The stock-flow-service nexus approach to socio-metabolic research: conceptual advances and first empirical examples

Universität für Bodenkultur Wien
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Social metabolism: A systemic perspective on resource use

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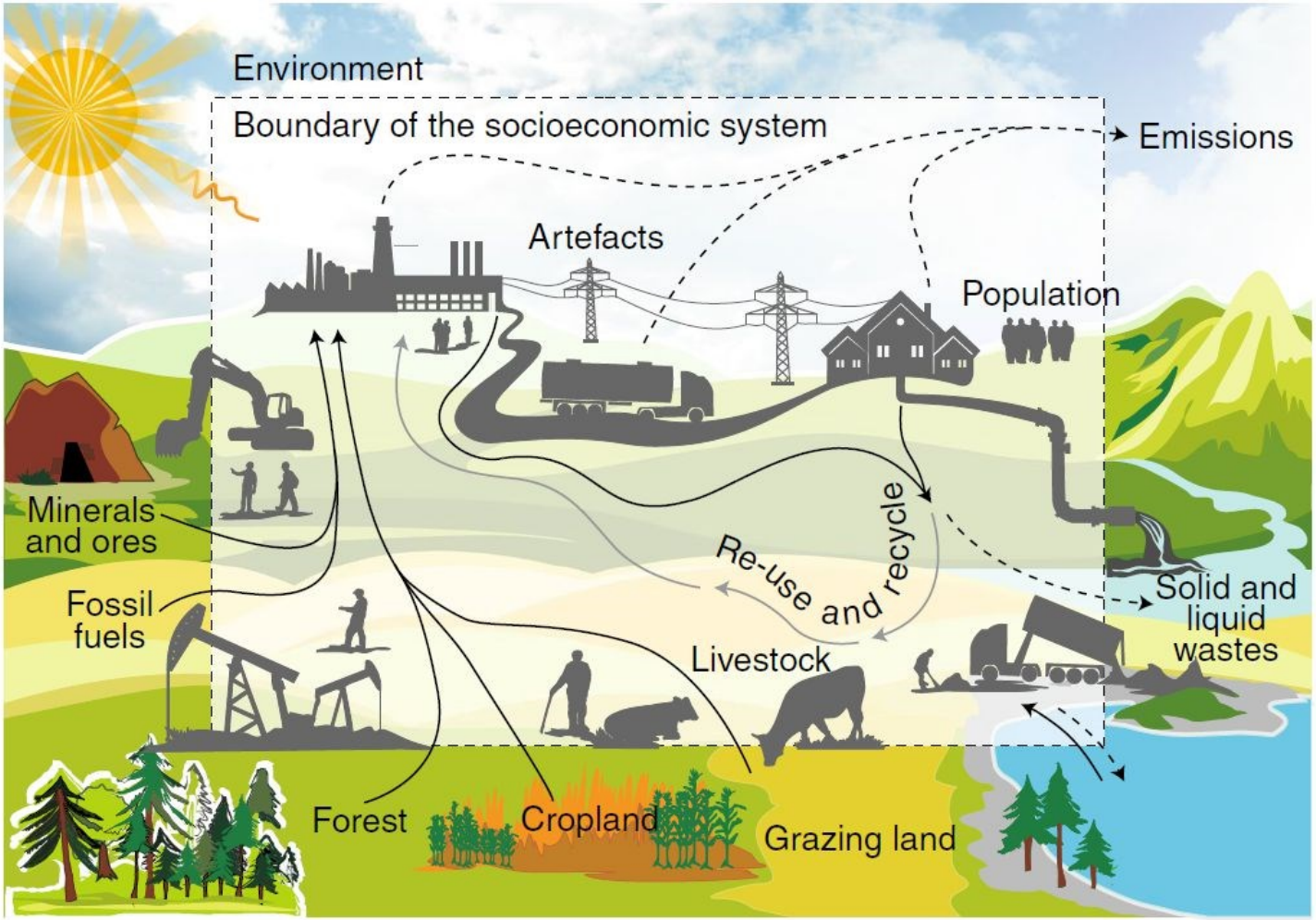

Haberl *et al* 2019. *Nature Sustainability* **2**, 173–184

The stock-flow-service nexus

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Stocks Buildings, infra-structures, machinery

Much richer than ratios such as
- materials/GDP
- energy/GDP
- GHG/GDP

Flows
Energy, materials

Services
Contributions to social well-being

Fotos: Helmut Haberl

Haberl *et al* 2017. *Sustainability* **9**, 1049
Kalt *et al.* 2019, *Energy Res & Social Sci*, **53**, 47-58

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Why material stocks are important

- They transform resources into services such as shelter, nutrition or mobility.
- Building up and maintaining stocks requires large amounts of resources.
- They shape social practices (including production and consumption), thereby creating path dependencies for future resource use

GHG emissions from fossil fuels required for using existing infrastructures until the end of their lifetime almost exhausts the emission budget for the 1.5°C target (Smith *et al.* 2019. *Nature Communications* 10, 101)

