Sustainability

- Information:

  http://zeus.nyf.hu/~szept/kurzusok.htm

- Theis, T. (2015): Sustainability: A Comprehensive Foundation. **https://open.umn.edu/opentextbooks/textbooks/96**

- David Attenborough : A life on our planet

https://www.netflix.com/title/80216393

One man has seen more of the natural world than any other. This unique feature documentary is his witness statement.

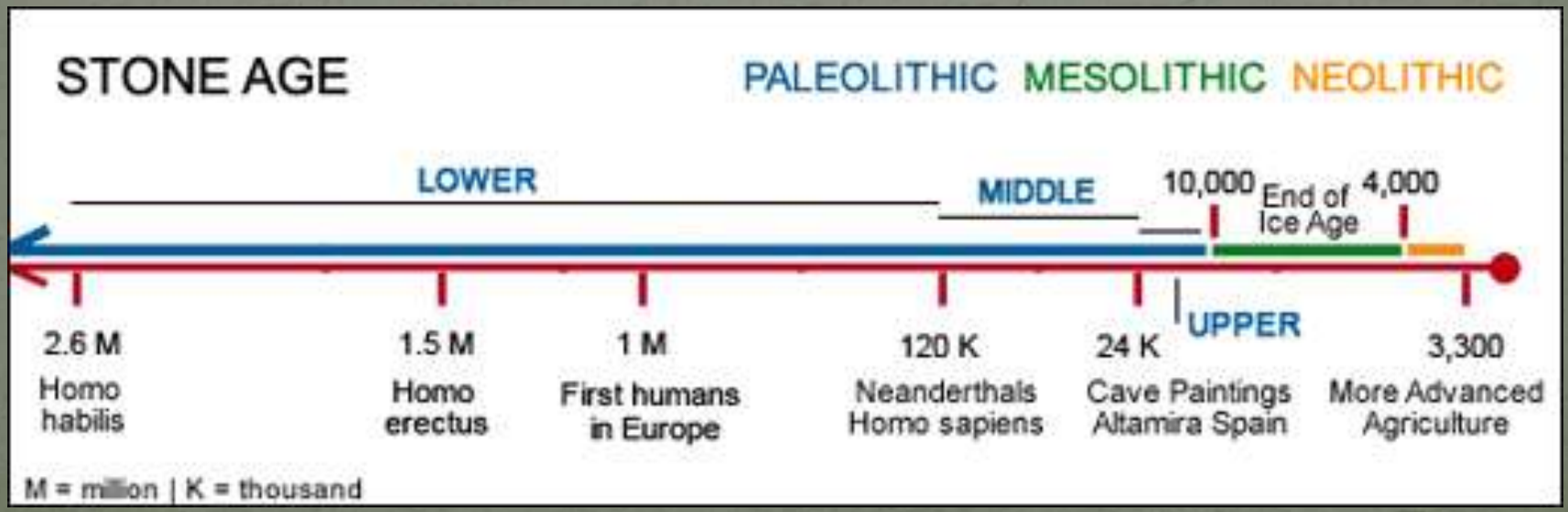
Prehistoric progress traps

Sustainability

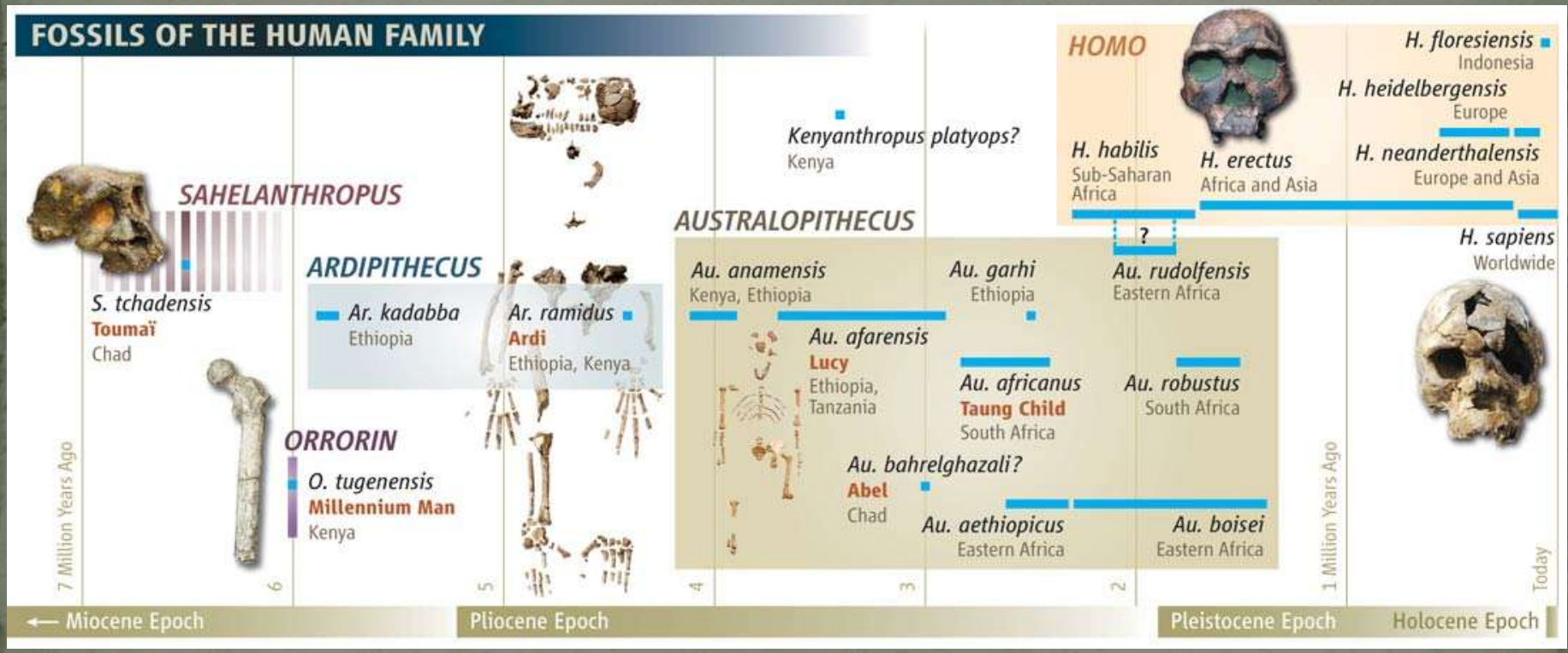
2023/2024

Prehistory

- Stone Age
  - Paleolithic (Old Stone Age)
    - Lower Paleolithic
    - Middle Paleolithic
    - Upper Paleolithic
  - Mesolithic (Middle Stone Age)
  - Neolithic (New Stone Age)



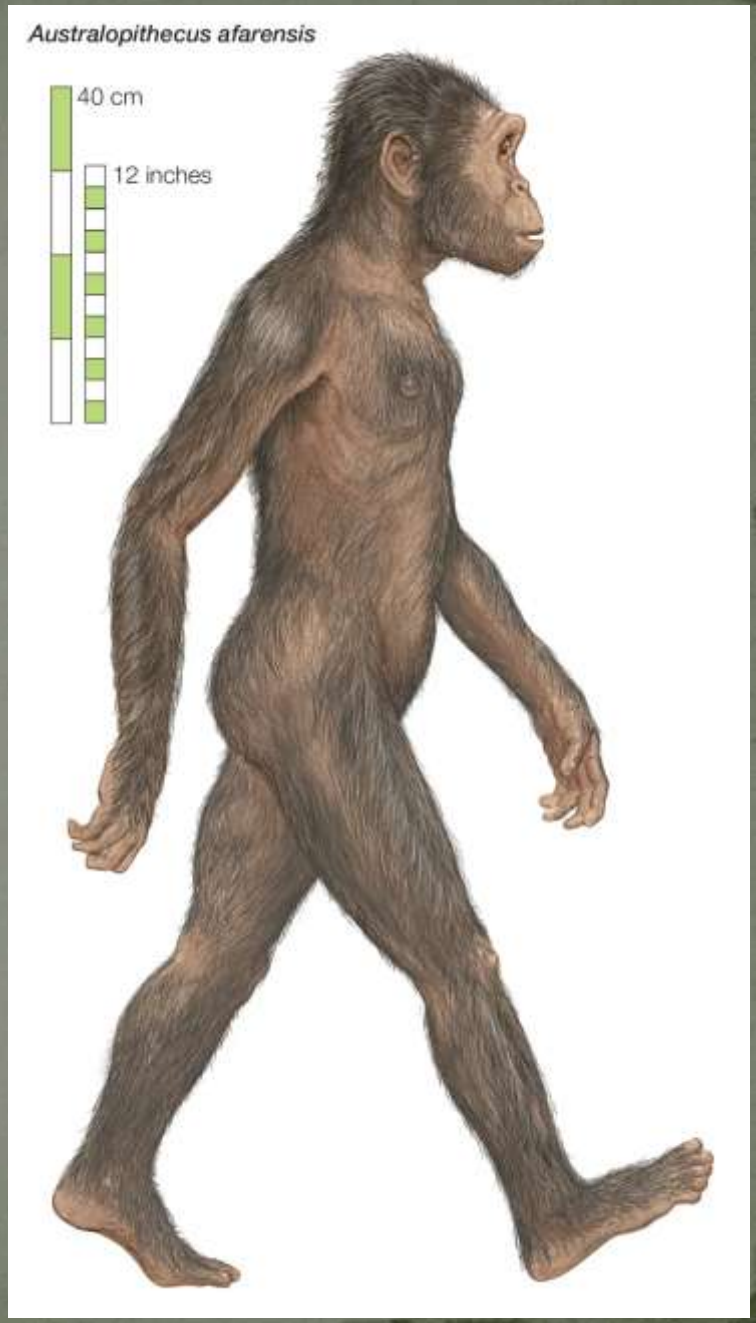
Fossils of the Human family (*Hominidae*)



Early hominins

- Omnivorous
- Hunter-gatherer lifestyle
- Usage of tools
- No creation of artifacts

- Environmental effects were not significant



Creation of artifacts

Homo habilis
(„handy man”)

Creation of chopper

Chopper:
A pebble tool with an irregular cutting edge formed through the removal of flakes from one side of a stone. (wikipedia)

Creation of artifacts

Homo erectus
(„upright man”)

Flake tools

Flake tools:
Stone Age hand tools, usually flint, shaped by flaking off small particles, or by breaking off a large flake which was then used as the tool. (Britannica)

Creation of weapons

Homo sapiens
(„wise man”)

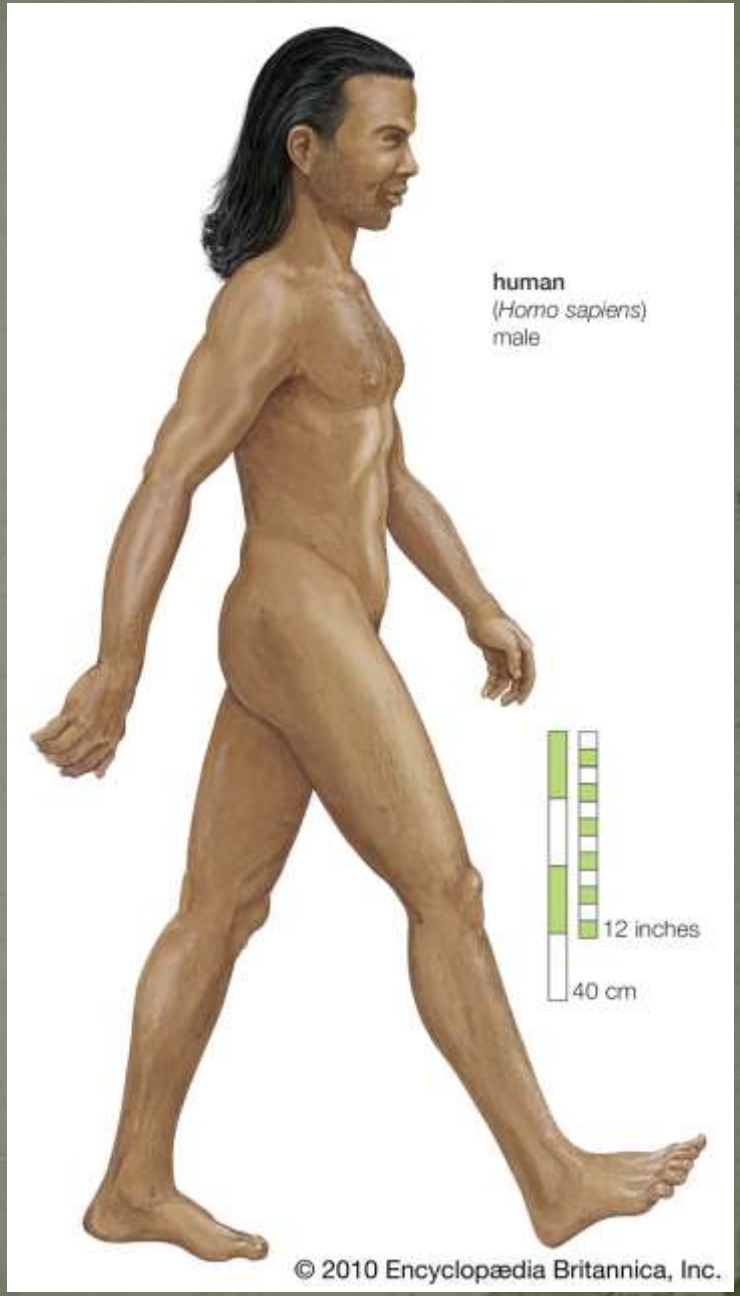
First weapons

- Harpoons
- Bows
- Arrows
- Spears

Homo sapiens

- Hunting in group
- Increasing number of killed wild animals
- Itinerant lifestyle

- Local and regional environmental effects

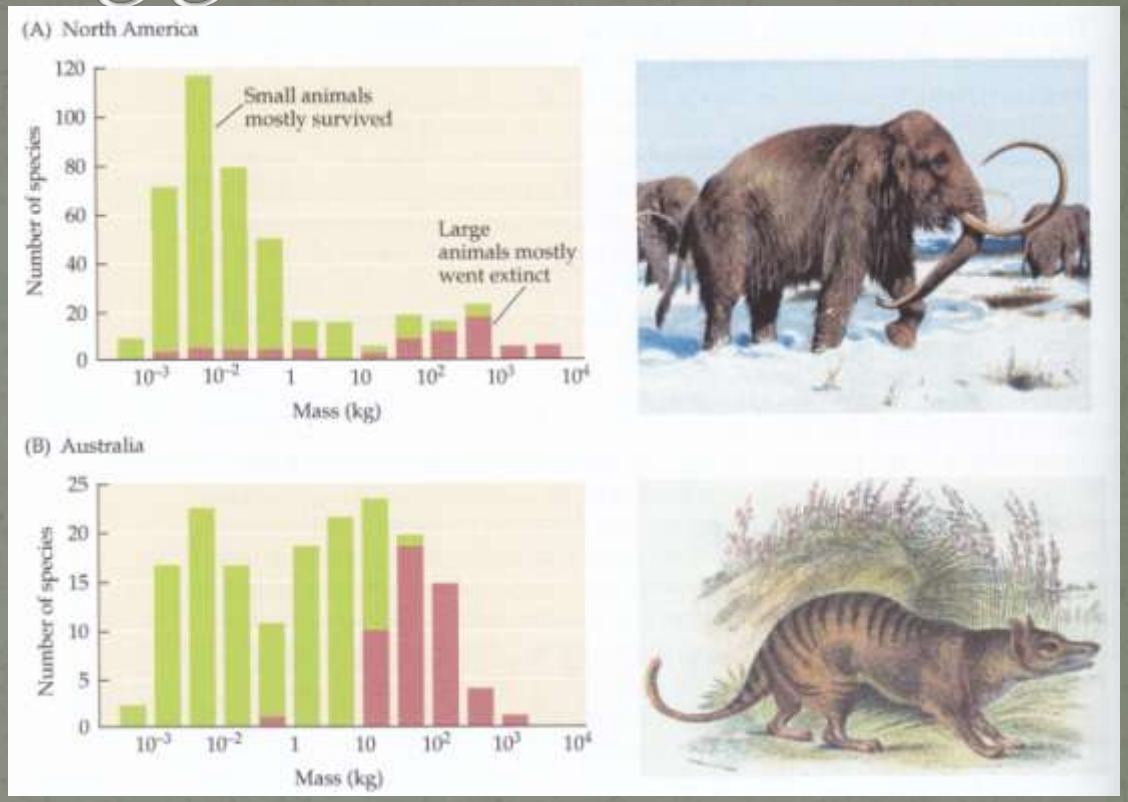


Endless hunting grounds?

- Storage and preserving were unknown
- They were not able to utilize the excess of prey
- Over-hunting
- Extinct animals

(Climate change and human hunting both played a part in the mammoth's demise. Mammoth had slow productive rate and juvenile mammoths were more exposed to hunting.)

Endless hunting grounds?



Body mass of herbivorous mammals from (A) North America and (B) Australia. **Green**: survived until European arrival, **Red**: survived since first human arrival

„Paleolithic hunters who learnt how to kill two mammoths instead of one had made progress.

Those who learnt how to kill 200 – by driving a whole herd over a cliff – had made too much.

They lived high for a while, then starved."

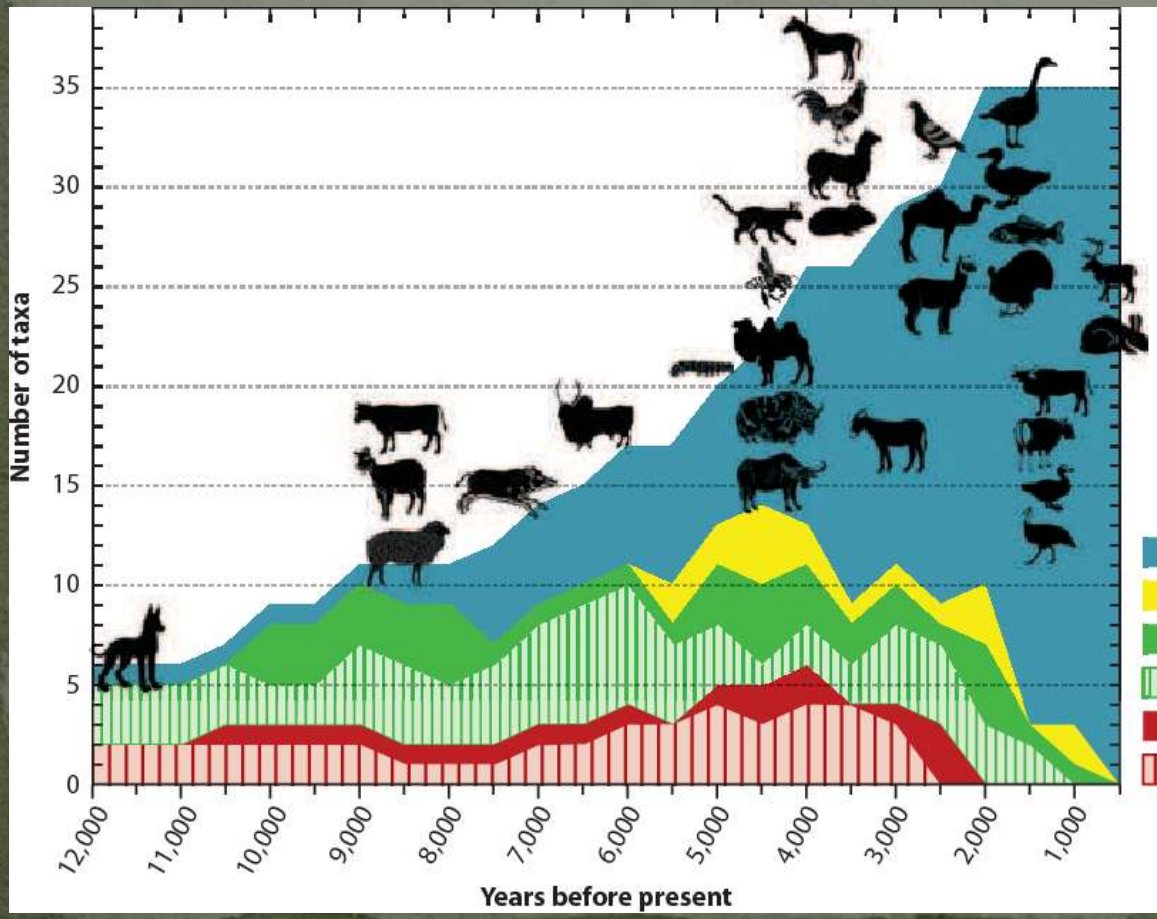
(*Ronald Wright:* A Short History of Progress)

Middle Stone Age (Mesolithic)

- The end of the itinerant lifestyle
- Settlements
- Constractions, firing (heating) ← deforestation
- Domestification of wild animals

  (pasturage → deforestation)

A summary of the timing and increase in animal domestications



Domestication of dogs:

- Protection
- Hunting
- Transport

Postdomestication improvement/introgression
Directed domestication
Prey domestication
Predomestication management (prey/directed)
Commensal domestication
Commensal anthropophily

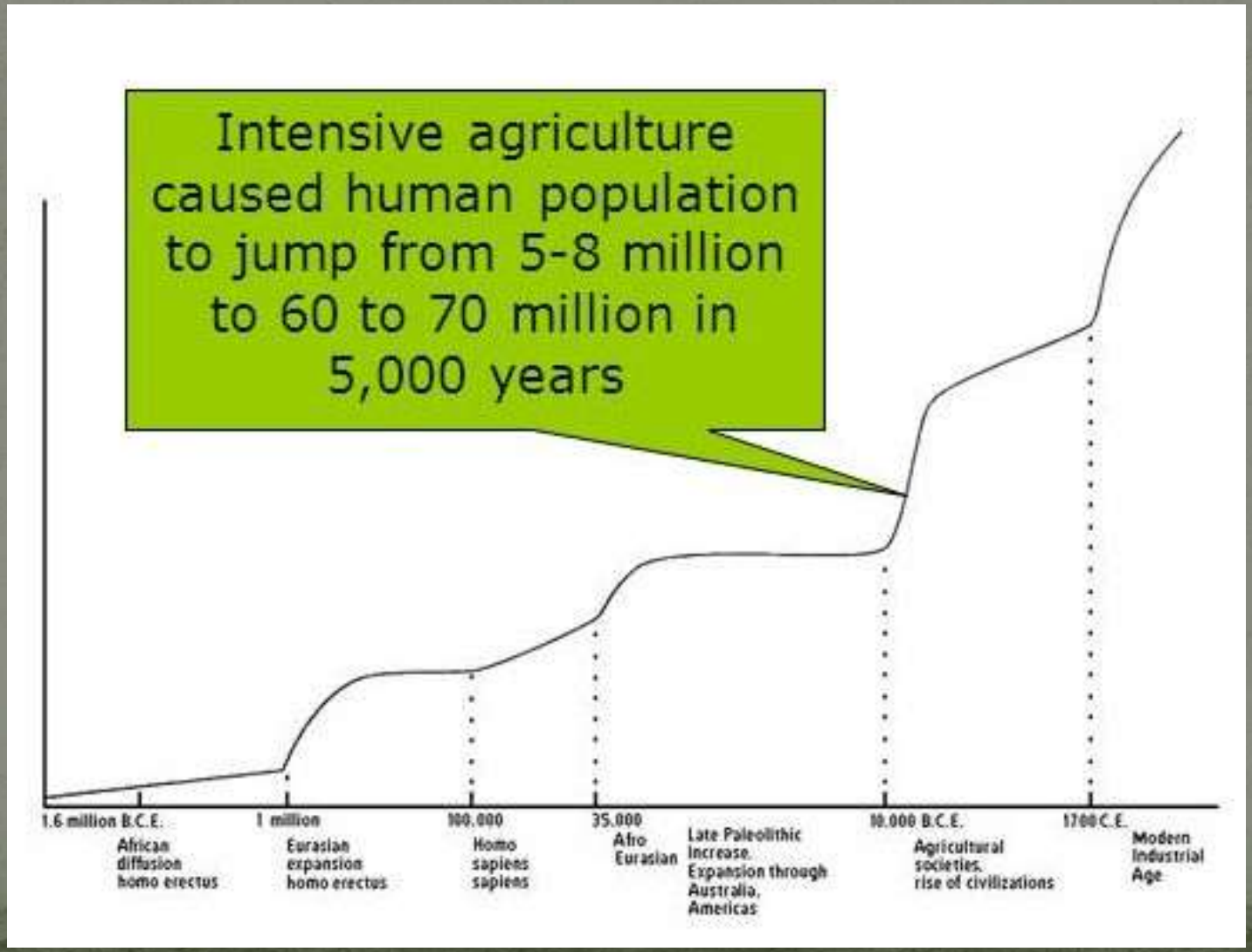
New Stone Age: Neolithic revolution

- Gardening: fruit-trees → fenced gardens
- Raising of cereal: preference of domesticated plants
- Eradication of natural vegetation

  → Biodiversity decreased
- Material and energy flow of soil changed

Animal husbandry and growing plants

- Population growth!



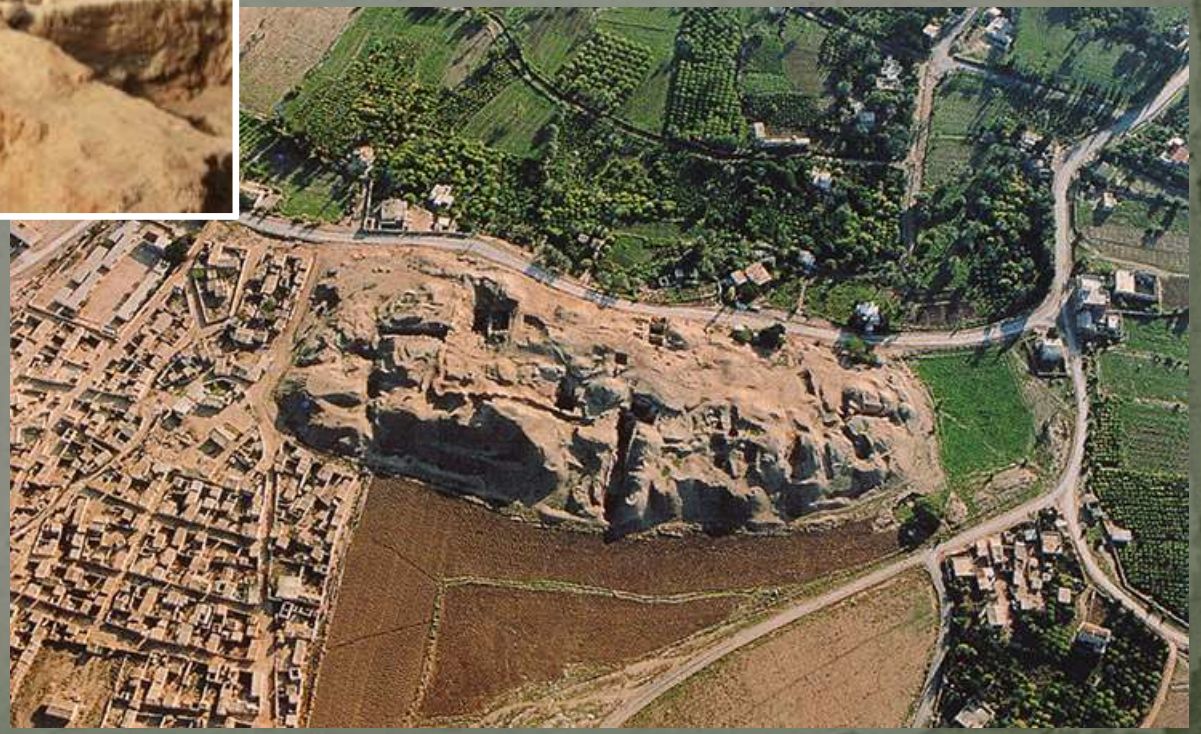
„The transition from hunter-gathering to nomadic herding systems and eventually to settled agriculture during the Neolithic period has been described as 'the most fundamental change in human history'. By allowing output of food to increase, the concept of 'property' to develop, and surplus food production to grow, the agricultural transition became the basis of human revolution. Food surpluses enabled the development of non-farmers within society, including the priesthood, the army and craftsmen. The distribution and collection of food was the basis for power and the development of wealth, and the ability to produce more from a smaller area of land lad the basis for population growth."

(*Adam C. Markham:* A Brief History of Pollution)

„Out of agriculture, grew the community. Small villages at first, then towns and eventually city-states. Jericho was a walled town of ten acres in 6500 BC, and the Mesopotamian temple city of Uruk had a population of 50,000 people by 3000 BC. For a modern comparison it is noteworthy that the French city of Toulouse had only reached a population of 55,000 nearly 5000 years later 1789. This development of towns and cities ushered in the pollution era." (Adam C. Markham: A Brief History of Pollution)

Jericho cityscape from wall ruins

Jericho (Palestine)
„The oldest city in the world”



„Much early sickness was undoubtedly caused by what we would today, call pollution. The very earliest form of pollution must have resulted from the act of defecation. The presence of human gut bacteria such as Escherichia coli in drinking water was the first water pollution and must have been a source of illness for prehistoric man, just as it is for millions of people today.

(Adam C. Markham: A Brief History of Pollution)

„The discovery of fire, at least half a million years ago, created the first significant air pollution source, and smoke remains a major problem in the modern world. Ancient human communities are thought to have suffered from sinusitis and blackening of the lungs (anthracosis) due to regular exposure to smoke."

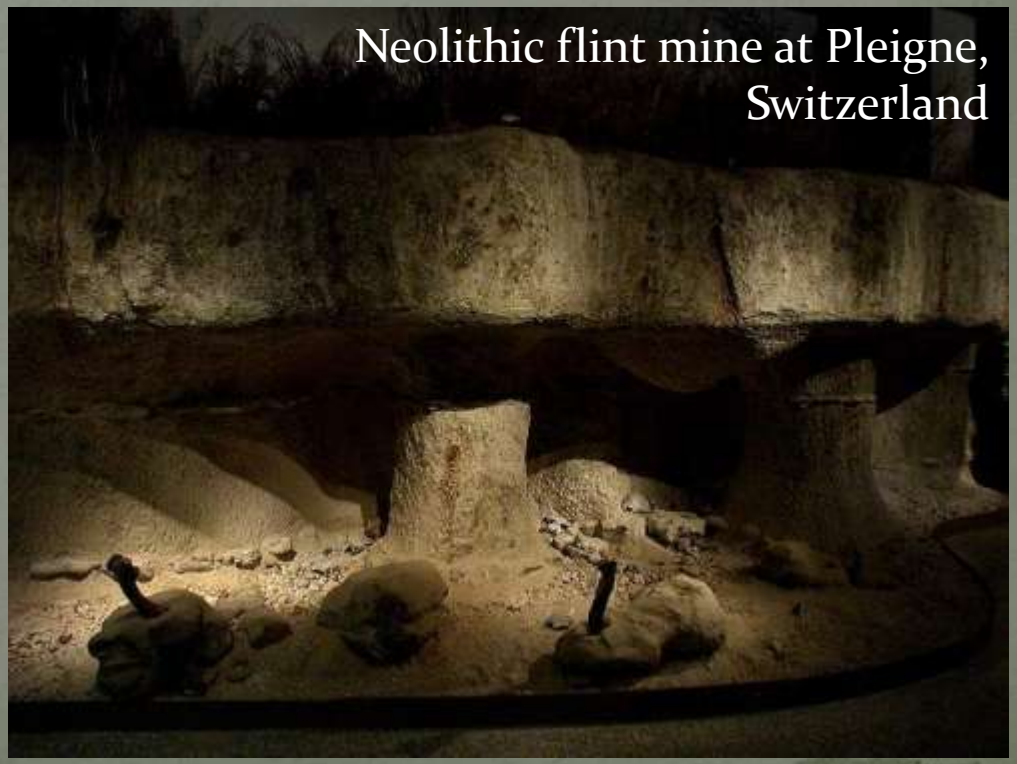
(*Adam C. Markham:* A Brief History of Pollution)

„Dust pollution also has early origins and Janssens speculated that the Neolithic miners of central Europe, who daily chipped flints from limestone quarries like that of Obourg, suffered from silicosis. Their every breath during the working day would have drawn in air polluted with dust from their labours. Simple geography sometimes influenced historical exposure to pollutants.

