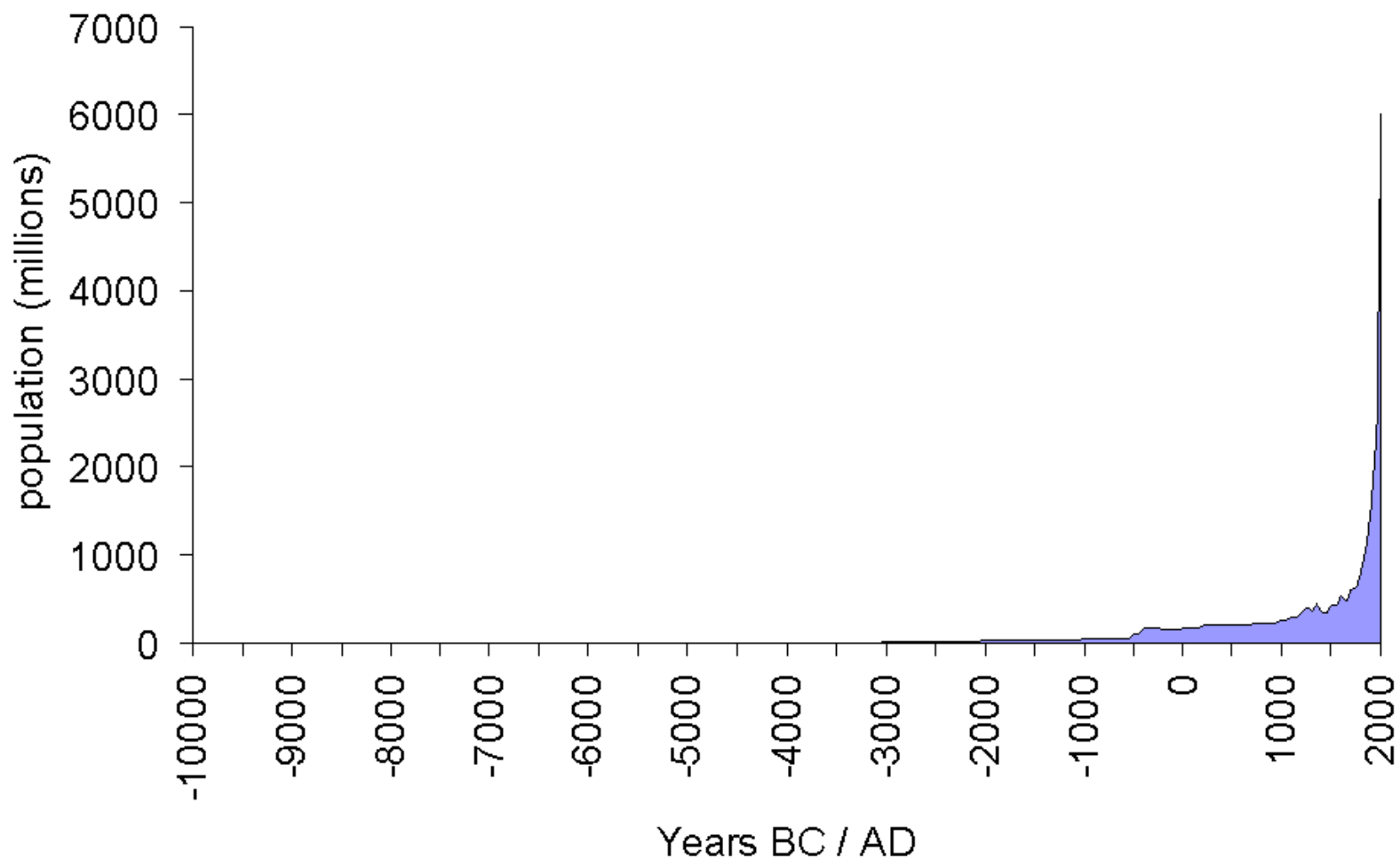


Population growth and energy

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Historic population growth



The fastest doubling of the world population happened between 1950 and 1987: a doubling from 2.5 to 5 billion people in just 37 years .

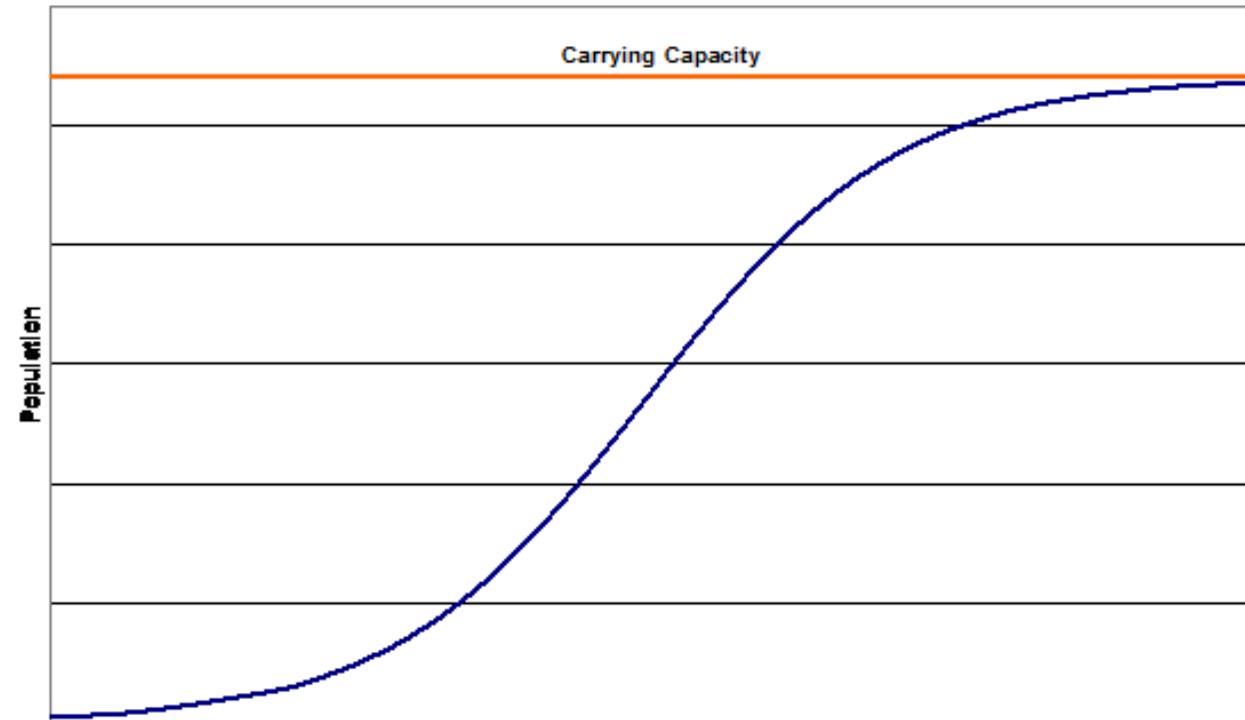
Source: US Census Bureau via Wiki

Population growth

- Driven by fecundity (reproductive rate) – how many offspring individual may have in his lifetime.
- A population doesn't grow to its full potential (indefinitely).
- Limits of population growth (limiting factors) – conditions for life and reproduction.
- Carrying capacity – number of inhabitants (also people) that ecosystem can sustain with available sources.

