Bringing it all back home

PEAS UNITE 2022-2023

Today's lecture

- We now (re)-start from scratch…
- …try to orderly pack stuff…
- …and bring it all back home.

Crude Facts

Crude facts

- Nine planets revolve around the Sun
- One of them is the Earth
- A tiny film covers the Earth. Call it Life.
- Life is about a billionth part of the Earth’ total mass

Crude Facts

- Homo Sapiens lives on Earth since 500K years
- Worms since 450 million years

Note well: HS will be used henceforth for Homo Sapiens

Note well: HS has IT as a chosen pronoun

Crude facts

- For thousands of years, HS lives on Earth as a hunter/gatherer species
- True: HS develops and implements better techniques (but still limited to hunt and gather)

Crude facts

- A 10.000 years BCE (between Proto-Neolithic and Neolithic) HS finds its way to some action.
- In the area now corresponding to Iran and Iraq, HS starts cultivating and breeding
- State, social organization, cities, math, accounting….

Crude facts

- Nothing really interesting happens up to 1750

Crude facts

- 1750: industrial revolution
- HS starts using tools, machines, physical capital.
- HS faces (qualitatively) new and unprecedented needs for (fossil) energy

Crude facts

- Nothing really new has happened ever since.

Energy

Energy

- Life as a whole stems on a complex energy stream
- Have "**energy**" defined as the quantitative property that is transferred to a body or to a physical system, recognizable in the performance of work (WIKI)
- Have "**work**" defined as the processes by which a thermodynamic system can interact with its surroundings and exchange energy (WIKI)

Energy

- First problem: every living organism must perform some work to live (i.e. not to die, i.e. not to termodyamically decay)
- Second problem: as a consequence, every living organism needs potential energy at its disposal
- Have **potential energy** defined as the energy held by an object because of its position relative to other objects, stresses within itself, its electric charge, or other factors (WIKI).

Energy

- HS faces a huge class of needs
- This class has no upper bound
- It has a lower bound, though. The lower bound is keep living.

Energy

- A way to measure the class of HS’ needs: measure their energy content of each of its members.
- We use Kcal as a unit of measurement of “energy content”.
- Kcal is the amount of heath one needs to raise the temperature of a Kilogram of water by one degree Celsius.

Energy

- HS thus needs energy but at the very same time it produces energy
- Chemical energy from food actually feeds it but gets transformed into mechanical energy as muscular work.
- Some energy gets however wasted (in the form of heath)
- As a matter of fact, the efficiency of HS is around 25% (i.e. 25% of ingested energy is actually transformed into actual work).
- Key fact: HS can produce energy to capture and dominate other energy sources.

Energy

- Key point: transform energy one has into energy one needs (at a reasonable cost).
- To this end, HS needs **converters**
- E.g. a steam machine is a converter that transform thermal energy into mechanical energy (where and when needed)
- However there is a twofold cost for that: dispersion and consume.
- Net energy is always less than energy used to produce it.

Energy

- We use the notion of technical efficiency of a converter to express the ratio between available net energy produced and total entered energy.
- Now to our main focus: animals and plants are indeed converters.
- Plants can actually use solar energy and produce complex organic compounds. Solar energy into chemical energy
- Animals do actually transform chemical energy from plants in energy that HS considers more useful to it (animal proteins feed it better than carbohydrates)

Phases and Eras

First question

- Is the quest for sustainability a recent/contemporary issue?
- It is way reasonable to assume that HS had been facing a quest for sustainability since the neolithic revolution
- Have a look at some historical antecedents (we shall both have failure and success stories)

Sumerian civilisation

- 3000 - 2370 BCE
- Irrigation technology was a key to success
- Consequence: stocks and surplus availability
- However, around 2350 they face a huge food crisis
- Consequence: decline and conquer by the Akkedeans (under King Sargon)
- Unending decay ever since. Main cause: salinisation due to irrigation

Indus civilization

- 2300 - 1800 BCE
- Irrigation and logging led to the civilisations decay

Easter Island

- In 900 CE, settlers from Polynesia landed on an island 2100 KM from Pitcairn islands (3700 KM from chilean shore)
- On Easter Day 1720 CE, Jacob Roggeveen lands on the very same island (henceforth “Easter Island”) and meets a haggard community of indigenous people (described as “sick, emaciated and miserable”).
- Roggeveen notices no trees in the island.
- History tells about intense logging due to population increase…
- …and need to transport *moai* on rolling logs (no draft animals in the island)
- Consequence: no boats to go fishing, no firewood, no tools, riots to get social supremacy,
- Consequence: in 1872 only 111 people are left from the 30.000 at the civilisations peak.

Tikopia Island

- South Western Pacific (230 KM from Solomon Islands). Colonised in 900 BCE
- Extremely effective at demographic control for an incredibly long period of time
- 20th century: european settlers (catholic missionaries) colonise the island and find their birth control systems (abortion and infanticide) repugnant and immoral.
- Population explodes, food crises …..

Japan: Tokugawa era (1603-1867)

- Around 1650 Japan gets close to an environmental collapse.
- This was due to demographic explosion and massive urbanisation leading to inconsiderate logging
- Around 1680: the Tokugawa shogun implement a wide set of food, forest and demographic policies all leading to success….
- ….this lasted until the Meiji period (1868 - 1912) during which massive industrialisation led to a new landscape of environmental issues.

