SVENSKA ARALSJÖSÄLLSKAPET

Swedish Aral Sea Society

Flows and Stocks of Resources in the Form of Energy and Materials

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Björn Frostell, professor Emeritus, KTH Stockholm

Lecture 2 in the Master Course

Sustainable Development and Sustainability Science

Spring 2024

Introduction

What are resources?

- a stock or supply of money, materials, staff, and other assets that can be drawn on by a person or organization in order to function effectively (Source: Oxford languages, 2024)
- A useful or valuable possession or quality of a country, organization or person (Source: Cambridge Dictionary 2024)

The concept resource has a quality of being something positive (normally of value for humans in a historical context). Here, the concept has a shortcoming in discussing energy and material flows that can both be of value and of harm for the physical ecologic reality we live in.

<u>Here, we use the term resources in a broader sense of Energy and Materials</u>

Our most important resource

The Sun

The Sun

Our Nuclear Reactor

Radiation reaching the Earth
= $4,4 * 10^{10}$ MW
= $1,39 * 10^{24}$ J/yr

Current Global Energy Use
= $620 * 10^{6}$ TJ
= $0,62 * 10^{21}$ J/yr

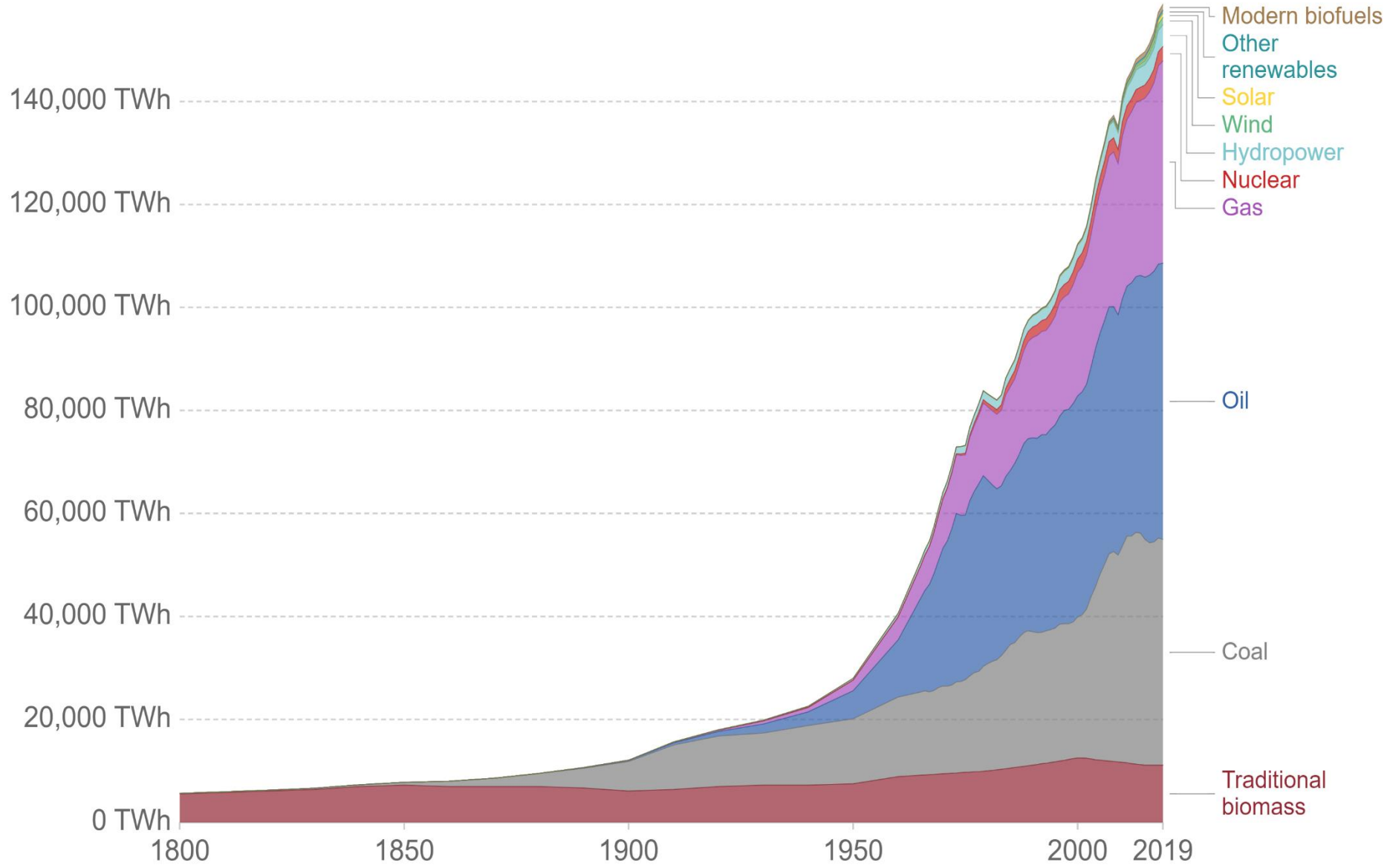
Our Nuclear Reactor the Sun gives us 2240 times more energy than current global energy use => Harvest the Sun

The Great Acceleration and the Growth Dilemma

Global direct primary energy consumption

Direct primary energy consumption does not take account of inefficiencies in fossil fuel production.

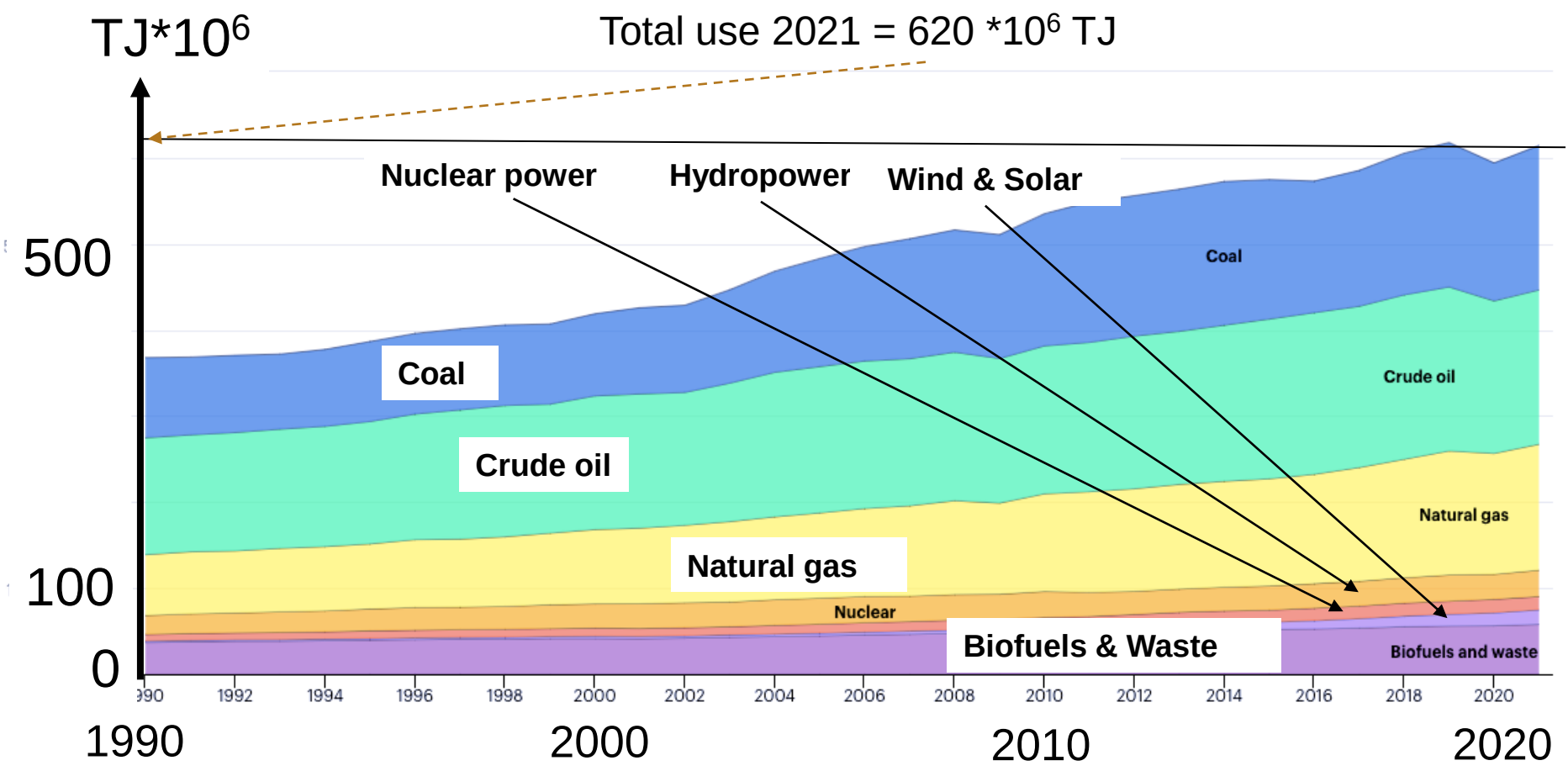
Our World in Data



Source: Vaclav Smil (2017) and BP Statistical Review of World Energy

OurWorldInData.org/energy • CC BY

World total Energy use 1990-2021, TJ



Source: International Energy Agency data browser, 2023

Something New Under the Sun

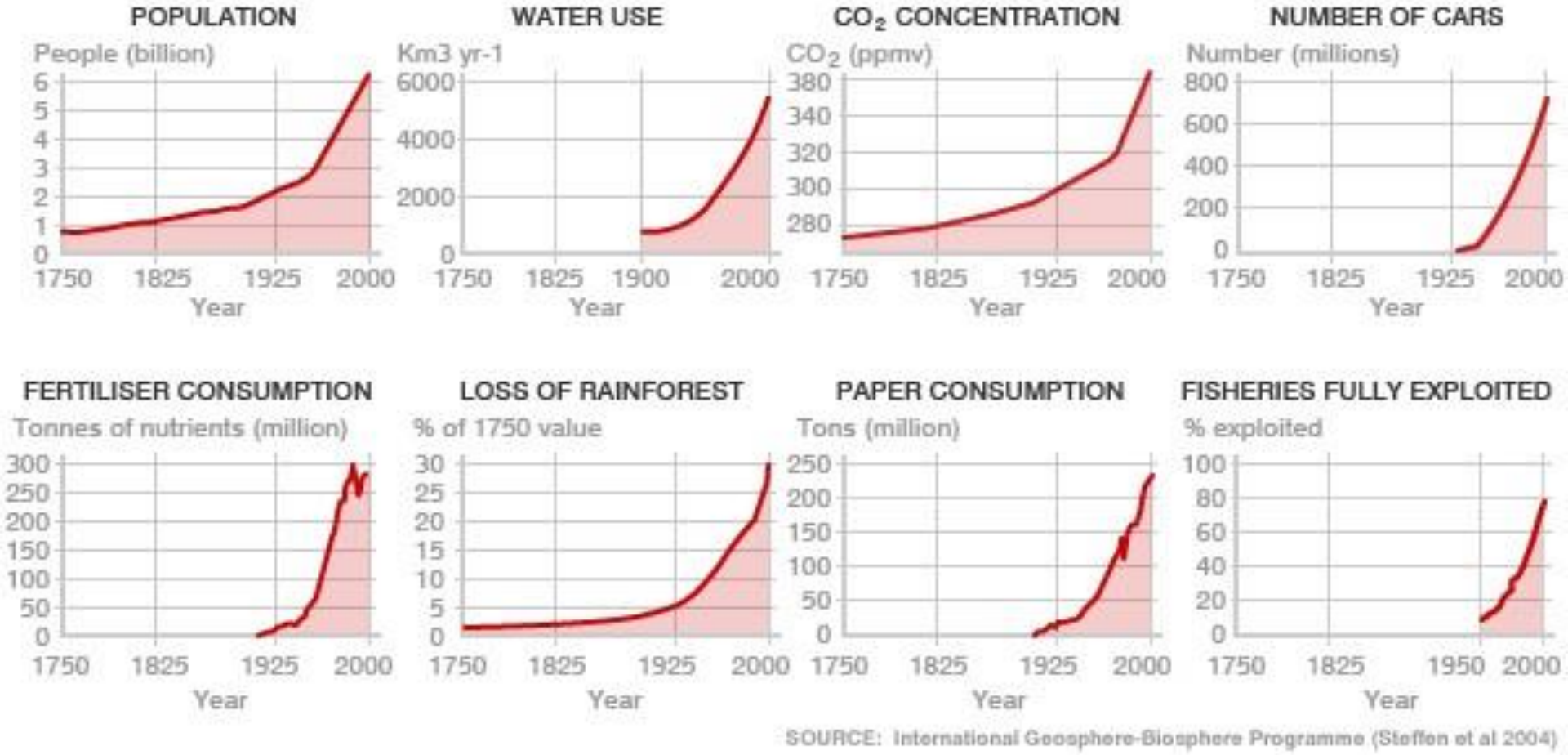
John McNeill, 2000

Development 1900 – 2000

- global population 4 x
- global economy 14 x
- industrial production 40 x
- energy use 16 x
- carbon dioxide emissions 17 x
- sulphur dioxide emissions 13 x
- ocean fishing catches 35 x
- number of pigs 9 x
- forests 0.8 x
- agricultural fields 2 x
- blue whale 0.0025 x