Population growth

- Early populations grow quickly, unimpeded by resource constraints.
- As population grows, competition for resources grows.
- Mature population tend to reach equilibrium and fluctuate around it. If outgrows its carrying capacity regulating factors (famine, emigration) come into play.
- If a population is below, birth rates tend to increase, population grows.



What factors determine carrying capacity?

- Density dependent factors
- Density independent factors

Hypothesizing the energy-population growth relationship

- Limits of growth are suppressed by „infinite“ amount of energy from fossil fuels (mechanisation of agriculture + medical advances + sewage systems + living in formerly uninhabitable places).

The first energy era (hunter - gatherers)

- Human metabolism + fire.
 - Muscles to secure food, shelter, acquiring material.
 - Useful work of healthy adult: 50 – 90W.
 - Energy returns in foraging – barely positive to as much as 40x .
 - First usage of draft animals to cultivate the field (the very beginning of the agriculture)
 - Sustainable (= able to be maintained at a certain level) economy = damages were reparable.
- = If the ecosystem was harmed too much and stopped providing the resources, people moved to another place (or died).

The first energy transition

- Early, preindustrial agriculture (beginning between 9000 BC and 6000 BC, lasting to app. 16th century)
- Domestication of draft animals + fire to produce metals = increase of energy usage.
- Animals: 200 – 500W (6-8 men).
- Fire to produce bricks and containers and to smelt metals.
- Charcoaling to convert wood to charcoal to iron (inefficient process).
- Nearly complete deforestation of some parts of Mediterranean (Spain, Cyprus, Syria – iron) and the Near East (Iran, Afghanistan – copper).
- Considerable impact of people on the environment. Development is prevented by the limits of the environment.
- Still no spare resources for education, science, tech development.

First prime movers

- Muscles replaced by waterwheels and windmills to grain milling, oil pressing, wood sawing etc.
- Late 11th century England – more than 5600 water mills, 1/350 people.
- Higher performance of draft animals (better harnessing, shoeing etc.)
- Production of metals limited by the limits of environment.
- Early 18th century – typical English furnace produced app. 300 tons of pig iron/year. 8kg of charcoal per 1kg of iron, 5kg of wood per 1kg of charcoal = annual demand 12 000 tons of wood. All natural forests gone.
- 1 mill tons of iron (1720 production) would require $\frac{1}{4}$ of the British Isles under coppiced wood.
- = in 1200 London surrounding is deforested, by 1500 metal ores shipped to Ireland, Scotland, Wales for smelting, then the the industry moved to U.S.

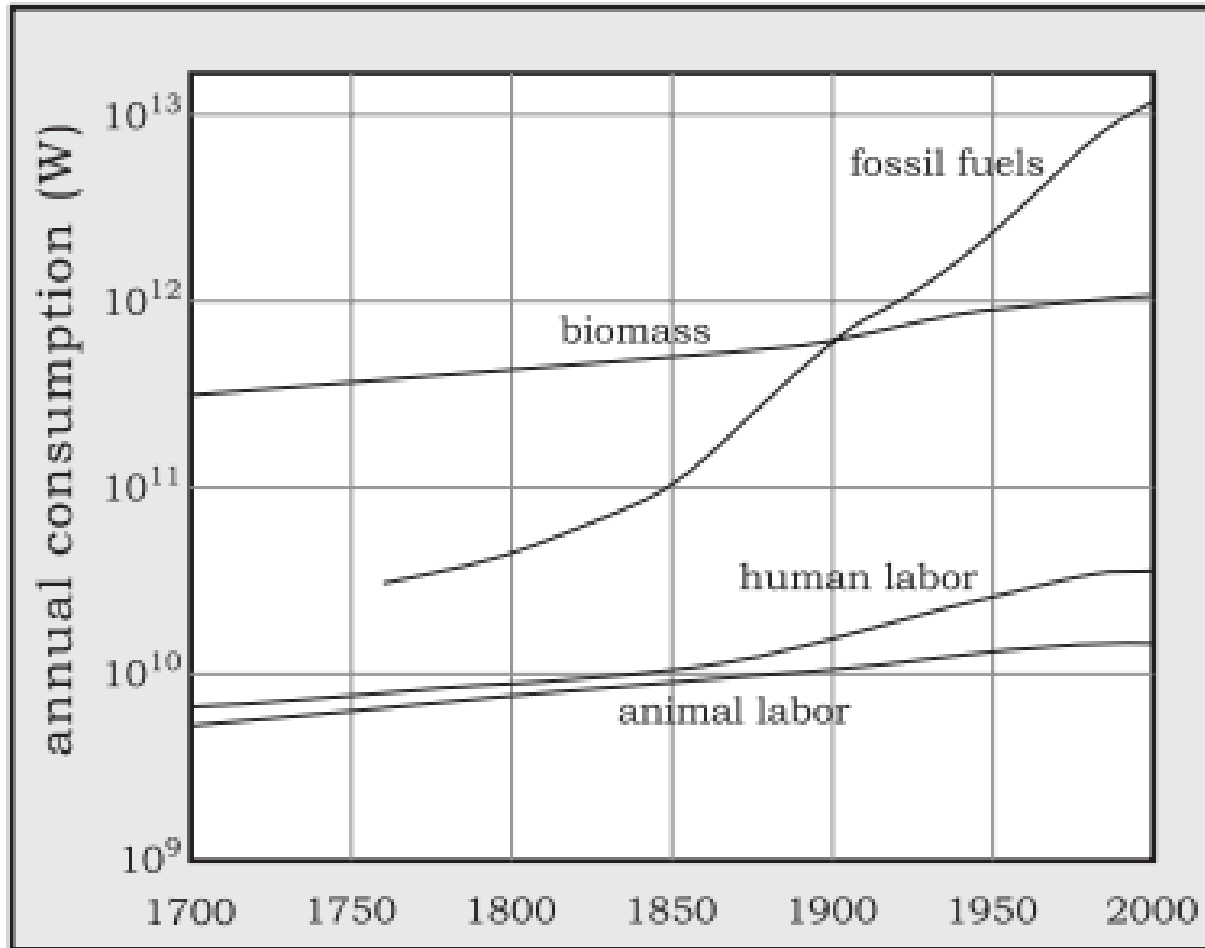
Industrial age

- Substitution of animate energy by engines and energies of fossil fuels (still in process in some areas – Africa)
- By 1900 several European countries energized by coal.
- Previously the lack of energy prevents the population from (also economic) expansion. No spare resources for education, science, technological development. It was changed by the fossil fuels.
- Watt's steam machines 20kW. Industrialization, transportation, rise of well being. An inexpensive and reliable supply of heat and electricity.
- But environmental consequences (serious changes of interactions in the ecosystem)
- = fossil fuels provided a critical amount of energy for the humankind to develop. They (for uncertain period of time) removes the limits of (economic and population) expansion.

