Nachhaltigkeits-Diät für den gesellschaftlichen Stoffwechsel? Die Rolle von Siedlungs- und Infrastrukturmustern

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Institute of Social Ecology

In: Spectacular Tentacular - Living the Chthuluzän – Utopias of Change

Staatliche Akademie der Bildenden Künste Stuttgart, Lehrstuhl für Wohnbau, Grundlagen und Entwerfen, The Baukunst Studio, 15.11.2021

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Social metabolism: A systemic perspective on resource use

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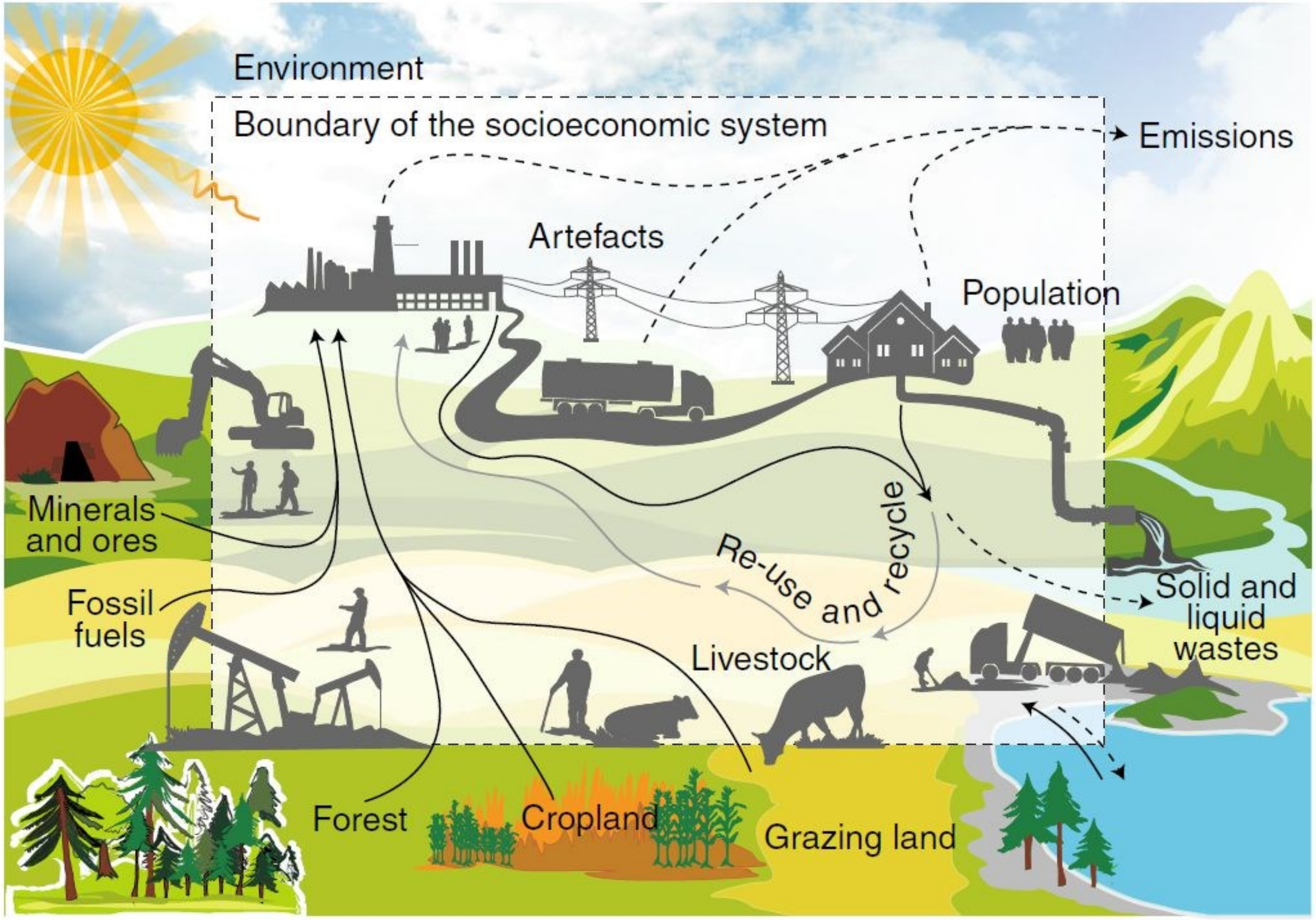

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Haberl *et al* 2019. *Nature Sustainability* **2**, 173–184

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Global stocks of „anthropogenic mass“ vs. biomass

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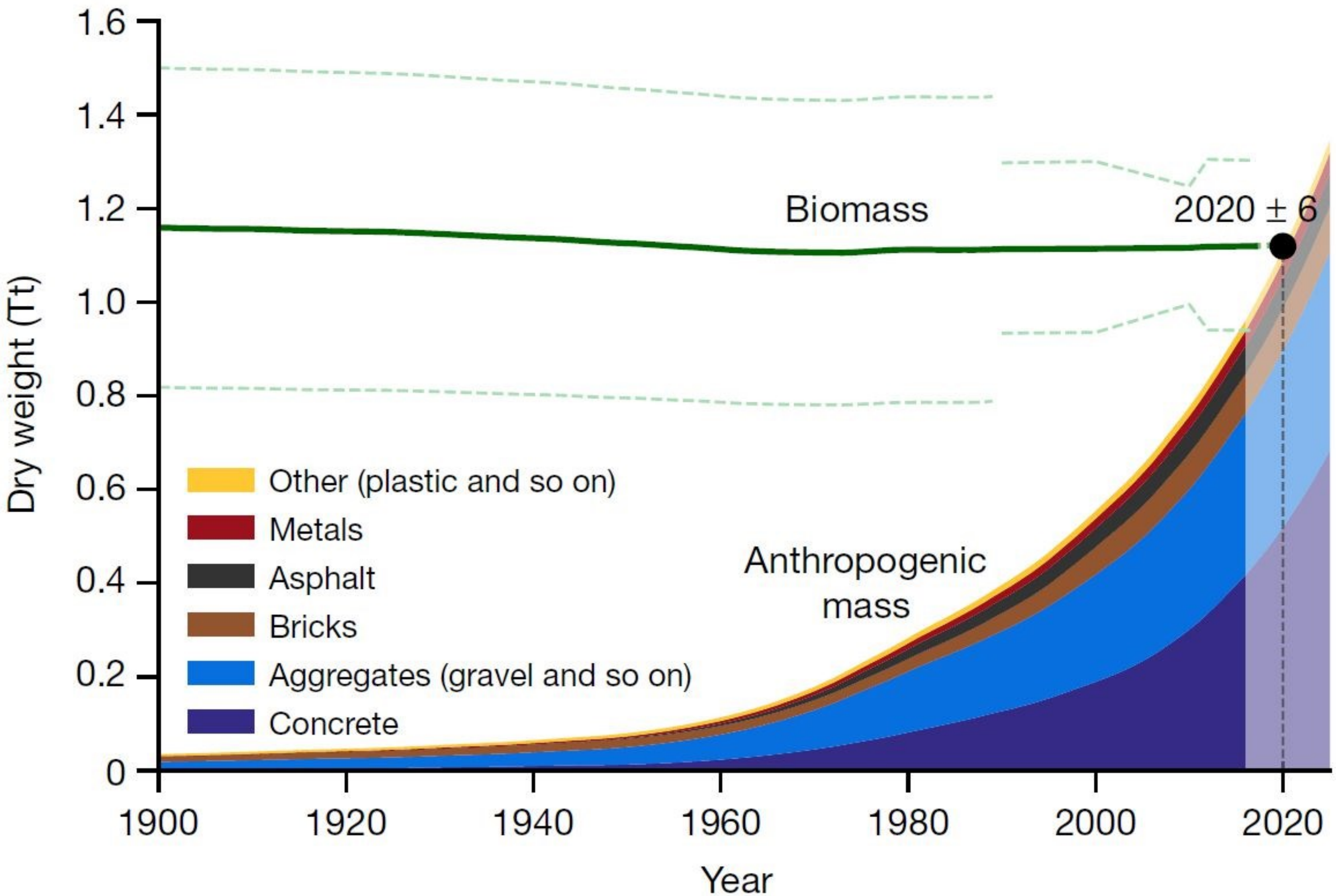

1:1 coupled with GDP

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**

Energy systems, sociometabolic regimes & sustainability challenges

University of Natural Resources and Life Sciences, Vienna

Energy system	Sociometa-bolic regime	Energetic basis	Core sustainability challenges
Uncontrolled solar energy system	Hunter-gatherers	Biomass from natural ecosystems	Extinction of mega-fauna (overhunting), climate change
Controlled solar energy system	Agrarian society	Biomass from agro-ecosystems & forests, conversion through livestock	Maintaining a viable balance between population (workforce) and agricultural productivity (Boserup)
Fossil energy system	Industrial society	Biomass, fossil fuels, nuclear, large hydropower, new renewables	Sustainability problems from non-renewable resources (e.g. fossil fuels)

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Mass of materials extracted before and during industrialization, and material demand of global convergence

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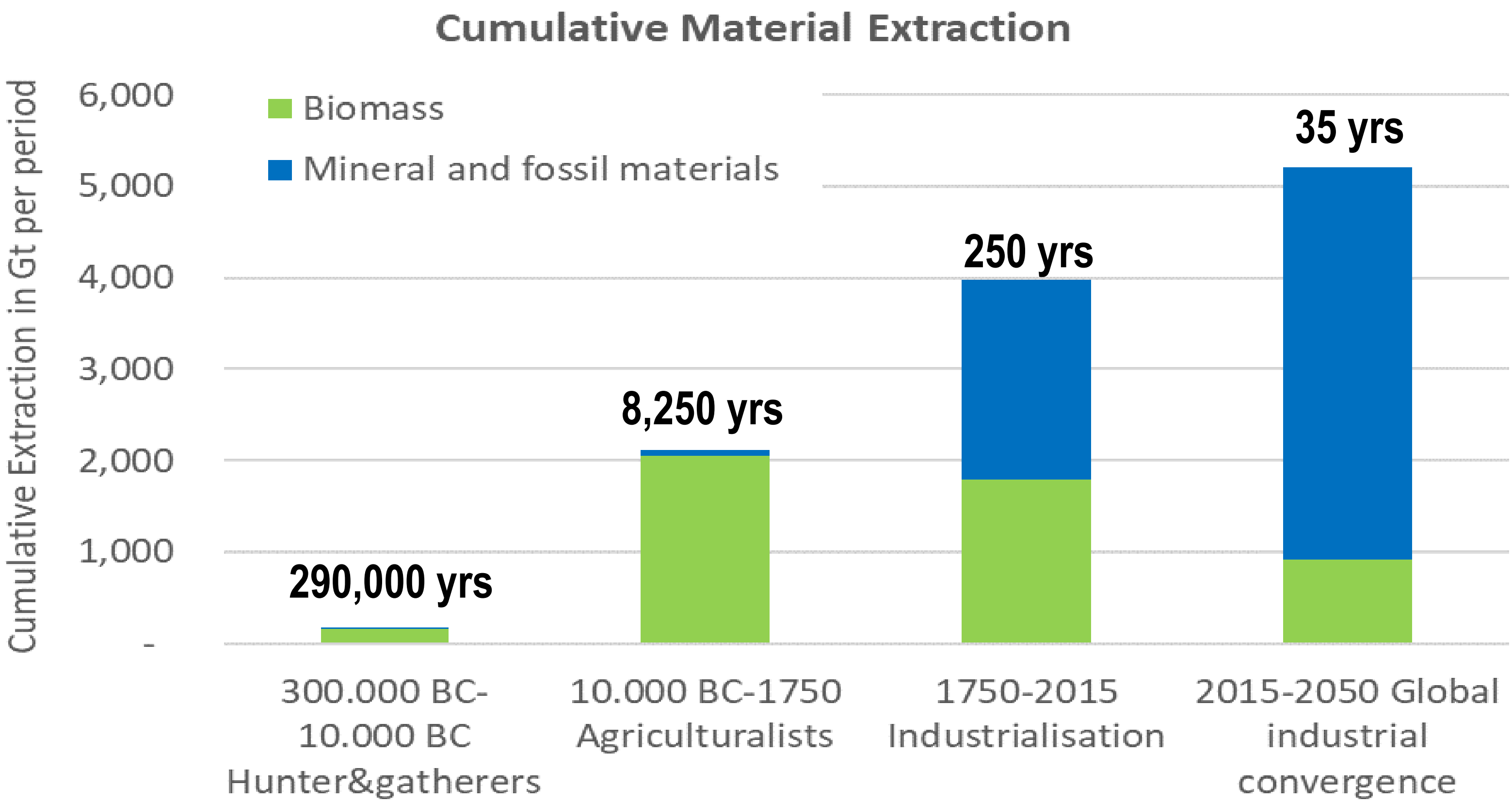

Source: Calculations by Krausmann based on Fischer-Kowalski *et al.* 2014 (*Anthropocene Review* **1**), Krausmann et al. 2016 (in *Social Ecology*, Haberl *et al., eds.*), Krausmann et al. 2020 (*Global Environmental Change* **61**)

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The climate challenge I
What limiting global warming to 1.5° means