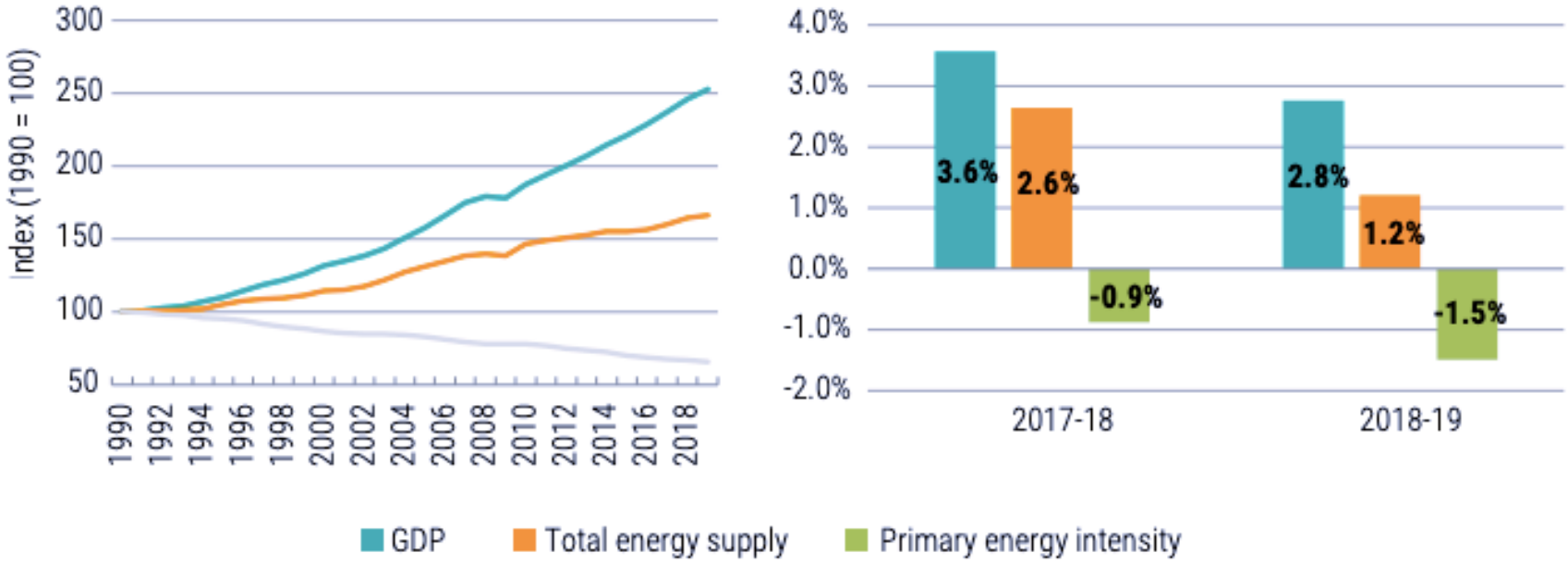
Alan Atkinson
Australian historian

Exponential Growth



A Growth Dilemma

Figure 4.3 • Trends in underlying components of global primary energy intensity, 1990–2019 (left); and growth rates of GDP, total energy supply, and primary energy intensity, 2017–19 (right)



Source: IEA, UN, and World Bank (see footnote 6).
Note: GDP = gross domestic product.

With annual GDP Growth substantially larger than improvement in energy intensity and with 80 % energy of fossil origin, overall climate pressure increases!

”We
in t
Anthrop

Non-renewable resources

Mined from the crust of the earth
They are slowly emptied

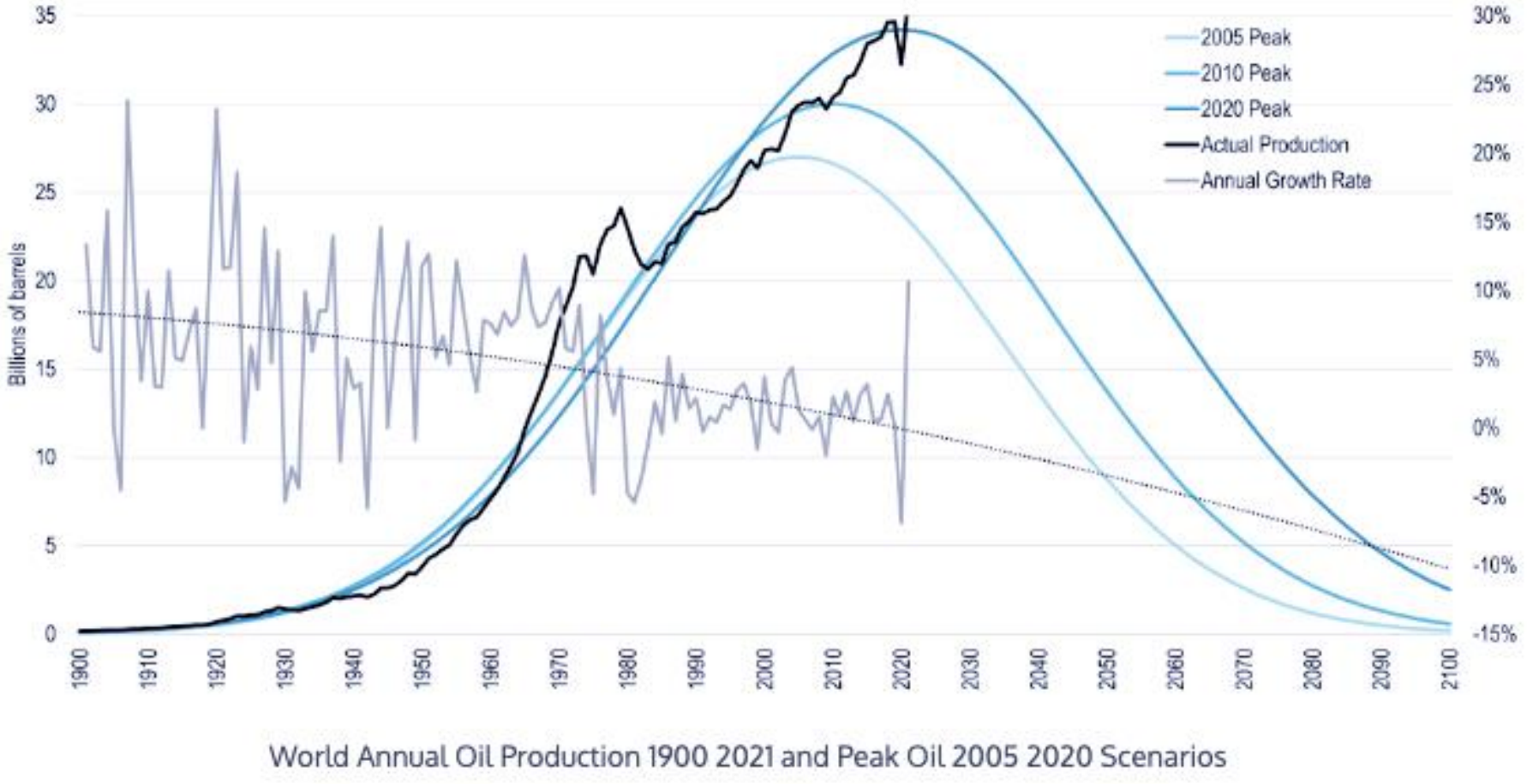
The environmental consequences
of the accumulation of the end product
will often appear before the resource is emptied.

Fossil fuels
coal, oil, gas

Lignite mining
Germany


Lignite Power Plant Belchatow, Poland

World Annual Oil Production and Expected Peak Oil Curves 1900-2100



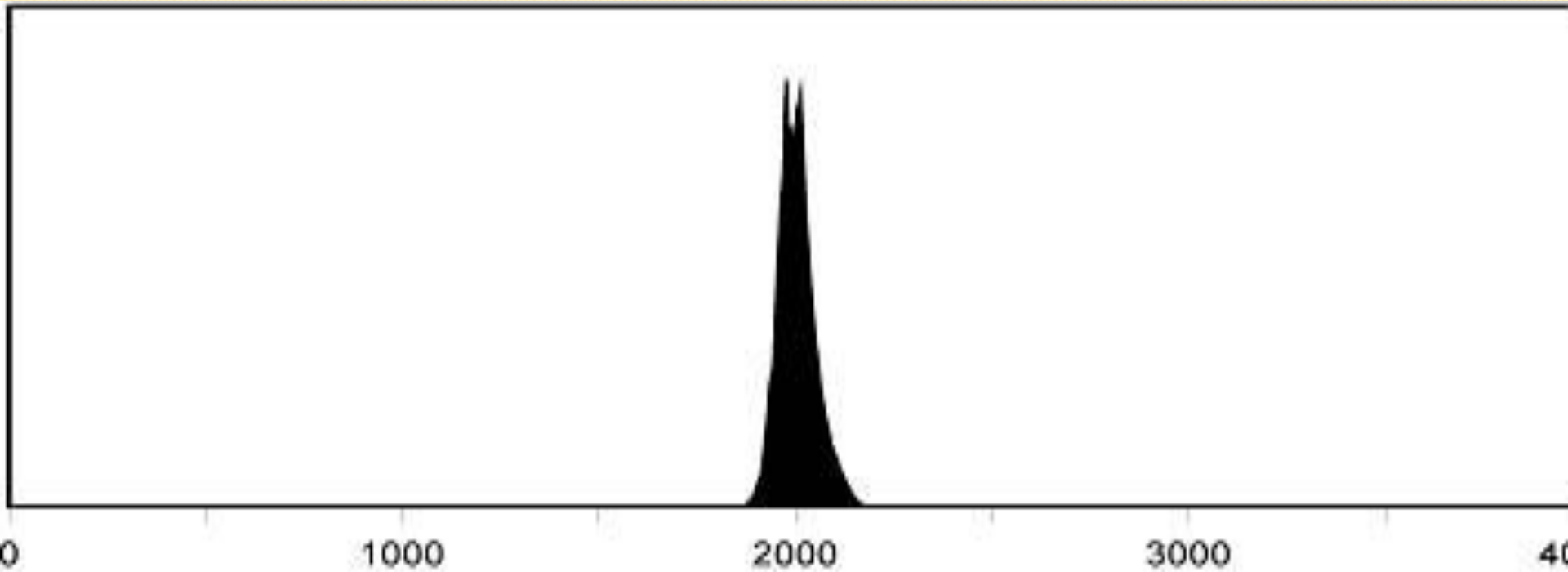
World Annual Oil Production 1900 2021 and Peak Oil 2005 2020 Scenarios

https://transportgeography.org/contents/chapter4/transportation-and-energy/peak-oil/

The future of energy

Economist.com

The end of the Oil Age



Efforts to out-phase fossils are ongoing in building sector, transport sector by developing new energy sources to combat climate change

