Energy Transition and Critical Commodities: Key challenges

CRU Consulting

July 2023

Critical Minerals Supply-Demand perspectives and challenges

The world **needs**

Accelerated, geopolitically resilient supply of key minerals extracted quickly and in an environmentally and socially responsible manner.

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- Energy transition itself is highly commodity intensive
- Urban, middle class population growth is super-charging demand
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The United States: Copper supply is the key risk to the energy transition

Supply story dominates in the US

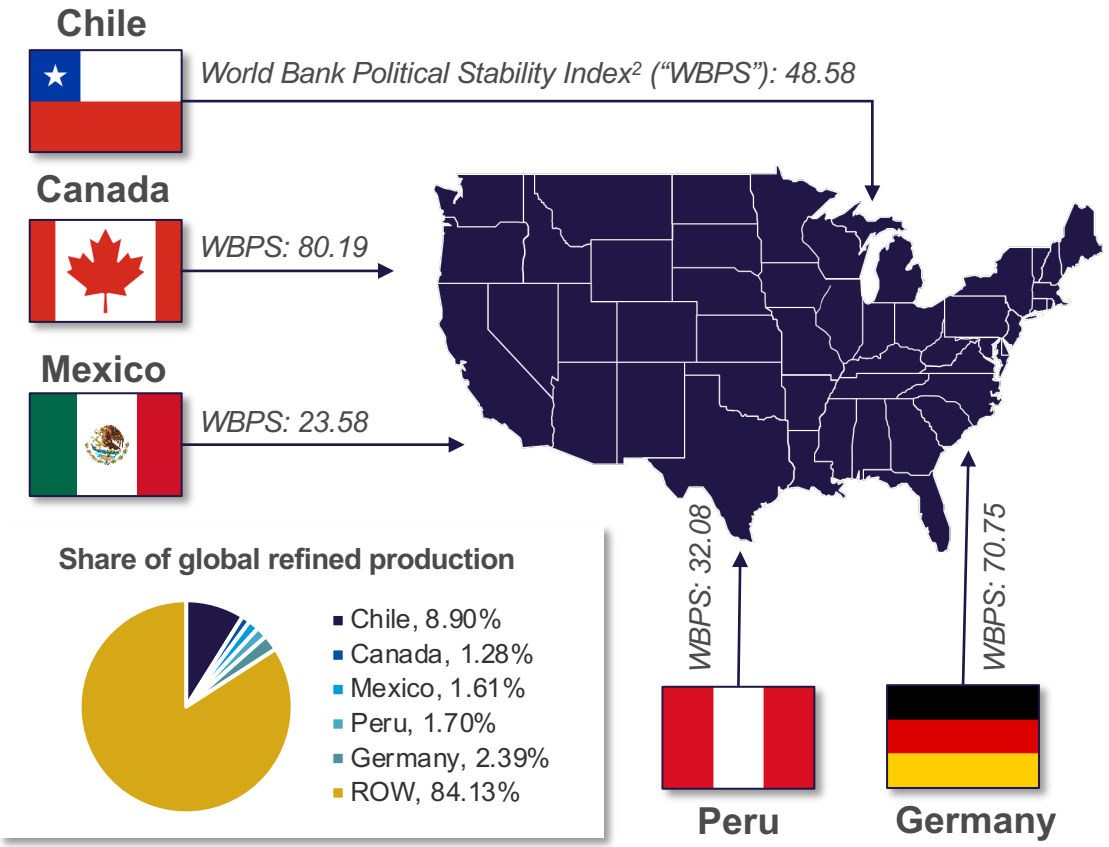
Years of known reserves:	Uncertainty of supply:	Geopolitical exposure:	Absence of substitution:	Recycling:
34 yrs.	**High**	**Medium**	**Medium**	**Medium**

- Increases in the **working age population** beyond 2050 drive growth
- Imports need to increase **to satisfy consumption growth**
- **Flexibility in existing supply chains may be sufficient** to meet this growth but other sources may be needed if stresses in the geopolitical situation in South America grow.
- **Domestic production of refined copper forecast to fall** across the medium term.
- **Future increase in recycling is not guaranteed**, without policy drivers, scrap prices shift rates of collection.

Domestic refined production and consumption, t, 2022 and 2027

Metric	2022	2027	Delta
Concentrate production	781,000	812,000	31,000
Refined production	840,000	826,000	(14,000)
Refined consumption	1,570,000	1,857,000	287,000
Green-energy related consumption[1]	214,000	662,000	448,000

The main importers of copper to the United States, 2022



Recent relevant legislation impacting on copper procurement: The US submitted its first NDC in March 2015 ahead of the Paris Agreement. The US submitted its second NDC in April 2021, after formally rejoining the Paris Agreement in January 2021: Commits to an economy-wide target to reduce net GHG emissions by 50-52% by 2030 compared to 2005 levels. More recently, in mid-2022, the US government launched the Inflation Reduction Act ("IRA"). The IRA provides $394 bn of climate and energy funding to households and businesses, much of it in the form of tax credits.

