A century of global material stock accumulation: implications for sustainability transformations

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Conference „Resources for a socio-ecological transformation“
2nd Austrian Conference on International Resource Politics
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Challenges for a socioecological transformation toward sustainability

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- **Socioeconomic**
  - eradicating poverty and hunger, reducing inequality
  - establishing good education, sanitation, housing, health-care, etc.
- **Ecological**
  - zero (or negative) carbon emissions in the next decades,
  - coping with limitations of exhaustible resources, e.g. metals or P
  - viable balance between the use of renewable resources and the maintenance of healthy, carbon-rich and biodiverse ecosystems

→**Fundamental transformation of resource use (use of materials, energy & land) are needed, requiring far-reaching changes in society, culture, and the economy**

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Social metabolism: A systemic perspective on resource use

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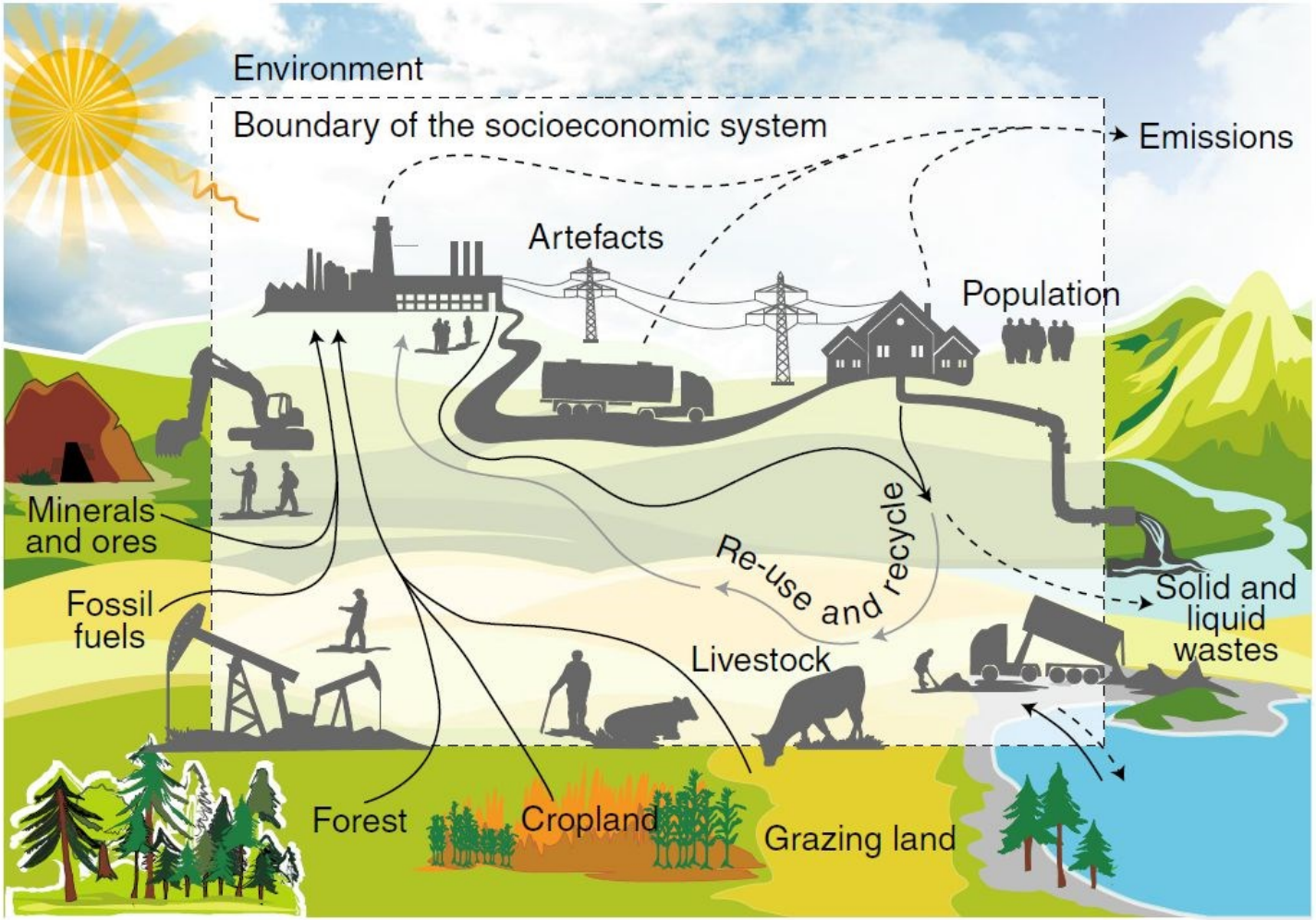

Haberl et al. 2019. Nature Sustainability, doi:10.1038/s41893-019-0225-2

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Economy-wide material and energy flow analysis: accounting for society's use of biophysical resources

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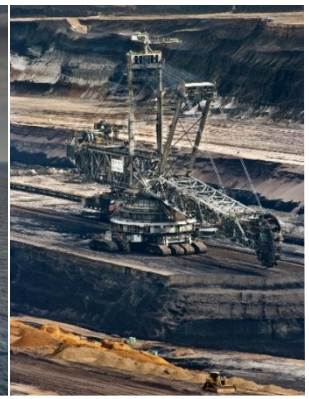
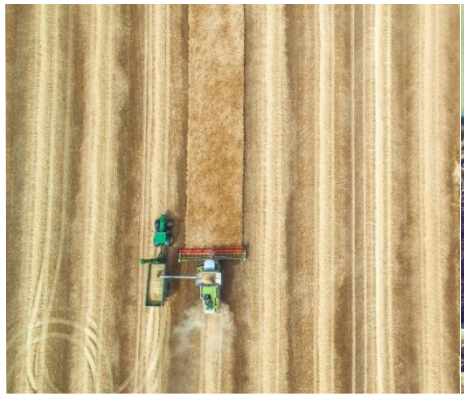
Fossil fuels





