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Center for Nuclear Engineering and Sciences
Center for Energy and Environmental Sciences

Pathways to Net Zero in Switzerland:

Critical Raw Materials and Global Environmental Impacts

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Energy Research Talks
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Introduction



*Integrated Assessment Models (IAMs) and Energy System Models (ESMs) facilitate the **exploration** of various **pathways** to **mitigate climate change** and **achieve decarbonization** goals.*

Bridge the Science/Policy interface

- Scenario Analysis: *What if?*
- What are the drivers or constraints of change?
- How do technology and policy choices lead to different outcomes?
- Uncertainties? Sensitivities?

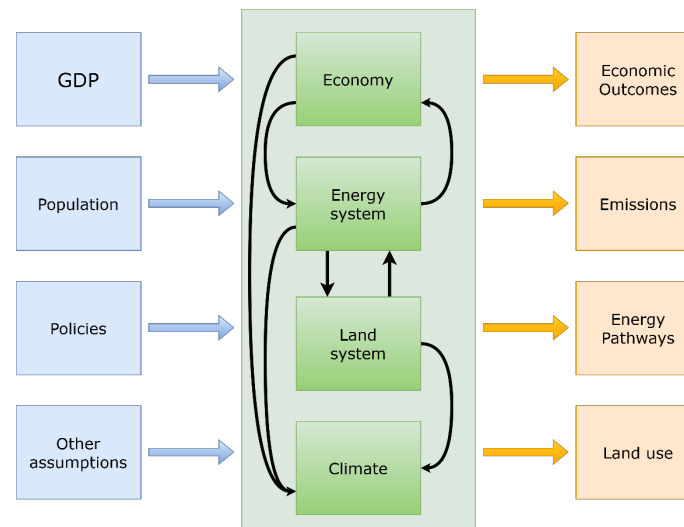
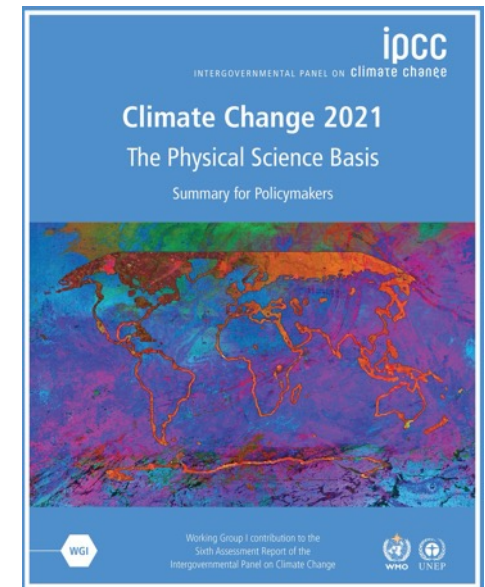
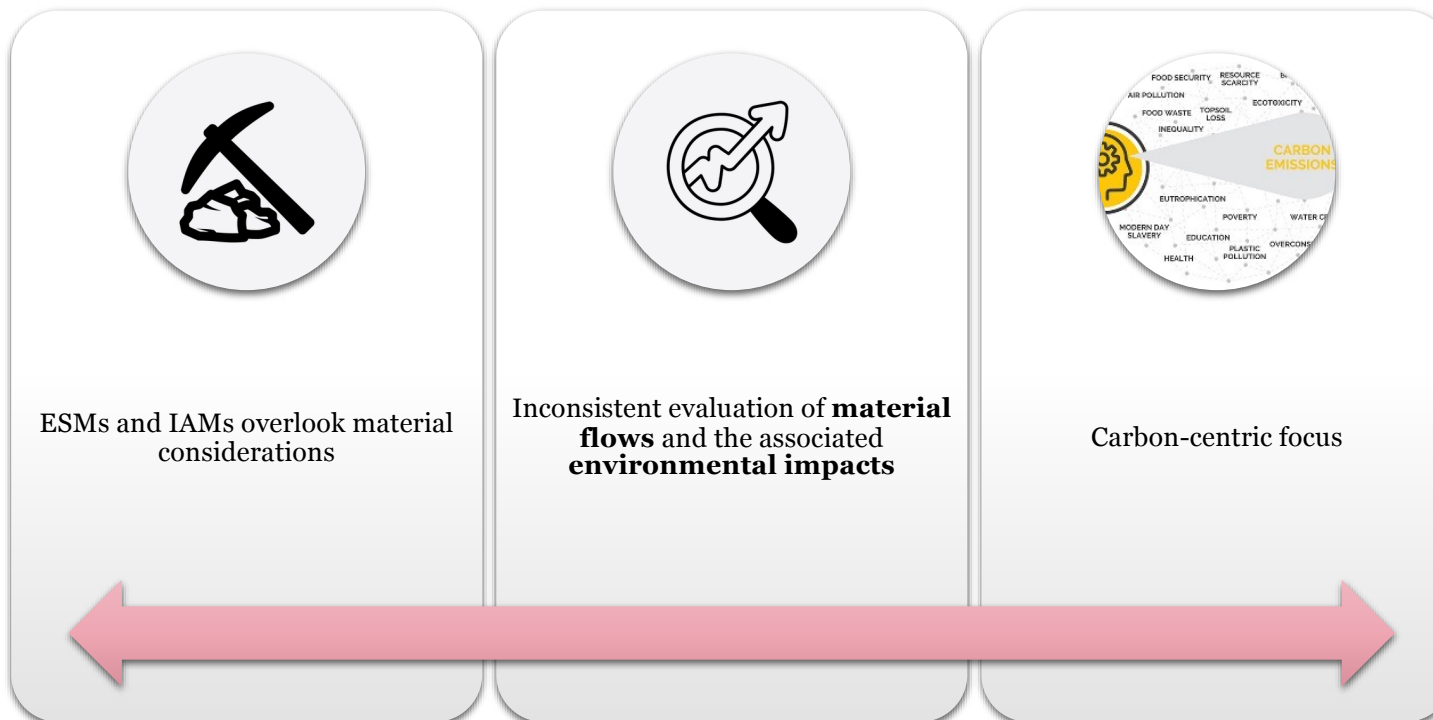


