What Makes a Material Critical?
What Makes a Supply Chain Resilient?

Rod Eggert
July 19, 2022
DOE Critical Materials Workshop
Argonne National Laboratory, Illinois

COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

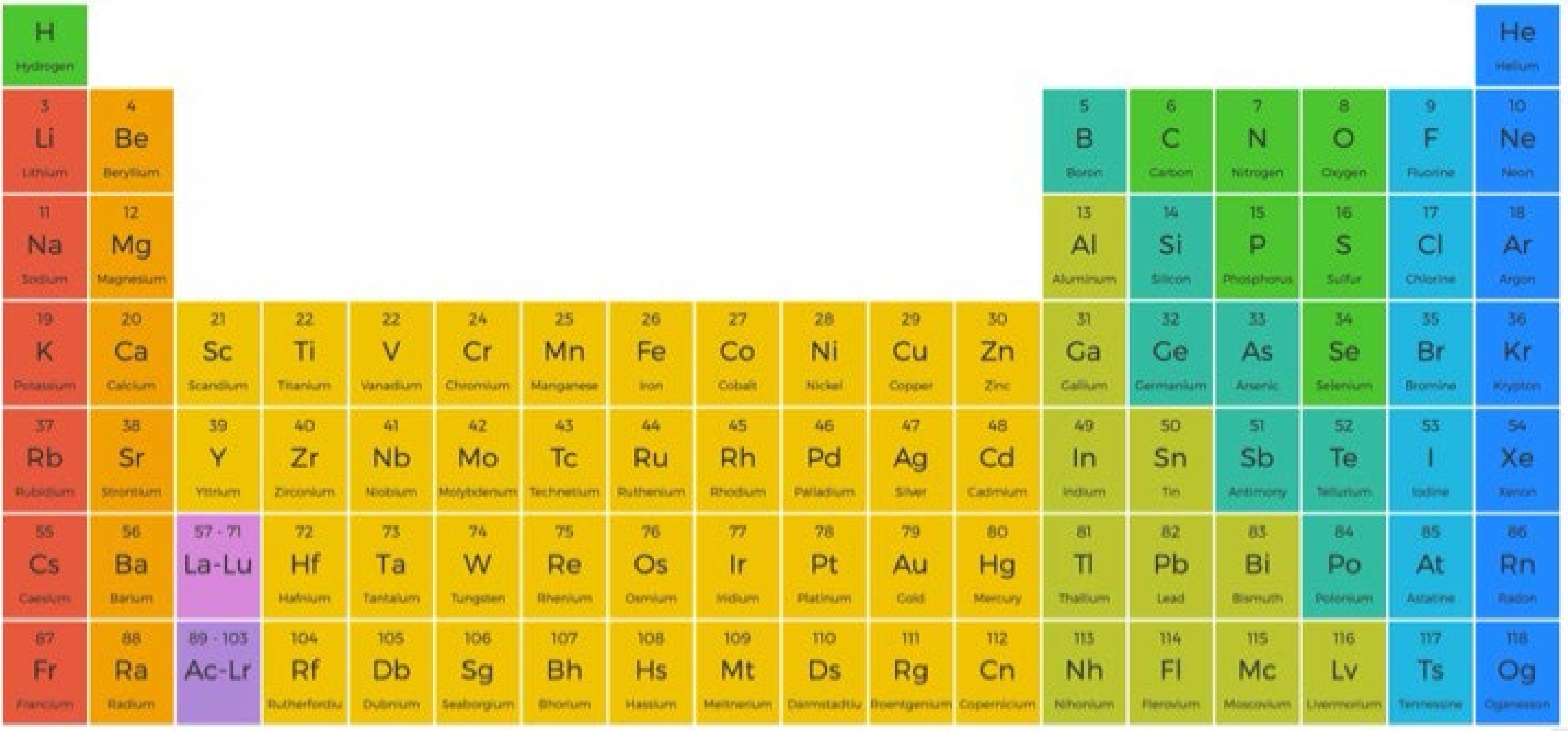
CMI Critical Materials Institute
AN ENERGY INNOVATION HUB

Critical

Vital
Essential
Indispensable

Source: lexico.com

Most of the 1st 83 elements in the periodic table are vital to someone



Source: mineralseducationcoalition.org

A narrower definition

Essential functionality (i.e., indispensable)
Difficult substitution
Supply-chain risks

US list 2022 – not much of a narrowing!

- Gallium
- Niobium
- Cobalt
- Neodymium
- Ruthenium
- Rhodium
- Dysprosium
- Aluminum
- Fluorspar
- Platinum
- Iridium
- Praseodymium
- Cerium
- Lanthanum
- Bismuth
- Yttrium
- Antimony
- Tantalum
- Hafnium
- Tungsten
- Vanadium
- Tin
- Magnesium
- Germanium
- Palladium
- Titanium
- Zinc
- Graphite
- Chromium
- Arsenic
- Barite
- Indium
- Samarium
- Manganese
- Lithium
- Tellurium
- Nickel
- Beryllium
- Zirconium

- Cesium
- Erbium
- Europium
- Gadolinium
- Holmium
- Lutetium
- Rubidium
- Scandium
- Terbium
- Thulium
- Ytterbium

Note: In rank order from top to bottom and then left to right; elements starting with cesium were not rank ordered.