DATA: CRU. Note: (1) Green-energy related consumption is for contained copper. (2) World Bank Political Stability Index ("WBPS"): low number is higher risk

The EU / Europe: Lack of copper reserves and high geopolitical exposure key challenges

Low reserves in EU and high geopolitical exposure

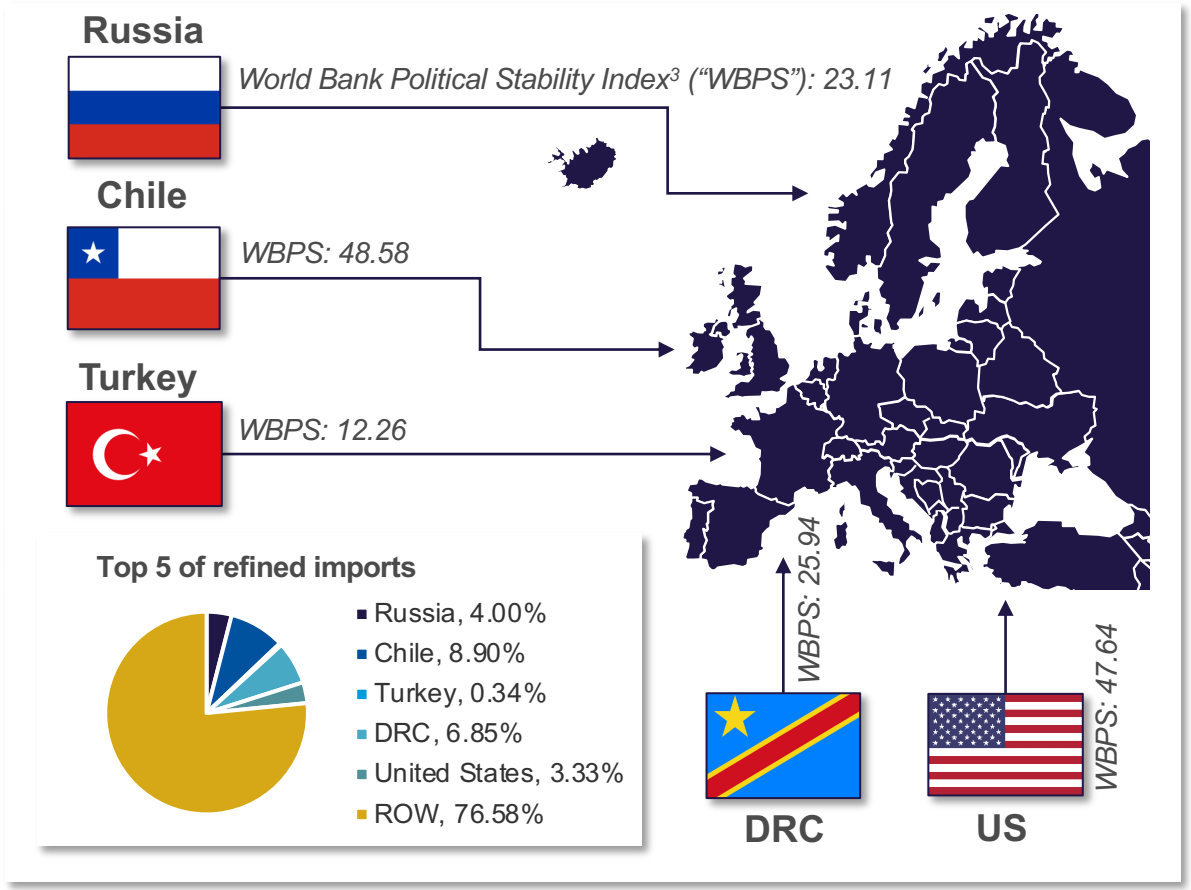
Years of known reserves:	Uncertainty of supply:	Geopolitical exposure:	Absence of substitution:	Recycling:
~15 yrs.	Medium	High	Medium	Low

- Substantial **rise in green-energy related consumption**, even by 2027.
- We expect G7 countries to start cooperating more closely on the sourcing of critical minerals.
- Such cooperation could be the first step towards the formal **launch of a critical minerals club.**
- One obstacle to establishing such a 'club' could be the World Trade Organisation's most favoured nations rules, which require countries to grant the same trade conditions to all countries outside formal free trade agreements.

Domestic refined production and consumption[1], t, 2022 and 2027

Metric	2022	2027	Delta
Refined production	3,497,000	3,685,000	188,000
Refined consumption	3,283,000	3,649,000	366,000
Green-energy related consumption[2]	465,000	1,119,000	654,000

The main importers of copper to the EU, 2022



Recent relevant legislation impacting on copper procurement: EU policymakers are concerned that the financial support offered by the IRA to US-based green businesses could make Europe relatively less attractive. To try and level the playing field, the European Commission ("EC") published its draft Green Deal Industrial Plan in February 2023. In March, the EC subsequently published its proposed Net-Zero Industry Act as well as its proposal for the Critical Raw Materials Act ("CRMA").

DATA: CRU. Note: (1) Results are for Europe cumulatively and not just the EU. (2) Green-energy related consumption is for contained copper. (3) World Bank Political Stability Index ("WBPS"): low number is higher risk

Japan: Extensive High-tech manufacturing domestically raises supply concerns for nickel