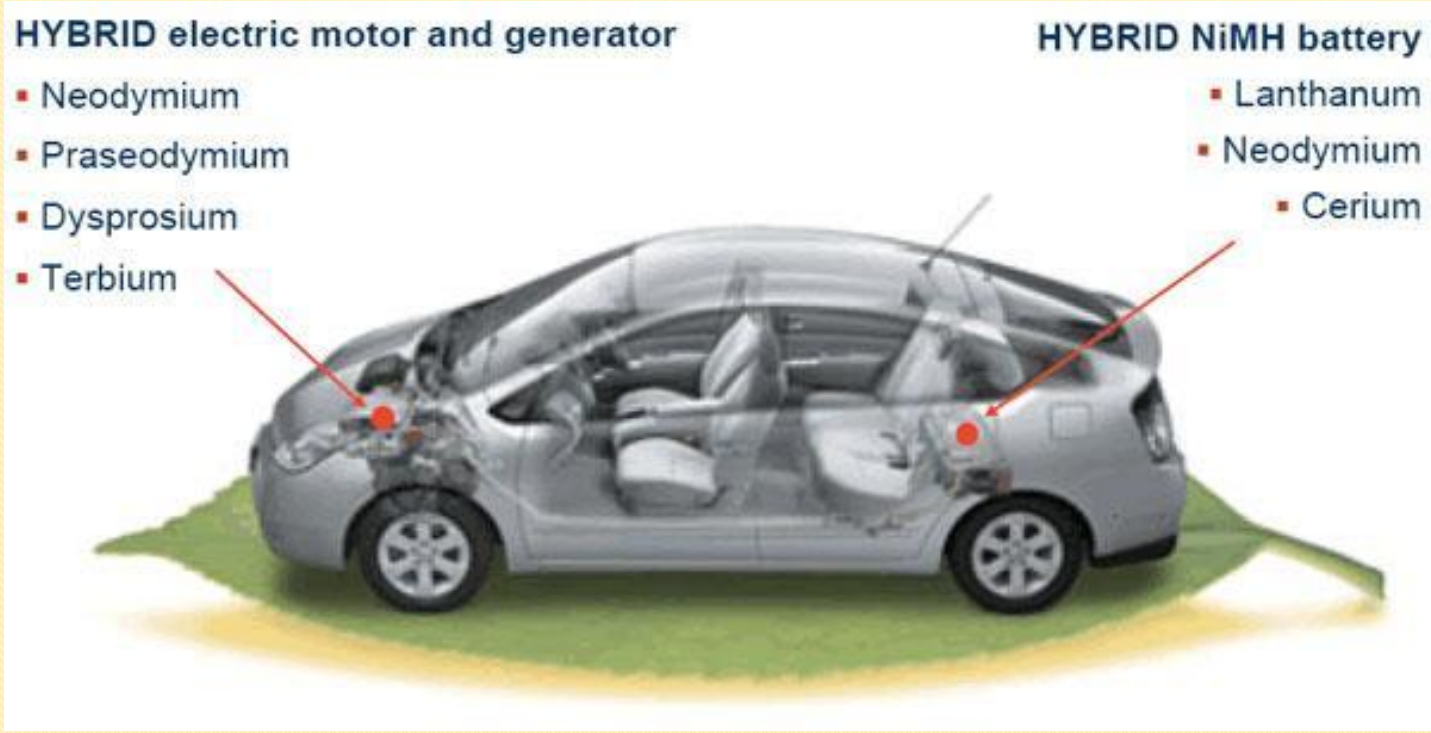
Iron mine Kiruna Sweden

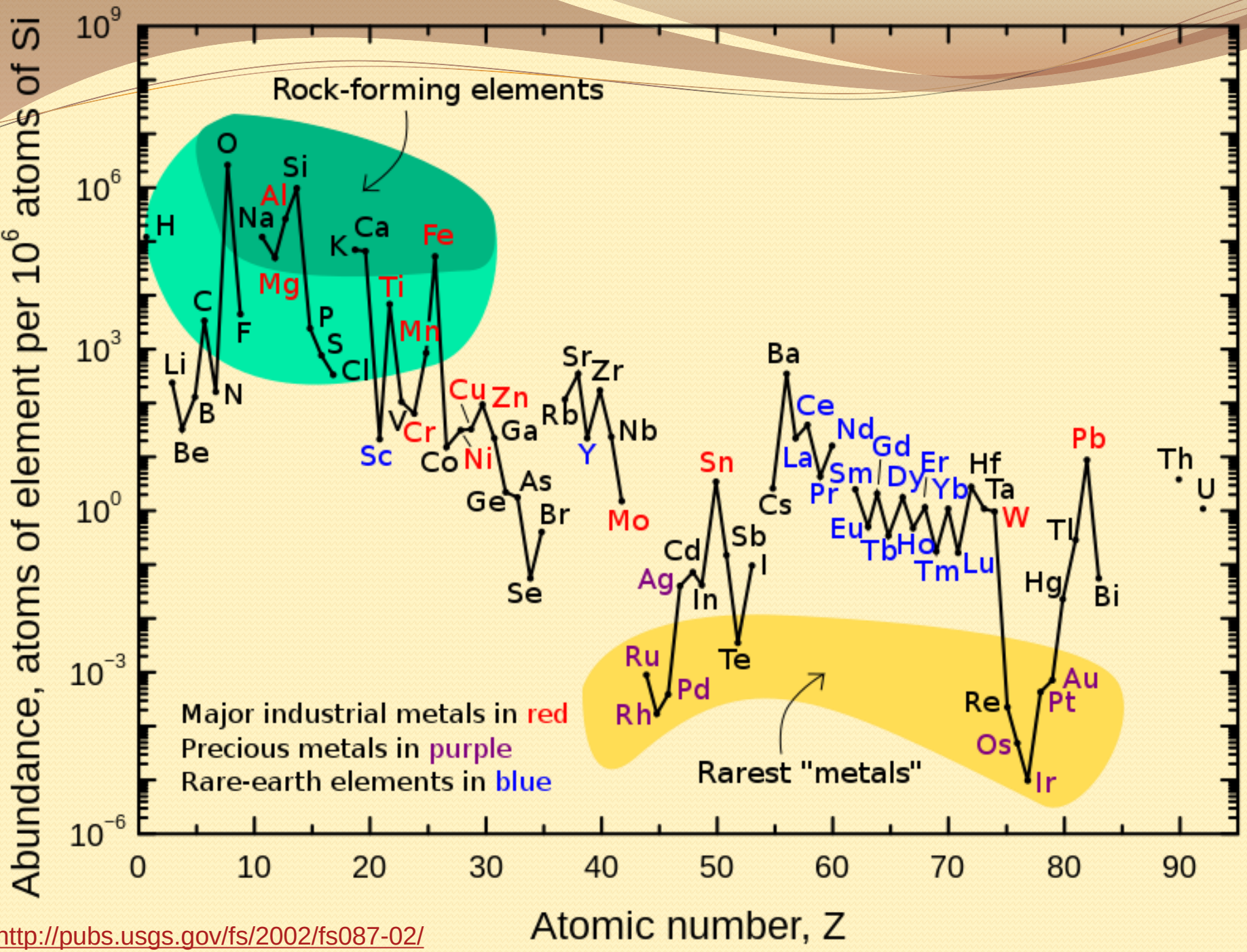
Looming crisis in rare earth metals

China produces and exports almost 70 % of the rare earth metals in the world. Virtually every developed nation in the world imports REM. Rare earths are vital to new technologies such as mobile phones, flat screen televisions and green energy technology.

Lately, REM faces declining worldwide supply and skyrocketing prices. This has worried Western governments, as rare earth metals are also key to high tech military applications.

Hybrid technology is totally dependent on Rare Earths





http://pubs.usgs.gov/fs/2002/fs087-02/

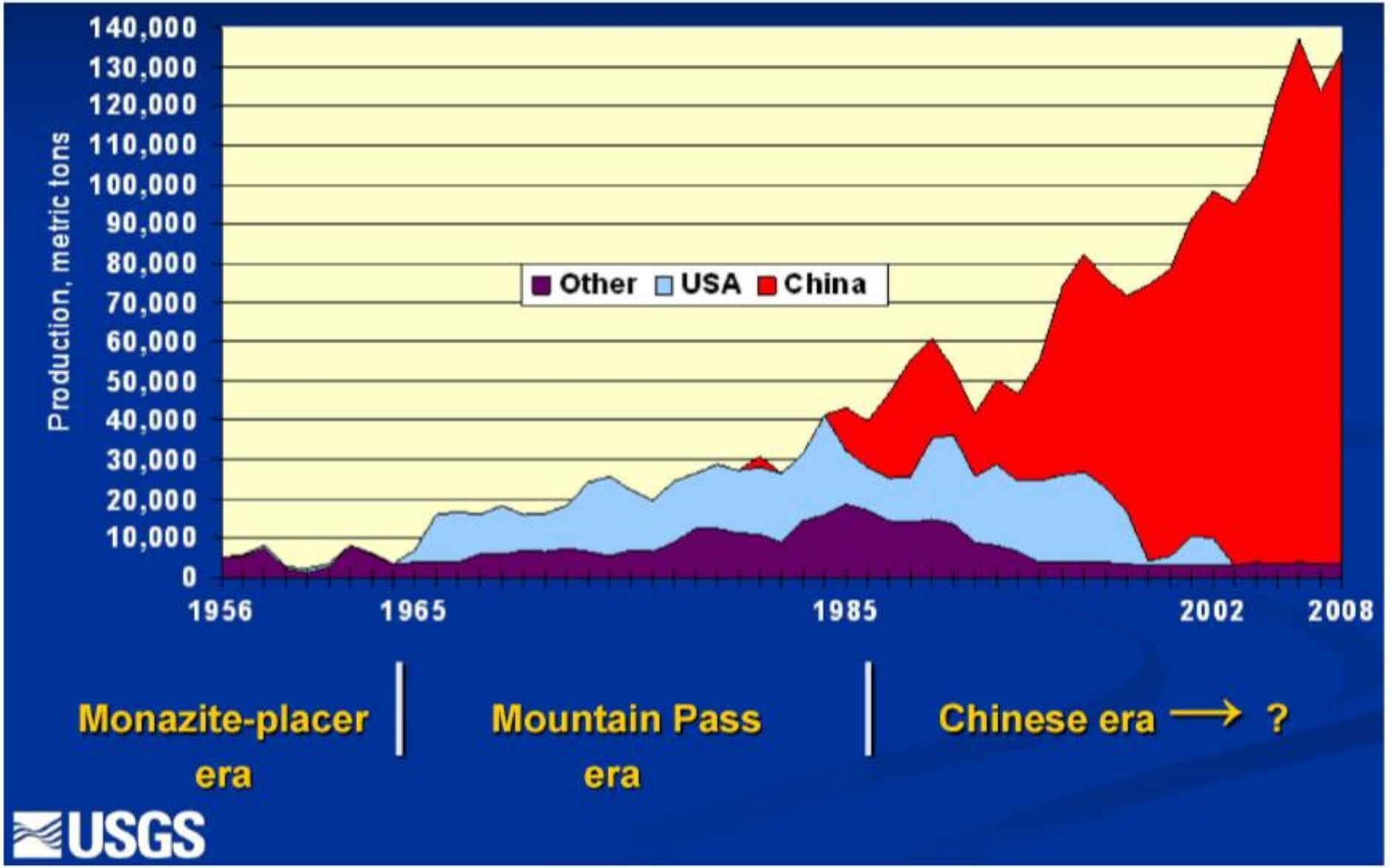
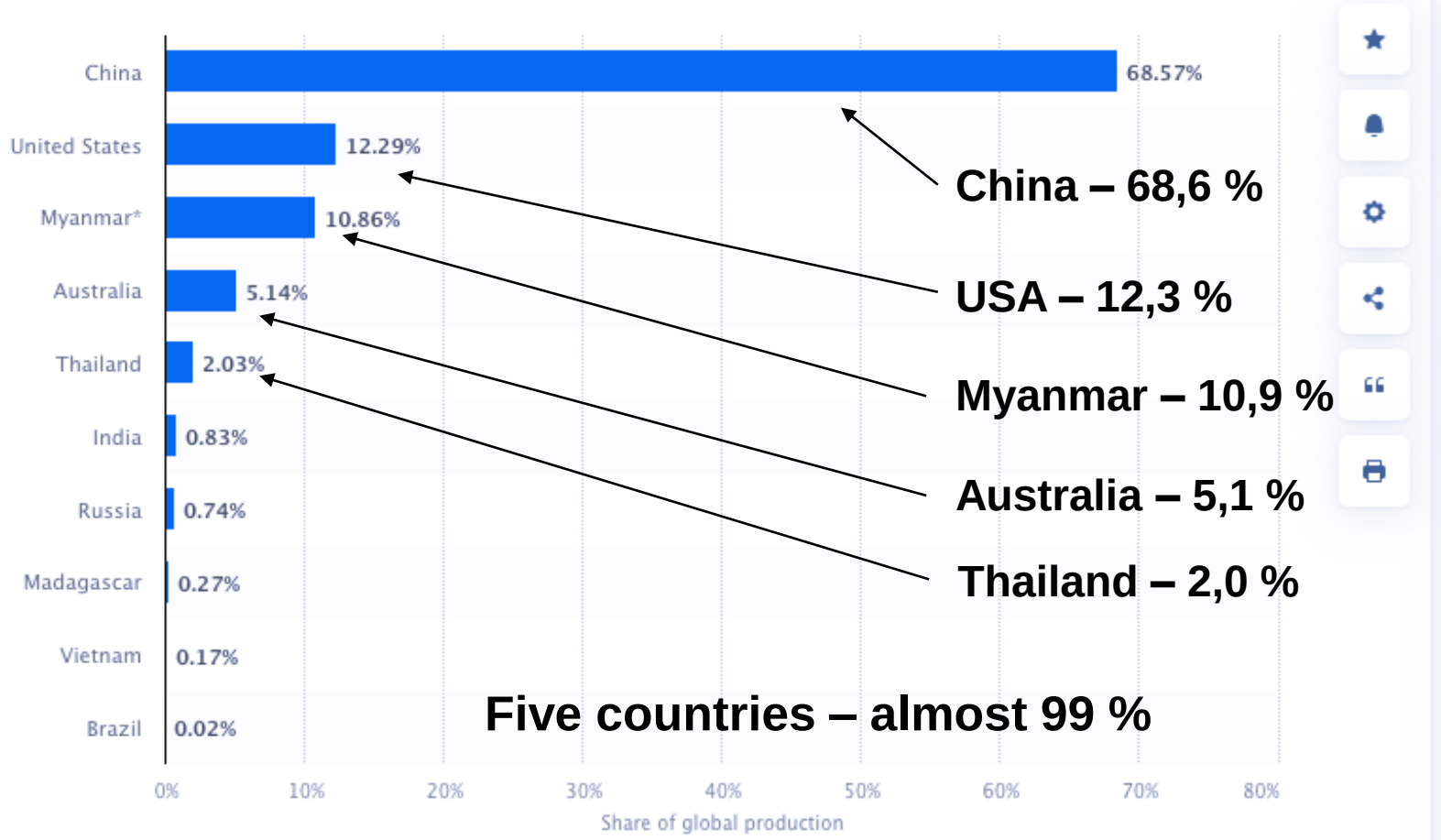


Figure 1. Global rare-earth-oxide production trends. The Mountain Pass deposit is in California, U.S.A. Graph from D.J. Cordier (U.S. Geological Survey, written commun., 2011) was updated from Haxel and others (2002, fig. 1).

