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# Need for critical mineral substitution and recycling in clean energy transition and to meet the 1.5 °C target

Tiina Koljonen & Antti Lehtilä

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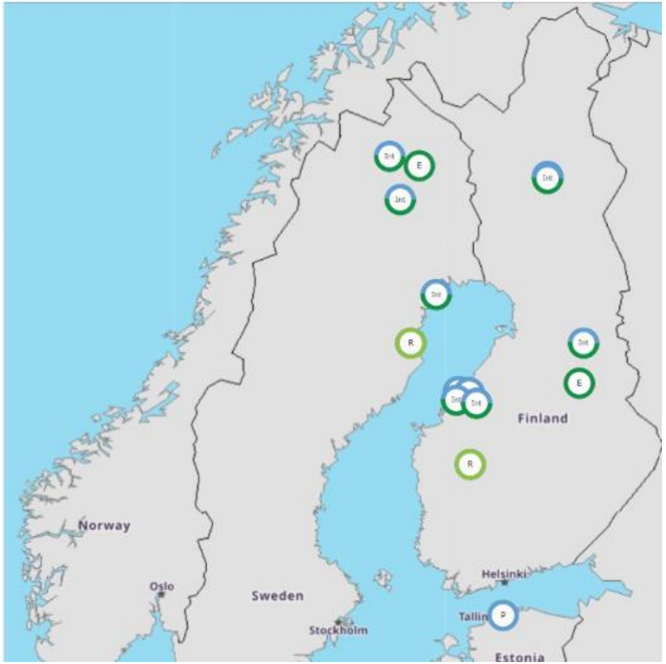
# Background and scope of the presentation

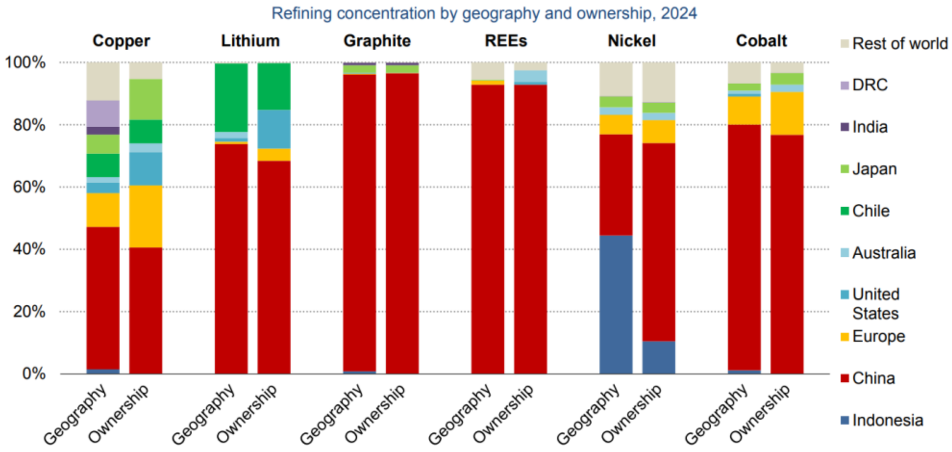
- At VTT, we are developing new energy and industrial technologies and process concepts, including sustainable material design, industrial circular economy, digitalisation, etc.
- In Finland, strategic several strategic projects under EU's Critical Raw Material Act.
- Scenario modelling with TIMES-VTT on global demands of selected metals and minerals started already ten years ago.
- Recently, demands of selected metals in energy related technologies were updated based on literature and new 1.5 C mitigation scenarios.