Figure adapted from carbonbrief.org



Research Gaps

How can we comprehensively assess and navigate the potential **environmental impacts** and **material demand** of **transition scenarios**?



Life Cycle Assessment

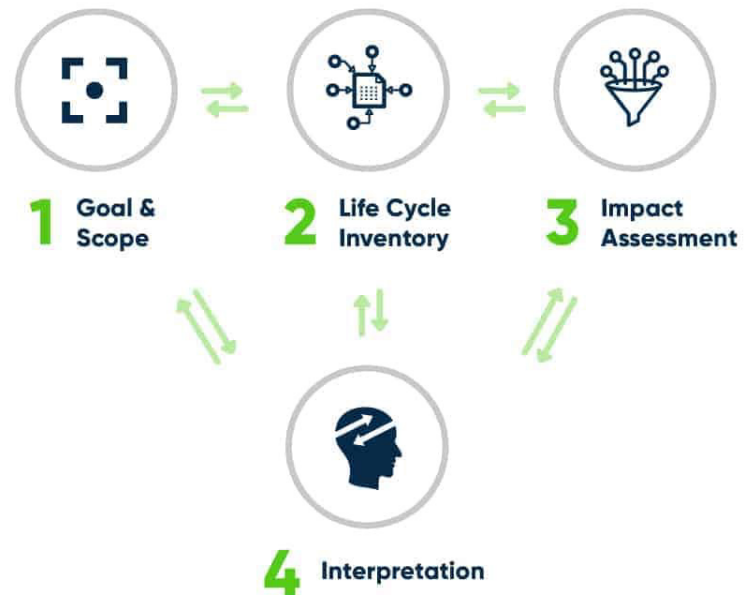
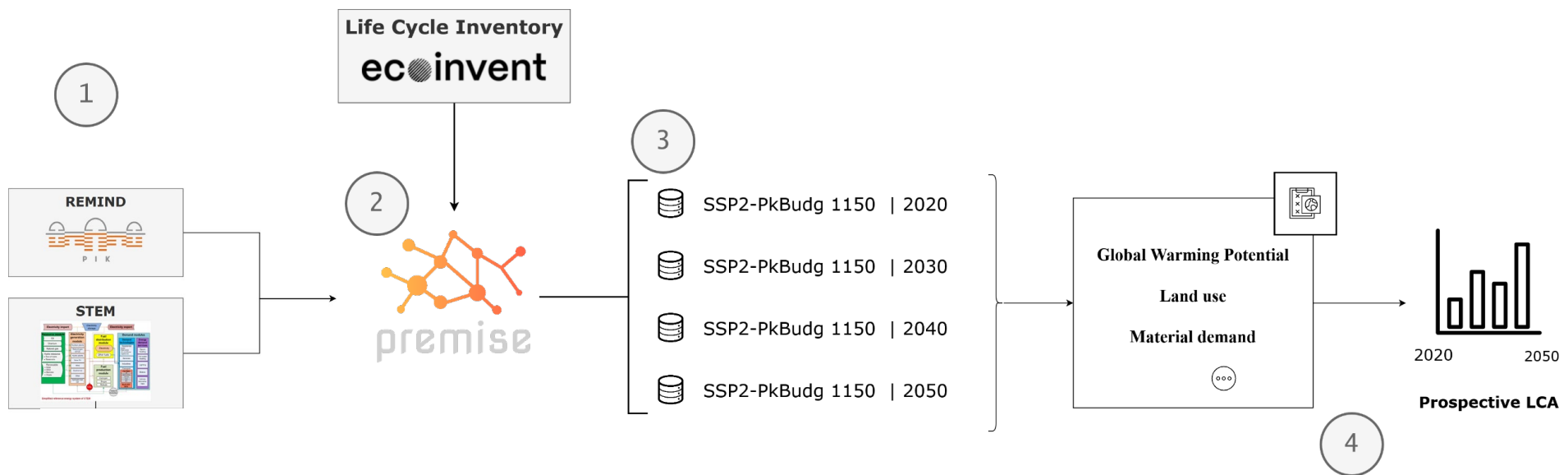