Source: Global rare-earth-oxide production trends, 1956-2008 (USGS)

Global Production of Rare Earth Metals in 2023 – most important countries



Recycling of non-renewable resources – metals

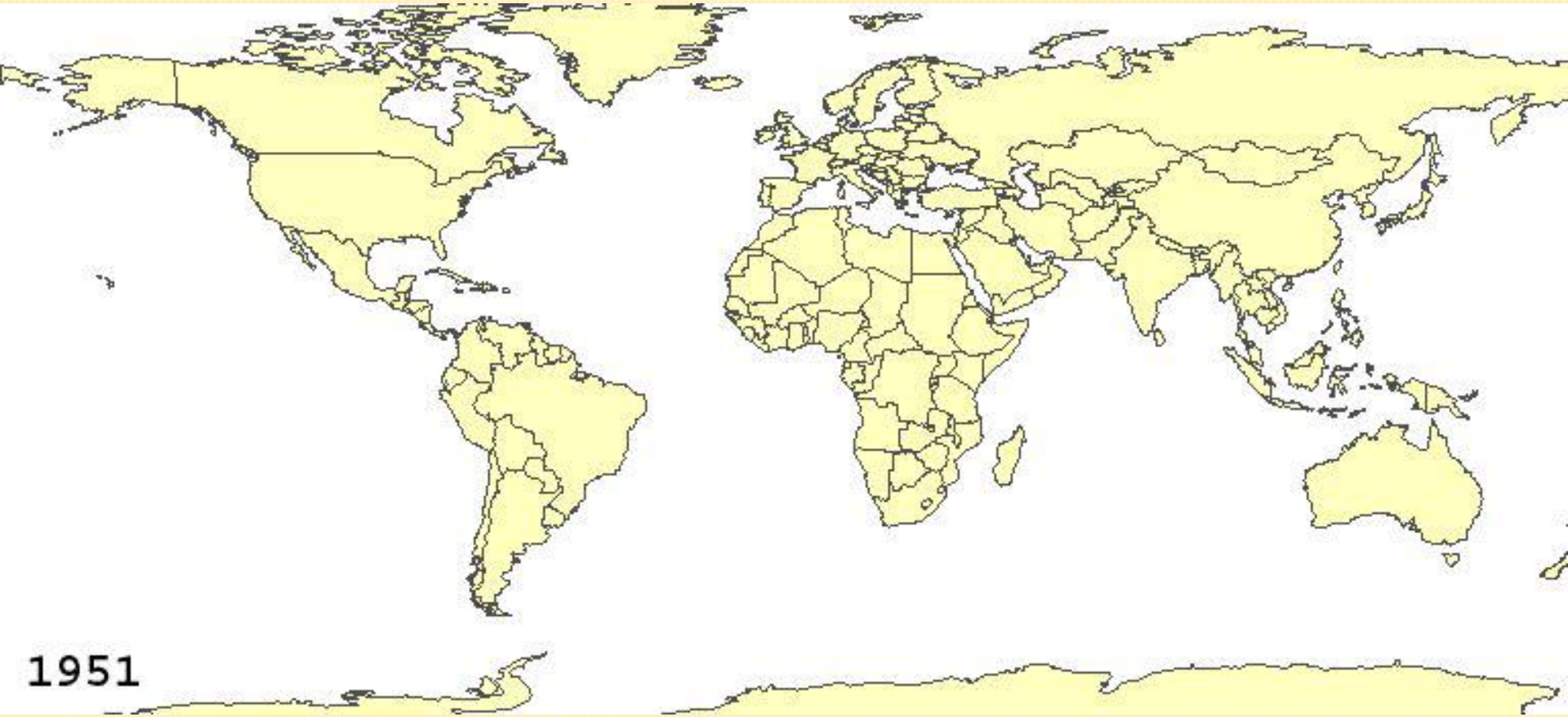
- **Steel** is today increasingly produced from scrap iron and some virgin metal
- Recycled **copper** is paid well
- **Lead** recycling is requested by law and is >99 %
- **Mercury** is taken out of use and stored
- Rycycling of **REM** has to be improved

Renewable resources

These resources cannot be harvested faster than the reproduction rate; also renewable resources can be depleted and emptied!


