The availability of copper – a perspective from science

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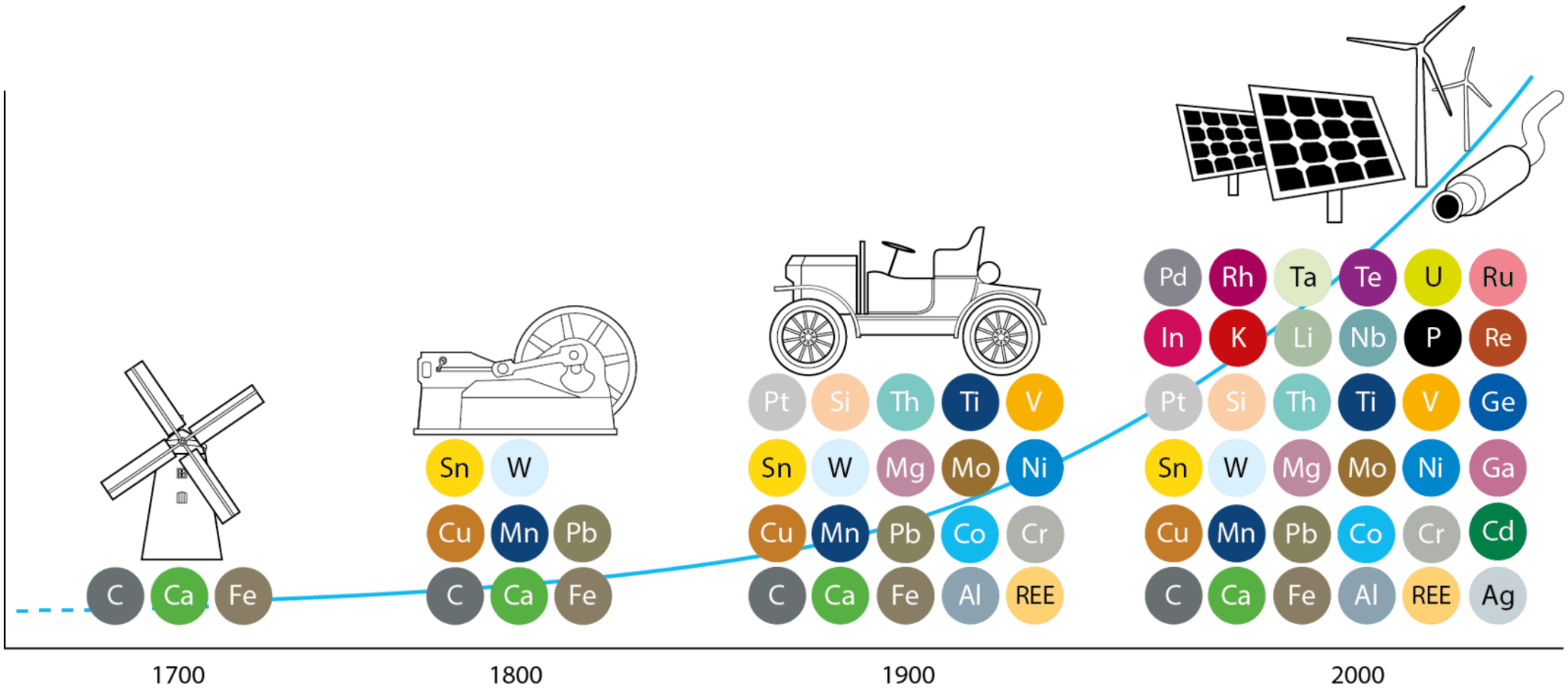
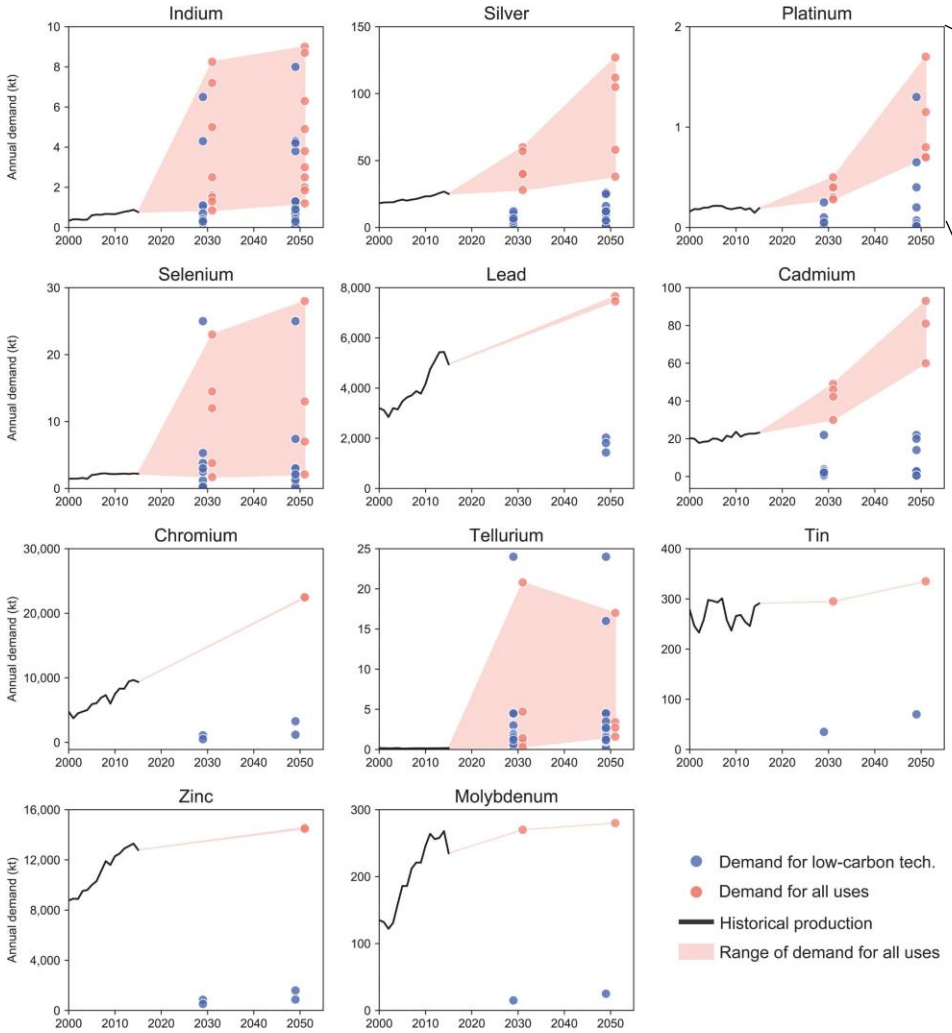
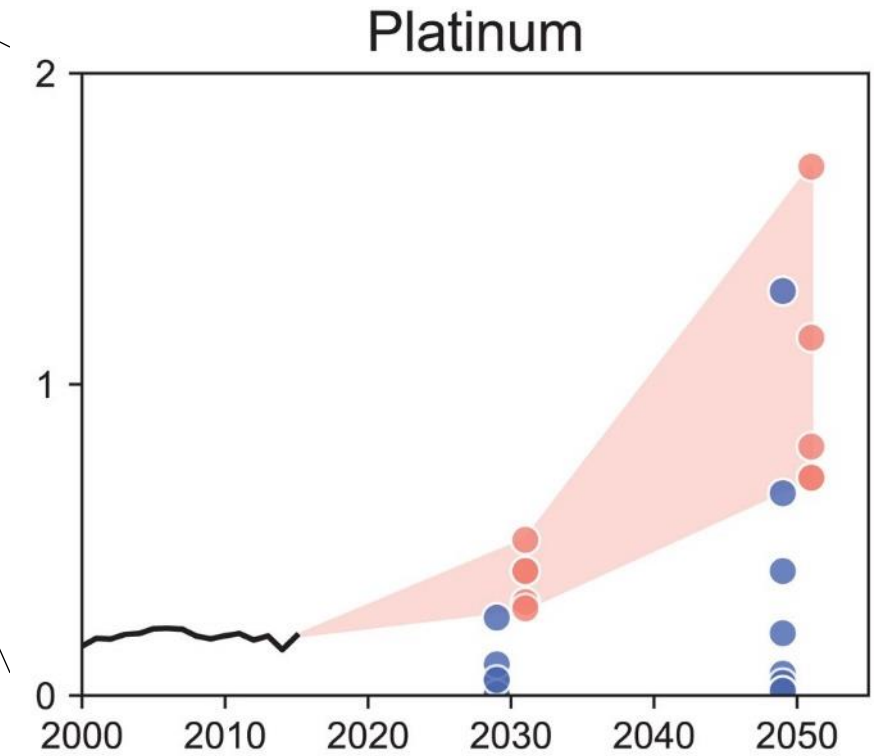
Metals underpin modern society and a decarbonized future



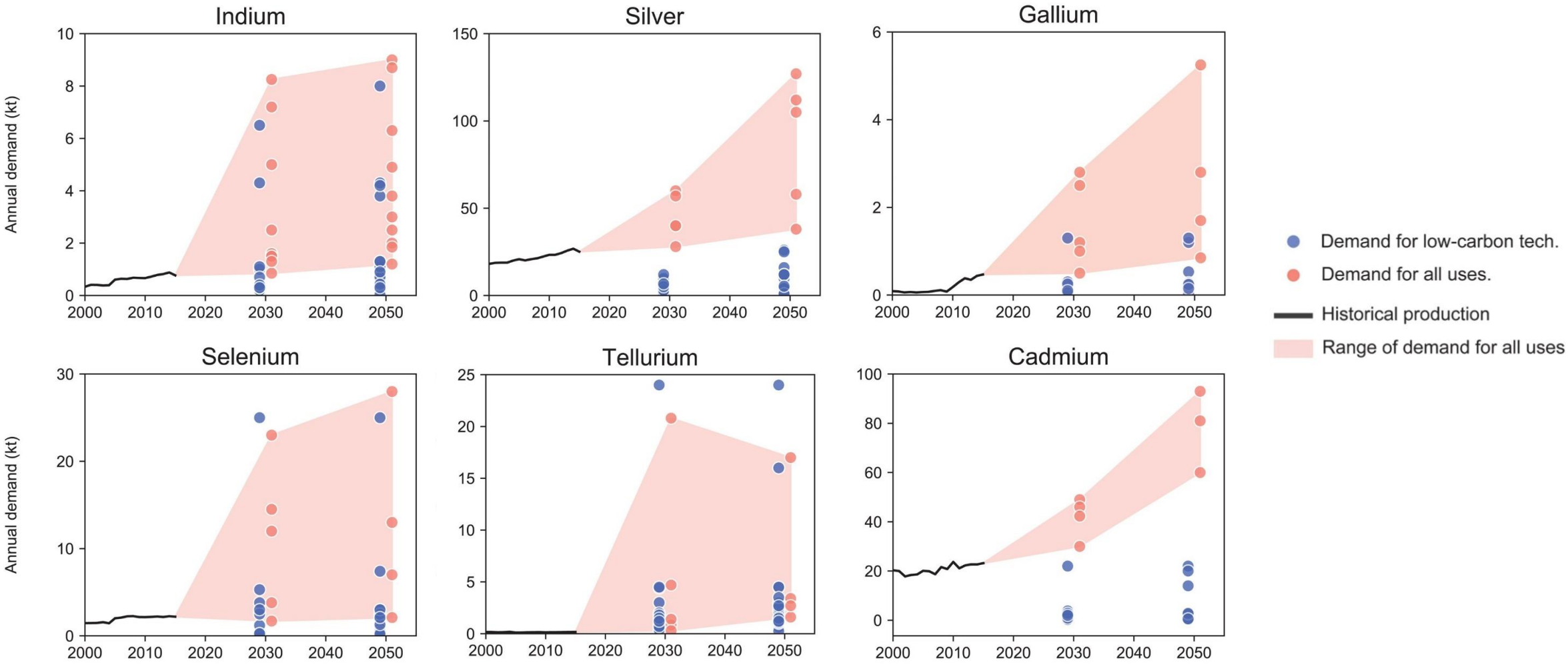
J. Simmons (2011) Materials critical to the energy industry

Global demand for metals is expected to grow





Global demand for metals is expected to grow



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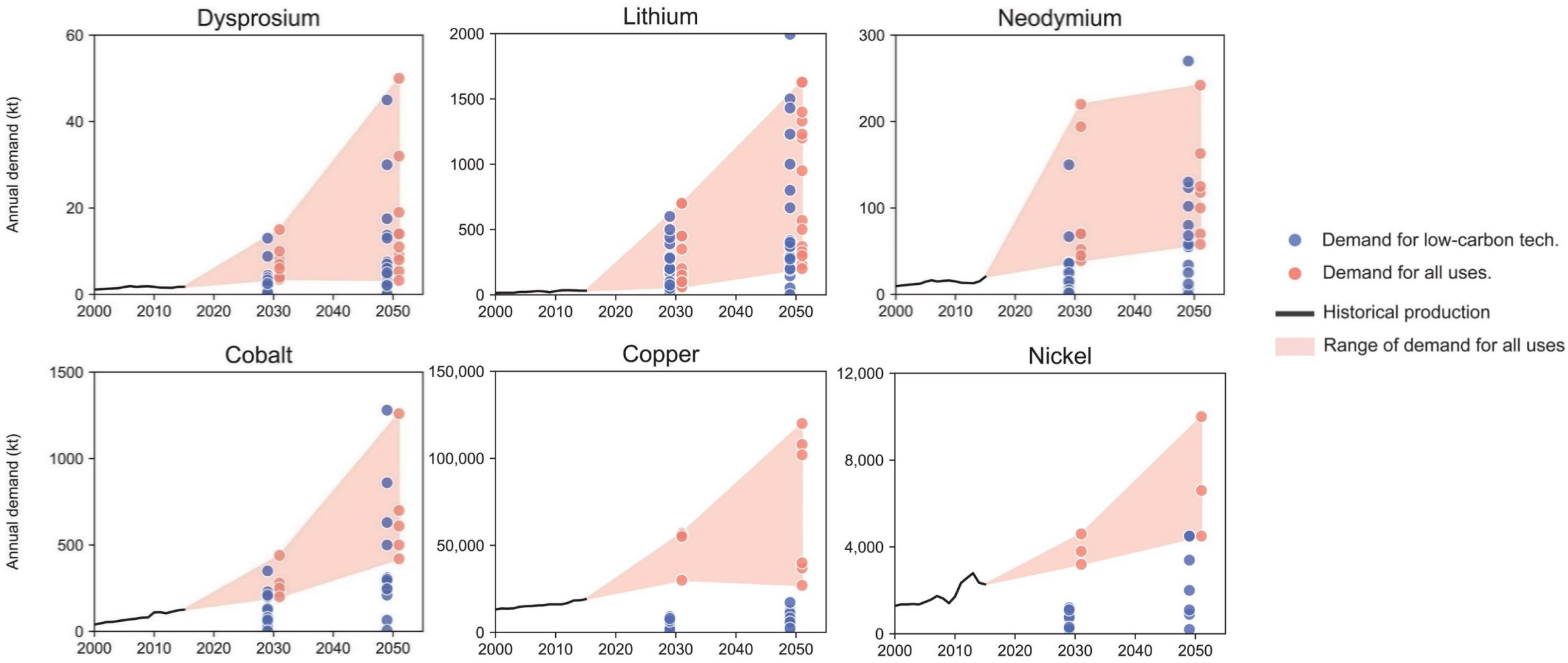

