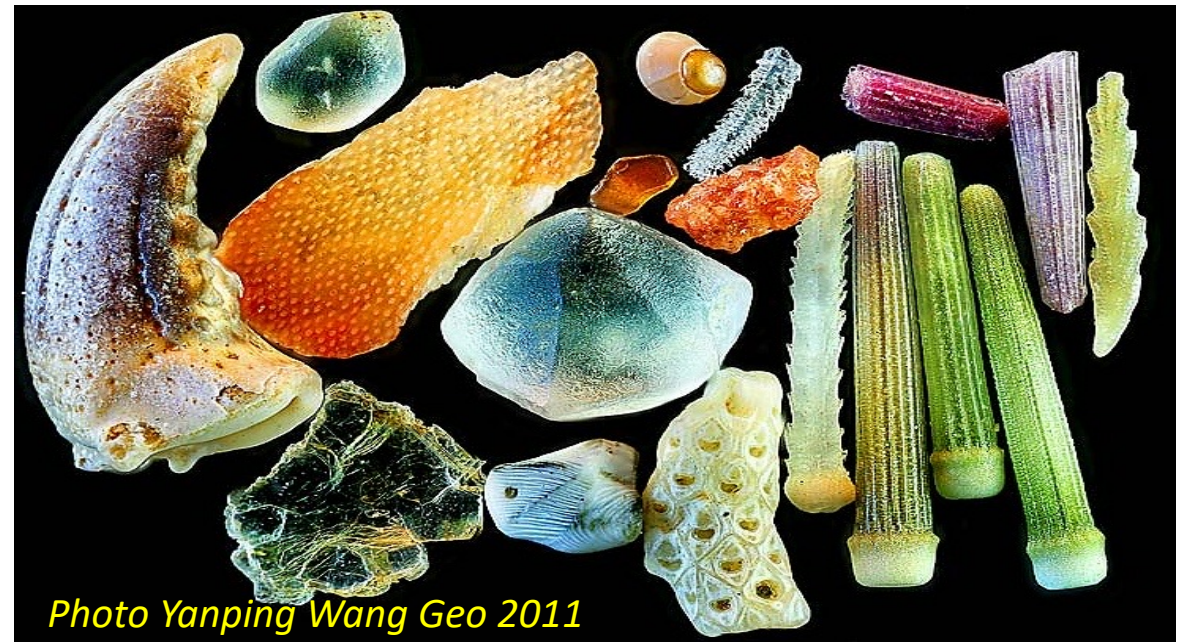


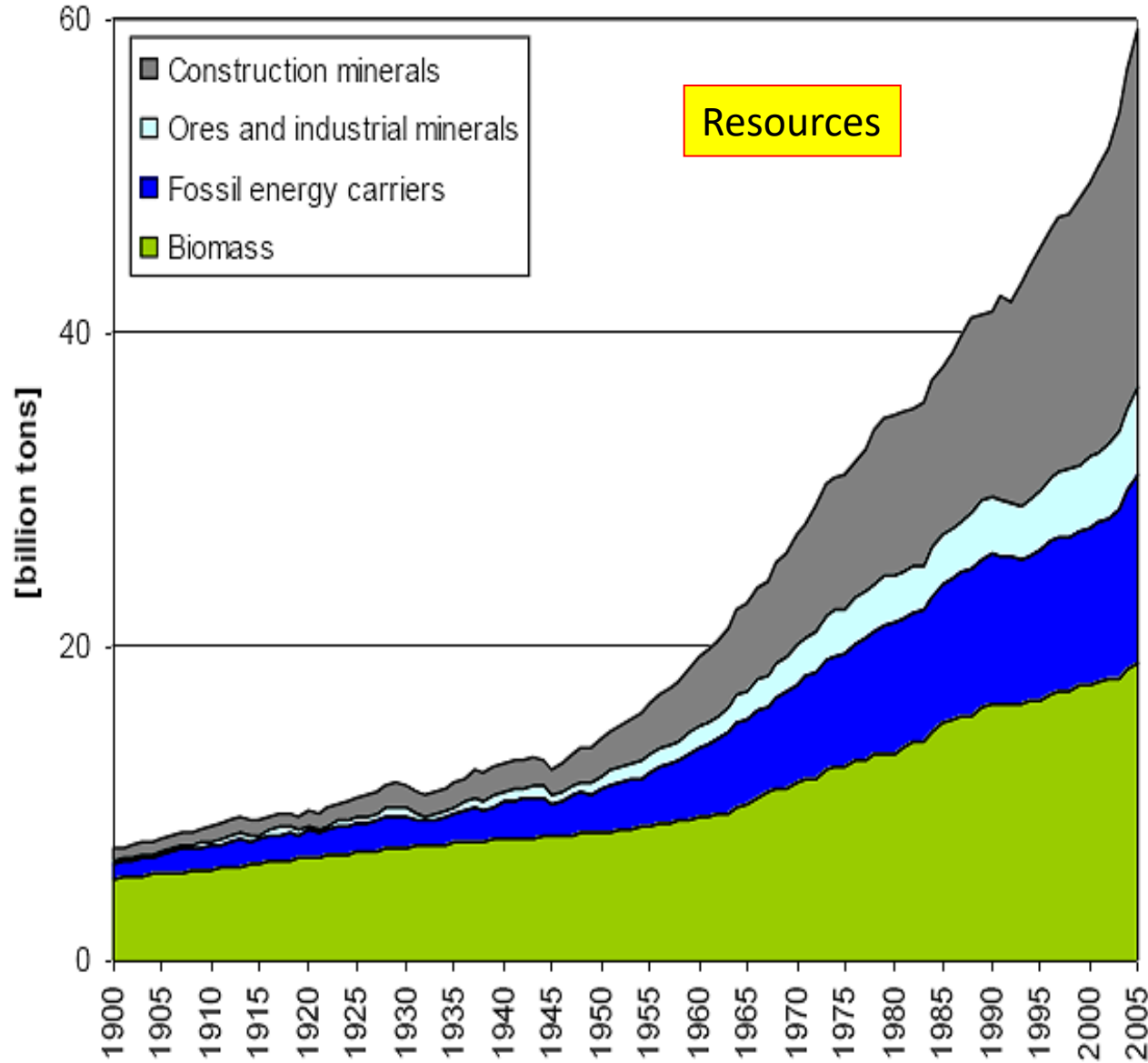


Alexander von Jawlensky 1905

## 6.3 Minerals and Fossil Resources



# Trends in Global Resource Consumption.



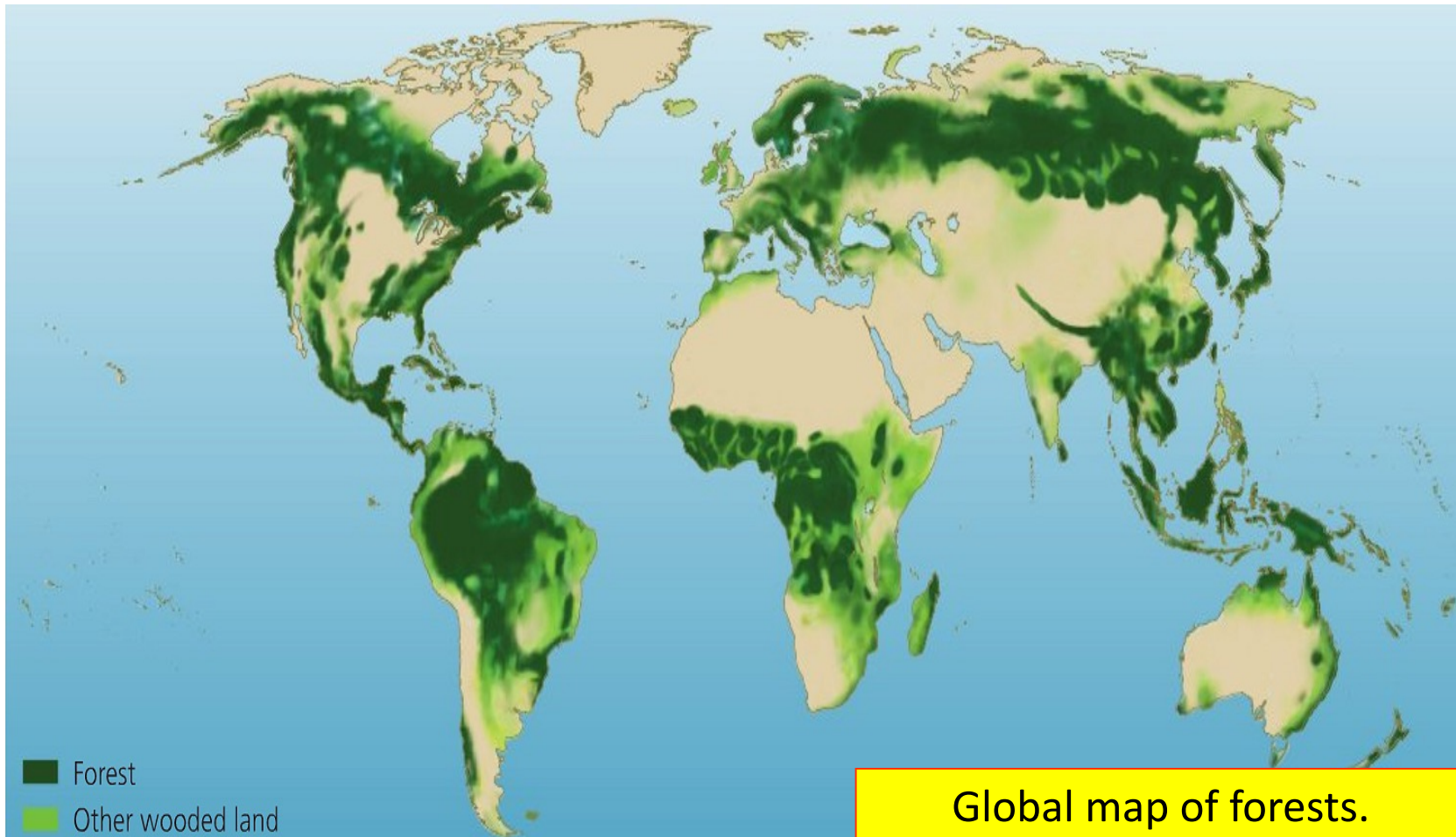
Source: Krausmann et al, Fischer-Kowalski 2009

- **Trend in resource consumption:**
  - The last century has been characterised by a steeply rising consumption of natural resources and energy.
  - Up to now there is no significant change in the global consumption trend.
- **Drivers of increased resource (and energy) use:**
  - Population numbers.
  - “Development” in the sense of transition from an agrarian to an industrial regime:
    - Person in industrial regime uses 3-5x more energy and natural resources than a person in an agrarian regime.
  - Rising income (GDP)

## 6.1 Forests.

- **Significance of Forests:**

- About 30 % of the global land surface is covered by forests.
- Most of this consists of the boreal forests in the North and the tropical forests of South America and Africa.
- Forest have a large economic value.



### **Ecosystem services:**

- Timber production.
- Biodiversity conservation.
- Soil and water protection.
- Leisure services and tourism.
- Living space for indigenous people.
- Major sink for CO<sub>2</sub> (photosynthesis and carbon storage in soil).

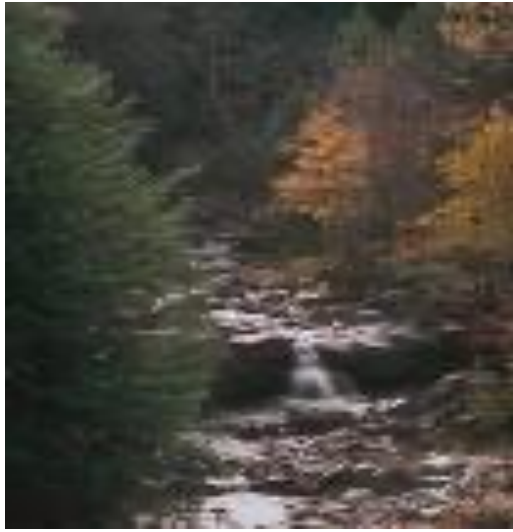
*Source: Withgott and Brennan:  
Environment, Pearson 2008*

# European Forests.

European Forest Monitoring and Information System  
(JRC-EEA).



Forests cover about one third of the European land area.



**Mountain forest**



**Mediterranean forest**



**Boreal forest**



**Alpine forest**



**Mediterranean protection forest**

# Deforestation.

**Conversion of forested areas to non-forest land for use such as arable land, pasture, urban use, logged area, or wasteland.**

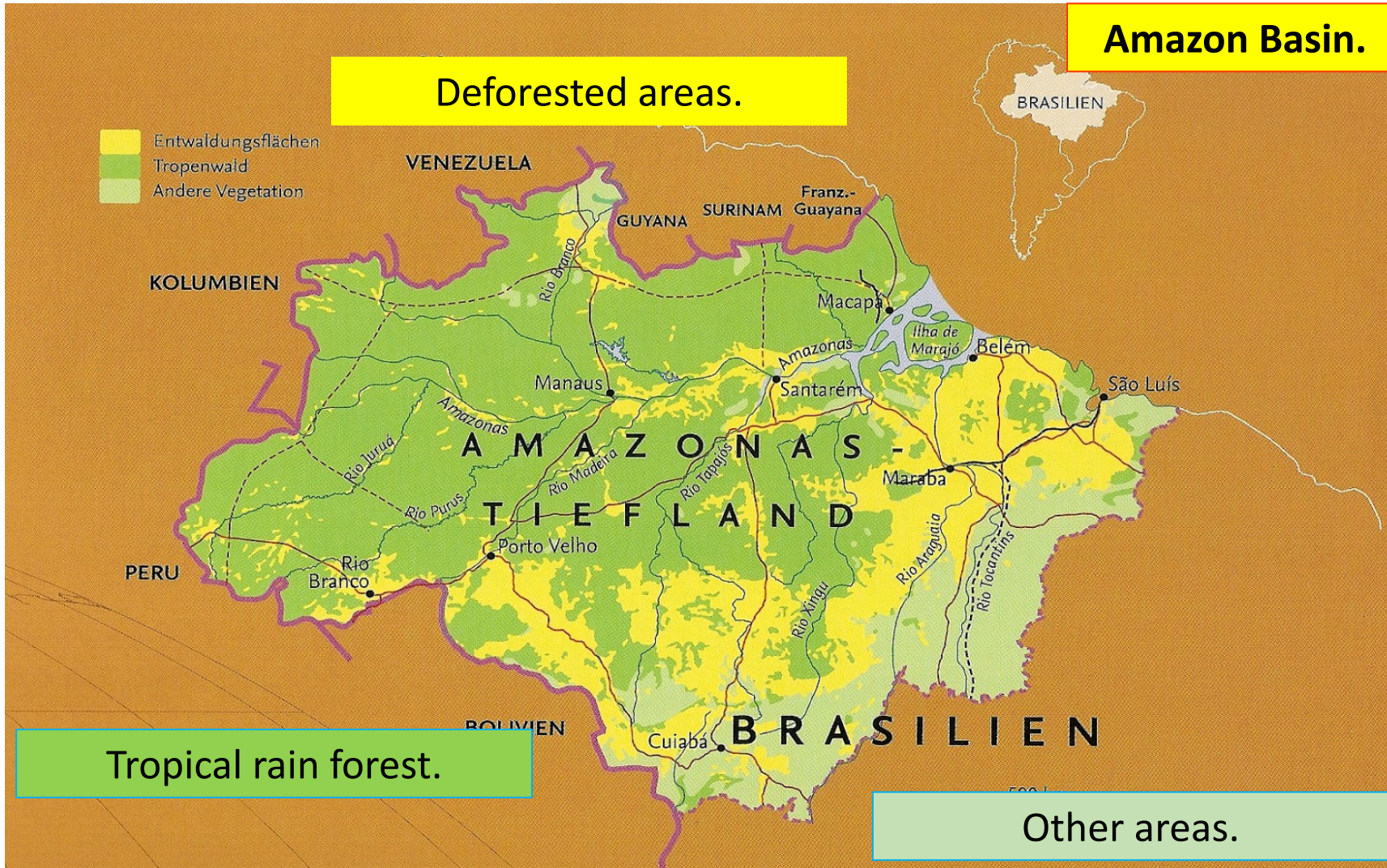
- **Deforestation in the historical context:**
  - Deforestation has been practiced by humans since 10.000 BC by conversion into agricultural land (fields, pastures).
  - Continuous reduction of forest areas over the centuries due to expanding human population, spread of agriculture, use of wood for housing and shipbuilding.
  - Beginning of the industrial age widespread use of charcoal (DE, UK...).
  - Since about the mid-1800s massive expansion of infrastructure (cities, roads, railways...).
  - During the recent past and now deforestation is most pronounced in the rain forest regions for gaining agricultural land and timber production.



**Atlantic rain forest (1820-1825):  
Now less than 10% left.**

# The Brazilian Amazon Rain Forest.

- Amazon rainforest: largest biodiversity and sweet water reservoir on earth.
- Major region for capture of CO<sub>2</sub> from the atmosphere.



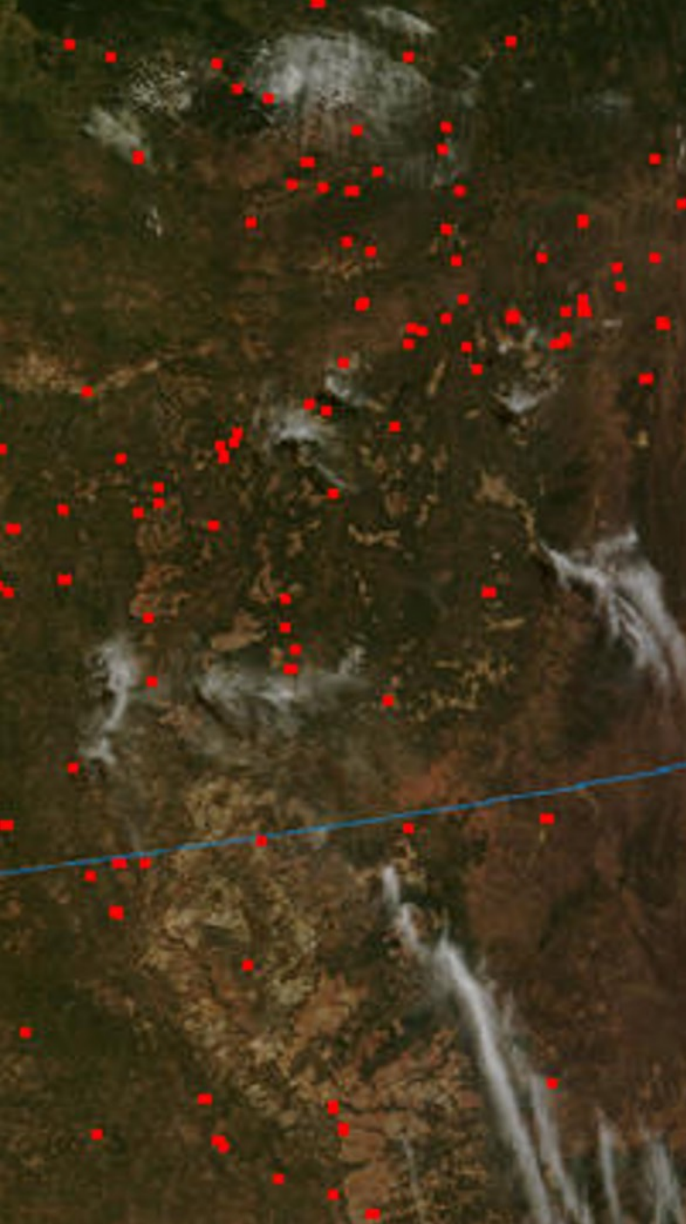
- **Extent of deforestation:**

- Since 1970 every year an area of 17.000km<sup>2</sup> is lost – in total now 20%.
- Only 3 % of the area are protected.

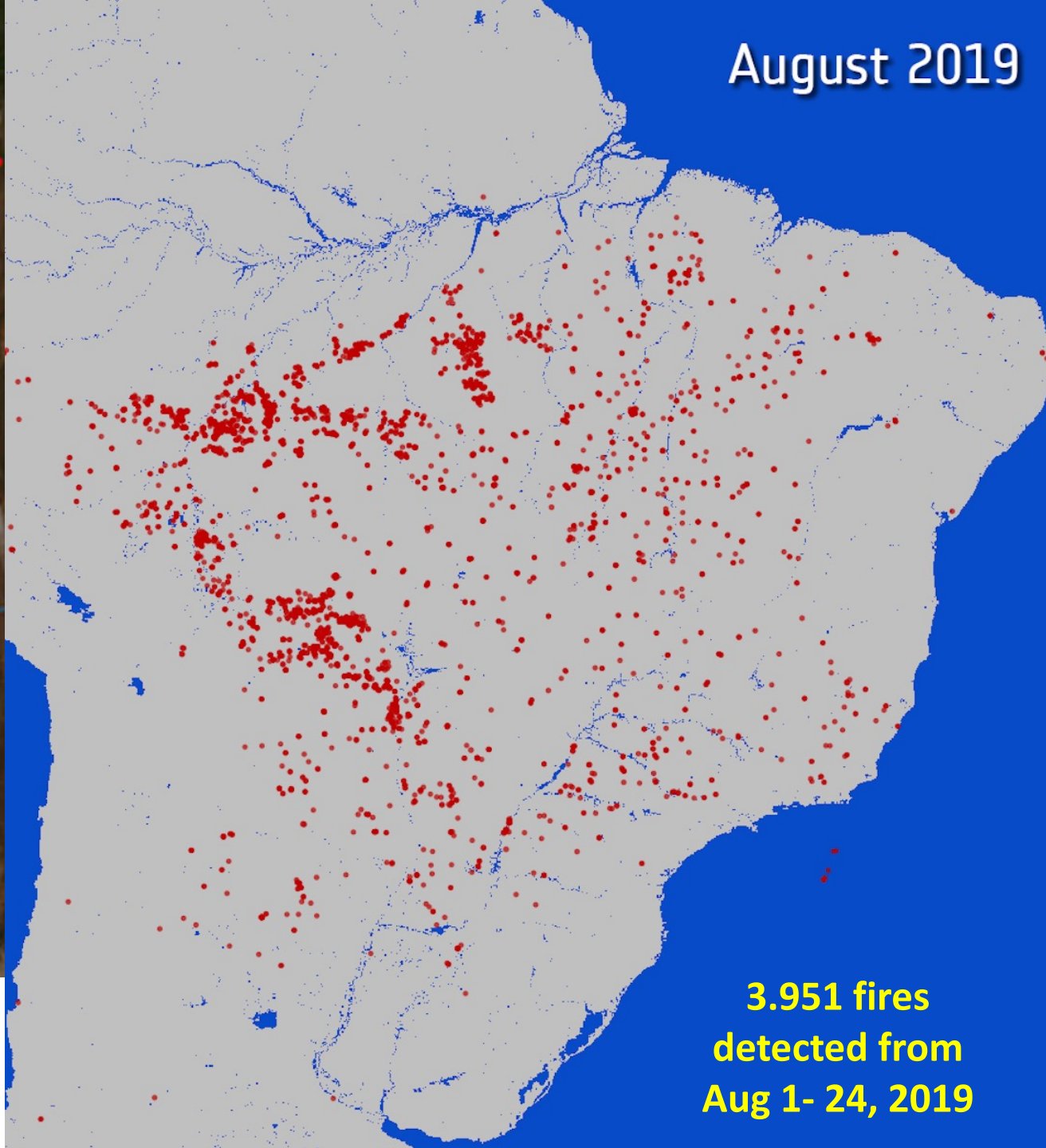
- **Major drivers:**

- Increased demand for soybean has led to the displacement of beef ranches and farms of other crops, which, in turn, move farther into the forest.
- Droughts.

Source:  
National Geographic Society,  
Wikipedia



Man-made fires around the  
Xingu National Park  
12<sup>th</sup> July 2007.