FISHERIES

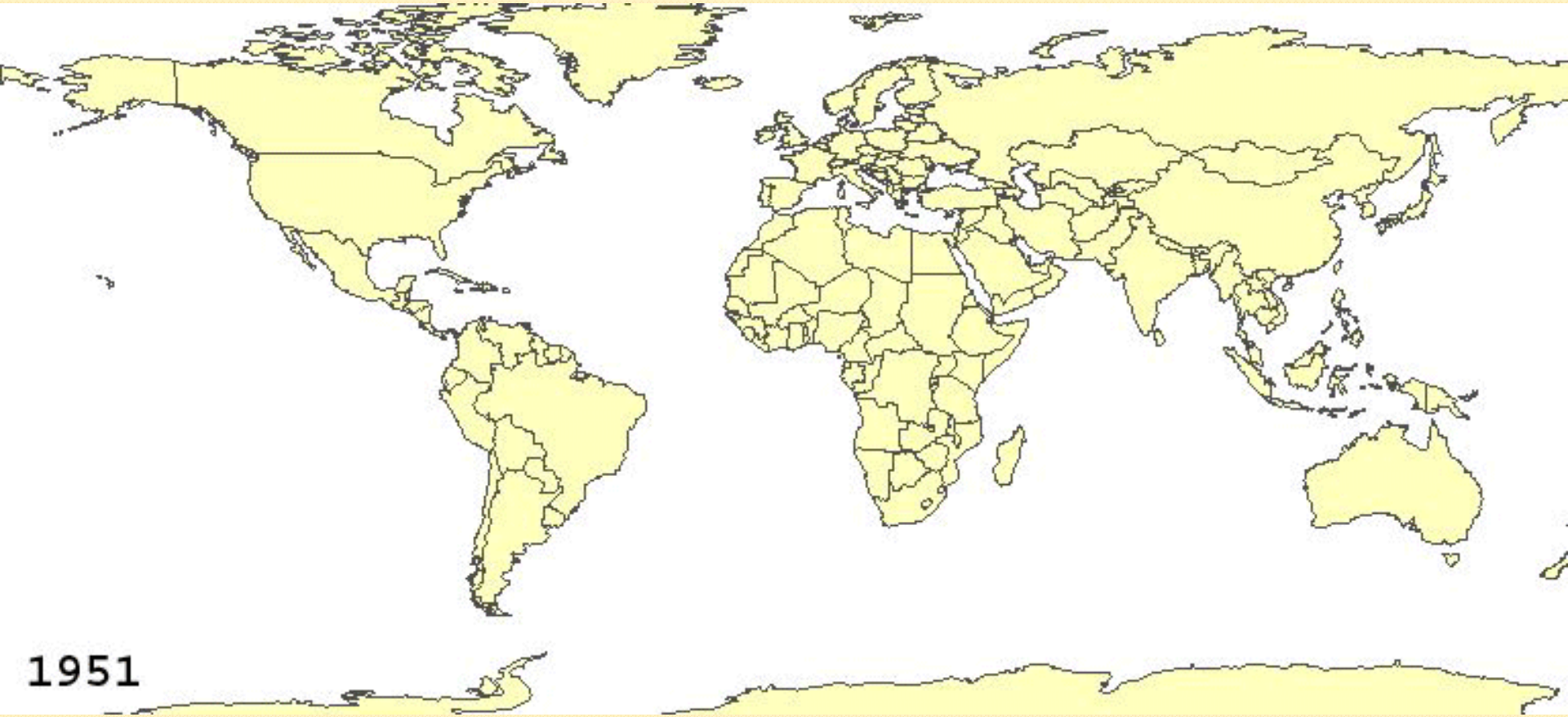
Fisheries



Year of Peak Fish Harvest

- Pre-peak
- Harvest peak
- Post-peak

Source: Millennium Ecosystem Assessment and Sea Around Us project



Year of Peak Fish Harvest

Pre-peak

Harvest peak

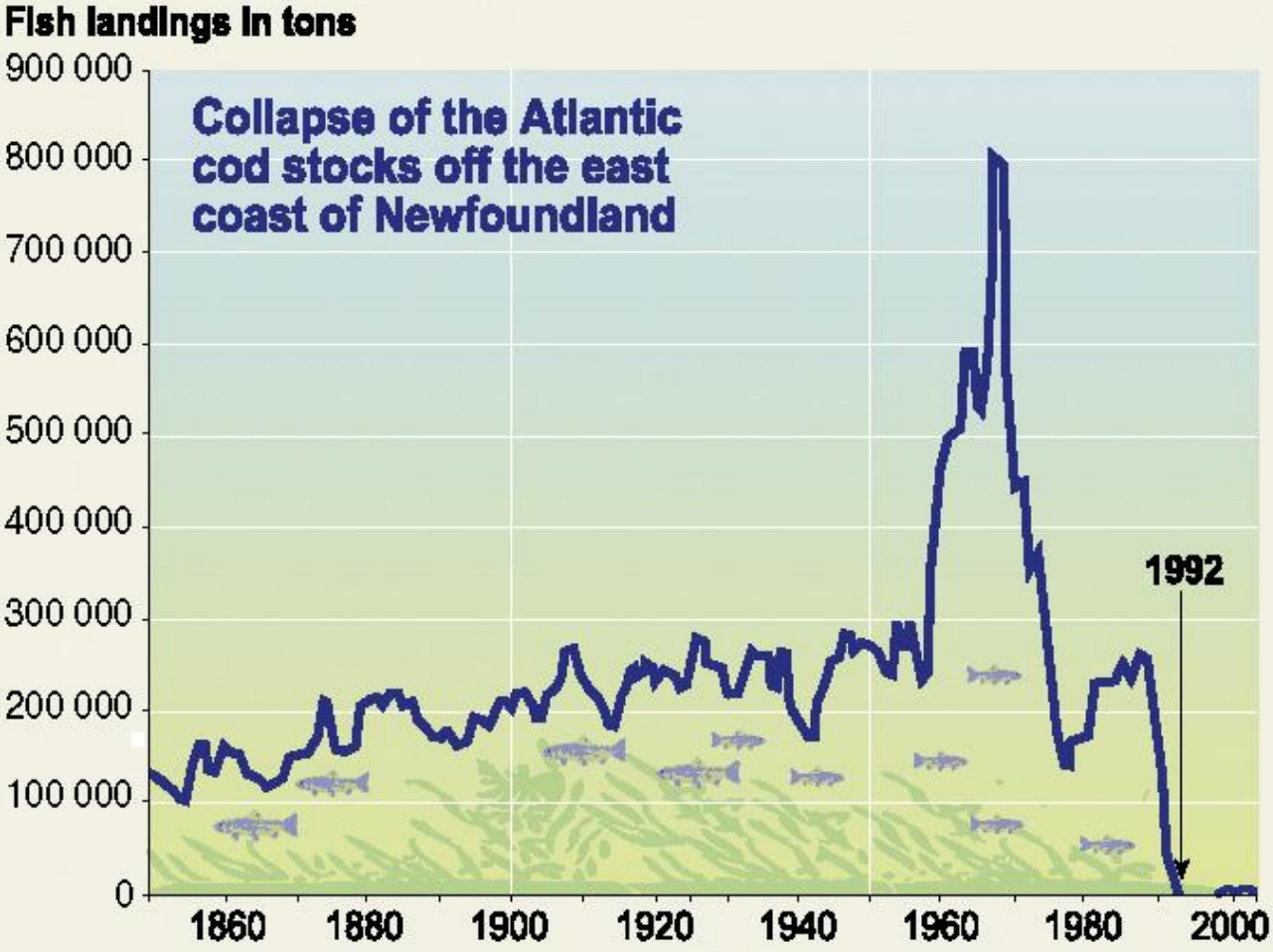
Post-peak

Source: Millennium Ecosystem Assessment and Sea Around Us project

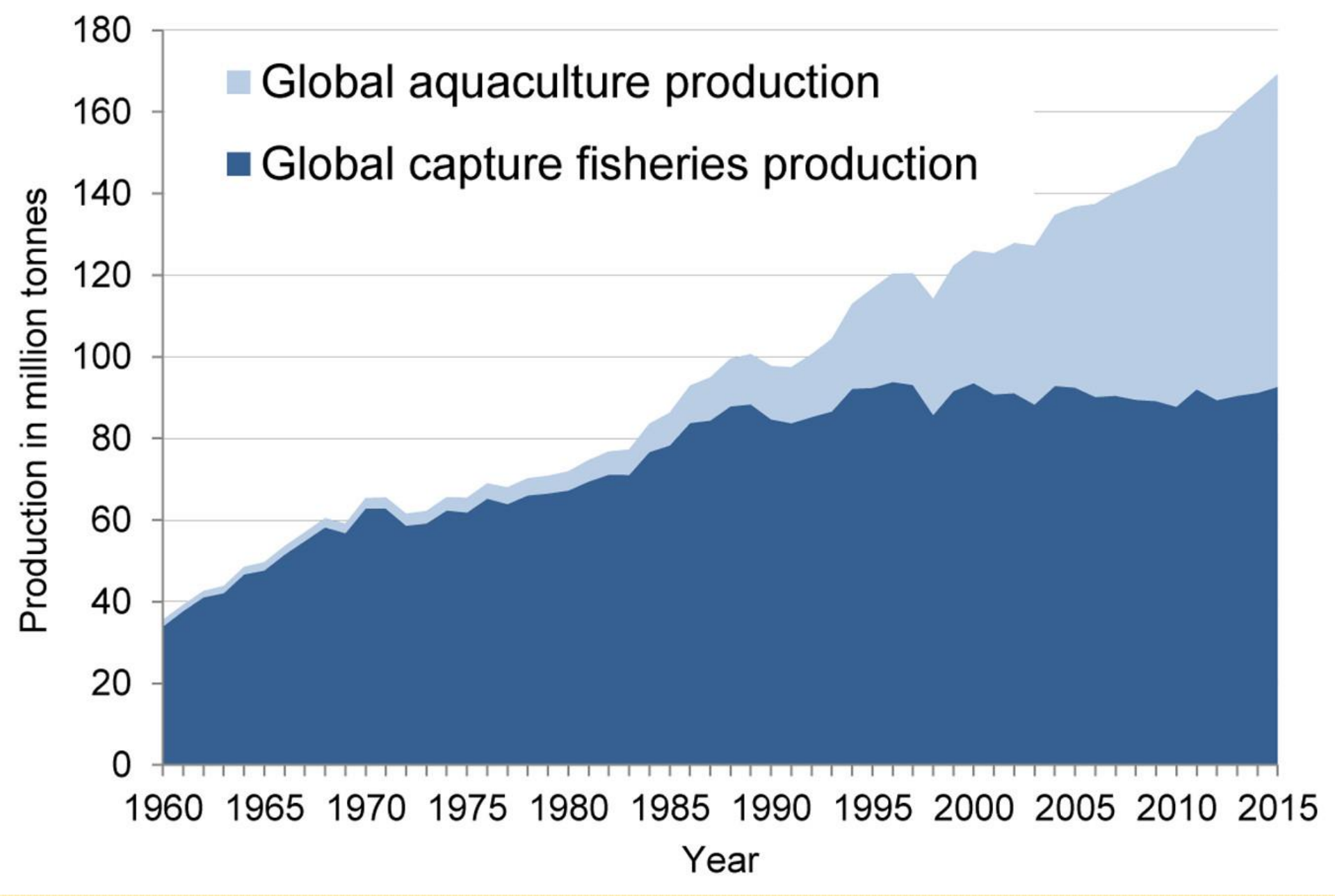
Global Footprint Network

Marine Fisheries

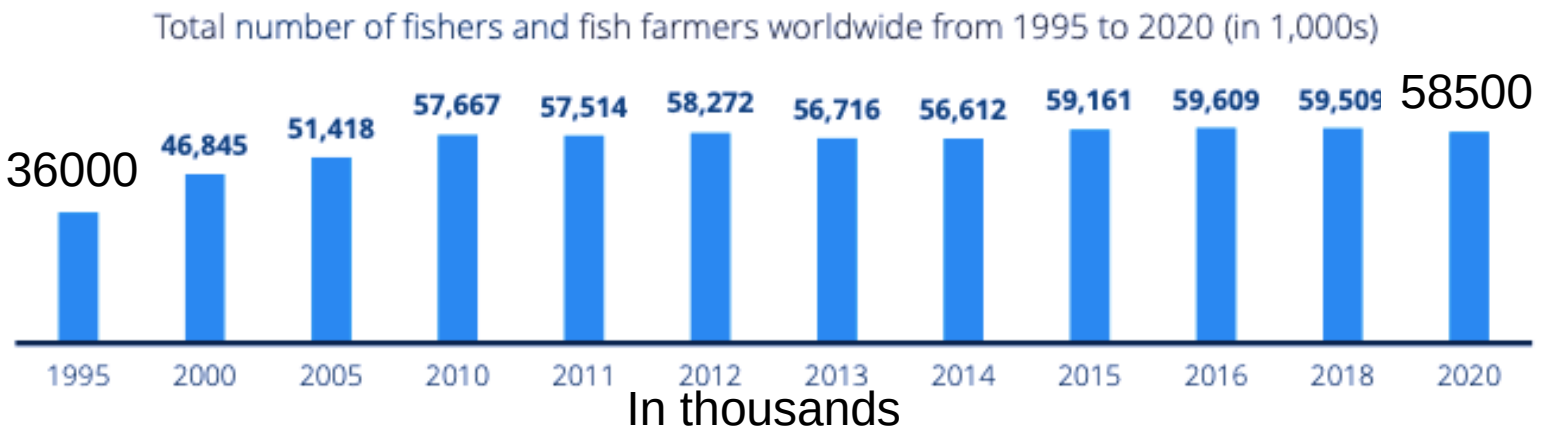
The dramatic collapse of cod stocks off Newfoundland illustrates how quickly the services of an ecosystem can disappear when its resources are overexploited.

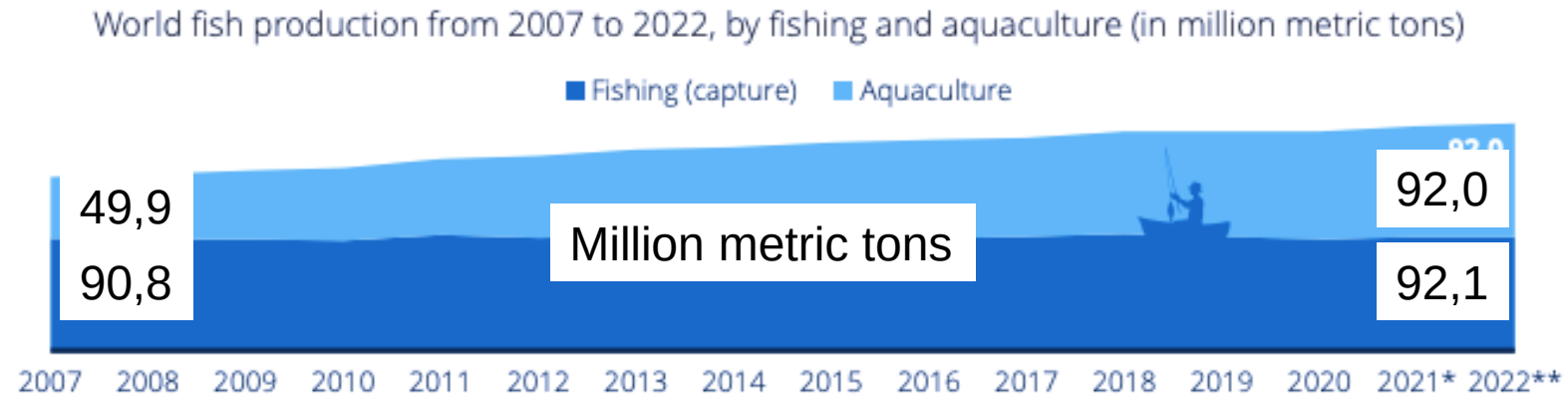


Source: Millennium Ecosystem Assessment


Global aquaculture production
Global capture fisheries production
Production in million tonnes
180
160
140
120
100
80
60
40
20
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year

Fishers and fish farmers 1995-2020 plus world fish production 2007-2020





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(1) Note(s): Worldwide; 1995 to 2020; 2017 and 2019 were not provided by the source
Source(s): FAO; ID 248767

(2) Note(s): Worldwide; 2007 to 2022; *estimated; **projected
Source(s): FAO; ID 272311

FORESTS

Sustainable Forest governance is a main concern in Sustainable Development

1. Ecosystem services

- Habitat for millions
- Biodiversity
- Photosynthesis & respiration
- Water retention & treatment
- Air filtration & treatment
- Recreation for humans

2. Human resource base

- Wood/timber
- Paper
- Chemicals
- Drugs
- Bioenergy

TOP SOIL


WATER

30 minutes break

- Discuss what you could do as individuals (family members) in order to improve your resource use
- What would be the single most efficient measure you could implement in your life in order to combat climate change?

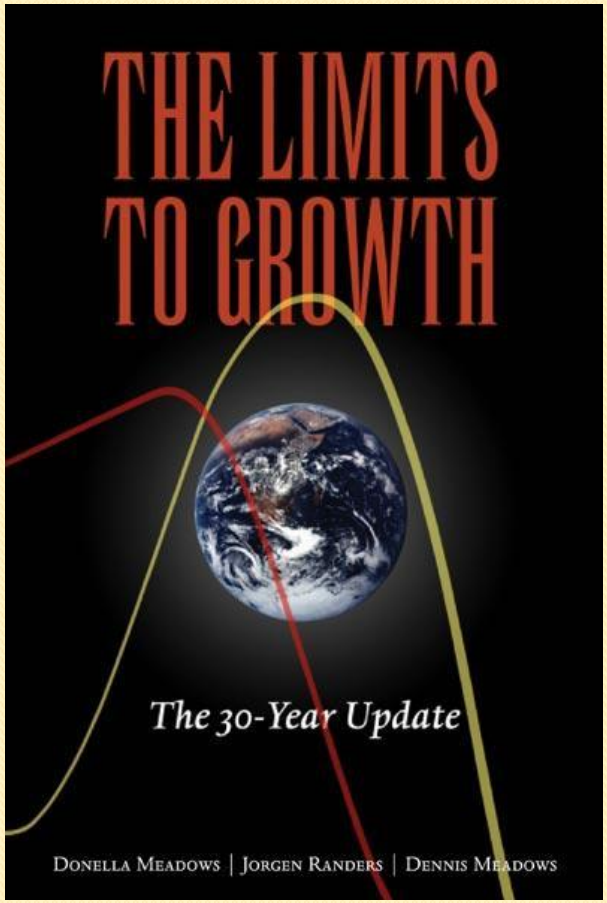
After 20 minutes we gather to listen to results of the discussion.

Concepts of identifying Unsustainability

The study of the limits of global resources

1. *Limits To Growth*, Meadows et al (1972) first computer model; the Limits To Growth a 30 year update (2003). Jörgen Randers 2052 (2012)
2. *Material flows* Wuppertal Institute and the ecological rucksack, *MIPS and Factor 10*. 1990s (Schmidt-Bleek).
3. *Ecological footprint network* and biocapacities, 1990s (Rees and Wackernagel).
4. *Planetary Boundaries* Stockholm Environment Institute, Stockholm Resilience Centre, 2009.

Limits to Growth (1972): The 30 year update (2003) We are Witnessing a Terrible Validation



- Original "Club of Rome Report" alerted world to the dangers of continued **exponential growth against natural limits in a finite system**
- Noted that humanity had the capacity to create **systems that were sustainable**
- Vehemently attacked at the time, especially by economists
- Now validated — unfortunately — by over 30 years of data

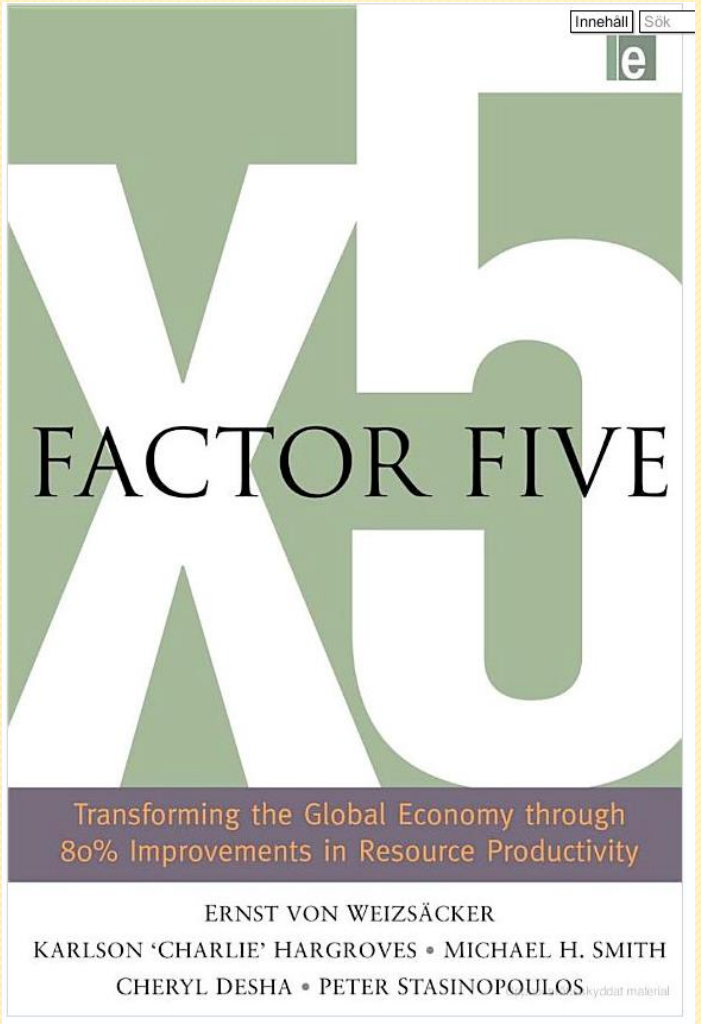
Wuppertal Institute for Climate, Environment, and Energy