EU's strategic projects under CRMA

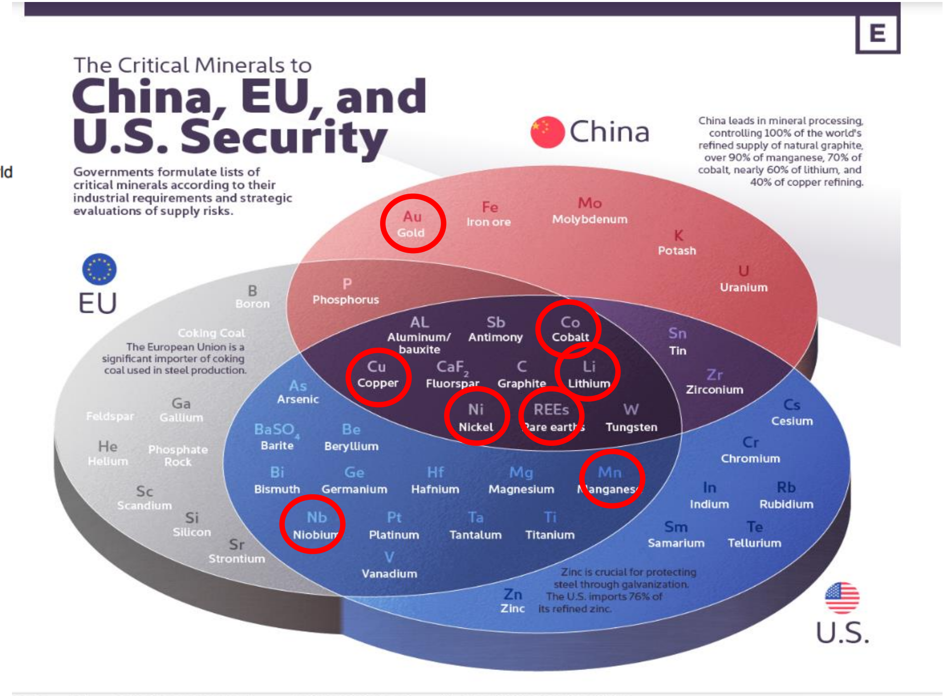



Source: [Selected projects - European Commission]

# Clean energy transition challenged by sustainable supply of several metals




Source: IEA 2025




Source: USGS 2022

# Integrated assessments with closer look at the demands of metals and minerals in clean energy transition since 2014

Renewable Energy 95 (2016) 53–62

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Role of critical metals in the future markets of clean energy technologies

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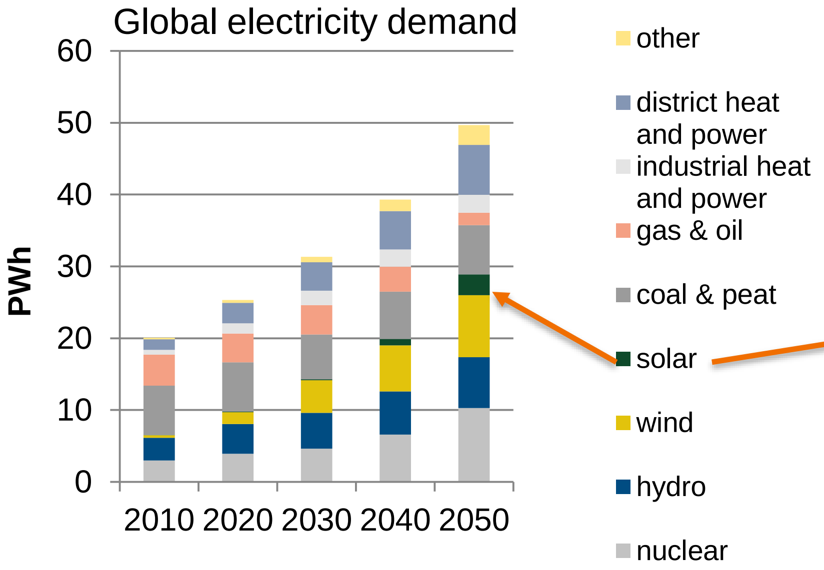
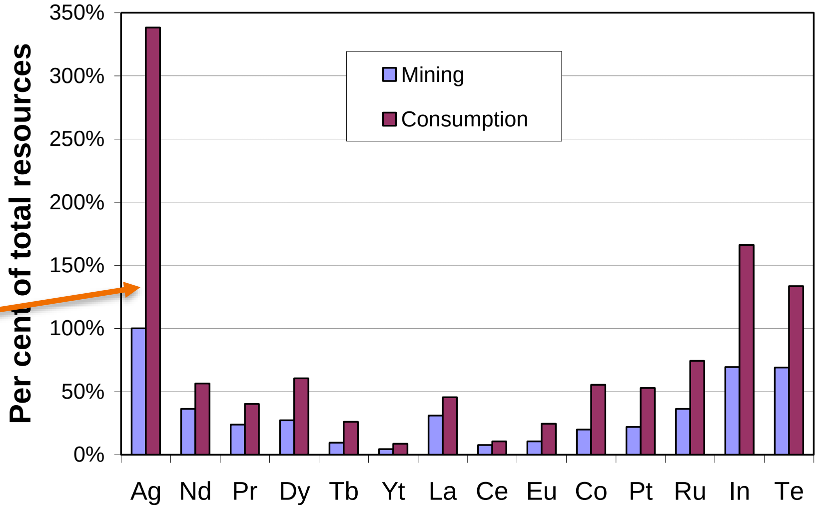
https://www.sciencedirect.com/science/article/abs/pii/S0960148116302816

