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Socioecological Transitions in human history and present, and their impact upon biodiversity

Marina Fischer-Kowalski

Institute of Social Ecology
IFF Vienna, Klagenfurt University, Austria

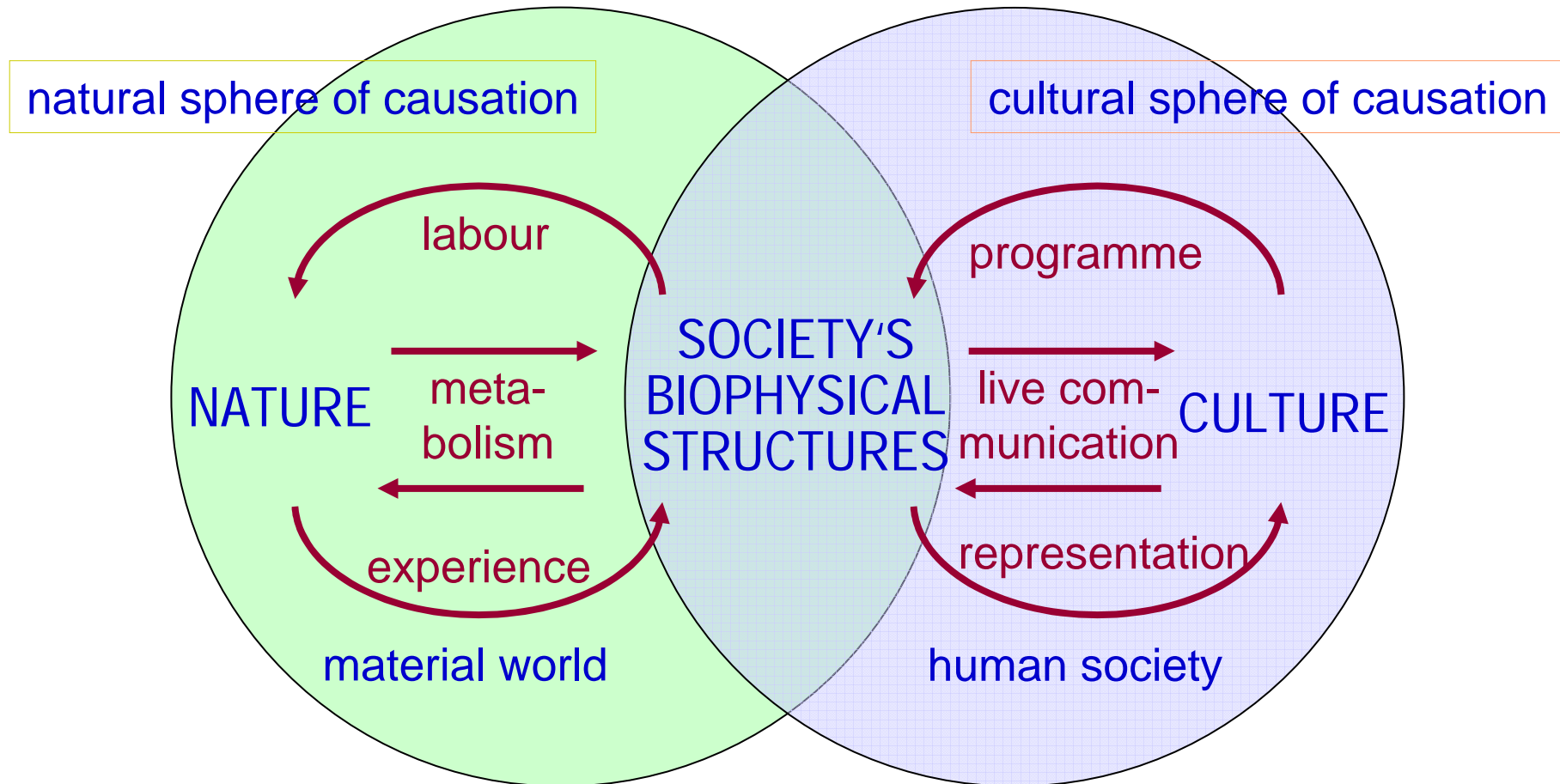
key assumptions

- On the global level, we still are in a late phase of a major transition that started ~300 years ago, from an agrarian to an industrial mode of subsistence, that is, from a land-based to a fossil-energy based socio-ecological regime
- countries in the global North and countries in the South are at different points of this transition; global interdependencies, however, modify the process
- striving for a next transition, towards sustainability, has to be based on an appropriate understanding of this historical and ongoing transition.

Outline

1. key features of the historical transition from the agrarian to the industrial regime (*illustrated for the forerunner United Kingdom, and the latecomer Austria*)
2. patterns of ongoing transformations in the South, in relation to the historical Northern transition, and in the context of global interdependency
3. concepts, methods, points of intervention – where do we stand?

Socioecological System



Socioecological regimes

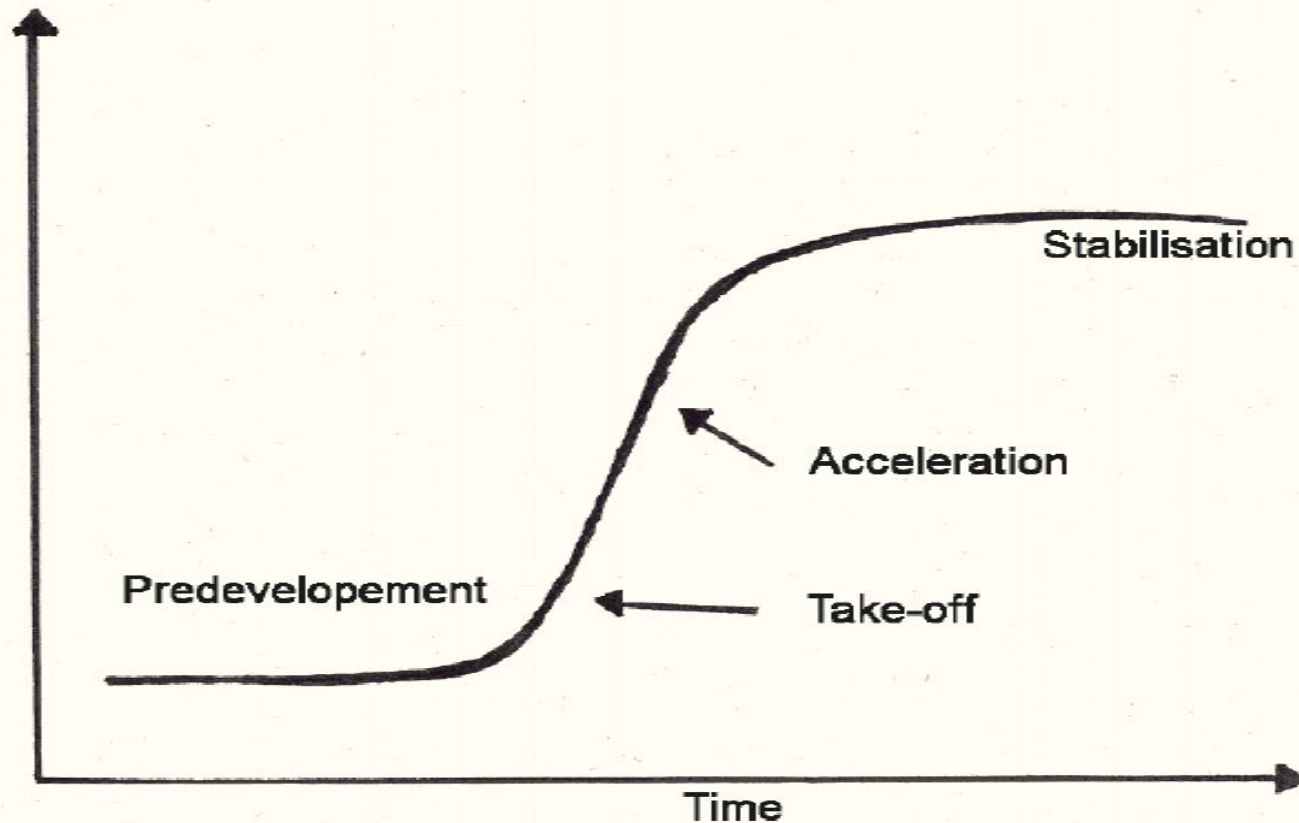
Socioecological regimes are dynamic equilibria of socioecological systems – that is, a certain range of social organisation coupled to certain natural systems on which they depend, and which they colonize and exploit in specific ways.

„Socioecological regimes“ are a way to say in terms of complex systems theory what many authors, using different terms, in world history have addressed as human modes of subsistence (Adam Smith, Diamond) or modes of production (Ricardo, Marx).

The formal notion of 'transition'

Indicator(s)
for social
development

Source: P. Martens & J. Rotmans: Transitions
in a Globalizing World, Lisse 2002



Transitions between socioecological regimes

Within regimes gradualism and path dependency prevails: the system moves along a path, „maturing“ into a certain direction, often towards a „high level equilibrium trap“ (Boserup 1965, Sieferle 2003), until:

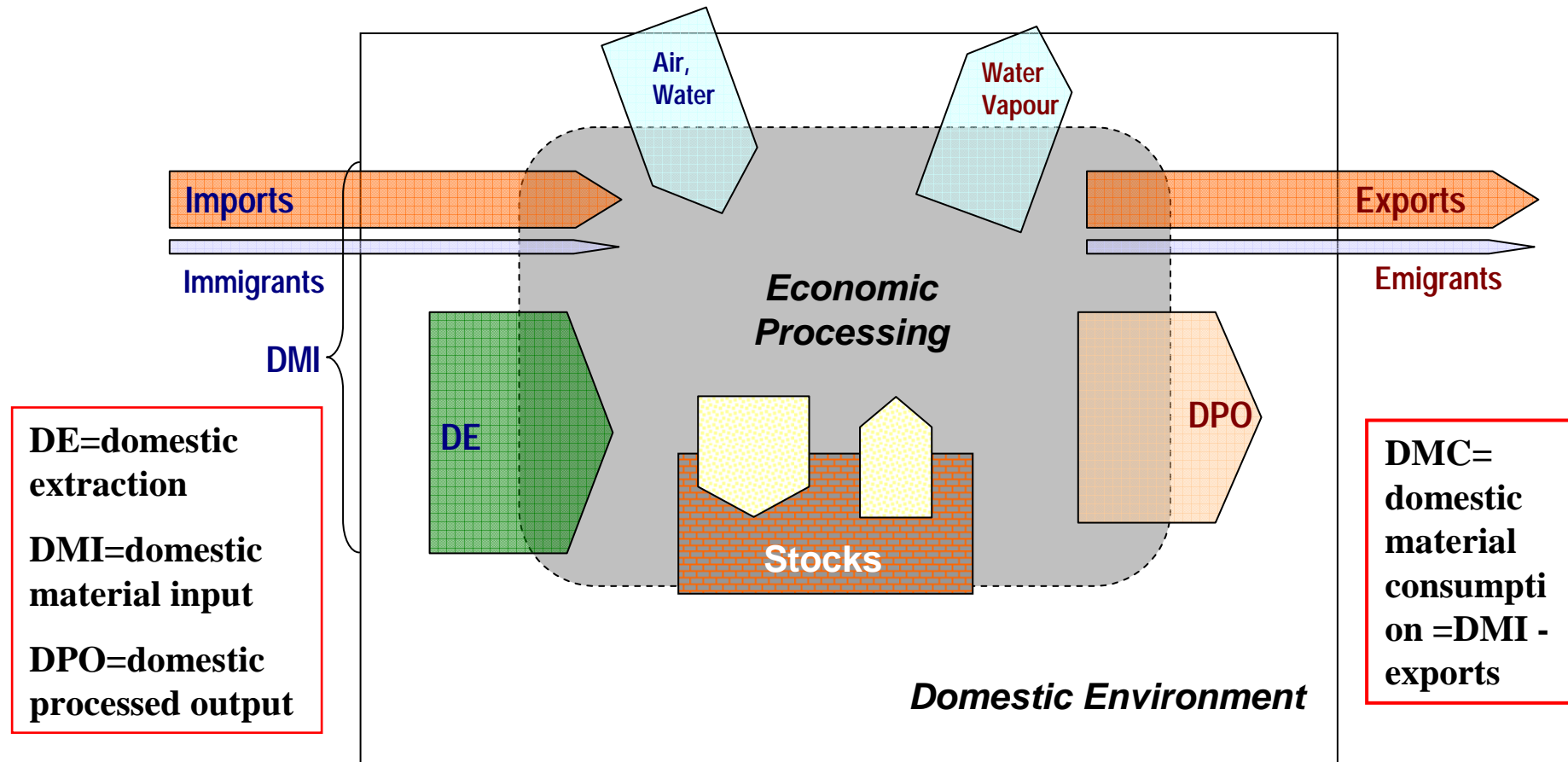
- that path is either interrupted from outside (such as: Mongol invasion, major volcano eruption), or
- the system implodes / collapses, and possibly falls back to an earlier stage of that same path (Diamond 2005)
- or particular (contingent) conditions allow for a transition into another socioecological regime

Transitions **between regimes** can be turbulent and chaotic; they are usually irreversible; there is no predetermined outcome or directionality.

