Shrinking global social metabolism

The role of infrastructure and settlement patterns

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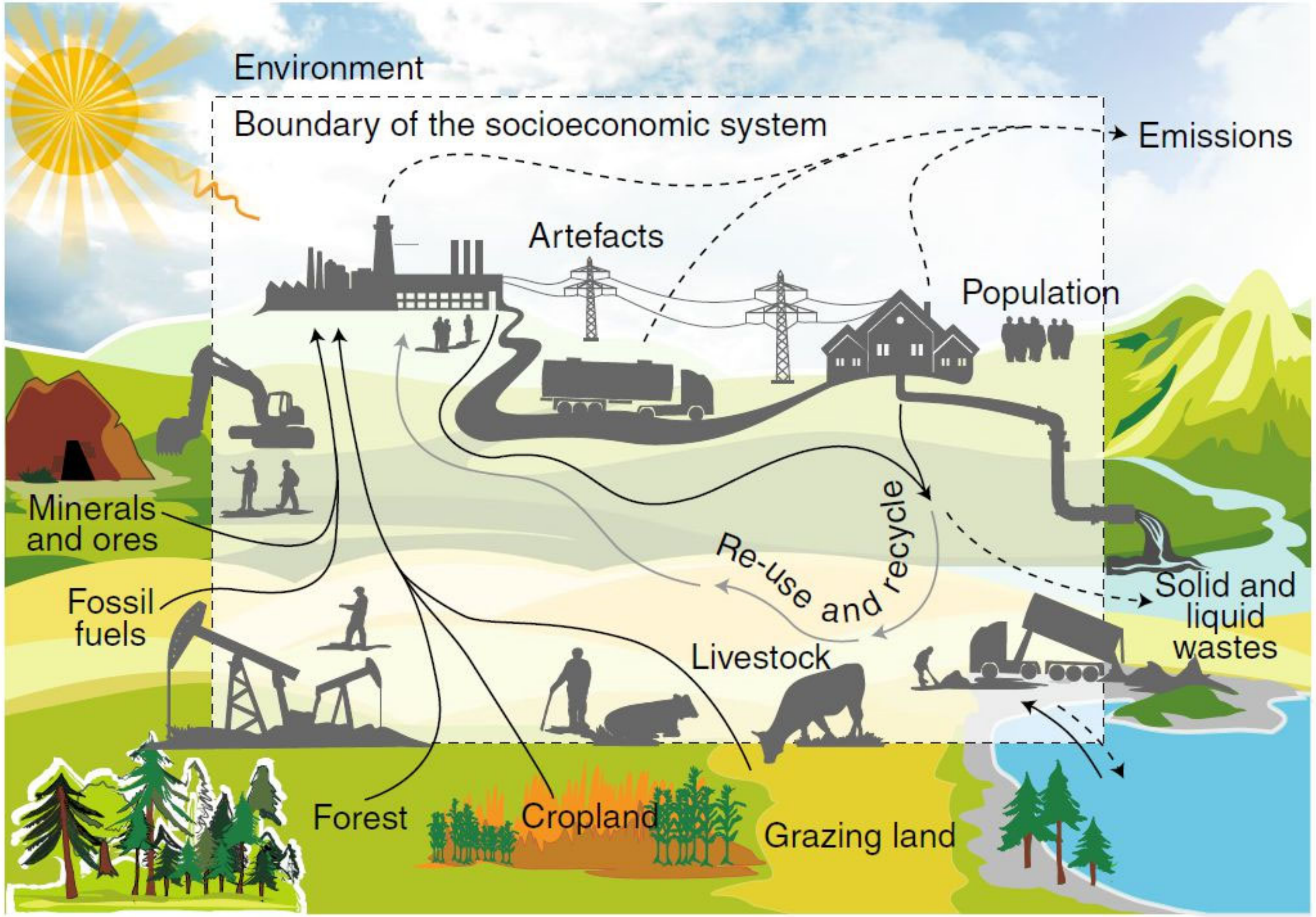
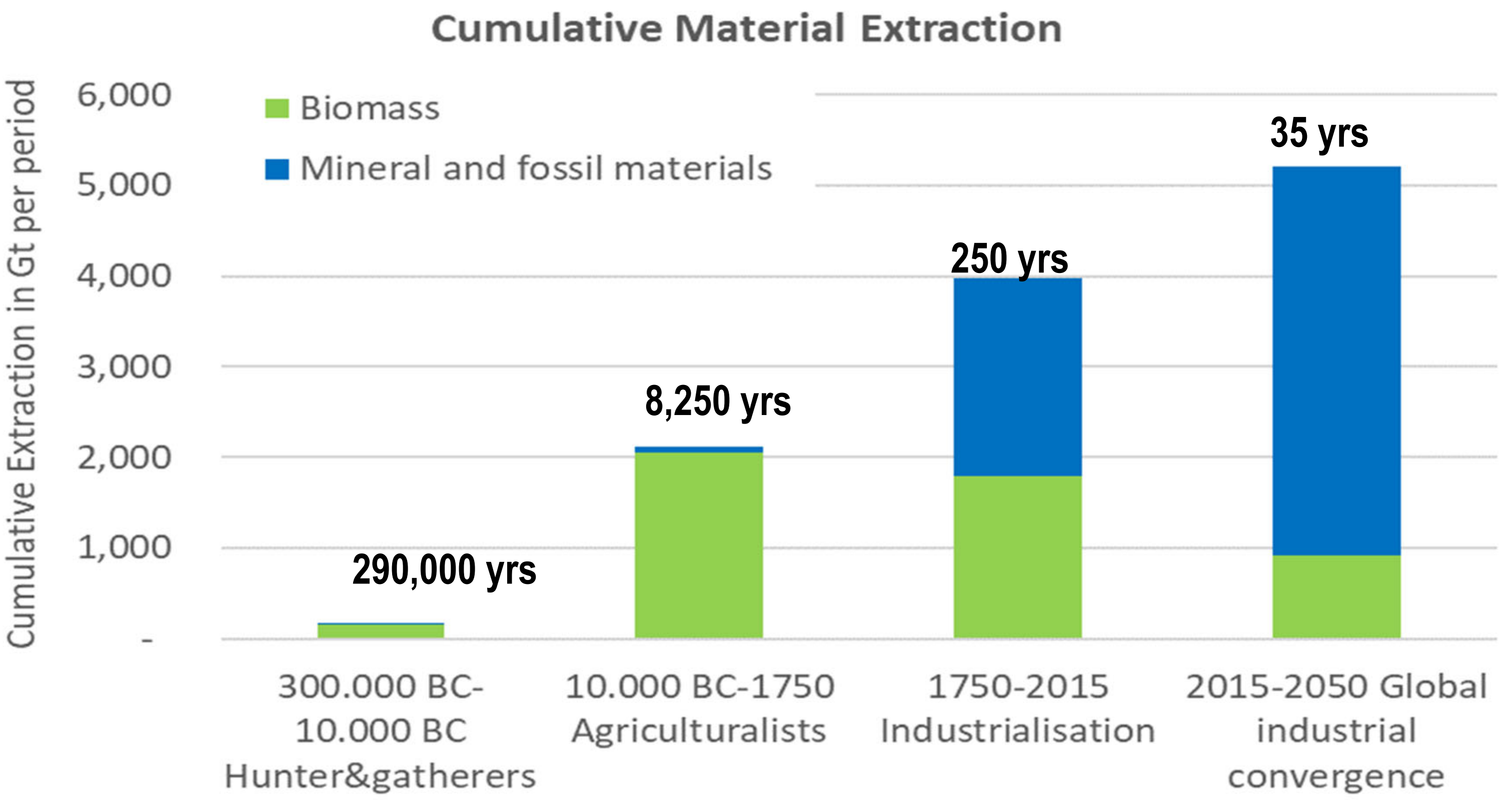
Social metabolism:
A systemic perspective on resource use



Social metabolism encompasses a society‘s extraction of biophysical resources (materials, energy, substances), their use in production and consumption processes, and the ensuing releases of wastes and emissions. **Flows** may be used dissipatively or accumulate as **stocks**, whose patterns in turn co-determine future flows.

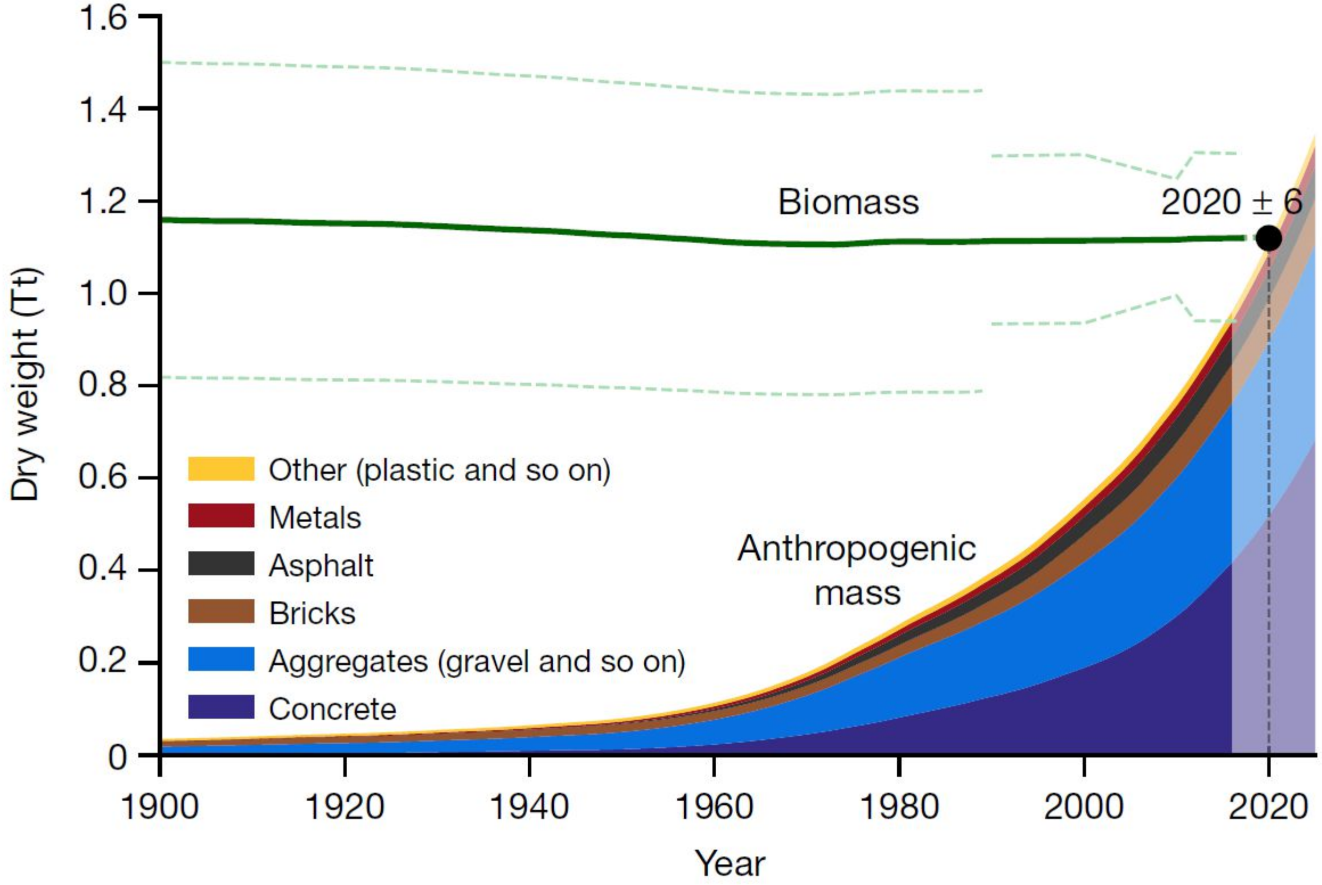
Haberl *et al* 2019. *Nature Sustainability* **2**, 173–184

Materials extracted by various socioecological regimes, materials required for convergence



Source: Calculations by Krausmann based on Fischer-Kowalski *et al.* 2014 (*Anthropocene Review* **1**), Krausmann et al. 2016 (in *Social Ecology*, Haberl *et al., eds.*), Krausmann et al. 2020 (*Global Environmental Change* **61**)

