Energy transition and (critical) raw materials

Is the supply of Critical Raw Materials a barrier for the Energy Transition?

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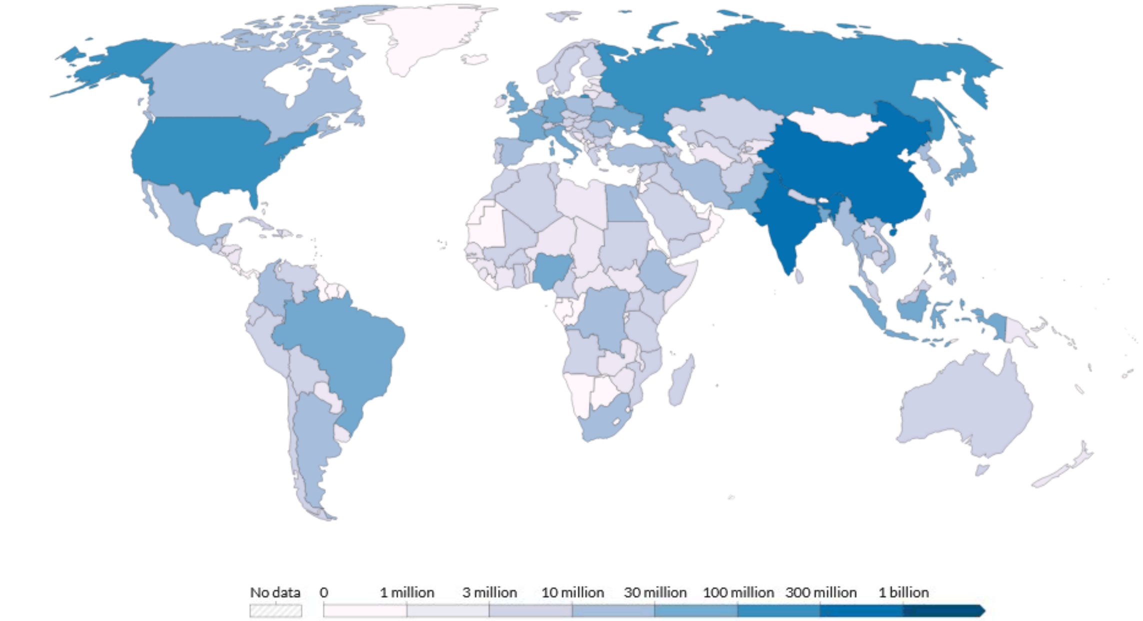
Challenges of the sustainable future

Population growth

- Increase in global population and increased urbanisation

1950



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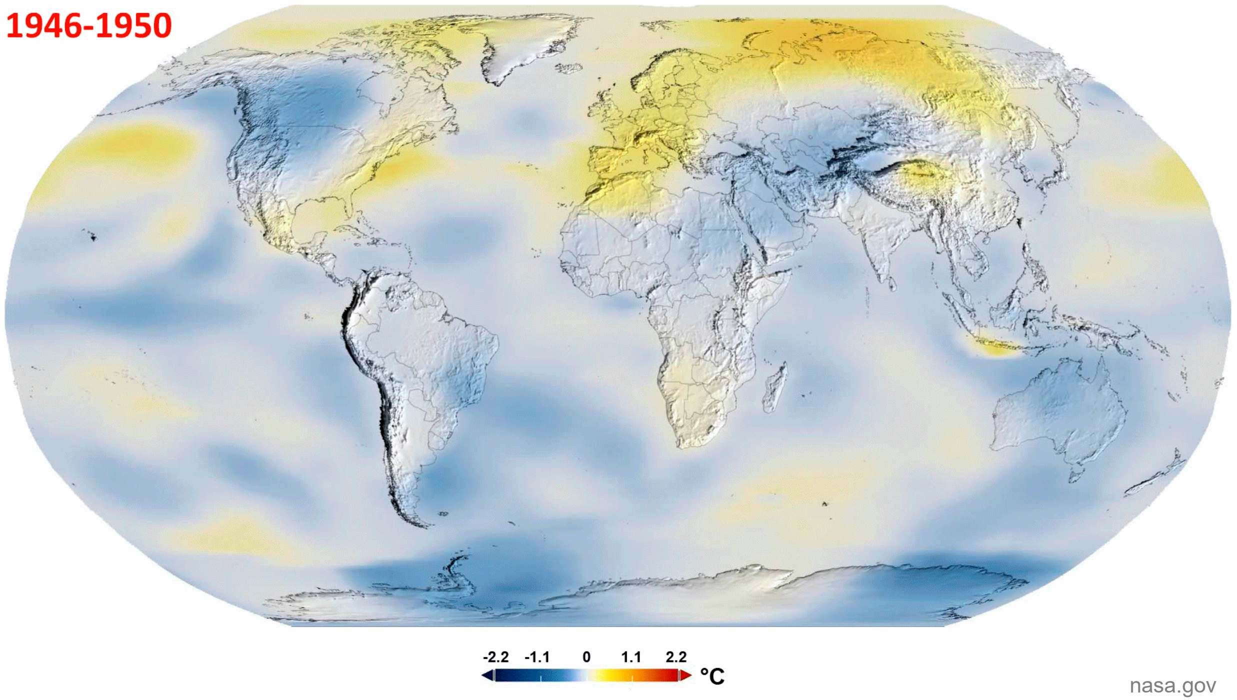
Climate change

- Warming climates, extreme weather events, need for carbon neutrality



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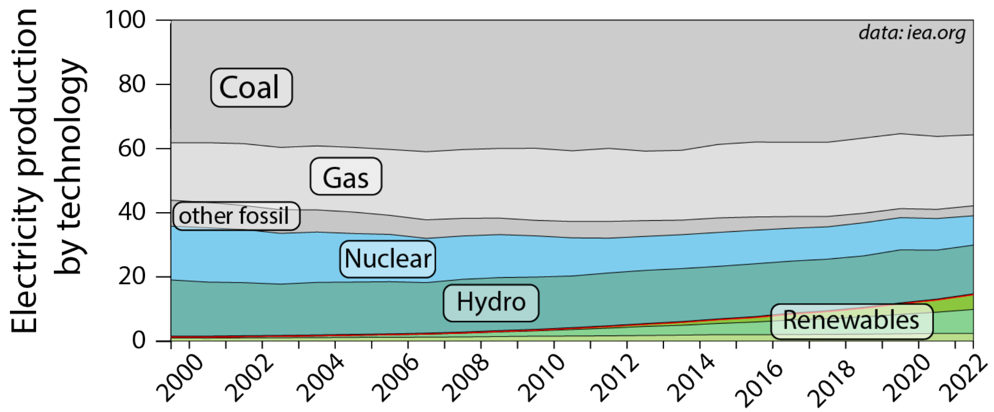
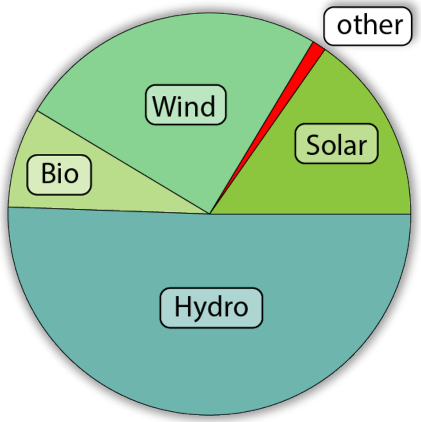
Future electricity supply needs to be sustainable