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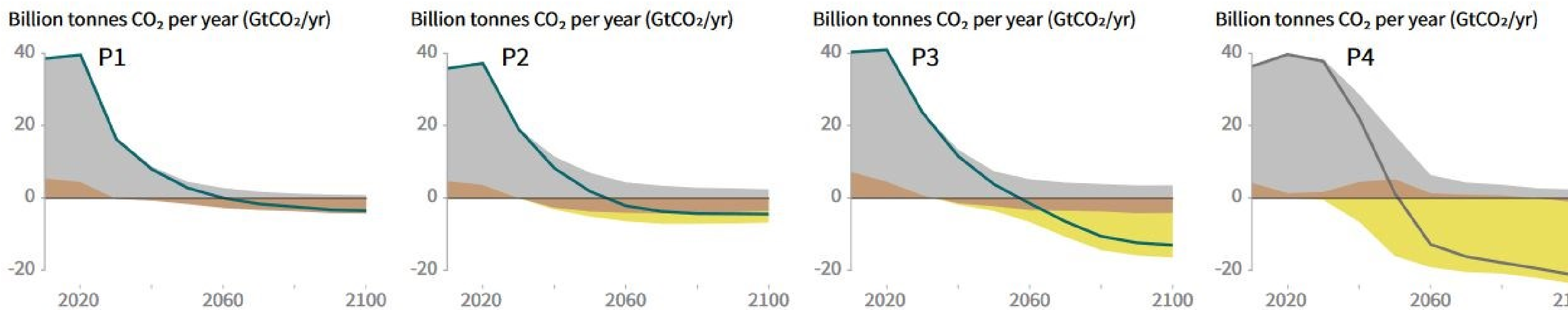
CO_2 emissions must reach net zero ~2050
Rapid reduction required to avoid risky technologies

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

Fossil fuel and industry | AFOLU | BECCS



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*

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The climate challenge II
Sociometabolic transformation in 20-30yrs

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- 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 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

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Social metabolism as a driver of biodiversity loss

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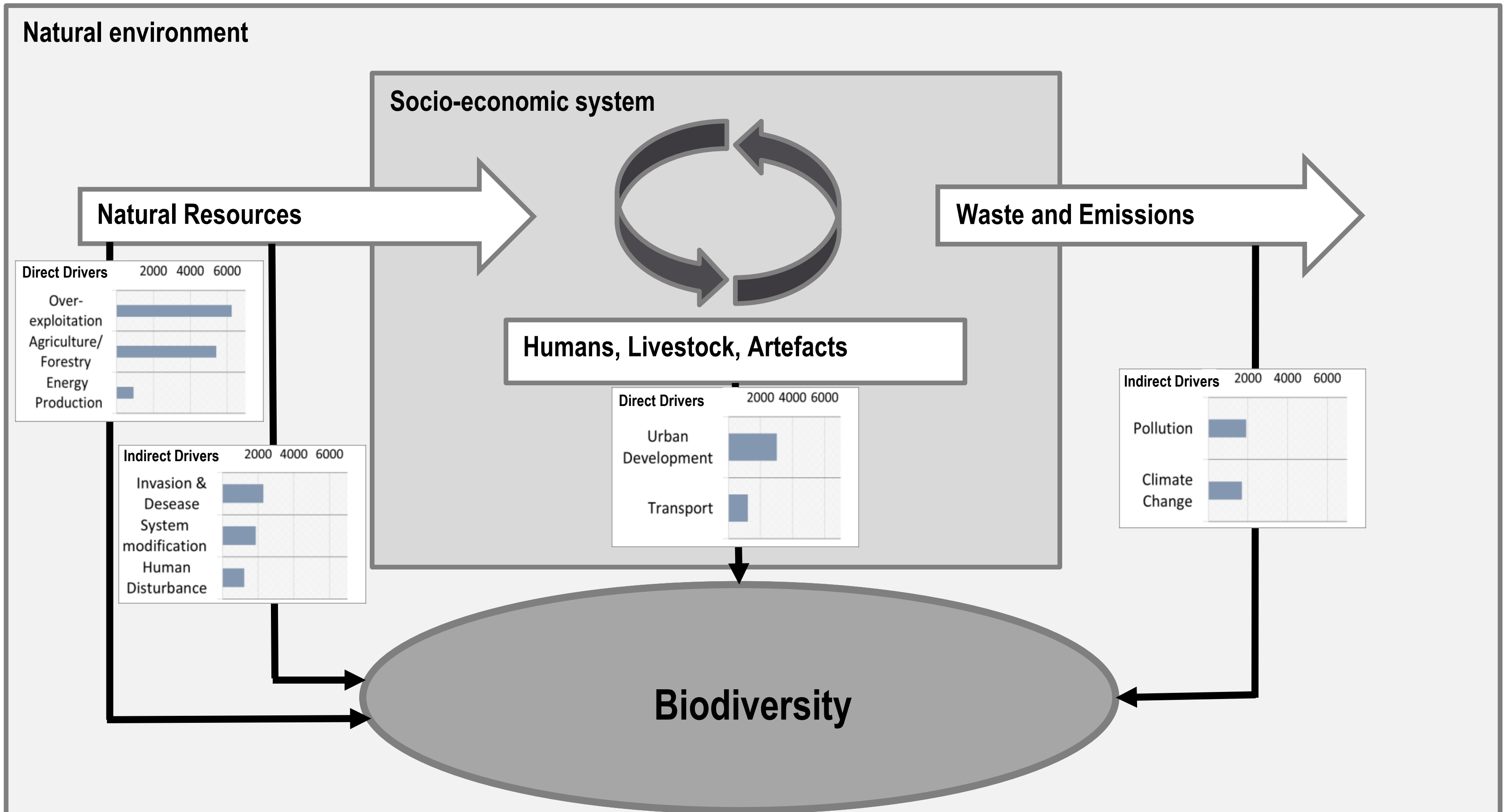

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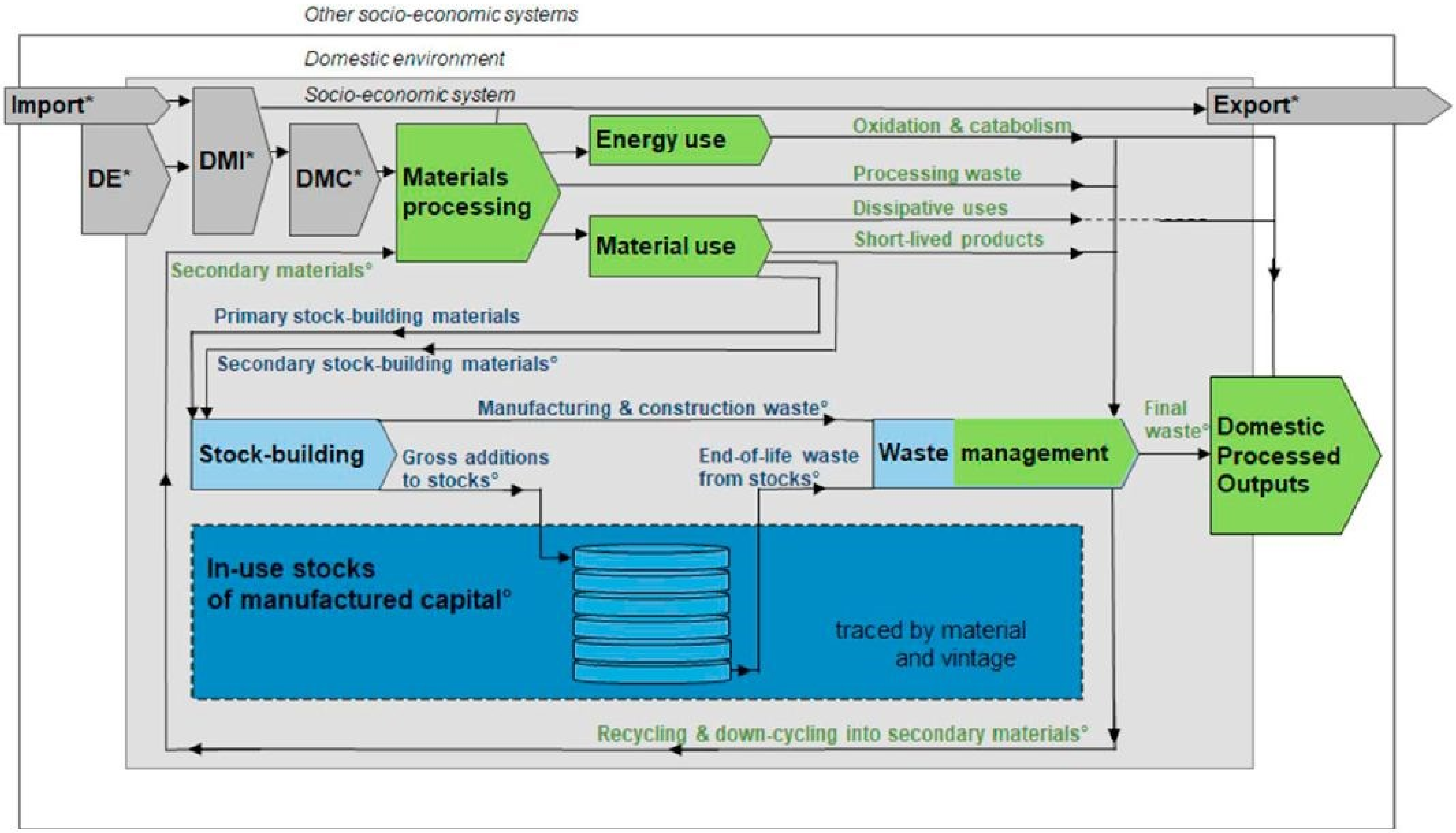
Biodiversity data: Maxwell *et al.* 2016. Nature **536**

Linking stocks and flows: The MISO model

University of Natural Resources and Life Sciences, Vienna



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

Stocks, flows and a glimpse on services (global 1900-2015)

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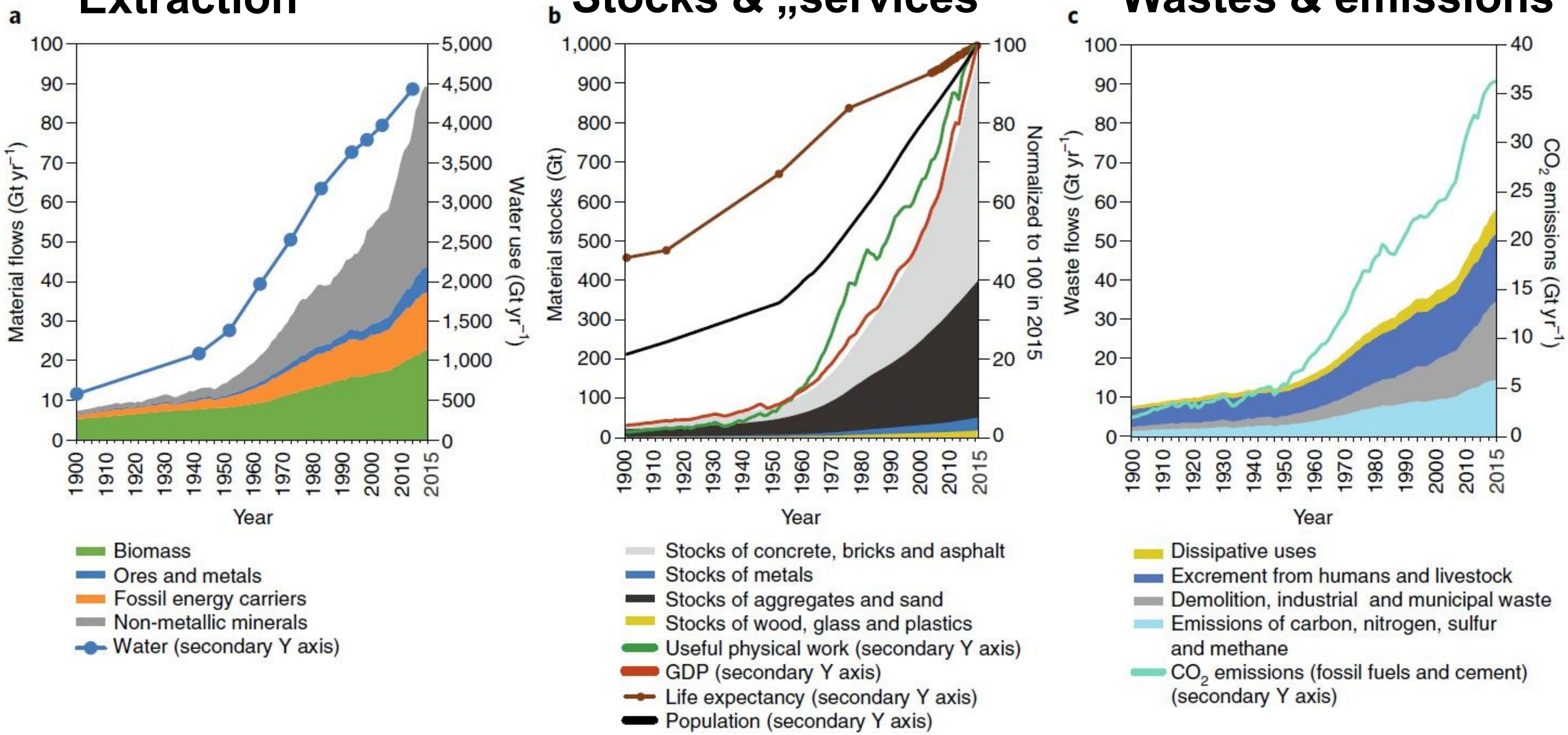
Extraction

Stocks & „services“

Wastes & emissions



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

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Global circularity and resource use
1900-2015

