Critical Minerals, Metals and Materials; a global overview

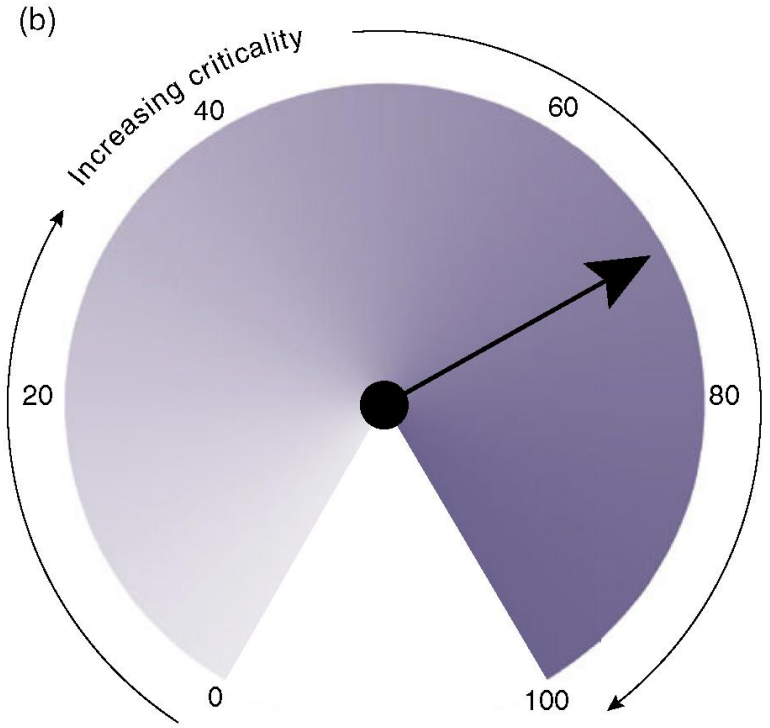
Simon Jowitt

Ralph J. Roberts Center for Research in Economic Geology
Nevada Bureau of Mines and Geology, University of Nevada Reno

sjowitt@unr.edu, @The_Jow

Critical metals and minerals and criticality in brief

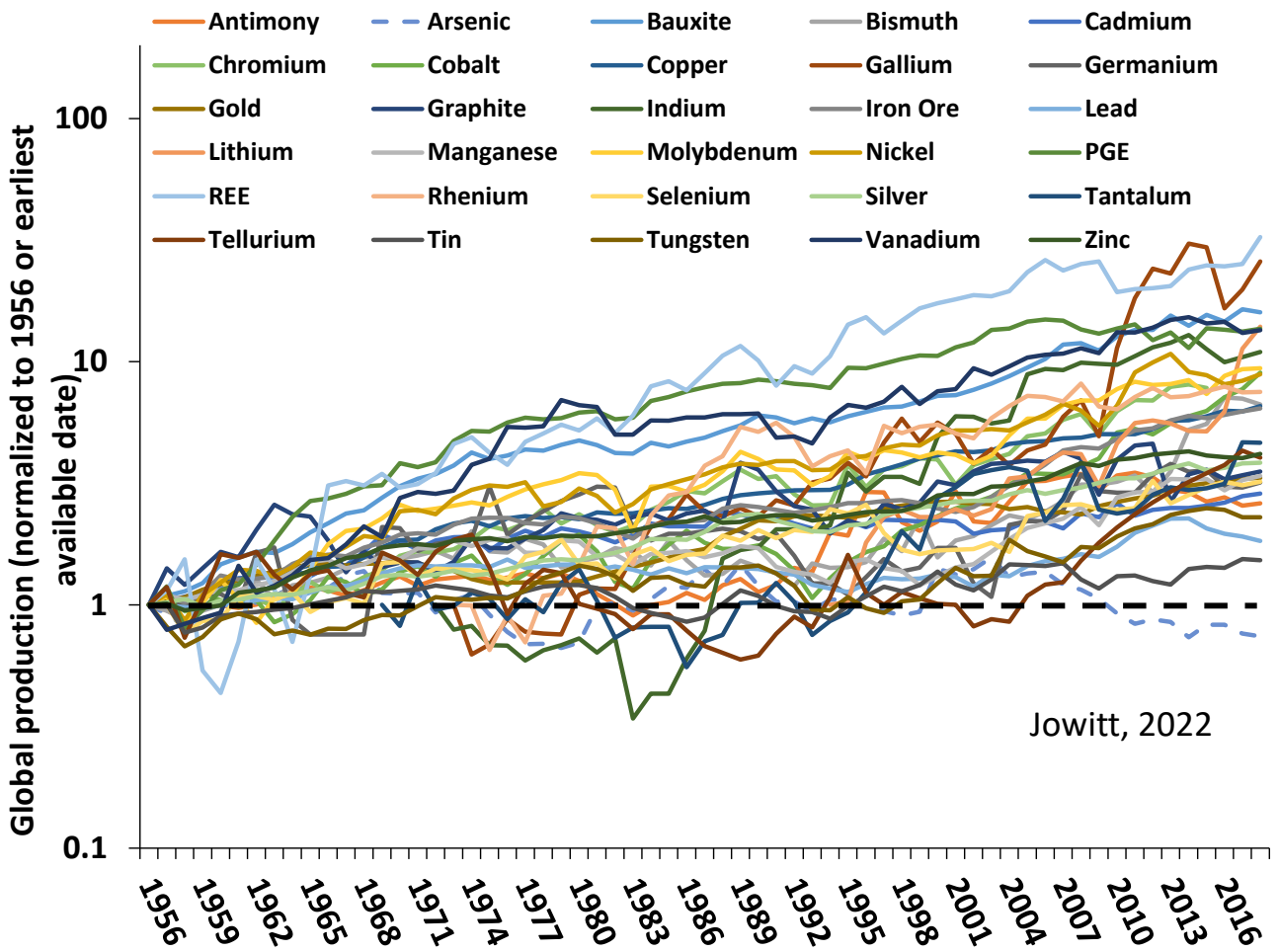
- We all know this, but this is a reminder to set the scene
- No strict definition nor global agreement on what metals and minerals are critical, but in general they:
  - Provide essential properties to a technology or product (low-CO_2 technologies, EVs, etc; vital for climate change mitigation, defense)
  - Not easily substituted or recycled (and recycling cannot meet increasing demand)
  - Have supply-chain risk, are often strategic
  - Not all are main products; ~50% by- or co-products
- Elements are not just critical or non-critical; spectrum of criticality
  - Some elements more critical than others
  - Dependent on viewpoint, e.g. industry, sector, country or group of countries, domestic production
- Critical minerals/metals also among the highest in terms of recent demand increase



