The stock-flow-service nexus

New directions for social-ecological transformation research

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Socioecological transformation: multiple crises require systemic solutions

The TWI 2050 approach

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TWI2050: Transformations to Achieve the Sustainable Development Goals. IIASA, 2018

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Social metabolism: A systemic perspective on resource use

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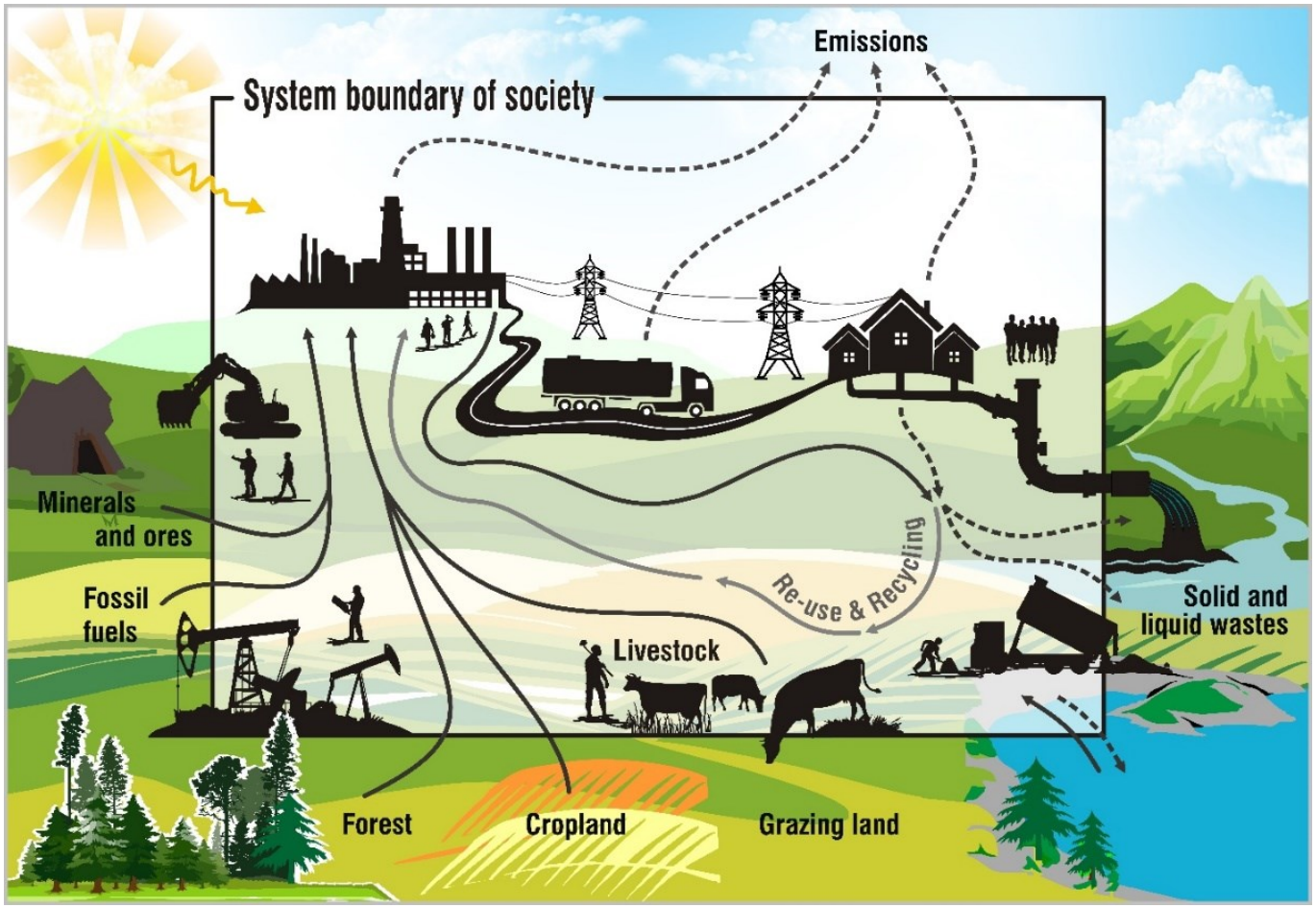

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A century of global resource extraction: from agrarian to industrial society