World view

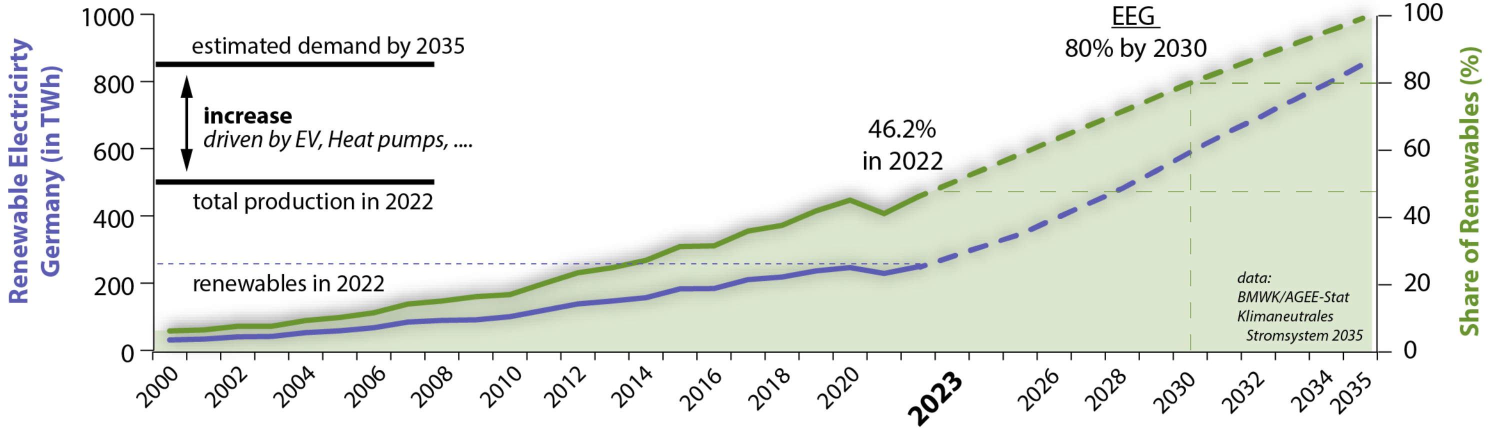




- Worlds renewable electricity production from solar and wind increased 5 fold over the last 10 years

German view

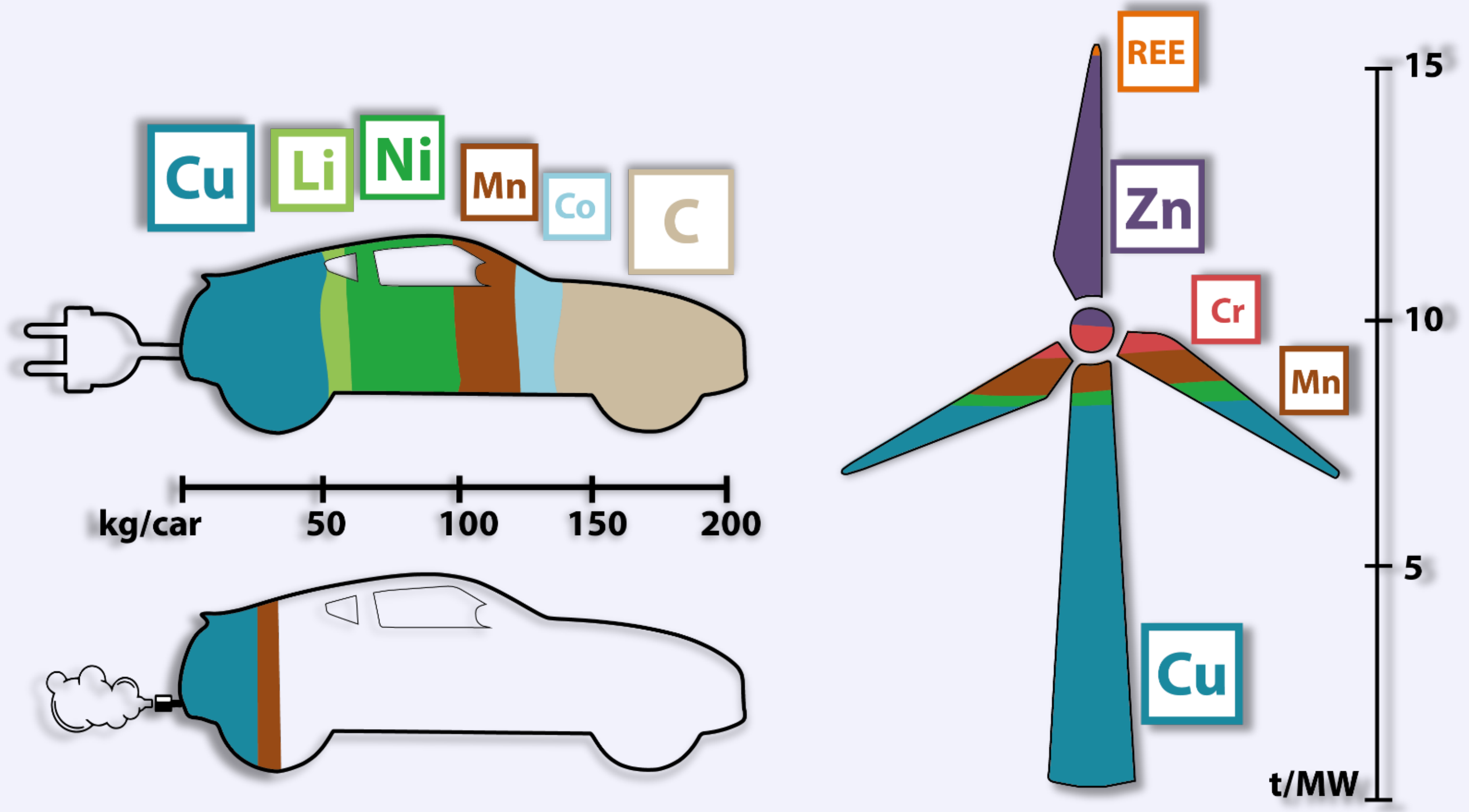
- Germany plans carbon neutrality by 2045.
- At the same time energy consumption will increase due to electrification of transport and heating.



Green technologies require vast amounts of metals

(New) technologies for energy production and energy storage require new resources !

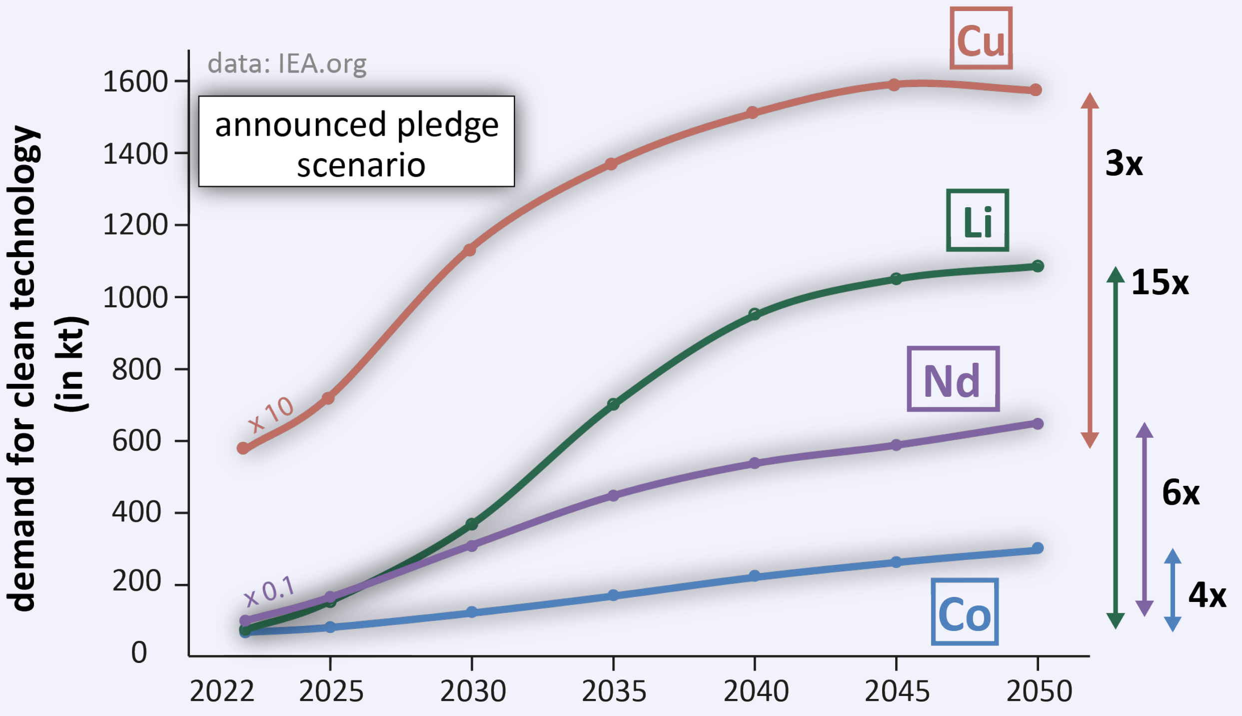
- Larger total amounts of each metal
- Larger variety of critical and strategic metals needed
- Complicated to predict future needs and markets