Graedel et al., 2014

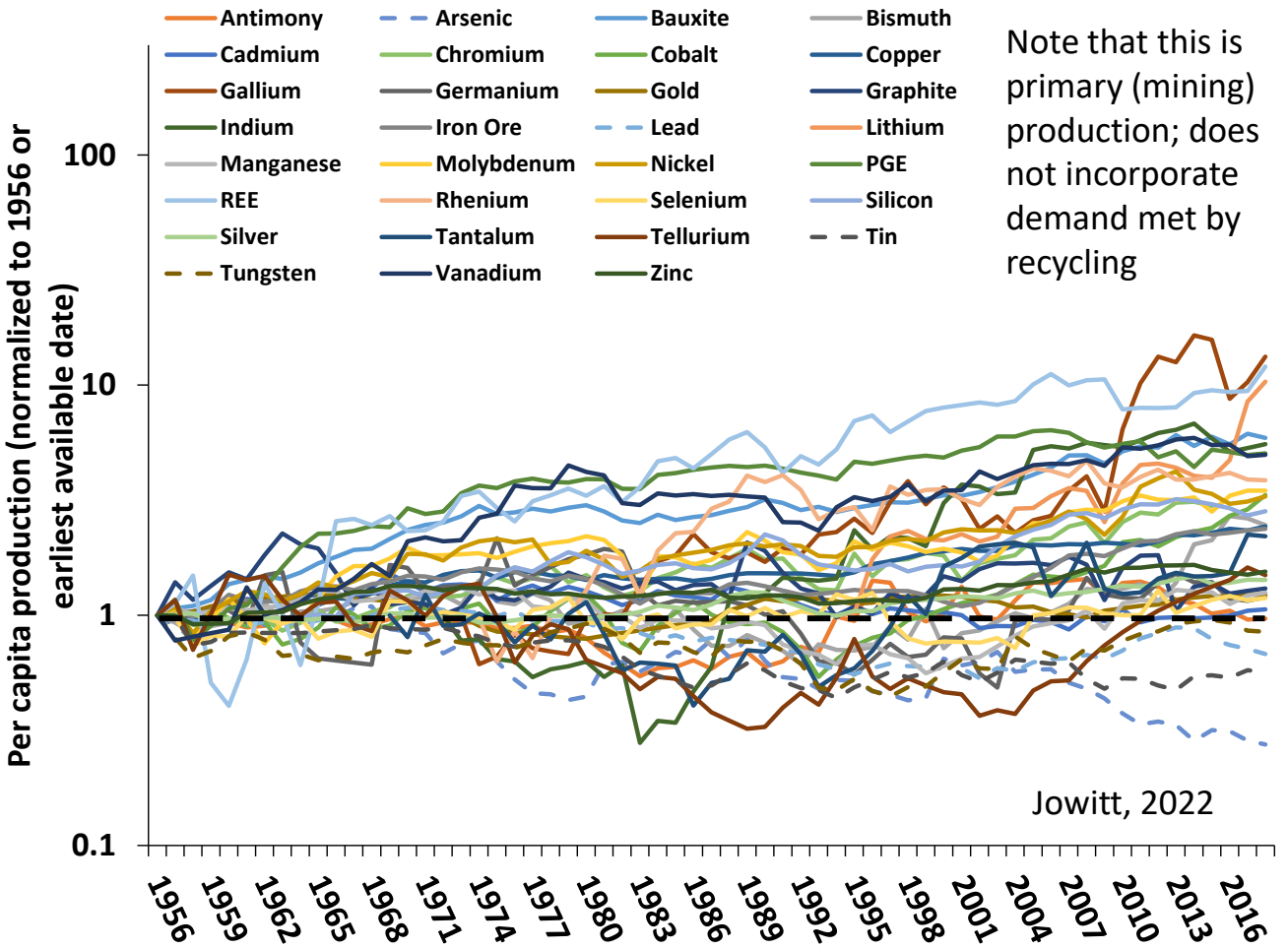
We currently mine more minerals and metals than ever before

- 2024 data:
- Cu: 7.2 x 1956
- Ga: 47.5 x 1973
- Li: 39.5 x 1994
- Ni: 14.3 x 1956
- REE: 74.6 x 1956
- Zn: 3.85 x 1956

