whack a mole” phenomenon. This is because supplies of nickel are increasingly constrained, posing a challenge to large-scale substitution of cobalt in the high energy-density batteries required for electrified transport. Global demand for nickel in EV batteries is projected to increase from 3% of all sources of demand (such as stainless steel, non-ferrous alloys, and other products) in 2018 to 12% by 2023, as global automakers are expected to introduce over 200 new EV models. But the volatility of prices for nickel has been a drag on investment in increased mining capacity. In consequence, metals analysts warn that “[t]here is no new nickel in the pipeline” even as other specialists highlight the time required to find alternatives.\(^5\)

Concerning nickel, the EU released a detailed study (by Roskill, on the EU’s behalf) on February 5, 2021. Figure 4 is taken from the report, which suggests that EVs will be the largest driver of nickel demand over the next two decades. Indeed, the figure shows that projected nickel use in EV batteries rises exponentially, even assuming that India and other countries do little EV deployment. In numerical terms, nickel demand for EVs is projected to rise from 920,000 tons in 2020 to 2.6 million tons in 2040. The analysis warns that this EV battery demand for nickel from China, the EU and rich “JKT” Asia (Japan, Korea, Taiwan) is likely to drive global nickel production into deficit in a few years. Yet nickel is crucial for stainless steel (eg, for sanitation systems) and other applications that the world needs for sustainable development.\(^6\) Therefore, trade-offs will have to be made lest real human needs be made forfeit to imagined needs for personal transport.


\(^6\) Nickel’s uses are described at “End use of nickel,” Nickel Institute, 2021: https://nickelinstitute.org/about-nickel/#05-end-use-nickel
The EU study on nickel includes a section on “implications for policy,” wherein the experts suggest the EU add nickel to their CRM list and get a grip on CRM via robust policy implementation. One suggestion is a focus on public transport and other approaches that dampen battery-nickel demand. These policies have to be implemented now, because CRM mining and processing capacity takes years to build (even ignoring environmental, human rights issues).

But those arguments fly in the face of a public debate transfixed by bold promises that ignore CRMs. One example is seen in the case of EV-maker Tesla, which has promised to raise EV production over 40 times in a decade, from 499,550 in 2020 to 20 million by 2030. Table 1 provides a summary of the CRM implications of Tesla’s 2030 target, which is merely one of the more outrageous of recent bold commitments by VRE, EV, and other stakeholders. The table is taken from a January 27, 2021 Mining.com analysis, that drilled down into the battery chemistries and other details and then assessed CRM demand to meet Tesla’s commitment. To put the numbers in perspective, the table includes 2019 mine production data (before COVID-19 disruption to supply chains) for nickel along with graphite.

![Figure 4](image.png)

**Figure 4** Nickel consumed in automotive batteries by region 2020–2040 (t Ni)

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49) Frik Els, “All the mines Tesla needs to build 20 million cars a year,” Mining.com, January 27, 2021: https://www.mining.com/all-the-mines-tesla-needs-to-build-20-million-cars-a-year/

and other CRMs.

As is evident from the table, and as the article highlights, “when Tesla makes 20 million cars in a year it will need more than 30% of global mined nickel production in 2019 (2020 saw a 20%-plus reduction in output) for its batteries. Put another way Tesla will have to buy the entire output of the top 6 producers – Norilsk Vale Jinchuan Sumitomo Glencore BHP and then some. Or build the equivalent of 23 mines like Sumitomo’s Ambatovy mine in Madagascar – at $8.5 billion a pop.” Tesla would also require an astounding 94% of the world’s production of natural graphite, and 39% of magnet rare earth mined output (in the table “MagREO (NdPr, Dy, Tb)” ). Since those CRM are also needed for almost equally ambitious VRE, green hydrogen, and related commitments – not to mention more mundane needs in high-tech health care, communications, education, and the like – huge compromises will have to be made. As the Dutch Centre for Research on Multinational Corporations (SOMO) warns in a December 2020 study of batteries, “any energy transition strategy should prioritise reducing demand for batteries and cars, thereby reducing mineral and energy use in absolute terms. Strategies proposed include ride-sharing, car-sharing and smaller vehicles. Combined, these approaches have the biggest potential to reduce the negative im-