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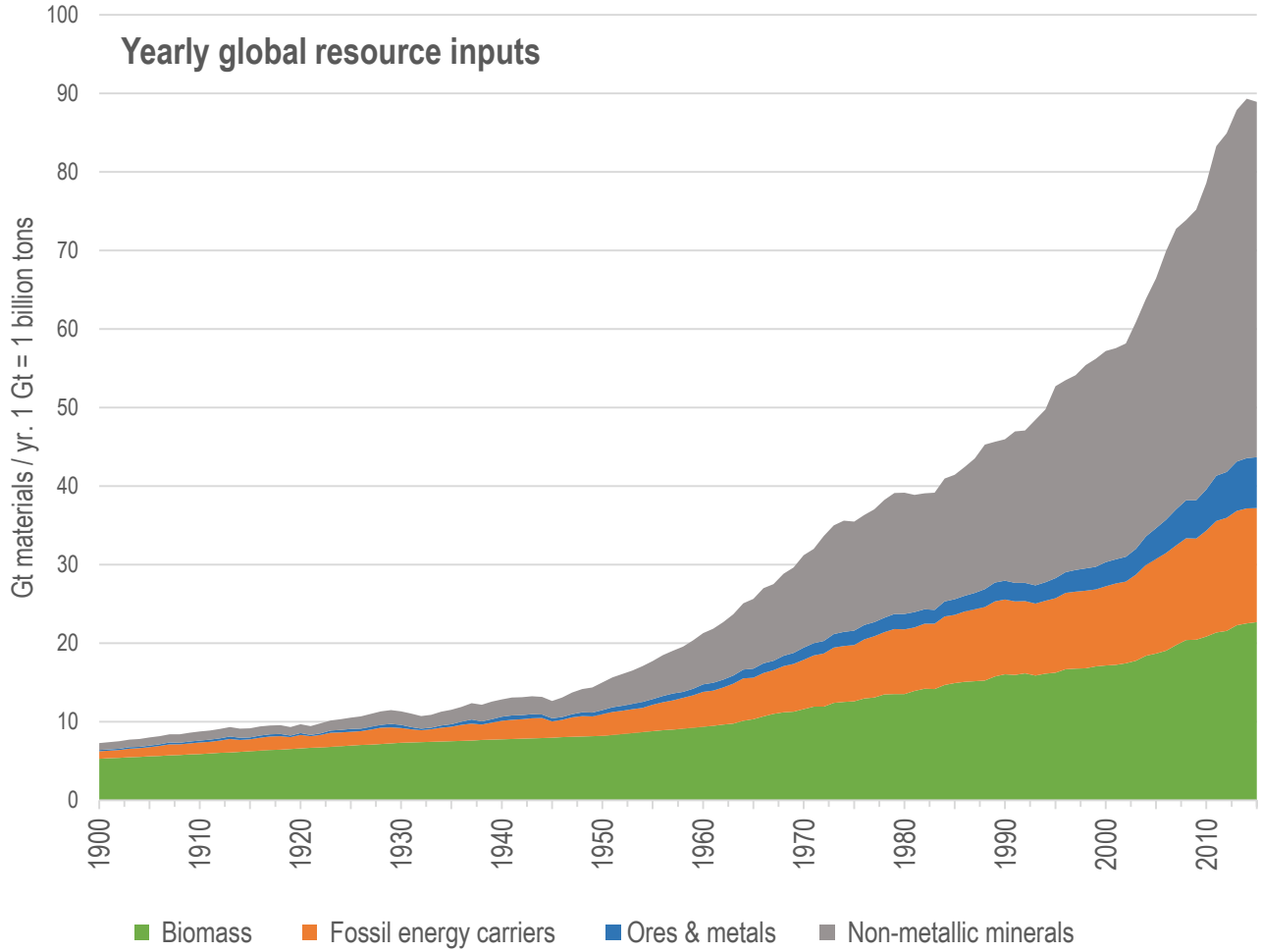

Biomass grows ~ with population

Industrialization fuelled by **fossil energy** and enabled by **growing building & infrastructure stocks**

Growth 2015/1900:
Resources x 12
GDP x 32

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

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Most sociometabolic research so far …

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- focused on yearly flows of resources (materials, energy) and **neglected material stocks** (e.g. buildings, infrastructures, machinery)
- analyzed resource efficiency as ratios such as:

  resources : GDP *or* emissions : GDP

Shortcomings

→ Neglects that materials stocks (co-)determine flows

→ Neglects that most services result from specific stock-flow combinations, not from flows alone *(how to use gasoline without a road & a car?)*

→ Focuses on economic indicators such as GDP that may be a part of the problem

Haberl et al 2017. Sustainability, 9, 1049

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 amount to ~one-half of the remaining emission budget for the 2°C target
(Raupach et al. 2014, *Nature Clim. Change* 4, 873–879