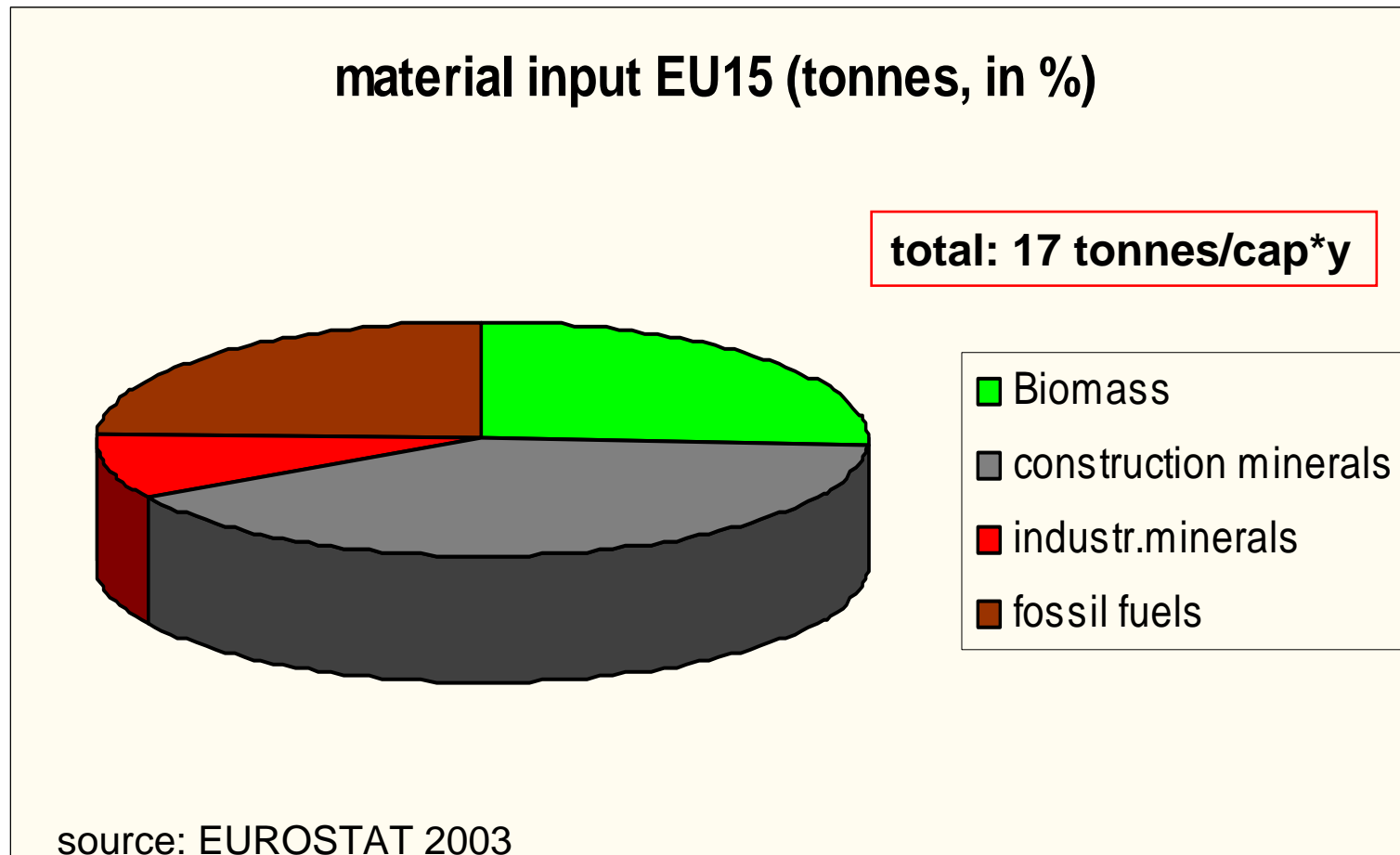
Socioecological regimes can be characterized by ...

1. a **metabolic profile**, that is a certain structure and level of energy and materials use (range per capita of human population)
2. secured by certain **infrastructures** and a **range of technologies**, as well as
3. certain **economic and governance structures**.
4. A certain pattern of **demographic reproduction**, human life time and labor structure, and
5. a certain pattern of **environmental impact**: land-use, resource exploitation, pollution and impact on the biological evolution
6. Key **regulatory positive and negative feedbacks** between the socio-economic system and its natural environment that mould and constrain the reproduction of the socioecological regime.

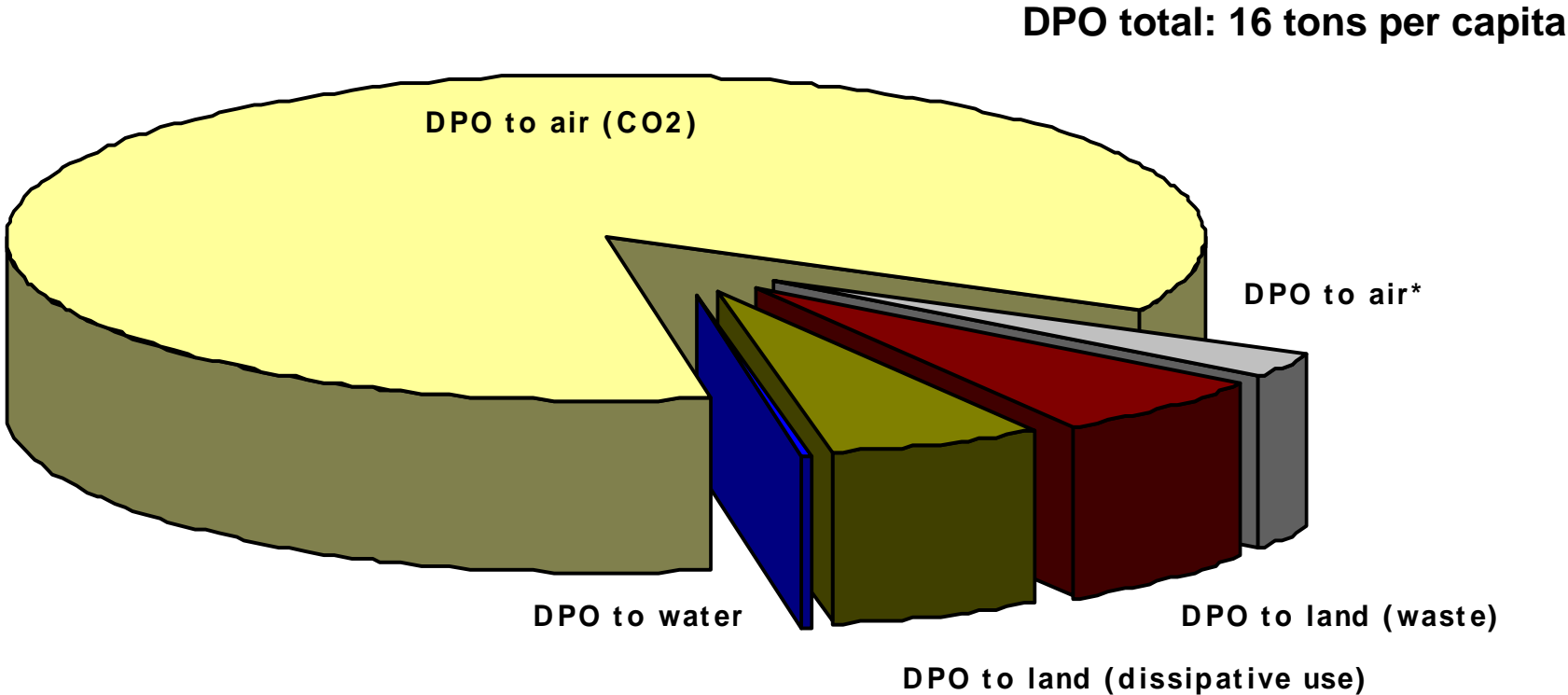
Model of material social metabolism (according to MEFA)



composition of materials input (DMC)



Composition of DPO: Wastes and emissions (outflows)



unweighted means of DPO per capita for A, G, J, NL, US; metric tons

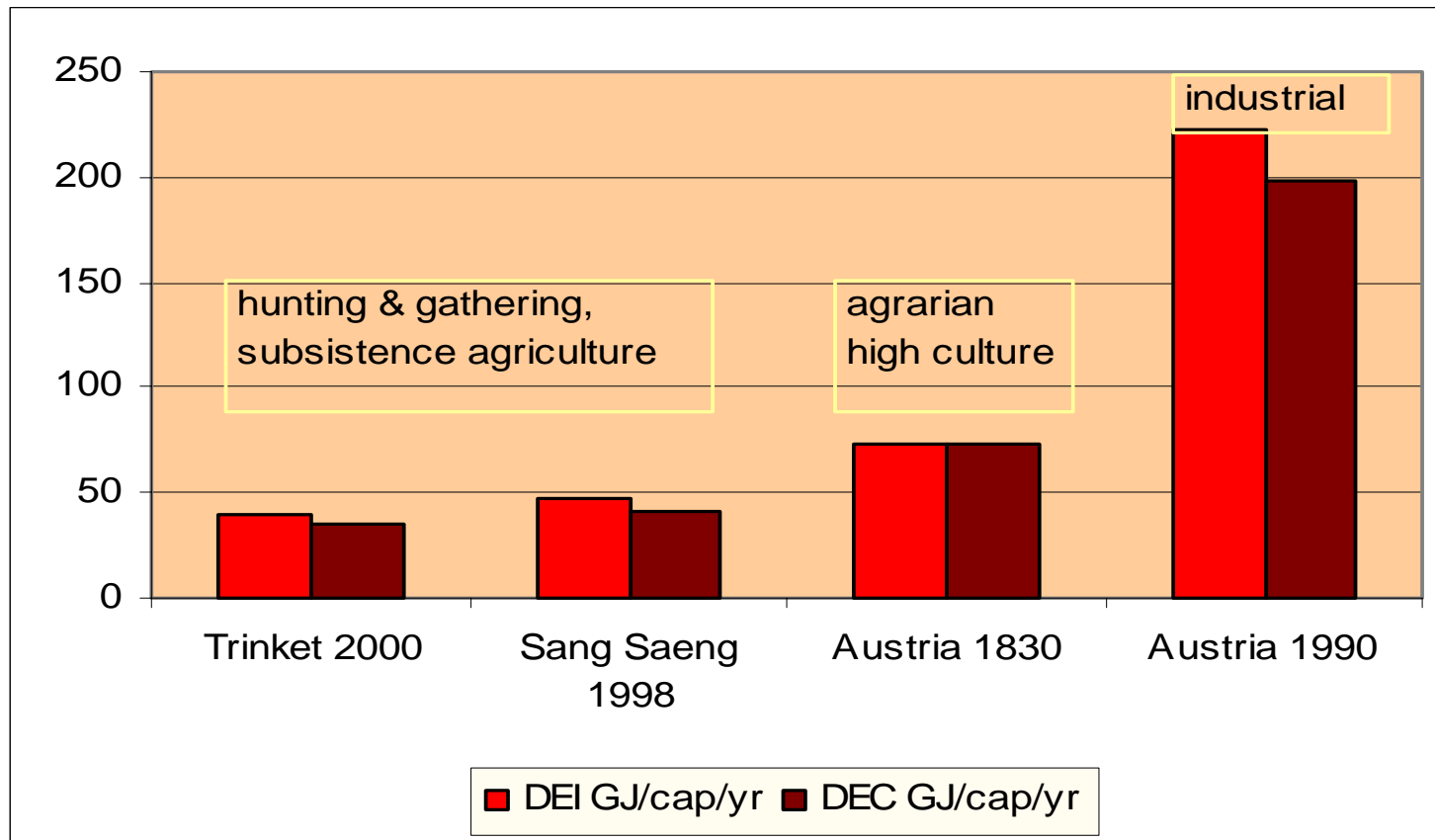
Metabolic profiles of socioecological regimes in world history

	per capita annual use	
	Energy	Material
Basic human metabolism (biomass intake by nutrition)	3,5 GJ	1 t
Hunter-gatherers (uncontrolled solar energy use)	10-20 GJ	2-3 t
agrarian societies (controlled solar energy use)	40-70 GJ	4-5 t
industrial societies (fossil energy use)	150-400 GJ	15-25t