Source: Nassar and Fortier 2021 (USGS Open-File Report 2021-1045)

"What is 'critical' depends on <u>who</u> you are, <u>where</u> you are, and <u>when</u> you ask"

- Alex King

World, national, company, technology

Something important is at risk

Each material has its own story

Lack of supply chain diversity
Geopolitical risks
Co-production risks and opportunities
Technology risks
Entry barriers
Opaque markets
Etc.

The time dimension often is ignored

Short- to medium-term risks

v.

Medium- to long-term availability

Short- to medium-term risks

Fragility due to:
Existing geography of production & use
Existing technologies

Specific risks:

Physical availability

Price volatility

Reputation

Medium- to long-term availability

- Demand
  - Will increase quickly and substantially for some materials, although at what rate and by how much is uncertain
- Supply
  - Is characterized by supply chains that often are fragmented, concentrated (insecure), small, opaque
  - May not grow 'appropriately' to meet growing demands (sufficiently, securely, affordably, sustainably, responsibly)
- The Fear
  - Lack of appropriate availability will become an obstacle to clean energy transitions

Financial Times, May 5, 2021

Commodities + Add to myFT

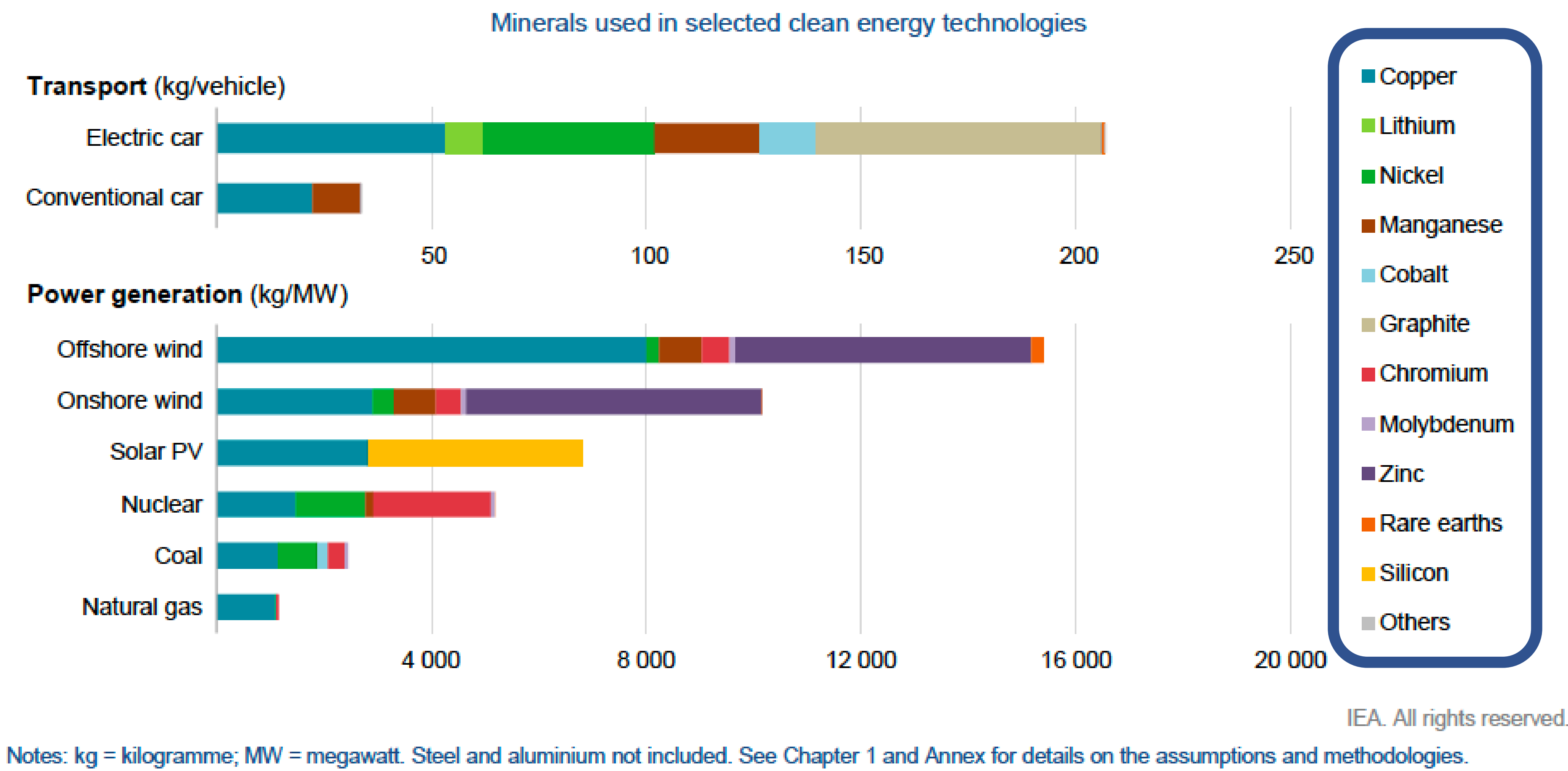
High metal prices could delay transition to clean energy, warns IEA