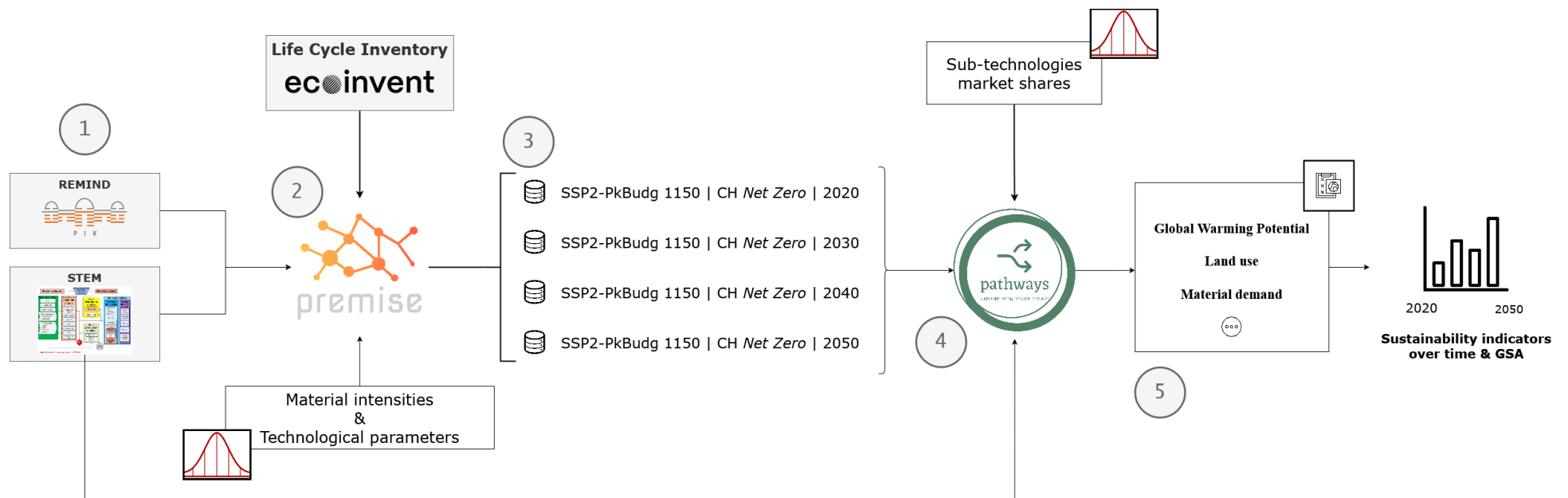
Figure retrieved from ecochain.com

Prospective Life Cycle Assessment framework | *premise*



Sacchi, R., et al. (2022). PProspective EnvironMental Impact asSEment (premise): A streamlined approach to producing databases for prospective life cycle assessment using integrated assessment models. *Renewable and sustainable energy reviews*, 160, 112311. doi: [10.1016/j.rser.2022.112311](https://doi.org/10.1016/j.rser.2022.112311)