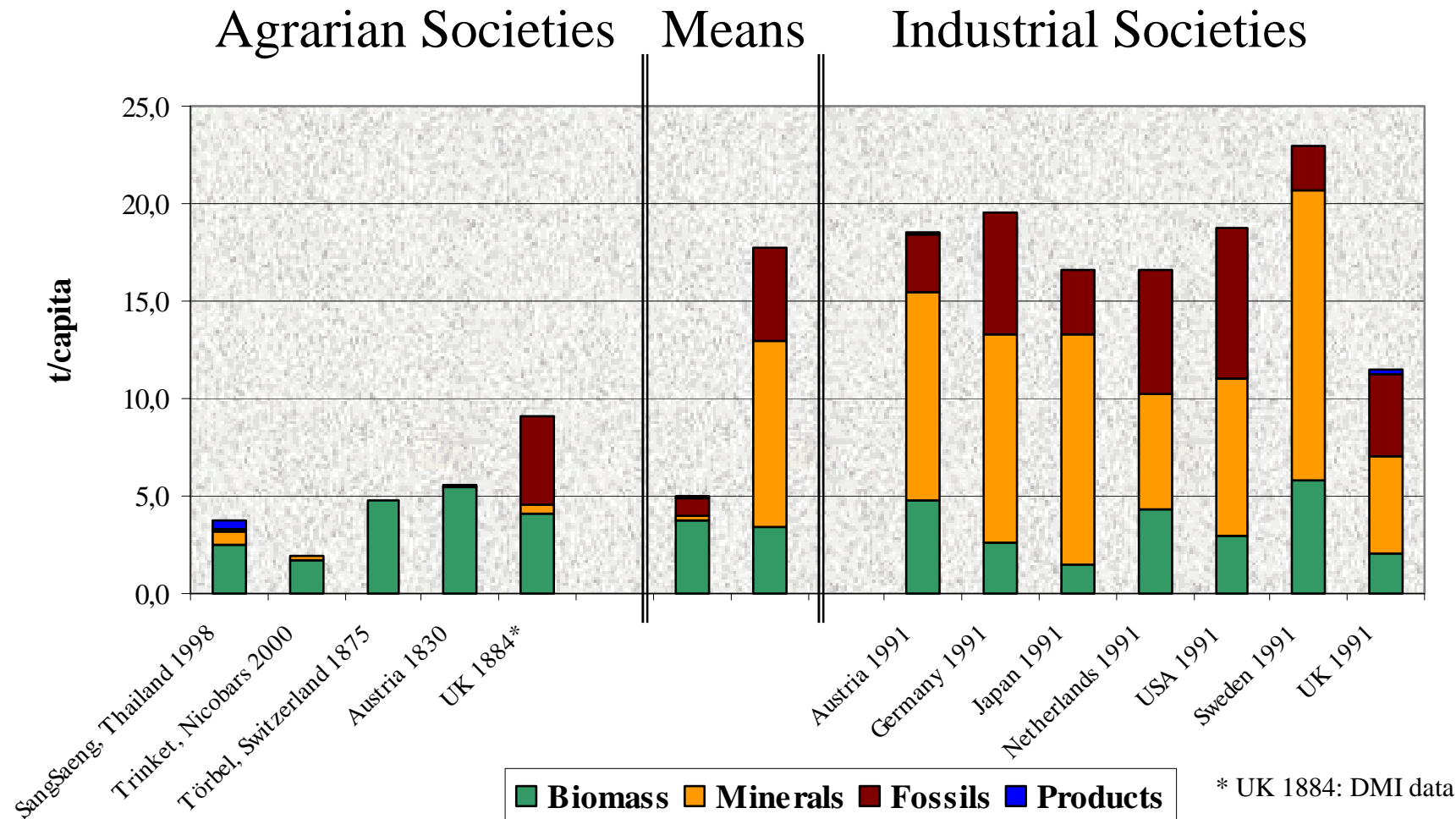
Metabolic profiles of the agrarian and industrial regime: transition = explosion

		Agrarian	Industrial	Factor
Energy use (DEC) per capita	[GJ/cap]	40-70	150-400	3-5
Material use (DMC) per capita	[t/cap]	3-6	15-25	3-5
Population density	[cap/km ²]	<40	< 400	3-10
Agricultural population	[%]	>80%	<10%	0.1
Energy use (DEC) per area	[GJ/ha]	<30	< 600	10-30
Material use (DMC) per area	[t/ha]	<2	< 50	10-30
Biomass (share of DEC)	[%]	>95	10-30	0.1-0.3

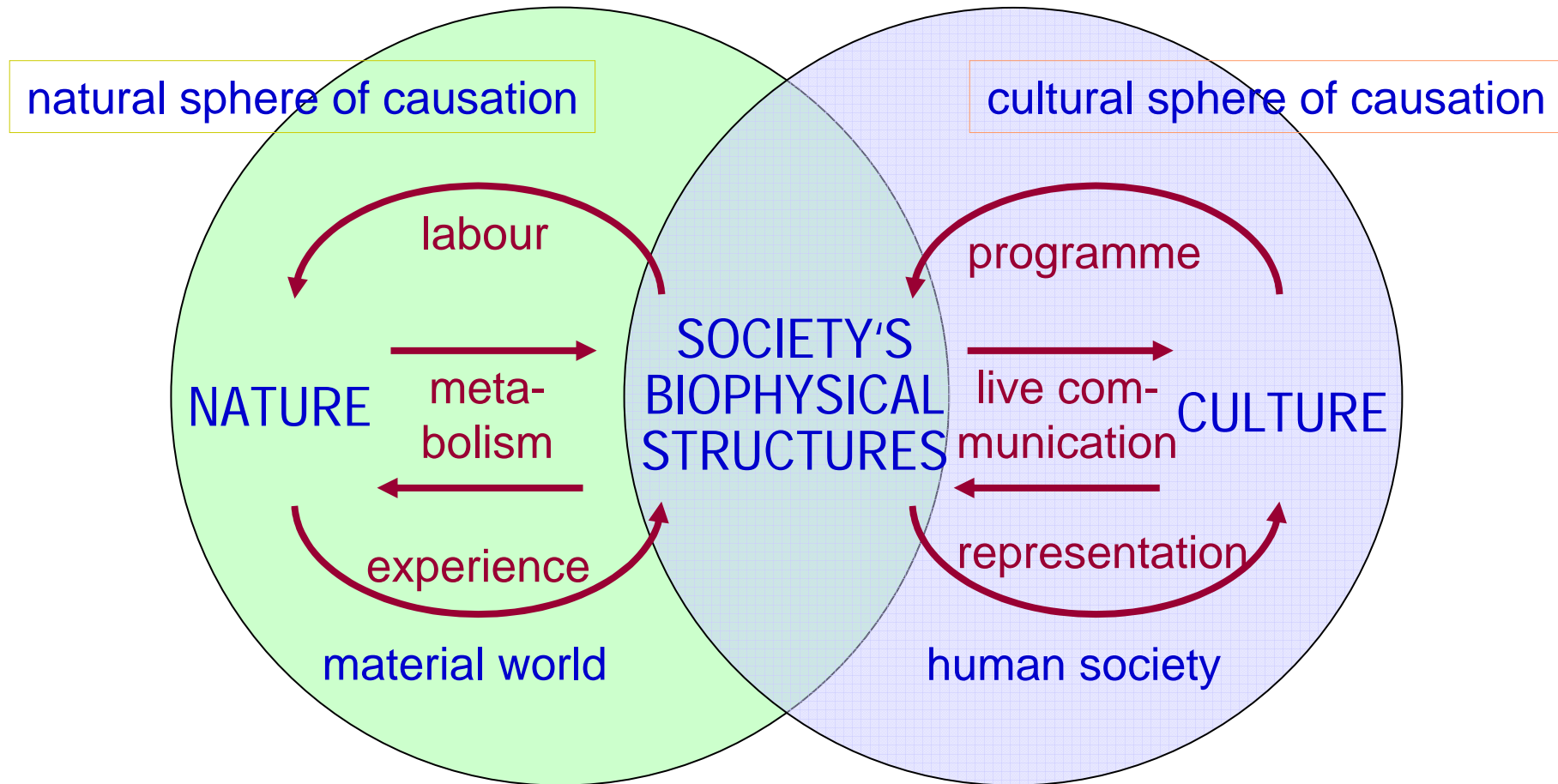
metabolic rates (energy) across socio-ecological regimes



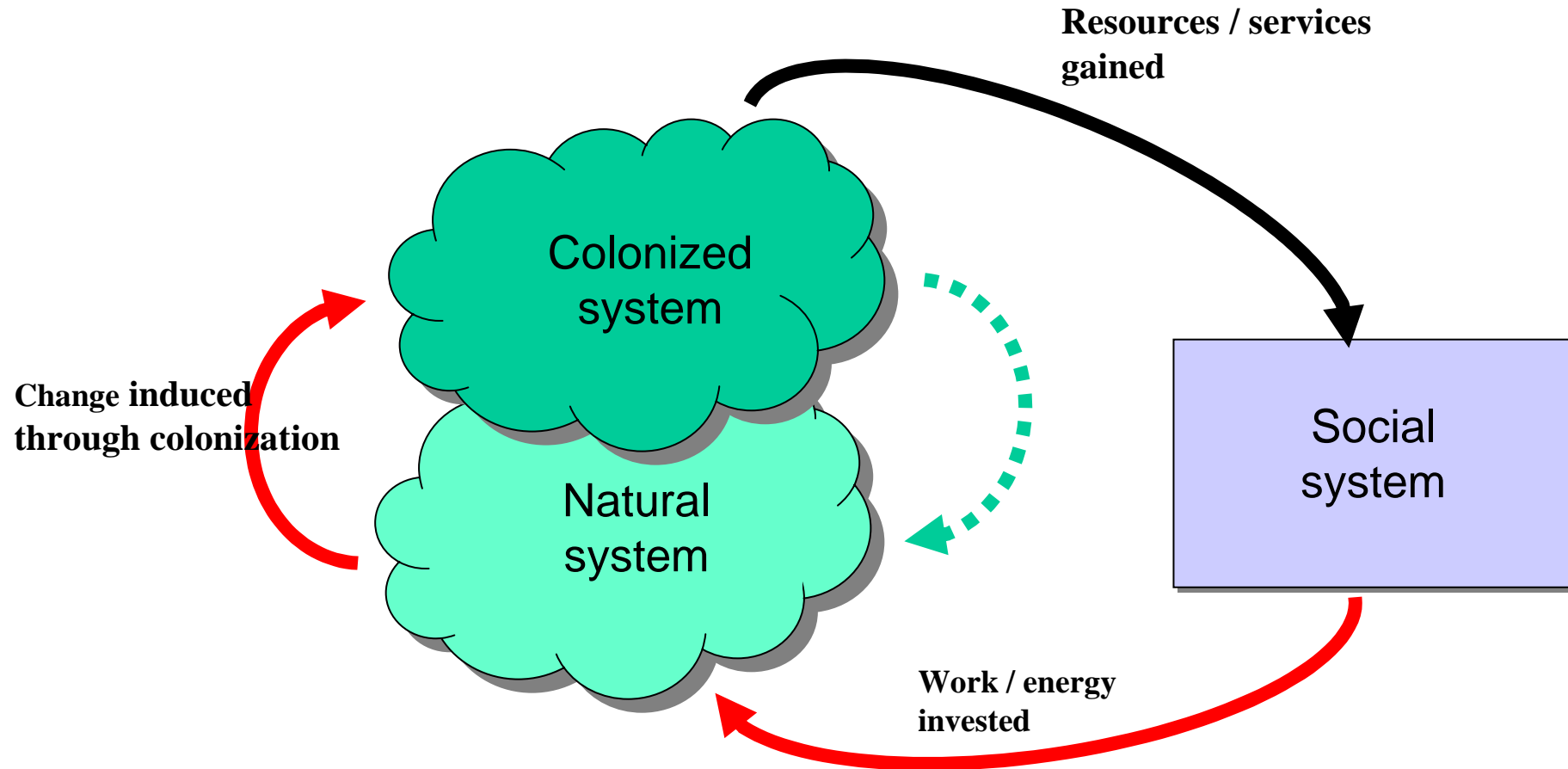
Metabolic profiles by socio-ecological regimes (DMC/capita)