Biomass

Metals: ores & waste rock

~ 50 categories of material flows

Non-metallic minerals: Construction & industrial

"Material Flow Accounting: Measuring Global Material Use for Sustainable Development"
Krausmann et al. (2017) *Annual Review of Environment and Resources*. doi:10.1146/annurev-environ-102016-060726
Haberl et al. (2019). Contributions of sociometabolic research to sustainability science. *Nature Sustainability* (in press)

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Why 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)

Social metabolism in the Anthrophocene

A century of inflows, outflows and stock accumulation

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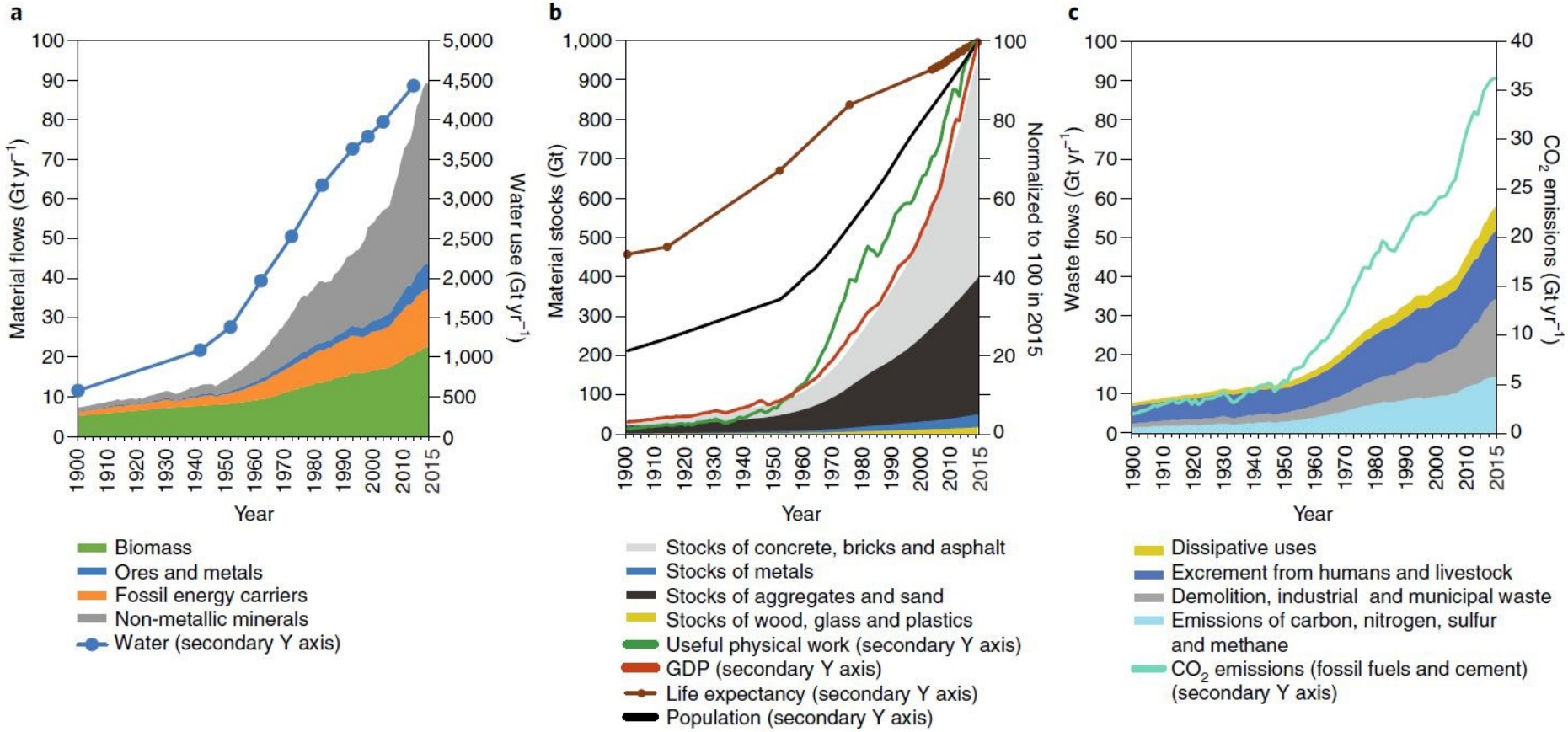

Haberl et al. 2019. Nature Sustainability,
doi:10.1038/s41893-019-0225-2

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Toward stockpiling society (*not* throwaway society)

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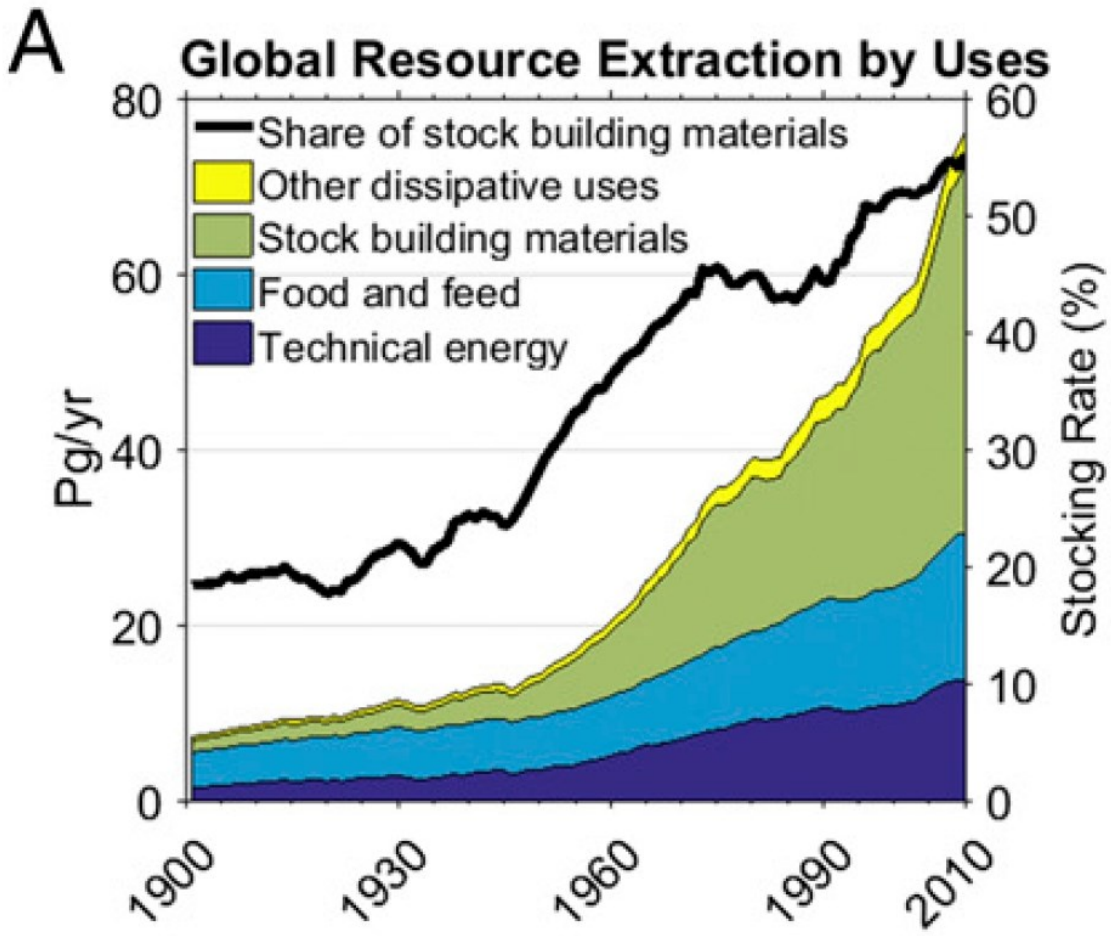