Colonization, Colonialism, Imperialism

Europe: the great expansion

- 15th century: a time interval of huge expansion for Europe
- Main engines:

1. population growth
2. tech innovation (agriculture)
3. end of endemic pandemics
4. scientific progress (medicine)
5. expanding commerce
6. diffusion of education
7. institutional development

- Two main paths:

8. expansion of european settlements: colonialism and imperialism
9. reinforcement of national states (after Westfalia)

Colonialism

- Four phases:

    1. 1415-1600 Spain (central and south America, Philippines) and Portuguese (Brazil, western India shores, Malaysia, Angola);
    2. 1606 - 1818 decline of the Spaniards and rise of France, Netherlands, Great Britain
    3. 1819 - 1860 French and Britons consolidate and expand
    4. 1860 - 1914: Imperialism

Industrialization

- The industrial revolution spreading throughout Europe
- Engines:

  1. technological innovation
  2. lowering costs for steel production
  3. new energy sources: fossil fuels, electricity
  4. invention and diffusion of communication media

The other side (Europe)…

- A **radical** and **unprecedented** transformation of the environment (both in Europe and in the colonies)
- Logging, enclosures (impossible to exaggerate on this…), urbanisation

The other side (Europe)…

- As to urbanisation: 1800 35% of world population live in cities

1. water (esp. rivers) pollution. Ink from the Calder river in Scotland
2. air pollution (massive use of coal: almost 14 bil tons in 1800, only 1000 tons in 1900). The word “smog” originates in this time
3. huge quantities of sulfur dioxide from coal combustion —> acid rain
4. solid waste (think Dickens on “Potteries”)

The other side (colonies)…

- Historian Alfred Crosby writes about “ecological imperialism” and “Europe’s biological expansion”
- First effect: desegregation and dismantling of natives communities
- Second effect: a radical mutation in natural landscapes (from traditional, unproductive agriculture to monocultural semi-intensive practices plus substitution of traditional crops with high value-added crops)
- As a consequence: salinisation, erosion, loss in fertility and biodiversity.

The other side (colonies)…

- Logging
- Mineral extraction
- Furs

1900 - 1950

Demography and urbanisation

- Early XX century: world population reaches 1.634.000.000
- 1950: world population reaches 2.500.00.00
- Causes? You name it…

Demography and urbanisation

- Alongside population growth came urbanisation
- As of 1930 in USA and Europe the majority of people live in cities (56% and 55% resp.)
- Japan and Latin America follow
- As of 1890 nine cities had more than a mil. inhabitants (London, NYC, Paris, Berlin, Tokyo, Vienna, Chicago, Philadelphia, San Petersburg)
- As of 1920, cities with more than a mil are 27
- More and more land is converted to urban settlings (noteworthy: conurbation e.g. Boston and D.C.)

A revolution in agriculture

- Mechanization: in Europe and the US 1920-1940 the number of tractors grows 300.000 to 3 mils
- Mineral Fertilizers substitutes for crop rotation and green manure, guano, potassium nitrate, calcium cyanamide
- Mineral fertilisers: 1900-1945 2 to 7.5 mil tons
- Pesticides: grow alongside monocultures (as these are more vulnerable)
- Need for irrigation: 1850-1950 irrigated surface from 8 to 94 mil ha
- World water consumption: same time interval 243 to 1360 bill. cubic meters

A revolution in agriculture

- As more and more wooded areas get converted to cultivated lands erosion starts to spread
- Note: 1850-1940 cultivated lands from 5.4 mil km2 to 10.8 mil km2

Industry, transports, fossil energy

- Growth of industry: main cause of pollution and non sustainable natural resources draft
- First half of XX cent. main air pollutants from industrial activities: carbon dioxide, sulfur dioxide
- First half of XX cent. main metal pollutants from industrial activities: lead, zinc, copper, nickel, cadmium
- As a whole: 1850-1900 metal emissions 41.500 tons; 1941-1950 we find 293.000 tons.

Industry, transports, fossil energy

- Forests and prairies: 1740-1940 from 62 mil Km2 to 55 mil Km2 and from 63 mil Km2 to 47 mil Km2 resp.
- Plus: an almost complete transition from an energy regime based on biomasses, muscular energy (both human and animal) to fossil energy
- Coal: 283 mil tons in 1875 to 1.800 mil tons in 1950
- Petrol: 9 mil tons in 1890 to 267 mil tons in 1940