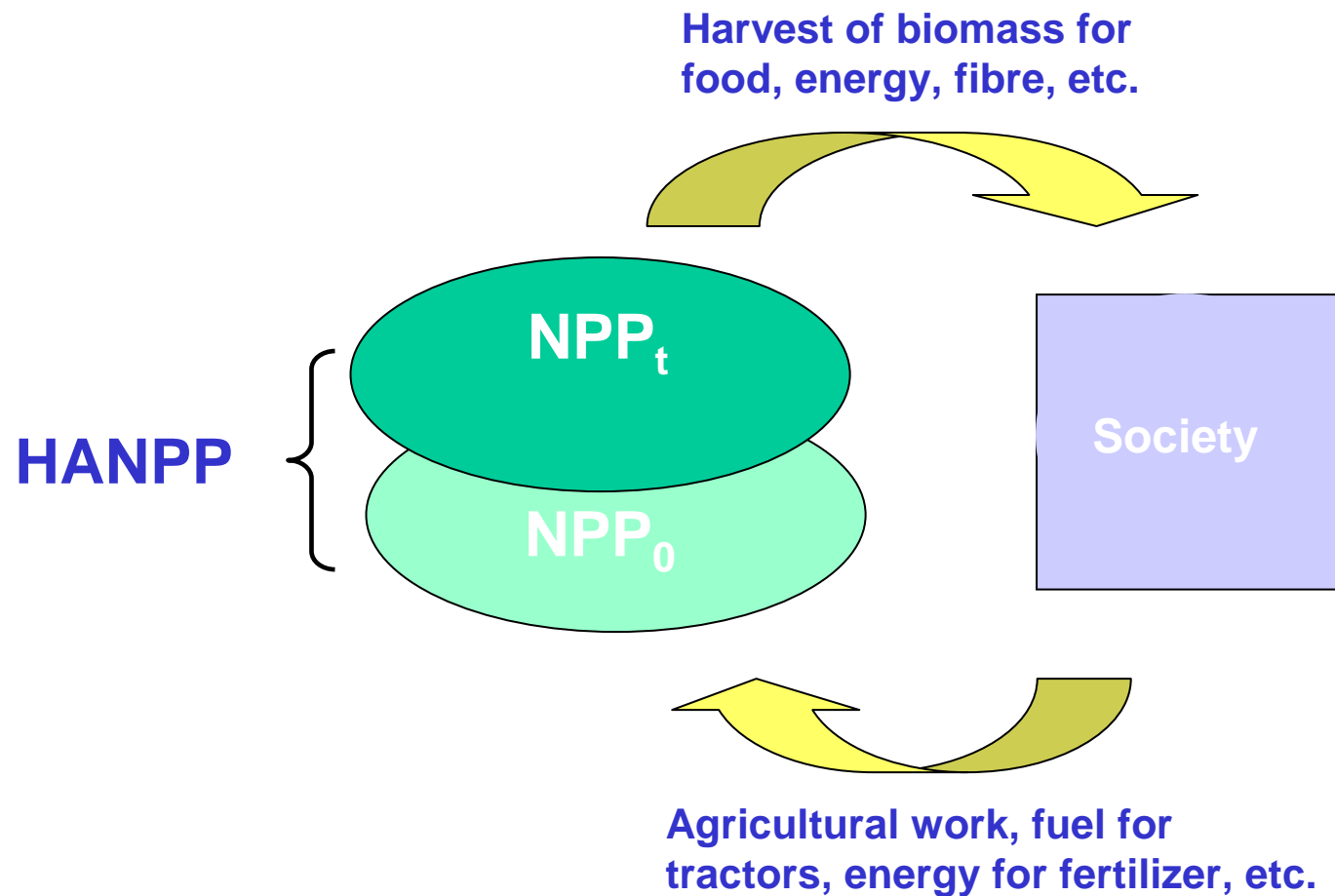
Socioecological System



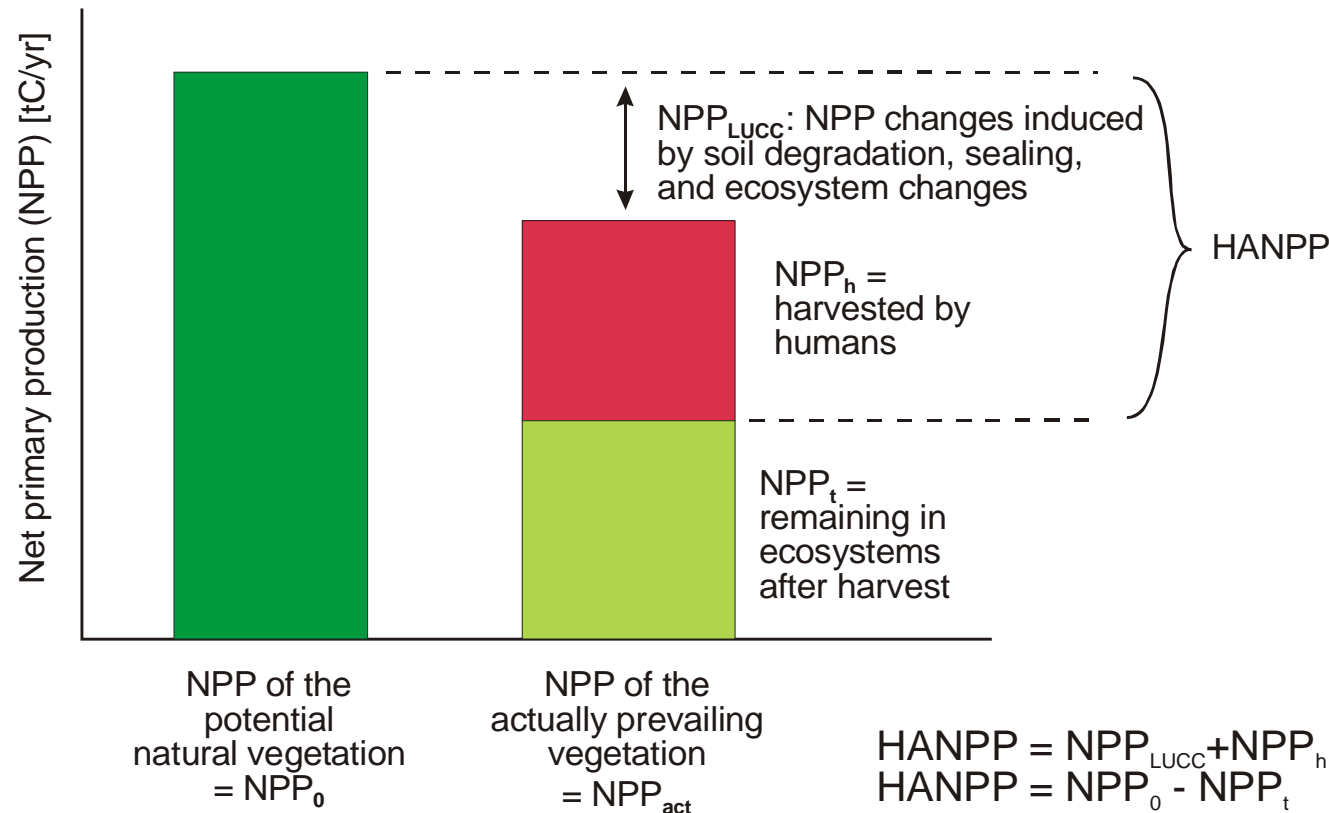
Colonization of natural systems



Colonization intensity of terrestrial ecosystems: HANPP



Definition of HANPP



Some papers on HANPP:

Vitousek et al. 1986. *BioScience* 36, 363-373.

Wright 1990. *Ambio* 19, 189-194.

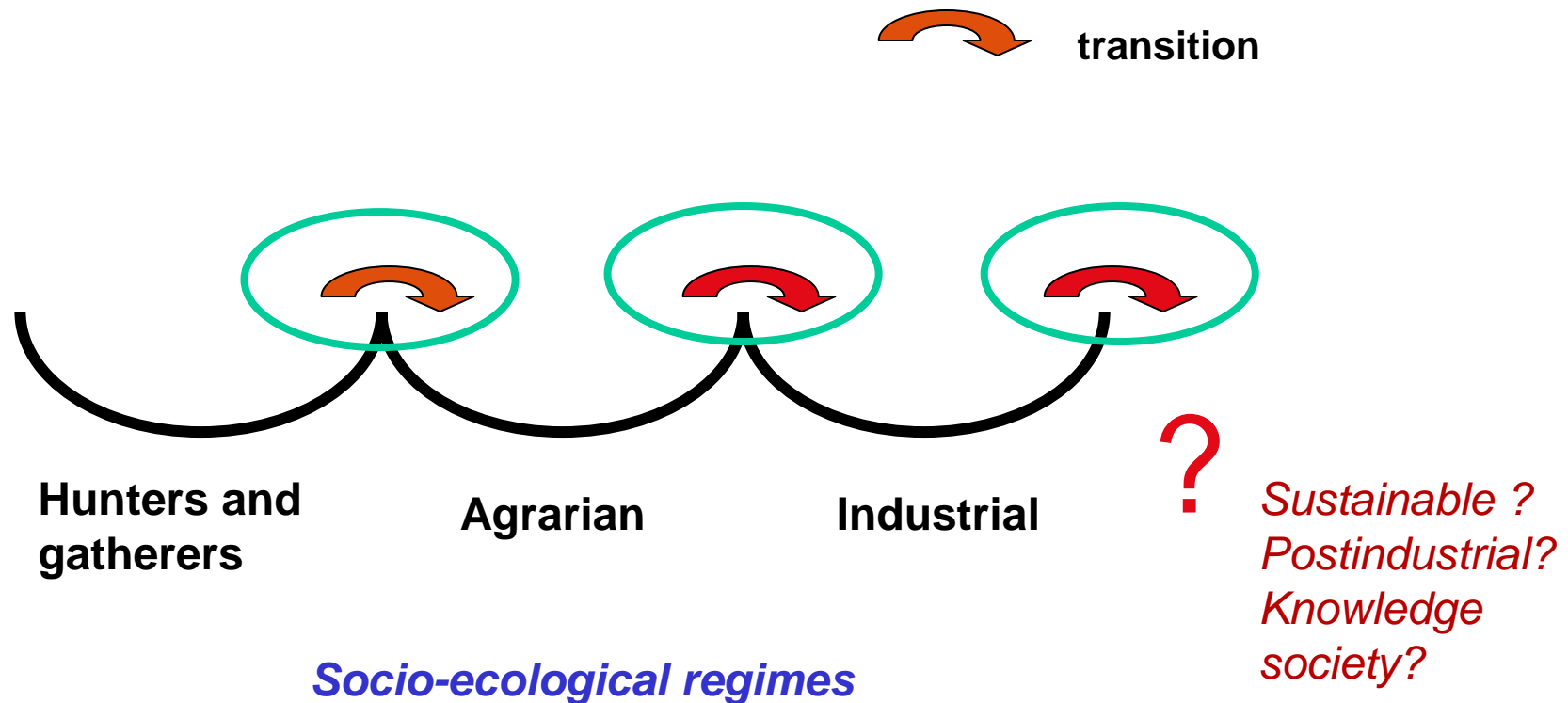
Haberl 1997. *Ambio* 26(3), 143-146.

Haberl et al. 2001. *Global Biogeochemical Cycles* 15, 929-942.

Imhoff et al. 2004. *Nature* 429, 870-873.

Rationale: HANPP measures changes in the availability of trophic energy for wild-living heterotrophic organisms in ecosystems induced by human activities

Transitions between socioecological regimes – research strategy

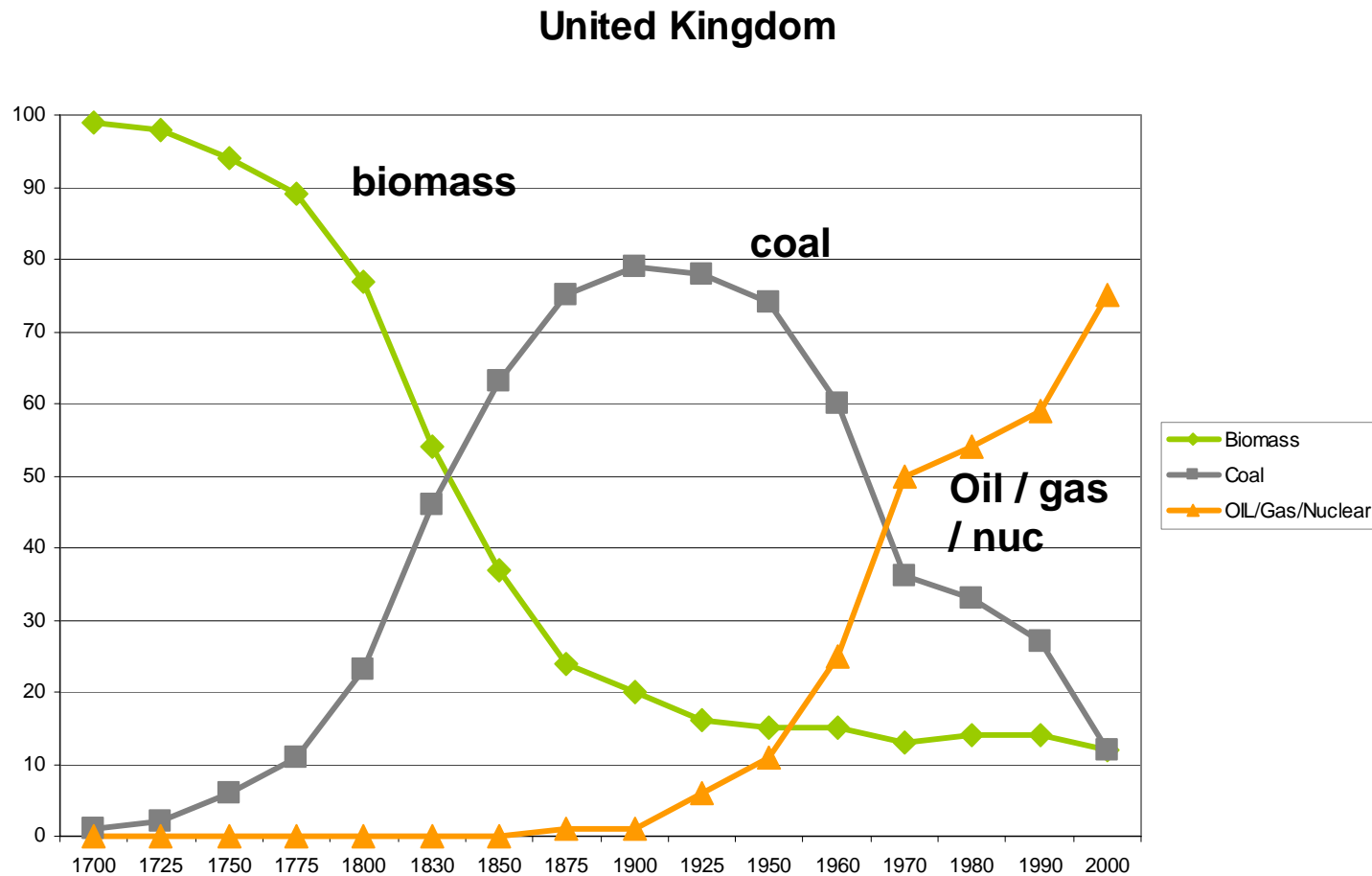


Part 2:

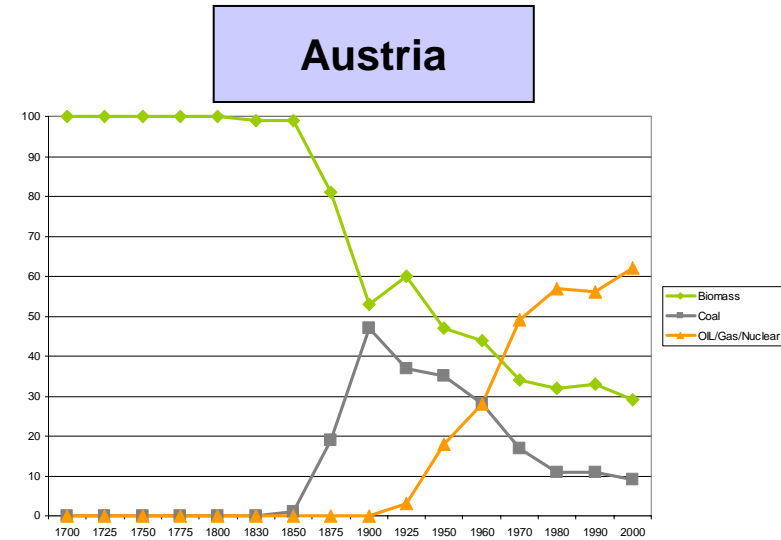
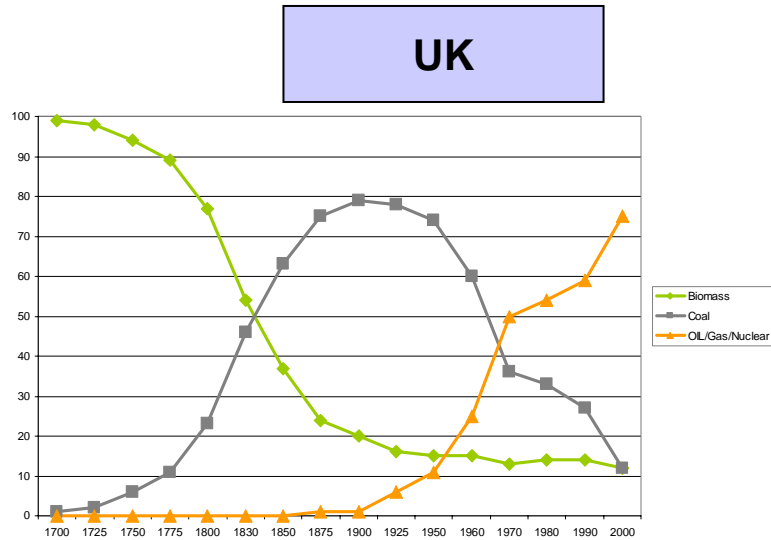
The transition from the agrarian to the industrial socioecological regime in history (1600-2000), and today

the energy transition 1700-2000: from biomass to fossil fuels

Share of
energy
sources in
primary
energy
consumption
(DEC)

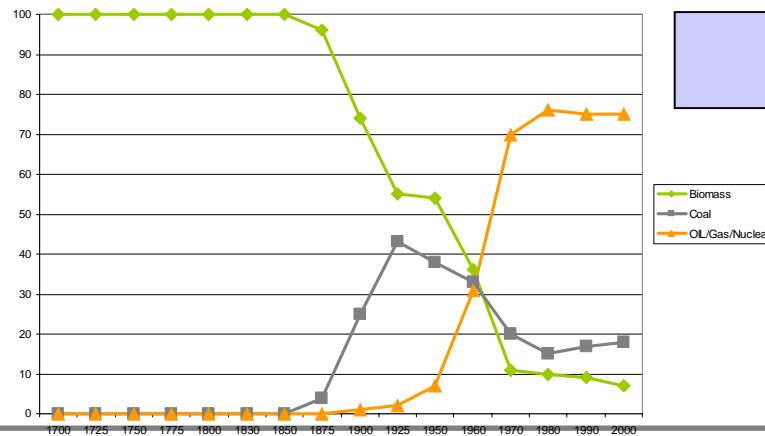


the energy transition 1700-2000 - latecomers



Japan

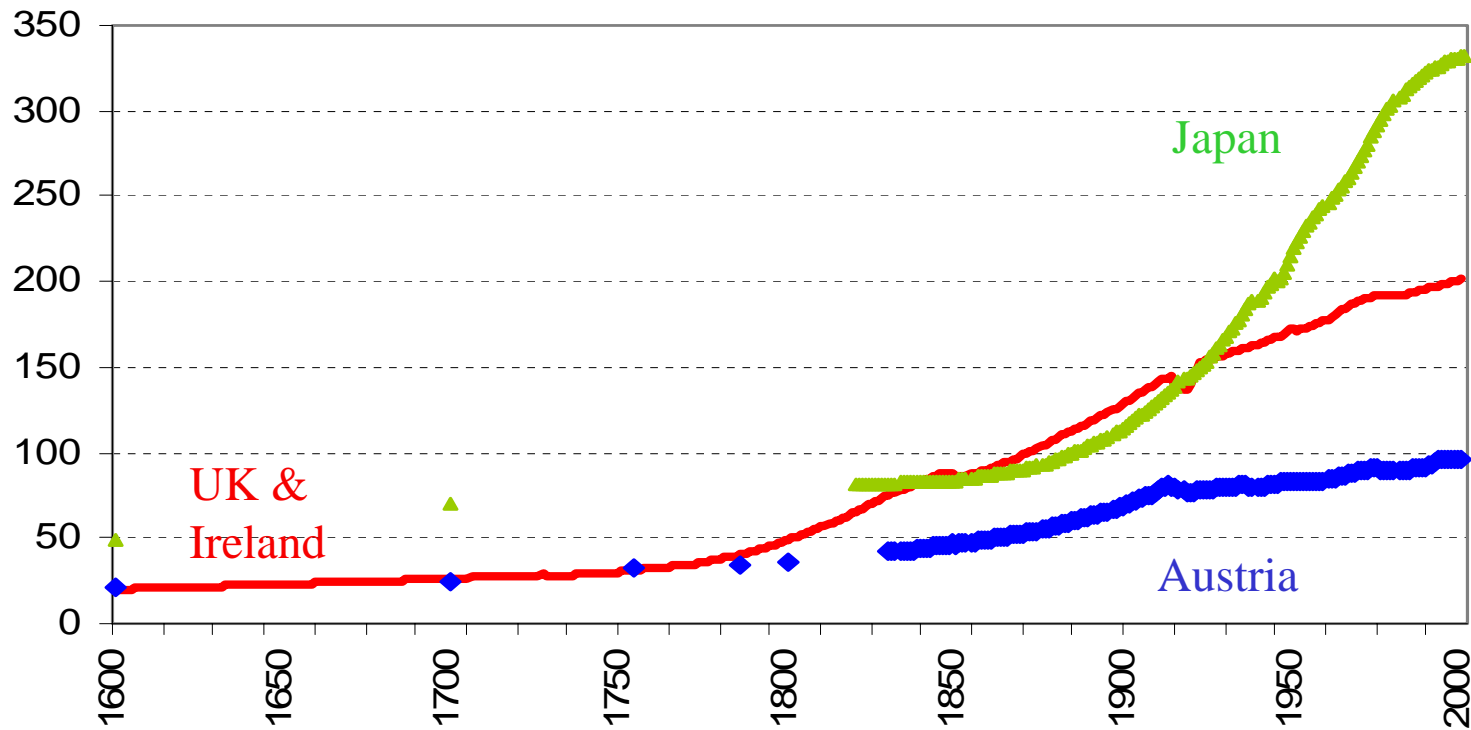
Share of energy sources in primary energy consumption (DEC)



Japan

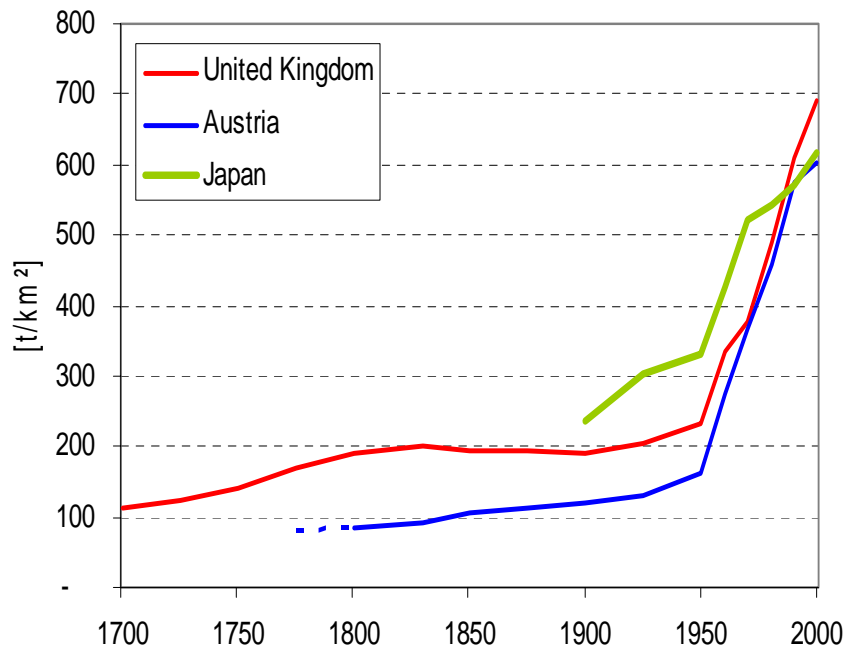
Increasing population (density) 1600-2000

Population density (UK incl. Ireland) (cap/km²)

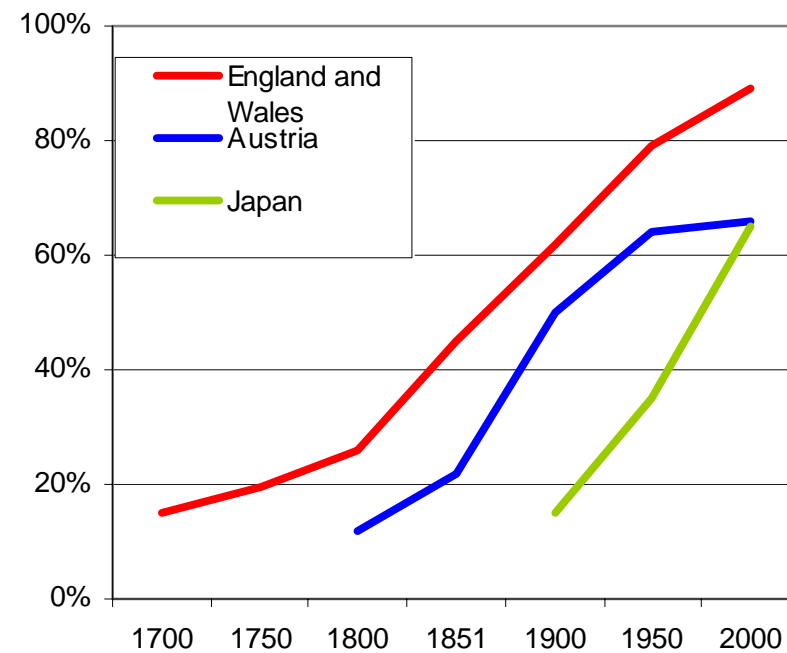


Early reforms in agriculture raise yields and allow for increasing urban population