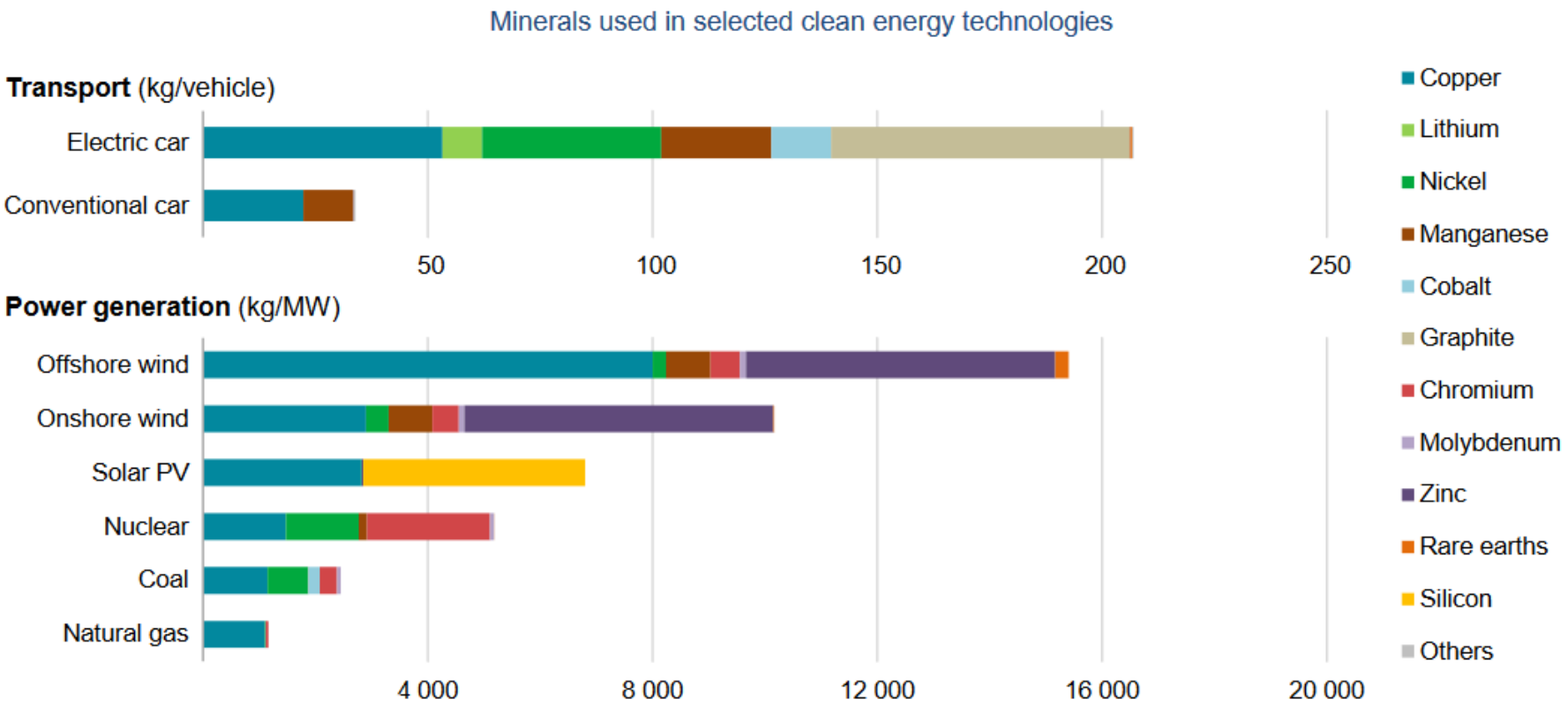


Not just total mining but on a per capita basis; modern life is metal and mineral intensive

- 2024 per capita data:
- Cu: 2.5 x 1956
- Ga: 22.9 x 1973
- Li: 27.4 x 1994
- Ni: 4.9 x 1956
- REE: 25.8 x 1956
- Zn: 1.3 x 1956



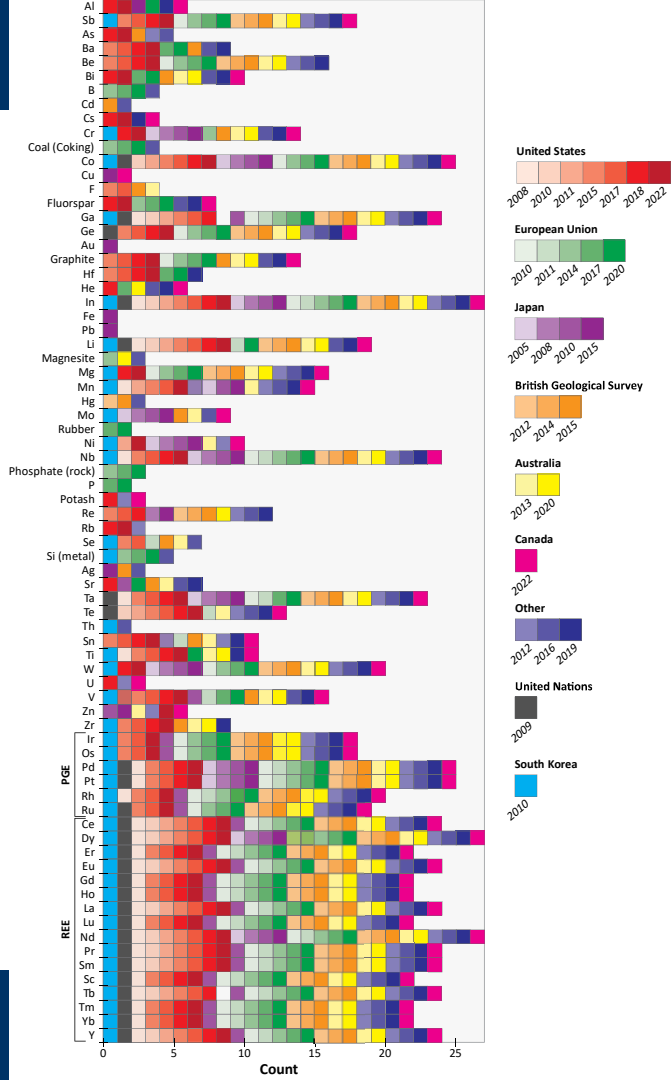
Drivers of criticality (of many!)