Uncertainty of supply the major concern

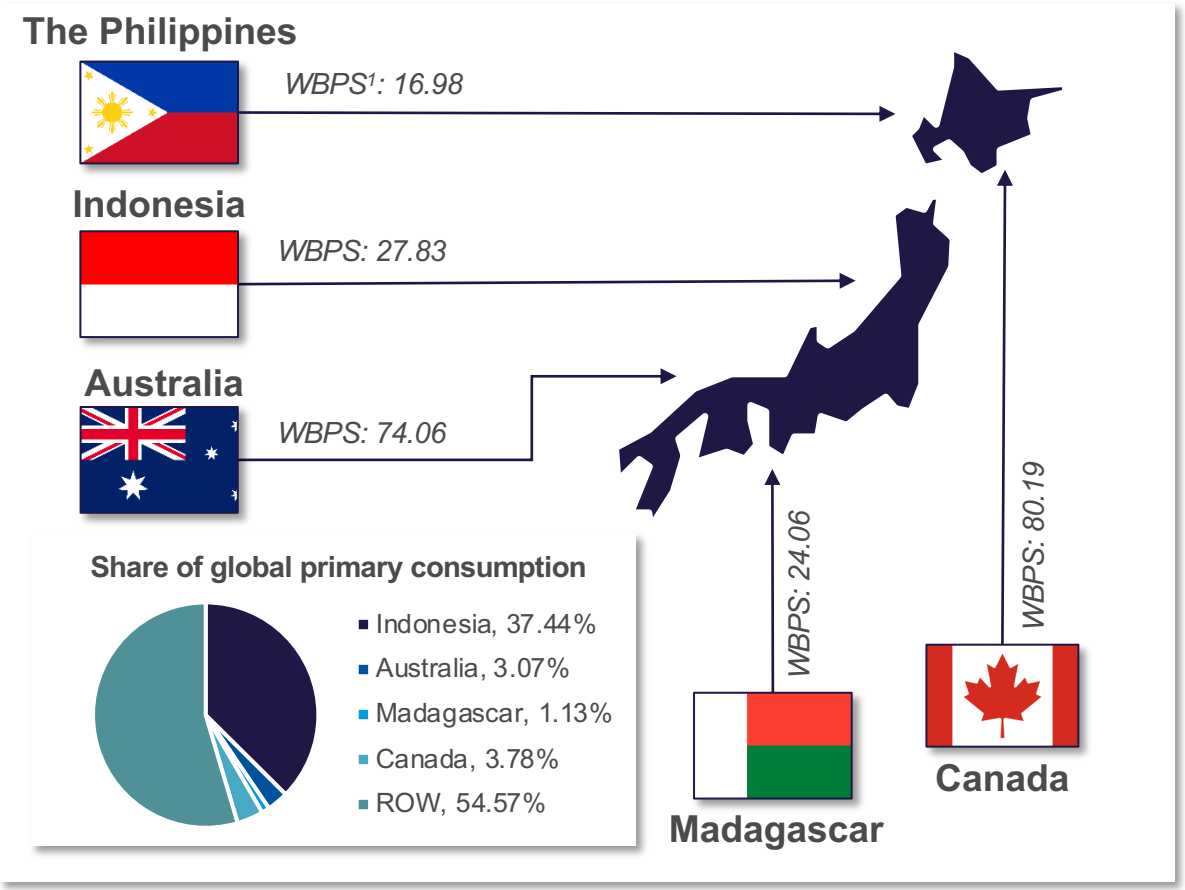
Years of known reserves:	Uncertainty of supply:	Uncertainty of demand:	Geopolitical exposure:	Absence of substitution:
-	High	Low	Medium	Low

- Japan is **dependent on the import of critical minerals such as nickel, cobalt and high rare earths** for their high-tech manufacturing.
- **Hydrogen is a potentially interesting alternative in Japan**
- Japan are amongst a number of countries with the **largest exports of embodied emissions**[1].
- **Carbon prices** will cause producers with emissions-intensive assets to lose relative competitiveness in foreign markets.

Domestic primary production and consumption, t, 2022 and 2027

Metric	2022	2027	Delta
Primary production	126,000	129,000	3,000
Primary consumption	166,000	241,000	75,000
World battery-related consumption	*486,000*	*1,230,000*	*744,000*

The main importers of nickel to Japan, 2022



The Japanese Government submitted its Updated NDC (4th Version) in October 2021. Commits to reduce GHG emissions by 46% by 2030 compared to 2013 levels. This is aligned with a long-term goal of reaching net zero by 2050. Japan plans to create their first market for trading carbon emissions, launching a demonstration project in September 2022. Auctions are to be introduced by 2023 and will be freely allocated until 2026. From 2026, we assume Japan moderately reduces the share of freely allocated allowances in the system.

DATA: CRU. SOURCE: (1) https://www.carbonbrief.org/mapped-worlds-largest-co2-importers-exporters/ Note: (1) World Bank Political Stability Index ("WBPS"): low number is higher risk.

Australia: Ongoing export opportunity dependent on continued demand for Ni in importing regions

Demand the main area of focus

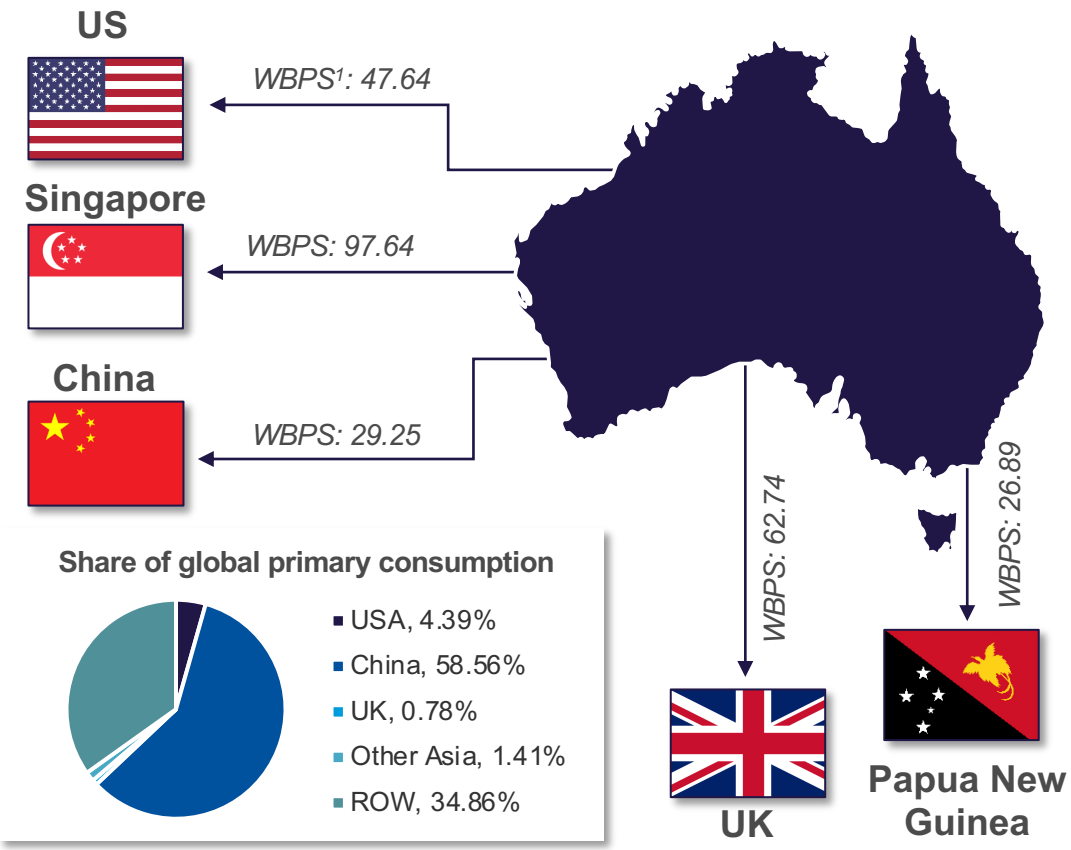
Years of known reserves:	Uncertainty of supply:	Uncertainty of demand:	Geopolitical exposure:	Absence of substitution:
216 yrs.	**Low**	**High**	**Medium**	**Low**