Latest energy transition

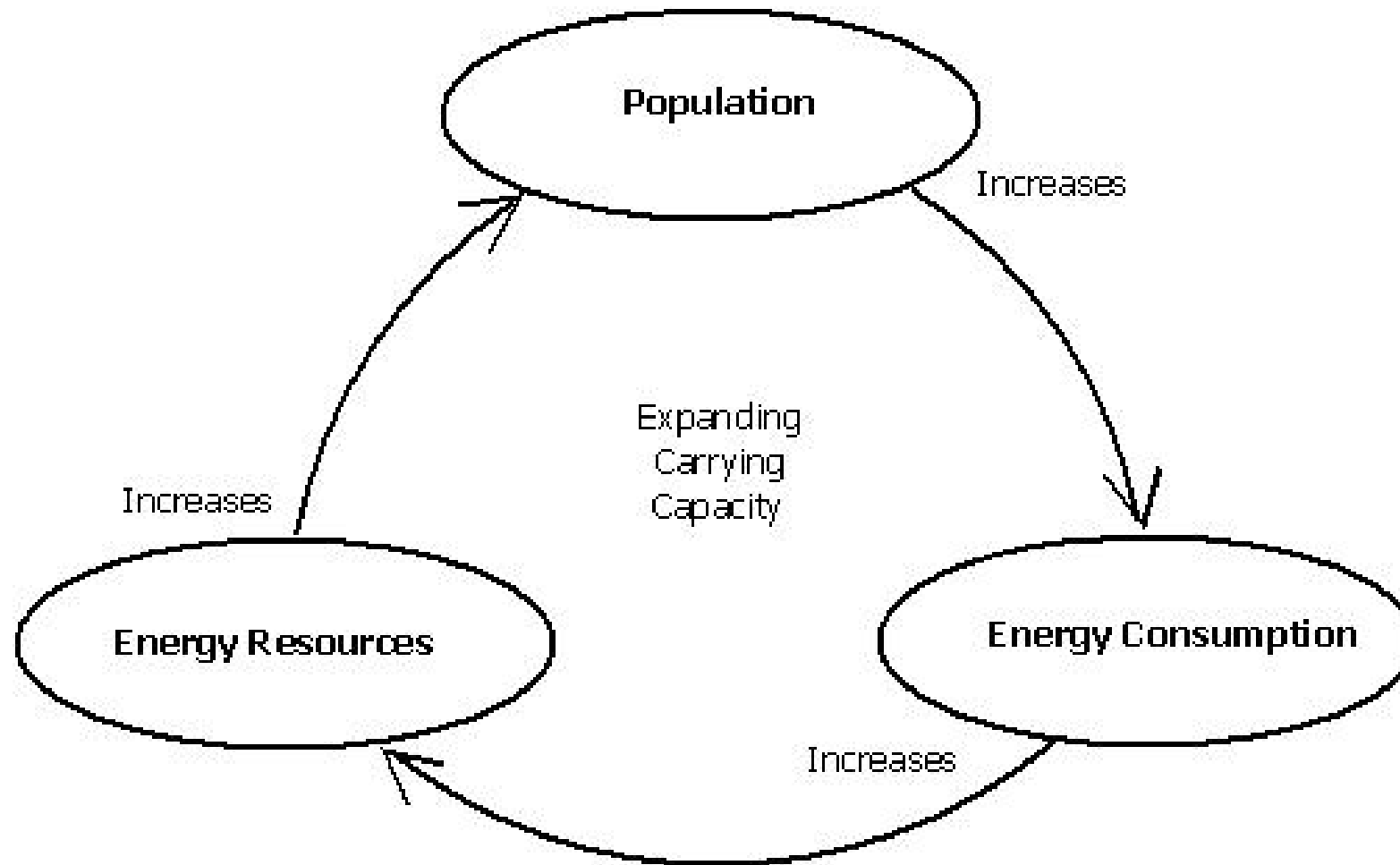
- Started by the first electricity plants in 1880s.
 - Electricification and innovation.
 - An inexpensive and reliable supply of electricity transformed every aspect of everyday activities – light, time-saving gadgets, energizing transport, boosting industrial production.
 - By 1950 oil and gas approx. 35% of the world's primary energy supply and by 2000 their combined share over 60%. With coal fossil fuels provides 90% of all commercial primary energy supply.
- = fossil fuels drive up farm productivity and hence reducing (drastically) agricultural population by mechanizing industrial production and letting the labor force move into the service sector.
- But their impact on the environment is tremendous.

