Sociometabolic regimes and transitions between them

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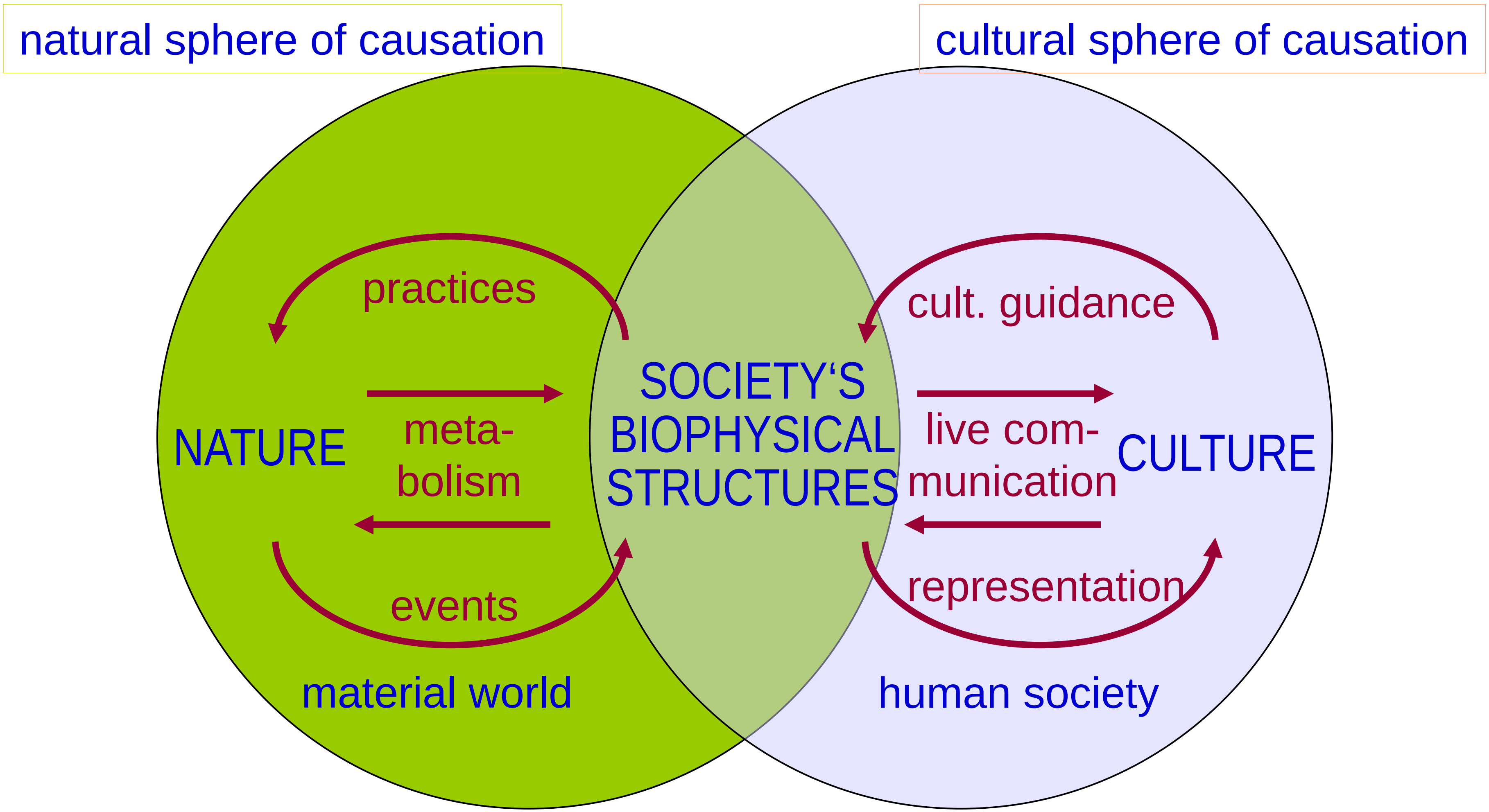
Outline

1. Basic assumptions of social metabolism
2. Distinguishing sociometabolic regimes
3. Dynamics of the agrarian regime
4. Conditions for a transition from agrarian to industrial
5. A next major transition ahead?

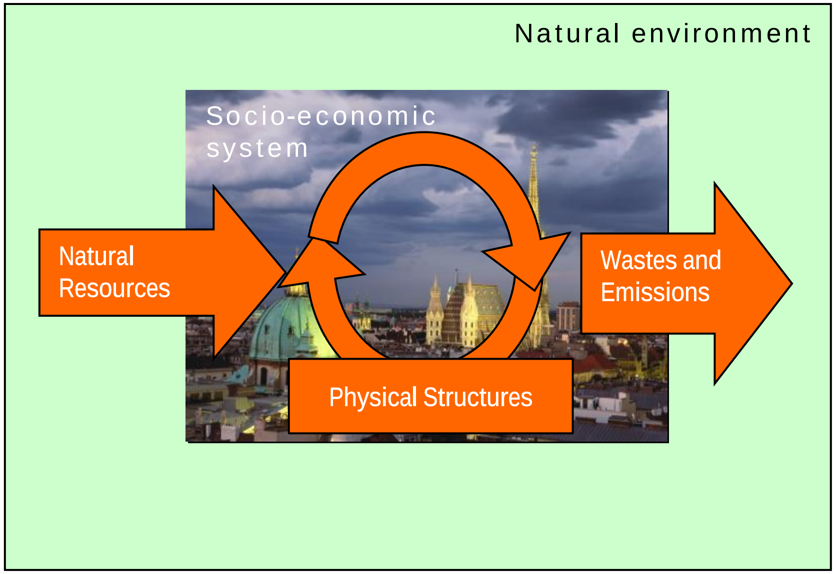
Human societies: Coupling of a cultural system with material elements



Source: Fischer-Kowalski and Weisz 2016

Socio-economic metabolism

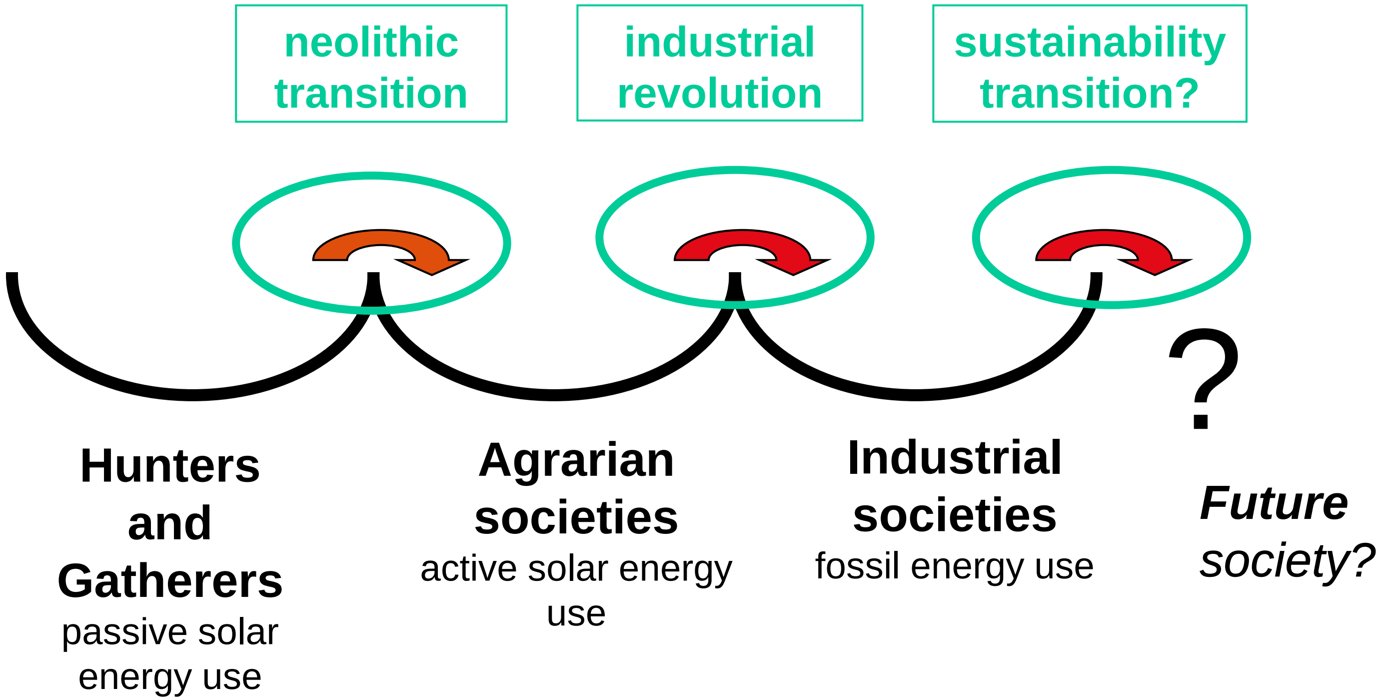
Social metabolism, the exchange of energy and materials across social and environmental systems, is needed to produce and to reproduce society's biophysical structures: its human and animal population, and its man-made infrastructures.



this theory delivers:

