Agenda for Section (Sustainability @ "Anthropocene")

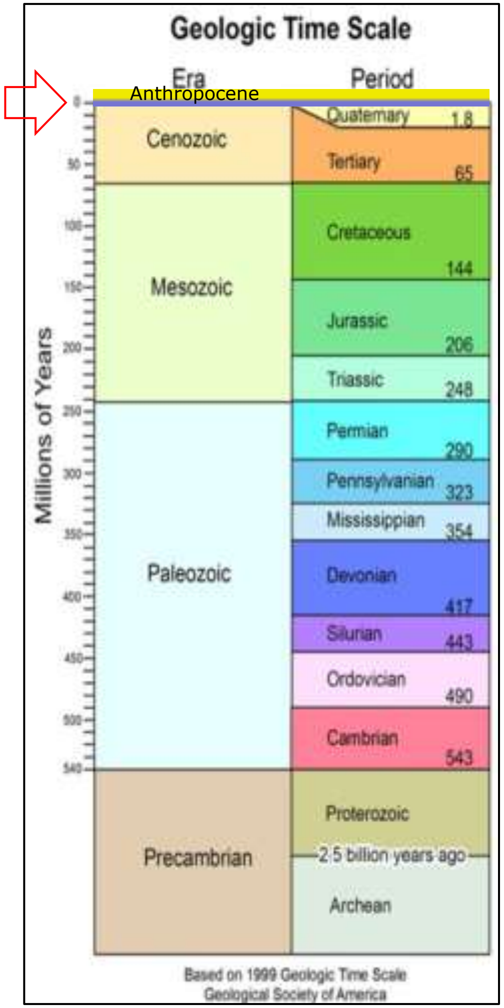
Grand picture Habitat and resource utilization

- Energy concept, human utilization of Energy
- Tools and fuels in human history

- Sustainability of Future Human Activity & Life on Earth (our habitat)
  Limit to growth, Club of Rome,
  Socio-economic/ecological network.

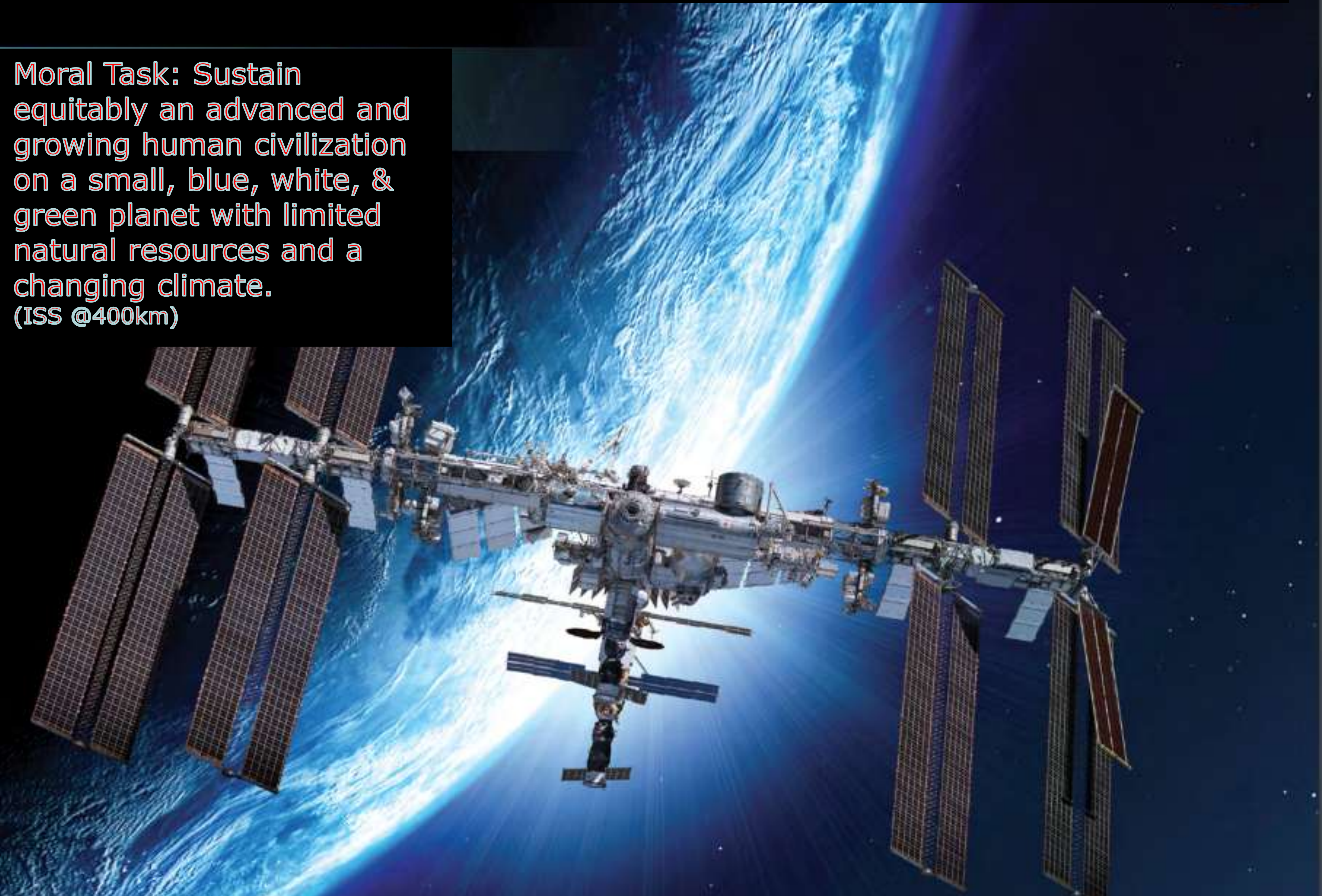
- Finite resources: arable land and water for food production, materials for fabrication & construction, fuels for machinery & transportation,
  Human eco-footprint, choices, and dilemmas,

- Energy utilization and environment,
  Energy consumption and human development
  External costs of energy use,
  Planetary climate, greenhouse effect.



Grand, Existential Theme of Our Time of Transition

Moral Task: Sustain equitably an advanced and growing human civilization on a small, blue, white, & green planet with limited natural resources and a changing climate.
(ISS @400km)



Where We Are (As Globally Evolving Civilization)

- **Global mean** (on average): Now in late phase of another major irreversible 300-year socio-economic transition.
  Agrarian mode of subsistence → Industrial mode, "1st machine age."
  Land based socio-ecological regime → Industrial/fossil-fuel based → 2nd machine age, digital revolution,
  Steady growth of global economy (Globalization), standard of living ↑

- **Ongoing transition**: Industrial/knowledge, fossil-fuel based economy → digital AI superstructure (?)
  Managing transition needs understanding interconnections and feedback, rooted in historic evolution (lessons learned?).
  Task: Non-chaotic/non-violent transition (population pressures).
  Transition to sustainable, equitable sustainable regime …?

- Present global North-South gradient:
  Countries in the global North are at different stage in transition than countries in the global South. North is more advanced; global influences exist but do not eliminate major inequities (conflicts).

Def: **Socio-ecological regime** (mode of organization, subsistence, and/or production) =complex system, social organization exploiting accessible ecological (natural) systems (land/soil, water, material resources, wild/domesticated animals,…)
After: M. Fischer-Kowalski, Institute of Social Ecology, IFF Vienna, Klagenfurt University, Austria (2008)

Main Task = Achieve Sustainability (Avoid Collapse)

Brundtland Commission of the United Nations (1987):

"sustainable … is development that meets the needs of the present without compromising the ability of future generations to meet their own needs…."

Human responsibility: Limit depletion of resources, detrimental/destructive impact on Earth's ecosystems, specifically the anthropogenic causes of environmental changes (climate, habitat pollution), and the utilization of non-renewable resources.

⇨ This includes limits on the production of energy and the associated byproducts of waste and pollution.

But:

Access to, and use of, natural resources and energy (≈ ability to initiate processes changing objects and/or their relations) is a prerequisite for all life and civilization.

→ Complex task with many dilemmas needs holistic approach

From linear, expanding economy towards a "cyclic economy" ?

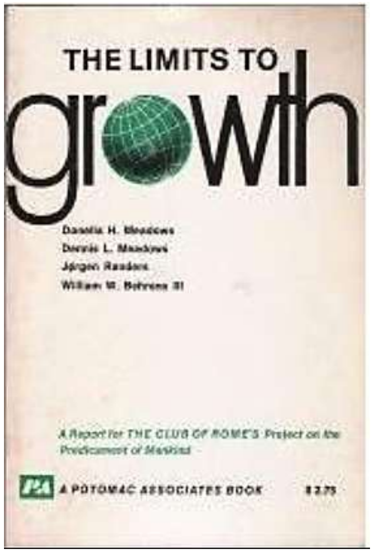
W. Udo Schröder, 2025

Ethical and Policy Dilemmas

1. Conservation of resources for future generations *vs.* sustaining larger population & developing capacity to solve future problems.
2. Protection of environment *vs.* economic efficiency.
3. Relative emphasis of current welfare *vs.* that of future generations.
4. Utilization of powerful new technologies *vs.* extensive risk/benefit study.
5. Imposition of technology risks/cost without public consent *vs.* paralysis of decision making. Role of experts *vs.* public.
6. Public interest *vs.* individual liberties and preferences (eminent domain).
7. Social and political merits of simple *vs.* complex technologies (coal/nuclear).
8. Responsibility of developed nations towards poor/emerging societies. Equitable resource/wealth sharing.
9. Technological possibilities *vs.* basic human needs (biofuels vs. bio-food).
10. Mitigation *vs.* adaptation to climate change.

Loosely adapted from: I. Barbour, H. Brooks, S. Lakoff, J. Opie, "Energy and American Values," Praeger Publishers, Nat. Hum. Center, Research Triangle Park, NC, 1982.