# Deriving resource sufficiency indicators:

## Example early analysis with the TIMES-VTT model: Cumulative use of "critical" metals 2000-2060 under a low-carbon scenario.

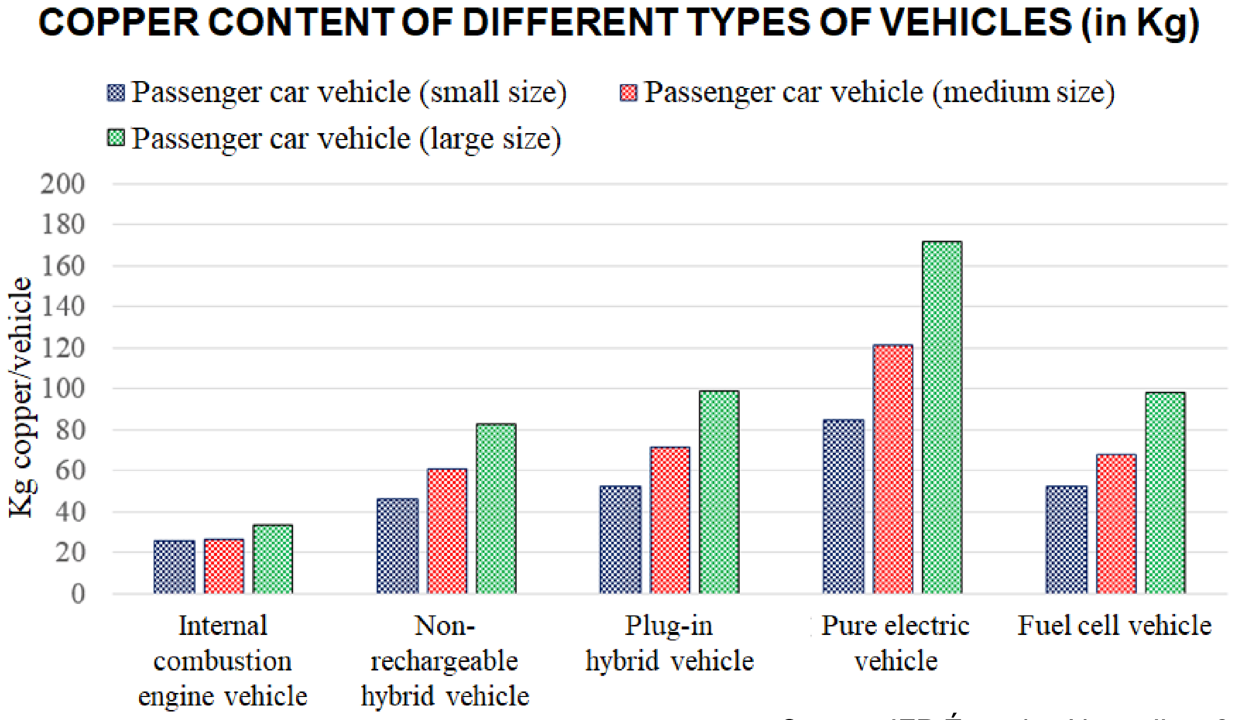



Grandell et al. Renewable energy 95 (2016) 53-62.