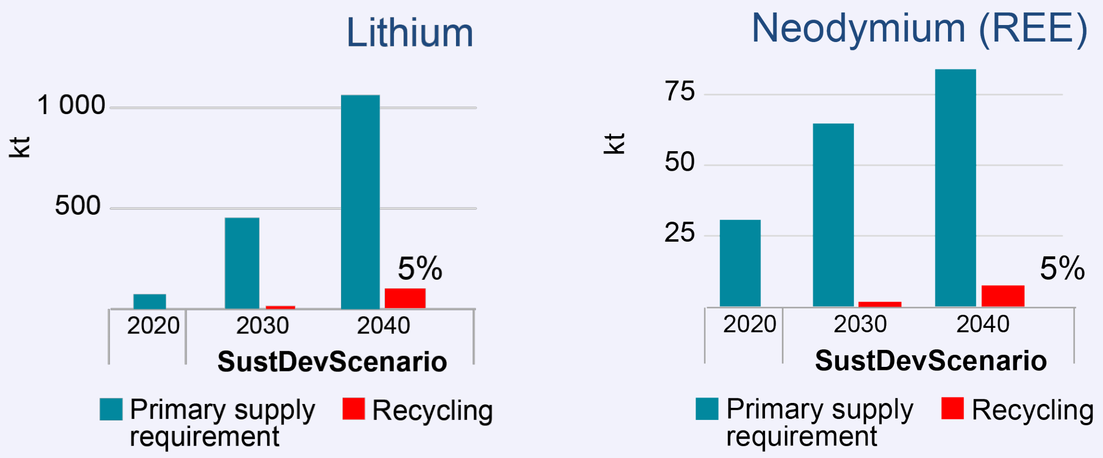
data: IEA report “The role of critical minerals in clean energy transition” (2021)

Metal demand for green technologies is not met by recycling

Future demand for metals is triggered by green technologies



Recycling forecast



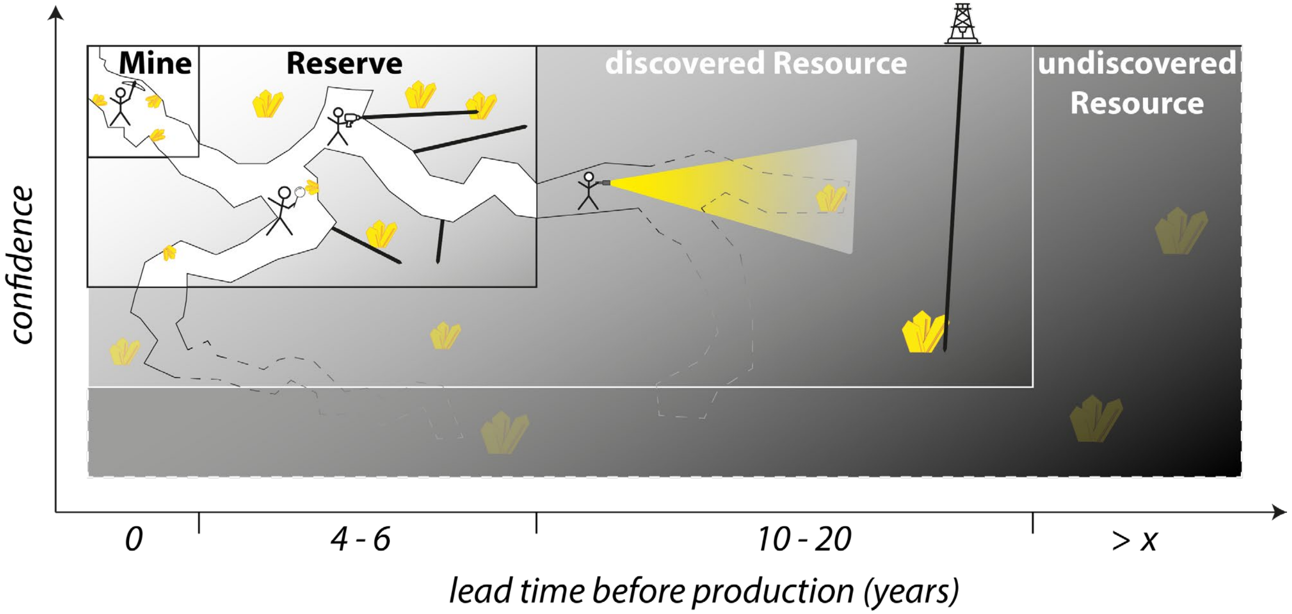
- Metals will still be in use
- Complex recycling at low recycling rates

→ **Need for primary resources i.e. mining**

How do we calculate how much is available?

Economic geology 101:

There are enough metals on earth but at what costs can they be mined.



Resources: a concentration of naturally occurring raw material in such form that economic extraction of a commodity may be possible now or at some future time.

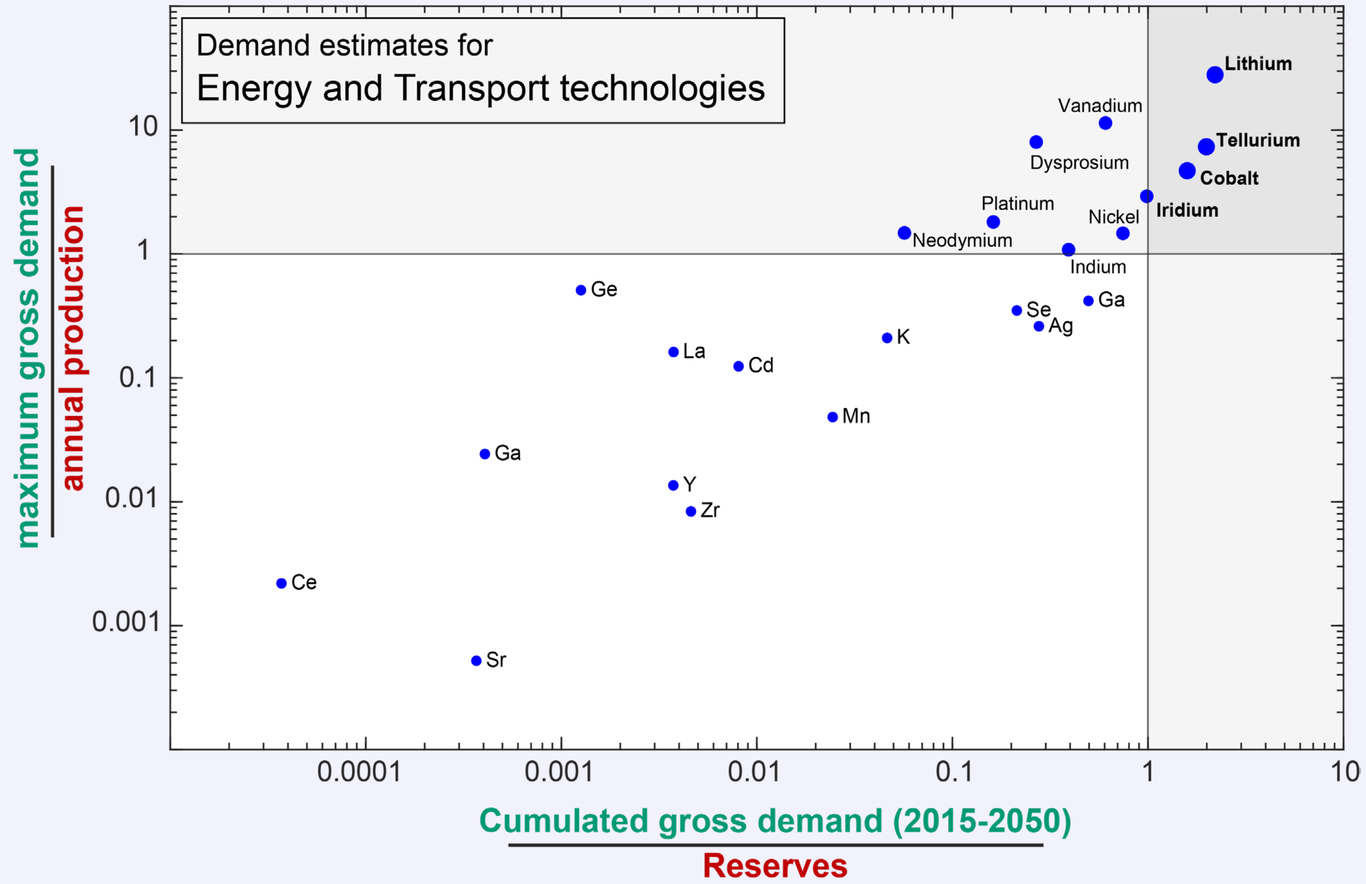
Reserves: the economically mineable part of resources that incorporate assessment of “modifying factors” such as material dilution and losses during extraction, available mining, processing, and metallurgical technology, and infrastructure, economic, marketing, legal, environmental, social and governmental factors.