<table>
<thead>
<tr>
<th>Tesla Production @ 20m</th>
<th>Material Required (t)</th>
<th>Production 2019 (t)</th>
<th>% of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite</td>
<td>1,028,775</td>
<td>1,100,000</td>
<td>94%</td>
</tr>
<tr>
<td>Nickel</td>
<td>750,410</td>
<td>2,460,000</td>
<td>31%</td>
</tr>
<tr>
<td>Lithium</td>
<td>127,302</td>
<td>77,000</td>
<td>165%</td>
</tr>
<tr>
<td>Copper (vehicle)</td>
<td>1,820,000</td>
<td>21,000,000</td>
<td>9%</td>
</tr>
<tr>
<td>Manganese</td>
<td>20,811</td>
<td>19,000,000</td>
<td>+0%</td>
</tr>
<tr>
<td>Cobalt</td>
<td>68,315</td>
<td>122,000</td>
<td>56%</td>
</tr>
<tr>
<td>Aluminum (battery)</td>
<td>16,544</td>
<td>64,000,000</td>
<td>+0%</td>
</tr>
<tr>
<td>Aluminum (vehicle)</td>
<td>3,380,000</td>
<td>64,000,000</td>
<td>5%</td>
</tr>
<tr>
<td>MagREO (NdPr, Dy, Tb)</td>
<td>18,000</td>
<td>46,000</td>
<td>39%</td>
</tr>
</tbody>
</table>

Battery graphite, nickel, cobalt, lithium, manganese, MagREO (NdPr, Dy, Tb) : Adamas Intelligence
Production: USGS, BMO, Morgan Stanley, BP, Fitch. Excl synthetic graphite
Copper, aluminum (vehicle) : UBS estimates of Chevy Volt
Source: Frik Els, 2021
pacts of road mobility.” 50)

But the global debate is not focused on making compromises in order to maximize the spatial efficiency and functional efficiency of CRM use. Hence our precarious present, where green-energy scenarios of “overbuild” 51) and “electrify everything” assume a cornucopia of copper and other CRMs, even as bemused CRM analysts show that the cornucopia does not exist. The present is not intellectually sustainable, and we should not expect the geologic and other facts of CRMs to yield. Thus, it is indeed timely that the IEA undertake a global study of CRM.

Japan's supply-chain vulnerabilities

A more long-term set of issues for Japan, in particular, are supply-chain vulnerabilities. Just as Japan has virtually no fossil-fuel resources, it does not have significant terrestrial endowments of CRM. The country has had strong trade ties but, at times, a rocky political relationship with neighboring China. Over the last decade, Japan has somewhat diversified its rare earths supply, wary of China’s demonstrated capacity to restrict exports. Even so, 58% of Japan’s rare earth imports came from China in 2018, according to the Center for Strategic and International Studies “China Power” project. As figure 5 shows, the Center’s data reveal a persistent reliance on China for rare earth imports among all the major developed economies, and not just Japan.

And as we see in Figure 6, a 2020 report from the Japan Oil, Gas and Metals National Corporation (JOGMEC) warns that China enjoys a continued monopoly in the separation and purification of rare earths. The figure shows the degree of Chinese dominance at various stages of the supply chain, from mining through to manufacturing. The figure shows that even some rare earth mining takes place in the US and Australia, nearly all separation and purification is done in China. One reason is that China’s willingness to bear the enormous environmental damage from mining and purifying rare earths allows it to weaken the investment incentives of would-be competitors.

51) On overbuild scenarios, see Michael J. Coren, “It’s time to start wasting solar energy,” Quartz, December 30, 2020: https://qz.com/1950381/the-case-for-producing-way-more-solar-energy-than-we-need/
Decarbonization and Critical Raw Materials: Some Issues for Japan

52) The figure is from “Does China Pose a Threat to Global Rare Earth Supply Chains?,” China Power, July 17, 2020: https://chinapower.csis.org/china-rare-earths/

It is quite concerning for Japan that China dominates the mining and processing of rare earths and many other CRMs. Last month, Japan’s Ministry of the Economy, Trade and Industry (METI) stated in its vision for the domestic offshore wind industry that Japan must aim to produce at least 60% of components locally in order to cut costs. Under business as usual, the viability of this goal depends heavily on China’s interest in continuing to export a large share of its CRMs to Japanese manufacturers. Japan is perhaps uniquely exposed because it has scarce resource endowments in tandem with fraught relations with China. Increased access to rare earths is imperative for building a high-tech and decarbonizing domestic economy and exports, yet China is a strategic competitor rather than partner.

Yet China is increasingly using its own rare earth and other CRM, in domestic deployments of solar, wind, electric cars, 5G communications, and other devices. And as Chinese scholars now warn, given increasing demand and competing uses there simply may not be enough for China to continue satisfying the bulk of Japanese and other international demand.