August 2019

**3.951 fires  
detected from  
Aug 1- 24, 2019**

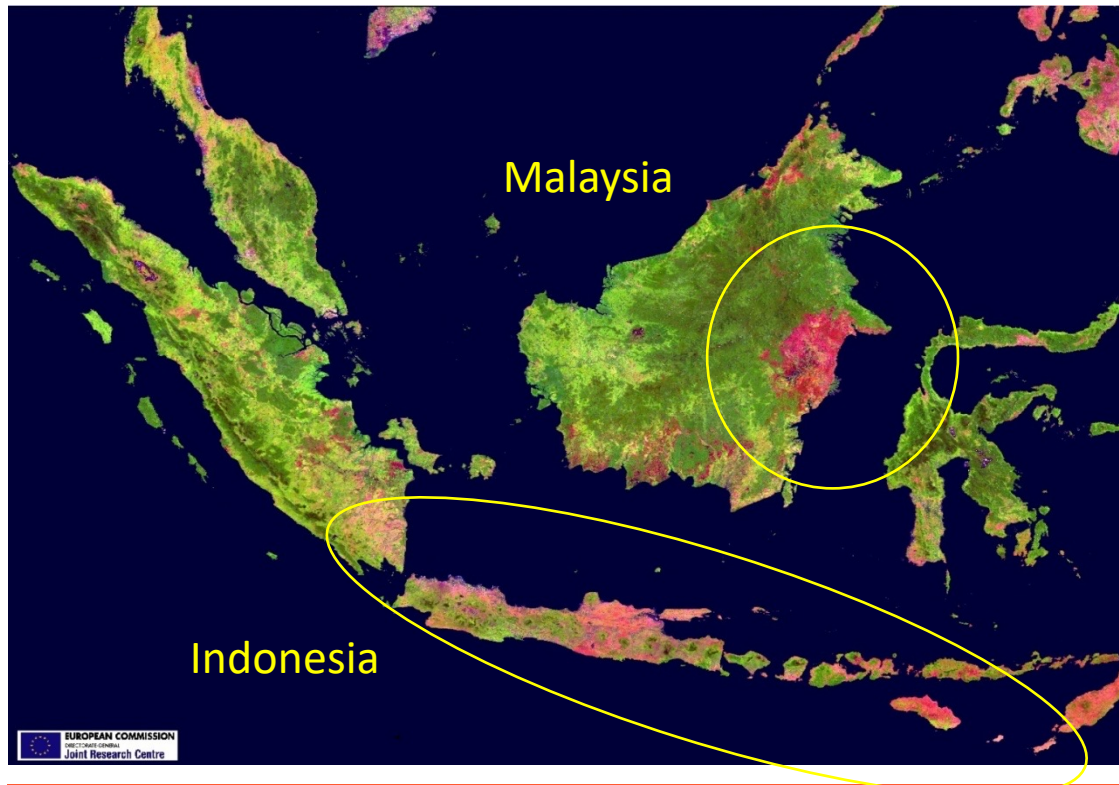
## Wildfires in the Amazon.

- 80.000 Forest fires from Jan.- Aug. 2019:
- Total area burnt ca 6.000 km<sup>2</sup>
- corresponds to 0,2% of total forest area of 3,4 million km<sup>2</sup>

Globally tropical  
rain forest  
capture about  
18% of the total  
CO<sub>2</sub> emissions.

*Source: ESA 2019*

- Very large areas of Siberia have been harvested since the collapse of the Soviet Union.
- In the last two decades, Afghanistan has lost over 70% of its forests.
- 90% of the forests of the Philippine archipelago have been cut.



Satellite image of Insular South East Asia 1998  
Dark green: Tropical evergreen rainforest, Dark red:  
Burnt lowland rainforest

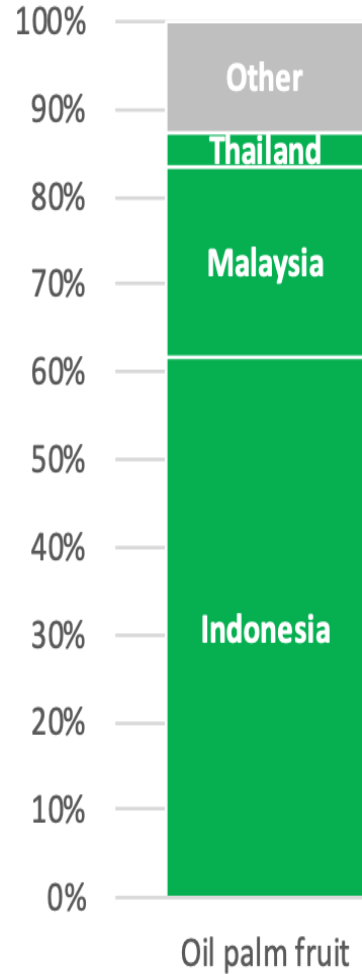
## Deforestation in Asia.

- In Indonesia and Malaysia native forest is cleared by large pulp and logging companies, many of them from China and Japan.
- Native rain forest is usually replaced by plantations with trees for paper or biofuel (palm oil) production.



Clearcut for Palm Oil Plantation, Borneo, Malaysia

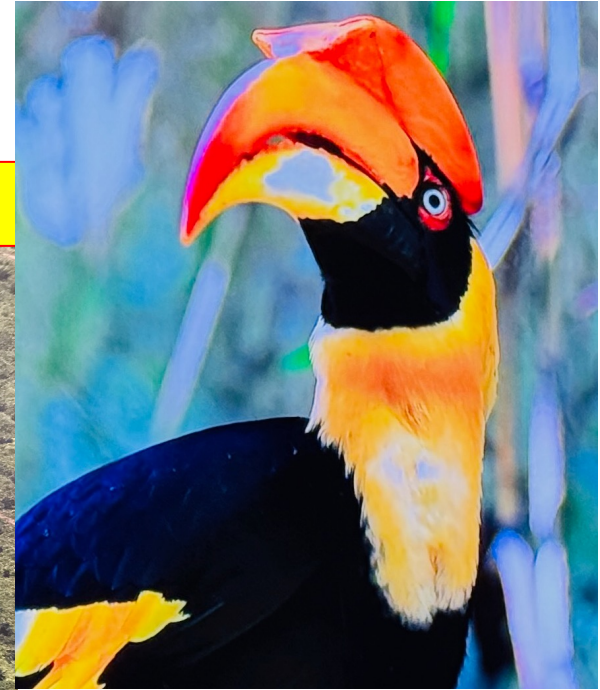
# Deforestation for Production of Palm Oil.



Palm Oil Plantation, Borneo, Malaysia



Annual global production: 416 Mto oil palm fruit. Increase of production from 2000-2020: **+250%**



Massive loss of biodiversity.

**Source:** FAO. 2022. FAOSTAT: Production: Crops and livestock products. In: FAO. Rome. Cited December 2022. <https://www.fao.org/faostat/en/#data/QCL>

# Loss of Biodiversity in SE-Asian Rain Forests.



Icebird.



Sumatra tiger.



Borneo pheasant.

Source: Phoenix 2024

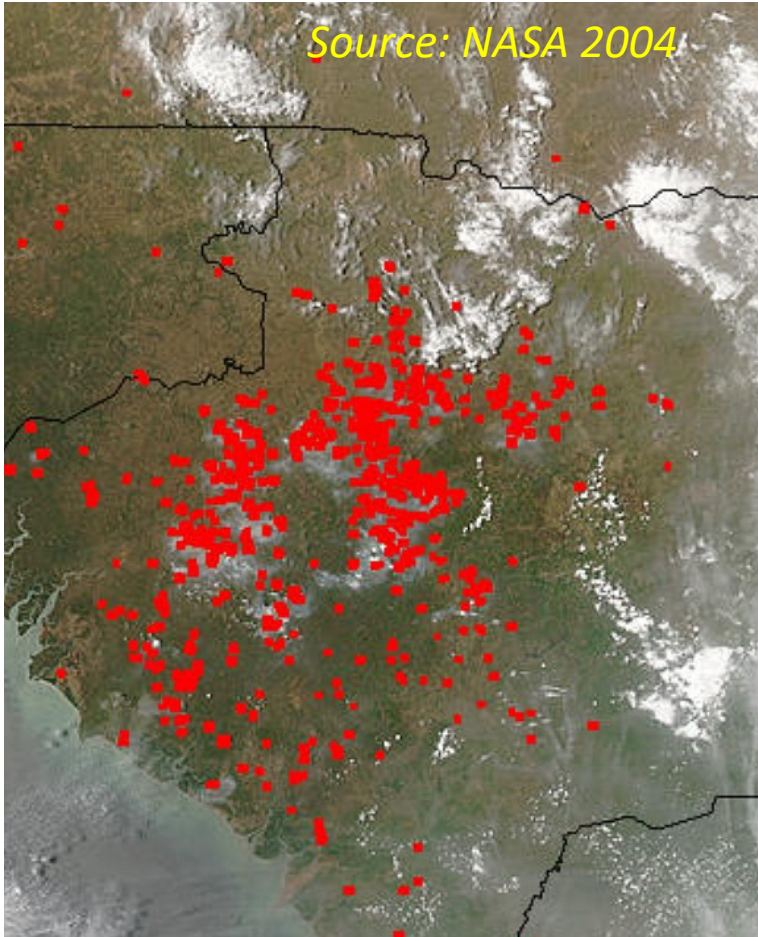


Orang Utang.

# Deforestation in Africa.

- From 1975 to 2000 Africa lost 16 % of its forests.
- Madagascar has lost 95% of its rainforests, Nigeria 80%.
- Annual loss of natural vegetation in Africa = 50.000 km<sup>2</sup>

Source: NASA 2004



Forest Fires in New Guinea.

Sudan:  
2,5 million km<sup>2</sup>,  
25 million people.

Dafour  
region

•2007 flash floods

Southern  
Sudan

150.000 homes destroyed,  
750.000 homeless.

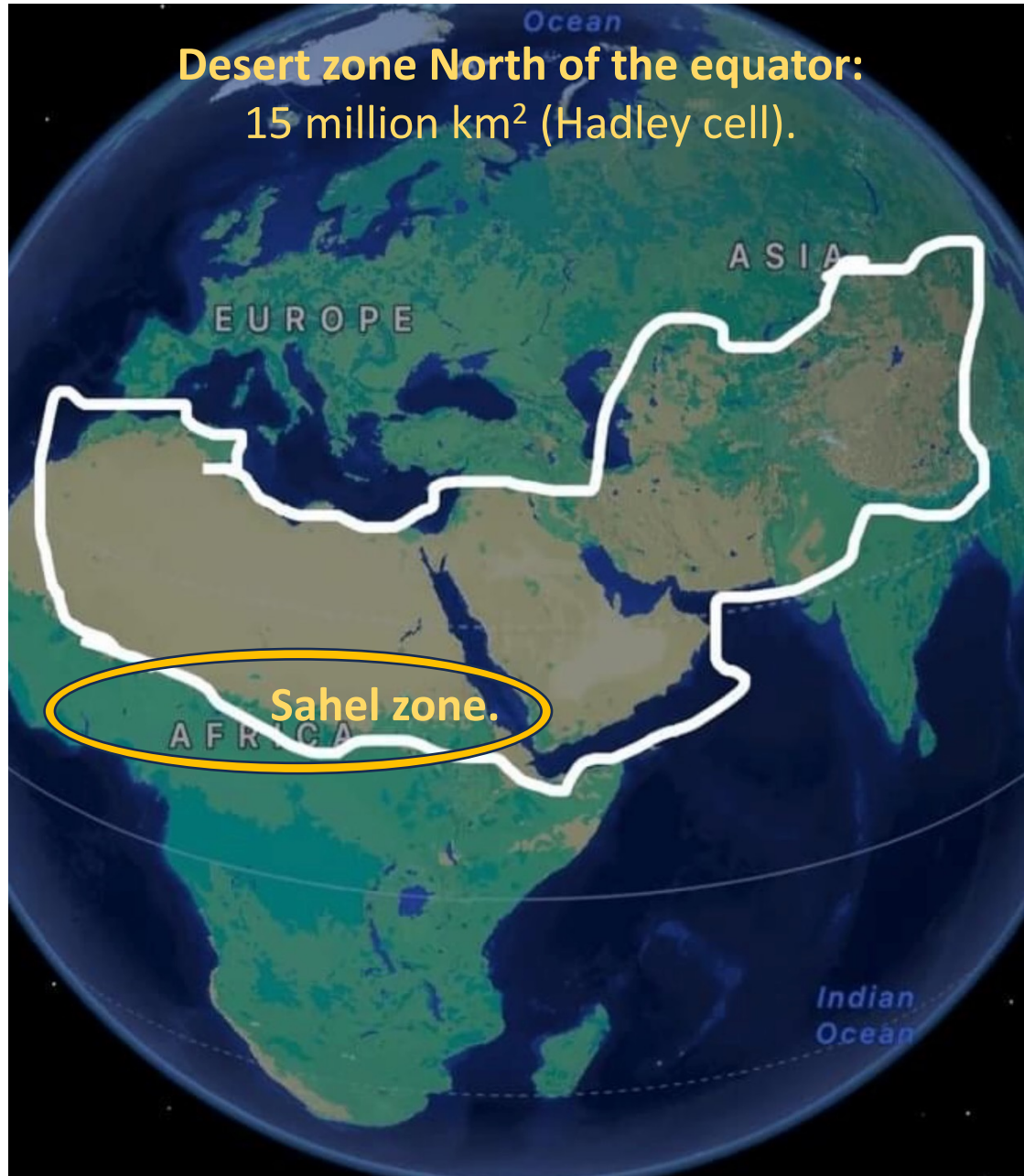
- **Main drivers:**

- Logging activities for precious tropical wood
- Slash-and burn practices for gaining agricultural land.

- **Impact:**

- Enhancement of green house gas emissions due to burning of forests.
- Land degradation, drying of the soil layers, eventually desertification.
- Affects the amount of water in the soil and groundwater.
- Reduction of the landscape's capacity to intercept, retain and transport precipitation.
- Deforested areas become sources of surface water runoff which can lead to flash flooding.

# Desertification.



**Desert zone North of the equator:**  
15 million km<sup>2</sup> (Hadley cell).

**Sahel zone.**

10% of global terrestrial area are deserts or semi-desert zones (excluding Antarctica).

**Africa:**  
25% complete dry desert, plus 40% arid zones.



Desertification often a consequence of deforestation.

# Global Climate Change Leading to Desertification.

5.000 years ago the green Sahara zone started to become arid and finally a desert due to changes in the earth-sun positions.

Desert area 9,2 million km<sup>2</sup>

Huge water reservoir beneath.



Height of dunes 160-180 m.

# Desertification.

- **Desertification** is the degradation of land in arid and semi arid areas.
- The primary reasons for desertification, is overgrazing, overcultivation, incorrect irrigation methods, deforestation, overdrafting of groundwater, increased soil salinity, and global climate change.
- The transition zones between deserts and the normal vegetation zones have fragile, delicately balanced ecosystems.
- In these marginal areas human activity may stress the ecosystem beyond its tolerance limit, resulting in degradation of the land.



Desert fringes Karzaz, Algeria

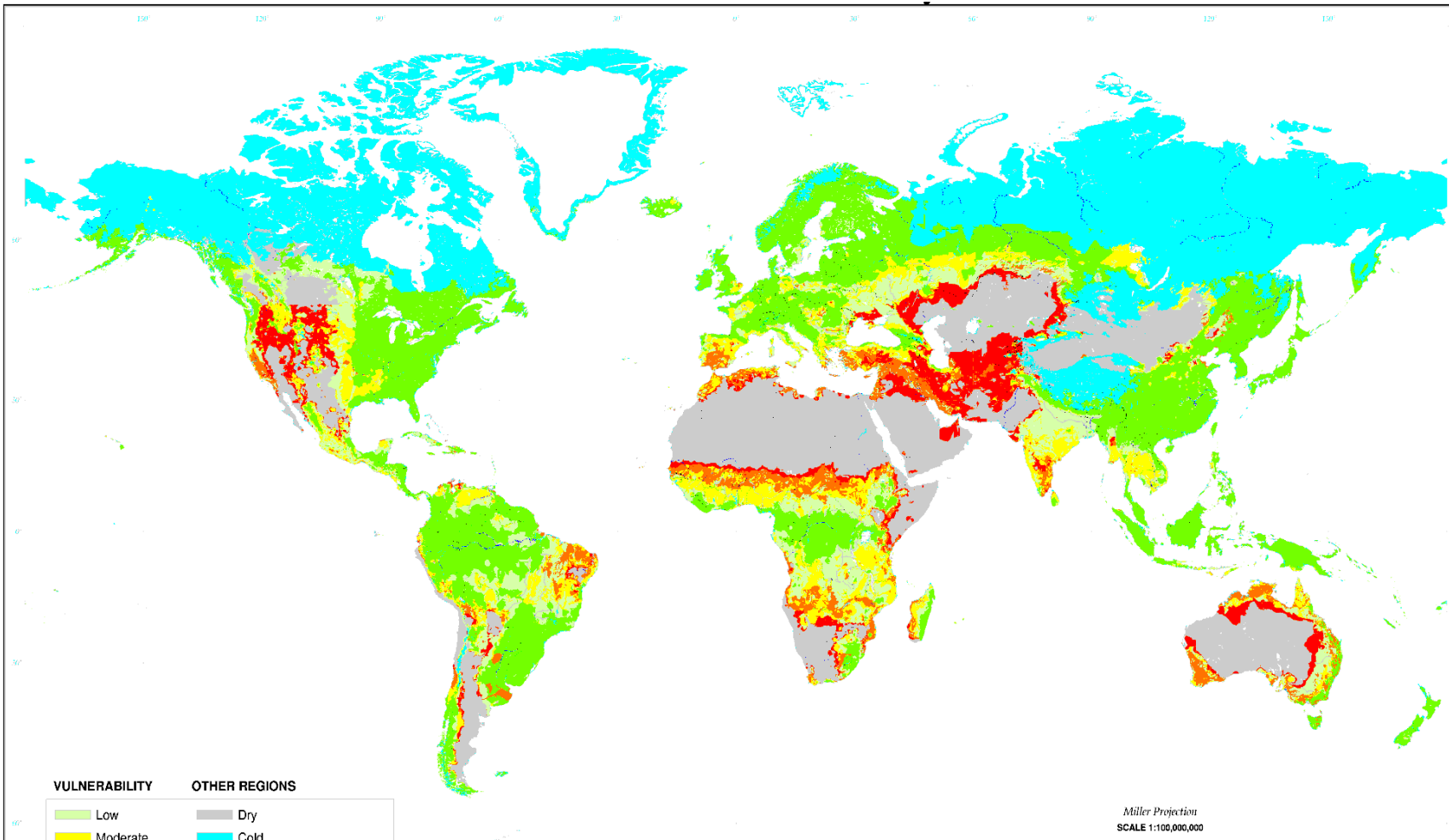
Main causes of desertification in the Sahel are slash-and-burn farming practised by an expanding human population and drought.



The Sahel zone – the buffer between the Sahara and savannas.

# Vulnerable Zones for Desertification.

- Globally 10 – 20 % of the drylands are deserted.
- Global warming is leading to increased desertification in many areas.



- A sequel to the deforestation is typically large scale erosion, loss of soil nutrients and sometimes total desertification.

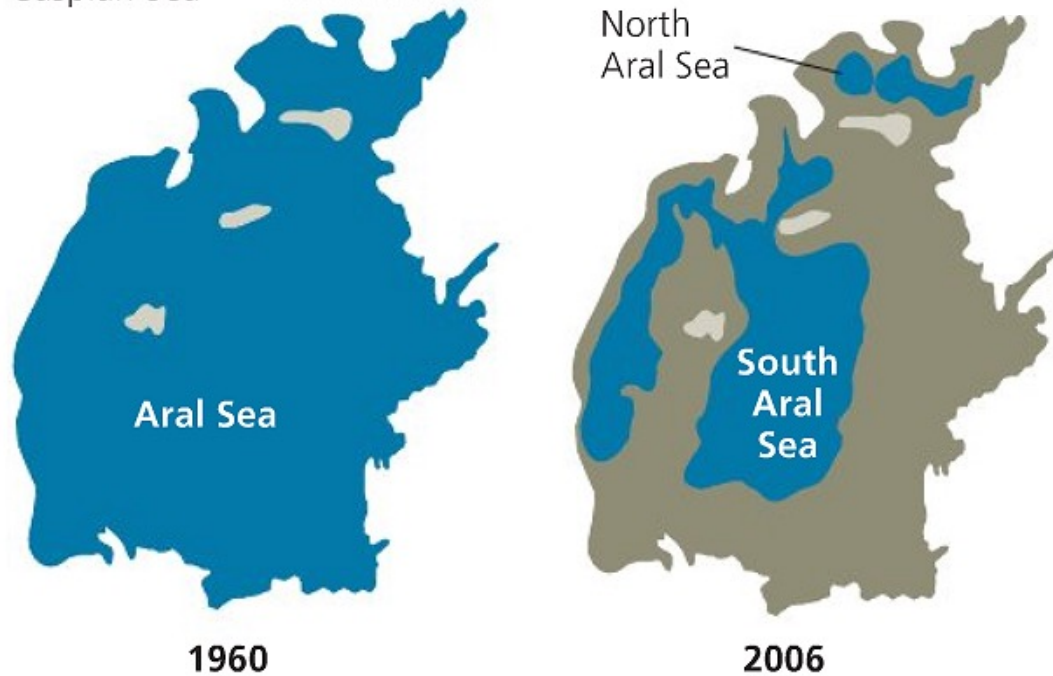
- Examples of this extreme outcome can be seen on Madagascar's central highland plateau, where about seven percent of the country's total land mass have become barren, sterile land.

Global map of desertification vulnerability.

Source: United Nations Convention to Combat Desertification (UNCCD)/USDA

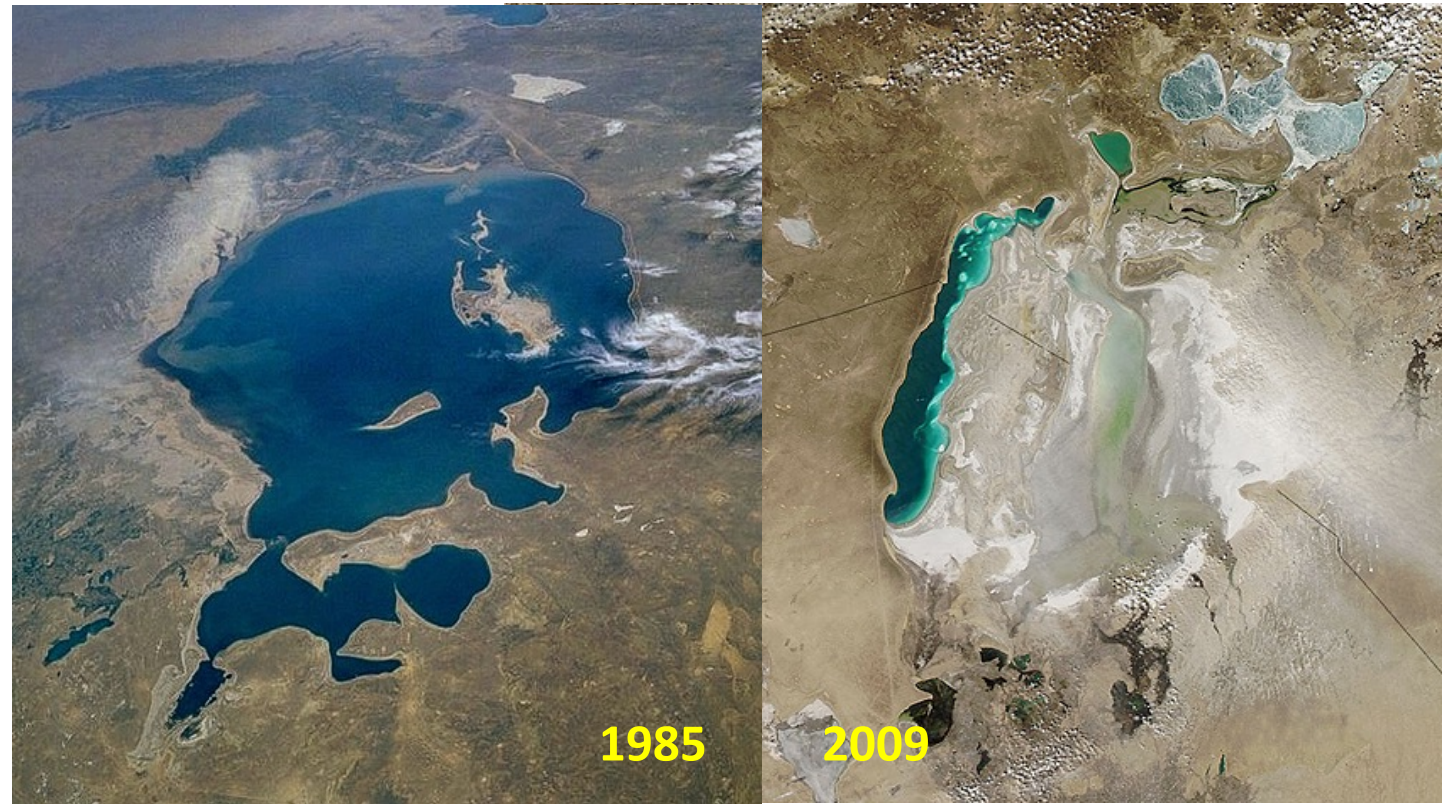
# Desertification of Aral Sea Region.

- The Aral Sea situated between Kazakhstan and Uzbekistan had originally a surface area of 68.000 km<sup>2</sup>.
  - Its water surface has shrunk to 10% of its original size.
  - The rest is now a salt desert.
  - Cause: Diversion of rivers feeding into the Aral Sea for irrigation of cotton fields in Kazakhstan.