Mine production:
Grade: average concentration of the element
Tonnage: tonnes of mineralised material in the deposit (above the “cut-off”)
Calculate the metal produced per year in Mtonnes

Demand Scenarios predict bottlenecks

- **Demand scenarios show that there is a significant risk of bottlenecks for supply of most metals in near future!**

after Schlichenmaier and Naegler, 2022 / DLR



Demand Scenarios predict bottlenecks

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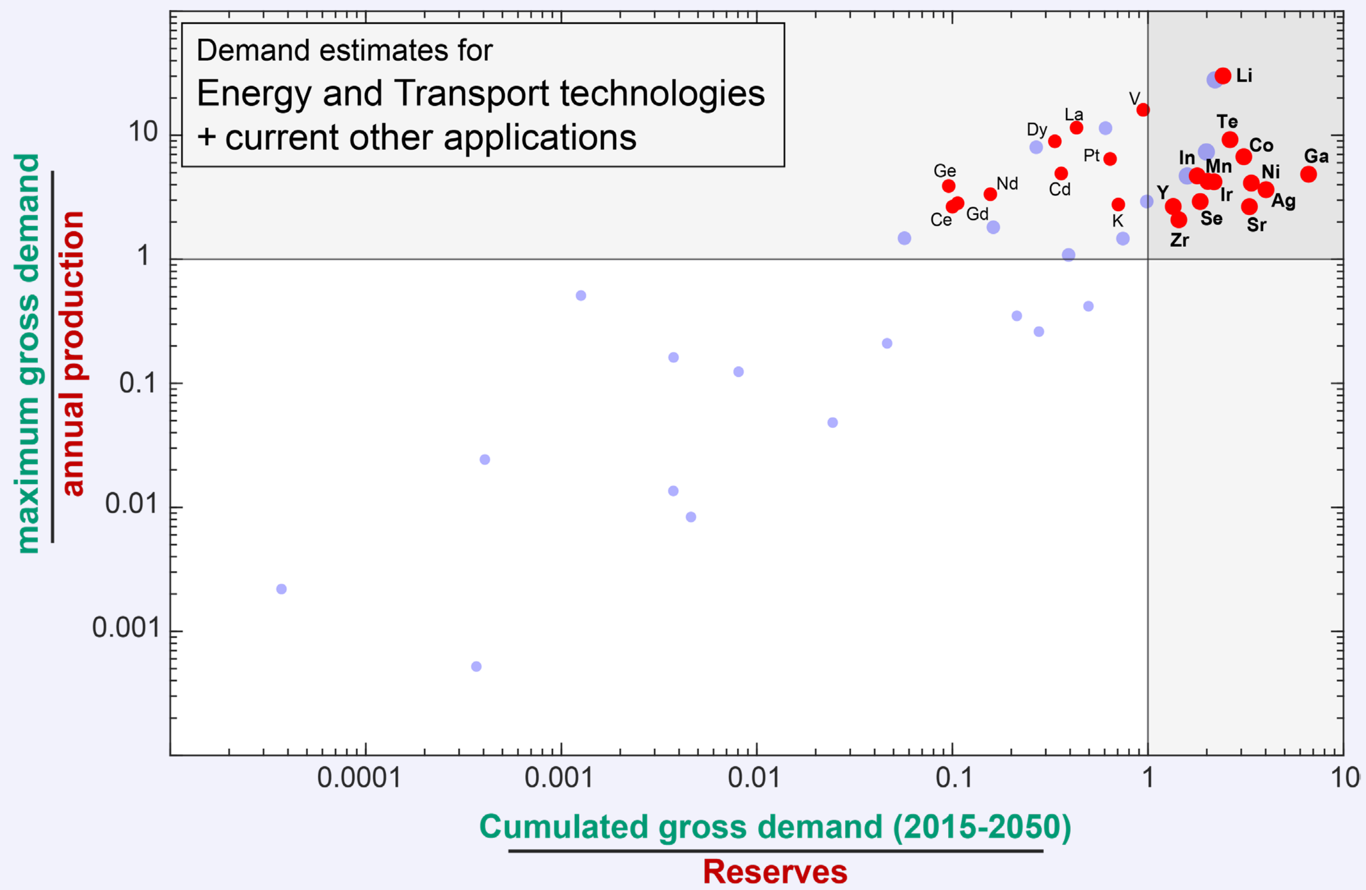
How to resolve the problem?

- **Reduce the demand?**
  → Increase efficiency (i.e., energy, material), life time and use of alternatives (e.g., public transport)
  → **Technology and material substitutions**

- Increase recycling (on the long term)

- **Increase mining production, reserves?**
  → **Find new deposits. Increase production/mining, but at what cost?**
  → **Develop unconventional resources of metals**

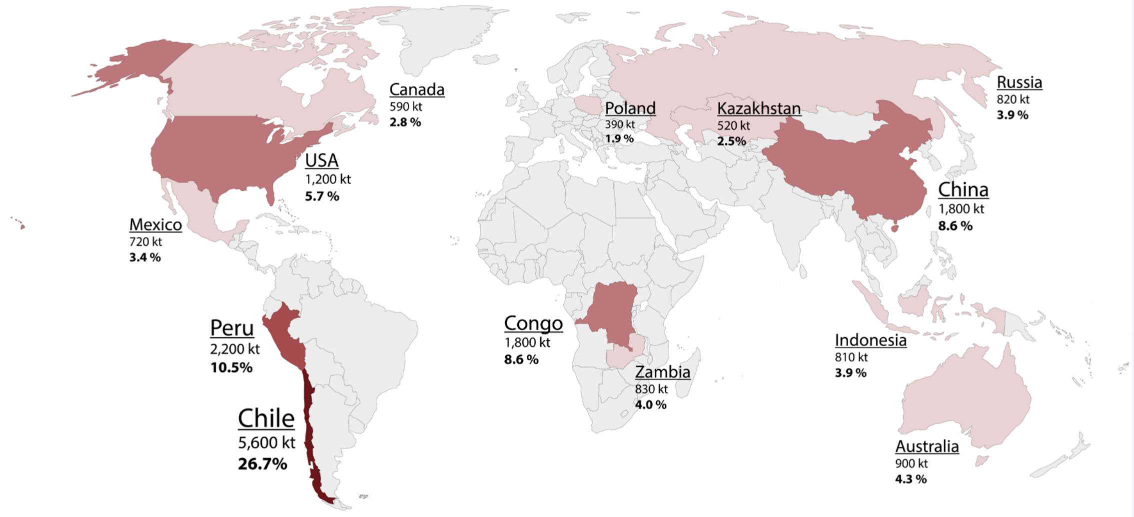
after Schlichenmaier and Naegler, 2022 / DLR



Where do our metals come?