- Australia **can be relied upon as a source of nickel** by the major producers of batteries and other end-uses required by the green energy transition.
- **Further opportunities for Australia**, with the imposition of new trade measures by some countries impacting on global sea-borne supply. E.g. August 2019 Indonesia imposed nickel export bans to encourage domestic development of nickel products
- Adding **downstream value** "in country" could mitigate demand risks for Australia but would increase supply risks for others

Domestic primary production and consumption, t, 2022 and 2027

Metric	2022	2027	Delta
Primary production	97,000	113,000	16,000
Primary consumption	3,000	3,000*	-
World battery-related consumption	*486,000*	*1,230,000*	*744,000*

The main exporters of nickel from Australia, 2022



Recent relevant legislation impacting on copper procurement: The Australian Government submitted its Updated NDC (4th Version) in June 2022.The updated NDC: commits Australia to reduce greenhouse gas emissions by **43% by 2030 from the 2005 level**; reaffirms Australia's commitment **to net-zero emissions by 2050**; commits the government to providing an annual statement to parliament on progress towards these targets; and restores Australia's Climate Change Authority as a source of independent policy advice.

DATA: CRU. Note (1) World Bank Political Stability Index ("WBPS"): low number is higher risk. (2) Australia's first gigafactory for stationary storage and large vehicles has been announced in 2023: https://www.afr.com/markets/equity-markets/entrepreneur-declares-australia-s-first-battery-gigafactory-20230314-p5crvj but will not be in production in 2027

Canada: Low domestic nickel reserves to limit upside from green energy transition

Limited reserves a source of concern

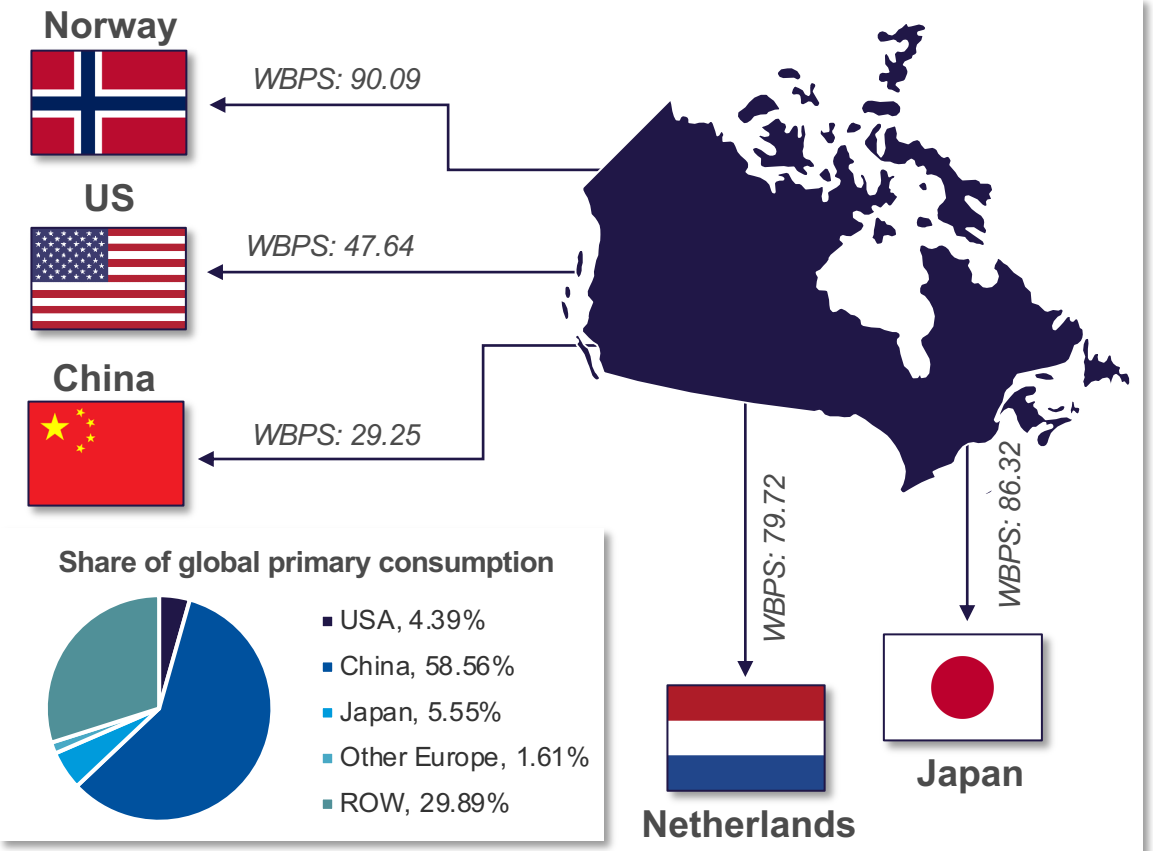
Years of known reserves:	Uncertainty of supply:	Uncertainty of demand:	Geopolitical exposure:	Absence of substitution:
19 yrs.	**Low**	**High**	**Low**	**Low**