Economic Growth: Analysis & Outlook (CoR→Sims)

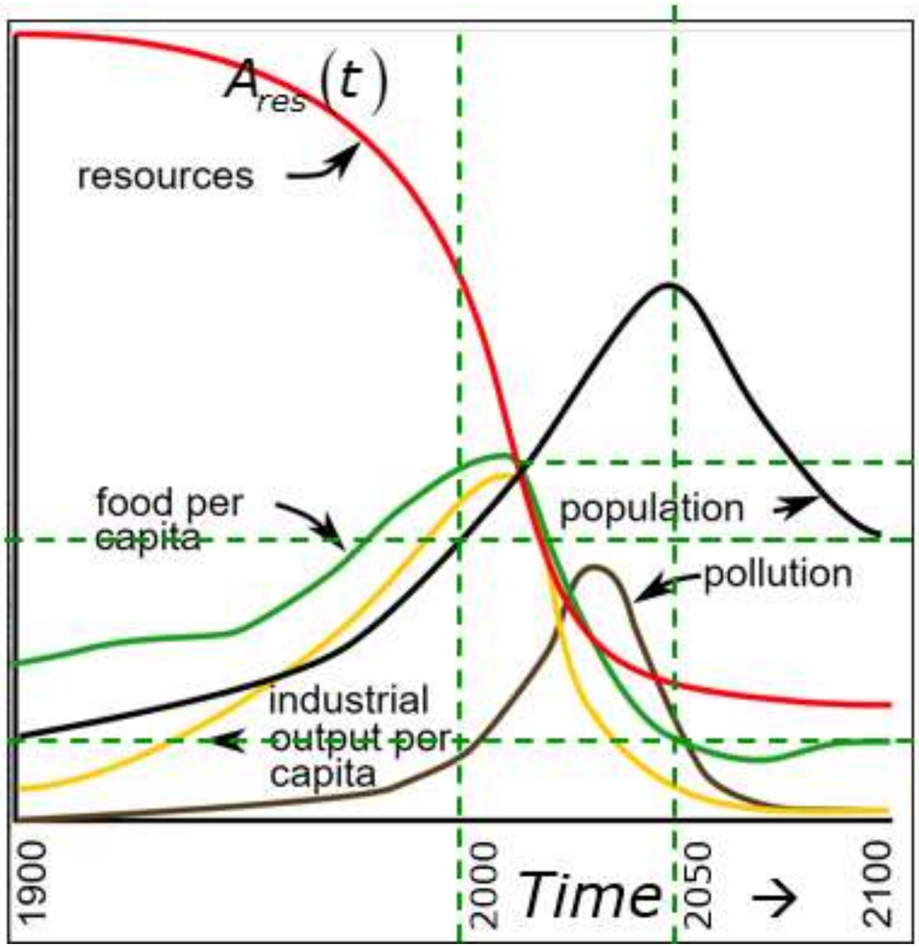


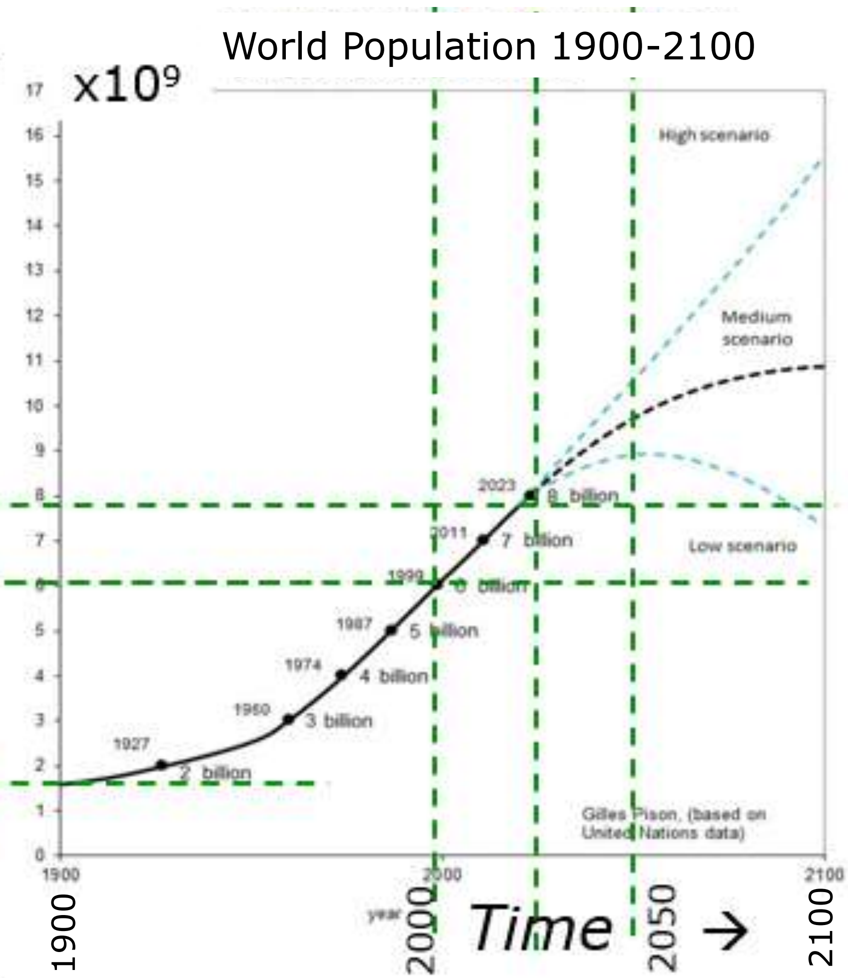
At the behest of the *Club of Rome*, a team of MIT scientists set out to code a computer simulation model of interconnected global developments and various alternative scenarios, i.e., set of model assumptions. Variations were made with respect to available resources, agricultural productivity, birth rates, and environmental protection measures. projecting from the basic understanding in the 1970s, the limit of sustainability of the model world was predicted to be reached around 2030, a "tipping point," unless certain counter-measures were put in place.

By then, the prediction went, the population had grown exponentially to a size that led to significant depletion of major resources like water, food, essential materials, and energy.

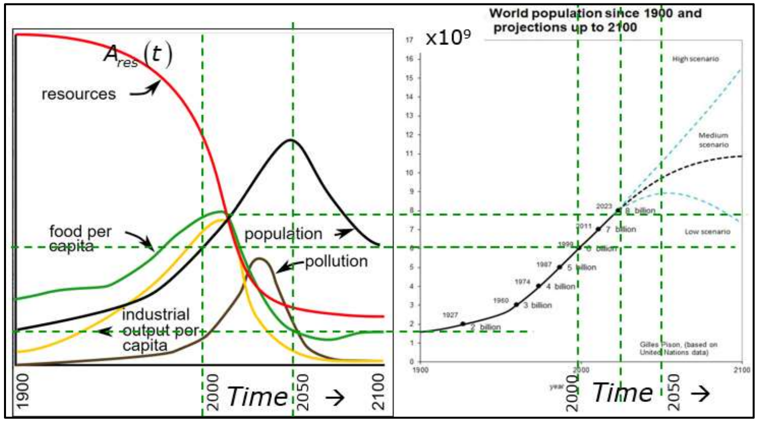
Enormous consequences were envisioned, including wide-spread poverty, famines, and diseases leading to mass migrations around the world. Fortunately, several of them turned out to be exaggerated.

Finite Resources: Extrapolating MIT Simulations





Examples for Resource Depletion



Assumed consumption rate

$$\frac{dA_{res}(t)}{dt} = -\lambda = const$$

$$\rightarrow A_{res}(t) = A_{res}(0) - \lambda t$$

Resource decreases linearly in time

Consumption rate @ constant fraction

$$\frac{dA_{res}(t)}{A_{res}(t)\,dt} = -\lambda = const; \quad \rightarrow A_{res}(t) = \textbf{??}$$

Resource decreases exponentially in time

Consumption rate proportional to population

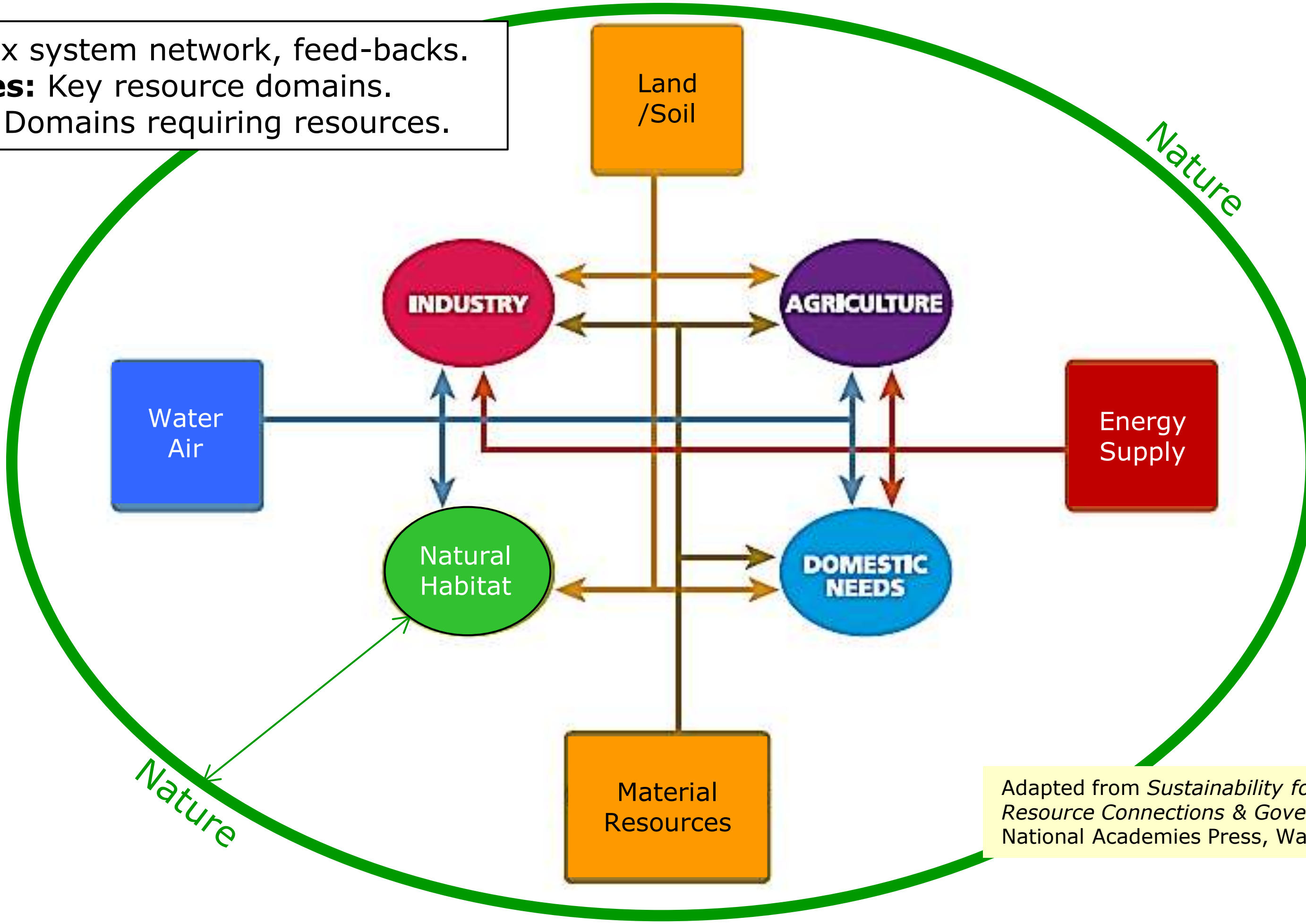
$$N_{pop}(t) \propto e^{+\nu \cdot t} \quad \textit{Simplest example} \quad \frac{dA_{res}(t)}{dt} = -\lambda \cdot N_{pop}$$

$$A_{res}(t) = \textbf{??}$$

Resource decreases in time *t* much faster than exponentially

Socio-Economic Network: Major Components

Complex system network, feed-backs.
Squares: Key resource domains.
Ovals: Domains requiring resources.