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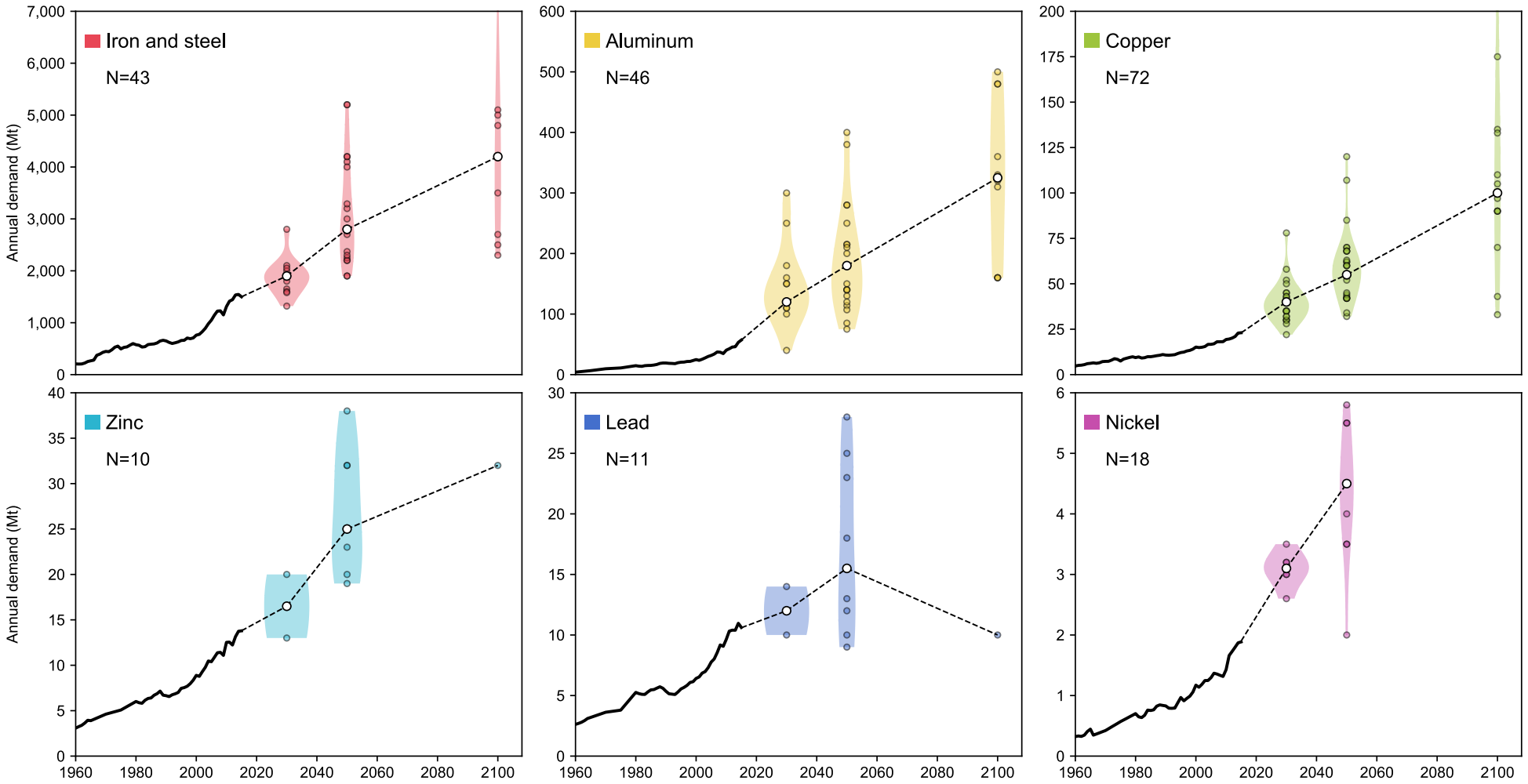
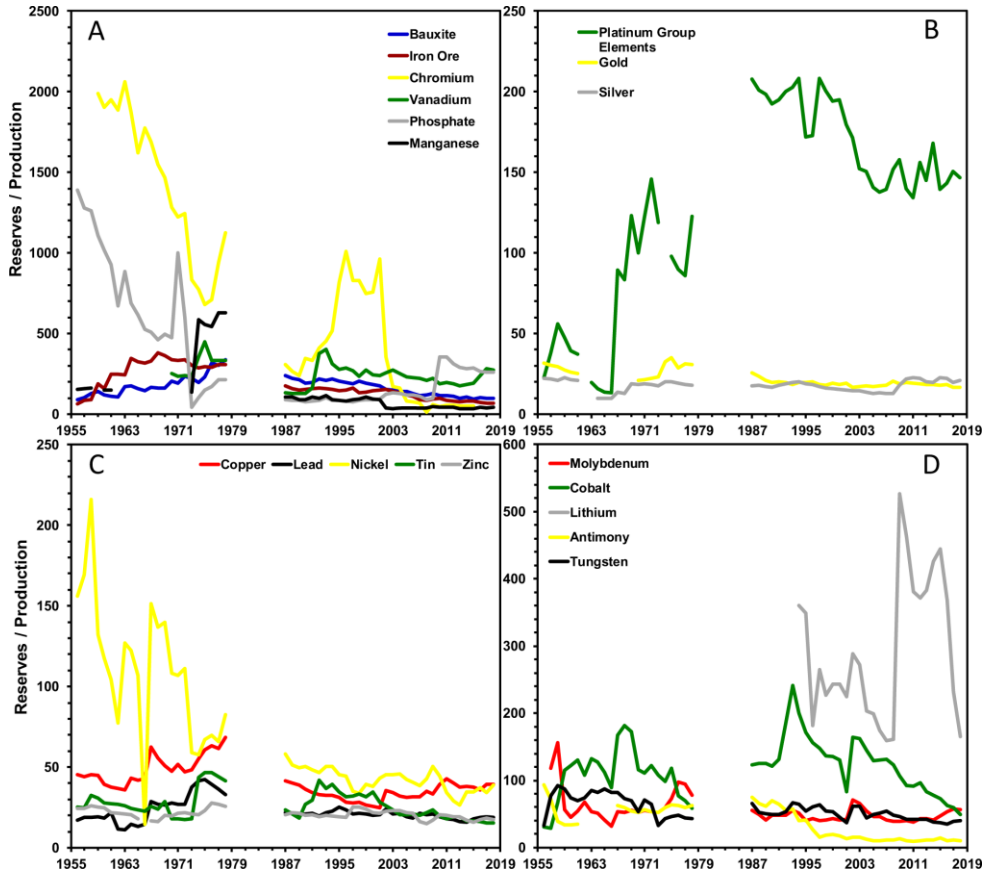
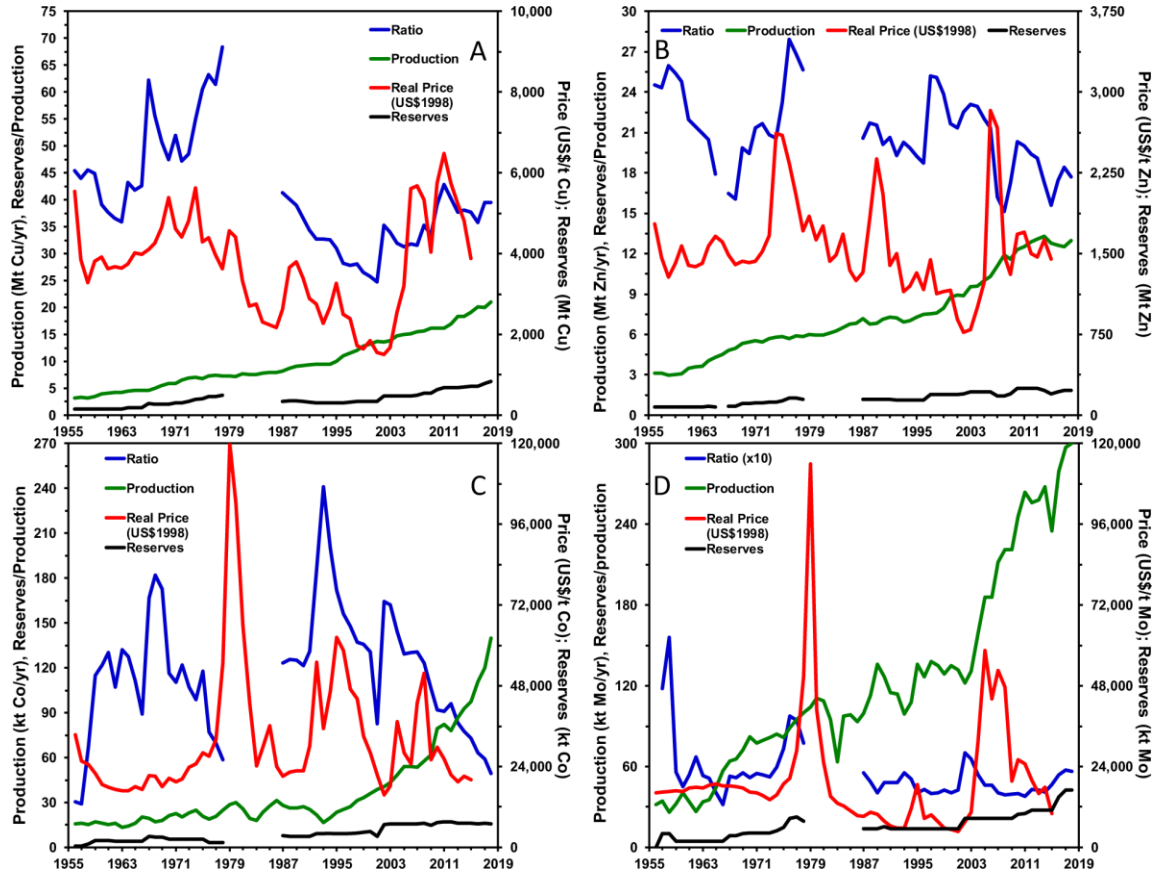


The problem is not physical depletion





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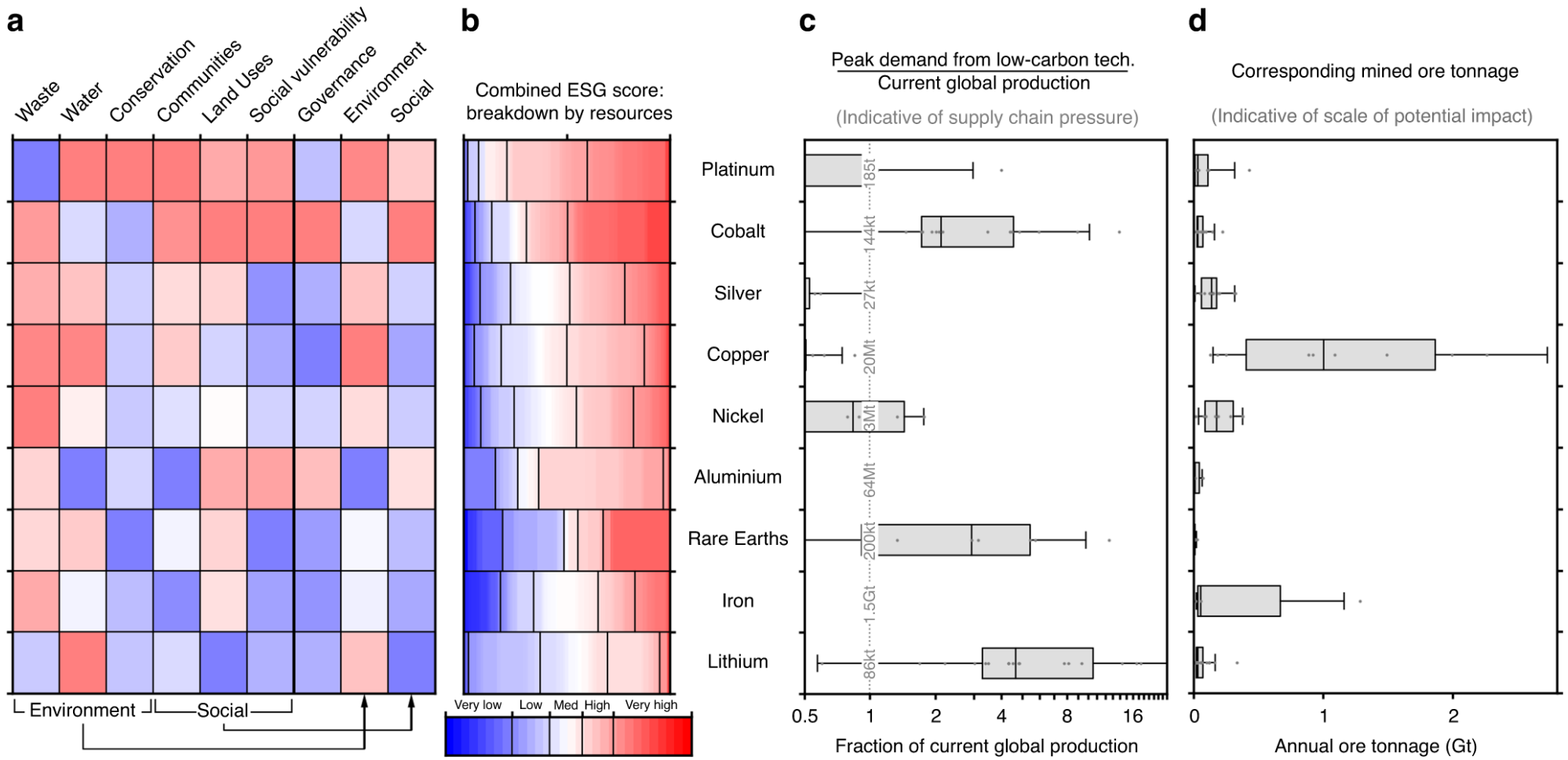
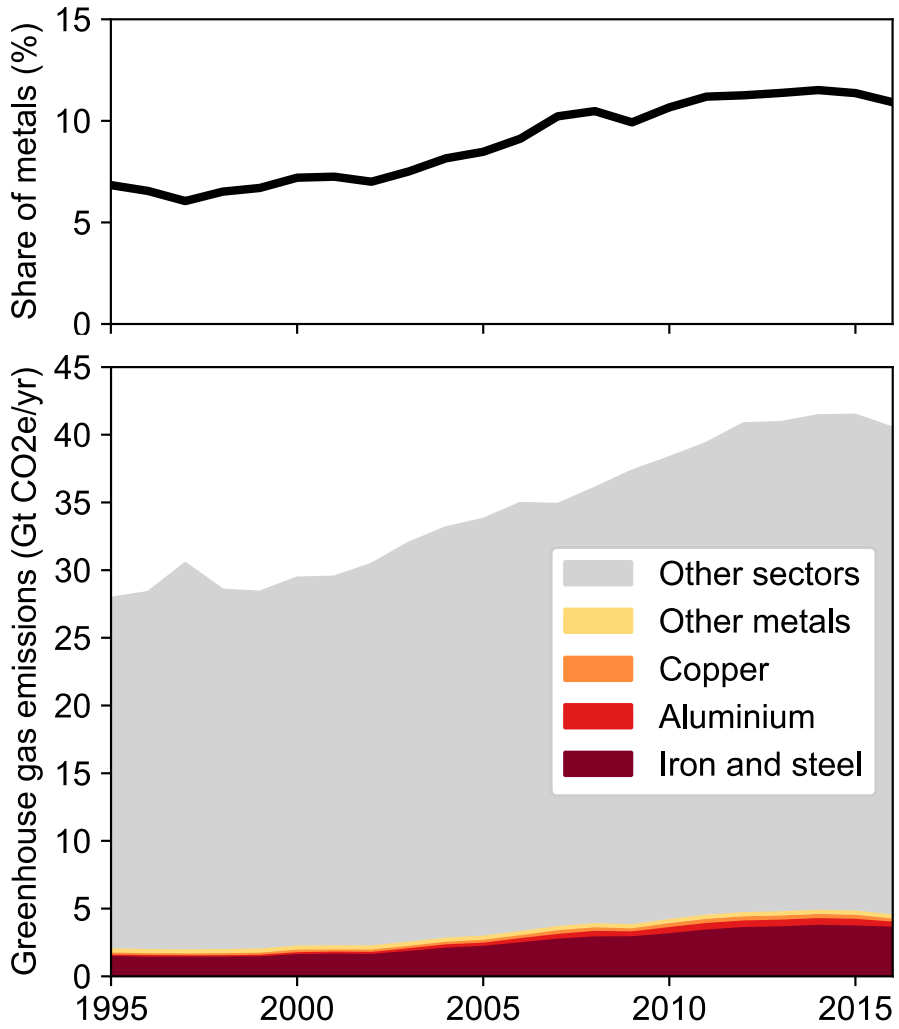


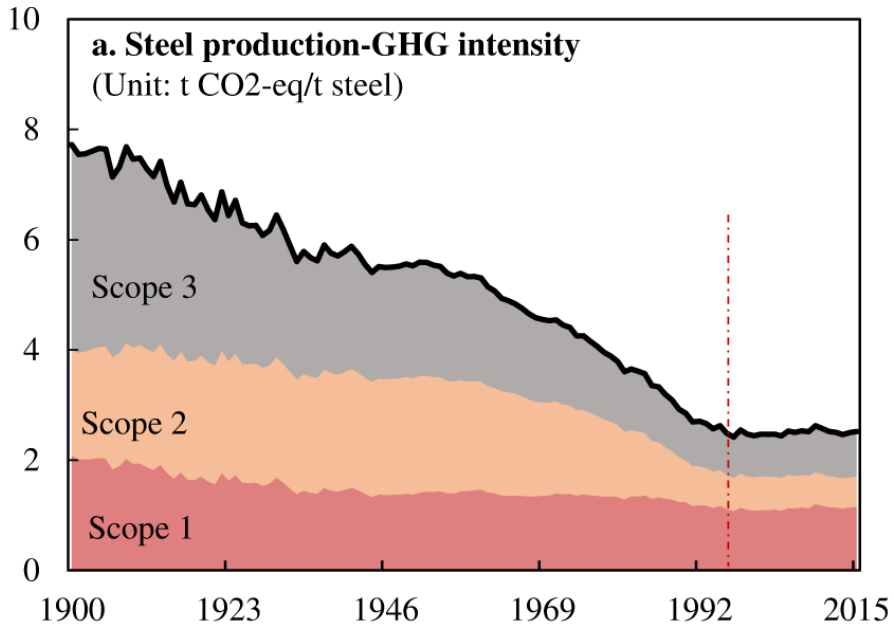
Climate impacts from metal production are increasing