Krausmann, Wiedenhofer et al. 2017. PNAS 114(8), 1880-1885

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The stock/flow/service nexus

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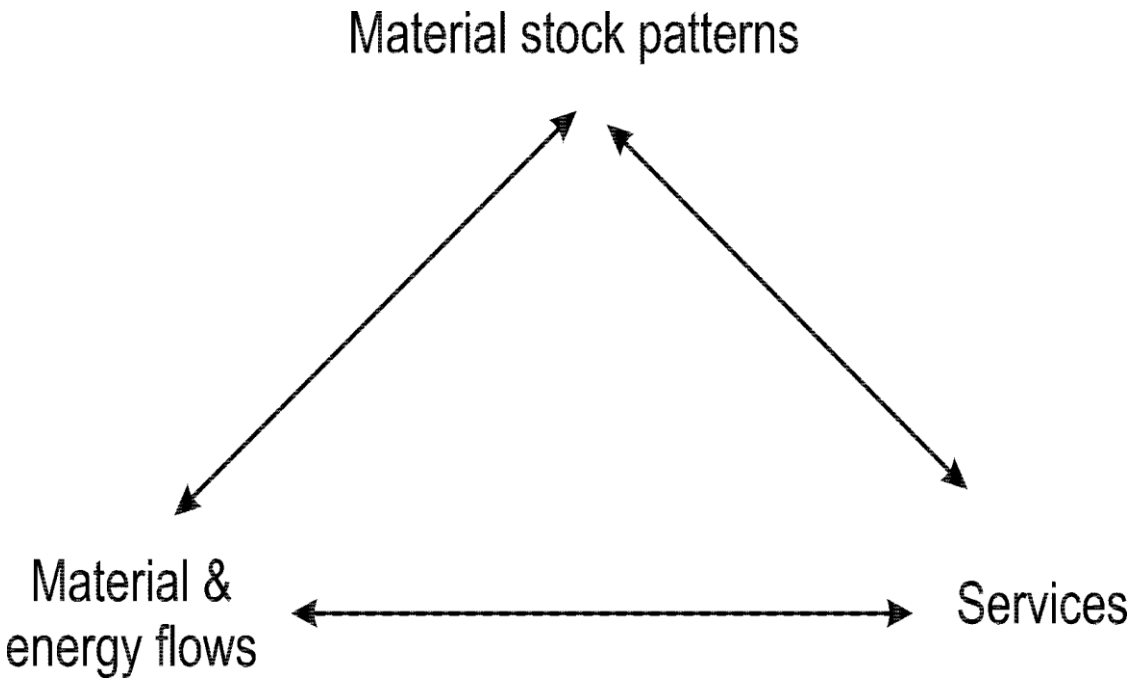

Key characteristics of stocks
- **Functional types** e.g. buildings, infrastructures, machinery
- **Spatial patterns** e.g. urban form
- **Qualities** e.g. thermal quality of buildings

Material and energy flows are key for understanding resource constraints & ecological impacts, e.g. climate change

Service indicators beyond GDP establish links between resource use, well-being and satisfaction of human needs

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Haberl et al 2017. Sustainability, 9, 1049