Paris agreement climate goals to 'turbocharge' demand for minerals amid lack of investment in mining

Prices for commodities — from lithium to cobalt — have rallied as demand for clean energy technologies has increased and governments have rolled out green stimulus packages © REUTERS

Source: https://www.ft.com/content/2f709342-3070-4b75-8924-3d9190f5c0c7

Demand for some mineral-based materials will increase significantly



Source: iea.org (*The Role of Critical Minerals in Clean Energy Transitions*, 2021)

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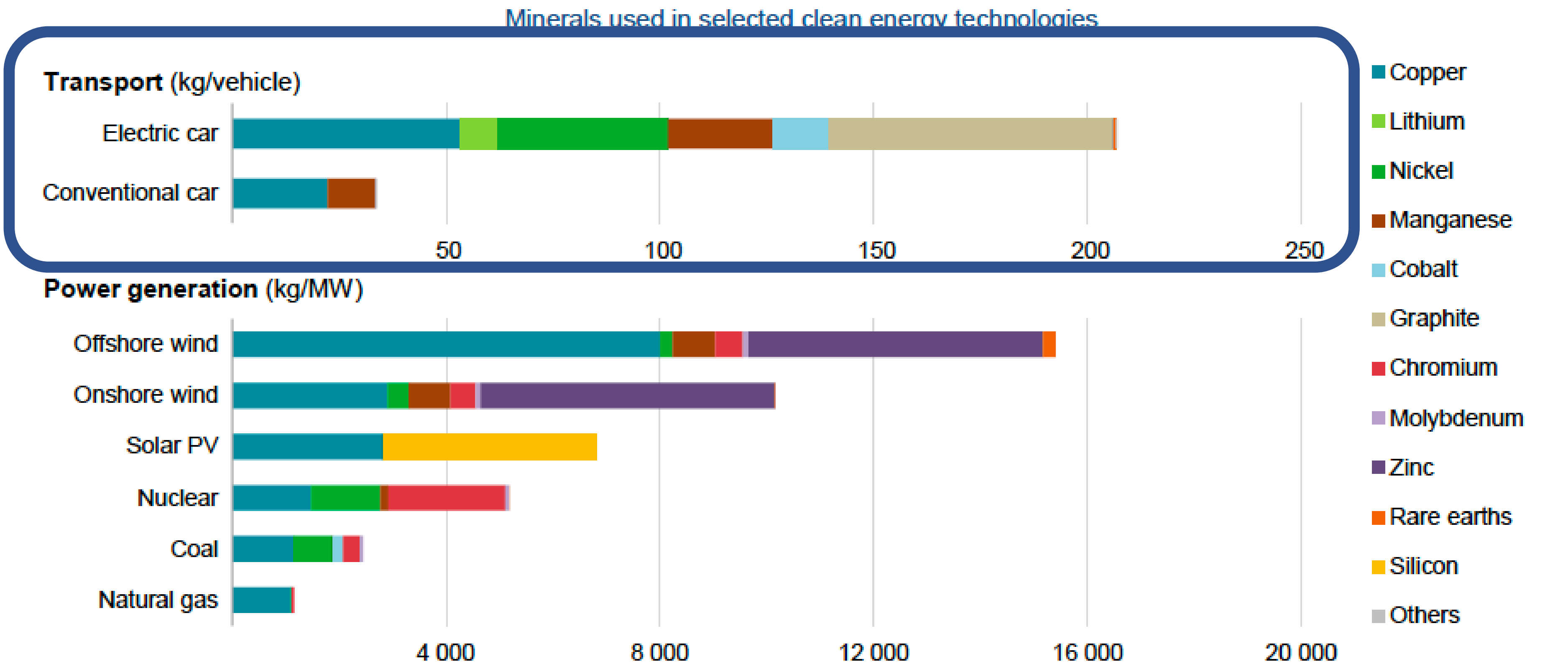

Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.