Development in energy consumption

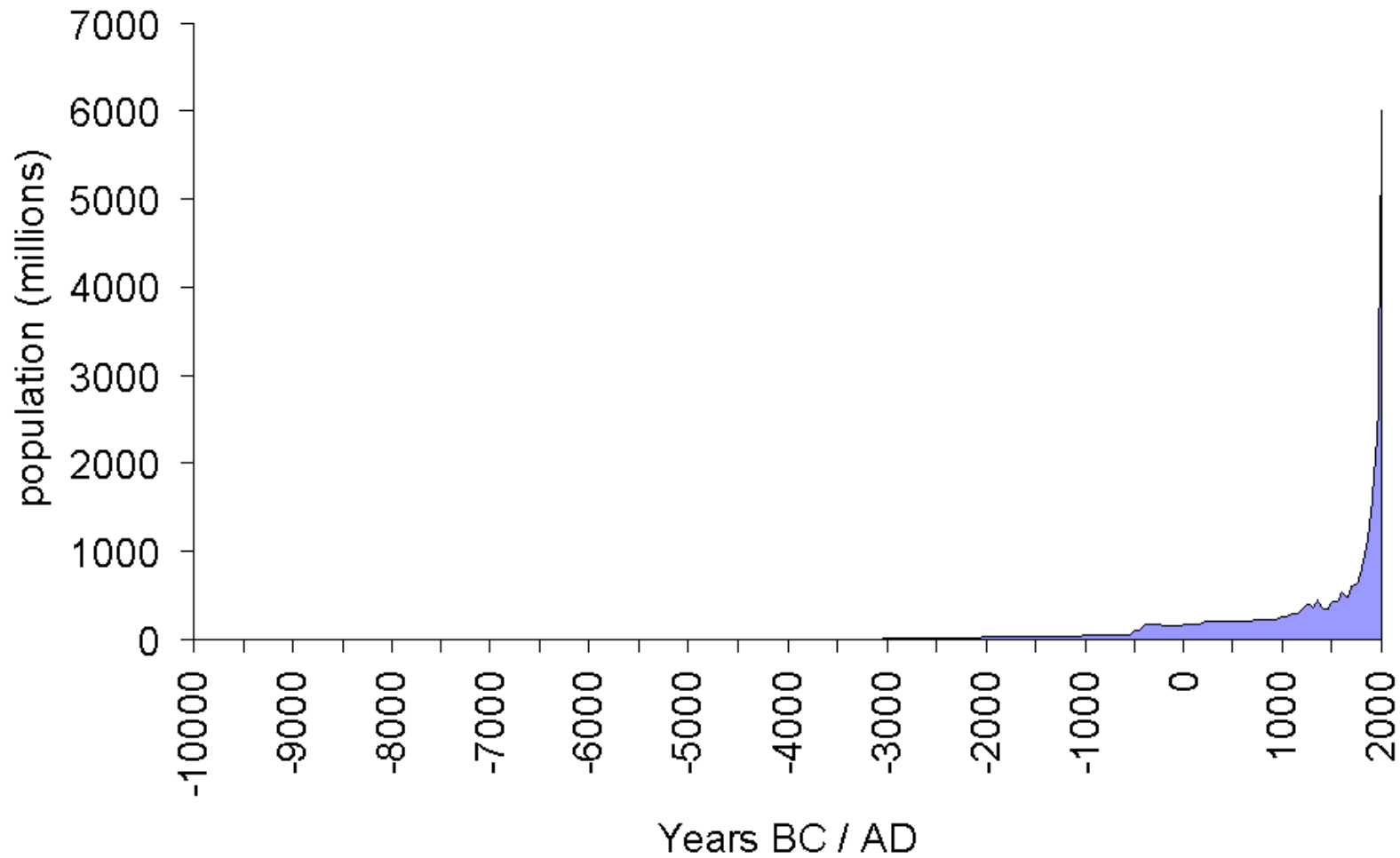


Global consumption of primary energy, 1750–2000.