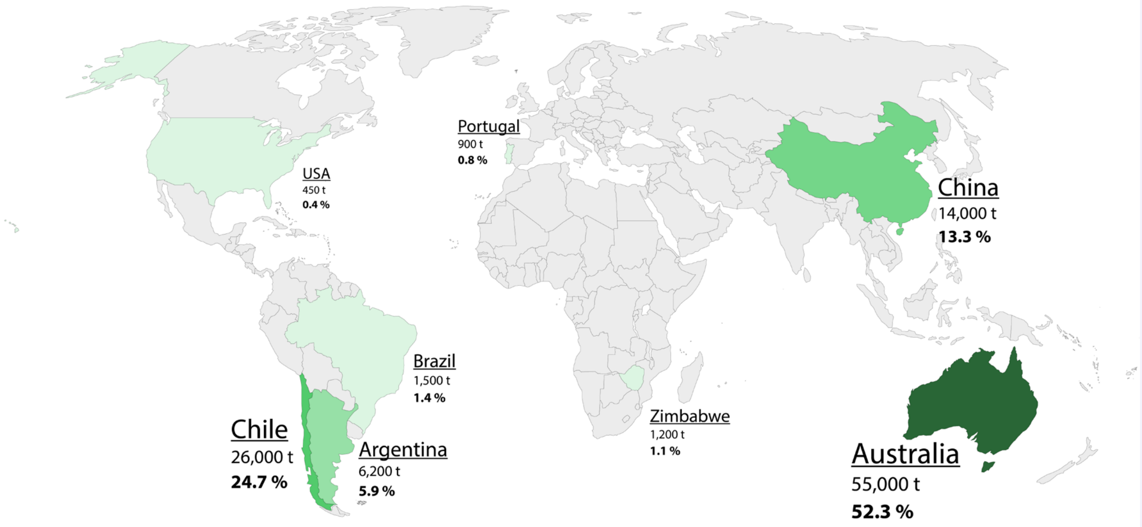
Copper sourced mainly from "Porphyry" deposits in South America

Copper (world mine production in 2022)



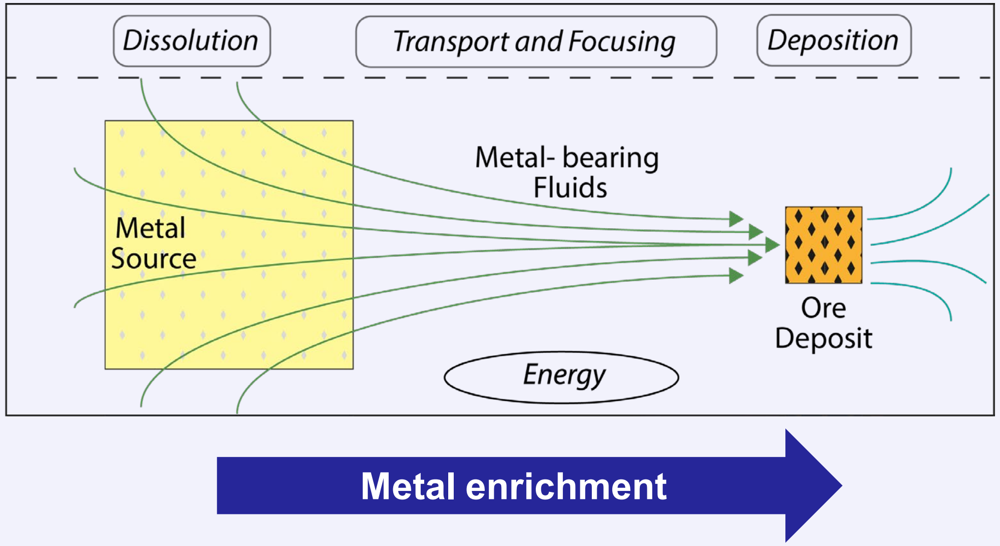
Current mining for Lithium concentrated in South America, China and Australia

Lithium (world mine production in 2021)



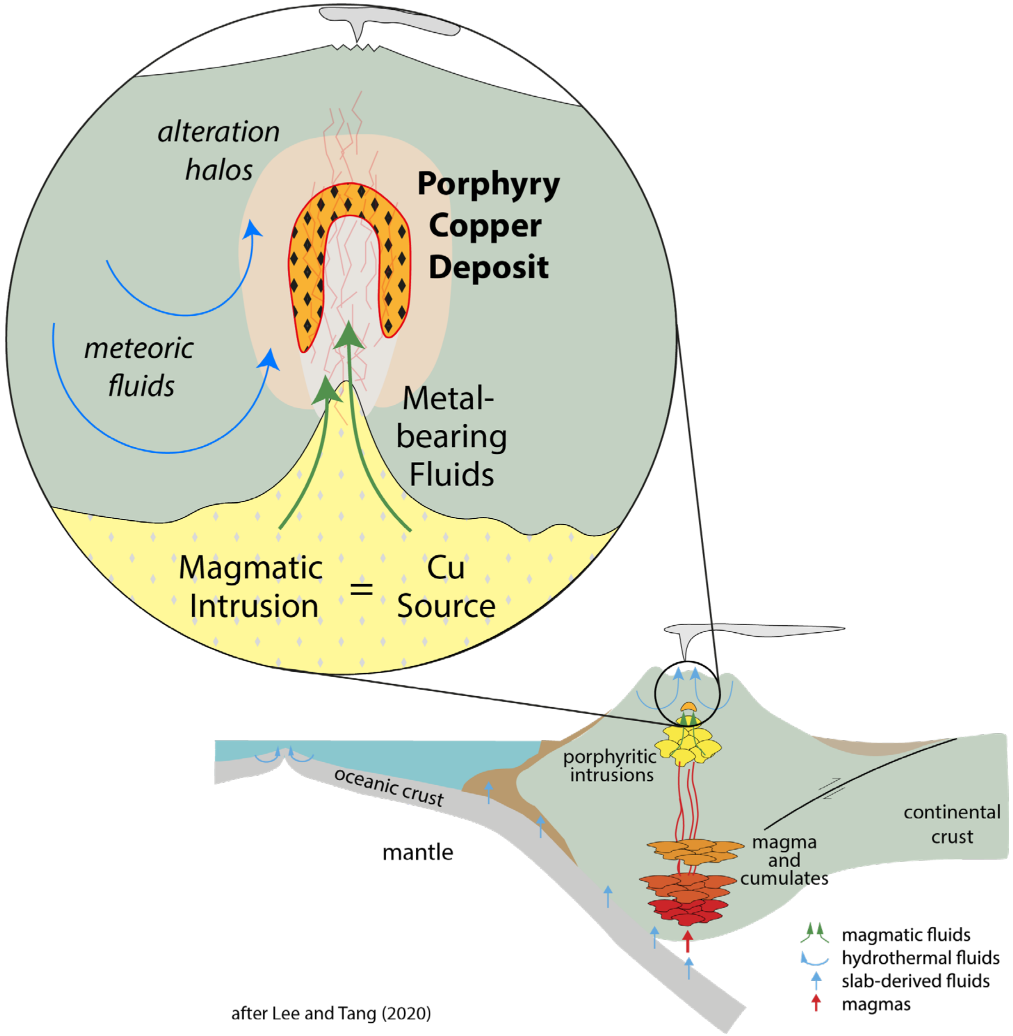
data: bgr.de

How do deposits form and how to find them?



