# Critical Materials in the Modern Energy Landscape

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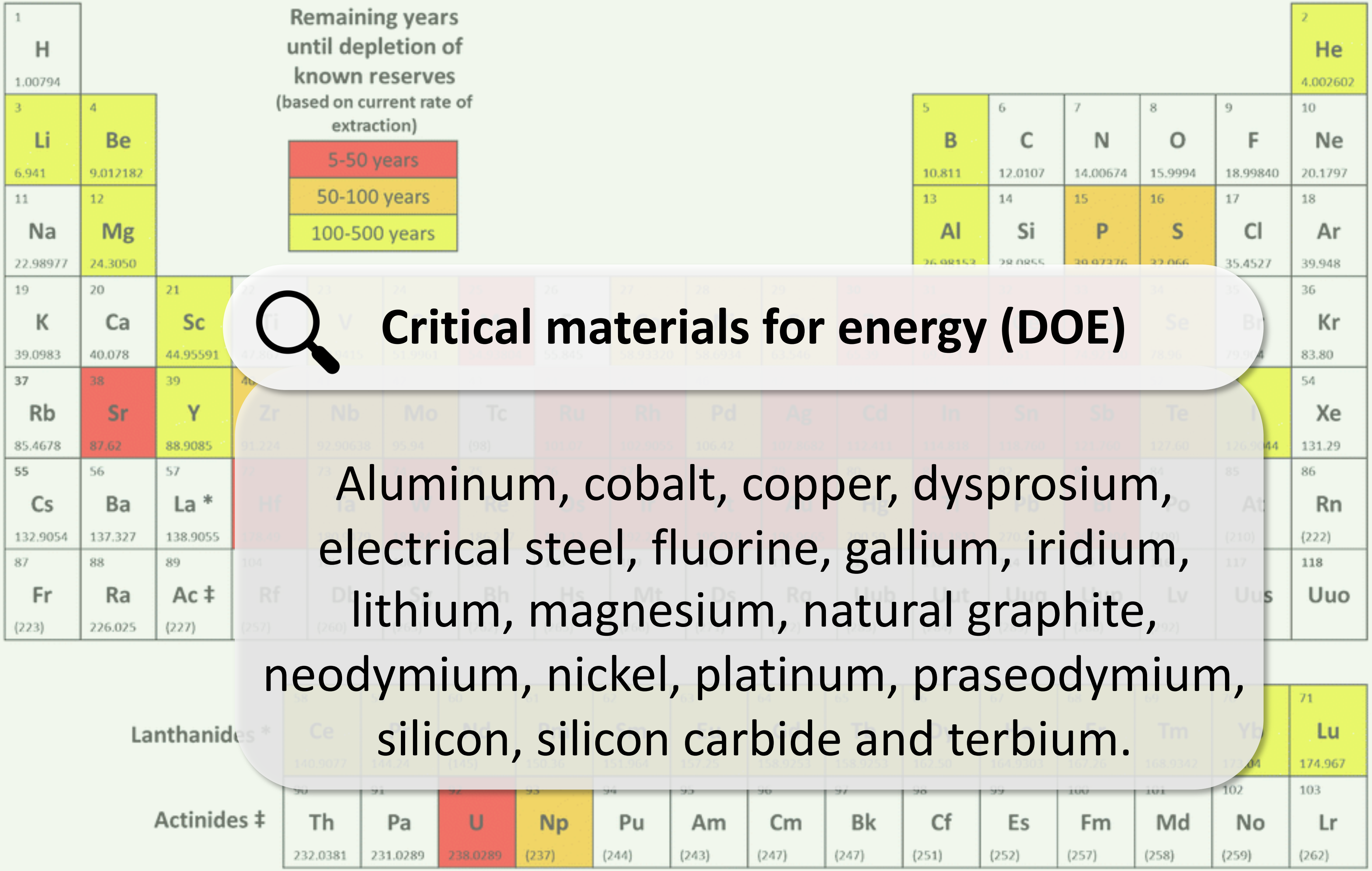
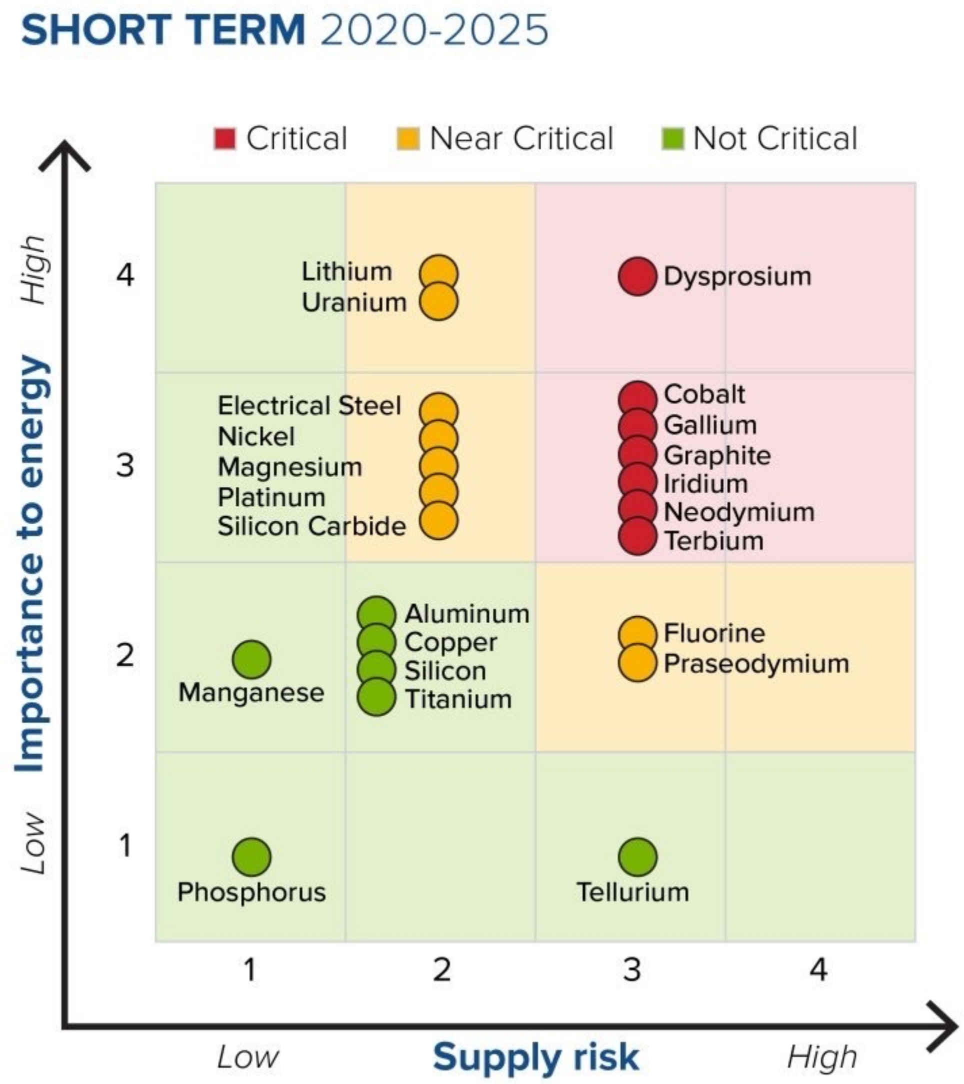
EGI Energy & Geoscience Institute AT THE UNIVERSITY OF UTAH 50 YEARS