# Case study: Electrification of global passenger car fleet by 2050 - Focus on demands and supply of selected metals, e.g. Cu, Co, Nd and Li

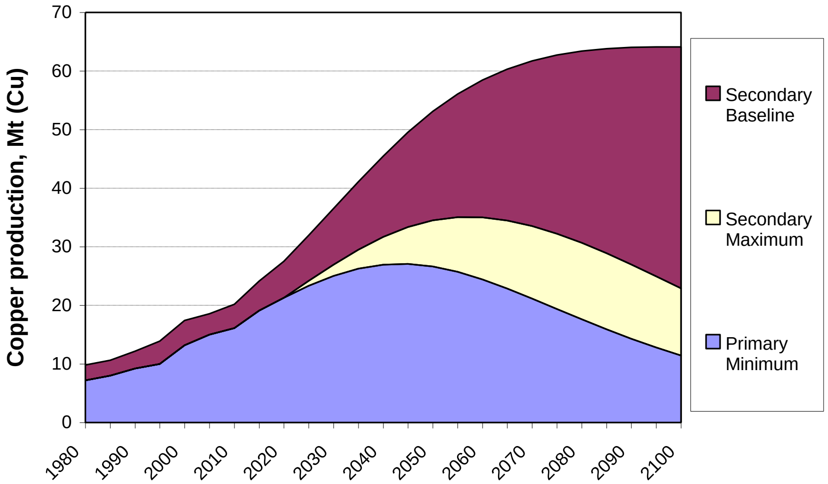
# Long term Cu demand projected to be significantly affected by electrification