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

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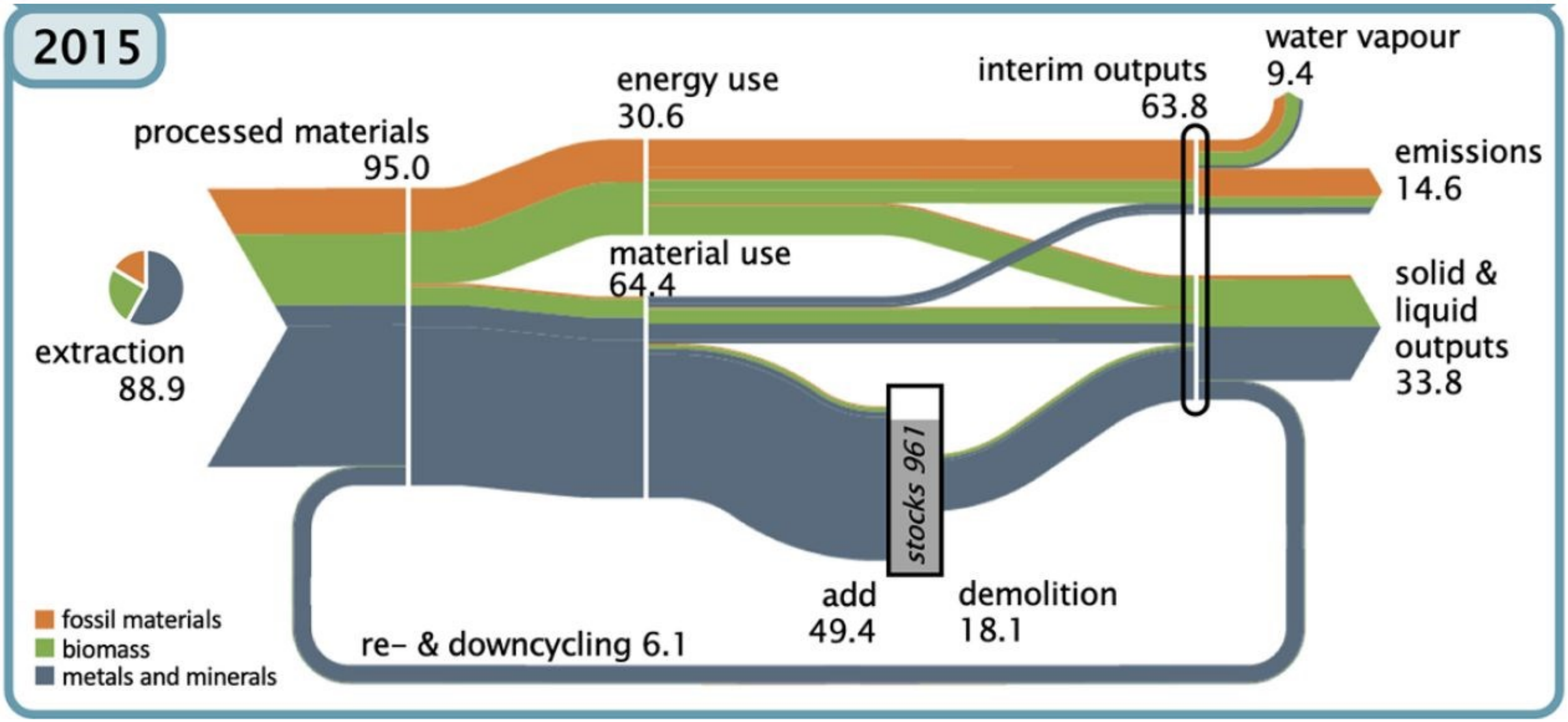

Haas *et al.* 2020, *Resources, Conservation & Recycl.* **163**, 105076

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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 (“lock-in”)

GHG emissons 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)

Cropland loss from global urban expansion until 2030

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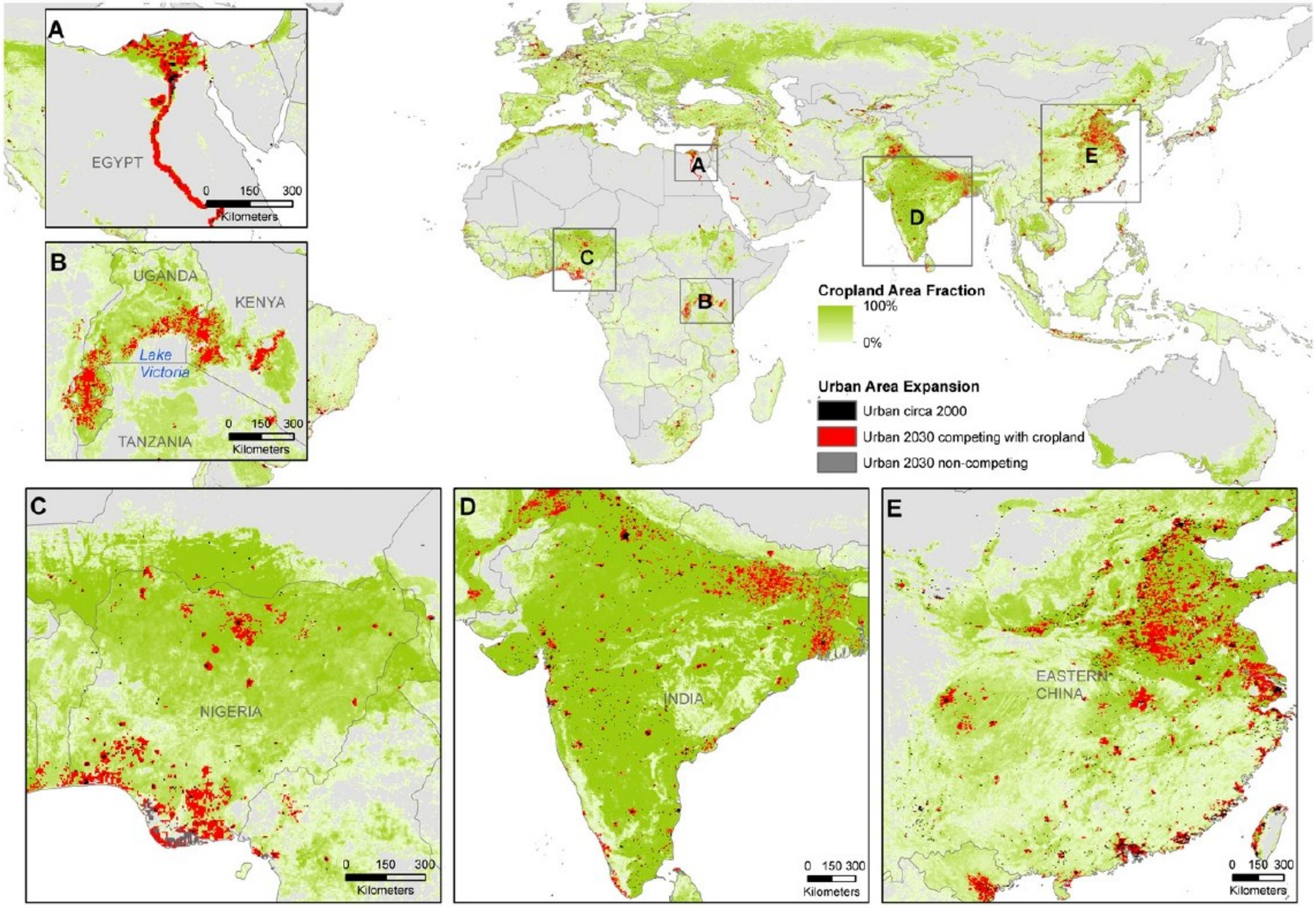

Fig. 1. Maps show where projected urban expansion until 2030 is expected to result in cropland loss. Competing areas (red) hold croplands but have a high probability (>75%; medium scenario) of becoming urbanized by 2030. (*A–E*) Close-ups of urban area expansion hot spots. Data on urban expansion are from ref. 4, and data on cropland are from ref. 16.

Urban expansion will consume 1.8-2.4% of current global cropland. This land currently produces 3-4% of all crops globally.

d'Amour *et al.* 2017. *PNAS* **114**, 8939–8944

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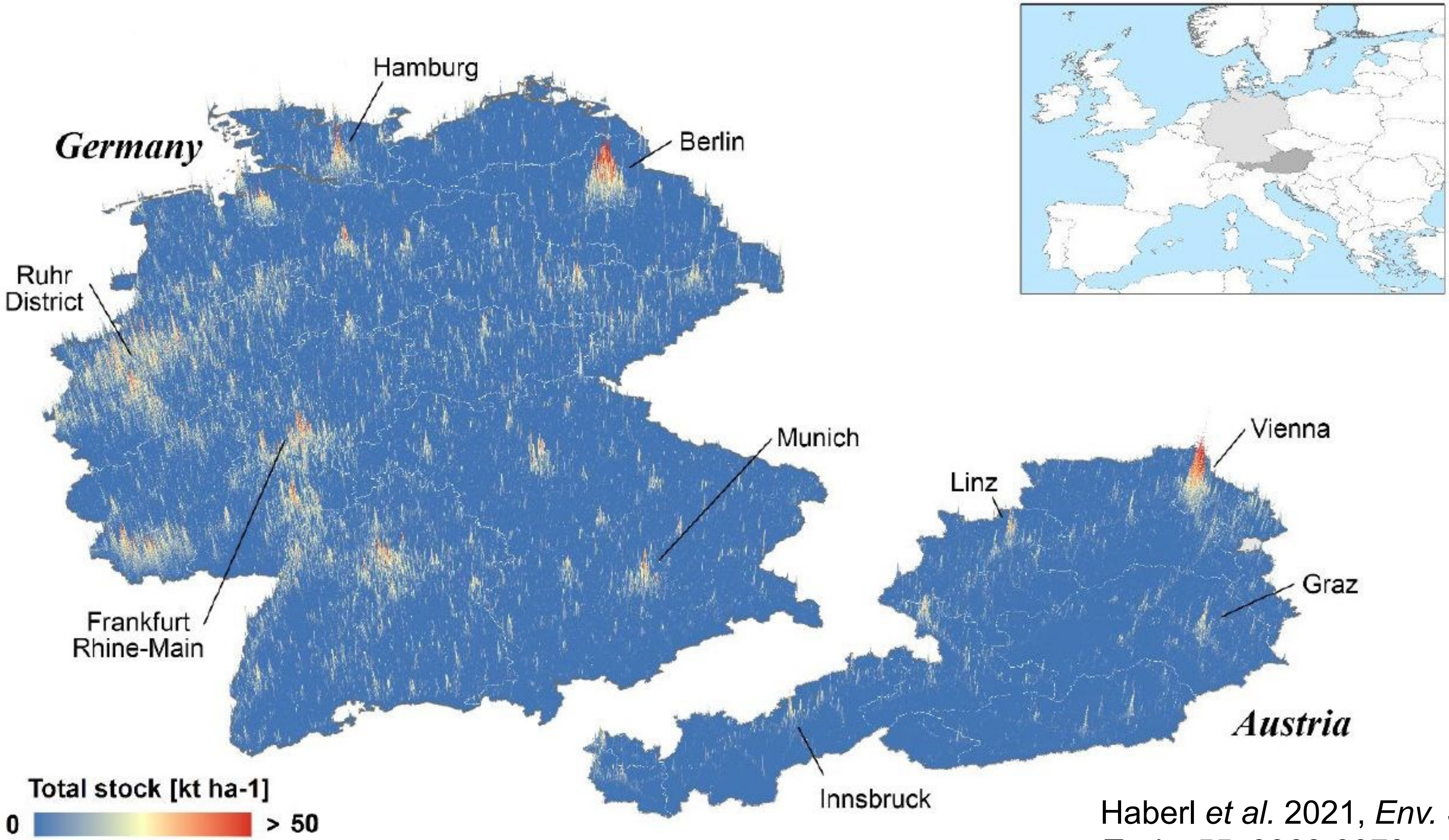
Mapping material stocks
Austria & Germany 2018



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

Fig 2. Three-dimensional maps of total material stocks in buildings and infrastructures in Germany and Austria (2018; 100m resolution), measured as kt/ha (1 kt = 1,000 metric tons; 1 ha = 10^4 m^2 = 0.01 km^2).