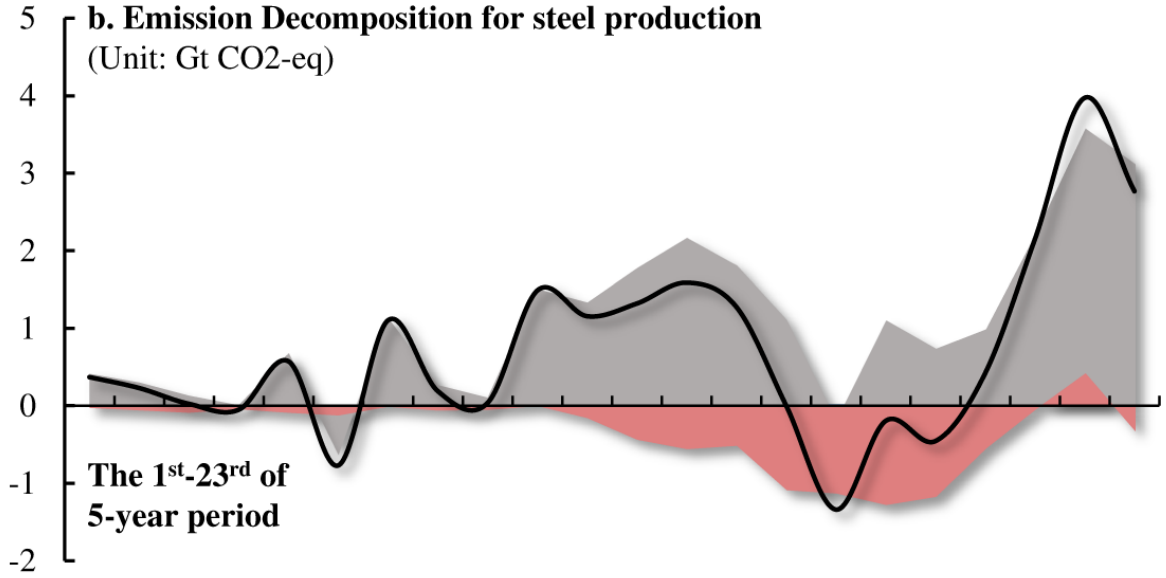


The share of GHG emissions from metal production in global emissions has increased over the years and now exceeds 10%

Data: E. Hertwich et al. (2021) *Nature Geoscience*, 14, 151-155

Why are climate impacts increasing? – Production growth

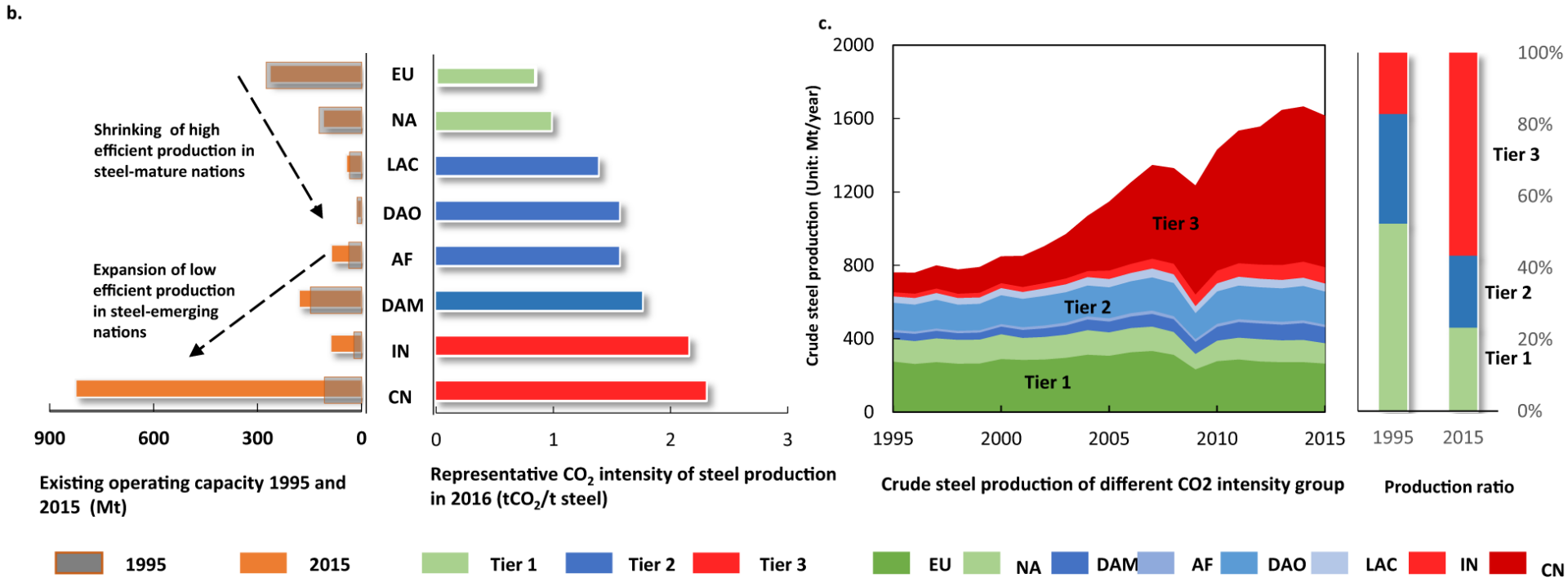




Efficiency gains have stagnated

Production growth is offsetting efficiency gains

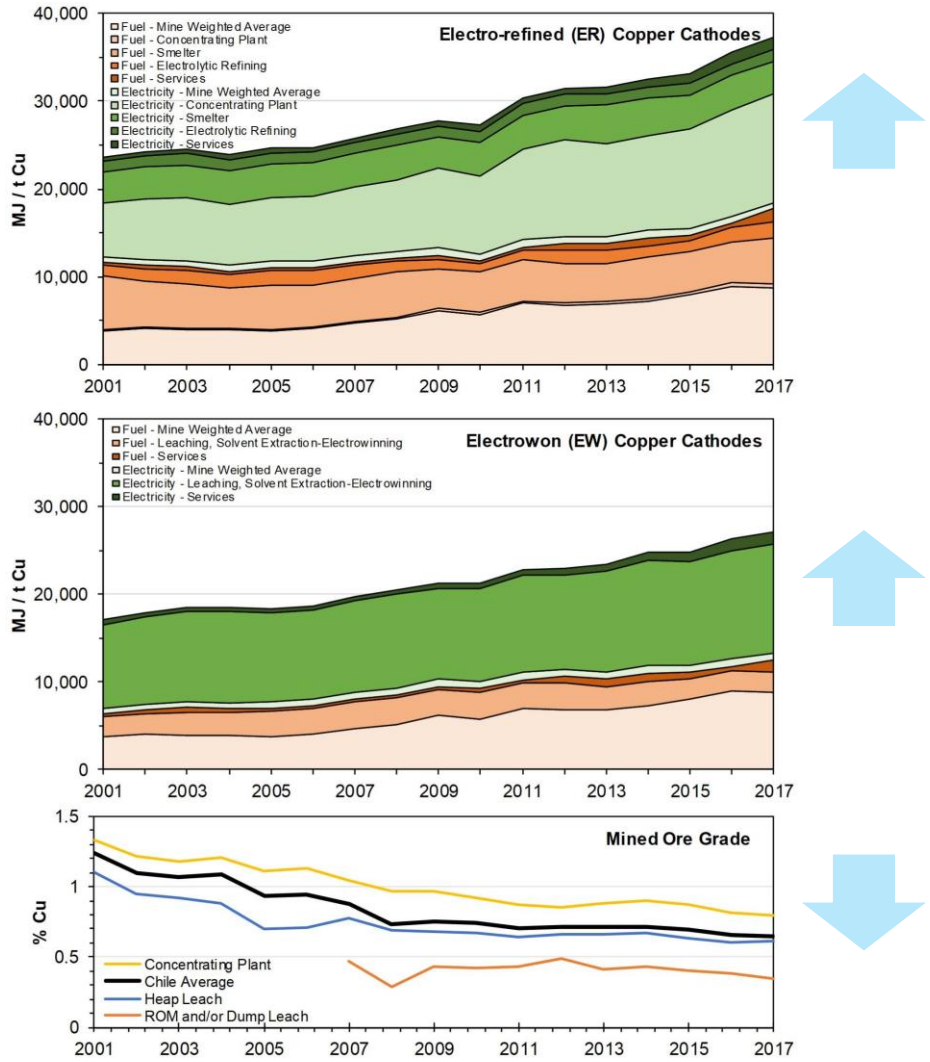
Why are climate impacts increasing? – Emerging countries



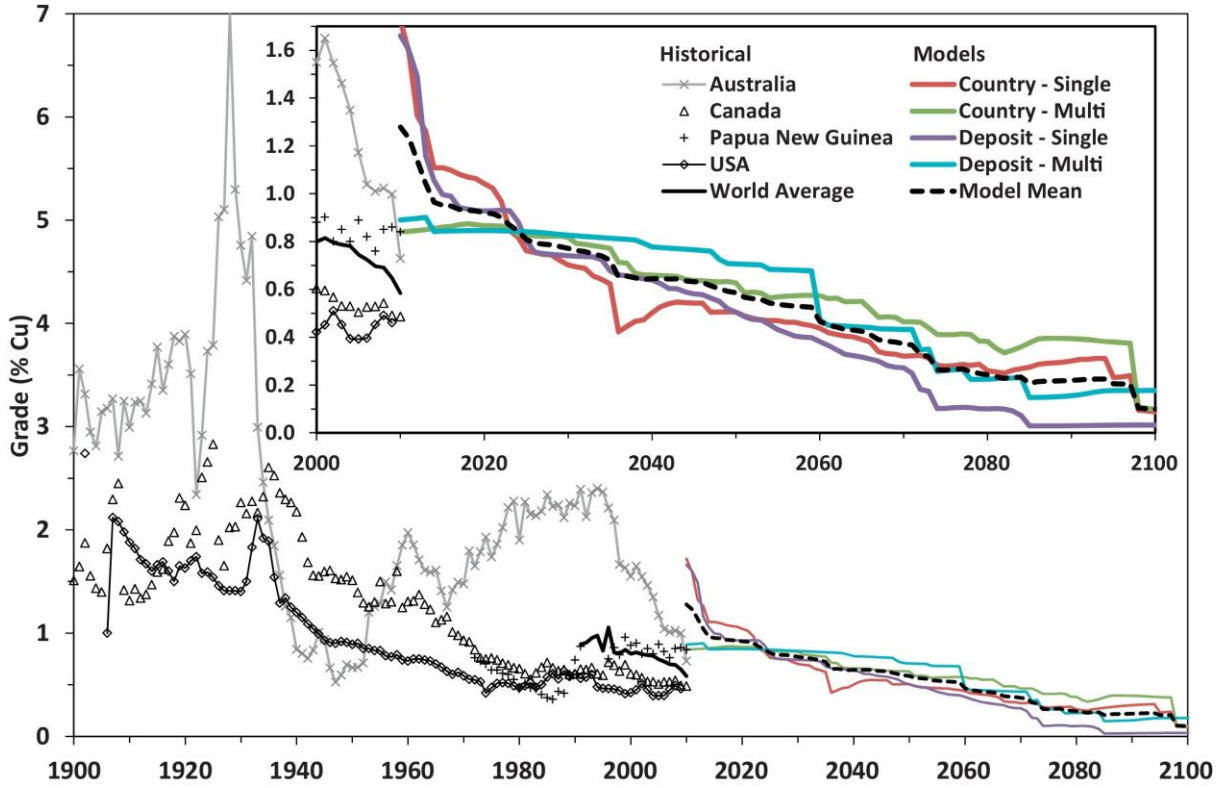
Why are efficiency gains becoming stagnant?

Production in emerging economies with less efficient technologies is exploding

Why are climate impacts increasing? – Ore grade decline

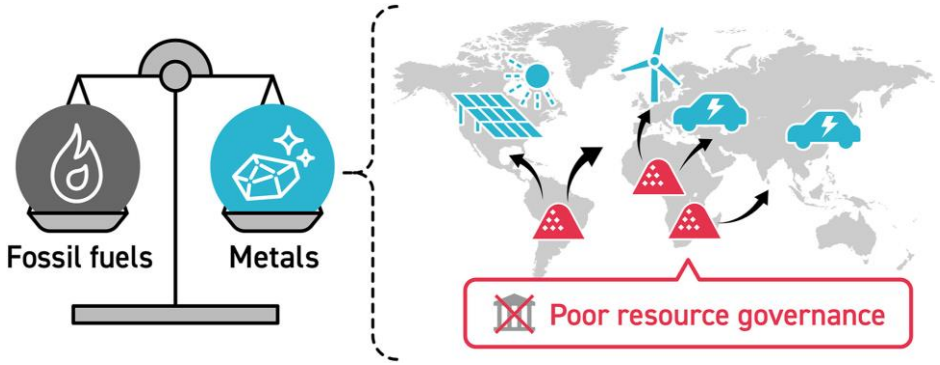


Ore grades are declining and will continue to do so



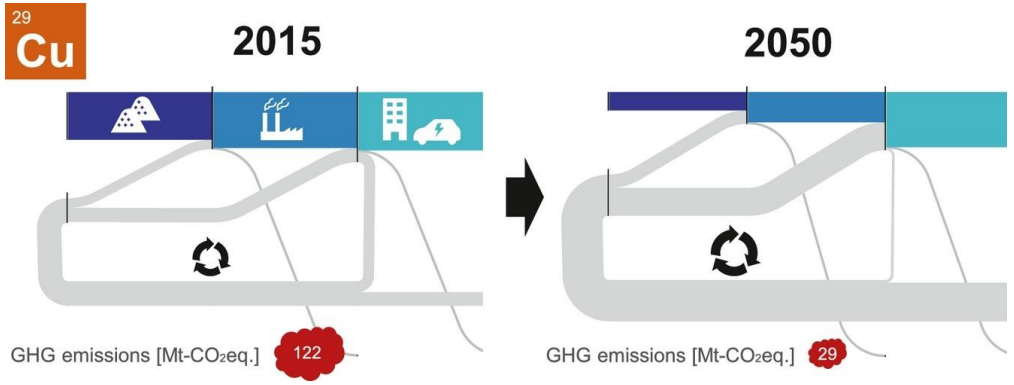
Two drivers of the future metal cycle

1. Implementation of decarbonization technologies



T. Watari *et al.* (2019) *Resource Conservation and Recycling*, 148, 91-103
T. Watari *et al.* (2021) *Journal of Cleaner Production*, 312, 127698

2. Imposition of an emissions budget on production activities



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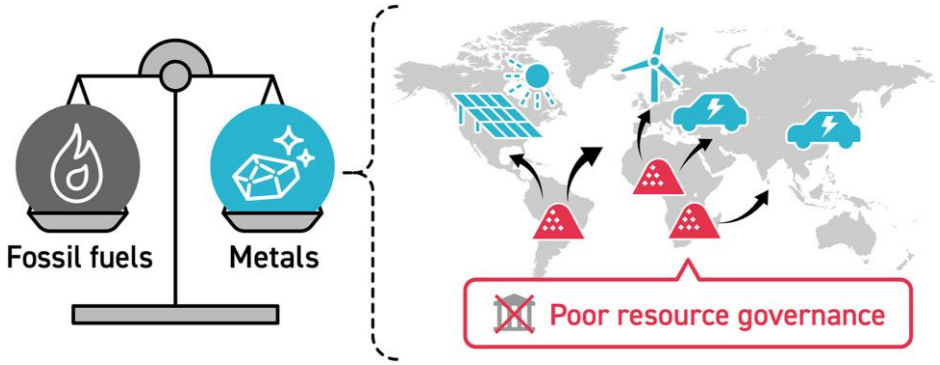