„ Recent analysis of the 200,000 year old Broken Hill hominid from Zambia has produced evidence that he suffered from lead poisoning due to an ore lode underlying the water supply of the cave dwelling." (Adam C. Markham: A Brief History of Pollution)

Pollutions

- Heavy metals in bones (e.g. lead/Pb)
  - Dissolution of metal ores to drinking water
- Stone pits, carving of flint stone
  - Pulmonary silicosis



Neolithic flint mine at Pleigne, Switzerland

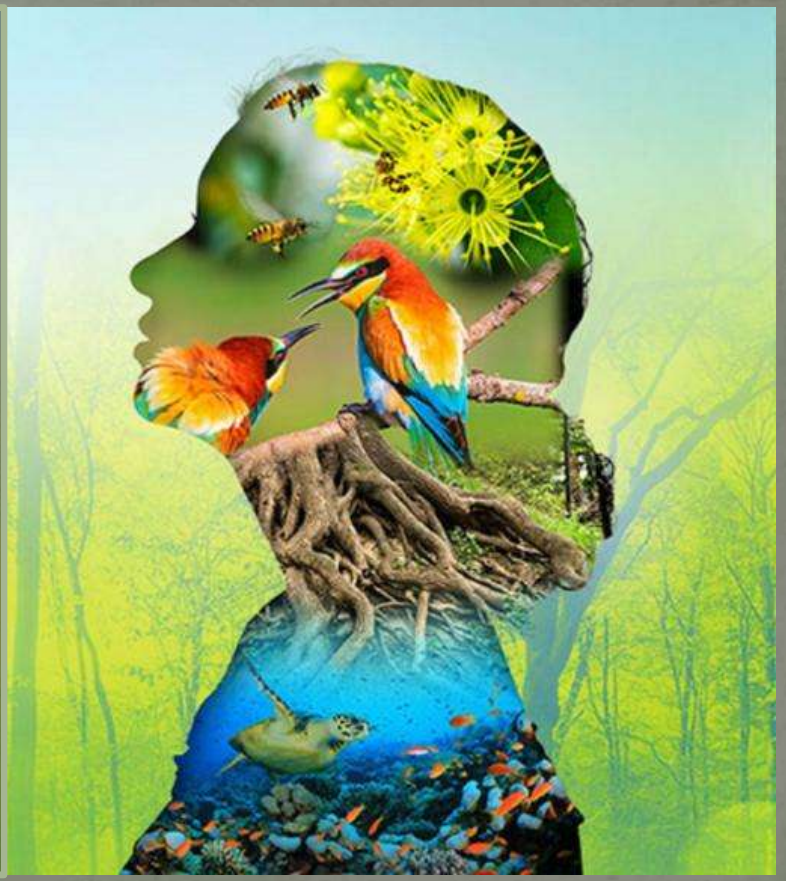
Questions

- What invention has basically changed the lifestyle of Homo sapiens?
- What caused the extinction of wolly mammoth?
- How sustainable was paleolithic hunting?
- How did neolithic revolution impact biodiversity?
- How has population changed in the stone age? What was the most remarkable step, and what was its background?

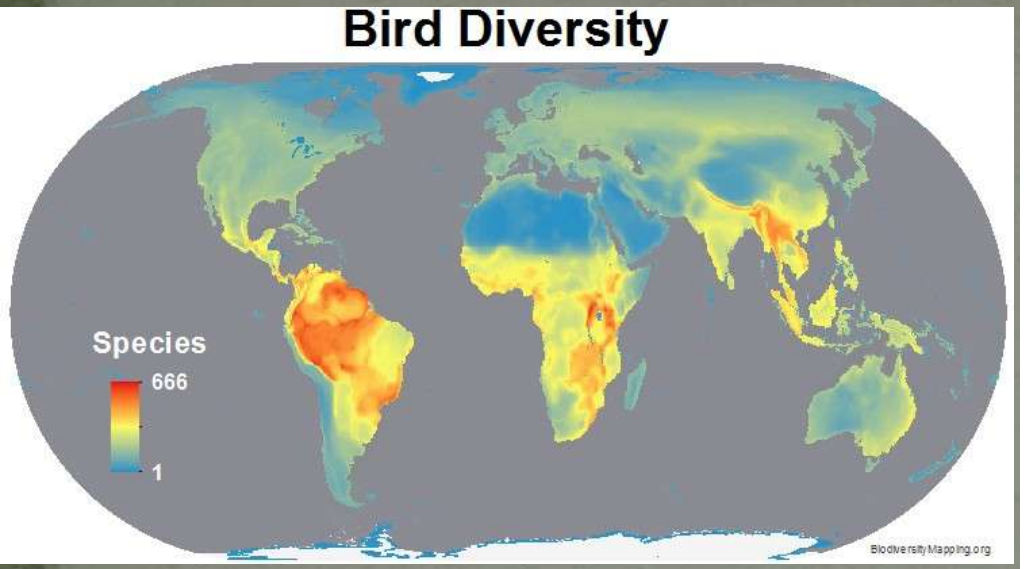
Biodiversity

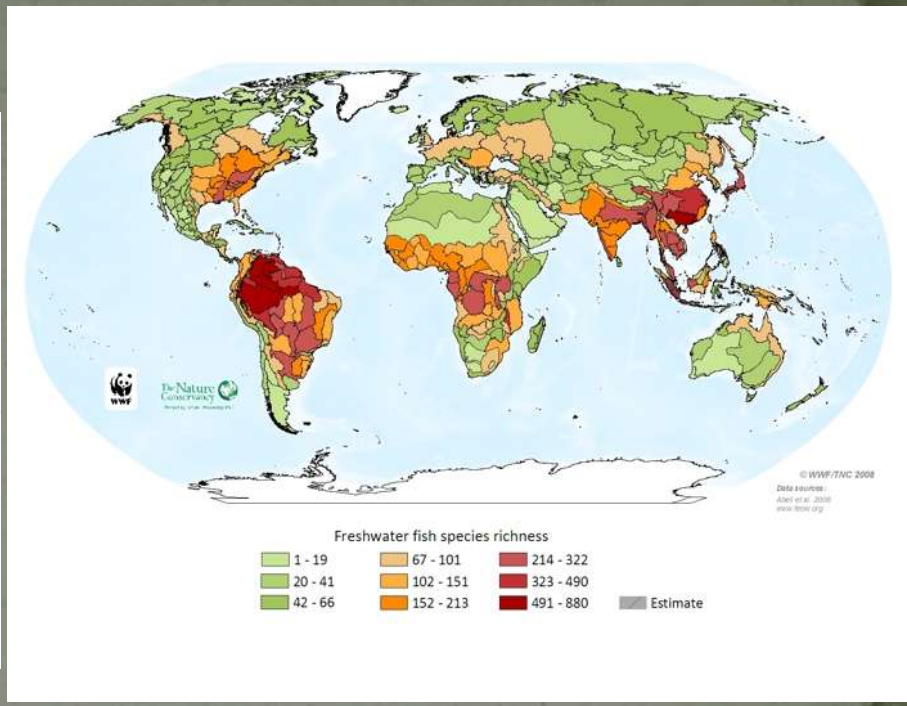
Biodiversity:

the variety of life found in a place on Earth or, often, the total variety of life on Earth. A common measure of this variety, called species richness, is the count of species in an area.

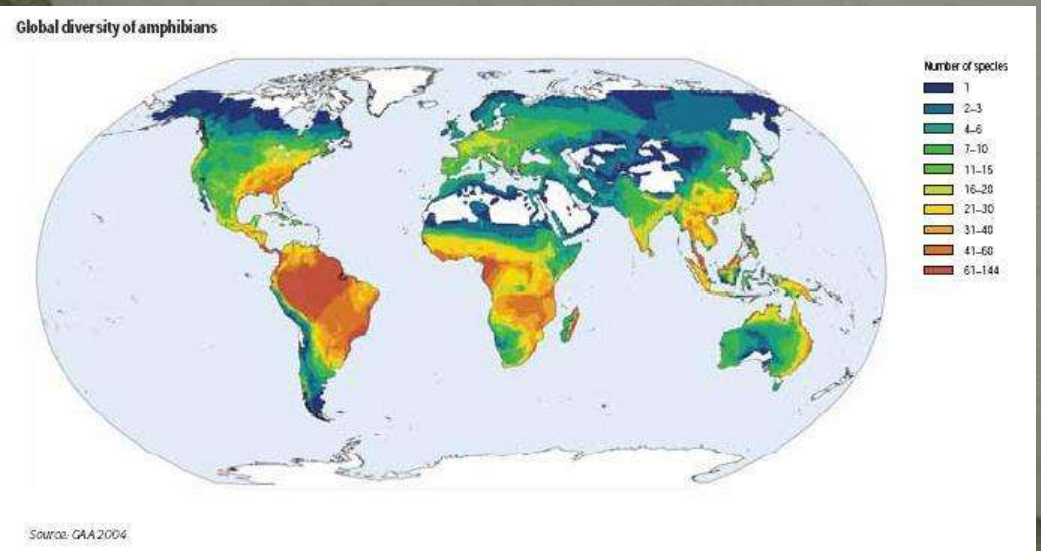


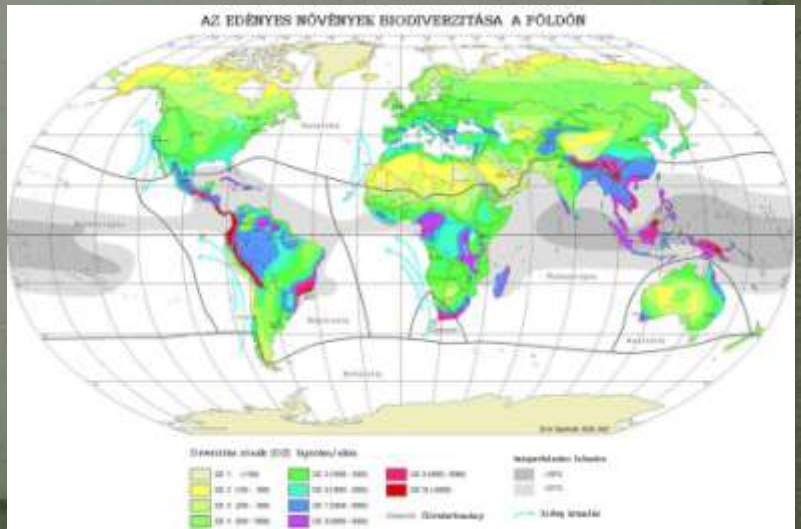
Biodiversity on the Earth





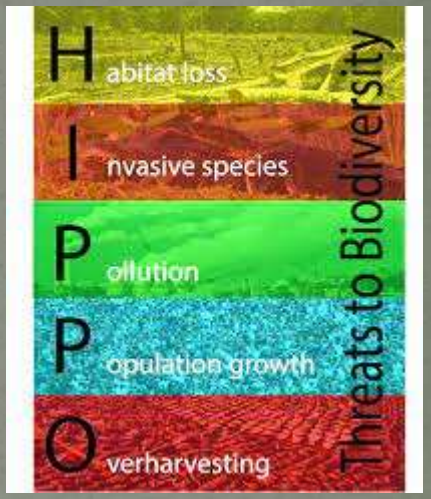
Plants



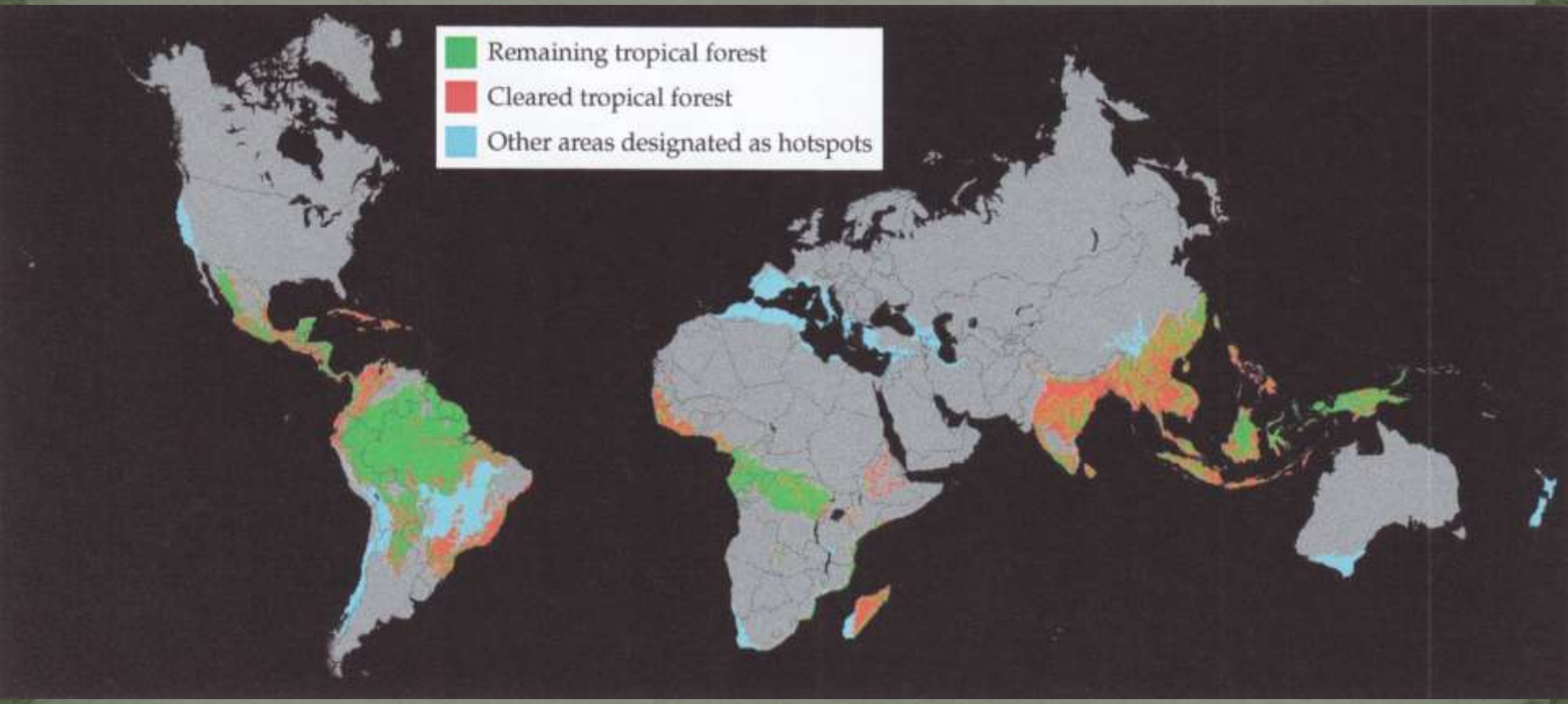


Causes of biodiversity loss (HIPPO)

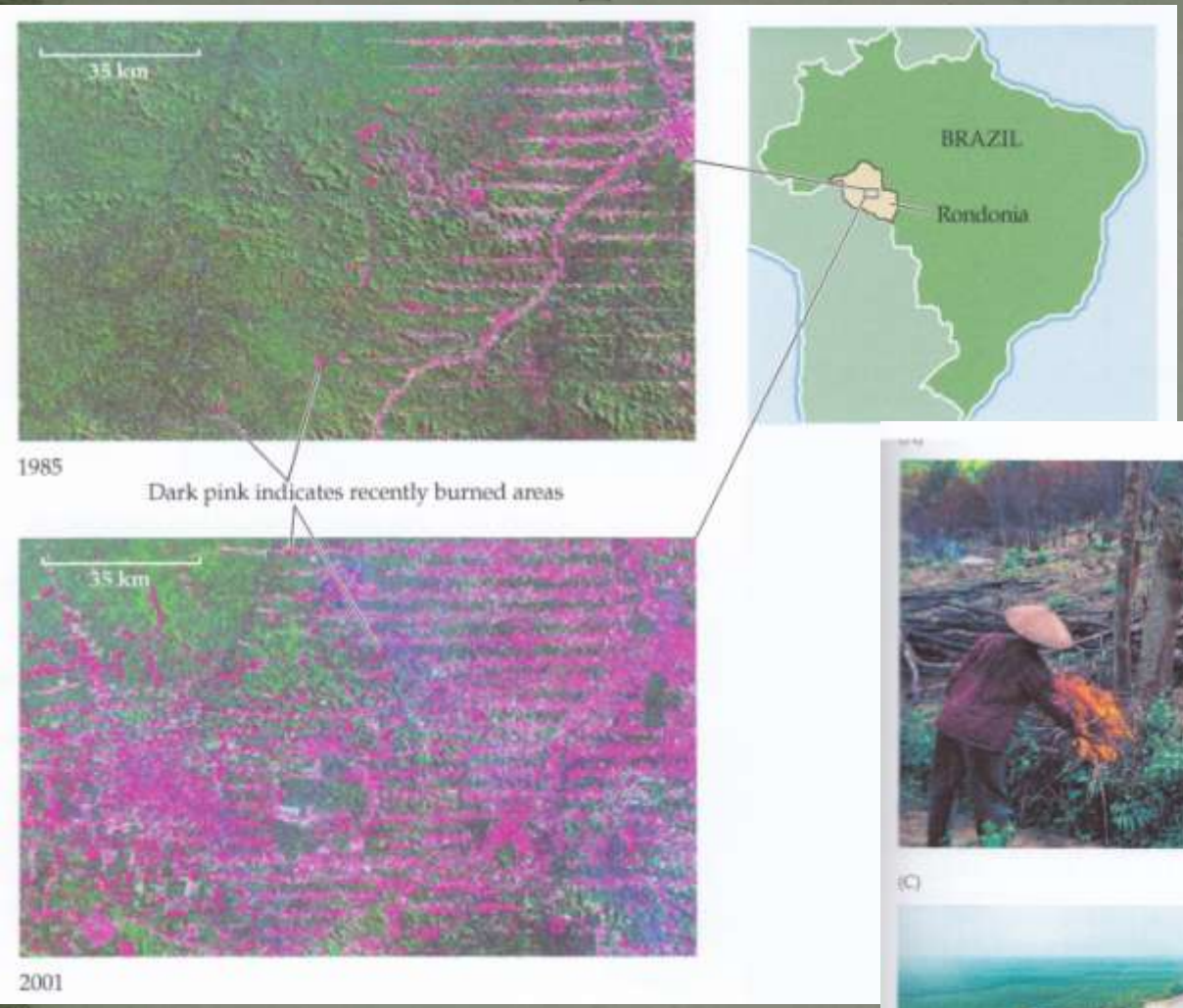
- Habitat loss
- Invasive species
- Pollution
- Population Growth (human)
- Overconsumption,
  Overharvesting,
  Overexploitation



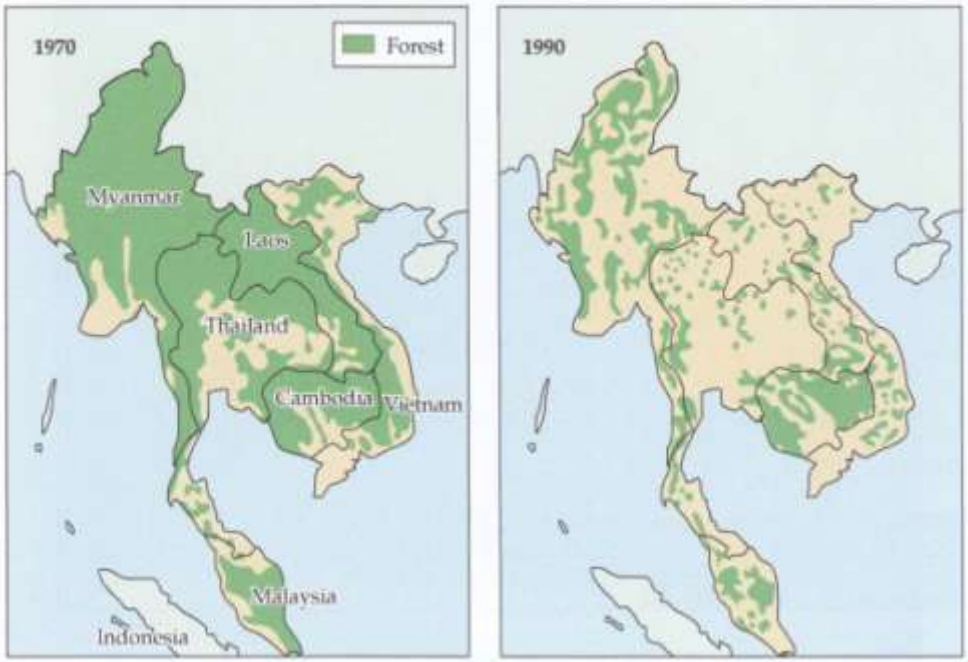
Loss of biodiversity in the tropical regions



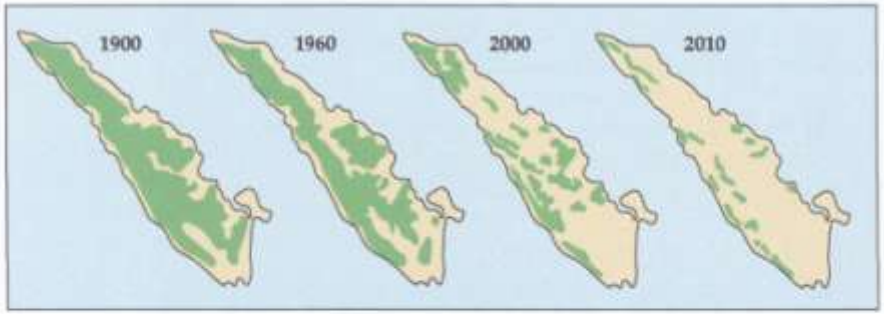
Esőerdők pusztulása



(A)



(B)



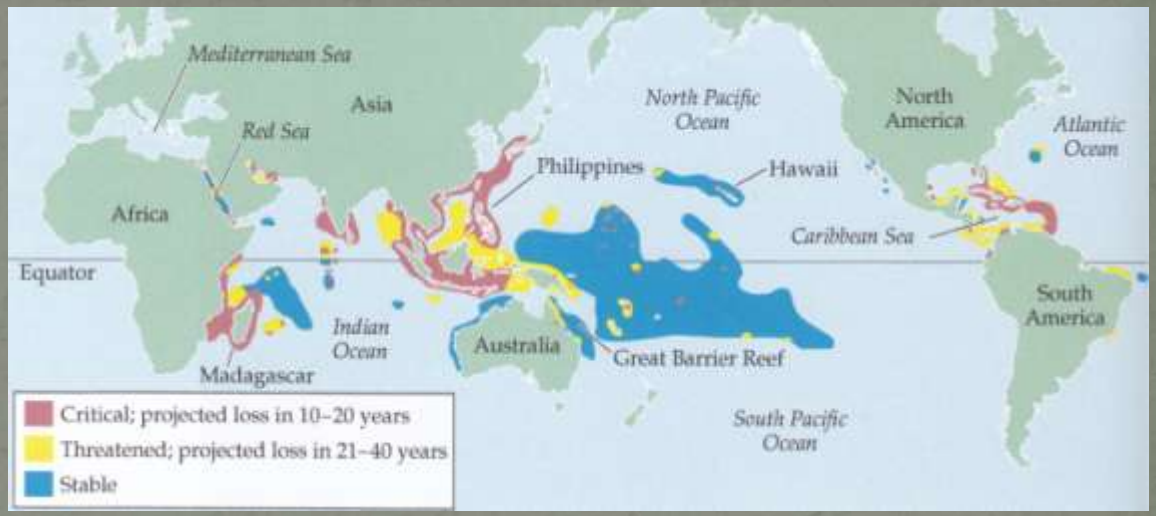
(C)

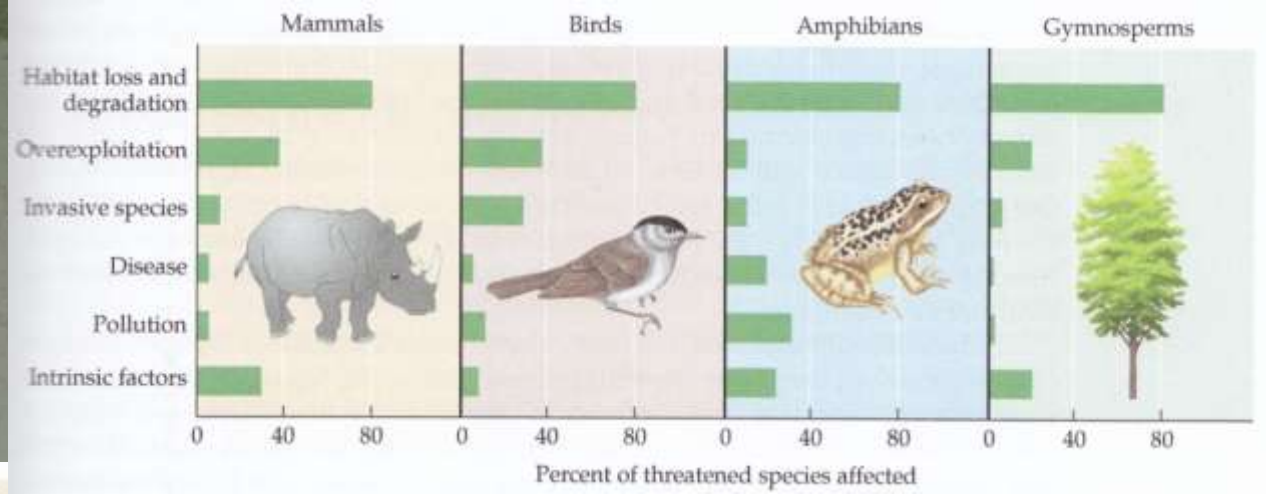
Figure 9.11 The forests of tropical Asia have experienced massive deforestation and fragmentation in recent decades. (A) Two forest maps of Southeast Asia from 1970 and 1990. (B) Sumatra, a large island of Indonesia, has experienced intense habitat destruction over the past 100 years. (C) A wide path (note the car for scale) has been cut through rain forest to allow construction of a gas pipeline in Thailand. Such disturbances often lead to the far-reaching effects of habitat fragmentation. (After Bradshaw et al. 2009.)