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Most material stocks are in buildings and infrastructures

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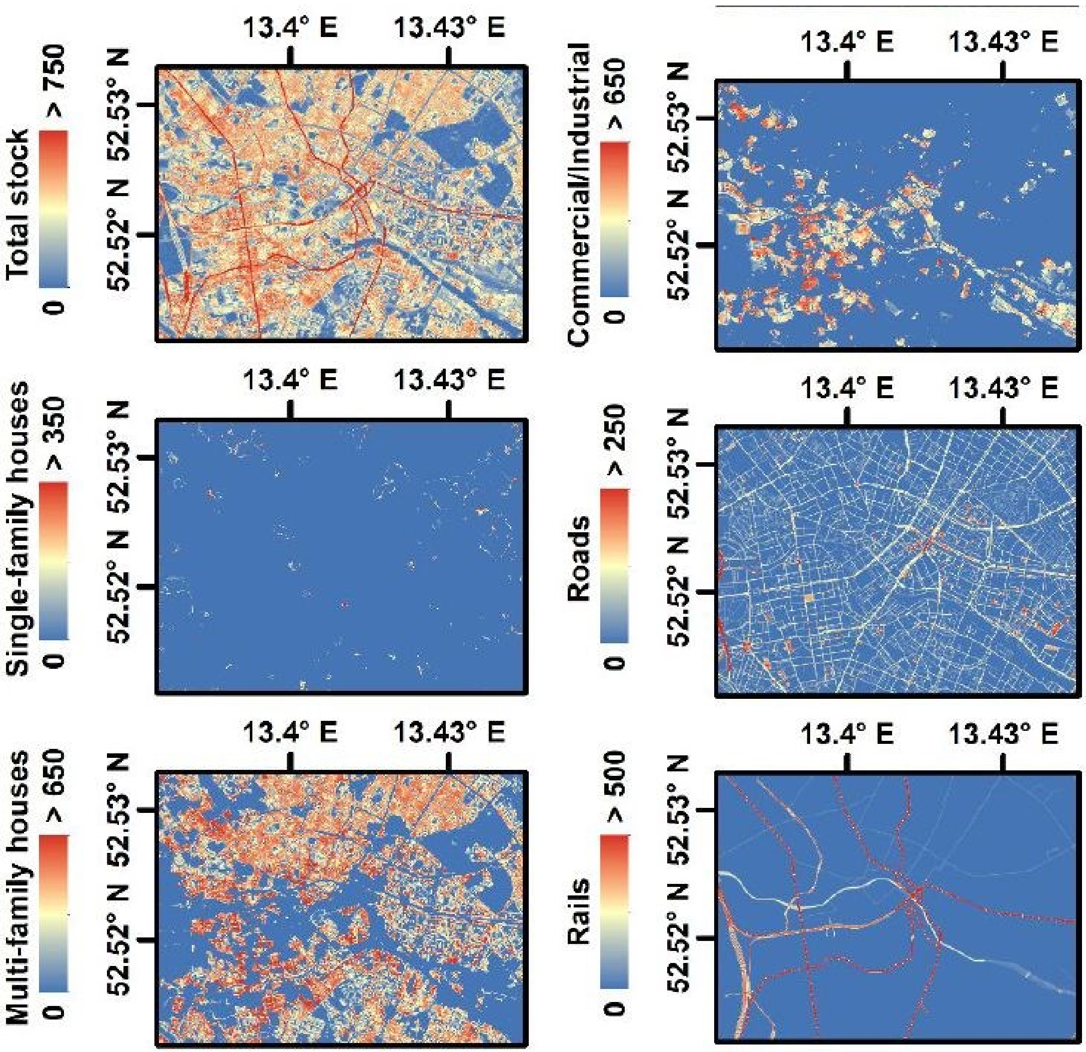
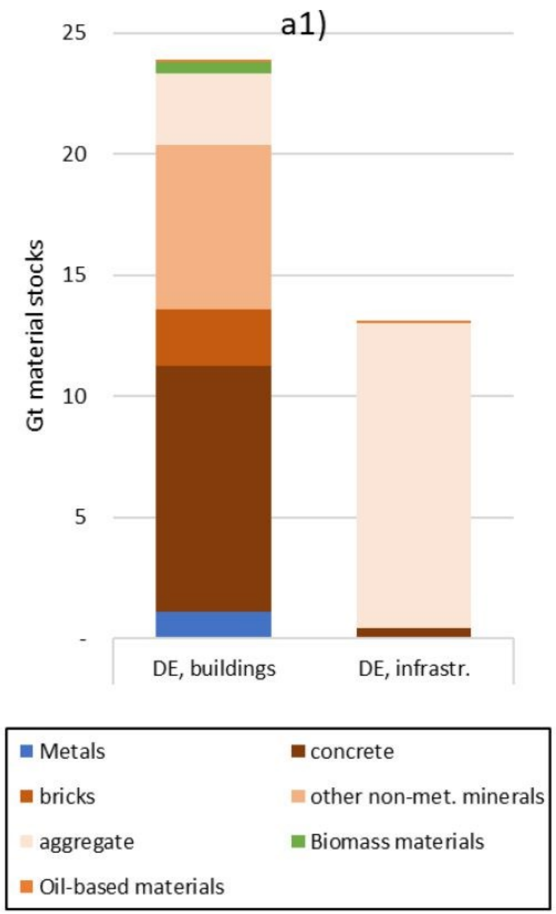
Berlin, 2018



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

Germany



Infrastructures and buildings in Austria outweigh trees by factor >2

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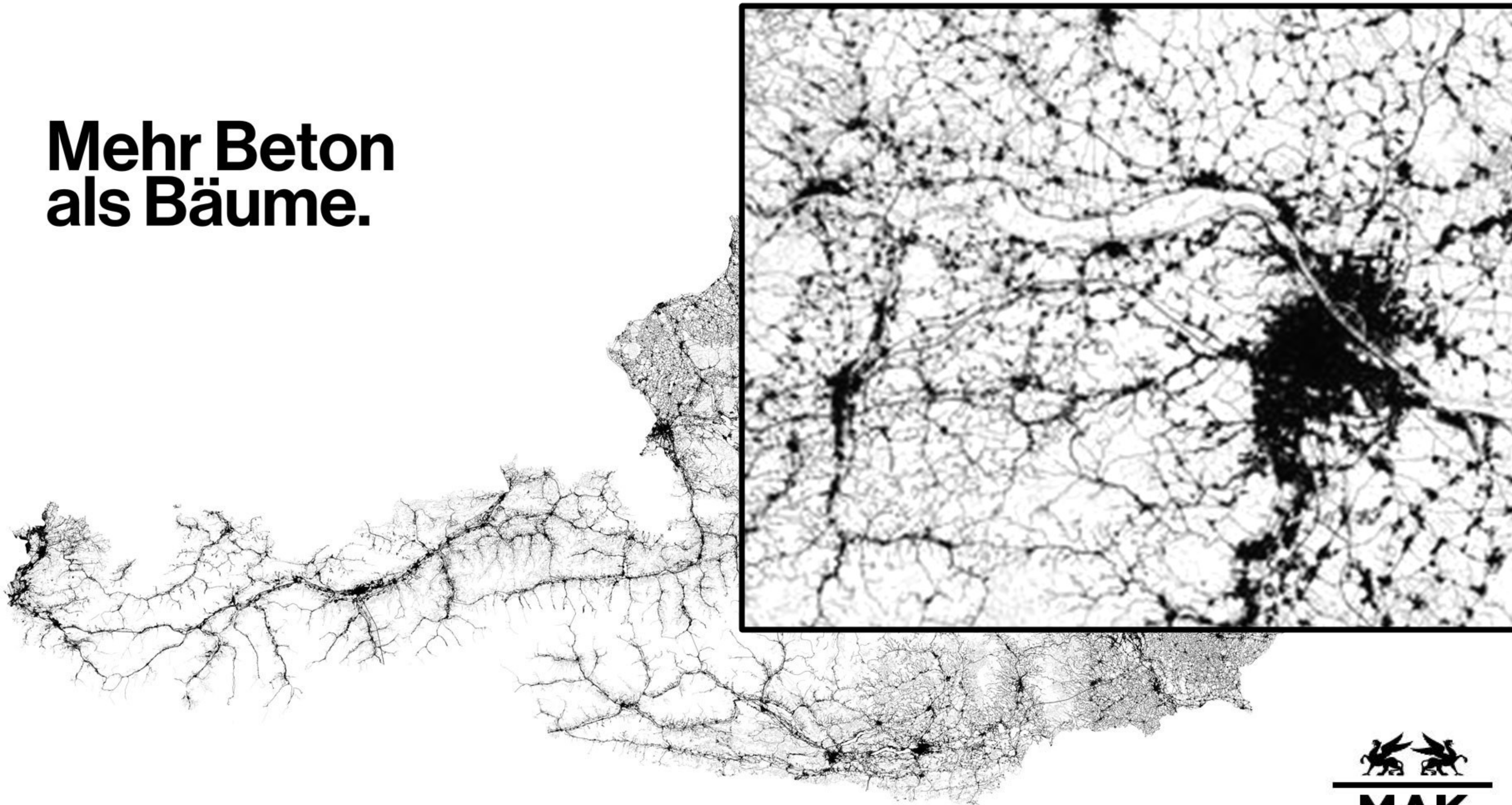

MAK

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

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The classical approach: Eco-efficiency

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

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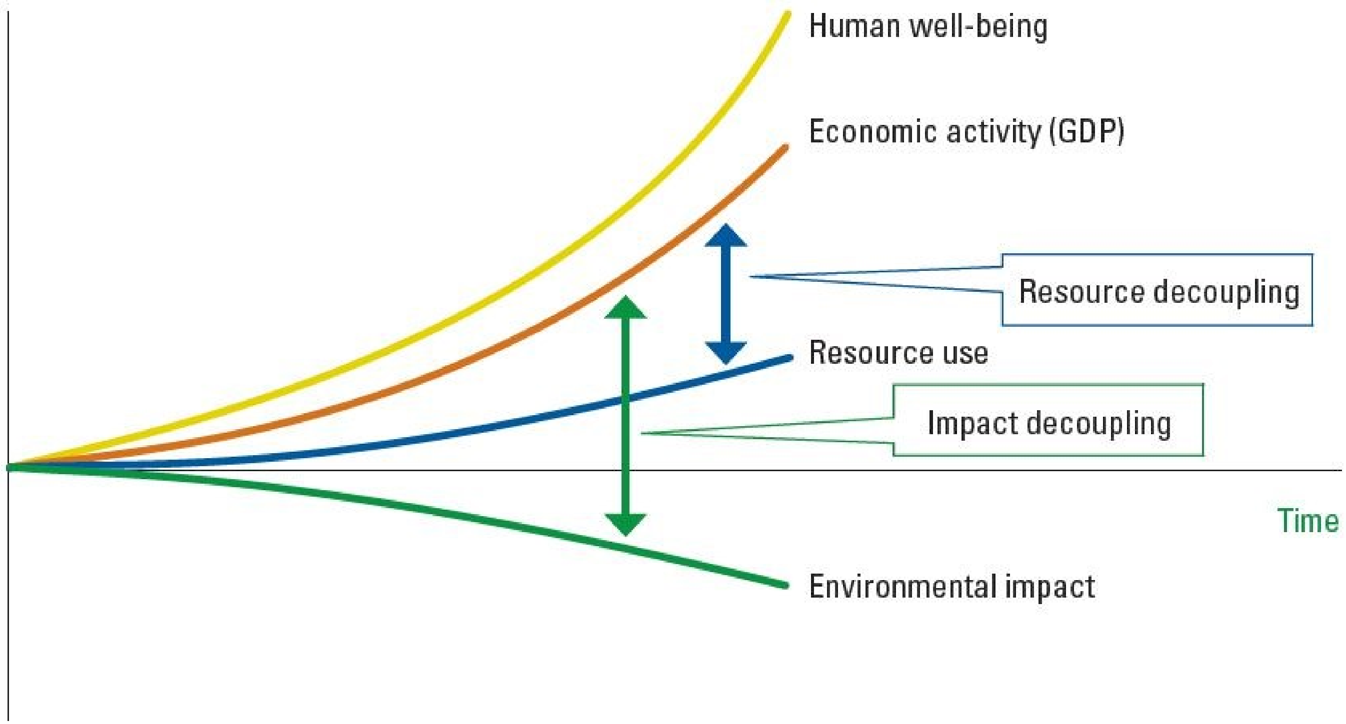
Relative decoupling:
- Resource use per unit GDP or impacts decline, but total amount of resources grows
- GDP grows faster than resource use

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)

DECOUPLING natural resource use and environmental impacts from economic growth
UNEP
International Resource Panel
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The *Gospel of Eco-Efficiency is good,* but not nearly good enough

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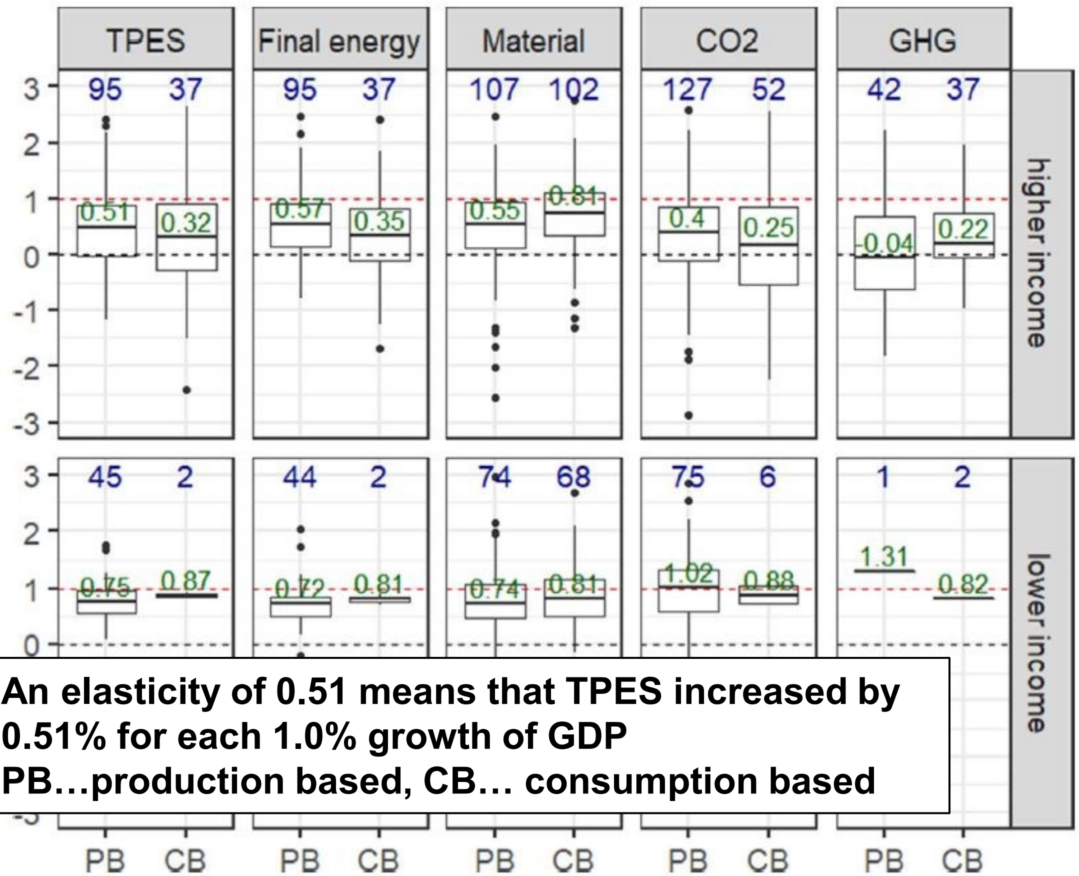
Observed GDP elasticities in the last decade