Prospective macro-level LCA framework | *pathways*



Sacchi, R., & Hahn-Menacho, A. J. (2024). pathways: life cycle assessment of energy transition scenarios. *Journal of Open Source Software*, 9(103), 7309. doi: [10.21105/joss.07309](https://doi.org/10.21105/joss.07309)

Our Approach

Switzerland and several other countries aim for **net-zero energy-related GHG** emissions by **2050**



We evaluate three different net-zero scenarios (and a baseline) where **international cooperation** levels and **technology acceptance** determine the scale and type of renewable deployment.

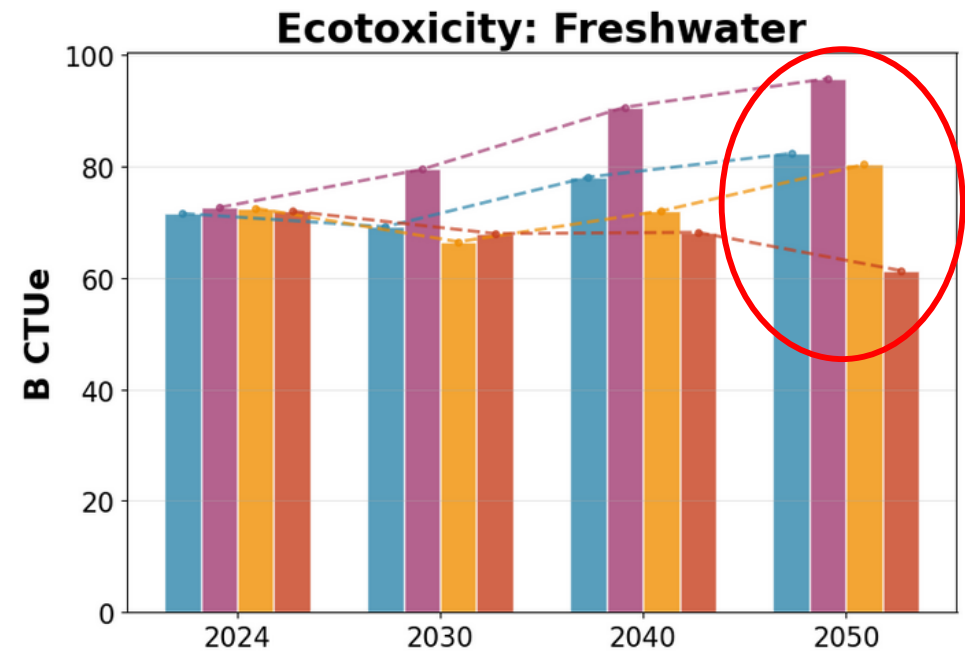
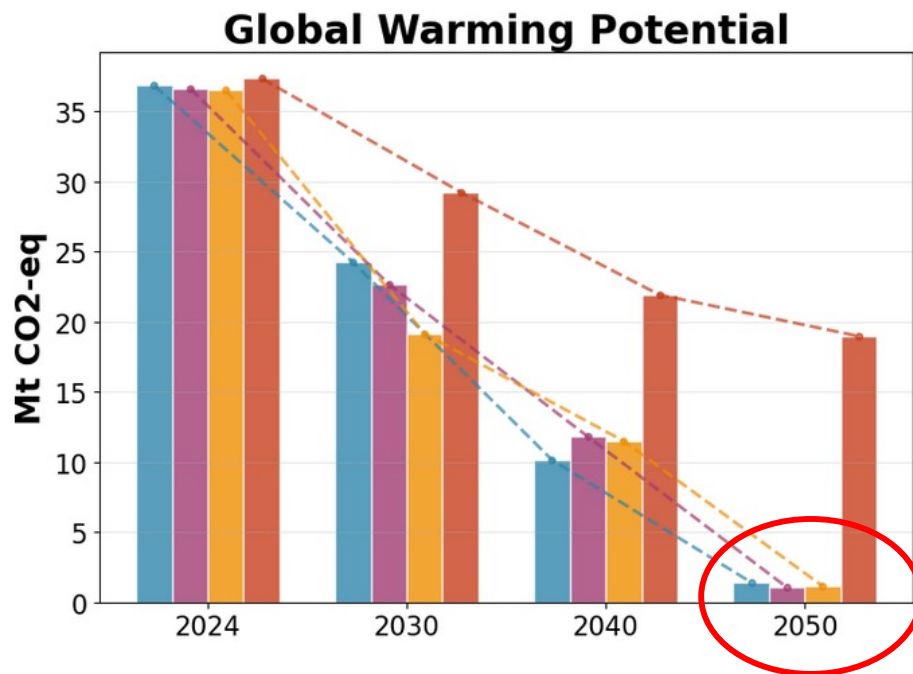
Net-Zero