Quantifying material stocks using the MISO model

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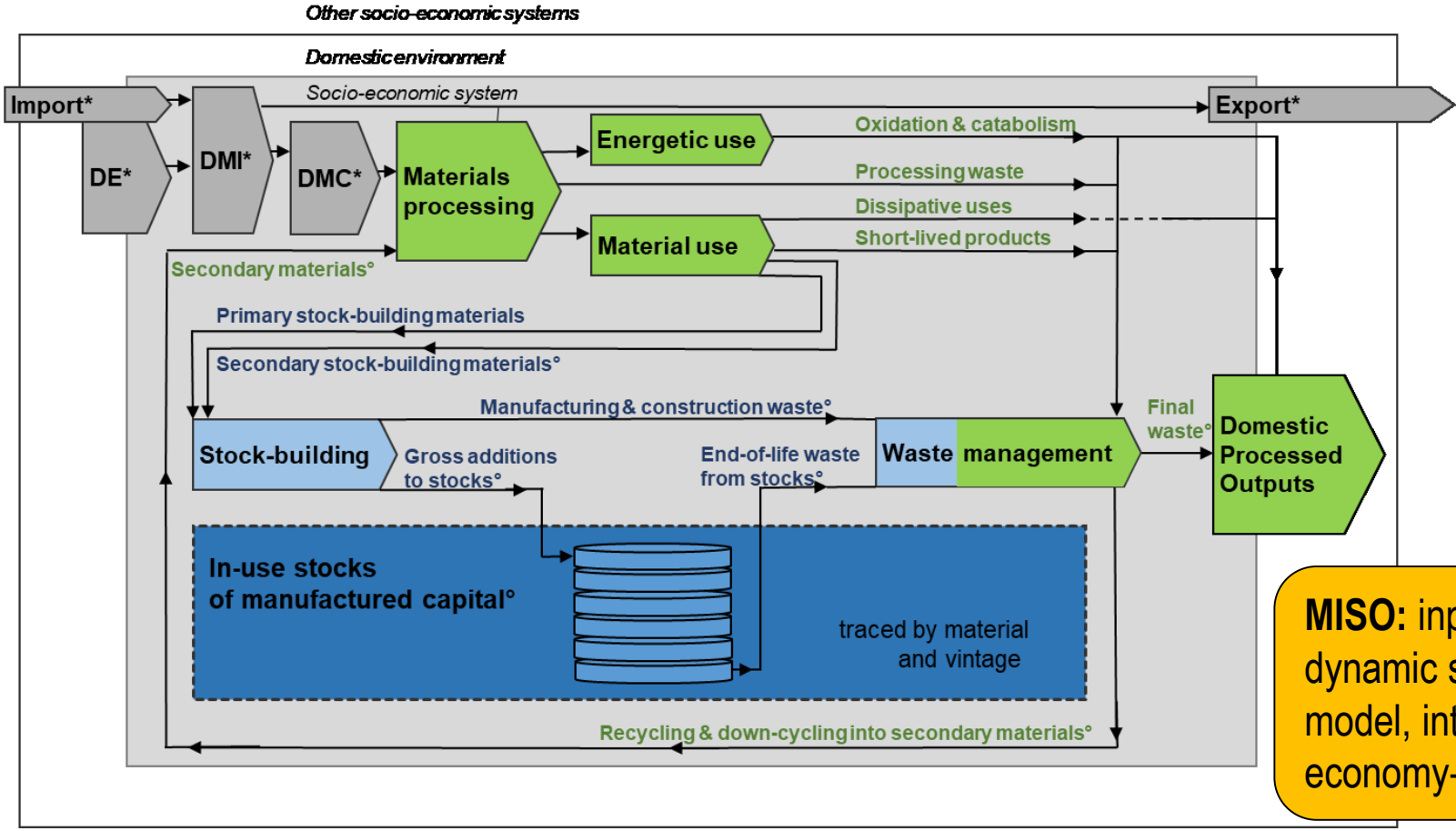

MISO: input driven, dynamic stock-flow model, integrated in economy-wide MFA

Wiedenhofer, et al. 2019. *Ecol. Econ.* **156**, 121-133

Global material stocks and flows
1900-2015

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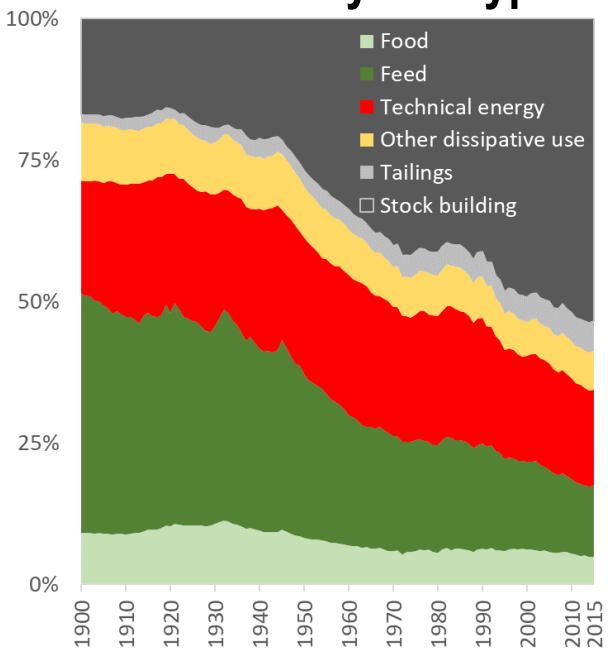
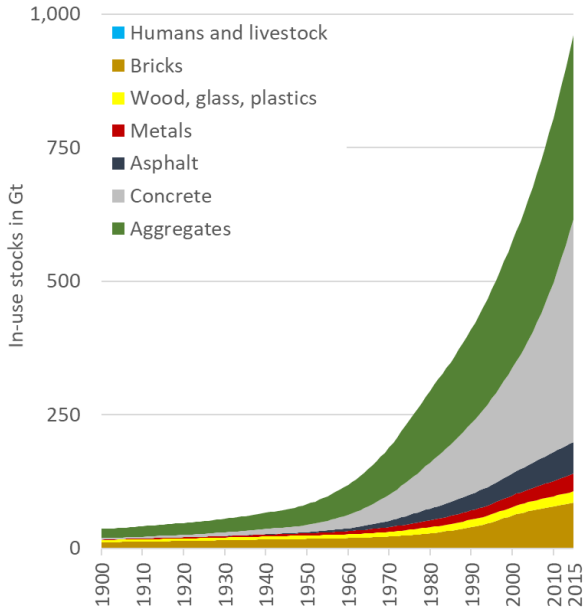
Share of stock-building materials increased from 20% to 50%
Stocks increased 27 fold to nearly 1000 Gt
Large differences in per capita stocks between countries