Energy-population relation

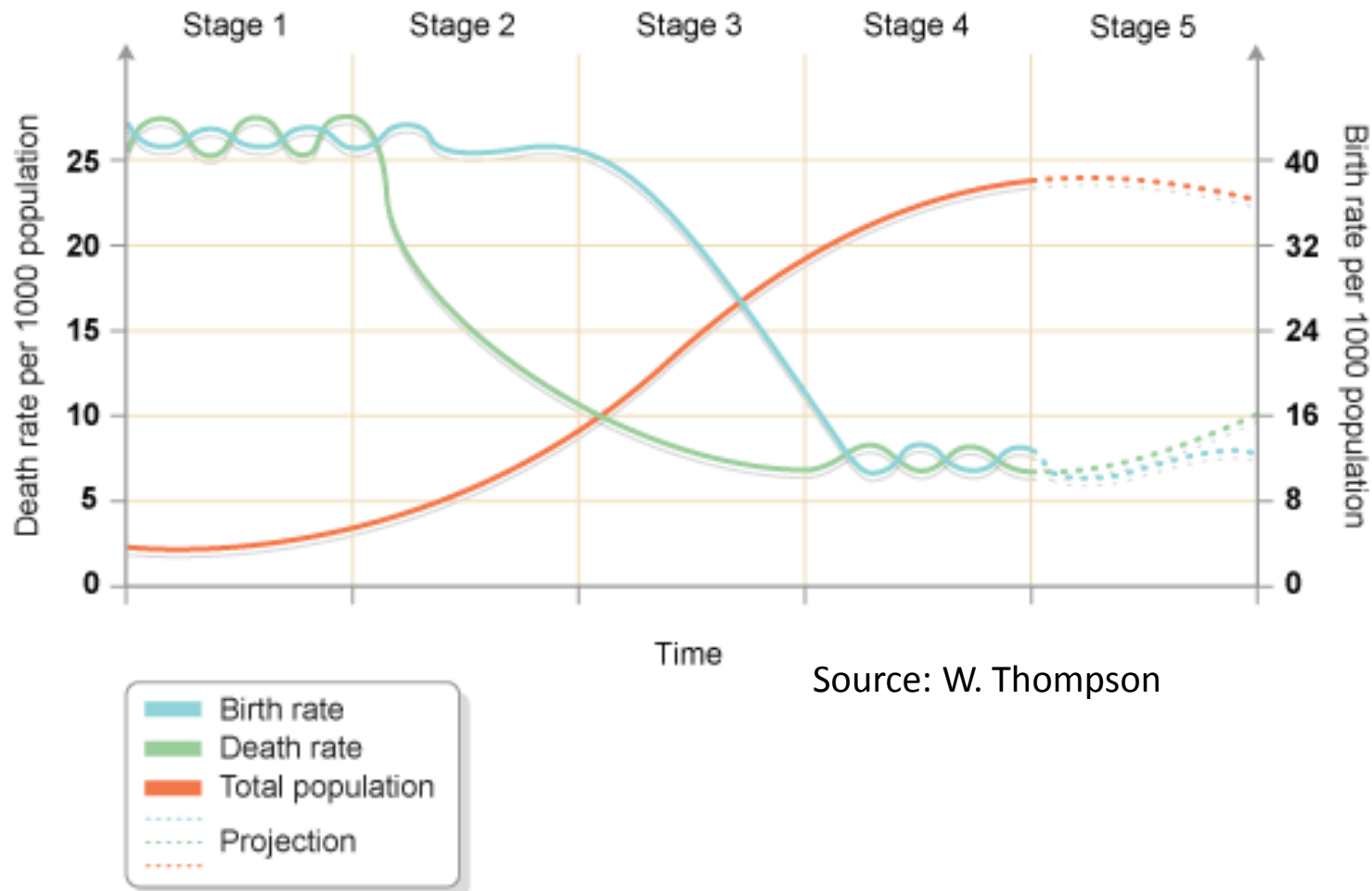


Historic population growth



Source: US Census
Bureau via Wiki

Demographic transition model

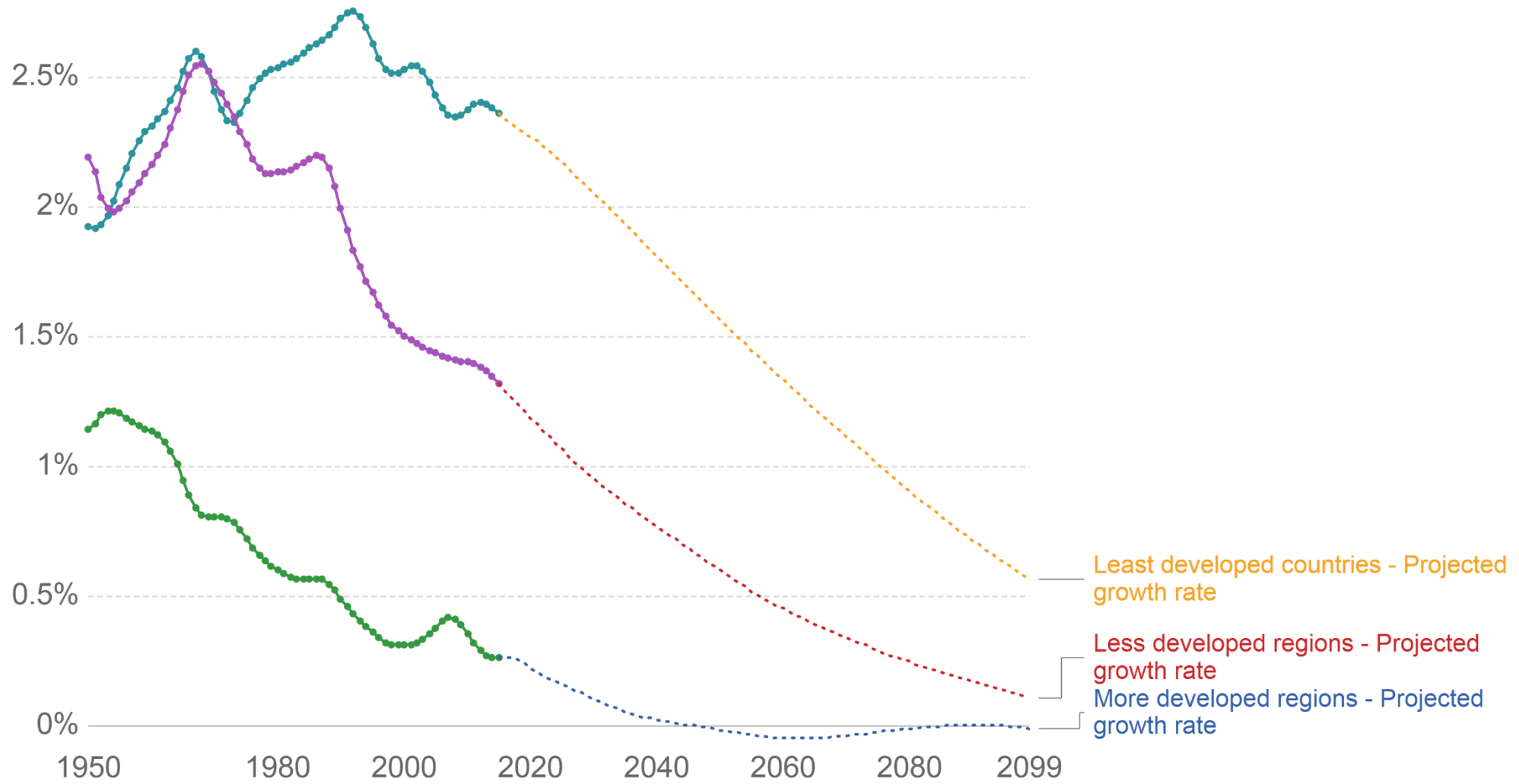


The number of people is growing but the rate of population growth actually peaked around 1962. And has been declining ever since. At its peak the human population was growing at about 2,2 % per year and these days it's declined to around 1,1 % per year and it is still falling.

Population growth rate by world region, 1955-2015 and projections through 2100

Projections use the UN medium variant

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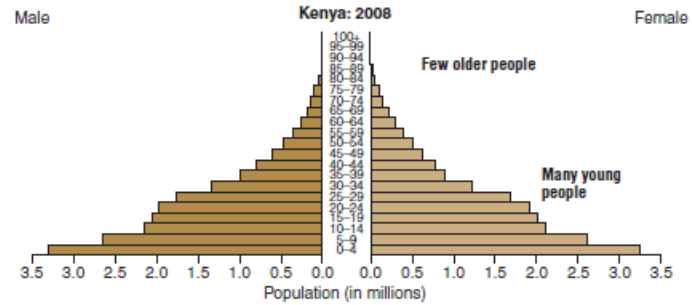


Source: UN Population Division (2017 Revision)

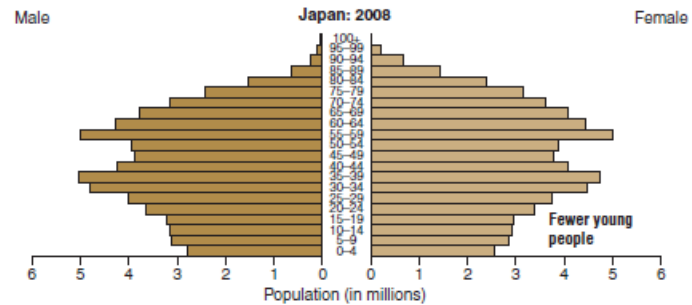
OurWorldInData.org/world-population-growth/ • CC BY-SA

Note: More developed regions comprise Europe, Northern America, Australia/New Zealand and Japan; less developed regions comprise all regions of Africa, Asia (excluding Japan), Latin America and the Caribbean plus Melanesia, Micronesia and Polynesia; least developed countries are 48 countries, 33 in Africa, 9 in Asia, 5 in Oceania plus one in Latin America and the Caribbean.

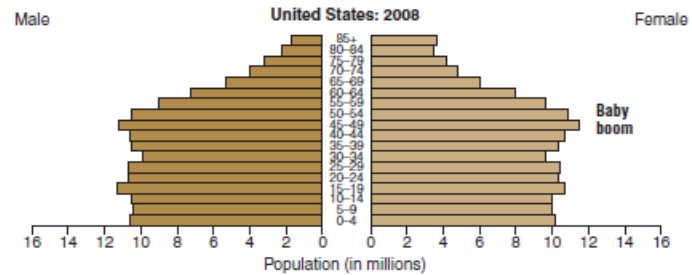
Age structure



Source: U.S. Census Bureau, International Data Base.



Source: U.S. Census Bureau, International Data Base.



Conclusions

= correlation between availability of energy and population (limiting factors suppressed by unlimited supplies of high-quality energy).

- energy needed to provide for existing population + accommodate expected increase.

= but fossil fuels are compromising the Earth's ability to provide essential services

= other source of energy needed?

Thomas Malthus (1766-1834)

- An Essay on the Principle of Population.
 - Food is necessary for people to survive
 - Children will continue to be born
 - The power of population growth is indefinitely greater than the power of the Earth to produce subsistence.
- Malthusian trap (population growth instead of high standard of living).

X

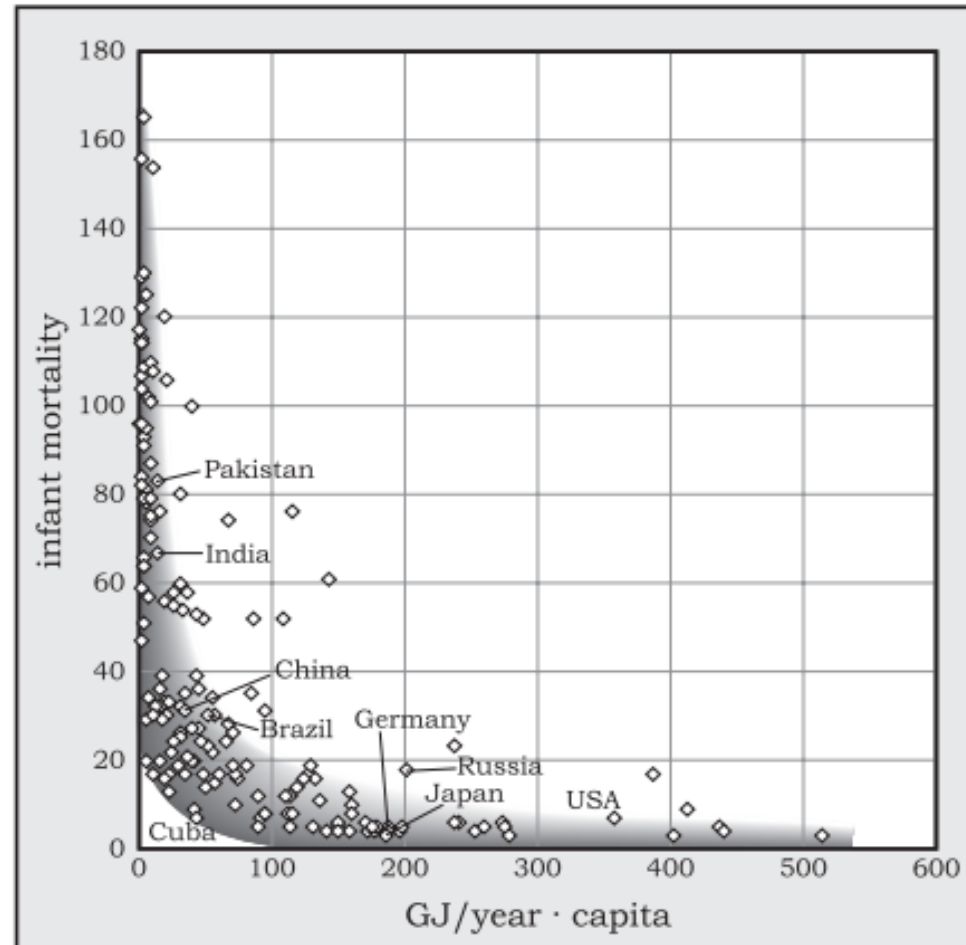
- Technological development.
- Relationship between affluence and population growth (demographic transition theory).