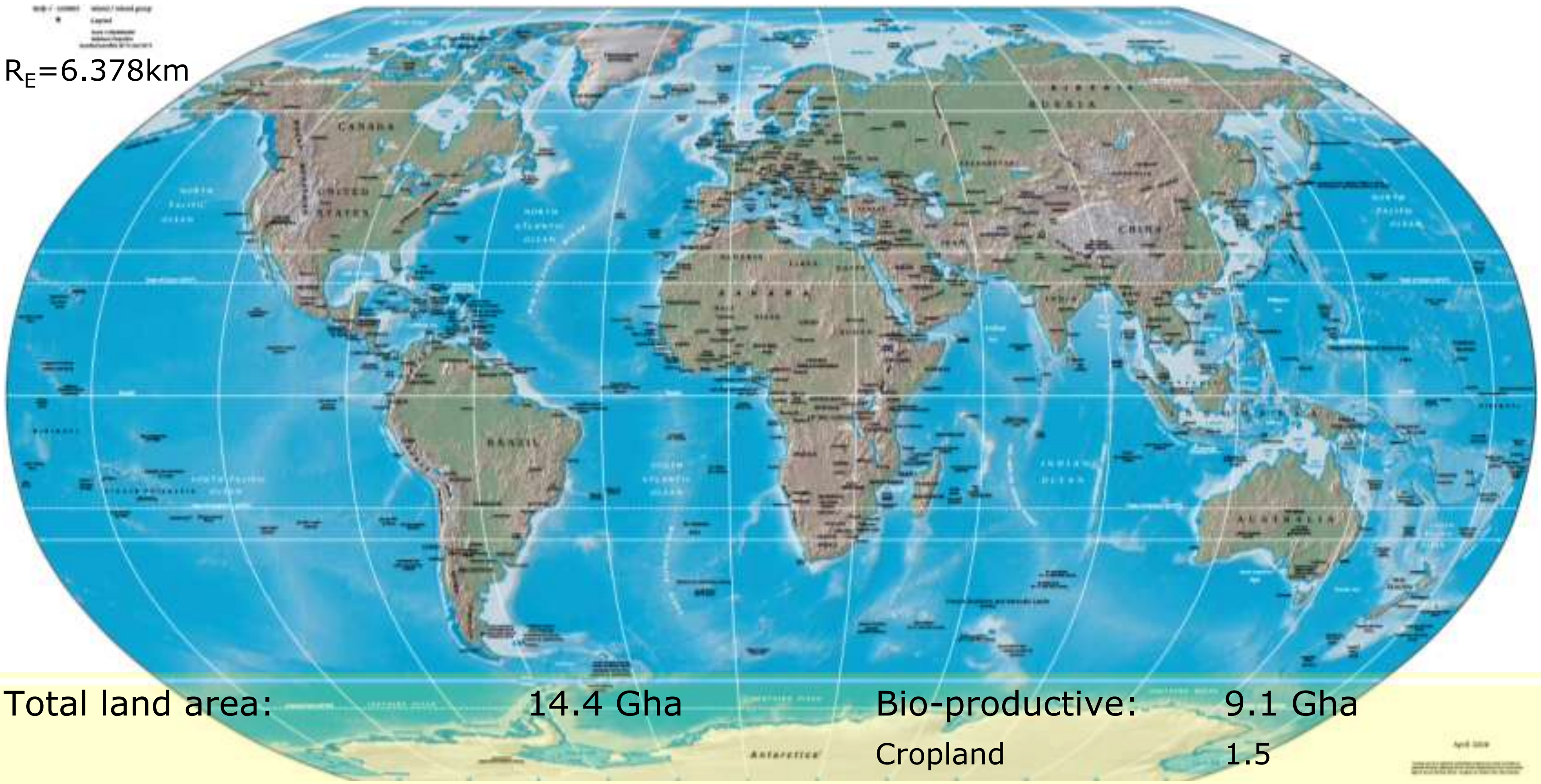


Adapted from *Sustainability for the Nation: Resource Connections & Governance Linkages,* National Academies Press, Washington, D.C., 2013

Interlinked socio-ecological system needs long-term, systems sensitive, adaptive, collaborative management. **Example**: Sustainably managing water resources

#1 Resource: Land, Biological Potential

R_E=6.378km



Total land area:	14.4 Gha	Bio-productive:	9.1 Gha
		Cropland	1.5
		Pasture	3.5
		Forest	3.8 (3.04.10^{12} trees)*
		Built-up	0.3
Ocean & inland waters:	36.6 Gha	Bio-productive:	2.3 Gha
		Fisheries	2.3

1ha=100 ares=10,000 m^2=2.471 acres) ***Nature, 2022***

After: M. Wackernagel, C. Monfreda, Encyclop. Energy V. 2, (Elsevier, 2004)

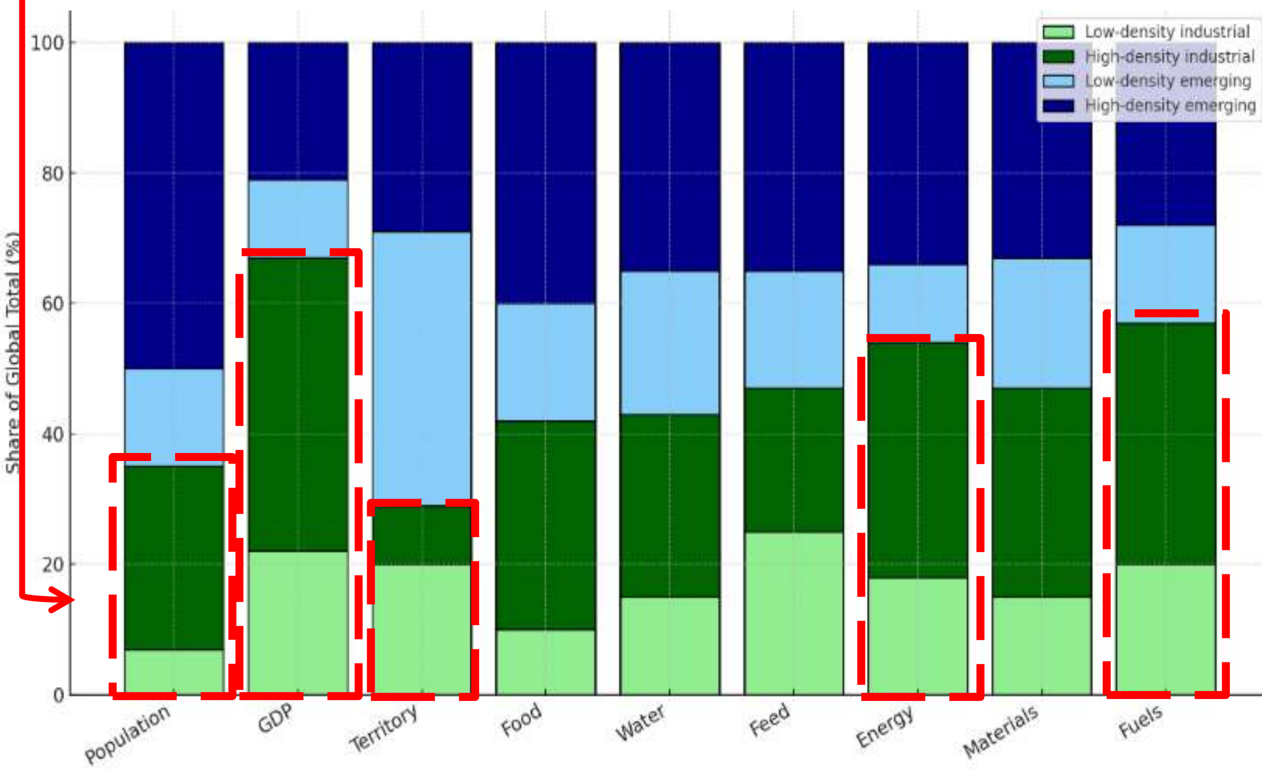
Distribution of Global Resources (2024)

Low-density(< 50/km²) industrial: US, Canada, Australia, Scandinavia, Fm. Soviet Union, New Zealand

Industrial high density: Europe, Japan, South Korea, China,

Developing low-density: Latin America, Africa, Middle East.

Developing high density: India, SE Asia, Nigeria, African countries.



Disparate distribution of essential global resources→ consequ.

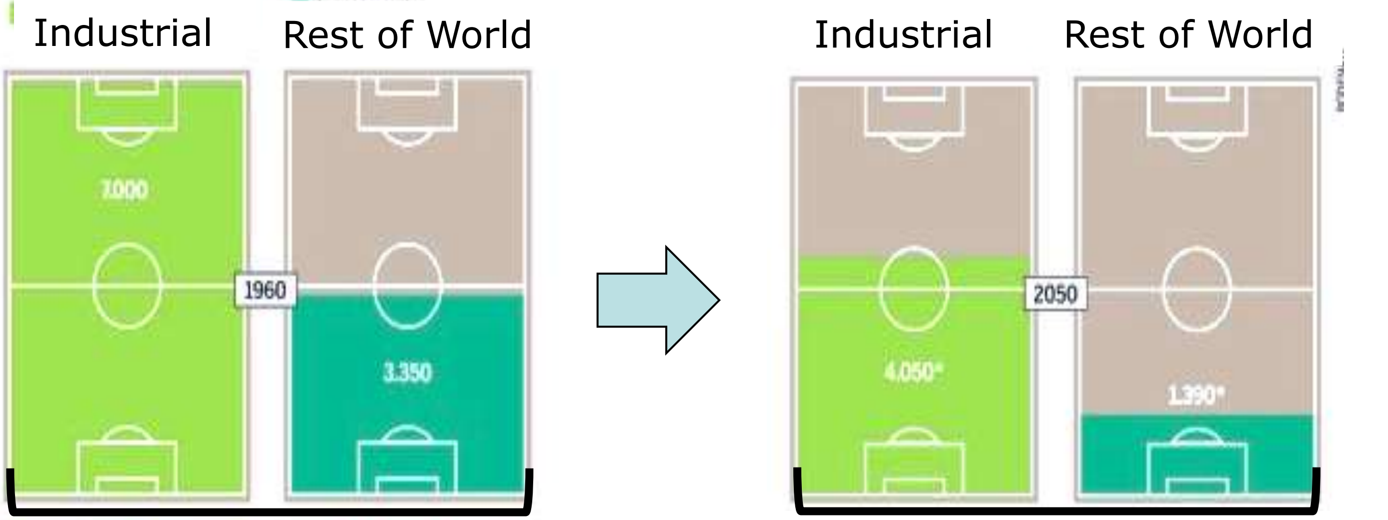
Resources: Food, water, feed, energy, materials (wood, construction minerals, industrial minerals, ores,..)

fuel categories: solid, liquid, gaseous

WUS: GPT 2024

Arable Land Allocation

High-Quality arable land mass decreases absolutely and per capita, despite gains through polar shift, thawing & reduced permafrost, deforestation.