Source: iea.org

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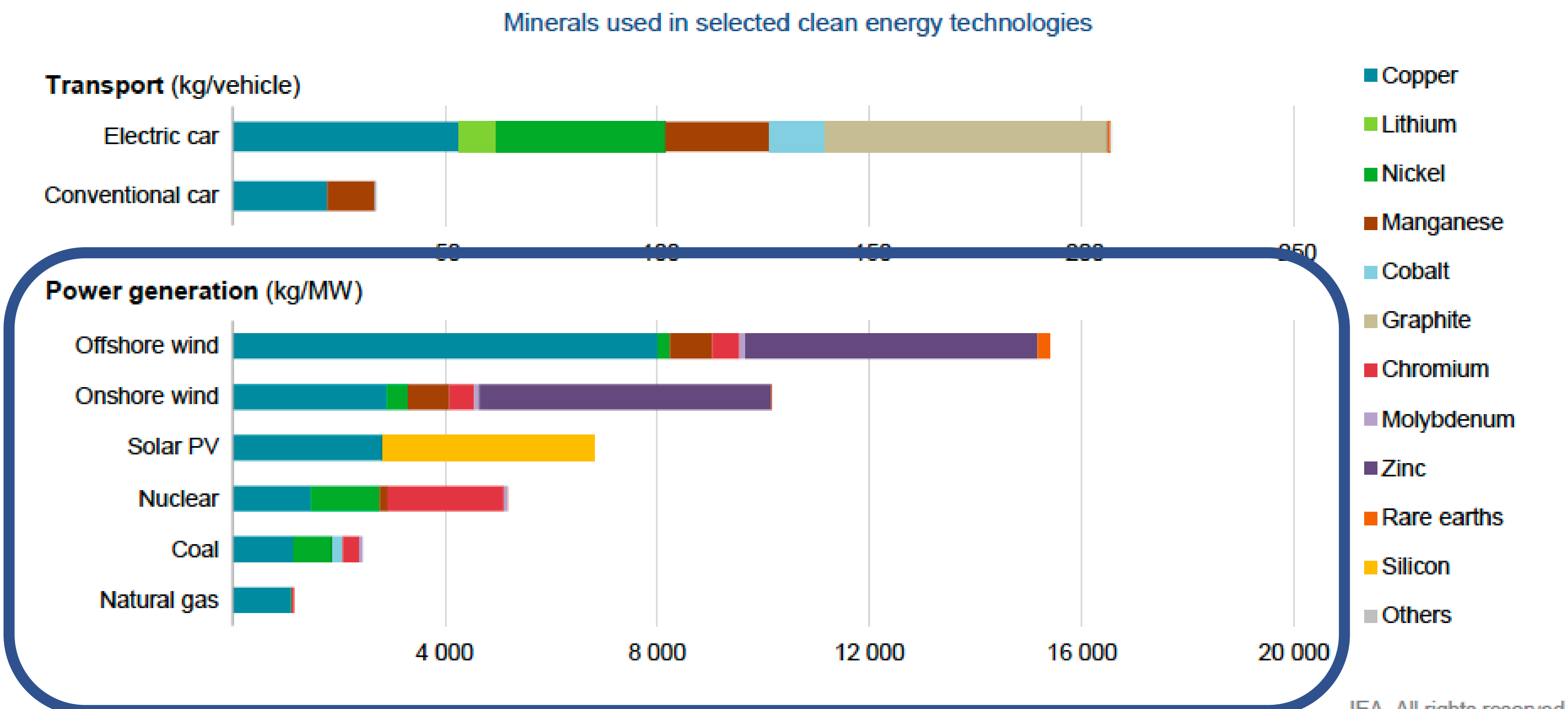