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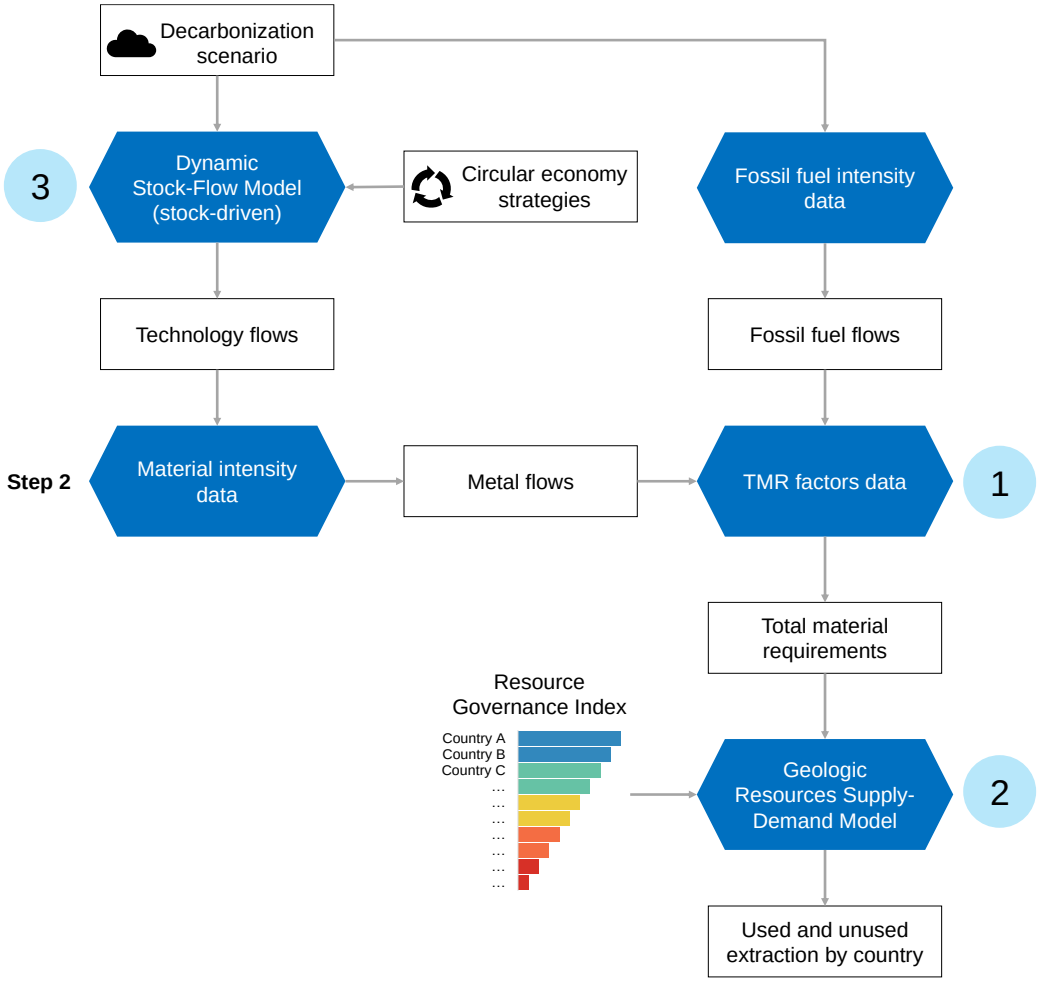
Modelling approach

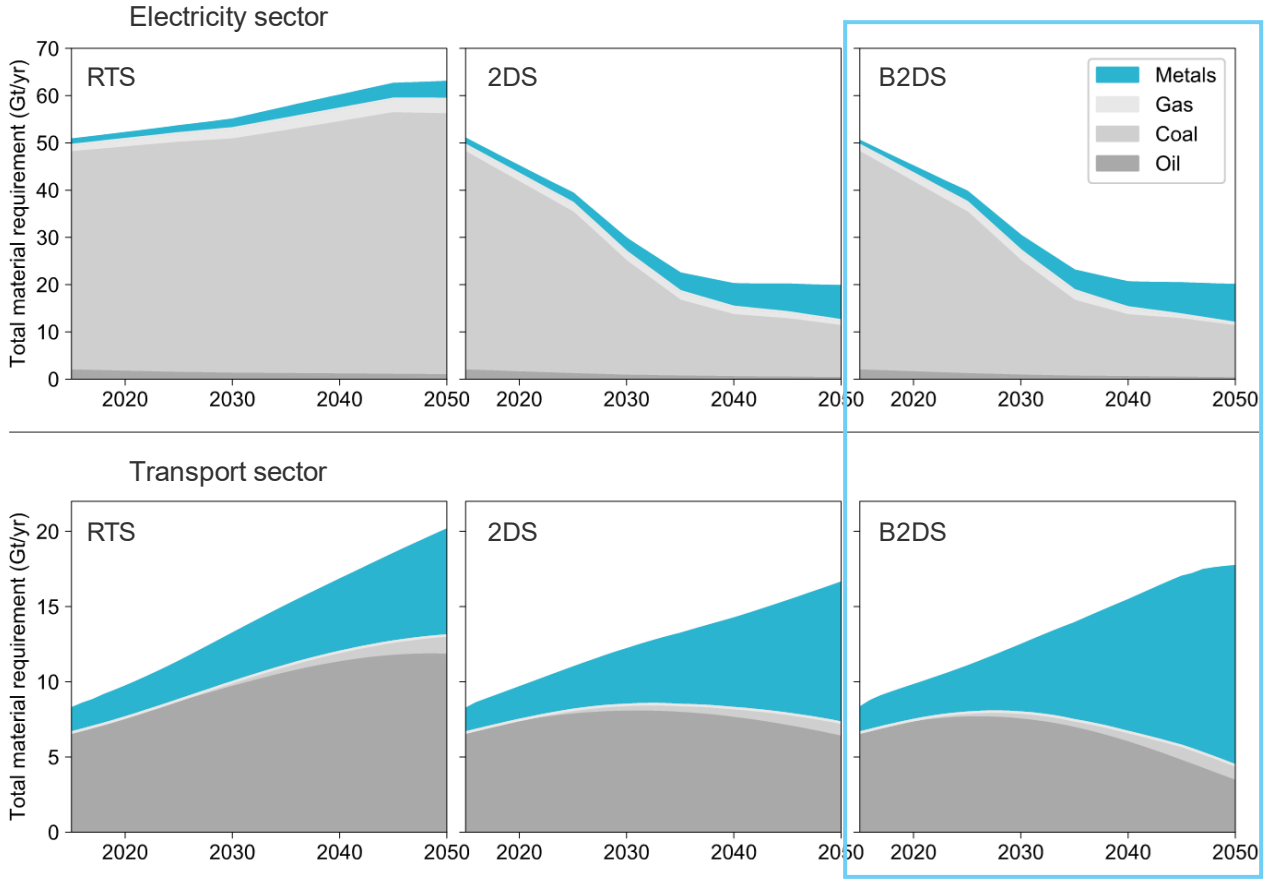
Model features

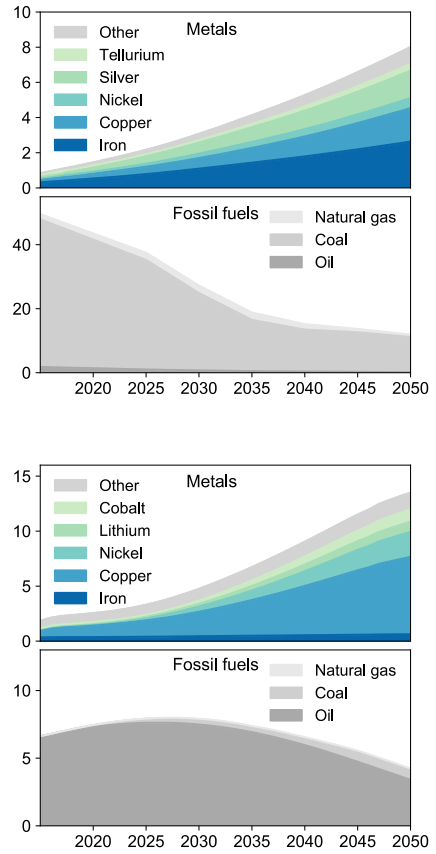
1. Quantifying all used and unused resource extraction
2. Improving regional resolution by using mine production data on a country-by-country basis
3. Exploring the impact of circular economy strategy interventions



How much material is needed for future energy systems?

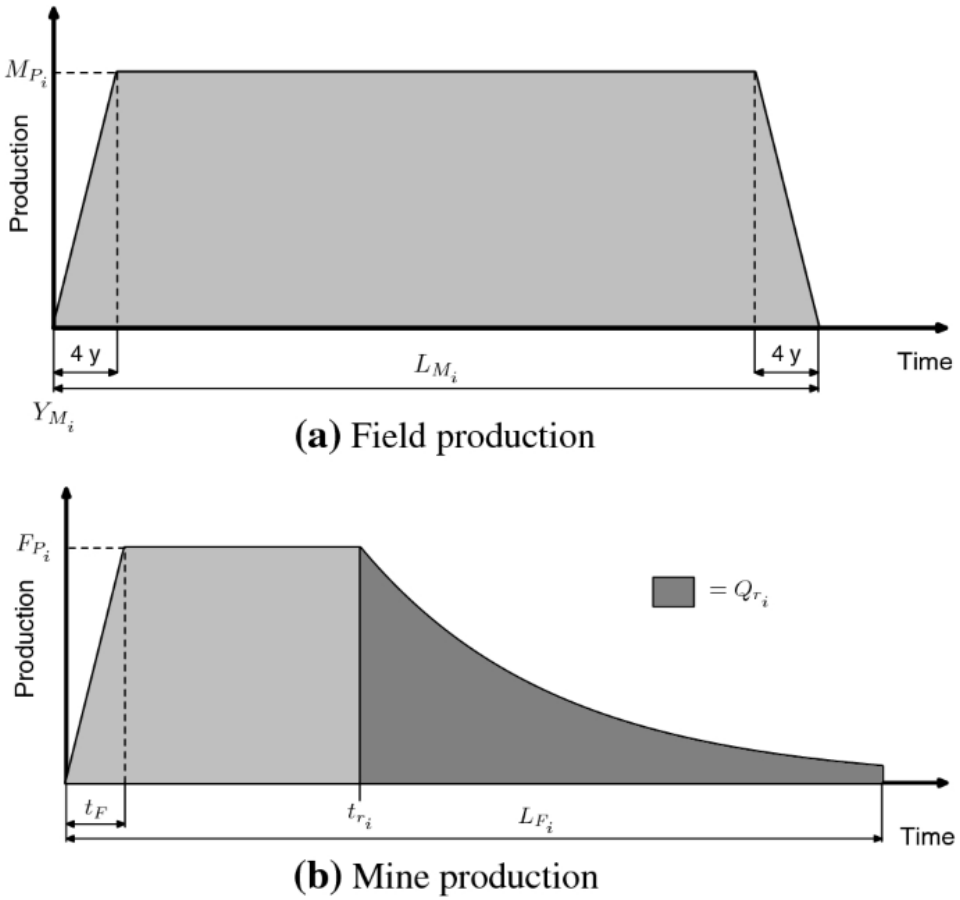
Inverse relationship exists between carbon emissions and resource extraction

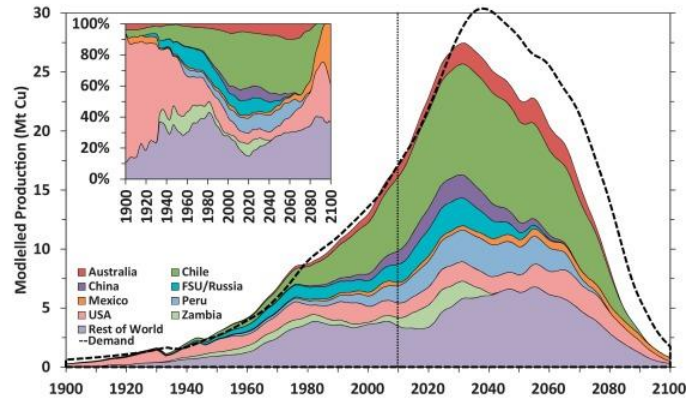


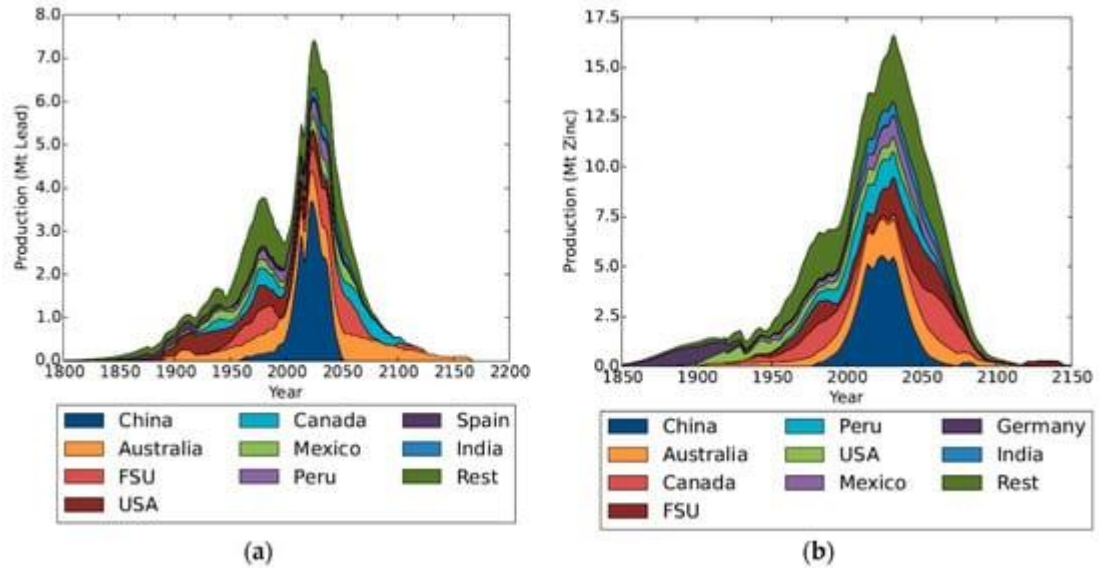


Where will the mining activity take place?

Mining model

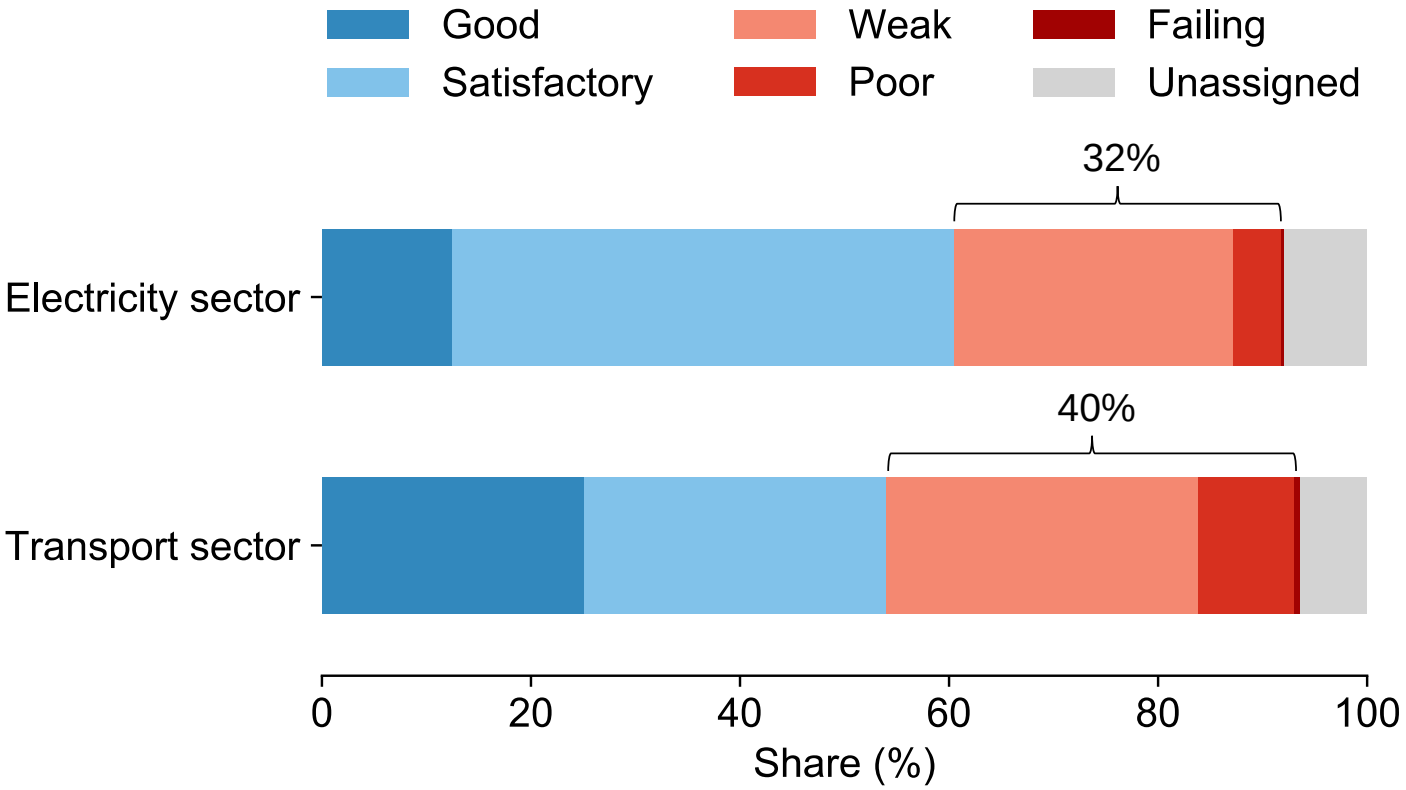






Where will the mining activity take place?