Perspectives

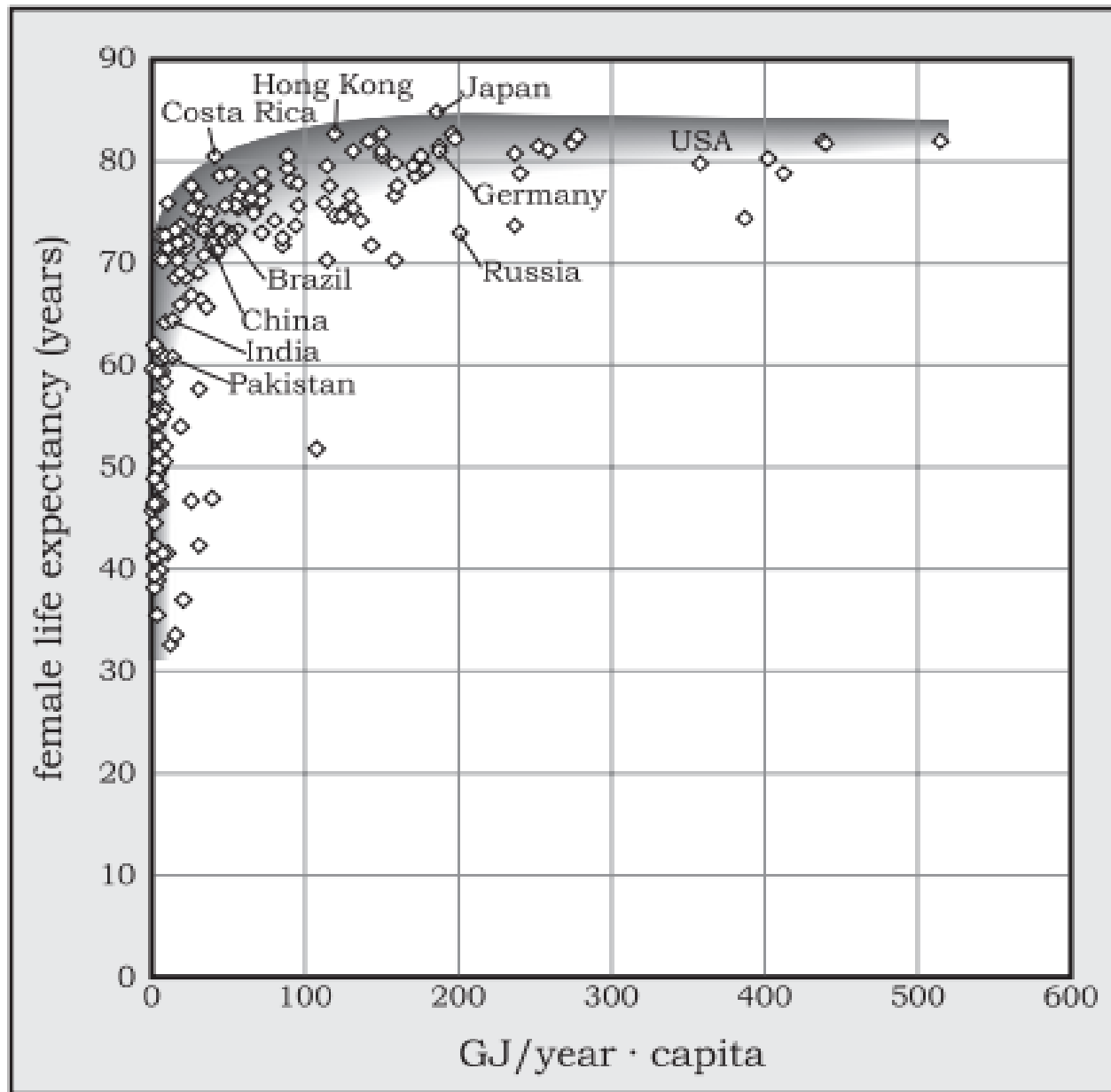
- Cornucopians (boomsters, vs. Malthus and followers = doomsters).
- Reformists: Work within existing structures to make society more “green”.
- Revolutionaries: Sustainability is not possible without radical change.
- Environmental determinists: Ecological limits will impose changes on society whether we like it or not.

- The Voluntary Human Extinction Movement.