An elasticity of 0.51 means that TPES increased by 0.51% for each 1.0% growth of GDP
PB…production based, CB… consumption based

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 CO2 by 3.3%-5% of the emissions in 2020 per year. This requires a *qualitatively new approach* for socio-ecological transformation

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

TPES… total primary energy supply, GHG… greenhouse gas

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Inequality of GHG emissions between super-rich and average people

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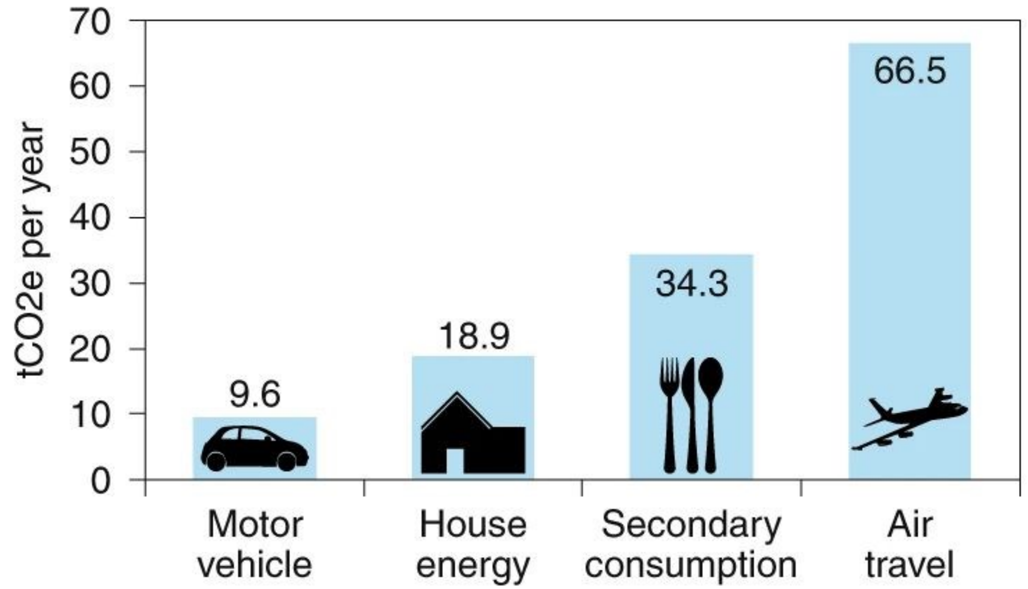
Fig. 1: The estimated carbon footprint of a typical super-rich household of two people.

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

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)



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.

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

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)*

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Krausmann *et al.*, 2020, *Global Env. Change*, **61**, 102034
* Davis *et al.*, 2018, *Science* **360**, 1419

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Calculation of CO_2 emissions
Based on material stocks and stock/energy flow/GHG emission relations

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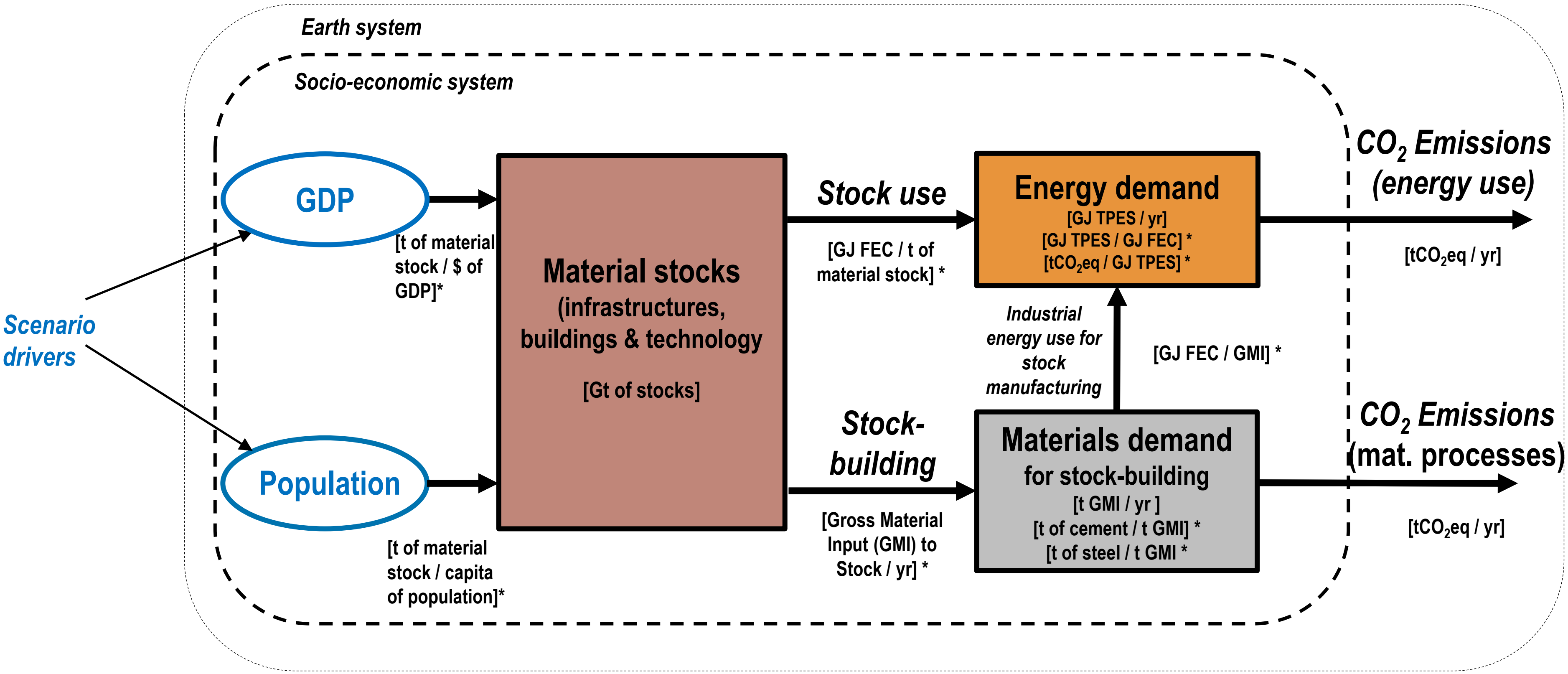

* Scenario variables historically-calibrated

Global Material Stock Scenarios
1970-2050

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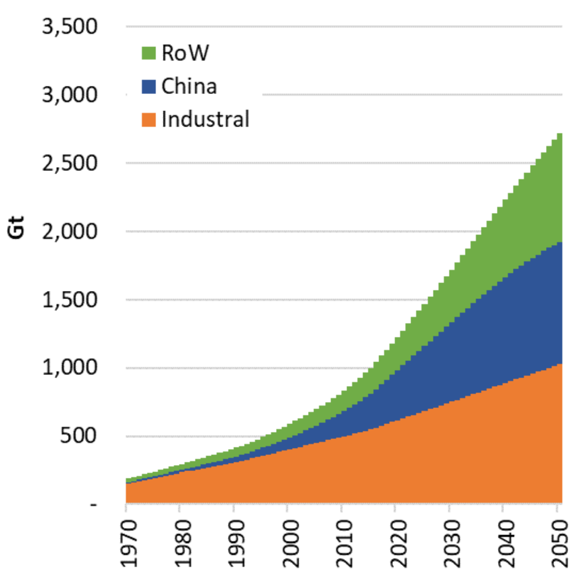
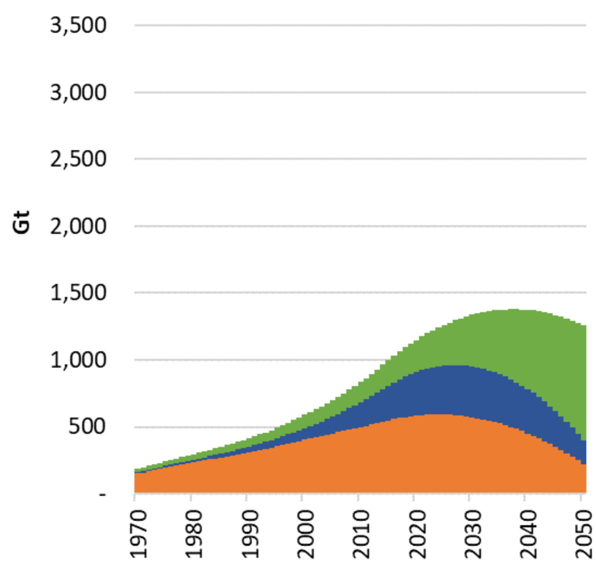
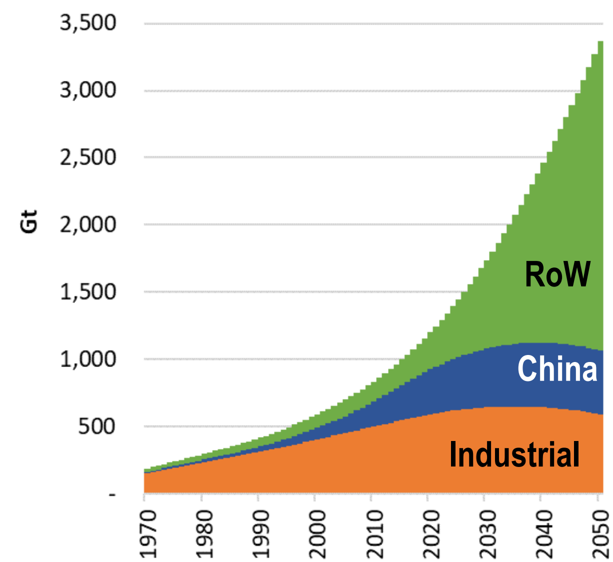
B GDP-driven high



C convergence1970



D convergence2015



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

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

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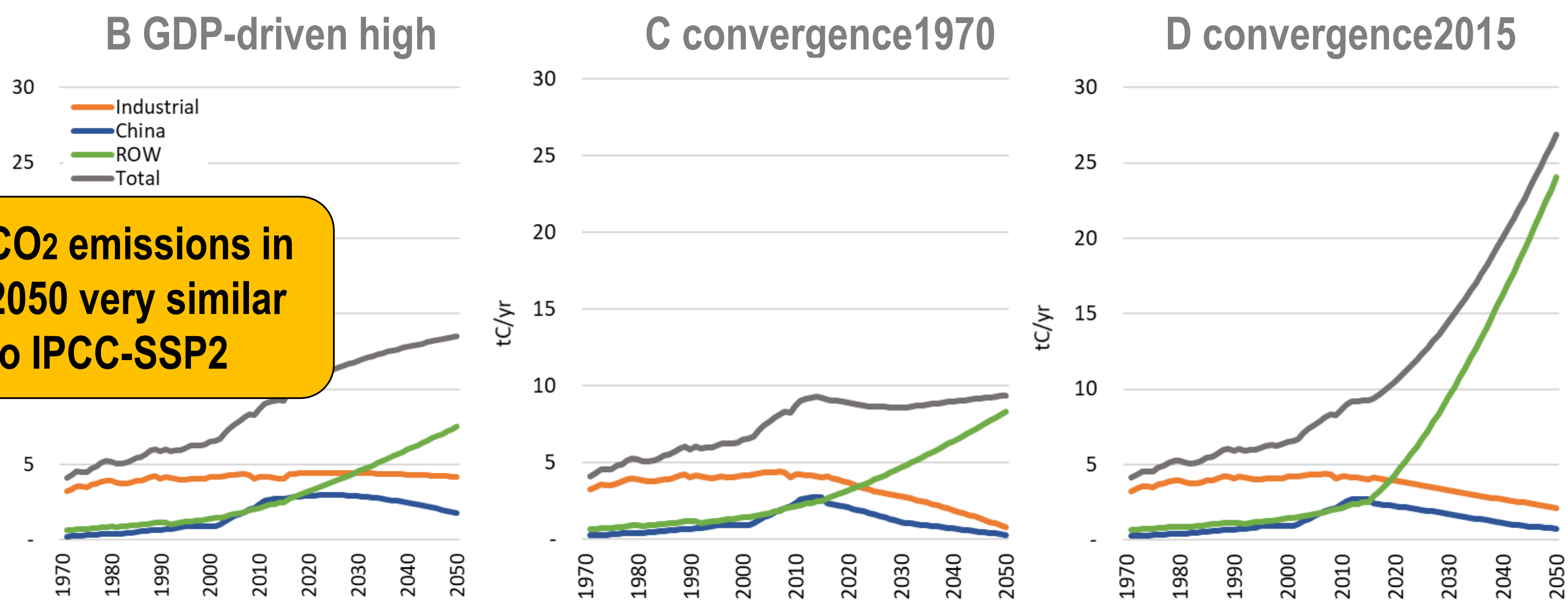