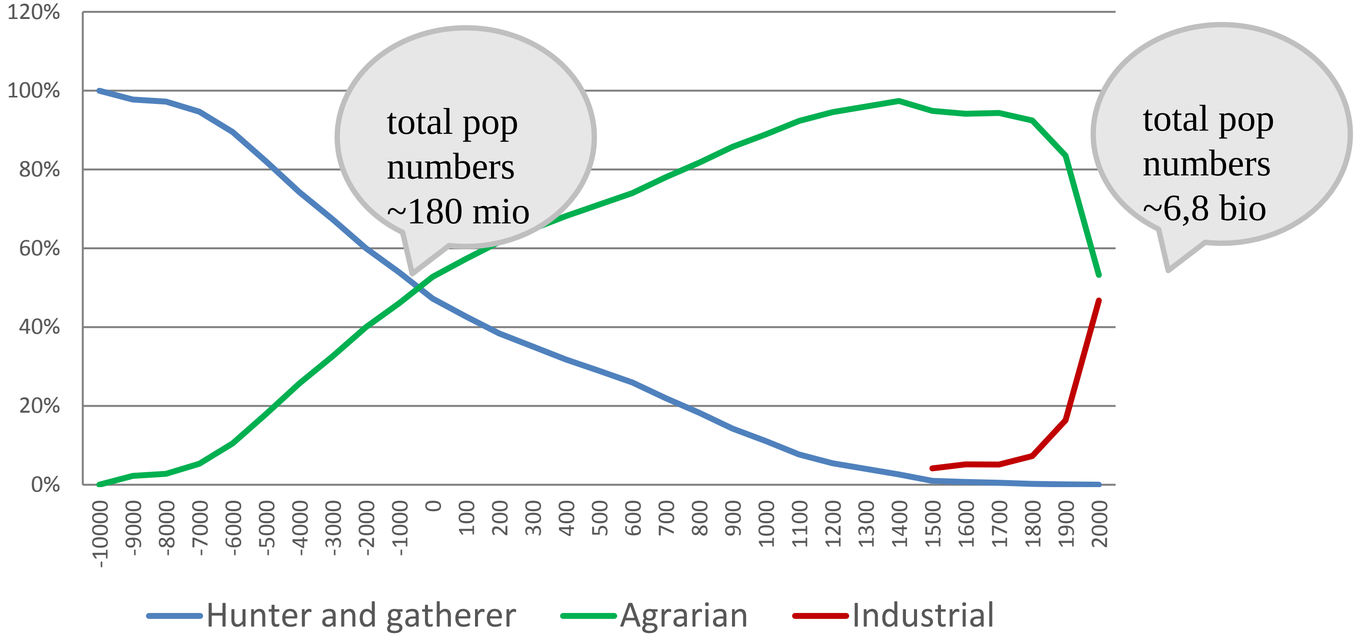
- a thermodynamic perspective on the economy (Georgescu-Roegen, Robert Ayres)
- Linking socioeconomic activity to ecosystem processes and ensuing sustainability problems
- a historical perspective: the distinction between socio-metabolic regimes with characteristic profiles and different system dynamics

Sociometabolic regimes in world history



Source: adapted from Sieferle et al. 2006

The share of sociometabolic regimes in the global human population, 10,000 BC- 2000 AD



Source: Fischer-Kowalski et al. 2014. A sociometabolic reading of the Anthropocene. *Anthropocene Review 1(1), pp 8-33*

Socio-metabolic profiles and rates

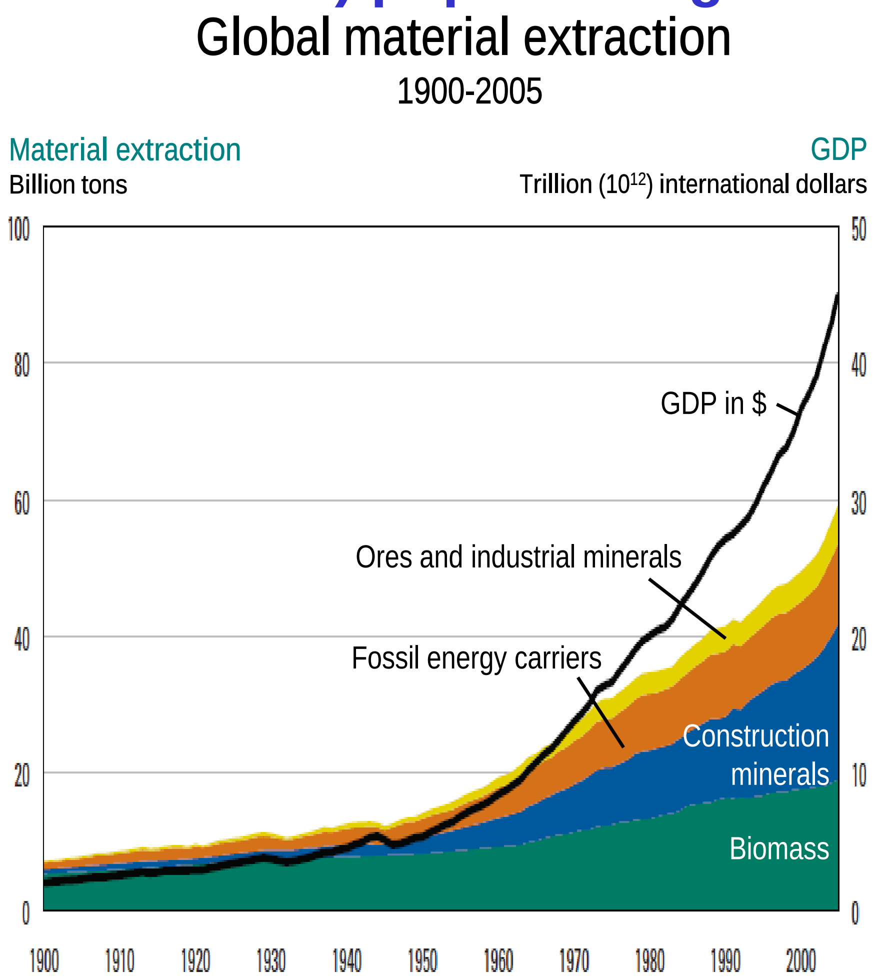
	foraging regime	agrarian regime	industrial regime
energy source	biomass (100%)	biomass (98%), wind & water (2%)	biomass (<30%), fossil fuels (>70%) nuclear, water, photovoltaics, wind ... (<5%)
amount/cap/yr	10 GJ	70 GJ	200 GJ
materials	biomass (100%)	biomass (95%); minerals and metals	biomass (35%)
			fossil fuels (25%)
			metals & ind. min. (5%)
			construction min. (35%)
amount /cap/yr	1 t	5 t	15 t
material stocks amount/cap	<1t	<10t	>300t

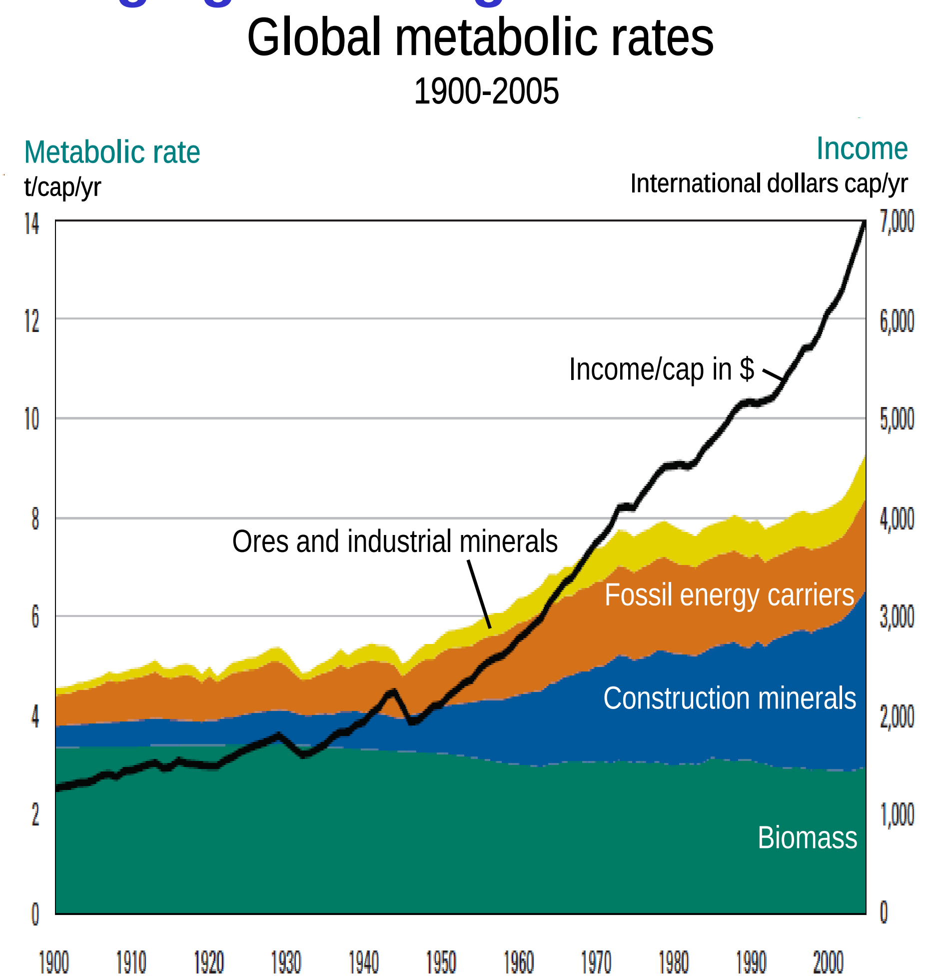
Human history: a story of increasing population by factor 40, and resource use per capita (metabolic rate) by factor 10-20. Next regime??