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Example: energy „services“

Global energy flows and services, 2005

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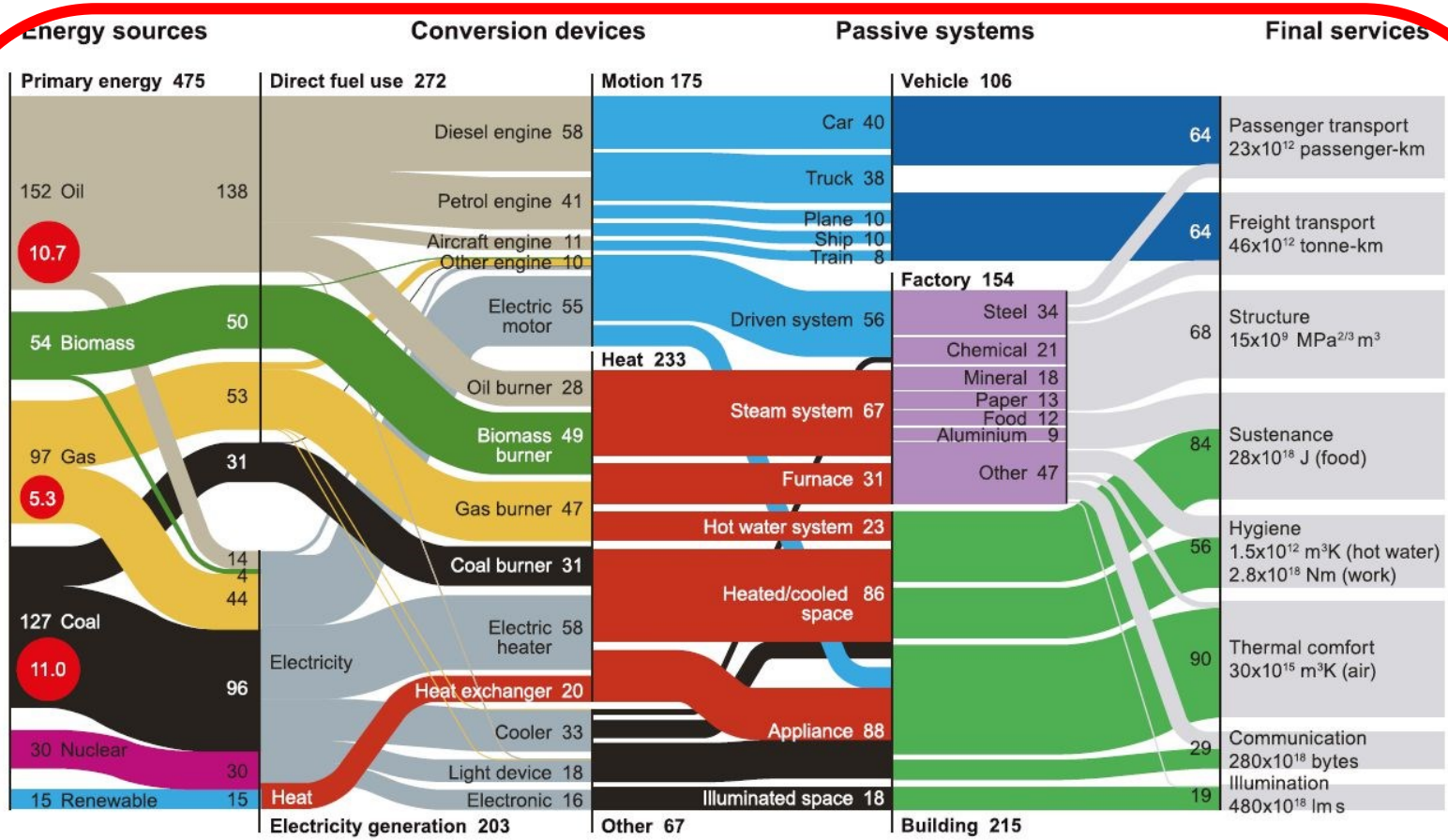
Extraction & conversions depend on stocks



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Cullen & Allwood. 2010. *Energy Policy* 38 (1): 75–81.

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Material stocks, flows, GDP, and GHG emissions

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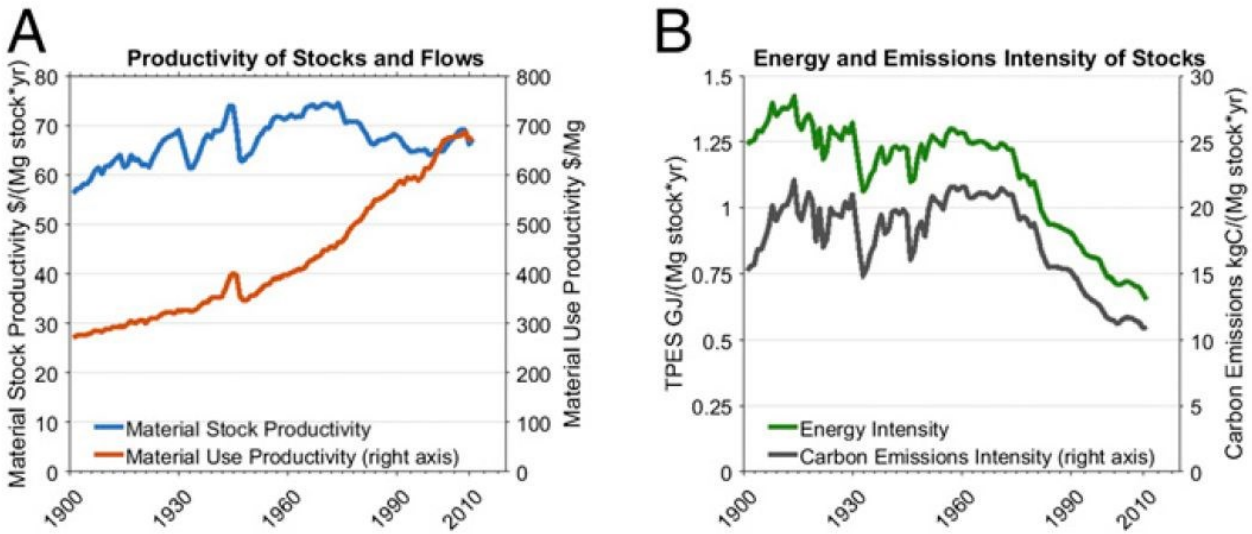

Fig. 2. Development of global stocks in relation to GDP, energy use, and CO_2 emissions 1900–2010. (*A*) Global stock productivity (GDP/material stock) and material use productivity (GDP/annual material consumption, right axis). (*B*) Energy and carbon emission intensity of material stocks. Total primary energy supply (TPES) and CO_2 emissions from fossil fuel use per megagram of material stock. Material use (domestic material consumption) is in megagrams (9), GDP in constant international dollars of 1990 (45), CO_2 emissions in kilograms of C (46), and TPES in gigajoules (9).

Rising resource efficiency is business as usual. Slow improvements of energy / GHG efficiency

Can GDP growth be decoupled from rising material stocks?

Should we rather focus on **sufficient delivery of services with less resources**, regardless of GDP?