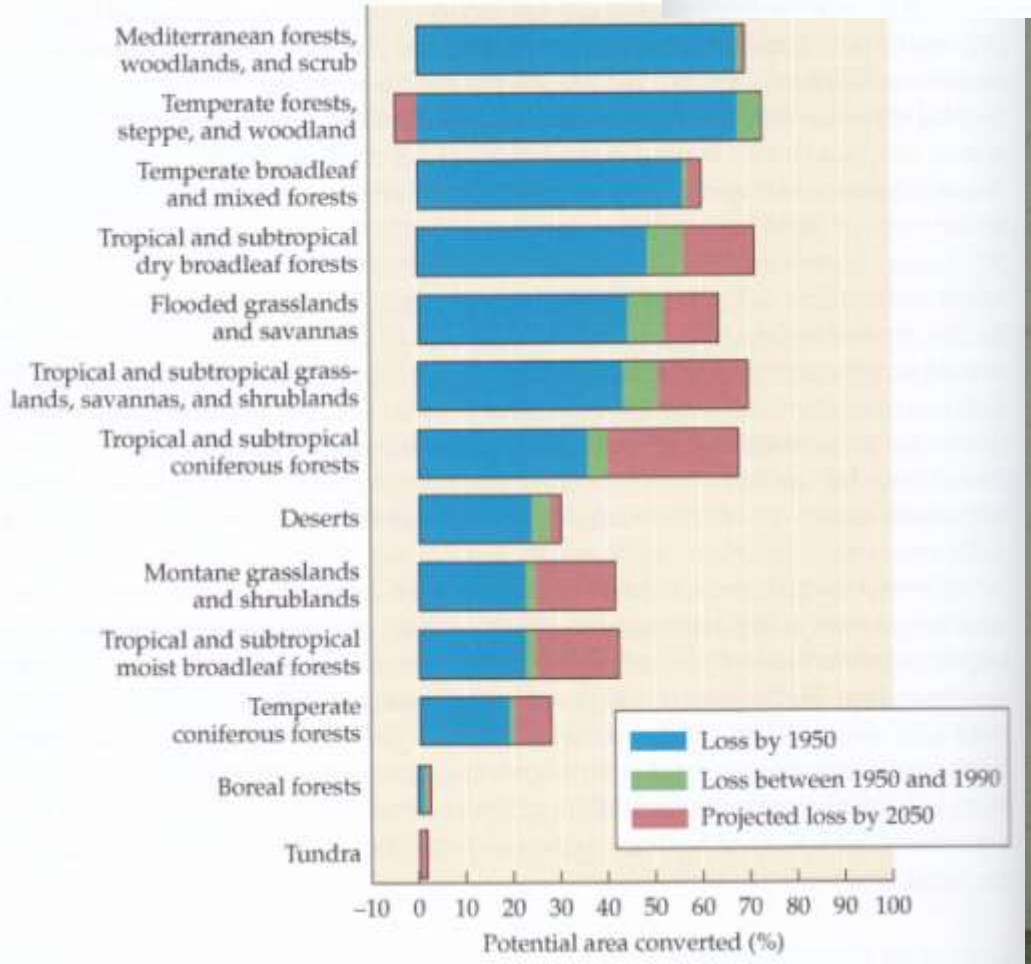
Wetlands

Coral reefs

Mangrove



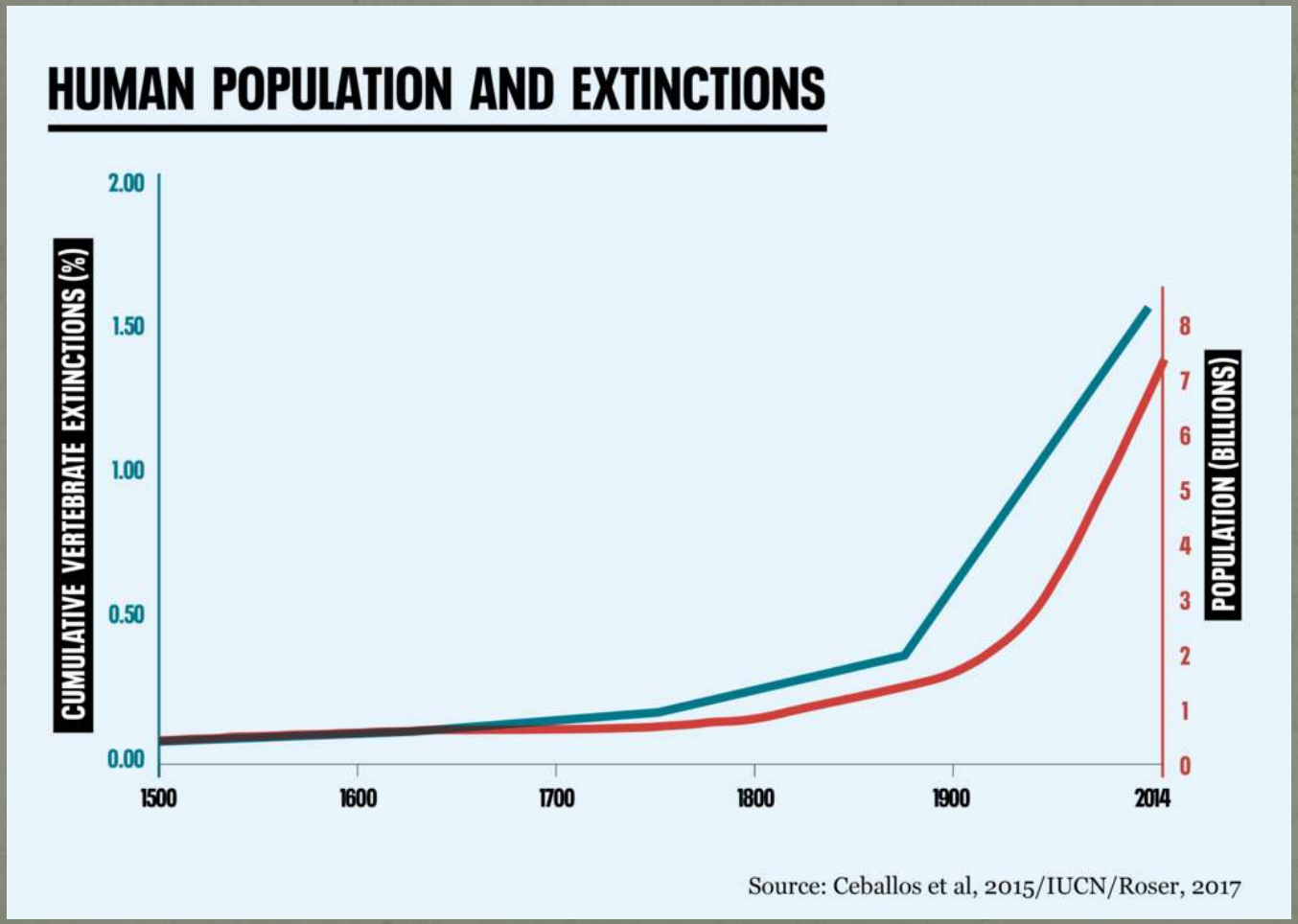

Mammals
Birds
Amphibians
Gymnosperms
Habitat loss and degradation
Overexploitation
Invasive species
Disease
Pollution
Intrinsic factors
0
40
80
Percent of threatened species affected


Mediterranean forests, woodlands, and scrub
Temperate forests, steppe, and woodland
Temperate broadleaf and mixed forests
Tropical and subtropical dry broadleaf forests
Flooded grasslands and savannas
Tropical and subtropical grasslands, savannas, and shrublands
Tropical and subtropical coniferous forests
Deserts
Montane grasslands and shrublands
Tropical and subtropical moist broadleaf forests
Temperate coniferous forests
Boreal forests
Tundra
Loss by 1950
Loss between 1950 and 1990
Projected loss by 2050
−10 0 10 20 30 40 50 60 70 80 90 100
Potential area converted (%)

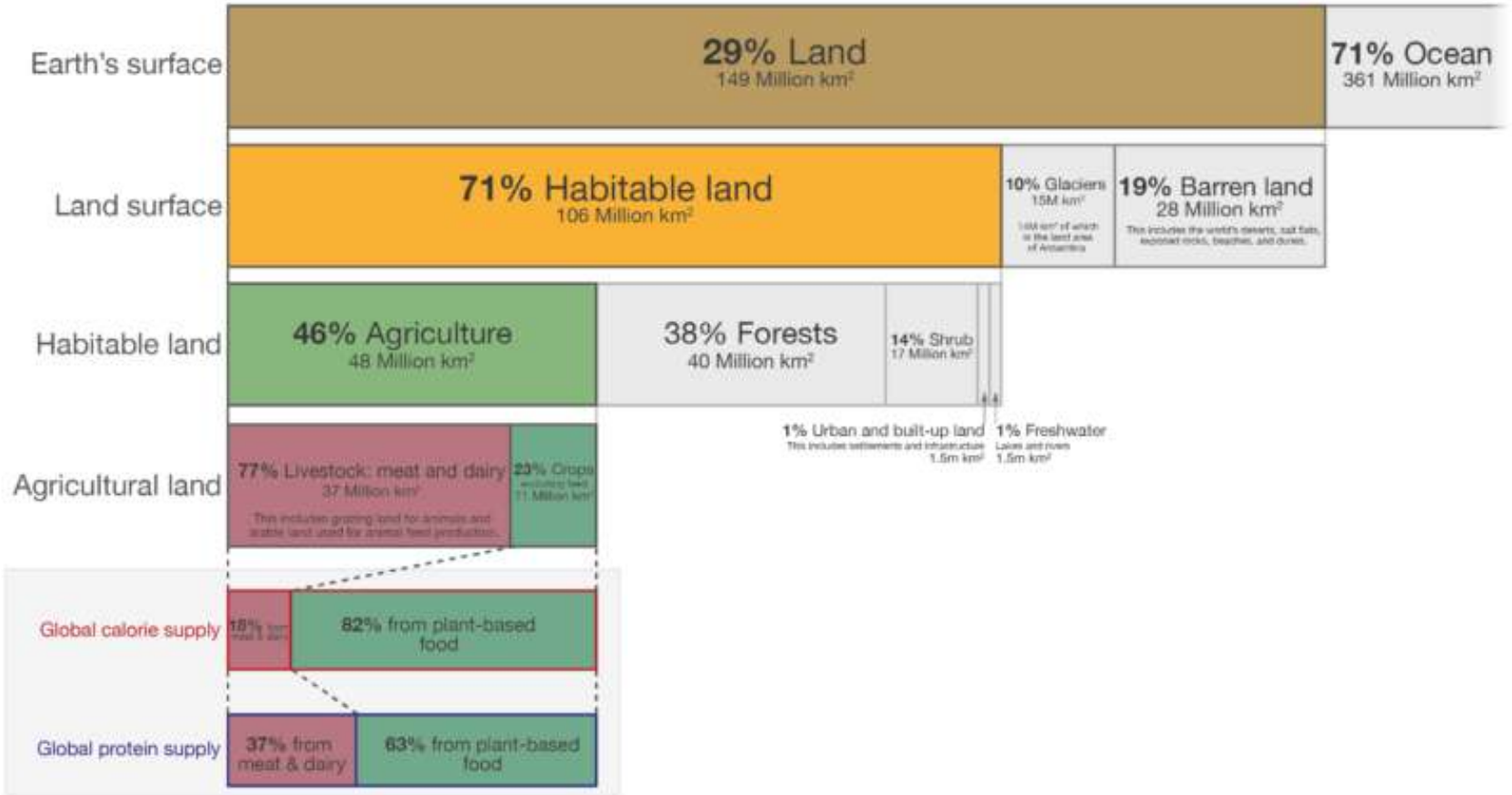
Habitat loss

- Agriculture practices
- Urbanization
- Global climate change

Population growth

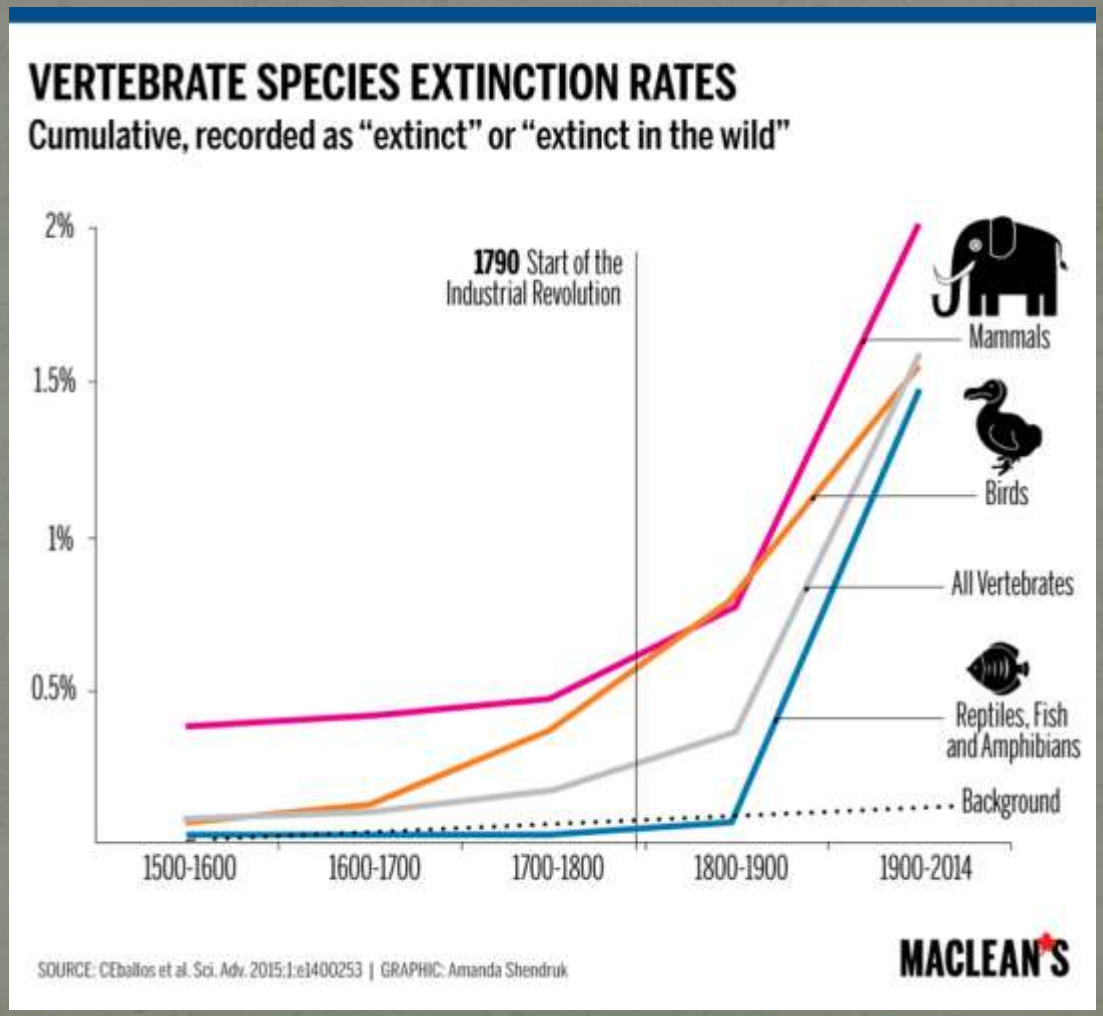


Global land use for food production



Data source: UN Food and Agriculture Organization (FAO)
OurWorldinData.org – Research and data to make progress against the world's largest problems.

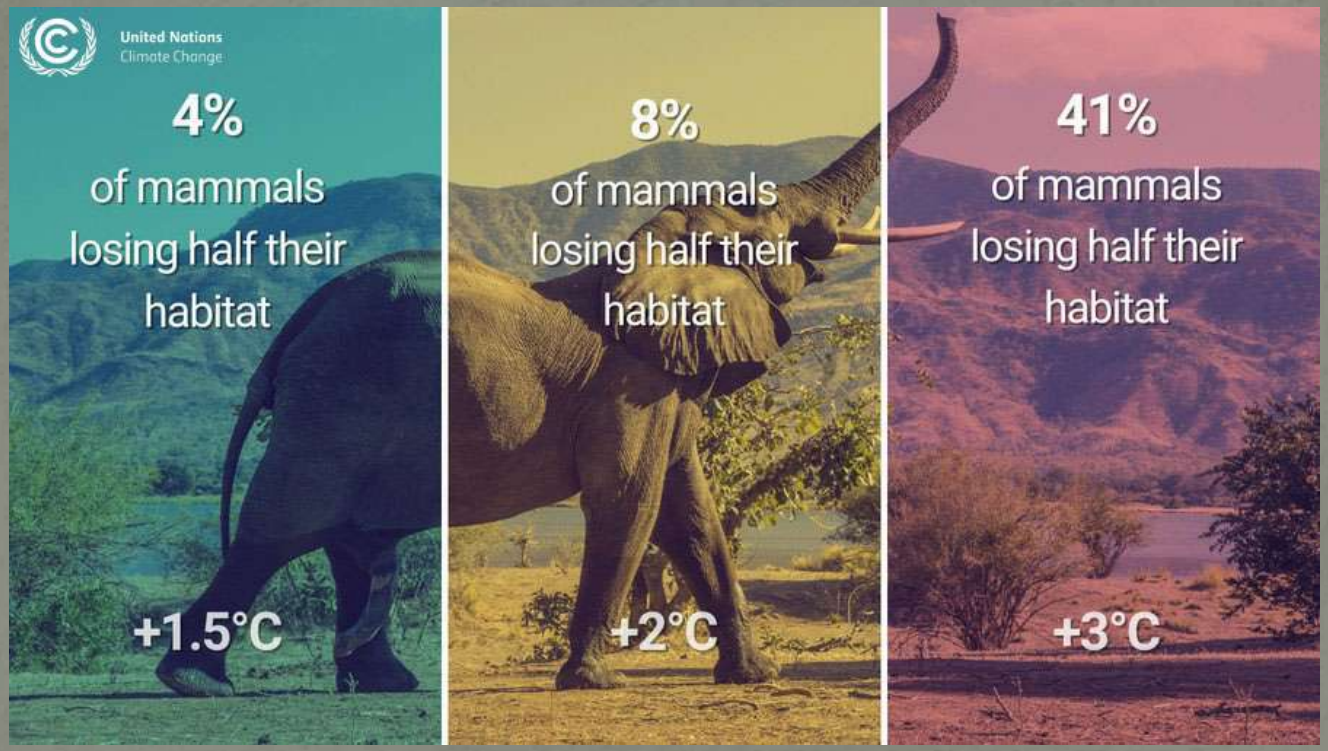
Date published: November 2019.


VERTEBRATE SPECIES EXTINCTION RATES
Cumulative, recorded as "extinct" or "extinct in the wild"
2%
1.5%
1%
0.5%
1790 Start of the Industrial Revolution
Mammals
Birds
All Vertebrates
Reptiles, Fish and Amphibians
Background
1500-1600
1600-1700
1700-1800
1800-1900
1900-2014
SOURCE: CEballos et al. Sci. Adv. 2015;1:e1400253 | GRAPHIC: Amanda Shendruk
MACLEAN'S

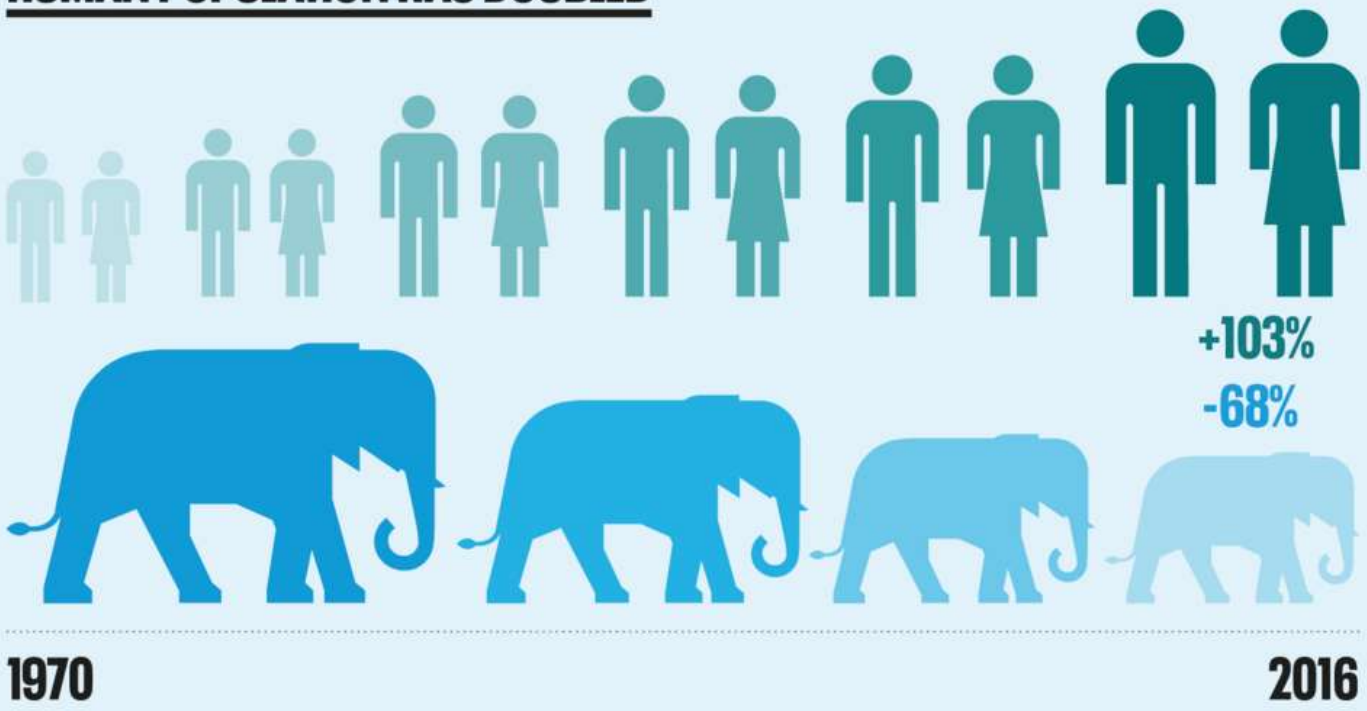
3. Pollution


“
Climate change is a primary driver of biodiversity loss. And climate change depends on biodiversity as part of the solution. So clearly the two are linked, and cannot be separated.”
Elizabeth Mrema, Executive Secretary, United Nations Convention on Biological Diversity
MAY 2022

How is climate change affecting biodiversity?



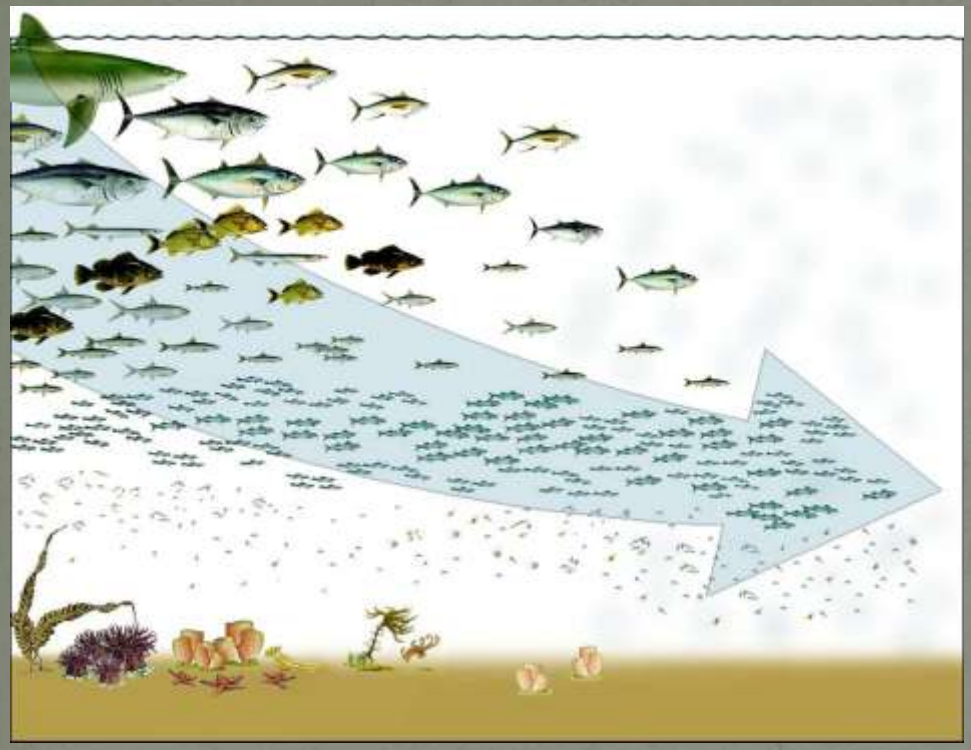
WILD VERTEBRATE ANIMAL POPULATIONS HAVE DECLINED BY TWO-THIRDS IN THE PERIOD THE HUMAN POPULATION HAS DOUBLED



Source: WWF Living Planet Report 2020/United Nations Population Division

IUCN Red List of Treathened Species (2021.05.21.)

5. Overexploitation



The fishing industry will then specifically target these smaller fish because they are considered the "largest" fish by then. This phenomenon is called "Fishing Down" (Pauly, 2009).

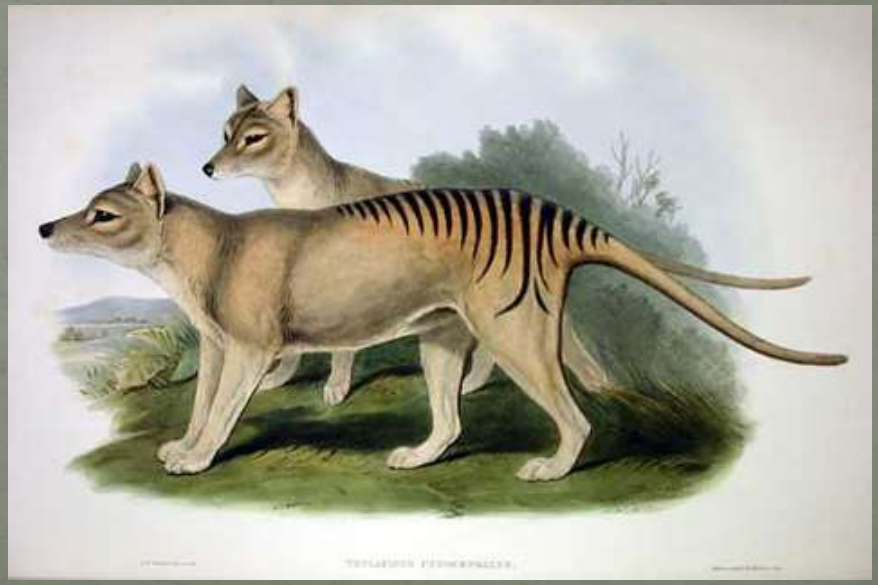
Fishing down: Commercial fishing selects for larger fish in order to get the most bang for their buck. This means that the fishing industry would rather harvest large fish and generally ignore the small ones. Due to the continuous selective pressure of over-exploitation, all the large fish will eventually die out, leaving just the smaller fish to take their place.

Extinct animals

Passenger pigeon 1914✝ (*Ectopistes migratorius*)

Thylacine, Tasmanian tiger 1936✝ (Thylacinus cynocephalus)

- Thylacine, the last existing member of family Thylacinidae, was the largest known carnivorous marsupial of the modern era. This species went extinct in the twentieth century. At times, they are referred as a cryptid.

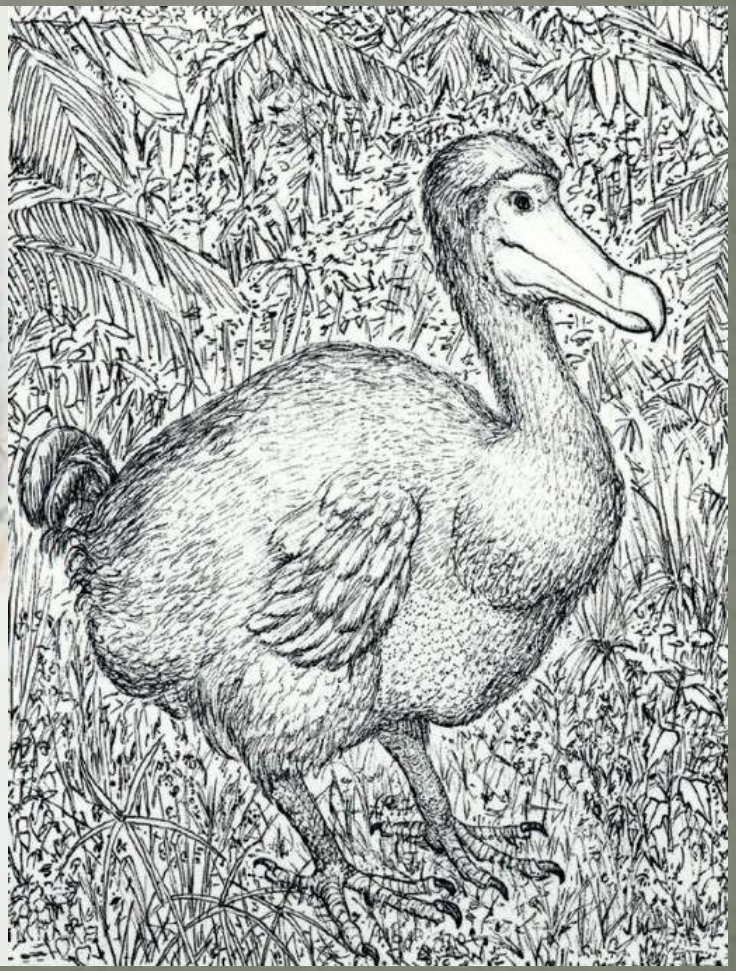


Pyrenean Ibex 2000✝

(Capra pyrenaica pyrenaica)

Pyrenean ibex, once commonly found in Southern France, Northern Pyrenees and Cantabrian Mountains, was one of the four subspecies of Iberian wild goat or Spanish ibex. This subspecies went extinct in early 2000. They were found in huge numbers even a few hundred years ago. However, by 1900 the numbers went down to less than 100, and after 1910, the number never went up above 40.

Dodo Bird 1662✝
(Raphus cucullatus)



Atlas Bear 1870†
(Ursus arctos crowtheri)

Carolina Parakeet
(Conuropsis carolinensis) 1918✝

Golden Toad
(Incilius periglenes) 1989✝

TABLE 7.1 | Some Species and Subspecies That Have Gone Extinct since 1985

Species	Common name	Date of extinction	Original range
Amphibians			
Atelopus ignescens	Jambato toad	1988 (last record)	Ecuador
Bufo baxteri	Wyoming toad	Mid 1990s[a]	United States
Bufo periglenes	Monteverde golden toad	2004	Costa Rica
Rheobatrachus vitellinus	Northern gastric brooding frog	1985 (last record)	Australia
Cynops wolterstorffi	Yunnan Lake newt	1986 (last record)	China
Birds			
Corvus hawaiiensis	Hawaiian crow	2002[a]	Hawaiian Islands
Cyanopsitta spixii	Spix's macaw	2000 (last record)	Brazil
Gallirallus owstoni	Guam rail	1987[a]	Guam
Melamprosops phaeosoma	Black-faced honeycreeper	2004 (last record)	Hawaiian Islands
Moho braccatus	Kaua'i	1987 (last report of vocalizations)	Hawaiian Islands
Myadestes myadestinus	Kama'o	2004	Hawaiian Islands
Tachybaptus rufolavatus	Alaotra Grebe	2010	Madagascar
Mammals			
Diceros bicornis longipes	West African black rhinoceros	2013	Cameroon
Lutra lutra whiteleyi	Japanese river otter	2012	Japan
Neofelis nebulosa brachyuran	Formosan clouded leopard	2013	Taiwan
Oryx dammah	Scimitar-horned oryx	1996[a]	Chad
Plants			
Argyroxiphium virescens	Silversword	1996	Hawaiian Islands
Commidendrum rotundifolium	Bastard gumwood	1986[a]	St. Helena Island
Nesiota elliptica	St. Helena olive	2003	St. Helena Island

Source: IUCN 2013 (www.iucnredlist.org).
[a]Species still exists in captivity.