Countries with poor resource governance will underpin the energy transition



Share of cumulative total material requirements associated with metal production from 2015 to 2050

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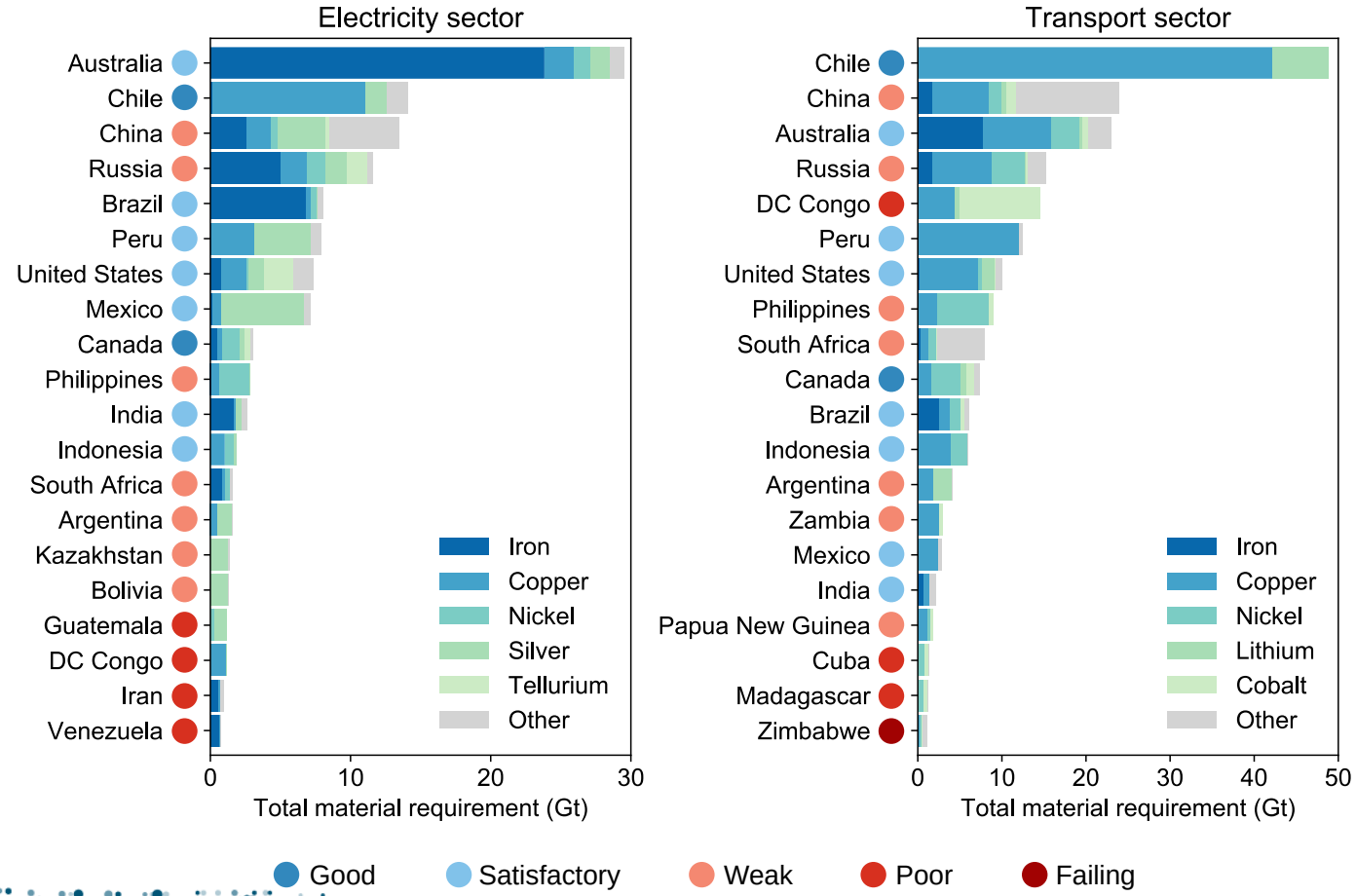
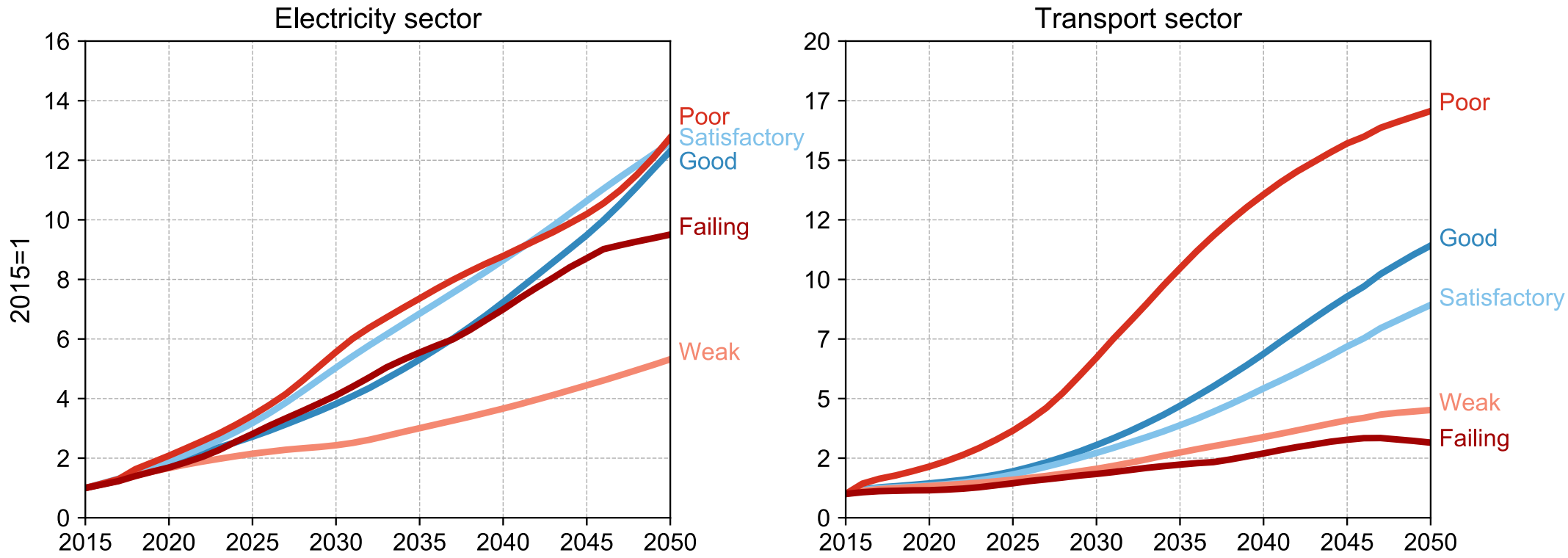


Share of cumulative total material requirements associated with metal production from 2015 to 2050

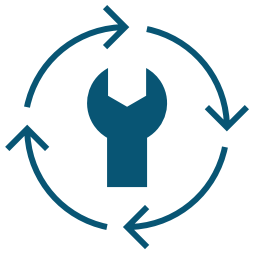
Where will the mining activity take place?

The largest increase in resource extraction due to energy transition is in countries with poor resource governance



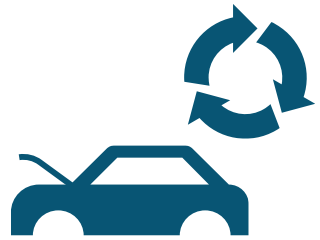
What is the role of the circular economy?

Lifetime extension



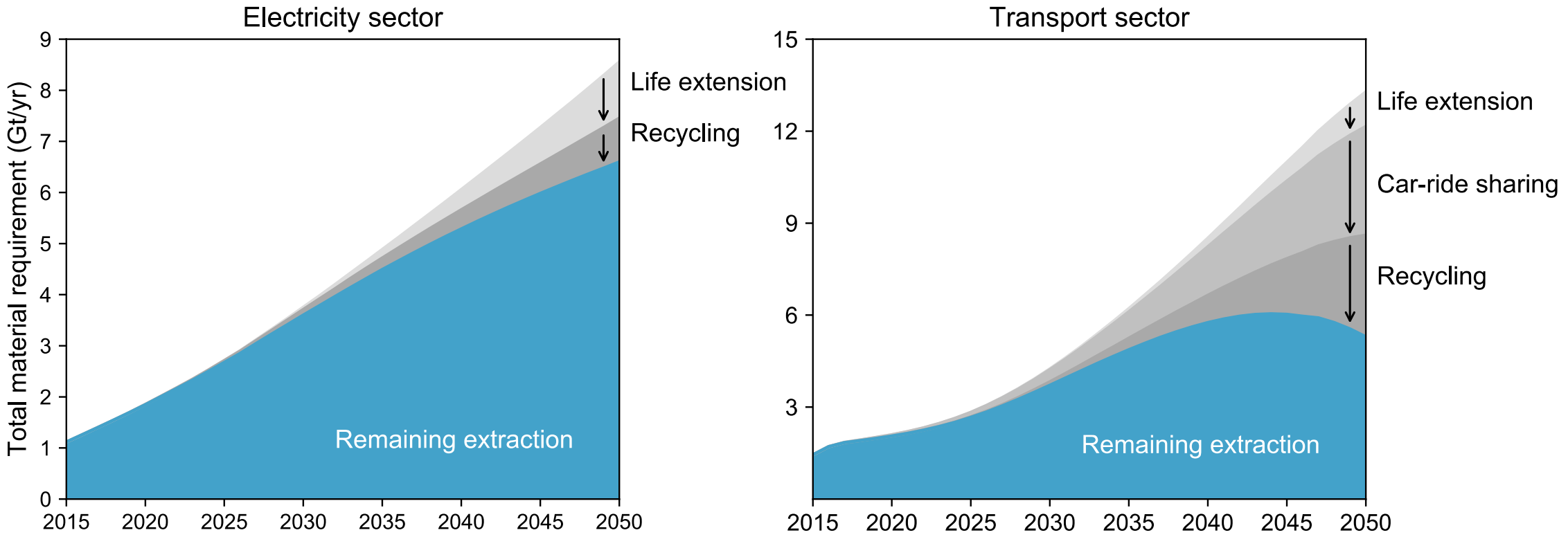
Servitization (e.g., car sharing)

EoL recycling



What is the role of the circular economy?

Circular economy strategies can moderate resource extraction growth, but…



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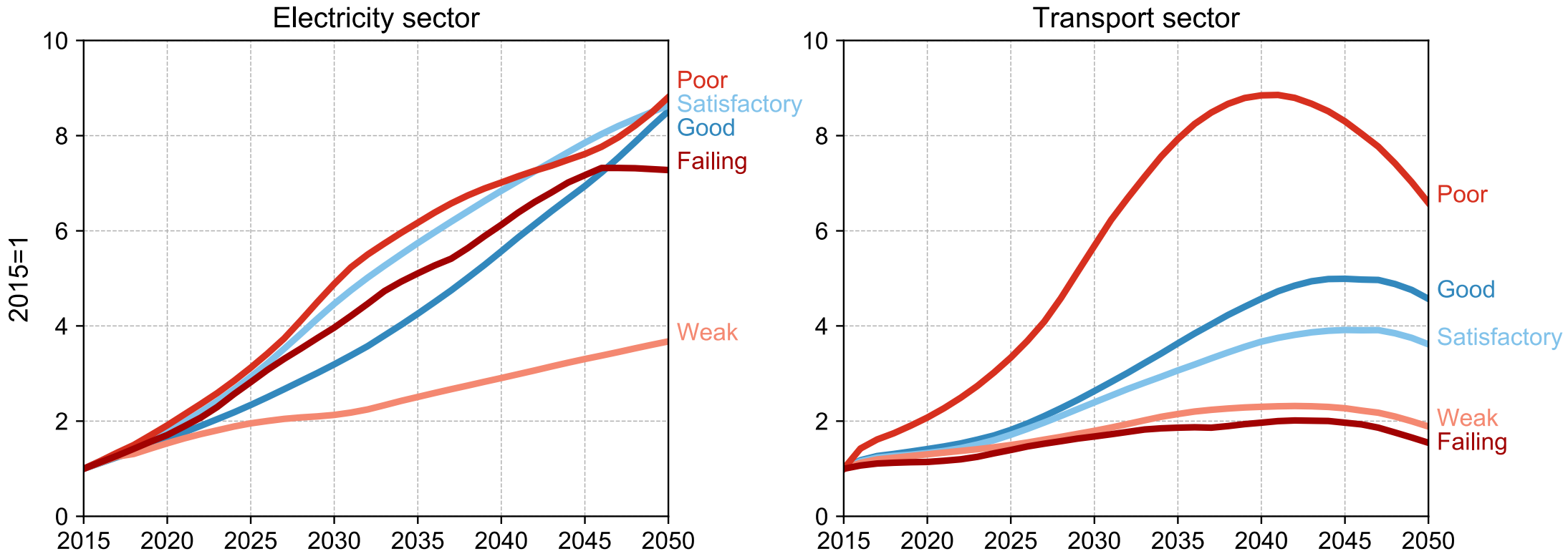


What is the role of the circular economy?

Examples of certification schemes

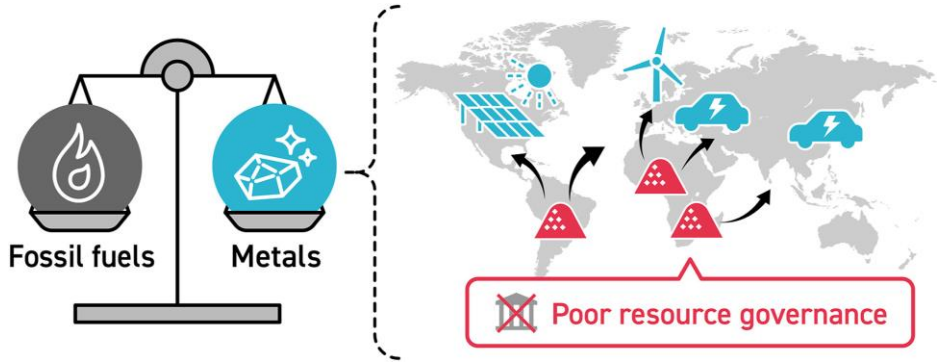
IRMA
Initiative for Responsible Mining Assurance

CERA
CERTIFICATION OF RAW MATERIALS

RESPONSIBLE MINERALS INITIATIVE

Summary

- An inverse relationship exists between carbon emissions and resource extraction
- Growth in resource extraction will be concentrated in countries with weak, poor, and failing resource governance
- Circular economy strategies can moderate resource extraction growth, but mine development is inevitable
- Responsible sourcing are required when supply cannot be met by circular resource flows



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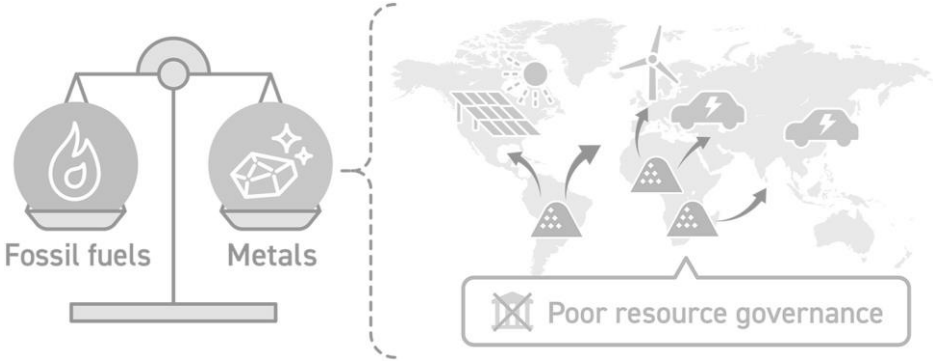

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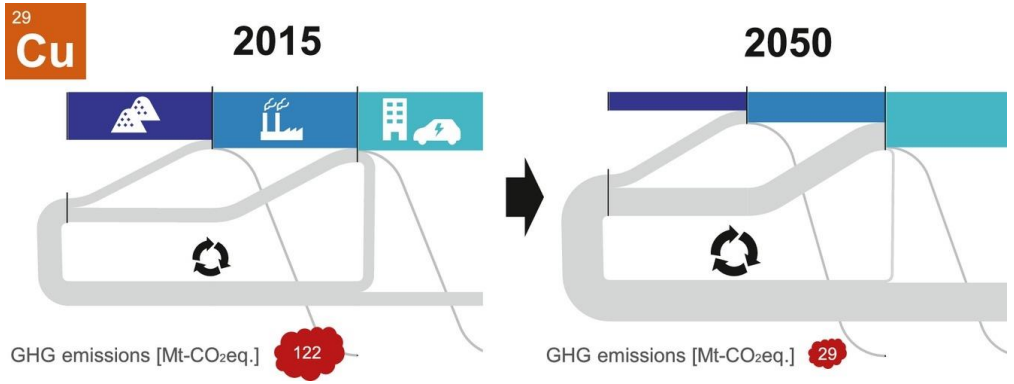