Cereal yields

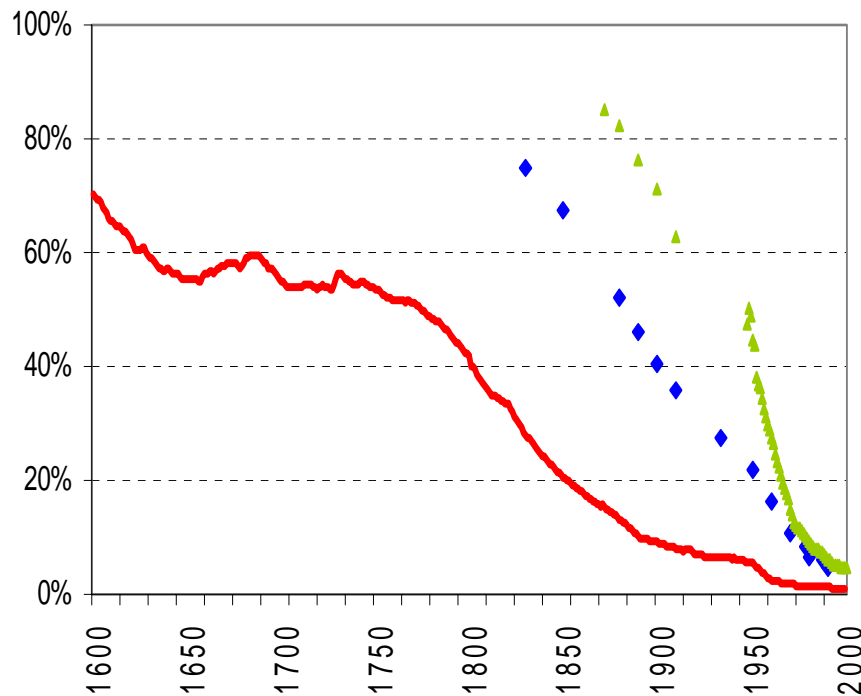


Urban population

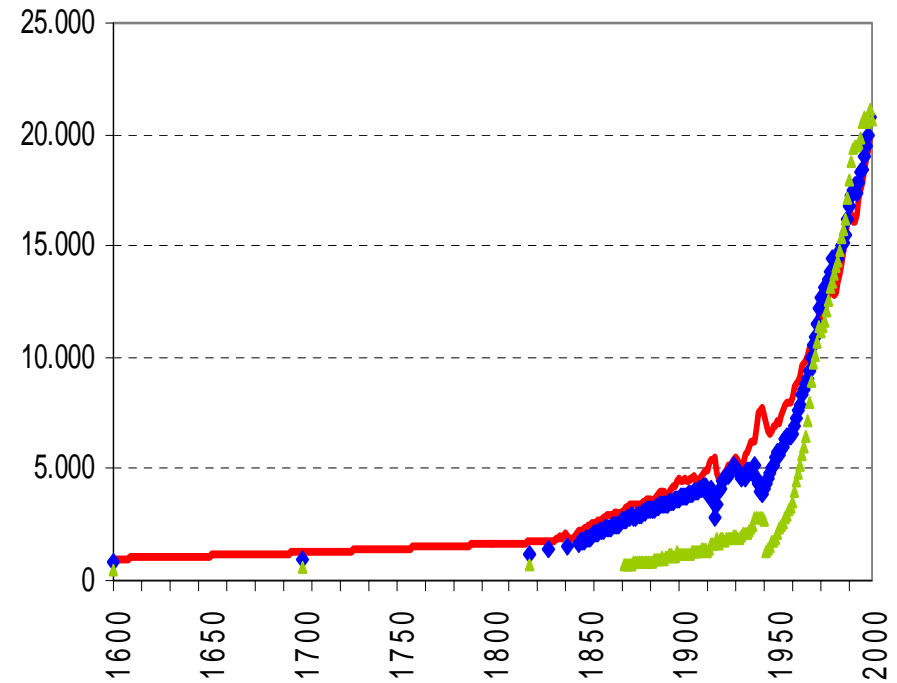


Reduction of agricultural population, and gain in income 1600-2000

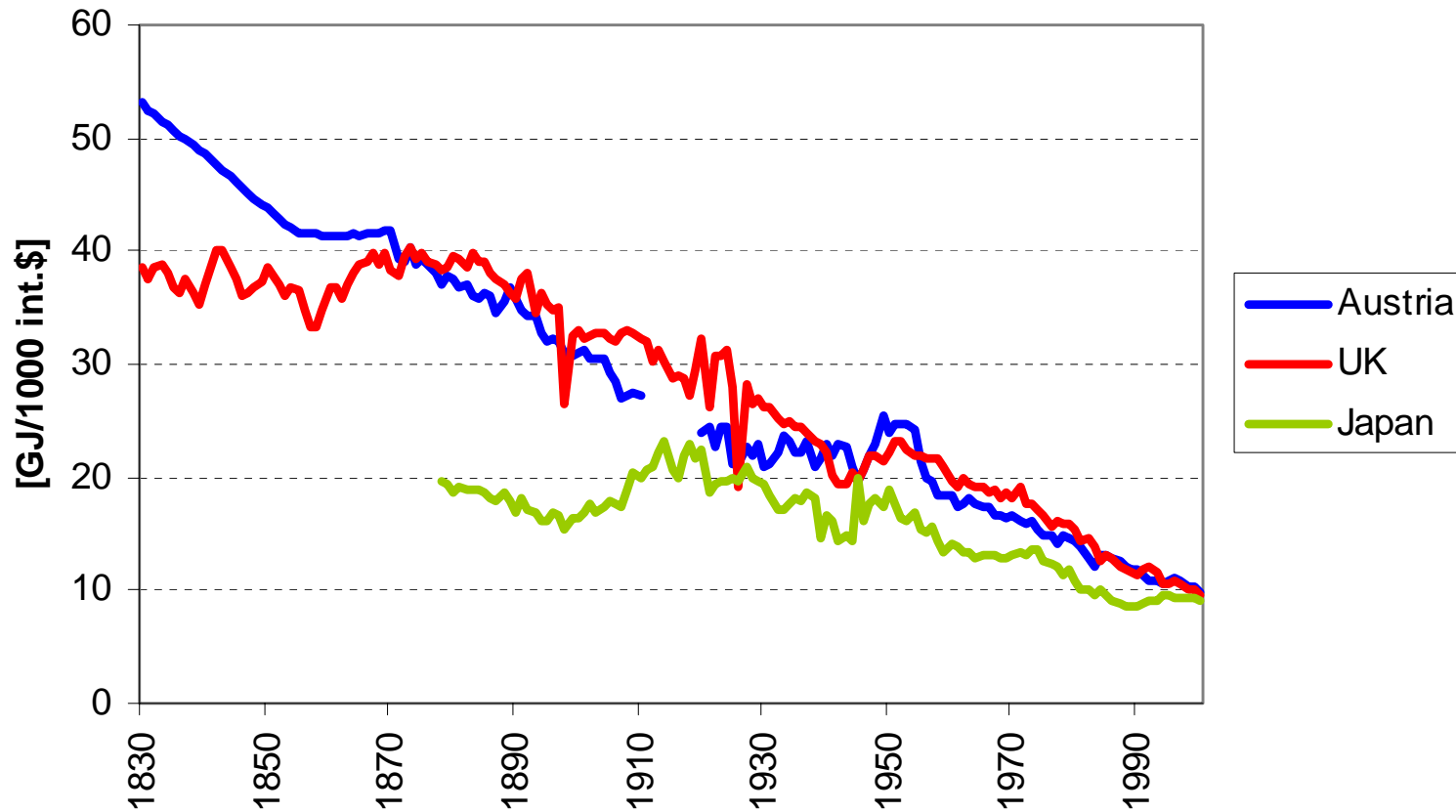
Share of agricultural population



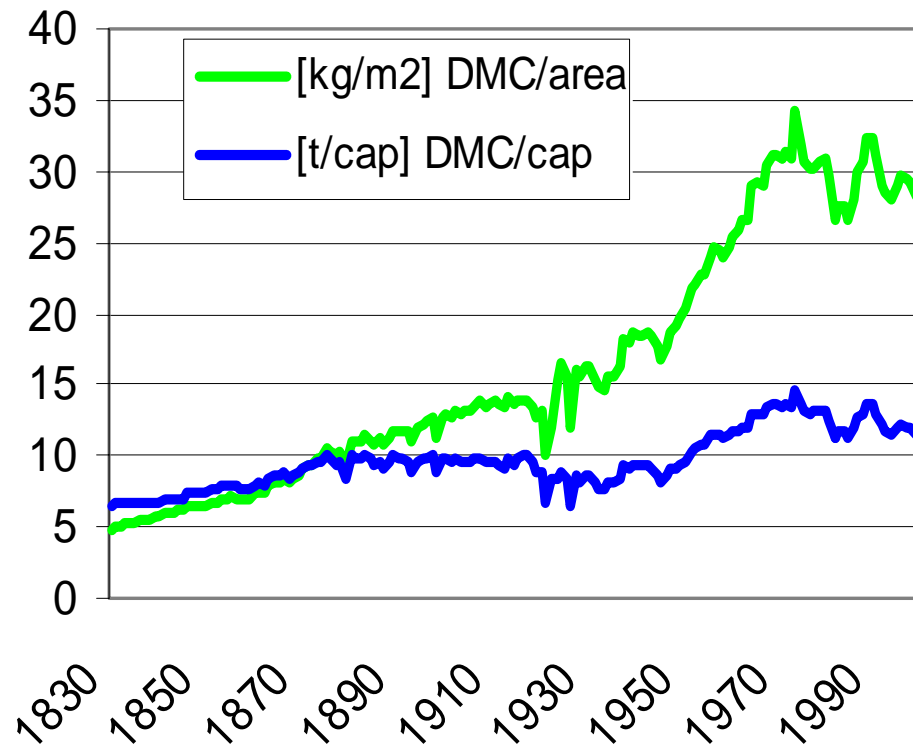
GDP per capita [1990US\$]



Decrease in energy intensity 1830-2000 (GJ primary energy use / \$ GDP)



United Kingdom: Long term change in Material Use



Historical socio-ecological regimes






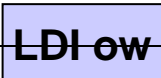
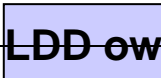
Agrarian regime:

1. Solar energy, resource base flow of biomass.
2. infrastructures decentralized. key technology: use of land through agriculture;
3. subsistence economies & market; if more complex, strong hierarchical differentiation;
4. tendency of population growth and increasing workload;
5. potentially sustainable, but soil erosion, wildlife / habitat reduction;
6. distinct limits for physical growth (low energy density);

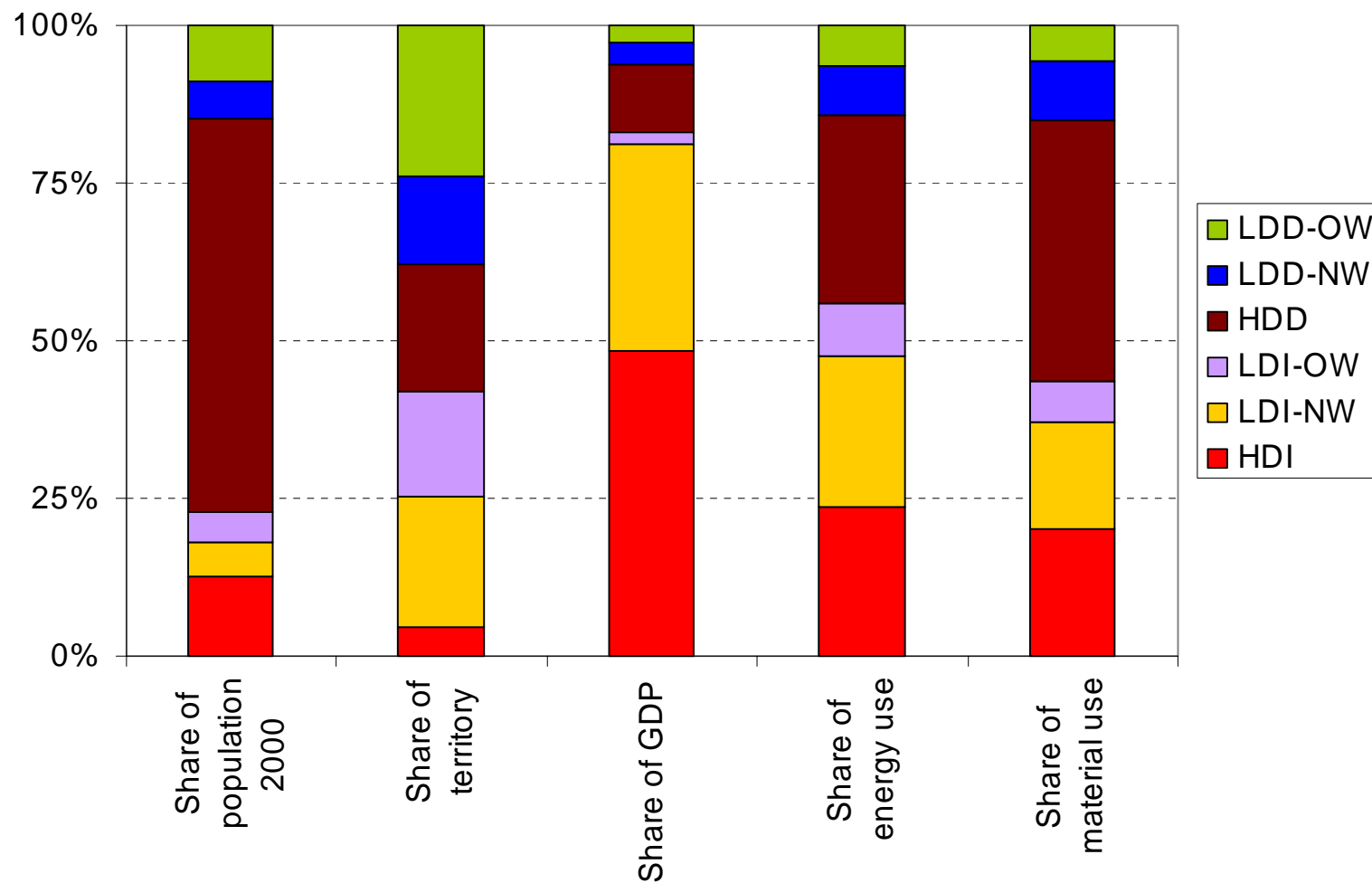
Industrial regime:

1. Fossil fuel based; exploitation of large stocks;
2. centralized infrastructures, industrial technologies;
3. capitalism and functional differentiation;
4. thrifty reproduction, prolonged socialization, somewhat lesser workload;
5. large-scale pollution (air, water and soil), alteration of atmospheric composition, depletion of mineral resources, biodiversity reduction;
6. abolishment of limits to physical growth; decoupling of land and energy and labour;

Country classification (165 countries worldwide, by the year 2000)

		Industrialization	
		Industrialized countries	Developing countries
History of agrarian colonization	High pop. density	High density industrial (HDI): European countries, Japan, South Korea, (N=30) 	High density developing (HDD): Most of southern/eastern Asia incl. India and China; Central America, some African countries, (N=63)  
	Low pop. density		
	New World	Low density industrial – new world (LDI-NW): North America, Australia, New Zealand (N= 4) 	Low density developing – new world (LDD-NW): South America (N=22) 
	Old World	Low density industrial – old world (LDI-OW): Countries of the former Soviet Union, Scandinavian countries (N=15) 	Low density developing – old world (LDD-OW): Northern Africa and Western Asia, parts of Africa, some Asian countries, (N=41) 

Unequal distribution: shares of country clusters in the World (for the year 2000)



Transition tracks: Population and Economy (2000)

	Population density [cap/km ²]	Agricultural population [%]	GDP (PPP) /capita [\$/cap]
HDI	149	9%	18,364
LDI-NW	12	2%	30,540
LDI-OW	12	14%	6,333
HDD	140	56%	2,866
LDD-NW	19	19%	6,312
LDD-OW	17	52%	2,802
World	45	42%	6,665
China	134	67%	3,491

Metabolic profiles in 2000: Material and Energy use per capita

Conclusion: New World (low density) countries have a more resource intensive profile than high density countries.

	Material use (DMC) per capita [t/cap]	Steel consumption per capita [kg/cap]	Energy use (DEC) per capita [GJ/cap]	Share of biomass of DEC [%]	Animal based food per capita [GJ/cap]	Electricity per capita [GJ/cap]
HDI	15	440	190	20%	1.28	22
LDI-NW	29	468	443	22%	1.58	52
LDI-OW	14	197	192	20%	0.99	20
HDD	6	61	49	53%	0.52	3
LDD-NW	15	109	131	68%	0.87	7
LDD-OW	6	42	76	49%	0.31	4
World	10	137	102	36%	0.70	9
China	7,5	108	55	42%	0,86	4

Environmental pressures 2000

Conclusion: **Regional environmental pressure** (DEC, DMC, HANPP) already fairly high in high density developing countries (HDD) and China

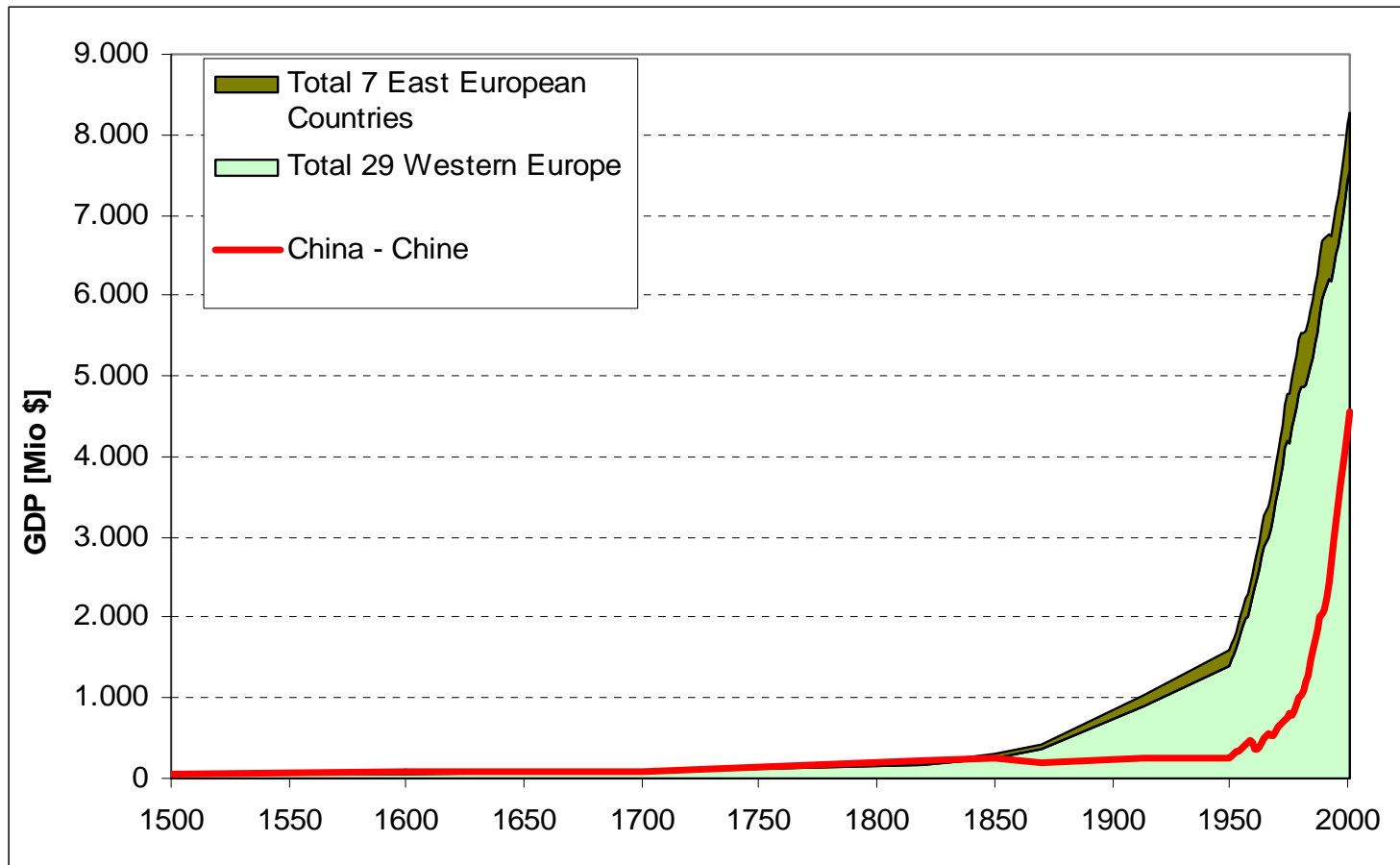
	Energy use (DEC) per ha [GJ/ha]	Material use (DMC) per ha [t/ha]	Carbon emissions [t/cap]	Ecological footprint [gha/cap]	HANPP Appropriated plant energy [%]
HDI	284	23.1	2.1	4.3	42%
LDI-NW	54	3.6	5.4	9.2	19%
LDI-OW	24	1.7	2.0	3.5	15%
HDD	69	9.0	0.4	1.2	40%
LDD-NW	25	2.9	0.6	1.9	14%
LDD-OW	13	1.1	0.7	1.4	15%
World	46	4.4	1.0	2.2	22%
China	73	10,0	0.6	1,6	38%

Roles in the World economy - Global resource transfers: trade

	Biomass	Fossils	Ores and minerals
<i>-net exports</i> /net imports	[mio t]	[mio t]	[mio t]
HDI	215	1,561	411
LDI-NW	-220	268	-89
LDI-OW	-53	-491	-165
HDD	87	-367	107
LDD-NW	-80	-184	-211
LDD-OW	43	-955	-40

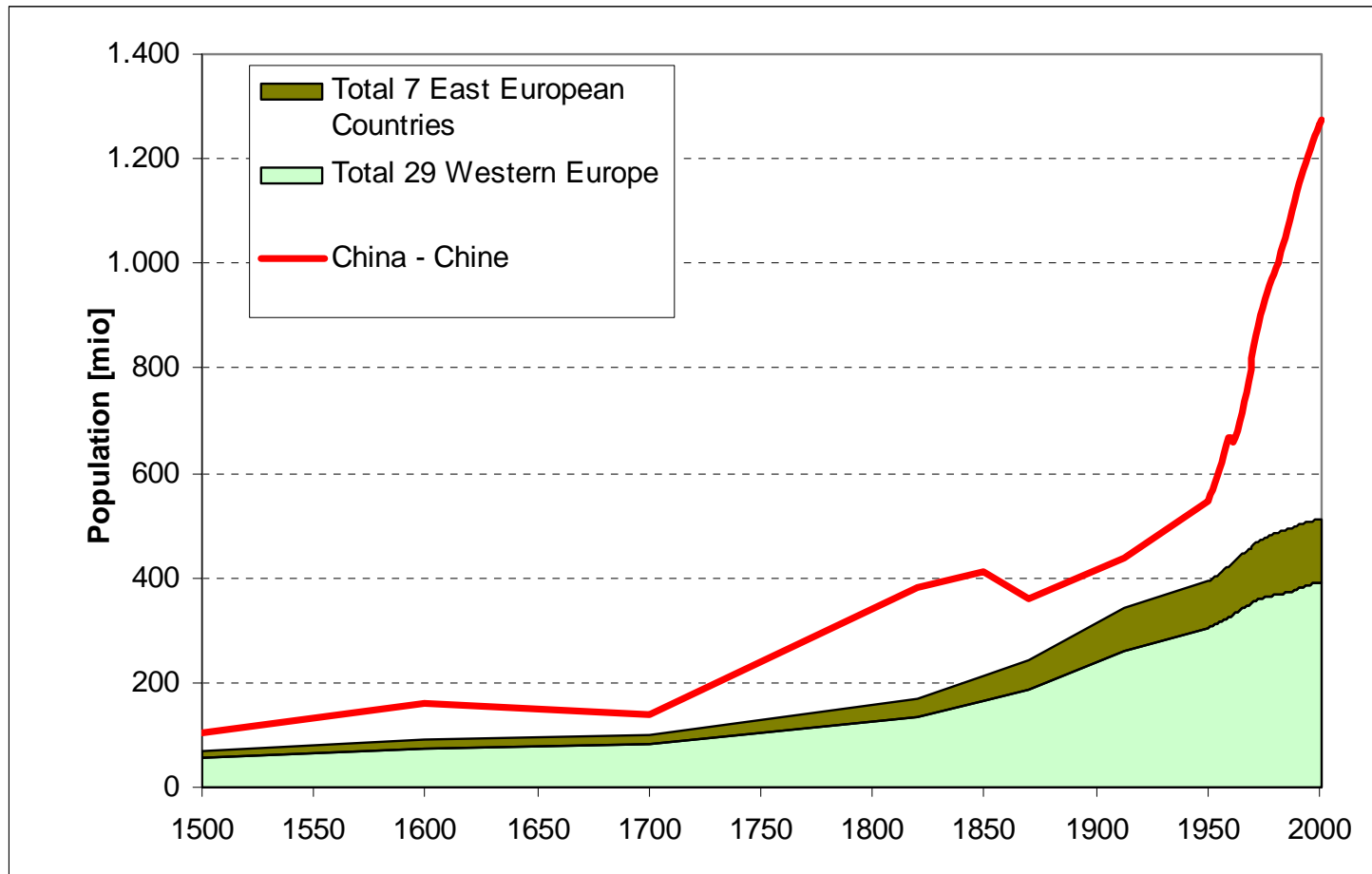
Conclusion: Low density countries tend to be net exporters, high density countries net importers of resources