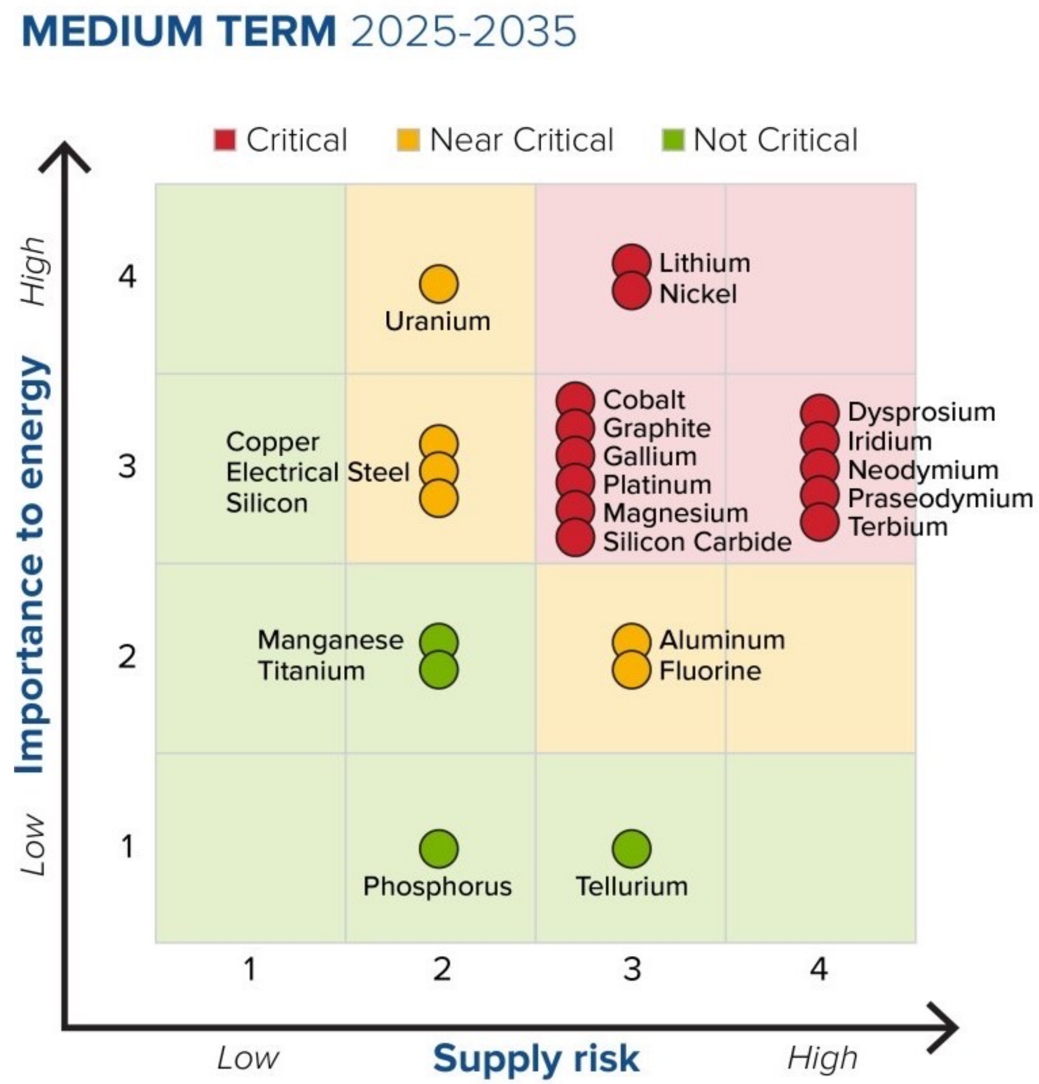
# What are Critical Materials/Minerals?



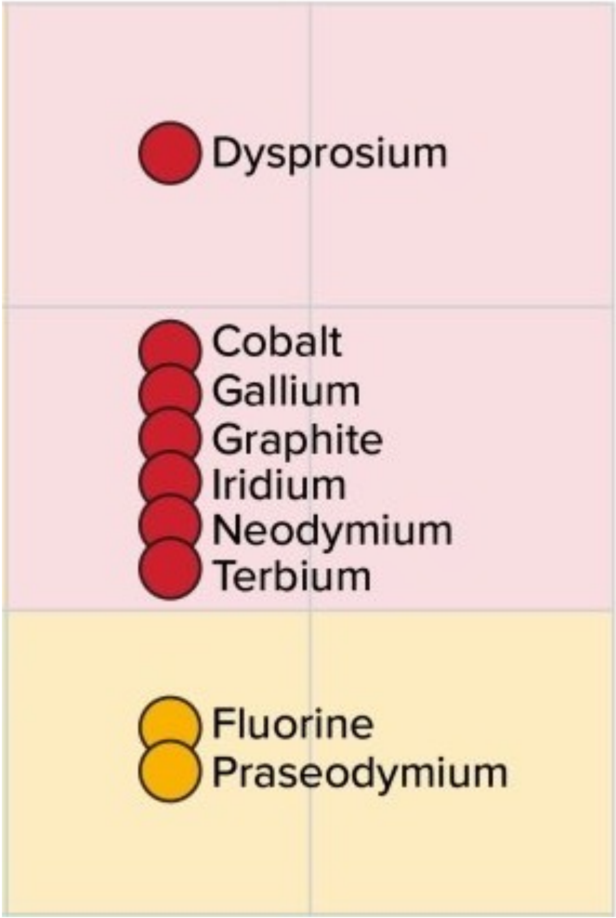

**Critical materials for energy (DOE)**

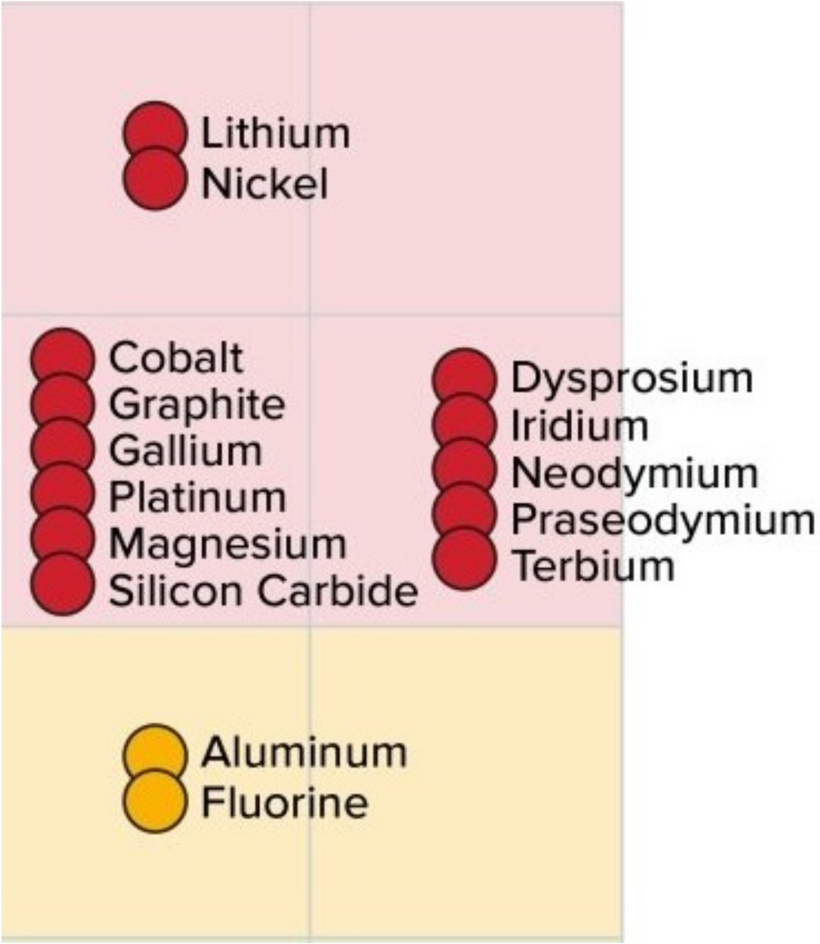
Aluminum, cobalt, copper, dysprosium, electrical steel, fluorine, gallium, iridium, lithium, magnesium, natural graphite, neodymium, nickel, platinum, praseodymium, silicon, silicon carbide and terbium.




# DOE Critical Materials

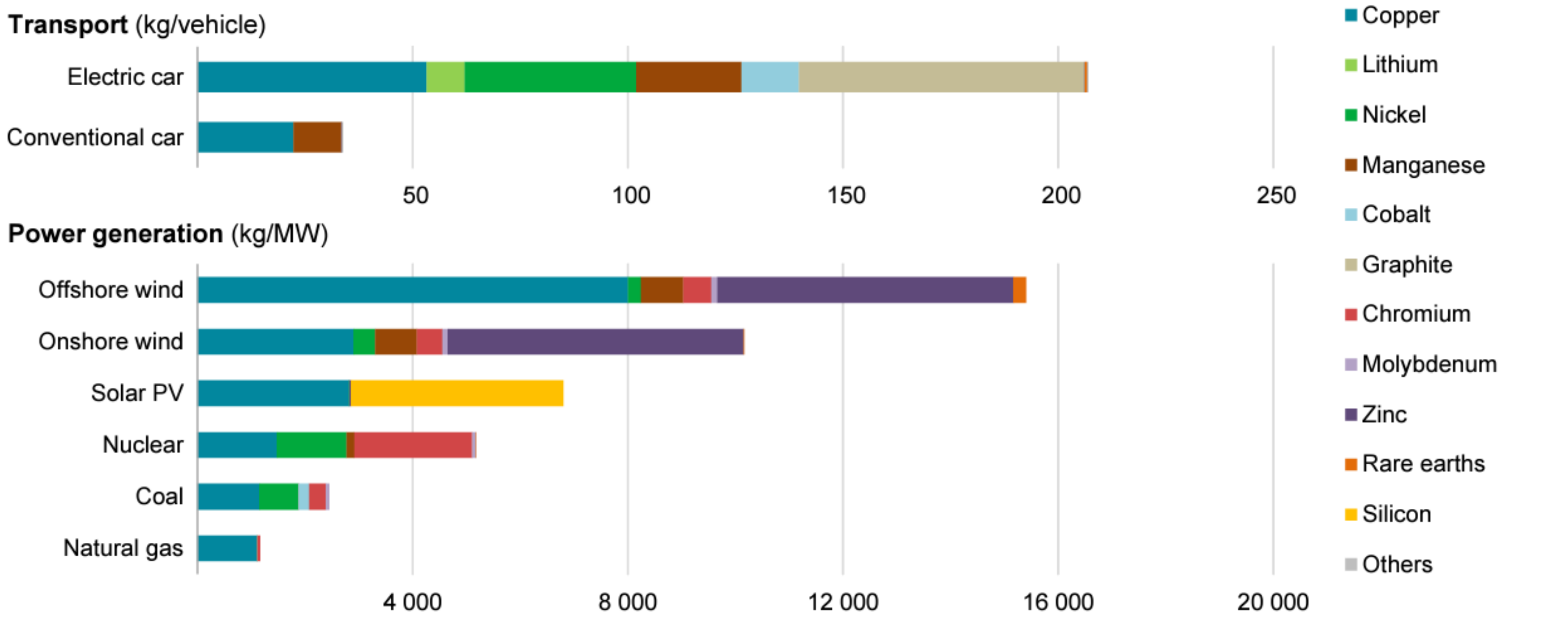



# DOE Critical Materials


Energy Transition
“In the transition to clean energy, critical minerals bring new challenges to energy security”