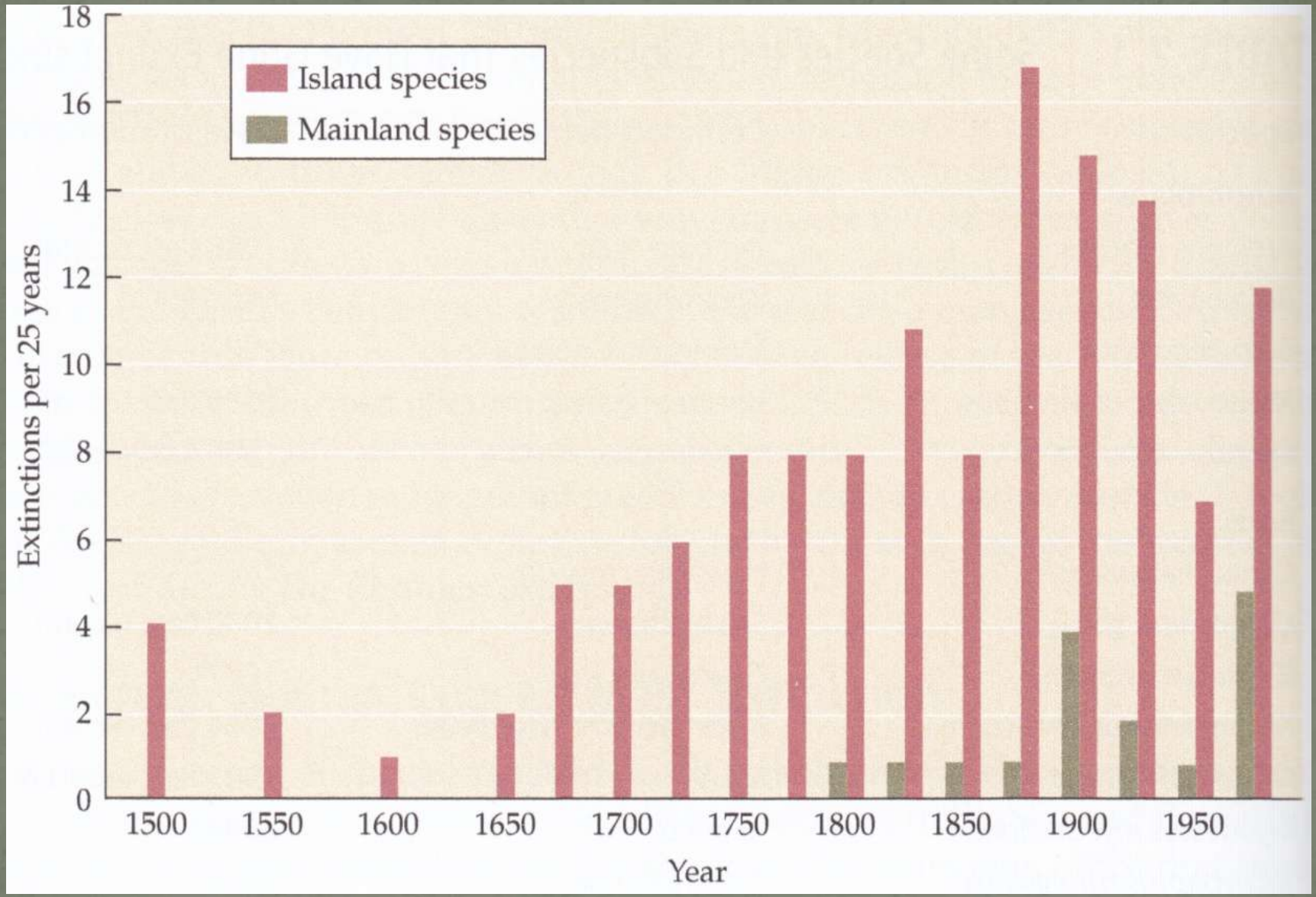

TABLE 7.2 | Numbers of Species Threatened with Extinction in Major Groups of Animals and Plants[a]

Group	Approximate number of species	Number of species threatened with extinction	Percent of species threatened with extinction
Vertebrate animals			
Fishes	28,000	2523	9[b]
Amphibians	6409	2339	36
Reptiles	9400	1160	12[b]
Crocodiles	23	10	43
Turtles	228	170	75
Birds	10,065	2196	22
Penguins	18	15	83
Mammals	5506	1467	27
Primates	420	229	54
Manatees, dugongs	5	4	80
Horses, tapirs, rhinos	16	14	88
Plants			
Gymnosperms	1010	567	56[b]
Angiosperms (flowering plants)	260,000	10,686	4[b]
Palms	521	371	71
Fungi	100,000	3	0

Source: IUCN 2013 (www.iucnredlist.org).

[a]Data include the categories critically endangered, endangered, vulnerable, and near threatened.

[b]Low percentages reflect inadequate data due to the small number of species evaluated. For example, 12% of reptiles are listed as endangered, but only about one-third of species have been evaluated. For reptile species that have been evaluated, 31% are considered endangered.


Island species
Mainland species
Extinctions per 25 years
0
2
4
6
8
10
12
14
16
18
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
Year

Progress Traps in Middle Ages

Sustainability

Antecedents in the Middle Stone Age

- The end of the itinerant lifestyle
- Settlements
- Constructions, firing (heating) ← deforestation
- Domestification of wild animals

  (pasturage → deforestation)

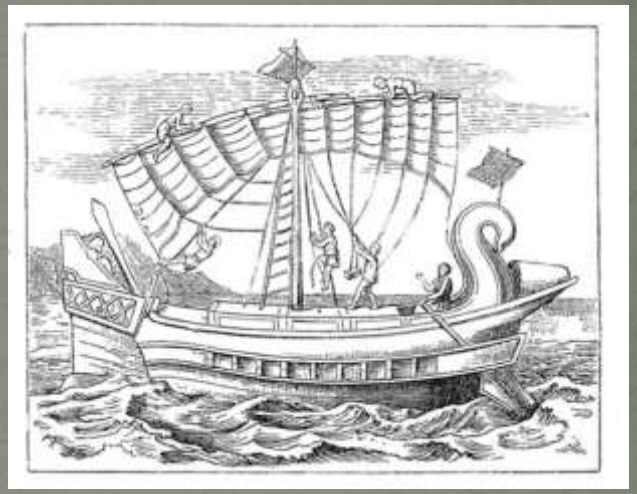
Antecedents in the New Stone Age

- Gardening: fruit-trees → fenced gardens
- Raising of cereal: preference of domesticated plants
- Eradication of natural vegetation (deforestation)

  → Biodiversity decreased
- Material and energy flow of soil changed!

Antecedents in Ancient Times

- Increasing population increasing growing plants, pastourage → deforestation
  (demand for agricultural land)
- Use of timber:
  - Building material from wood
  - Vehicles from wood
  - Metallurgy (with charcoal)
- Heating of houses
  (and roman spa)

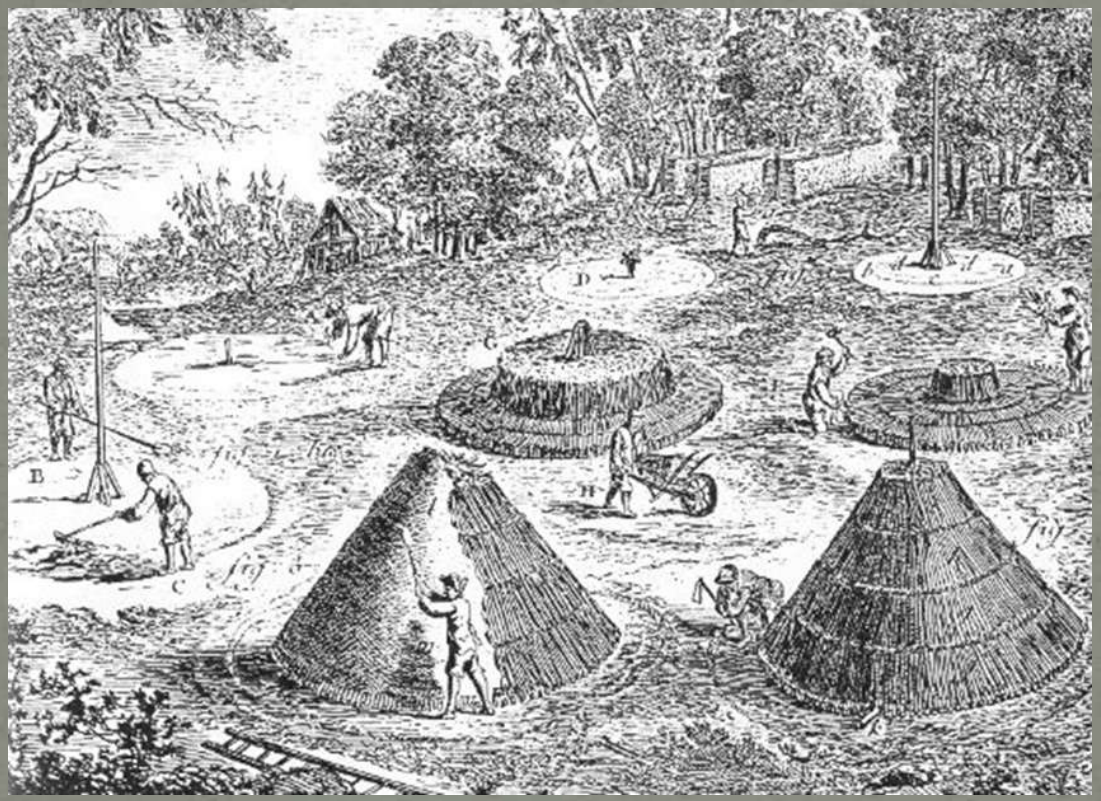


Medieval Era

Medieval Environmental Effects

- Further decrease of forest areas
  - Demand for wool↑ → pasture lands ↑
  - Brick burning ← demand for wood
  - Construction of mills
  - ←Building materials from wood
  - Vehicles from wood
  - Heating of houses
  - Wood ash for laundring
  - Wood charcoal production

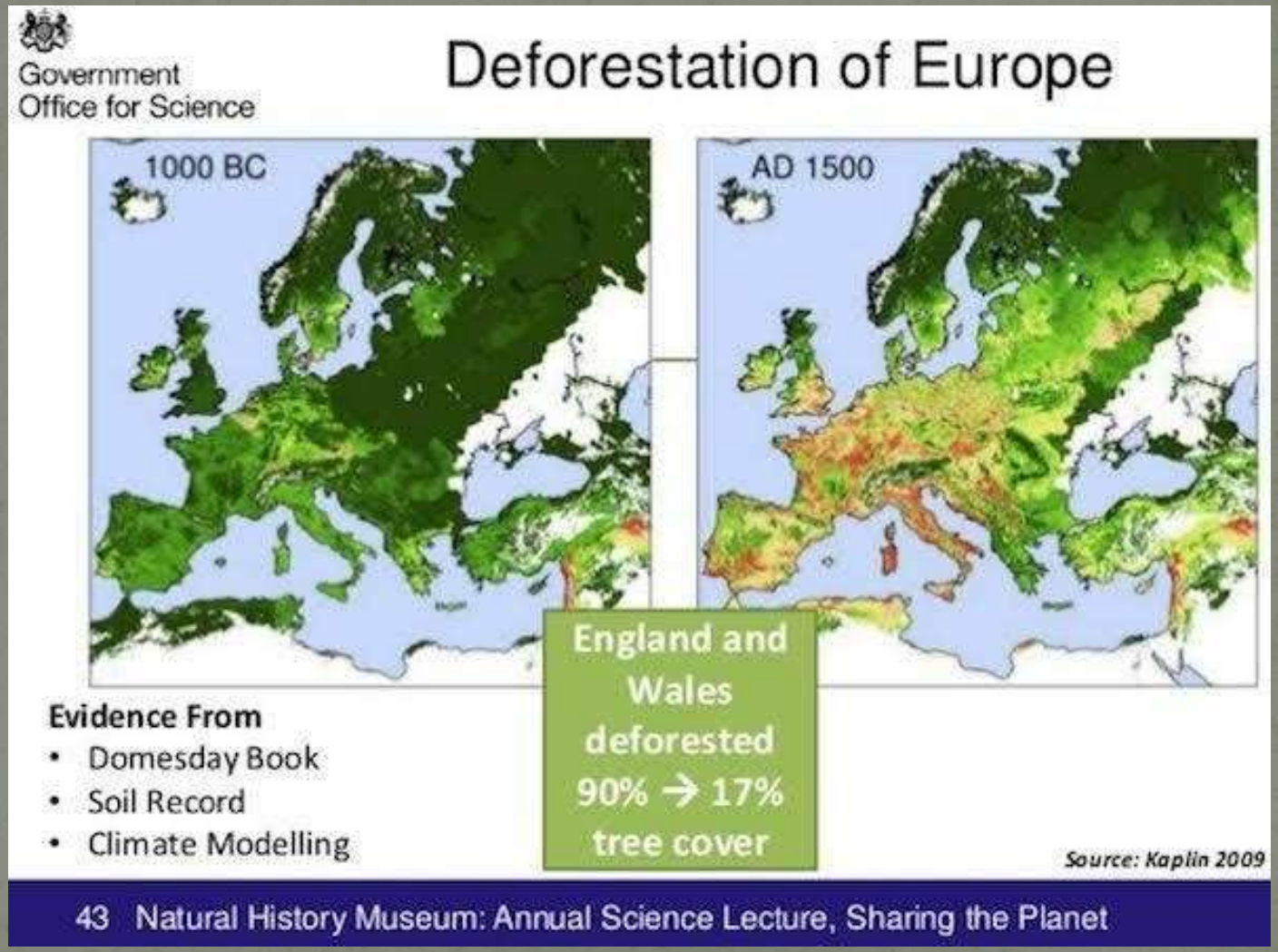
Increasing energy demand



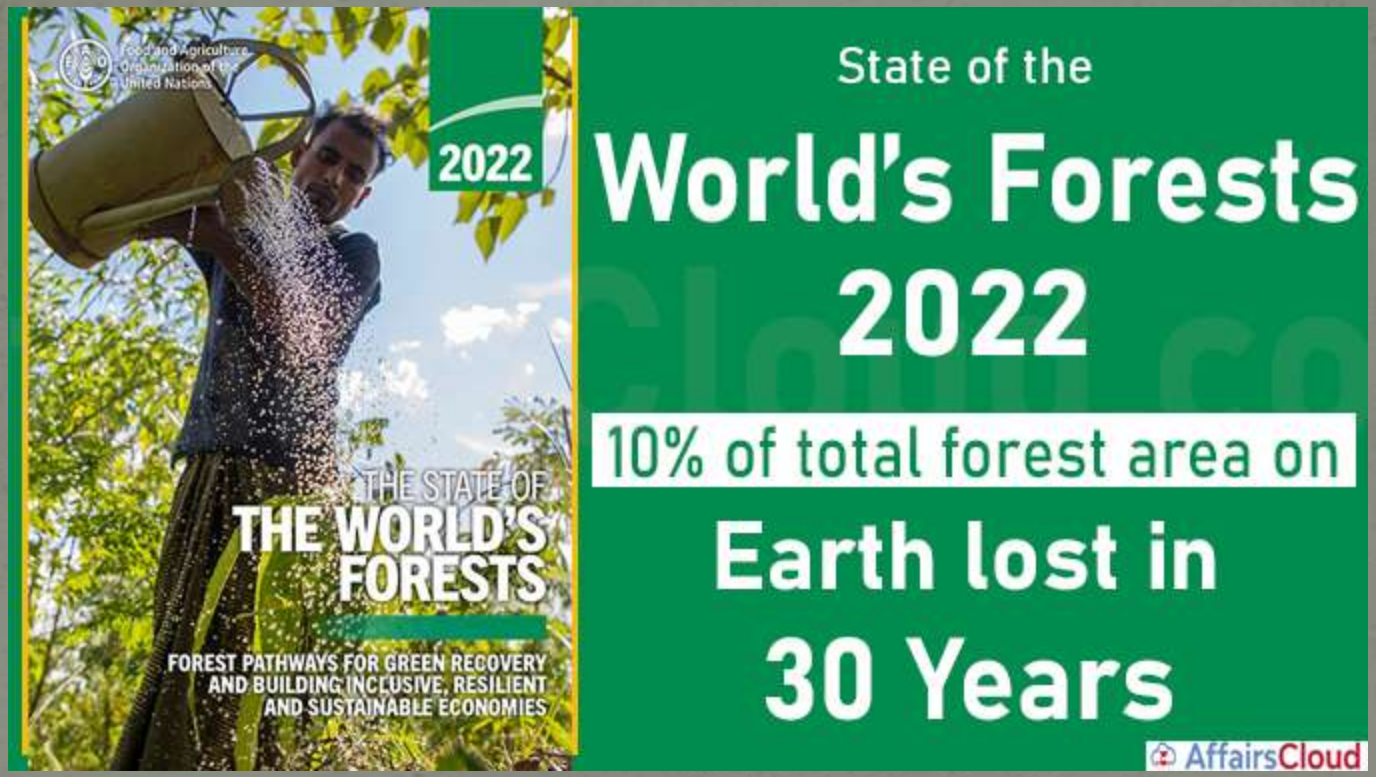
- Wood
- Charcoal
- Mining of hard coal

(not earlier than 16th century!)

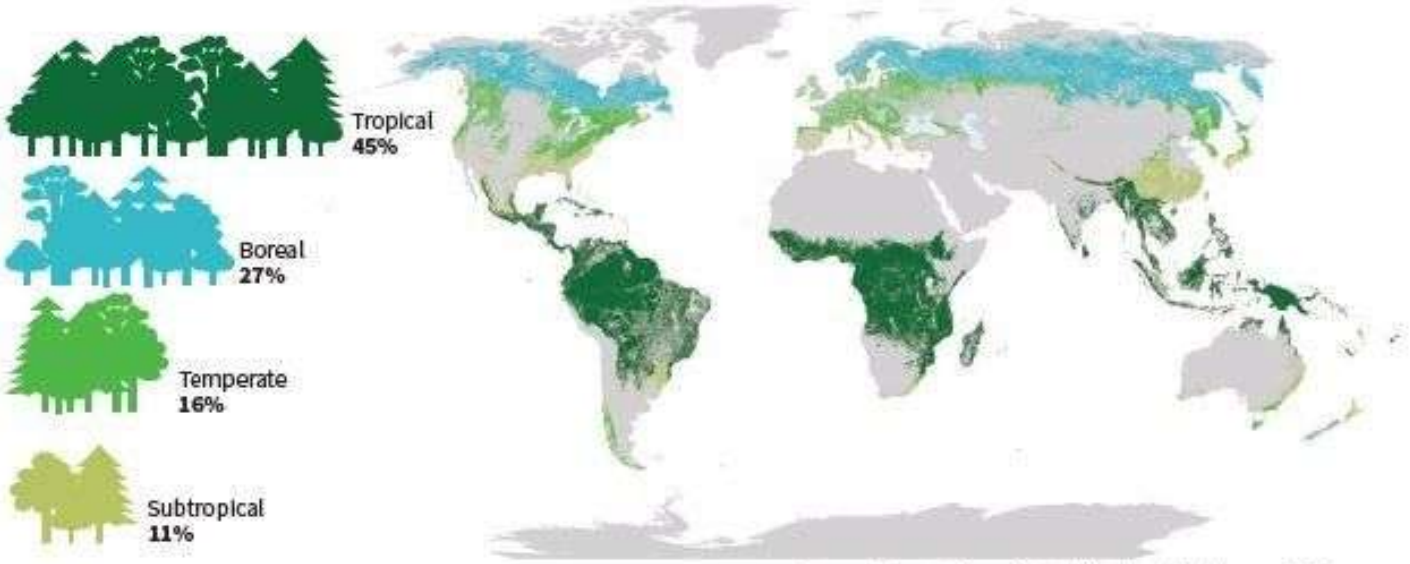
Medieval deforestation



The State of Forests in these days



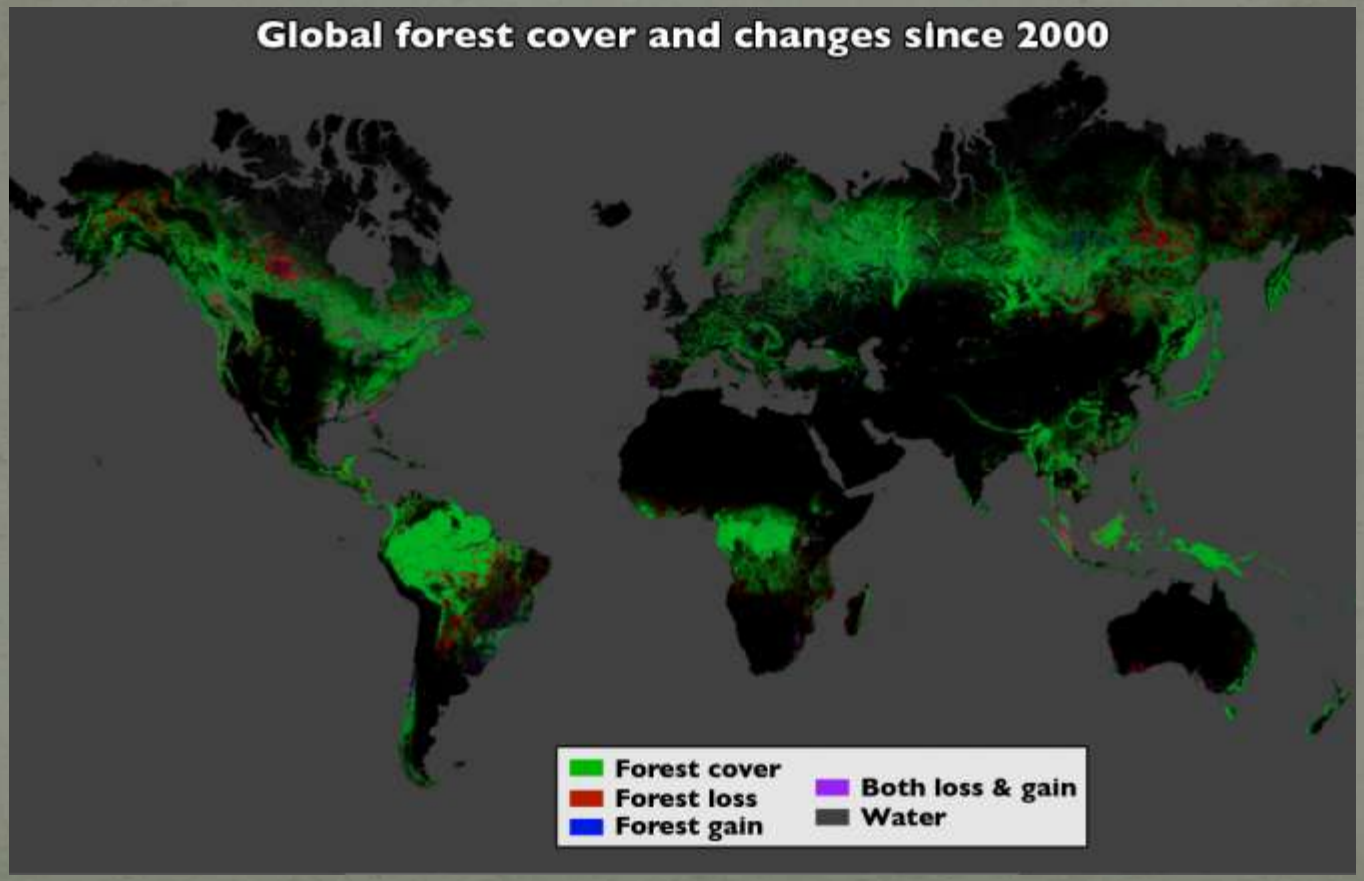
Proportion and distribution of global forest area by climatic domain, 2020



Source: Adapted from United Nations World map, 2020.

Top five countries for forest area, 2020 (million ha)

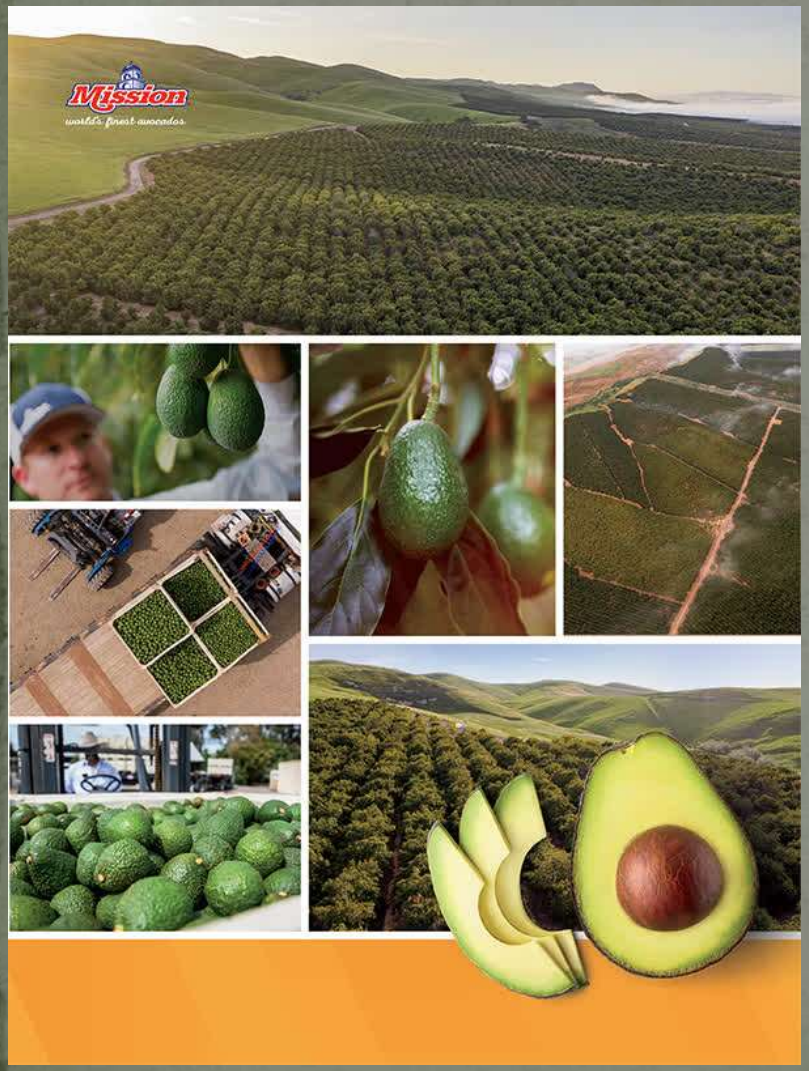
Changes in world's forest from other space 2000-2013(NASA)



Examples of deforestation

1. Pine forests of Mexico (avocado)
2. Rain forests of Southeast–Asia (oil palm)
3. Rain forests of West-Africa (cocoa)

1. Avocado (Mexico)



- Destruction of pine forest
- Endangerment of native species
- Avocado trees need double amount of water
- Long-distance transport
- Its production is profitable for drug cartels also (!)

https://www.theecoexperts.co.uk/blog/avocados-bad-for-environment

2. Palm oil (Southeast–Asia)

- Indonesia, Borneo, Sumatra
- Eradication of rain-forests (480 ha/day)
- Forest burning

high carbon content of peat bog → carbon dioxide emission

- Endangered species

(orangutan, sumatran tiger)

- Water pollution
- Exploitation of inhabitants
- Child labour!

PALM OIL FREE

#Boycott
4Wildlife

HOW TO AVOID PRODUCTS WITH

PALM OIL

Including Your Favorite Brands

GREENGLOBALTRAVEL.COM

Nutella Unmasked

8% cocoa and milk powder

14% hazelnut

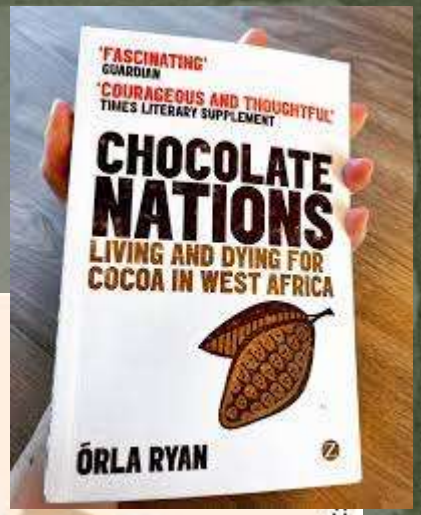
23% palm oil

55% sugar

Mercola.com

https://www.worldwildlife.org/pages/which-everyday-products-contain-palm-oil

Cocoa, chocolate (West-Africa)



GLOBAL COCOA PRODUCTION & CONSUMPTION

(Thousand tonnes)

Most of the world's cocoa comes from West Africa, with more than a third coming from the Ivory Coast alone. Cocoa is grown mainly on small, family-owned plantations by farmers living in poverty.

By contrast, most of the world's chocolate is consumed in the wealthy regions of Europe and North America.

Source: International Cocoa Organization (ICCO), Cocoa Barometer

Global cocoa production and consumption, year 2010/2011.

BRYONY JONES & INEZ TORRE/CNN

Cocoa, chocolate (West-Africa)

- Eradication of rain-forests

  (80% decrease since 1960)
- Illegal plantations in national parks and protected forests
- Farmers in deep poverty

  (modern slavery)
- Child labour!

CHOCOLATE UNWRAPPED

PROBLEMS

LAND RIGHTS

Many cocoa farmers in West Africa do not have clear legal rights to their own land, and women often have an even harder time proving ownership.

LOW PRICES

The average household income of cocoa farmers in West Africa is $2,707 per year, well below the poverty line.

CHILD LABOR

An estimated 2 million West African children are engaged in hazardous labor in the cocoa sector, with a significant percentage in forced or slave labor.

DEFORESTATION

Nearly all of Côte d'Ivoire's native forests have been cut down, driven in part by low prices and low productivity, forcing poor farmers to expand their cultivation.

FOREST EXTRACTION

Ghanaian law grants the government rights to all timber, including on private land. This law discourages farmers from growing shade trees on cocoa farms.

CLIMATE CRISIS

Increasing temperatures and a changing climate in West Africa could reduce cocoa production by up to 30-40%.

SOLUTIONS

LIVING INCOMES

Too often, cocoa prices are based on the distant commodity market. To better support farmers, Fairtrade International is piloting a program that focuses on living incomes, starting with what a farm family needs to live and building from there.

MORE FAIR TRADE CHOCOLATE

87% of fair trade cocoa is sold into the conventional marketplace, robbing farmers of the benefits of the fair trade system. If more companies sourced more fair trade cocoa, more small-scale farmers could escape poverty.

LAND REFORM

Clear land titles can safeguard farmers and provide them with the security needed to invest in their crops. Supporting women's access to land could double farm profitability.

INCOME DIVERSIFICATION

Biodiversity isn't just good for the planet. It also gives farmers additional crops to eat and sell. A diverse food forest can almost double a farm family's income.

AGROFORESTRY

Growing fruit, shade trees, and timber alongside cocoa can help sequester carbon and combat climate change. These diverse agroforestry systems also protect cocoa trees from heat spikes and pests.

STEPS YOU CAN TAKE

1. **BUY CHOCOLATE FROM COMPANIES COMMITTED TO FAIR TRADE.**
   Find a list at FairWorldProject.org.
2. **INVEST IN FARMER-LED AGROFORESTRY PROJECTS.**
   Learn more at GrowAhead.org.
3. **IS YOUR CHOCOLATE SUPPORTING FORCED AND CHILD LABOR?**
   Ask your favorite chocolate company what steps they are taking in their supply chains.
4. **SUPPORT SMALL-SCALE FARMERS AND COMBAT CORPORATE CONSOLIDATION.**
   Find current campaigns at FairWorldProject.org.

Fairtrade and Sustainability!

https://www.fairtrade.org.uk/buying-fairtrade/chocolate/

Effects of deforestation

- Oxigen production ↓
- Carbon dioxide absorption ↓
- Forest burning → carbon dioxide emission ↑

The Great Green Wall Project (16 km x 7775 km)

The Great Green Wall of the Sahara and the Sahel is a project led by the African Union, initially conceived as a way to combat desertification in the Sahel region and hold back expansion of the Sahara, by planting a wall of trees stretching across the entire Sahel.

Source: Great Green Wall

The modern green wall has since evolved into a program promoting water harvesting techniques, greenery protection and improving indigenous land use techniques,

aimed at creating a mosaic of green and productive landscapes across North Africa.

Questions

- What where the reason of deforestation in Mesolithic?
- How are these reasons changed later?
- How did the application of wood broaden?
- Why do we immolate our forests?
- What is the wrongest way of deforestation?