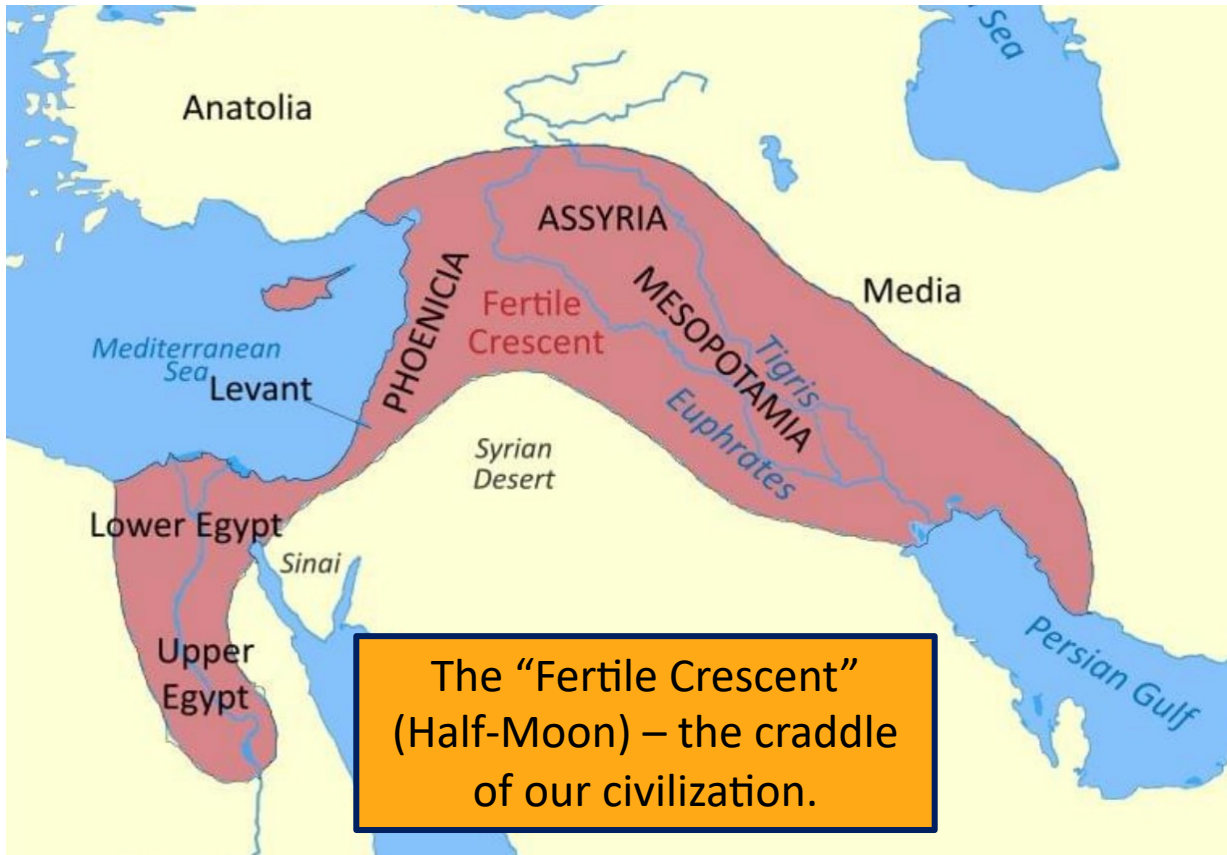
(c) The shrinking Aral Sea, then and now

Source: Withgott and Brennan: Environment, 2008



## 6.2 Crops and Food.

- **Development of Agriculture:**
- **Agriculture** is the artificial cultivation and processing of animals, plants, fungi and other life forms for food, fibers and other byproducts.
- Agriculture started 10.000 years ago in Mesopotamia (and in many other regions of the world).
- In Mesopotamia the eight so-called Neolithic founder crops of agriculture appear: wheat, barley, peas, lentils, bitter vetch, chick peas and flax.
- 7.000BC farming spread to Egypt creating the basis for a new great culture.
- 3.500BC the plough was developed in Egypt.

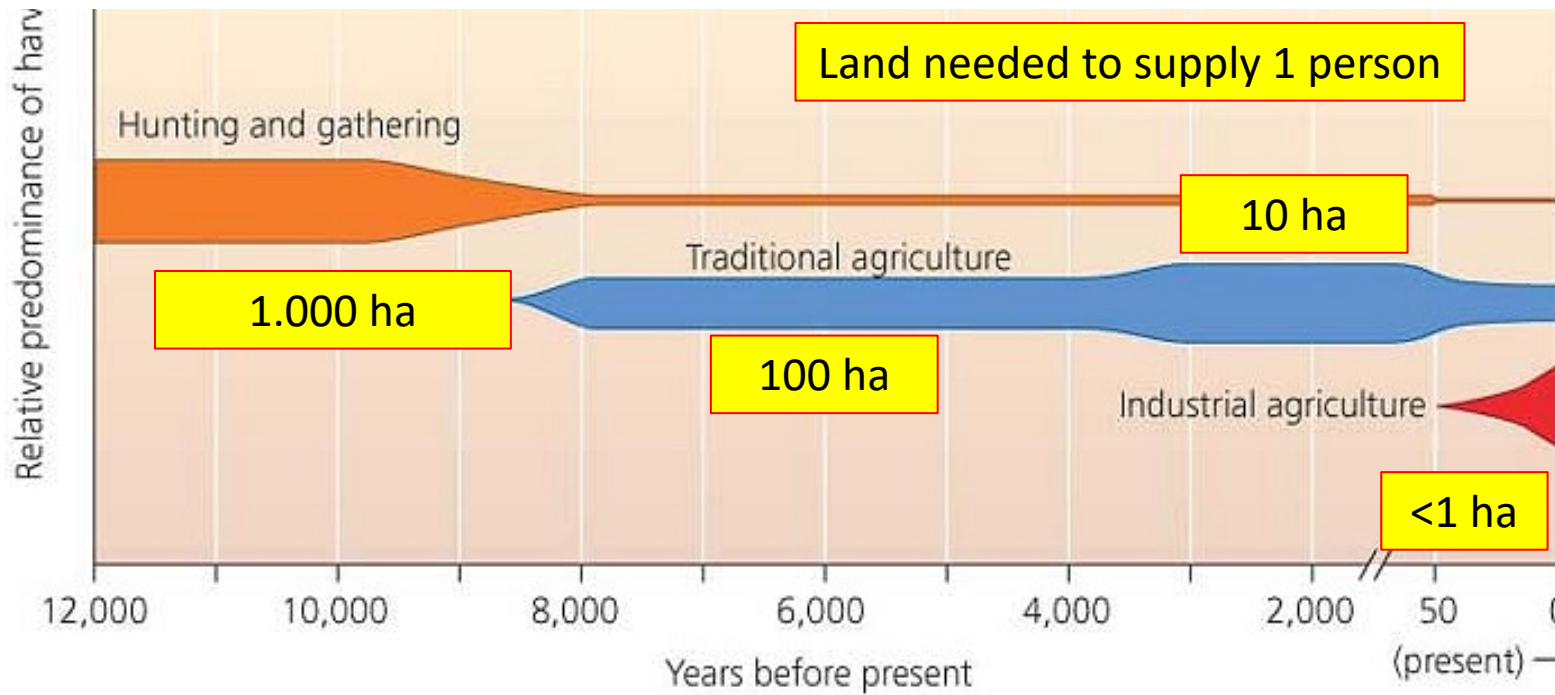
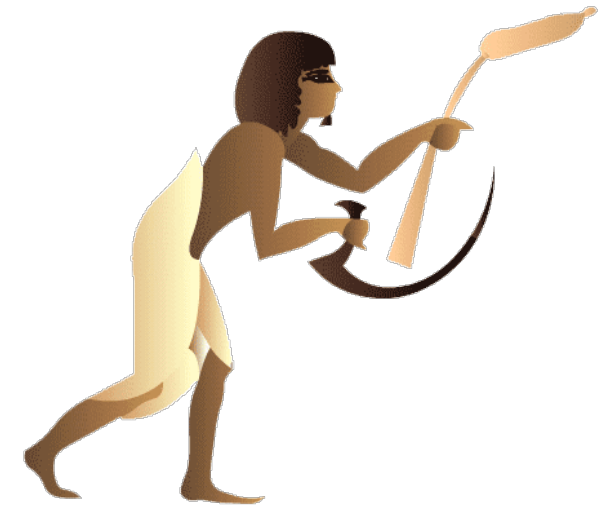


The "Fertile Crescent"  
(Half-Moon) – the cradle  
of our civilization.



# Development of Agriculture.

- **Agriculture** replaced gathering and hunting reducing the area needed to supply food for 1 person from 1.000 ha to 100 ha.
- Traditional agriculture based on manual labor dominated, until the second industrial revolution (1850-1945) introduced mechanisation reducing the necessary area for food supply of 1 person to 10 ha.
- This period was followed by „industrial agriculture“ based on improved cultivation techniques reducing this area to less than 1 ha.
- Every one of these changes lead to a massive increase in population.



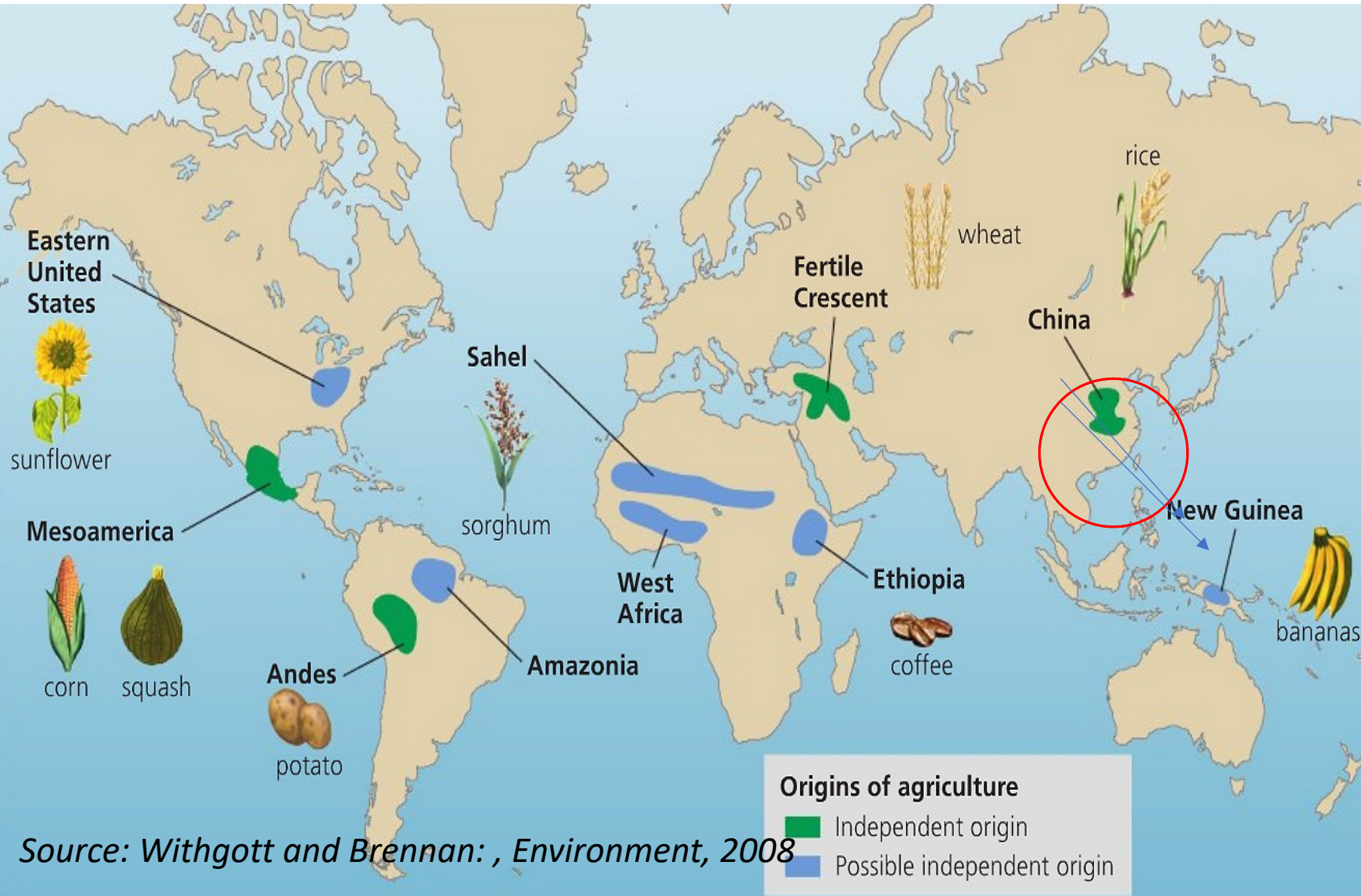
# Traditional Agriculture.

Secured the existence and growth of our society for thousands of years.



Pieter van Breugel.

# Origin of Crops and Food.

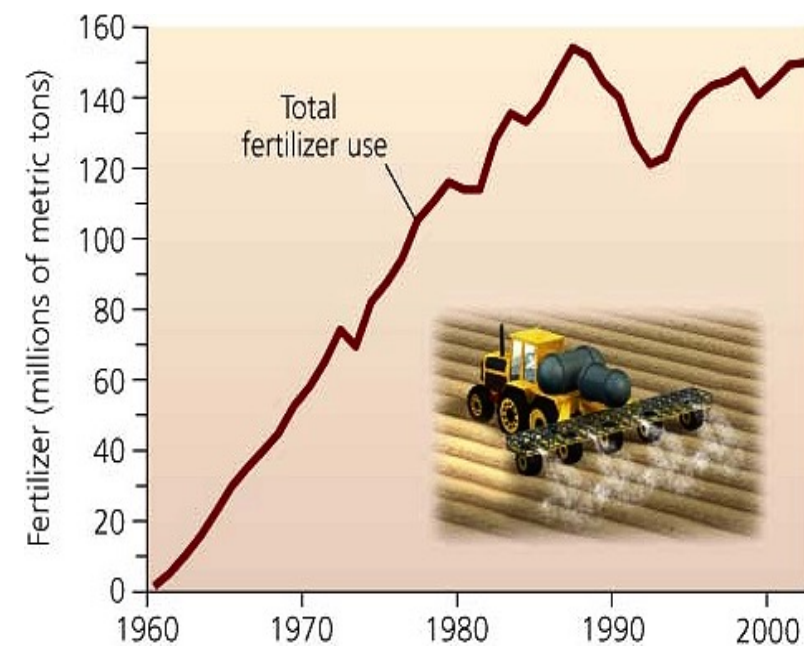


Agriculture developed independently in several regions of the world as civilisations domesticated wild plants and animals from species living in their environment.

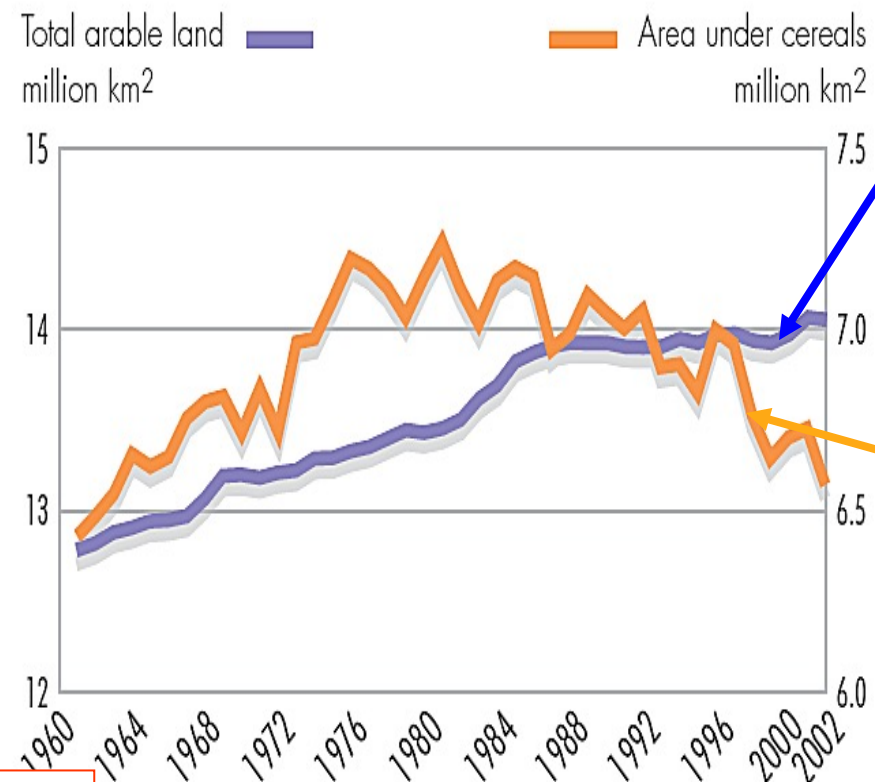
A variety of potatoes from Peru.

# Evolution of Production in Agriculture.

- Since the 1940s, agriculture has dramatically increased its productivity, due to increased mechanization and the use of petrochemical derived pesticides and fertilizers.
- Modernisation of agriculture has allowed the world population to double over the last 50 years.



Arable land (left scale) and area under cereals (right scale).



Area of arable land is still slightly increasing due to draining of wetlands, irrigation and deforestation.

36% of the world's workers are employed in agriculture, but agricultural production less than five percent of the GDP

• But area used for cereals is decreasing due to increase in meat production.

• Areas needed for crops and meat production:

- 1 kg of vegetable 1 m<sup>2</sup>
- 1 kg of chicken 14 m<sup>2</sup>
- 1 kg of eggs 22 m<sup>2</sup>
- 1 kg of beef 250 m<sup>2</sup>

# Global Production of Crops and Food.

## •Top agricultural products (FAO 2022):

- 1.200 Mto maize (feed and food)
- 787 Mto rice (food)
- 771 Mto wheat (food)
- 416 Mto oil palm fruit (+250% since 2000!!!)
- 372 Mto soy beans (feed and food),
- 746 Mto cow's milk and 138 Mto water buffalo milk (food)
- 93 Mto eggs (food)
- 376 Mto potatoes, 315 Mto cassava, 189 Mto tomatoes, 107 Mto onions, 93 Mto cucumbers, 71 Mto cabbage
- 125 Mto bananas, 104 Mto water melons, 93 Mto apples, 76 Mto oranges, 74 Mto grapes, 38 Mto mangos
- 120 Mto pig meat, 122 Mto chicken meat, 73 Mto beef

*Source: FAO 2022*

## • Production trends in food: 2000-2021

- Primary crops: +54%
- Meat: +51%
- Milk: +58%
- Growth in agricultural production faster than population growth (+29%).
- **Reasons:**
  - Intensification of farming activities (increased use of irrigation, fertilisers, pesticides, and cropland expansion).
  - Enhanced production technologies (improved farming practices, increase of high yield crops).

Meat makes up only ca 5 % of the global food and feed production – but takes 2/3 of the agricultural land.

Meat has only a slightly higher energy content than crops.



## Crops and Food: Largest Food and Feed Exporters.

### Intensification of Agriculture.



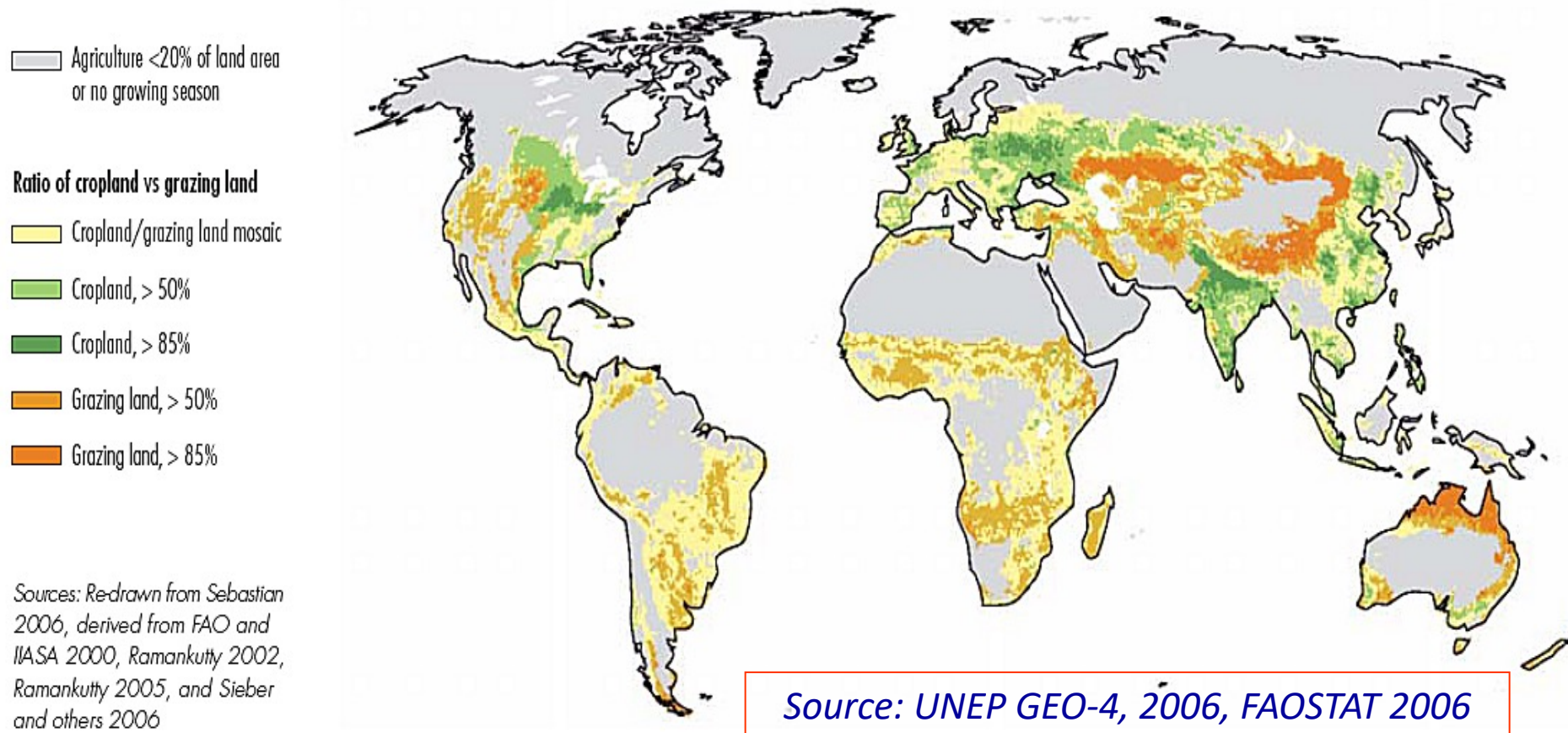
Chinese stables for raising pigs - 26 stories high.

Source: Facebook 2024

# Agricultural Areas.

- Globally only 12 % of land surface usable for agriculture with only 2,5 % high value farmland and very unbalanced distribution between different regions.
- Agricultural farmland subject to degradation in many areas.

Figure 5.4 Contemporary extent of agricultural systems

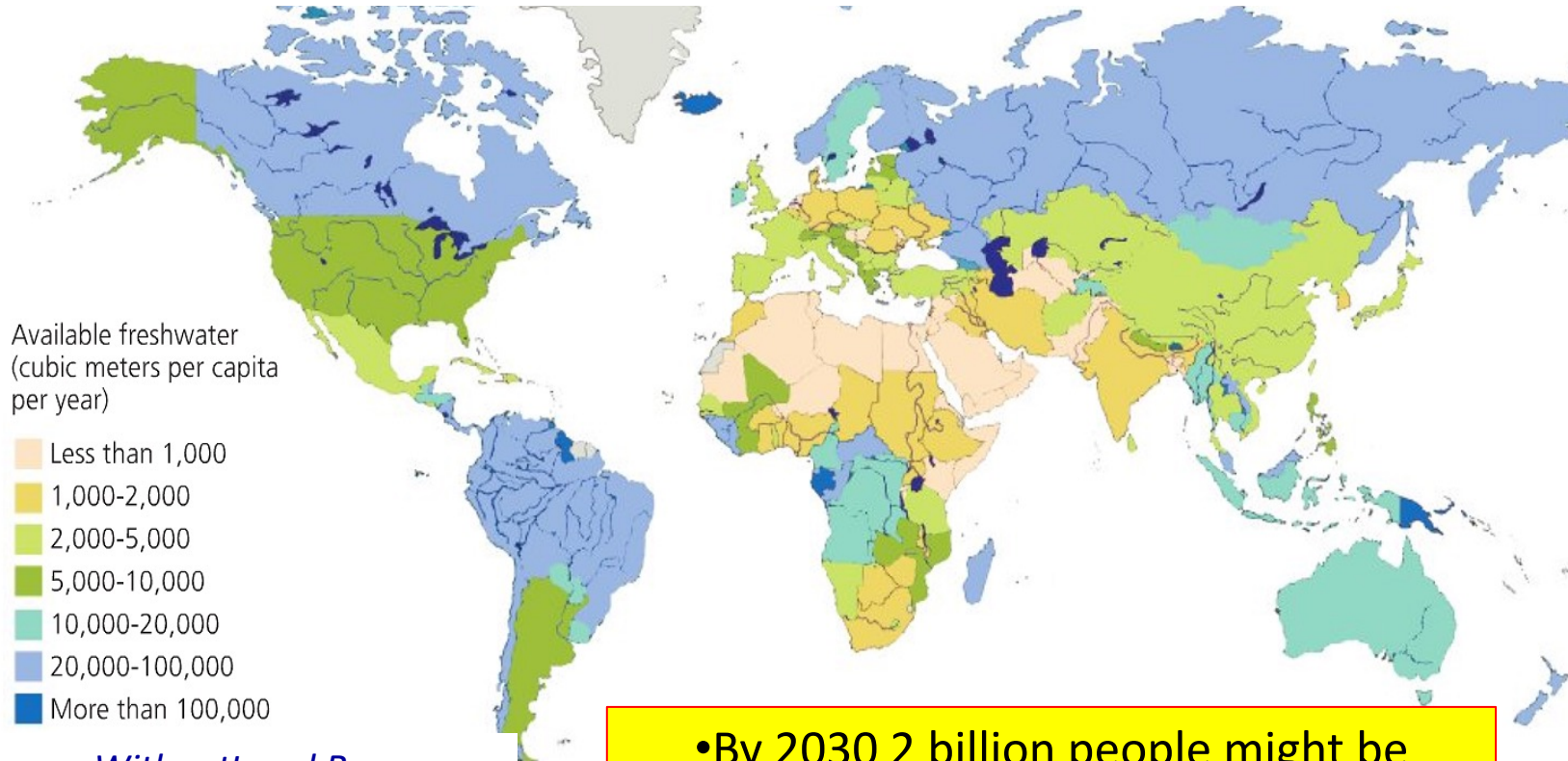


- **Major threats to agricultural soils:**
  - Degradation of soil quality due to overgrazing, overload with fertilisers and pesticides, overextraction of groundwater causing a lowering of ground water levels and rising of saline waters.
  - Soil erosion by wind and water leading to desertification.
  - Globally 15% of the agricultural areas have very degraded soils.