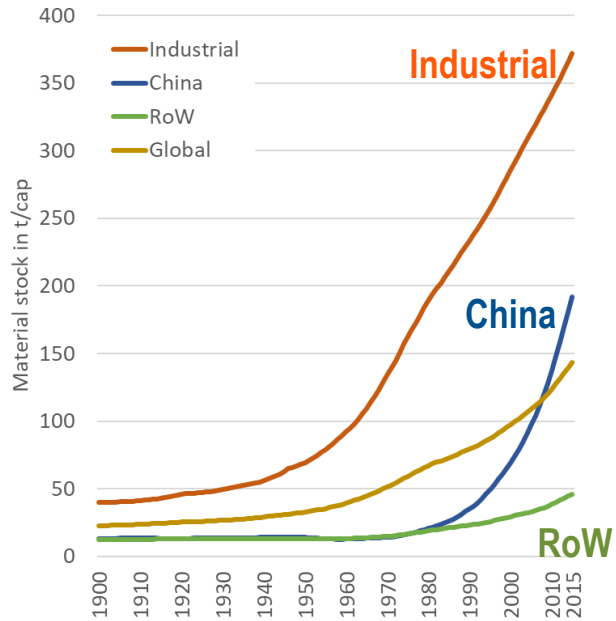
Extraction by use type



In-use stocks of materials



Stock per capita



Krausmann *et al.* 2018. *Global Environm. Change* **52**, 131-140
Krausmann *et al.* 2017. *PNAS* **114**, 1880-1885

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Scenarios for stock development and GHG emissions 2050

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- **GDP-driven scenarios:** GDP development taken from IPCC-SSP2, assumptions on GDP per unit of stock ratio.
  - A GDP-driven high: Constant GDP/stock ratio
  - B GDP-driven low: Trend GDP/stock ratio, only selected results shown here
- **Population-driven scenarios:** Population development (UN median) and assumptions on per capita stocks in 2050.
  - C Convergence1970: Contraction-convergence of global per capita stocks at industrial level of 1970
  - D Convergence2015: Convergence of global per capita stocks at ind. level of 2015
- **Decarbonisation pathways**
  - Trend: little or no improvements in CO_2 intensity of TPES
  - Full decarbonization of energy system in 2070, 2060, 2050, 2040 & 2030
  - C emissions from cement production (calcination) and coke use in blast furnaces continue (hard to decarbonize)*

Krausmann, Wiedenhofer, Haberl, *submitted* **Do not cite, quote or distribute**
* Davis *et al.*, 2018, *Science* **360**, 1419

Global Material Stock Scenarios
1970-2050

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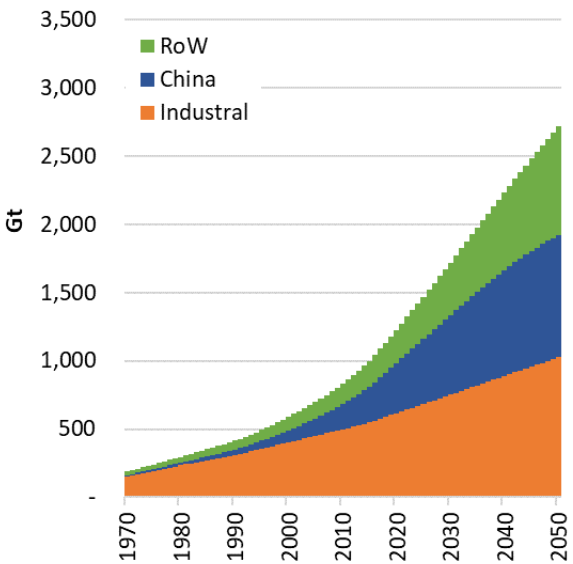
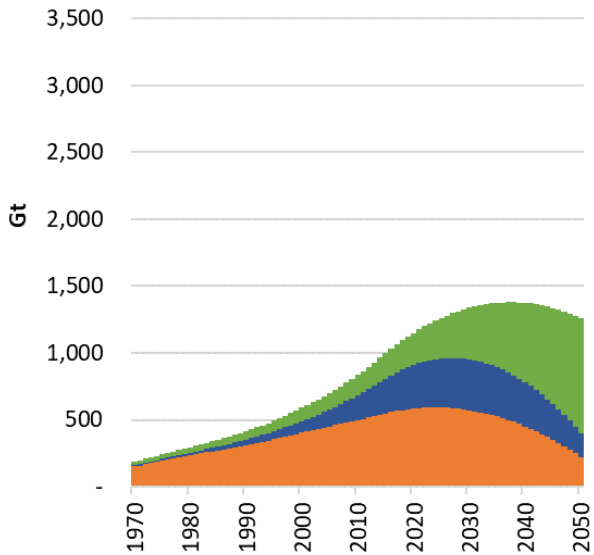
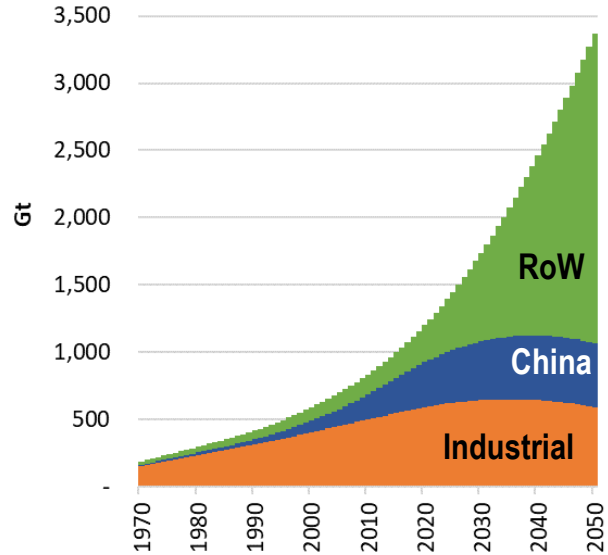
B GDP-driven high