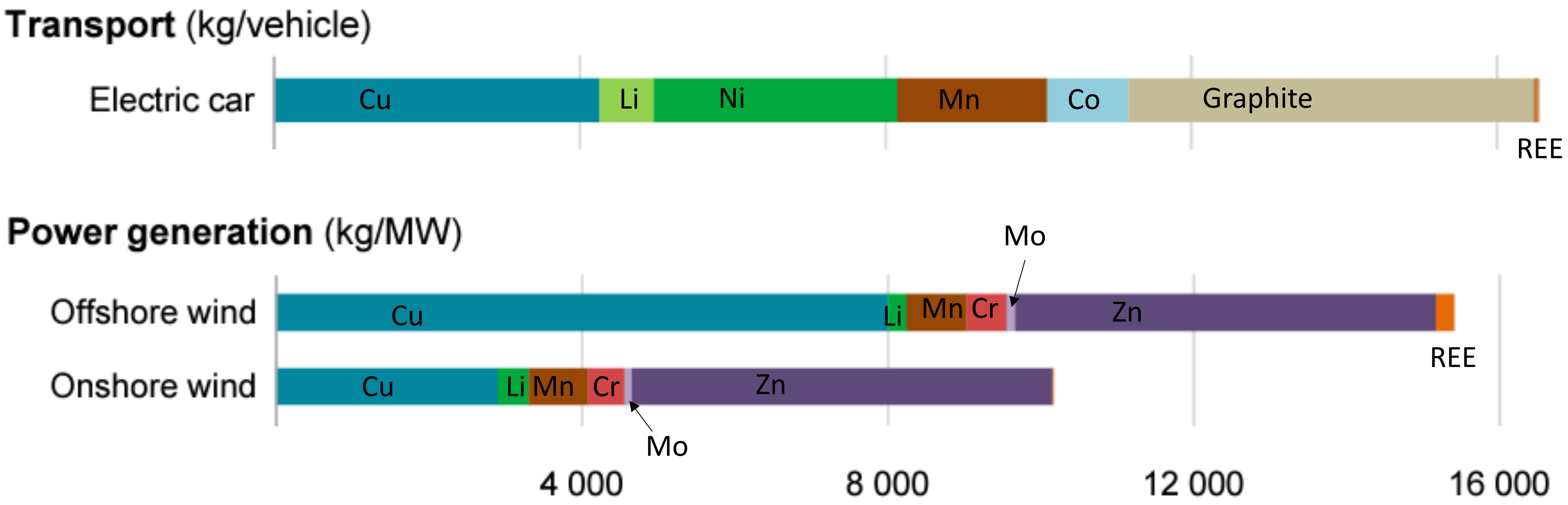
# Minerals used in Clean Energy Technologies






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

# Expansion in Electric Vehicles and Wind Power Will Drive Demand for Critical Materials/Minerals



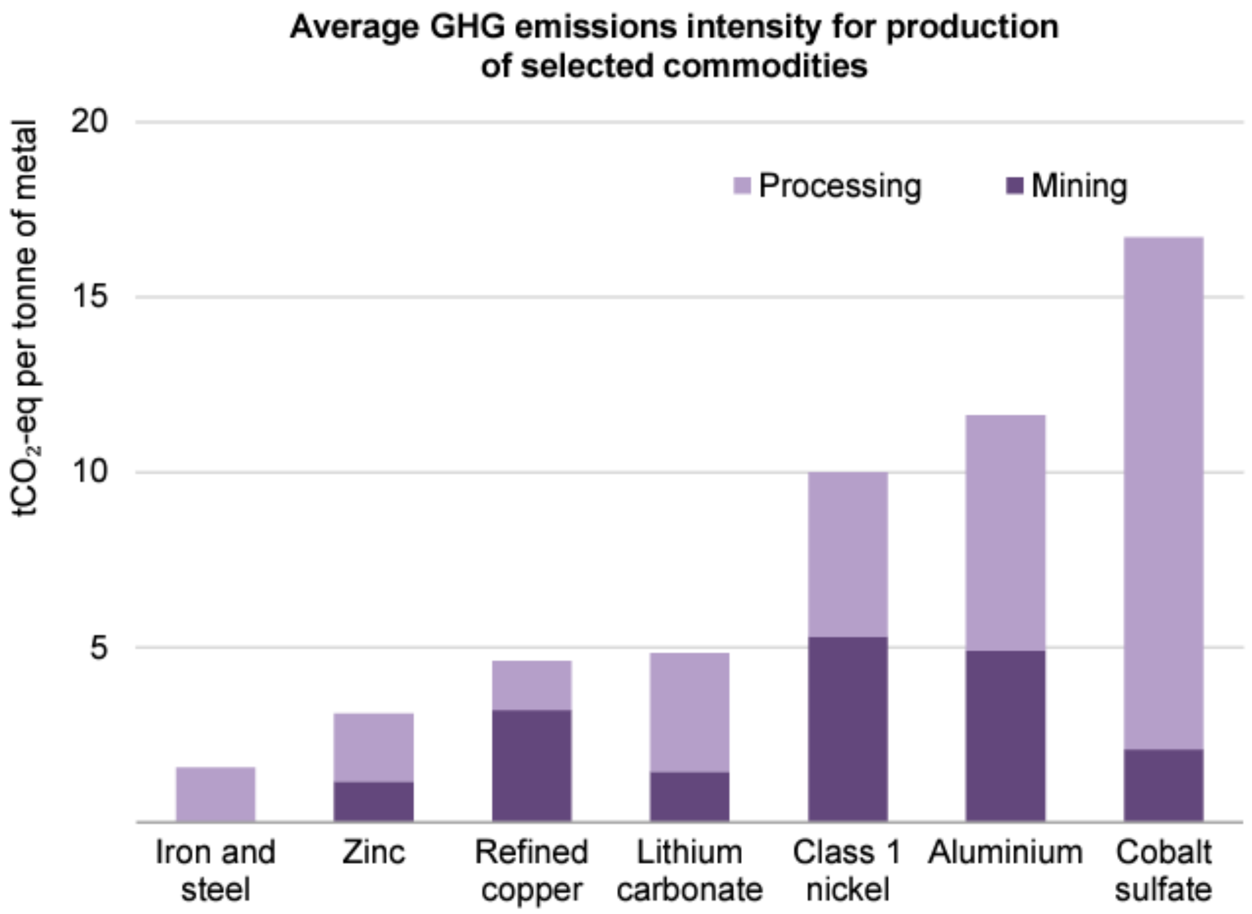
# Critical Material/Mineral Needs by Clean Energy Technology