- Canada's ambition to have a domestic carbon price of ~€130 / tCO2 by 2030 will ensure that material exported from the country will **continue to be competitive** even in those countries considering implementing a carbon border adjustment mechanism.
- Leading producers are **Vale and Glencore**.
- Limited domestic reserves will constrain any potential ramp up in exports
- The recent announcement from Volkswagen in relation to the establishment of **a large domestic gigafactory** will further draw on production in country.

Domestic primary production and consumption, t, 2022 and 2027

Metric	2022	2027	Delta
Primary production	119,000	131,000	12,000
Primary consumption	6,000	6,000*	-
World battery-related consumption	*486,000*	*1,230,000*	*744,000*

The main exporters of nickel from Canada, 2022



Canada submitted its Updated NDC (3rd Version) in July 2021. Commits to an emissions reduction of **40-45% by 2030** compared to 2005 levels. CAT analysis states that the new target is not sufficient to achieve compatibility with the Paris Agreement. Passed the Canadian **Net-Zero Emissions Accountability Act** in June 2021 which enshrines its 2050 net zero target into law. The act mandates the setting of intermediate emissions reduction targets at 5-year intervals.

DATA: CRU. Note: (1) World Bank Political Stability Index ("WBPS"): low number is higher risk (2) Announcements of new Gigafactories in Canada will increase demand in the period beyond 2027: https://www.volkswagen-newsroom.com/en/press-releases/volkswagen-group-steps-up-activities-in-north-america-canada-chosen-as-location-for-first-overseas-gigafactory-of-its-battery-company-powerco-se-15615

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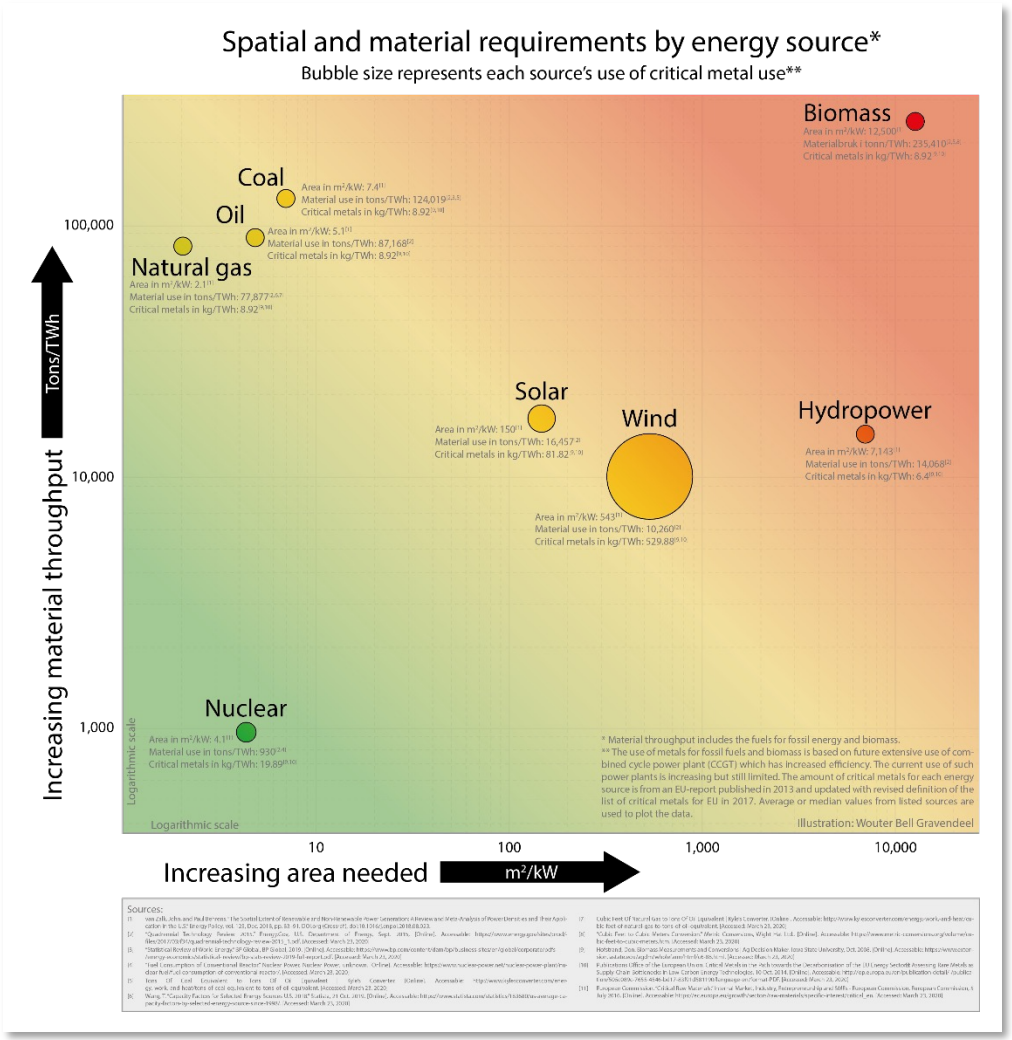
- Need new technology to manage increasing mine costs

Challenge 1: The energy transition will require a high critical metal usage



Key takeaways

Area requirements

- Conventional fossil-fuel based energy sources (i.e., coal, oil and natural gas) have amongst the lowest spatial requirements (between 2 and 8 m^2/kW).
- The only energy source with a smaller area needed is nuclear.