- A) **High renewable deployment** with no technological barriers (rapid electrification)
- B) **Limited large-scale renewables** due to import constrains (domestic energy focus)
- C) **Small-scale distributed solutions** (rooftop PV, small wind, local biomass)
- D) **Business-as-usual:** Current technology trends continue

Life Cycle Assessment (LCA) of energy transition scenarios

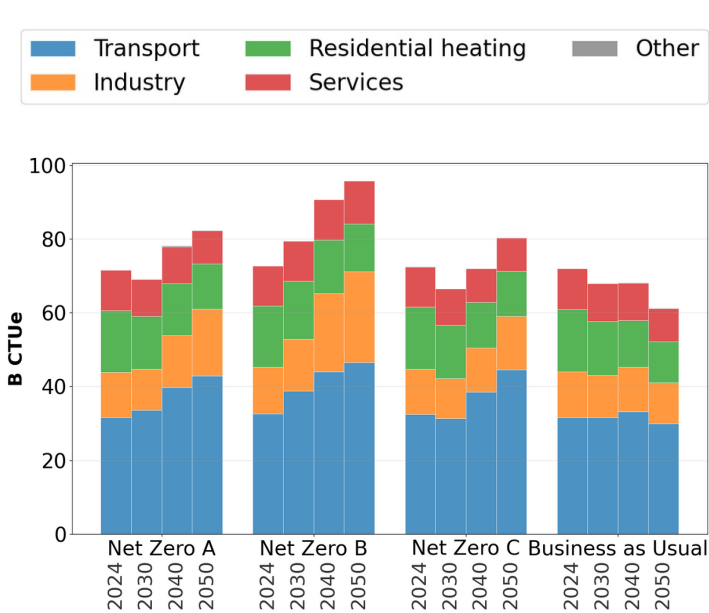


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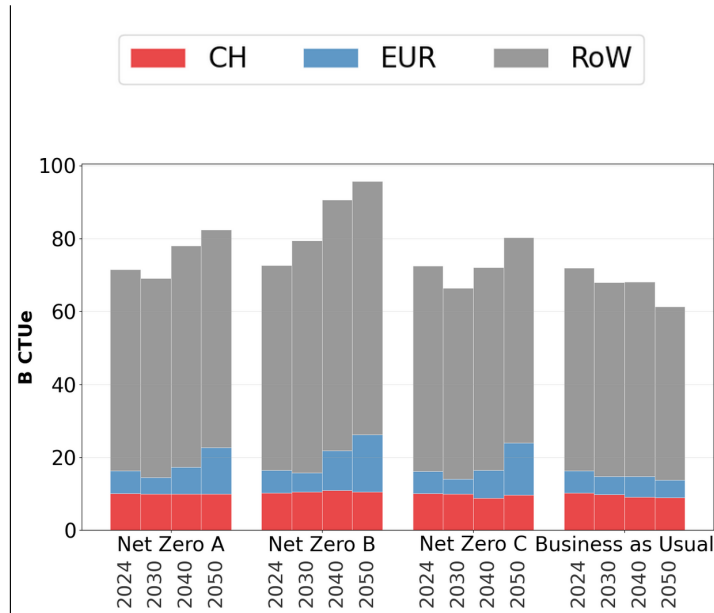