Progress and Regression in Waste Management

Solid waste

- „Any garbage
- or refuse,
- or sludge
  - from a waste water treatment plant,
  - water supply treatment plant,
  - or air pollution control facility
- and other discarded material,

including solid, liquid, semi-solid,

or contained gaseous material

resulting from industrial,
commercial,

mining,

and agricultural operations,
and from community activities.„

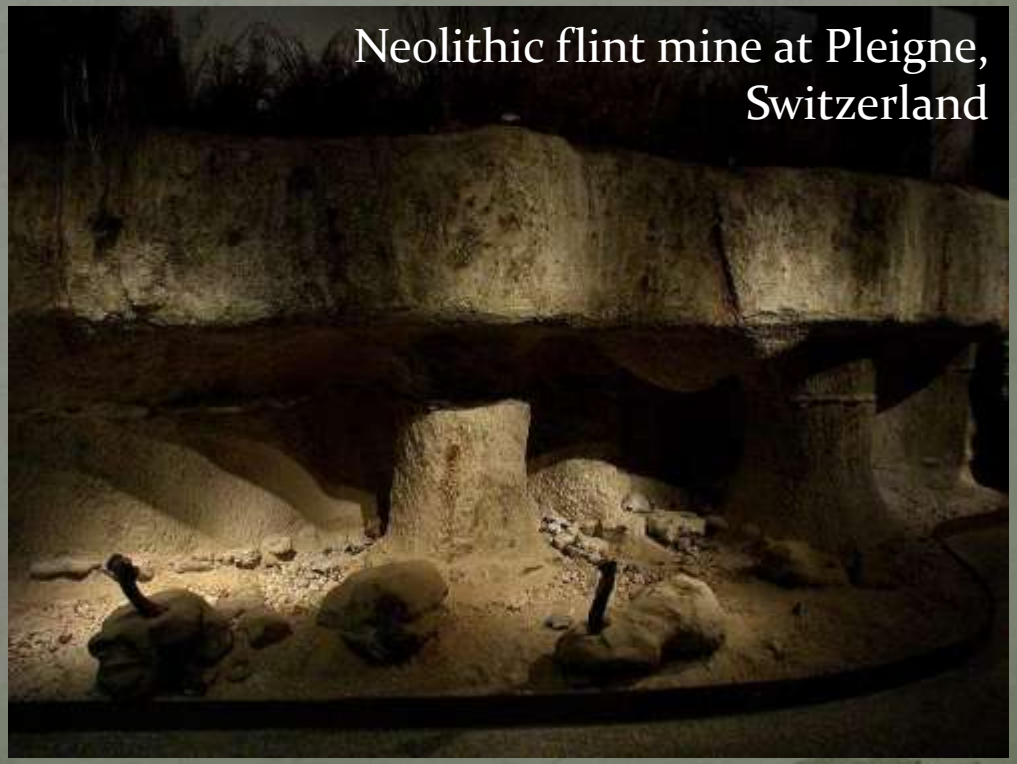
(epa.gov/rcra)

Upper Paleolithic

- Natural waste materials
  - Conclusions about lifestyle:
    e.g.: seashells ← fishing

Pollutions in New Stone Age

- Heavy metals in bones (e.g. lead/Pb)
  - Dissolution of metal ores to drinking water
- Stone pits, carving of flint stone
  - Pulmonary silicosis



Neolithic flint mine at Pleigne, Switzerland

Ancient villages, cities, city-states

- Enormous water demand ← Channelling
- Sewage drain
  - Irrigation of agricultural areas
- Waste production
  - Water supply in the cities

Ancient Times: Counterbalancing of harmful effects

- Garbage collection
  (e.g. manure)
- Location

of polluting workrooms:

- Distance!
- Wind direction!

- Parks and resorts (Rome)

„The first sewage system was the Roman Cloaca Maxima, built in the sixth century BC during the Etruscan dynasty of the Tarquins. The initial purpose of this massive structure was to drain the swamp between the Palatine and Capitoline hills, leading eventually to the Roman Forum, which became the hub of the Republic and later the Empire. The hydraulic pioneers of the ancient world, the Romans constructed a whole network of cloacae, or sewers, as well as a maze of aqueducts bringing water into the city. (Adam Markham: A Brief History of Pollution)

Medieval living conditions

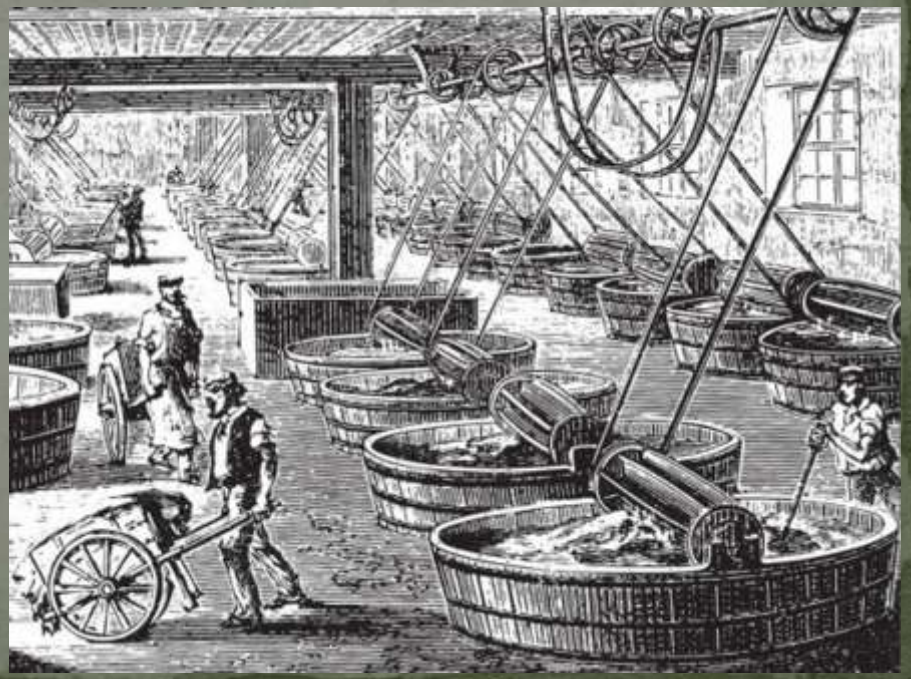
„Despite the lead taken by the Romans, public access to sanitation and safe water did not become a priority for most countries until the nineteenth century. The usual motivation behind the removal of organic waste and sewage was the problem of odour, the desire for clean drinking water, and a dislike of wading through streets running with ordure. The direct connection of disease-carrying organism with water pollution was not proven until the second half of the nineteenth century, when the germ theorists finally proved their case against miasmists." (Adam Markham: A Brief History of Pollution)

Medieval water pollution and waste

- Water demand and the problem of sewage
  - Not enough drinking water
  - Continuous smell
  - Chemical and biological pollutions in rivers

  e. g. from tanneries and butcheries
  - Saturation of digestive pits

  → Pollution of surface waters



„Nevertheless, hard-pressed municipal administration were already attempting to tackle water pollution problems in the early fourteenth century. An official investigation into the state of the Fleet River in London in 1307 concluded that the main cause of pollution problems was tanning waste and butchers' offal from Smithfield market. In the same year, the Palace of Westminster installed a pipe connection the King's lavatory with another sewage pipe that had been constructed earlier to remove waste from the palace kitchen. Needless to say, this was not a privilege available to many commoners, and most people's sewage continued to flow direct from privies jutting over the river, or into the open gullies and trenches that ran down the streets. Sewers and cesspools were being developed, but their efficacy was doubtful. Sewers were often blocked (and in any case simply emptied into the nearest river or stream), while cesspools stank, overflowed and tended to leak into neighbours' wells."
((Adam Markham: A Brief History of Pollution)

Medieval water pollution and waste

- Accumulation of urban waste

was a continuous problem.

- Waste on the street
- Waste was washed away by the rain to channels and rivers
- Rudimentary actions,

  e.g. scavengers

„The towns and villages of medieval Europe seem not to have been very sweet-smelling places. Pigs were a convenient means of removing waste, and what they didn't eat would eventually be washed away by rains. Many towns and cities had rudimentary regulations for the disposal of waste and teams of 'rakers' or 'scavengers' were often employed to remove garbage from city. But by and large, the water management advances of the Roman Empire had been long forgotten. (Adam Markham: A Brief History of Pollution))

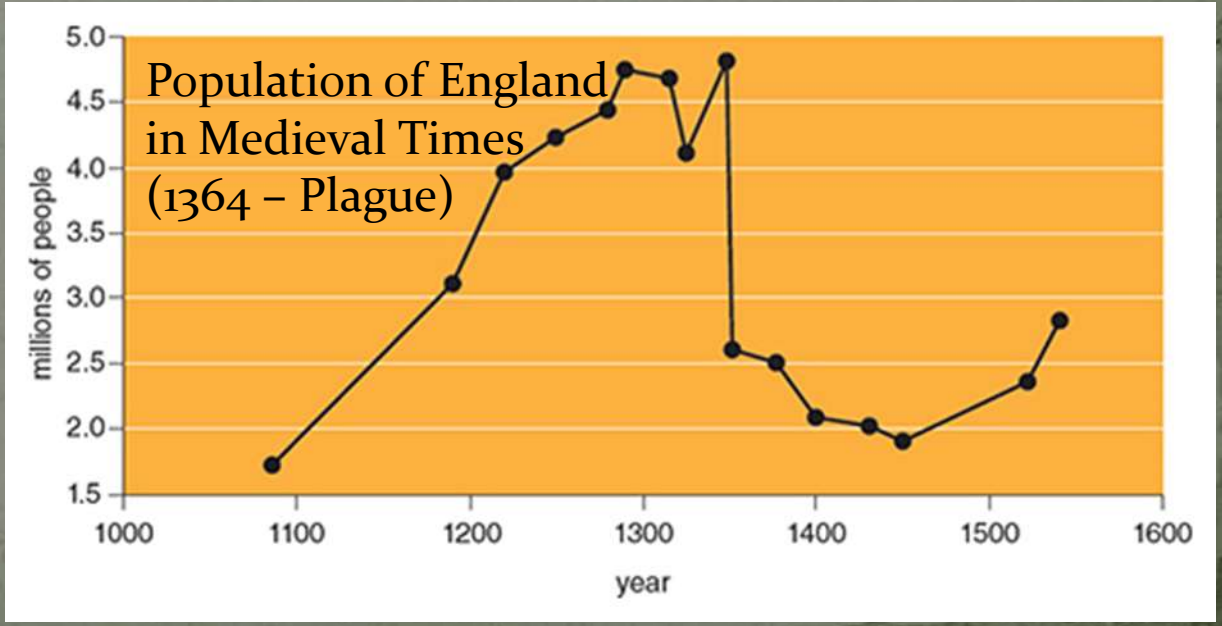
Emergence of epidemics

- Waste → epidemics e. g. plague
  - e.g.: ships → rats → fleas → humans
- Not enough infield + unusual cold weather

→ starvation

→ weakened people

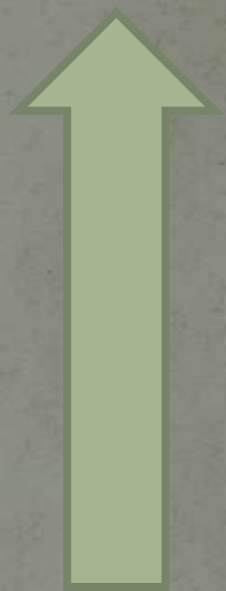
→ epidemics → DEATH



Changes in modern history

Industrial revolution

More waste!



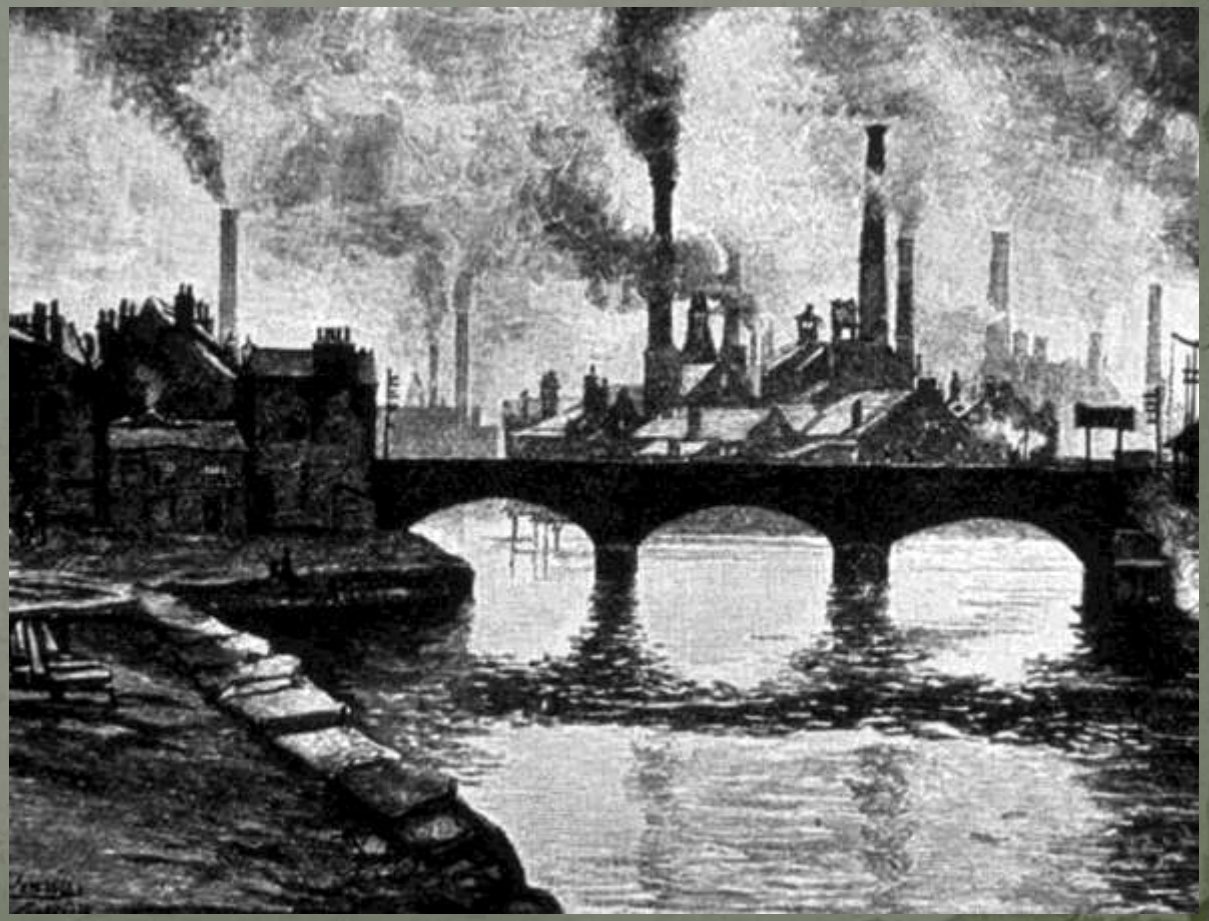
- Discovery of steam engine
- Mechanization of textile industry
- Mechanization → mass production
- New branches
  - Chemical industry
  - Production of plastics

  (e.g.: artificial silk „Chardonnet”)
- Growth of population → new consumers

Effect in society

- Population ↑
- Urbanization!
- Pollution ↑
- Deteriorating health conditions

Typhus
Tuberculosis
Cholera

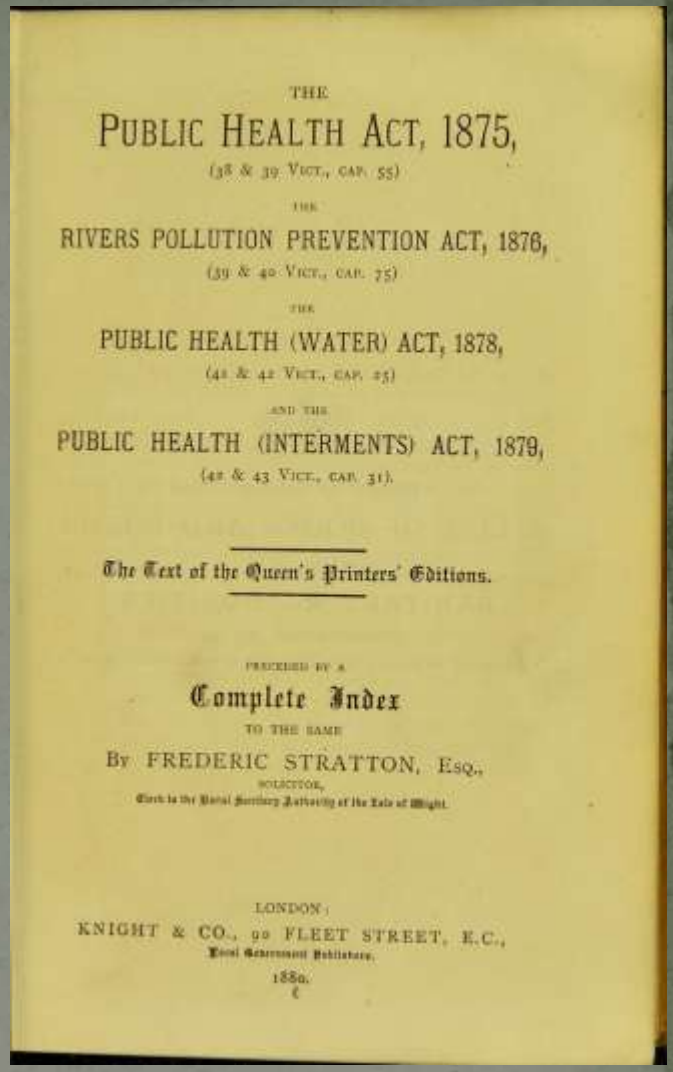


First Public Health Acts

- 1875 – Great Britain
  - Improvement

  of health conditions of people
  - Improving conditions

  of the living world of wetlands



THE

PUBLIC HEALTH ACT, 1875,

(38 & 39 VICT., CAP. 55)

THE

RIVERS POLLUTION PREVENTION ACT, 1876,

(39 & 40 VICT., CAP. 75)

THE

PUBLIC HEALTH (WATER) ACT, 1878,

(41 & 42 VICT., CAP. 25)

AND THE

PUBLIC HEALTH (INTERMENTS) ACT, 1879,

(42 & 43 VICT., CAP. 31).

The Text of the Queen's Printers' Editions.

PRECEDED BY A

Complete Index

TO THE SAME

BY FREDERIC STRATTON, ESQ.,

SOLICITOR,

Clerk to the Naval Secretary Authority of the Isle of Wight.

LONDON:

KNIGHT & CO., 90 FLEET STREET, E.C.,

Local Government Publishers.

1880.

e.g.: London

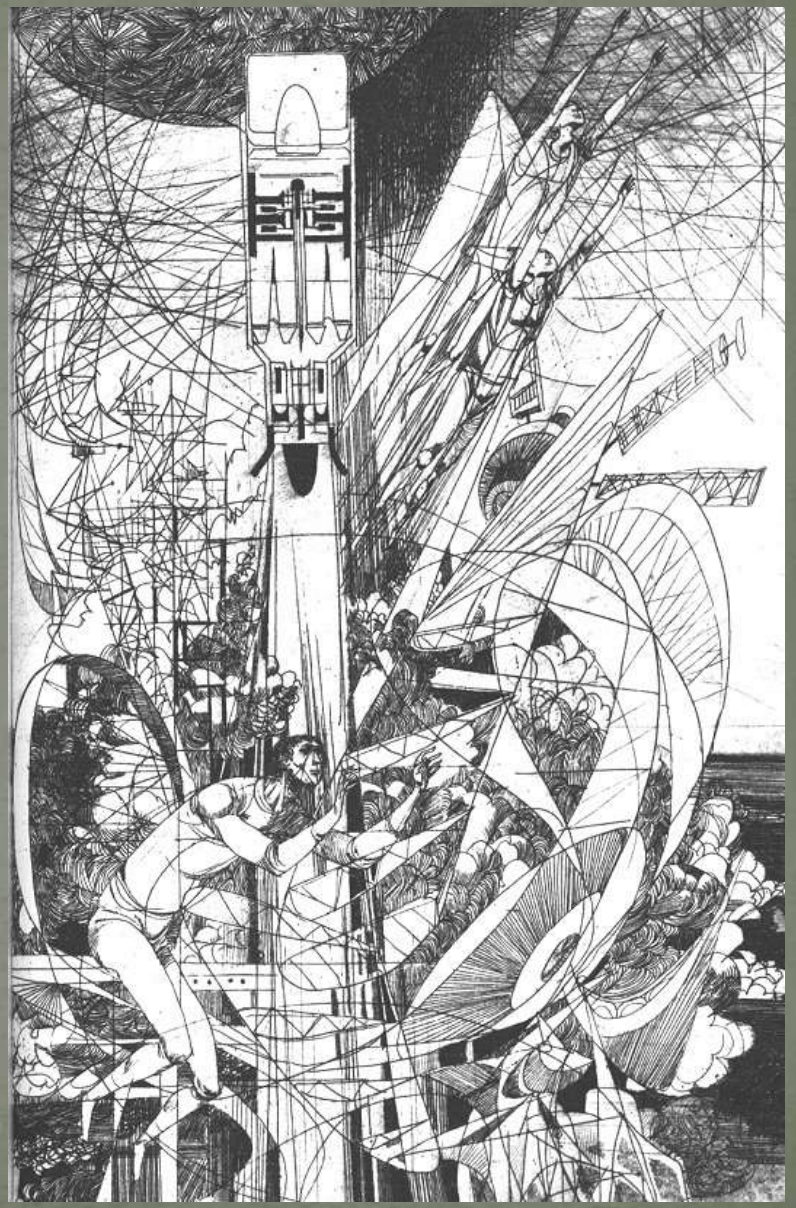
Filtration of solid waste from sewage

+ They didn't release sewage to the river directly.

→ Return of fishes

Global waste problem in these days

Few examples



Microplastics

Small pieces of plastic, less than 5 mm (0.2 inch) in length, that occur in the environment as a consequence of plastic pollution. Microplastics are present in a variety of products, from cosmetics to synthetic clothing to plastic bags and bottles. Many of these products readily enter the environment in wastes.

(britannica)

- Primary microplastics:

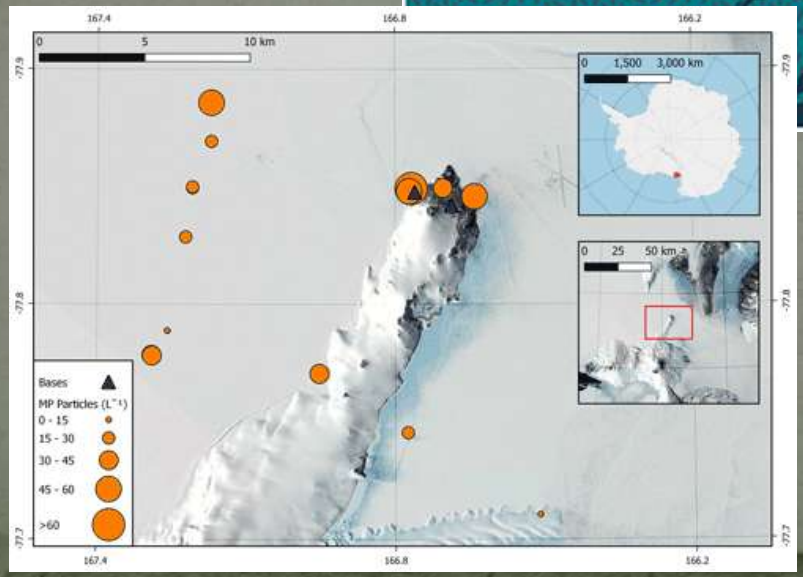
Examples of primary microplastics include microbeads found in personal care products, plastic pellets (or nurdles) used in industrial manufacturing, and plastic fibres used in synthetic textiles (e.g. nylon).

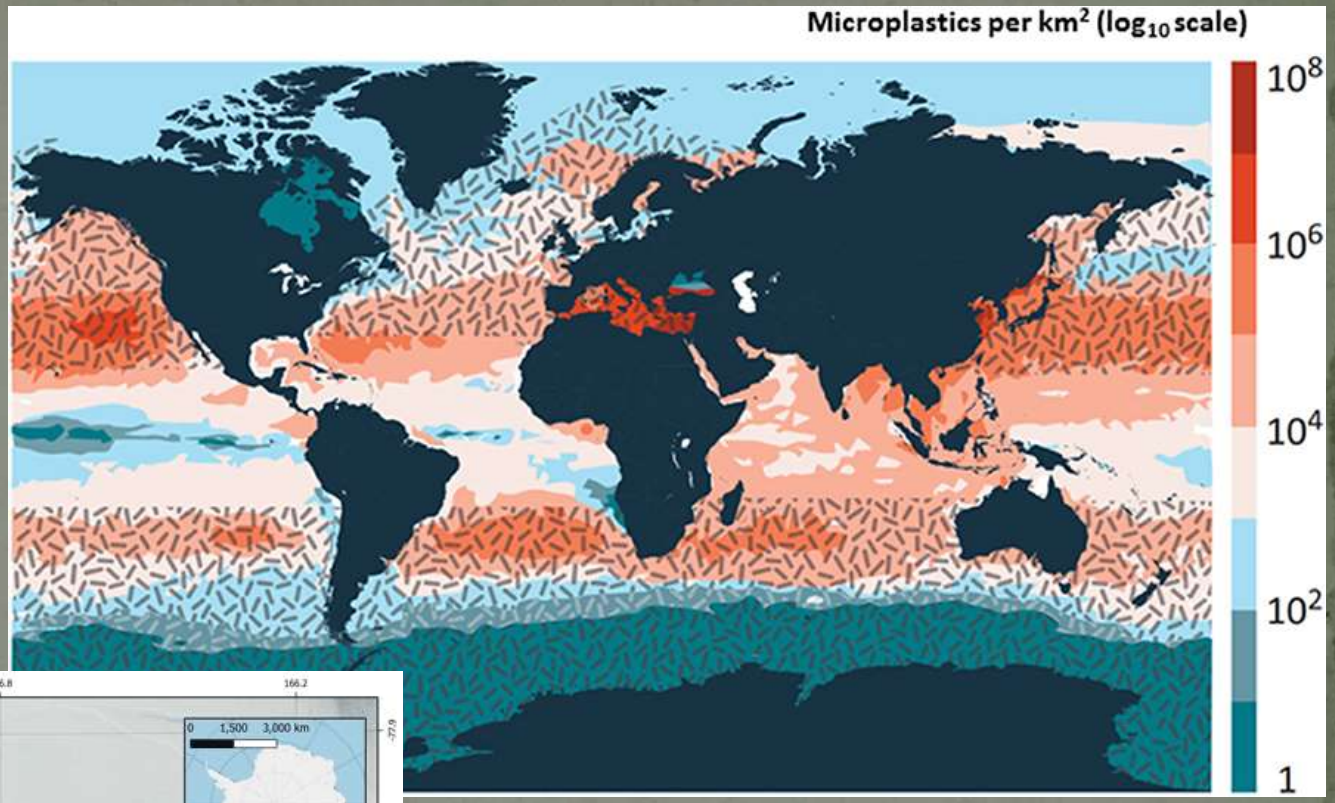
- Secondary microplastics

form from the breakdown of larger plastics; this typically happens when larger plastics undergo weathering, through exposure to, for example, wave action, wind abrasion, and ultraviolet radiation from sunlight.

Incidence of microplastics

Concentration of microplastics in the Ross Island region of Antarctica





Concentration of microplastics in world ocean

- By 2018, in marine and freshwater ecosystems combined, microplastics had been found in more than 114 aquatic species. Microplastics have been found lodged in the digestive tracts and tissues of various invertebrate sea animals, including crustaceans such as crabs. Fish and birds are likely to ingest microplastics floating on the water surface, mistaking the plastic bits for food.
- The ingestion of microplastics can cause aquatic species to consume less food and therefore to have less energy to carry out life functions, and it can result in neurological and reproductive toxicity. Microplastics are suspected of working their way up the marine food chains, from zooplankton and small fish to large marine predators. (britannica)

Cosmic pollution: space debris

Artificial material that is orbiting Earth but is no longer functional. This material can be as large as a discarded rocket stage or as small as a microscopic chip of paint… (britannica)

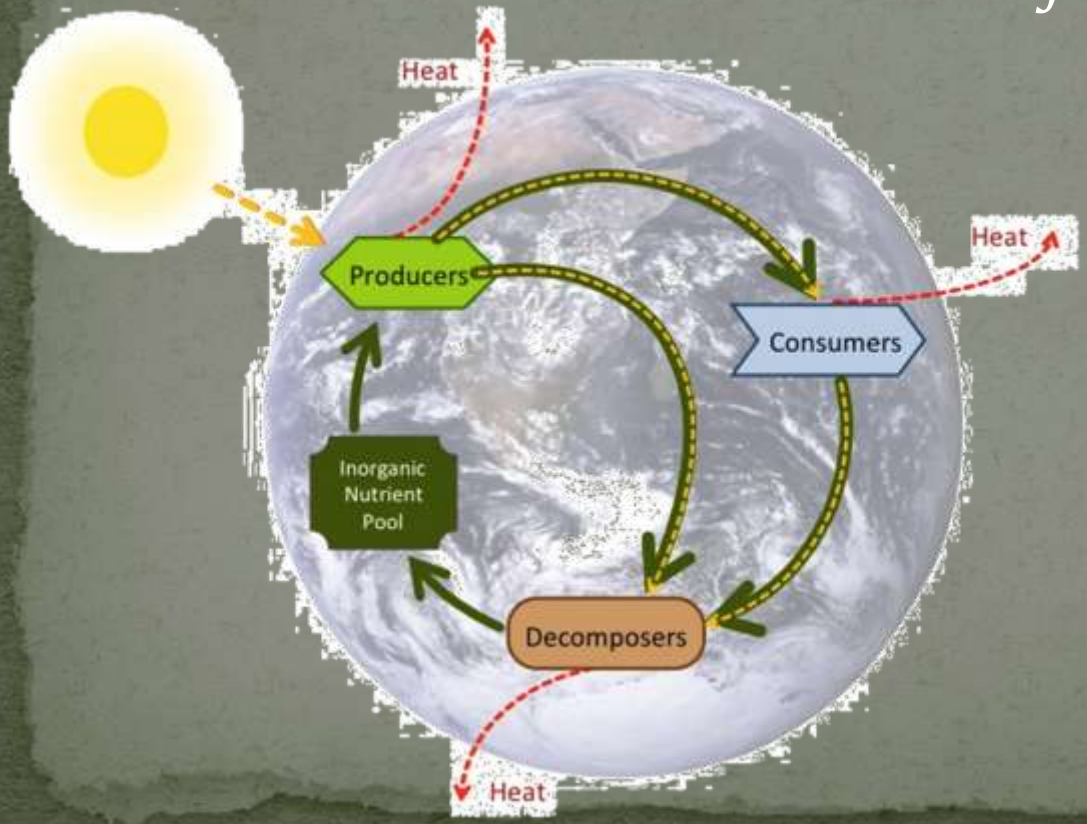
As of 2021, the United States Space Surveillance Network was tracking more than 15,000 pieces of space debris larger than 10 cm (4 inches) across. It is estimated that there are about 200,000 pieces between 1 and 10 cm (0.4 and 4 inches) across and that there could be millions of pieces smaller than 1 cm.