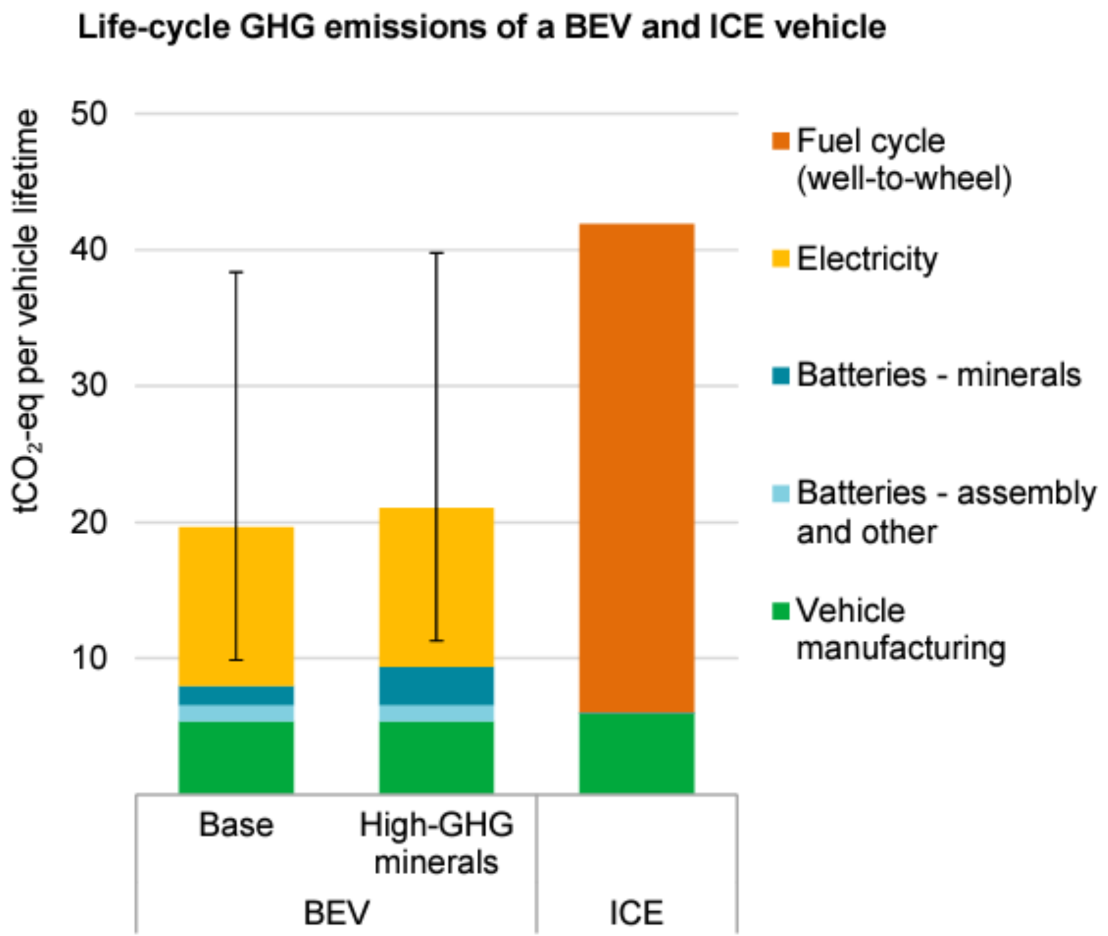
| | Copper | Cobalt | Nickel | Lithium | REEs | Chromium | Zinc | PGMs | Aluminium* |
|---|---|---|---|---|---|---|---|---|---|
| **Solar PV** | ● | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● |
| **Wind** | ● | ○ | ◍ | ○ | ● | ◍ | ● | ○ | ◍ |
| **Hydro** | ◍ | ○ | ○ | ○ | ○ | ◍ | ◍ | ○ | ◍ |
| **CSP** | ◍ | ○ | ◍ | ○ | ○ | ● | ◍ | ○ | ● |
| **Bioenergy** | ● | ○ | ○ | ○ | ○ | ○ | ◍ | ○ | ◍ |
| **Geothermal** | ○ | ○ | ● | ○ | ○ | ● | ○ | ○ | ○ |
| **Nuclear** | ◍ | ○ | ◍ | ○ | ○ | ◍ | ○ | ○ | ○ |
| **Electricity networks** | ● | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● |
| **EVs and battery storage** | ● | ● | ● | ● | ● | ○ | ○ | ○ | ● |
| **Hydrogen** | ○ | ○ | ● | ○ | ◍ | ○ | ○ | ● | ◍ |

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.

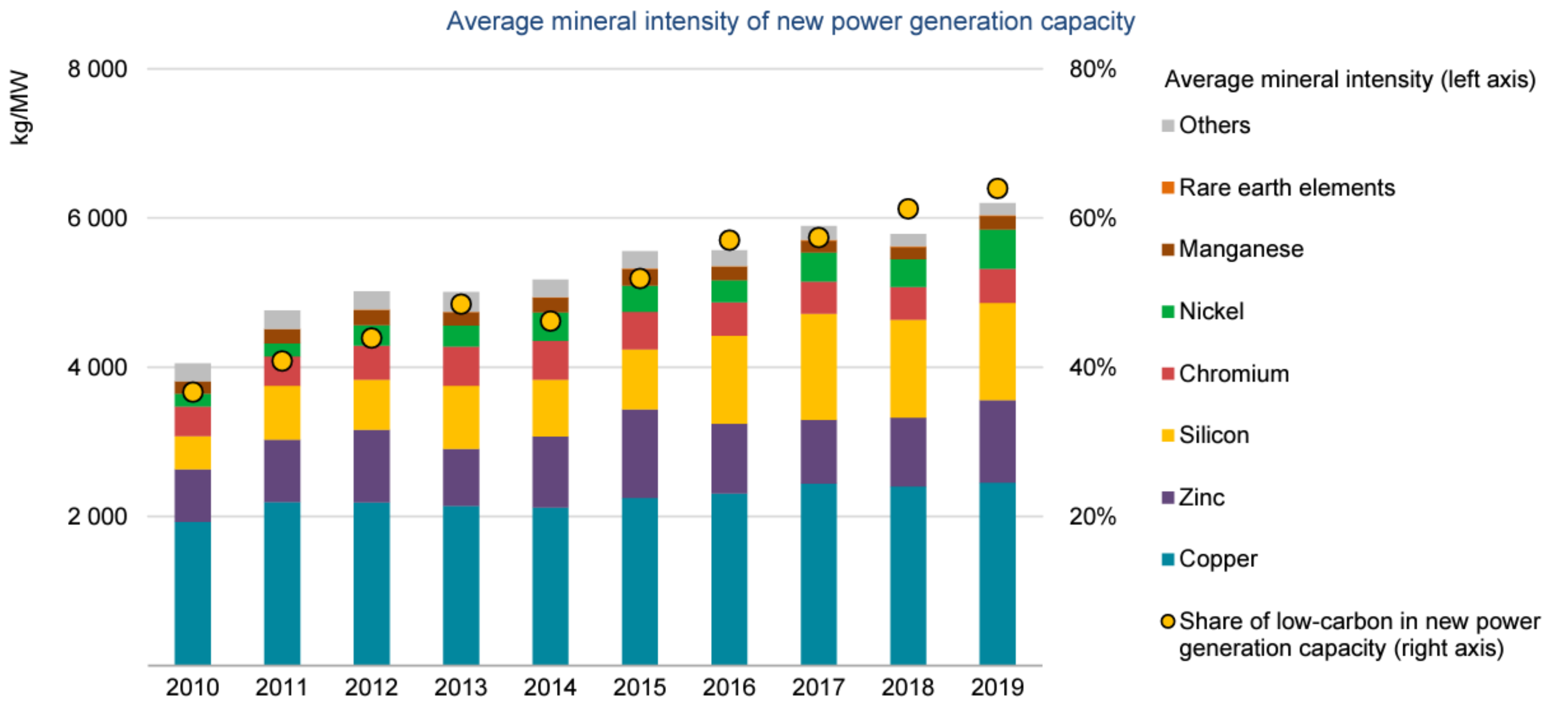
* In this report, aluminium demand is assessed for electricity networks only and is not included in the aggregate demand projections.

# Critical materials/minerals production provide increase pressure on GHG emissions, but clean energy technology still has advantages.