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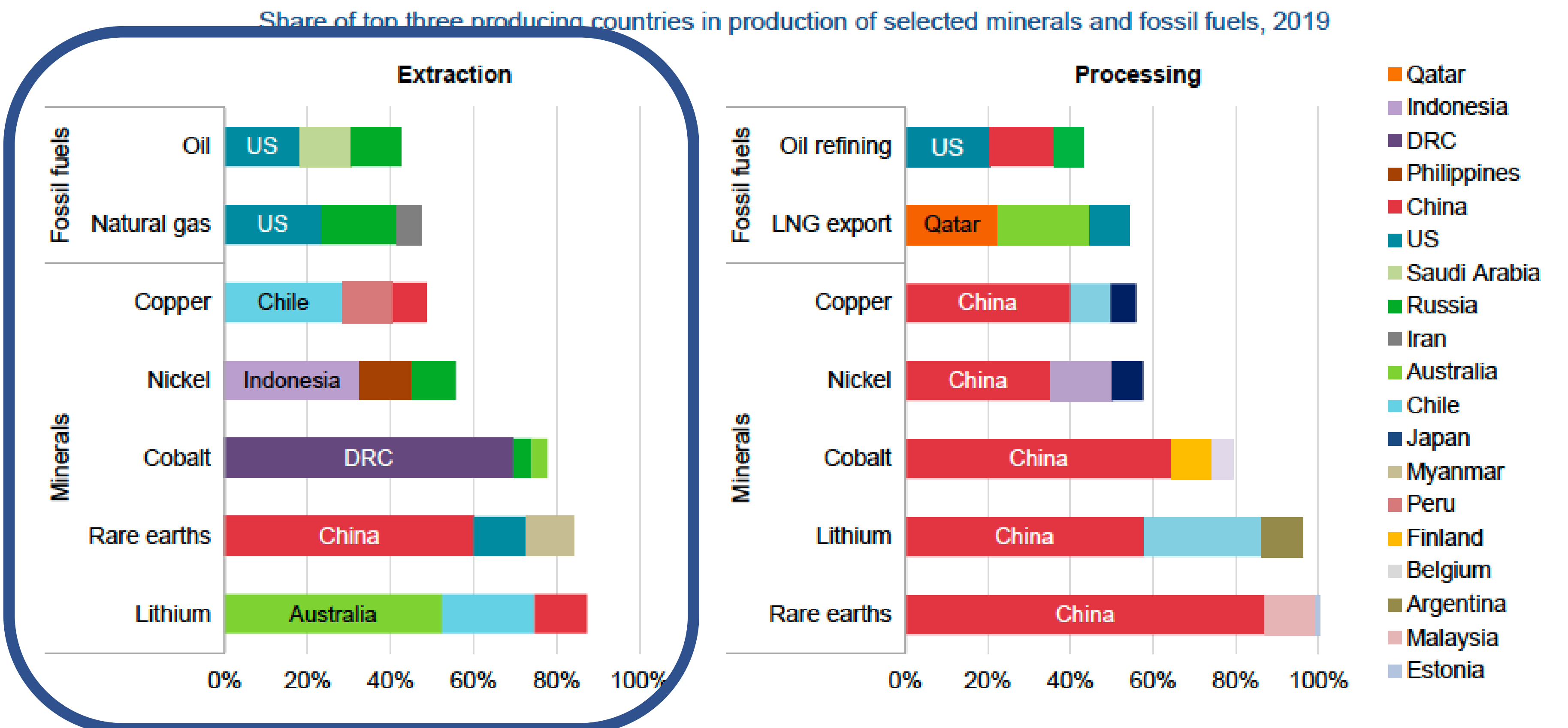
Source: iea.org

It’s about supply chains not just mining

Production of many energy transition minerals today is more geographically concentrated than that of oil or natural gas



Notes: LNG = liquefied natural gas; US = United States. The values for copper processing are for refining operations.
Sources: IEA (2020a); USGS (2021), World Bureau of Metal Statistics (2020); Adamas Intelligence (2020).

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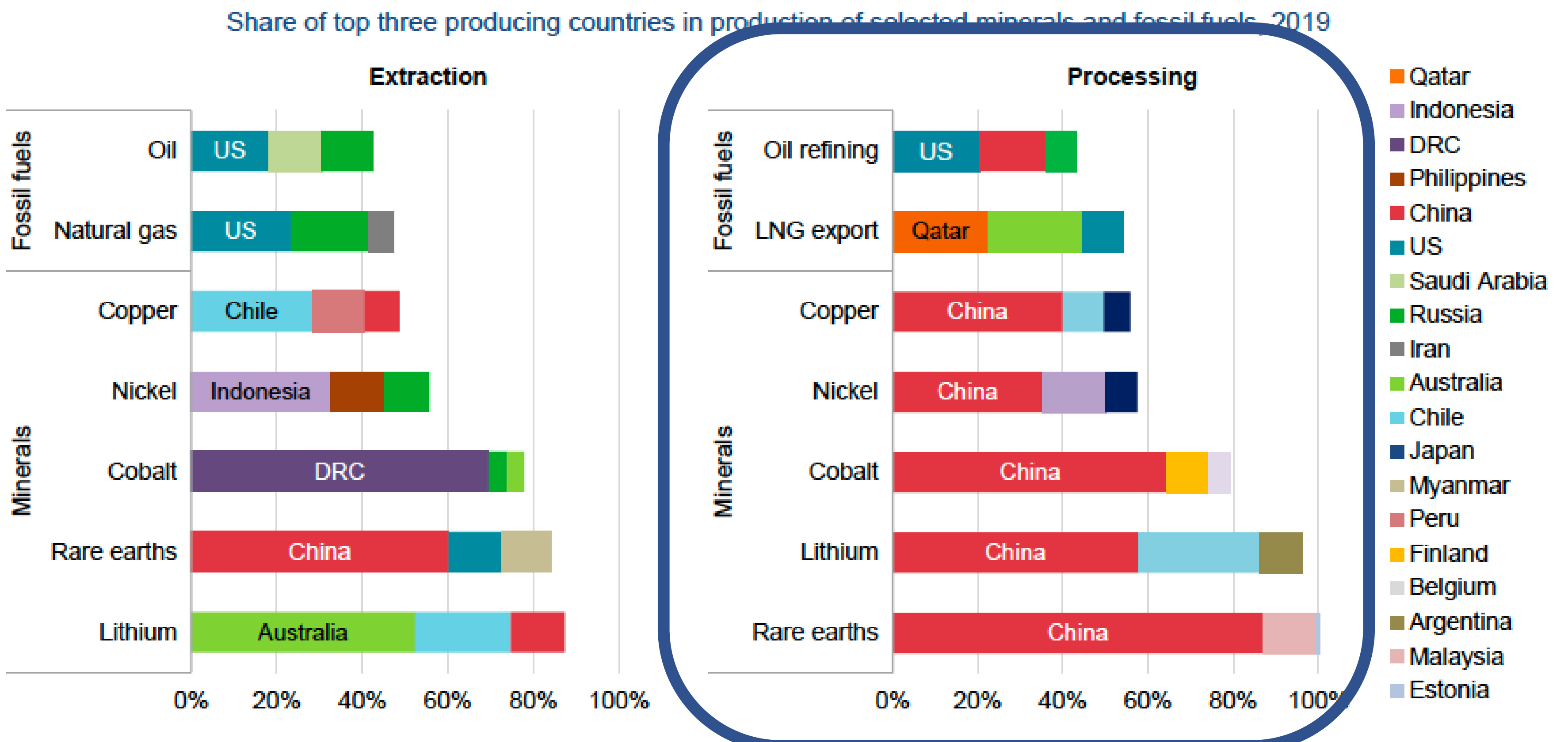