Because of the high speeds at which objects orbit Earth, a collision with even a small piece of space debris can damage a spacecraft.

The Nature of Nature

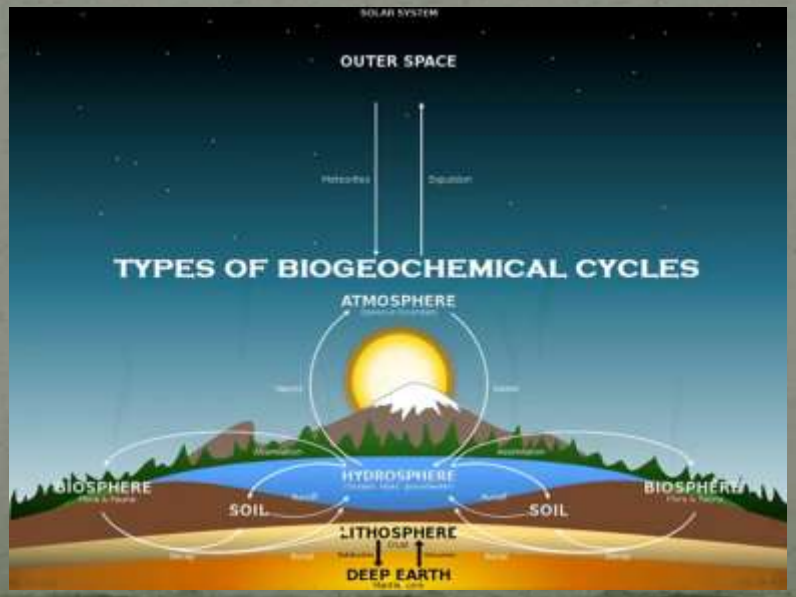
"Everything is reused or repurposed in nonhuman ecosystems. The natural world is the perfect circular economy, where everything, even after its lifetime, becomes a source for something else."

(Enric Sala)



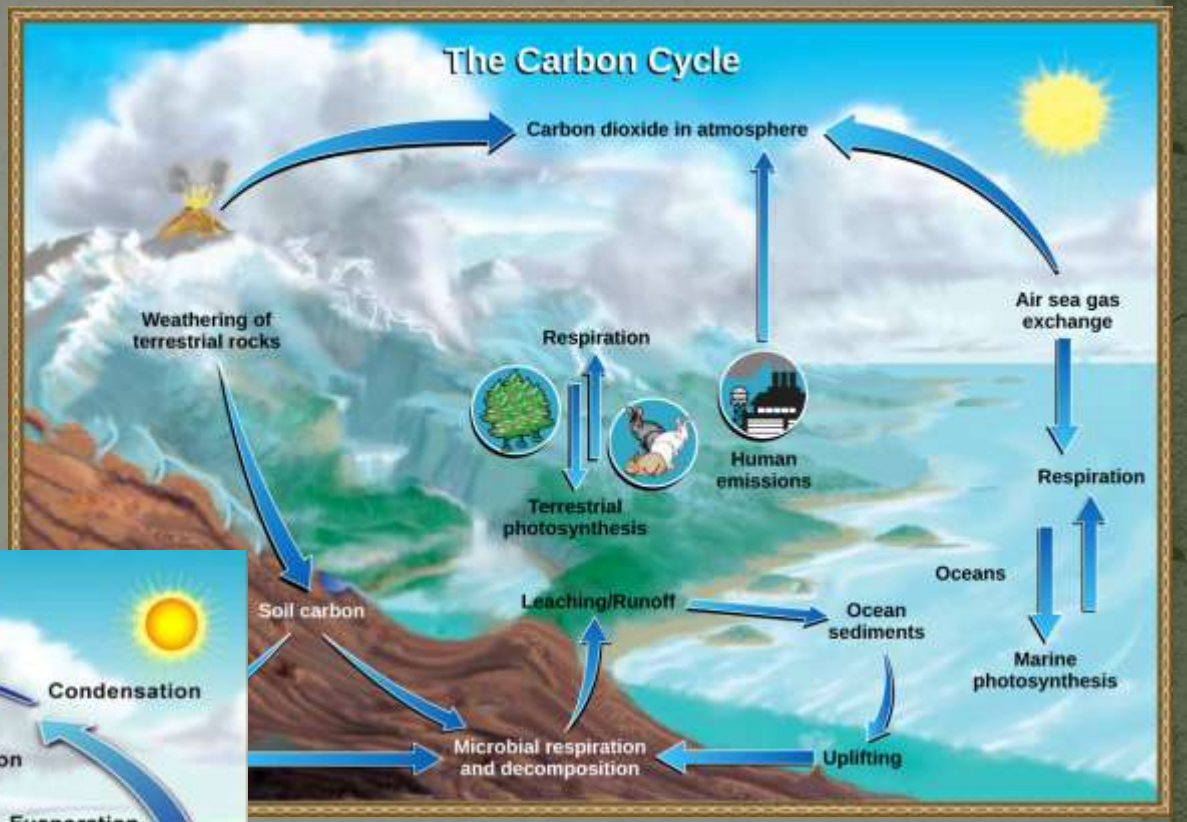
BIOSPHERE → Biogeochemical cycles

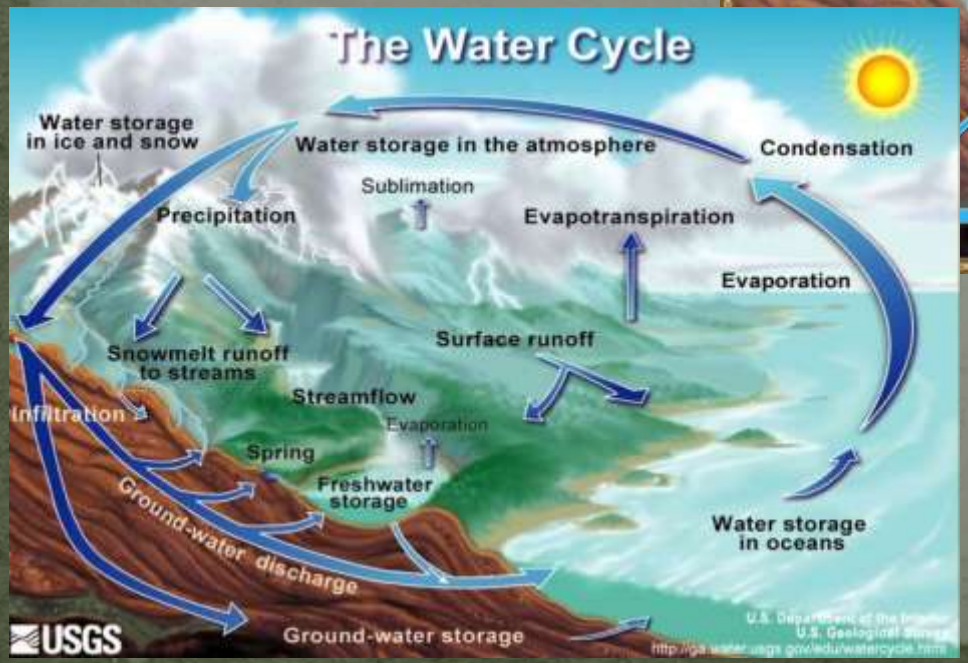
Artificial any of the natural pathways by which essential elements of living matter are circulated. The term *biogeochemical* is a contraction that refers to the consideration of the biological, geological, and chemical aspects of each cycle.



Renew and Regenerate!

- The circular economy of nature is the cycling of resources back into new or existing systems. E.g.: Water, Carbon, Minerals



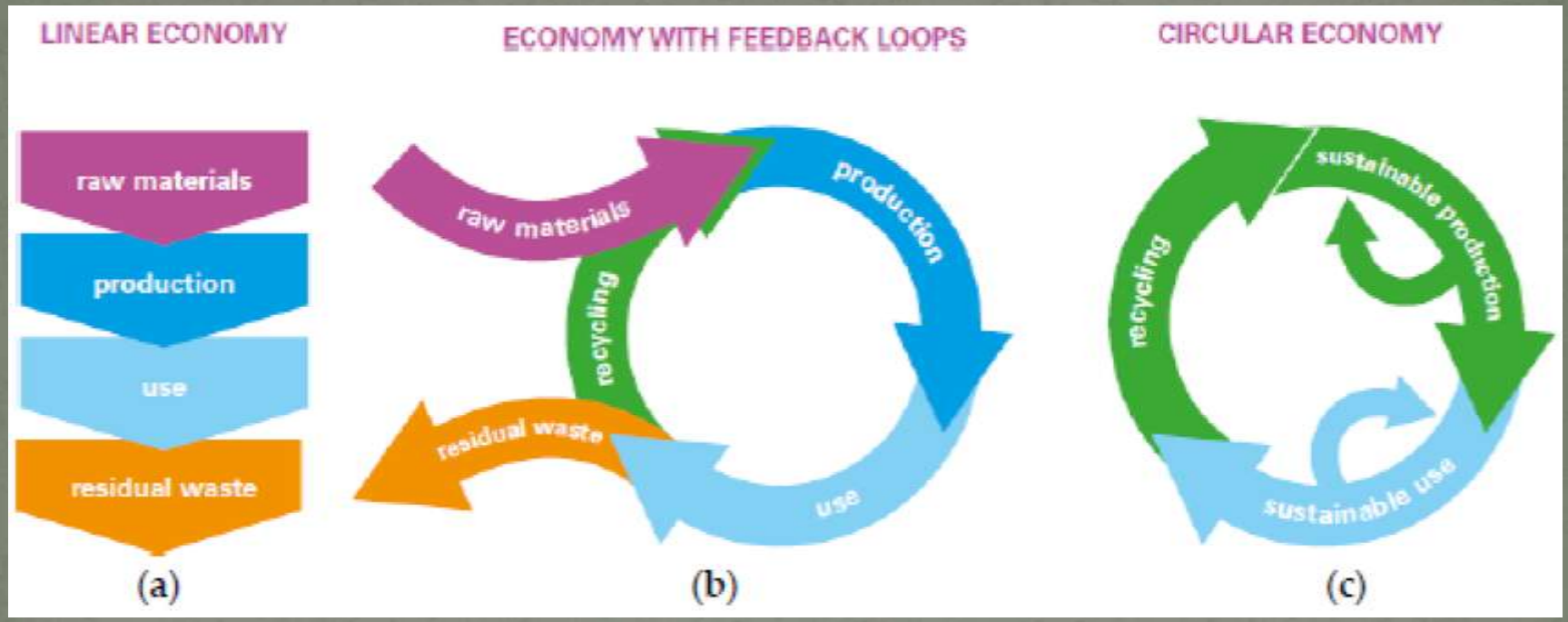


TECHNOSPHERE → Linear economy

DEF

An economic system based on collecting raw materials, using them to create consumer goods, and disposing of resulting waste products.

From LINEAR to CIRCULAR economy

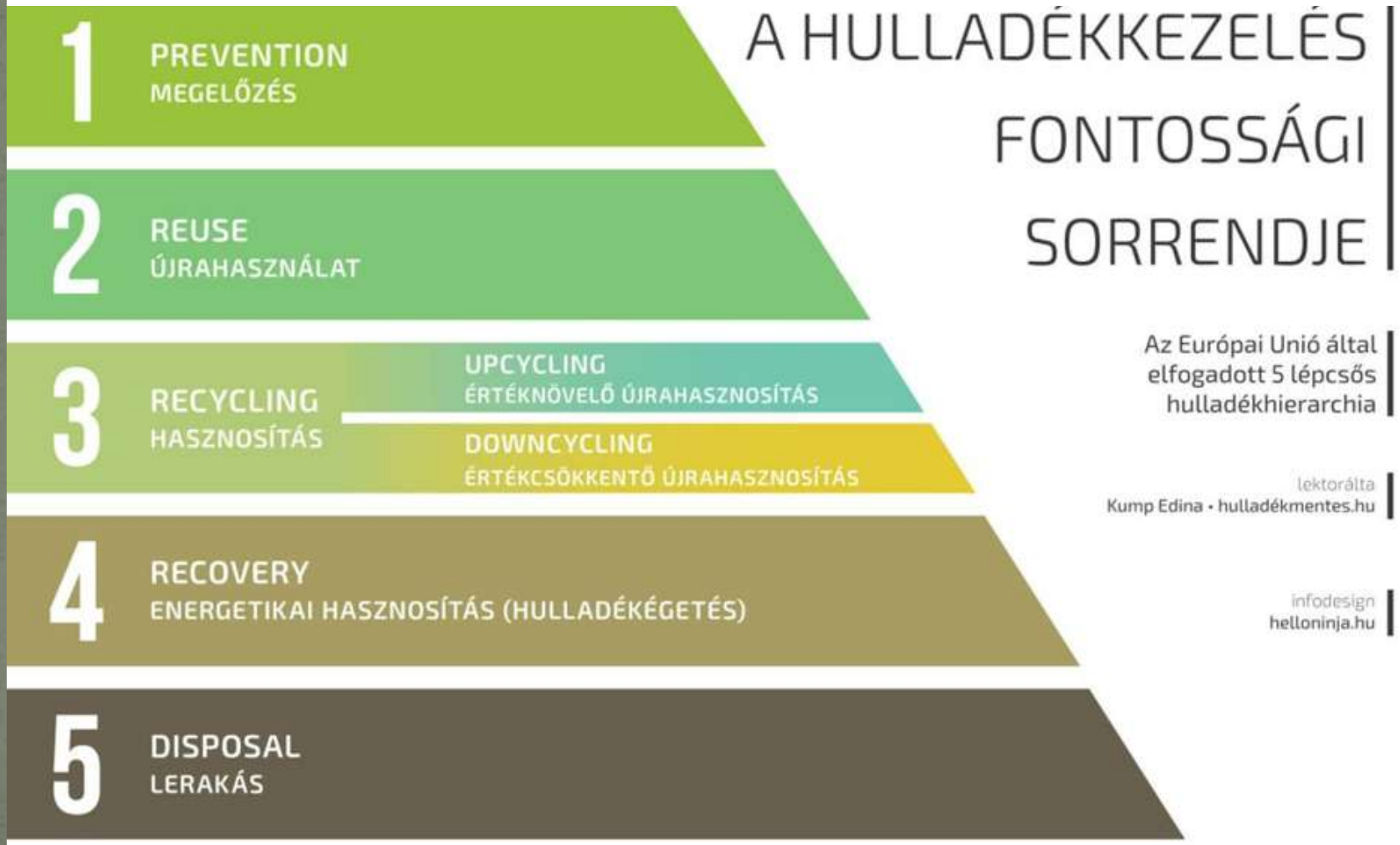


- Sustainable production
- Sustainable use
- Recycling

New values in waste management

1. Inhibition of formation of waste
2. Reduction of amount of produced waste
3. Utilization of waste

Responsible Waste Management Hierarchy

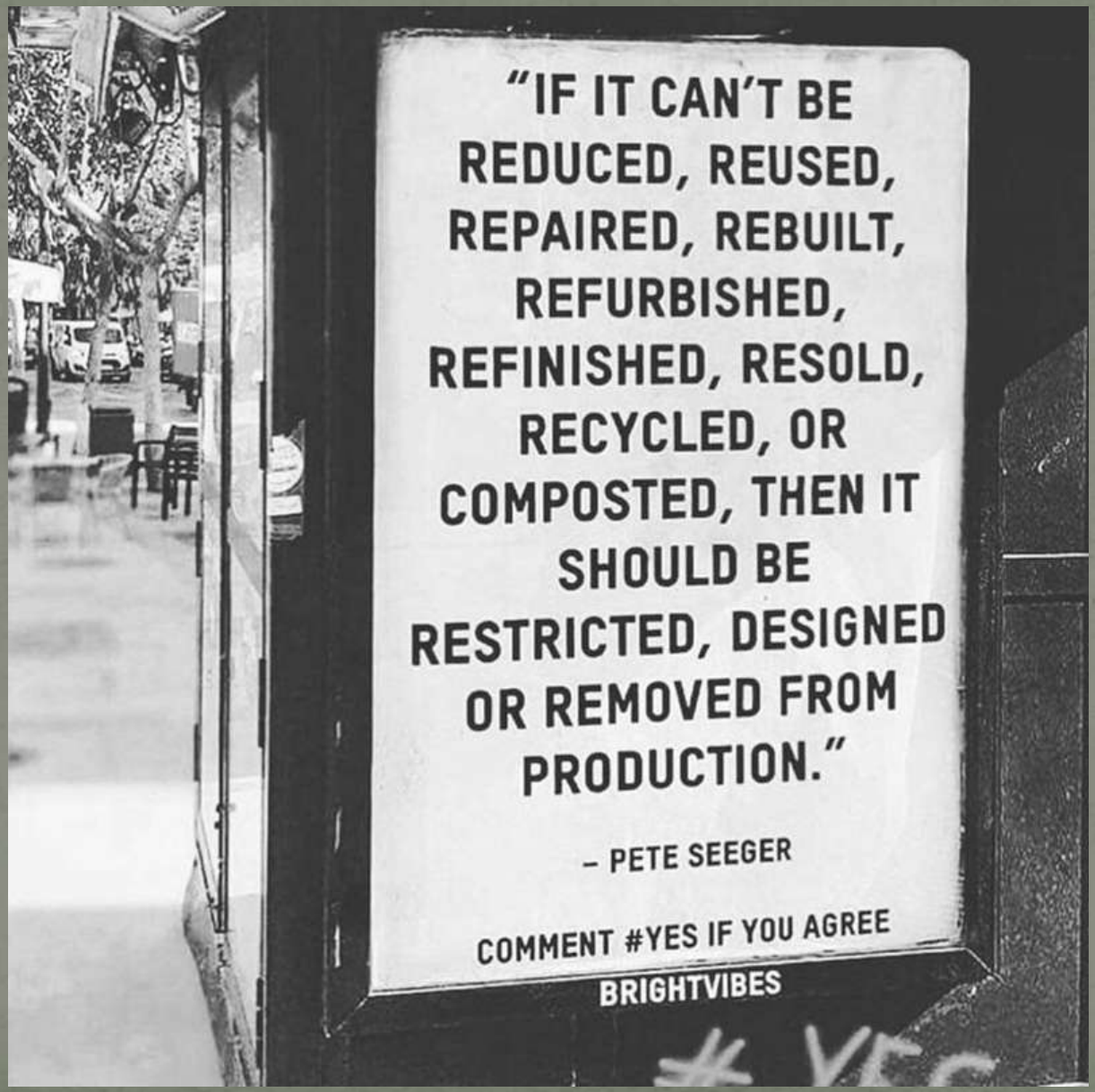


A HULLADÉKKEZELÉS FONTOSSÁGI SORRENDJE

Az Európai Unió által elfogadott 5 lépcsős hulladékhierarchia

lektorálta
Kump Edina • hulladékmentes.hu

infodesign
helloninja.hu


"IF IT CAN'T BE REDUCED, REUSED, REPAIRED, REBUILT, REFURBISHED, REFINISHED, RESOLD, RECYCLED, OR COMPOSTED, THEN IT SHOULD BE RESTRICTED, DESIGNED OR REMOVED FROM PRODUCTION."
– PETE SEEGER
COMMENT #YES IF YOU AGREE
BRIGHTVIBES

Advantages of RECYCLING

→ Production of secondary raw material

→ Saving the reserves of raw materials

→ Reduced energy demand

Branches	Primary commodities	Recycled commodities
Paper production	6.3-10.5	2.94
Plastic manufacturing	2.94	0.42
Glass-making	11.76	1.26
Steel production	25.2	2.52
Aluminium production	58.8	8.40

Importance of Saving of Mineral Resources

→ Lack of rare noble metals

← Disruption in catalytic converter production

← Thefts! from parking automobiles → Recycling

→ Switching to renewable energy ← Disruption in solar panel production because of the lack of rare metals

← Importance of recycling

→ Production of smart tools (coating of condensers)

← mining of coltan in Congo

→ illegal mines

→ child labour

→ Exploitation of inhabitants

→Endangered species

(mountain gorilla, Grauer's gorilla, bonobos, chimpanzees)

Collection and recycling of outdated mobiles!

Photo: JGI/Bill Wallauer

Learn more at mobilerecyclingday.org

#forestiscalling

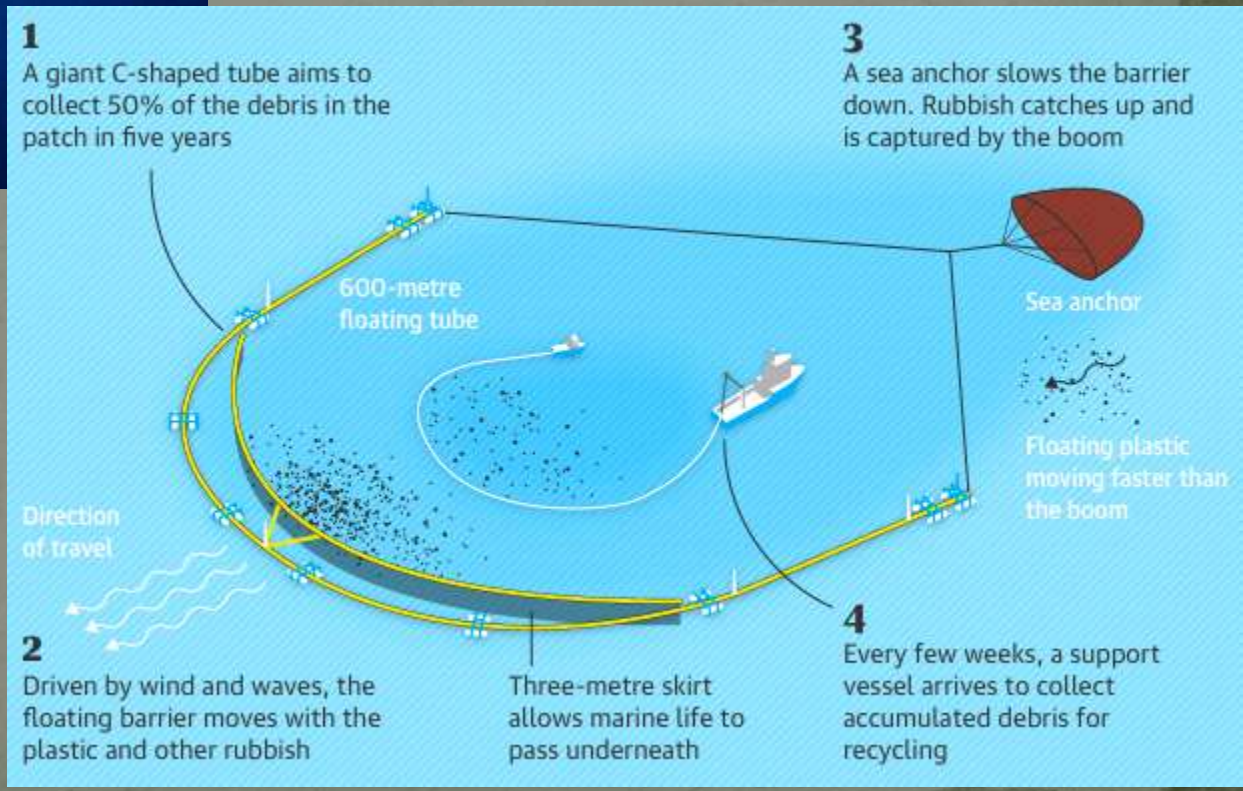
The forest is calling

the Jane Goodall Institute

Zero Waste. Can you do that?

„– I'll pick up only one trash
– said 8 billion people
and the Earth depurated." (unknown)

The Ocean Cleanup



Questions

- In which period did the waste and sewage management become a remarkable problem?
- What were the consequences of the inadequate sanitary conditions in the Middle Ages?
- Which branches were the origins of waste production after the industrial revolution?
- What is the main difference between the operation of biosphere and technosphere? How can we change our economy from linear to circular?
- How can we change primary commidities and mineral resources?

Effects of Industrial Revolution: The Beginning of Air Pollution

Sustainability

Discovery of Fire (Lower Paleolithic)

- Recognition of wildfires
- Passive use of fire
  - Burned animals and fruits/vegetables
- Active use of fire: repetition and contol a natural phenomenon
  - Hunting
  - Protection
  - Alleviation of weather conditions
  - Food preparation
  - Preservation
- Indirect use of fire

Discovery of Fire (Lower Paleolithic)

- Indirect use of fire
  - Burn of earthenwares
  - Science of cooking

  e.g.: soups and extracts of plants

Legend of endless forests

- Firewood was the single energy source.

Application of metals in Ancient Times

- Gold, lead, copper
- Arsenic bronze and tin bronze
- Iron tools and weapons (Greece)

Charcoal is needed to reduce metal ores

Air pollution!

Ancient villages, cities, city-states

- Heating with firewood

(e. g. roman spa)

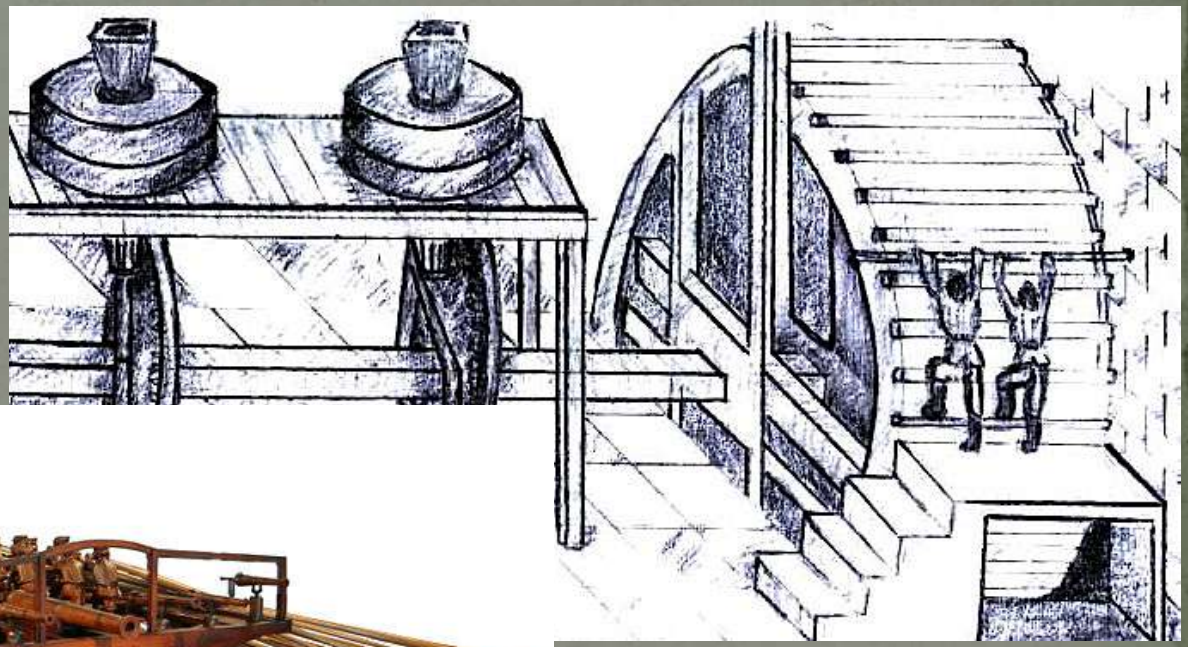
- Metallurgy with charcoal

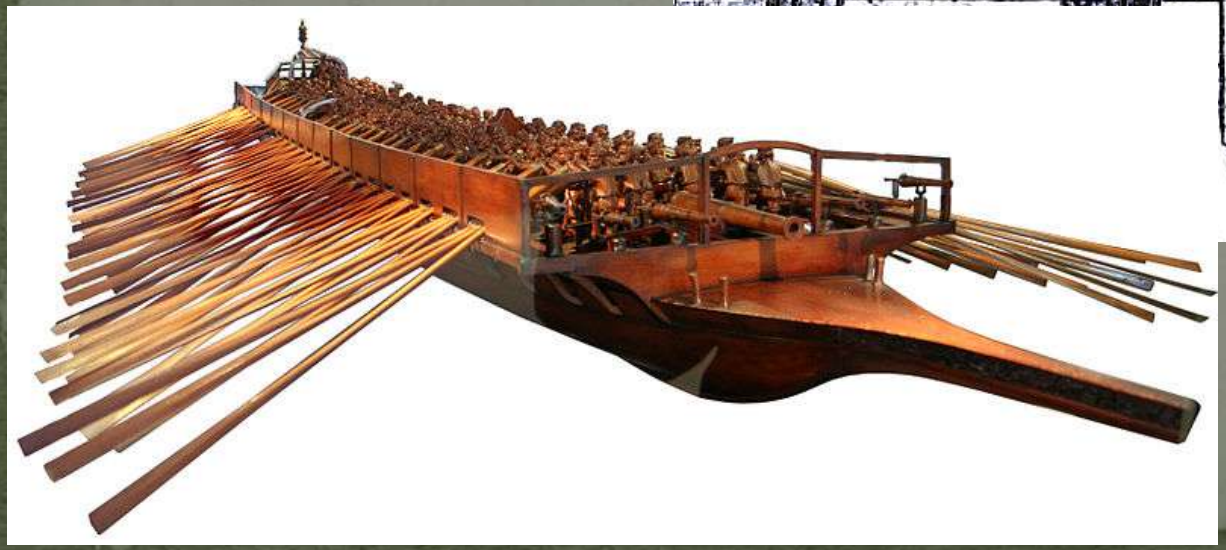
AIR POLLUTION

- Counterbalancing of harmful effects:
  - Location of polluting workrooms was controlled. (Distance based on wind direction)
  - Establishment of parks and resorts (Rome)

Energy Sources in Ancient Times

- Force of muscles / animal or human
  (treadmills, rowing galley)



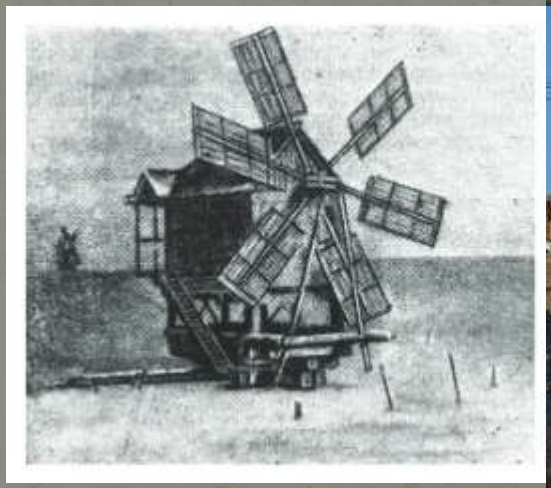


Energy Sources in Ancient Times

- Wind power
  - Sailing boats
  - Wind mills

(BC 1200, Egypt)