Contemporary extent of agricultural systems.

# Water Availability for Agriculture.

- Agriculture accounts for 70% of the global consumption of freshwater water.
- Globally 40% of crops are produced in irrigated fields.
- Water availability is very different in the various regions of the world.
- Water scarcity affects large parts of Africa, the Middle East and South Asia.
- Overextraction of ground water for land irrigation magnifies this problem.



Source: Withgott and Brennan:  
*Environment 2008*

•By 2030 2 billion people might be affected by severe water shortage.

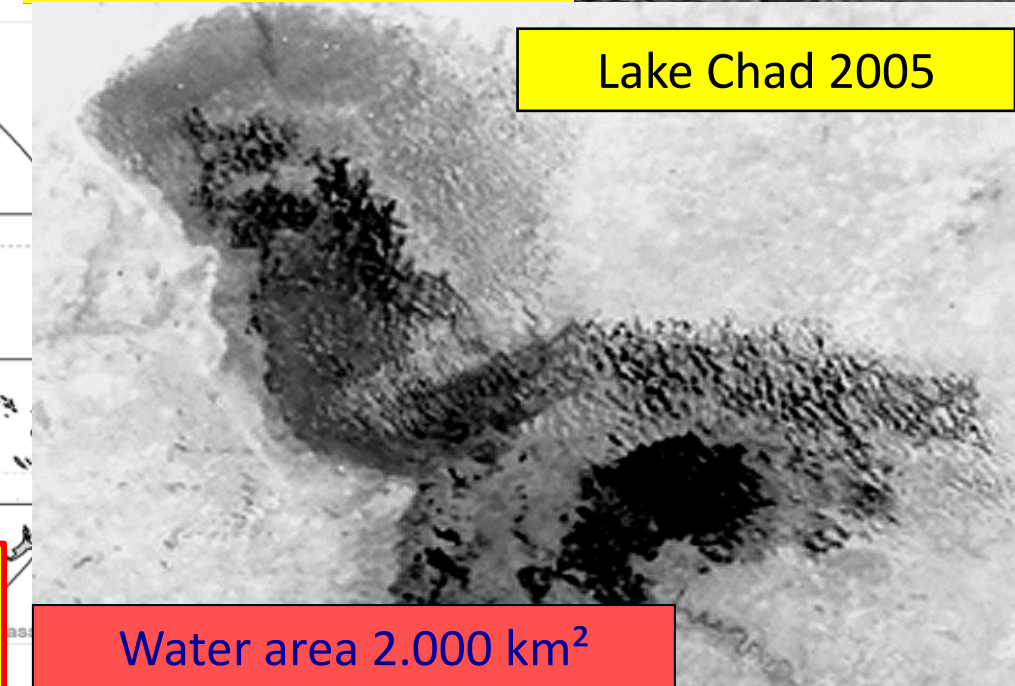
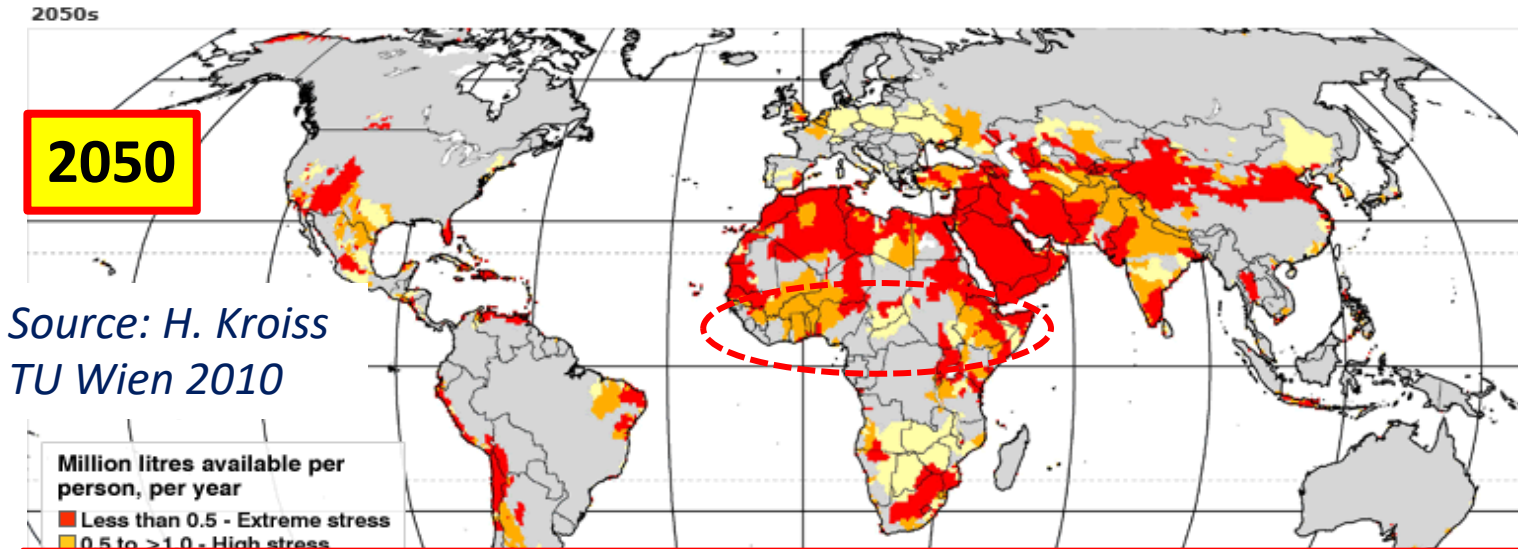
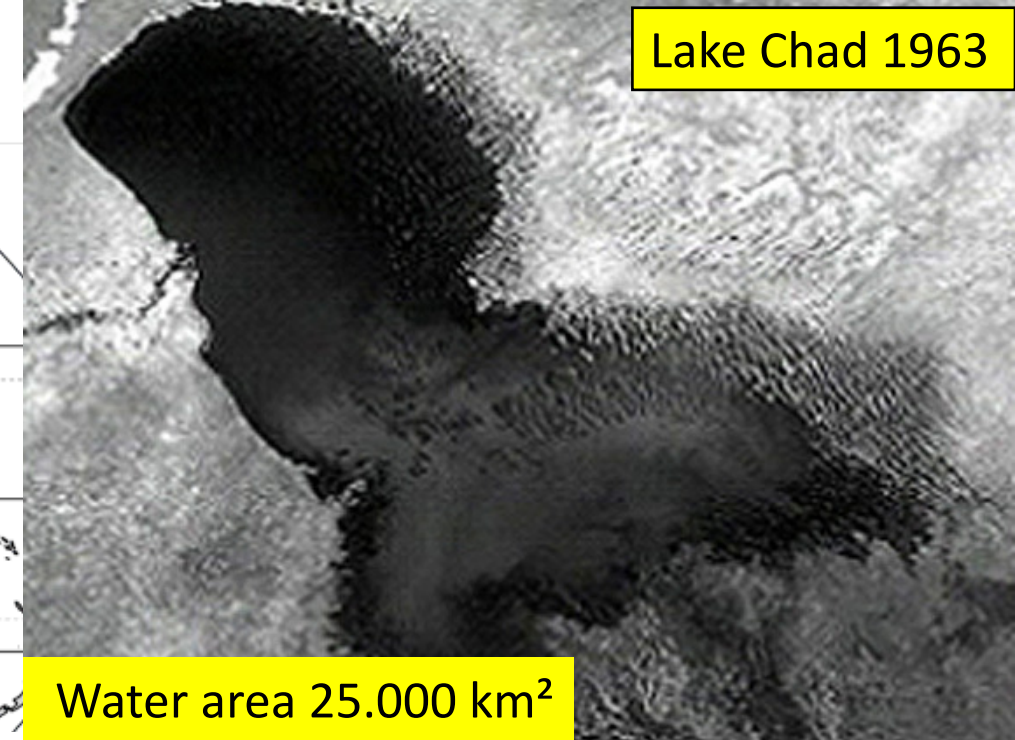
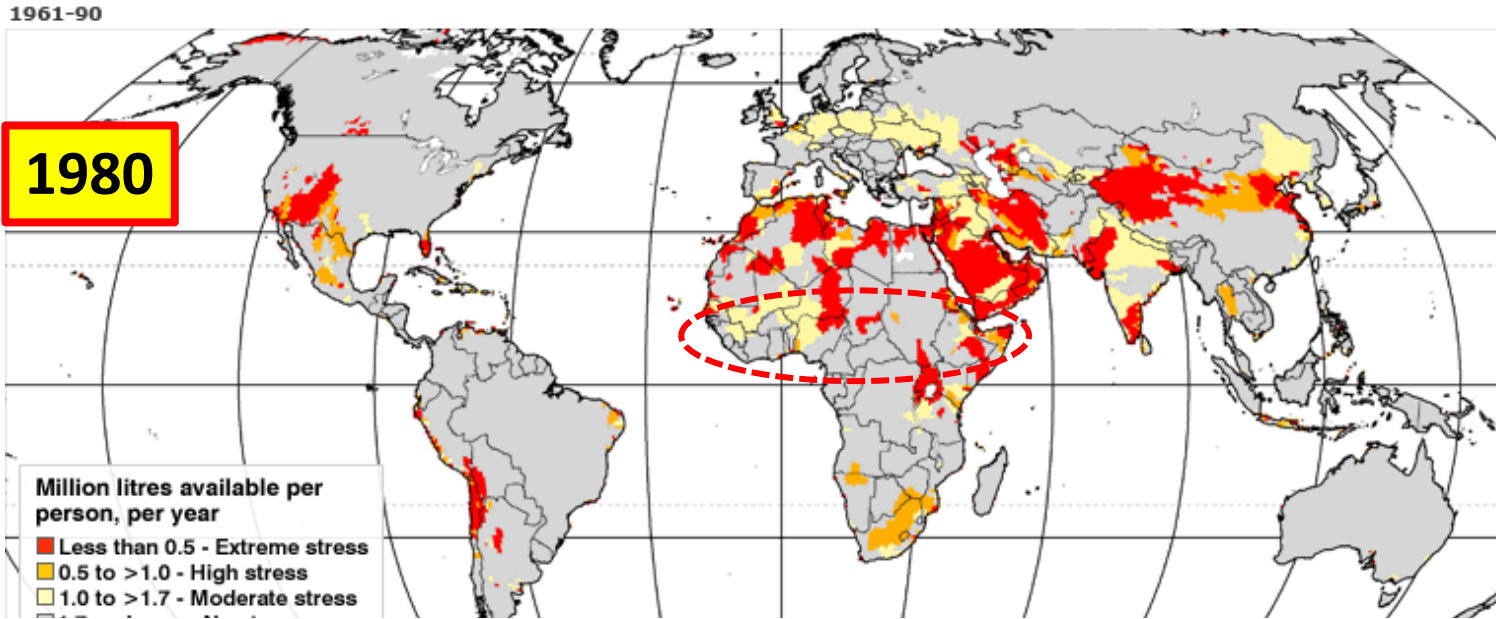


Wine grown on volcanic lava ash with dew as sole water supply (Lanzarote).



Desert agriculture in Saudi Arabia using water from underground aquifers.

# Scenario of Future Water Availability.



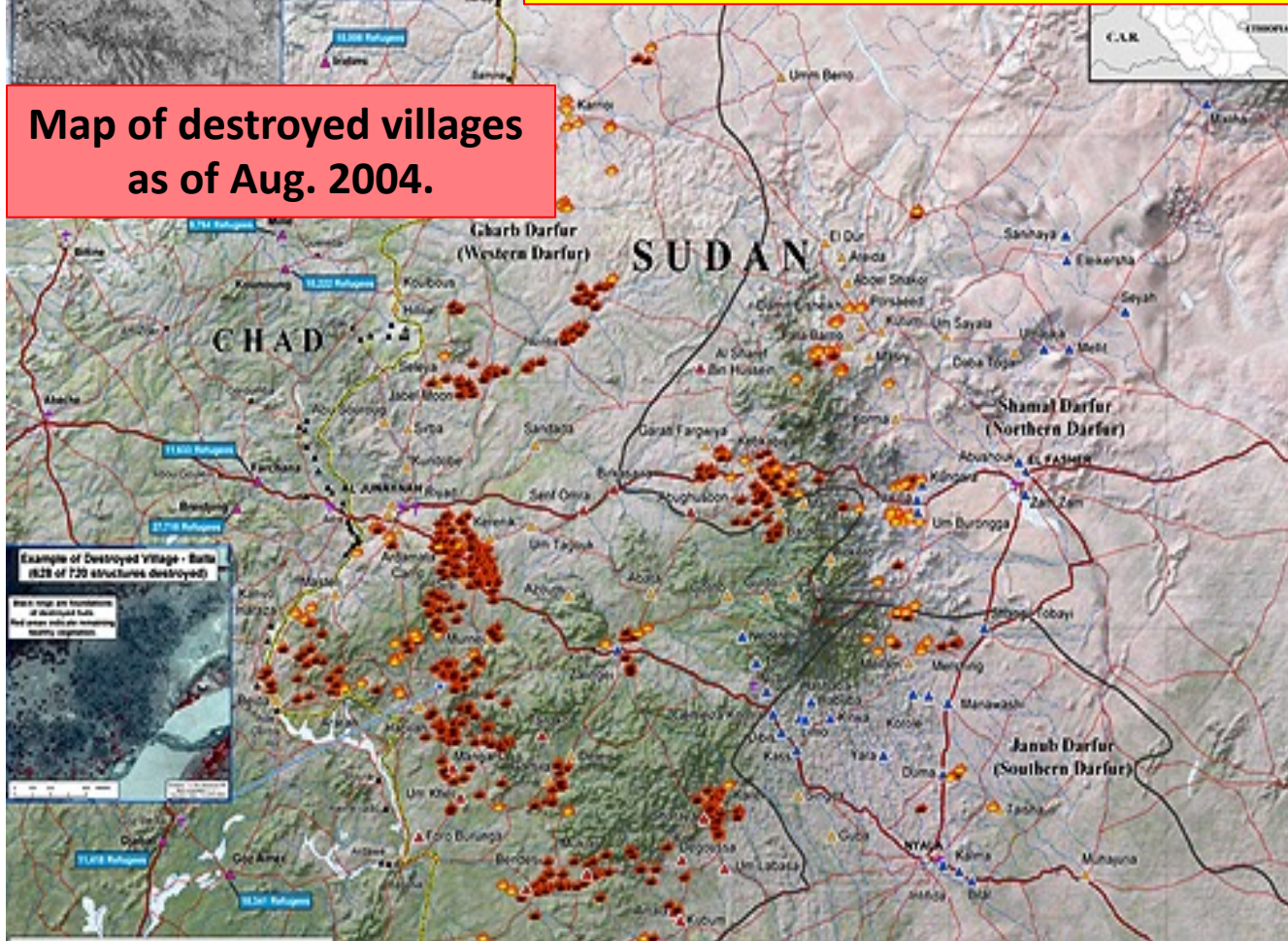
Source: H. Kroiss  
TU Wien 2010

Areas with insufficient water supply: “water stress” for populations and reduced agricultural productivity from 1980s till 2050s.

# Crops and Food: Fighting for Agricultural Land – Darfour/Sudan.

Decades of drought, desertification, and overpopulation are the main causes of the Darfur conflict starting in 2003.

Map of destroyed villages  
as of Aug. 2004.



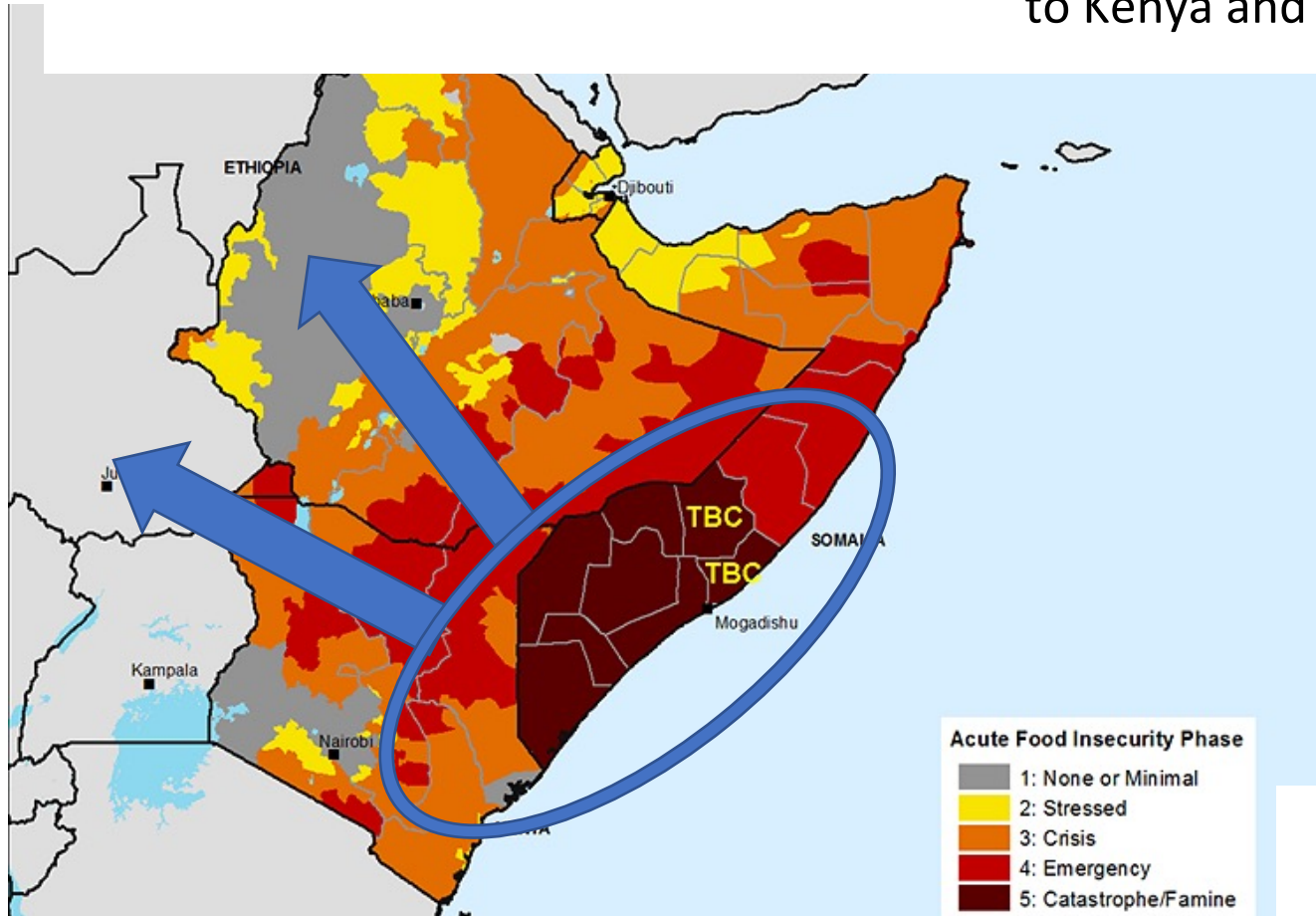
Baggara nomads searching for water have taken their livestock further south, to land mainly occupied by non-Arab farming communities.



In the conflict 400,000 died and 2,5 million people were displaced, and many of them now living in the Darfour refugee camps. *Source: UN and Wikipedia*

# Food Crisis in East Africa of 2010-2012.

Worst drought since 60 years exacerbated by local conflicts caused over 800,000 people to flee from Somalia to Kenya and Ethiopia.



Crisis areas in Eastern Africa 2010-2012  
Famine spread over more than 1 million km<sup>2</sup>



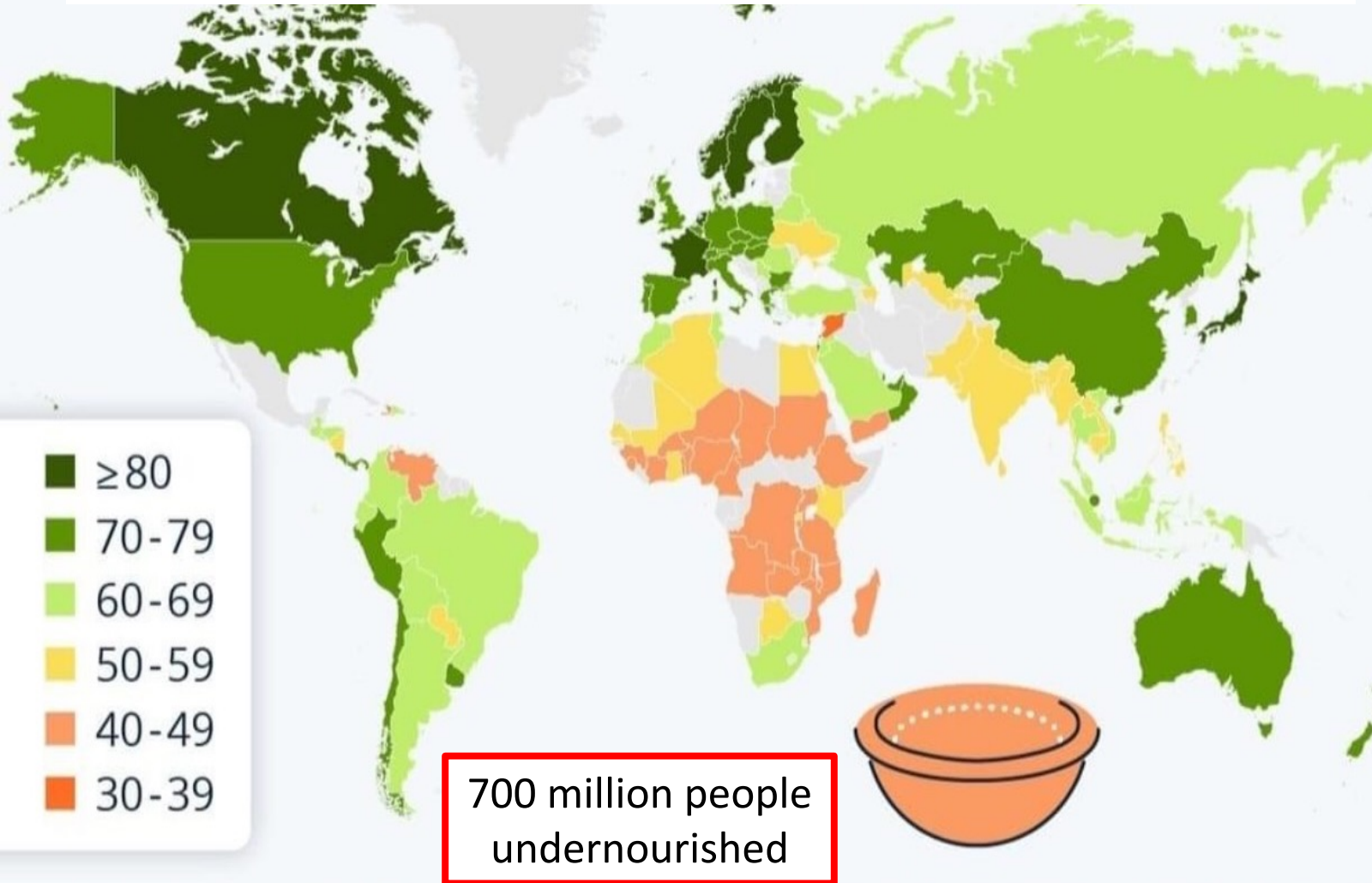
## Lack of rain:

- loss of livestock of up to 60%
- decreased milk production
- very poor harvest of crops

More than 260.000 people died between Oct. 2010 and Apr. 2012.