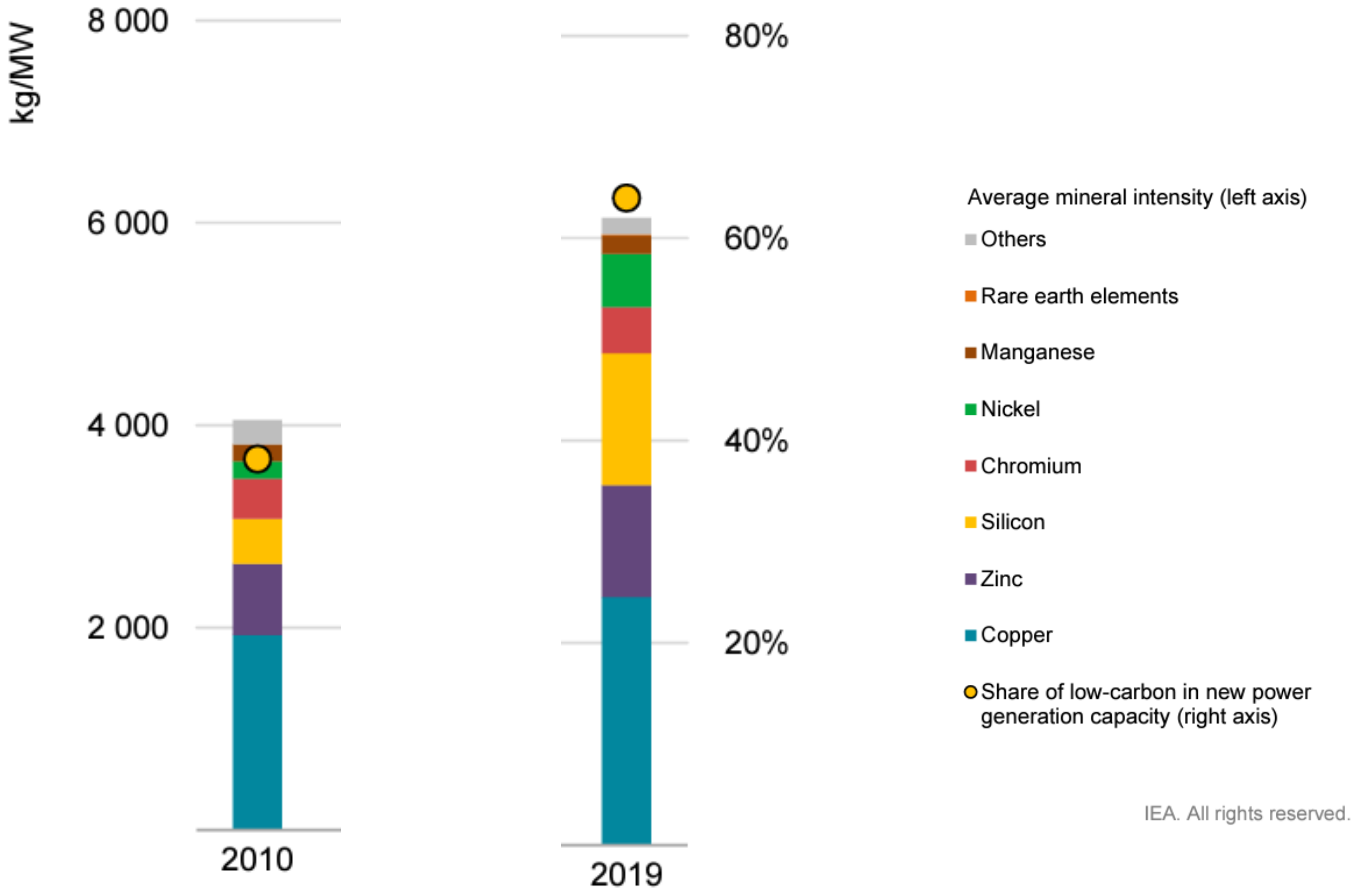



# Mineral Requirements for New Power Generation Increased by 50% since 2010

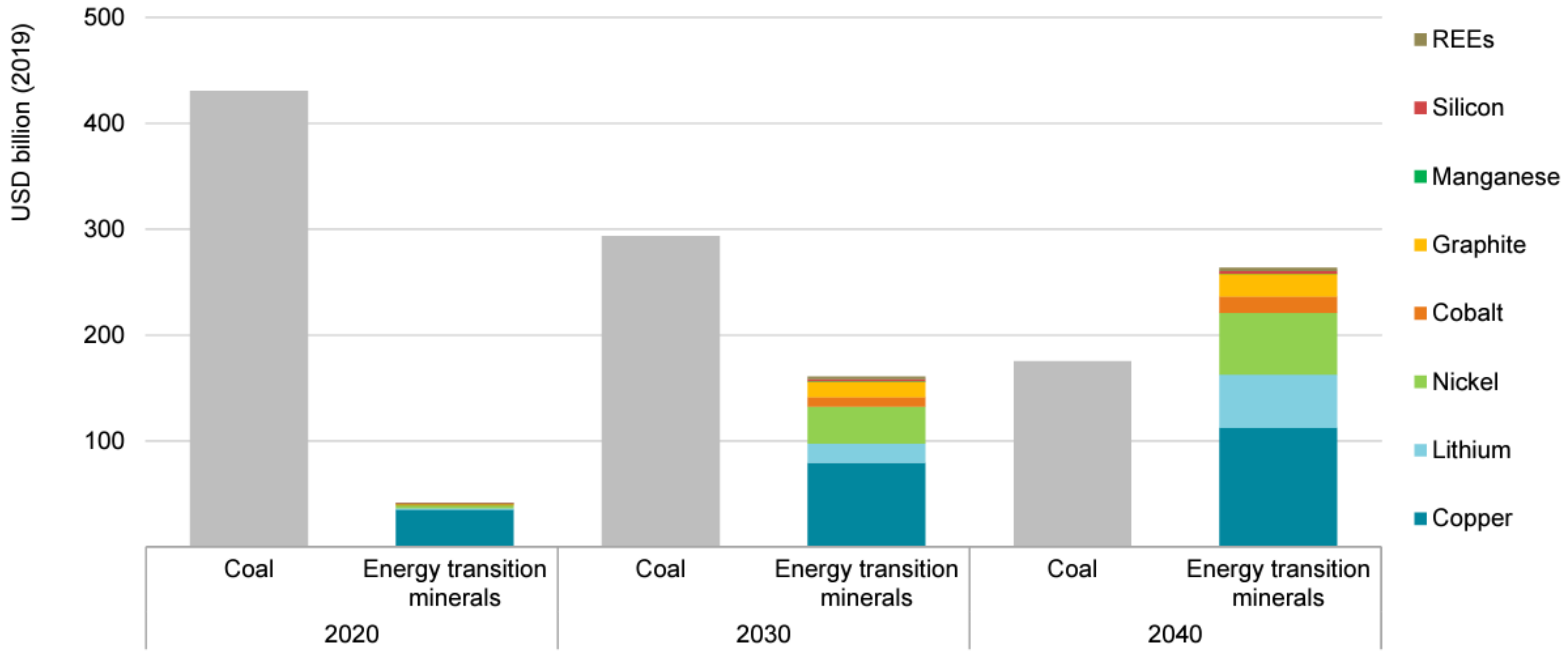





Note: Low-carbon technologies include renewables and nuclear.


kg/MW
8 000
6 000
4 000
2 000
80%
60%
40%
20%
2010
2019
Average mineral intensity (left axis)
Others
Rare earth elements
Manganese
Nickel
Chromium
Silicon
Zinc
Copper
Share of low-carbon in new power generation capacity (right axis)

# Energy revenue is projected to change.






Notes: Revenue for energy transition minerals includes only the volume consumed in clean energy technologies, not total demand. Future prices for coal are projected equilibrium prices in *WEO 2020* SDS. Prices for energy transition minerals are based on conservative assumptions about future price trends (moderate growth of around 10-20% from today's levels).

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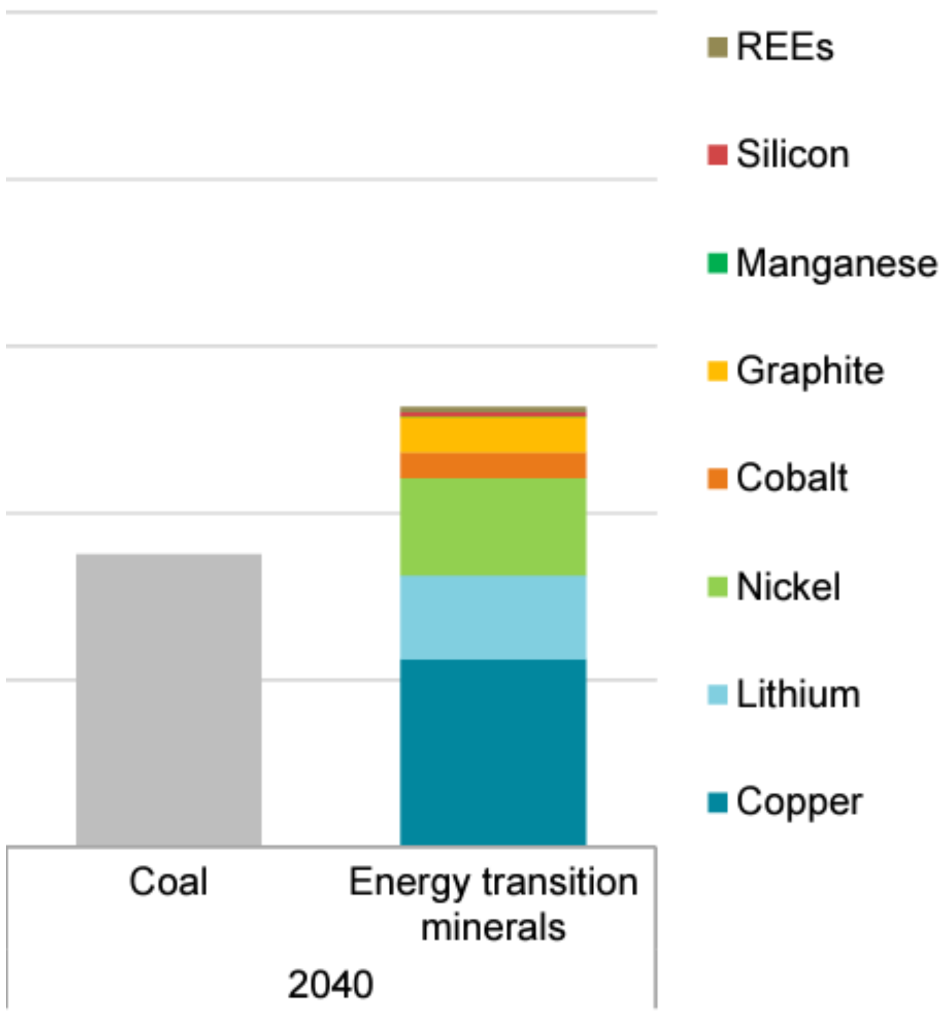
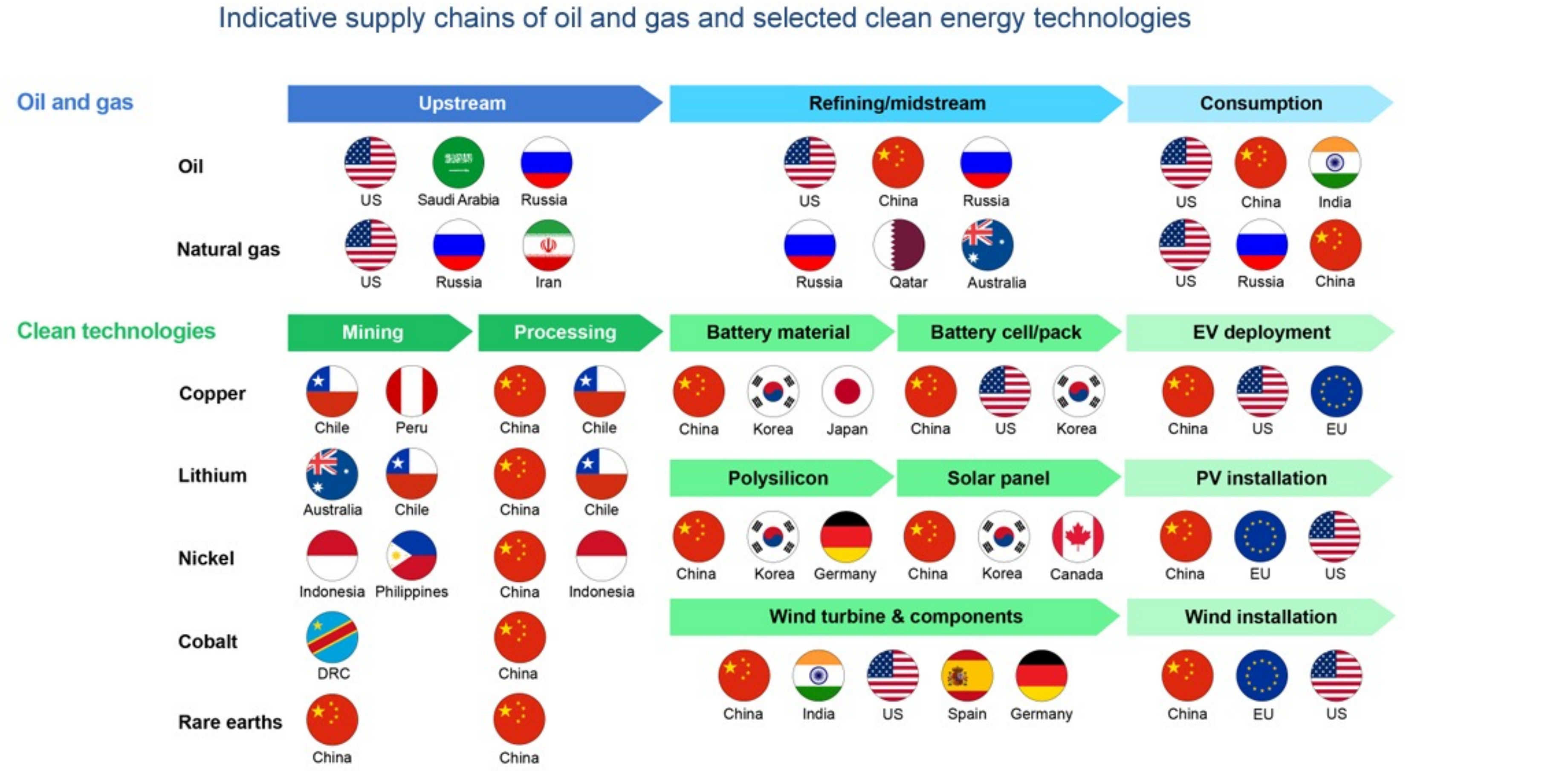