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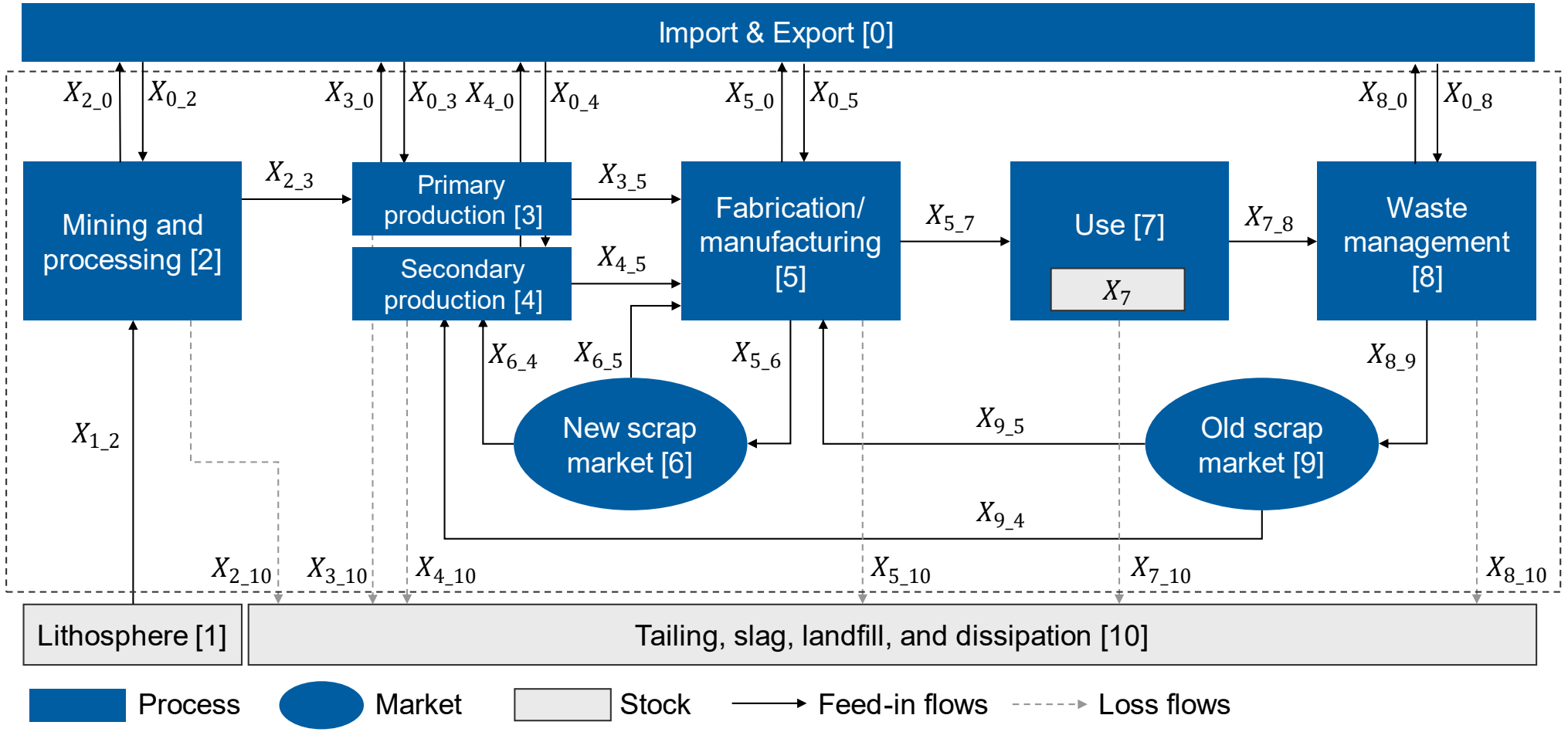
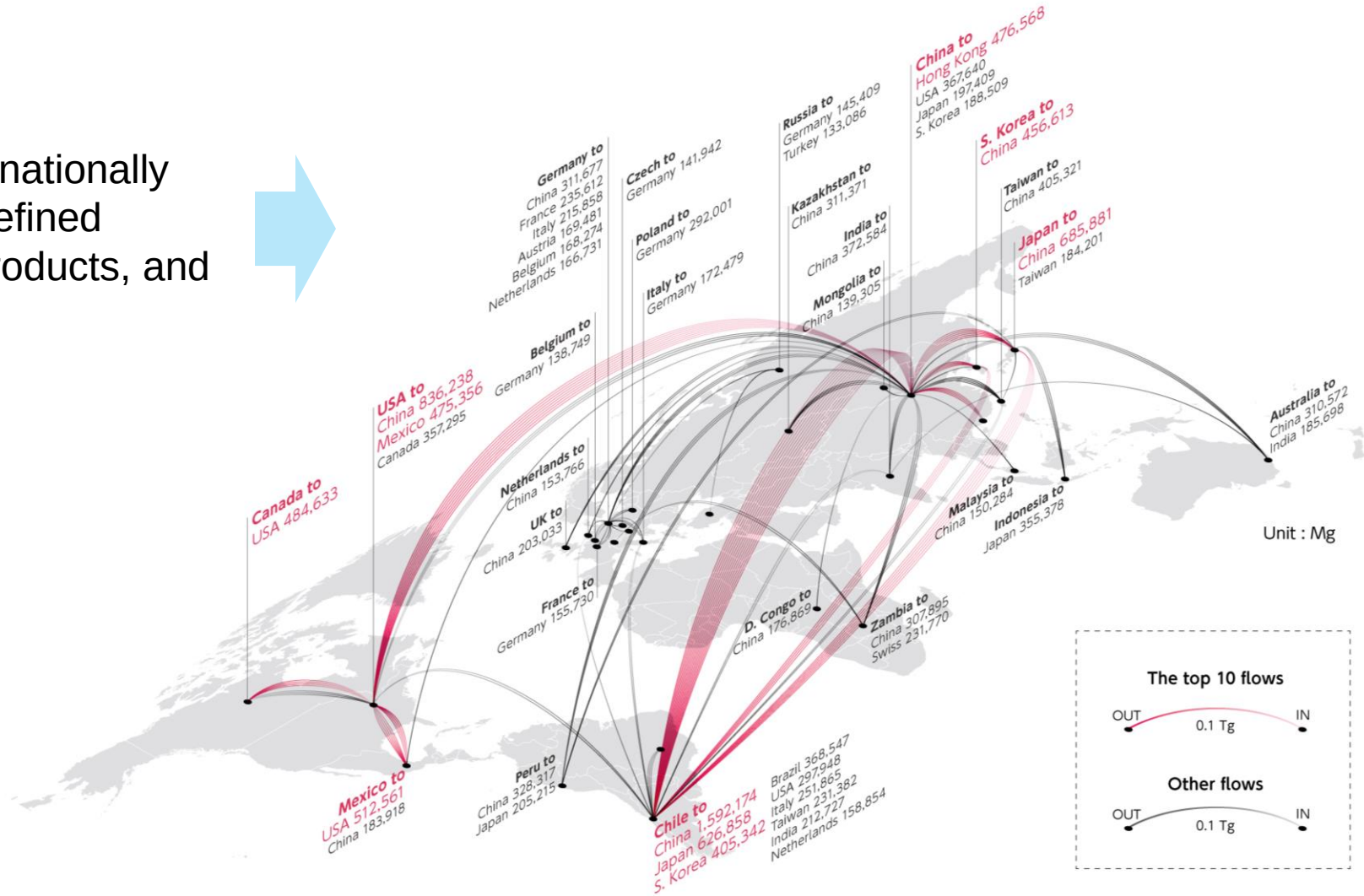
Modelling the global copper cycle

System boundaries: Copper, World, 1900-2050



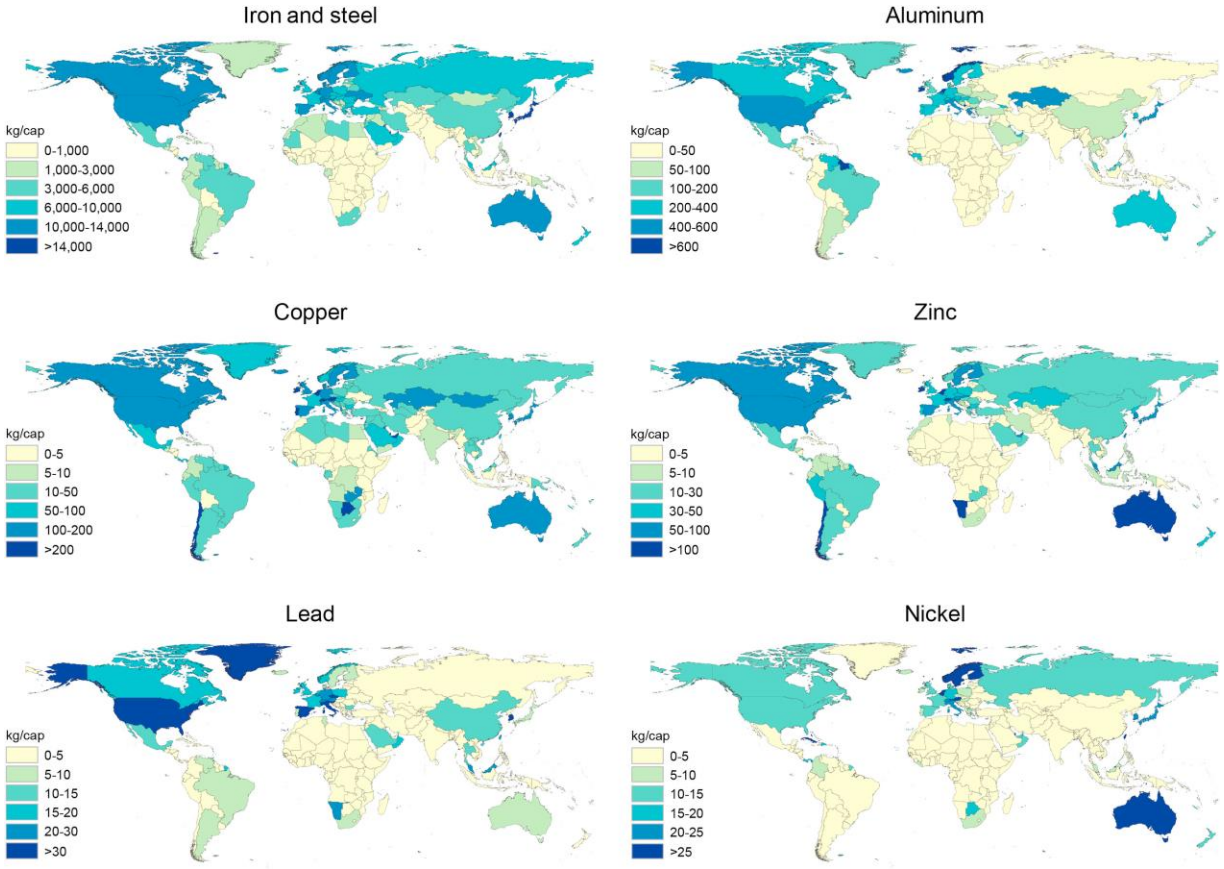
International trade flows

Copper is traded internationally as ore, concentrate, refined metal, intermediate products, and finished products



Where does the metal accumulate as a product?

A substantial inequality exists in international in-use metal stocks

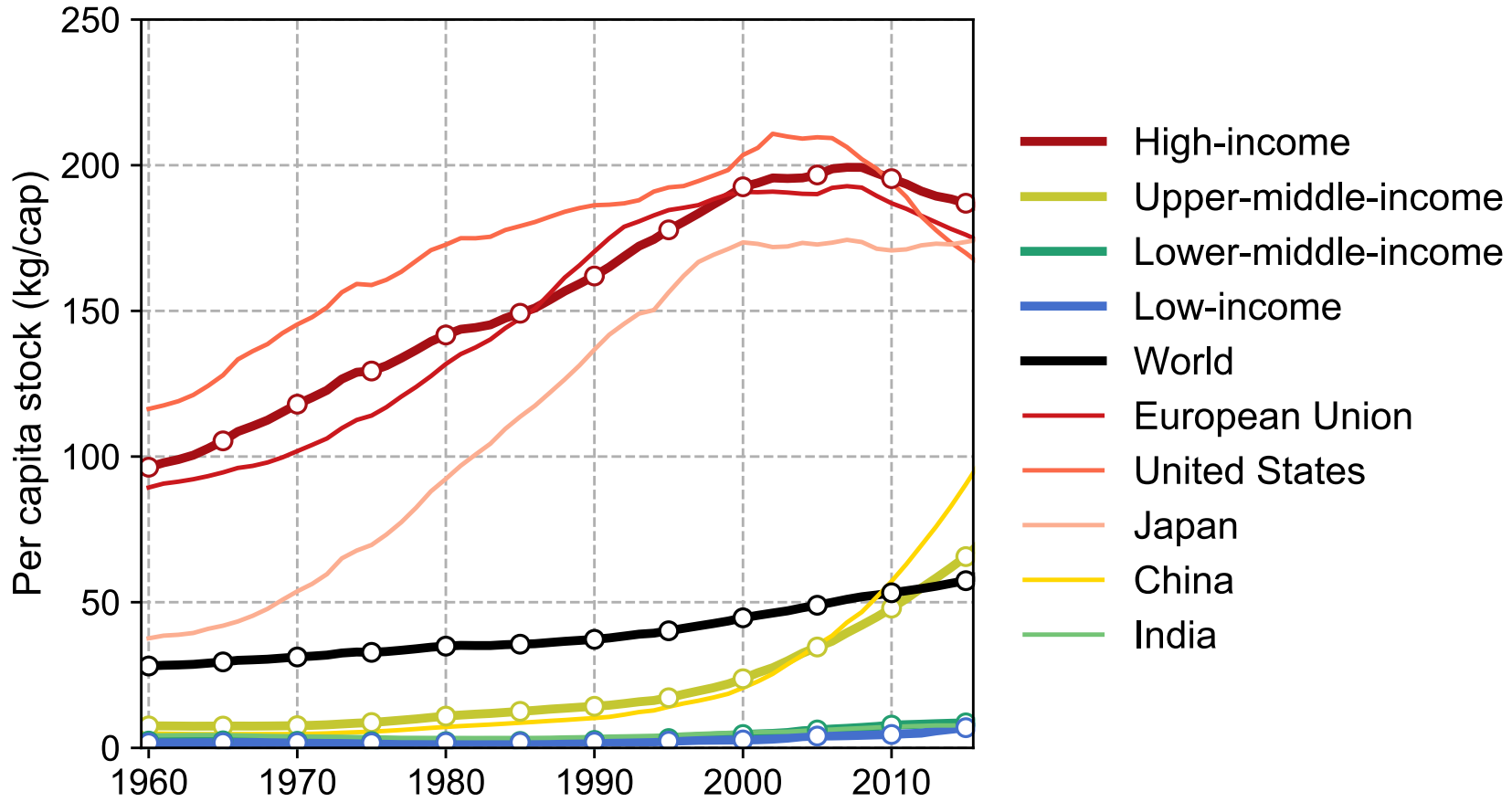


The highest 20% of the population accounted for 60–75% of the world's total metal stock, while the lowest 20% accounted for only about 1%

Where does the metal accumulate as a product?