Critical metals use

- Wind eclipses all other energy sources in regard to critical metal usage owing to its reliance on rare earths, nickel, manganese, copper and aluminium and as such has a value of ~530 kg/TWh.
- By comparison, coal, oil and gas require substantially less with a critical metal use of ~9 kg/TWh.

Material throughput

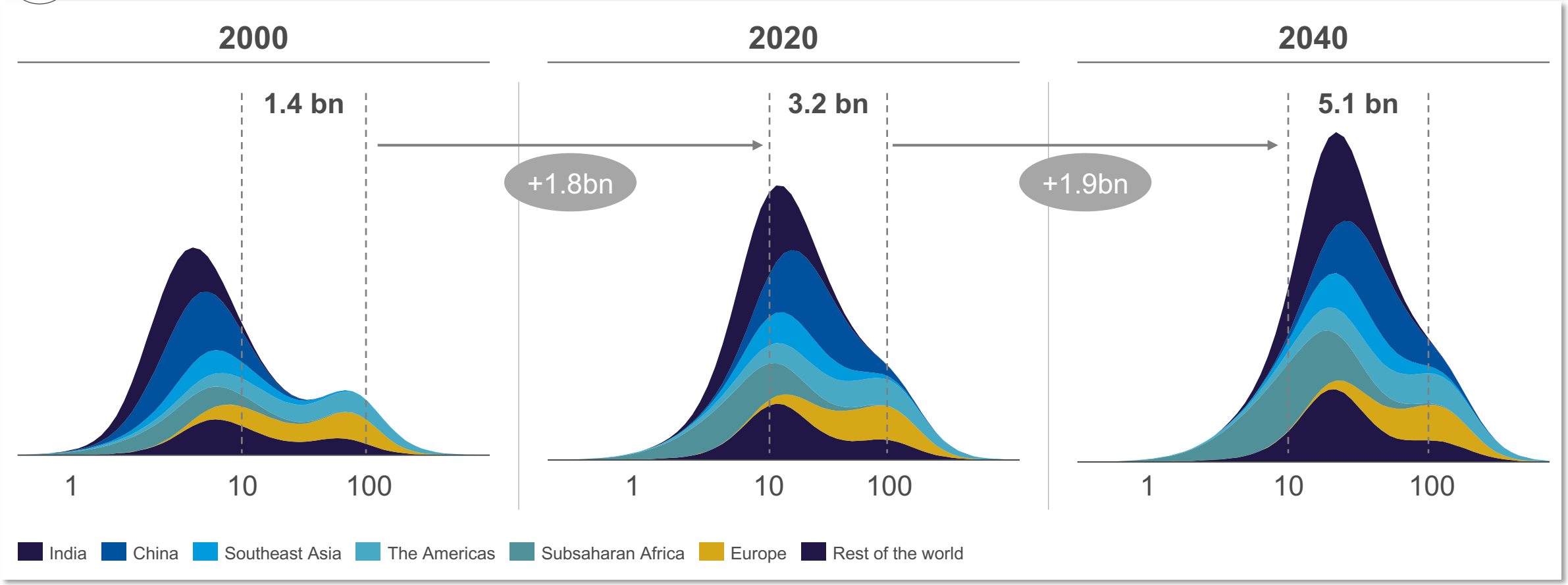
- In contrast to spatial requirements, conventional fossil-fuel based energy sources have amongst the largest material throughput, only being exceeded by biomass.
- Renewable energy-based energy sources (i.e., solar, wind and hydropower) have significantly less, albeit not a little as nuclear.

	Coal	Oil	Natural gas	Solar	Wind	Hydropower	Nuclear	Biomass
Area (m^2/kW)	7.4	5.1	2.1	150	543	7,143	4.1	12,500
Critical metals (kg/TWh)	8.92	8.92	8.92	81.82	529.88	6.4	19.89	8.92
Material use (tons/TWh)	124,019	87,168	77,877	16,457	10,260	14,068	930	235,410

DATA: CRU, Jonny Hesthammer (CEO Norsk Kjernekraft and M Vest Energy) with permission for use at WMF

Challenge 2: The global middle class will grow by 1.9 bn between 2020 and 2040, amplifying the demand for commodity-intensive goods