C convergence1970



D convergence2015



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Modelling GHG emissions from fossil fuels & cement production

Based on material stock/energy ratios

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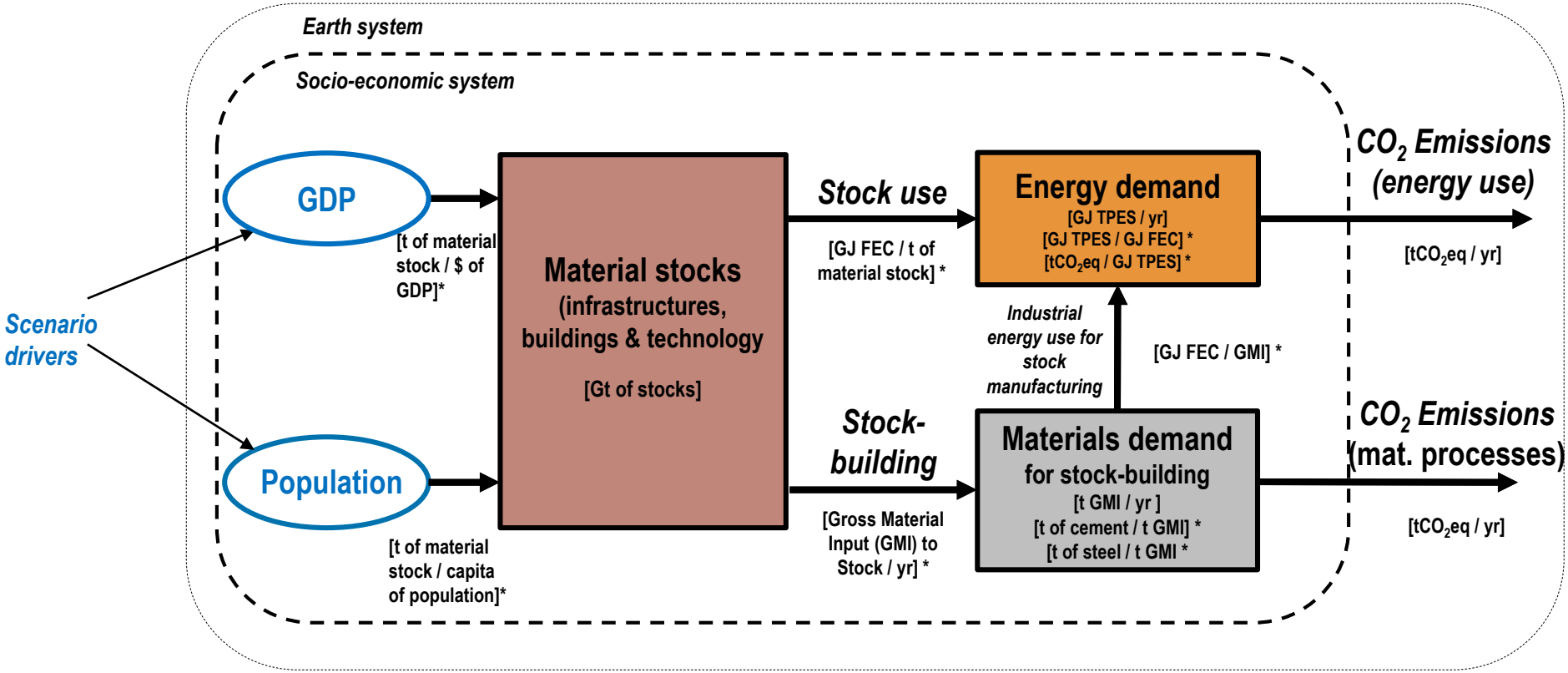

* Scenario variables historically-calibrated

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Scenario results: Development of CO_2 emissions 1970-2050

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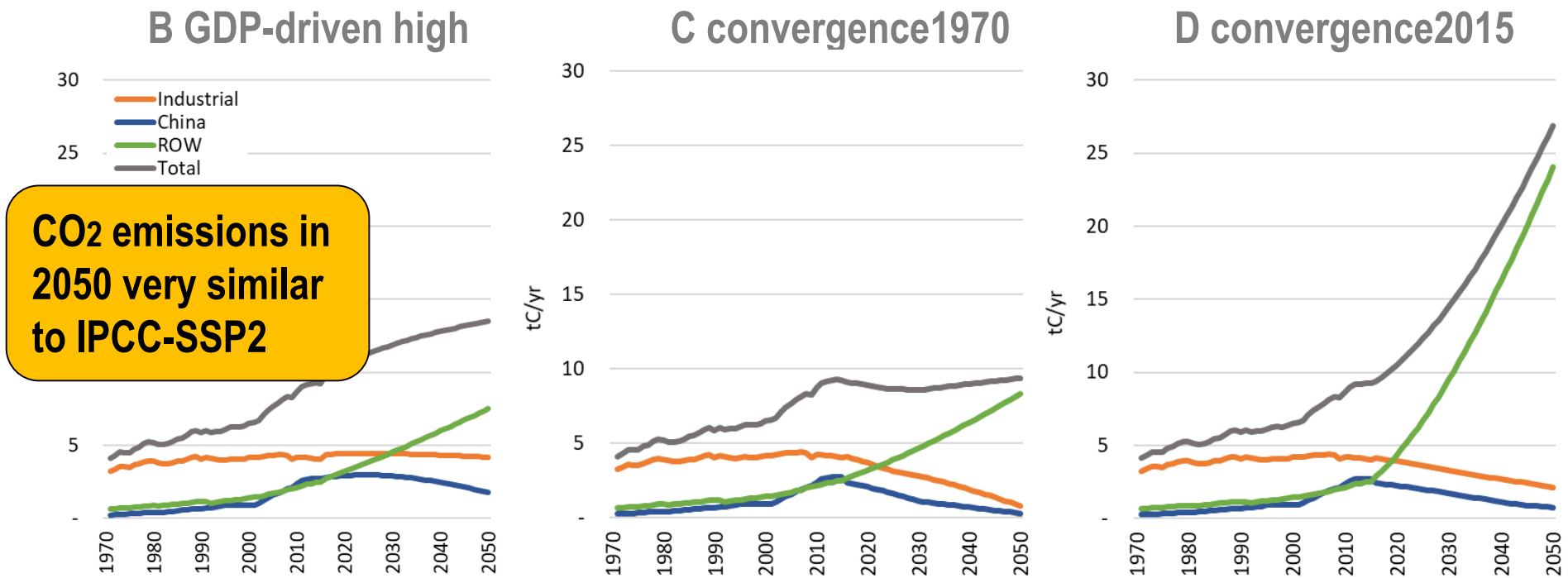
CO_2 emissions in 2050 very similar to IPCC-SSP2