CO_2 emissions in 2050 very similar to IPCC-SSP2

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

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

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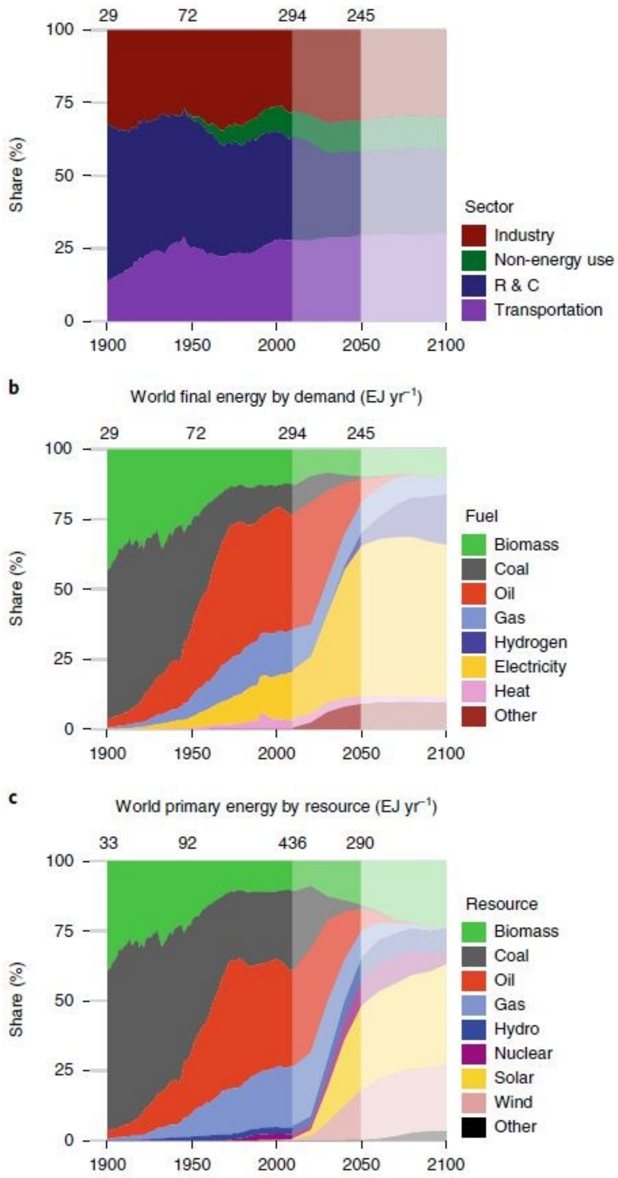

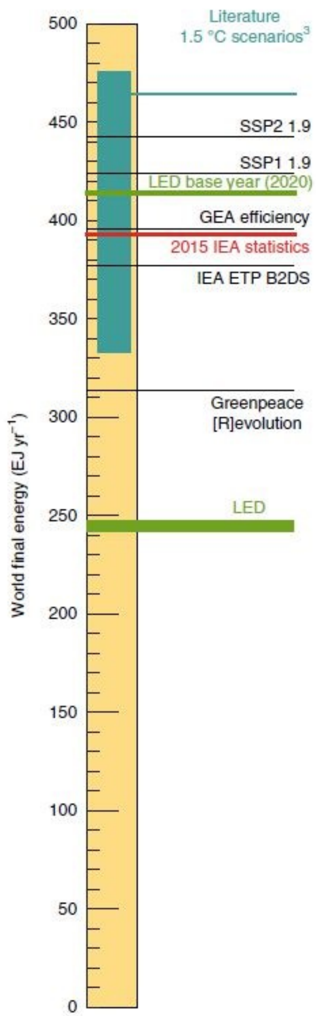

- Global final energy strongly reduced until 2050
- Same energy services as in current trend
- Meets 1.5° climate target
- Avoids controversial technologies (BECCS)
- Completely different investment patterns:
  - Low-energy buildings
  - Transport-sparing settlements
  - Resource-sparing as top priority

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

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Towards sustainability?
Reshaping the stock-flow-service nexus

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Stocks Buildings, infra-structures, machinery

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

Flows Energy, materials

Services Contribution s 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**

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Stocks and flows vs. social progress

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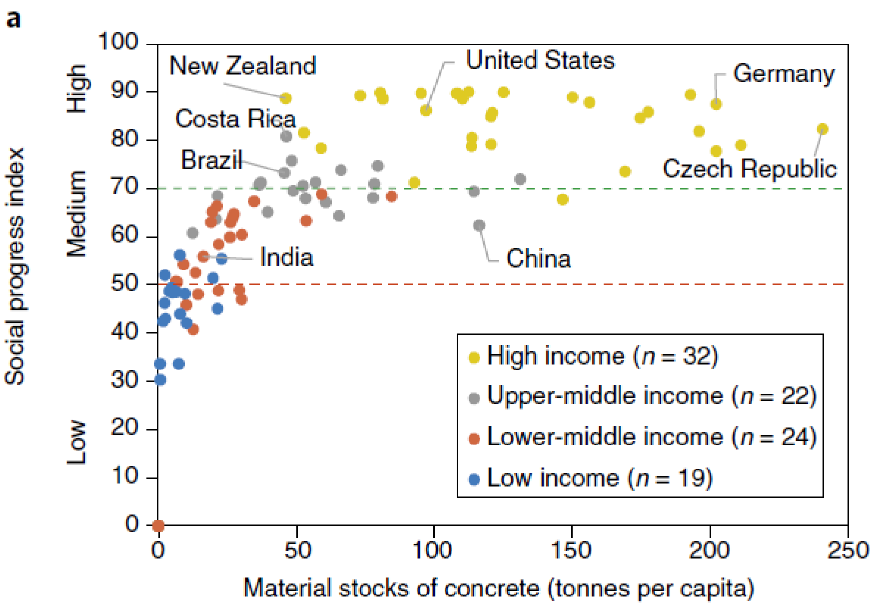
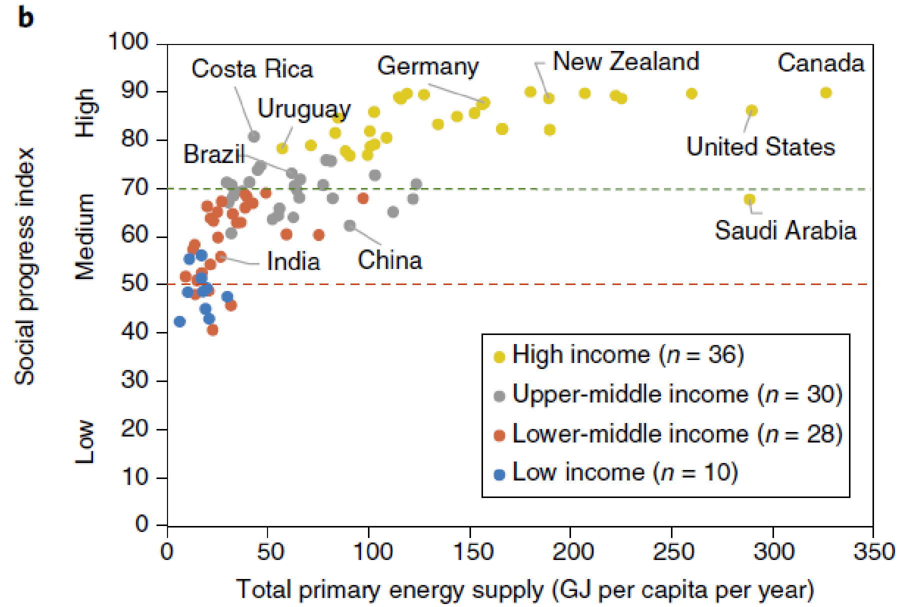
Concrete stocks



Primary energy supply



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

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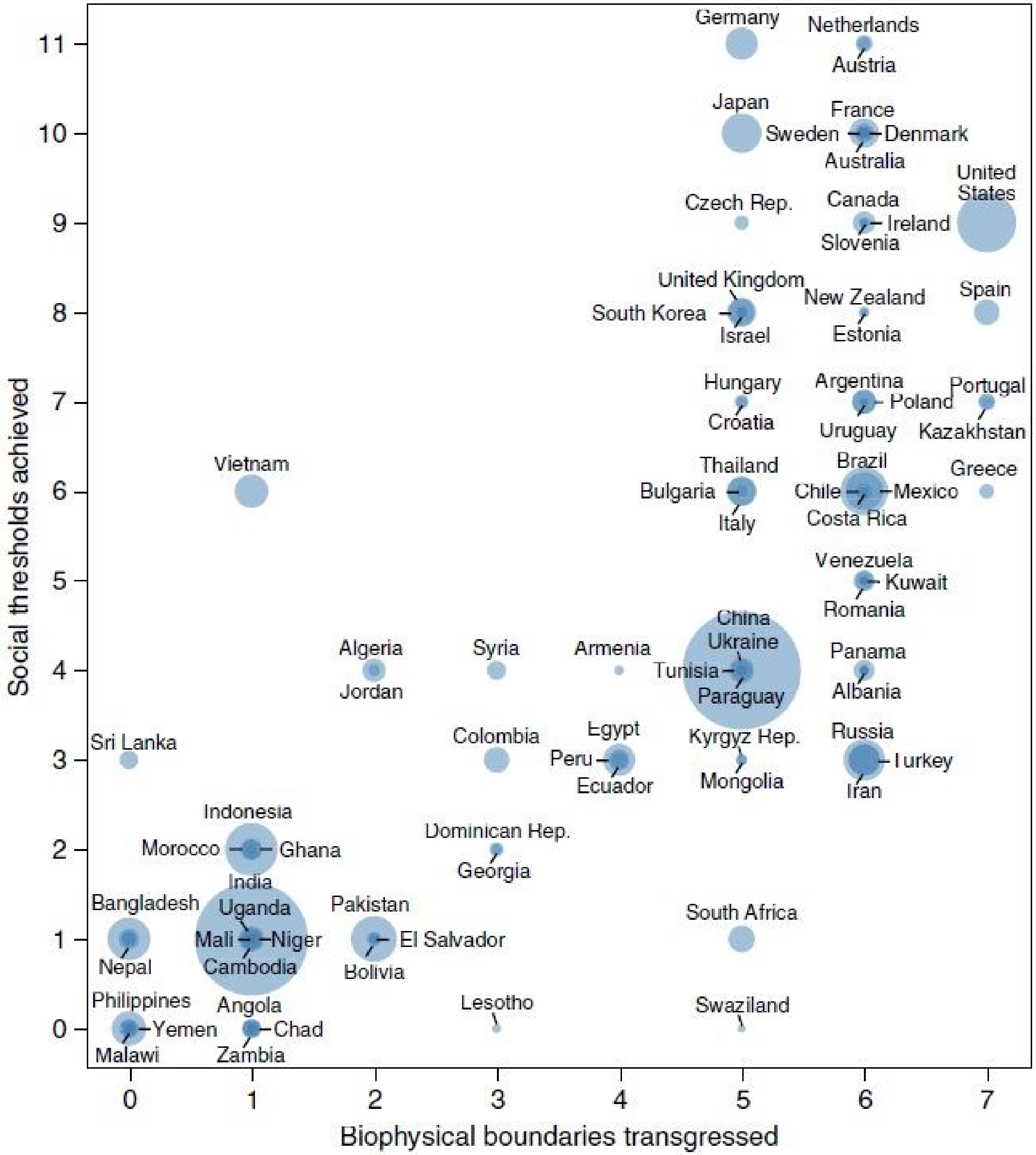

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Donut economics:

empirical data – no countries achieve social thresholds without trespassing biophysical boundaries

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

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Provisioning systems link resource use to societal well-being