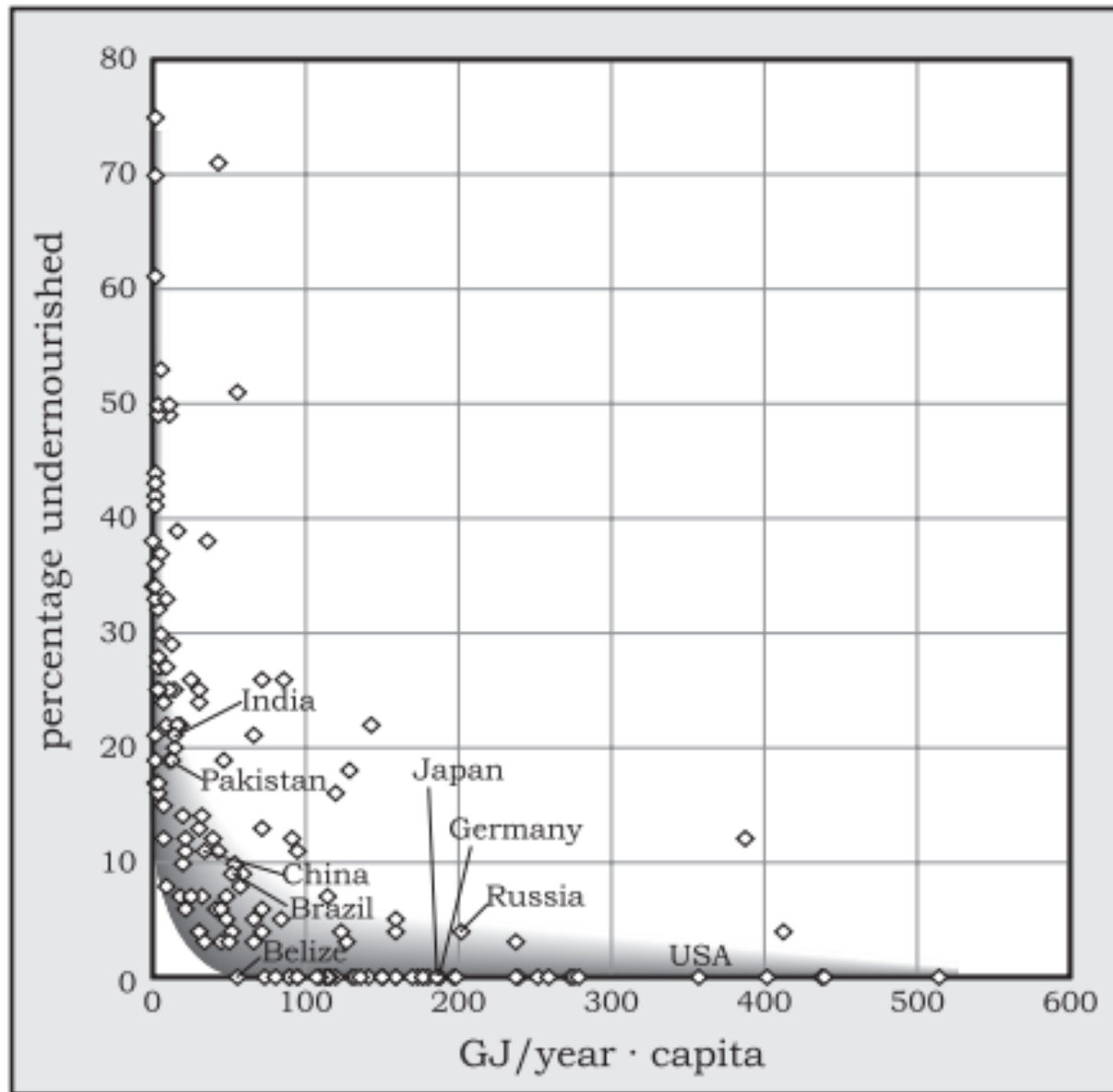
Technological development



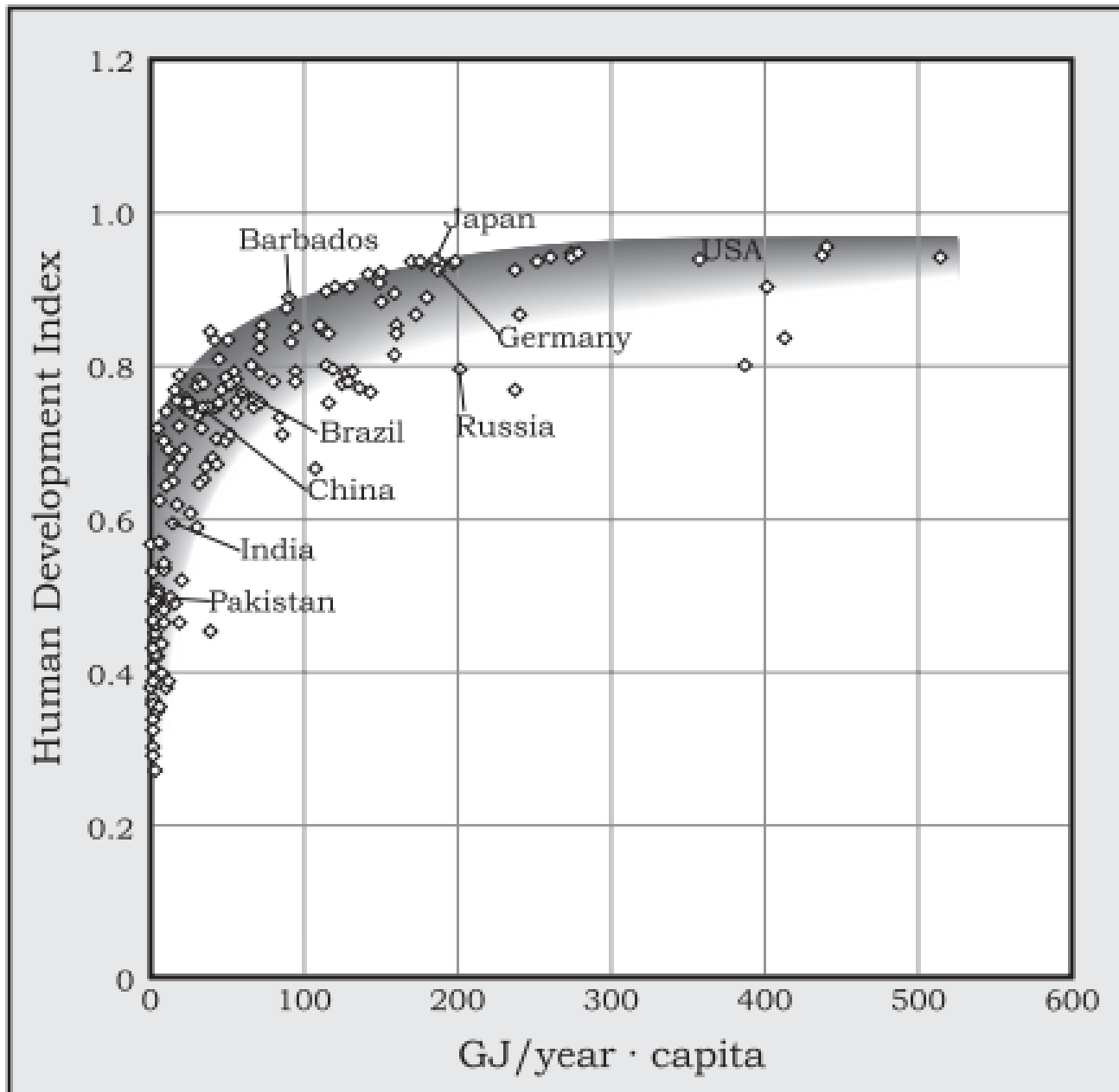
Per capita energy use and infant mortality.