# Global Food Supply.

How can we feed 10 billion people in 2050?



\* Index measures the affordability, availability, quality and safety, sustainability and adaptation of food based on 68 indicators across 113 countries.

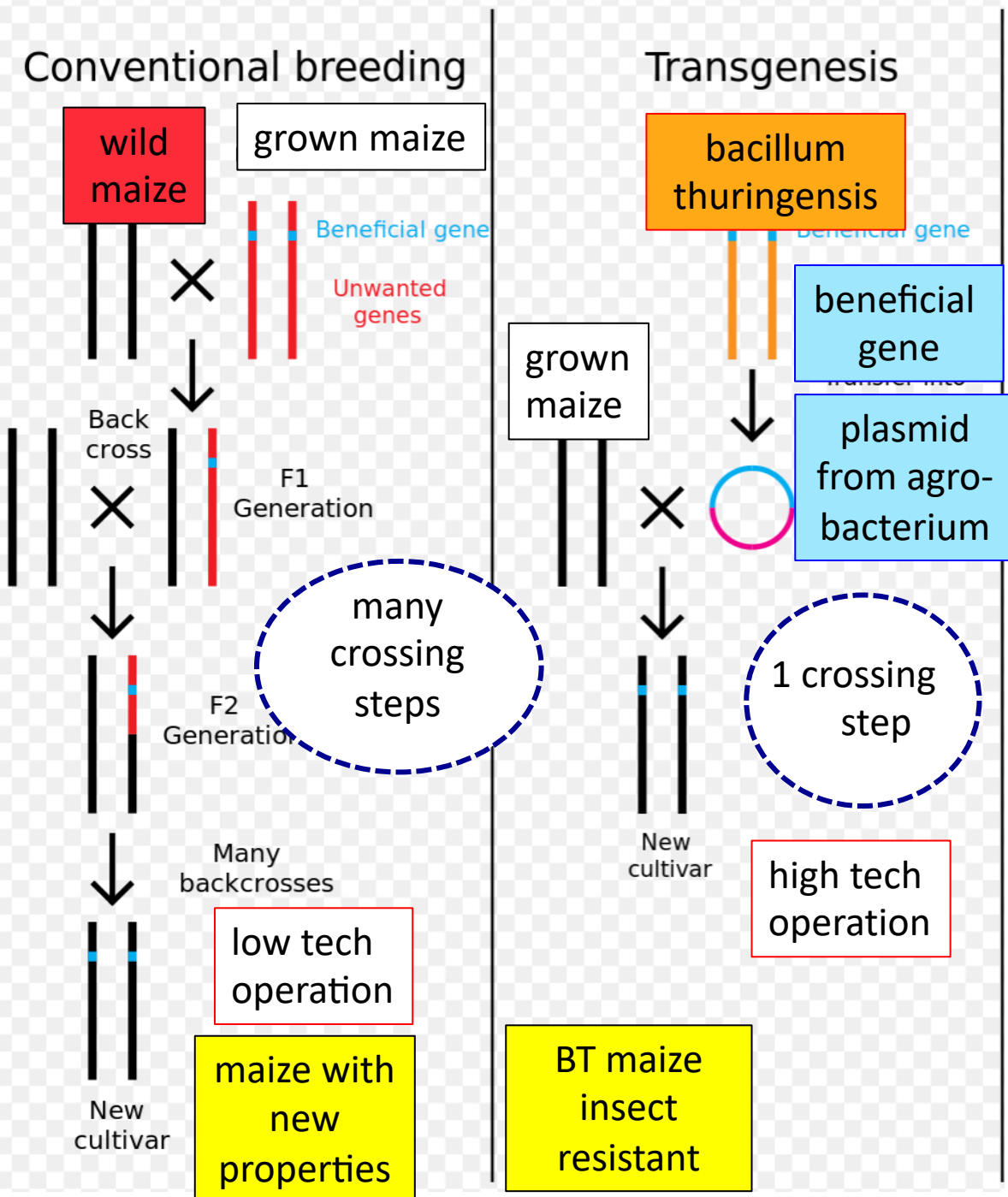
Source: Economist Intelligence Unit

- **Problem:**

- Arable land per capita decreasing due to population growth: now 0,25 ha per capita and 0,20 ha in 2050.
- In order to also eliminate present undernourishment a doubling of global food production seems necessary.

- **Approaches:**

- Increase of the agricultural yield: only 20% in developing countries due to pests, poor storage, lack of fertilisers as compared to 70% in industrialised countries (“sustainable intensification”).
- Reduction of food waste in developed countries: per capita food waste in Europe is 150 kg annually.
- Breeding of new drought and salt resistant plants (GMOs).



# Crops and Food: Genetically Modified Organisms (GMOs).

- Genetic modification of seed material allows to produce plants with new properties („Biocrops“):
  - Enhanced resistance against insects (Bt-maize).
  - Enhanced resistance against efficient broad band pesticides (RoundupReady Soy).
  - Improved nutrient content.
  - Higher drought resistance.
  - Higher salt resistance.

- **Share of GM crops (2023):**
  - soy beans USA 94%, **global 74%**
  - maize USA 93%, **global 33%**
  - cotton USA 90%, **global 80%**
  - canola (rapeseed) USA 93%, **global 24%**

**Global area of GM crops increased by a factor 100 since 1996.**

# Genetically Modified Organisms for Future Food Production?

## Biotech Crops in Waiting

[www.goldenrice.org](http://www.goldenrice.org)



**Golden Rice**

Genetic modification allows rapid cultivation of new crop varieties with improved properties. Conventional breeding techniques are much slower.

**Late Blight-Resistant Potatoes**



**Insect-Resistant Eggplant**



<http://static.guim.co.uk/sys->

<http://www.medindia.net/news/featured-news/BT-Britjal.jpg>

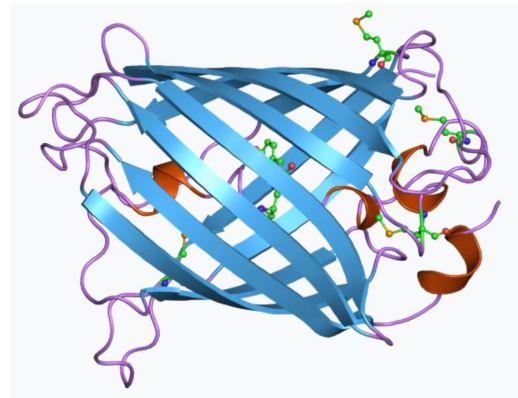


## Genetically Modified Plants and Animals.

GloFish (Singapore University) was the first genetically modified animal to be sold as a pet.



„Suntory Blue Rose“



Structure of GFP.

Blue plant pigment delphinidin added from the pansy.

Alba, the „Glowing Bunny“



Green fluorescent protein (GFP) gene found in the jellyfish inserted into the DNA of the rabbit. The rabbit then fluoresces green when exposed to blue light.

**Towards a “Biological Revolution” ?**

# The European Position on GMOs.

- For genetically modified products In Europe the term "Frankenstein food" was coined.
- European consumer thoroughly dislike GMOs, are afraid of negative health effects and introduced labelling requirements.
- European Commission Report on GMO Biosafety (2010):
  - Reports on 130 research projects covering a period of more than 25 years and involving 500 research groups:
  - GMOs are not *per se* more risky than plants obtained with conventional breeding technologies.
- EU tried to ban imports of GM food and feed into the EU, but lost the WTO case:
  - Only labelling acceptable.
- EU is now developing a new biotech strategy focusing on gene editing.
- With this technique genes can be deleted or added from the same or similar species.

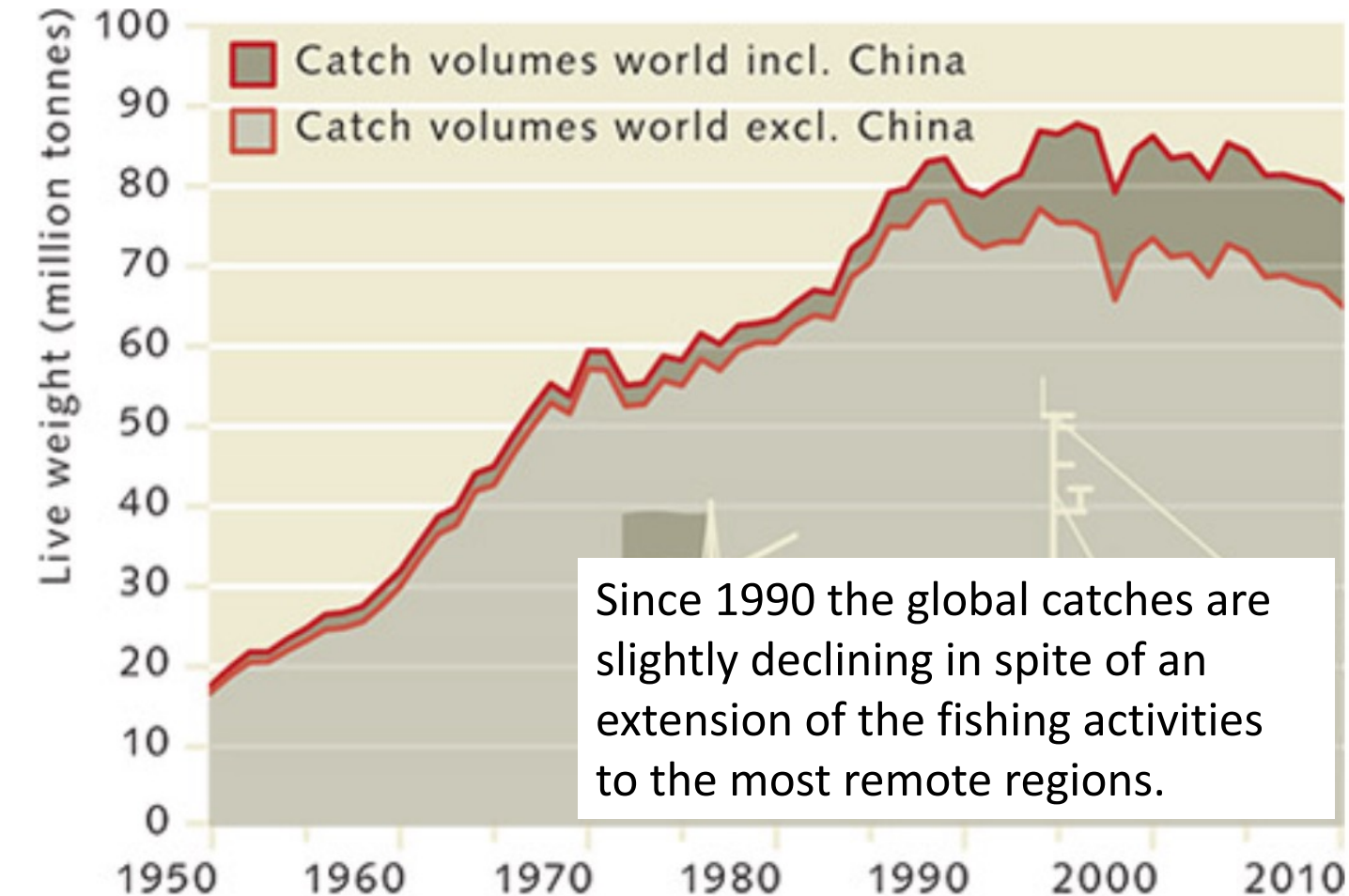


Gene editing (CRISPR/Cas method) developed by Emmanuelle Charpentier and Jennifer Doudna (Nobel Prize 2020)

- Gene editing would allow to create new varieties of crops which also in principle could be achieved through traditional breeding techniques, but much faster.
- It is distinct from genetic modification, which introduces DNA from foreign species.

# Crops and Food: The Issue of Overfishing.

- 14 fish species are important for the food supply of the humans.
- Global fish catch rose from 20 million tons in 1950s to 90 million tons in the 1990s due to the use of new technologies for commercial fishing, radar detection of fish swarms, trawling, purse sein....



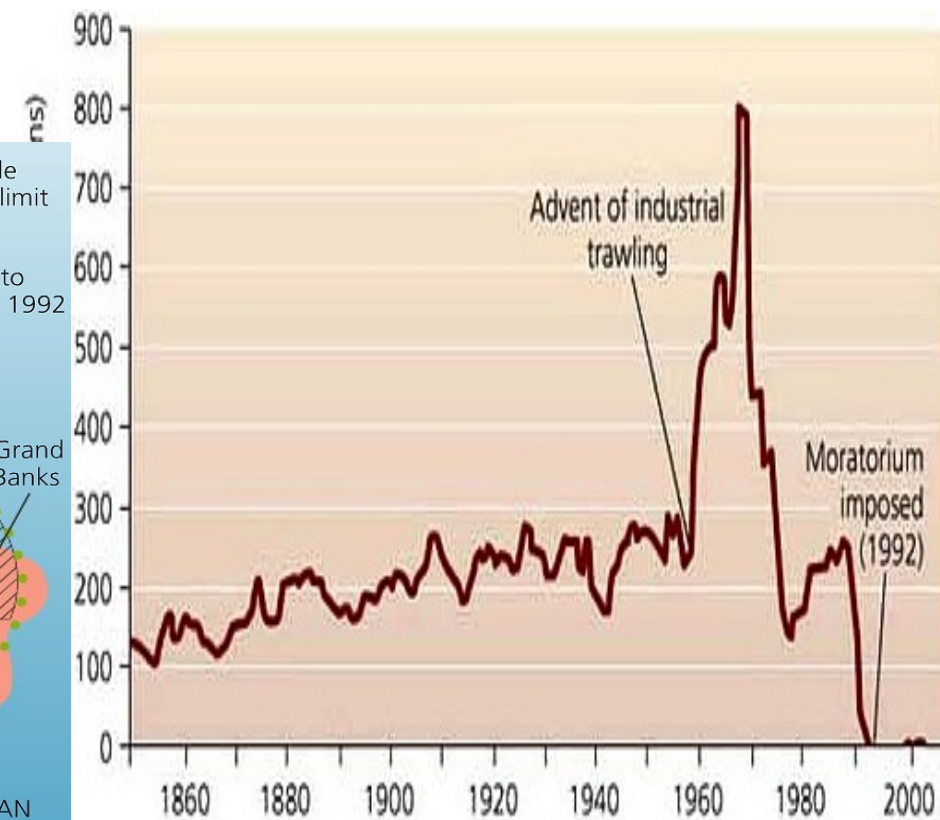
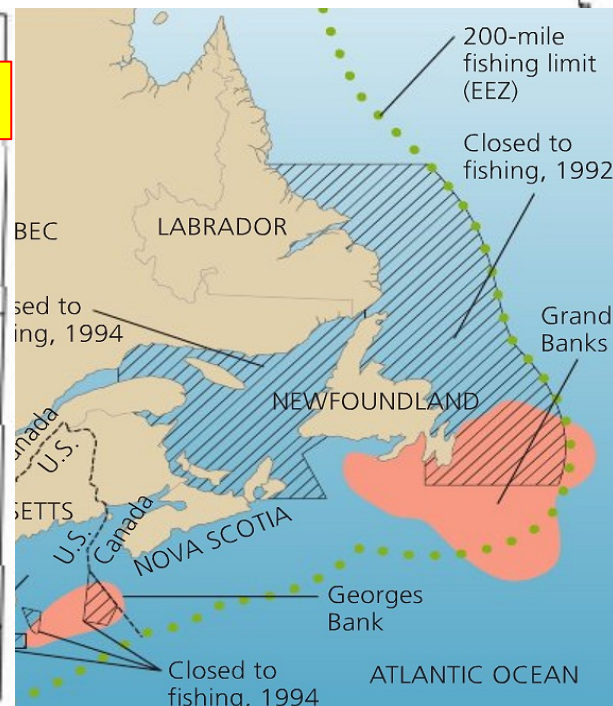
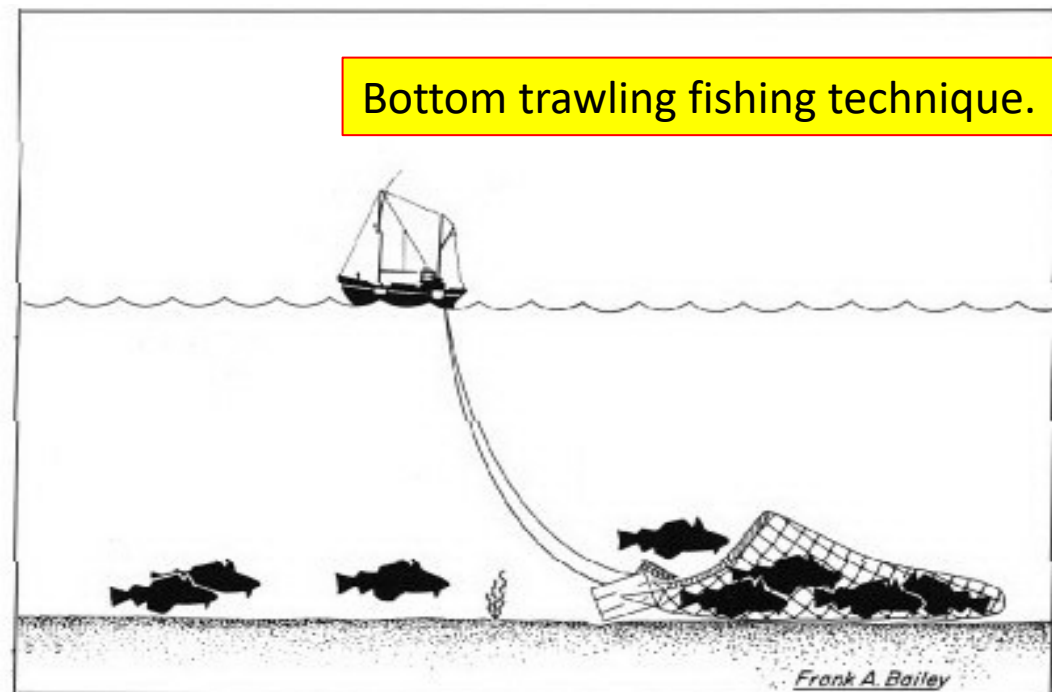
Fish catch using the Purse-Sein technique.

# Modern Fishing Techniques.

- **Purse Seine:** Fish swarm is detected by sonar and an up to 200m deep net is laid around the fish. With this method whole swarms can be captured, inclusive all the small fish.
- **Trawling:** ship drags nets of up to 20.000 m<sup>2</sup> which allow to catch several hundred tons at once. Lack of selectivity.
- **Bottom trawling:** lack of selectivity and physical damage to the seabed.

- Fish catches of certain species and in specific regions have dramatically decreased due to reduction of the fish stocks: e.g. North Atlantic cod, salmon, tuna.
- Large areas had to be closed for fishing to enable recovery of cod stocks.

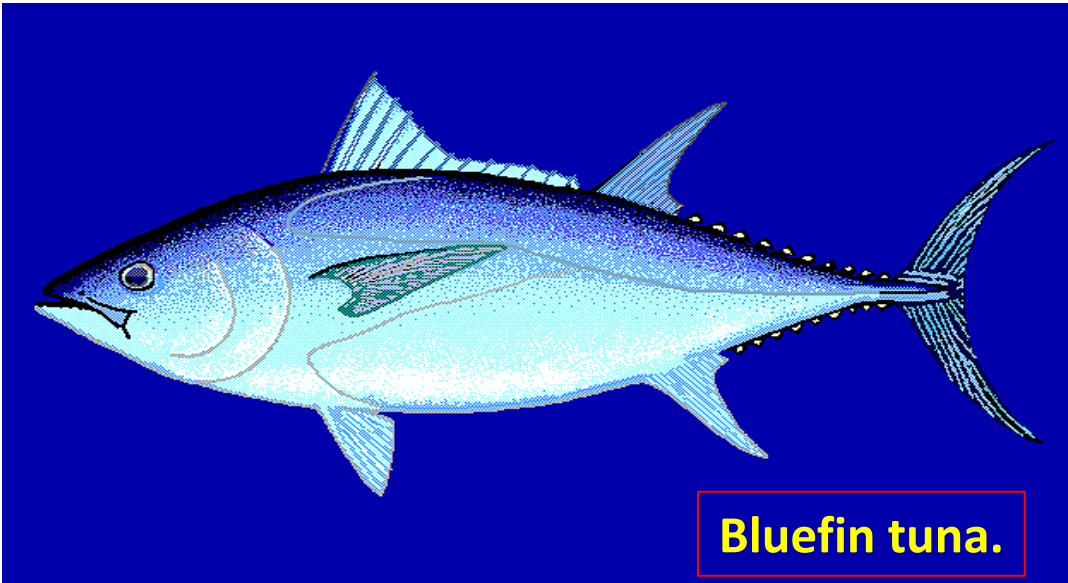
Bottom trawling fishing technique.



# Tuna Fish – an Endangered Species.

- In the 1960s, the annual world catch of tuna fish was about 1 million tons, most of it taken by hook and line.
- Now with purse seine catches are more than 4 million tons annually.
- 60% of the catch of the catch are skipjack tuna, 25% yellow fin tuna.
- Bluefin tuna, the most valuable species, amounts to only 1,5%
- 60.000 tons caught annually in the Mediterranean and Atlantic.
- Scientifically recommended catch of blue fin tuna is 15.000 tons maximum, consequently stocks were heavily reduced during the last decades.

- A 200 kg tuna fish can be sold for up to 600.000 \$ on the Japanese market (2016).
- Extensive illegal fishing activities.



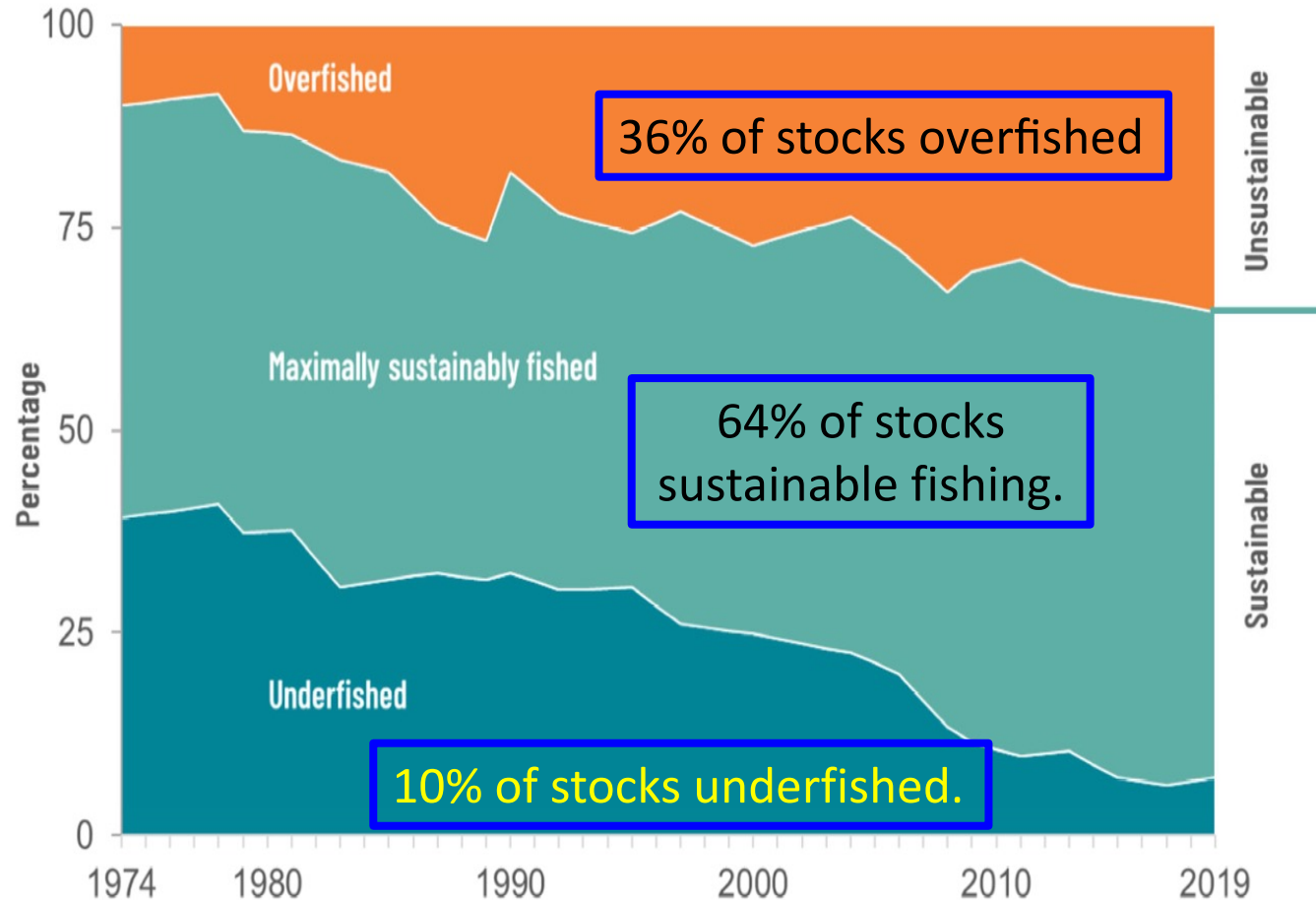
**Bluefin tuna.**



**Frozen tuna in the Tsukiji fish market, Tokyo.**

# Global Trends in Fish Stocks 1974-2019

- Overfishing has not only proved disastrous to fish stocks but also to the fishing communities relying on the harvest causing a substantial drop in the number of fishers.