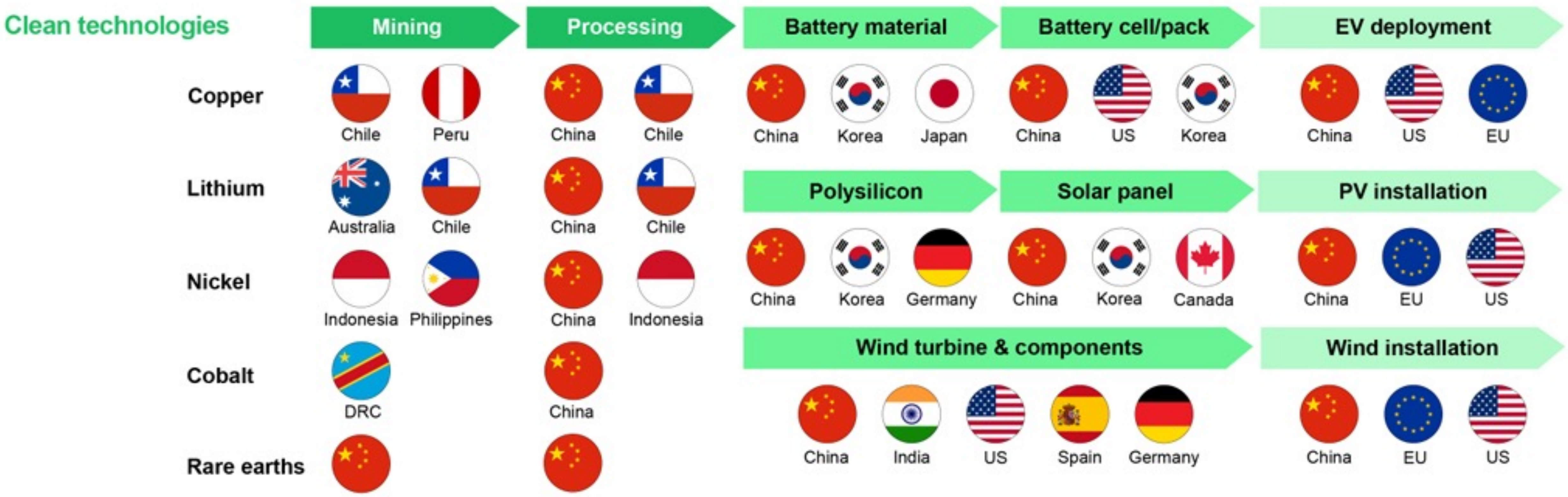
# Supply chain for clean technologies drastically different than oil and gas






Notes: DRC = Democratic Republic of the Congo; EU = European Union; US = United States; Russia = Russian Federation; China = People's Republic of China. Largest producers and consumers are noted in each case to provide an indication, rather than a complete account.

# USA role is currently not upstream at a significant level, mostly focused on parts and deployment.



# Supply Chain Challenges

# Domestic Critical Materials Deposits

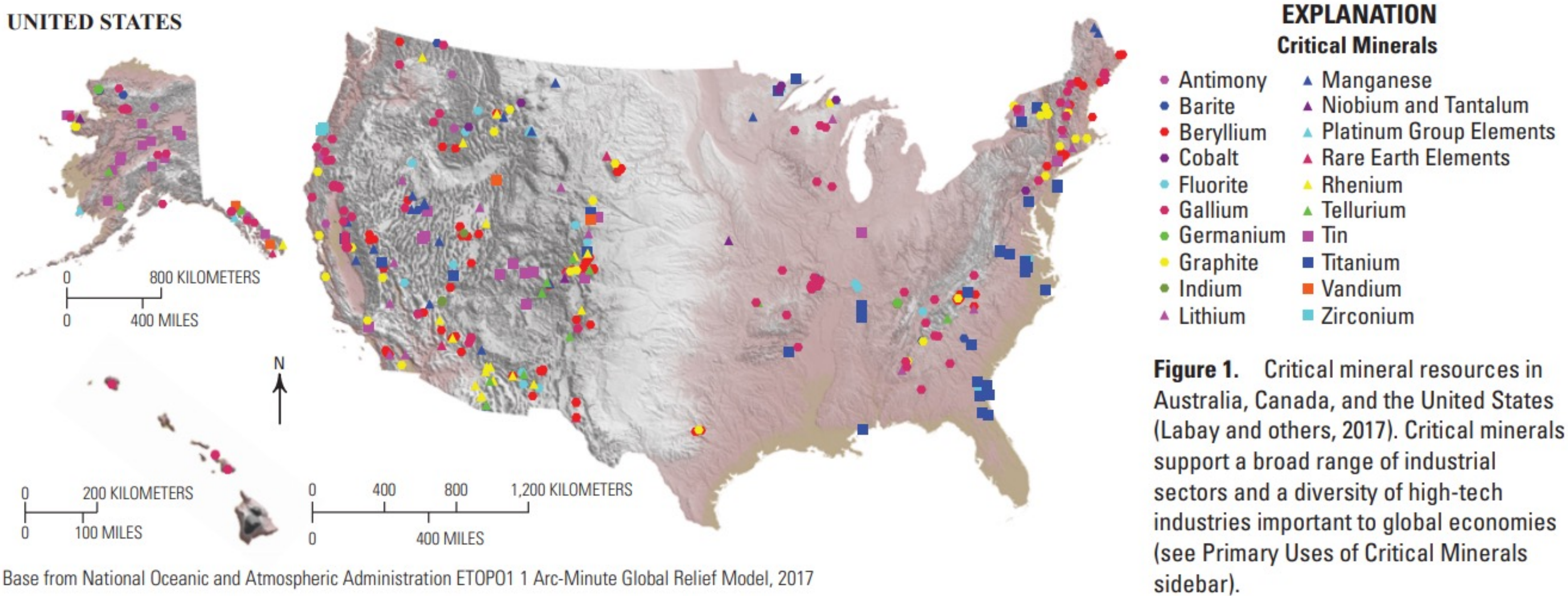
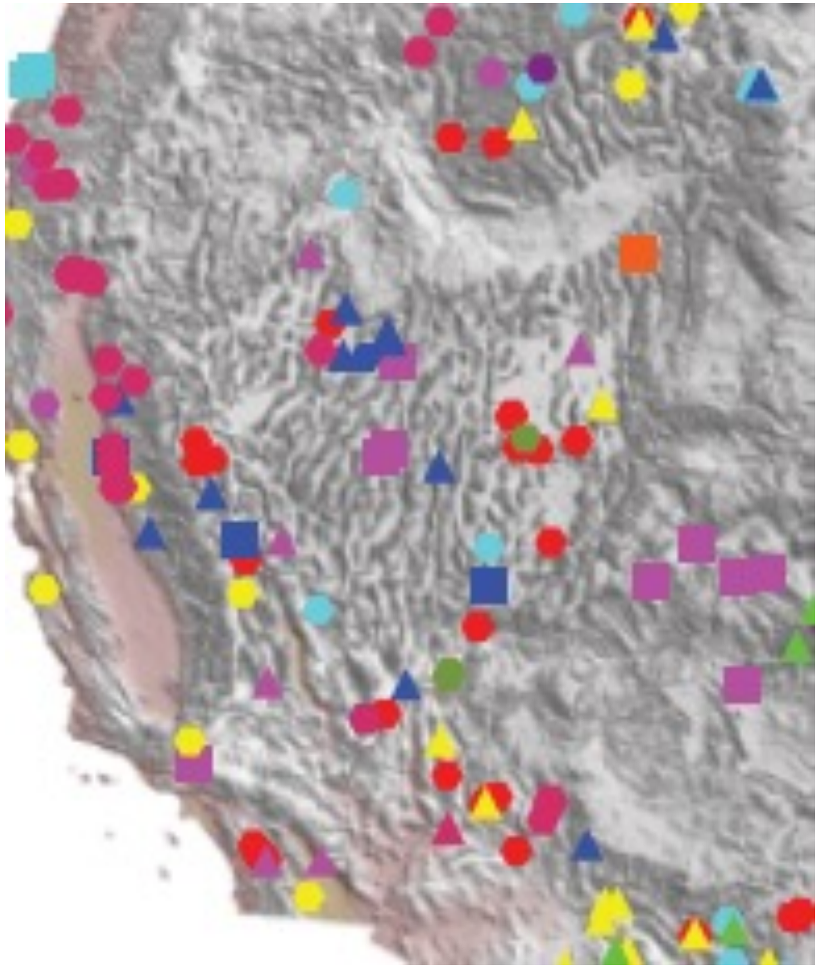