Ecotoxicity - freshwater

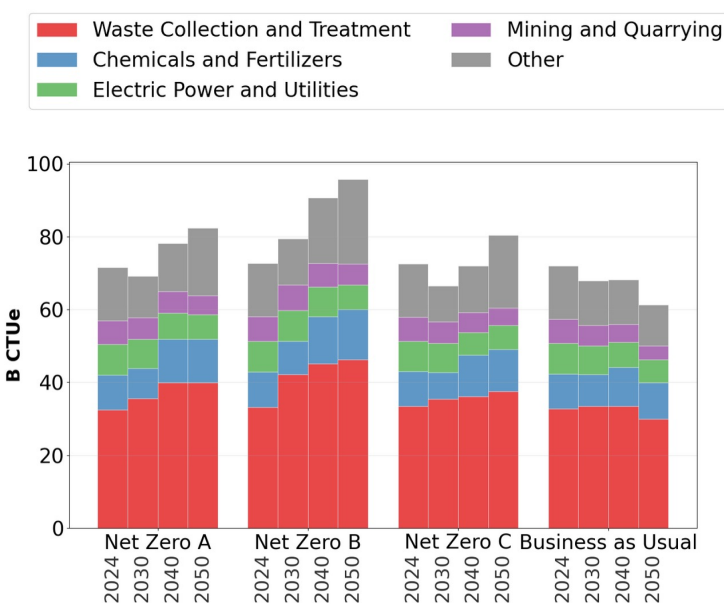
Consumer perspective



Regional perspective



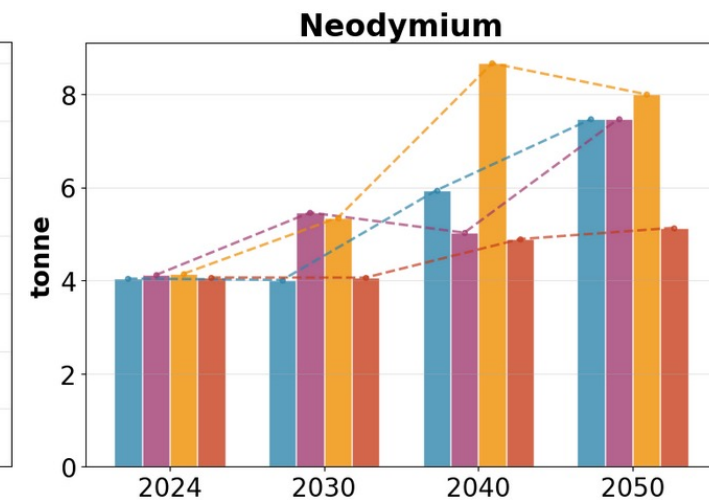
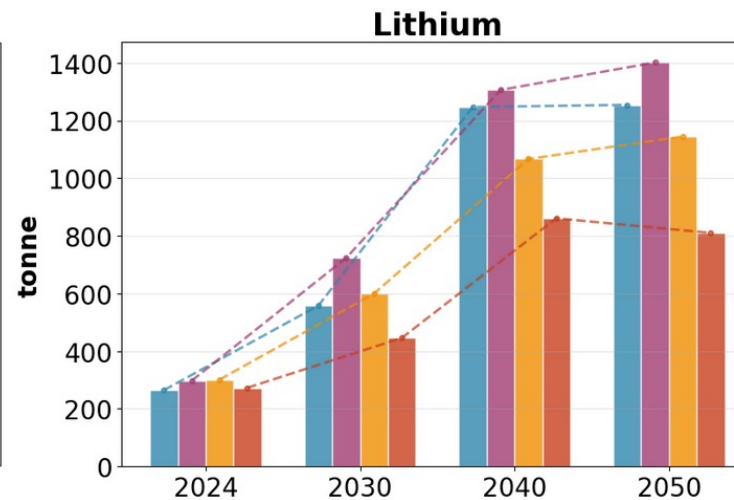
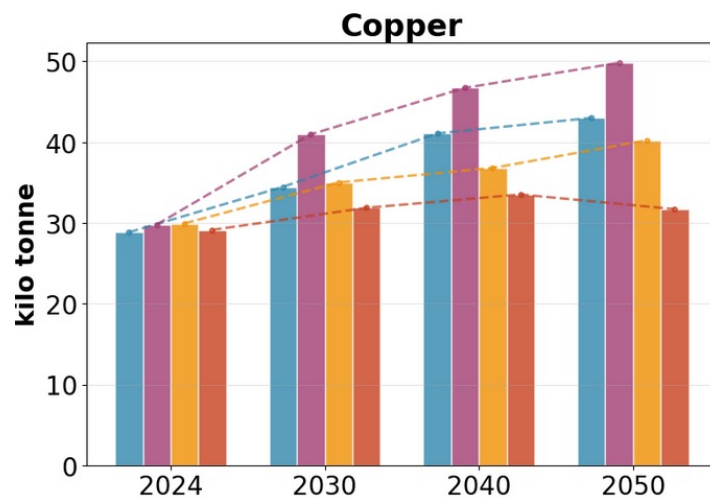
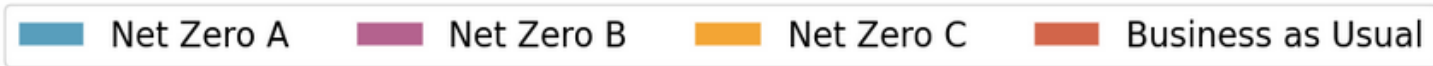
Production perspective