Global sociometabolic dynamics during the 20th century as joint result of

2

a) shift agrarian > industrial regime, b) economic growth, c) population growth among agrarian regime





Source: UNEP International Resource Panel, Decoupling Report 2011

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Dynamics of the agrarian sociometabolic regime

- By the beginning of the 21st century, about half of the world population are still living mostly in ways of the agrarian regime
- Energetically, the agrarian regime can be characterized in the following way:
  - the principal source of *energy* is **land**, more precisely, the products of photosynthesis from land.
  - The principal source of *mechanical work* is **human labor.**
  - How much energy the land has to offer depends on a number of natural conditions, but also critically on the human labor invested in this land. We may call this the **land-labor-constraint of energy** in the agrarian regime.

The Low EROI of agro-ecosystems allows only modest life for farmers, and small surplus for non-farmers

- As agriculture and agrarian systems evolve, more energy is harnessed by taking ever more land under cultivation – hence the large deforestation effect that Earth System scientists find.
- Compared to foraging societies, in agrarian systems much more food can be extracted per unit land; thus, population density can increase. But this comes at the expense of a substantial human labor input.
- Human labor power and its biological reproduction requires most of the energy harvested. The EROI (or EROEI; Hall 1986) of agro-ecosystems is very low. (see Galan et al. 2016)
- Thus, in agrarian societies over 90% of the population have to work the land to provide for food and other needs of the population. The surplus that can be used by non-farmers (landlords, religious leaders, urban citizens, kings, administrators, armies...) is very small.

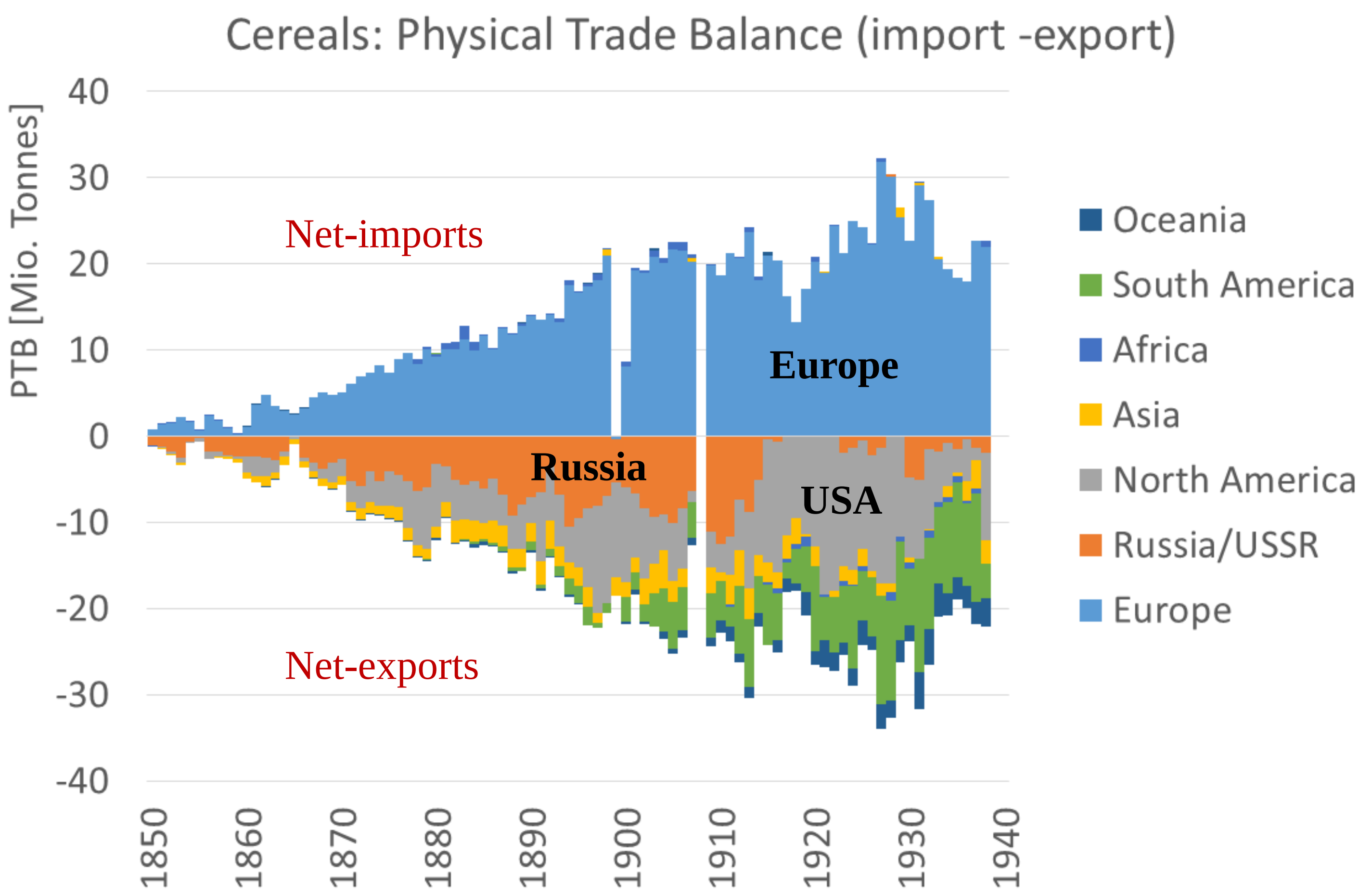
The bottom-up dynamics in the agrarian regime

- The people working the land are interested in improving the process. When expanding their land comes to limits, they develop better tools and techniques, better breeds, better storage...
- In the longer term, these efforts lead to a higher return from land at the expense of investing more labor per unit land (Boserup 1965, Ringhofer et al. 2014). This does hardly improve the EROI but **raises working hours** per person.
- Key response is **high fertility**: children can work while needing less food, often die before adolescence, and surviving they share in the workload of their aging parents.
- Over time, this process results in increasing the population and the workload per capita – a vicious cycle.

The top-down dynamics in agrarian regimes

- People that extract and live upon the surplus from the agricultural process (landlords, religious leaders, urban citizens, kings, administrators, armies...) seek to maintain and eventually expand this surplus. How can they do that?
  - **territorial expansion to increase the energy base**: they can invest part of their surplus in an army (navy) that seeks to conquer additional land (e.g. Roman Empire, European colonialism...). Competing empires try the same – leads to continuous warfare.
  - **reduce the energy cost of mechanical work**, i.e. human labor. Starving those very farmers who deliver the surplus is not wise. Using the able population of conquered territories as slaves or forced labor is another strategy. But: military control and supervision costs may exceed the benefits.

Global cereal (net) trade before the industrialization of agriculture



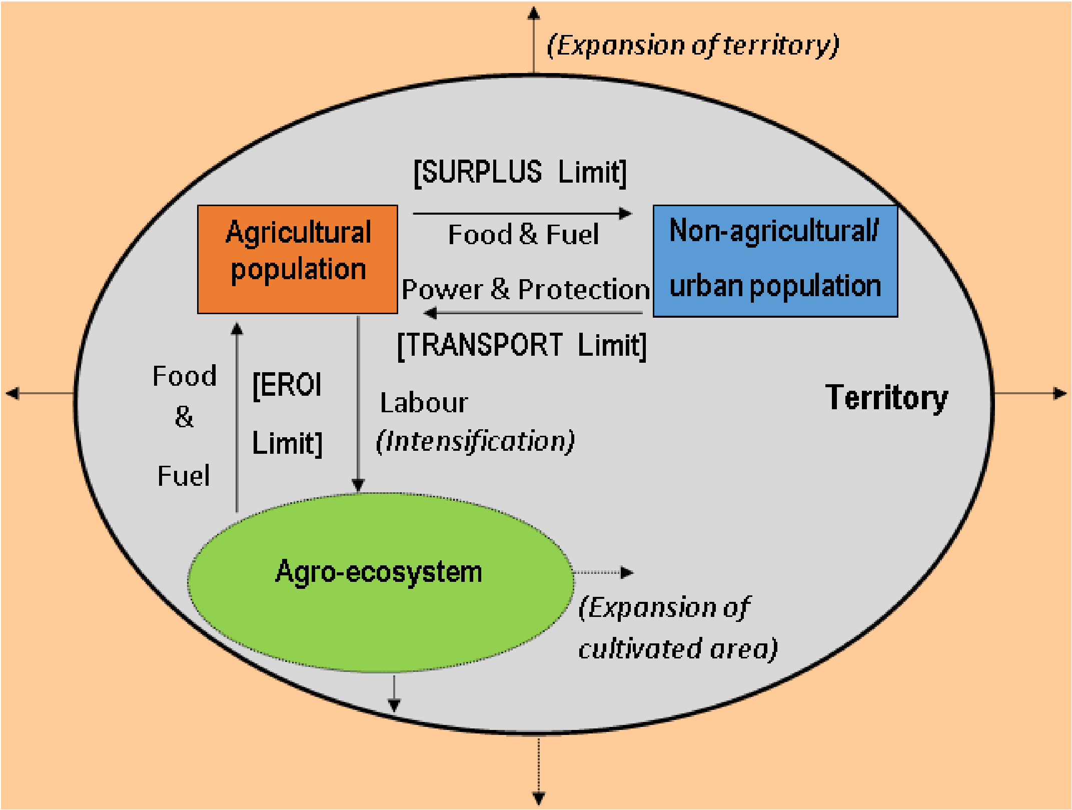
Krausmann and Langthaler 2016

The limits of the agrarian energy regime

- Obviously, constrained by the low EROI of the basic process, the room to maneuvre within the agrarian energy regime is not large:
- Bottom up improvements tend to be self-defeating by increasing population pressure, lead to a miserable life, and eventually to periodic epidemics and civil strife.
- Top down strategies cannot achieve surplus to be self-reinforcing in the long run: endemic warfare in the end leads to periodic collapse of agrarian empires (see Tainter 1988).