The ESG imperative

The coal-fired power and lax environmental regulations that have helped make China a formidable player in CRMs, and by extension a major factor affecting Japan’s manufacturing and energy strategies, may soon work against it. Extracting and processing rare earths and other CRMs is very energy-intensive, with massive carbon footprints when undertaken in locales dependent on fossil-fuels, as China still is. Certainly, China is seeking to strengthen environmental rules relating to rare earths and other CRMs. But its big handicap may be energy, as the most recent data from the IEA show that China’s power mix in November 2020 was 66% coal and rising.

China’s very GHG-intensive energy is an issue because of the striking rise in prominence of environmental, social and governance (ESG) rules. These rules are now forcing firms to forego the business-as-usual approach in securing CRMs, obligating them to accept responsibility for the lifecycle environmental cost of products. These rules are expanding among governments (especially the EU), global finance agencies (such as the Financial Stability Board), and investor services. ESG rules are thus becoming of increasing concern to miners. For example, figure 7 displays the results of a White & Case survey of 68 high-level stakeholders in metals and mining (not just CRM), released January 13, 2021. The survey shows that ESG is by far the top issue, at 45.4% versus 13.6% for COVID-19 supply-chain risks.

As with any other business sector, the extension of ESG rules into the CRMs involves three areas, or “scopes,” that apply to the firms producing them. First are scope 1 direct GHG emissions from the firm’s in-house fuel combustion and the like. Scope 2 include GHG emissions from the firm’s use of electricity and heat generated elsewhere. And scope 3 emissions are the indirect, value-chain emissions that are beyond the firm’s control but generally susceptible to its influence. Figure 8 portrays these 3 scopes in some detail, provid-

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ing examples of how they relate to the reporting firm per se, in addition to its upstream and downstream activities. Of particular importance concerning CRMs is that their GHG-intensity is increasingly not simply an issue for the mining and processing firms. Rather, the firms that use refined CRMs in building wind turbines, electric vehicles, and other devices also have to assess those materials’ ESG implications.

It would be wrong to assume that these ESG and other rules mean little in practice. ESG rules are becoming one of the primary mechanisms countries are using to build strategic autonomy and resilience. The EU experts have already undertaken detailed comparative assessments of the carbon footprints of CRMs made in China versus those produced in Europe. Figure 9 provides a summary of the details for the CRMs aluminum, nickel, silicon and zinc. The data indicate that a given weight of Chinese-made aluminum was 2.8 times as carbon-intensive as its EU-made equivalent. For nickel, the difference was even greater, at 8 times. Similar China-EU gaps are evident for the silicon needed in solar, semiconductors, and other applications; the zinc used in galvanizing steel, batteries; and other areas pertinent to decarbonization.

Indeed, the EU “taxonomy” of sustainability rules applied to its Critical Raw Material Action Plan is very strict. The carbon thresholds for aluminum (one of the EU CRMs) is so

![Figure 9: Carbon footprint of primary metals production, EU vs China (tCO2)](https://www.ies.be/files/Metals_for_a_Climate_Neutral_Europe.pdf)

Source: Institute for European Studies, 2019


restrictive that “[o]nly producers with access to massive volumes of nuclear or hydropower can meet such a requirement.” 61) Chinese aluminum, produced via its coal-based power grid, would certainly not make the cut.

The upshot of these rules is that a Japanese manufacturer of, say, wind power equipment will need to factor in the additional “cost” of the environmental impacts of CRMs they import. Put simply, in the choice between a bar of metal produced with clean energy and another with dirty energy, the former will become more attractive. This is a major reason one sees Finnish nickel sulphate producer Terrafame arguing that a kilogram of its nickel sulphate leads to 1.75 kg CO2–eq (carbon-dioxide equivalent of all GHGs released) versus the industry average of 5.4 kg. 62) At the very least, the cost of the metal will be assessed in terms of both production costs and ESG impacts. The resulting all-in cost may in time also include an emissions tax and similar measures. 63)

But these extra costs present a serious challenge for Japan. Figures 10 and 11 are taken from the EU study prepared by Roskill and released on February 5, 2021. Japan already does include nickel as CRM, and the Roskill numbers suggest how vulnerable it is in the face of “seismic” demand drivers. Figure 10 shows that Japan’s electricity cost to process nickel sulphate into useable materials is higher than the global average in addition to neighbouring competition in South Korea, Taiwan, and China. Japan’s natural gas costs, for producing nickel sulphate, are assessed at roughly the global average. But the country is disadvantaged through a lack of international pipelines and other infrastructure to use demand to reduce costs.

And figure 11 reveals that Japan is also disadvantaged by high labour costs for its domestic refining capacity. These facts underscore Japan’s difficulties in responding to the challenge from emerging competitors. Without an integrated and intelligent national strategy, Japan may lost a great deal of business.