- Metal source
- Fluids or magmas to carry metals
- Heat (e.g. magmatism)
- Geological structures to focus flow (stratigraphic layers, faults)
- Trap site
- All controlled by Geodynamics (plate tectonics)

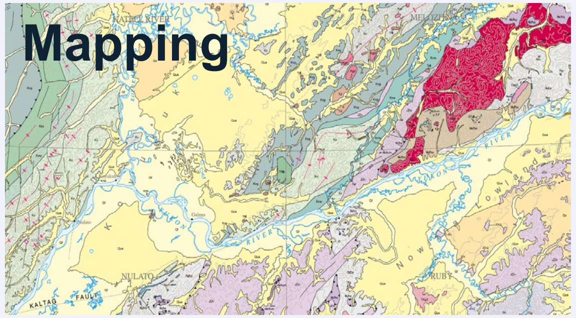
Complex interactions which only occur very rarely certain times and places in Earth's history



after Lee and Tang (2020)

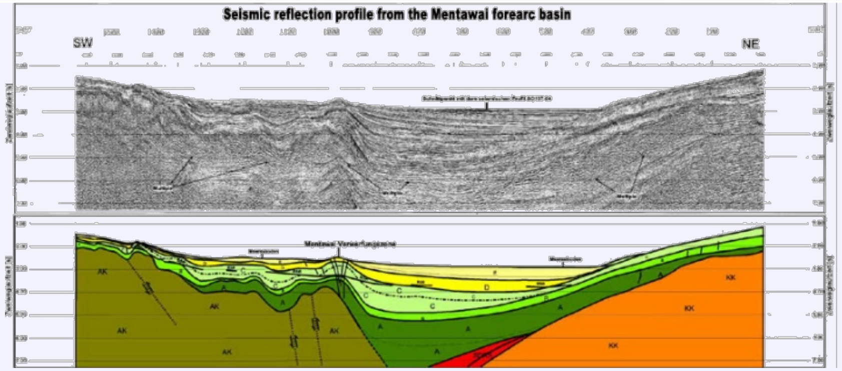
Exploration below the surface becoming more important

Field work

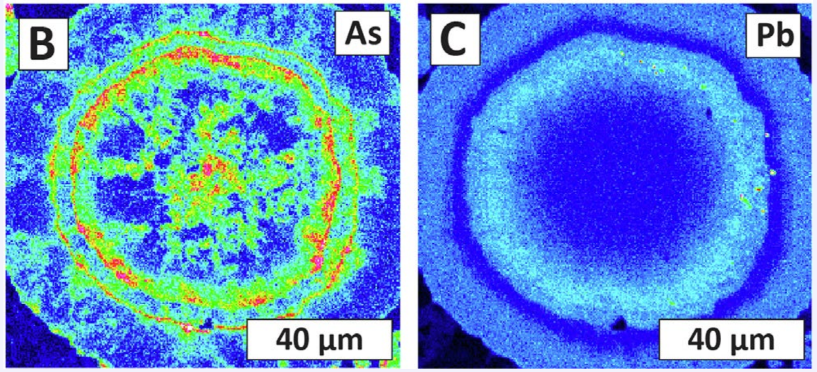


Advanced tools

Geophysical
(to image the subsurface)

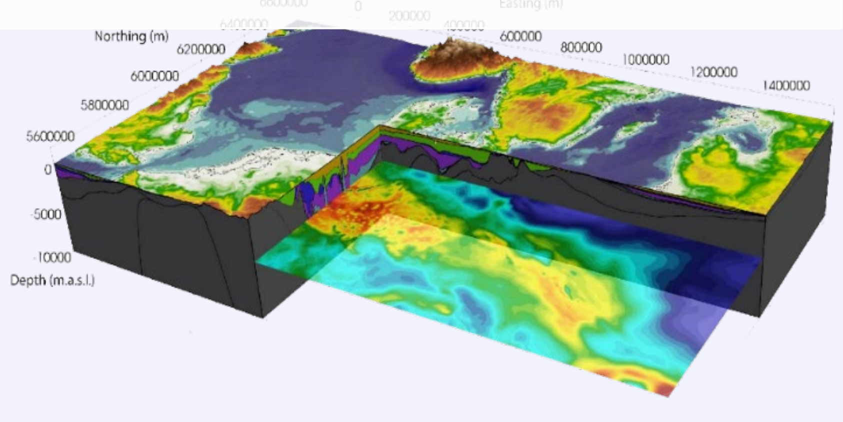


Geochemical
(to analyse the composition)

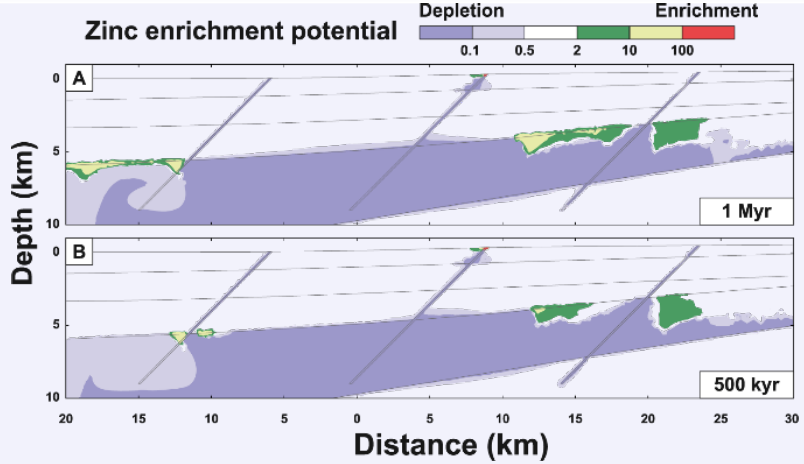


Models

Geodynamic (100 km scale)



Deposit formation (local scale)



Environment, social and governance is now a major project risk

Copper sourced mainly from "Porphyry" deposits in South America

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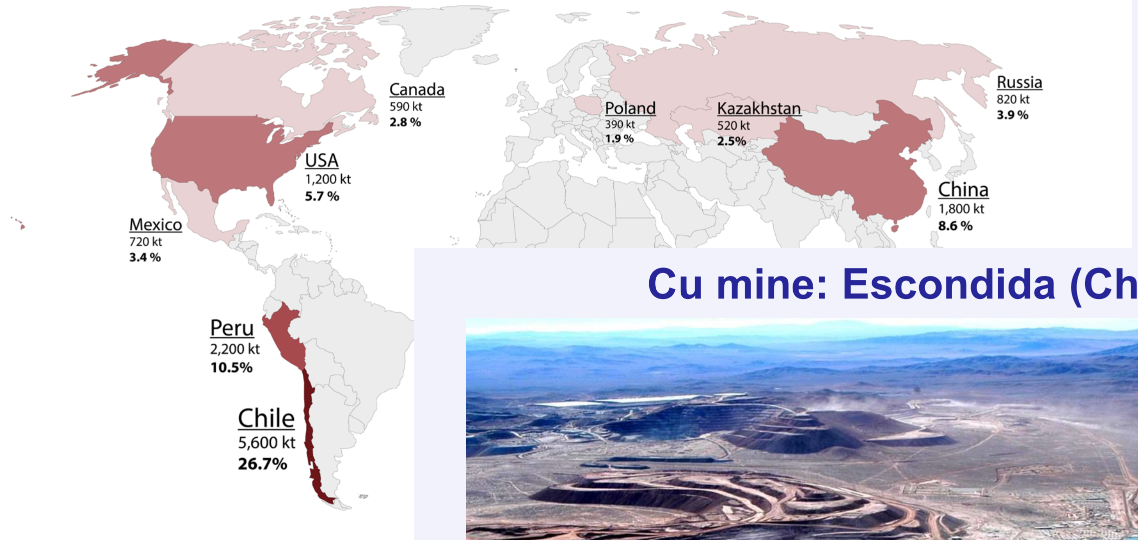

Cu mine: Escondida (Chile)