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Remaining carbon budget in 2050 (1.5°C goal): Decarbonization pathways

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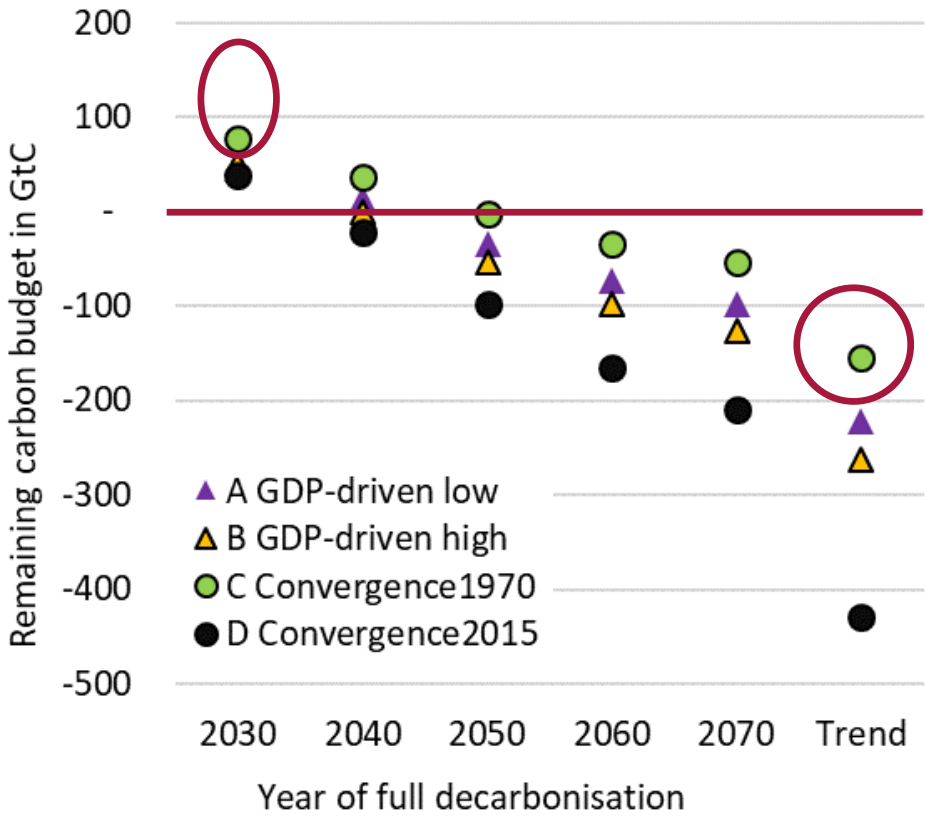

Source: Own calculations, C budget from IPCC 2018

Negative values: Cumulative emissions exceed the available budget of 150 GtC.

Krausmann, Wiedenhofer, Haberl, *submitted*

How to gauge future services from stocks? – many viewpoints

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- **Continuation of the past *(plus large technol. options)***
  Material stocks and exergy tightly coupled with GDP; reducing resource use will reduce wealth; only nuclear, CCS, BECCS and/or geoengineering available to cope with climate change (many IAM runs)
- **Techno-optimistic „eco-efficiency“ view**
  Highly efficient systems allow delivery of simililar service levels with half the final energy and almost zero CO_2; achievable through huge changes in investment patterns (e.g. Grubler *et al.*, 2018, *nature Energy* **3**, 515)
- **Socioecological transformation**
  Services / use values emerge in historically contingent societal processes. Different patterns of material stocks and resource flows co-evolve with socioeconomic institutions and structures

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Stocks and flows vs. social progress