  - Wind wheels

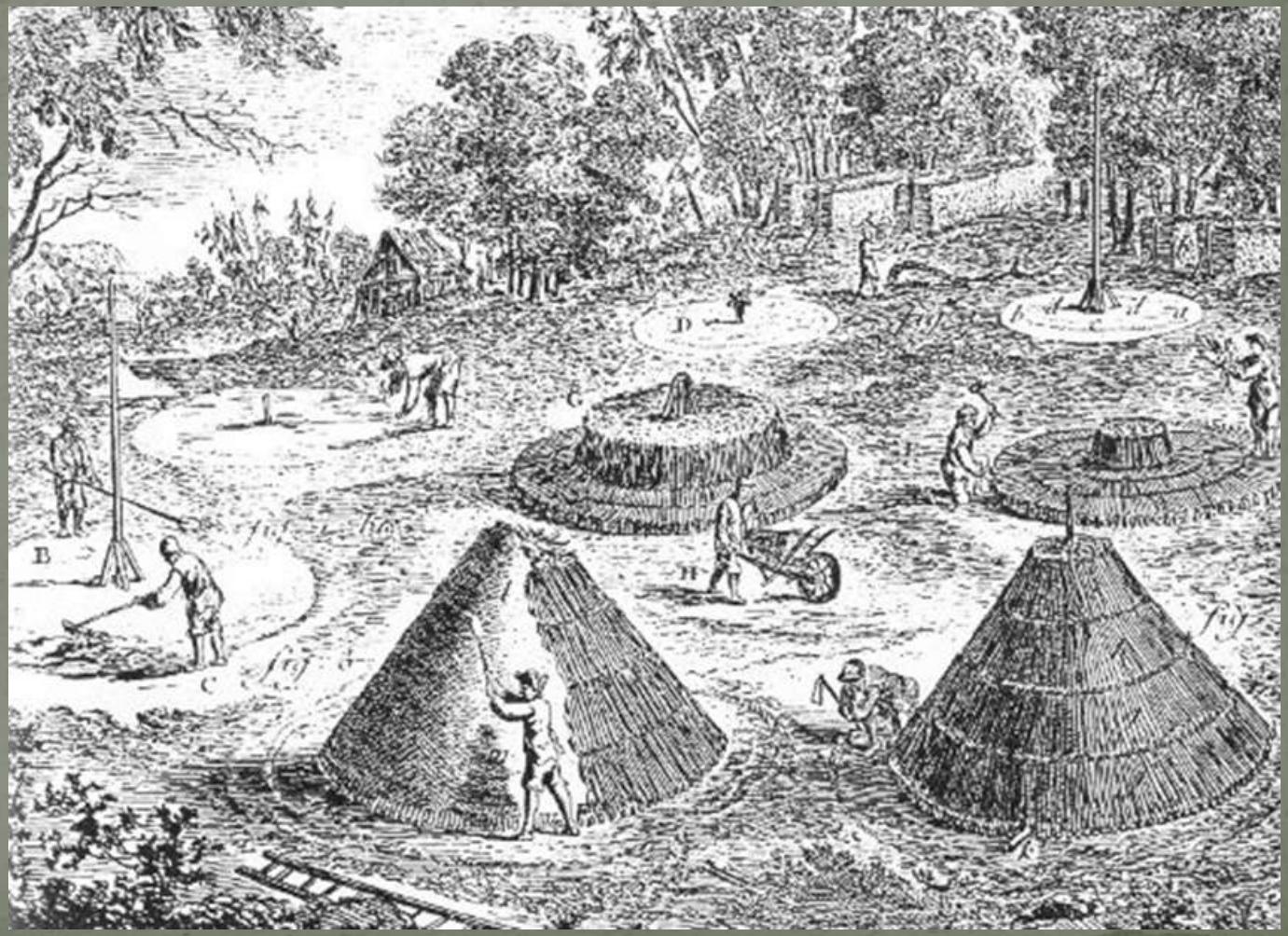


Ancient wind mills in Nashtifan,Iran

Energy Sources in Ancient Times

- Firewood
- Charcoal

AIR POLLUTION



Medieval living conditions

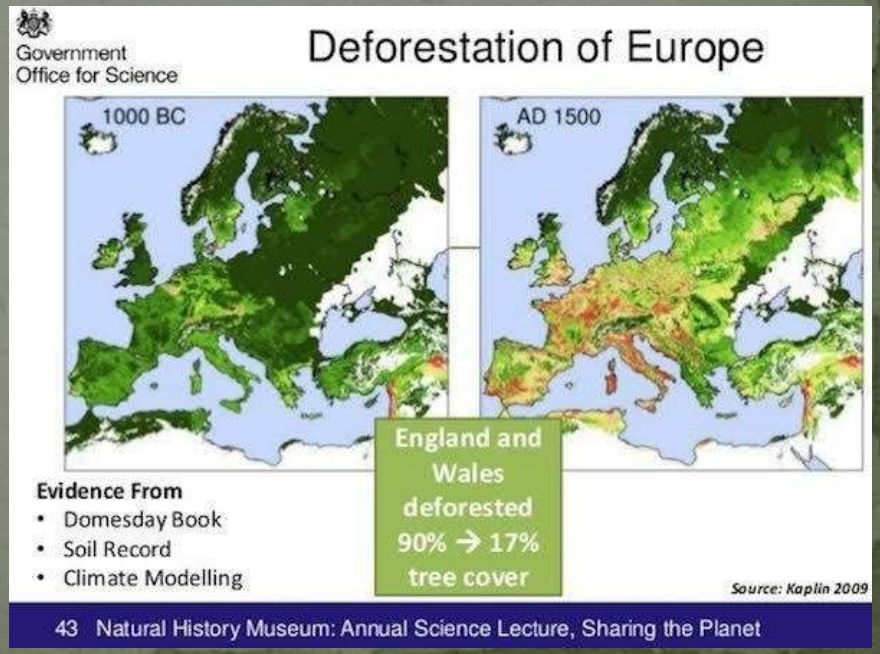
Environmental effects

- Further decrease of forest areas
  - Demand for wool↑ → pasture lands ↑
  - Wood charcoal production
  - Brick burning

  ← demand for wood
  - Heating of houses
  - Wood ash for laundring
  - Stock of vehicles
  - Construction of mills

  ← Building materials from wood

AIR POLLUTION



Energy Sources in Medieval Era

- Hydropower
  - Water wheels

(ancient Greek invention)

  - Water mills
  - Ebb/flow force power, tidal mills

(7th century)

Energy Sources in Medieval Era

- Force of muscles (tread mills)
- Wind power

(sailing boats, wind wheels , wind mills)

- Hydropower

(water wheels, water mills, tidal mills)

- Smelters
- Mining: ore moving devices
- Wire-drawing mills

- Paper mills
- Sawmills
- Silk weaving mills

Dürer: The Wire-drawing mill

Albertini: Medieval sawmill with hydraulic power

Medieval paper mill in Vetrní

Water driven silk throwing mill at Tring (19th century)

Increasing energy demand

- Wood and charcoal weren't enough
- Hard coal is an option
- But they perceived harmful effects of its usage
- Strict control of coal burning

- Extensive use of hard coal just from 16th century

Chinese coal miners (17th century)

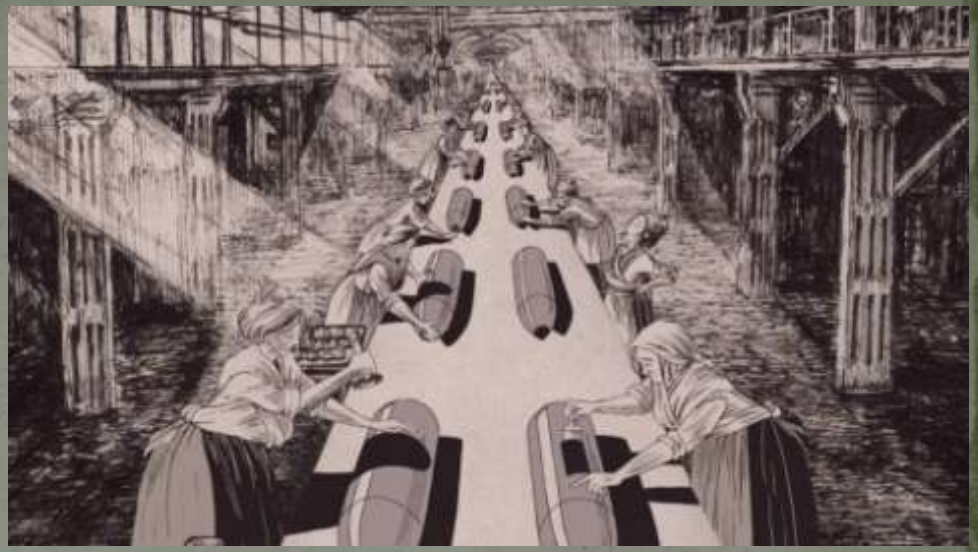
New chapter of air pollution

„Air pollution has been a political issue in Britain for almost 800 years. When Queen Elenaor of Provence visited Nottingham Castle in 1257 the fouled atmosphere, full of heavy coal smoke, forced her to move to Tutbury Castle. Numerous attempts to control coal burning and punish offenders were made during the thirteenth and fourteenth centuries, but largely failed. Queen Elizabeth the First was herself 'greatly grieved and annoyed' by coal smoke in the Palace of Westminster; a complaint which led the local brewers to agree to burn wood instead. Widespread damage to vegetation was reported in the first years of the seventeenth century, as was soiling of household leather furniture and wall hangings.

(Adam Markham: A Brief History of Pollution)

Changes in modern history

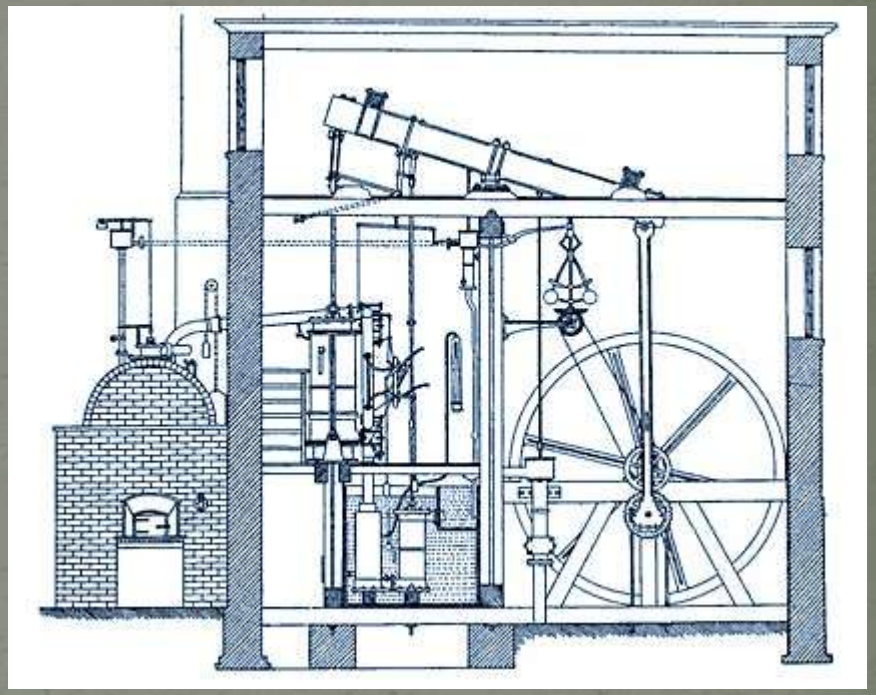
Industrial revolution



- Starting point:
  England
- Antecedents:
  - Advanced agriculture
    (crop rotation, industrial crops from America)
  - Saltatory growth of population
  - Manpower for industry
  - Demand for clothing
    (Merino sheep, yarn production,
    mechanization of weave)

Increasing demand in military industry

- It stimulated:
  - Mining,
  - Metallurgy,
  - Metalworking.



- Discovery of steam engine
- Increasing use of coal
- Production of cast iron/steel in large quantities

New branch: Machine manufacturing

- Means of production for other branches

(e.g.: textile industry)

- Railway network,

  steam locomotives,

  ships form iron/steel
- Agricultural machines

- Demand for clothing (textile industry)
- Increasing demand in military industry

Discovery of steam engine

Increasing use of hard coal

Machine manufacturing

- Mining
- Metallurgy
- Metalworking

- Agricultural machines
- Vehicles

Increasing use of coal

- Major fuel
- Propellant of vehicles
- Raw materials of chemical industry
- Increasing CO_2-emission

STARTING POINT OF GLOBAL AIR POLLUTION

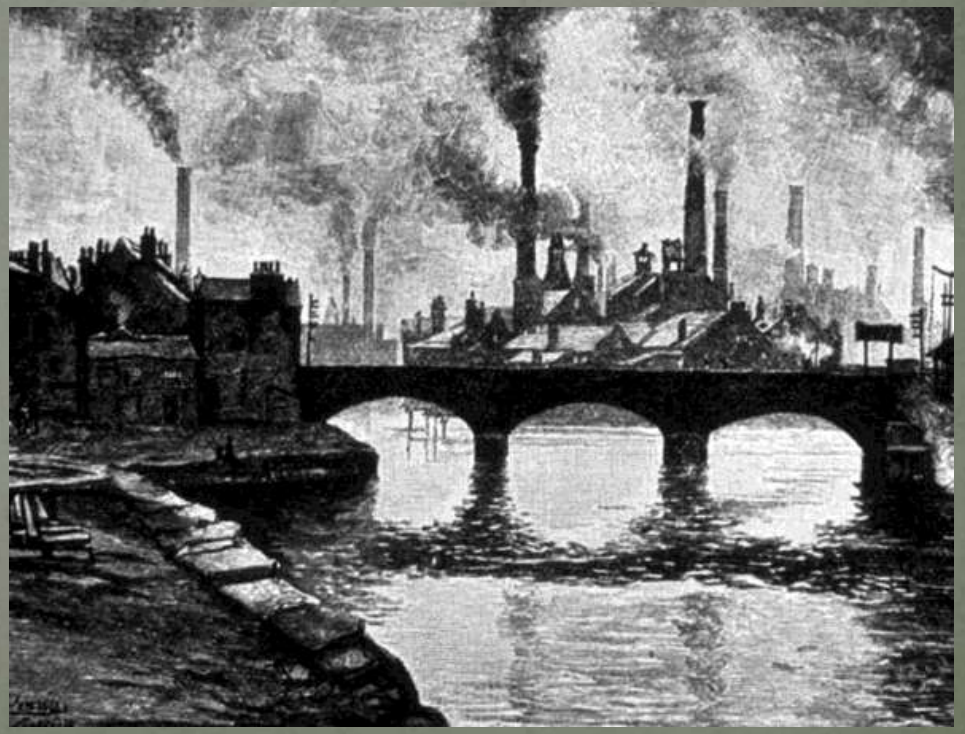
Effect in society

- Importance of craftmen and farmers ↓
- Mass production

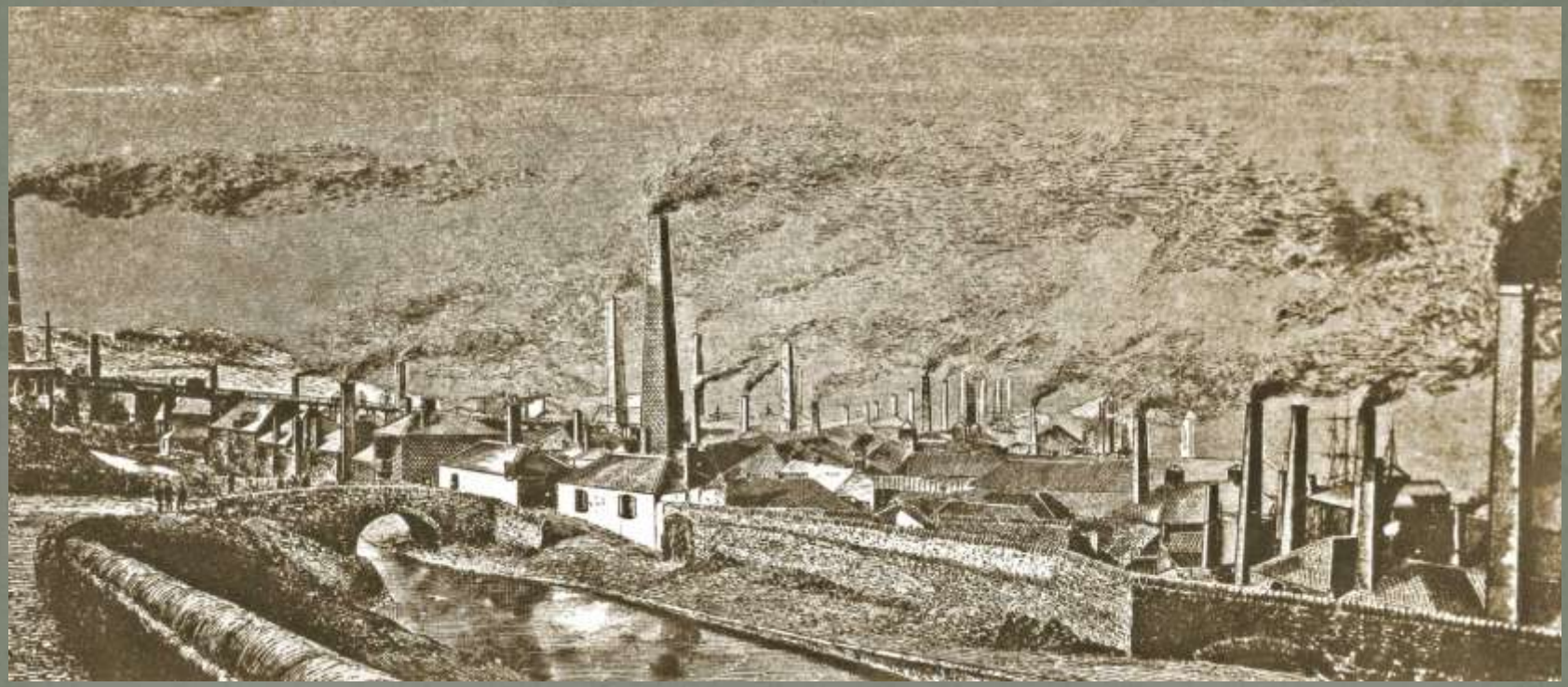
(instead of handicrafts)

- Mechanization
- Urbanization
- Population ↑

  = New consumers!
- Pollution ↑
- Health conditions ↓



Increasing environmental pollution



„Indeed, South Wales was a veritable witches cauldron of industrial pollution. In the early nineteenth century the English Vivian family and the Anglesey mine owner, Thomas Williams, were able to turn the 75 hectare lower Tawe Valley into the world's most powerful metallurgy centre. At the peak of the region's prosperity there were probably 400 chimneys belching smoke in this tiny Glamorganshire valley. In nearby Llanelli the world's highest stack (320 feet) was erected in 1861 to carry away fumes from the tiny town's huge copper works.

(Adam Markham:
A Brief History of Pollution)

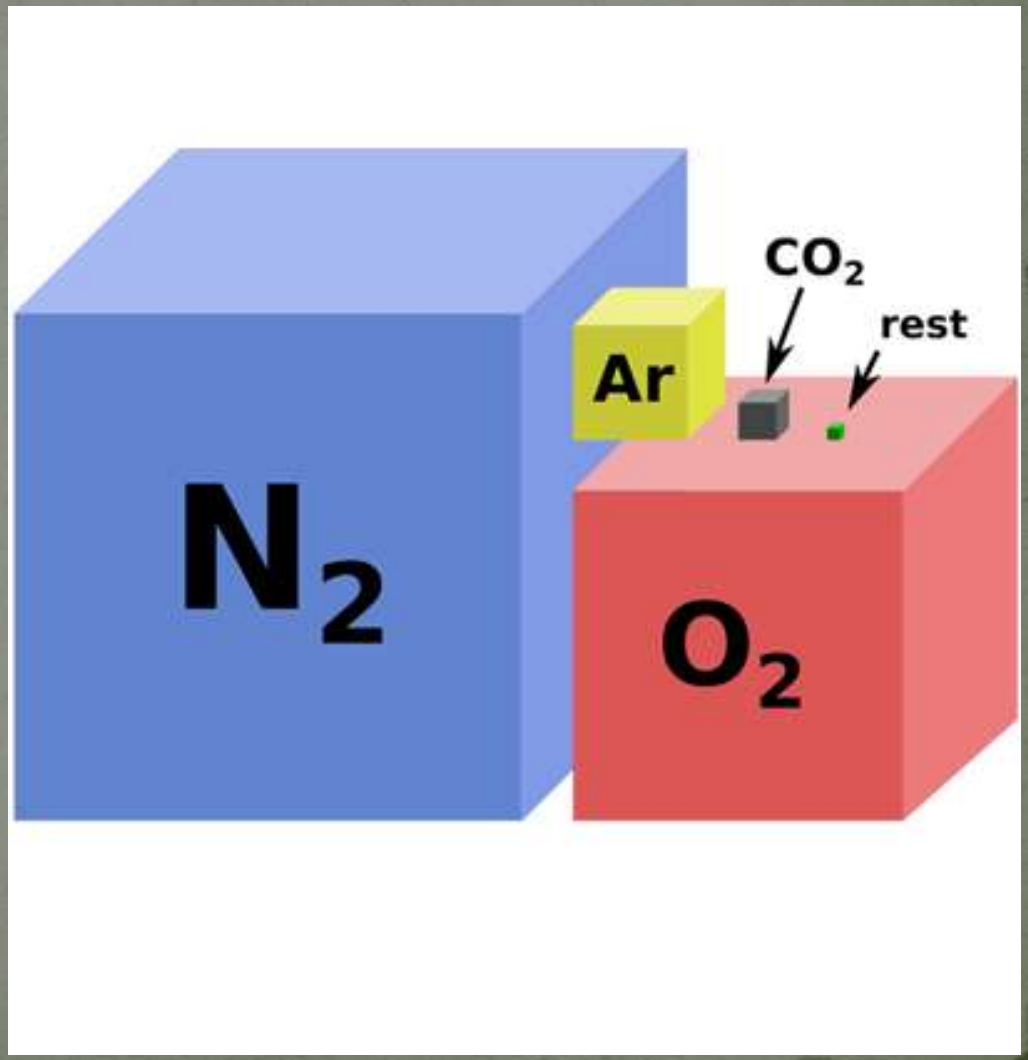
„The 1880s saw the Welsh copper industry being replaced primarily by zinc, but also lead, nickel, arsenic and silver, to be followed in the early twentieth century by tin plate and steel. For more than a century, local rivers were sterilized and forests died. As early as the 1830s farmers began to report the death of cattle and by 1888 the average age of people in Swansea was only 24. Similar depressing statistics could be cited for the rest of the country, and the impact of industrial pollution was breaking out like environmental eczema on the English landscape.

(Adam Markham:
A Brief History of Pollution)

Global problems in the atmosphere

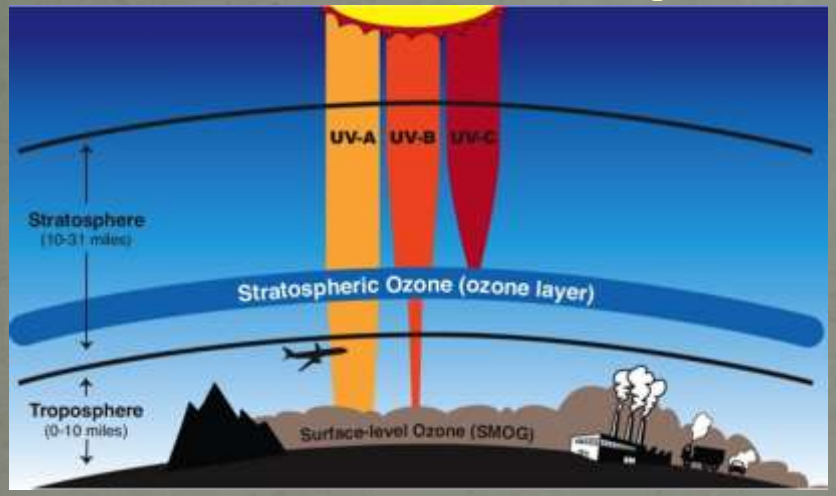
Composition of the atmosphere

- Nitrogen ~ 78%
- Oxygen ~ 21%
- Argon ~ 0.9%
- Carbon dioxide et al.
  ~ 0.1%



The roles of the atmosphere

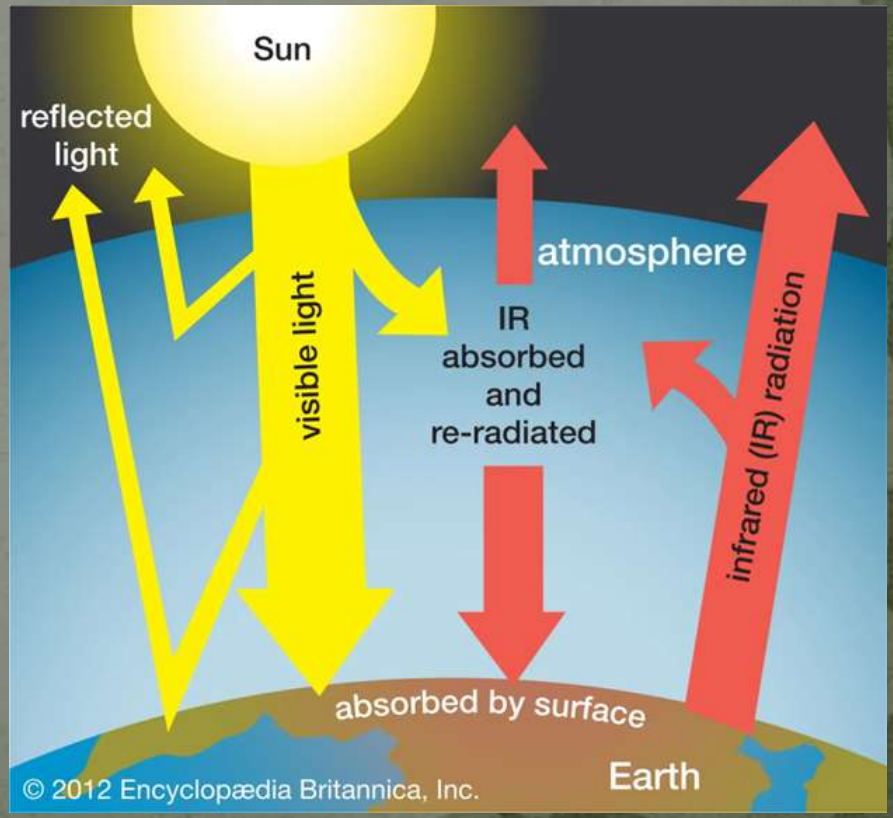
- Ozone layer → Protection from harmful radiation (X-ray, UV)



- Greenhouse gases in normal level → Advantageous greenhouse effect

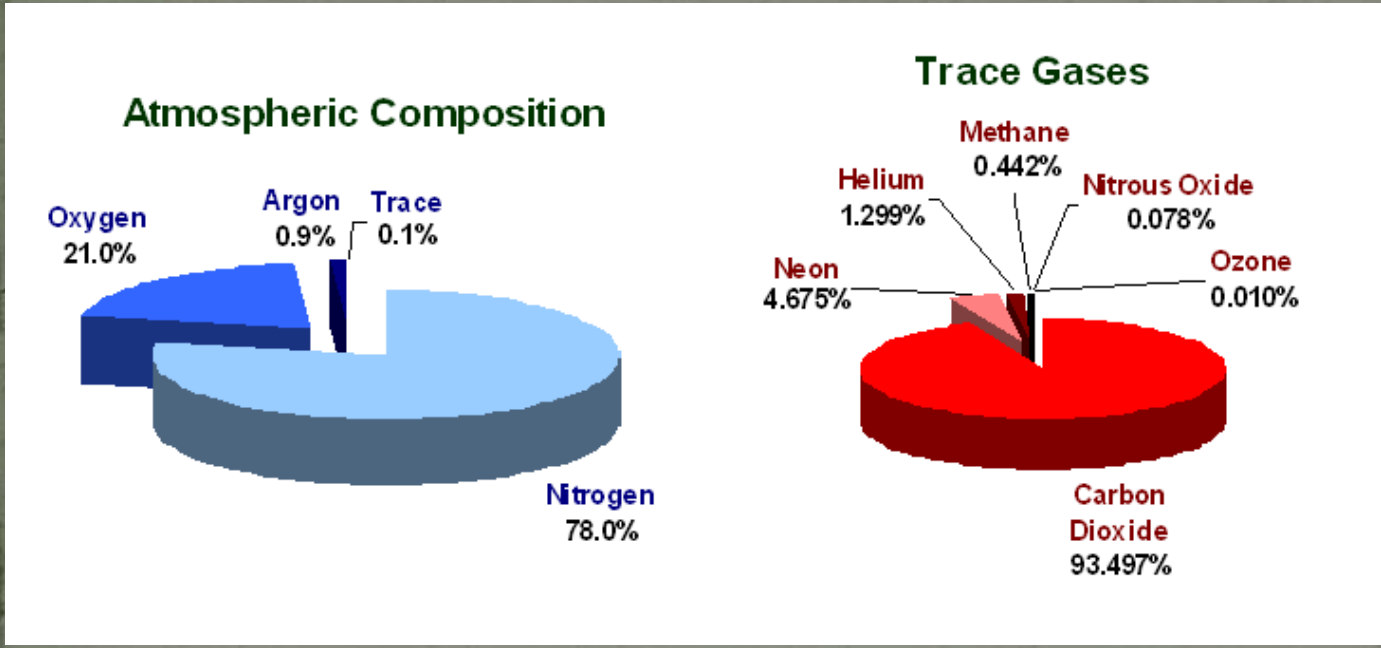
(It warms the planet to its comfortable average of 15 degrees Celsius)