1. The MIPS Concept (MIPS = Material Intensity Per Service unit

2. The Factor 4, Factor 5 and Factor 10 concepts for reduced material use in production

https://wupperinst.org/en/topics

Look for publications



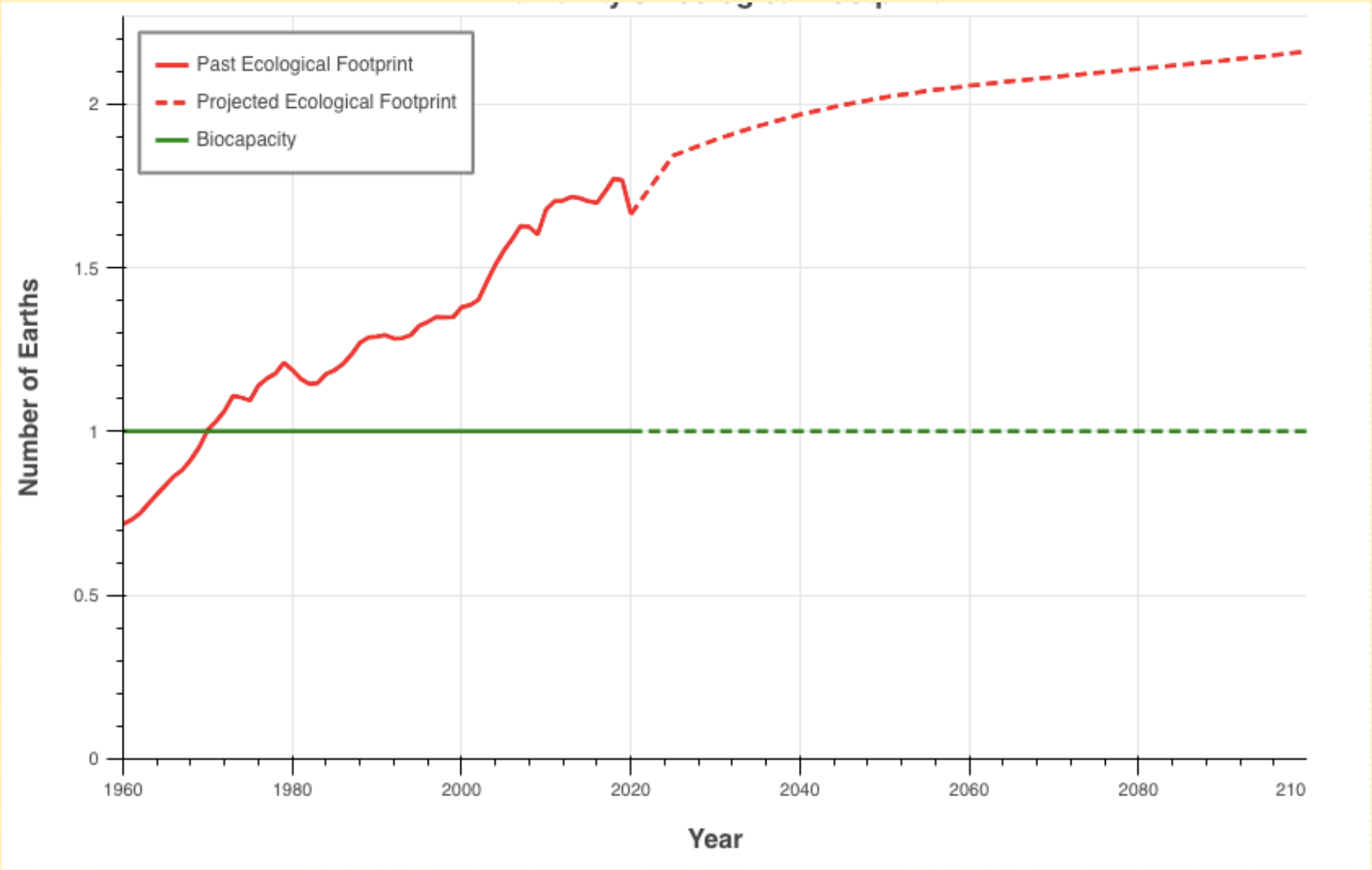
MILJÖ STYRNINGS RÅDET

The Ecologial Footprint

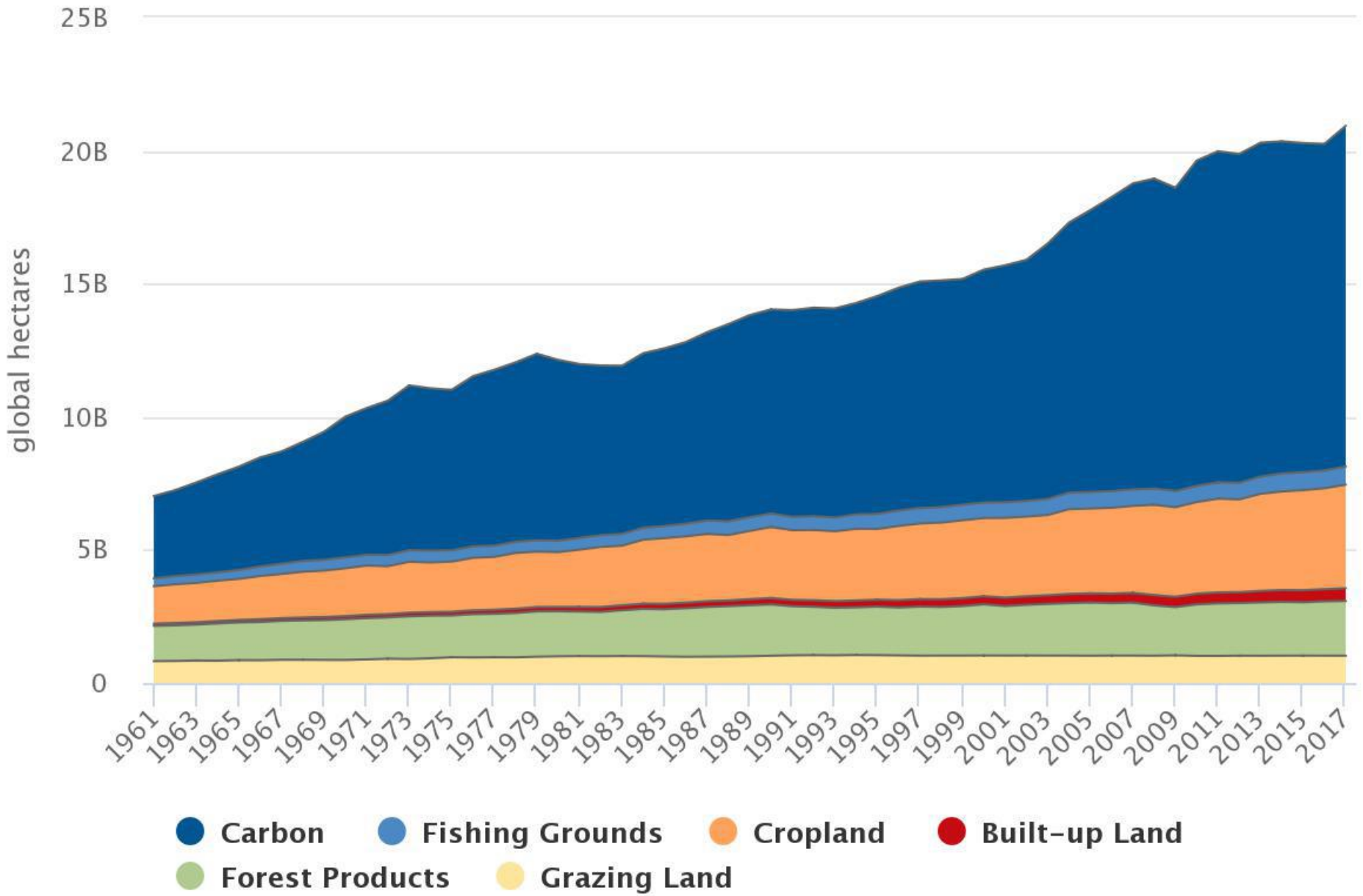
- William Rees introduced the concept of ecological footprint in 1992.
- The ecological footprint is ”*the surface area a population needs to continually satsify its needs and produce its products and services”*. It is measured in so-called global ha.
- Ecological footprint is a quantitative information and not the same as environmental labelling.
- Ecological Footprint is a vey pedagogical way of illustrating the unsustainability of current development, but has also been criticized
- http://www.footprintnetwork.org