63) A discussion of these ESG-related tax and other measures can be found in the “OECD Business and Finance Outlook 2020: Sustainable and Resilient Finance,” OECD, 2020: https://www.oecd-ilibrary.org/sites/bebb0add-en/index.html?itemId=/content/component/bebb0add-en
Japan’s specialist debate should be animated by these concerns. One reason is that this new trajectory of competition and price–discovery is already emerging in conventional energy fields, such as LNG. Producers are being encouraged to offer carbon offsets as part of...
the sale, anticipating compulsory rules. That is, businesses are anticipating stricter formal
rules by bringing in measures that help reduce the overall LNG supply chain.\(^{66}\)

And as we have seen above, these trends are already emerging in the CRM space – not in spite of, but because of the strategic importance of these materials. As US mining financier Robert Friedland put it in the January 18 meeting of the Association of Mineral Exploration annual conference, “There will be no one price for copper, there will be no more one price for gold... Everything will be priced in relation to its ESG components.”\(^{67}\)

**Whither Japan?**

As it stands, Japan’s laudable zero-carbon ambitions effectively commit it to a massive increase in imported CRMs, even in the short run. Targets for 2050 matter far less than the fact that virtually all the major economies are implementing CRM-intensive green recovery projects. Japan’s green initiatives have this larger context. As we have seen, wind power and electric vehicles requires many multiples of CRM than the many gigawatts of conventional power and millions of vehicles they are to displace in a decade or so.

One would think resource-poor Japan would be leading the world on means to maximize CRM-efficiency and engagement with ESGs. But Japan has a weak mining industry and consequently poor public and specialist debate on CRMs. To date, resource-poor Japan has emphasized CRM recycling and substitution. But as the IEA and other studies show, those strategies are buckshot rather than silver-bullet solutions. And over the next several years, Japan will have to secure much larger volumes of CRMs in the midst of increasing resource nationalism, worsening ore-grades, and other complications. At the same time, life-cycle emission commitments will push Japan to be choosy: if it fails to procure ESG-conforming “green CRMs” rather than the environmentally costly “gray CRMs” it currently sources, it will risk forfeiting business in the midst of history’s biggest energy revolution. And Japan will have to find some way to control its energy and labour costs, even as VRE and EV material inputs prices likely rise. Yet so far, Japan’s domestic resource and energy-environmen-

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*67* See the quotations in Nicholas Bennett, “Revenge of the miners,” Business in Vancouver, January 18, 2021: https://biv.com/article/2021/01/revenge-miners
tal policy debates have yet to grapple with the dilemmas. We have seen that Japan has a list of CRMs, but its policymaking has yet to link them to ESGs. The METI is yet to produce data on the CRM-intensity of, for example, the gigawatts of offshore wind and millions of tonnes of green hydrogen being bandied about.\(^{68}\) And Japan’s business media, green-energy advocates, and other stakeholders pay virtually no attention to the enormity of CRM challenges in tandem with ESGs. As of this writing, the focus is on the comparative costs of nuclear and VRE, with the reigning assumption being that prices will fall.

Japan’s attention deficit and knowledge erosion in regard to CRM are quite startling for a resource-poor country. At the same time, Japan has a significant opportunity. For one thing, its exposure to CRM supply uncertainties give it ample incentives to act. It also has a lot of capital to invest in solutions. Moreover, its policymakers are debating the strategic energy plan, with the prospect of revising it in the summer of 2021. And Japan’s purchasing power affords it significant capacity to lead on CRMs – to be a rule maker rather than a rule taker. This may happen, as Japanese industry stakeholders at the core of Japan’s decarbonization industrial strategy are increasingly (and quite legitimately) concerned that rules “stipulated, regulated and decided by the EU will become the global standard.”\(^{69}\) The IEA’s announcement of its critical mineral initiative has been followed by a flurry of high-level international governance changes and collaborative deliberations. Perhaps Japan’s comparative complacency on CRMs and ESGs will undergo rapid change during 2021.

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69) This concern was expressed on December 6, 2020 to the Financial Times by Suntory chief executive Niinami Takeshi. Niinami is one of two private-sector advisors on Japan’s Council on Economic and Fiscal Policy, which is chaired by the prime minister and oversees integrated green-growth and industrial policy. See Niinami’s comments in Robin Harding, et al., “Japan warns against allowing EU to set emission rules,” Financial Times, December 6, 2020: https://www.ft.com/content/13d09498-54e5-4886-9626-8a259529146b