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Source: iea.org

Electronic materials

e.g., solar applications, power electronics

Gallium, indium, selenium, silver, tellurium, tin

Source: pexels.com

Magnets & motors

Wind turbines, EVs, other industrial and household uses

Selected rare earths

Source: pexels.com

Energy storage & batteries

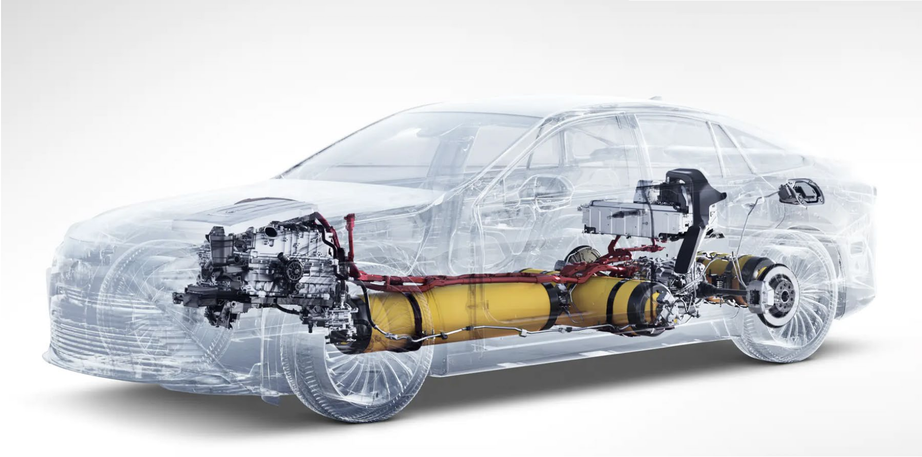
Lithium ion, solid-state lithium, sodium ion, flow, etc.

Lithium, nickel, cobalt, manganese, graphite, vanadium, sodium, lead, etc.

Sources: new.siemens.com, amazon.com, telegraph.co.uk

Fuel cells

Platinum-group elements, selected rare earths



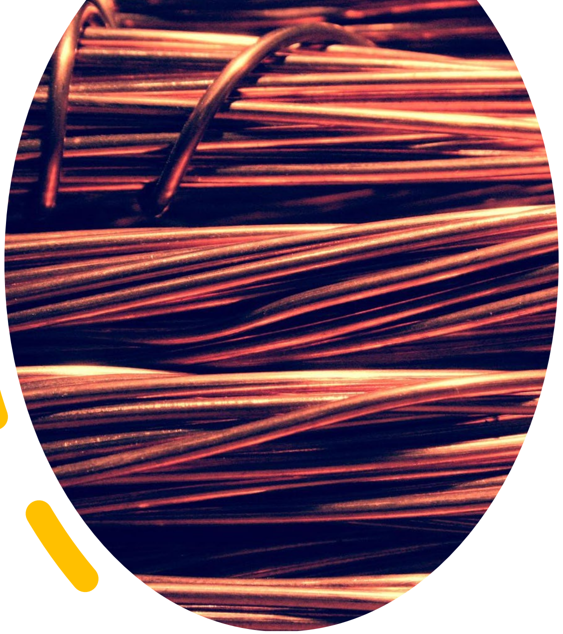
Source: Toyota.com

Nuclear

Cobalt, dysprosium, gadolinium, hafnium, indium

Source: Photo by Patrick Federi on Unsplash

Electrification



- Copper
- Not officially a US ‘critical’ mineral – but certainly essential with few if any substitutes

Financial Times, July 13, 2022

Opinion **Copper**

‘Dr Copper’ has a worrying message about the energy transition

The metal has become central to the drive to net zero given its use in electric car batteries and other technologies