**Figure 1.** Critical mineral resources in Australia, Canada, and the United States (Labay and others, 2017). Critical minerals support a broad range of industrial sectors and a diversity of high-tech industries important to global economies (see Primary Uses of Critical Minerals sidebar).

# Supply Chain Challenges

## Domestic Critical Materials Deposits



**EXPLANATION**

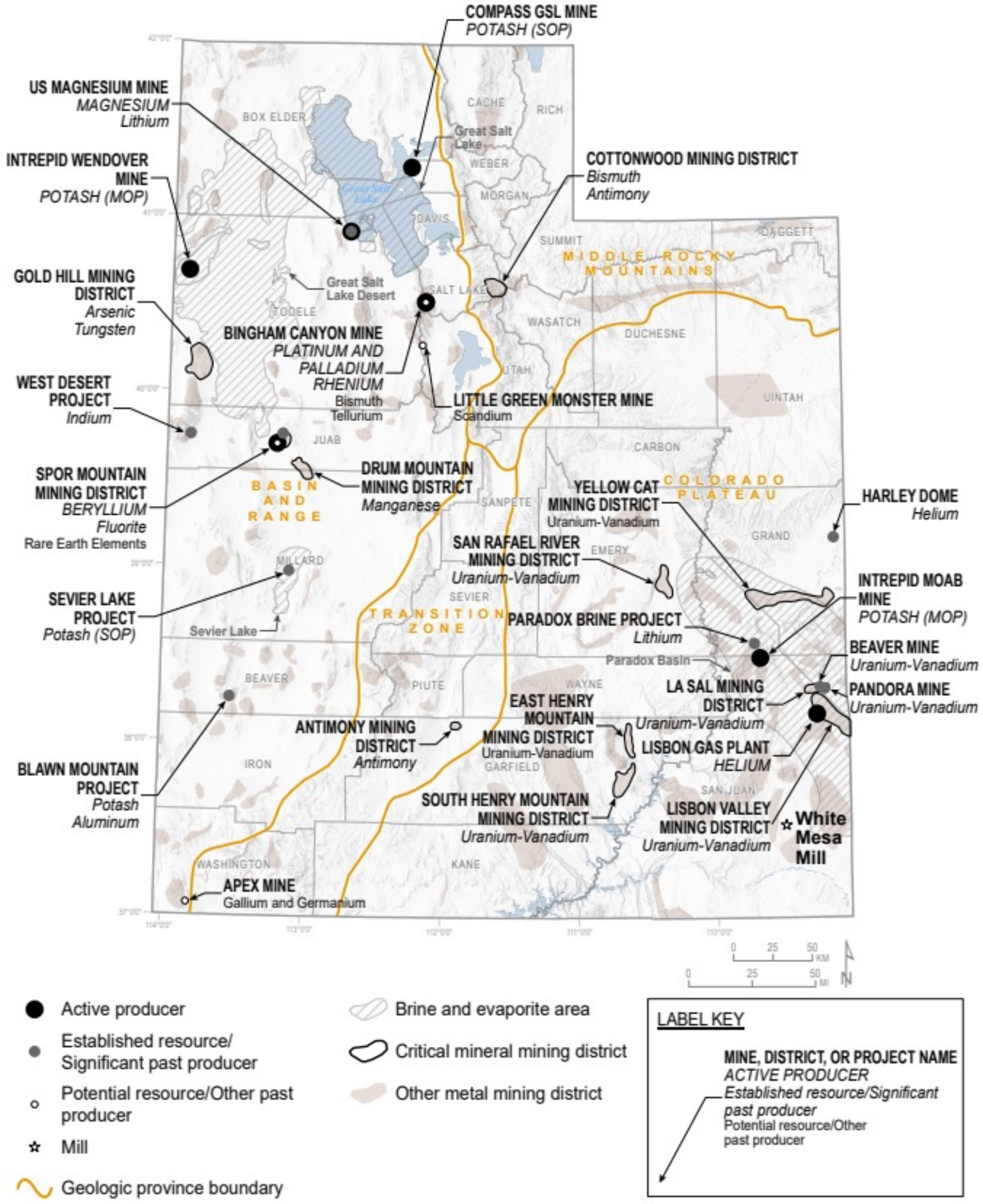
**Critical Minerals**

- ● Antimony
- ● Barite
- ● Beryllium
- ● Cobalt
- ● Fluorite
- ● Gallium
- ● Germanium
- ● Graphite
- ● Indium
- ▲ Lithium
- ▲ Manganese
- ▲ Niobium and Tantalum
- ▲ Platinum Group Elements
- ▲ Rare Earth Elements
- ▲ Rhenium
- ▲ Tellurium
- ■ Tin
- ■ Titanium
- ■ Vandium
- ■ Zirconium