Mass consumption

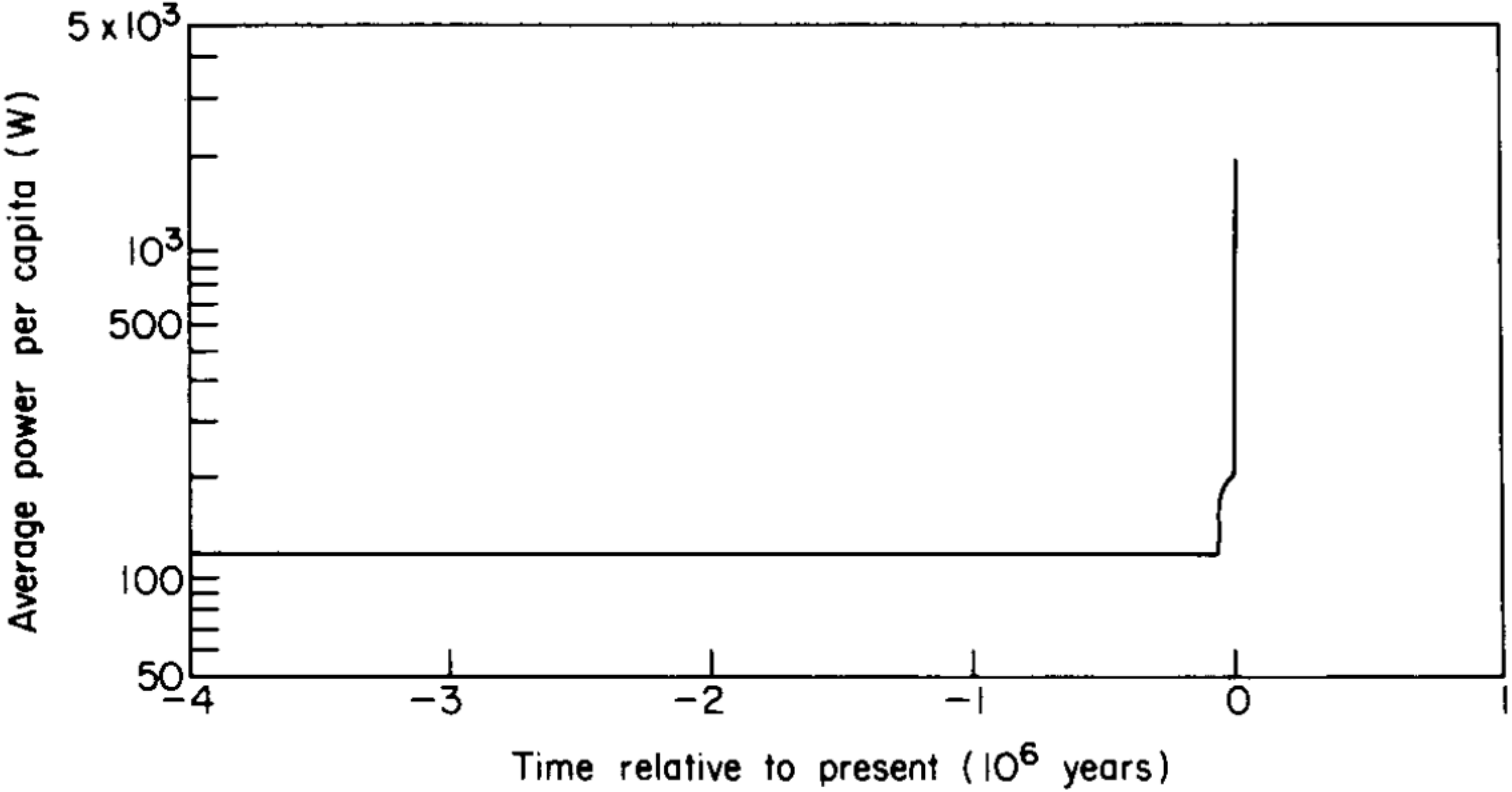
- Everyting starts with Henry Ford 5 dollars a day wage.
- Huge consequence: blue collars (huge masses of them at the time) get to be producers and consumers and the very same time!
- Model T: 440 dollars in 1915 (produced in a wholly electrified assembly line)
- …MORE TO COME…

Mass consumption

- Starting from 1910 mass consumption gets to be the first cause of environmental degradation
- Cars: 1940 51 mils
- Food and food refrigeration:
    1. 1876 Carl Von Linde (first ammonia-based refrigerator);
    2. 1919: General Motors starts commercialising home refrigerators (brand is *Frigidaire*)
    3. 1930 Thomas Midgley (freon based refrigerators): freon is the class of chlorofluorocarbon
- NOTE WELL: chlorofluorocarbons are the main do alterate atmosphere’s chemical composition having a strong impact on the ozone layer.