Energy and growth under the agrarian metabolic regime: Limitations and challenges

- **Energy availability can be increased** through expansion of territory or through increasing biomass yield per unit of land (intensification).
- **EROI limit:** Agriculture has to yield an energy surplus; declining marginal return, declining resource availability per capita.
- **SURPLUS limit:** Social differentiation is limited **(**Urbanisation; non-agricultural sectors).
- **TRANSPORT limit**: high energy cost of bulk transport
- **Maintaining soil fertility** as core sustainability challenge.



A regime transition out of the agrarian regime has the following preconditions

1. A new energy source with a higher EROI than biomass = fossil fuels: coal, oil and gas. This, in principle, frees human labor power from food production.
2. An institutional liberation of people from personal dependence (servanthood, slavery…) on land and landlords, to be able to use their labor power on other activities.
3. A re-investment of surplus into infrastructure, further production and technological development - and not into the consumption of local or colonial elites, or warfare.

2. and 3. require sociopolitical, economic and cultural change, against the interests of colonial / feudal masters

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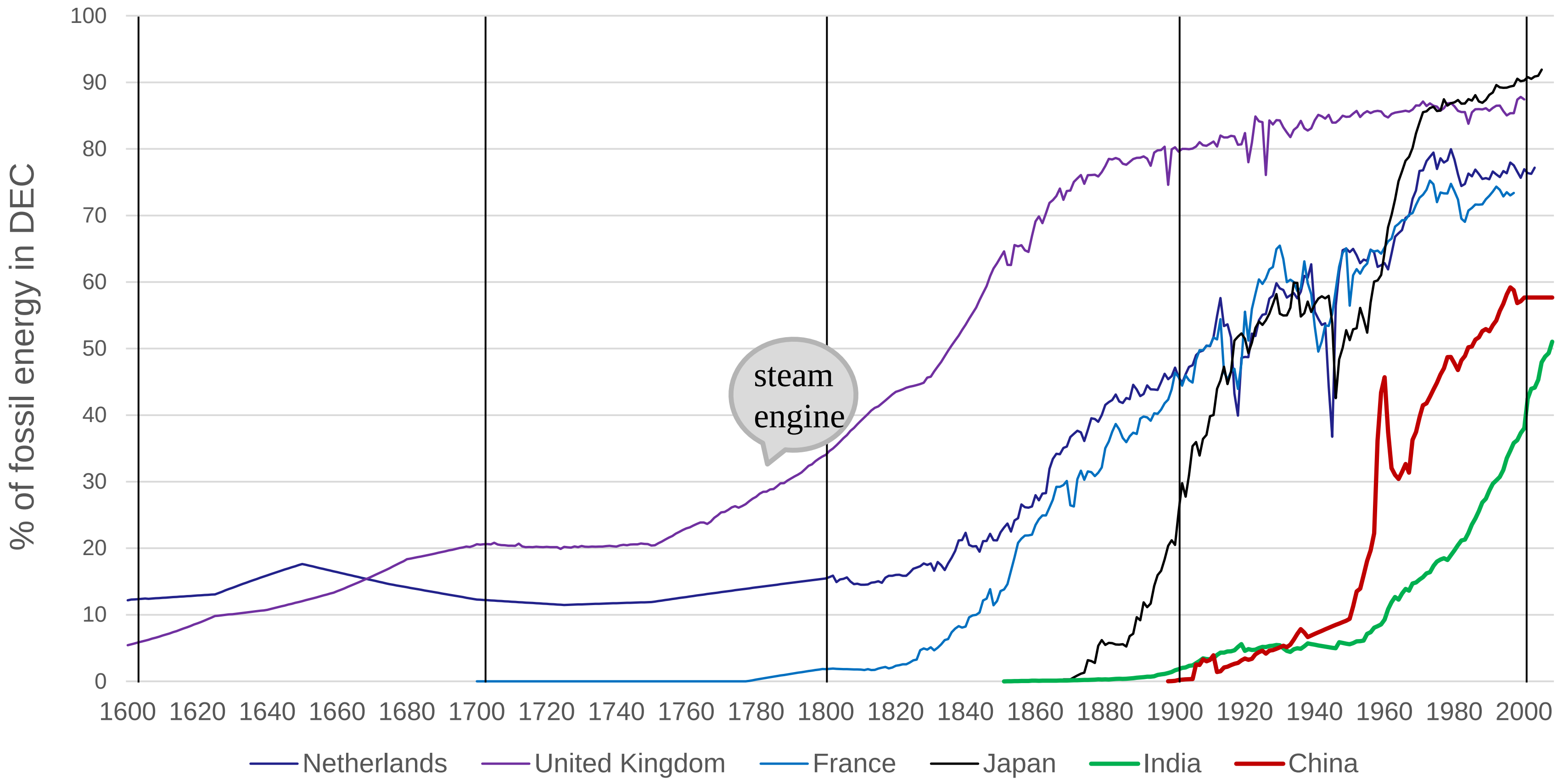
Condition 1: Transition to a fossil fuels based energy system, starting around 1500



The global transition from biomass to fossil fuels based primary energy 1500-2010

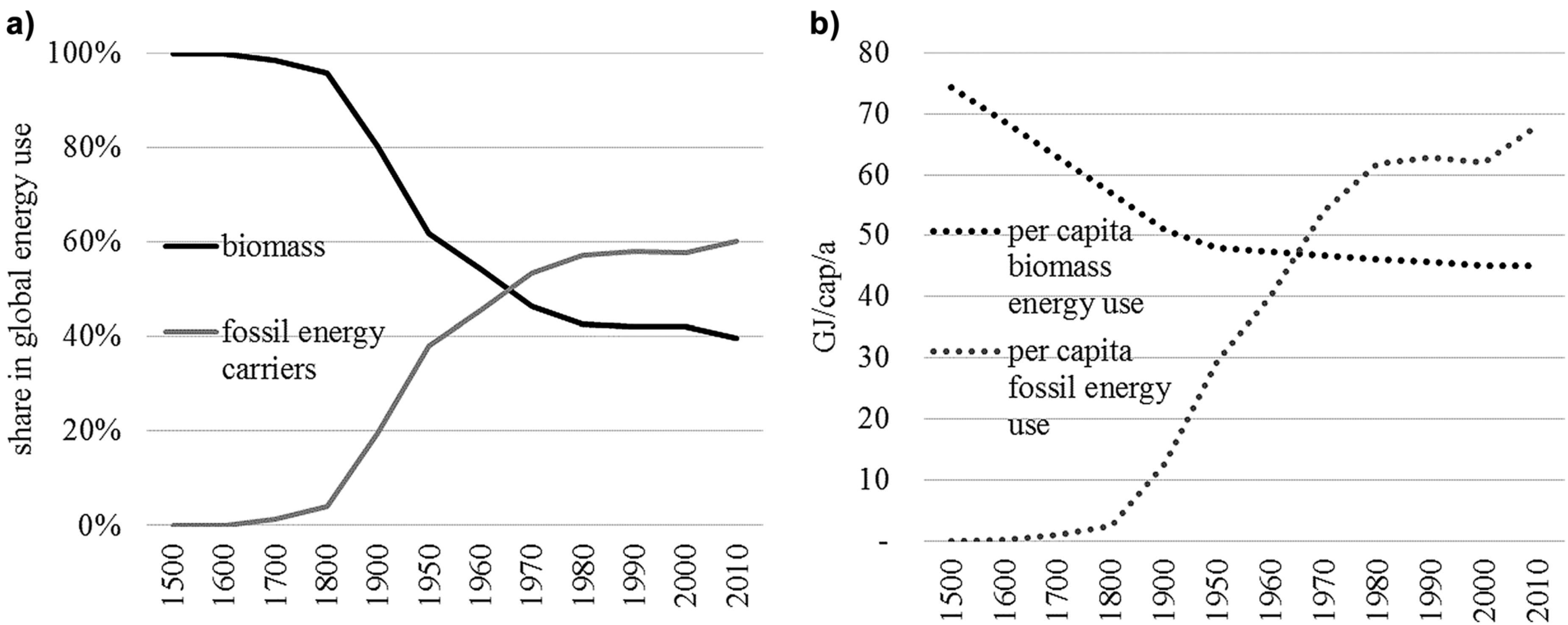
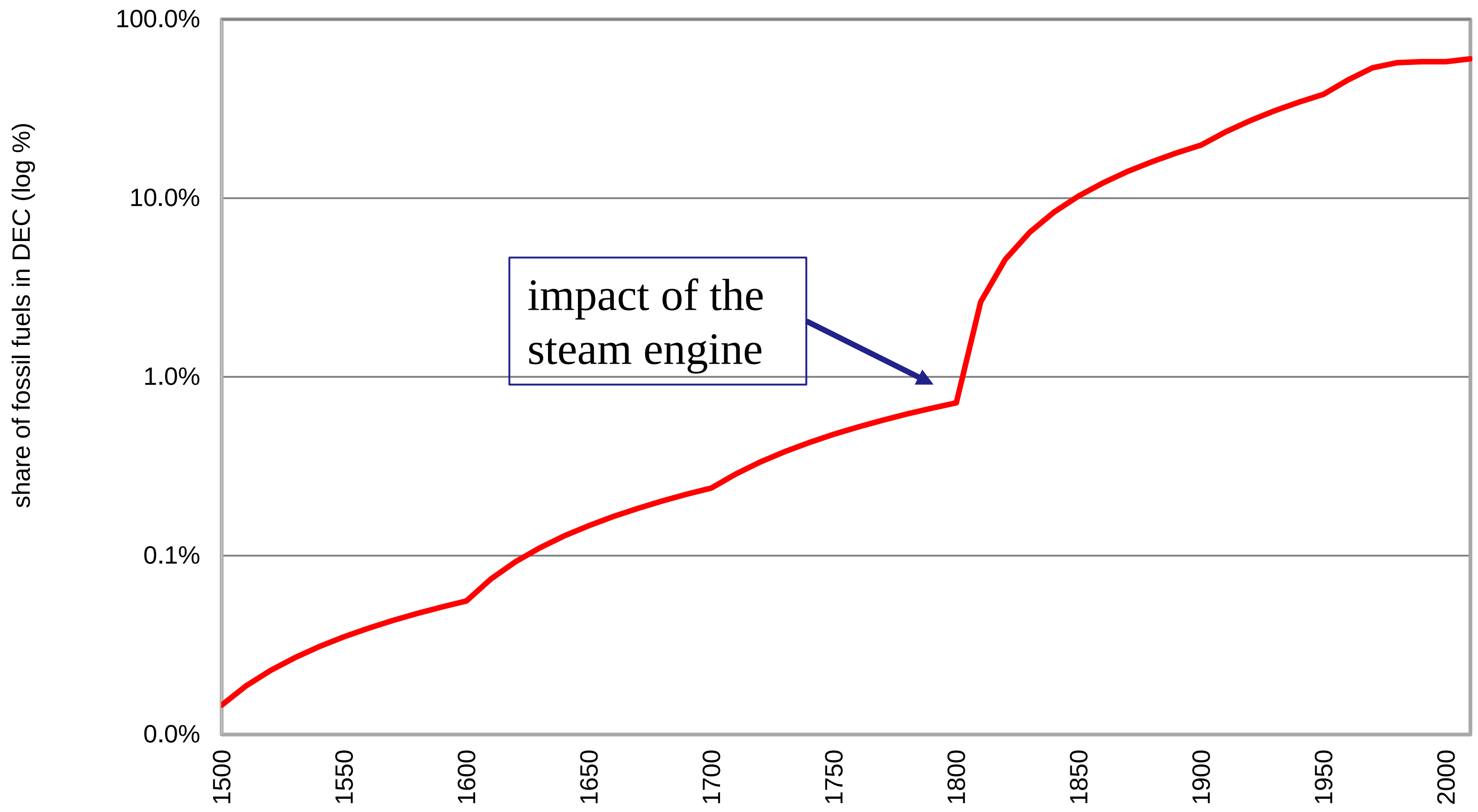