Global material stocks 1900-2010

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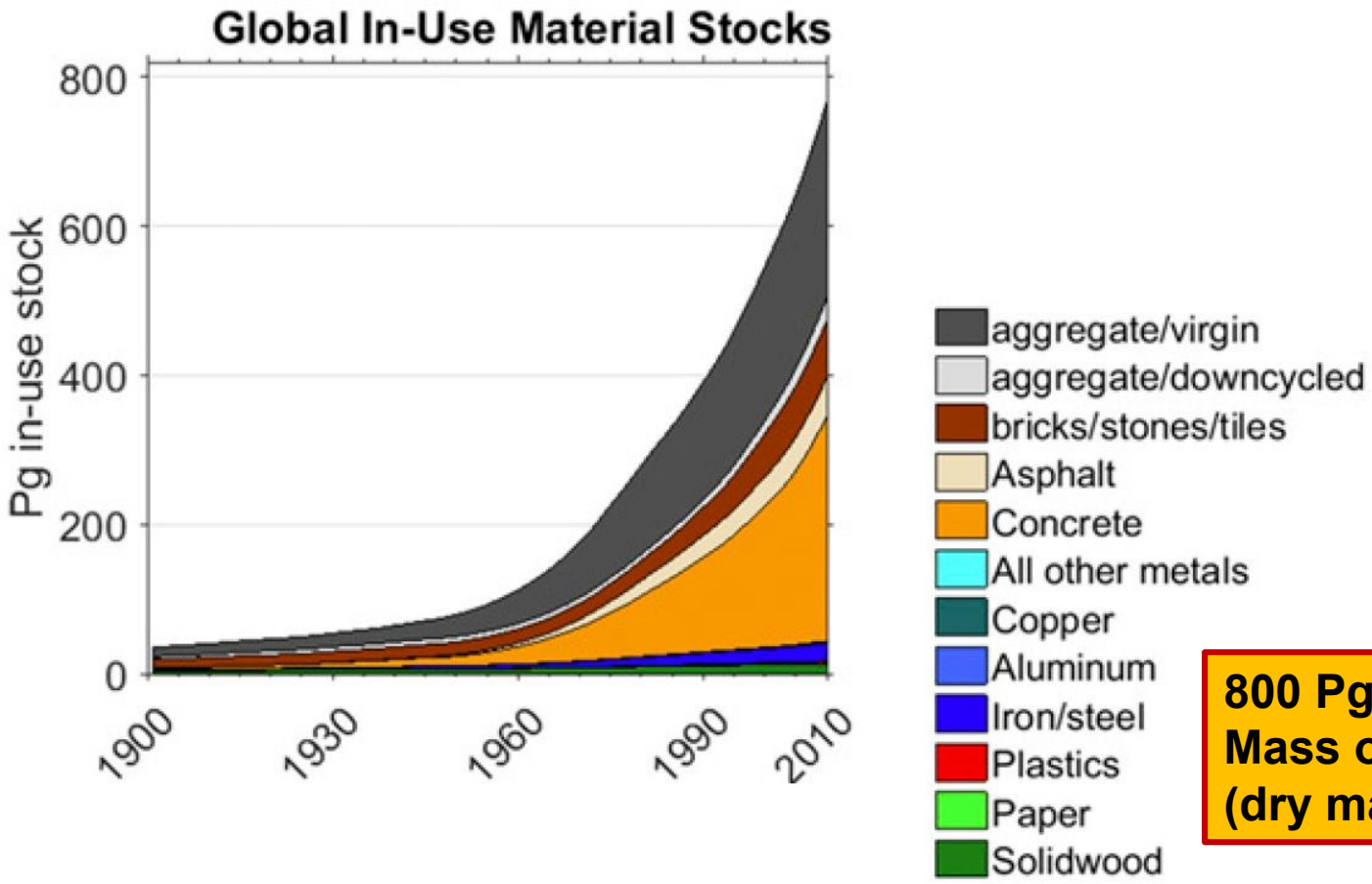

800 Pg = 800 billion tons
Mass of plants on land (dry matter): ~900 Pg

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

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Toward stockpiling society (*not* throwaway society)