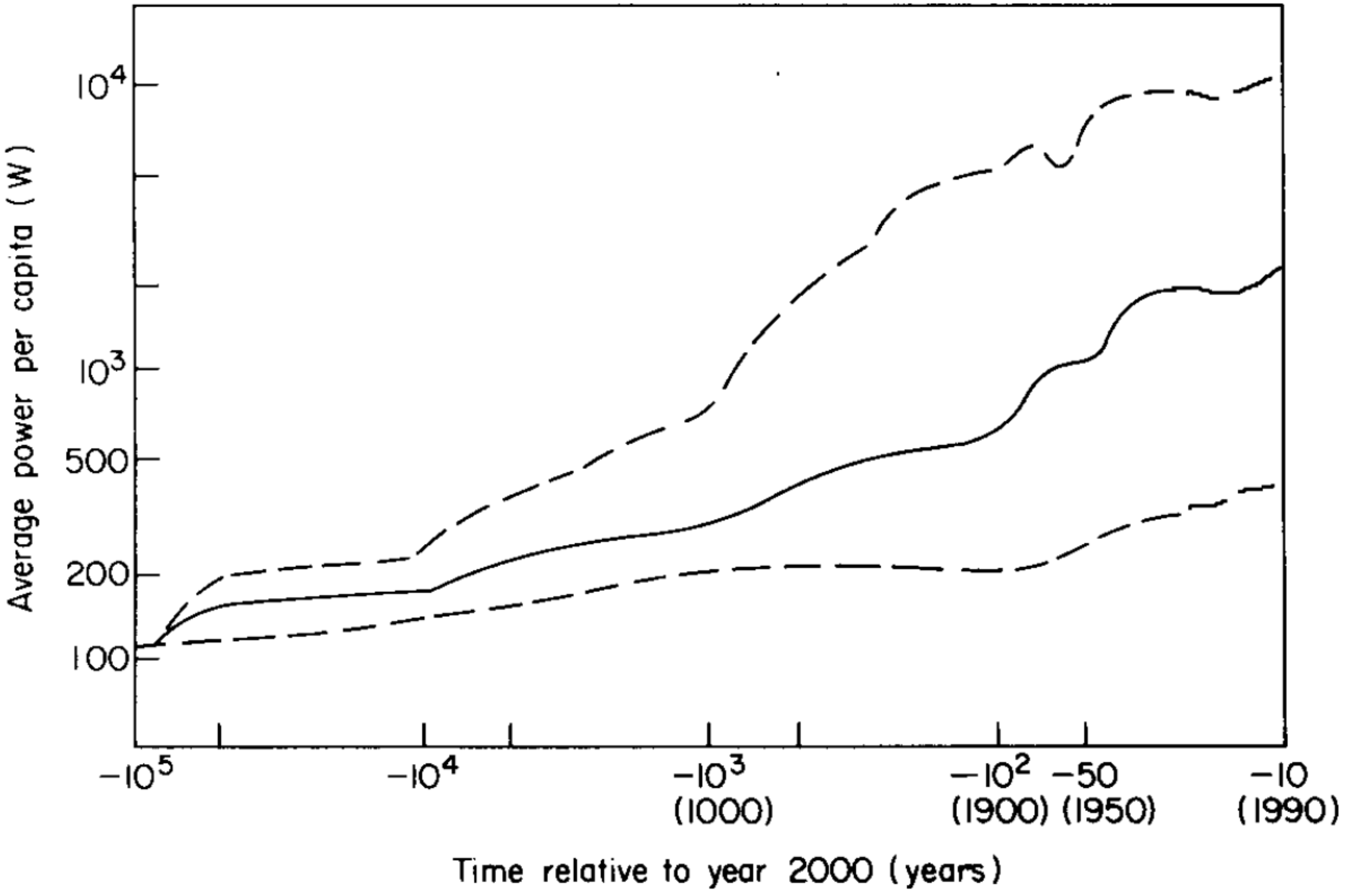
Intermezzo: back to some crude facts

Energy consumption over time



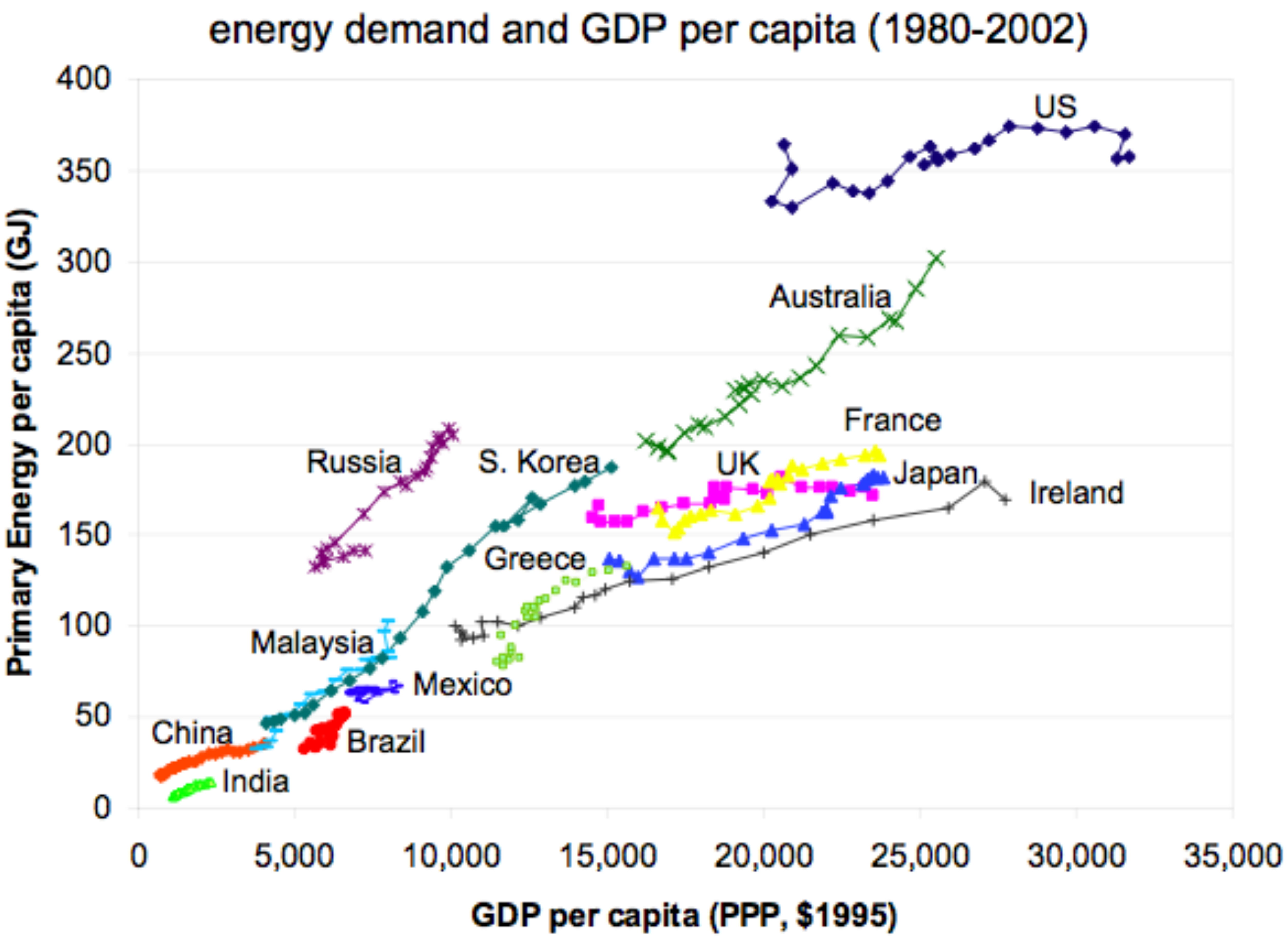
Energy consumption over time

A logarithmic time axis is necessary. Solid