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

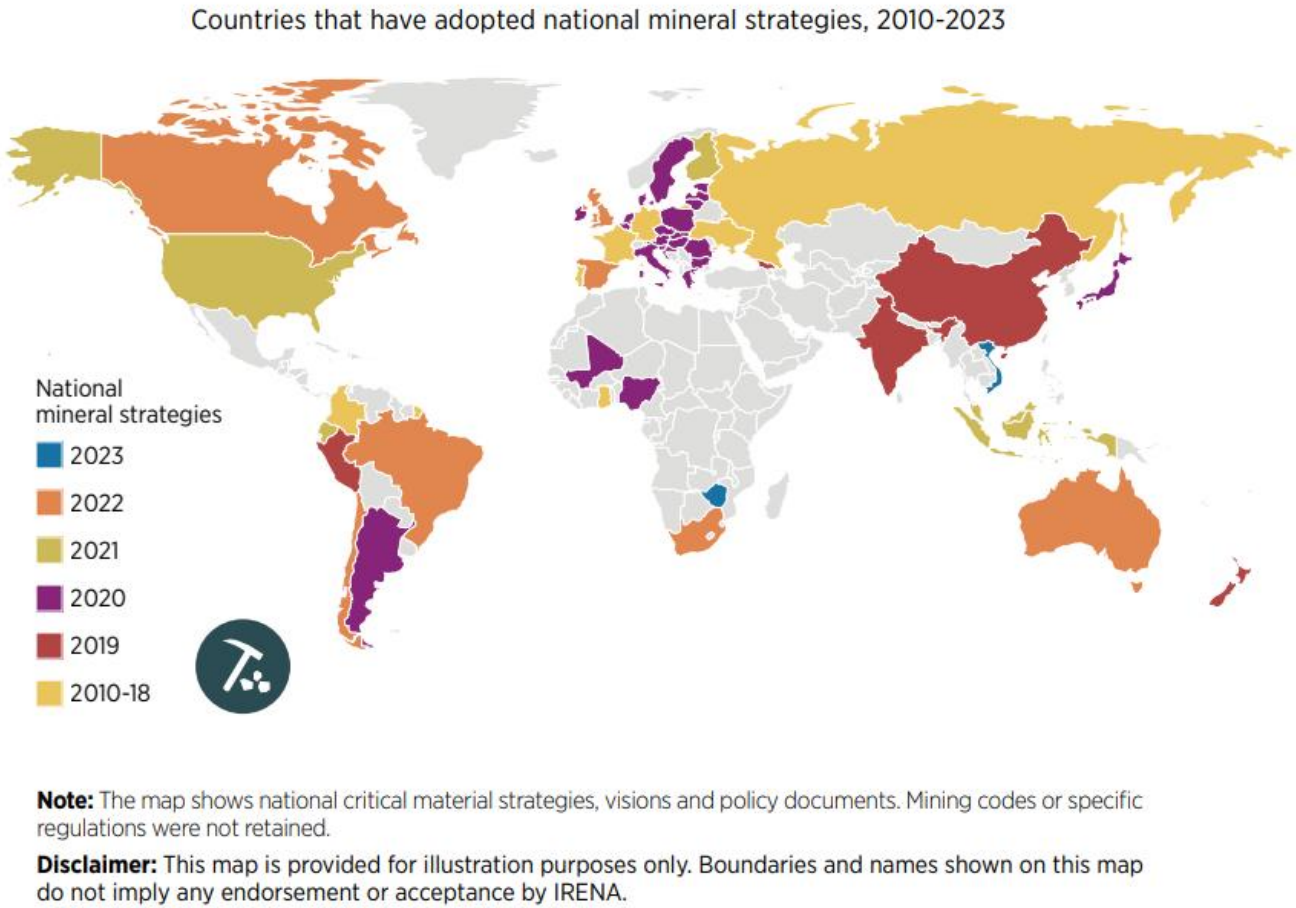
Variations in criticality

- Diagram to the right outlines variations in criticality viewpoints by jurisdiction and over time (McNulty and Jowitt, 2021; Jowitt, 2023), and this continues to change
- Reflects changes in domestic production, processing, smelting and refining as well as changes in the concept of criticality
- Domestic demand and single points of failure considered by some criticality assessments, as well as importance of industry to national economies etc.
- Need to consider critical metals in context, individually while also considering the entire minerals sector
- New critical metal assessments are changing this on a regular basis; timelines are crucial



Global critical metal policymaking

- Critical mineral/ metal/raw material considerations and policymaking is global
- Not sure all policy developments are good/impactful/made for the right reasons
- Continued need to educate policymakers (and to try and encourage them to listen)
- Timescales are crucial but are often ignored



Critical mineral uncertainties

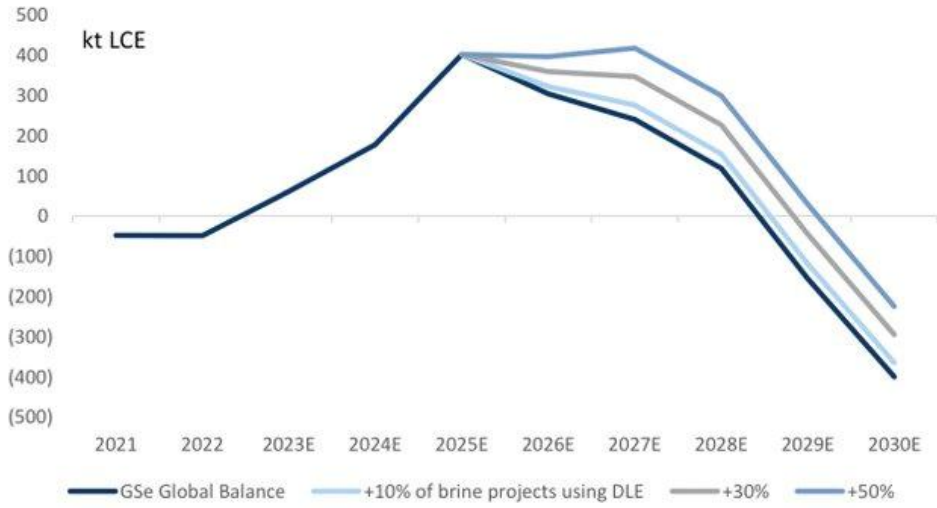
- The good side for the minerals industry is that we are likely to see critical mineral demand continuing to increase…
- The bad is that there isn't a clear future with guaranteed huge demand that is free of volatility; number of uncertainties to consider that are sometimes being ignored:
- (1) **Demand uncertainty**, uncertainties over critical metal and mineral demand and the timing of this demand
- (2) **Supply uncertainty**, the timing of supply changes as a result of increases or decreases in mining capacity
- (3) **Technology uncertainty**, uncertainty over the technologies used during the energy transition (see cobalt, data centers…?)
- (4) **Policy uncertainty** or the negative and positive impact of policy relating to mining and critical metal and mineral supply – especially right now!
- Uncertainties are **interlinked** and demand and supply often operate at different timescales (= price volatility, short term oversupply, long term undersupply?)
- Urgent need to **quantify these uncertainties** and their potential impacts on the minerals industry, manufacturing, the energy sector and more
- Understanding this will **outline more opportunities** for all concerned

Demand and supply uncertainties and timescales

- Production can be delayed, reducing supply at times of increasing demand
- However, many critical metal sectors (even lithium, 0.29 Mt/yr production vs Cu at 23 Mt/yr) are still small
- Multiple (large) mines coming onstream over short timescales can cause oversupply and price slumps
- Markets already volatile as a result of other uncertainties
- Predicting economics and influence on mine development etc. is hard
- Price volatility will be an ongoing problem; could cause issues for both new and existing operations

Exhibit 16: Global lithium balance under DLE scenarios

Global lithium supply surplus/(deficit) (kt LCE)