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Per capita material stocks in nine world regions in 2015

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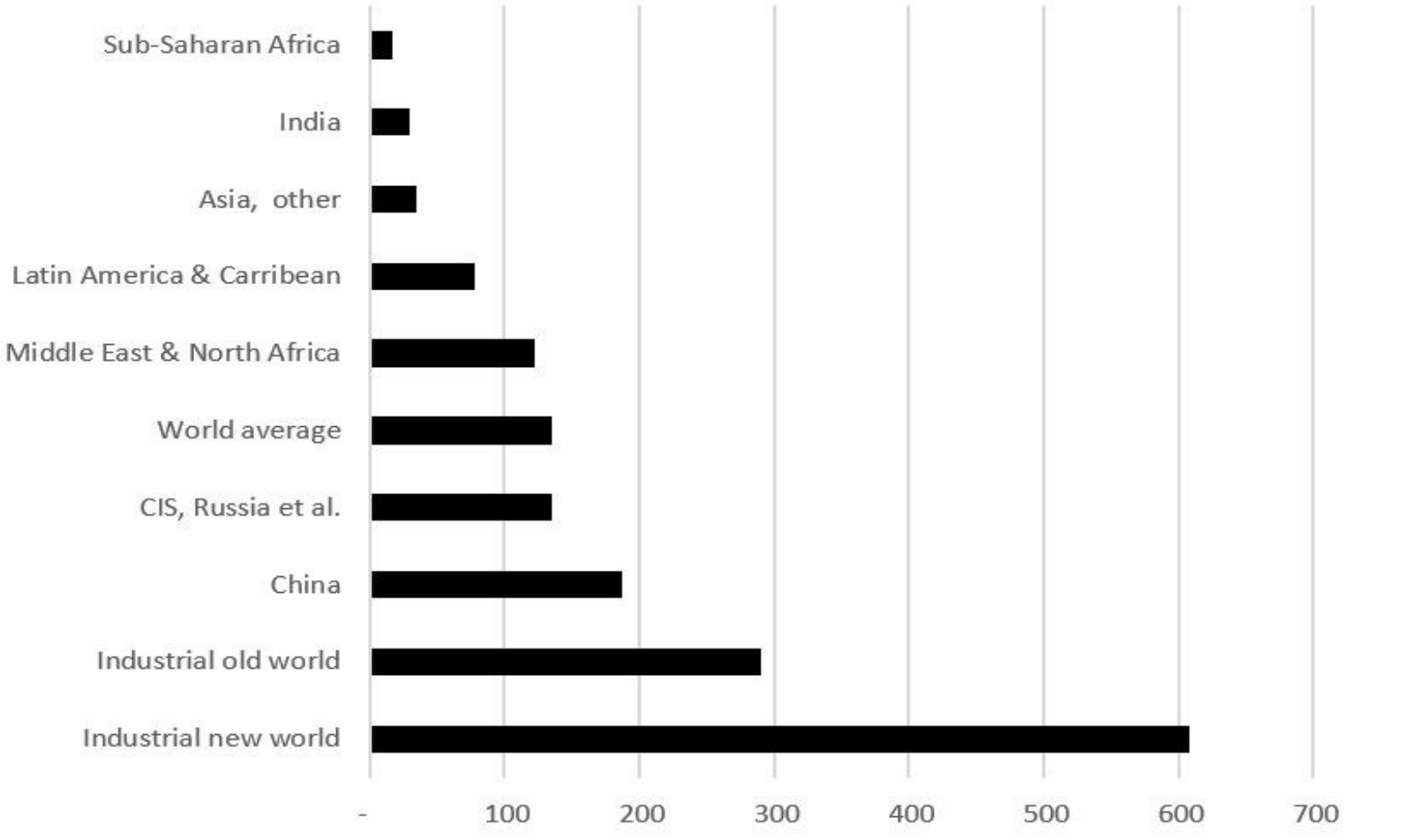

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Wiedenhofer et al. (in preparation) – do not cite or quote

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Stocks and flows vs. social progress

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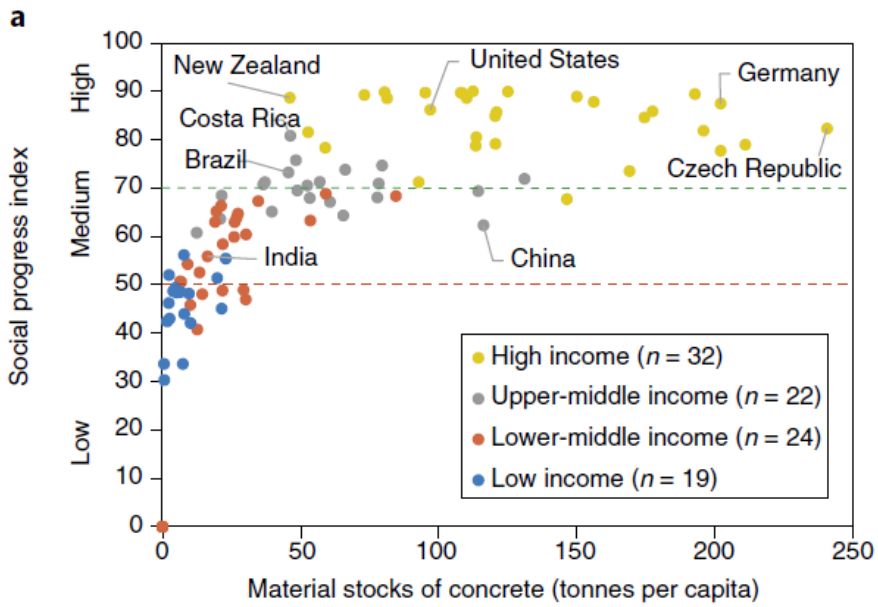
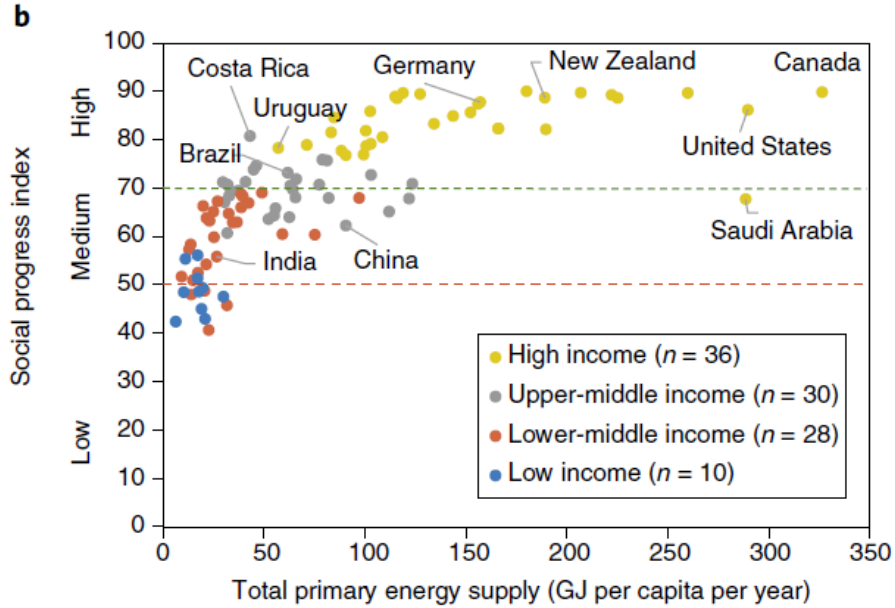
Concrete stocks