Figure 1. Share of biomass and fossil energy carriers in total global energy use (a) and per capita energy use in Gigajoules per capita and year (GJ/cap/a) by energy source (b) between 1500 and 2010 (source of data: SEC Database; global energy use measured as DEC). (Fischer-Kowalski & Schaffartzik 2015, p.2)

Global share of fossil fuels (and other „modern" energy carriers) in primary energy use 1500-2000



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Condition 2: freeing human labor from personal dependence on landlords

- In the agrarian sociometabolic regime, 85-98% of the population work the land, usually in personal dependence from landlords.
- the urban share is an approximation of the people **not** working the land, that is people that do not need to invest their labour power to produce their own food.
- in the early phase of fossil fuel use (below 10 GJ_{FF}/cap/yr), urban growth is being kicked off.

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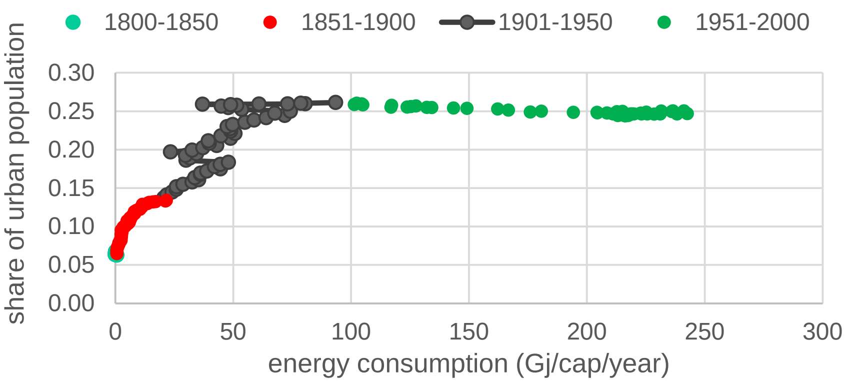
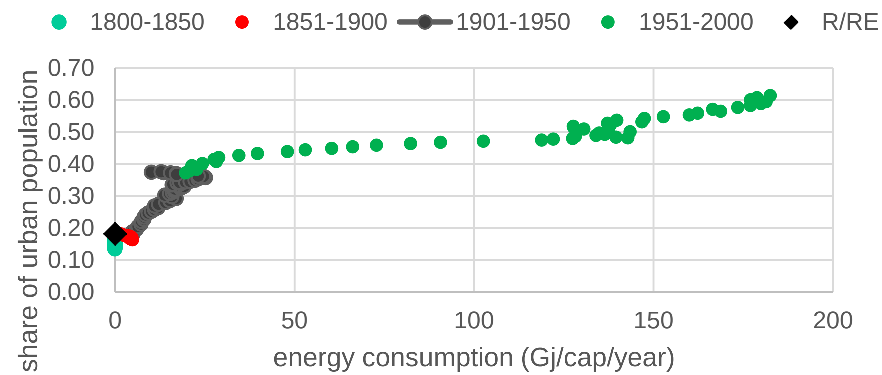
Urbanization related to fossil fuel use, and incidence of revolutionary events (black dots)

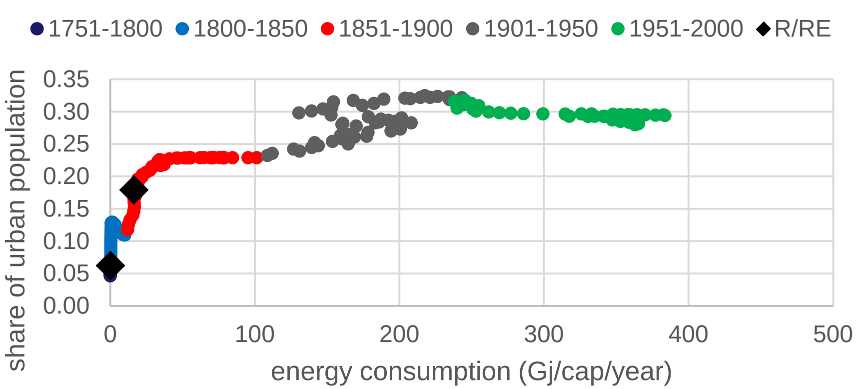
Sweden



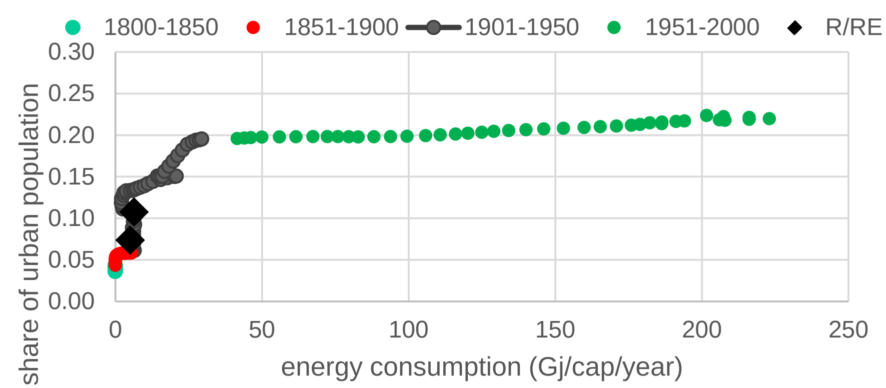
Japan



USA



USSR/Russia



source: Klein-Goldewijk et al. 2010 (urban pop: 2500+ inhabitants). Fischer-Kowalski, Krausmann, Rovenskaya, Pallua, McNeill, in preparation.