1960: 7000 m²/cap (industrial)   Extrapolating →2050: 4050 m²/cap (ind.)
3350 m²/cap for rest   1390 m²/cap for rest

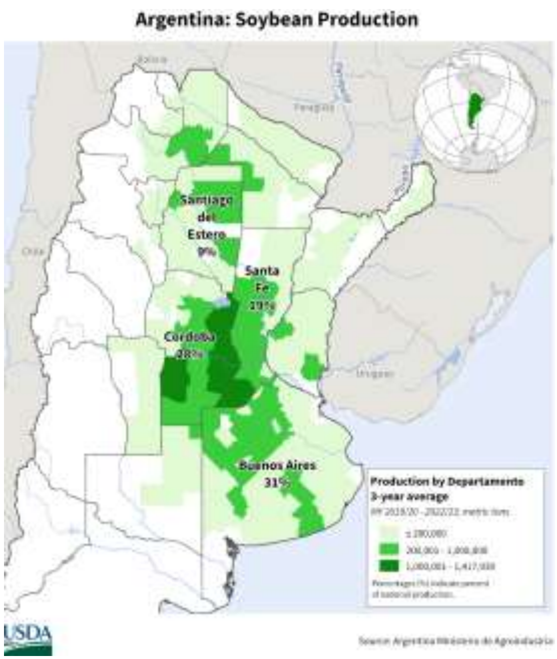
Inequity between industrial and developing world:

Sustainable at expected populations: ≤ 2000 m²/cap on average.

Q: Is this sufficient? Must count on industrial agriculture „Efficiency" gains via, fertilizer, pesticides, gen-mod. But: decreasing soil quality, run-off pollution,...

Arable Land Use: Examples

High-Quality arable land mass decreases absolutely and per capita, despite gains through polar shift, thawing & reduced permafrost, deforestation.



2024: 52Mt
"Soy for the world"
(1988)→ (2024)
4Mha → 18Mha

Inequity: industrial (rich) vs. developing (poor)

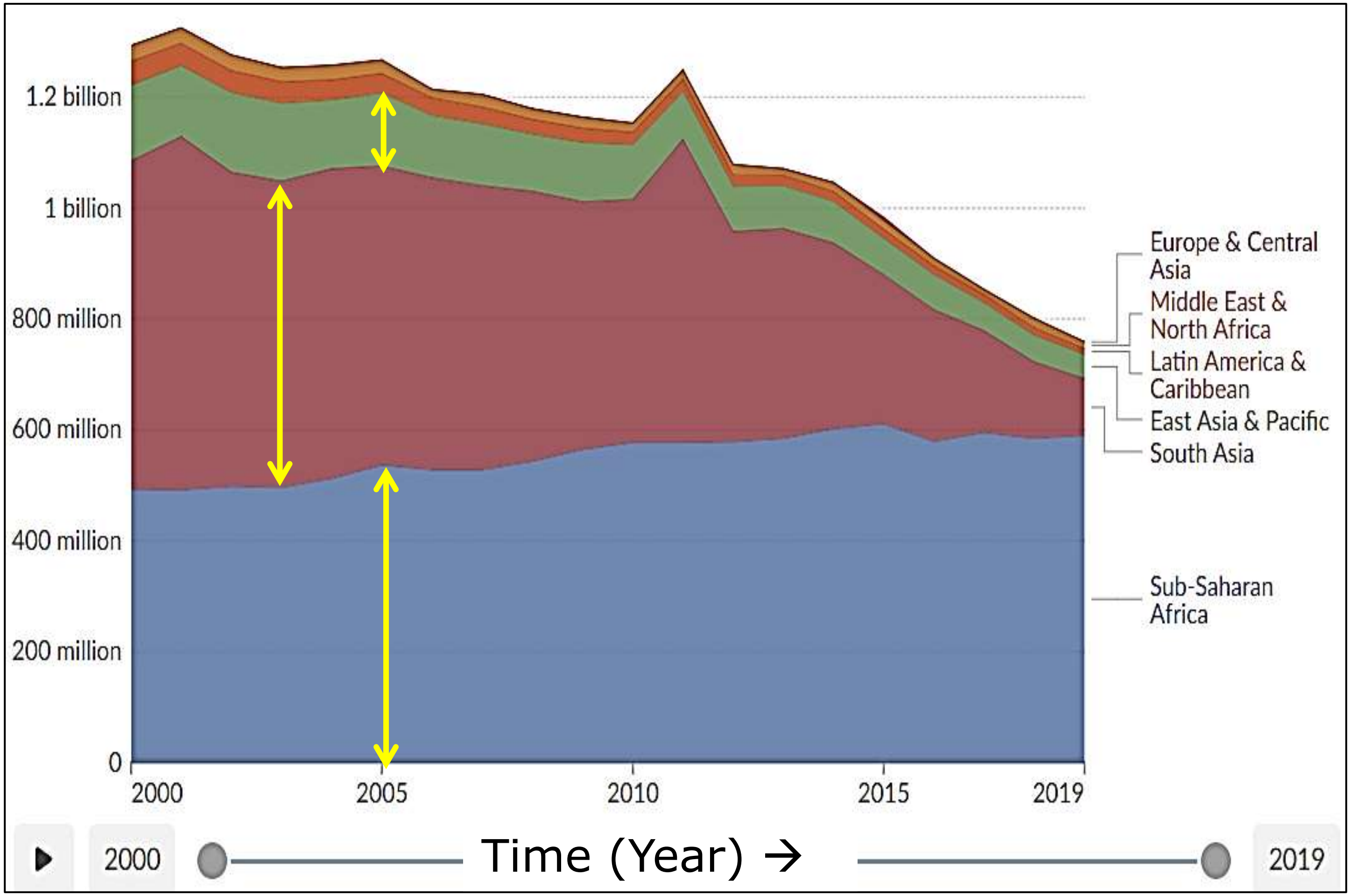
Rich countries rent arable for growing food, feed for livestock, bio-fuel,…

World: 33% arable land for lifestock feed.
Example: EU lifestock feed uses arable land = size of England.
Example Saudi U.S. rental: Arizona alfalfa farms

Reduction in SA (Argentina) forest and grass land
Much of it for soy production (new immigrants).
Massive deforestation: Rainforest in Brazil,....
in SE Asia (Indonesia,..) for oil, bio-fuels.

New: Rental of arid lands S-America for mining of Li etc. utilizing scarce water resources.

Resource Energy: Populations without Access to Electricity



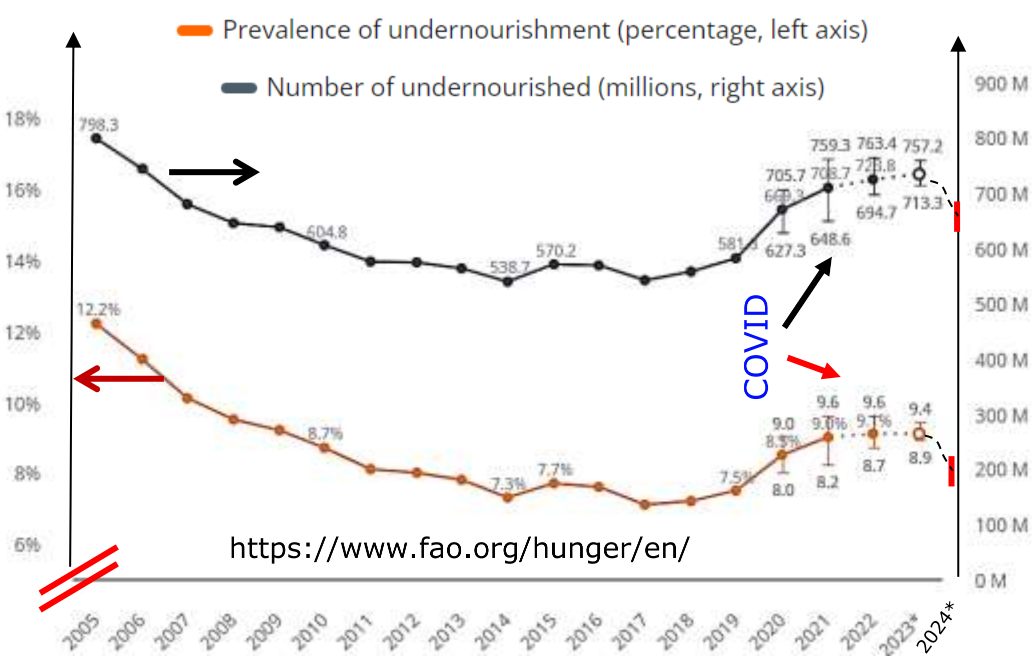
World Hunger (Dilemma: Bio-Energy Generation)

UN Food and Agriculture Organization (FAO) measures 'under-nutrition': relatively unchanged around 2015-2018. In 2018→2022 high/increased number of under nourished people to 9.8% of world population due to:

1) Covid pandemic,
2) Russia's war on Ukraine, Sudan internal war,
3) Disruption of trade.

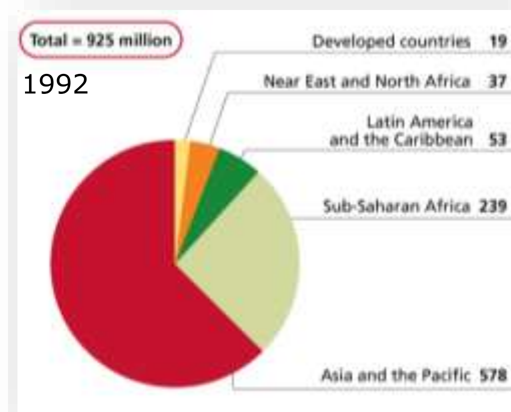
Root causes for food insecurity, hunger:

1) Mega droughts on various continents (Africa, NA, Europe, Australia)
2) Worldwide economic crisis/wars
3) Renting arable land for animal feed and biofuels



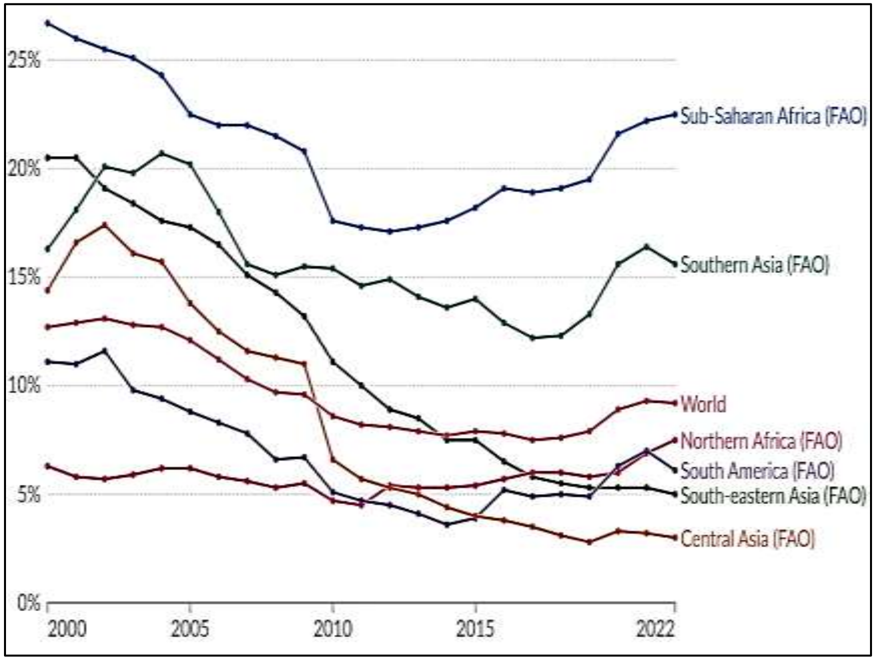
2023/24* WHO/FAO Estimates

Wars Russia, Sudan,… 2022 , Gaza 2023→



What would it cost to more fully develop poor regions? Investment, energy

Hunger Mitigation: Options/Dilemmas



Cultural options

Protect & promote rural lifestyle/liveliness

Reconcile demand with ecologically sustainable production of healthy, affordable food. → Difficult, dilemmas.