Global stocks of „anthropogenic mass“ vs. biomass



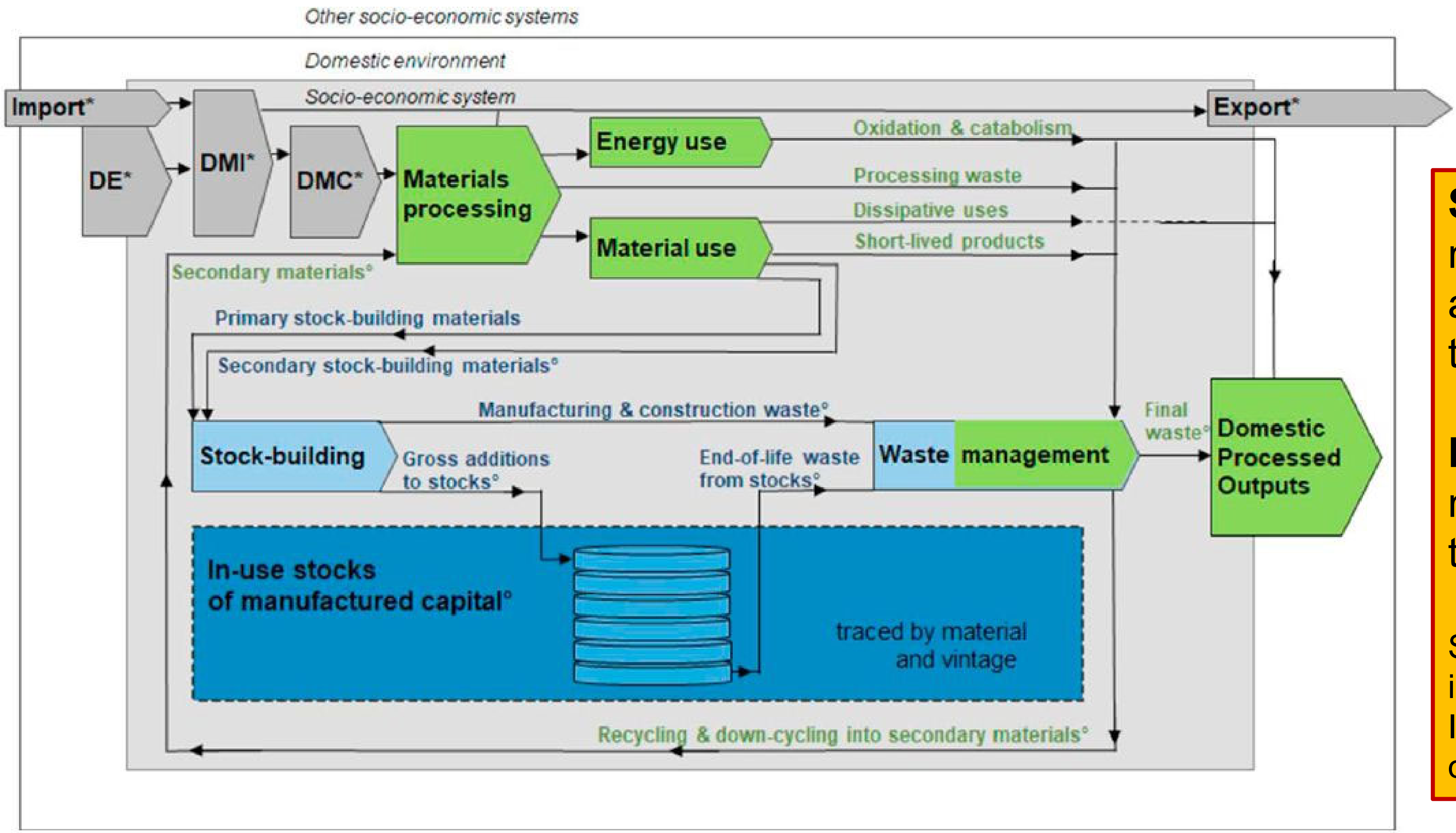
Material stocks 1:1 coupled with GDP

1900: stock-building materials ~20%

Now: stock-building materials ~55%

Elhacham *et al.* 2020, *Nature* **588;** based on Krausmann *et al.* 2017, *PNAS* **114** and Erb *et al.* 2018, *Nature* **553**

Linking stocks and flows: The MISO model

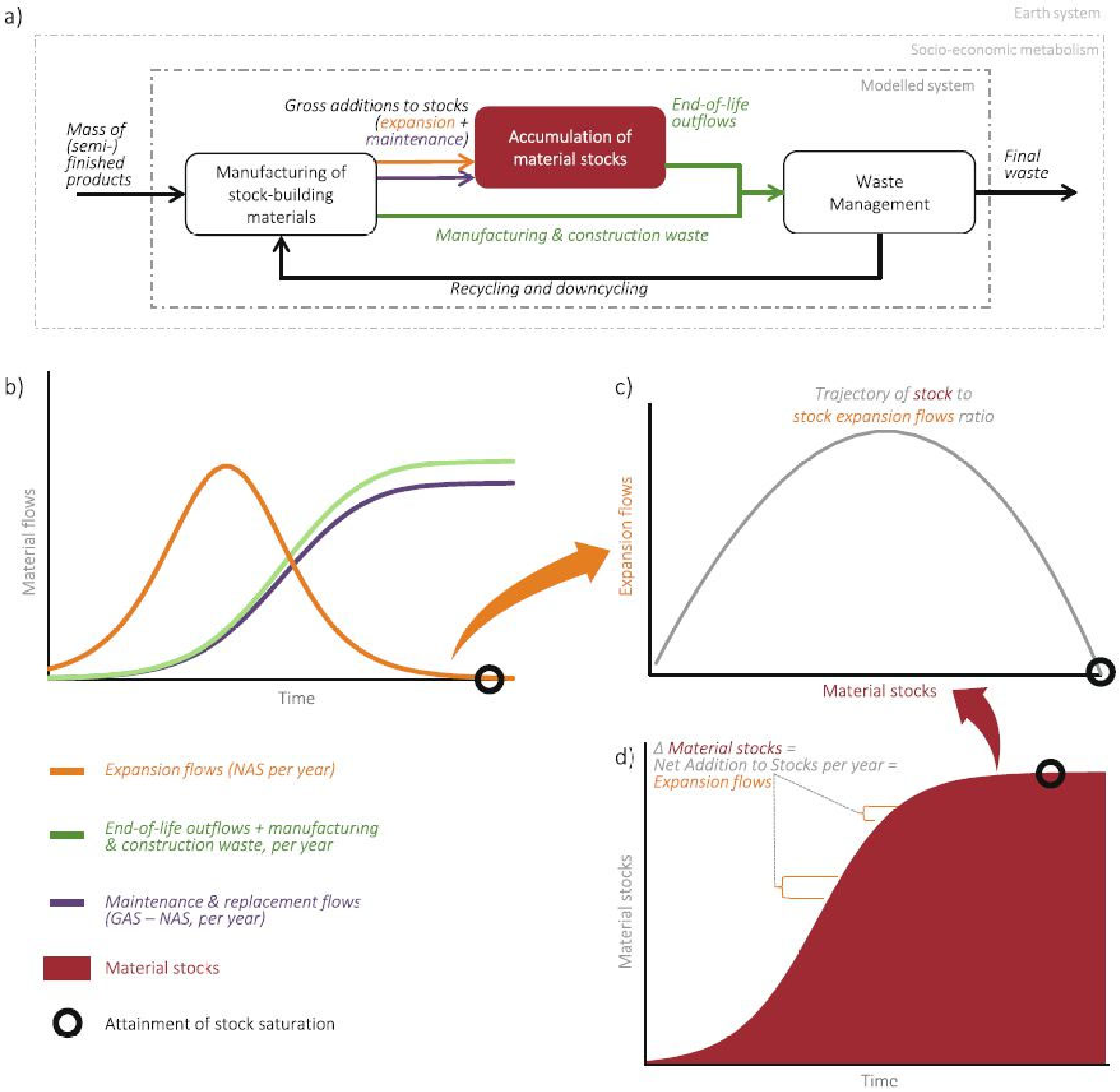


Stock: Mass of materials existing at a defined point in time [kg]

Flow: Mass of materials used over time period [kg/yr]

Stocks and flows are incommensurable. Inflows augment stocks, outflows reduce stocks

Wiedenhofer *et al.* 2019, *Ecol Econ* **156**



Stock-flow dynamics in social metabolism

Conceptual diagram of the requirements for a stabilization of societal material stocks

- **NAS = zero**
- **GAS = end-of-life outflows**

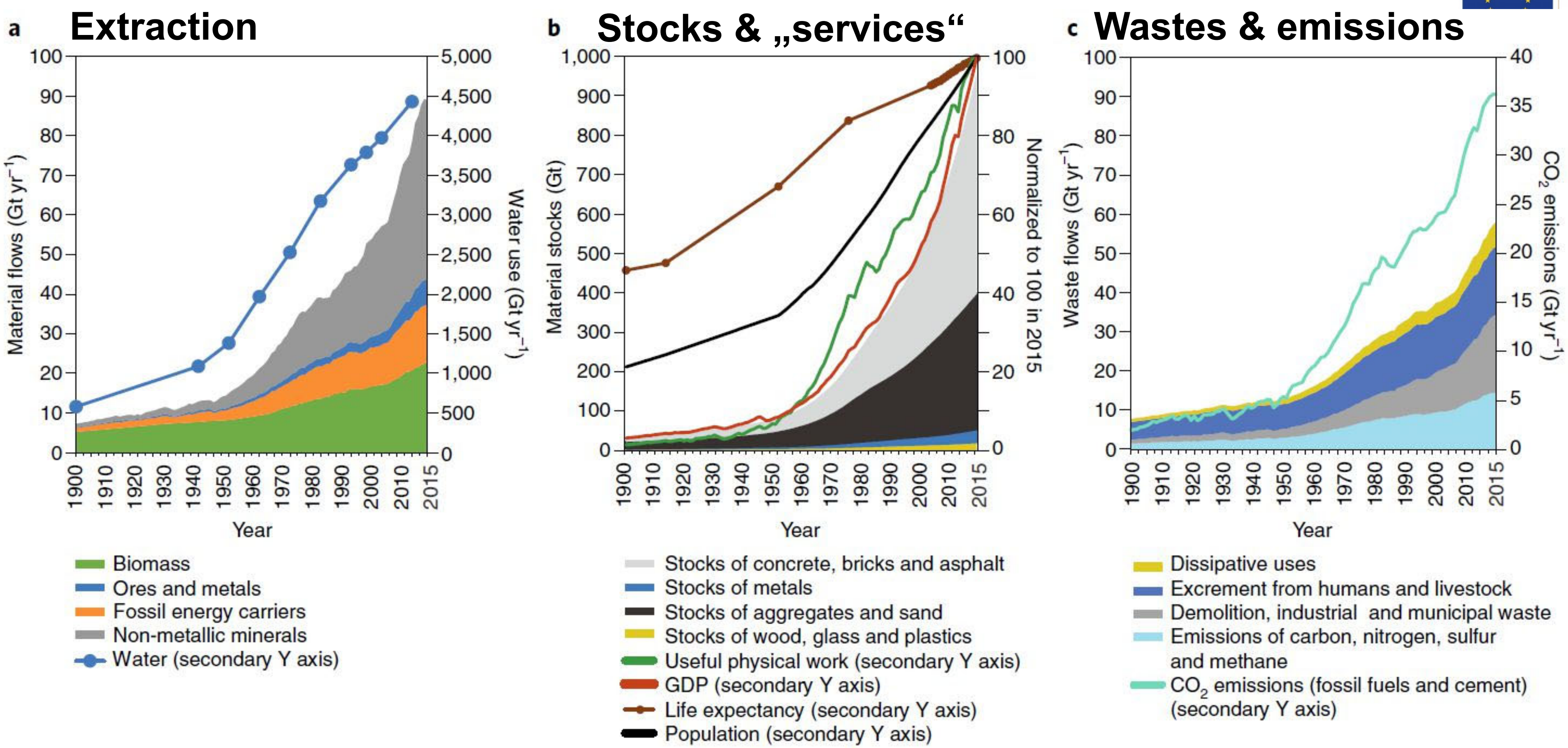
Wiedenhofer *et al.* 2021. *Global Environmental Change*, **71**, 102410