line is world average, dashed lines show societies with highest and lowest energy use.



Economic growth and energy use

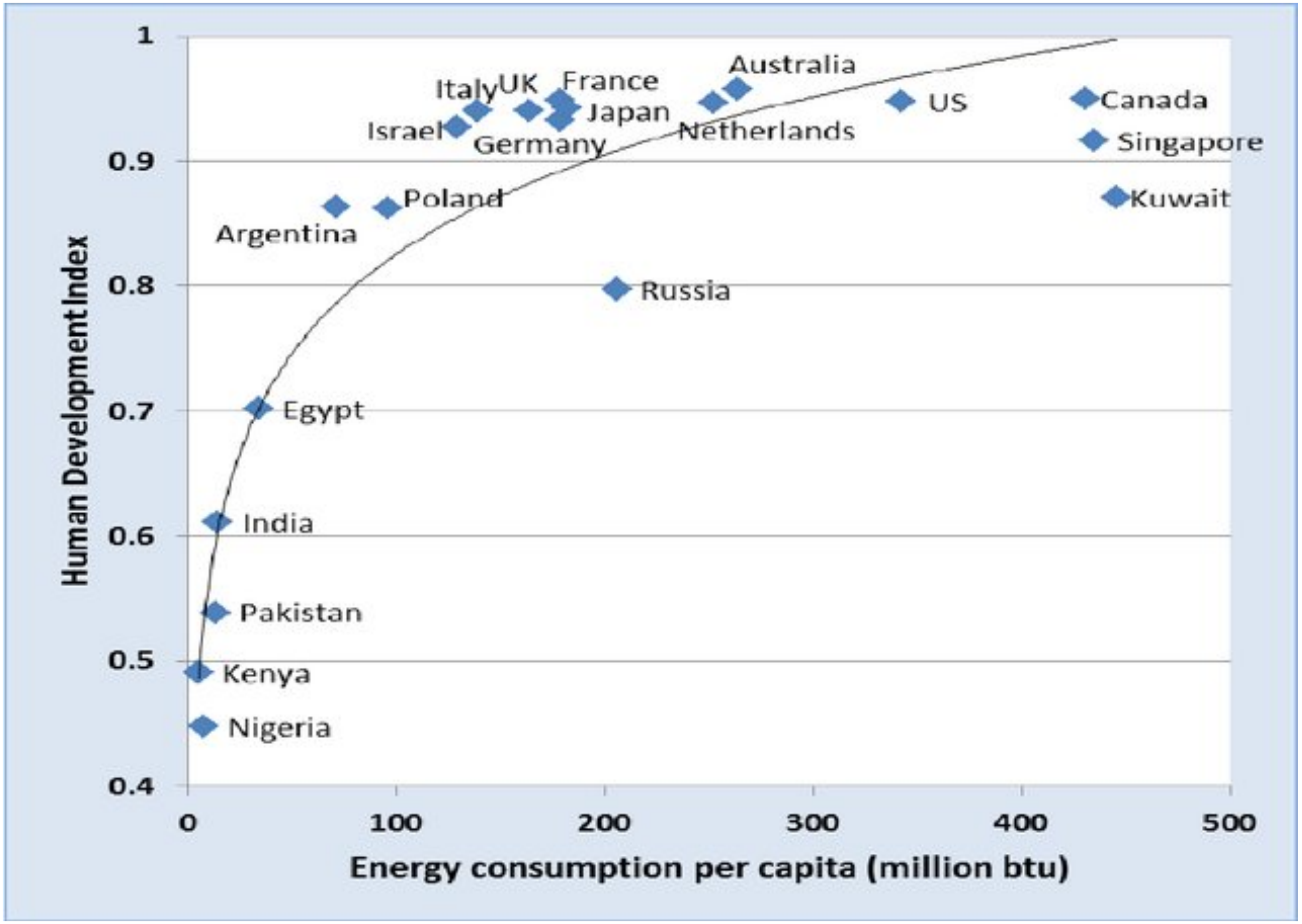
Energy demand versus GDP over time for selected countries.