Overfishing still increasing!

- Globally 60 million people employed in the fishing sector with 600 million depending on this income: majority in Africa, SE-Asia, South America.
- Harvest Control Rule (HCR) management principles have been introduced in the main fisheries around the world.
- The "United Nations Convention on the Law of the Sea" grants coastal states exclusive fishing rights for a 200 mile zone and requires all coastal states to ensure that the maintenance of living resources in their exclusive economic zones is not endangered by over-exploitation.
- Some States and Regions have enacted stringent fishing restrictions (e.g. Canada, EU – Community Fishing Control Agency, Vigo).

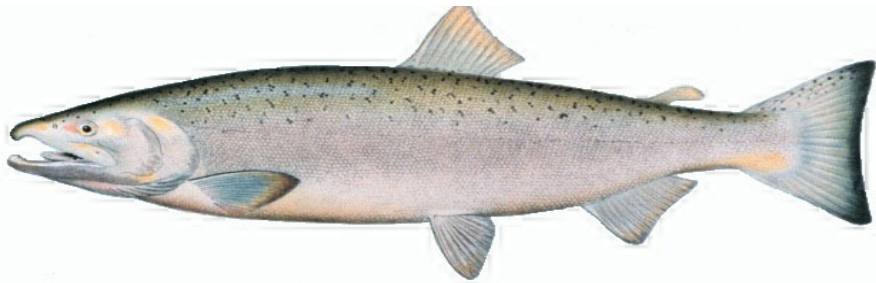
# Aquaculture.

- **Aquaculture production:**

- salmon, sea bass, cat fish, shell fish, tilapia, pangasius, trout, carp, oysters, shrimps, prawns.....
- Total production volume in 2022: 88 million tons with annual increase of 10 % (FAO)

- **Environmental problems:**

- pollution with antibiotics and excrements
- breed fish escape and genetic crossing with wild species
- spread of parasites to wild species



Atlantic Salmon



Carp



Tilapia

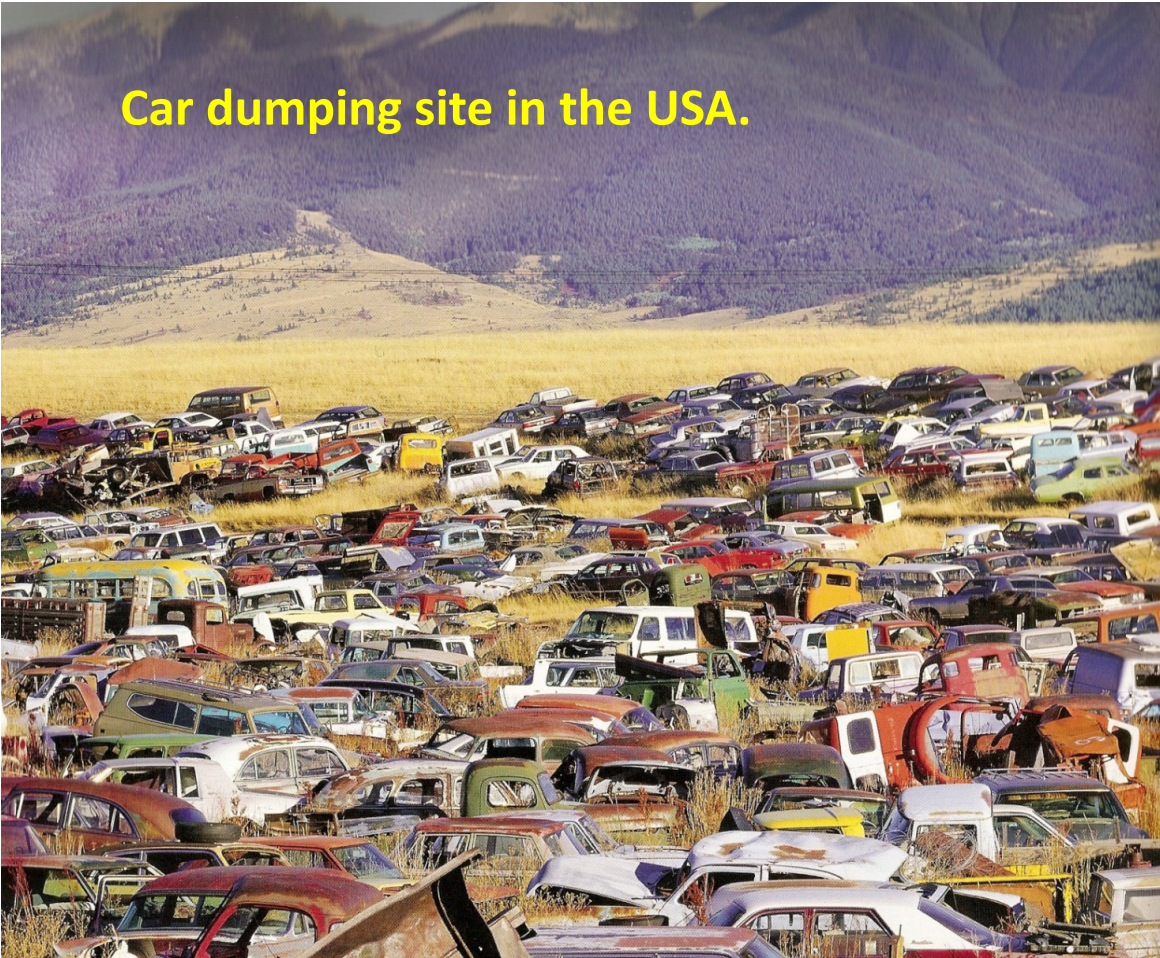


Fish cages in Abu Dhabi.

## 6.3 Minerals and Fossil Resources.

### Waste as a Resource:

Car dumping site in the USA.



Each year about 20 million cars are taken out of service in the USA, in Europe ca 30 million become obsolete each year – many of these are sold to Africa.

Agbogbloshie in centre of Accra, Ghana.



In Europe each year about 100 million mobile phones and 20 million tv sets are taken out of service. Many of these are shipped to Africa for disassembling.

# The EU Resource Strategy.

## Example: Waste as a resource – Towards a recycling society

Recycling rate in EU is  
now 50%.  
Very slow increase.

### Legal recycling targets to improve resource efficiency

- **Household waste:** 50% (paper, metal, plastic & glass)
- **Construction and Demolition:** 70%
- **Electrical & Electronic Equipment (WEEE):**  
50 to 75% (collection requirement 4 → up to 16 kg/person/year)
- **End-of-Life Vehicles (ELV):** 85%
- **Packaging:** 55 to 80%

- Each person in the EU produces ca 500 kg of municipal waste per year.
- Total waste (including minerals) is 5.200kg/person (2018).
- “Circular economy” is now gaining impact as a model to transform today’s “take-make-dispose” economy into one that aligns business models with product and material design to decouple growth from resource constraints.

### Waste Packaging Materials in the EU (2020).

Pack Material	
Flexible Packaging	19%
Glass Summe	14%
Other Summe	0%
Paper & Board	12%
Rigid Metal	11%
Rigid Plastics	45%
	100%

EU: 422 Mio tons/year.

# Recycling of Plastics – an African Approach.

R



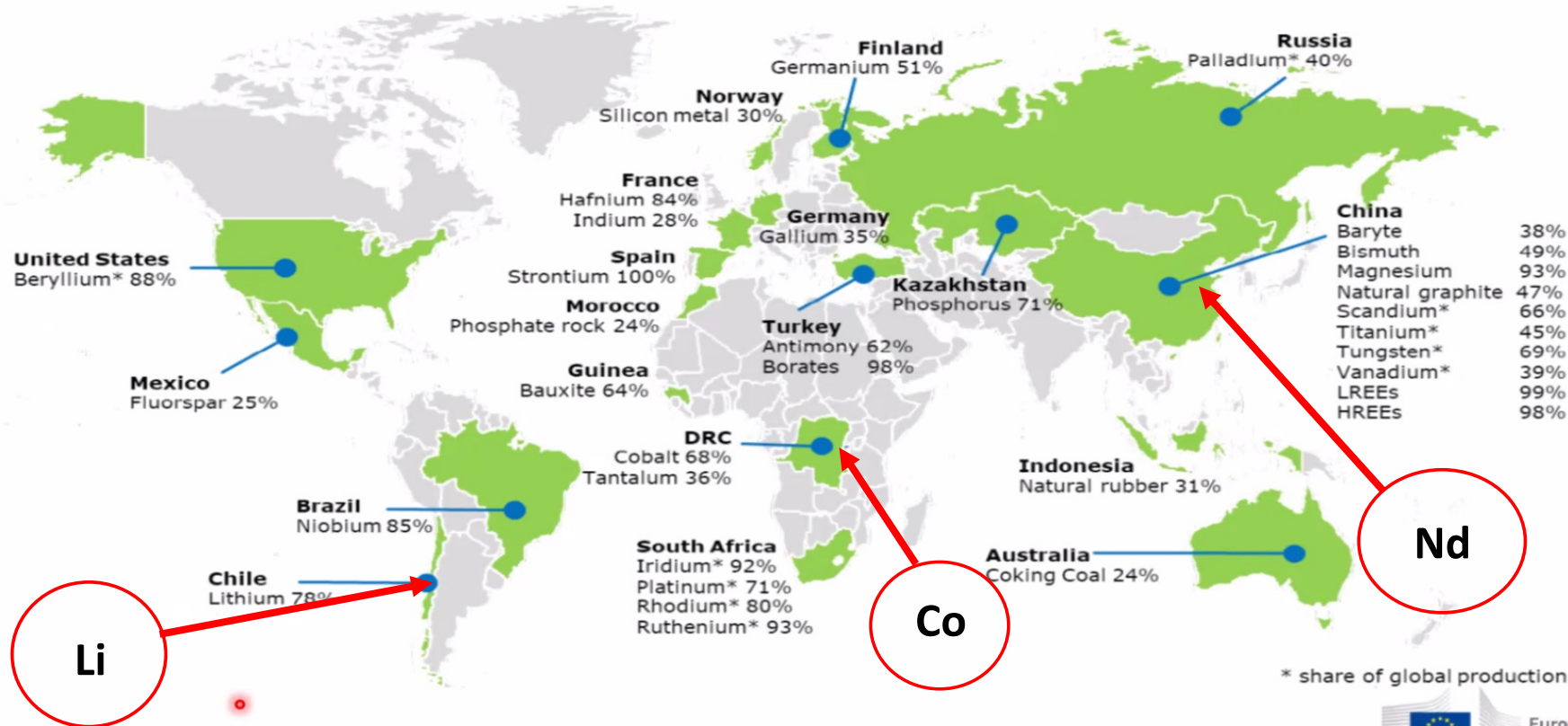
Dandora Landfill Nairobi

Source: E. Burtynsky et al.: ANTHROPOCENE, Steidl, Göttingen 2018

# Critical Raw Materials.

- New technologies are the basis of the Green Deal to make the EU carbon neutral by 2050:
- Wind turbines and photovoltaics, batteries, hydrogen production, nuclear power plants.....
- Increasing supply needs: Li 13x, Co 7x, Nd 2x, graphite 4x.

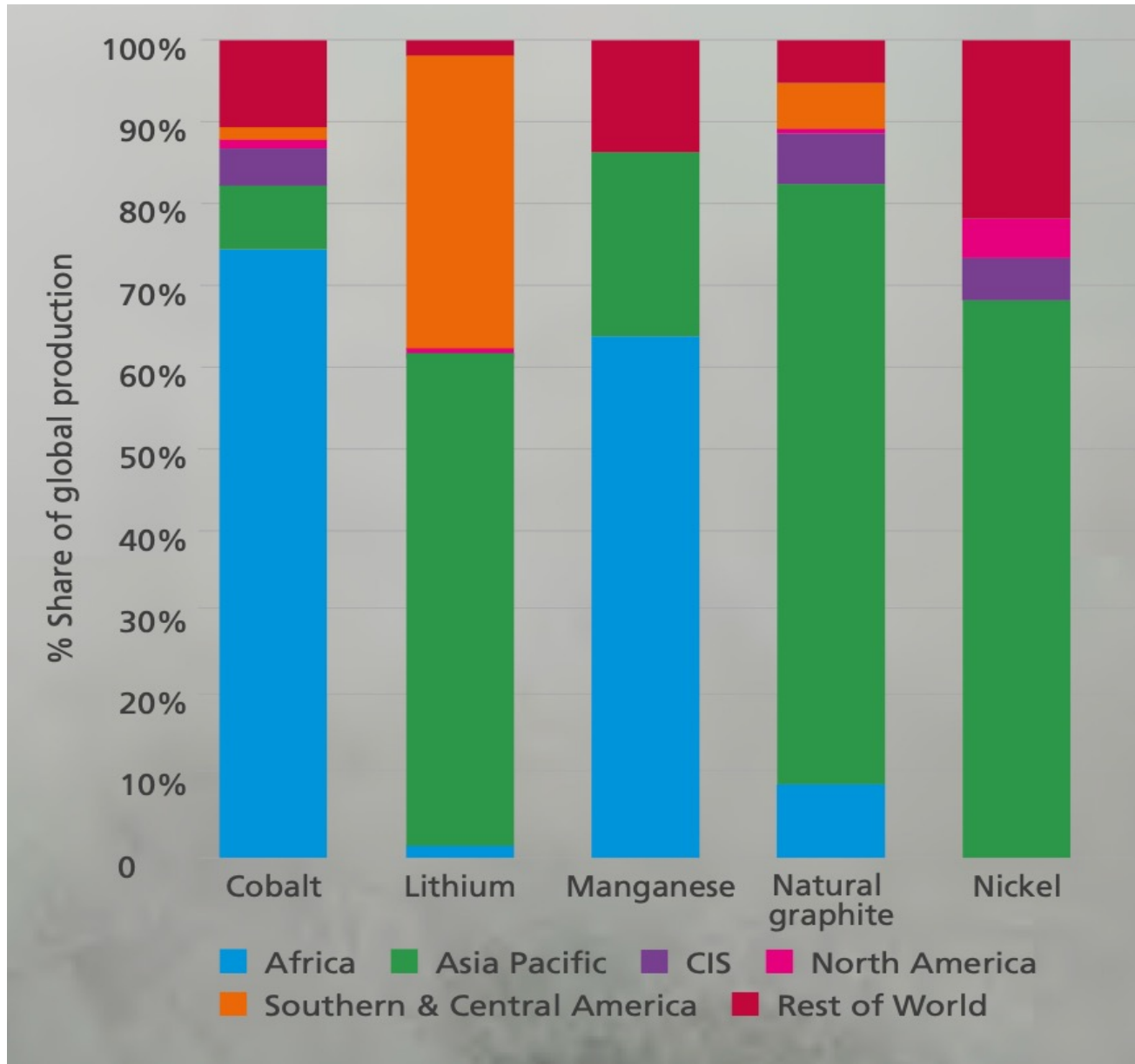
## Main CRM suppliers of the EU



EU is heavily dependent on imports of Critical Raw Materials (CRMs).

Annually 300.000 tons of Li and 400.000 tons of Co needed in EU for E-mobility (twice the present global production).

# Global Suppliers of Critical Raw Materials (2023)



**Cobalt:** 197.000 tons, mainly Africa (70% Congo)

**Lithium:** 198.000 tons, Asia Pacific (44% Australia, 17% China), South America (28% Chile)

**Manganese:** Africa, Asia Pacific

**Natural graphite:** Asia Pacific

**Nickel:** Asia Pacific

The production of minerals critical to the global energy system, continued to grow on average at around 4% per annum.

In 2023, the Asia Pacific region produced nearly 70% of the metals and materials critical to the manufacture of Li-ion batteries.

*Source: BP Statistical Review of World Energy 2024*

# Environmental Problems with Mining of Lithium.

R

Lithium Brines pumped from underground reservoirs, Atacama Desert, Chile.  
Contain about a quarter of presently known Lithium reserves.  
Massive contamination and ground water issues.





David, Michelangelo 1504.

## Impact on Landscapes in Mining.

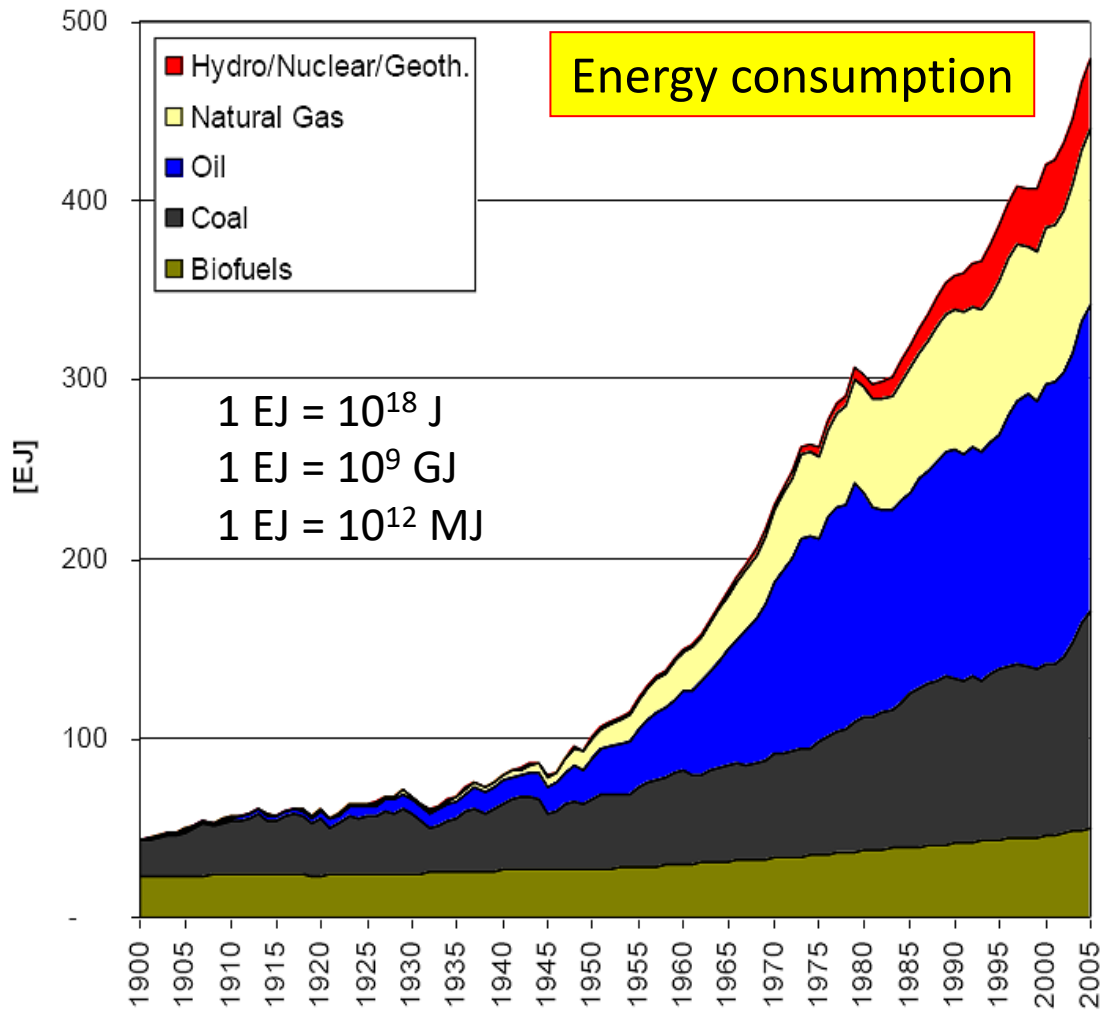


Carrara marble quarries, Italy.

# Fossil Fuels.

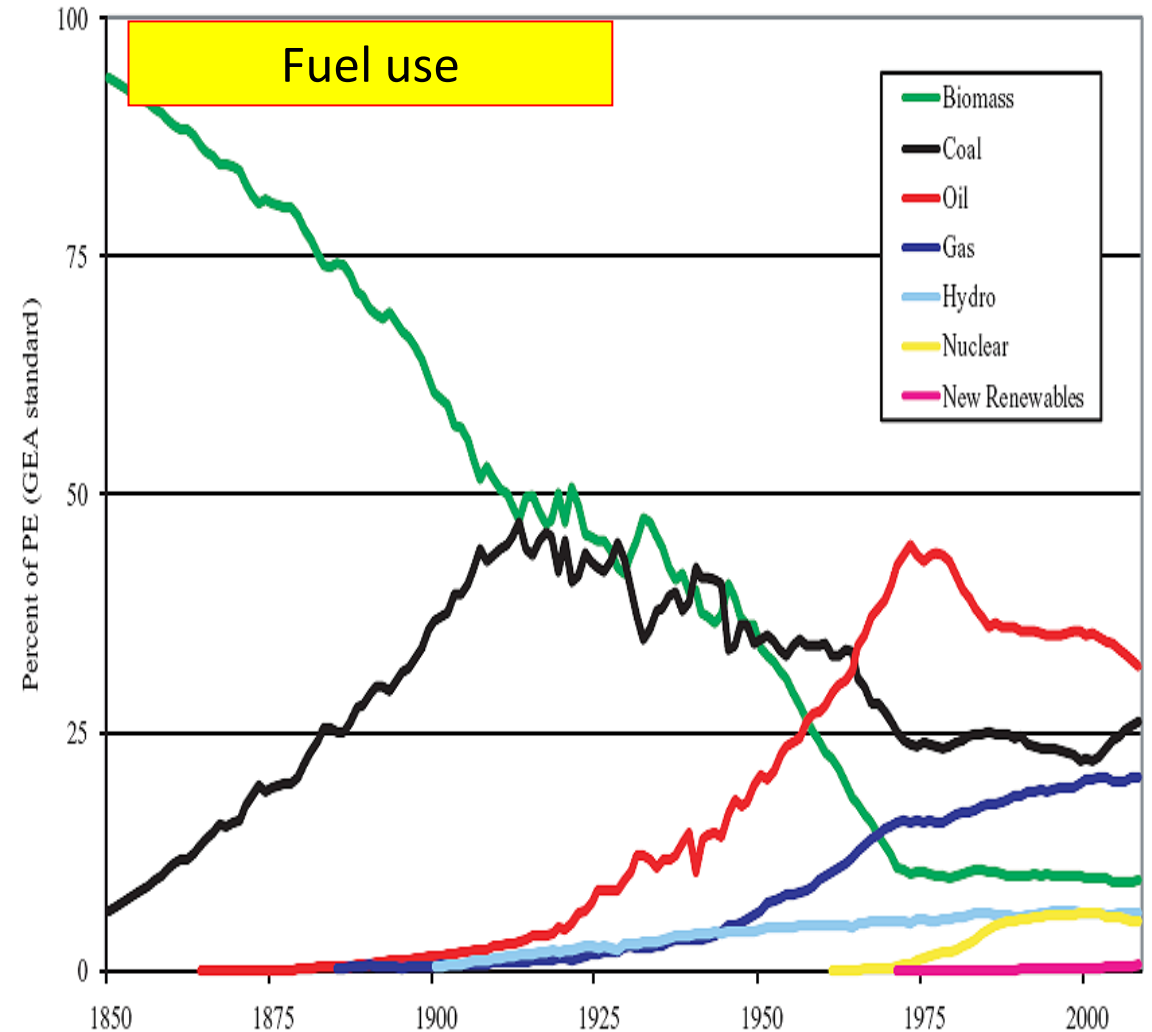
## Trends in Global Energy Consumption:

- Steep increase in energy consumption.