Why material stocks are important

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

Stocks, flows and a glimpse on services

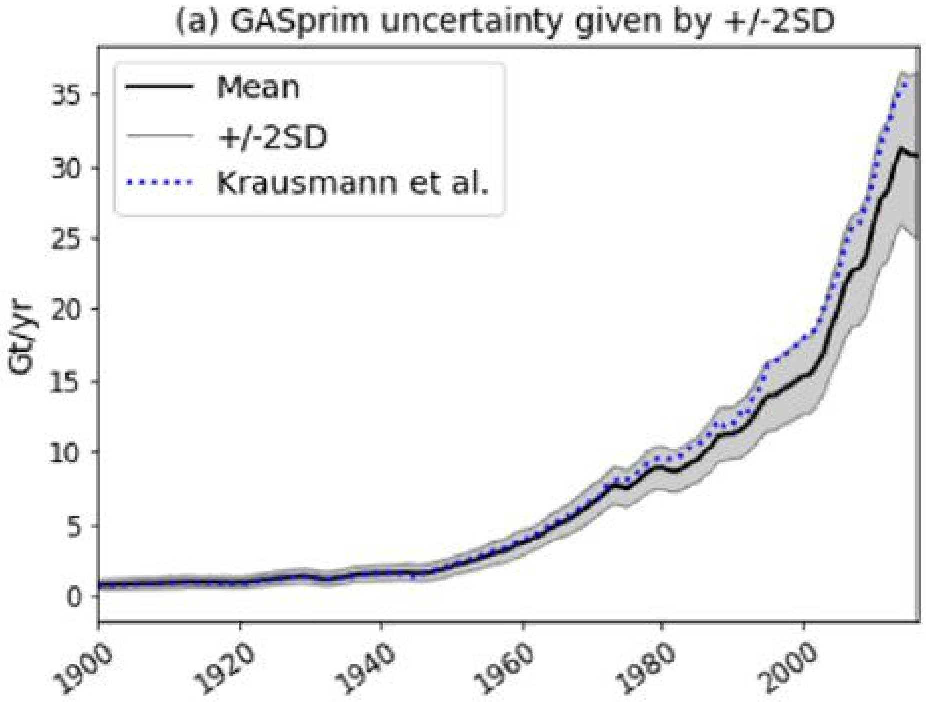
Global data, 1900-2015

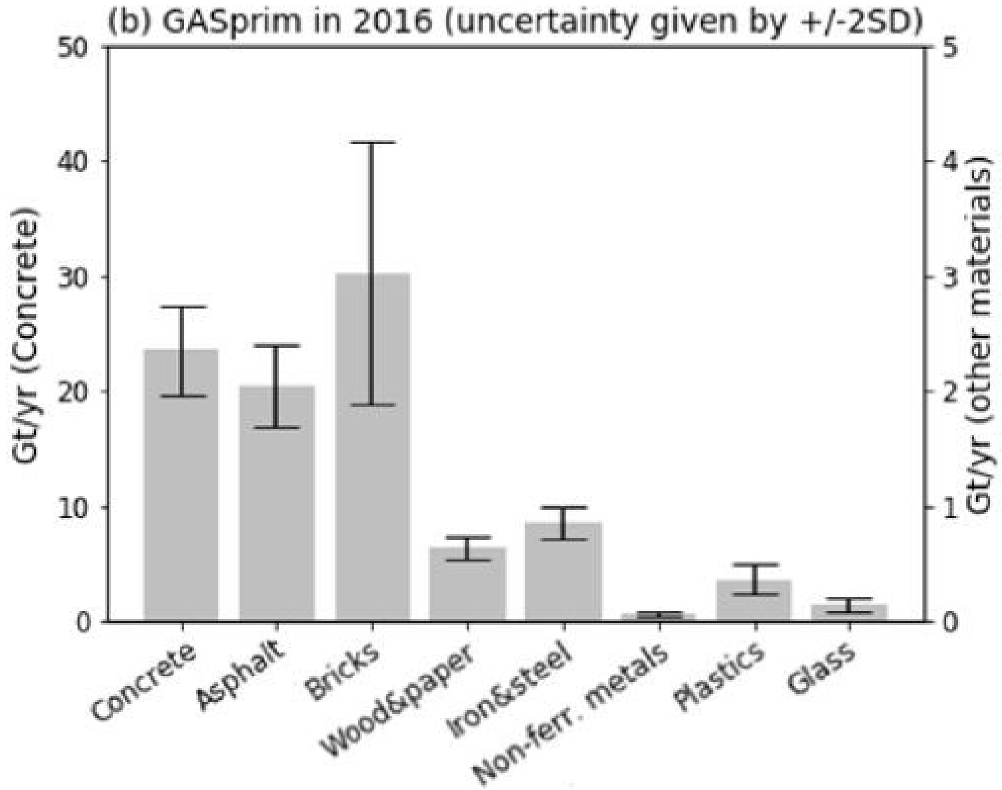


Haberl *et al*. 2019. *Nature Sustainability*, **2**, 173–184

Global Gross Additions To Stock (GAS)

1900-2016

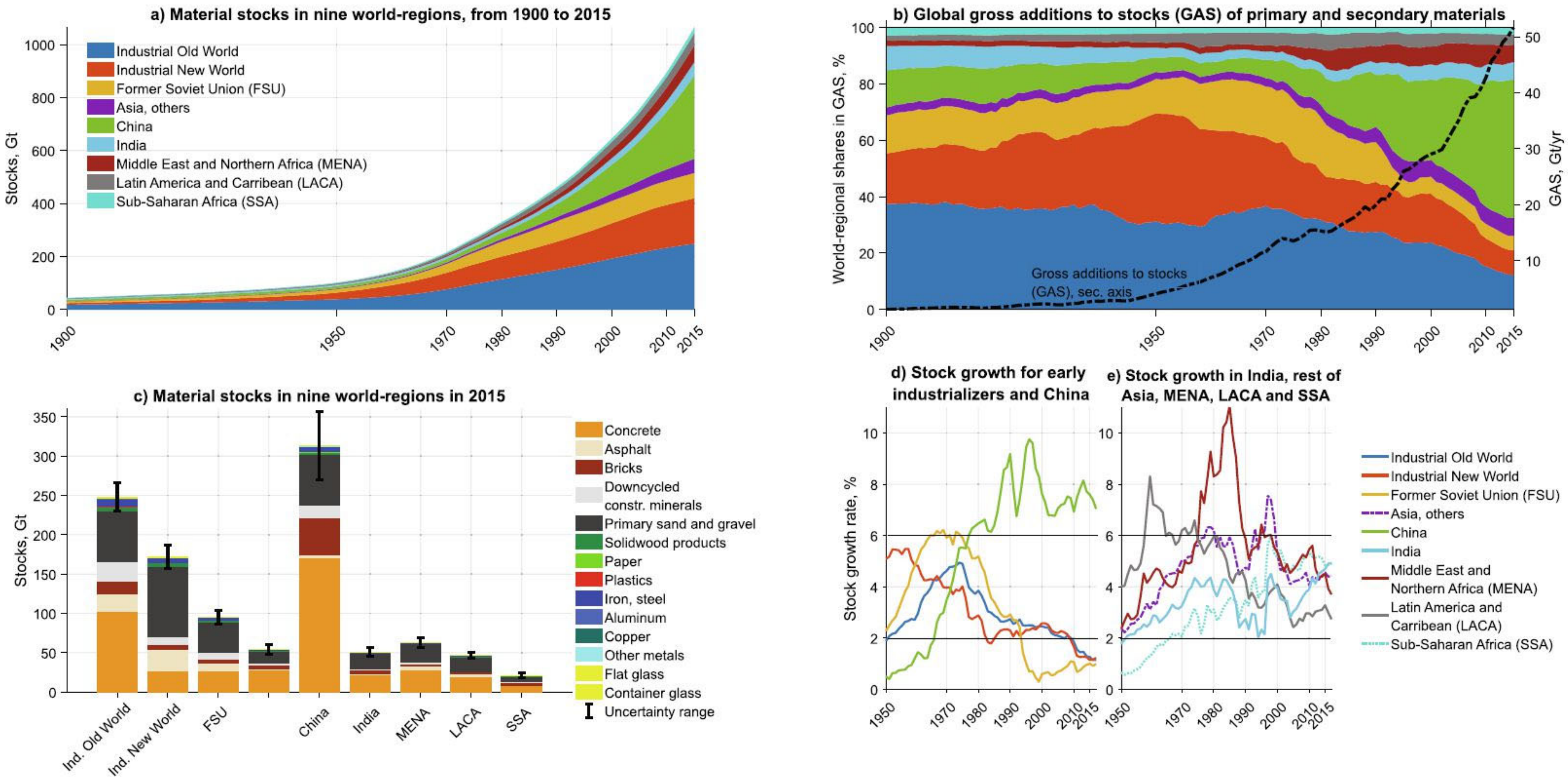




Plank *et al.* 2022. *Resources, Conservation & Recycling*, **179**, 106122

Stock-flow dynamics in nine world regions

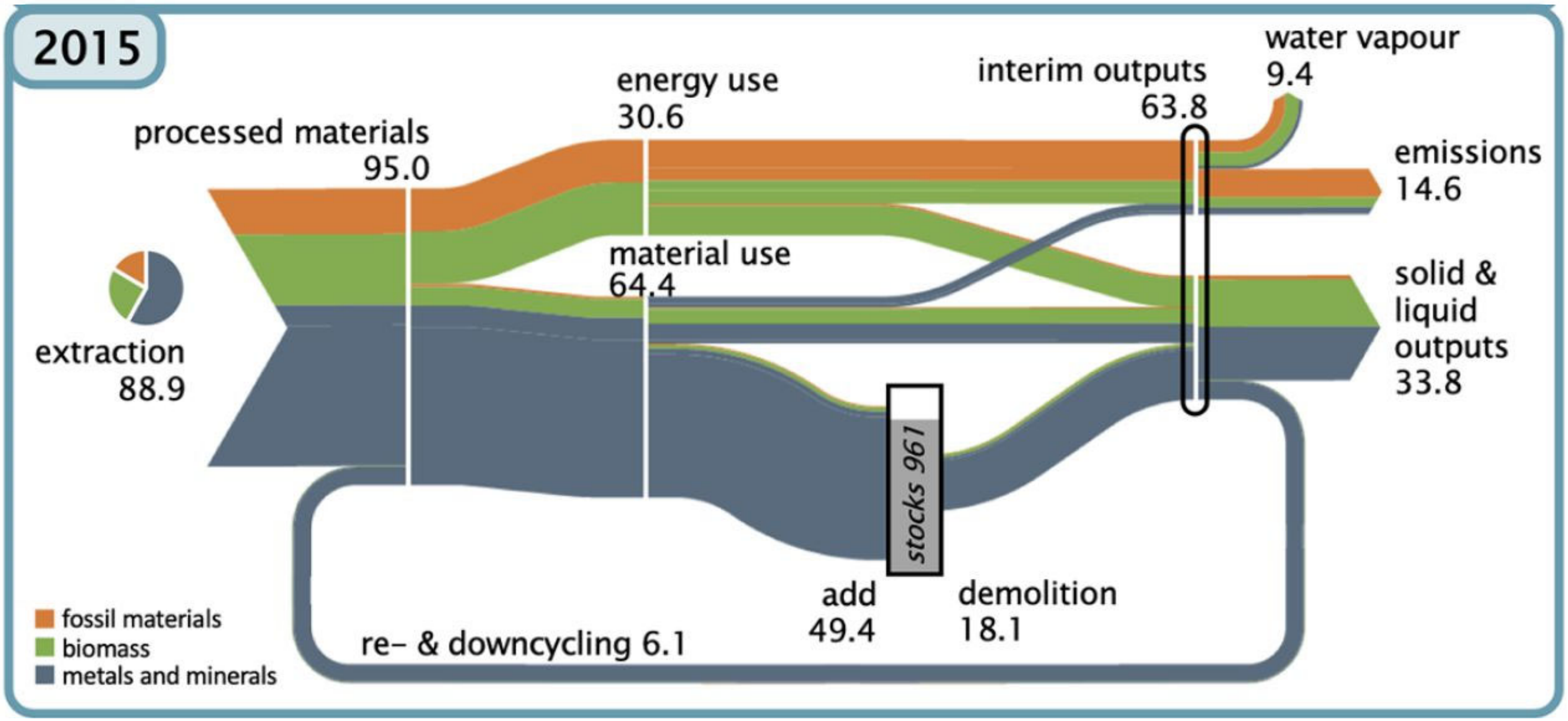
1900-2015



Wiedenhofer *et al.* 2021. *Global Environmental Change*, **71**, 102410

Global circularity and resource use
1900-2015

Input cycling 43% → 27%
Output cycling 46% → 40%



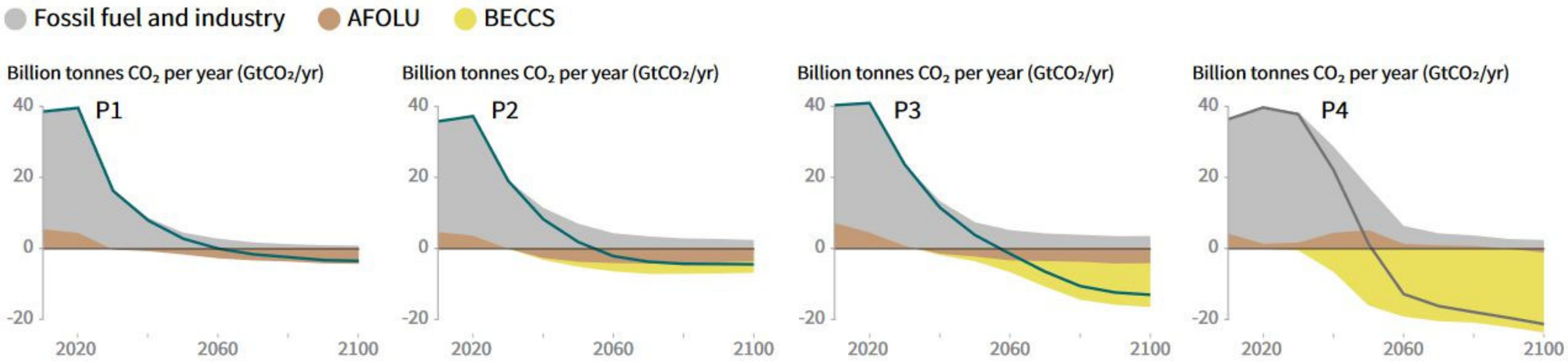
Haas *et al.* 2020, *Resources, Conservation & Recycl.* **163**, 105076