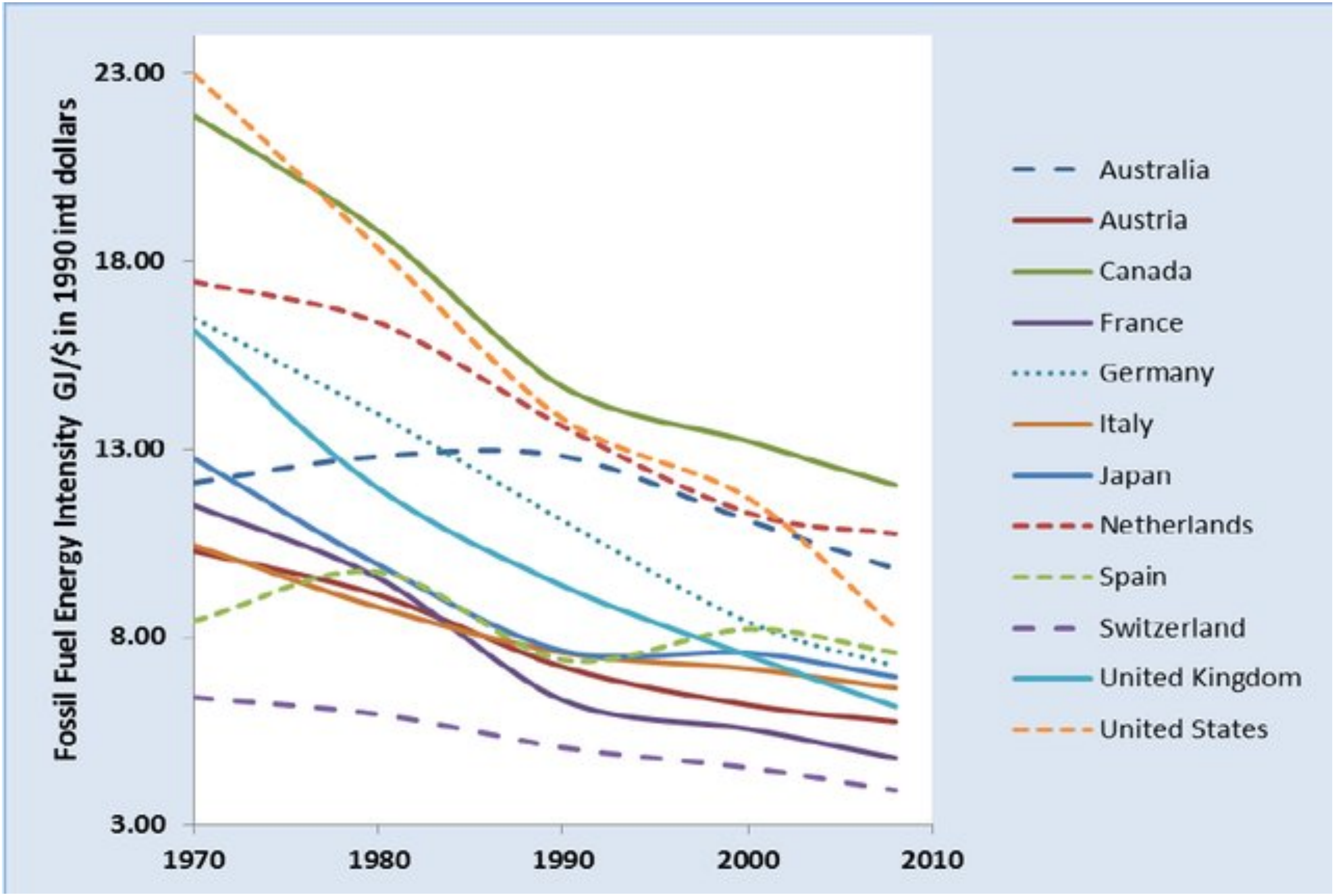
Source: UN and DOE EIA

Economic development and energy use

Modern prosperity depends on a functioning energy supply for electricity, warmth/c
mobility and energy-intensive food and products.



Fossil fuel intensity is decreasing



Energy Economics

Energy economics

Some unique features of energy

- Essential for modern life: for farming, cooking, lighting, comfort in buildings (heating and cooling) communication, mobility, production of most goods. This makes it a political concern.

- Essential to all economic activity. Cf. negative economic consequences of electricity blackouts in South Africa, gas shortages in UK in 2021.

- Reserves of fossil fuels and production capacity/minerals for renewables & storage are concentrated in a few countries. Geopolitics!

- Large externalities: most greenhouse gas emissions come from use of fossil fuels in energy, leads to climate breakdown; air pollution leads to widespread health impacts; for nuclear in meltdown and waste risk; for renewables in landscape impact.