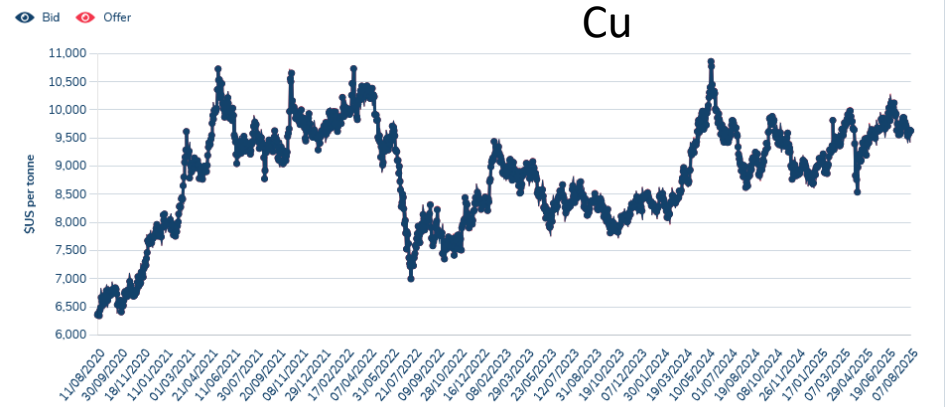


SD balance reflects recently updated demand estimates

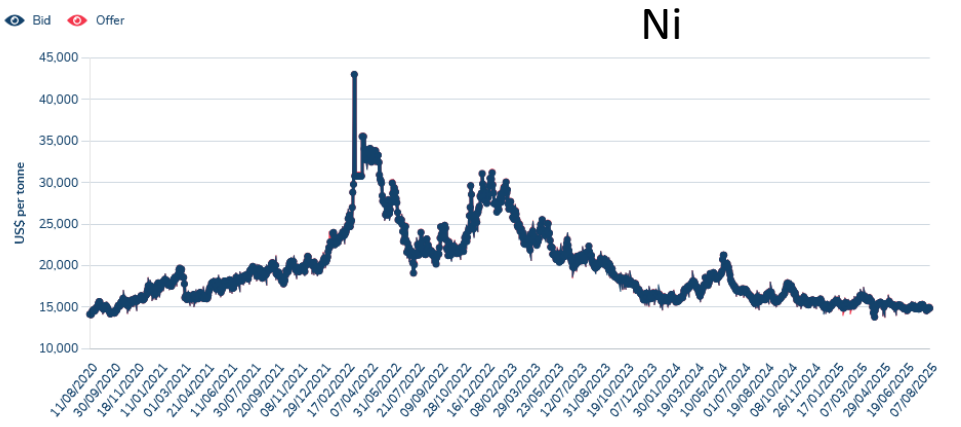
Source: Goldman Sachs Global Investment Research