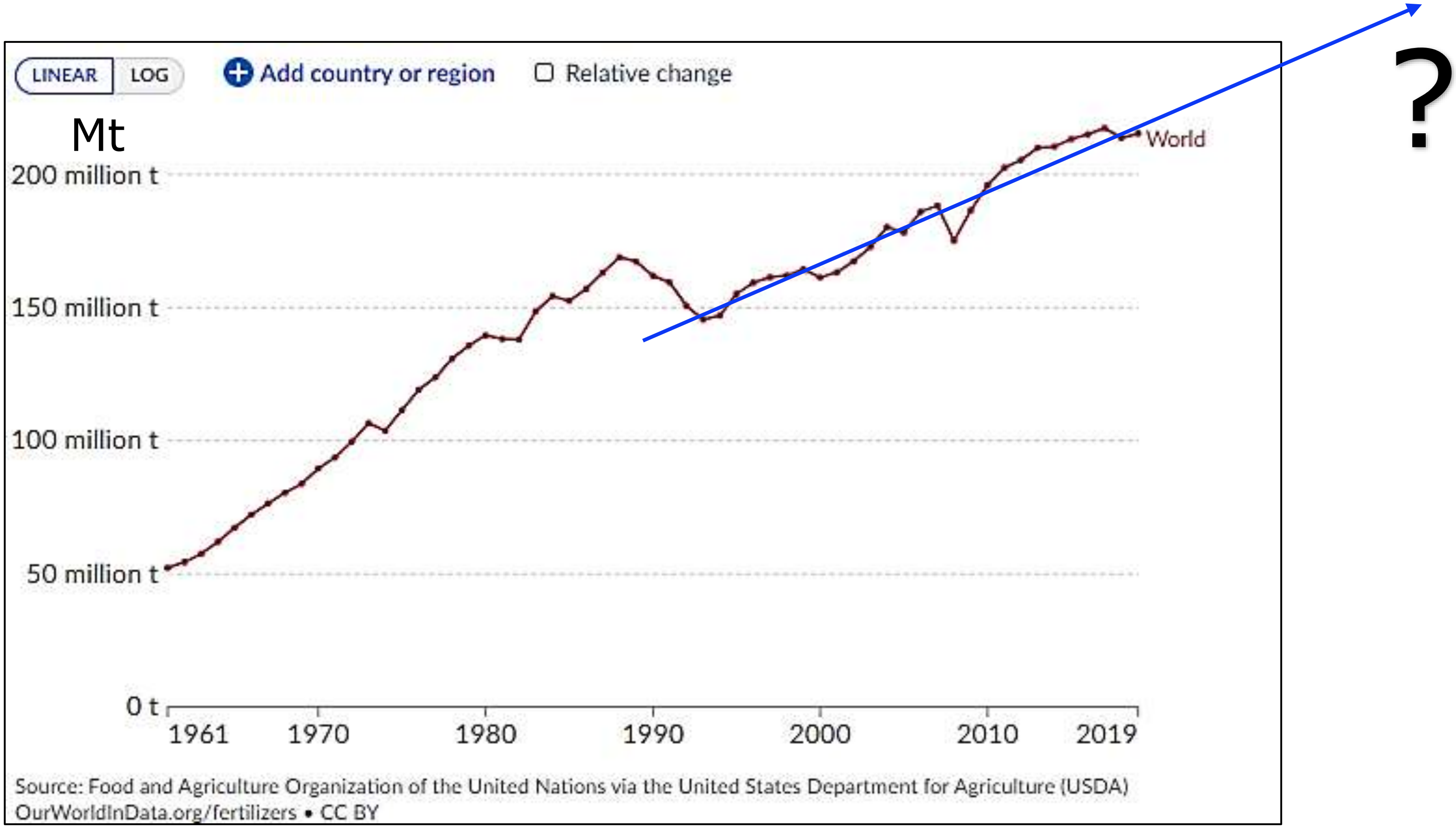
Reduce food waste in rich countries
- Improve equitable food distribution
- Invest in safe distribution systems
- Refocus use of crops on nutrition

Increase arable land
- Reduce pasture/range land
- Clear forestland/deforest
- Drain wetlands

Increase crop yield per area
- Develop new agricultural methods
- Increase autom./industr. agriculture
- Increase chemical fertilization
- Merge individual farms

Expand/refocus diet and food base
- Consume less meat/animal products
- Consume more local ag. products
- Research innovative food sources (sea weed, insects,…)

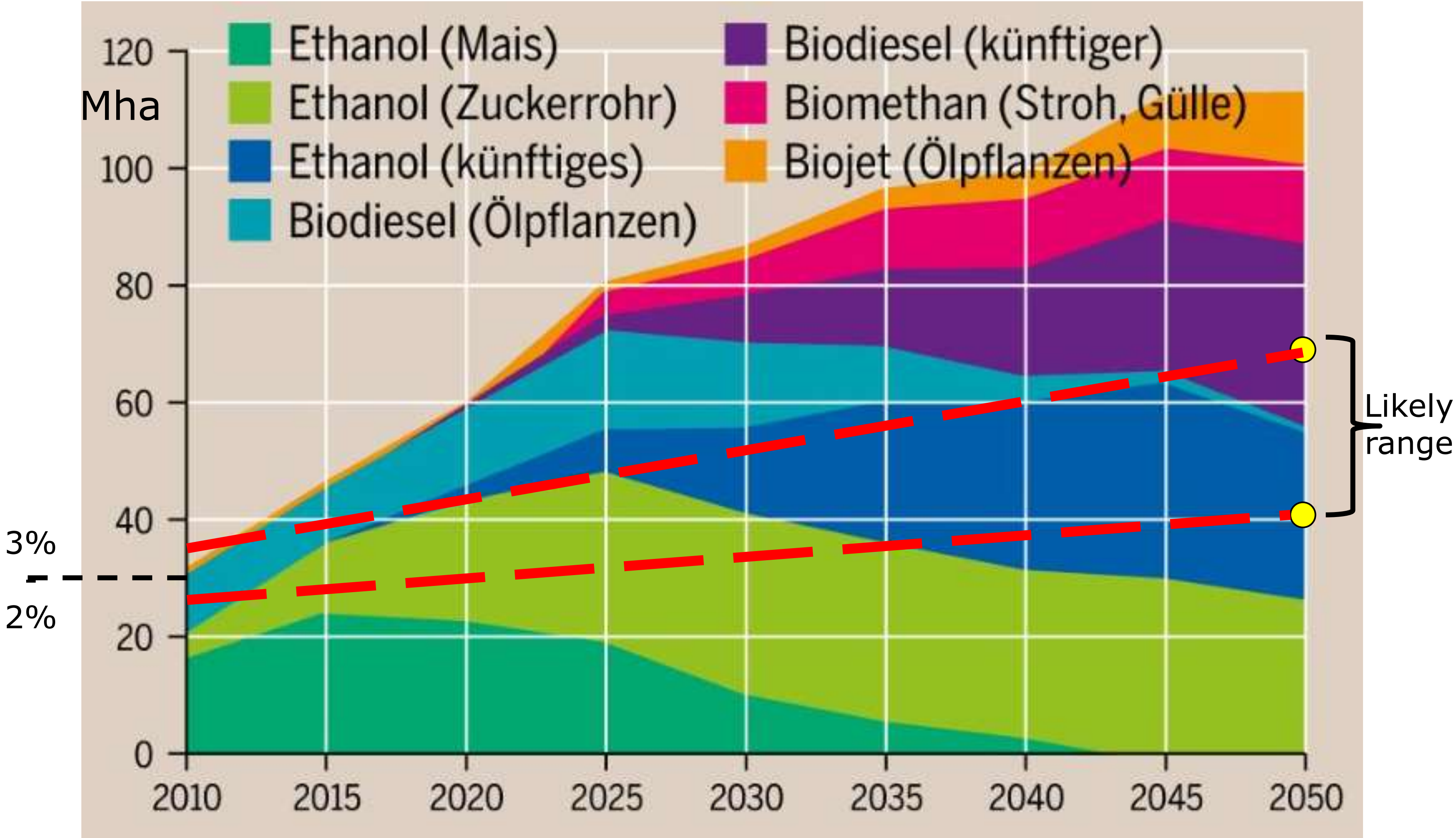
Chemical Fertilizer Consumption/Year



https://ourworldindata.org/fertilizers

Global agricultural yields keep increasing slowly but require increased use of synthetic fertilizers. Running out of natural/organic fertilizer materials (Guano, nitric), phosphate). Negative **run-off** effects for soil, marine life,…

Choices and Dilemmas: Land Use (Fuel vs. Food)



Use of arable land (Mha) projected in some policies promoting biofuels.
Competes with food, livestock feed (fodder). Scalability problem for biofuels

Socio-Economic (Ecological) Network Resource: Water

Interlinked socio-ecological system needs long-term, systems sensitive, adaptive, collaborative management.