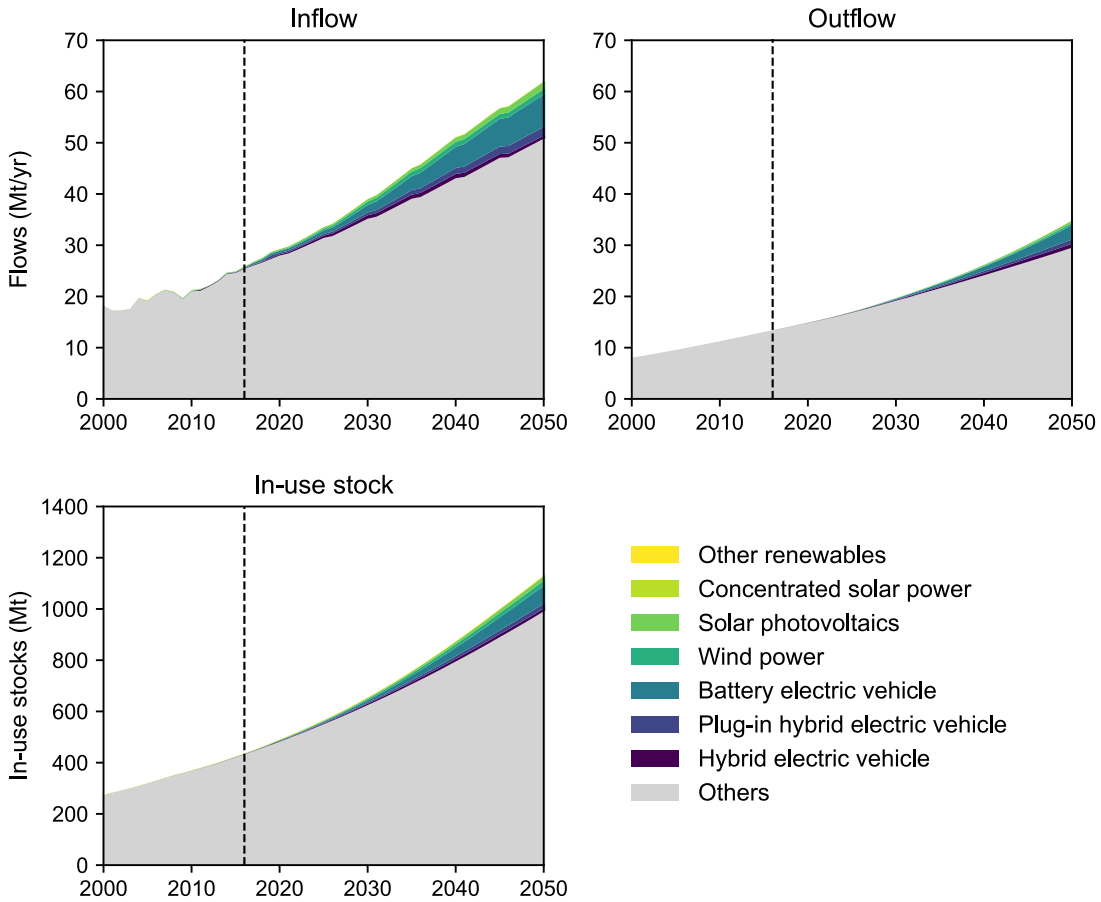
A substantial inequality exists in international in-use metal stocks

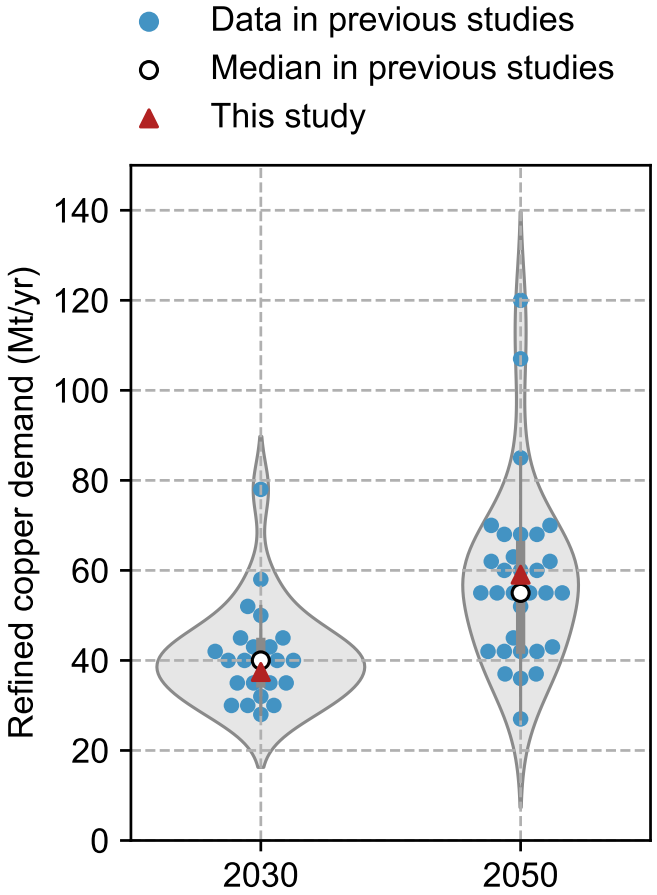
29
Cu



To what extent will copper demand grow?

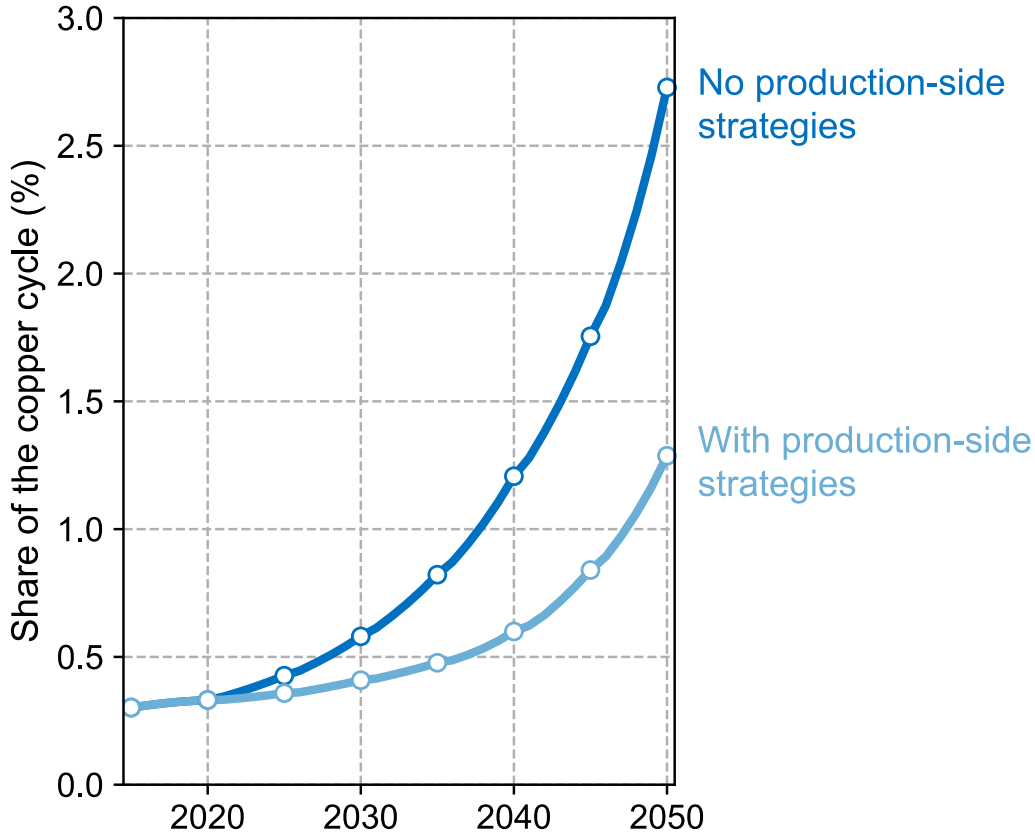
Global demand for copper could increase by a factor of 2.5 by 2050

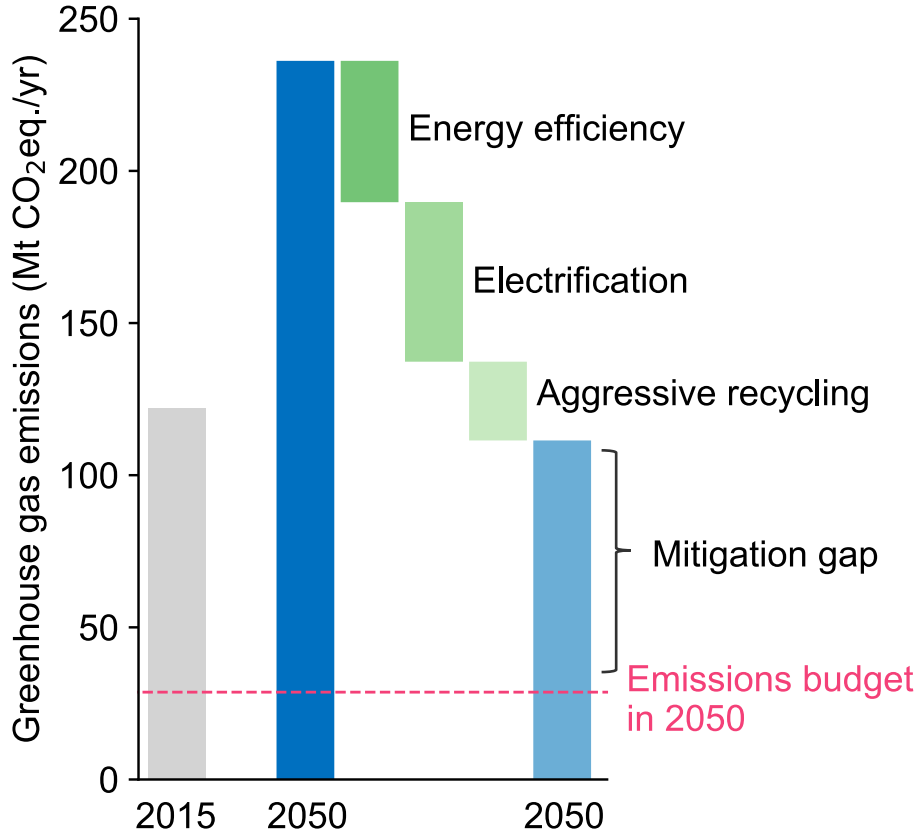




What will be the contribution of copper to the carbon budget?

Copper cycle related emissions could account for 2.7% of the total emissions budget by 2050





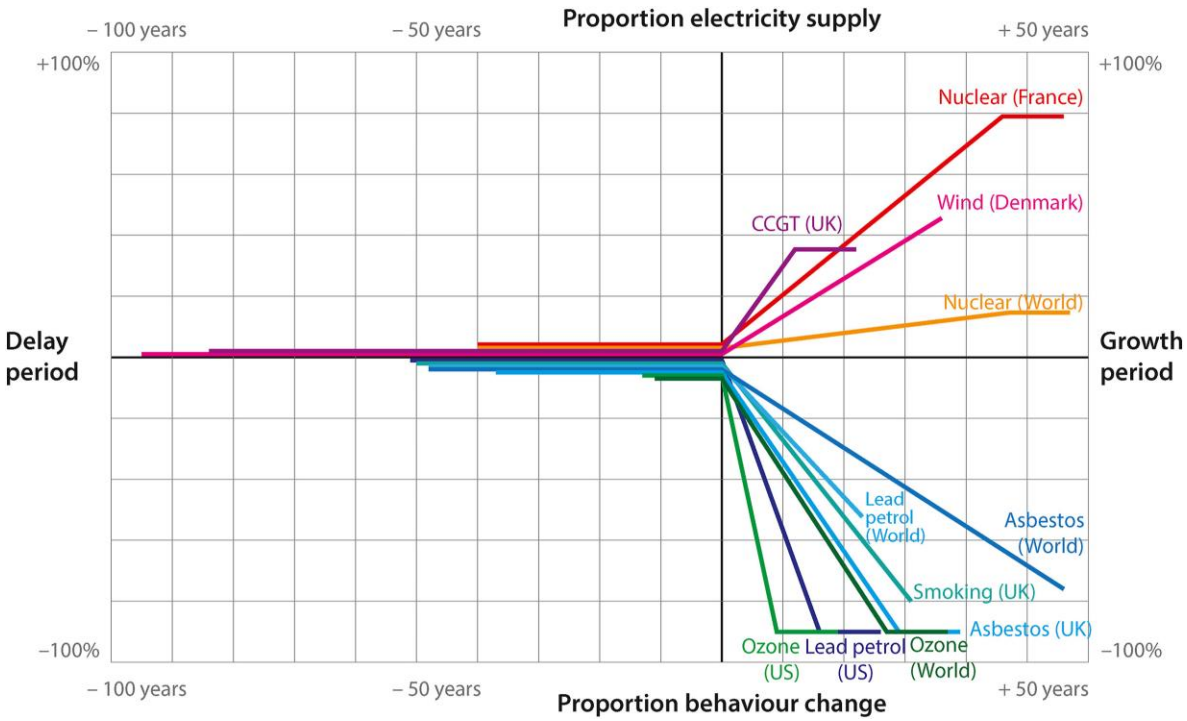
How can the mitigation gap be filled?

- If we were to rely 100% on production-side measures to close the mitigation gap, the emission intensity of primary production routes would need to be reduced by **52-56%** by 2030 and **95-99%** by 2050 compared to today

- The key point is that the time we have left is extremely limited, and the adoption of new technologies on a global scale will take time

- If production-side measures cannot be scaled up sufficiently in the limited timeframe, how can the mitigation gap be filled?

Implementation of new technology takes time



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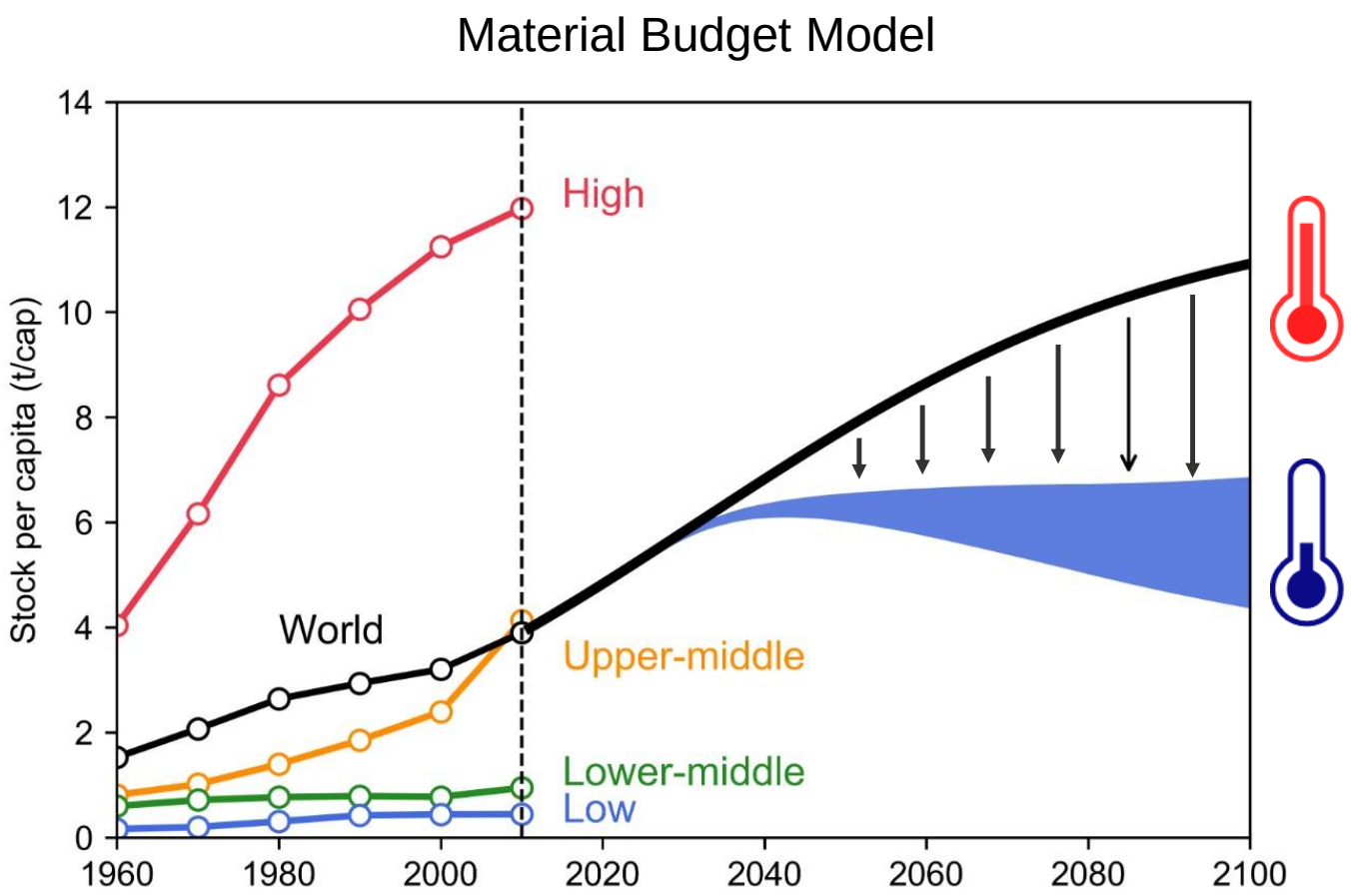
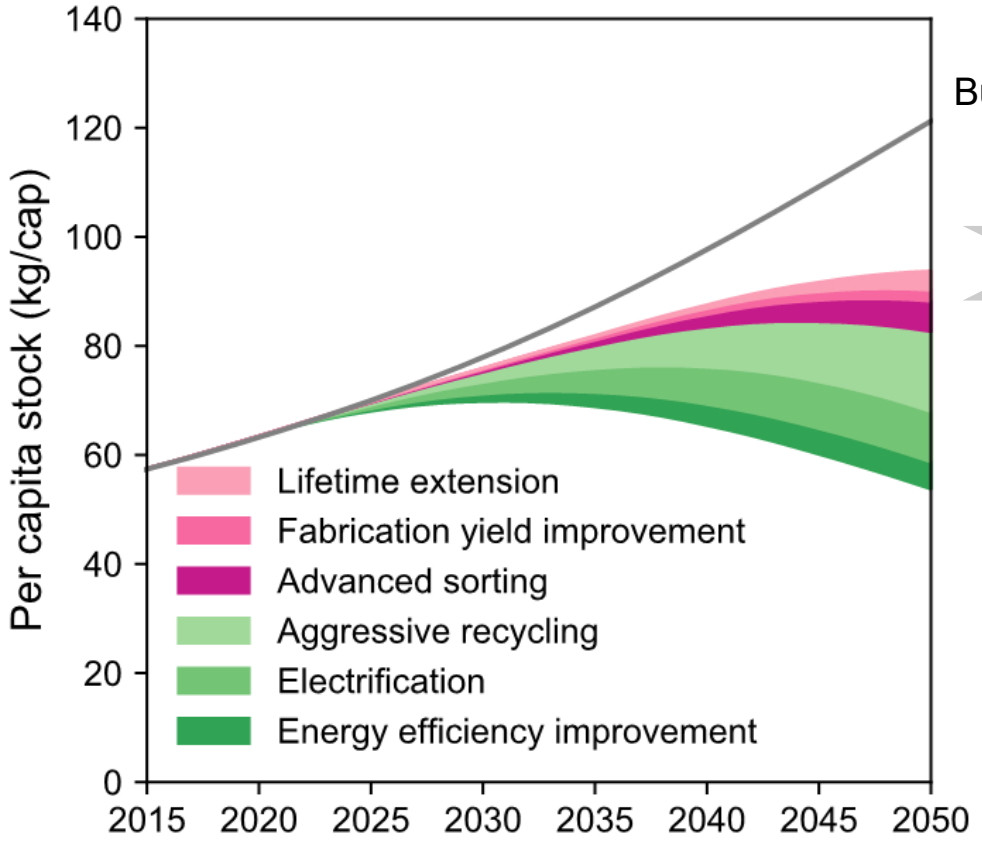


The optimization routine determines the annual copper supply to maximize the in-use stock available under the emissions budget within the scenario period

How can the mitigation gap be filled?