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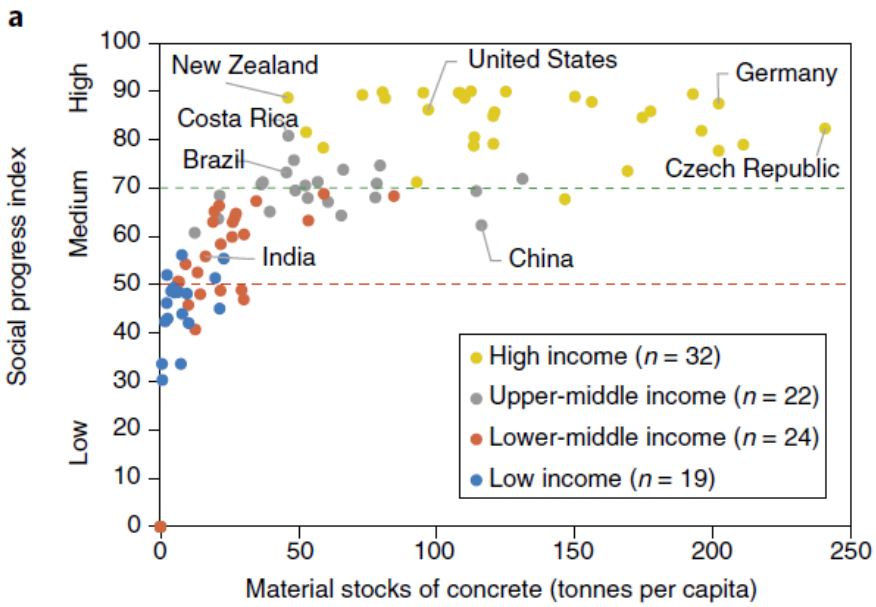
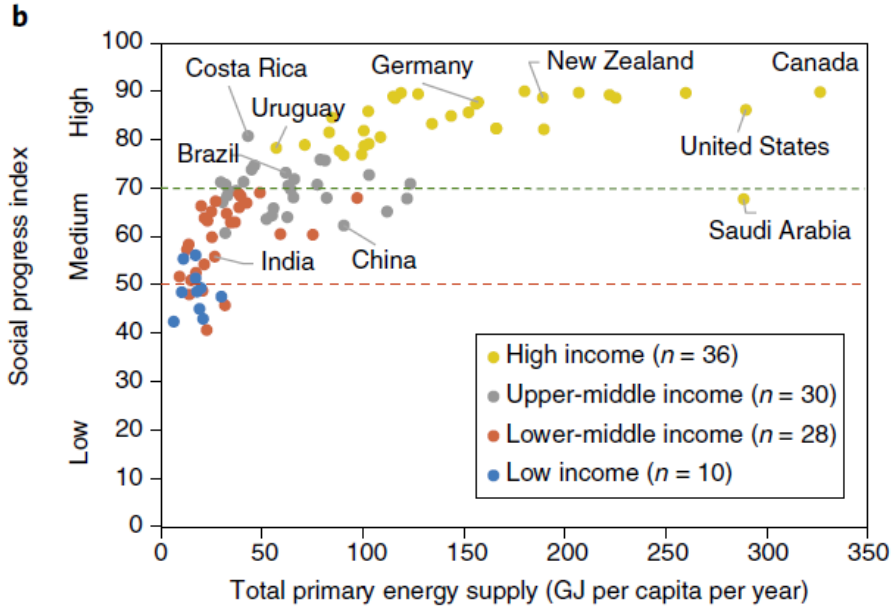
Concrete stocks



Primary energy supply



Social Progress Index (SPI) is an outcome-based index of social wellbeing considering nutrition, shelter, water, sanitation, safety, access to knowledge, freedom, human rights, environmental quality, but no monetary indicators such as GDP

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Haberl *et al* 2019. *Nature Sustainability* **2**, 173–184

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Stocks, flows and services in the Anthropocene

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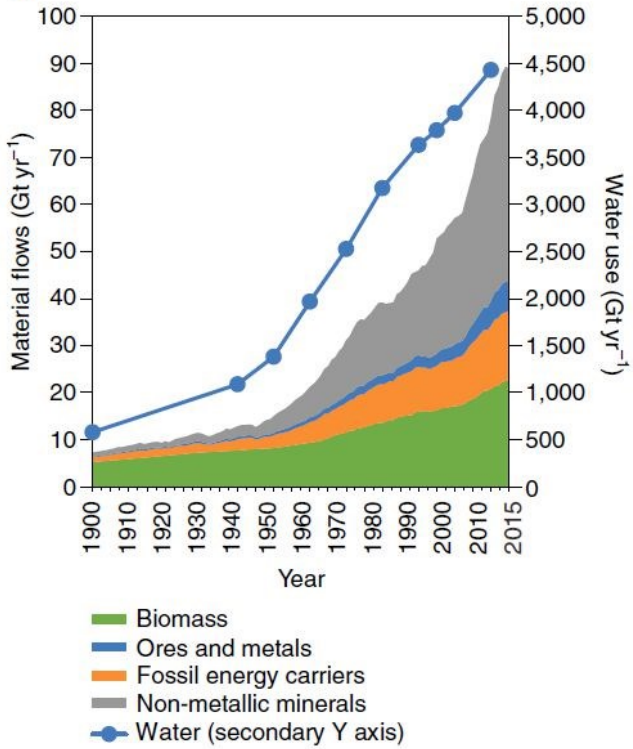
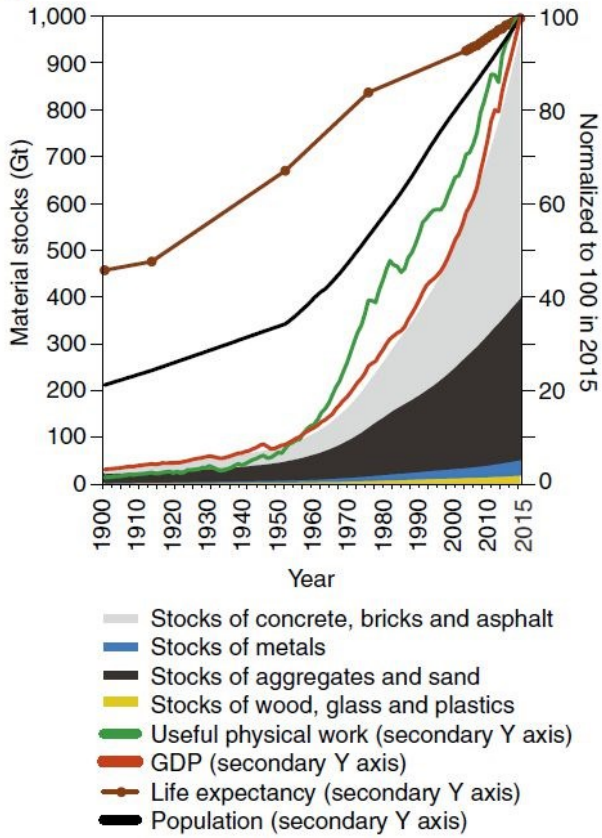
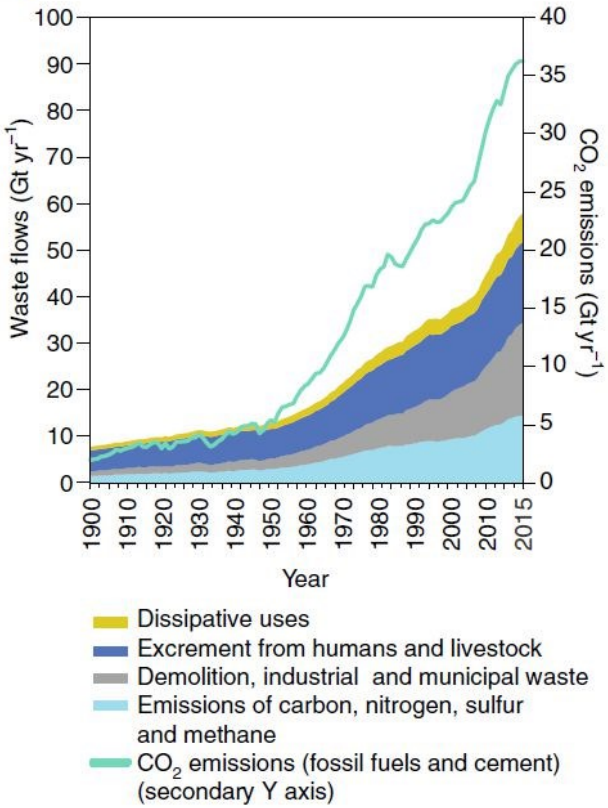
Inflows