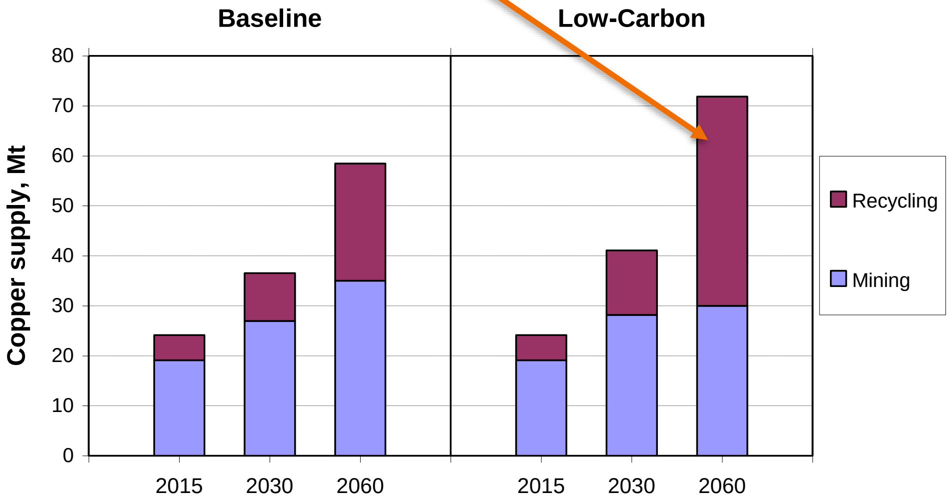



Source: IFP Énergies Nouvelles, 2021

# Long term Cu demand and supply projections – after 2050 most of Cu supply should be secondary

## Scenario projections with TIMES-VTT model

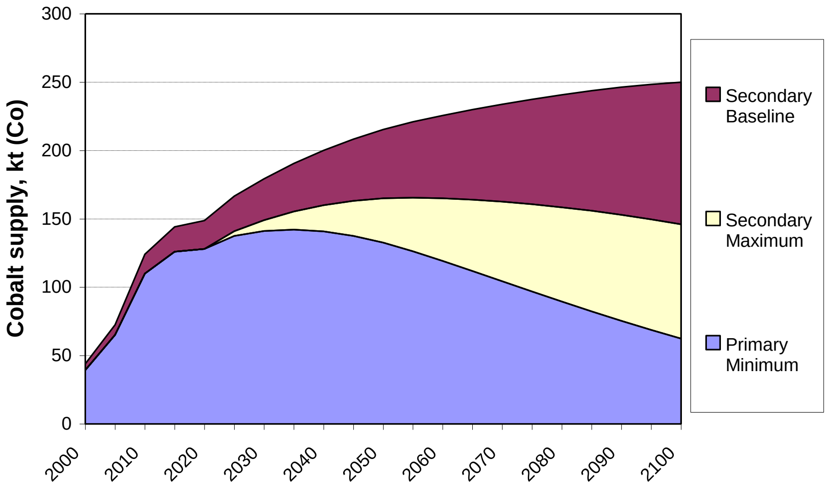


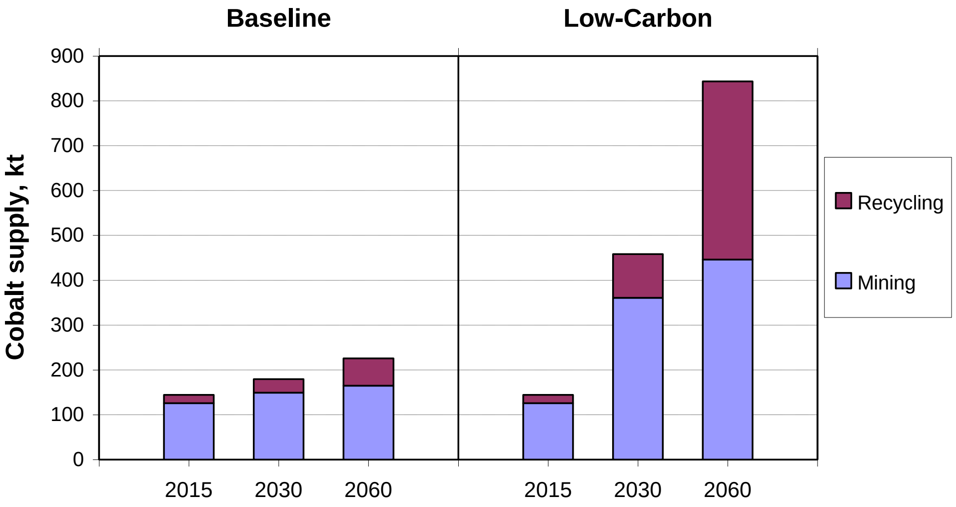



# Long term Cobalt demand and supply projections

## Increased penetration of electric vehicles and electricity storages dramatically increases Co demand

### Scenario projections with TIMES-VTT model



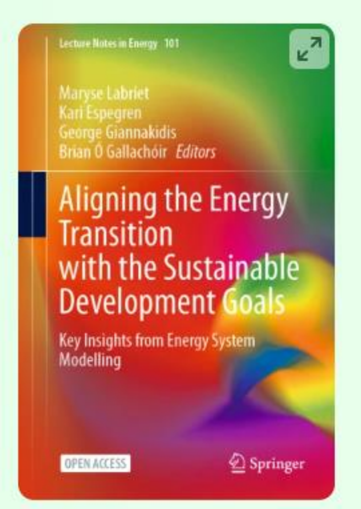



# Case study: The impact of negative emissions technologies and practices on demands of selected metals

**Modelling of Demands of Selected Minerals and Metals in Clean Energy Transition with 1.5–2.0 °C Mitigation Targets**

Check for updates

Tiina Koljonen, Antti Lehtilä, Kirsikka Kiviranta, Kati Koponen, and Lassi Similä




NEGEM

Ref. Ares(2022)4794626 - 30/06/2022

Quantifying and Deploying Responsible Negative Emissions in Climate Resilient Pathways

Report on assessment of impacts on key non-renewable resource chains: case study on global demand, supply and trade-offs for selected metals and minerals in global mitigation pathways