Service efficiency of copper in-use stock needs to be improved



Business as usual

Using less by increased service efficiency

Strategies to increase available in-use stock

If our service demand could be met with about **a quarter less** stock per capita relative to the business as usual, emissions from copper production could be kept within the emissions budget

T. Watari et al. (2022) *Resource Conservation and Recycling*, 179, 106118

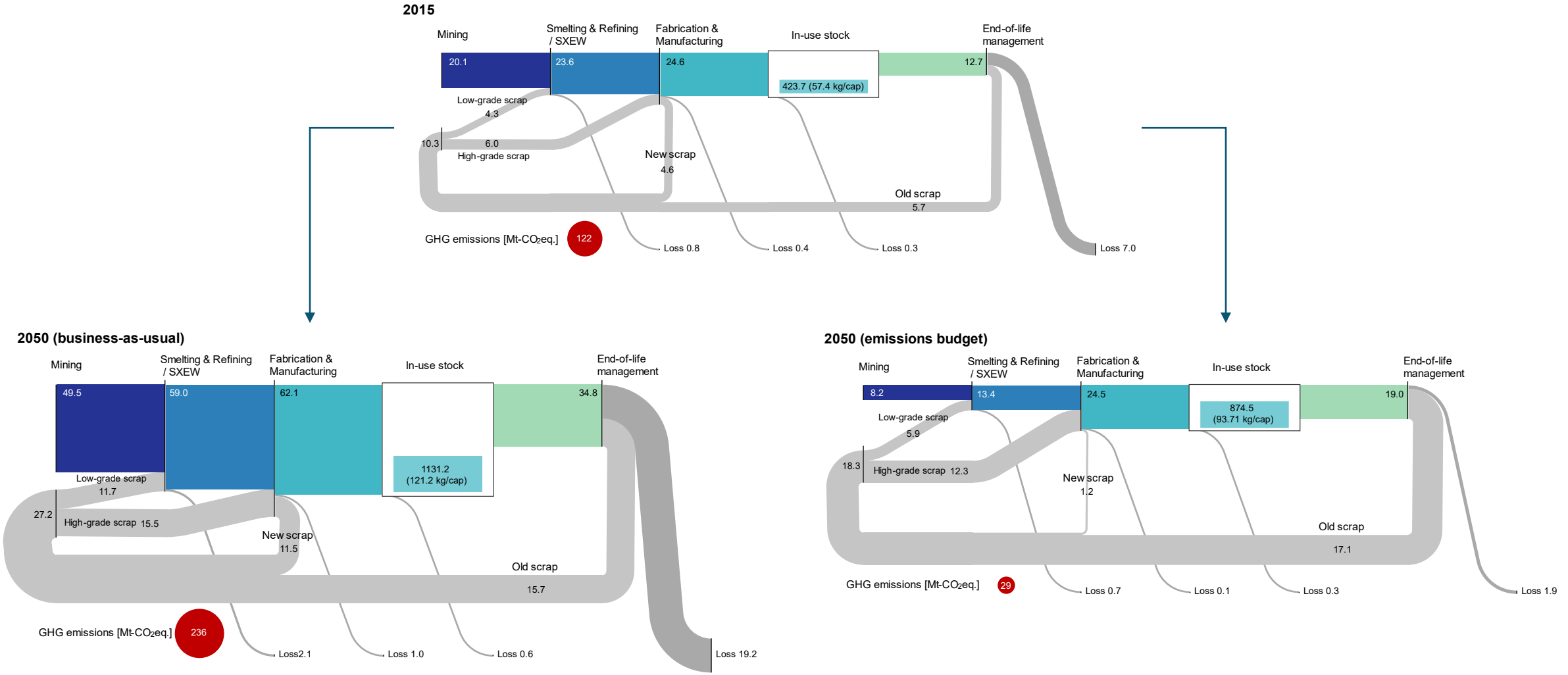
How can the mitigation gap be filled?

System-wide solutions require the collective action by diverse stakeholders

Strategies	Production-centric	System-wide	Key stakeholders
Energy efficiency			Miners / Smelters / Refiners
Electrification			Miners / Smelters / Refiners
Aggressive recycling			Waste processors
Further innovation (e.g., biofuels, CCUS)			Miners / Smelters / Refiners
Advanced sorting			Product designers / Waste processors
Fabrication yield improvement			Manufacturers
Lifetime extension			Product designers / Manufacturers / Property owners
Using less by design or more intensive use			Product designers / Urban planner/ General consumer
Total			

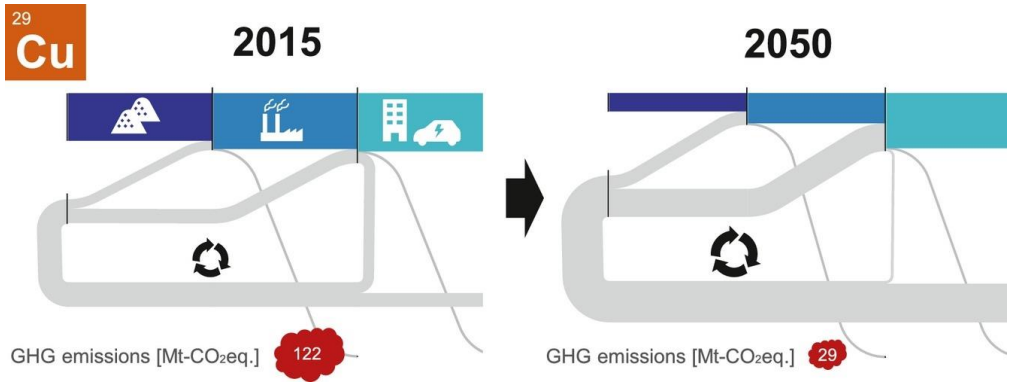
GHG emissions savings: 500 Mt-CO_2eq

Understanding the copper cycle with Sankey diagrams



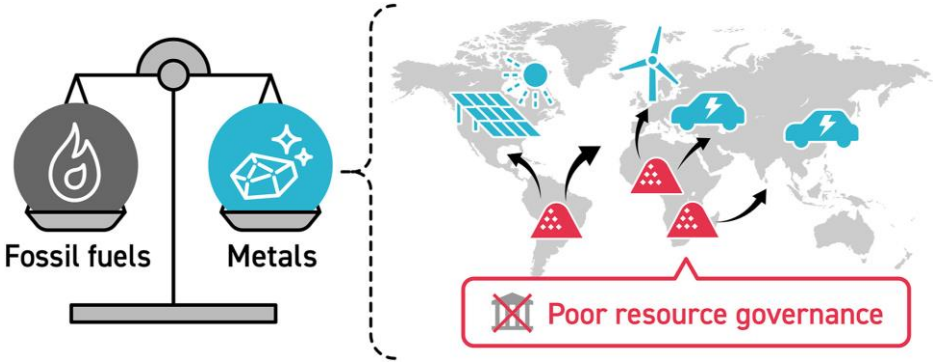
Summary

- Global final demand for copper could increase by a factor of 2.5 between 2015 and 2050
- Copper cycle related emissions could account for 2.7% of the total emissions budget by 2050, up from 0.3% today
- Service efficiency of copper in-use stock needs to be improved through such measures as enhanced sharing practices and better design
- System-wide solutions require the collective action by diverse stakeholders



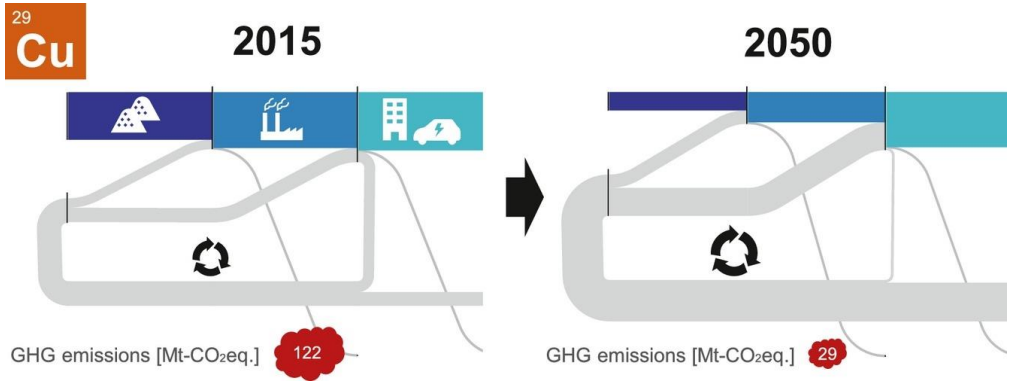
Two key perspectives

1. Implementation of decarbonization technologies



Responsible governance of resource extraction, in relation to the deployment of energy technologies

2. Imposition of an emissions budget on production activities



Improvement of material efficiency to meet our service demands with less material use

Material flow innovation research program - Innovative Transitions in Material Flows toward Planetary Health

National Institute for Environmental Studies, Japan

Goals

The research program aims to accumulate scientific knowledge on the embodiment of transition pathways for material flows, which build a foundation for planetary health, and supporting the enhancement of resource productivity and circular economy policies. Outcomes of the program are expected to encourage the various stakeholders involved in material life cycles to implement new long-term strategies to innovate material flows.

PJ1

Material flows transition and social adaptation

Direction for transition, science-based target, adaptation measures

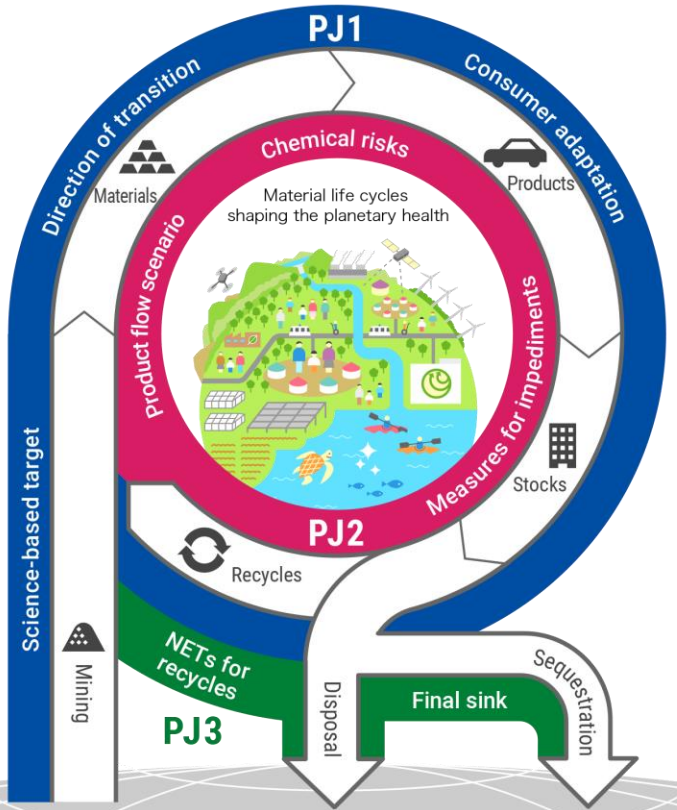
- Disciplines: Environmental systems
- Viewpoint: Macroscopic view of natural resource flows
- Focused materials: Metals and biomass
- Time frame of analysis: 2050 > 2100
- Target region: Global and Japan

PJ2

Chemical management for material flows transition

Measures for chemicals and pollutions impeding transition

- Disciplines: Environmental systems and risk
- Focused materials: Plastics, WEEE, By-products of soil and stone
- Viewpoint: Microscopic view of material product flows
- Target region: Japan
- Time frame of analysis: 2030 > 2050



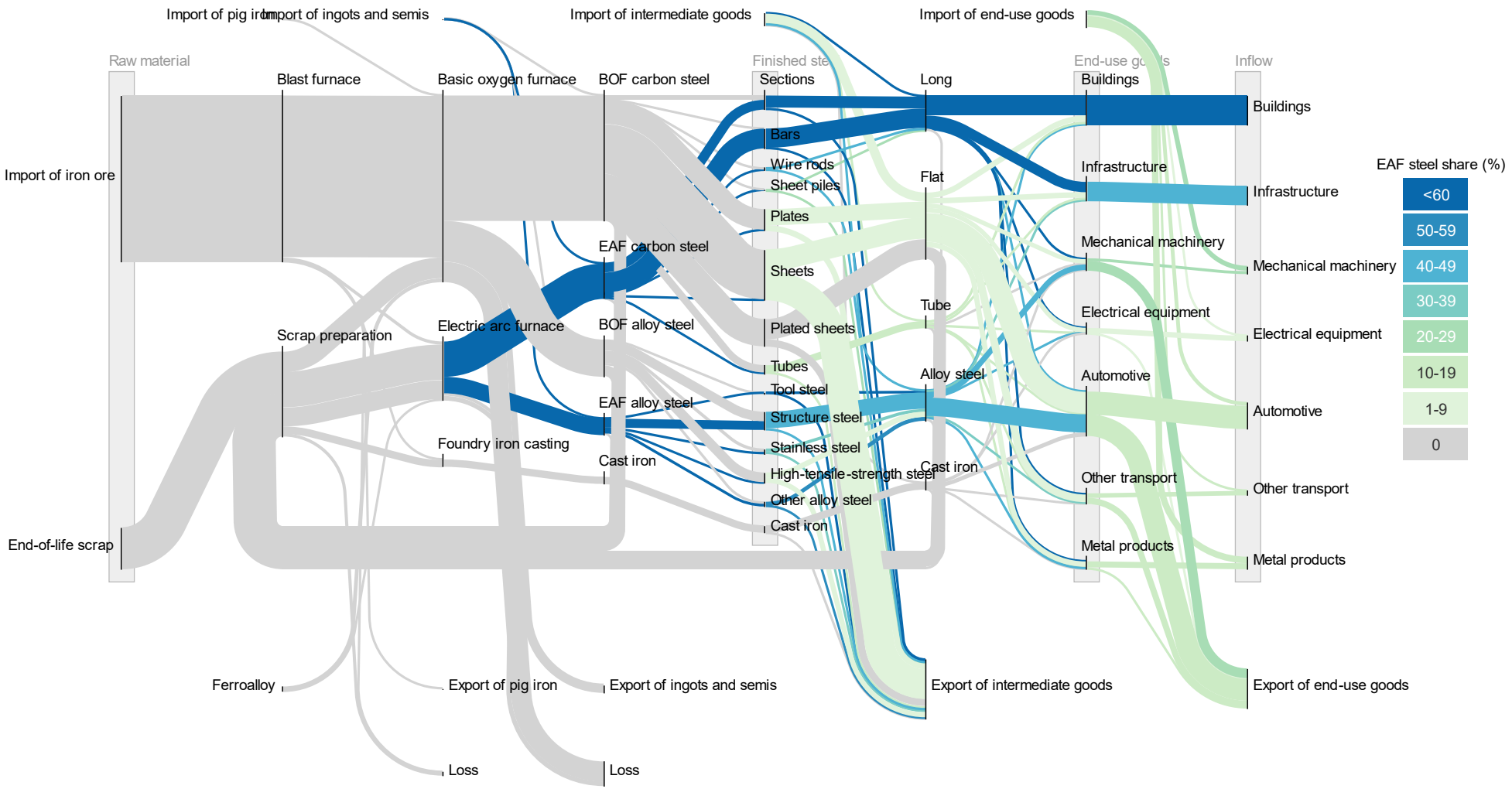
PJ3

Material circulation and sequestration technology

Development of material circulation and sequestration technologies and systems that are adaptable to transition

- Disciplines: Environmental systems and engineering
- Viewpoint: Microscopic view of materials to be recycled and sequestrated
- Focused materials: Wastes
- Target region: Japan
- Time frame of analysis: 2030 > 2050

Ongoing works – Steel



Thank you for your kind attention

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