Supply and demand uncertainty = price volatility

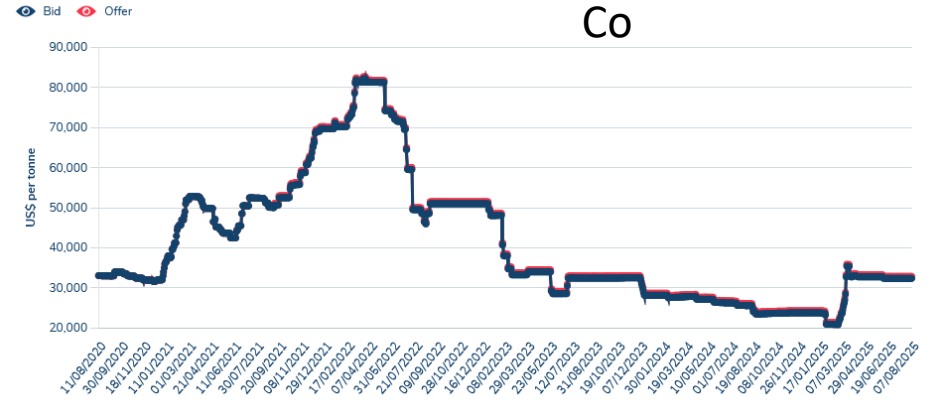
LME Copper Official Prices graph



LME Nickel Official Prices graph

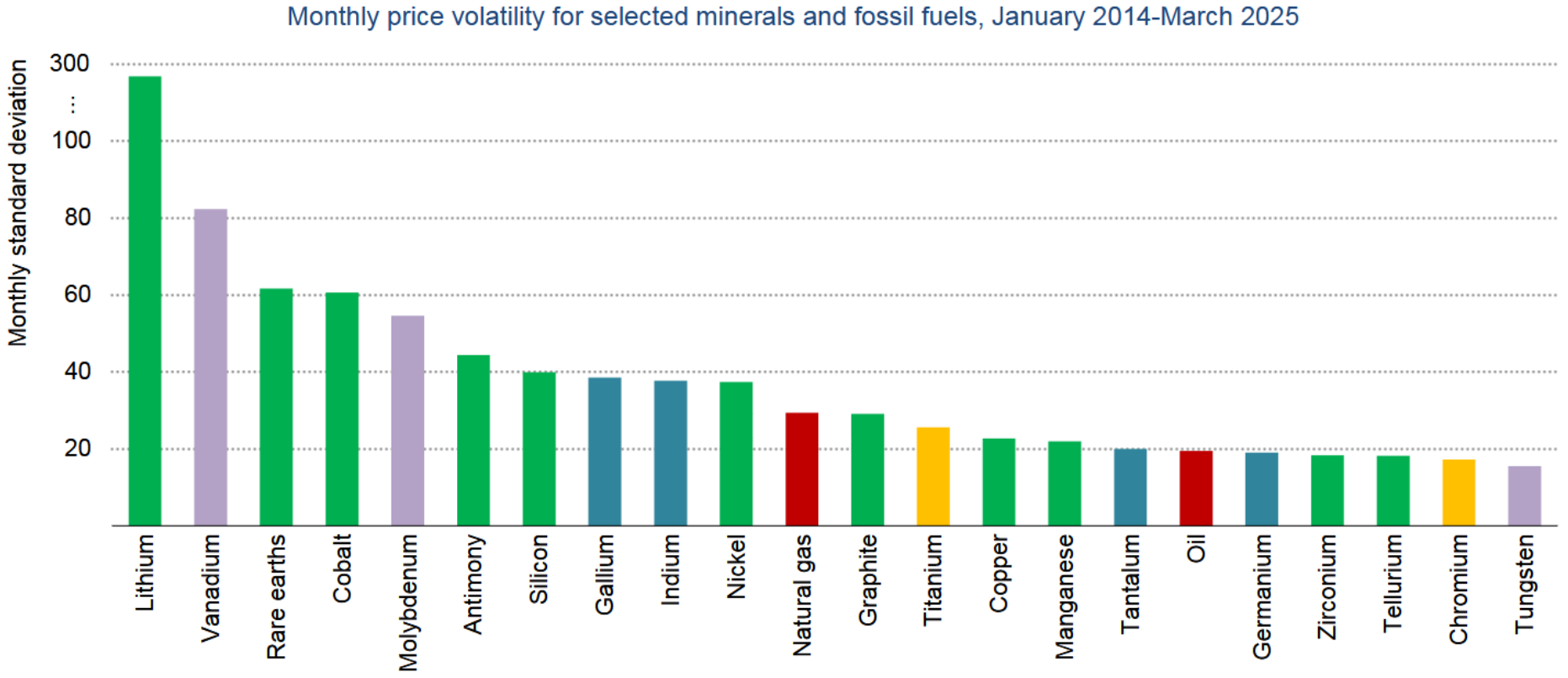


LME Cobalt Official Prices graph



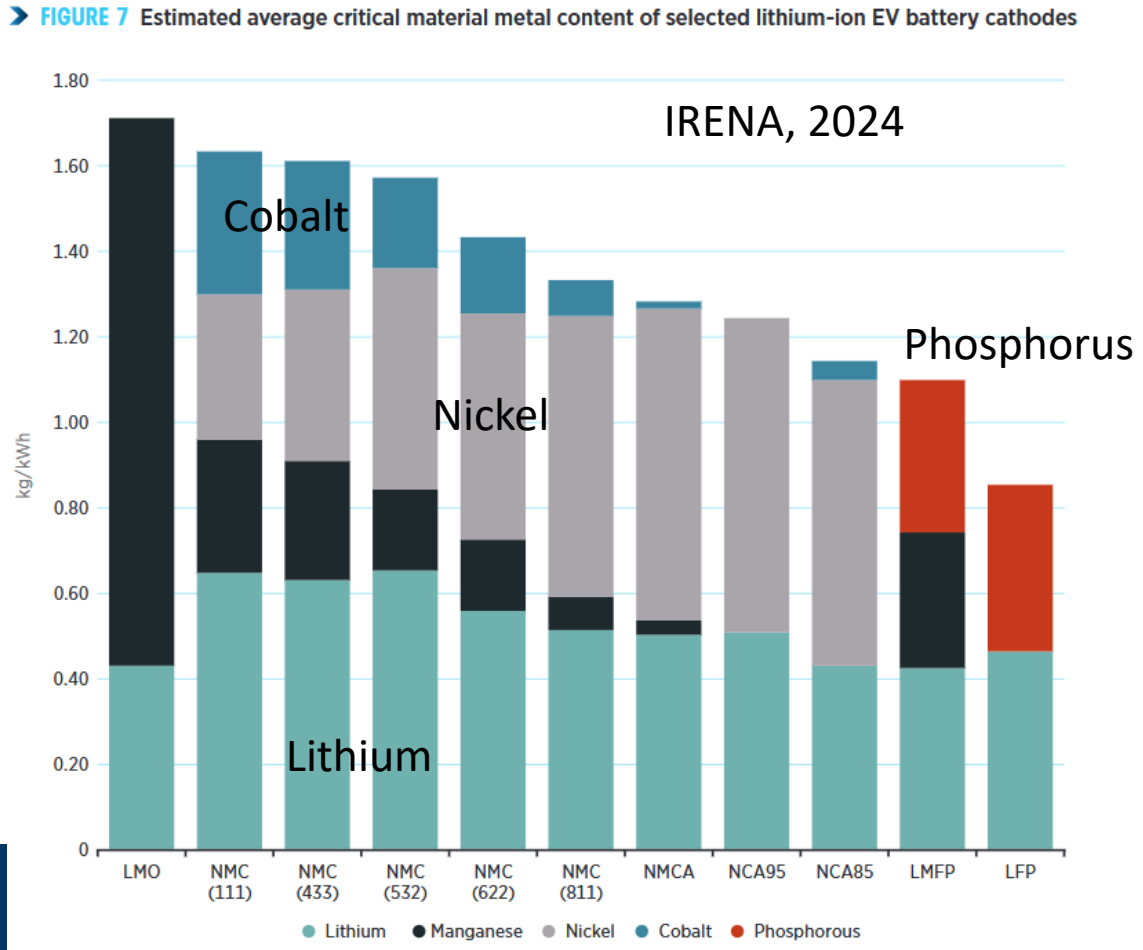
Price volatility (IEA, 2025)

- Small sectors, co- and by-product production increases volatility; ideally need transformational change in some sectors by growth?



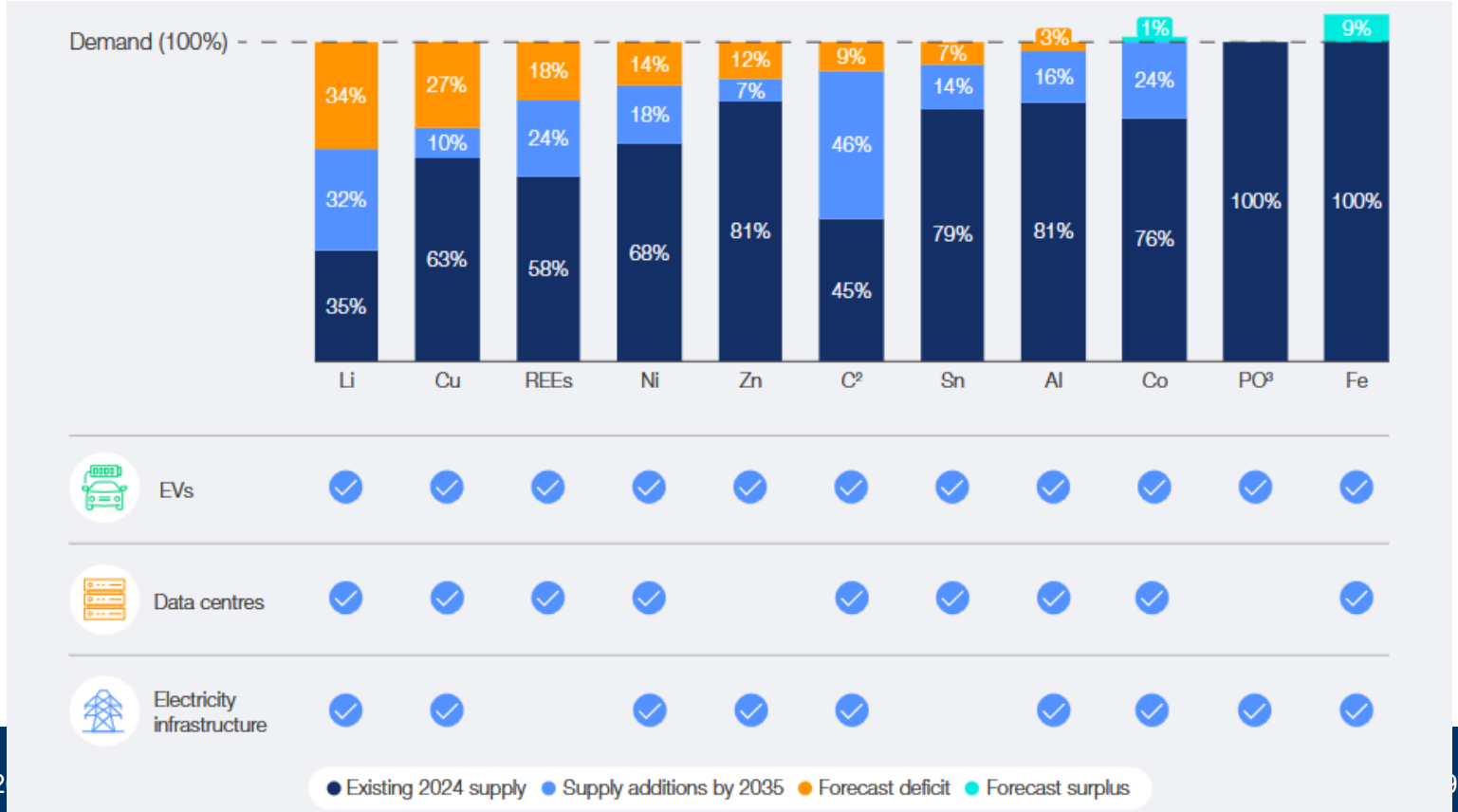
Technology uncertainties – technology mixes and uptake rates?