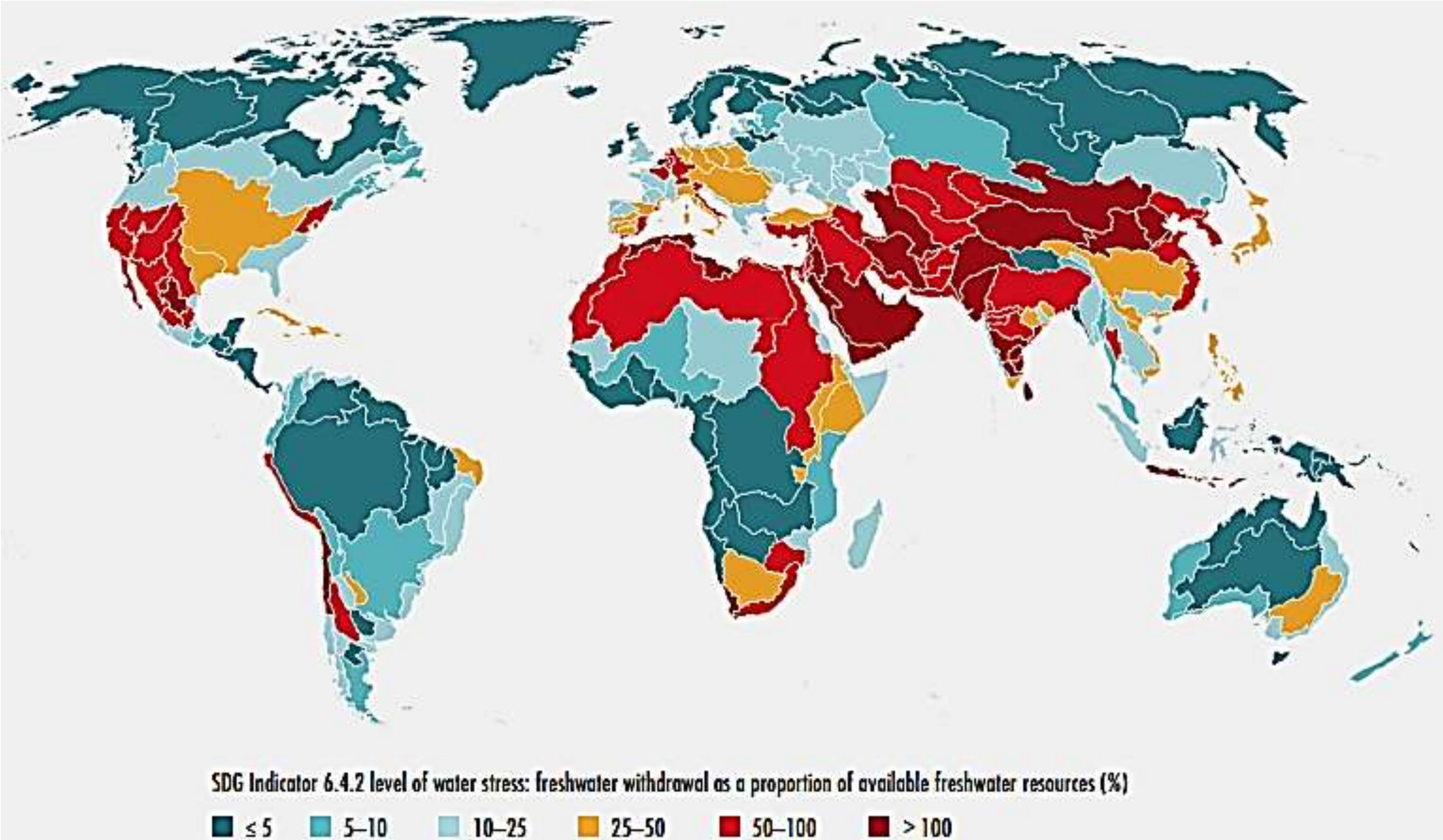
Example: Sustainably managing water resources requires consideration of

- water quantity/quality,
- connection to air quality (acid rain),
- use (food vs. bio-energy), hydro-energy vs. irrigation, wetlands,
- effect on land, urban development, drinking water, wastewater,
- electricity from hydropower ←→ fisheries, recreation,
- impacts on human health,
- cultural impact.

⇒ Present governments ill prepared (fractionation of agency tasks, competition for funds,.., **politics**), Poor Results.

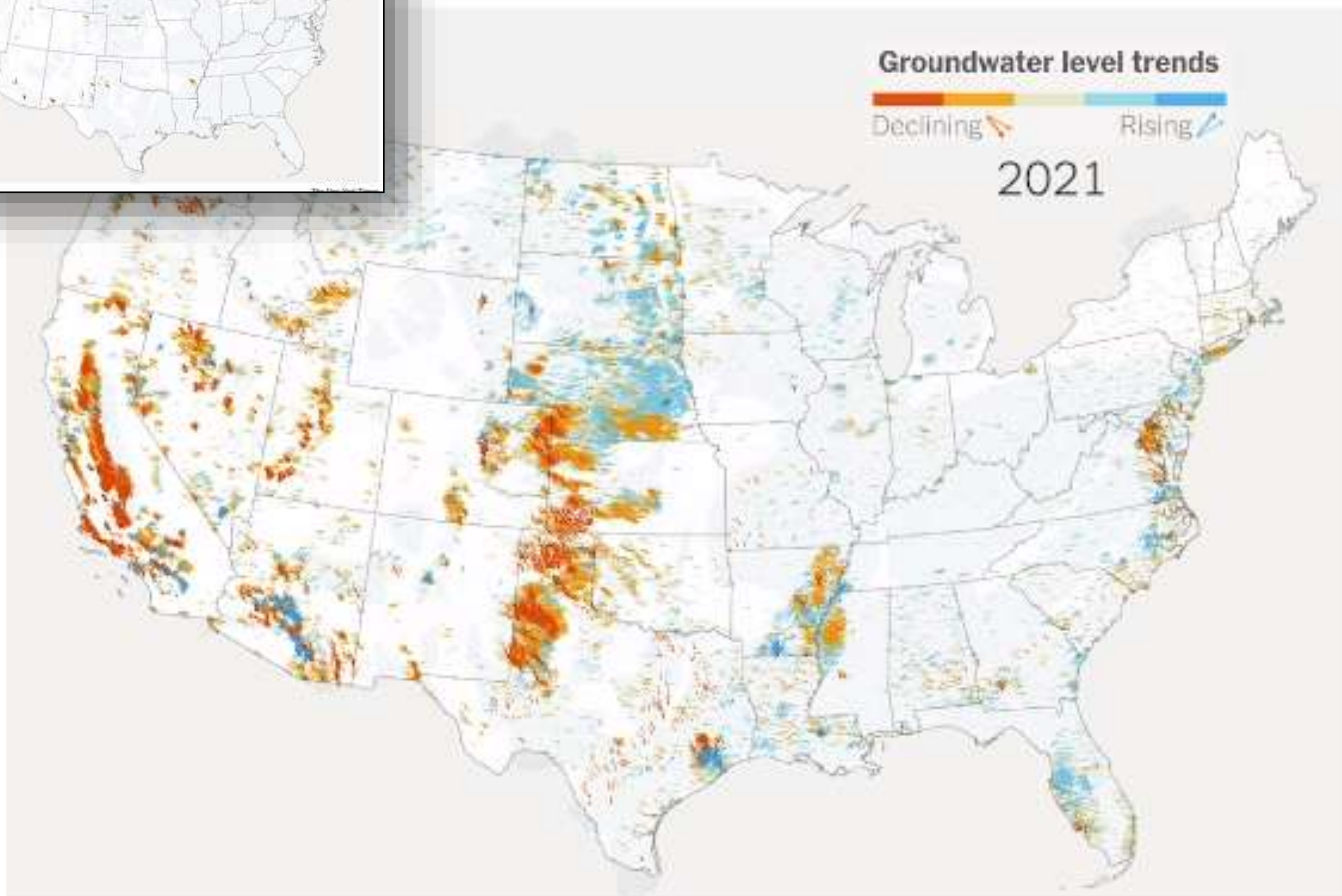
Example: Great Lakes as (US+Canada) fresh-water resource, urban development, industry,+…., Hydro-dams on large rivers (Colorado,..) Westcoast water trading, Ca ←→ OR, WA? Industrial agriculture.

Overuse of Water Resources: Stressed Aquifers



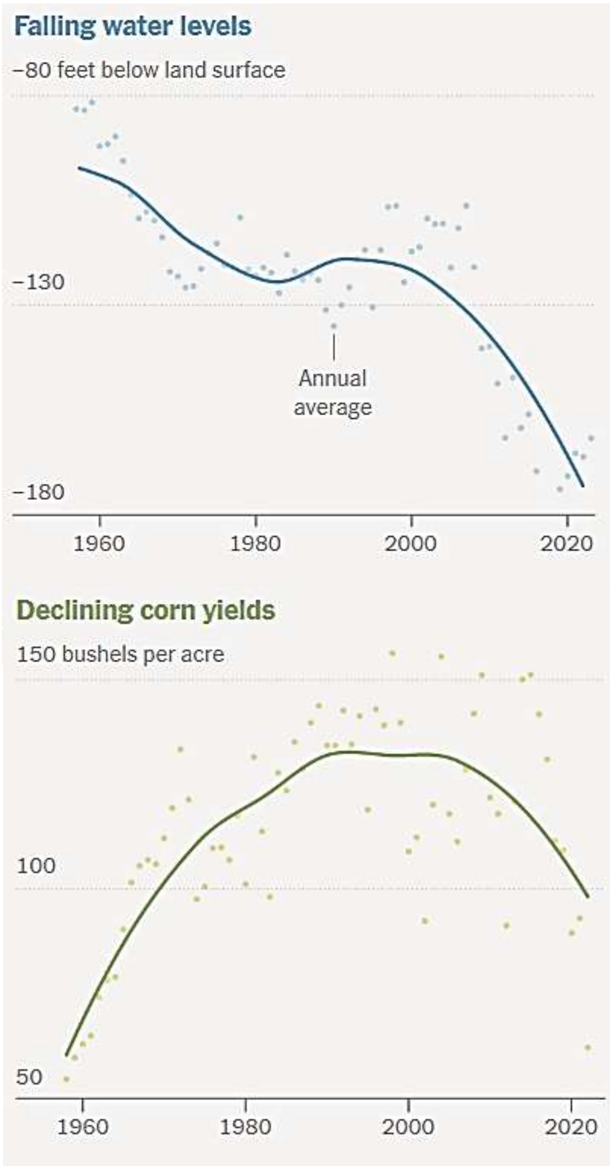
Ratio (%) between total freshwater withdrawn by all major sectors (agricultural, industrial and municipal) and total renewable freshwater resources, after considering environmental flow requirements.