- Cu mining causes stress on water, loss of biodiversity and land resources

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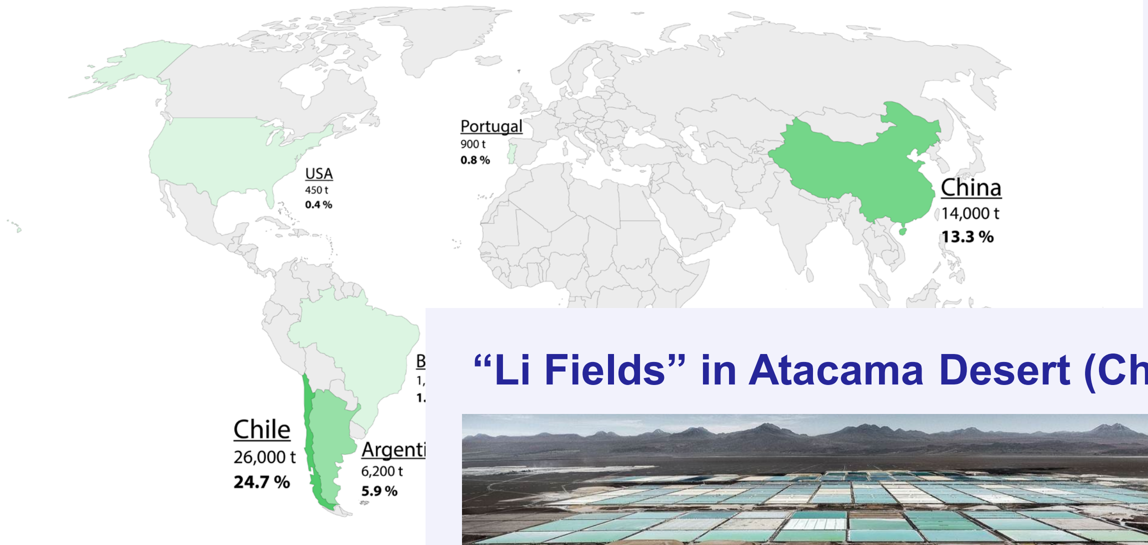
Lithium (world mine production in 2021)



"Li Fields" in Atacama Desert (Chile)

- about 2/3 of German Li is imported from Chile

Putting environmental impacts into life cycle assessments

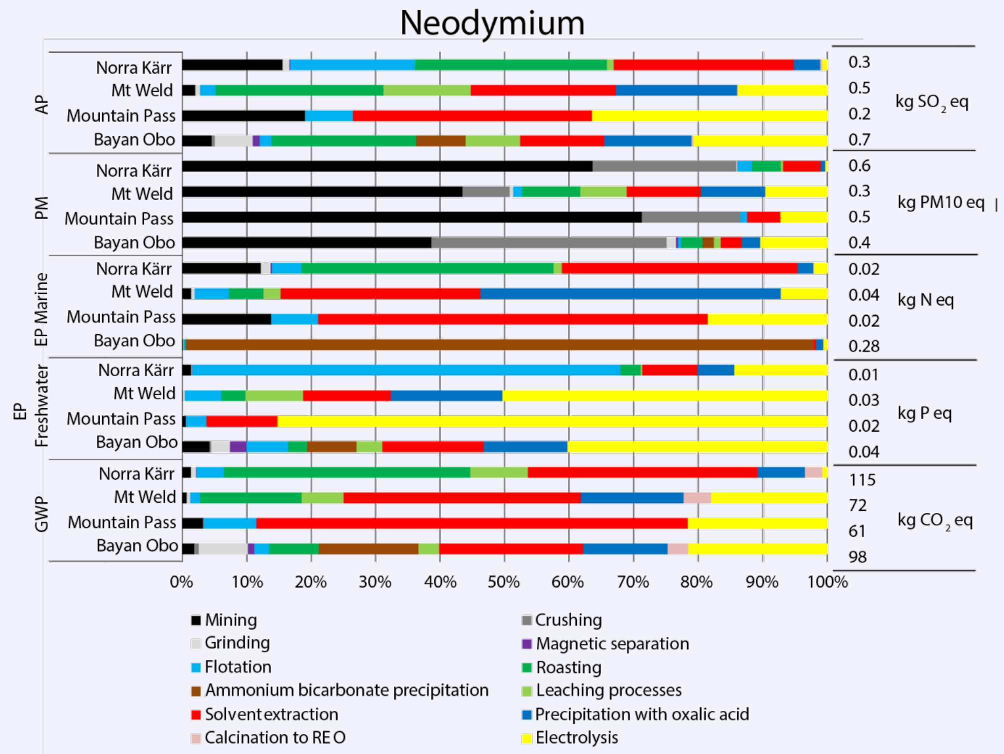
Category / Process	Global warming potential (GWP)	Acidification (AP)	Eutrophication (EP)	Toxicities to Ecosystems and Humans (ETP, HTP)	Particulate matter (PM)

- Mining
- Benefication
- Cracking
- Leaching
- Separation
- Precipitation
- Calcination
- Refining
- Metal product

after Zapp et al., 2022 / FZJ

- Each process has an environmental impact depending on e.g.:
  - Methods and technology
  - Recycling of chemicals
  - Waste and emission treatment
  - Source of energy
  - Mineralogical factors (e.g. radioactive contaminants, ore grade, gangue minerals)
- Some can be minimized, some not.

Example: REE production from different deposits

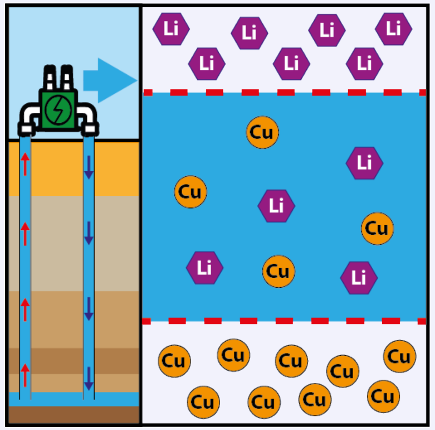


Zapp et al., 2022 / FZJ

Need to develop unconventional resources

Metals from geothermal fluids!

- Fluids in Earths crust can contain large quantities of metals
- Potential for local supply with Li (± other metals)
- Currently at demonstrator stage




SPIEGEL Wirtschaft

Rohstoffstudie

Deutschland könnte jahrzehntelang Lithium fördern

Lithium ist ein Rohstoff der Zukunft, unentbehrlich für E-Autos und Solaranlagen. Karlsruher Forscher sind jetzt sicher, dass in Deutschland erhebliche Mengen relativ einfach erschließen sind.

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Handelsblatt

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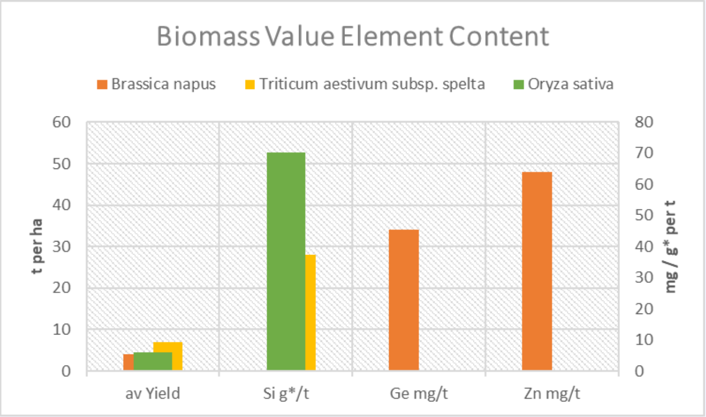
BATTERIEROHSTOFF

Vulcan Energy nimmt Lithium-Demonstrationsanlage in Betrieb

Das Start-up will demnächst 40 Tonnen des begehrten Rohstoffs pro Jahr produzieren. Bis zur kommerziellen Förderung braucht Vulcan aber noch Jahre – und viel Kapital.