The climate challenge I

What limiting global warming to 1.5° means

CO_2 emissions must reach net zero ~2050
Rapid reduction required to avoid risky technologies

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

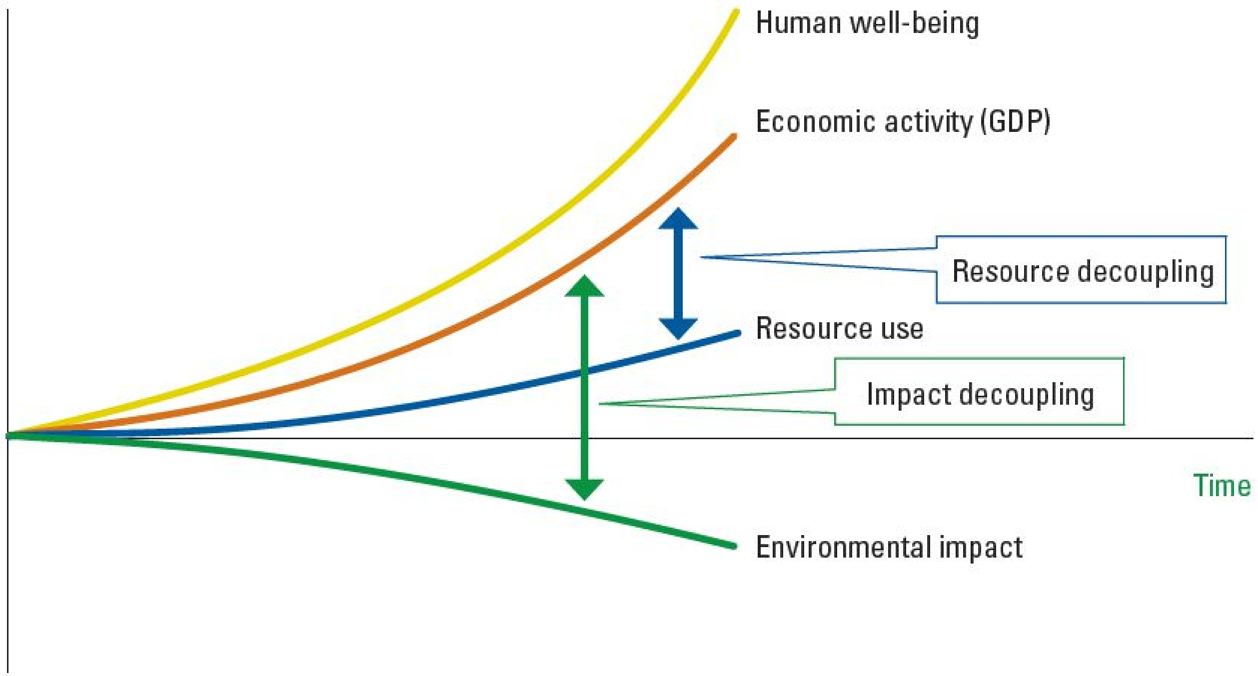
IPCC, 2018. *Special Report: Global Warming of 1.5° C*

The classical approach: Eco-efficiency

Decoupling: can resource use and emissions decline while the economy is growing?

Relative decoupling:
- Resource use per unit GDP or impacts decline, but total amount of resources grows
- GDP grows faster than resource use

Absolute decoupling: resource use or impacts decline while GDP grows

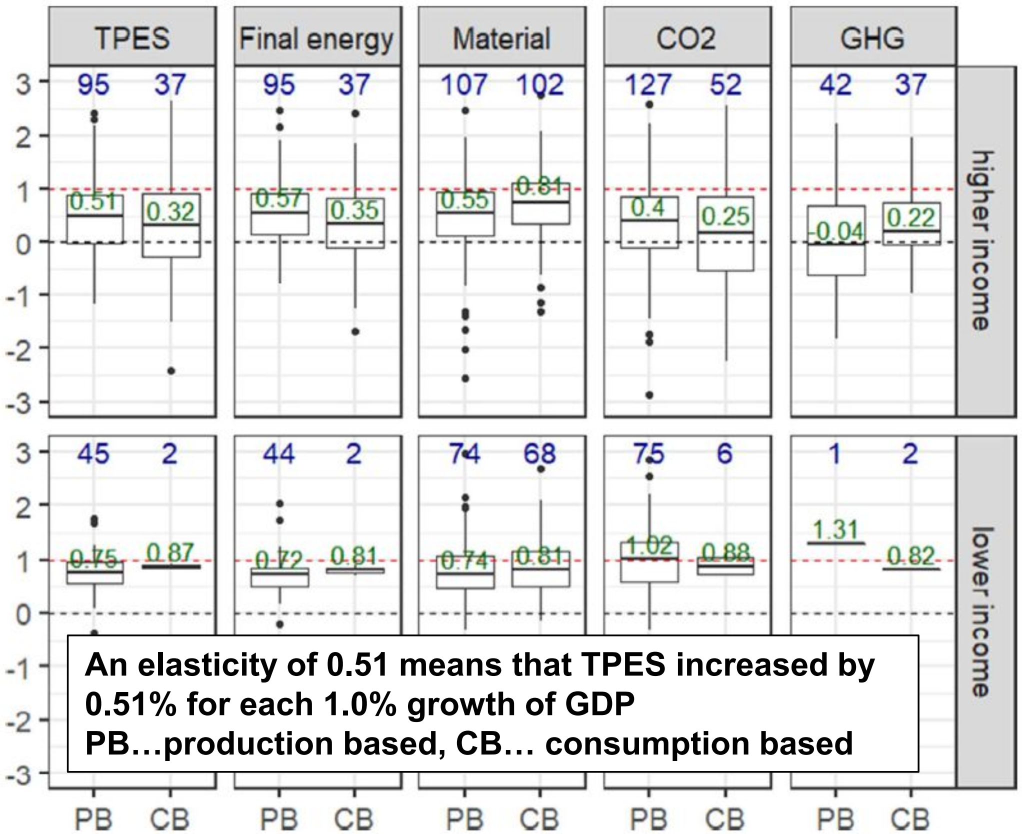


Most sustainability or climate policies explicitly or implicitly are focused on decoupling

UNEP – International Resource Panel, Decoupling Report (2011)

The *Gospel of Eco-Efficiency is good,* but not nearly good enough

Observed GDP elasticities in the last decade



Current sustainability strategies rely on promoting a „decoupling" of GDP from resource use or emissions

The 1.5°C target requires a linear absolute reduction of CO_2 by 3.3%-5% of the emissions in 2020 per year. This requires a *qualitatively new approach* for socio-ecological transformation

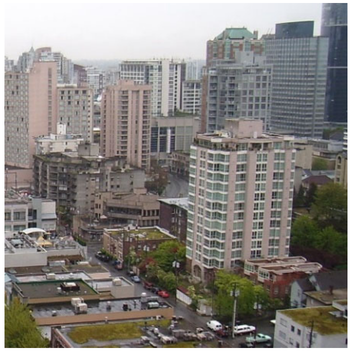
TPES… total primary energy supply, GHG… greenhouse gas

Haberl *et al.*, 2020, *Environmental Research Letters* **15**, 065003

Now recognized by IPCC, WGII, AR6 (2022)

Towards sustainability?

Reshaping the stock-flow-service nexus



Stocks Buildings, infra-structures, machinery

Stocks shape social practices of everyday life (mobility, shelter, etc.)

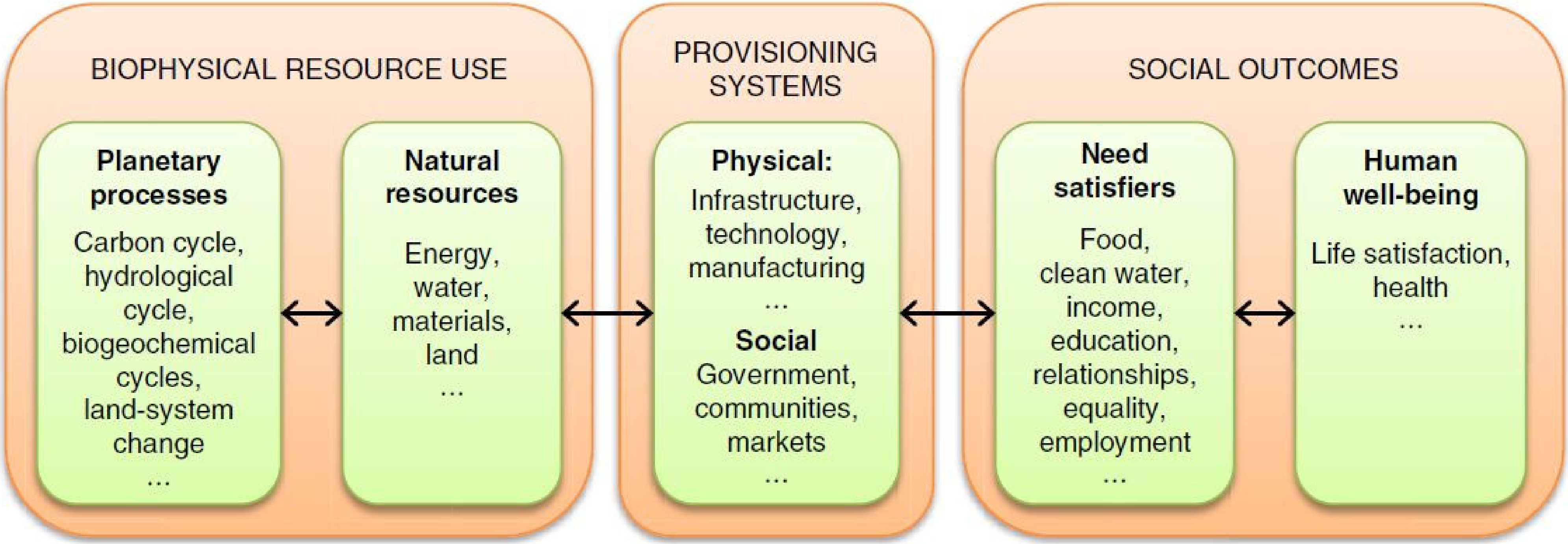
Flows
Energy, materials

Services
Contributions to social well-being

Fotos: Helmut Haberl

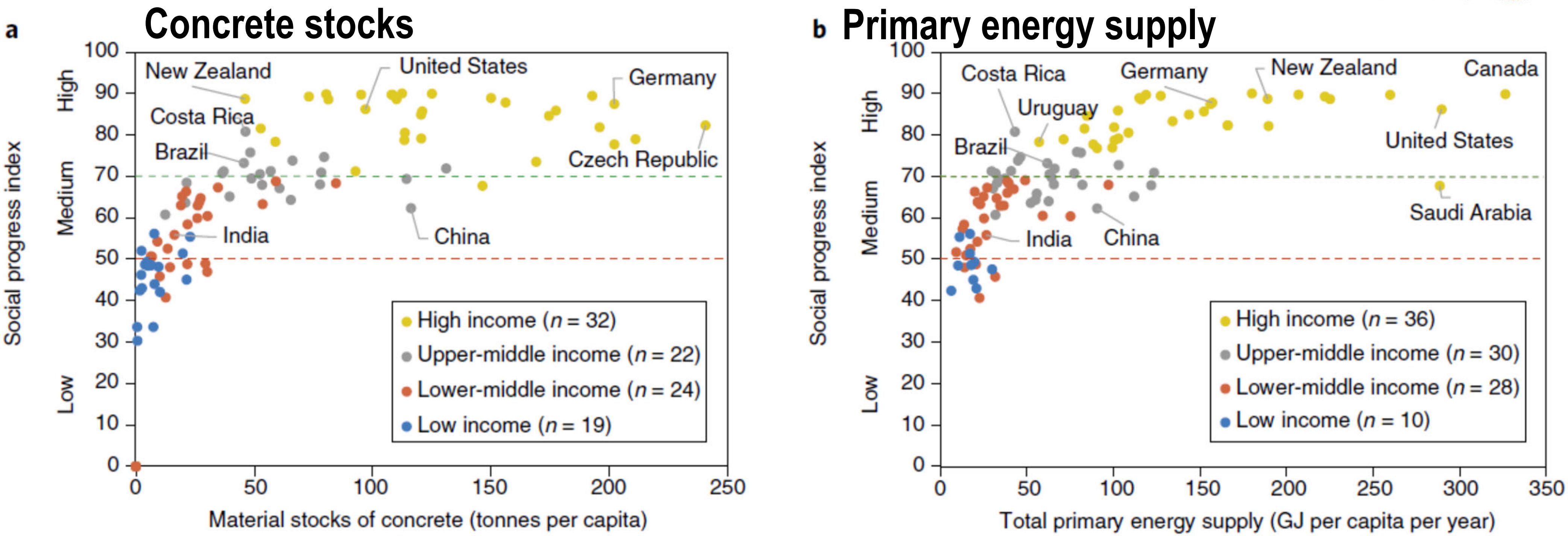
Haberl *et al.* 2017, *Sustainability* **9;** Kalt *et al.* 2019, *Energy Res. & Social Sci.*, **53**, Haberl *et al.* 2021, *Ecol. Econ.* **182**