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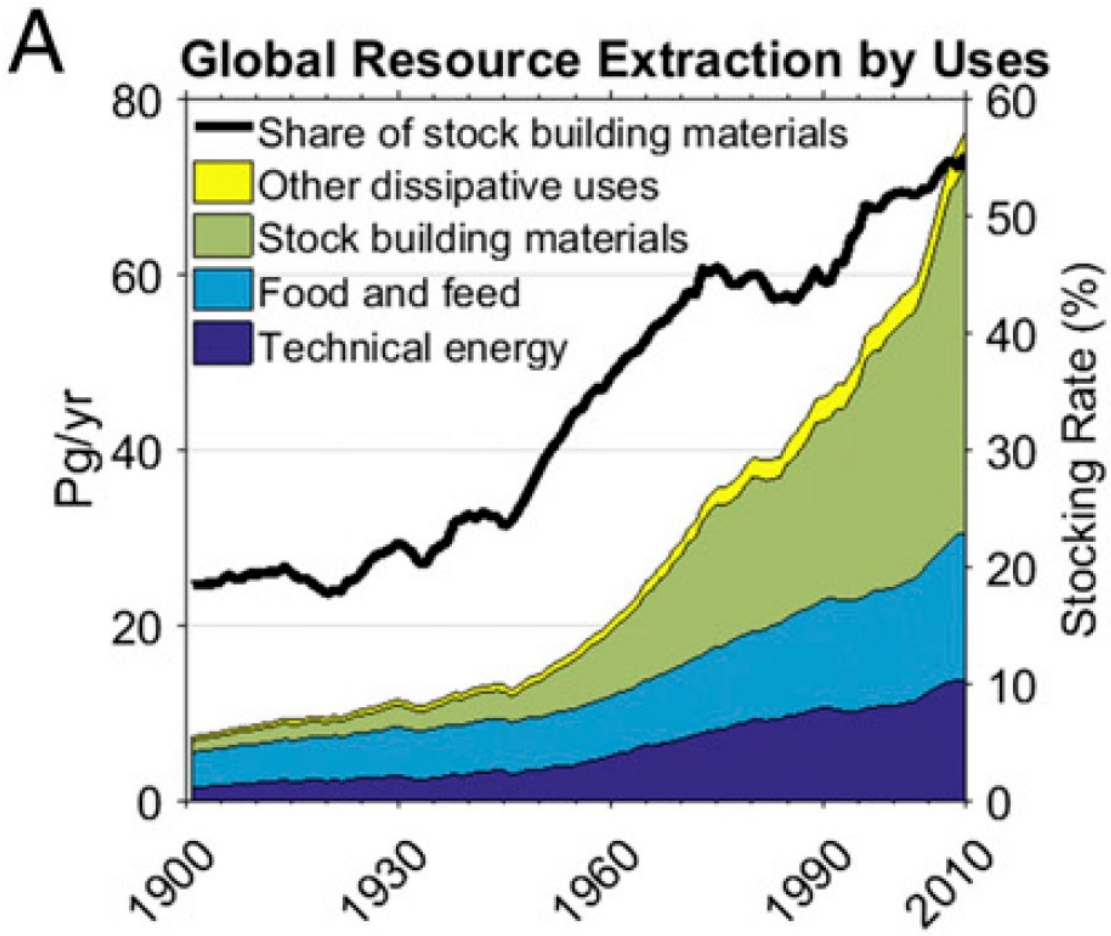

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The stock/flow/service nexus

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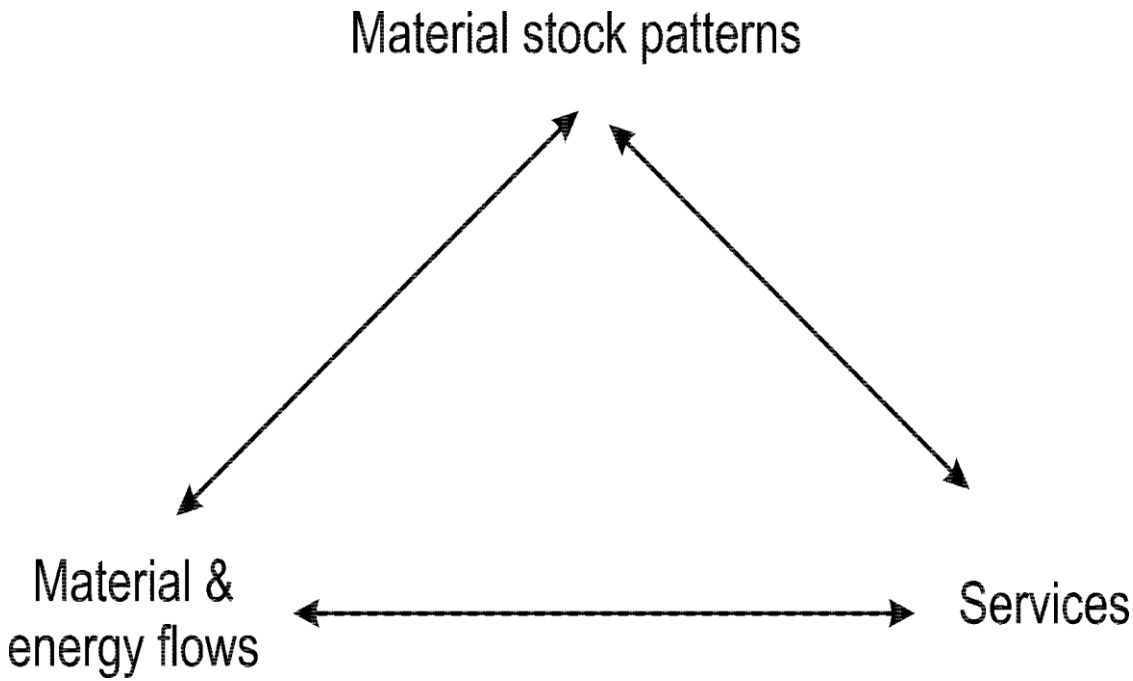

Key characteristics of stocks
- **Functional types** e.g. buildings, infrastructures, machinery
- **Spatial patterns** e.g. urban form
- **Qualities** e.g. thermal quality of buildings

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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Example: energy services

Global energy flows and services, 2005

Extraction, conversions & services depend on stocks & flows!