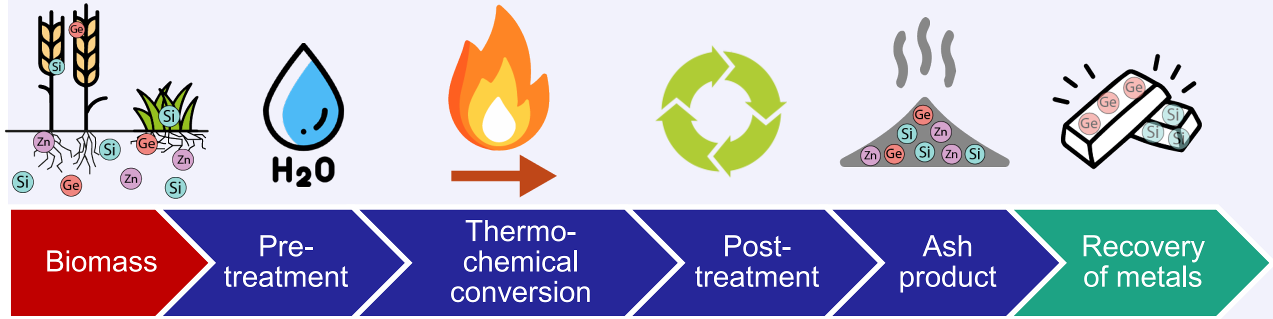
CRM geothermal

Raw material recovery from biomass resources



- Plants can accumulate metals and become a potential future resource

Process chain of value element recovery



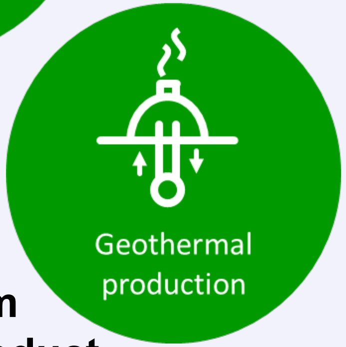
after Formann & Schliermann (2023) EERA Bioenergy 19:12 / DBFZ

Technology and material substitutions

Lithium is one bottleneck (beside Co, Ni, Cu, C, …) … but alternatives in sight!

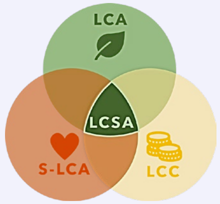
Alternative provision of lithium

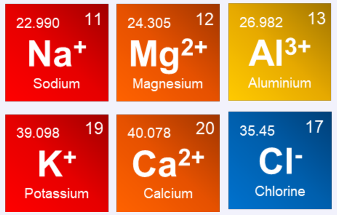
High efficient recycling

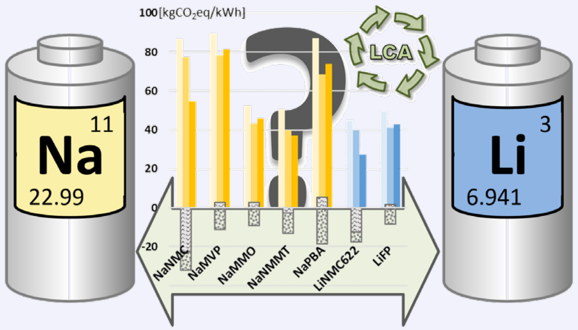


Lithium as a by-product

Development and investigation of alternative chemistries







Sustainability assessment of different batteries

Sodium batteries are most promising and close to industrial application (in Asia)

FARADION
中科海钠 HiNa BATTERY
TIAMAT
NGK INSULATORS, LTD.
CATL

In which sectors Na batteries can replace Li batteries in the near future?

itas

HIU HELMHOLTZ INSTITUTE ULM
Electrochemical Energy Storage

POLiS
Post Lithium Storage Cluster of Excellence

Baumann & Weil et al. (2022) Advanced energy materials, 12 (46) / KIT

Peters, Baumann, Binder, Weil (2022) Sustainable energy & fuels, 6 (2) / KIT

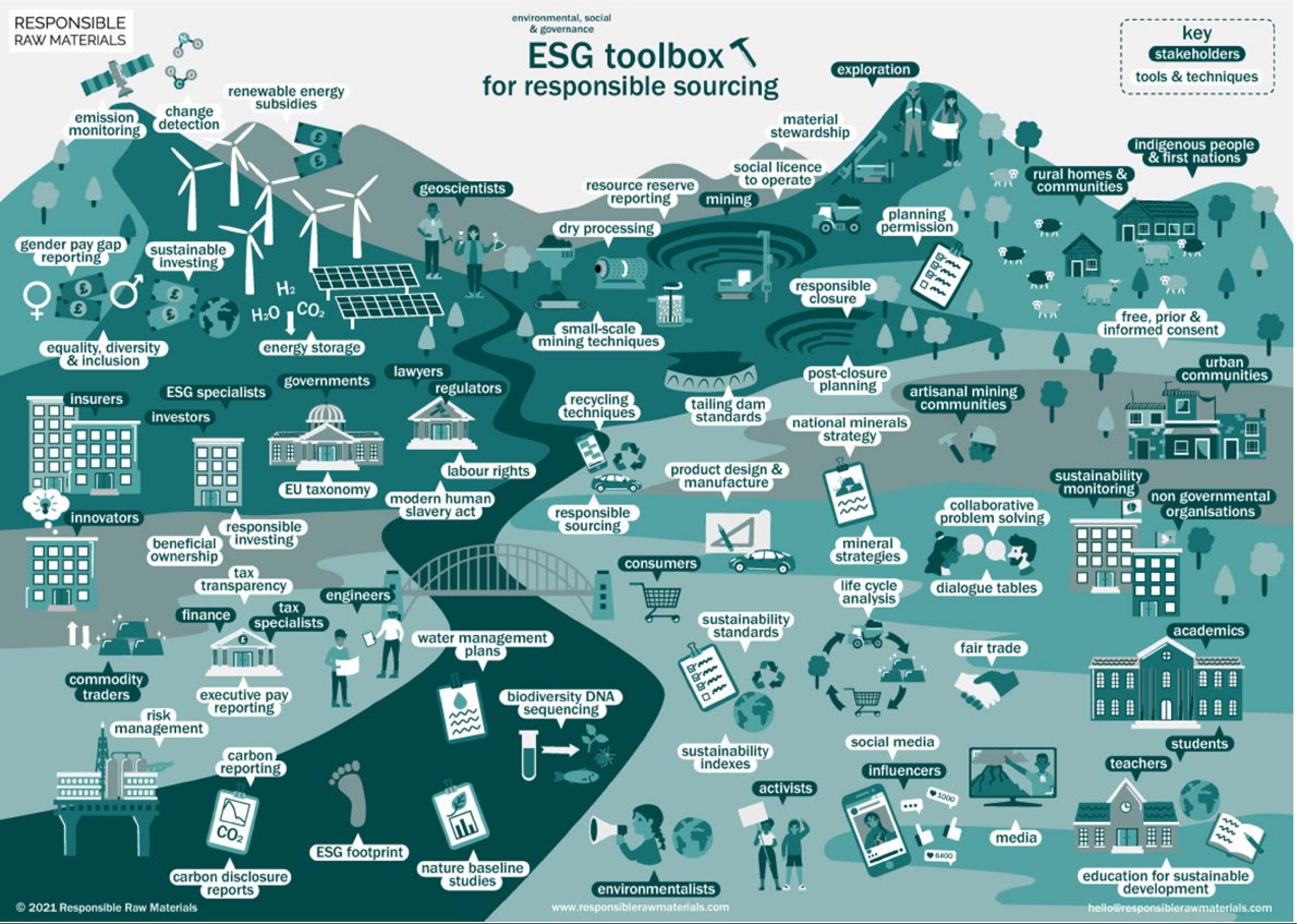
Is the supply of Critical Raw Materials a barrier for the Energy Transition?

No

- In theory, there is enough metal on earth (discounting geopolitics, environmental, social governance issues)
- Alternative resources and technologies, substitutions in development stage but we need these NOW.

Yes

- Green technologies require massive amounts of metals.
  - Demand will exceed current and projected mine production
  - Finding and developing new mines is challenging and takes decades
  - Recycling rates (must be improved) but are not sufficient and will only mitigate bottlenecks in the long run
- Significant geopolitical/supply chain risks in terms of single country dependencies for mining AND mineral processing
- Environmental, social and governance issues are a significant risk to increasing production



www.responsiblerawmaterials.com

Mining and production

is embedded in a large network of stakeholders