Provisioning systems link resource use to societal well-being



O'Neill *et al.*, 2018. *Nature Sust.* **1**, 88–95

Stocks and flows vs. social progress



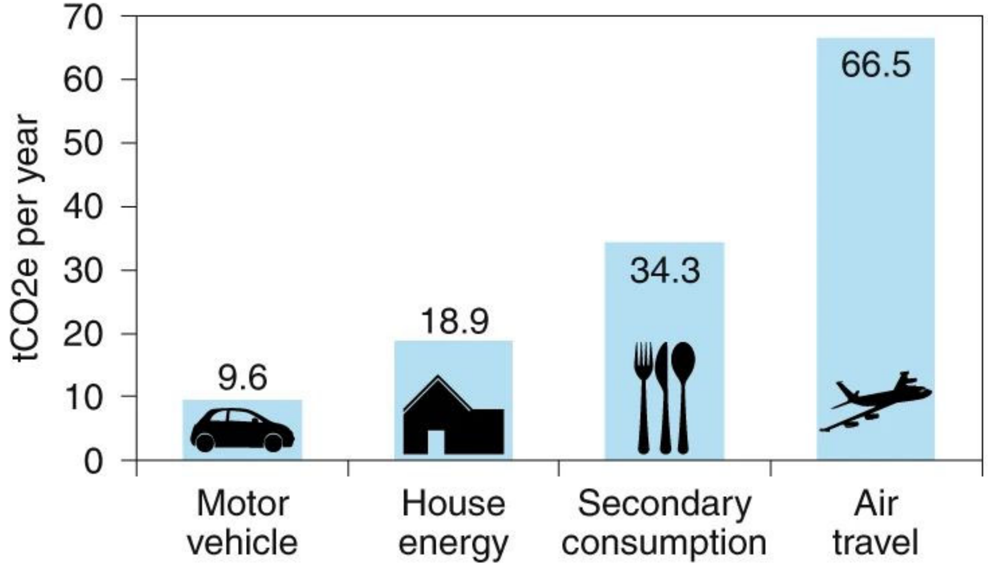
The Social Progress Index (SPI) is an outcome-based index of social wellbeing con-sidering nutrition, shelter, water, sanitation, safety, access to knowledge, freedom, human rights, environmental quality, but no monetary indicators such as GDP

Haberl *et al* 2019. *NatureSust.* **2**, 173–184

Inequality of GHG emissions between super-rich and average people

Fig. 1: The estimated carbon footprint of a typical super-rich household of two people.

From: Shift the focus from the super-poor to the super-rich

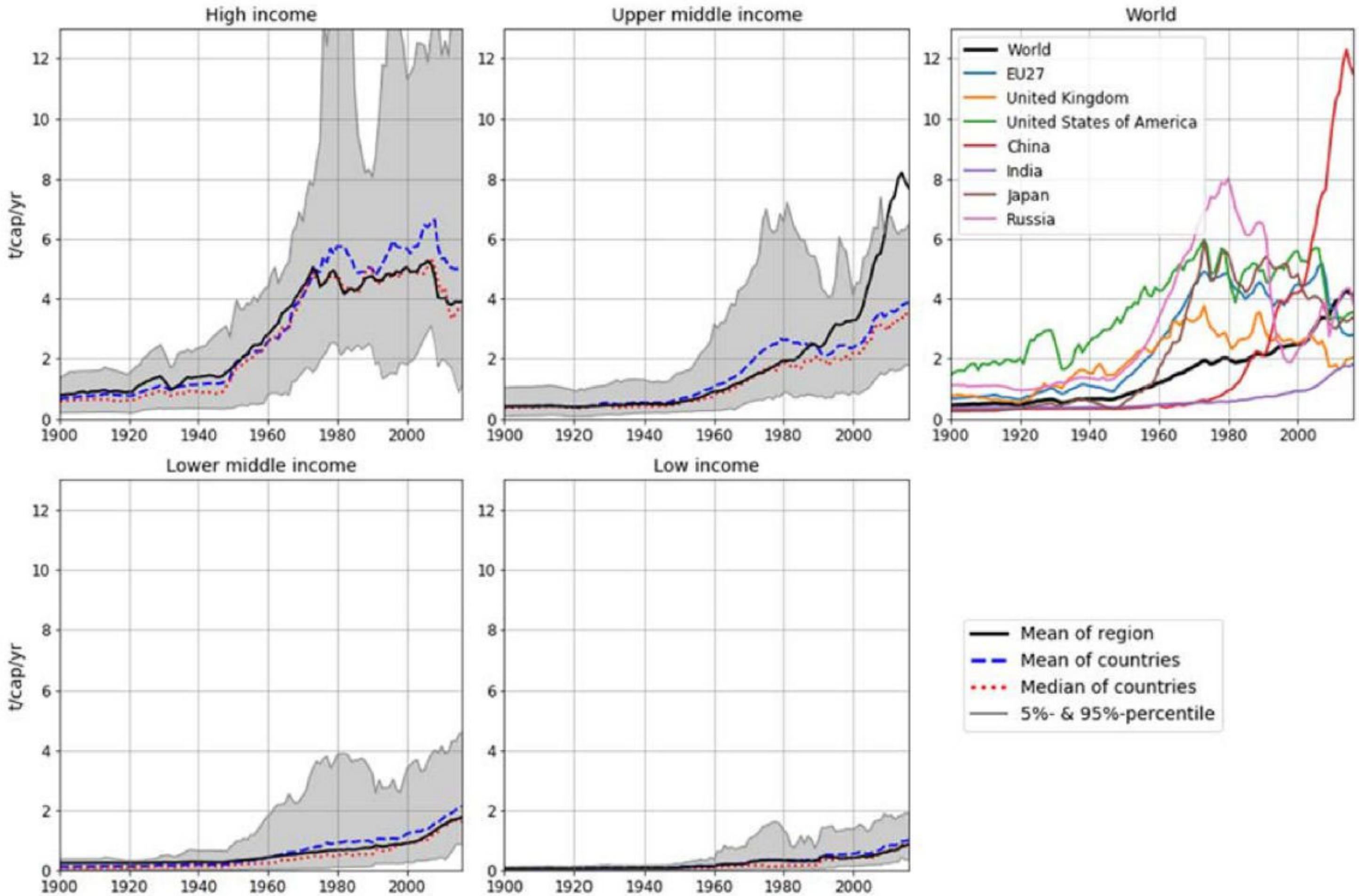


Data were derived from four consumption habit surveys, and show the average of four carbon-footprint calculators for each of four consumption categories. Total emissions are approximately 129.3 tCO_2e per year.

Super-rich:
65 tCO_{2eq}/cap/yr
Austrian average:
9 tCO_{2eq}/cap/yr
Global average:
6.5 t CO_{2eq}/cap/yr
(AT: UBA, Global: PBL)

Otto *et al.* 2019. *Nature Clim Change* **9**

Gross additions to stock – income groups



Plank *et al.* 2022. *Resources, Conservation & Recycling*, **179**, 106122

Scenarios for stock development and GHG emissions 2050

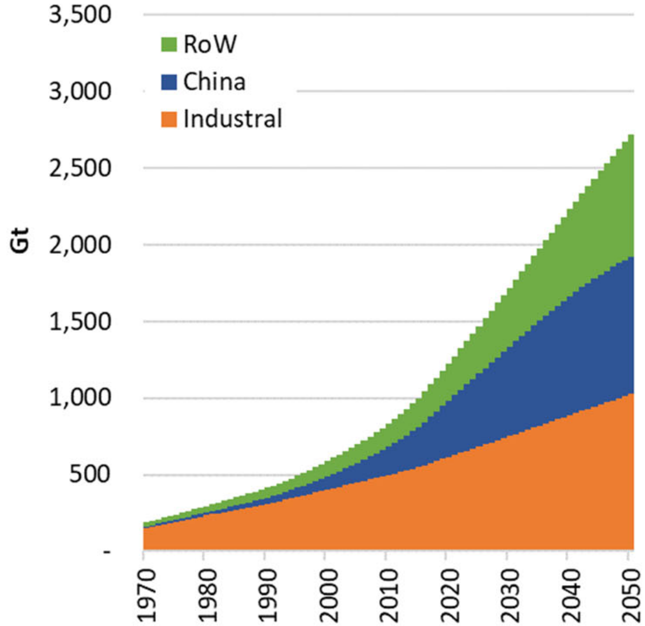
- **GDP-driven scenarios:** GDP development taken from IPCC-SSP2, assumptions on GDP per unit of stock ratio.
  - A GDP-driven high: Constant GDP/stock ratio
  - B GDP-driven low: Trend GDP/stock ratio, only selected results shown here
- **Population-driven convergence scenarios:** Population development (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 *et al.*, 2020, *Global Env. Change*, **61**, 102034   * Davis *et al.*, 2018, *Science* **360**, 1419