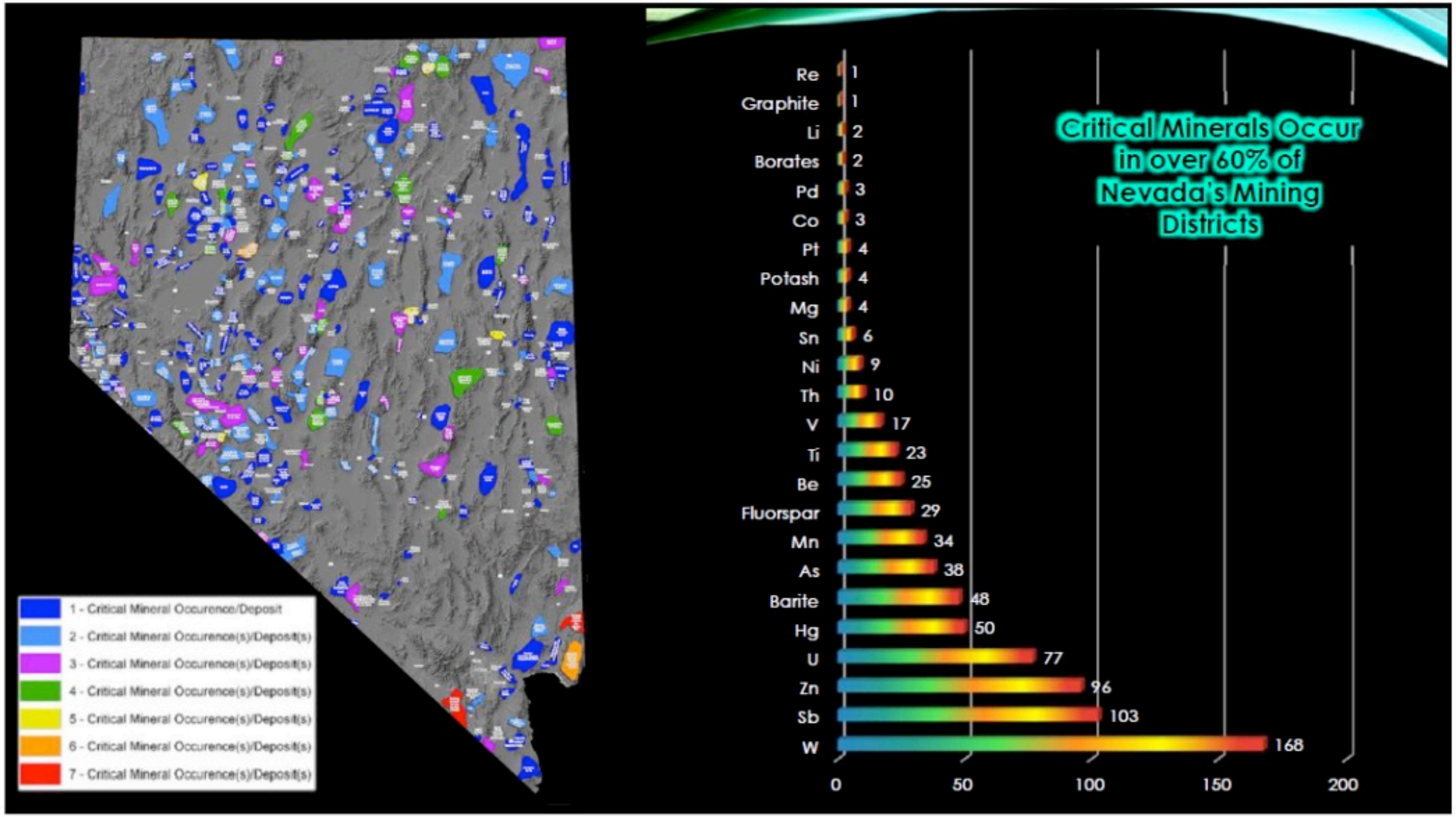
**Figure 1.** Critical mineral resources in Australia, Canada, and the United States (Labay and others, 2017). Critical minerals support a broad range of industrial sectors and a diversity of high-tech industries important to global economies (see Primary Uses of Critical Minerals sidebar).

# Potential Source of Critical Materials and Rare Earths  in Utah (Utah Geological Survey)

*Many of these sources are considered low grade making them suitable for phytoextraction*



# Potential Source of Critical Materials and Rare Earths in Nevada from Low Grade Sources (Nevada Division of Materials)




*Many of these sources are considered low grade making them suitable for phytoextraction*

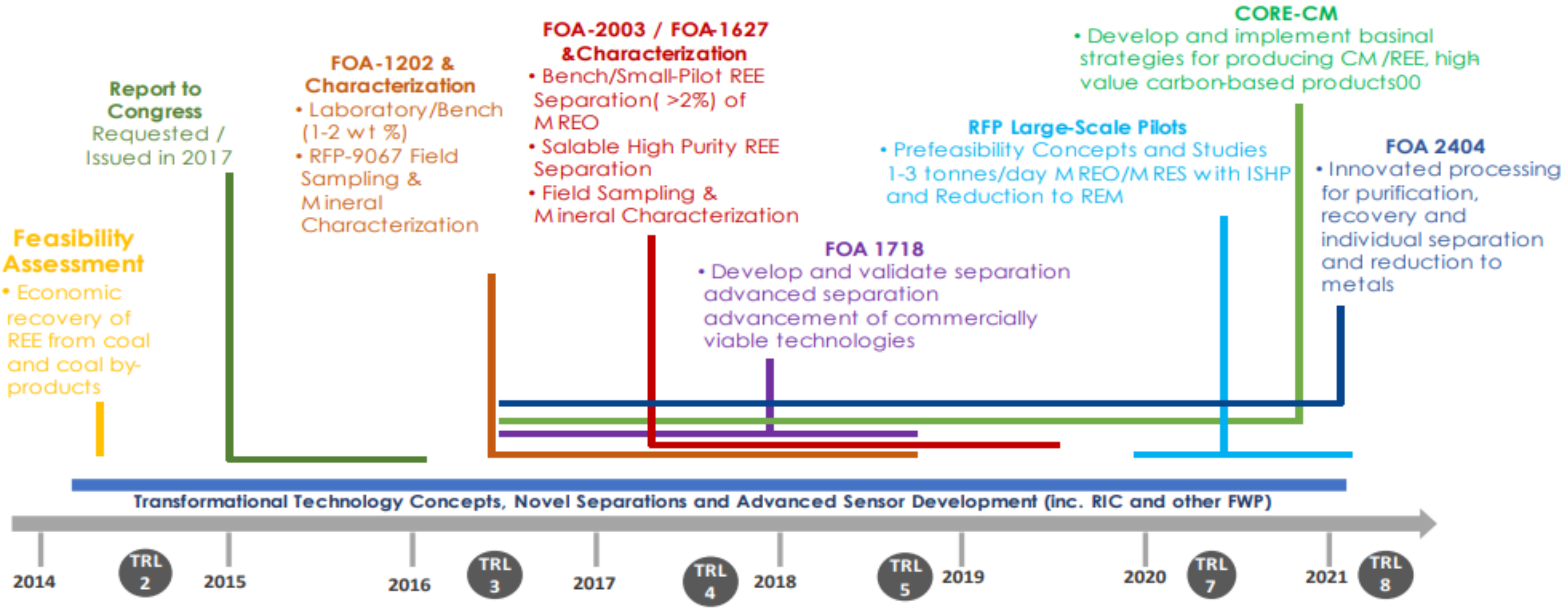
Science > Green Tech

# A Caldera in Nevada Now Has the Most Lithium in the World. Let the Gold Rush Begin.

But mining the area is controversial.

# Idaho Cobalt Belt

# Government Programmatic Activities in Critical Materials 2014-2021



# Technical Hurdles

- “Ground Truth” data one resources not widely available
- Need for environmentally friendly recovery approches
  - Low water
  - Low energy
- New recycling approaches

# Innovation and Research: Critical Materials from Un-conventional Resources

- Unconventional sources concentrations 0.0000001 percent to 0.03
- Conventional is 0.5 percent to 40 percent for conventional ores.

# Environmental and Social Challenges

| Areas of risks | | Description |
|---|---|---|
| Environment | Climate change | • With higher greenhouse gas emission intensities than bulk metals, production of energy transition minerals can be a significant source of emissions as demand rises<br>• Changing patterns of demand and types of resource targeted for development pose upward pressure |
| | Land use | • Mining brings major changes in land cover that can have adverse impacts on biodiversity<br>• Changes in land use can result in the displacement of communities and the loss of habitats that are home to endangered species |
| | Water management | • Mining and mineral processing require large volumes of water for their operations and pose contamination risks through acid mine drainage, wastewater discharge and the disposal of tailings<br>• Water scarcity is a major barrier to the development of mineral resources: around half of global lithium and copper production are concentrated in areas of high water stress |
| | Waste | • Declining ore quality can lead to a major increase in mining waste (e.g. tailings, waste rocks); tailings dam failure can cause large-scale environmental disasters (e.g. Brumadinho dam collapse in Brazil)<br>• Mining and mineral processing generate hazardous waste (e.g. heavy metals, radioactive material) |
| Social | Governance | • Mineral revenues in resource-rich countries have not always been used to support economic and industrial growth and are often diverted to finance armed conflict or for private gain<br>• Corruption and bribery pose major liability risks for companies |
| | Health and safety | • Workers face poor working conditions and workplace hazards (e.g. accidents, exposure to toxic chemicals)<br>• Workers at artisanal and small-scale mine (ASM) sites often work in unstable underground mines without access to safety equipment |
| | Human rights | • Mineral exploitation may lead to adverse impacts on the local population such as child or forced labour (e.g. children have been found to be present at about 30% of cobalt ASM sites in the DRC)<br>• Changes in the community associated with mining may also have an unequal impact on women |

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# References


- What Are Critical Materials and Critical Minerals? | Department of Energy (https://www.energy.gov/cmm/what-are-critical-materials-and-critical-minerals#:~:text=DOE%20has%20determined%20the%20final,silicon%2C%20silicon%20carbide%20and%20terbium

- Critical materials for the energy transition: Rare earth elements (https://atf.asso.fr/media/technews/39/tnf39-prof3-irena-rare-earth-elements-2022.pdf)

- “TheRoleofCriticalMineralsinCleanEnergyTransitions” (https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf)

- Recovery of Rare Earth Elements and Critical Materials from Coal and Coal Byproducts (https://www.energy.gov/sites/default/files/2022-05/Report%20to%20Congress%20on%20Recovery%20of%20Rare%20Earth%20Elements%20and%20Critical%20Minerals%20from%20Coal%20and%20Coal%20By-Products.pdf)

# Any Questions?