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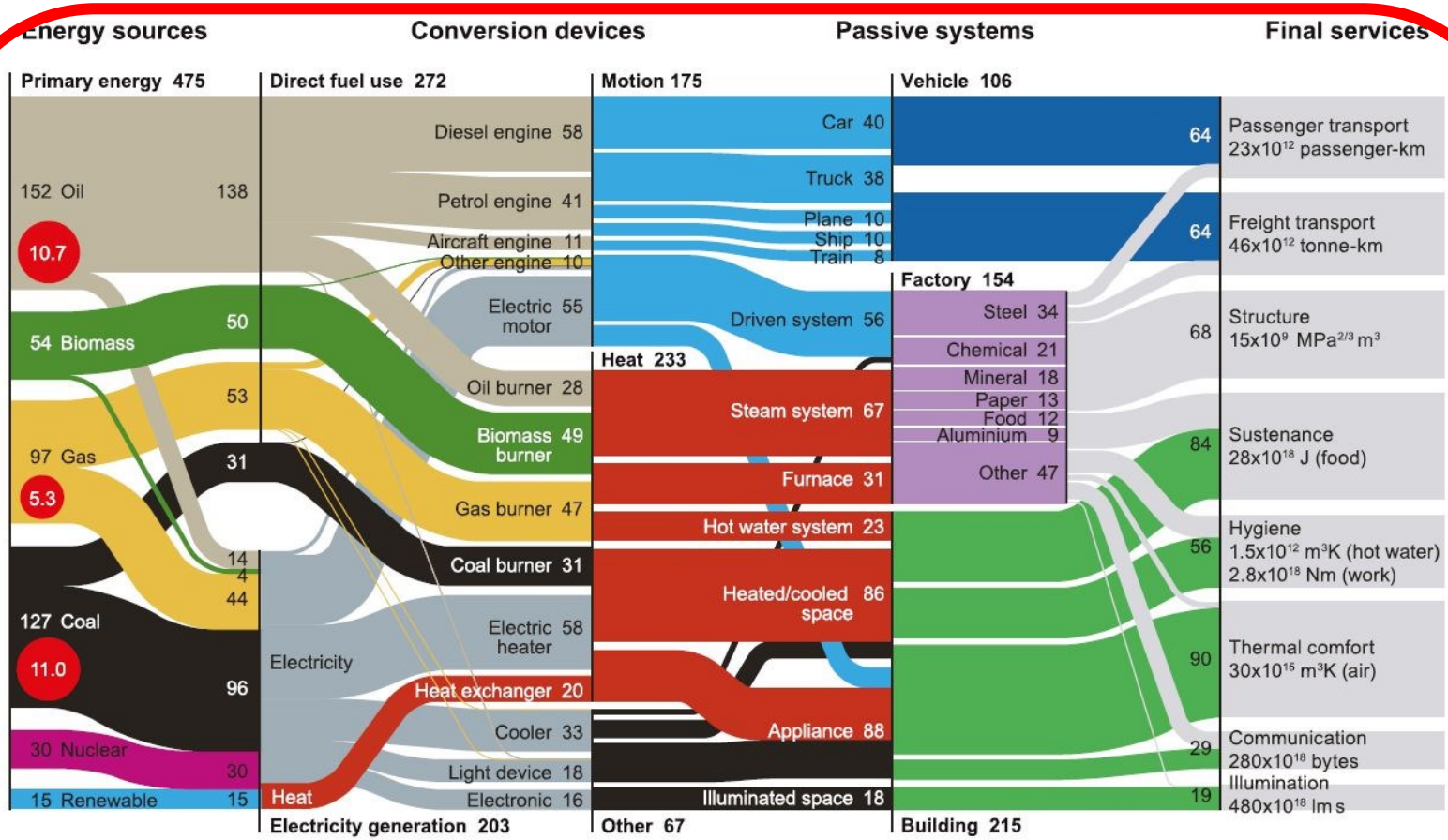

Cullen & Allwood. 2010. *Energy Policy* 38 (1): 75–81.