Drained U.S. Groundwater



The New York Times

Cause & Consequences of Falling Aquifer Levels

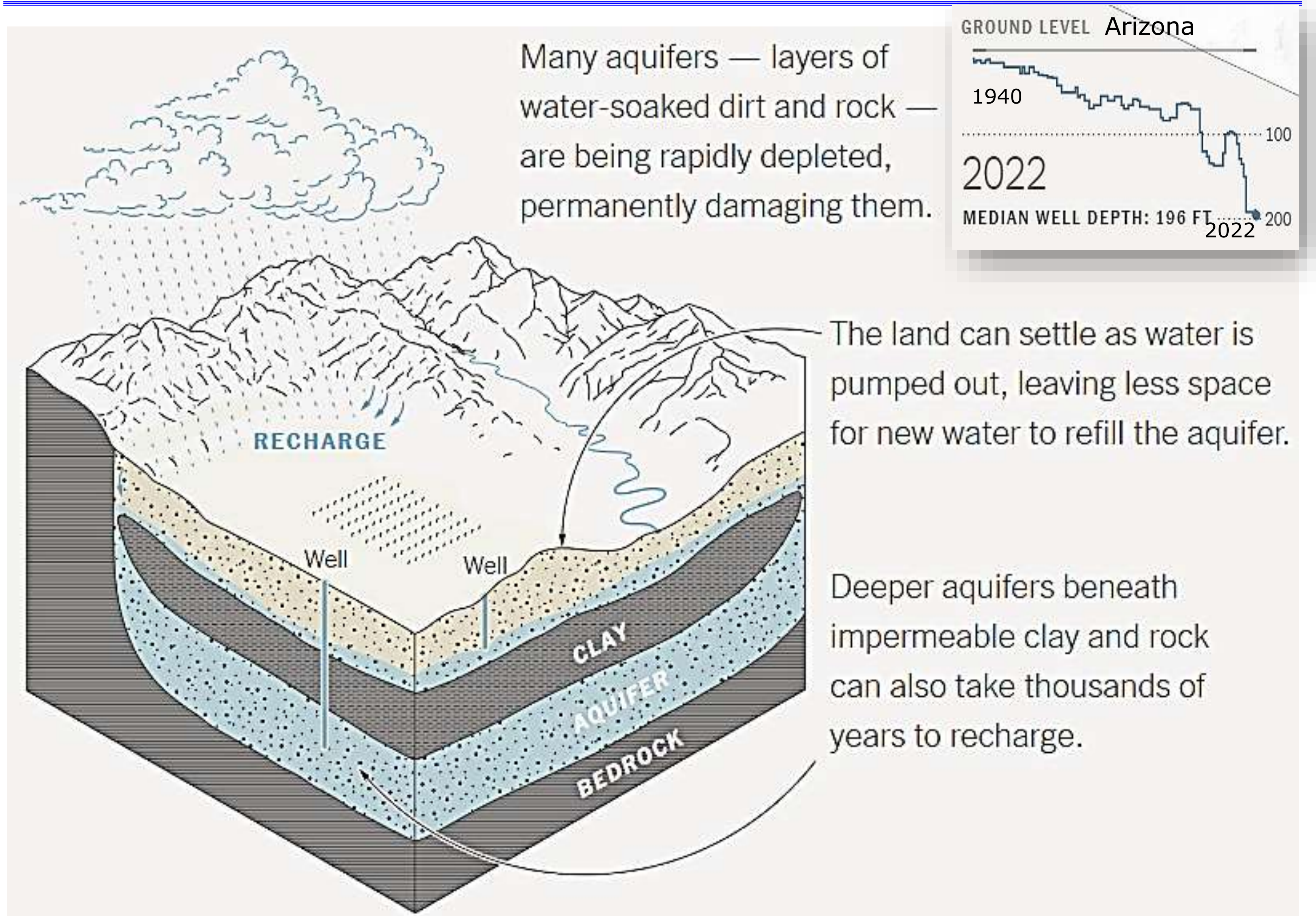


Center-pivot irrigation. Farming is a major groundwater user.

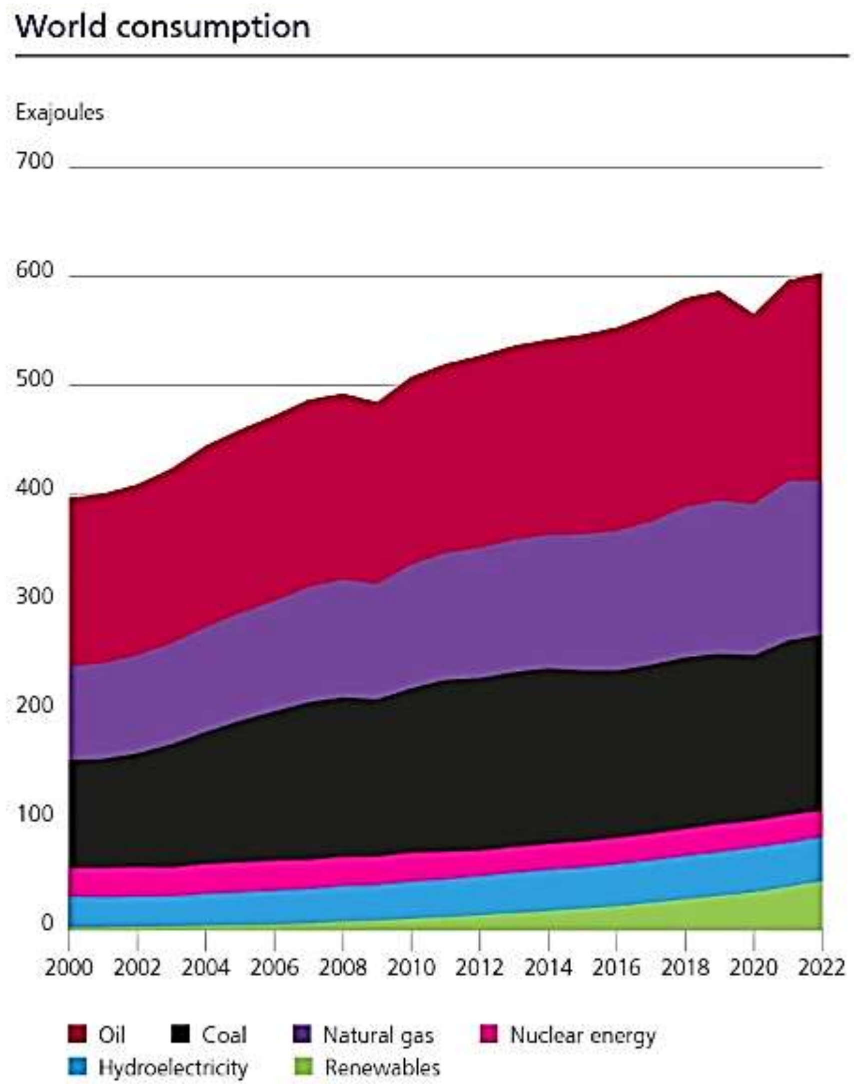
Industrial-type agriculture on the High Plains produces large fractions of global supply in several crops (corn, alfalfa, soy,…).
Feed for stock, bio-fuels, human food

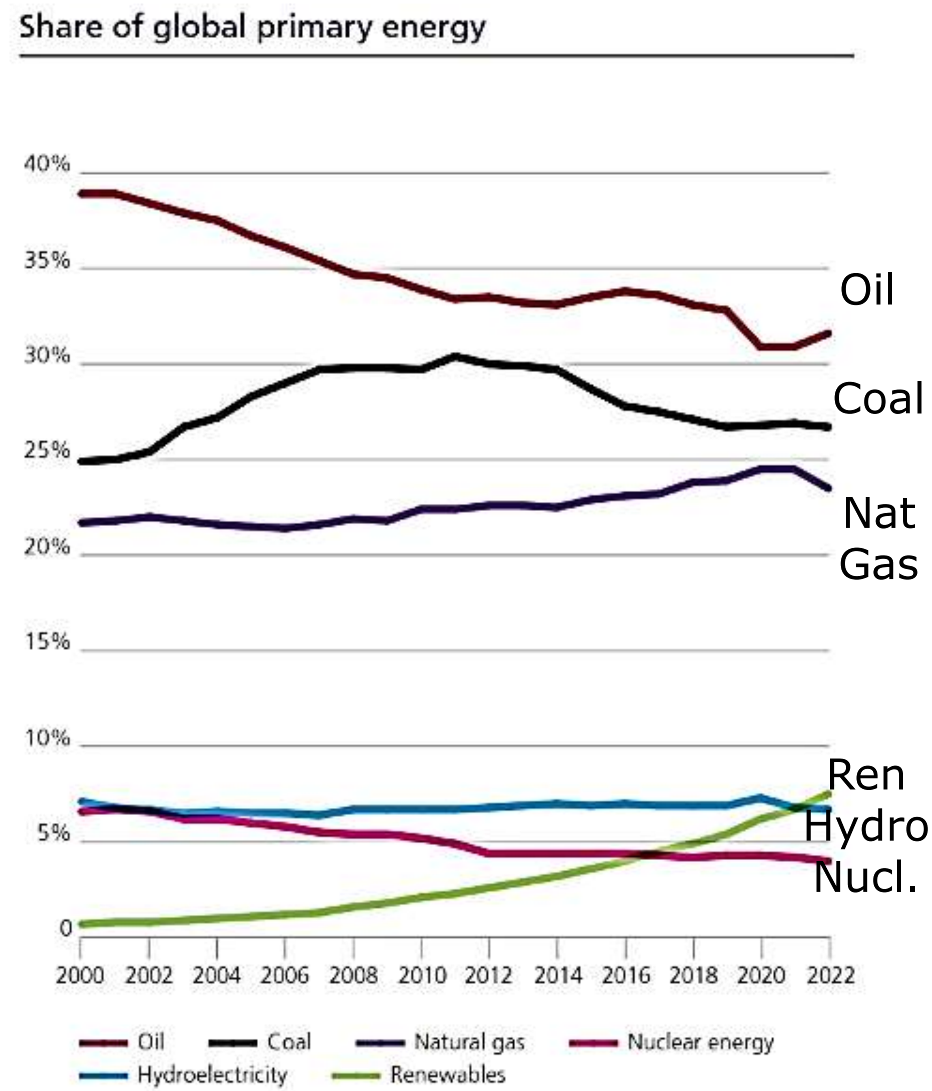
Pivotal irrigation systems hooked up to aquifers. Drained groundwater requires deeper wells, declining yields.

Tapping and Recharging of Aquifers



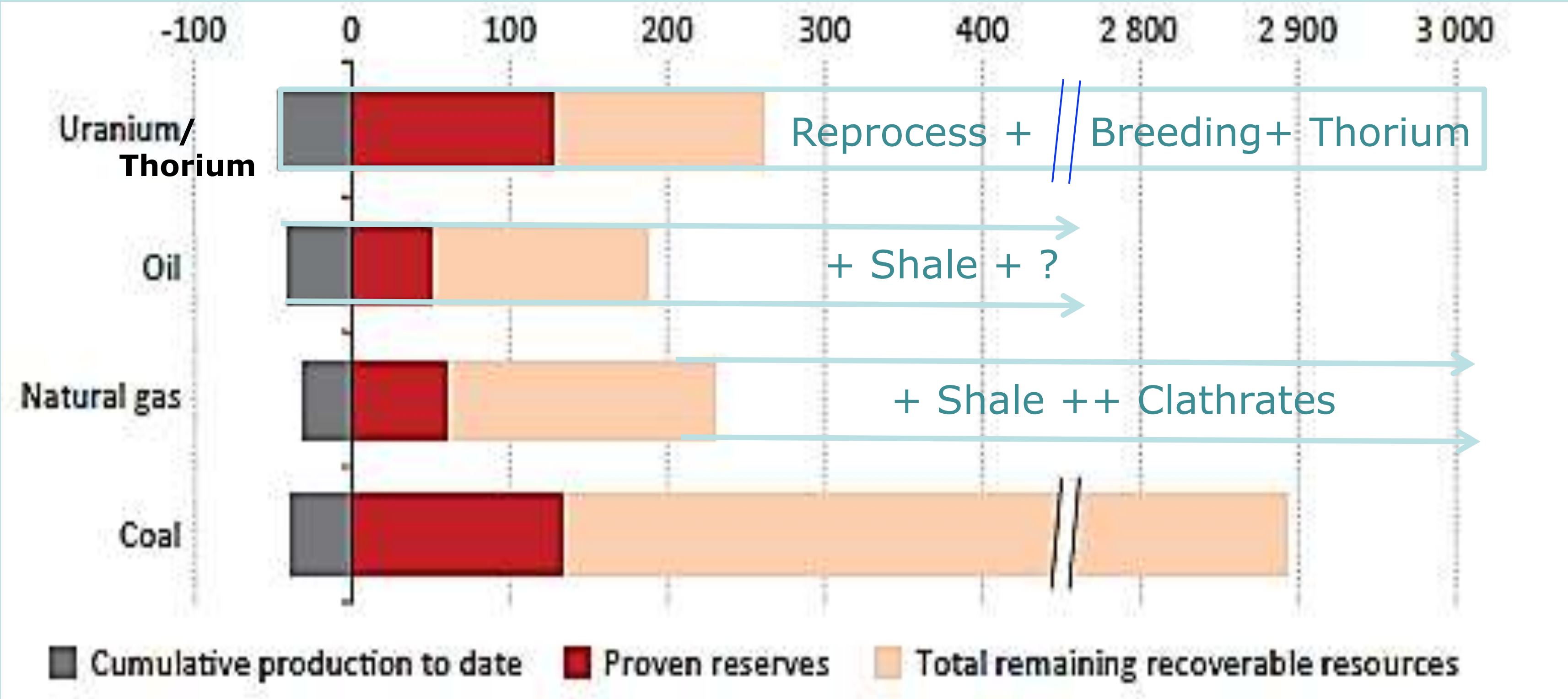
Major Resource Energy: World Consumption/a