Primary energy supply



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

Haberl et al. 2019. Nature Sustainability,
doi:10.1038/s41893-019-0225-2

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Modelling GHG emissions from fossil fuels based on material stock – energy relations

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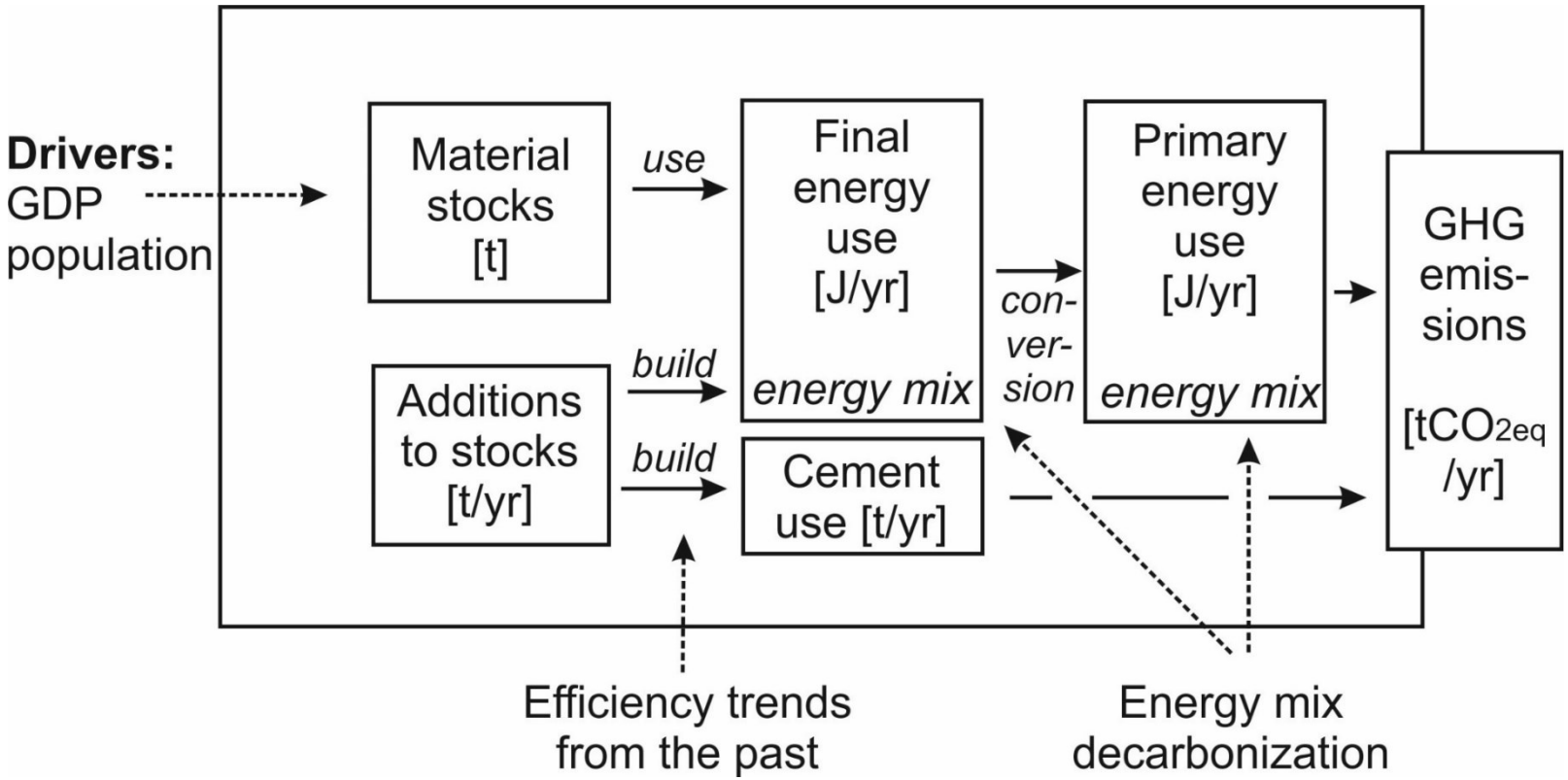

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Krausmann et al. In preparation, do not cite or quote!

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Scenarios for stock development and GHG emissions 2050

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- **GDP driven scenarios:** GDP development in SSP2, assumptions on GDP per unit of stock ratio.
  - Constant GDP/stock ratio
  - Trend GDP/stock ratio
- **Population driven scenarios:** Population development (UN median) and assumptions on per capita stocks in 2050.
  - IND2015: Convergence of global per capita stocks at industrial level in 2015
  - IND2070: Contraction-convergence of global per capita stocks at industrial level 1970
- **Decarbonisation pathways**:
  - Trend: Energy mix of 2015
  - Full decarbonisation of energy system in 2070, 2060, 2050, 2040 & 2030
  - Estimated C emissions from cement calcination and coke use in blast furnaces (no decarbonisation)

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Remaining C-budget after 2050 for the 1.5° target by year of full de-carbonization