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Material stocks, flows, GDP, and GHG emissions

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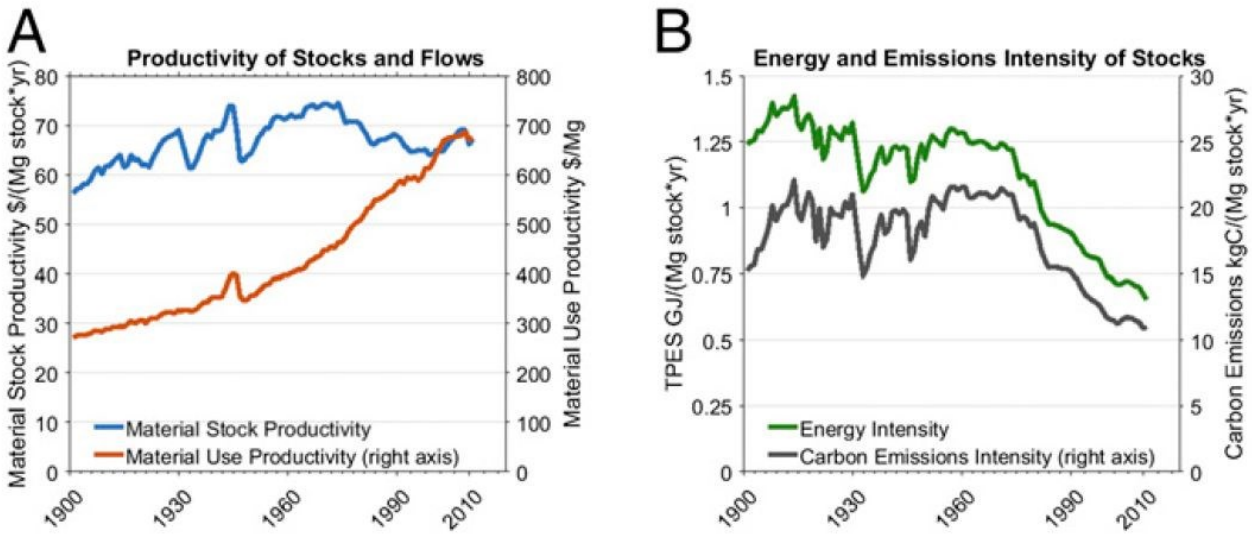

Fig. 2. Development of global stocks in relation to GDP, energy use, and CO_2 emissions 1900–2010. (*A*) Global stock productivity (GDP/material stock) and material use productivity (GDP/annual material consumption, right axis). (*B*) Energy and carbon emission intensity of material stocks. Total primary 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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Stock growth as driver of GHG emissions

Limiting stock growth needed for climate change mitigation

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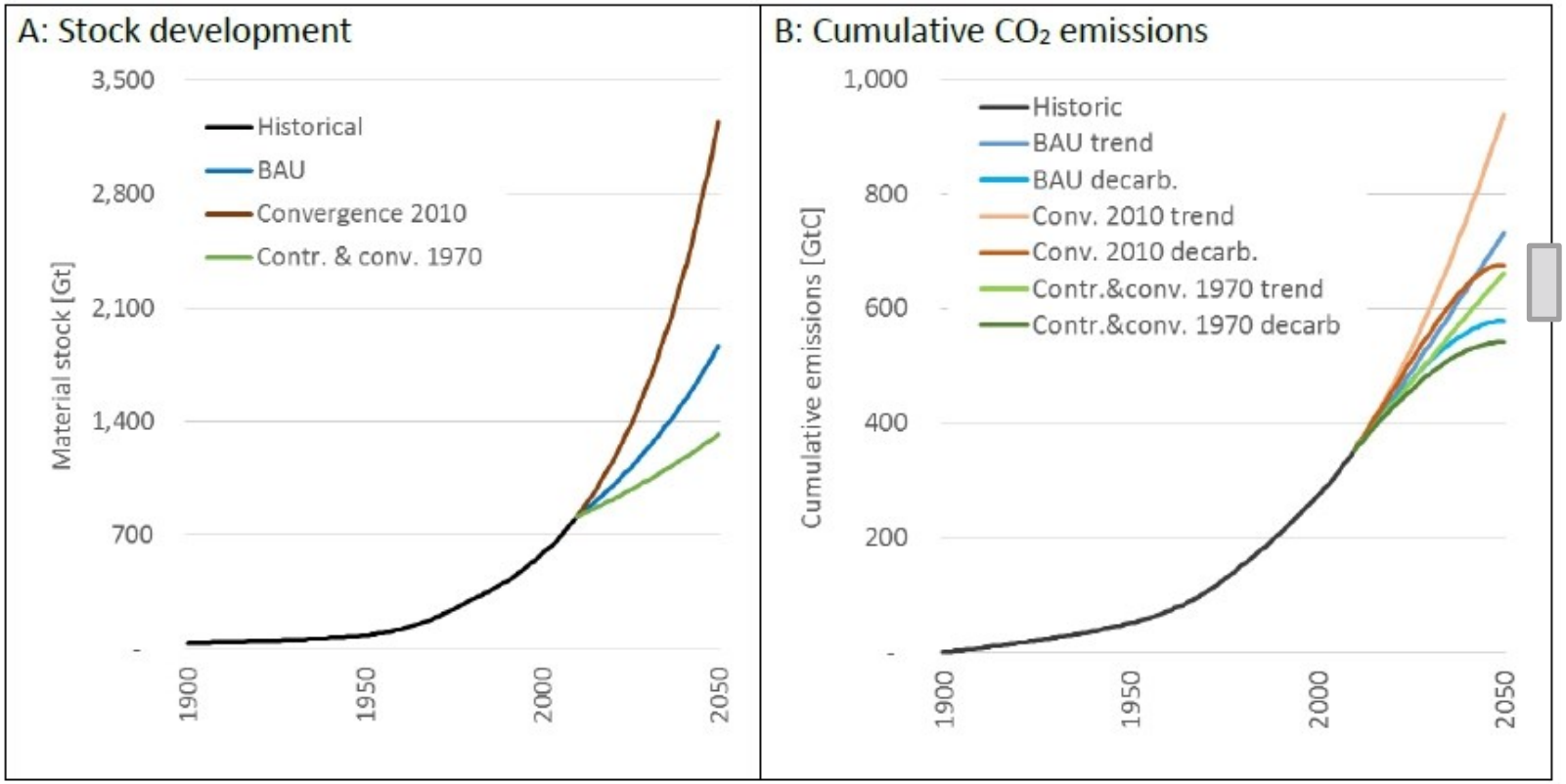
Figure S4: S4A: Stock development 1900-2010 and three scenarios 2010 to 2050; S4B: Cumulative CO_2 emissions in Gt C from 1900 to 2010 (historical) and 6 scenario variations for the development to 2050.