Horizon 2020, Grant Agreement no. 869192

# Specific metal demands of selected technologies were updated in our assessments based on literature

| Technology | References |
| --- | --- |
| Wind power | Carrara et al. (2020), IEA (2021a) |
| Solar photovoltaics (PV) | Carrara et al. (2020), IEA (2021a) |
| Concentrated solar power (CSP) | Watari et al. (2019) |
| Geothermal | Moss et al. (2011) |
| Hydropower | Ashby (2013) |
| Biomass-based combustion and biofuels | Ashby (2013), Moss et al. (2011) |
| Solid and gaseous fossil fuel combustion | Ashby (2013), Moss et al. (2013) |
| Nuclear power | Moss et al. (2011) |
| Bioenergy with carbon capture and storage (BECCS) | Moss et al. (2011) data on fossil-based combustion with CCS |
| EV batteries | Assumptions based on Volkswagen (2021) |
| EV motors | Assumptions based on IEA (2021a) and Månberger and Stenqvist (2018) |
| Electrolysers | IEA (2021a) |

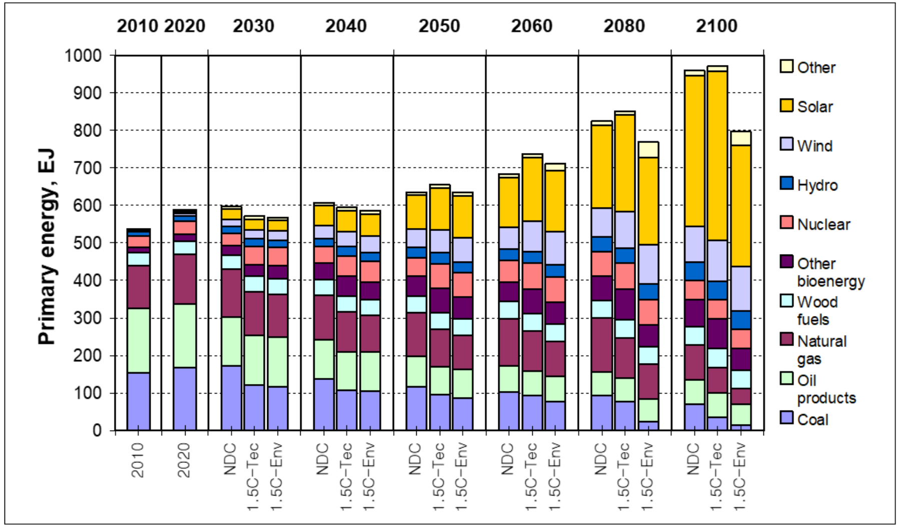
# Characteristics of the metals selected for TIMES-VTT modelling and net EoL and recycling rates