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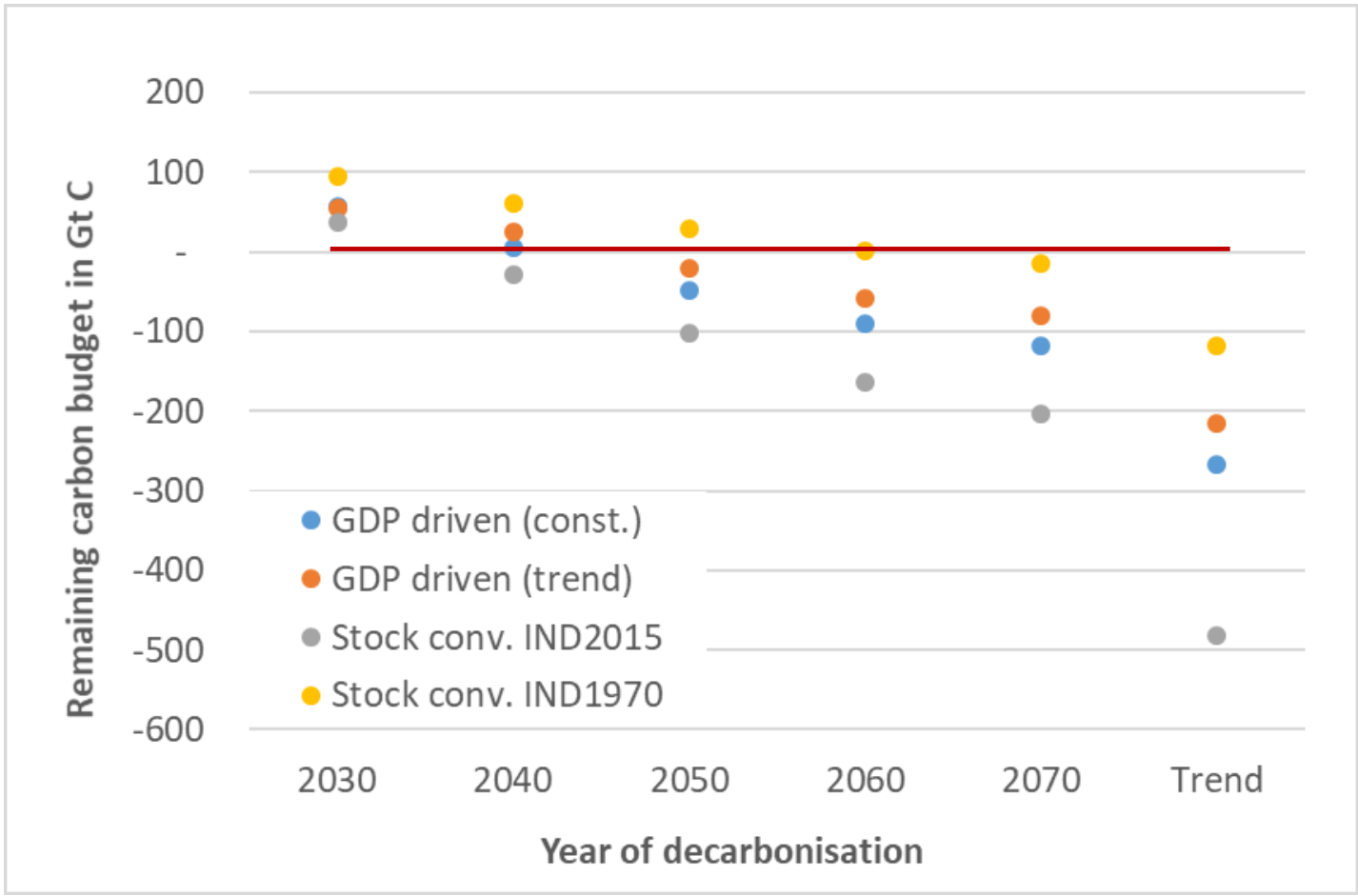

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Can 1.5° be achieved without BECCS?

… perhaps, with a service-centred approach

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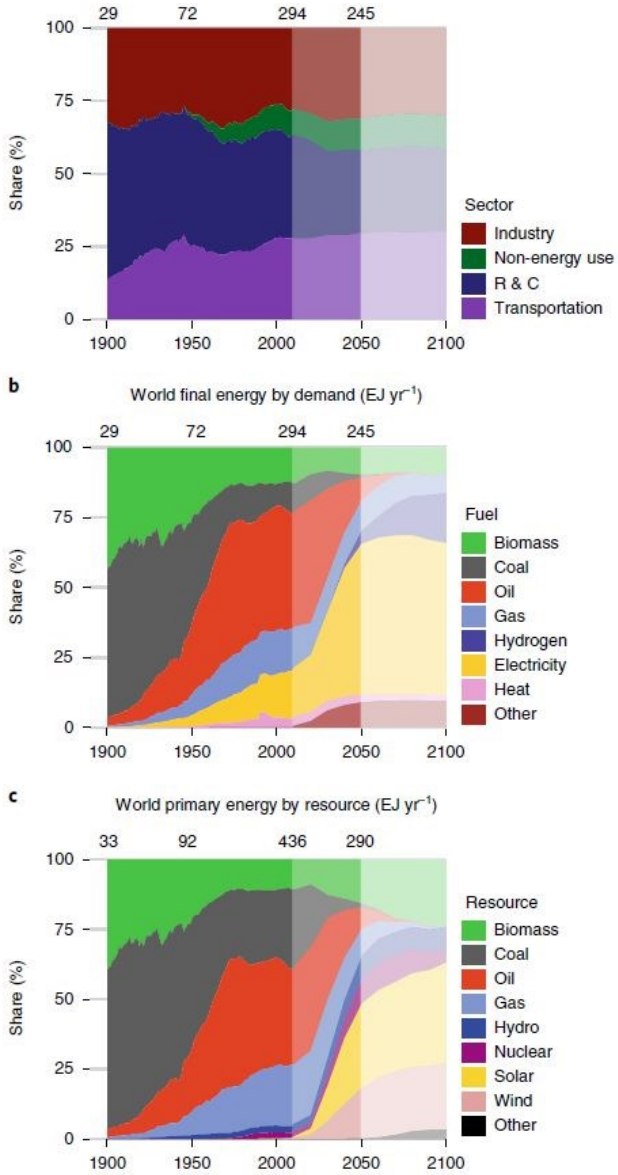