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Is avoiding BECCS possible?

… perhaps, with a service-centred approach

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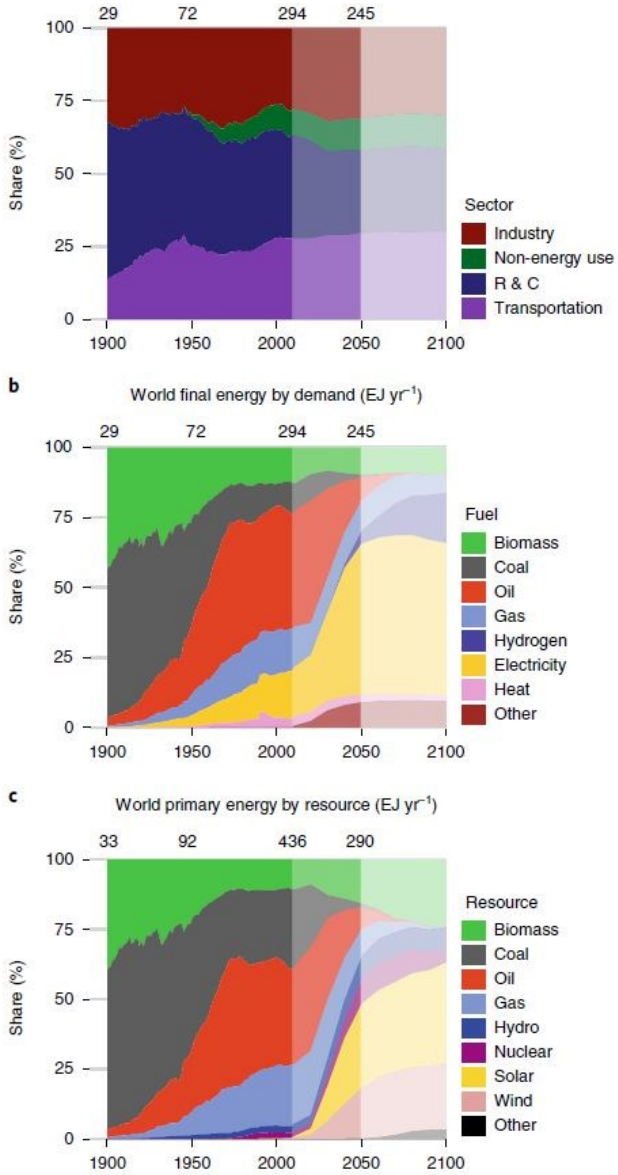

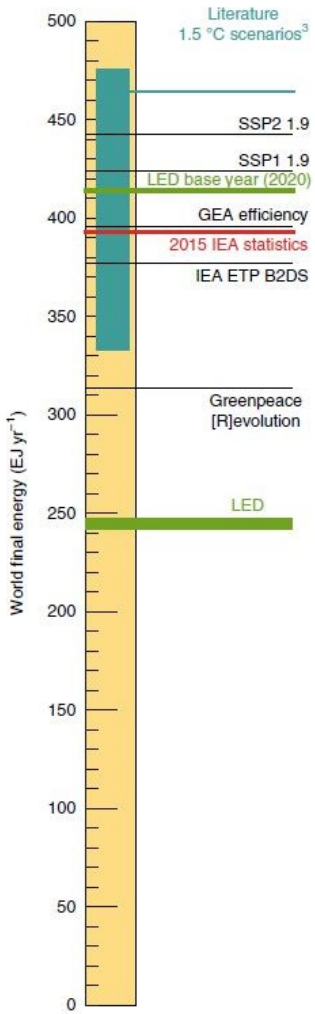

A new study by Arnulf Grübler and others suggests that **focusing on the demand-side** can
- supply sufficient energy services
- almost halve energy use
- ~ achieve the 1.5 degree target.