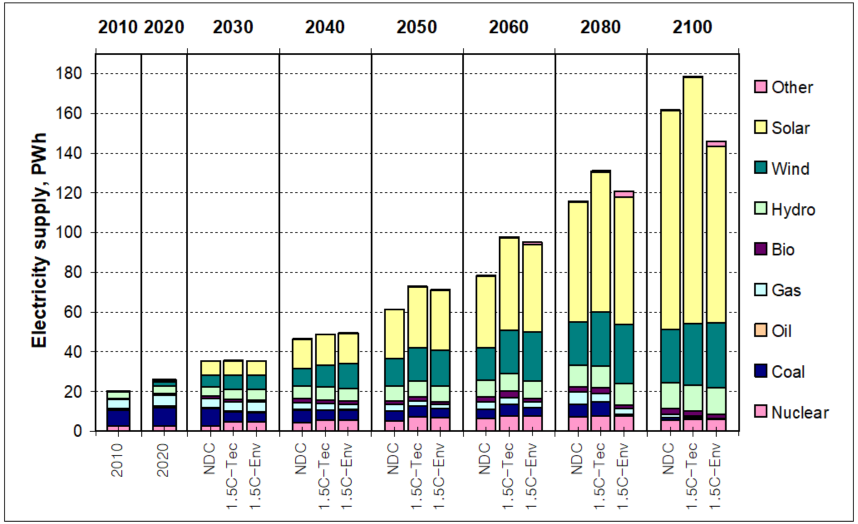
Very large uncertainty

| Metal[a] | | Unit[b] | Reserves | Identified resources | Largest Reserves | Current extraction | R/E Years | Current demand[c] | EoL recycling, net 2020 (%) | 2050 (%) | 2100 (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Silver | Ag | kt | 550 | 750 | Peru, AUS, POL | 25 | 30 | 33 | 52 | 63 | 80 |
| Cobalt | Co | Mt | 8.3 | 25 | DRC, AUS, Indonesia | 0.19 | 132 | 0.20 | 35 | 52 | 80 |
| Copper | Cu | Mt | 890 | 2100 | Chile, AUS, Peru | 21 | 100 | 30 | 45 | 62 | 80 |
| Dysprosium | Dy | kt | .. | 1600 | China, Vietnam, Russia | 2 | 800 | 2 | 7 | 18 | 50 |
| Lithium | Li | Mt | 26 | 98 | Chile, AUS, Arg. | 0.13 | 750 | 0.13 | 6 | 15 | 43 |
| Manganese | Mn | Mt | 1700 | 17,000 | S-Africa, Brazil, AUS | 20 | 850 | 21 | 23 | 41 | 75 |
| Neodymium | Nd | kt | .. | 29,000 | China, Vietnam, Russia | 30 | 960 | 33 | 8 | 20 | 50 |
| Nickel | Mi | Mt | 100 | 300 | Indonesia, AUS, Brazil | 3 | 100 | 4 | 62 | 71 | 85 |

[a]Main data source for reserves, resources and demands: USGS (2022), Liu et al. (2023)
[b]Applies to all the columns except R/E (Resources per extraction). R/E indicates the number of years the resources can cover the consumption based on the resources and the current consumption numbers of the commodity
[c]Current demand includes total global consumption for all the end use sectors

# Energy technology demands of selected metals were modelled in three mitigation scenarios



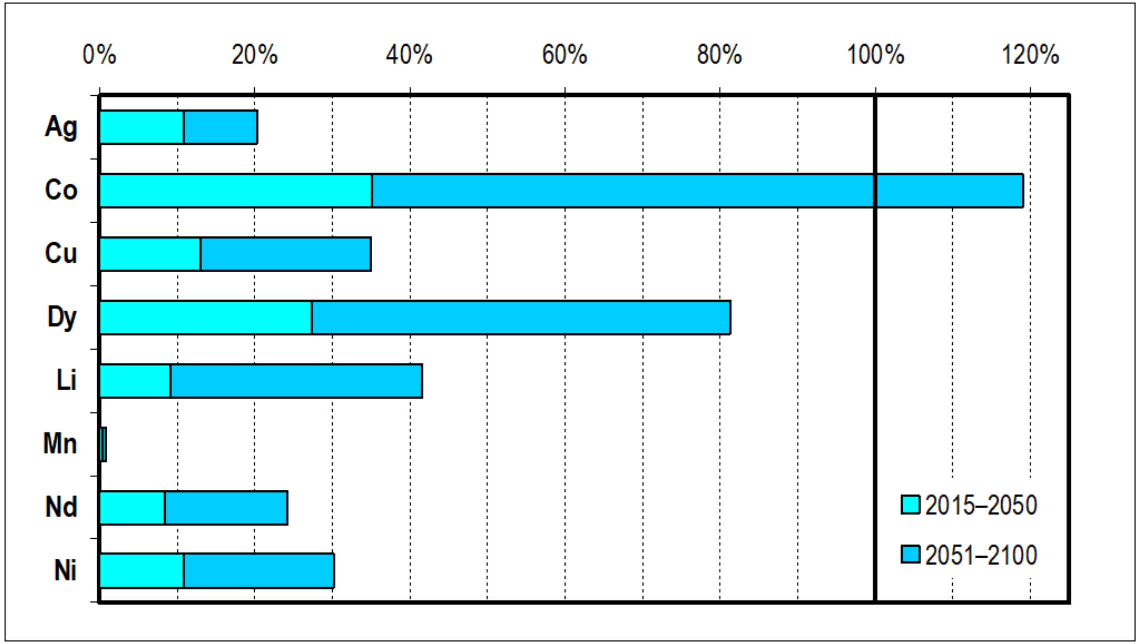
# Summary of the modelled cumulative net demand for primary production of metals