Humanity's Ecological Footprint

cf. https://www.footprintnetwork.org/resources/footprint-scenario-tool/

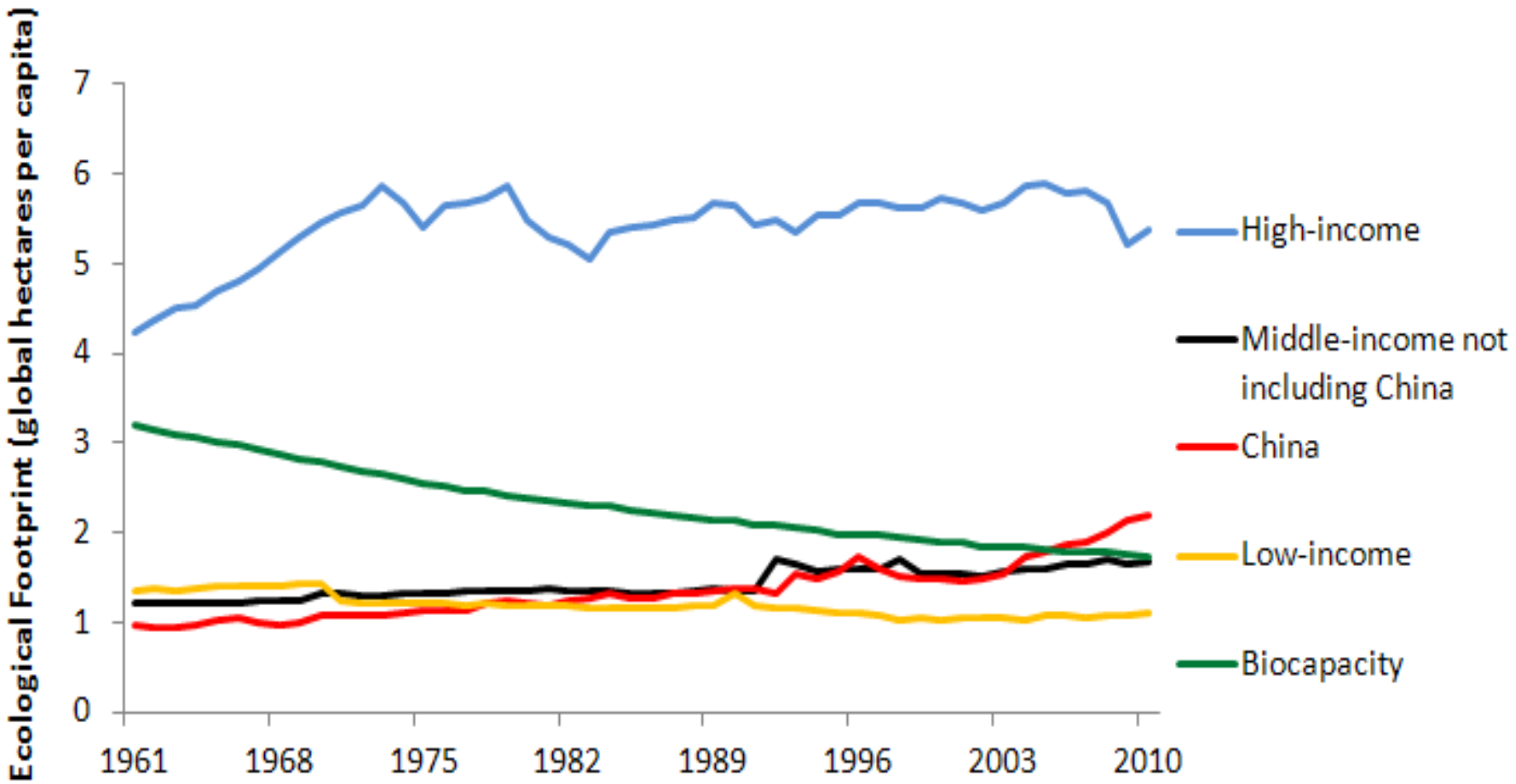


World Ecological Footprint by Land Type



Global Footprint Network, 2021 National Footprint and Biocapacity Accounts

Ecological Footprint Per Capita in High-, Middle- and Low-Income Countries

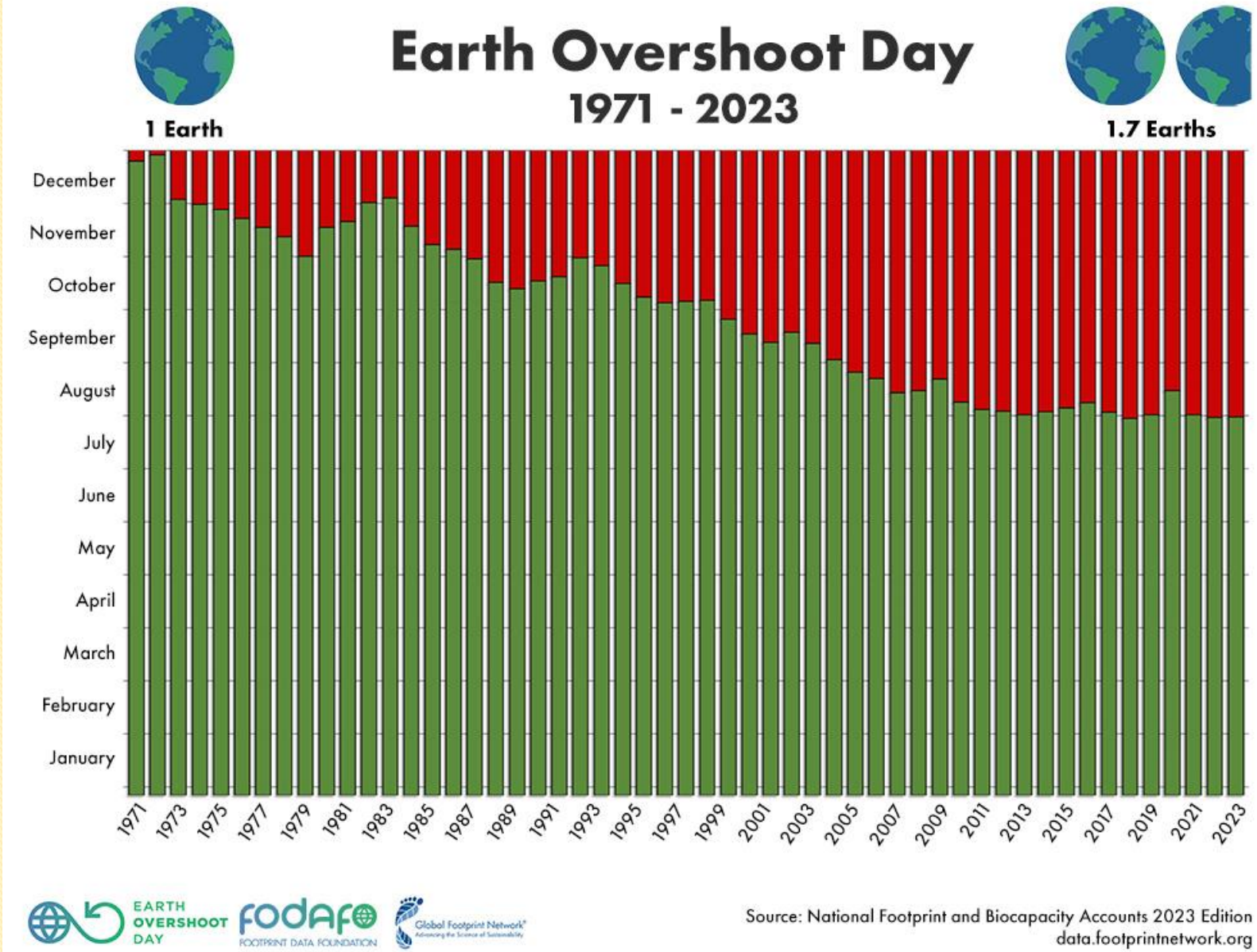


Global earth overshoot day 2023 was August 2

in Uzbekistan September 18, in Sweden April 21

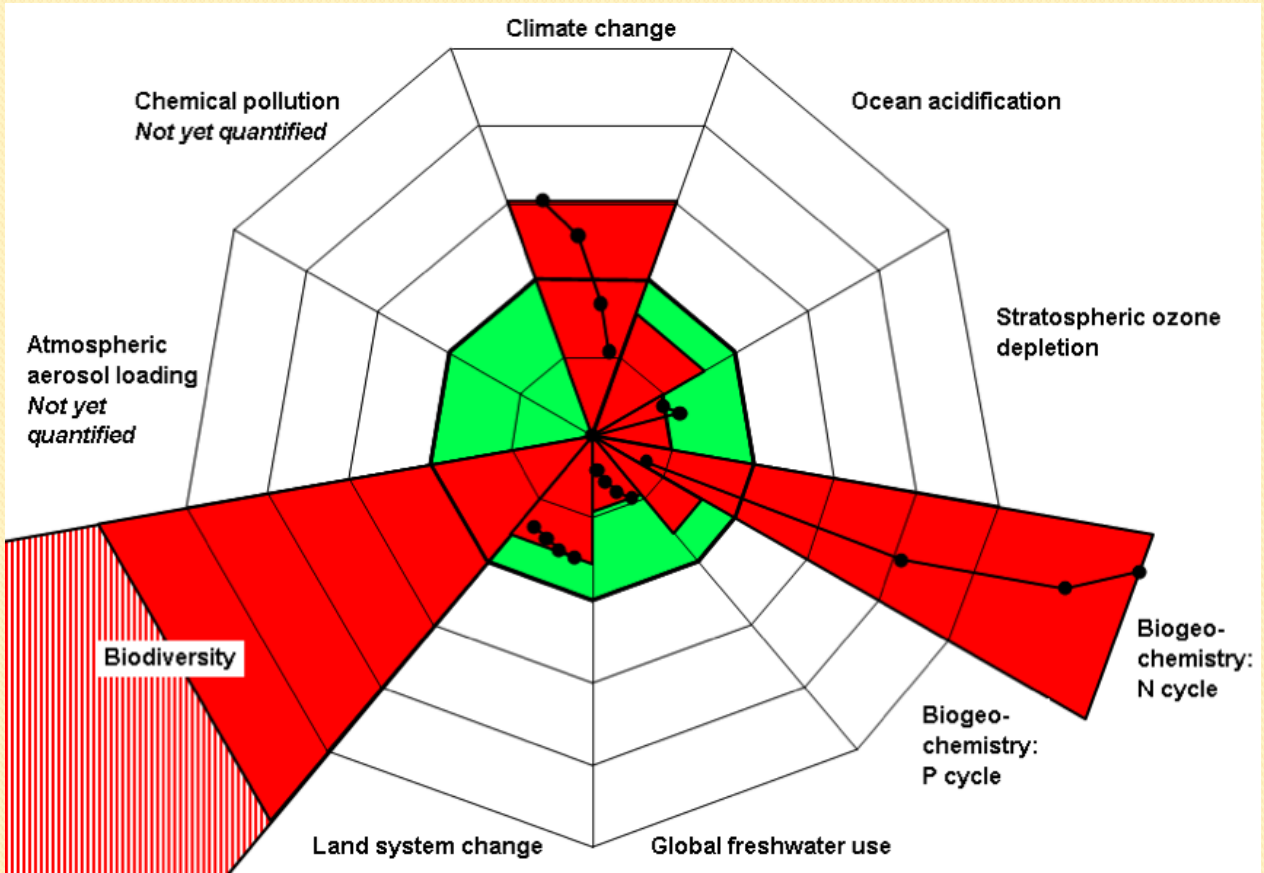
Global ecological overshoot became a reality in the early 1970s and is driven by these key factors: how much we consume, how efficiently products are made and used, how many people are living on our planet, and how much nature's ecosystems are able to produce.

Global biocapacity is 1.6 gha per person (in 2017). To support human activities today we use just over 1.6 Earths per year. To keep up with our level of demand by 2030 we would need the capacity of two Earths. This puts the well-being of many of the planet's residents at risk.


Earth Overshoot Day
1971 - 2023
1 Earth
1.7 Earths
December
November
October
September
August
July
June
May
April
March
February
January
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023
EARTH OVERSHOOT DAY
FOOTPRINT DATA FOUNDATION
Global Footprint Network
Source: National Footprint and Biocapacity Accounts 2023 Edition
data.footprintnetwork.org

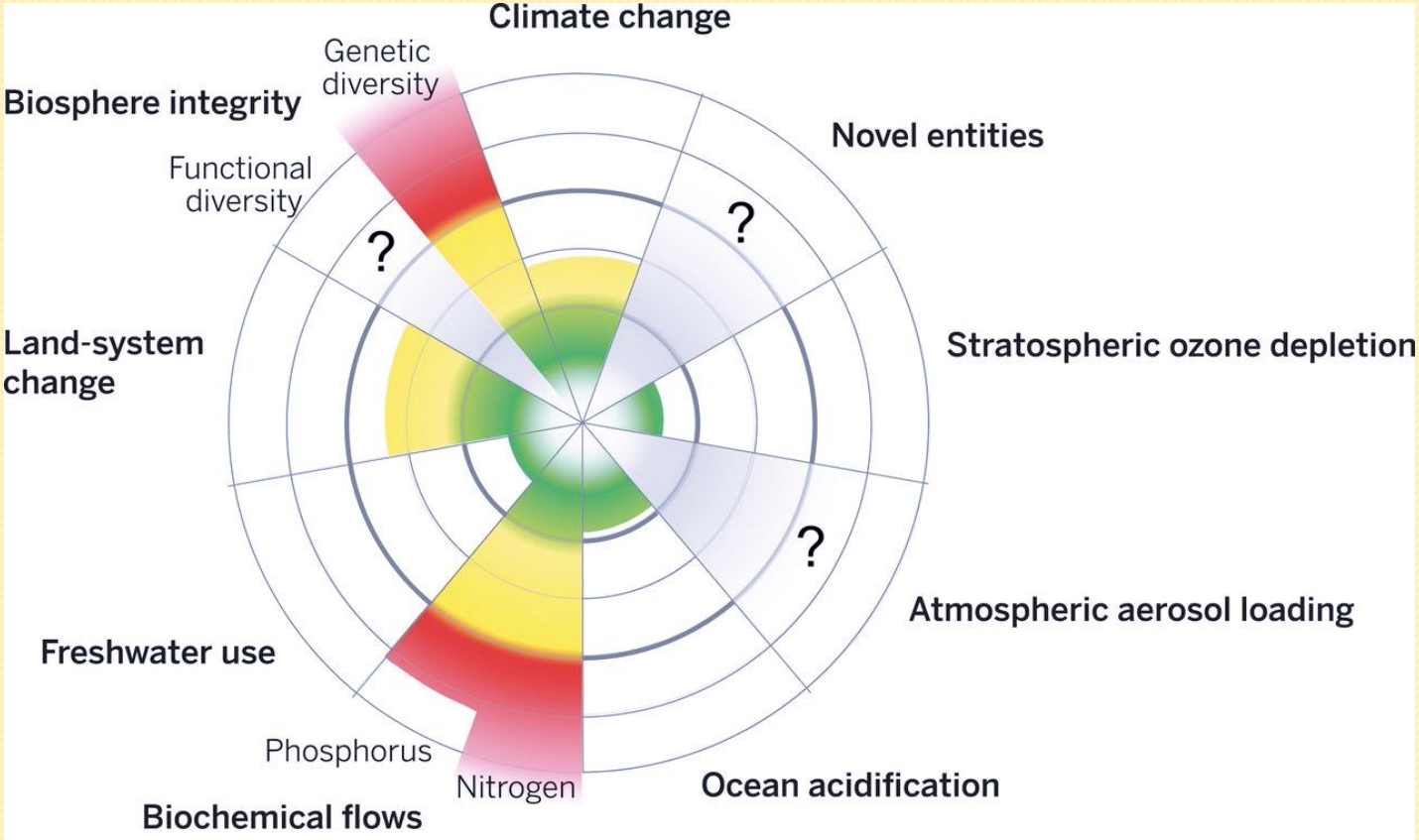
The Planetary Boundary Concept

Planetary Boundaries 1: A stable operating space for humanity, NATURE Vol 461. 24 September 2009.



The Planetary Boundary Concept

Planetary Boundaries 2: Steffen et al 2015.



How can we improve things?

There are many ways to an increased resource efficiency!

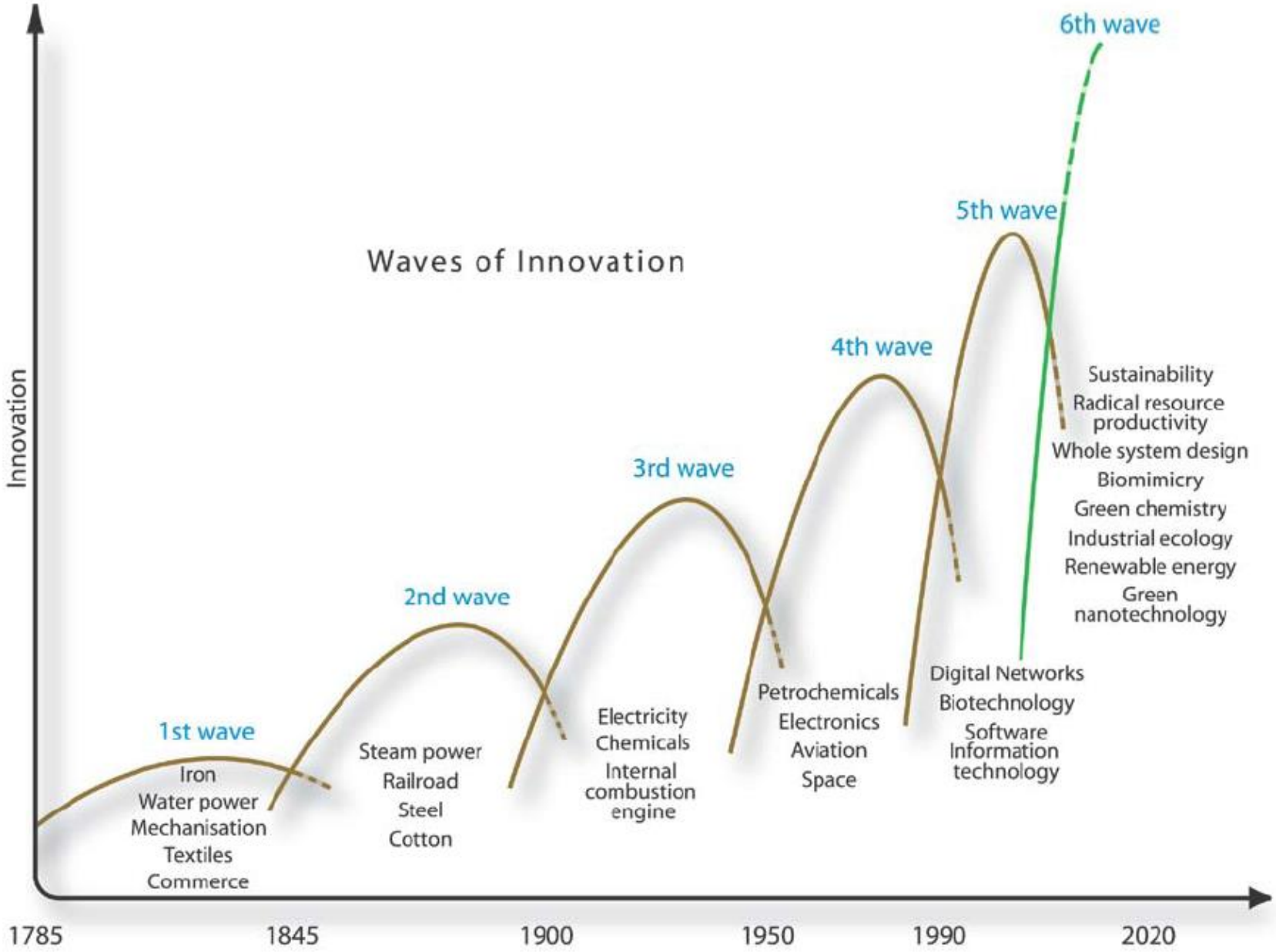


Figure 4 *Waves of Innovation*

Source: Courtesy of The Natural Edge Project[19]

3R

Reduce-Reuse-Recycle

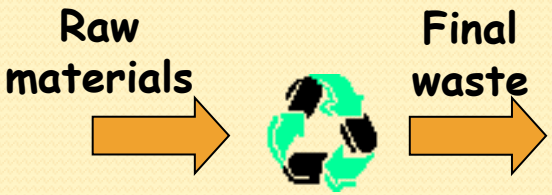
3R

Reduce-Reuse-Recycle

4R

Reduce-Reuse-Recycle-Recover

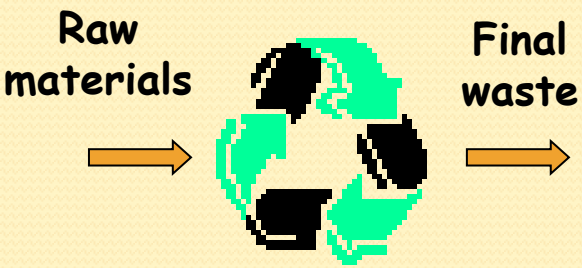
Resource Management can be improved!