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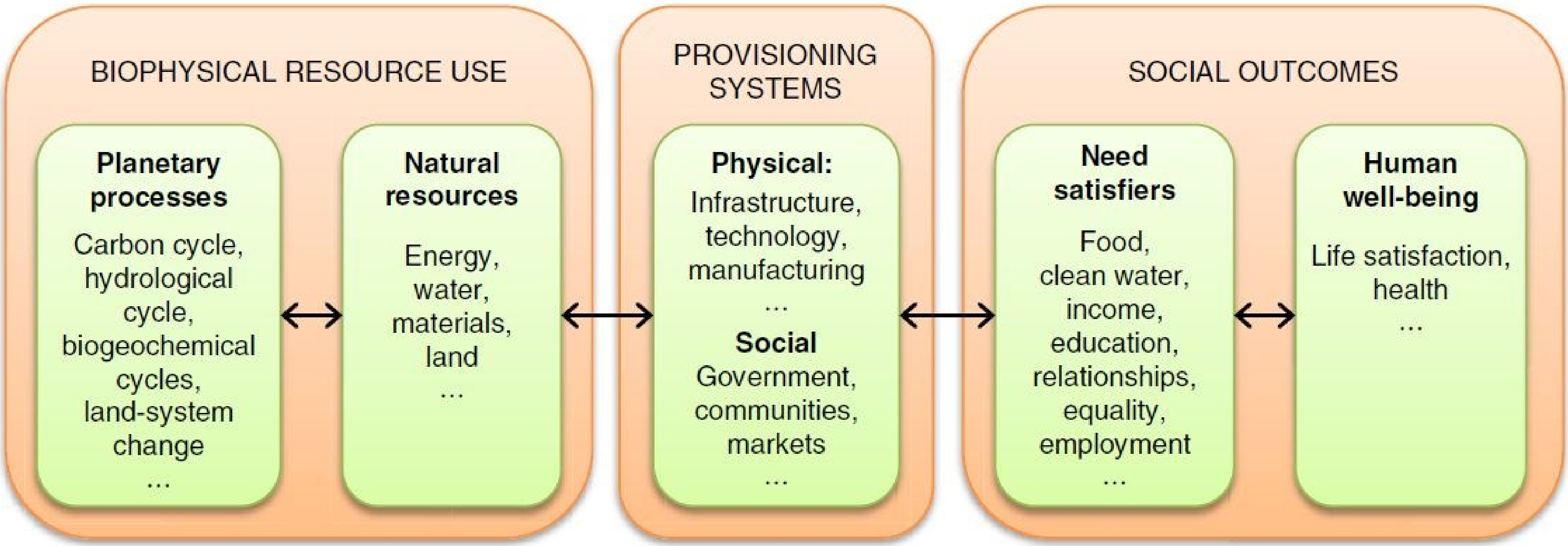
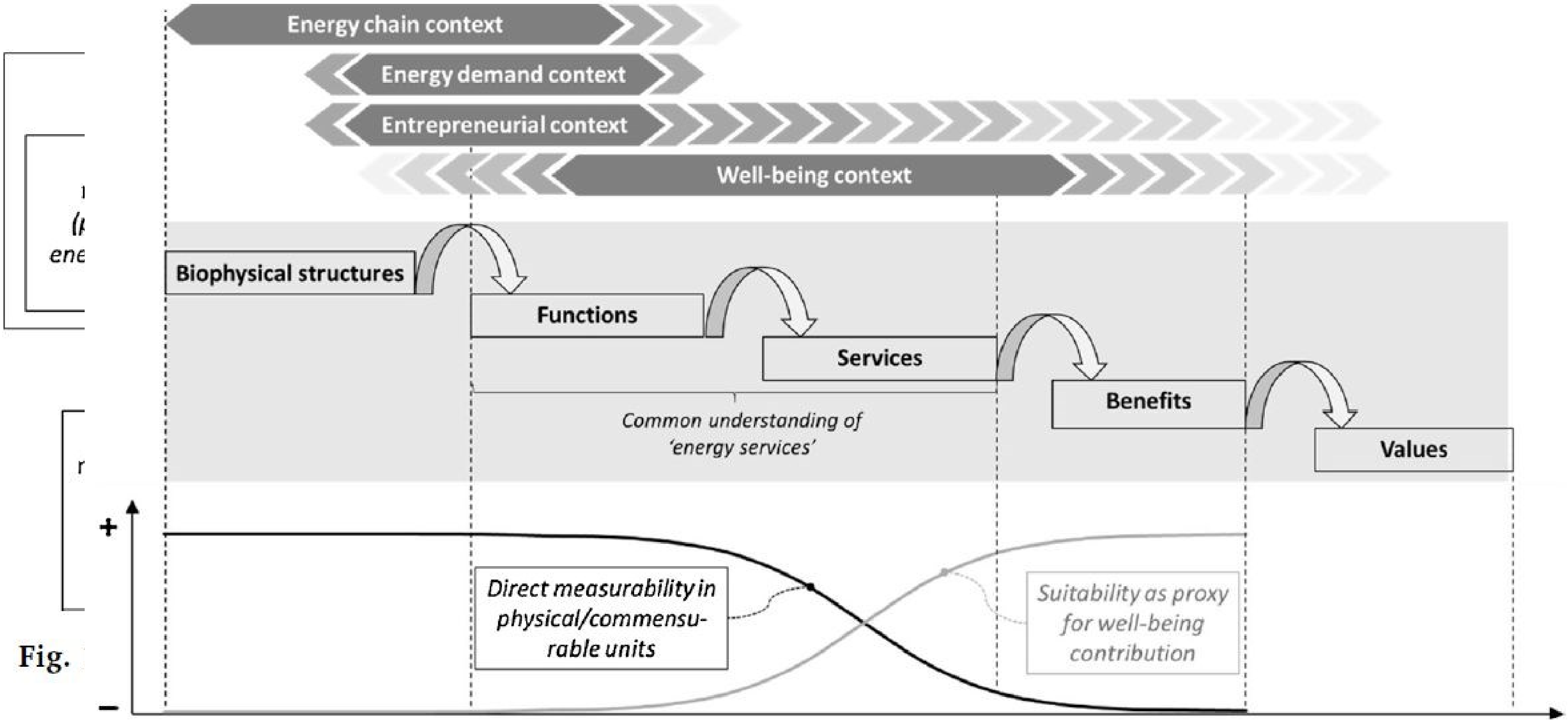


O'Neill *et al.*, 2018. *Nature Sust.* **1**, 88–95

Conceptualizing services: the energy service cascade

University of Natural Resources



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

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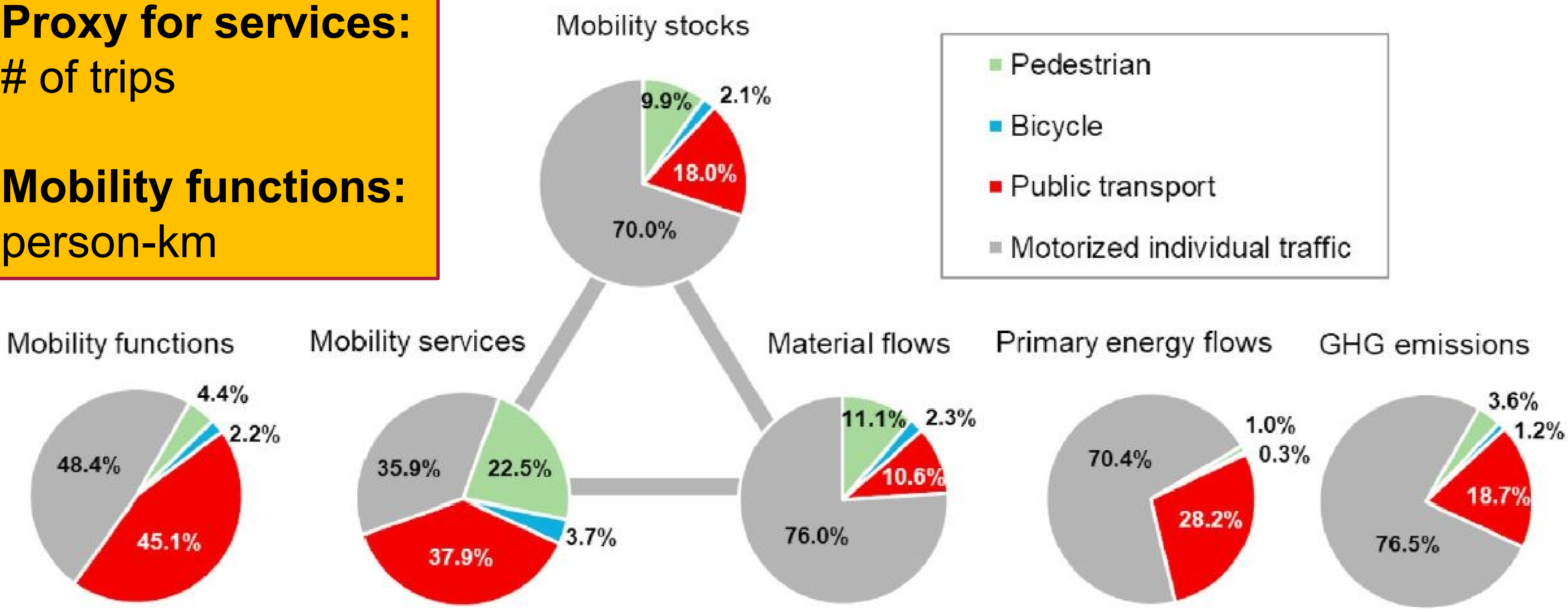
Example: The SFS nexus of personal mobility in Vienna

University of Natural Resources and Life Sciences, Vienna
Institute of Social Ecology

Proxy for services:
# of trips

Mobility functions:
person-km



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

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Transforming the SFS nexus as part of provisioning systems

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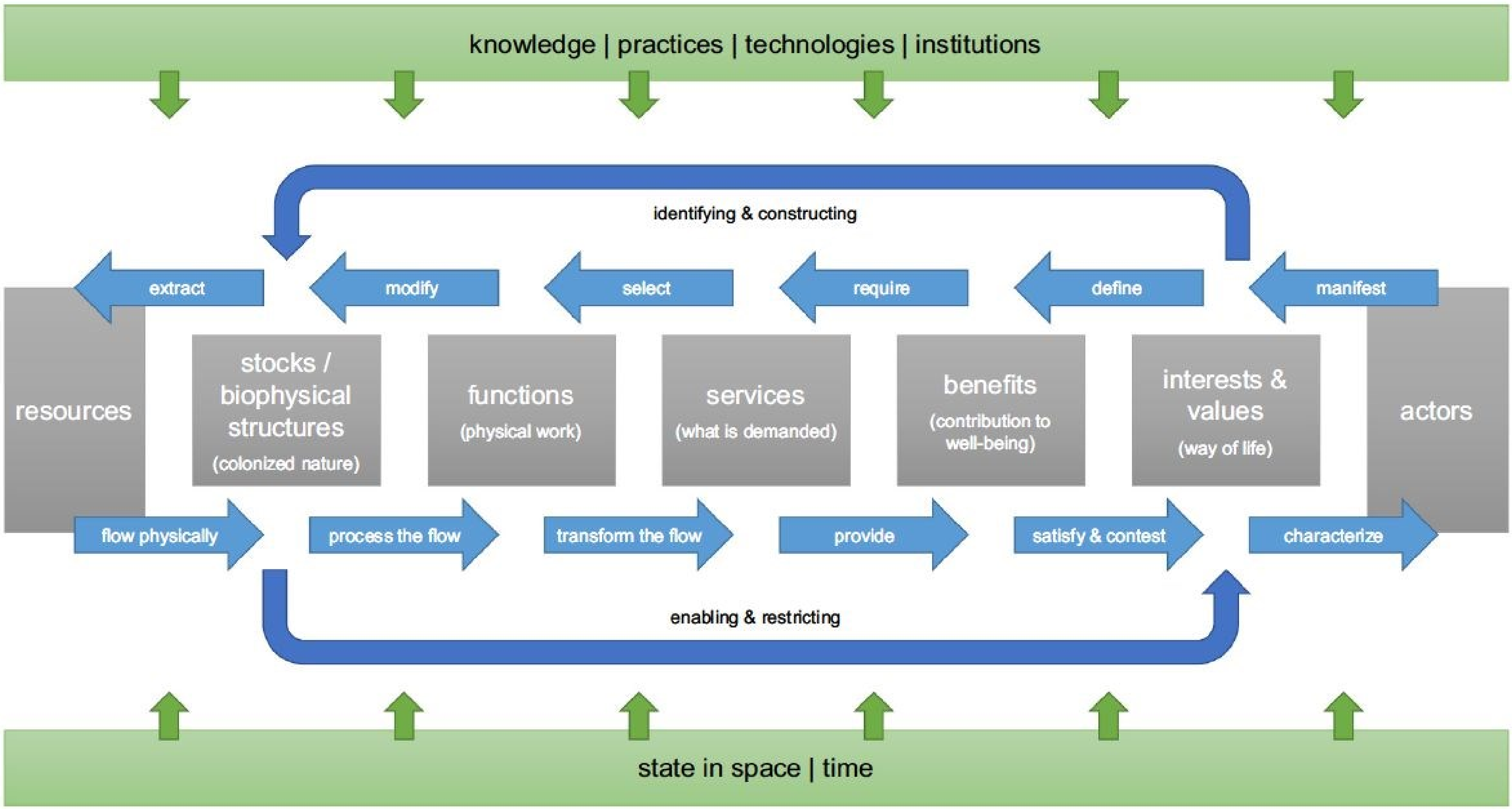

Plank *et al.* 2021. *Ecol. Econ.* **187**, 107093.

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The spiraling constriction of the socio-metabolic corridor

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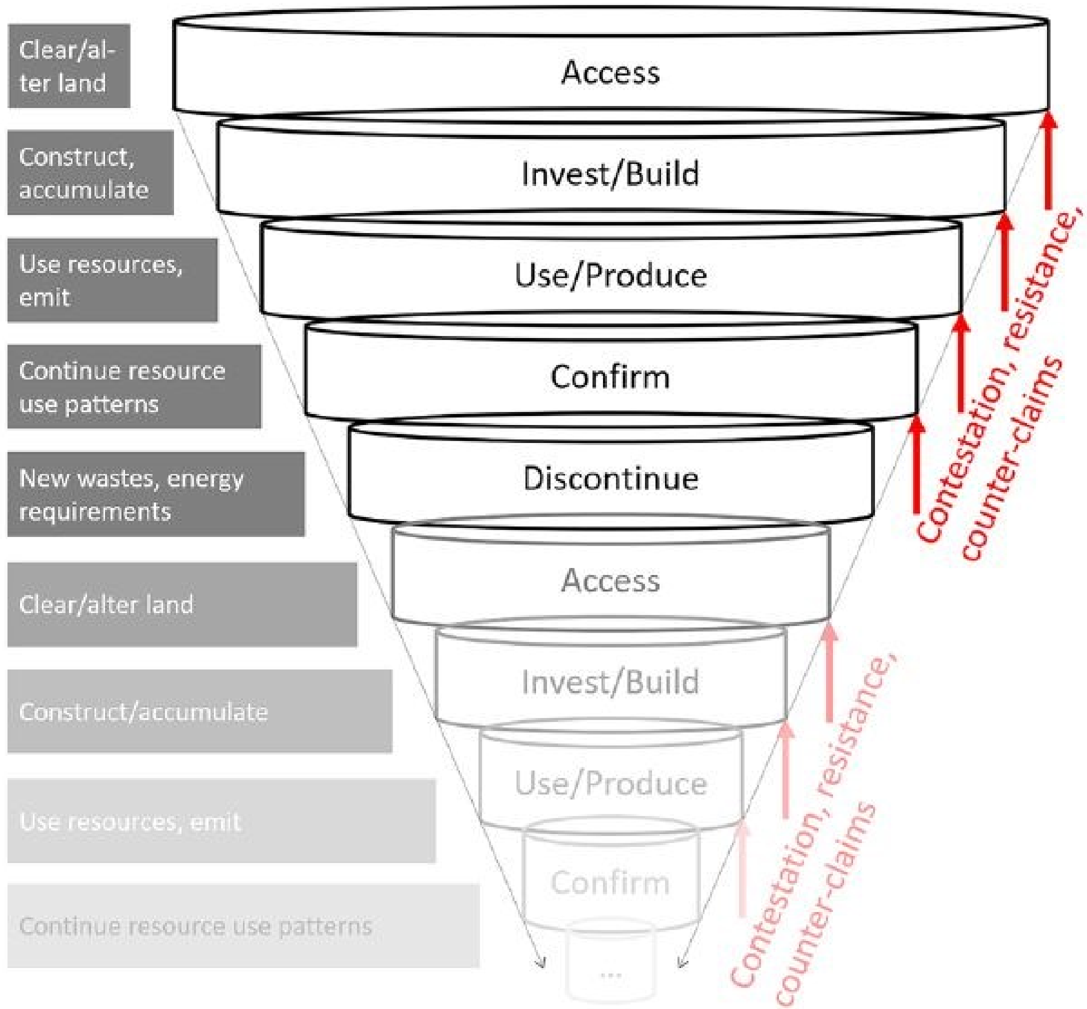

Provisioning systems are built in several steps, each creating fixes that constrict future sociometabolic corridors. How long the ensuing legacies last, depends on the durability of the infrastructures and institutions created.