- High potential for innovation and cost reduction: wind, solar, batteries, electrolysers.

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Energy economics

- Energy is abundant in nature, but mostly not immediately available for doing useful work.
- Infrastructure (transmission, generators) requires long periods of planning, investment and operation. Leads to slow change - inertia!
- In many markets there are monopoly structures, which are resistant to market solutions and need regulation (e.g. transmission networks, but also vertically-integrated utilities in some regions).
- Infrastructure property rights (e.g. underground, hydro) are sometimes with public rather than private sector.
- Some risks are diffuse and widespread (nuclear, hydro, landscape impact of wind).

Sample questions

Here is a typical selection of energy economics questions:

- How do we allocate consumption and production of energy by existing assets (short run)?
- How do we decide investment in energy consumption and production assets in the long run?
- How can we most efficiently reduce greenhouse gas emissions and air pollution from the energy sector?
- Wind and solar power are low-cost, but how do we efficiently deal with their variability?
- How do we design markets for variable renewable energy?
- Is a decentralised system design better than a centralised one?

Jevons 1865

In 1865 William Stanley Jevons published The Coal Question, whose concern was the exhaustion of coal reserves in Britain giving exponentially rising demand.

- “With coal almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times.”
- “I must point out the painful fact that such a rate of growth will before long render our consumption of coal comparable with the total supply. In the increasing depth and difficulty of coal mining we shall meet that vague, but inevitable boundary that will stop our progress.”
- He reviews renewables, including wind used to pump water up into reservoirs, and also green hydrogen, before dismissing them all.

Jevons 1865

Jevons' Paradox: "It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth...Whatever, therefore, conduces to increase the efficiency of coal, and to diminish the cost of its use, directly tends to augment the value of the steam-engine, and to enlarge the field of its operations."

"If we lavishly and boldly push forward in the creation and distribution of our riches, it is hard to over-estimate the pitch of beneficial influence to which we may attain in the present. But the maintenance of such a position is physically impossible. We have to make the momentous choice between brief greatness and longer continued mediocrity.

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A famous bogus argument: the Club of Rome

1972 report The Limits to Growth, commissioned by the Club of Rome, examined consequences of exponential economic and population growth with a finite supply of resources with a computer simulation.

- Conclusion: “the most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity”.