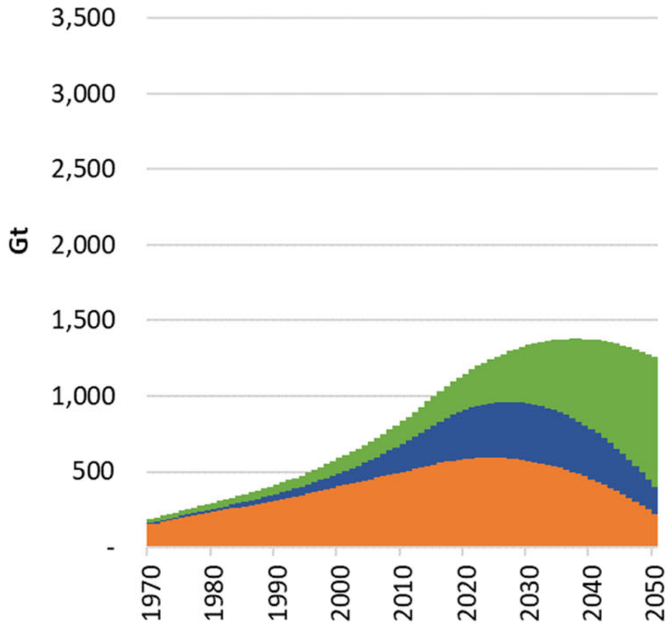
Global Material Stock Scenarios

1970-2050

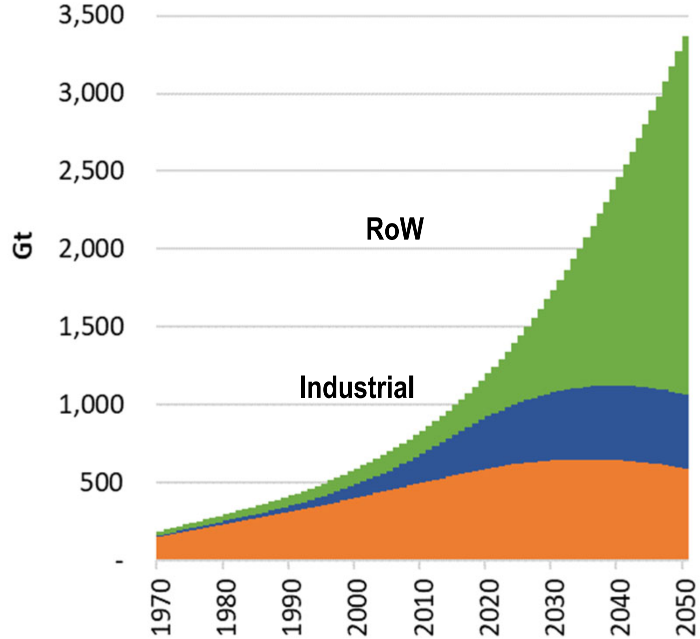
B GDP-driven high



C convergence1970

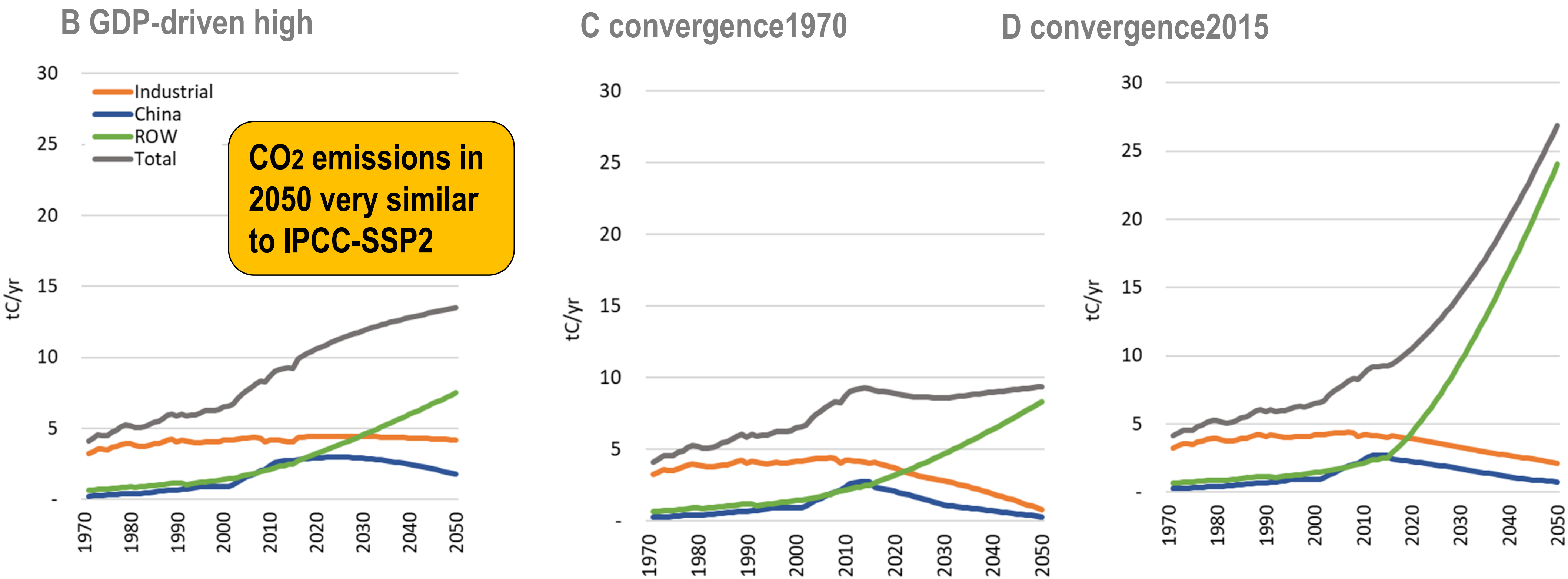


D convergence2015



Krausmann *et al.*, 2020, *Global Environmental Change*, **61**, 102034

Scenario results:
Development of CO_2 emissions 1970-2050
(without additional decarbonization)



Krausmann *et al.*, 2020, *Global Environmental Change*, **61**, 102034

The climate challenge II
Sociometabolic transformation in 20-30yrs

- Current **global primary energy mix**: 80% fossil fuels, 10% biomass, 5% nuclear energy, 3% hydropower
- Current **primary energy mix in Austria**: 67% fossil fuels, 17% biomass, 10% hydropower

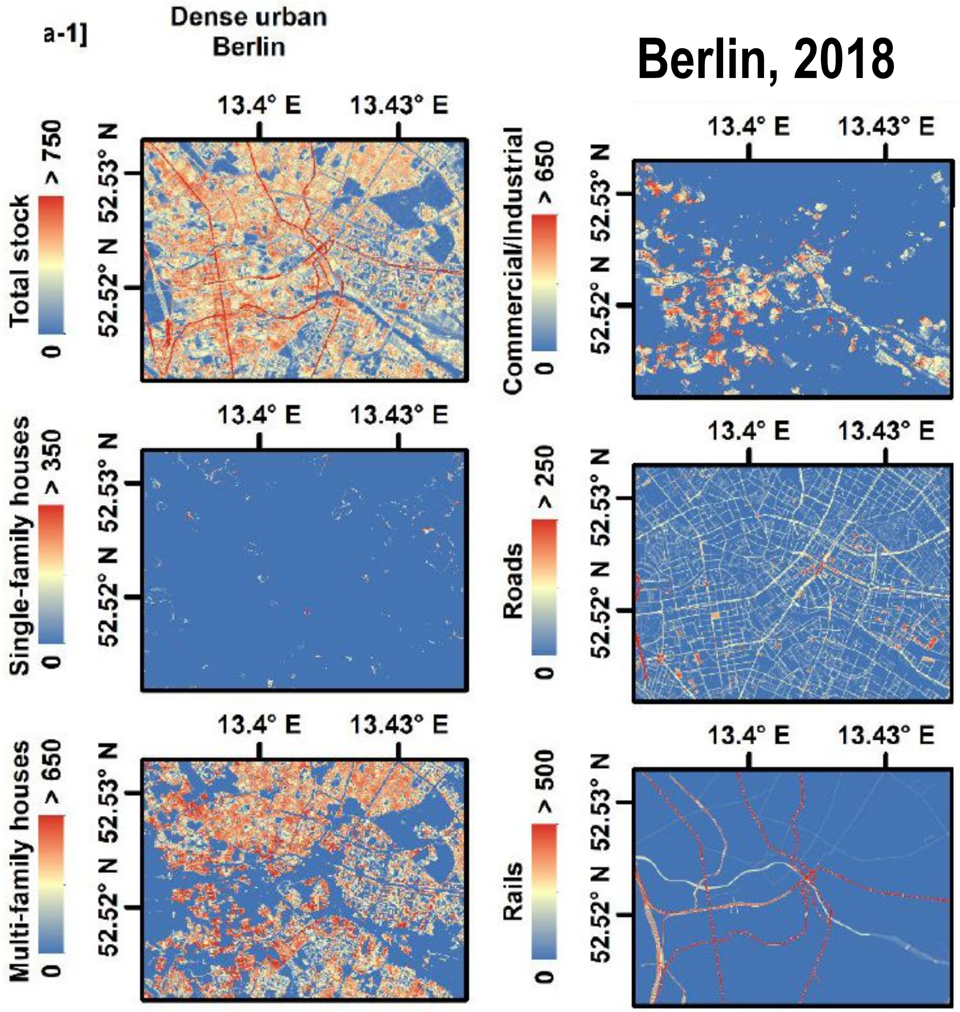
→ Climate-neutral energy needs to replace two thirds (Austria) to four-fifth (global) of primary energy supply. Hence:

- **No new structures with lifetimes >8-10 years** that require fossil fuels must be built or be made operational (buildings, infrastructures, machinery)
- **Existing buildings, infrastructures and machinery** need to be refurbished and/or replaced by zero fossil-fuel input options

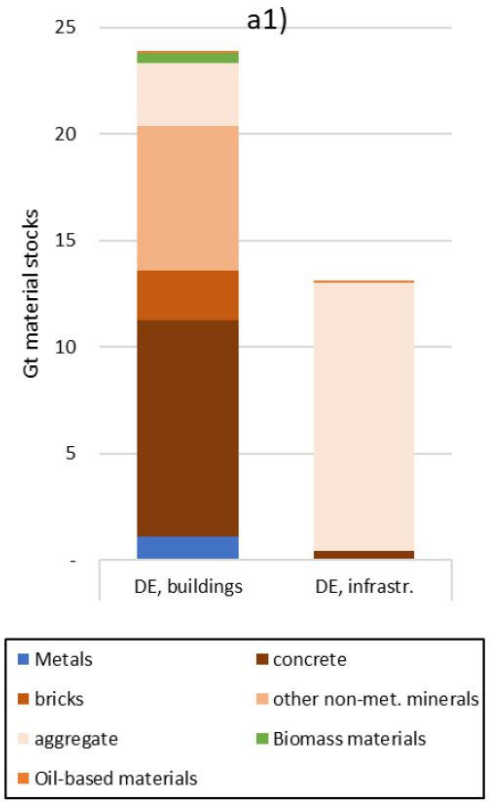
Most material stocks are in buildings and infrastructures

Haberl *et al.* 2021, *Env. Sci. Tech.*, **55**, 3368-3379

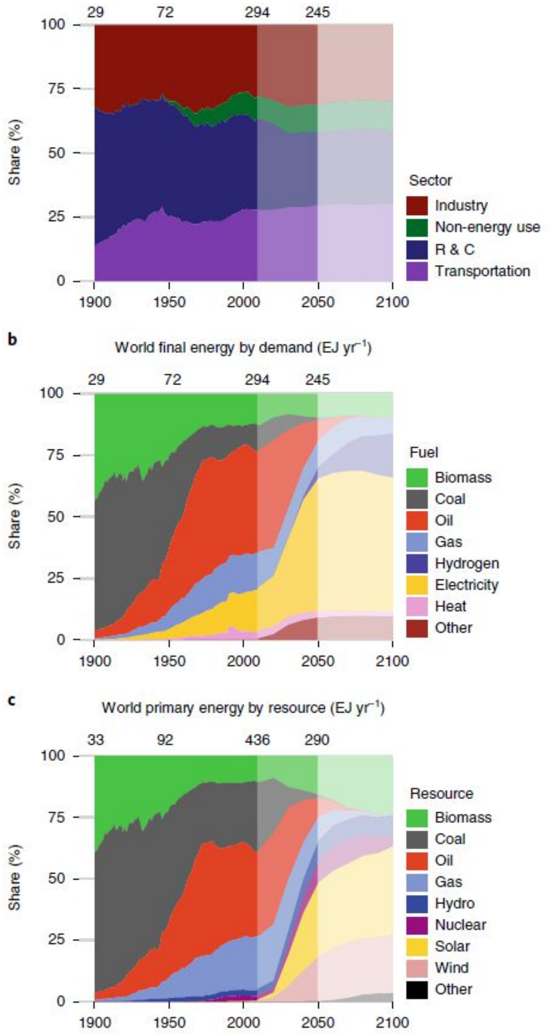
Berlin, 2018

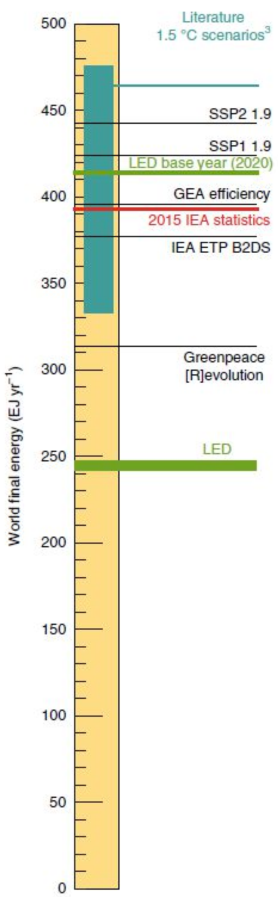


Germany



Global low-energy demand scenario: less energy, same services *(possible – but how?)*