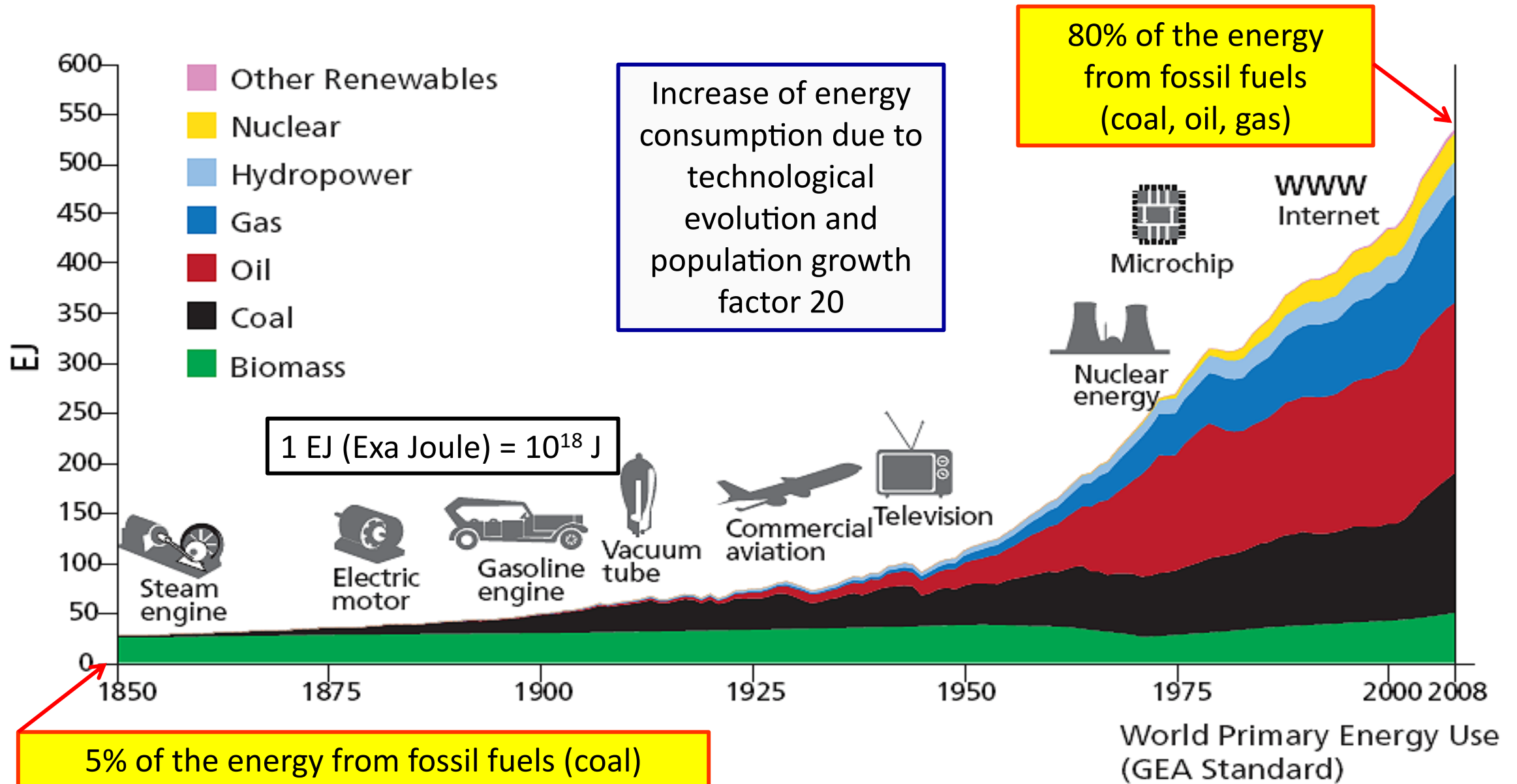
Source: Krausmann et al, Fischer-Kowalski 2009

- Shift in fuel use: from biomass to fossil fuels.



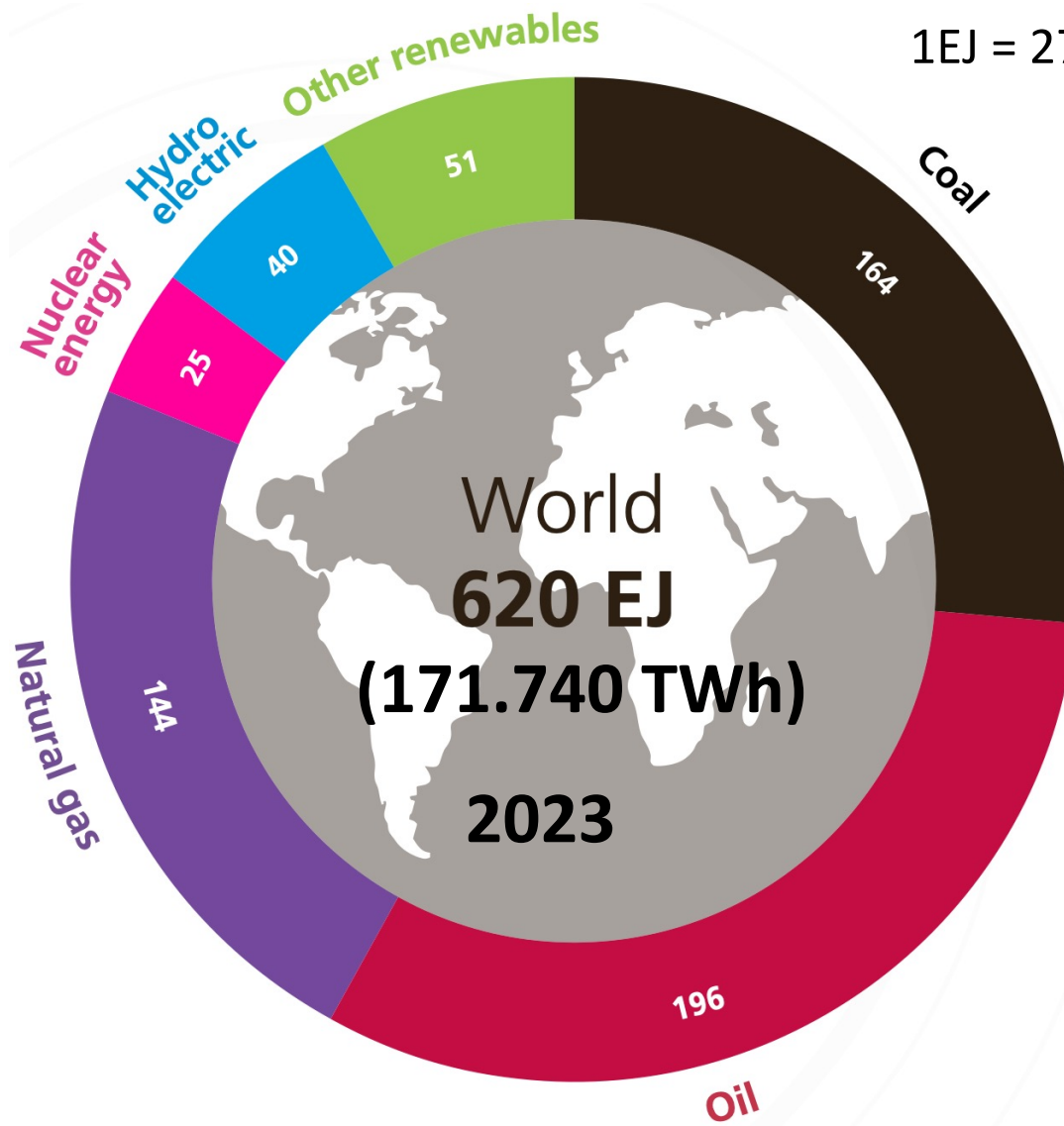
Source: IIASA 2011

# New Technologies and Energy Consumption.



Quelle: IIASA 2011

# Sources for World Primary Energy Production 2023.



- **Share of fuel in total energy production:**

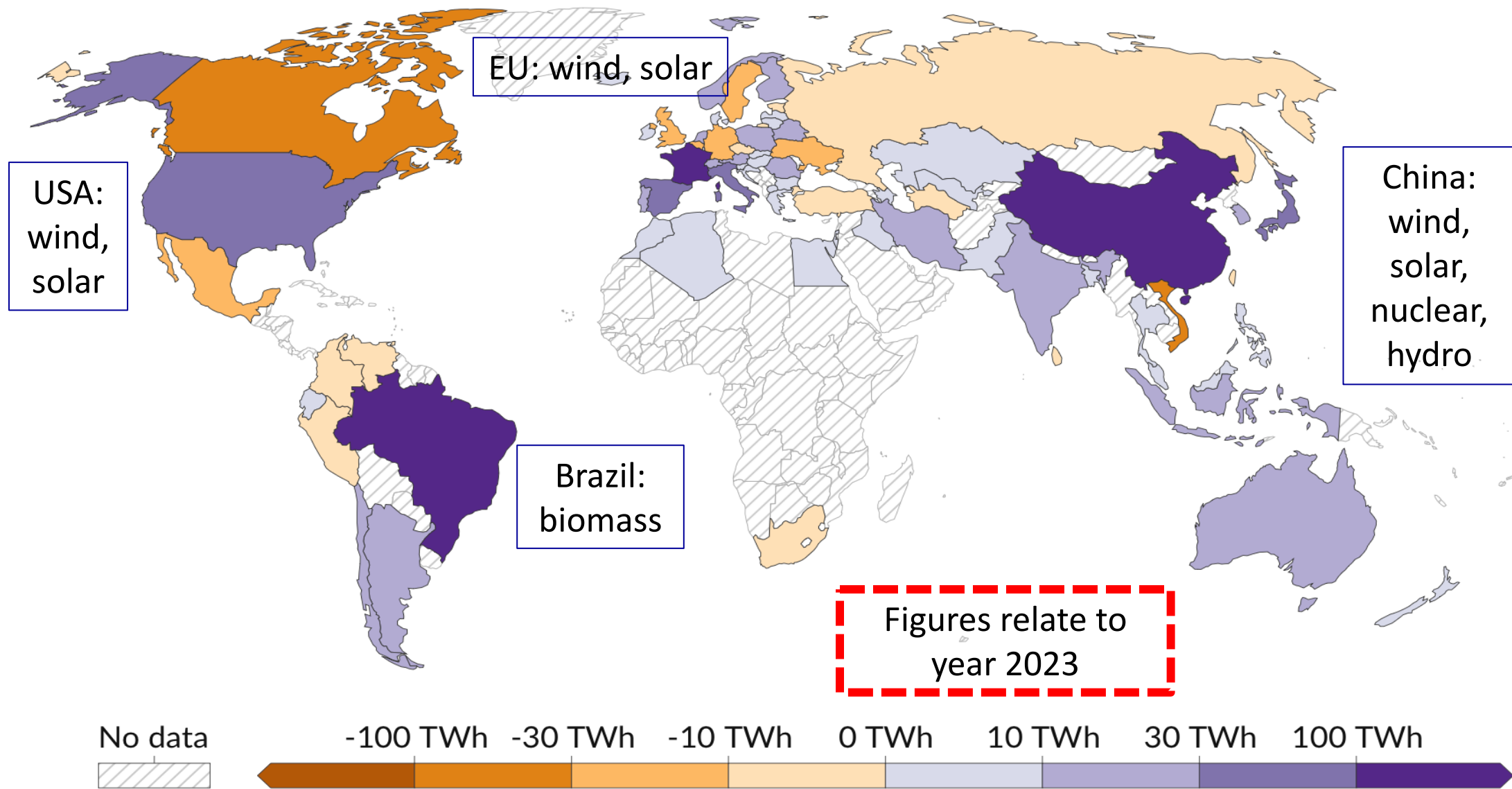
- Oil: 31,6%
- Coal: 26,5%
- Natural gas: 23%
- Nuclear: 4%
- Hydro: 6,5%
- Other renewables: 8%

- 81,5% of global energy production is from fossil fuel.
- Oil, coal and gas use were rising steeply in the past.
- By 2050 (?) coal will be gradually phased out, but consumption of oil and gas expected to remain at present levels.
- 18,5% of global production is low carbon (8% renewables, 6,5% hydro, 4% nuclear) with strongly rising trend.

Energy conversion: 1 kWh = 3,6 MJ, 1 J = 1 Ws

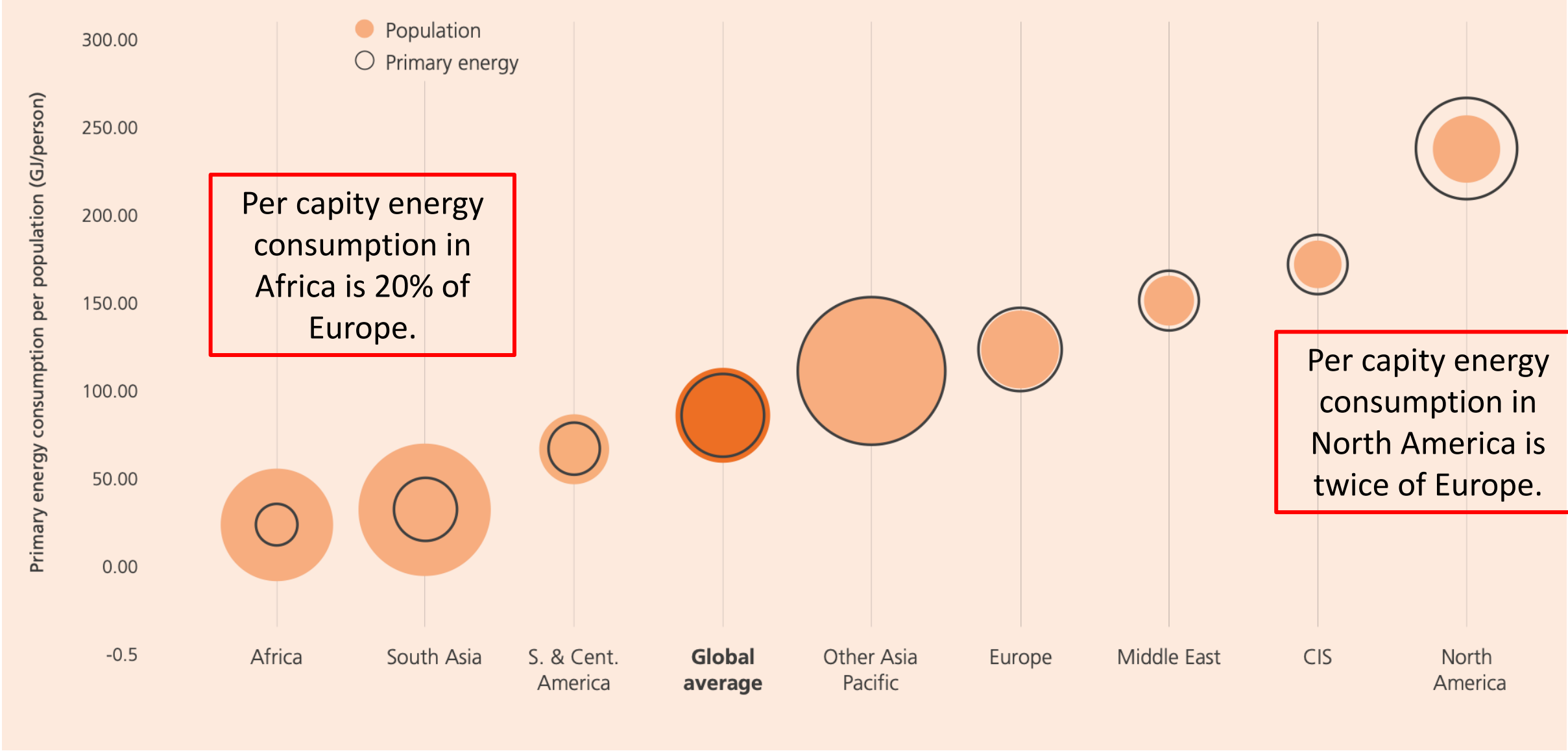
Source: BP Statistical Review of World Energy 2024

# Energy Sources: Annual Change in World Low Carbon Energy Consumption. R



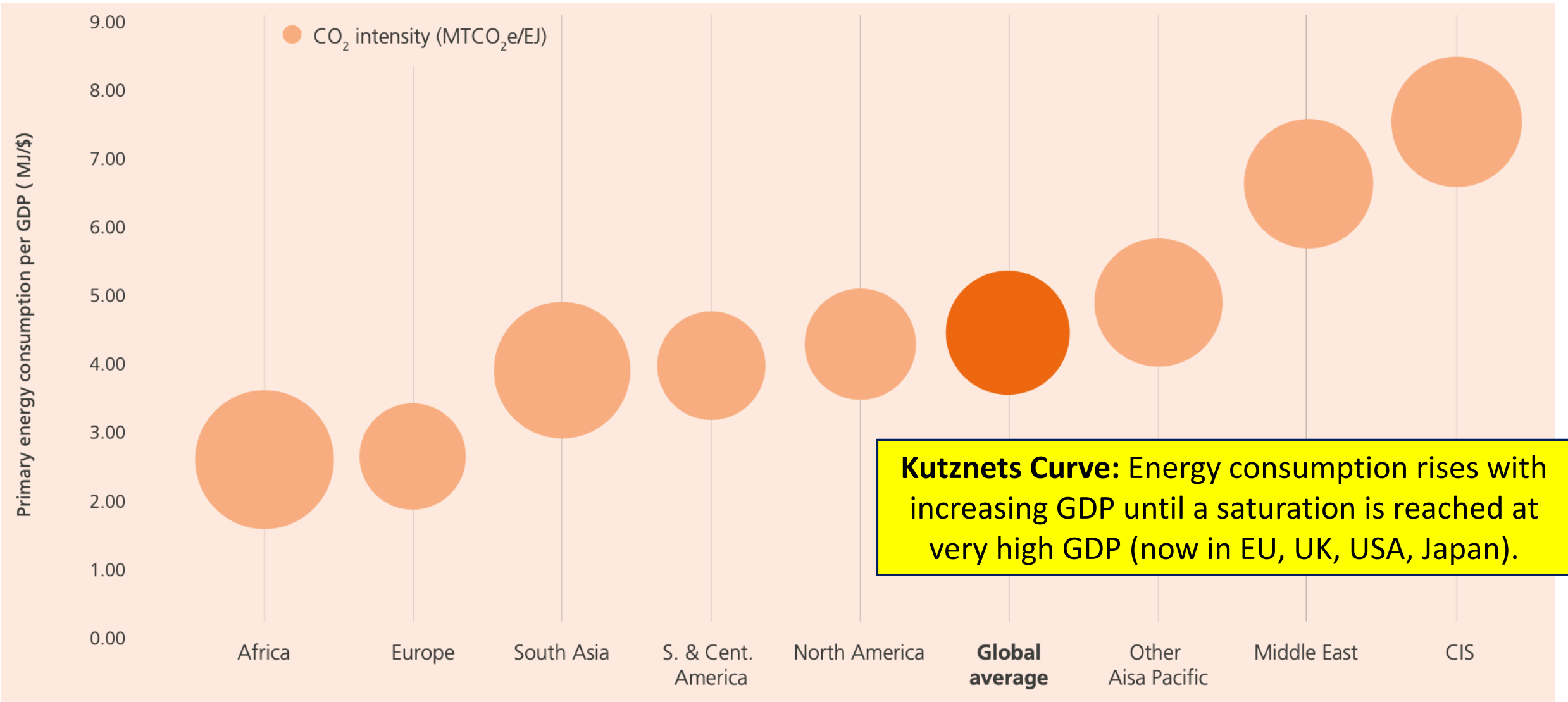
Source: Energy Institute - Statistical Review of World Energy (2024)

# Primary Energy Consumption per Person.



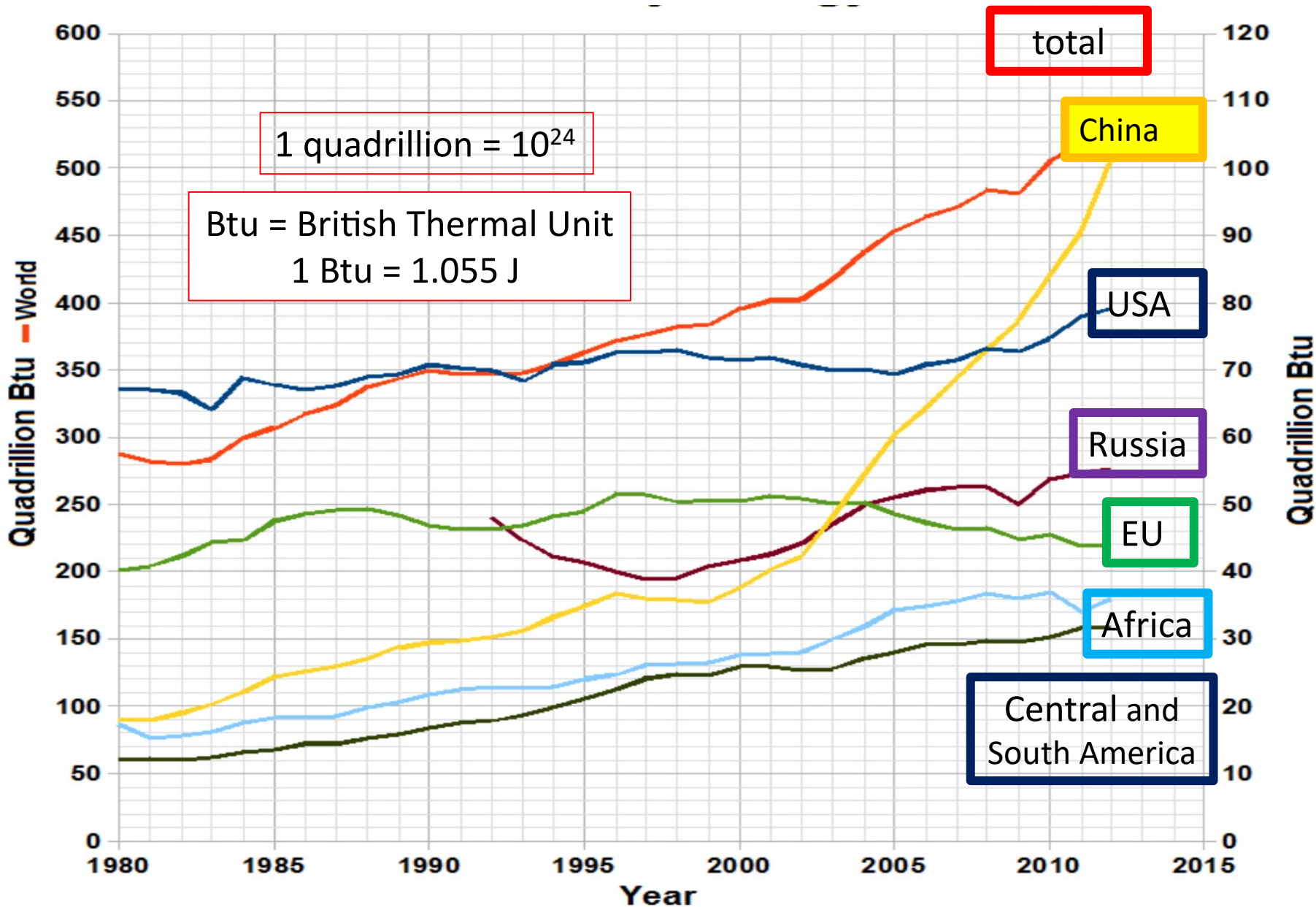
Source: BP Statistical Review of World Energy 2024

# Relation Between GDP and Energy Consumption.



*Source: BP Statistical Review of World Energy 2024*

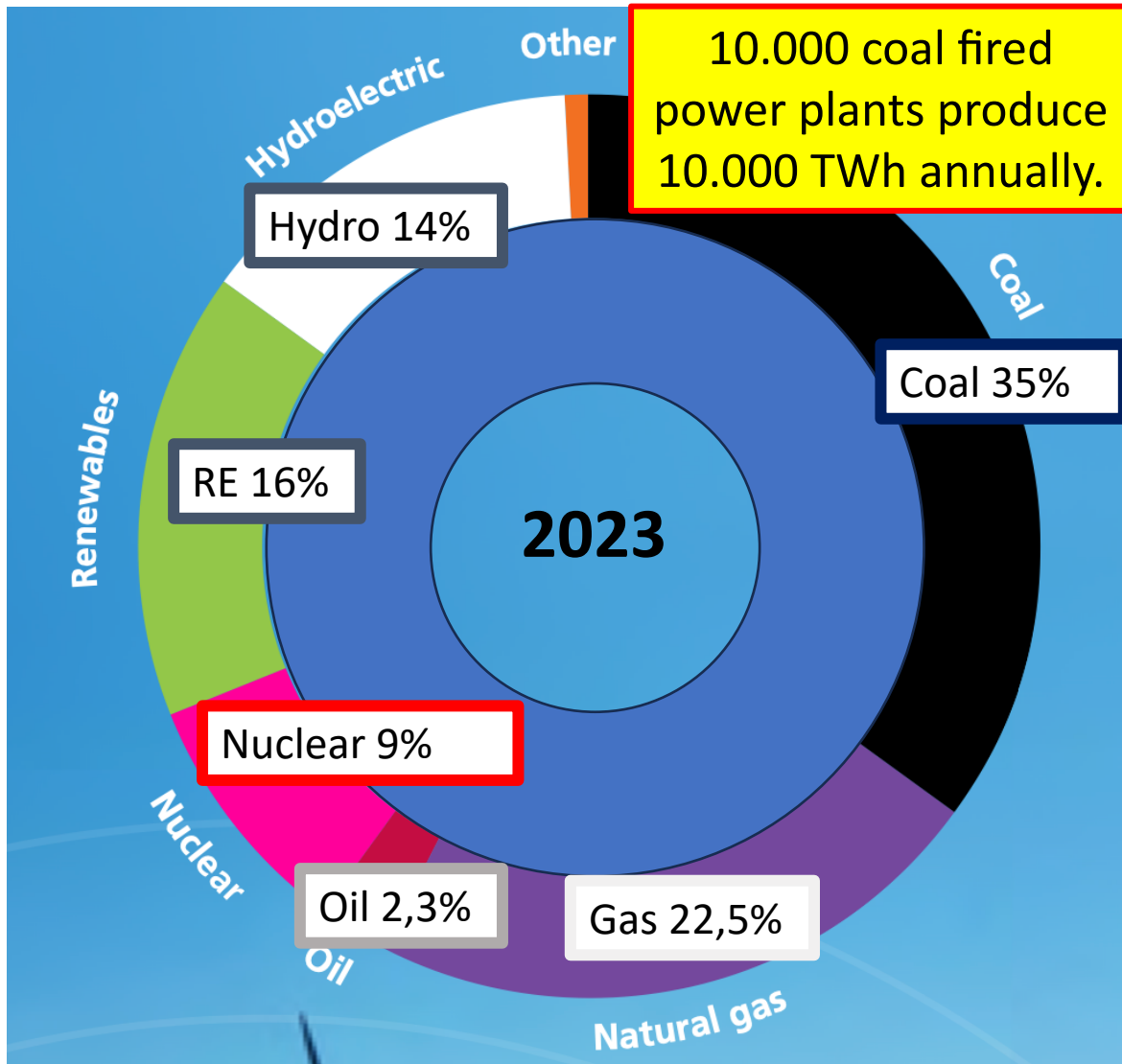
# World Total Primary Energy Production and Consumption by Regions.