This will require **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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Prospects for attempts to move toward a circular economy in a stockpiling age

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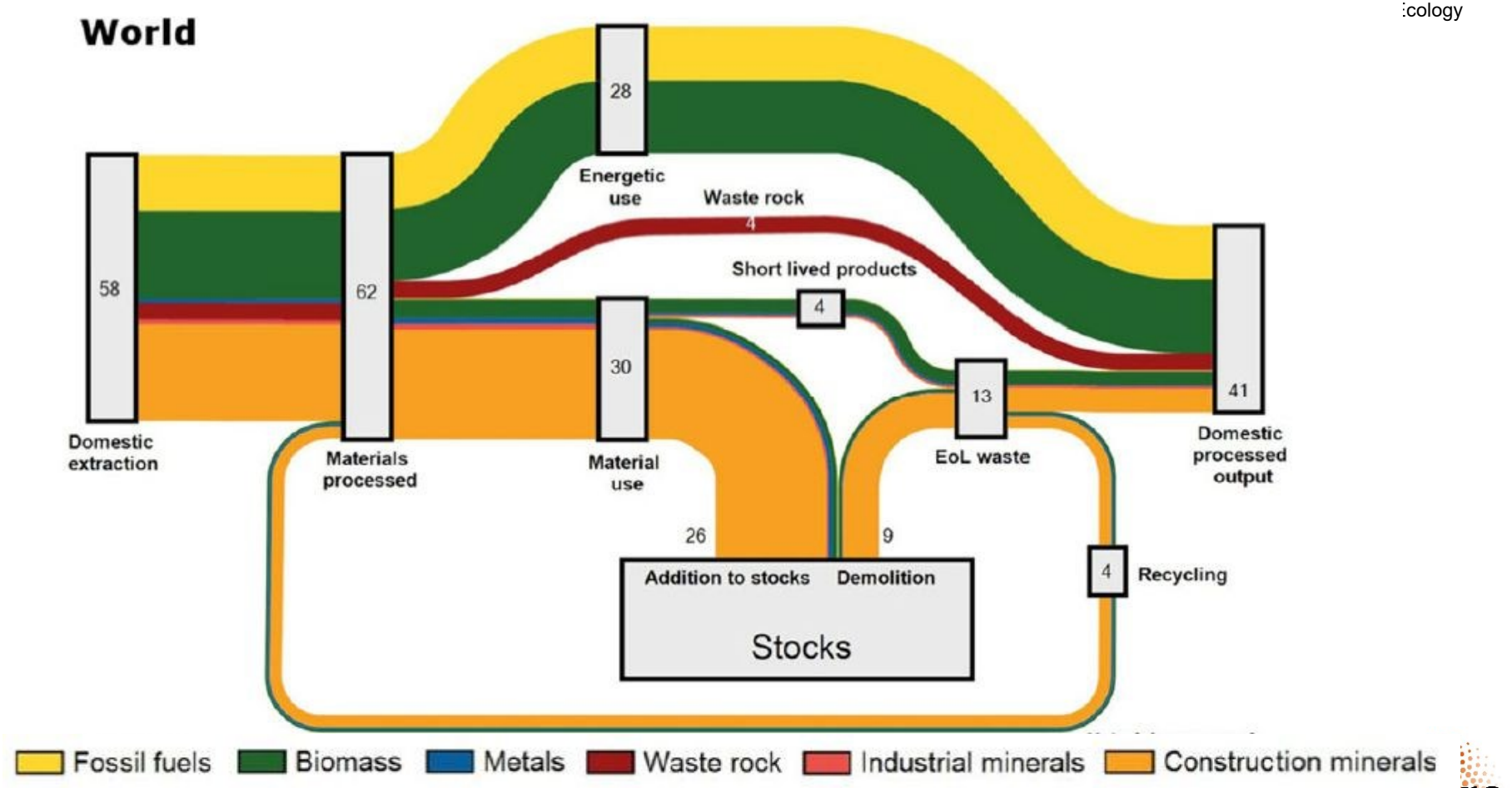

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Haas et al. 2015. *J. Industr. Ecol.* 19, 765–777.

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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!
- Reaching **circularity** requires stabilization 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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