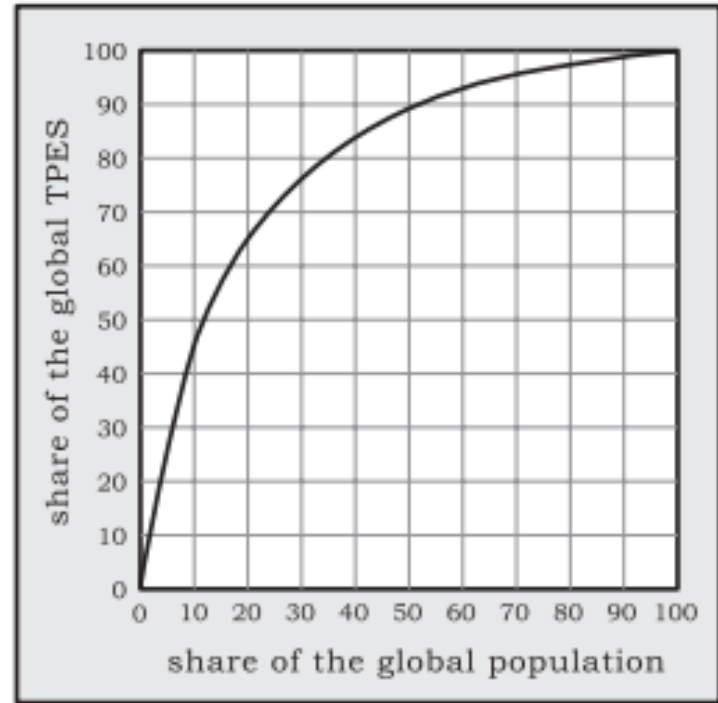
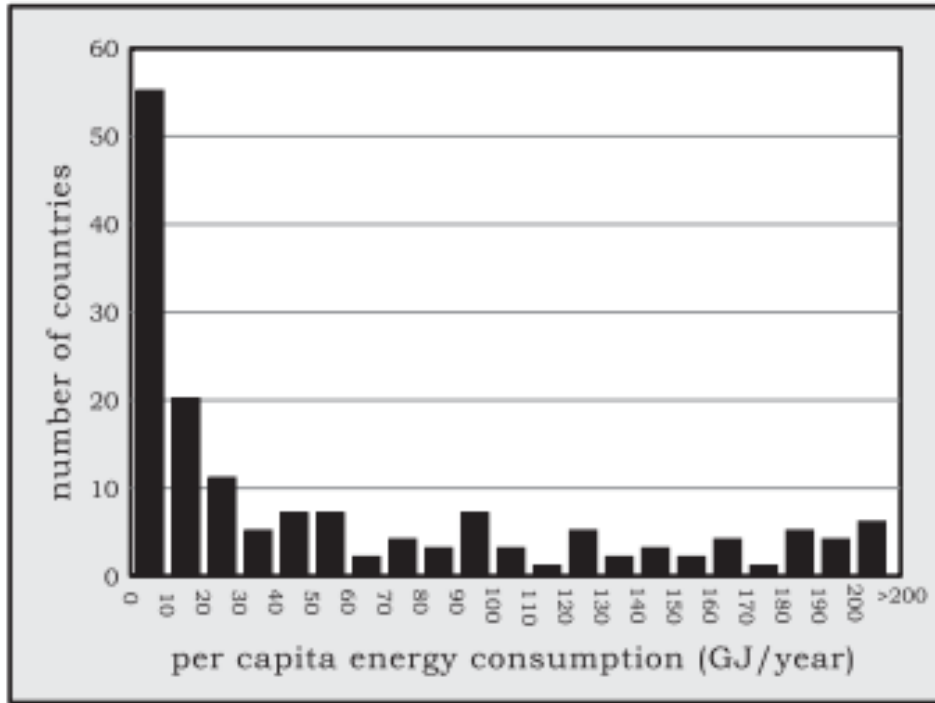
Per capita energy use and female life expectancy at birth.



Per capita energy use and malnutrition.



Per capita energy use and HDI.



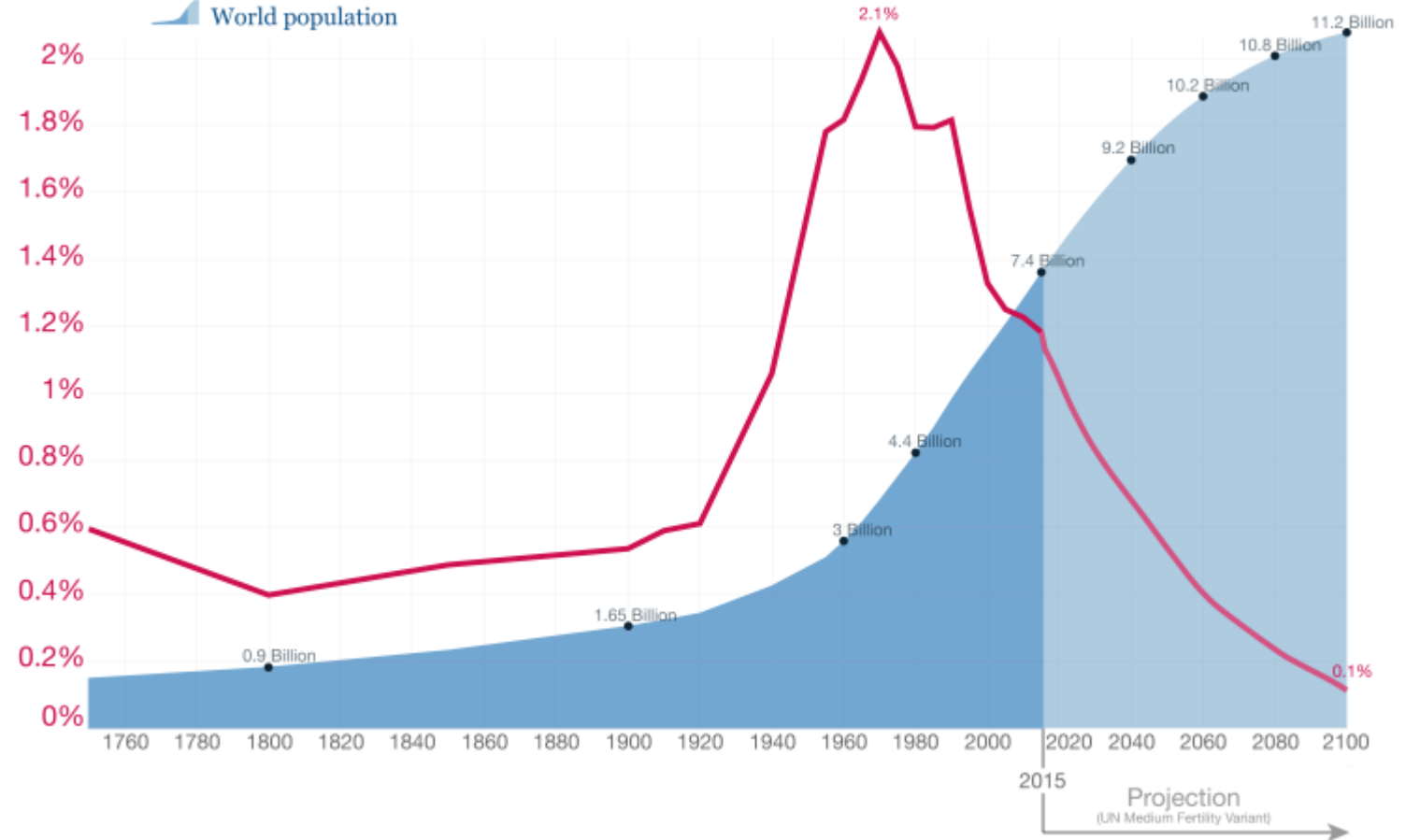
Pronounced inequities of global energy consumption.

Sources

Zabel, G.: Peak People: The Interrelationship between Population Growth and Energy Resources. Energy Bulletin.

World population growth, 1750-2100

Annual growth rate of the world population
World population



Data sources: Up to 2015 OurWorldInData series based on UN and HYDE. Projections for 2015 to 2100: UN Population Division (2015) – Medium Variant. The data visualization is taken from OurWorldInData.org. There you find the raw data and more visualizations on this topic.

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