## • General Trends:

- Total energy consumption rising: doubling until 2050 (?).
- Extreme growth in China.
- Decoupling of economic growth and energy consumption in EU.
- Growing energy consumption in Africa (population to rise from 1,3 billion to 2 billion by 2050) and South America.

# Energy Sources for Global Electricity Production 2023:



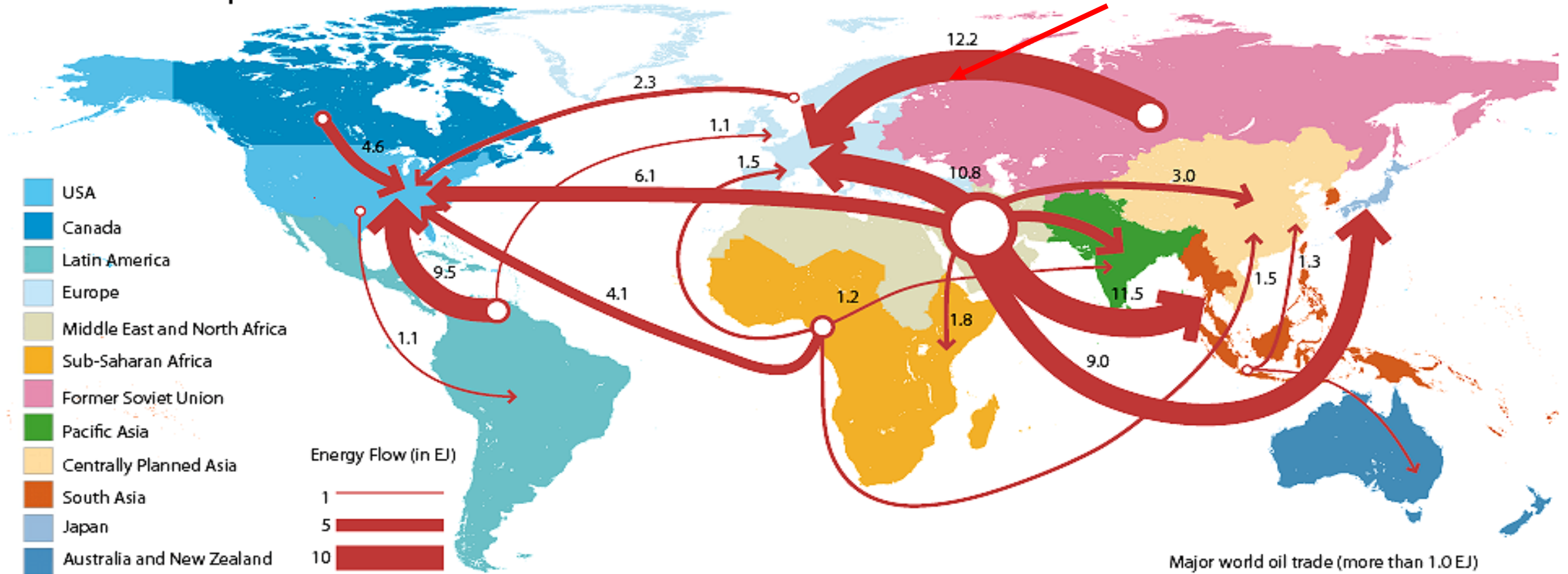
- **Global electricity production was 29.925 TWh.**
  - Europe: 3.805 TWh (growth minus 2,4%)
  - North America: 5.482 TWh (growth minus 1%)
  - Central and South America: 1.464 TWh (growth 4%)
  - CIS: 1.525 TWh (growth 1,3%)
  - Middle East: 1.463 TWh (growth 5,1%)
  - Africa: 902 TWh (growth 6%)
  - Asia Pacific: 15.282 TWh (growth 5,1%)

- 51% of global electricity production is from fossil fuel.
- Coal and gas use have been rising steeply in the past.
- Till 2050 phase-out of coal (?).
- 39% of global production is low carbon (16% renewables, 14% hydro, 9% nuclear)

*Source: BP Statistical Review of World Energy 2024*

# Global Oil Flows

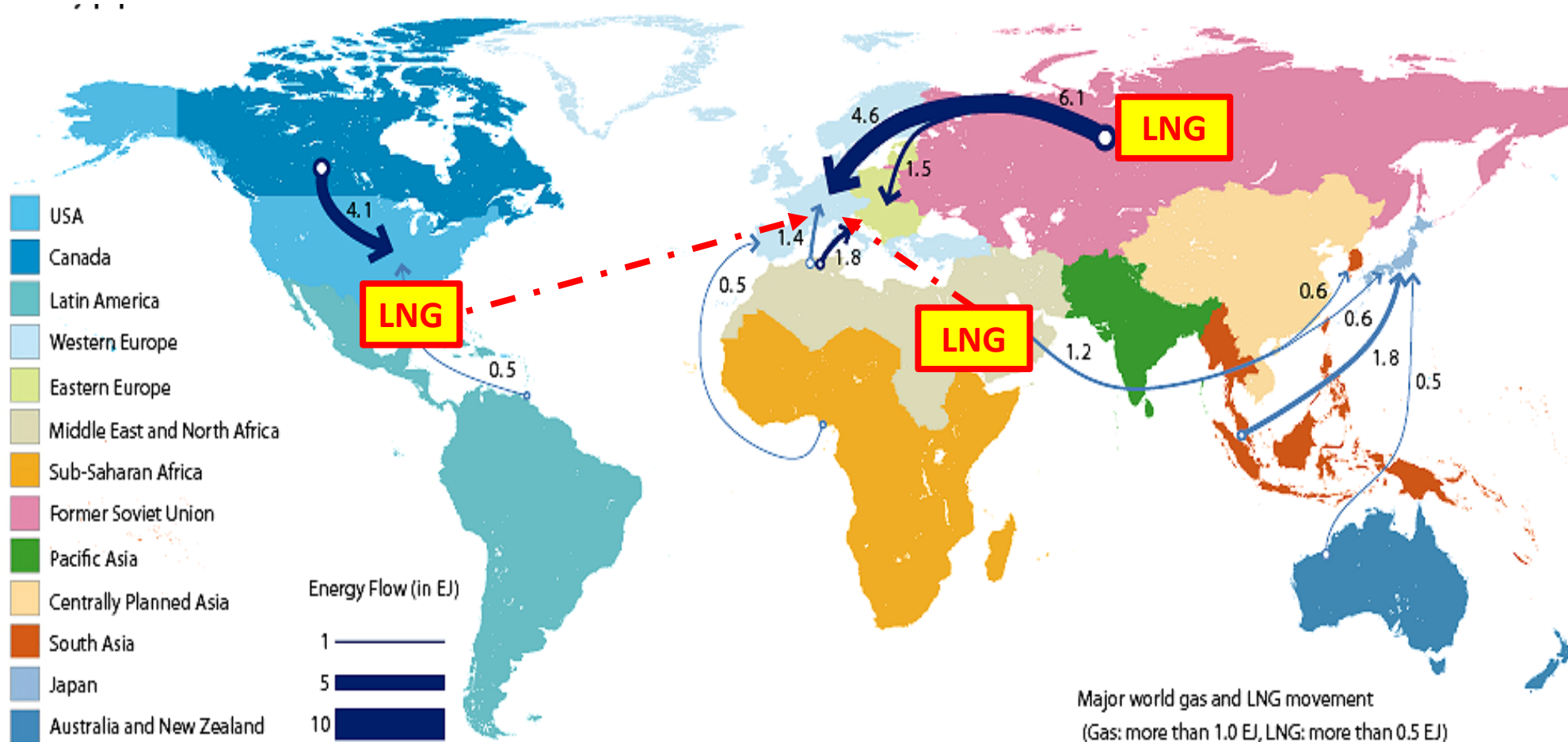
Crude oil and oil products



**Main oil suppliers:** Saudi Arabia, Iran, Iraq, Kuwait, UEA, Qatar, Venezuela, Norway, Canada, Nigeria, Russia, Libya, Kazakhstan

Source: IIASA 2011, [http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/GEA\\_SPM.pdf](http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/GEA_SPM.pdf)

# Supply of Europe with Natural Gas.



- **Austria 2024:**
- 80% of gas consumed is from Russia.
- Total consumption 80 TWh/a
- 40% industry, 30% electricity production, 20% private.

**Main global gas suppliers:** Russia, Canada, Iran, Saudi Arabia, Iraq, Turkmenistan, UEA, Venezuela, Nigeria, Algeria, Kazakhstan (plus USA, Qatar Liquid Natural Gas – LNG: price 3-5x higher)

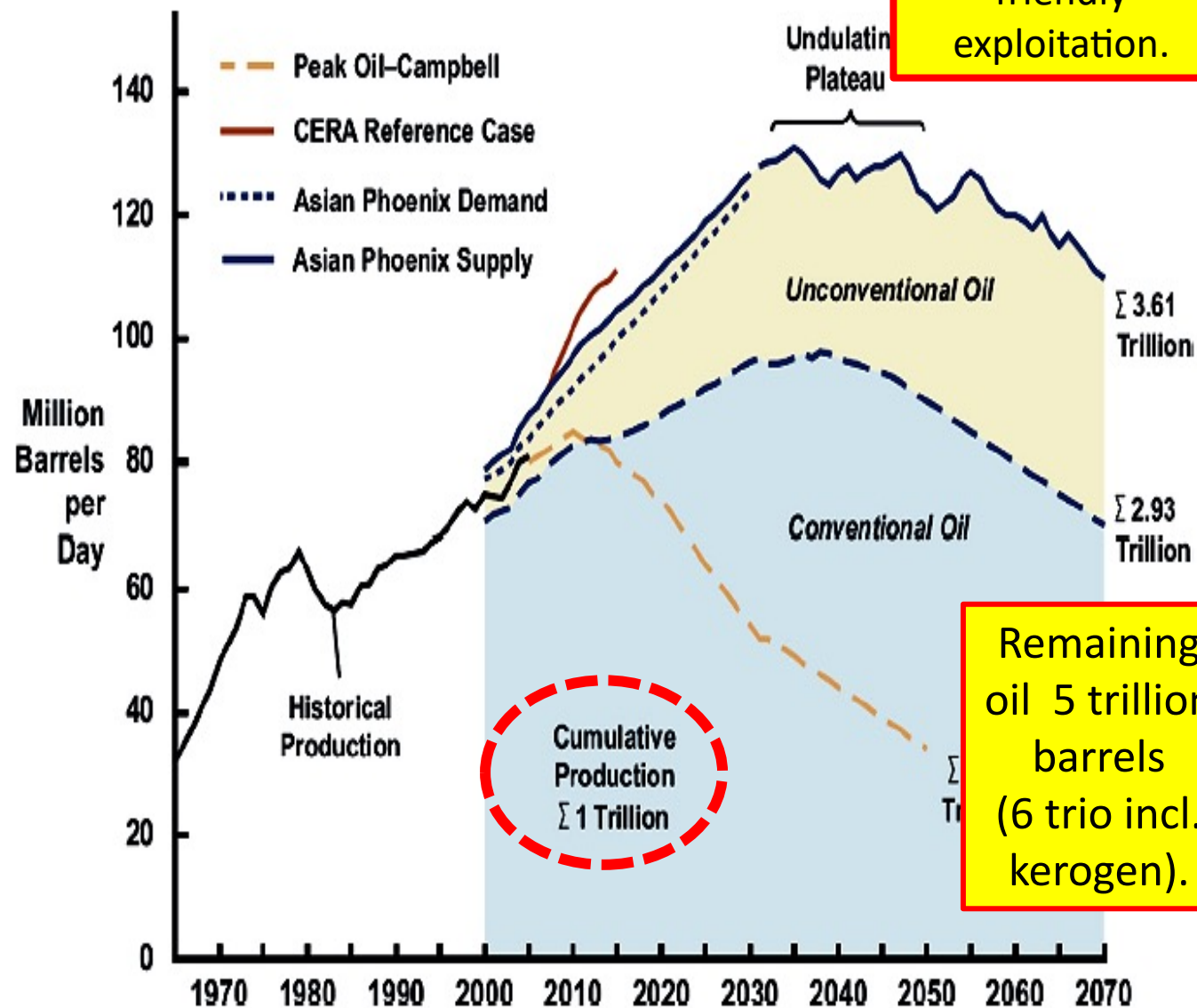
Source: IIASA 2011

Russian pipeline gas delivery into EU largely stopped 2022/2024.  
Shift to LNG.

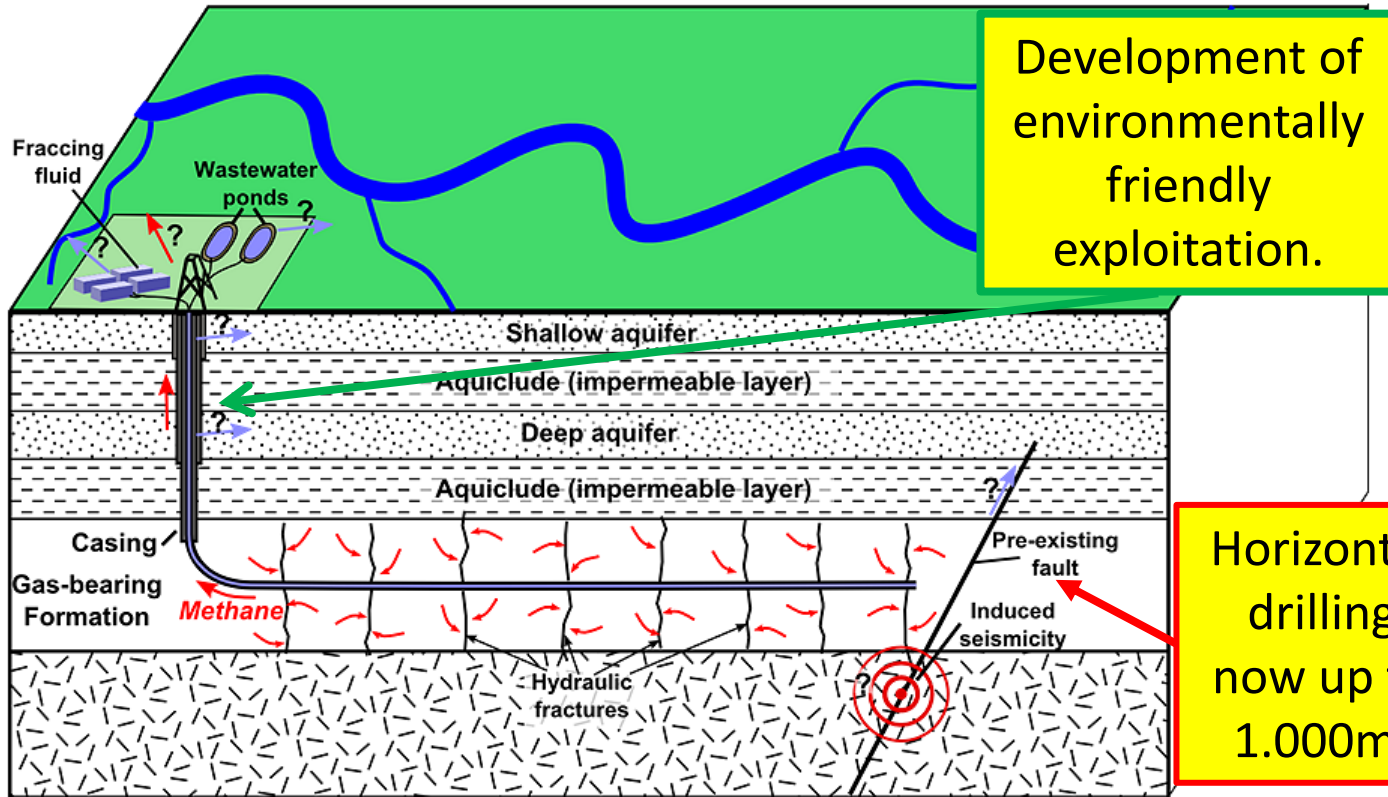
# Fossil Fuels: Reserves and Resources.

- **Oil:**
  - 50% of the global known conventional reserves now consumed.
  - known „unconventional resources“ ca 3x the amount consumed by now:  
oil sands (bitumen-like materials) and oil shales (organic-rich fine-grained sedimentary rock containing significant amounts of kerogen).
- **Natural gas:**
  - 30% of the global known conventional reserves now consumed.
  - „unconventional resources“ ca 10-20x the amount consumed: shale gas.
- **Coal:** nearly unlimited supply
- **Uranium:** practically unlimited supply

Source: IIASA 2011



# Unconventional Gas – Fracking.



Development of environmentally friendly exploitation.

Horizontal drilling now up to 1.000m.



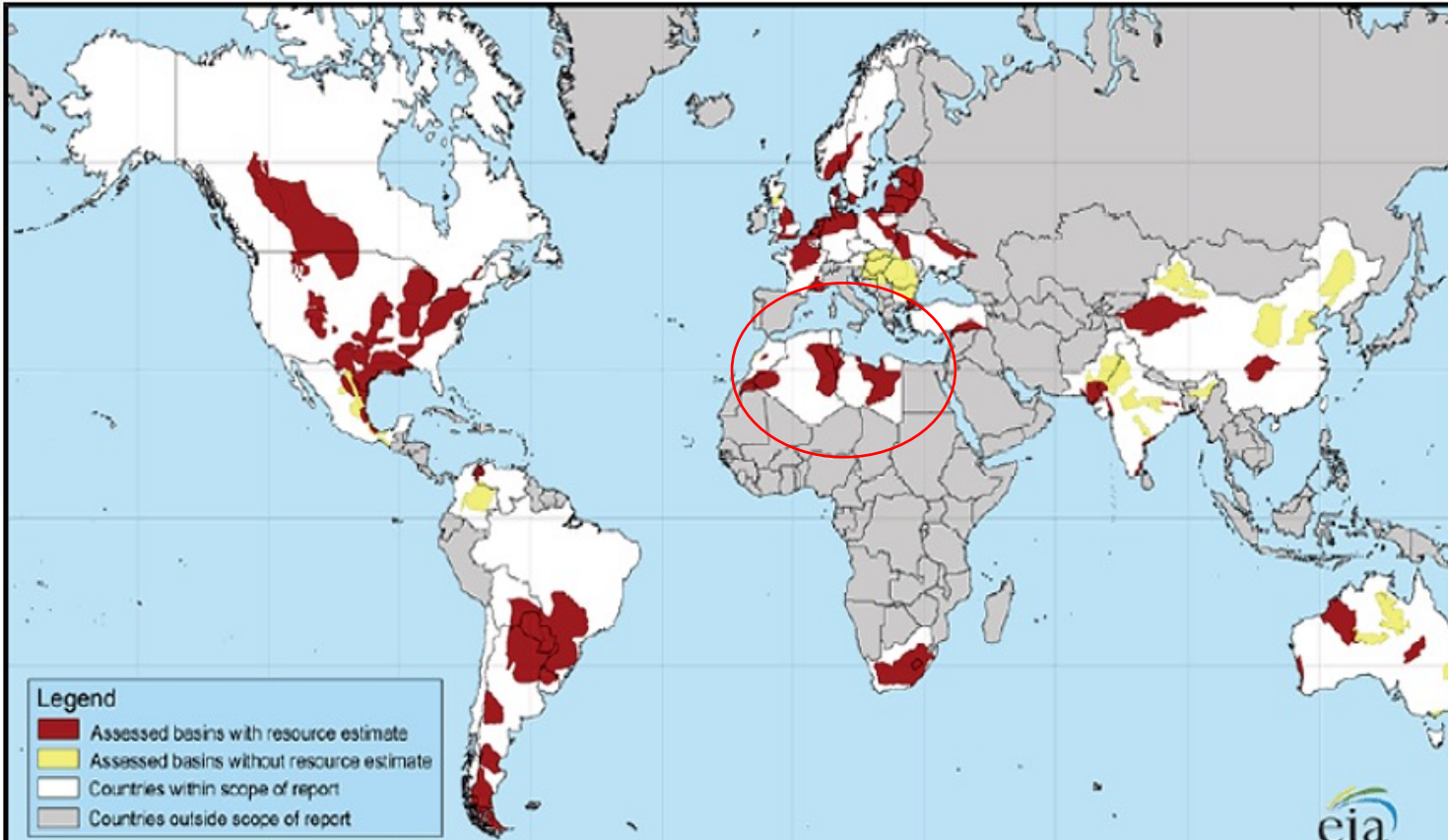
LNG Transporter

Environmental concerns focus on the contamination of ground water by the additives in the fracking fluids.

- Induced hydraulic fracturing, known as fracking, is a technique used to release petroleum or natural gas (including shale gas) for extraction. Estimated resources are 10-20x the amount of natural gas consumed so far.

# Fossil Fuels: The New Gas World.

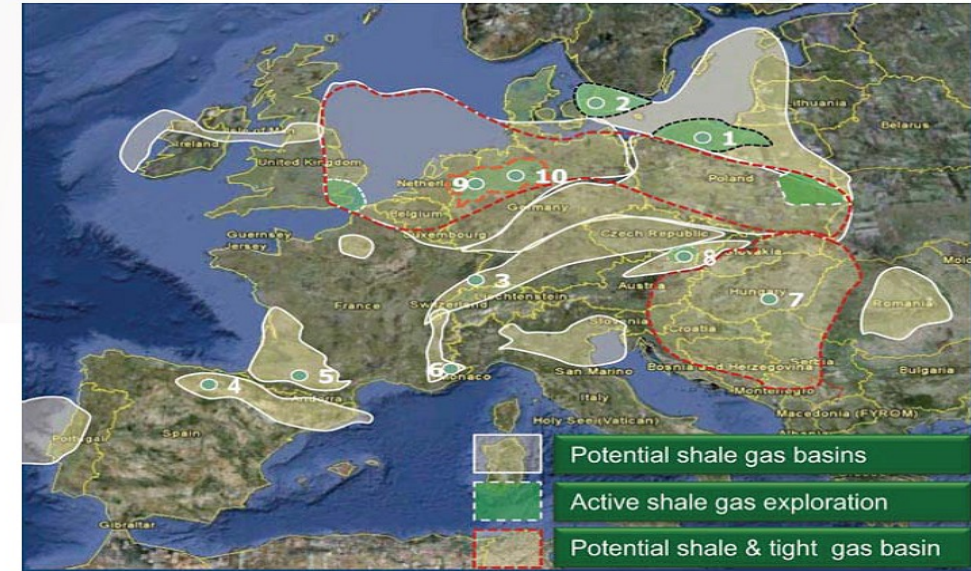
## World shale reserves



The USA is vigorously exploiting these reserves, has become the largest producer of natural gas (25% share) and a major exporter.

Source: Dieter Helm 2012, <http://www.dieterhelm.co.uk/node/1328>,  
*Statistical Review of World Energy 2024*

## Shale gas in Europe



European reserves not very well defined and sometimes overestimated. Exploitation difficult due to often rather complex geological formations.

Fracking technology presently forbidden in the EU.

Exploitation of fracking gas now under discussion due to supply problems.