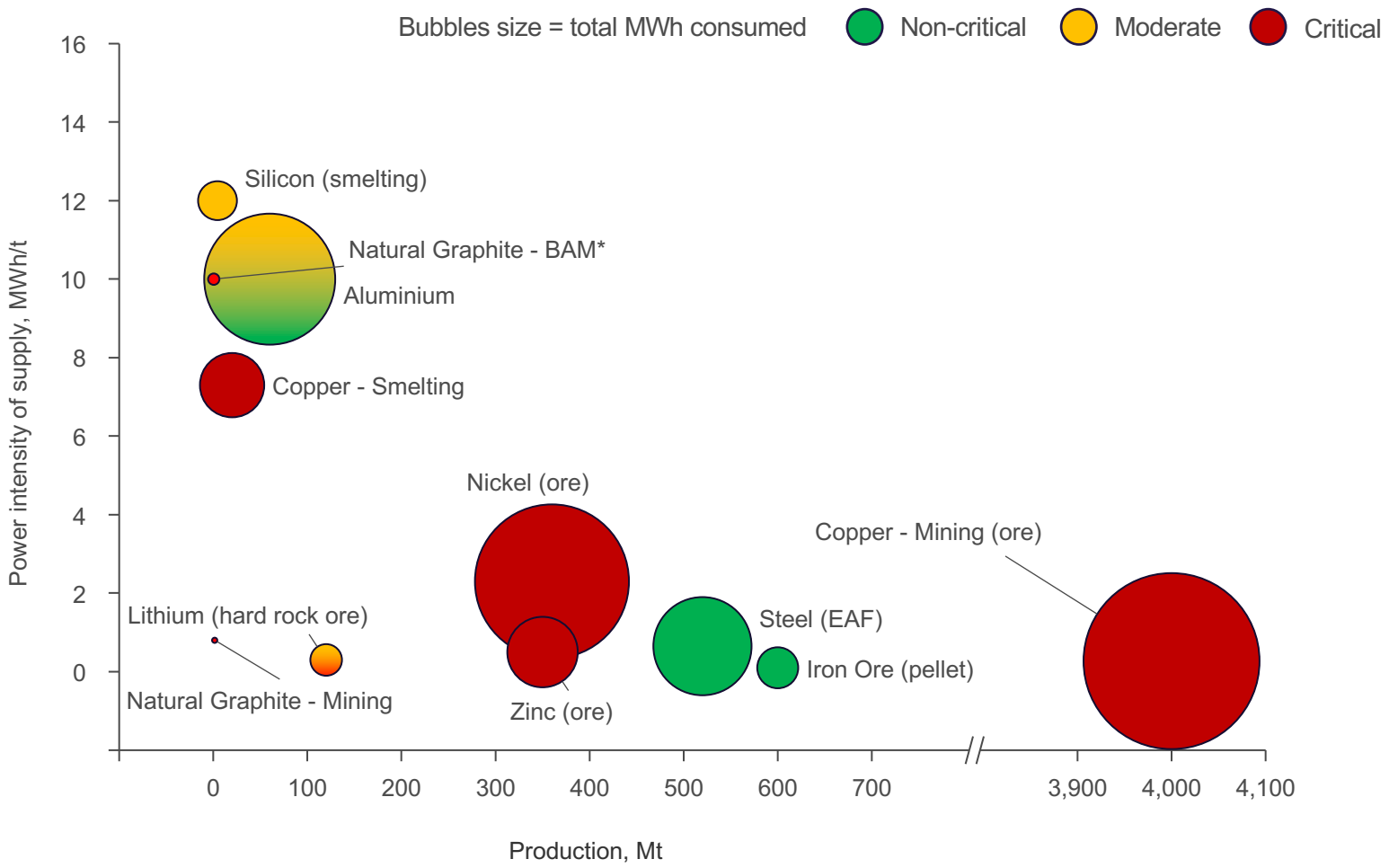
Global number of people in the middle class, USD/day[1], billion people



DATA: McKinsey analysis in partnership with Oxford Economics, Gapminder, OECD, MGI (used here with permission) . Note: (1) Middle class identified as share of the global population with an expenditure range of 10 to 100 USD/day at 2011 purchasing power parity (PPP)

Challenge 3: Who can solve the conundrum of power availability?

Power requirements of critical minerals in the context of the wider mining industry[1]



Main challenges

Many critical industries are power-hungry at almost every step of the value chain, creating big logistical and geographical challenges:

- Resource must be matched with power availability and jurisdictional appetite
- Power availability is disputed by multiple sectors (industrial, commercial, residential, infrastructure & utilities)
- Rapidly available solutions frequently involve unwanted environmental impacts

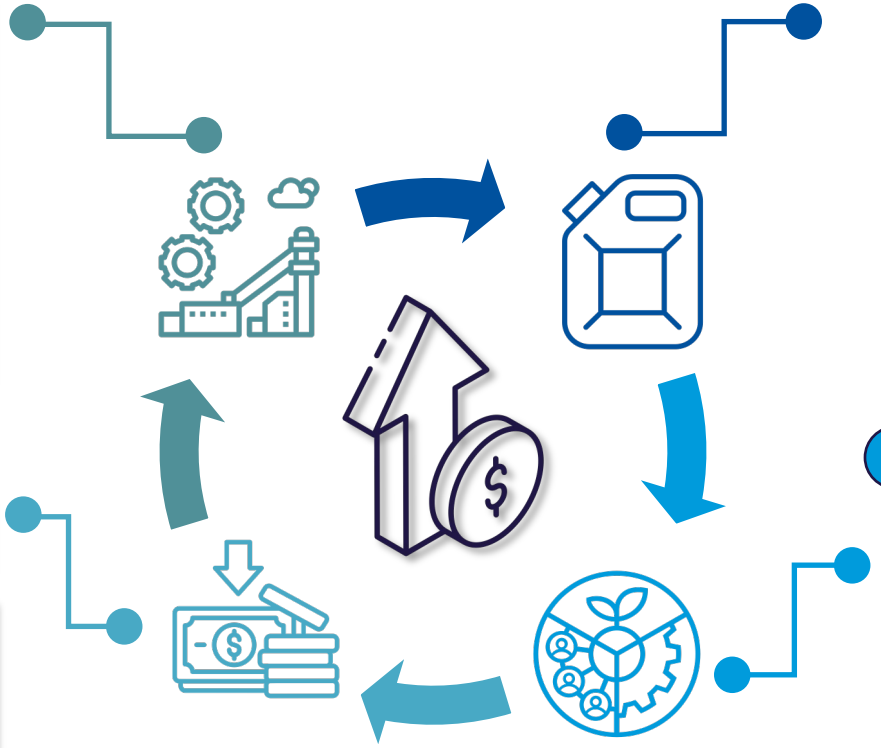
DATA: CRU. Note: (1) The criticality has been determined using the principal constituent element of the material.

Challenge 4: Why is the cost of mining getting more expensive?