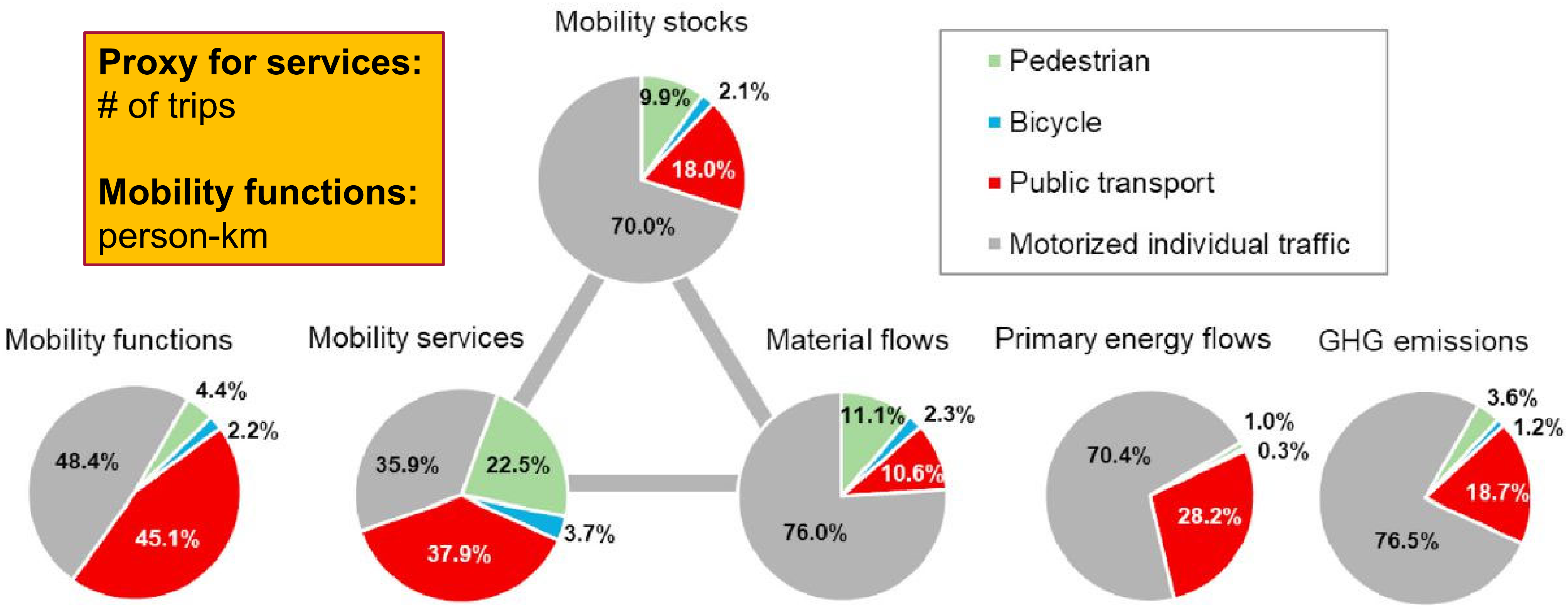
- Global final energy strongly reduced until 2050
- Same energy services as in current trend
- Meets 1.5° climate target
- Avoids controversial technologies (BECCS)
- Completely different investment patterns:
    - Low- or zero-energy buildings
    - Transport-sparing settlement patterns
    - Public transit prioritized over cars
    - Resource-sparing as top priority

Grubler *et al.* 2018, *Nature Energy* **3**

Example: The SFS nexus of personal mobility in Vienna

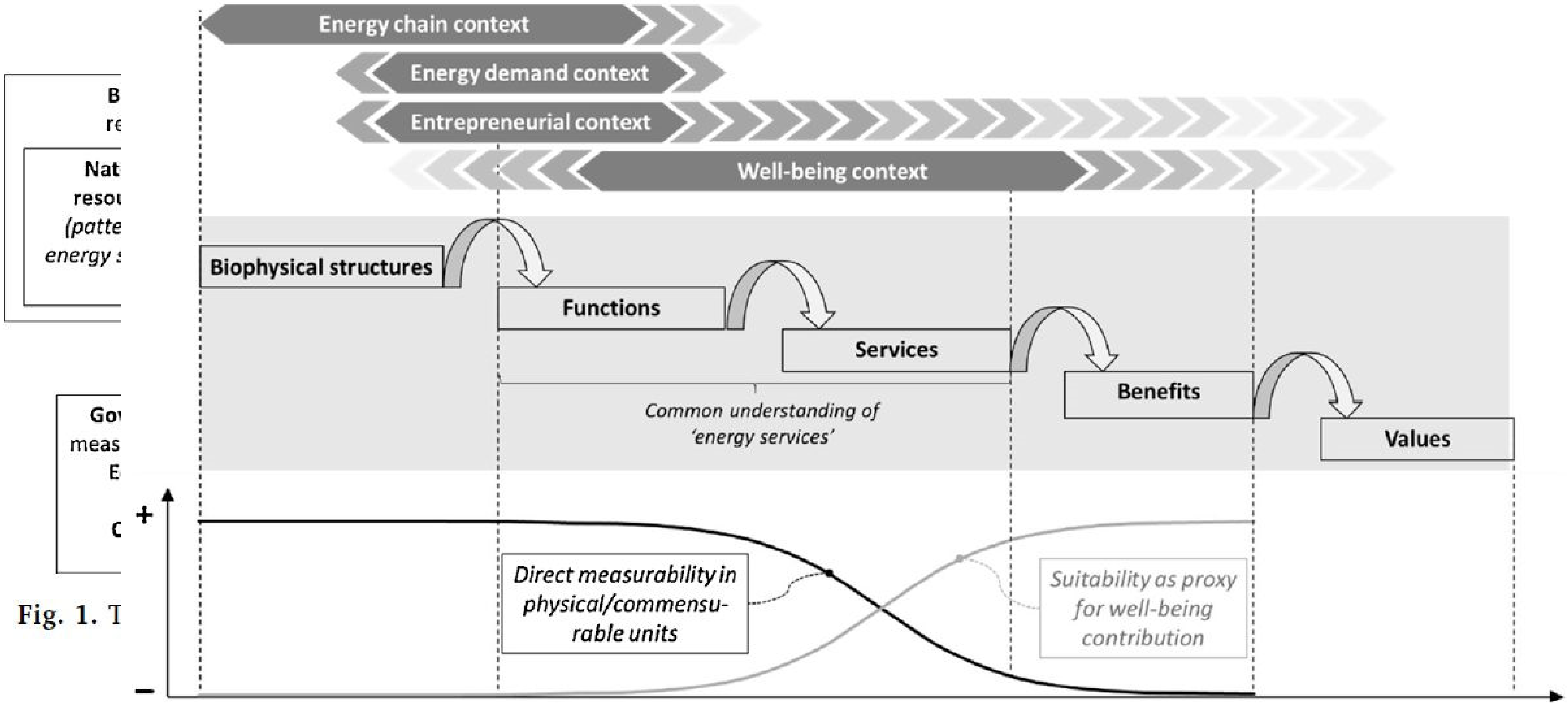
Proxy for services:
# of trips

Mobility functions:
person-km



Virág *et al.* 2021, *Environm. Develop* 10.1016/j.envdev.2021.100628

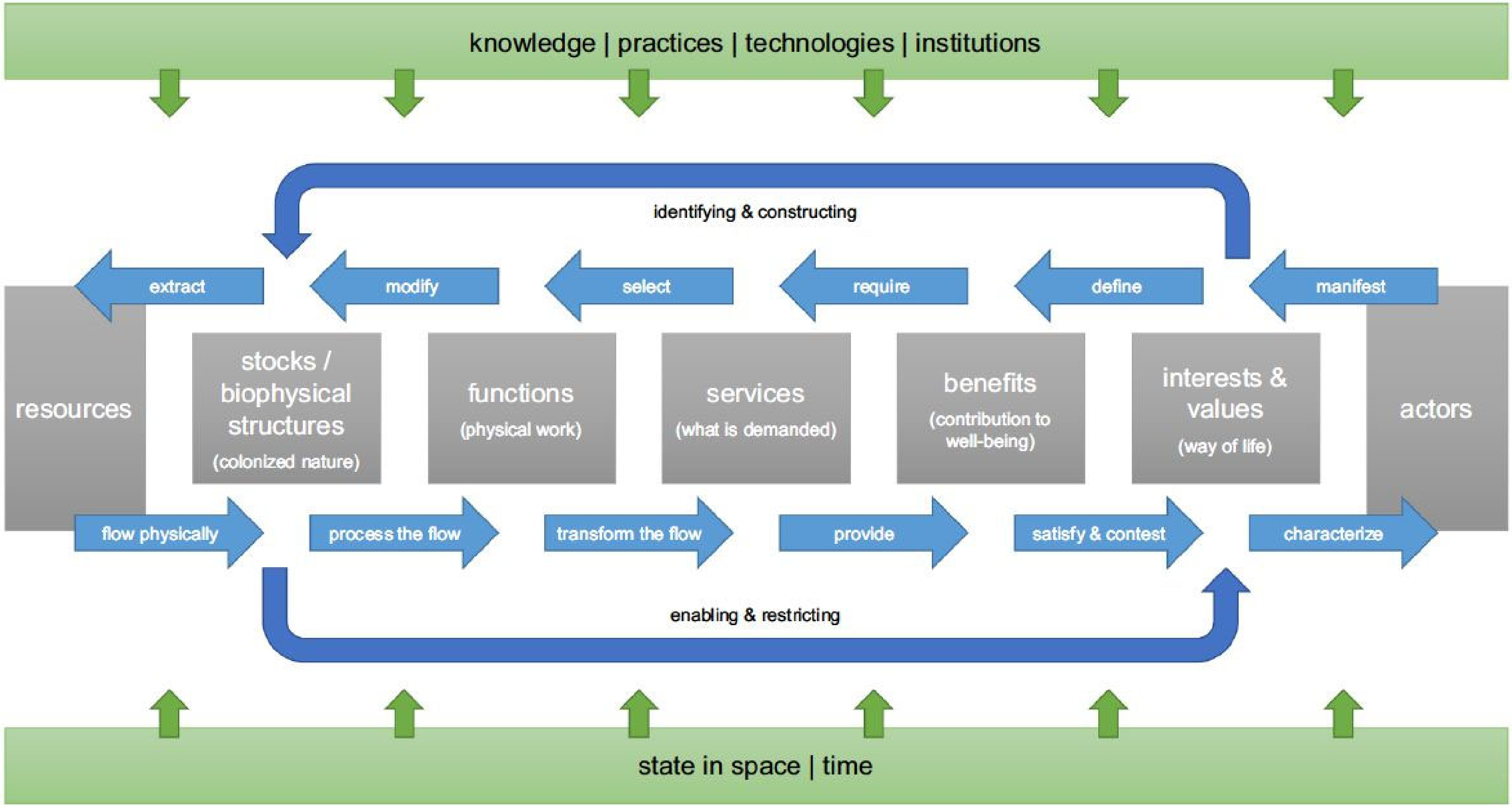
Conceptualizing services: the energy service cascade



Understanding contributions to social well-being requires more than just counting contributions to GDP

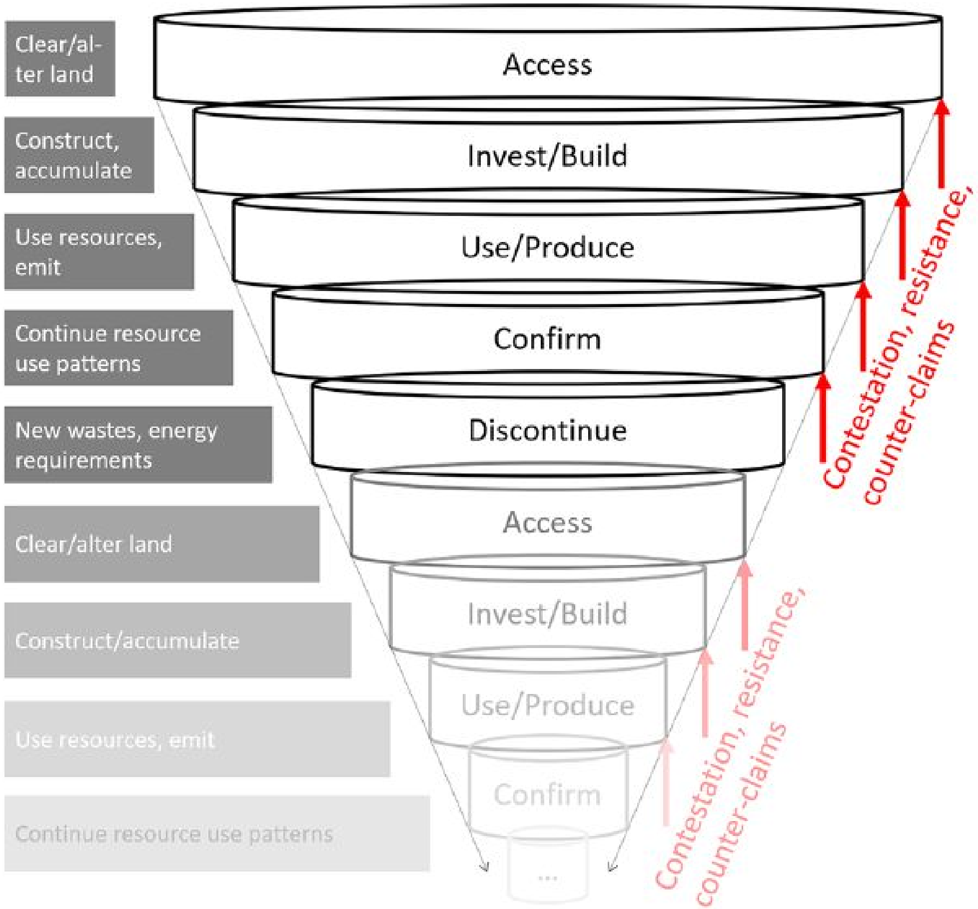
Kalt *et al.*, 2019. *Energy Research & Social Sciences* **53**, 47-58

Transforming the SFS nexus as part of provisioning systems



Plank *et al.* 2021. *Ecol. Econ.* **187**, 107093.