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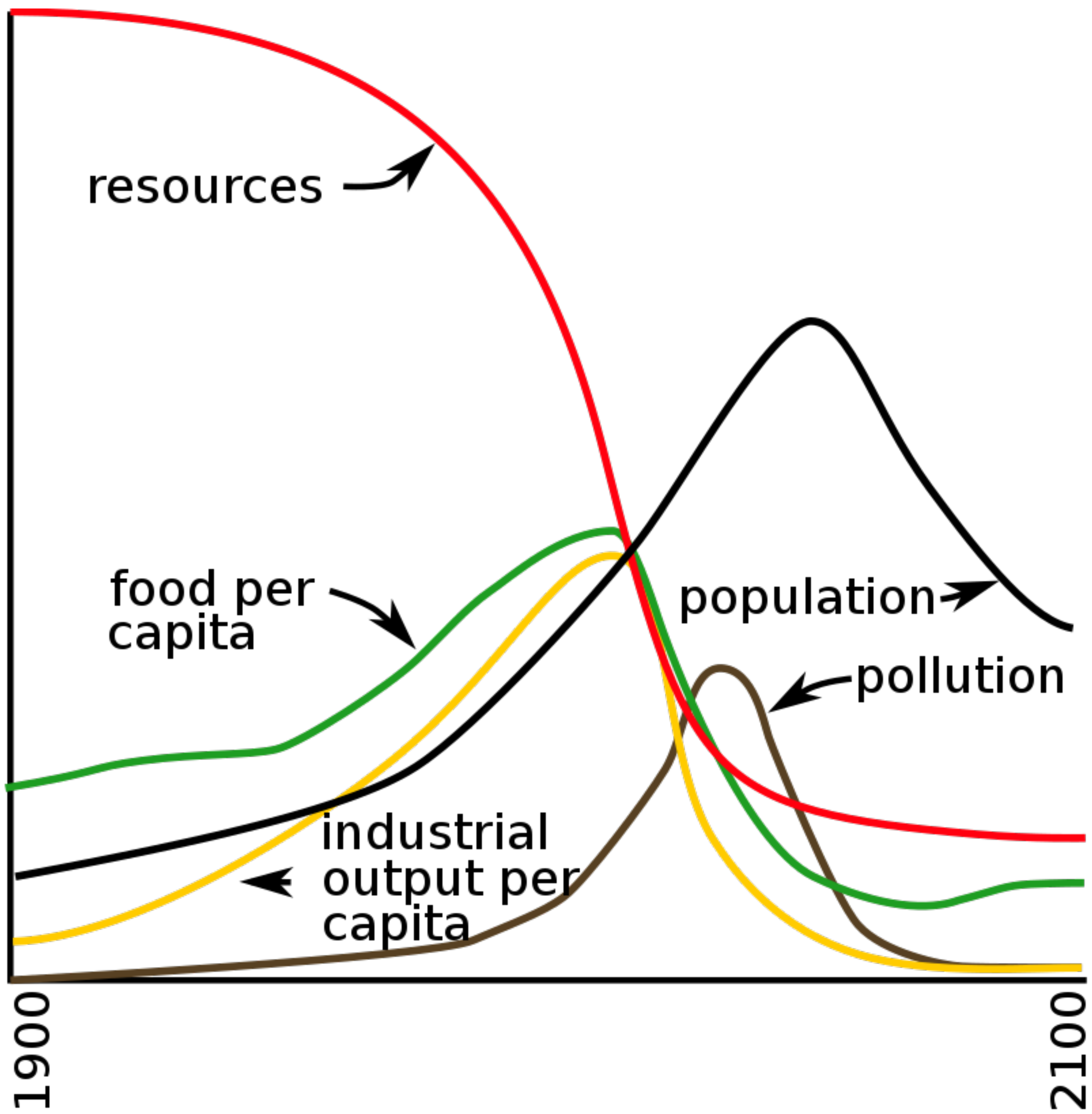
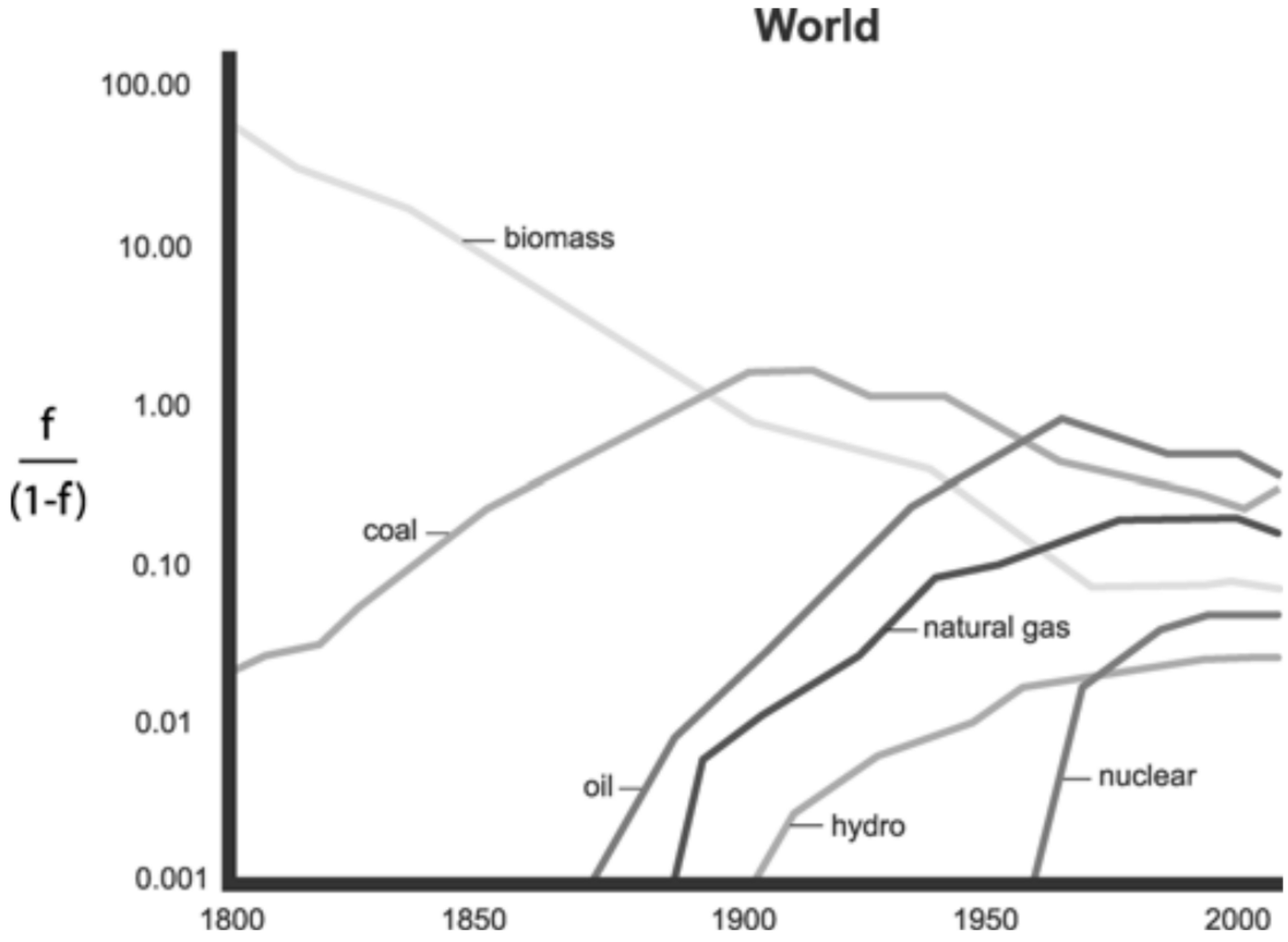
A famous bogus argument: the Club of Rome



Transitions

Transitions

From 1800 to 2010 biomass dominance replaced by hydrocarbons and electricity. Fossil fuel shares steady since 1970. f is fraction of primary energy supply.



Transitions