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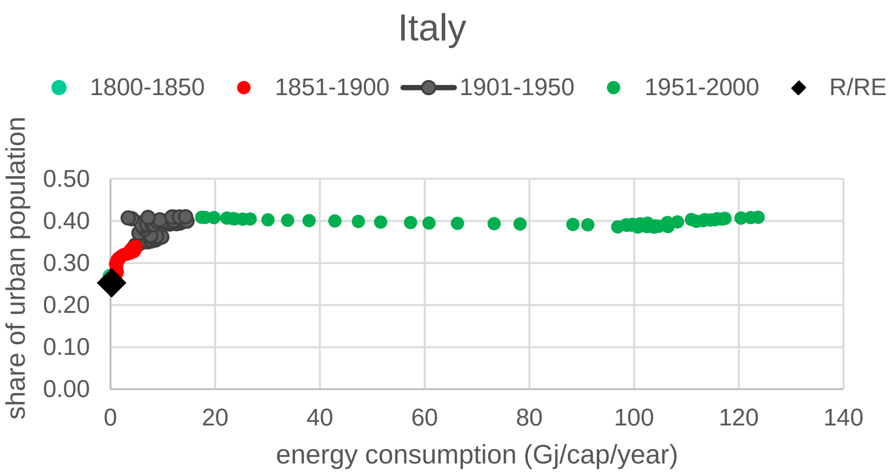
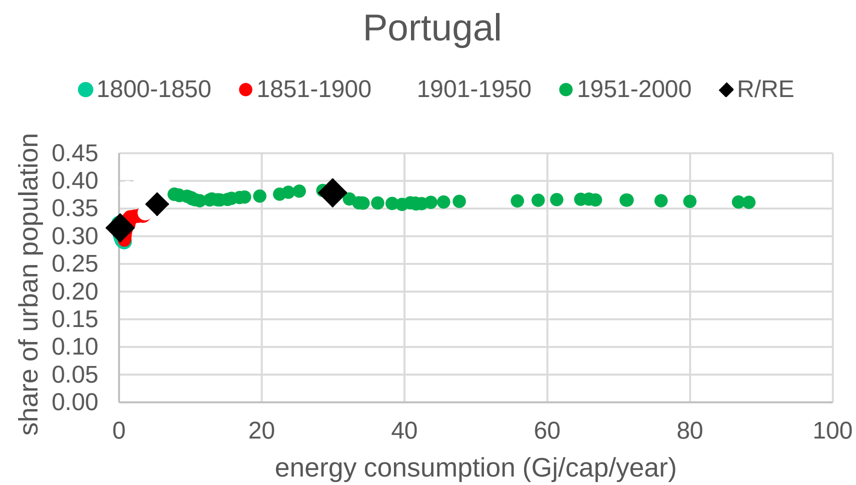
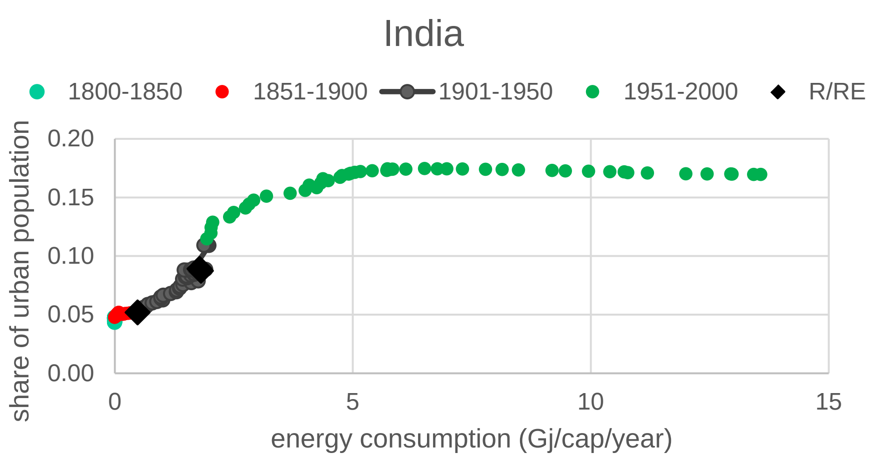
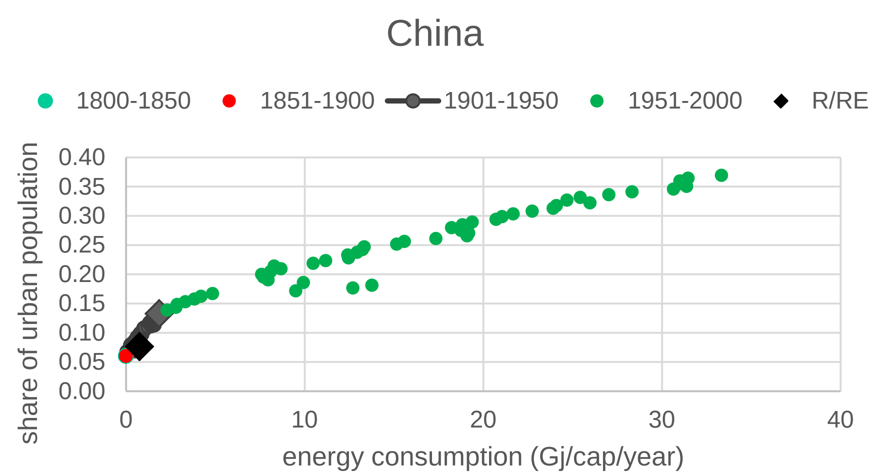
Urbanization related to fossil fuel use, and incidence of revolutionary events **(black dots)**









source: Klein-Goldewijk et al. 2010 (urban pop: 2500+ inhabitants). Fischer-Kowalski, Krausmann, Rovenskaya, Pallua, McNeill, in preparation.

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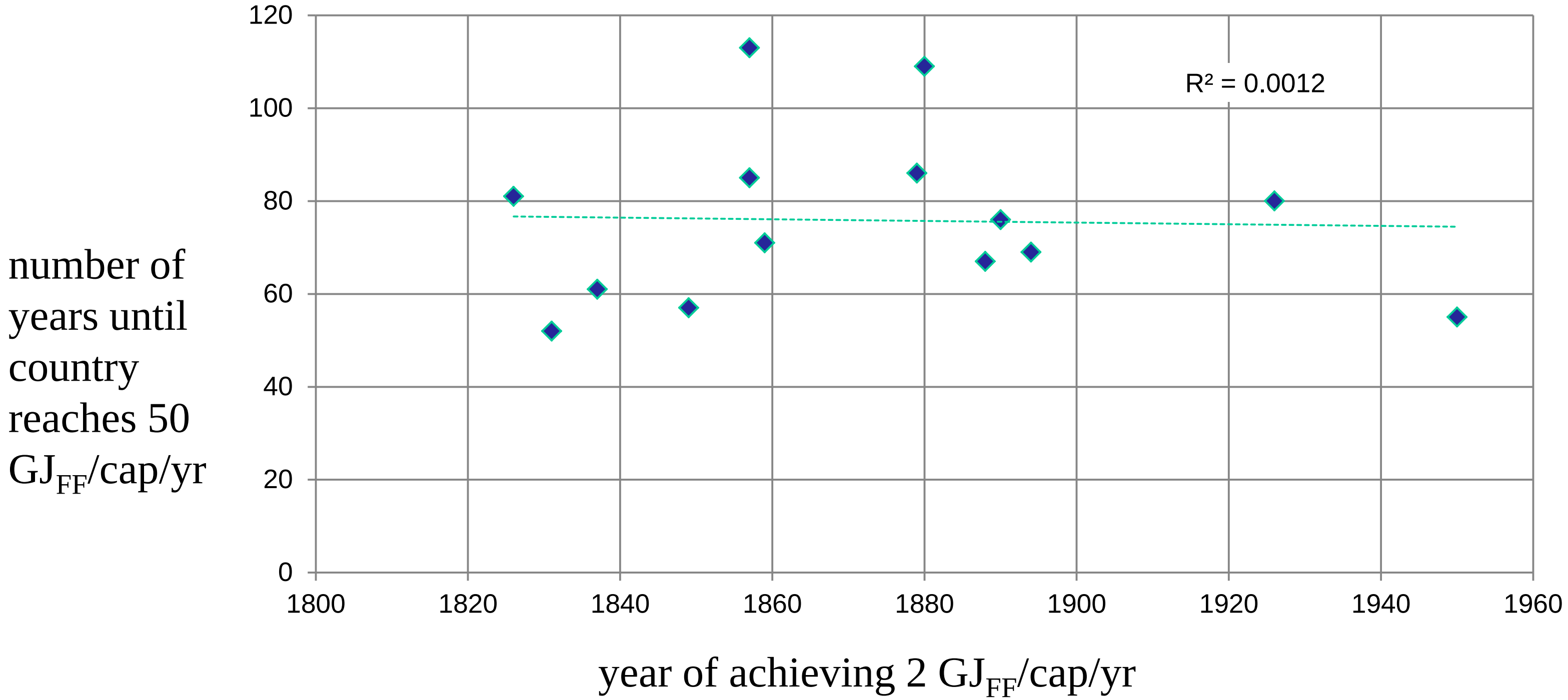
Condition 3: sociopolitical and economic change

- in several countries, there was an outright social revolution in the early take-off phase towards fossil fuel use, designing new constitutions, shaking off colonial domination, abolishing slavery and serfdom, separating politics and religion...
- Whether by revolutions or more calmly, the economic focus shifts from aristocratic conspicuous consumption / colonial exploitation to investment in infrastructure and production. Wage labor becomes the dominant form of labor, technological change accellerates, and surplus becomes self-reinforcing.
- GDP growth follows suit, though interrupted by major crises.
- Warfare continues, as WWI and WWII amply exemplify.

Once conditions 1-3 are met ...

- Once conditions 1-3 are given, the industrial transformation can take off.
- Apparently, in each country this is a complex systemic transformation in which technology plays a role as one among other, but not necessarily the primary factor.
- In contrast to other literature, (e.g. Gruebler 2004), the duration of countries‘ industrial transition has not accellerated during the past 200 years.
- The time period between a country‘s annual use of 2 GJ fossil fuels pc („kick-off“), and its use of 50 GJ pc(„half term“), lasts 77 years on average, and is highly variable.

Duration of Countries‘ take-off towards Fossil Fuel use, by the year of its start



Mean 77, sd 96 years (14 countries)

source: Fischer-Kowalski, Krausmann, Rovenskaya, Pallua, McNeill, in preparation.