1 CAPEX (see following slide)

Capital costs are increasing:

- **Declining ore grade** increase throughput and hence capacity requirements
- Many new projects are located in developing economies with **minimal existing infrastructure**
- Some **green technologies are not yet as cost effective** as the less green technologies they are replacing
- High rates of **inflation** are increasing the costs of mine-building components



2 OPEX (see following slide)

Rising inflation impacting all aspects of mining. A survey of miners[1] found the greatest increase in costs over the past few years from:

1. **Fuel/Power (88%)**
2. Maintenance/repair (47%)
3. Explosives (37%)
4. Tyres (35%)
5. Labour (25%)

3 ESG

- More stringent ESG practices have **developed rapidly** since COP27 driven by tighter policy
- Reduced environmental footprint of operations in line with these regulations could come at a **substantial economic cost**
- **Social licence to operate is hard obtain** and requires partnership with many stakeholders

4 Disruption and uncertainty

- **Geopolitical disruption** re-orientating supply chains and breaking long standing relationships
- **Technological evolution** increases uncertainty of long term demand at asset level delaying decision making
- Capital markets have **low confidence**. Eg debt funding more difficult to secure and higher interest rates make it more expensive.

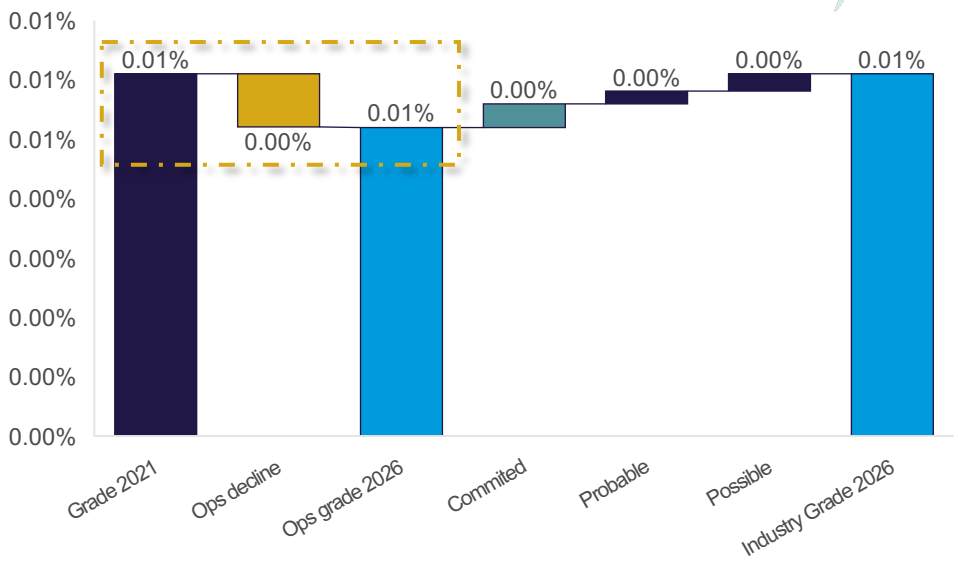
DATA: CRU. GlobalData. Note: (1) 2022 survey by GlobalData of more than 100 miners , Participants were asked to pick the top three areas where they have seen the greatest increase in mining operating costs.

Challenge 4: case study examining why cost of copper mining is increasing

Ore grades drive capex and throughput

Existing operation grades will decline by 15% in the next five years but new high-grade projects will allow the average grade to stay at the present level (although these are not yet assured).

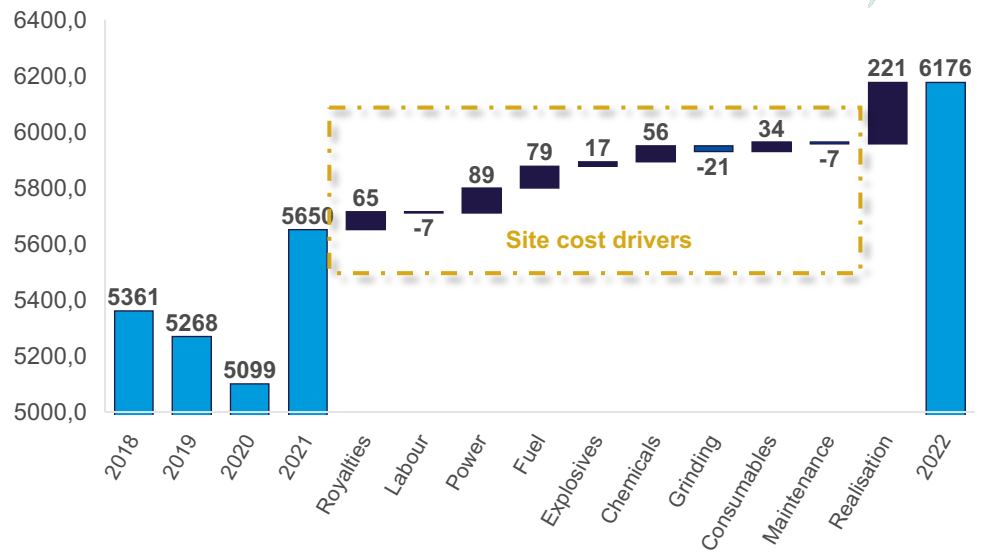
Average industry feed grade by project type, 2021-26 Cu%



OPEX driven up by energy costs

Cost increases will be primarily driven by site expenses. In particular, power costs have increased by an average of 10% in the main copper jurisdictions (Australia, Canada, Chile, Peru, DRC).

2022 Value-adjusted cash costs before by-product by driver, $/t CU



DATA: CRU. Cash costs in real 2022 USD

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Frank will now share with you some solutions

Rebecca Gordon

Thank you

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WORLD MATERIALS FORUM