The spiraling constriction of the socio-metabolic corridor



Provisioning systems are built in several steps, each creating fixes that constrict future sociometabolic corridors. How long the ensuing legacies last, depends on the durability of the infrastructures and institutions created.

Schaffartzik *et al.* 2021. *Sustainability Science*, doi.org/10.1007/s11625-021-00952-9

The Stock-Flow-Practice nexus

Practices are routine activities that are embedded in social relations, infrastructu-res, perception and context. Consumption happens as part of practices.

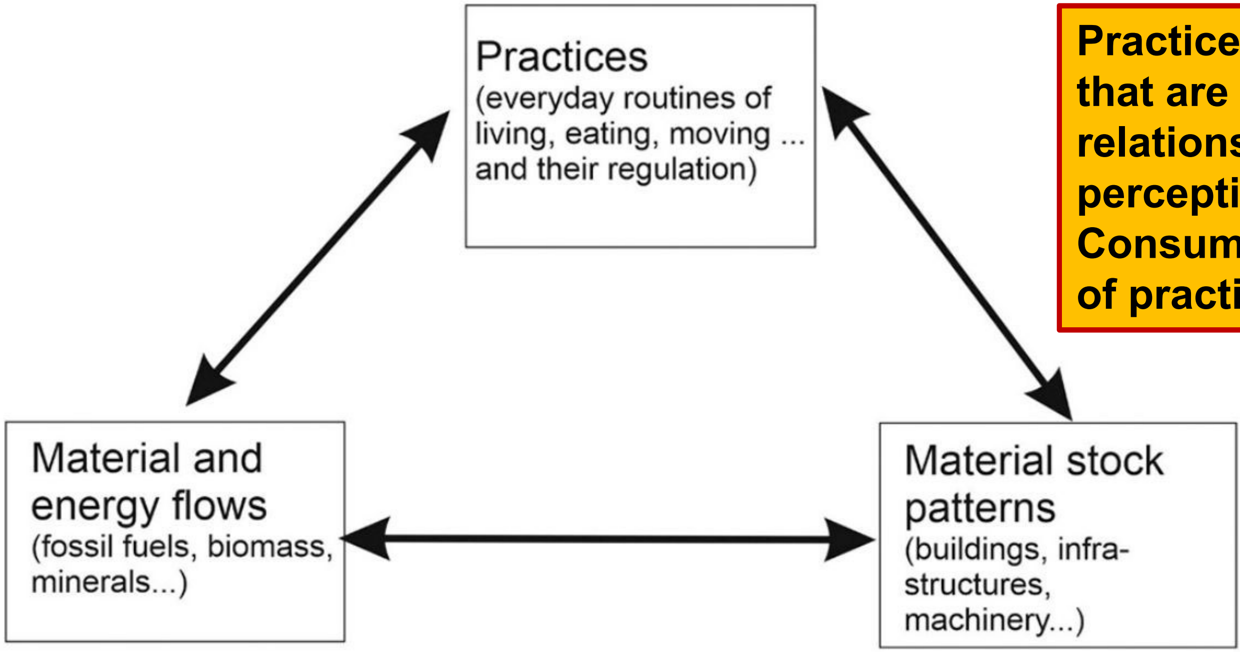
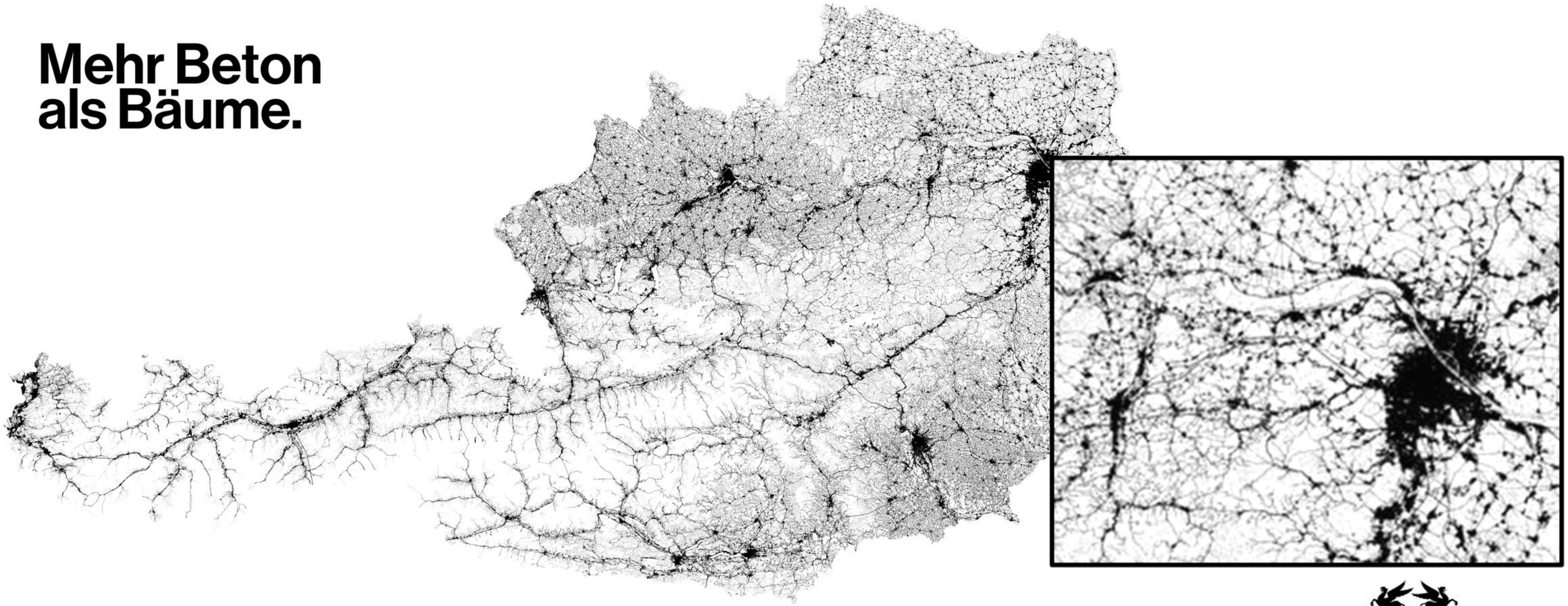


Fig. 1. The Stock-Flow-Practice nexus (SFP nexus). Own graph, based on the SFS nexus graph in Haberl et al. (2017).

Haberl *et al.* 2021. *Ecol. Econ.* **182**, 106949

Infrastructures and buildings in Austria outweigh trees by factor >2



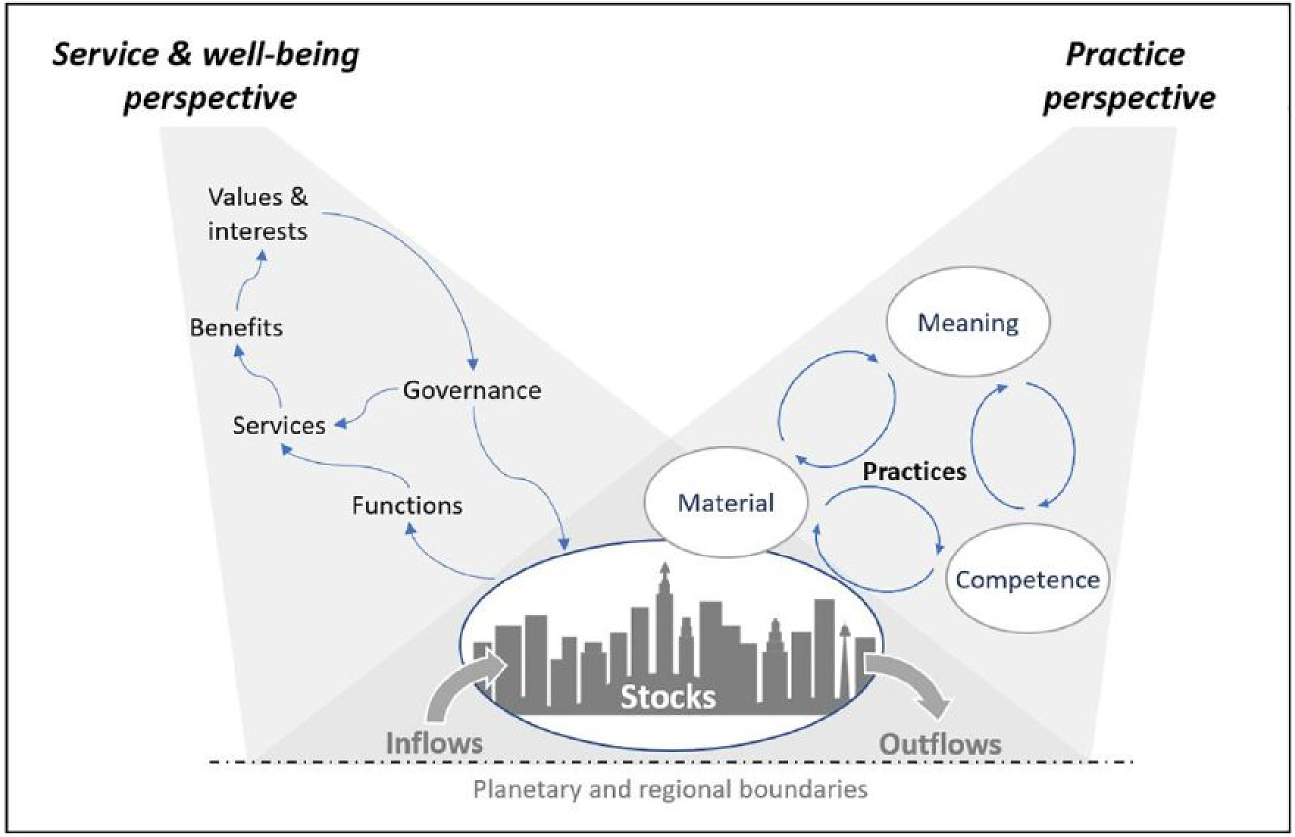
Grafik: EOOS Next / Process Studios **Data**: Haberl *et al.* 2021, *Env. Sci. Tech.* **55**

Nexus approaches relating social metabolism to services and practices

The stock-flow-service nexus: services are derived from specific stock-flow combinations. Broadens concepts of eco-efficiency.

The stock-flow-practice nexus: focused on interrelations between the routines of everyday life and stock-flow constellations. Connects theories of practice with social metabolism thinking.

Both approaches provide heuristic models for analyzing the role of material stock patterns for (un)sustainability.



Haberl, H., M. Schmid, W.Haas, D. Wiedenhofer, H. Rau, V. Winiwarter 2021. *Ecological Economics*, **182**, 106949. https://doi.org/10.1016/j.ecolecon.2021.106949

Conclusions

- **Construction of buildings and infrastructures** requires a major part of the physical resources used by societies
- The dissipative use of resources (energy!) is shaped largely by the **quantity, quality and spatial patterns of society's material stocks**
- Meeting **ambitious climate targets** will not allow any new long-lived (>8-10 years) structures locking societies into new GHG emissions, plus refurbishing all existing structures to zero-carbon standards in ~30 years
- As long as stocks grow, **full circularity is theoretically impossible**. Even if net additions to stock were zero, full circularity would still be thermodynamically impossible (downcycling & waste can't become zero)
- Alternative development models are needed in which a **good life requires much lower material stocks and resource flows, consistent with the need to reduce GHG emissions to zero** (or below)

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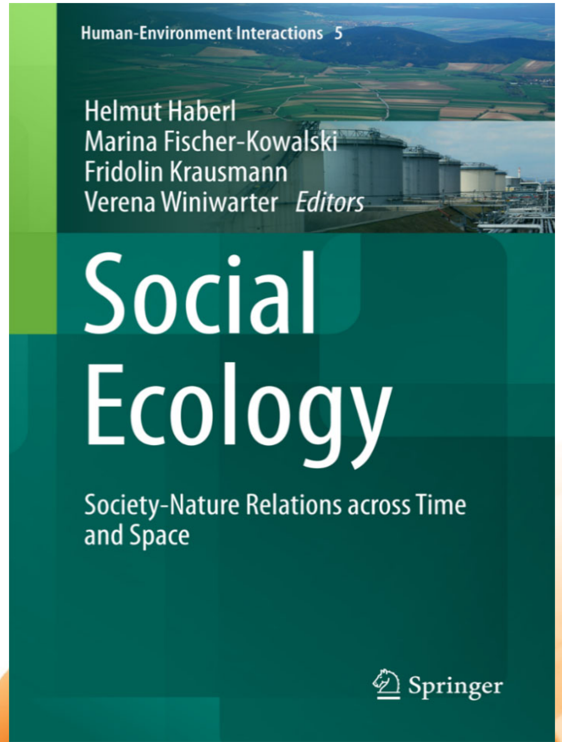
https://www.wiso.boku.ac.at/en/institut-fuer-soziale-oekologie-sec/data-download/



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