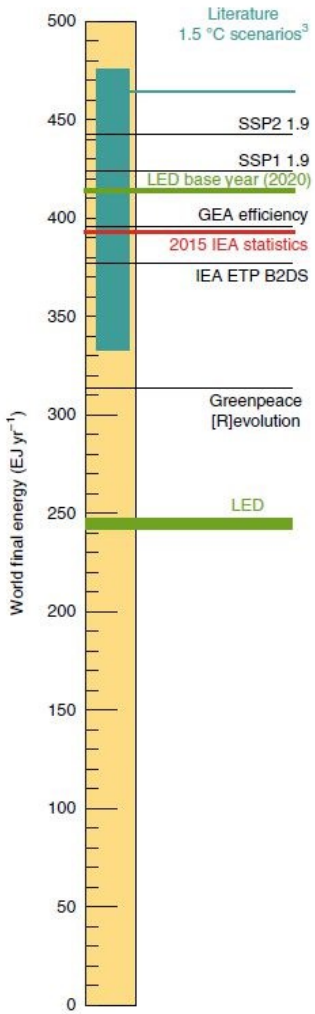

Focusing on the demand-side can
- supply sufficient energy services
- almost halve energy use
- ~ achieve the 1.5 degree target.

Requires **massive improvements of buildings** (thermal quality) and **completely different investment patterns** in new urban developments, transport infrastructures and strongly altered patterns of production and consumption

Grubler et al. 2018. *Nature Energy* 3 (6): 515.

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How to link stock mapping & services?

LETTER

doi:10.1038/nature25181

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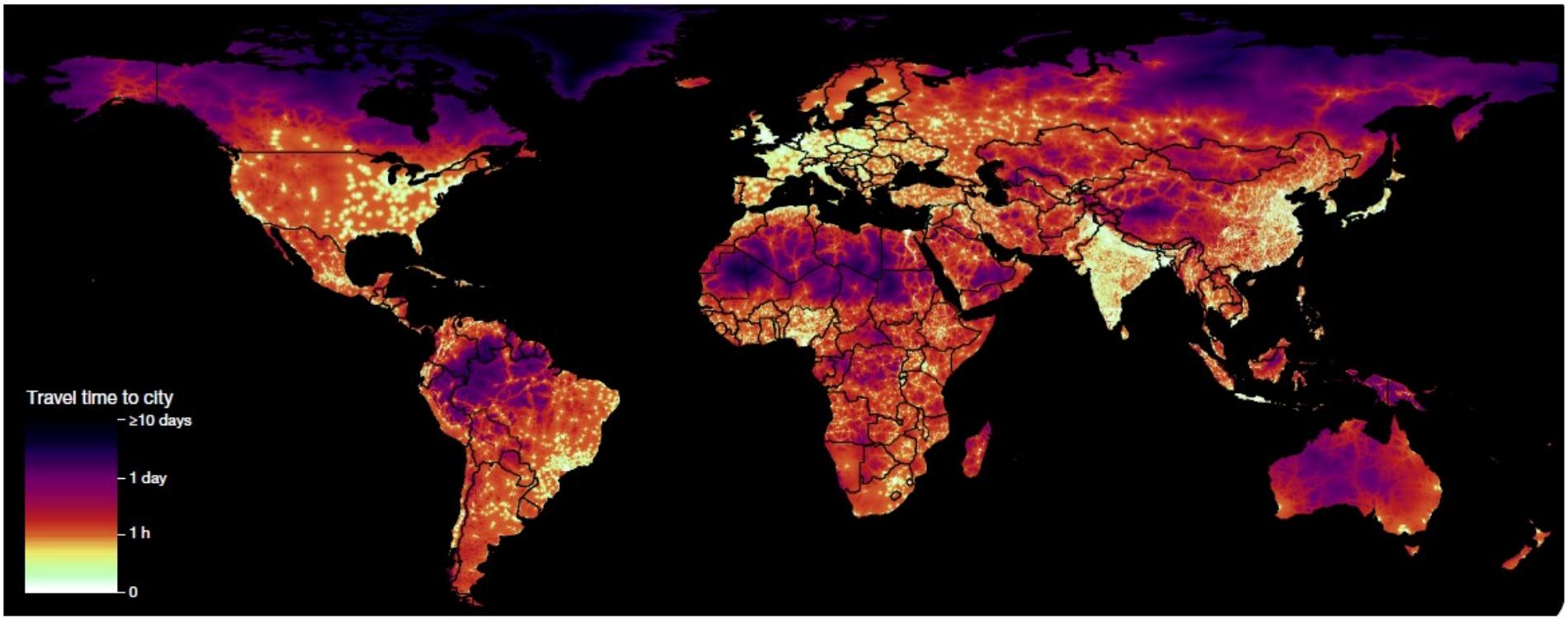
A global map of travel time to cities to assess inequalities in accessibility in 2015

D. J. Weiss[1], A. Nelson[2], H. S. Gibson[1], W. Temperley[3], S. Peedell[3], A. Lieber[4], M. Hancher[4], E. Poyart[4], S. Belchior[5], N. Fullman[6], B. Mappin[7], U. Dalrymple[1], J. Rozier[1], T. C. D. Lucas[1], R. E. Howes[1], L. S. Tusting[1], S. Y. Kang[1], E. Cameron[1], D. Bisanzio[1], K. E. Battle[1], S. Bhatt[8] & P. W. Gething[1]

80% of humans live <1h to city, but only 50% in low-income countries.

Only ground-based transport considered



Implications for sociometabolic transitions towards sustainability

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- Current sustainability strategies inadequate or insufficient to „bend the curve“ - the **gospel of eco-efficiency is not good enough**
- **Focus on demand-side** (energy, food, etc.) → Δ qualities of stocks!
- Different investment patterns can shift incentives towards **low-resource living** compared to wasteful lifestyles prevailing today
  - Thermal quality of **existing building stock** rises much faster
  - All **new housing** meet low-energy & zero-GHG-emission standards
  - **Transport-saving** patterns of settlements & infrastructures
  - **Low-GHG transport** infrastructures (roads? airports?)
  - Changing patterns of **production & consumption in all sectors**

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