DANIEL YERGIN + Add to myFT

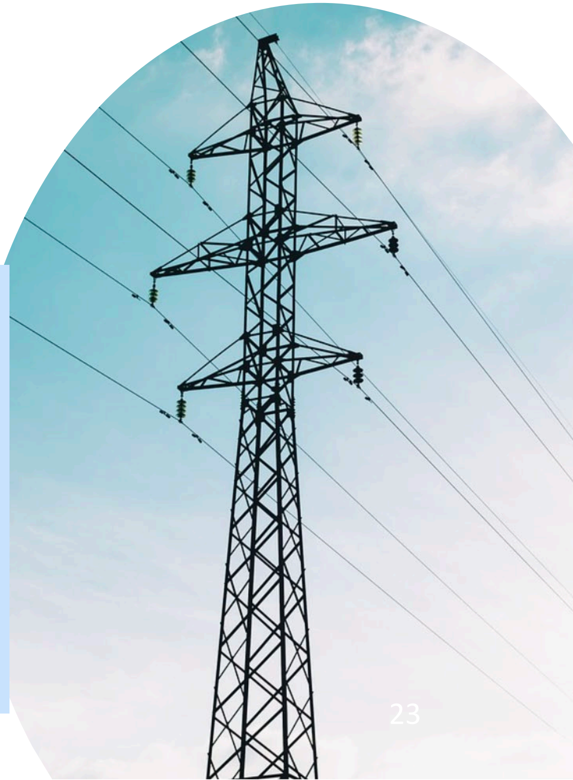


Image source: pixabay.com

What makes a supply chain resilient?

Resilient

Able to withstand or recover quickly from difficult conditions

Source: lexico.com

Options

Short- to medium-term options

- Increase stockpiles/working inventories
- Develop sourcing arrangements
- Adopt off-the-shelf technologies
  - A material or process

Medium- to long-term options

- Diversify and increase primary production
  - Develop supply chains in more places
- Waste less
  - Increase manufacturing efficiency
  - Enhance re-use and recycling
- Use less
  - Develop substitutes

What mix of private initiative and public policy do we want?

A topic for another time

But a bit of the broader context

Reconsideration of globalization

After Hyper-Globalization

What should the next trading system be? Can we restore the capacity of the U.S. to produce—and of all nations to regulate capitalism?

BY ROBERT KUTTNER MAY 31, 2022

The Myth of the Global

Why Regional Ties Win the Day

By Shannon K. O'Neil July/August 2022

Businessweek | Remarks

'Onshoring' Is So Last Year. The New Lingo Is 'Friend-Shoring'

The Biden administration recognizes that the U.S. can't go it alone.

By Peter Coy
June 24, 2021, 3:00 AM MDT

★ ★ ★

Minerals Security Partnership

MEDIA NOTE

JUNE 14, 2022

Reconsideration of industrial policy

MAY 24, 2022

Reboot: Framework for a New American Industrial Policy

Protection Without Protectionism

Getting Industrial Policy Right

By Shannon K. O'Neil January/February 2021

The New Productivism Paradigm?

Jul 5, 2022 | **DANI RODRIK**

President Biden Invokes Defense Production Act to Accelerate Domestic Manufacturing of Clean Energy

JUNE 6, 2022

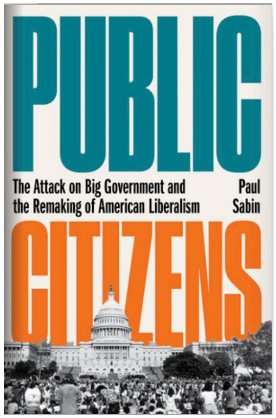
Reconsideration of relative roles of Congress, the Administration, and Civil Society

Supreme Court restricts the EPA's authority to mandate carbon emissions reductions

Updated June 30, 2022 · 10:30 AM ET

Government regulation is vital, but it also needs to be efficient

Jimmy Carter had a vision for protecting the environment and consumers — while cutting wasteful regulations



Biden mining order won't change biggest hurdle: Permits

By Jael Holzman, Hannah Northey | 04/08/2022 01:34 PM EDT

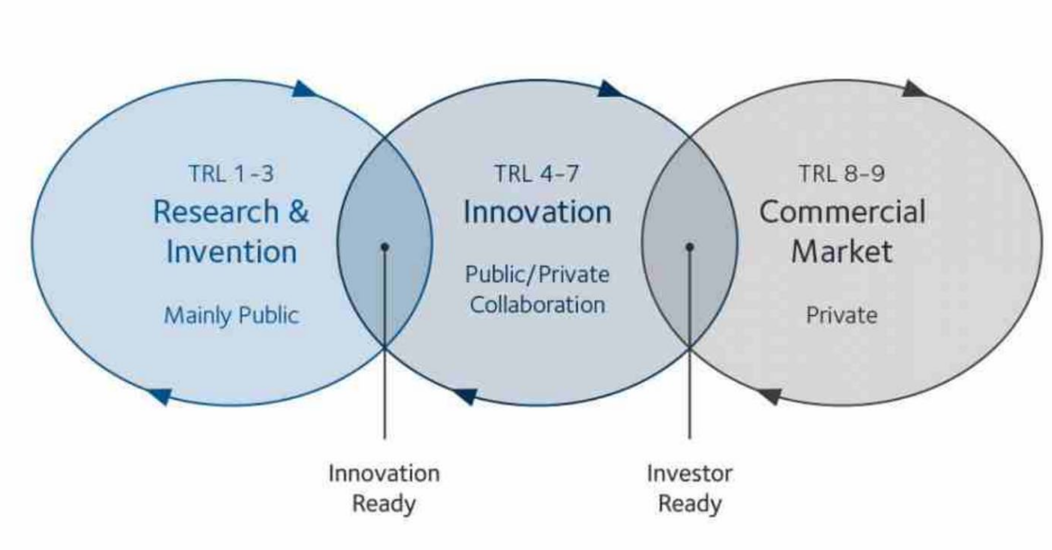
Reconsideration of science and technology policy