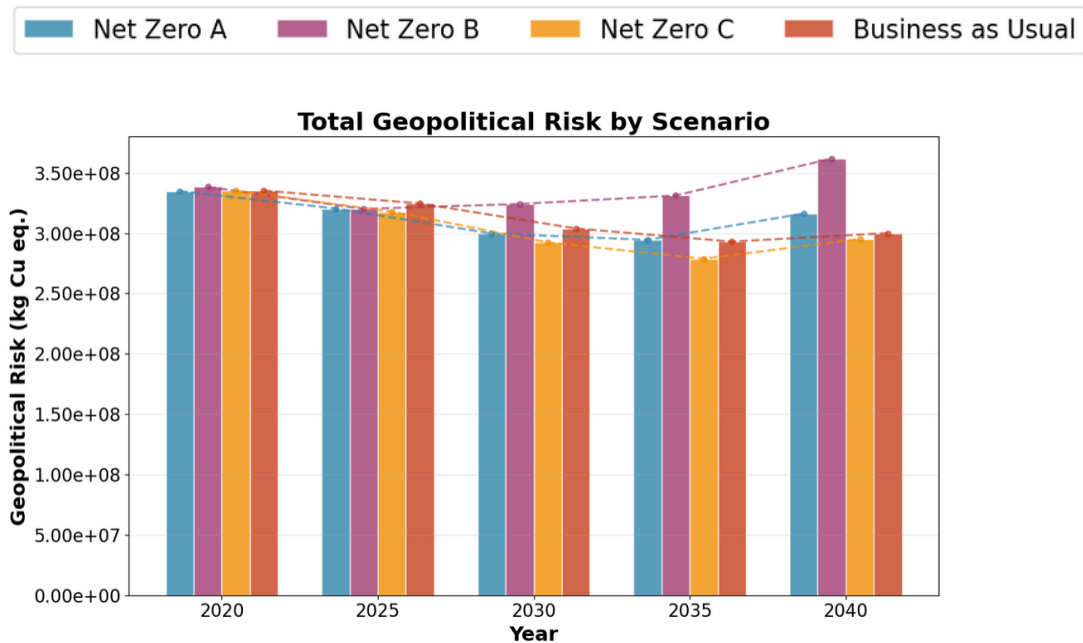
Life-cycle metal demand



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Criticality

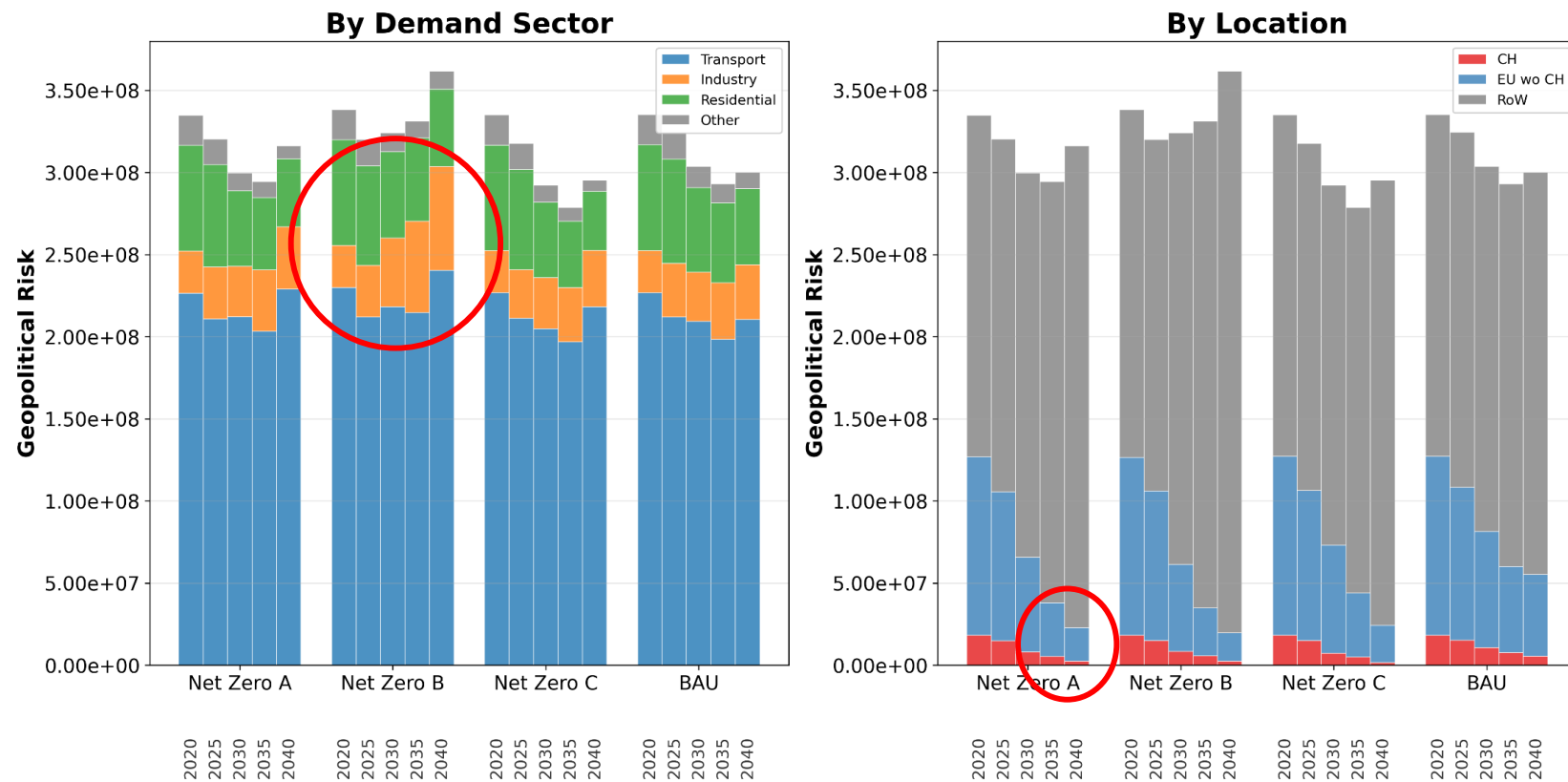


GeoPolRisk Characterization Factors

- Method to assess the **risk of raw material supply disruption**
- Developed primarily at Uni of Bordeaux
- Main factors for each resource:
 - i) Concentration of global production
 - ii) Import exposure weighted by exporter political stability
 - ii) Dependence on foreign supply

Koyamparambath, A., Loubet, P., Young, S. B., & Sonnemann, G. (2024). Spatially and temporally differentiated characterization factors for supply risk of abiotic resources in life cycle assessment. *Resources, Conservation and Recycling*, 209, 107801. doi: [10.1016/j.resconrec.2024.107801](https://doi.org/10.1016/j.resconrec.2024.107801)

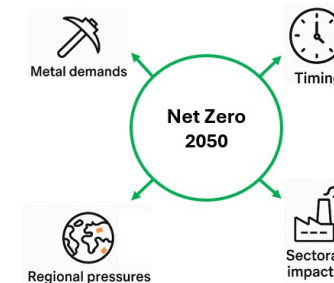
Criticality



Conclusions

→ Different net-zero pathways create distinct resource and environmental challenges

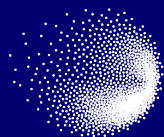
- Metal demand shifts → supply chain risks
- Environmental pressures will potentially concentrate in different regions and sectors.



→ Reproducible workflow for calculating life-cycle environmental impacts of transition scenarios:

- Assess life-cycle GHG emissions, environmental co-benefits, and trade-offs.
- Estimate material demand, highlights key drivers.
- LIMITATION: Extrapolating risks into the future is uncertain, due to the uncertainties in the future supply





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Thank you!

Technology Assessment Group (<https://www.psi.ch/en/ta>)

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