Part 5:
What could a next major transition look like?

Three different perspectives:

1. What goals have we decided upon globally? Where do we wish to head for?
2. In what direction are we actually moving, at what speed?
3. What will the Earth‘s resource base permit?

1. What goals have we decided upon: Normative approaches

- IPCC **climate protection** goals. Paris agreement: Keep global warming below 2 (below 1,5) centigrades. Implication: No further CO2 emissions from fossil fuel combustion after 2050. Phasing out fossil fuel use or putting very strong carbon sequestration in place.
- **Sustainable Development Goals** (SDGs) up to 2030: Goal no 1: poverty reduction. Eradicating extreme poverty (<$1,25/day), halving poverty in all its dimensions (national standards). Goal no 7: energy: Access to affordable, sustainable and modern energy for all. Goal no 8: decent work and economic growth.
- **Convention on Biodiversity** (CBD), Aichi biodiversity targets: By 2020, each country should a) address underlying causes of biodiv loss, b) reduce direct pressures (e.g. fishing), c) safeguard ecosystems, d) enhance benefits to all from biodiv and e) enhance implementation through strengthening participatory approaches.

2. In what direction are we actually moving?

Will the fossil fuel based industrial regime loose momentum? What can we see?

- many high income industrial countries, since the 1970s, show stagnating fossil fuel use (Schaffartzik et al. 2014), some even declining. For the first time, there seems to be a decoupling of energy/exergy use and GDP (Ayres & Warr 2005). Renewable energies are on the rise.
- In so-called „emerging economies“, in particular in China, fossil fuel use is rapidly on the rise, and so are global fossil fuel use and CO2 emissions.
- How about the so-called „rest of the world“, the latecomers to the industrial transformation? Are they moving along the same track?

5 Fossil fuel use in Western Industrial countries 1950-2010

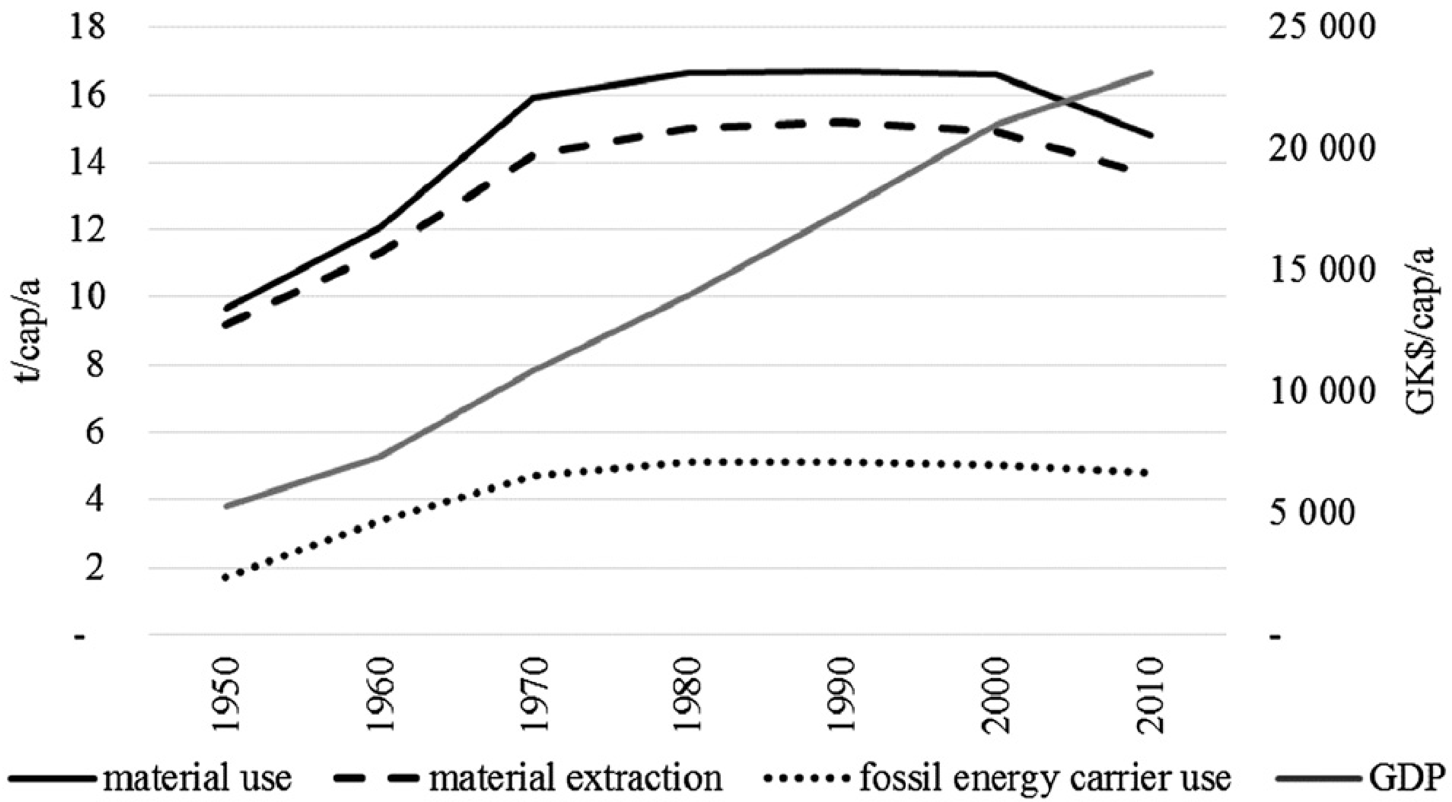


Figure 6. Per capita material extraction (domestic extraction, DE), material use (domestic material consumption = DE + imports – exports), and fossil energy carrier use in tons per capita and year (t/cap/a) and GDP in international Geary–Khamis dollars per capita and year (GK$/cap/a) in the Western industrial countries between 1950 and 2010.

source: Fischer-Kowalski & Schaffartzik 2015, p. 9

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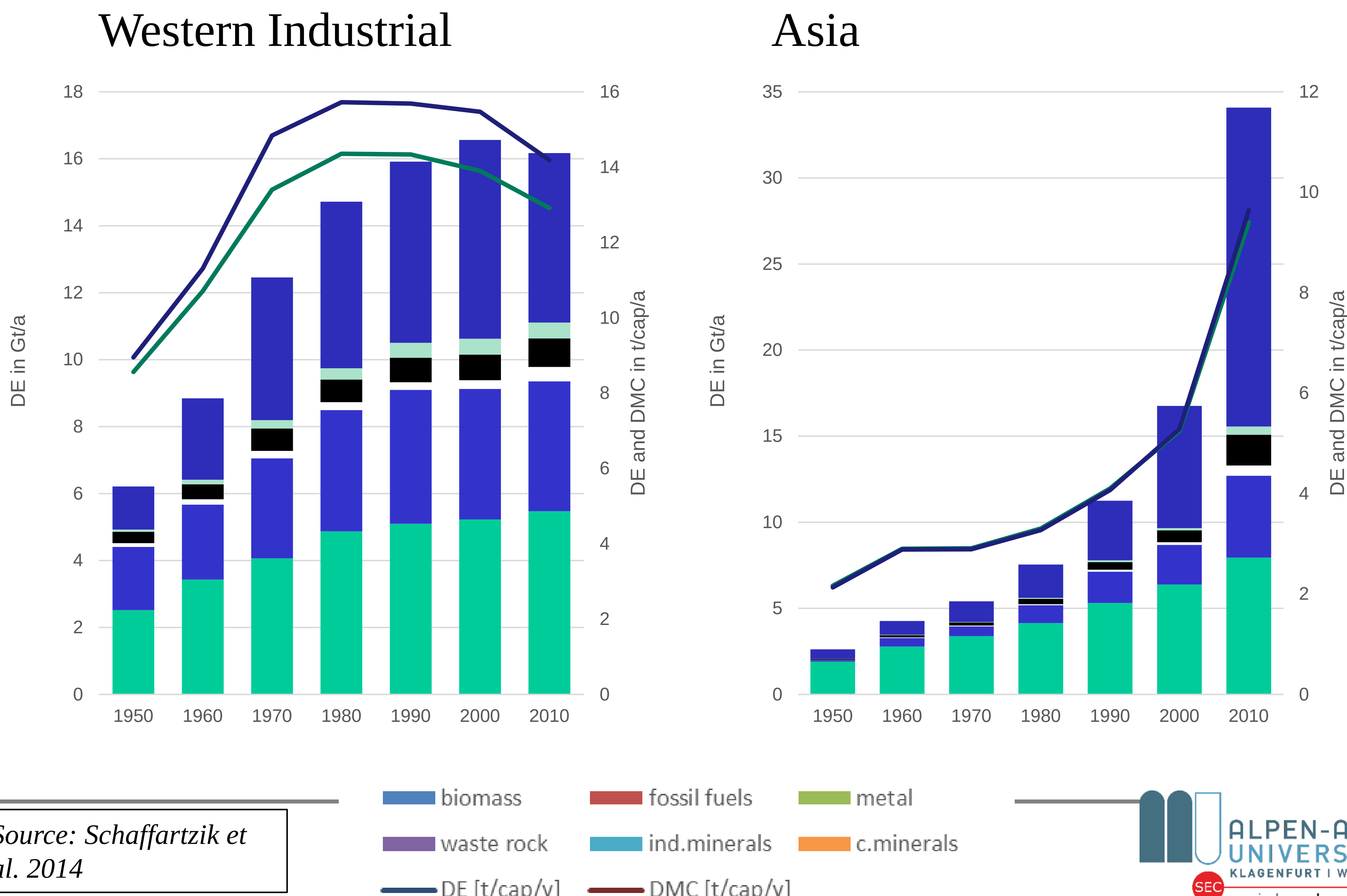
Material flow profiles by world regions