| Metal | Unit | Identified Resources | Modelled cumulative primary metal use by 2100 | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | NDC | % | 1.5C-Tec | % | 1.5C-Env | % |
| Ag | kt | 750 | 130 | 17% | 150 | 20% | 120 | 16% |
| Co | kt | 25000 | 18600 | 74% | 29740 | 119% | 29910 | 120% |
| Cu | Mt | 2100 | 640 | 30% | 720 | 34% | 650 | 31% |
| Dy | kt | 1500 | 930 | 58% | 1290 | 81% | 1310 | 82% |
| Li | kt | 89000 | 27200 | 28% | 40660 | 41% | 40950 | 42% |
| Mn | Mt | 17000 | 100 | 1% | 130 | 1% | 130 | 1% |
| Nd | kt | 11200 | 6400 | 22% | 6910 | 24% | 7020 | 24% |
| Ni | Mt | 300 | 60 | 20% | 90 | 30% | 90 | 30% |

Note: Percentage indicates the cumulative use of metal in energy technologies compared with its identified resources.

# Estimated cumulative primary requirements of selected minerals for energy technologies*

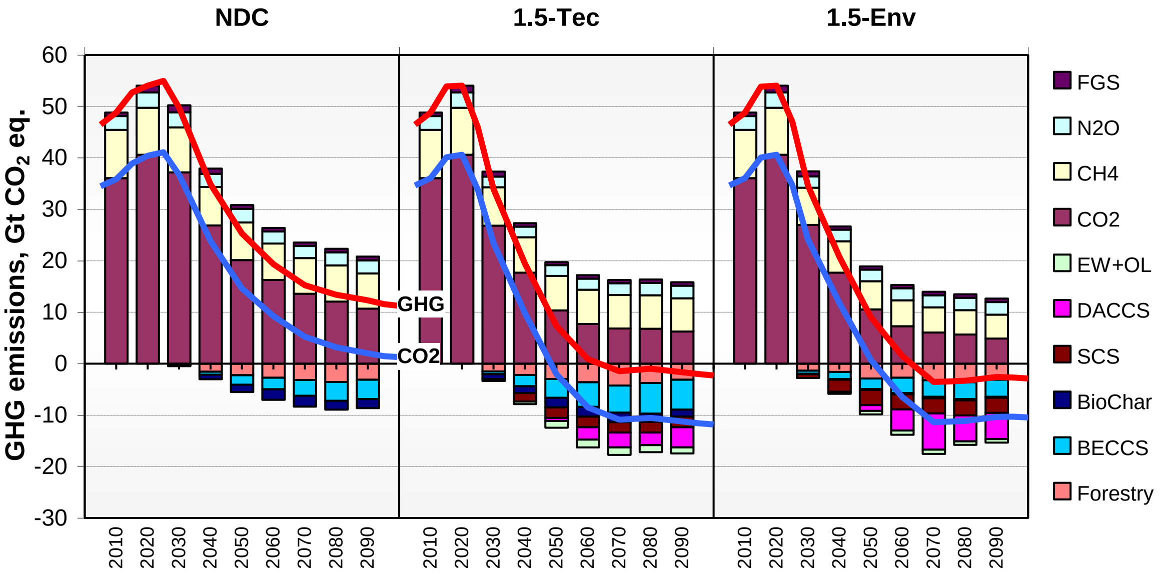
## Results are shown for the 1.5C-Tec scenario in proportion to identified total global resources




* Excluding electricity networks

# Negative emsission technologies doesn’t seem to require critical metals but there is lacking data available

- Investments in negative emission technologies constrained in 1.5Env scenario due to assumptions on more strict sustainablity criteria on land use.
- In 1.5Env scenario metal demands increased even more as even more rapid elctrification was required.



# Conclusions

Based on our scenario assessments the most critical in terms of sufficiency are cobalt (Co) and dysprosium (Dy).

Above 90% of the cumulative energy technology use of these metals in the energy sectors are used in cars, which reflects the urgency for radical changes in our mobility and transport.

Energy system modelling is a useful tool for assessing not only energy but also material demands for a clean energy transition.

We need better understanding of recycling and substitution of critical metals, analysis of future critical metal demands outside of the energy sector, and realistic analysis of new mine development.

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# beyond
## the obvious

Thank you!

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