Income: GDP (1990 US \$) China – Europe (1500 – 2000)

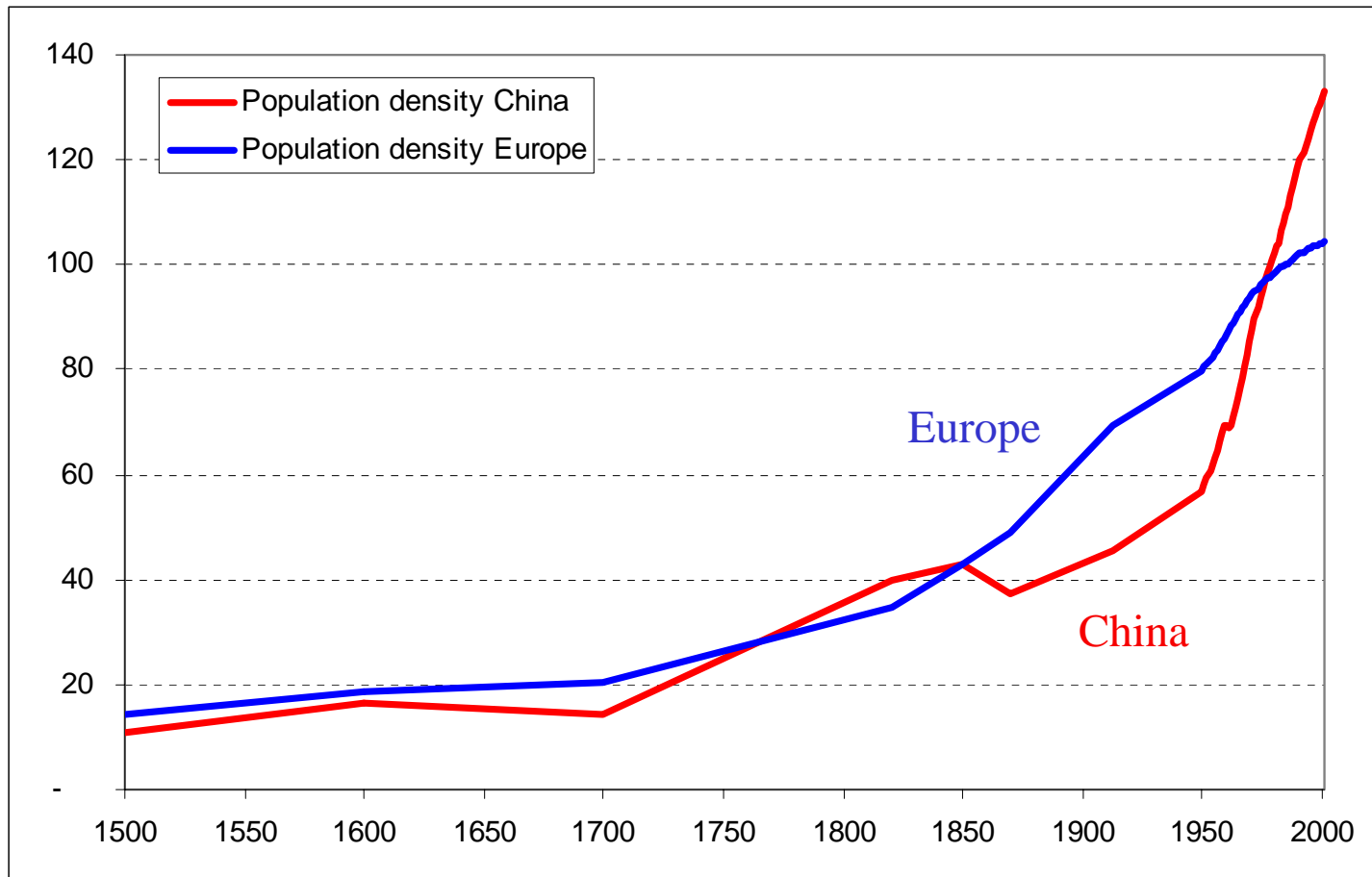


Population development 1500-2000

China and Europe compared



Population density Europe – China (1500 – 2000, in persons / km²)



Part 3:

How does all that relate to biodiversity???

(some loose ideas, based in part on RP Siefertle (2003), and Social Ecology team work)

Principal mechanisms

- Impacts of social metabolism:
 - Outcompeting other species of (certain) general life sustaining resources, such as land, water and plant biomass
 - Pollution of environmental media by wastes and emissions
 - Creation of new opportunities and niches
- Impacts of human colonization strategies:
 - Interventions into ecosystems (biotopes)
 - Interventions into organisms / populations
 - Interventions into evolution

> Both depend on socioecological regime!

Hunters & gatherers

- Metabolism:
 - Risk of regional eradication of prey species (particularly large herbivores). Particularly high in „pioneer situations“ (new immigration). [example: eradication of North and middle American megafauna?] **Cultural regulation through hunting, area and food taboos, leisure culture, control of population growth (Sahlins)**
 - barely pollution, no particular niches
- Colonization:
 - Mainly self-colonization (sex and reproduction regulation, body tattoos ...)
 - Sometimes: use of fire in hunting [example: modification of Australian flora & fauna by aborigines]

Agrarian societies

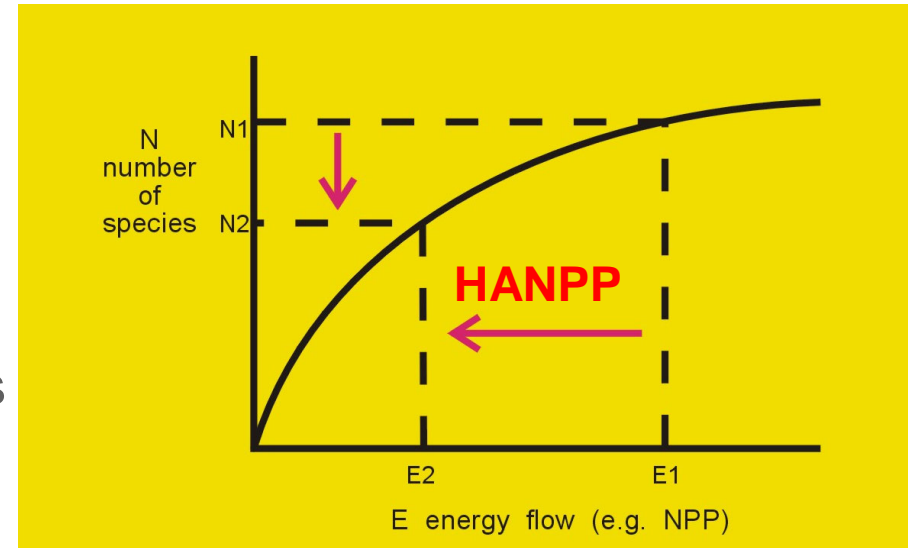
- Metabolism:
 - Metabolism (almost) completely based on local biomass; monopolization of terrestrial ecosystems for human and livestock nutrition (gradual eradication of forest – „clear the land“. But dependence on functionally diverse land cover). Eradication of competitors (large carnivores).
 - More or less closed cycles, barely pollution
 - Great time for parasites: dense homogenous man, animal and plant populations create new niches for plants, animals and microorganisms (McNeill, Cohen, Crosby)
- Colonization:
 - Colonization of terrestrial ecosystems: modification of plant and soil species. Increase of erosion. **[cult. measures for erosion control]**
 - Breeding and importing of functional species. Risk of bioinvasions.
 - Self-colonization for production of labor power (many children), diligence and thriftiness. **Move themselves into lock-in of high population density, high yields per area, low labor efficiency.** (Boserup, Netting)

Industrial society

- Metabolism:
 - Energy base = fossil fuels, no competitors (reliance on land and biomass). Nutritional base: much more animal protein, increase in livestock. Energy surplus allows mobilisation and transport of huge amounts of materials, restructuring of earth surface and water bodies.
 - Large scale pollution; local impacts can be controlled, global impacts (CO₂) not (yet?)
 - Niches: diversity of plant and animal life, protected areas. Less aggressive attitude towards „useless“ plant and animal life.
- Colonization:
 - New strategies to intervene in organisms and evolution (medicine and bio-technologies)

The species-energy hypothesis

- **Basic claim:** The number of species is positively related to the flow of energy in an ecosystem.
- **Corollary:** If humans reduce energy flow (e.g., through HANPP), then species richness will decline.
- **Notes**
 - Can explain species diversity gradient from equator to poles.
 - Not undisputed. Competing (complementary) hypotheses exist (e.g., intermediate disturbance hypothesis).



Brown, J.H. (1981) *Am. Zool.* **21**, 877-888.

Gaston, K.L. (2000) *Nature* **405**, 220-227.

Hutchinson, G.E. (1959) *Am. Nat.* **93**, 145-159.

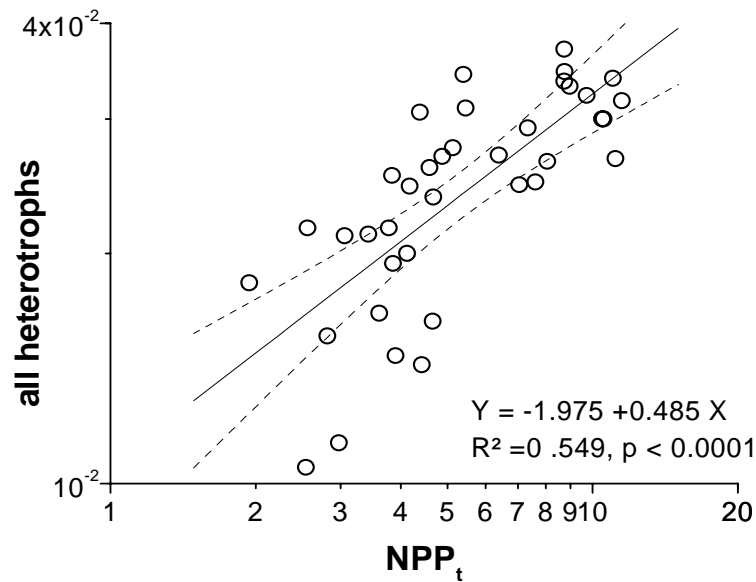
Rapson, G.L. et al. (1997) *J. Ecol.* **85**, 99-100.

Waide, R.B. et al. (1999) *Ann. Rev. Ecol. Syst.* **30**, 257-300.

Wright, D.H. (1983) *Oikos* **41**, 495-506.

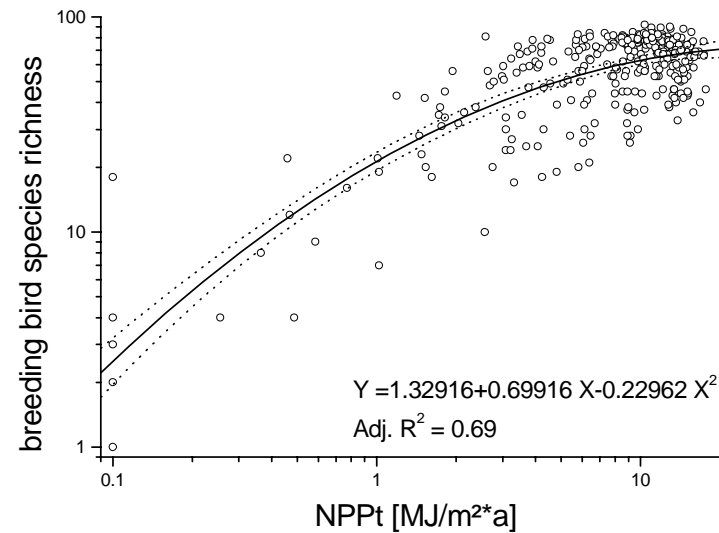
Wright, D.H. (1990) *Ambio* **19**, 189-194.

Empirical studies support the HANPP / biodiversity hypothesis



Case study 1: Correlation between NPP_t and autotroph species richness (5 taxa) on 38 plots sized 600x600 m, East Austria

Haberl et al., 2004, *Agric., Ecosyst. & Envir.* 102, p213ff



Case study 2: Correlation between NPP_t and breeding bird richness in Austria, 328 randomly chosen 1x1 km squares.

Haberl et al., 2005. *Agric., Ecosyst. & Envir.* 110, p119ff

Ways out

- Global commitment to climate policy (reduction of fossil fuels combustion)
- Learning to do with less in the industrial core, focusing on solving distributional problems better, and depending institutionally less on economic growth
- Creative design of new types of infrastructure (energy provision, transport, water supply, housing...) for high density developing countries: Inventing a new industrial revolution
- Low density developing countries: retain some degree of nature preservation