World Primary Energy Resources/Constant Use

Use up to 2000 with current (inequitable) resource allocation

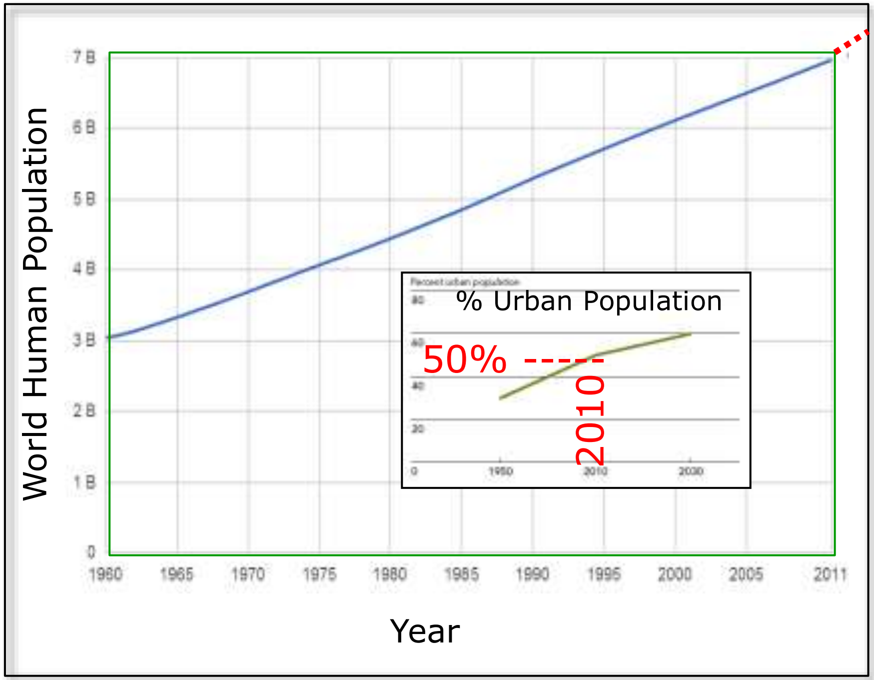


Modified after IEA World Outlook 2014, in light lettering: use reprocessing + U-238 breeding, Th 232 fertile fuel,

unconventional gas (fracking) + clathrates in frozen environments.

Neglect losses in reprocessing and breeding. Assumed present rate of consumption in future.

Testing the Limits: Human "Ecologic Footprint"



Present population: 8.0 *B* (1 Billion = $1 \cdot 10^9$) ~0.8 *B* food insecure/starving/impoverished

Estimated for 2050 → 9 B (+urbanization → more energy dem.)

Present (2022) eco-footprint of humanity ~ 1.7 Earths → global ecologic overshoot, diffuse unsustainability effect.

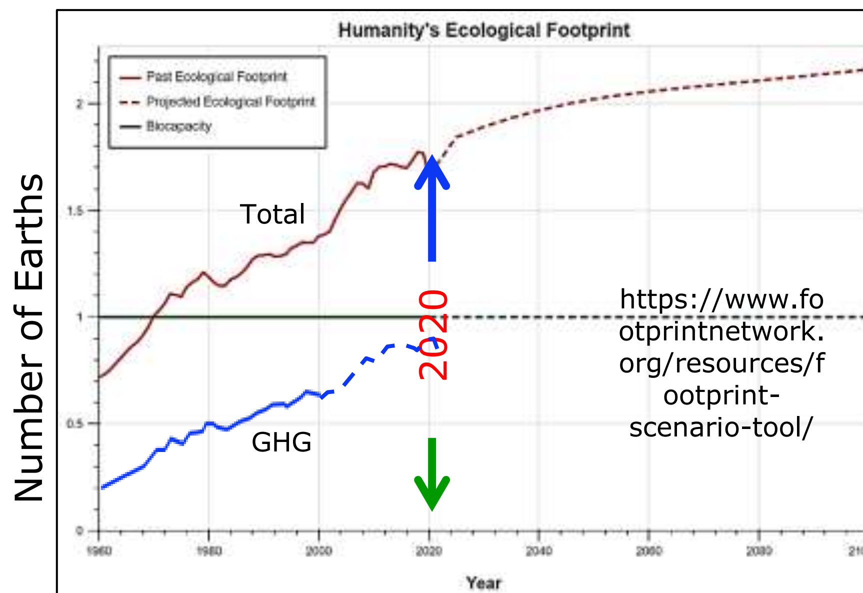
Method to estimate eco-footprint: Sum regenerative capacity (observe+model) of land w/r to maintaining resource, power production, absorbing waste.

Example (1990s): fossil fuel combustion → 6.3 Gt CO_2/a, Ocean absorbs 1.7 Gt CO_2/a

Land absorbs 1.4 Gt CO_2/a

Total absorbed 3.1 Gt CO_2/a

→ 3.2 Gt CO_2/a waste not absorbed but released to atmosphere (= measured).



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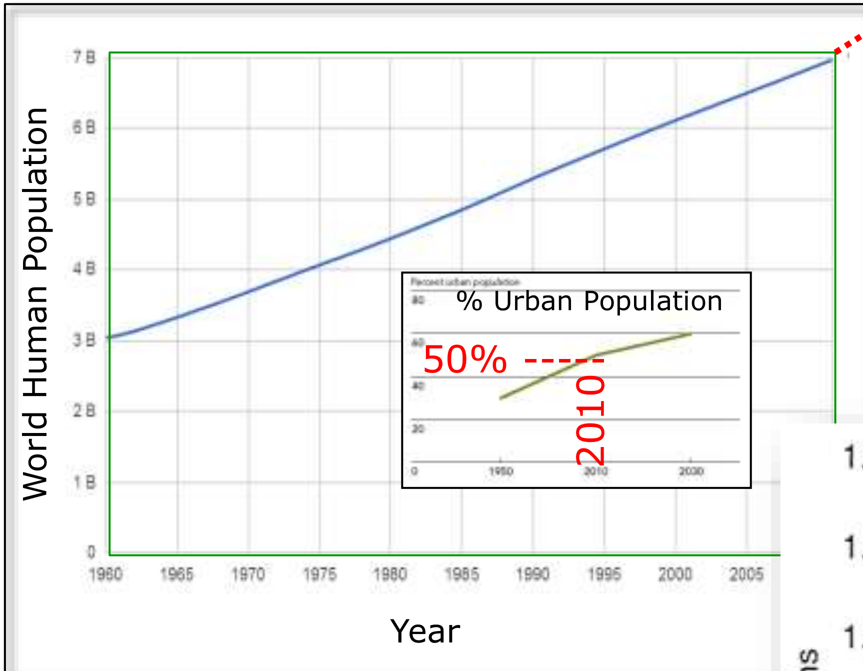
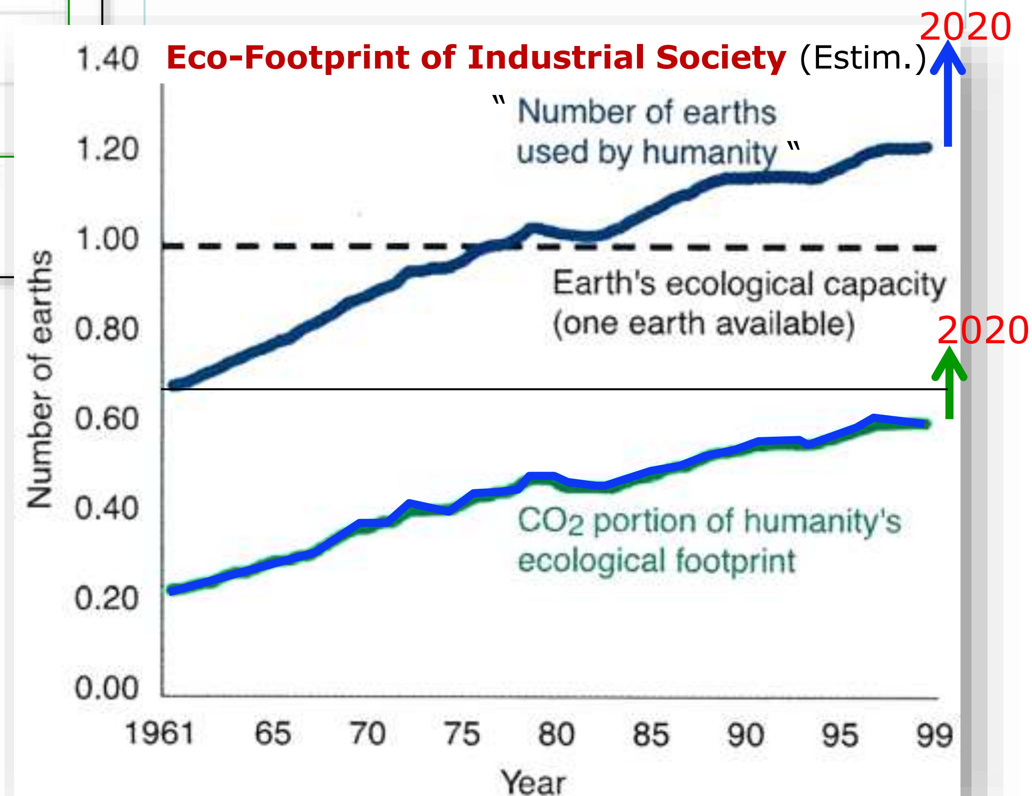


Present population: 7.9 *B* (1 Billion = $1\cdot10^9$)
~0.8 *B* food insecure/starving/impoverished

Estimated for 2050 → 9 B (+urbanization → more energy demand)

Present (2020) eco-footprint of humanity ~ 1.5 Earths → global ecologic overshoot, diffuse unsustainability effect
(not everywhere immediate impact).



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End of Sustainability 2025a