The Chinese Way of Innovation

What Washington Can Learn From Beijing About Investing in Tech

By Matt Sheehan **April 21, 2022**

‘Deploy, deploy, deploy’
- DOE, mid to late 2021



Source: https://www.uk-cpi.com/blog/the-innovation-challenge-and-the-valley-of-death

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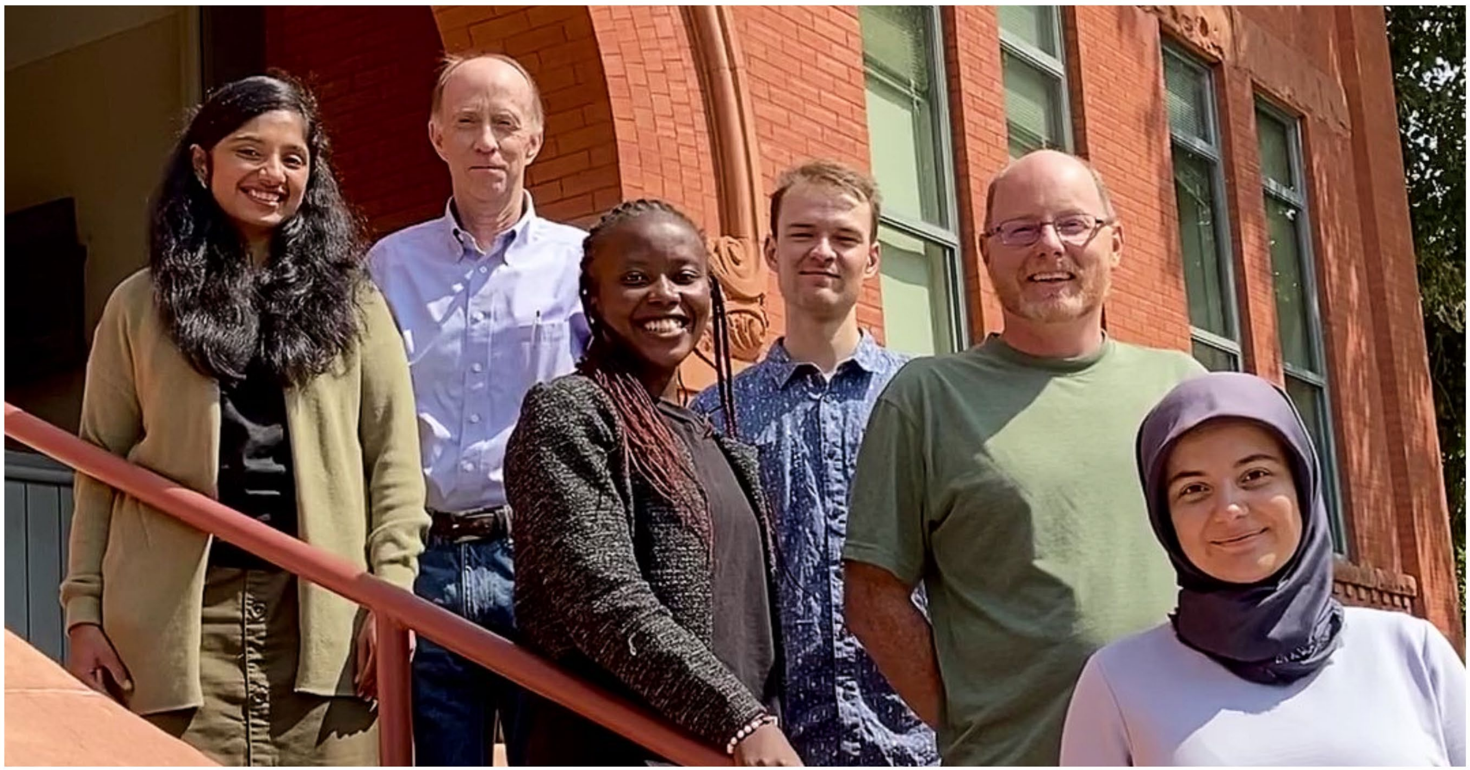


Spring 2022, Eggert Research Group