- Li vs solid state vs Na or Fe batteries
- LCO vs NCA vs NMC cathodes, natural vs artificial flake graphite…
- Different batteries for different uses
- CdTe vs silicon-based PV
- Where will we be in ten years time?



New developments; data centres, AI

- Global demand-supply balance for key commodities in 2035



Relevance

Growth trajectory

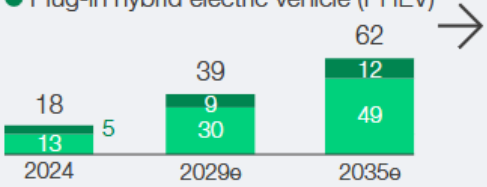
Key metals and minerals

Sorted by contribution to global metals and minerals demand

Electric vehicles

- **EV** demand will exceed **20m cars** in 2025
- **>40% of new car sales** by 2030 will be EVs
- Global vehicle investment is estimated at **$3.5t annually**

Global sales of EVs (million vehicles)

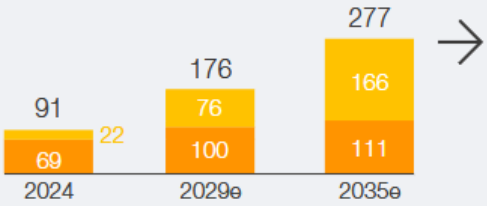


Lithium	Cobalt	Graphite
REEs	Nickel	Magnesium
Copper	Tantalum	Aluminium
Zinc	Silver	Manganese
Phosphorous	Silicon	Iron

Data centres

- Data centres are becoming key for **national economic security**
- **Capacity will triple** between now and 2035
- **$3-7t in global investments are** estimated by 2030

Global data centre capacity (gigawatt)

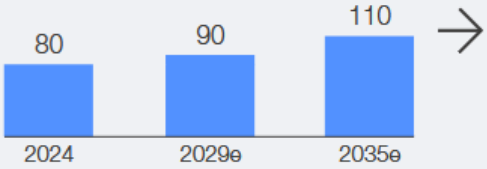


Gallium	Germanium	Tin
Copper	Gold	Cobalt
Silver	Nickel	Aluminium
Lithium	Silicon	Graphite
REEs	Iron	Lead

Electricity transmission and distribution

- **60m km of new or replacement electricity lines** are needed by 2035
- Electricity demand is forecast to rise at **4% annually through 2027**
- **$600b investment** in electricity grids is needed by 2030

Global ET&D grid length
(million kilometres)



Vanadium	Copper	Lithium
Graphite	Aluminium	Zinc
Iron	Phosphorous	Silicon

Policy uncertainties

- Policy uncertainty; negative and positive impact of (often critical) mineral-related policy
- Changes to criticality considerations (e.g. Australia's assigning of critical status to nickel, met coal in the US)
- Difficult to predict, but can model impact on supply, demand, and economics and timing of projects etc.
- Learn from past experience; what happened when e.g. government funding supported critical metal project development, battery manufacturing development or added tariffs to the metals sector
- Remember that uncertainties lead to investments in safe havens (gold!)

New report highlights how to improve critical material sustainability in the UK

Alex Tyrer-Jones

9–11 minutes

A new report published by the National Engineering Policy Centre has called on the UK Government to develop an integrated materials strategy. Led by the Royal Academy of Engineering, the report emphasizes the need to reuse and recycle critical materials to improve economic security and achieve net-zero goals.

blogs.worldbank.org

The double-edged sword of export bans on critical metals

7–9 minutes

Restrictions and bans on exports of metals critical for the world's green transition are gaining traction but could be a double-edged sword.

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Mining + Add to myFT

Australia classifies nickel as a 'critical' mineral to protect ailing industry

Producers of EV battery material fear collapse as supply glut from Indonesia knocks prices

politico.com

Biden administration weighs price support for US critical minerals amid Chinese pressure - POLITICO