Stocks & services



Outflows



Haberl *et al*. 2019. *Nature Sustainability*, **2**, 173–184

Conclusions

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- Future stock scenarios demonstrate the **importance of inequalities** in per capita stocks and population growth for future emissions
- Planetary boundaries **will not allow abolishing global inequalities by achieving the same levels of stocks and flows** across the globe
- Alternative development models are required where a **good life requires much lower material stocks and resource flows**
- Such models will transform socioeconomic institutions and structures: **raising eco-efficiency is good, but not sufficient**

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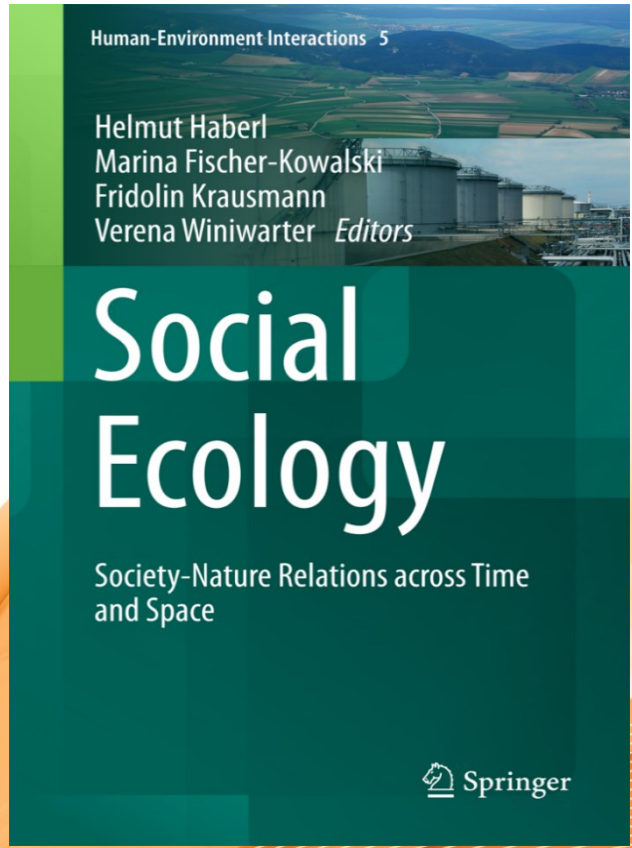

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Per capita stock in 2050: Large differences across groups and scenarios

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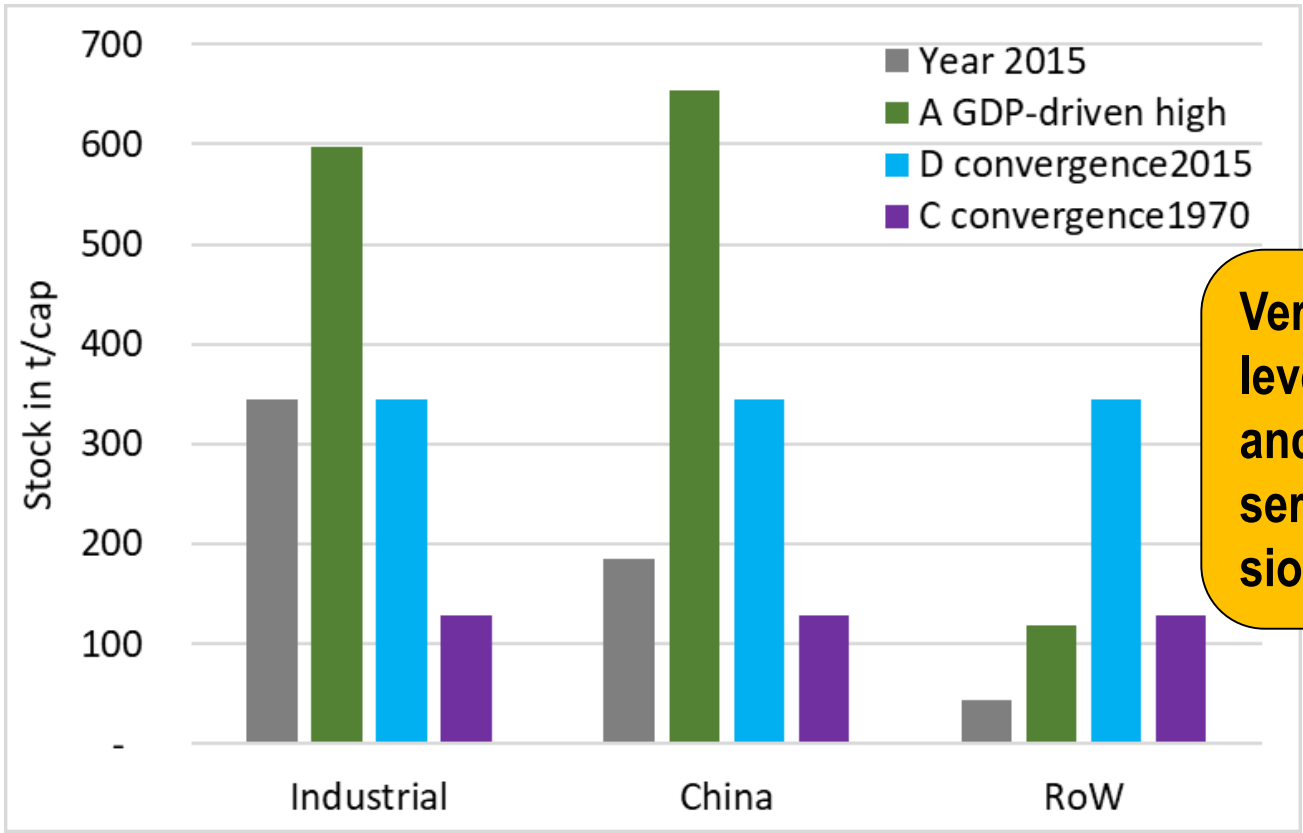