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

The Stock-Flow-Practice nexus

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

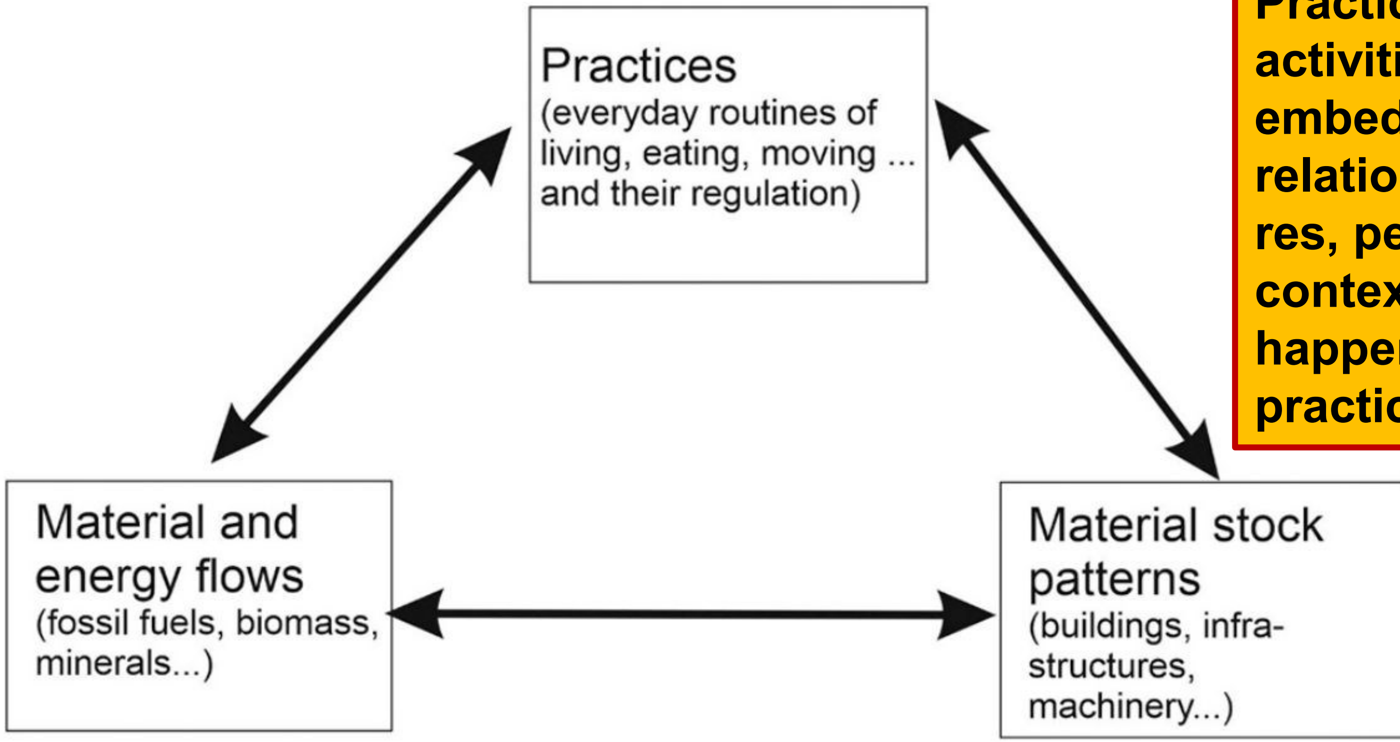

Fig. 1. The Stock-Flow-Practice nexus (SFP nexus). Own graph, based on the SFS nexus graph in Haberl et al. (2017).

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

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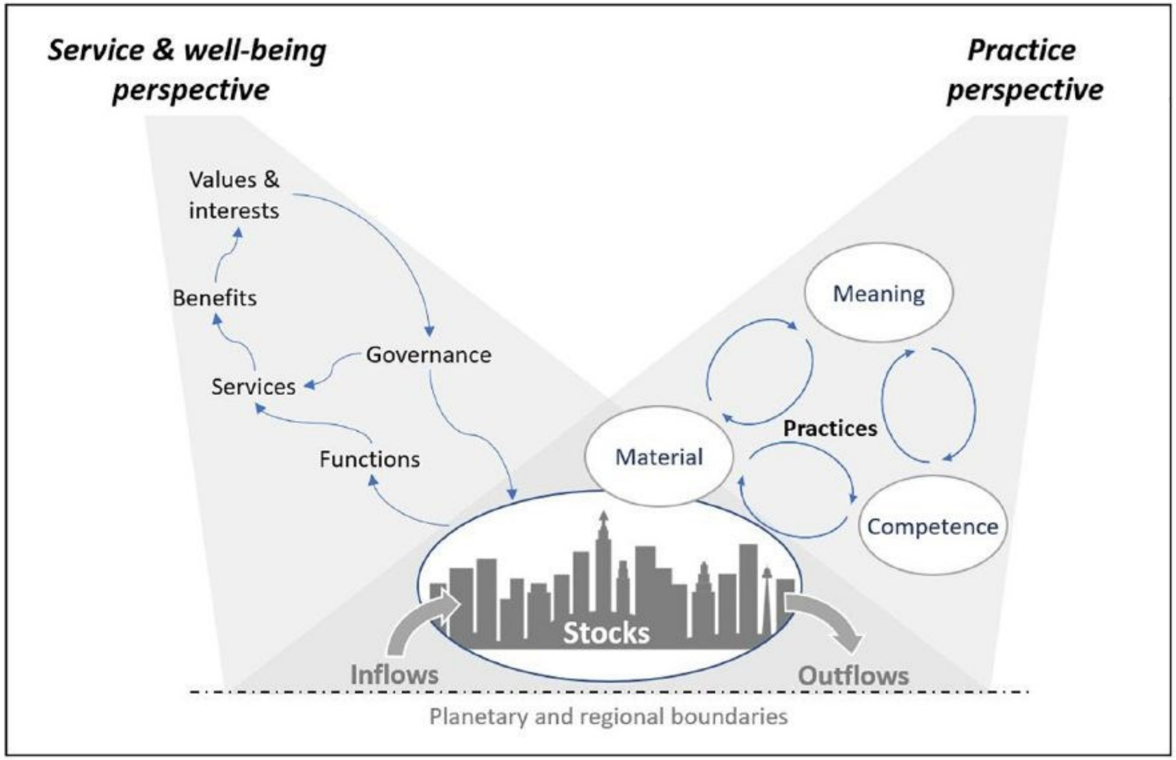
Nexus approaches relating social metabolism to services and practices

Universität für Bodenkultur Wien
Department für Wirtschafts- und Sozialwissenschaften
Institute of Social Ecology

The stock-flow-service nexus: services are derived from specific stock-flow combinations. Purposes of ‚resource use' are diverse and potentially conflicting. Broadens concepts of eco-efficiency.

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

Both nexus approaches provide heuristic models for interdisciplinary sustainability research to analyze the key 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

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Conclusions for a successful sustainability diet

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- **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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A transition .... towards sustainability?

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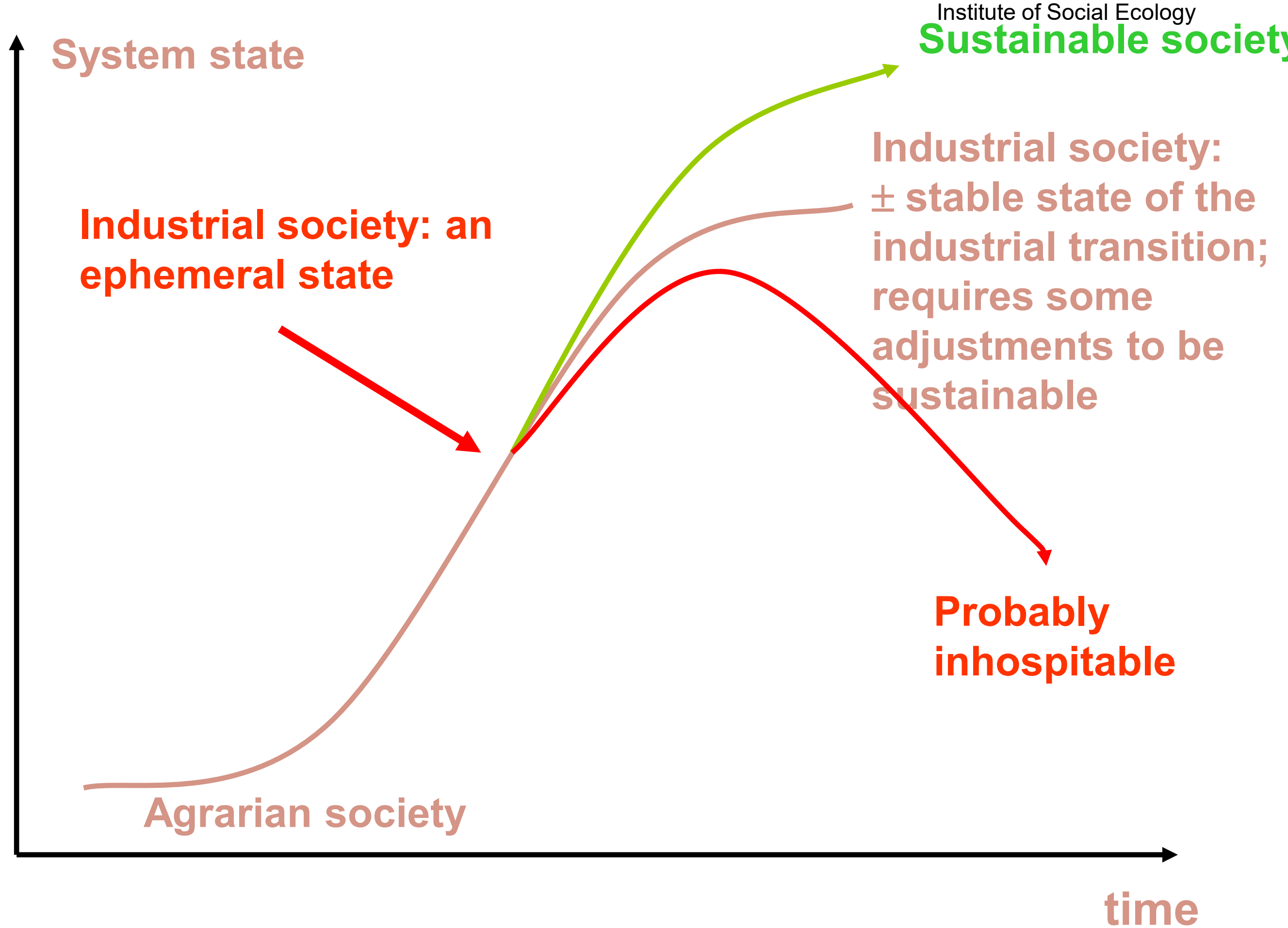
Where many think we are

Where we probably are

Where some want to go



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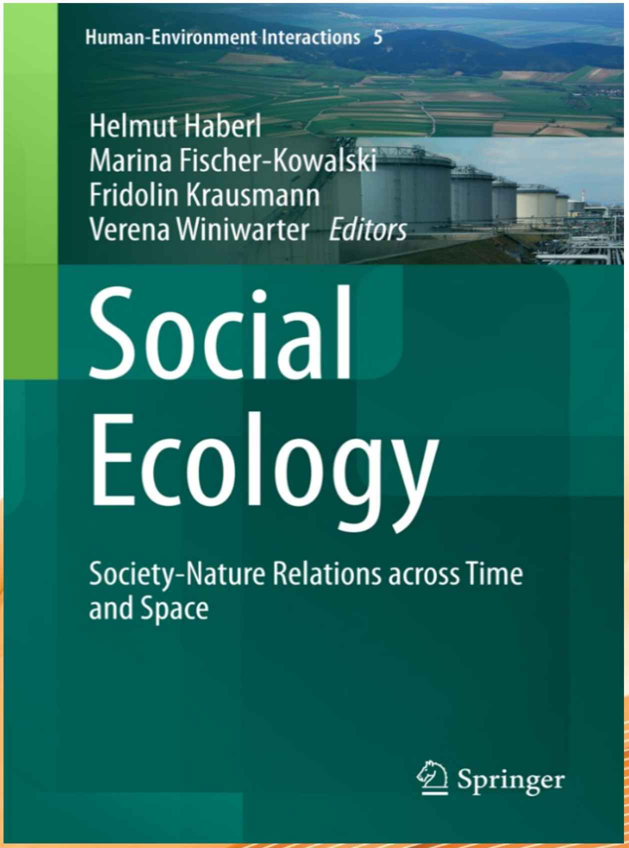

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