Schematic situation today

Relatively high raw material use

Relatively low recycle rate



Schematic future situation

Relatively lower raw material use

Relatively higher recycle rate

The production itself is a very important part – it may be improved tremendously by

Cleaner Production, CP

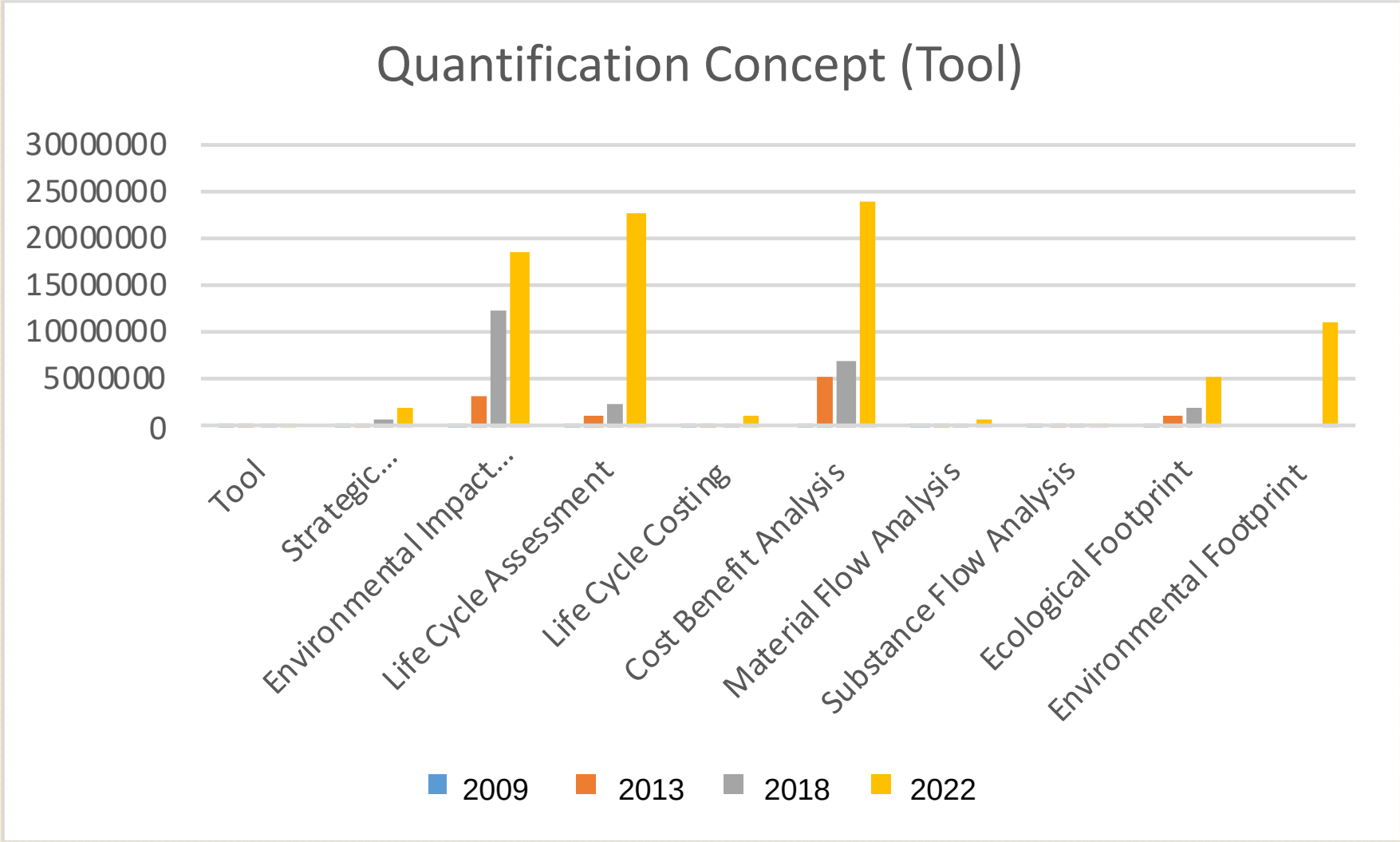
Cleaner Production is good not only for the environment but also for the economy!

Of course!

You make products efficiently, not pollutants - inefficiently

Quantification of resource flows

Quantification of Resource Flows – Google Hits for 2009, 2013, 2018 and 2022



Ecological Rucksack

Today, less than 5 % on average of the material resources taken from nature ends up in products. The rest becomes waste on the way. Some 30 tons of nature is used to create one ton of car – without counting water consumption - and for many industrial goods the ratio is similar.

Information and Communication Technology [ICT]: the costs for one message on Internet is equal to that of producing four aluminum cans for soft drinks.

Wuppertal Institute – Material Intensity factors of materials and energy sources
https://www.gdrc.org/sustdev/concepts/27-rucksacks.html

Life Cycle Assessments, LCA Material intensities

Material intensities can be used for calculating LCA for many products.

Ecological Rucksack for the cradle to the point of sale, the amount of material used which is not in the product itself can be calculated from LCA.

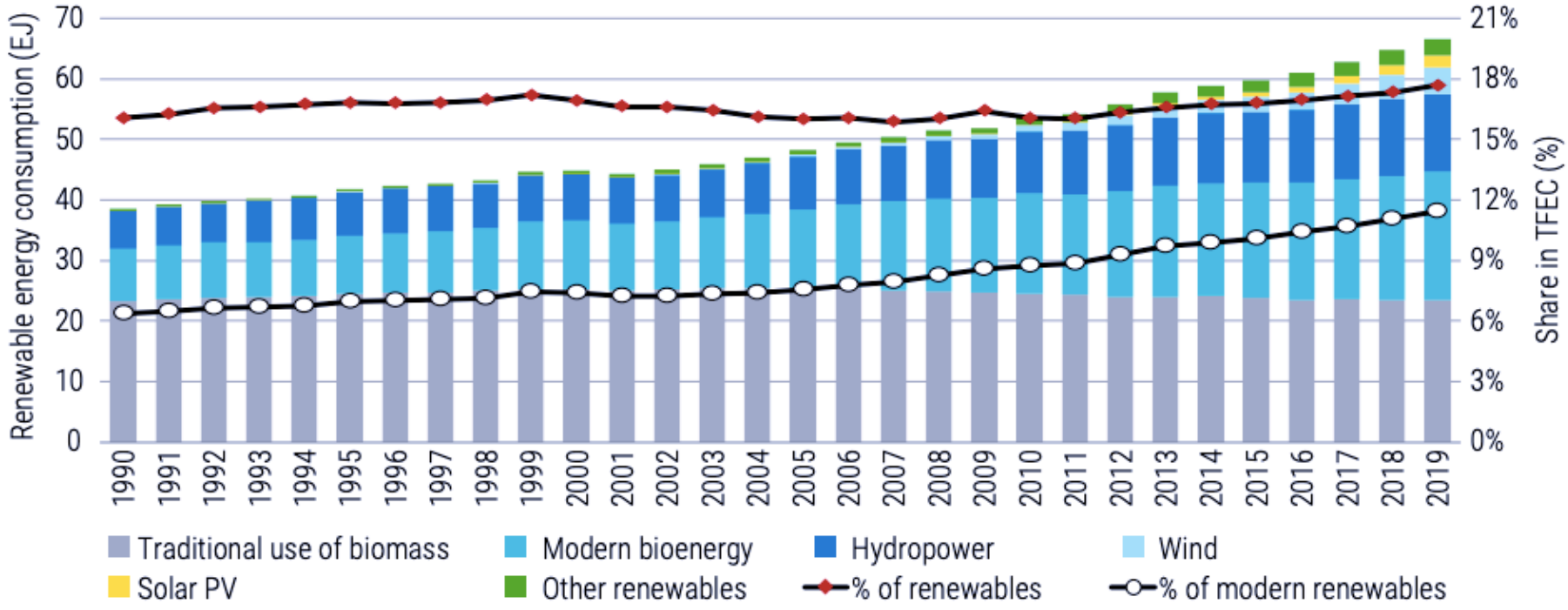
MIPS for cradle to cradle Material Input [in kg] Pro unit Service (per unit value or utility) obtained.

Material intensities and LCA for many products are available in databases. Total Material Flows, TMF output and input, are available for many countries.

Things are moving

Renewable Energy in the world

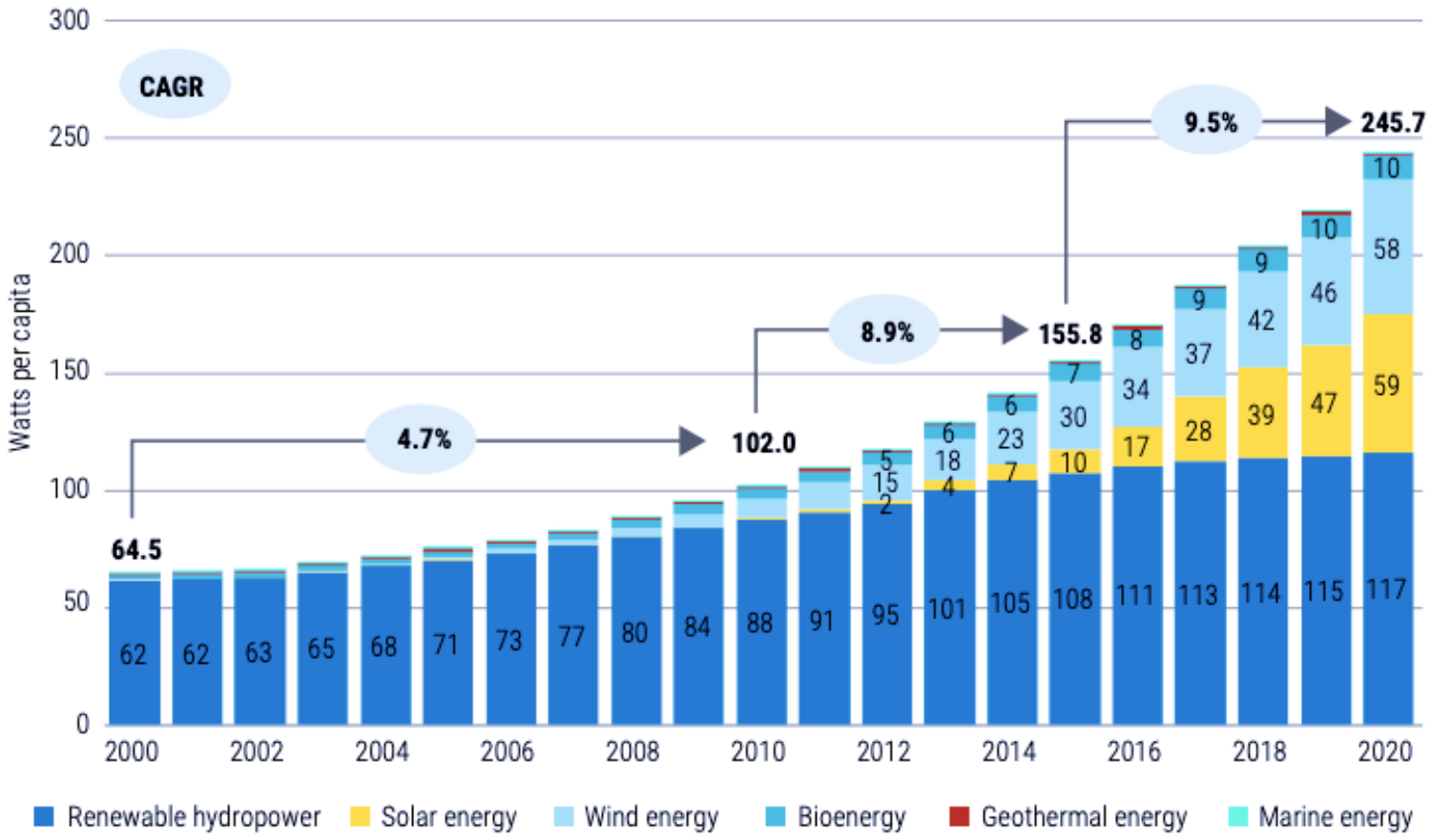
FIGURE ES.5 • Renewable energy consumption by technology and share in total energy consumption, 1990–2019



Source: IEA 2021a and UNSD 2021.

Installation Rate of Renewable Energy in Developing Countries

Figure 3.3 • Renewable installed capacity per capita in developing countries (2000–20) and compound annual growth rate for selected periods



Source: International Renewable Energy Agency (IRENA, 2021b)

Paper and board recycling in Europe

Source:
MONITORING REPORT 2022
European Declaration on Paper Recycling 2021-2030

Two initiatives for improved resource use

1. Cradle to Cradle Products Innovation Institute

https://c2ccertified.org/

Mission statement: ”We are powering the shift to a circular economy by setting the global standard for materials, products and systems that positively impact people and planet”.

2. The MacArthur Foundation

https://www.macfound.org/about/

The MacArthur Foundation boldy invests in creative solutions to urgent challenges, sparking hope for our future.

Key Messages

- The use of energy and physical matter in the global economy (the physical resource metabolism) has increased tremendously during the last century and is still increasing – this is regarded as ecologically unsustainable
- The climate issue is the single most burning aspect of current development, but several other ecological issues are in critical condition, e.g. water availability and biodiversity loss
- The access to energy and material goods is very unevenly distributed between people in different countries
- Many positive developments in renewable energy supply and mitigation of ecological threats are at hand, but has yet not been able to change the overarching ecological threats – the transition will have to accelerate

Something to practice

Estimate your footprint

1. **Global Footprint Network**

   How much land area does it take to support your lifestyle? Take this quiz to find out your Ecological Footprint, discover your biggest areas of resource consumption, and learn what you can do to tread more lightly on the earth. www.footprintcalculator.org.

2. **World Wildlife Found, WWF**

   Worried about your impact on the environment? The way we use the planet's resources makes up our ecological footprint. Measuring yours takes less than 5 minutes and could set you on a life-changing journey…
   https://footprint.wwf.org.uk/#/

3. **Earthday Network**

   Welcome to the Earthday Network Footprint calculator
   https://www.footprintcalculator.org/
   https://footprintcalculator.henkel.com/us

To read

Lecture 2. Flows and Stocks of Resources in the form of Energy and Materials

- IEA (2023) World Energy Outlook 2023 (Executive Summary, pp 22-27), International Energy Agency, https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf

- IBRD (2022) Tracking SDG7: The energy progress report 2023 (Executive Summary, pp 1-4), International Bank for Reconstruction and Development/ The World Bank Washington DC 20433, USA, https://www.irena.org/Publications/2023/Jun/Tracking-SDG7-2023

- Sustainable Use and Management of Natural Resources. Chapter 2 *The planet and its natural resources*. pp 26-45.

- Sustainable Use and Management of Natural Resources. Chapter 11 *Reducing the resource flows by a Factor of 4, 5 or 10*. pp 189-207.

Thanks for your attention!

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