James Bikales

19–24 minutes

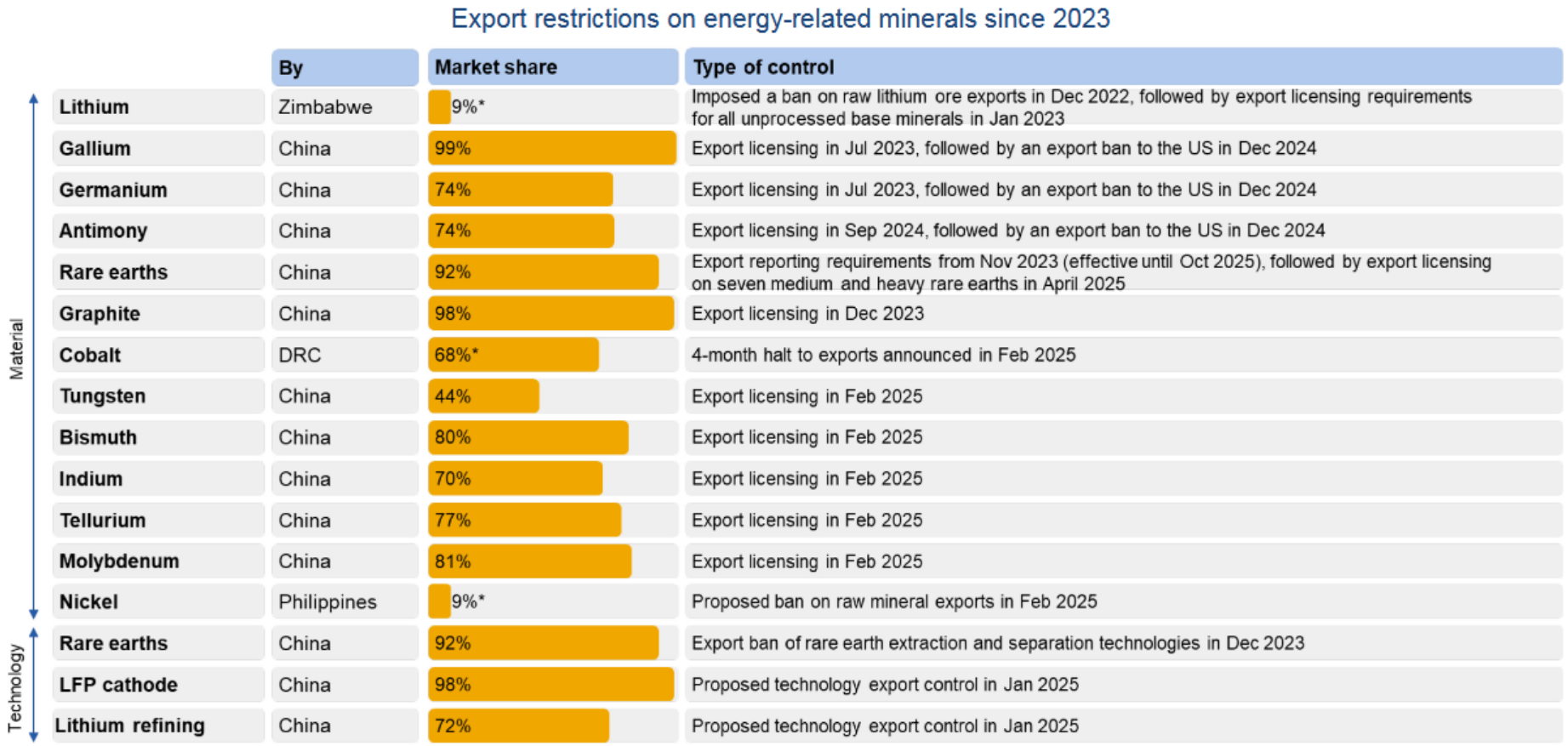
President Joe Biden's efforts to boost domestic production of minerals have been challenged by China's stranglehold on the industry. | Brendan Smialowski/AFP via Getty Images

theglobeandmail.com

Struggling to survive 'the valley of death,' some of Canada's emerging critical mineral miners are now fleeing overseas

Niall McGee

Critical mineral export constraints also increasing (IEA, 2025)



	By	Market share	Type of control
Lithium	Zimbabwe	9%*	Imposed a ban on raw lithium ore exports in Dec 2022, followed by export licensing requirements for all unprocessed base minerals in Jan 2023
Gallium	China	99%	Export licensing in Jul 2023, followed by an export ban to the US in Dec 2024
Germanium	China	74%	Export licensing in Jul 2023, followed by an export ban to the US in Dec 2024
Antimony	China	74%	Export licensing in Sep 2024, followed by an export ban to the US in Dec 2024
Rare earths	China	92%	Export reporting requirements from Nov 2023 (effective until Oct 2025), followed by export licensing on seven medium and heavy rare earths in April 2025
Graphite	China	98%	Export licensing in Dec 2023
Cobalt	DRC	68%*	4-month halt to exports announced in Feb 2025
Tungsten	China	44%	Export licensing in Feb 2025
Bismuth	China	80%	Export licensing in Feb 2025
Indium	China	70%	Export licensing in Feb 2025
Tellurium	China	77%	Export licensing in Feb 2025
Molybdenum	China	81%	Export licensing in Feb 2025
Nickel	Philippines	9%*	Proposed ban on raw mineral exports in Feb 2025
Rare earths	China	92%	Export ban of rare earth extraction and separation technologies in Dec 2023
LFP cathode	China	98%	Proposed technology export control in Jan 2025
Lithium refining	China	72%	Proposed technology export control in Jan 2025

Reshoring, friendshoring, or “Threatshoring”

- Very few countries or groups of countries will be self-sufficient in all metals and minerals; not just geology and processing but it doesn’t make sense to do it all, even in a command economy
- Policy in some areas has moved from carrot to stick; **Friendshoring vs. Threatshoring**… which is better?

Implications for the minerals industry and the energy sector

- We know mineral and metal demand is going to increase as a result of the energy transition, especially for critical minerals/metals/raw materials
- The timing and rate of this demand increase is **uncertain**
- The timing and rate of supply increase is **uncertain**
- **Timescales of supply** (5-10+ years to develop a mine) **and demand** (can decrease on a week or month timescale *especially with volatile or unclear policy changes*) are different; potential oversupply and price crashes, potential longer term undersupply and price hikes – causing alternatives to be examined
- The influence of **changing technology** is also uncertain; what compositions of batteries we will be using? What will the takeup rate of EVs be?
- Hanging over all of this is the influence of **policy on a national and global basis,** including demand for safe haven metals
- Urgent need to inform policymakers and to understand what works rather than potentially wasting money and becoming more “inefficient”
- Whoever understands these challenges can turn them into **opportunities**

Conclusions

- Critical minerals/metals/raw materials globally are becoming more of a focus for governments, industry sectors, and more
- Differing viewpoints combined with lack of knowledge of the mining sector and mineral deposits in general means policymaking may not be hugely effective in all cases
- Lack of consideration of uncertainty could become rapidly problematic; putting all ones eggs in one basket
- Complete domestic supply chains are a fantasy because of geology, economic factors, and much much more; need to think how to do this collectively
- Some critical minerals may always be challenging because of the small to tiny nature of the demand for a given commodity and lack of potential for transformational change; need to think of different approaches
- Lots of challenges remain, but all of these are opportunities
- One final thing to remember; projected supply gaps are always in the future, but we never seem to get there, always a correction of some sort…

Any questions?

- If not now, can always email me at sjowitt@unr.edu
- Happy to pass on papers, resources and continue this discussion