Source: *Schaffartzik et al. 2014*

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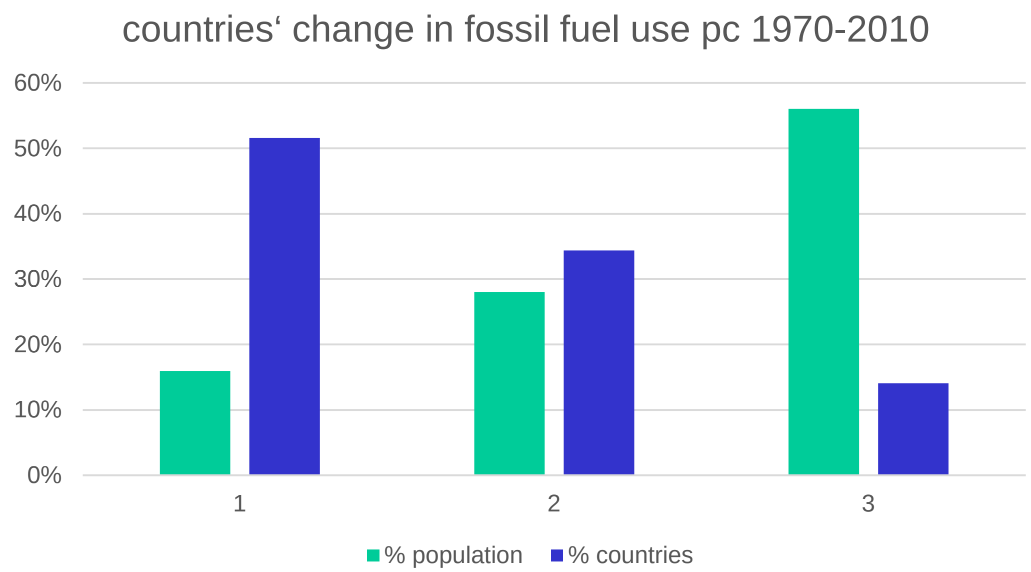
Are the latecomers moving along the same track?

- In 2010, almost half the world population lives in the 64 countries that began their transition from agrarian to industrial, if at all, after WWII, and had less than 10GJ/cap modern energy in 1971 (start of IEA statistics).
- If their transition would have followed the same average pace as with the earlier industrializers, many of them would have arrived at 50 GJ/c by now. But: among those 64 countries,Thailand is the only one that met this pace.
- In 40 years of observation, half of the countries actually had decreasing energy availability (population outgrowing energy), and half of the people lived in countries that saw just an increase of 10 GJ pc or less during this period. At this pace, the transition process, if it continues at all, will take many decades longer, into the next century.
- And if these 3,1 billion people would actually satisfy their additional energy needs by fossil fuels, ... Or can we believe this would be satisfied by renewables?

Latecomers to the industrial transition: their pace of introduction of modern energy



1 >fossil fuel use pc is declining
2 >fossil fuel use pc rises less than 10 GJ/c
3 >fossil fuel use pc rises 10 GJ/c or more

Latecomers = countries that in 1971 use less than 10 GJ/c of fossil fuels

N= 64 countries, with a population of 3,1 billion people in 2010

source: IEA and Social ecology DB

New political currents

- In the earlier transitions, there had been a political divergence between liberal capitalist and socialist variants, but the basic idea of progress had been very similar. („*Communism is Soviet power plus the electrification of the whole country*", Lenin in 1921).
- Among several of the „latecomer" countries to the industrial transition, there are explicitly „antimodernist" political currents, such as the Taliban, Boko Haram and the Islamic State. The islamistic variant does not propagate an industrial transformation, is opposed to enlightenment, emancipation, democracy, non-violence and human rights. This supplies a novel cultural identity to global underdogs, and a persistent security threat to the established powers.
- On the modernist side, some scientists seek to reconcile the gap between what we may want and what we can with highly invasive technologies (geoengineering, terraforming, global bioremediation ...) which would shift the risks to still another level.

What will Earth‘s resource base permit?

- How long will fossil fuel supply last? There is a controversial debate since Hubbert (1962), ranging from Murphy (2012) claiming that not just peak oil is practically there but also coal and gas limitations will soon become relevant, to e.g. Jackson & Smith (2012) who anticipate no shortage ahead. In a geological time frame, fossil fuels won‘t last.
- What is the EROI of future alternative energy sources? In a most recent debate on the SCORAI listserve, William Rees contributed the wide definition of EROI required:

  „Will this energy source provide enough output to completely produce itself from the ground up – mining, refining, manufacturing, transportation , installation, energy distribution.. – while simultaneously supplying the energy demands to run modern society?“ (Sept.13, 2016)
- The estimates he gives range from 1 to 7,5 – fairly far away from the 10-30 EROI of conventional oil. My conservative estimate: the energy abundance Western industrial societies now enjoy will not last.

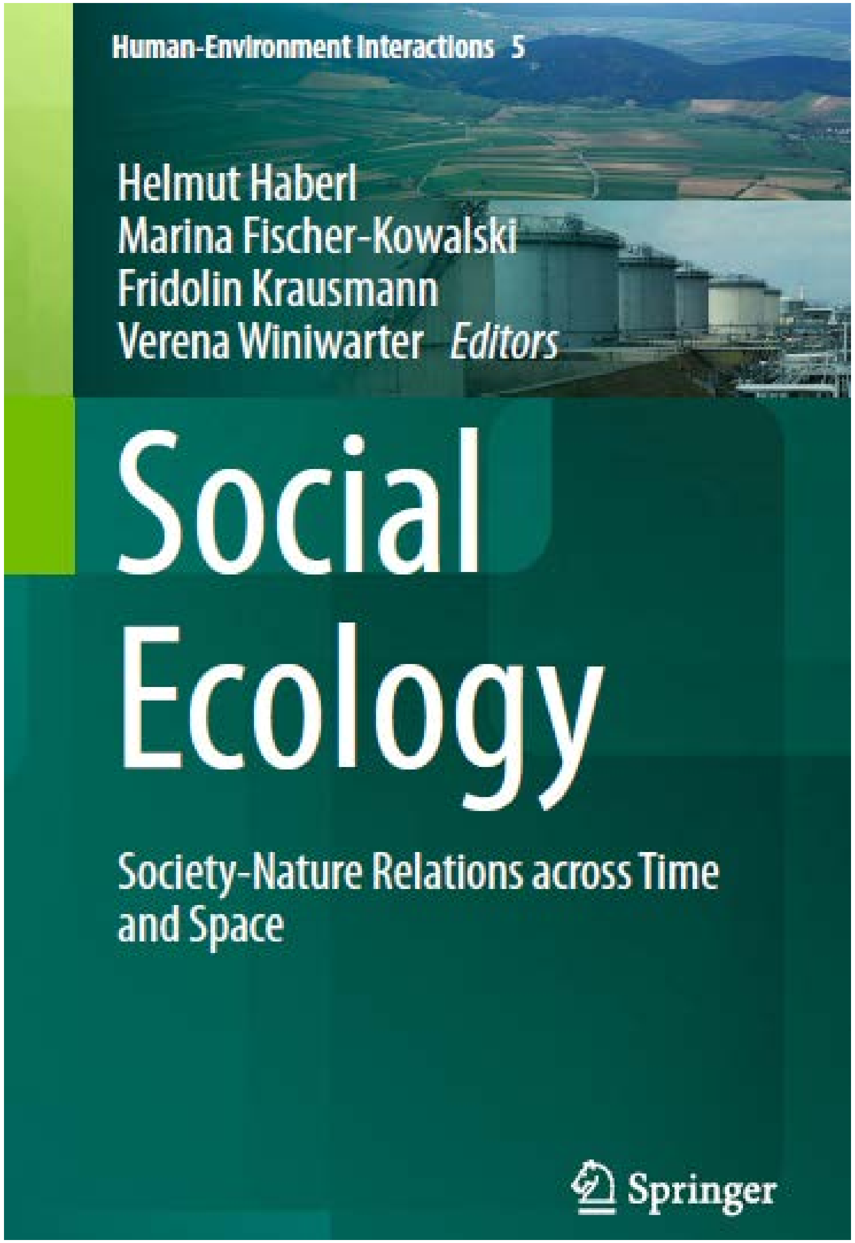
Resumé: What can Industrial Ecology's theory of social metabolism contribute?

- The insight that for thermodynamic reasons, human societies can change the functioning of the Earth System in proportion to the amount of excess energy they control. (see also Hamilton 2016)
- The insight that also socio-economic systems have a complex dynamic, marked by tipping points and major transformations. Understanding these processes is essential for understanding future perspectives.
- The insight that there is a huge gap between what we want (and decide upon with our global institutions), and what the multiple socioeconomic actors and forces can and will do.
- Trying to reconcile this gap with highly invasive technologies (geoengineering, terraforming, global bioremediation ...) shifts the risks to still another level.

„Smaller by design not desaster !“

Industrial Ecology carries a co-responsibility to achieve that.

Thank you!



new book by the Vienna Social Ecology Team (2016)

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