Very different levels of stocks and probably service provi-sion per capita!

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Selected Scenario assumptions and model parameters 1980-2050

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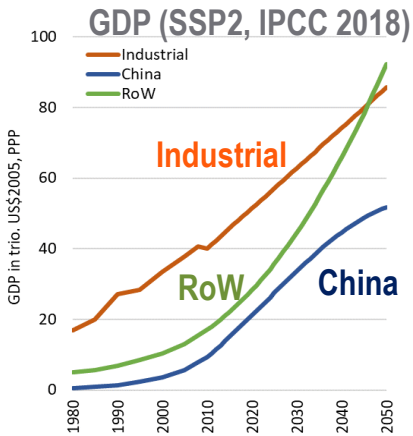

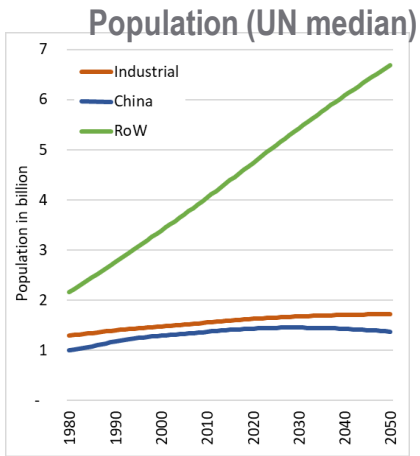

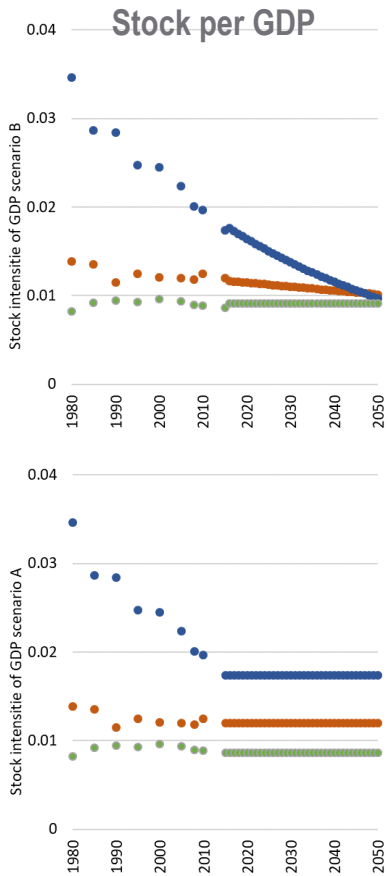

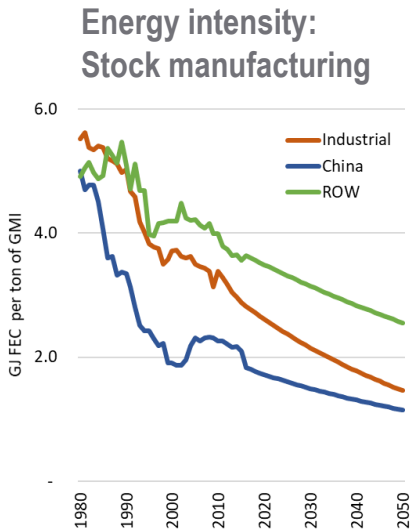

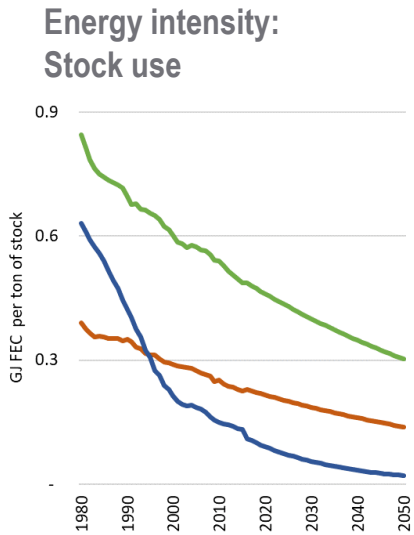

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Scenario results: CO_2 emissions from stock manufacturing and stock use

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	Average yearly TPES (2016-2050) [EJ/yr]	Share of manufacturing in TPES [%]	Cumulative CO_2 emissions (2018-2050) [GtC/yr]	Share of manufacturing in CO_2 emissions [%]
2015	554	37%		44%
A GDP-driven high	724	35%	401	42%
B GDP-driven low	673	31%	361	38%
C convergence1970	567	29%	293	35%
D convergence2015	1066	37%	568	42%

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