- Oxigen content → Breathing



TECHNOSPHERE → Linear economy

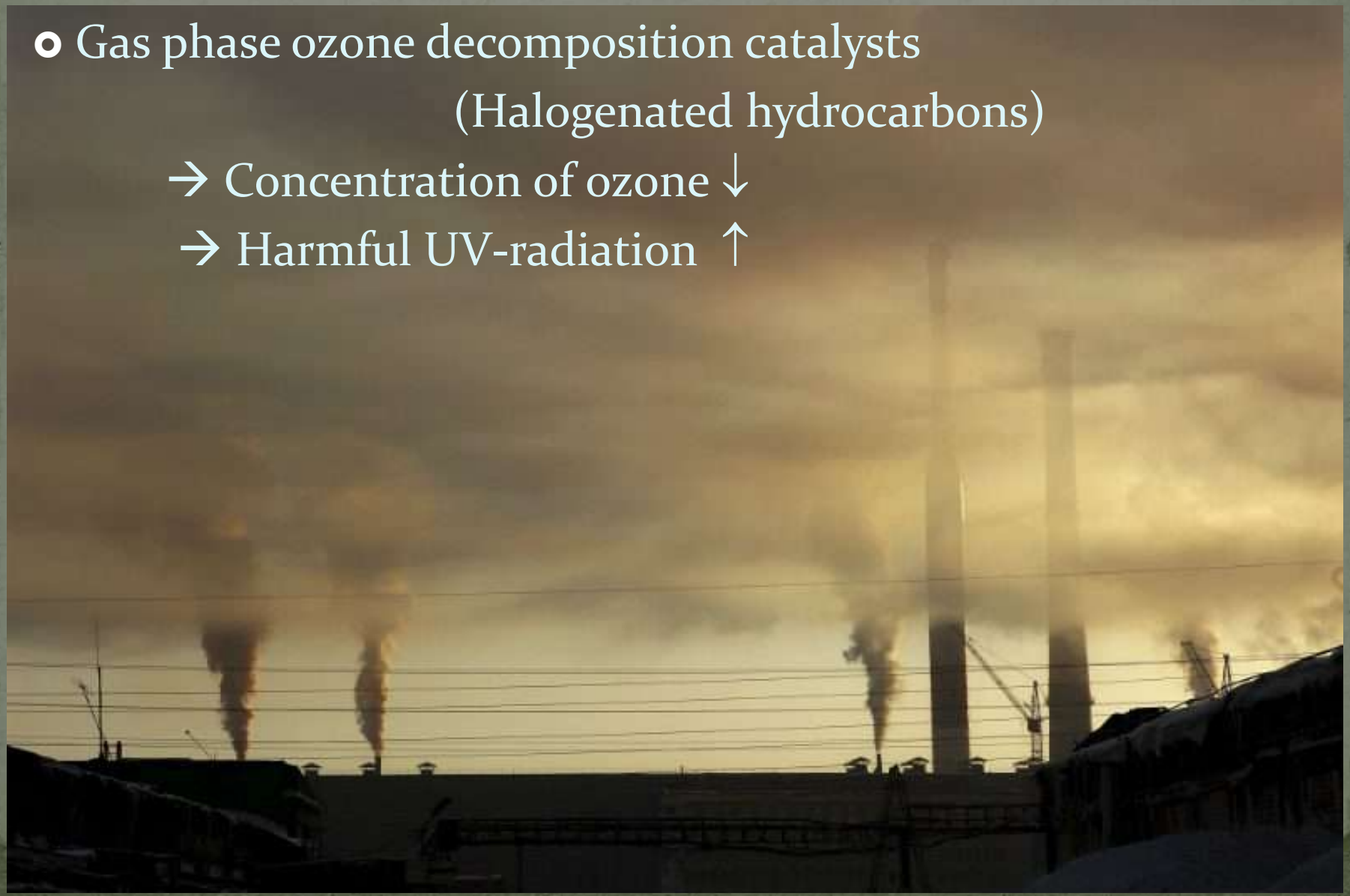
Composition of the atmosphere



- Carbon dioxie ↑
- Carbon monoxide ↑
- Oxides of nitrogen ↑
- Halogenated hydrocarbons ↑
- Oxides of sulfur ↑
- Methane ↑

Global effects

- Gas phase ozone decomposition catalysts
  (Halogenated hydrocarbons)
  → Concentration of ozone ↓
  → Harmful UV-radiation ↑

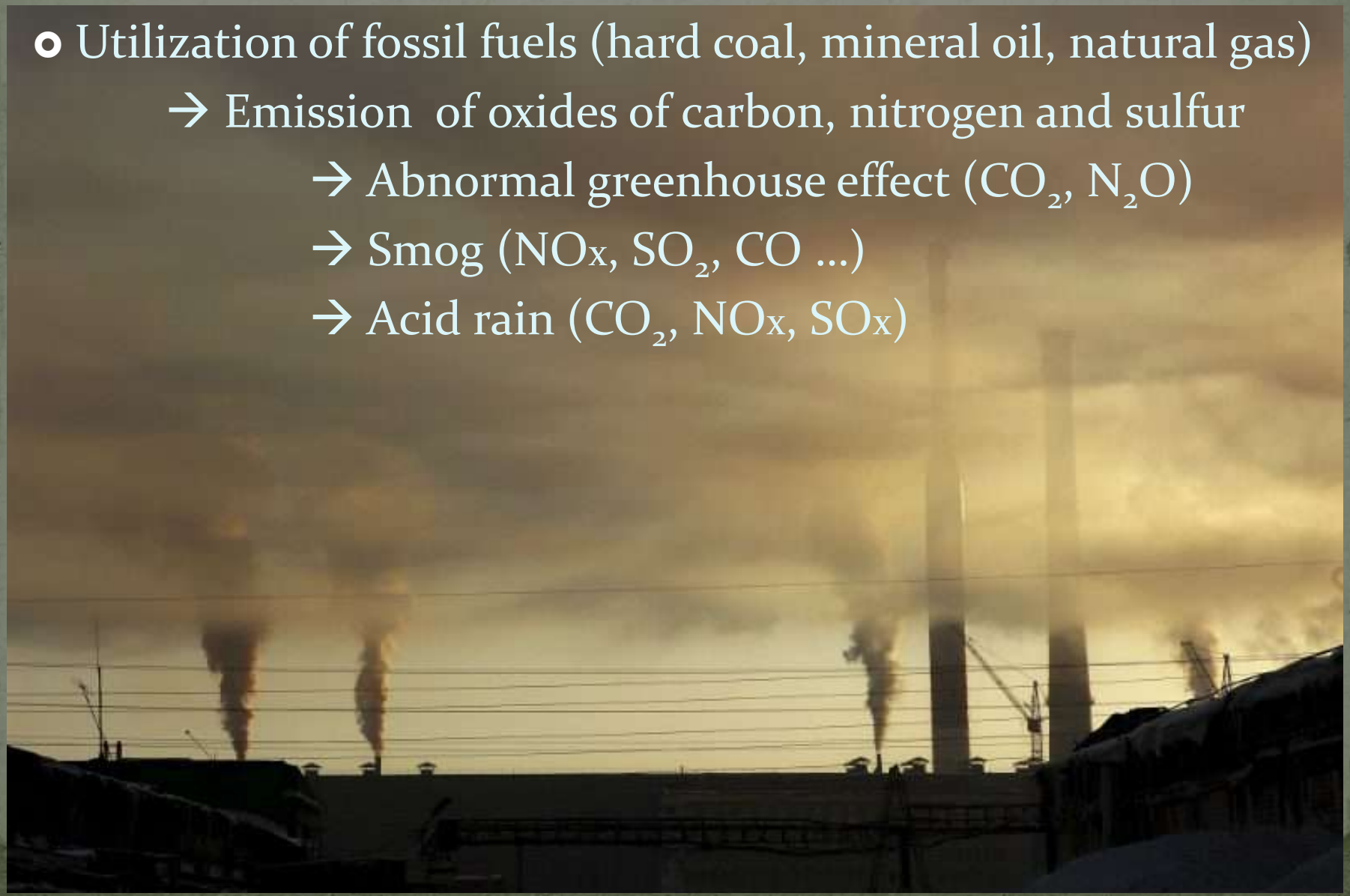


Global effects

- Emission of greenhouse gases ↑
  → abnormal greenhouse effect
  → global warming, climate change

Global effects

- Utilization of fossil fuels (hard coal, mineral oil, natural gas)
  - → Emission of oxides of carbon, nitrogen and sulfur
    - → Abnormal greenhouse effect (CO_2, N_2O)
    - → Smog (NO_x, SO_2, CO ...)
    - → Acid rain (CO_2, NO_x, SO_x)



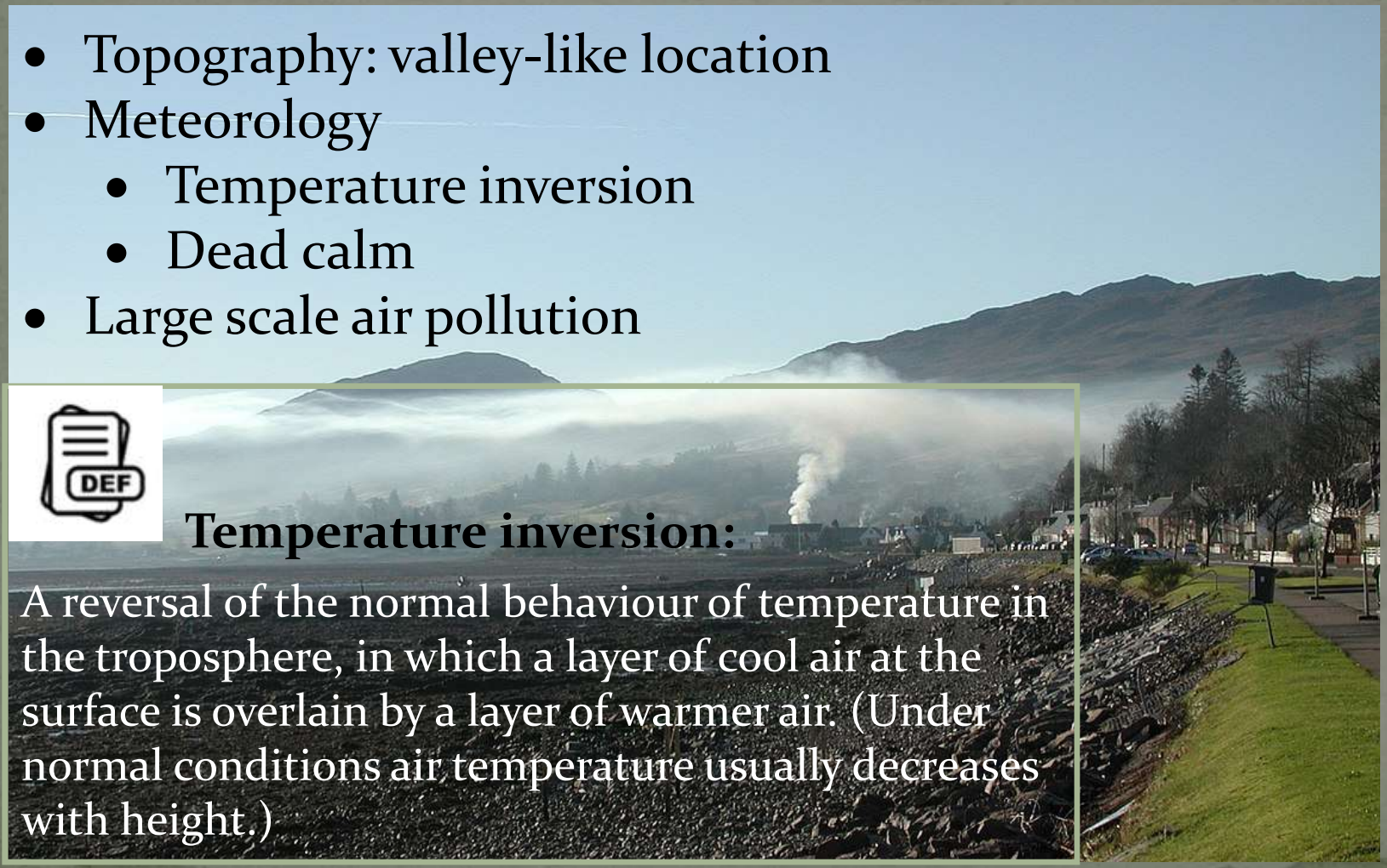
Sulfurous and Photochemical SMOG

London, 1952

Los Angeles, 1943

Common elements of the formation of sulfurous and photochemical smog

- Topography: valley-like location
- Meteorology
  - Temperature inversion
  - Dead calm
- Large scale air pollution



Temperature inversion:

A reversal of the normal behaviour of temperature in the troposphere, in which a layer of cool air at the surface is overlain by a layer of warmer air. (Under normal conditions air temperature usually decreases with height.)

Properties	Photochemical (Los Angeles)	Sulfurous (London)
Temperature of air	24-32 °C	-1-4 °C
Humidity	< 70 %	85 % (fog)
Temperature inversion	1000 m	< 500 m
Speed of the wind	Calm wind	Calm wind
Visibility	<0.8-1.6 km	< 30 m
Incidence	August-Sept.	Dec. – Jan.
Main reasons	Transport	Heating
Main components	NO, NO_2, CO, O_3	SO_2, H_2SO_4, CO, grime
Types of reactions	Oxidative	Reductive
Daily incidence	During the day	Morning and evening
Primary harmful effects	Irritable eyes	Damage of respiratory system
Effect on built environment	Tire (because of O_3)	Iron, concrete

Source of sulfur dioxide

- Burning of mineral coal
- Metallurgy
- Volcanic activity
- Decomposition of organic materials

Solutions of the problem:

- Desulfurization of fuels
- Substitution of fuels

  (alternative energy sources)
- Remediation of damaged areas

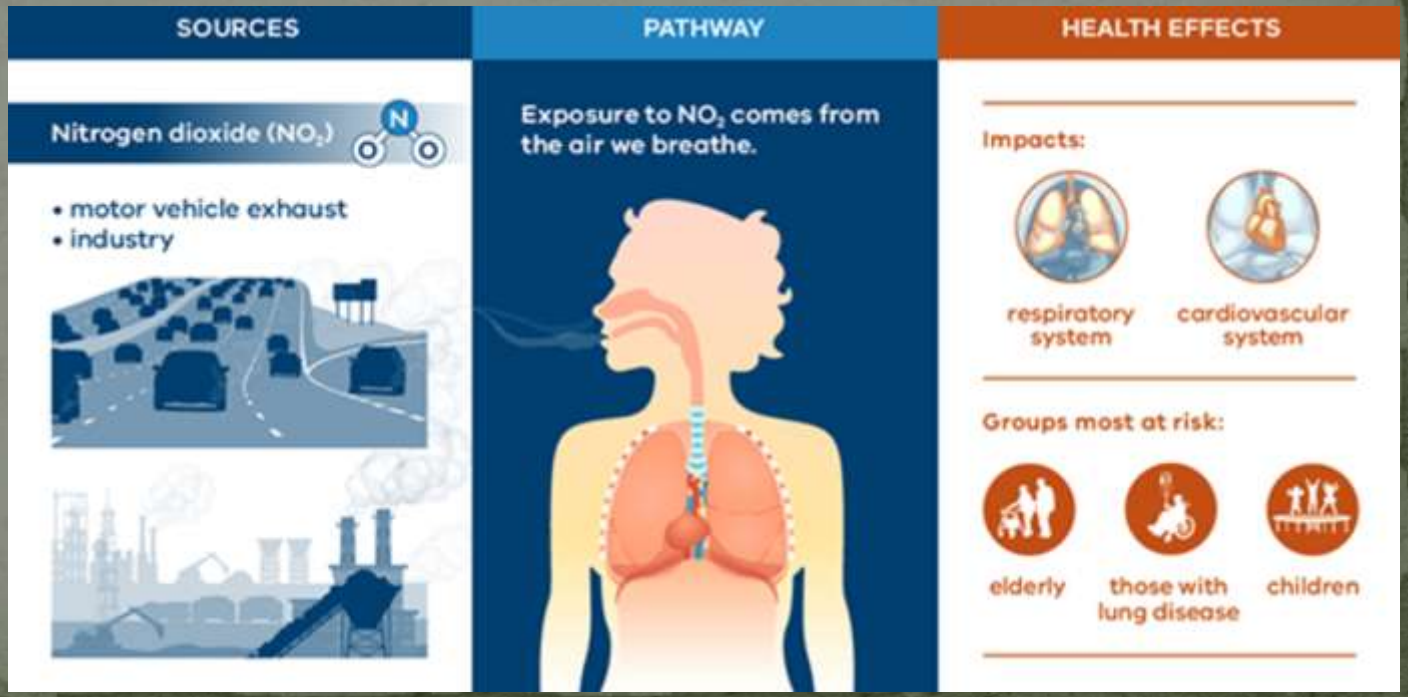
Source of oxides of nitrogen

- Burning of fossil fuels
- Combustion of biomass
- Lightning
- Stratospheric processes
- Oxidation of ammonia
- Emission of soil

70-80 %

Harmful effects of nitrogen oxides

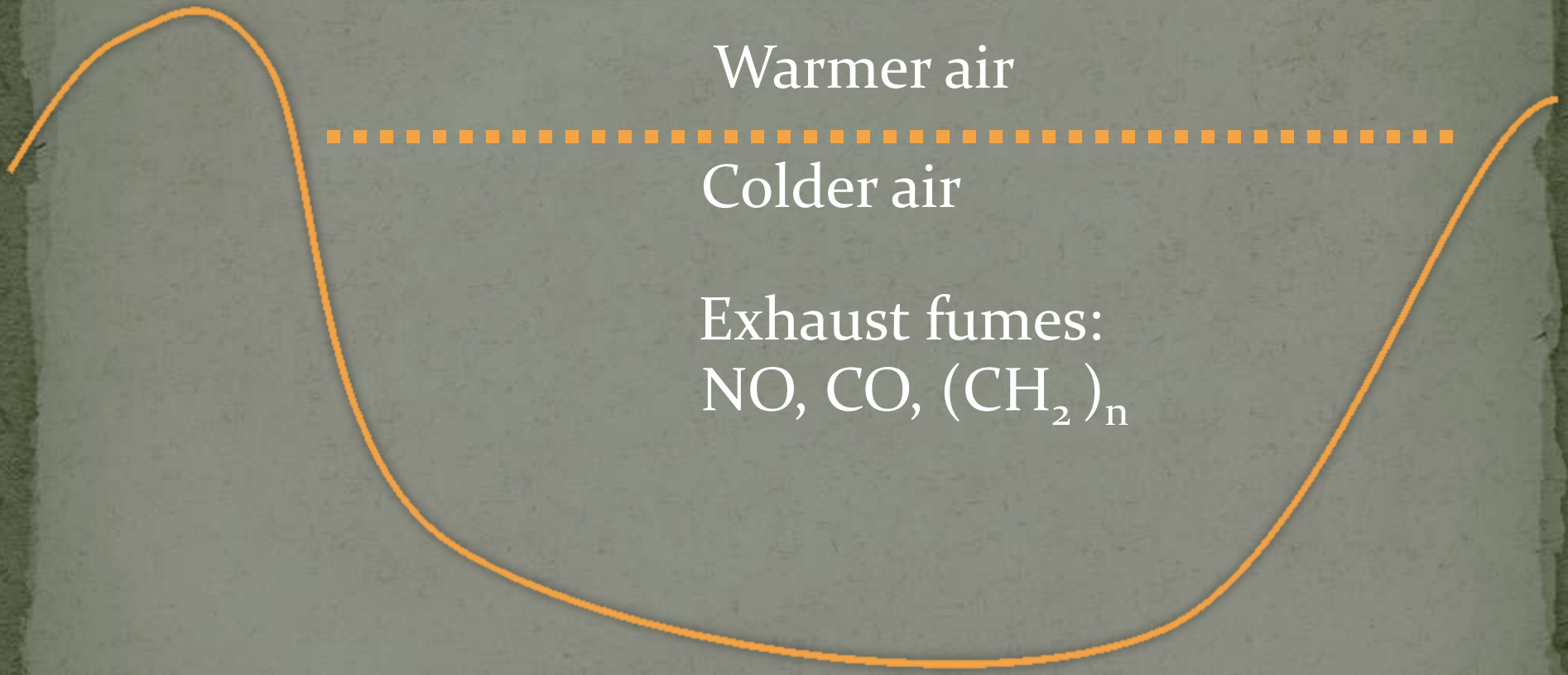
- Irritate the respiratory tract, asthma and chronic bronchitis
- Harmful effects of nitrogen oxides
- NO_2 is harmful in low concentration (300 µg/m³!)
- Cooking: 470-1880 µg/m³
- Smoking (one cigarette): 150000-226000 µg/m³



Formation of Photochemical SMOG

Formation of Photochemical SMOG

Early morning



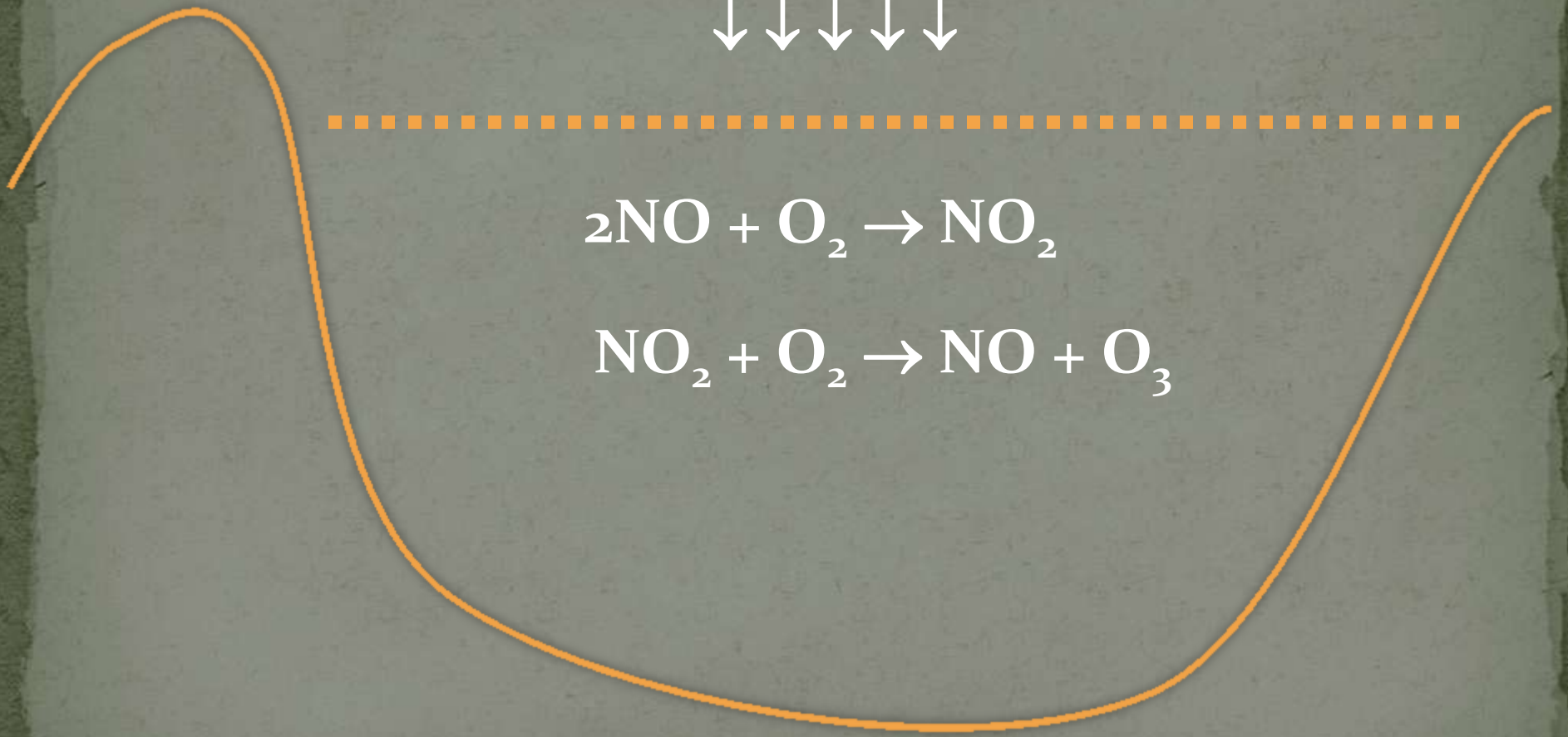
Inversion prevents the mixing.

Formation of Photochemical SMOG

In the morning

UV radiation

↓ ↓ ↓ ↓ ↓



$$2NO + O_2 \rightarrow NO_2$$

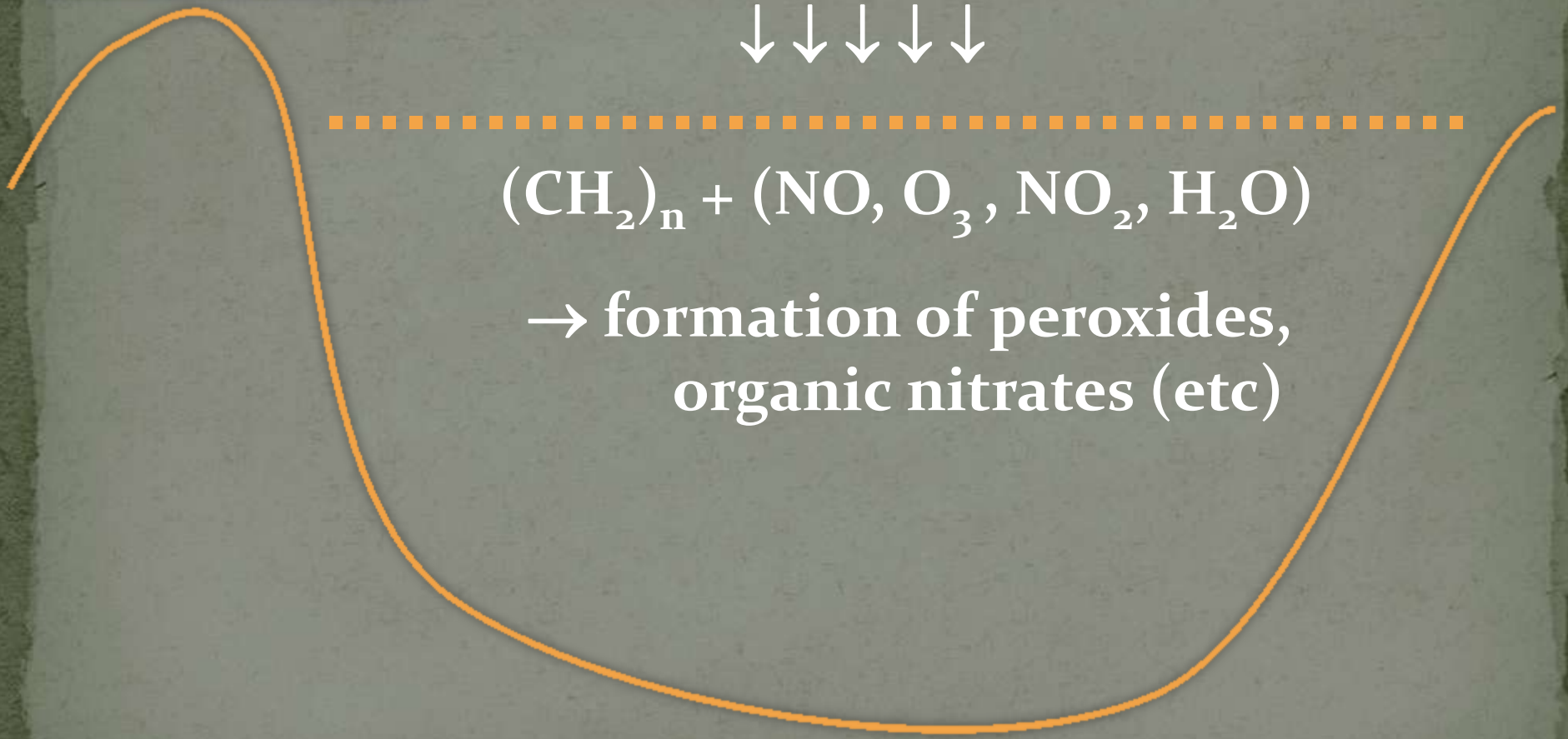
$$NO_2 + O_2 \rightarrow NO + O_3$$

Formation of Photochemical SMOG

Afternoon

UV radiation

↓ ↓ ↓ ↓ ↓

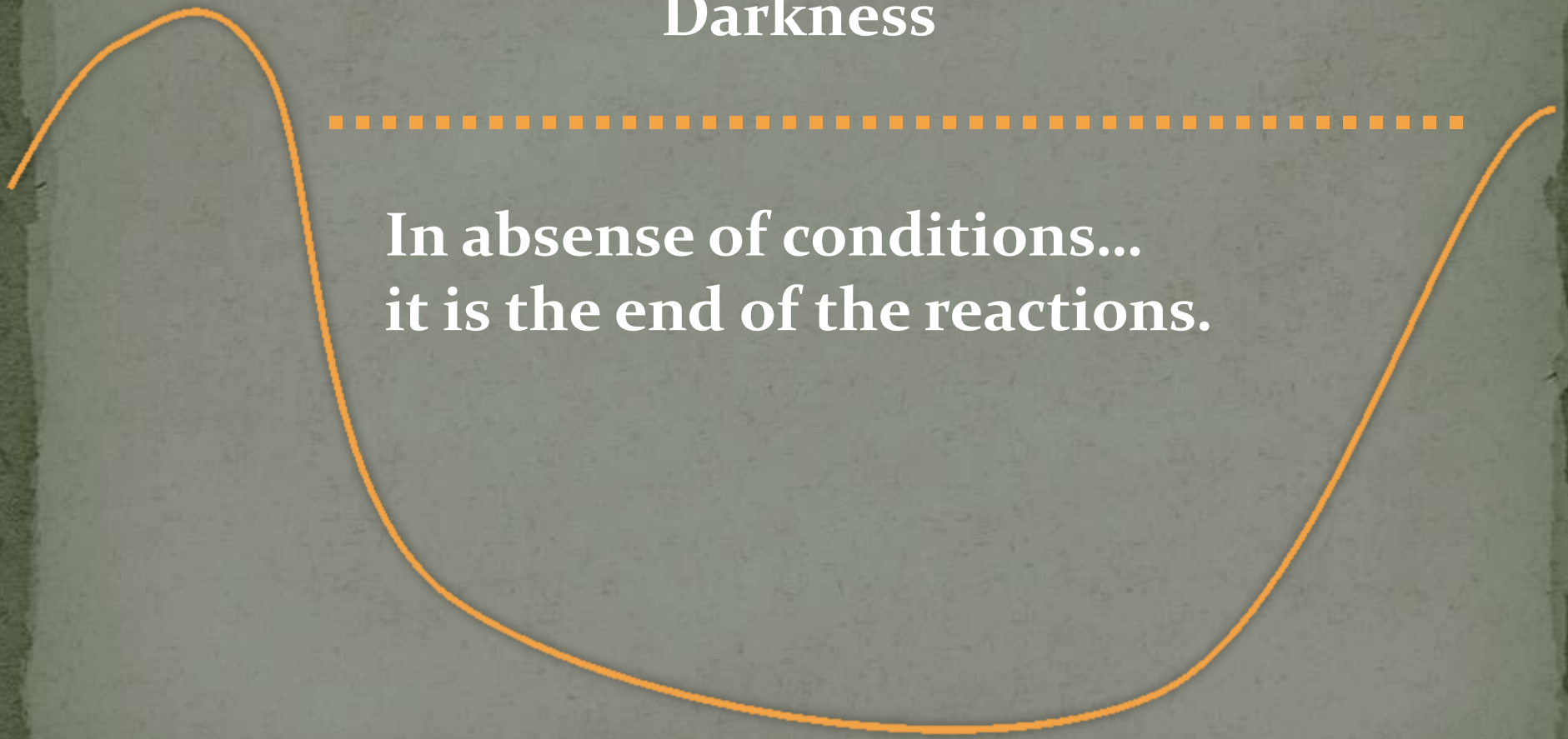


$(CH_2)_n$ + (NO, O_3, NO_2, H_2O)

→ formation of peroxides, organic nitrates (etc)

Formation of Photochemical SMOG

Night



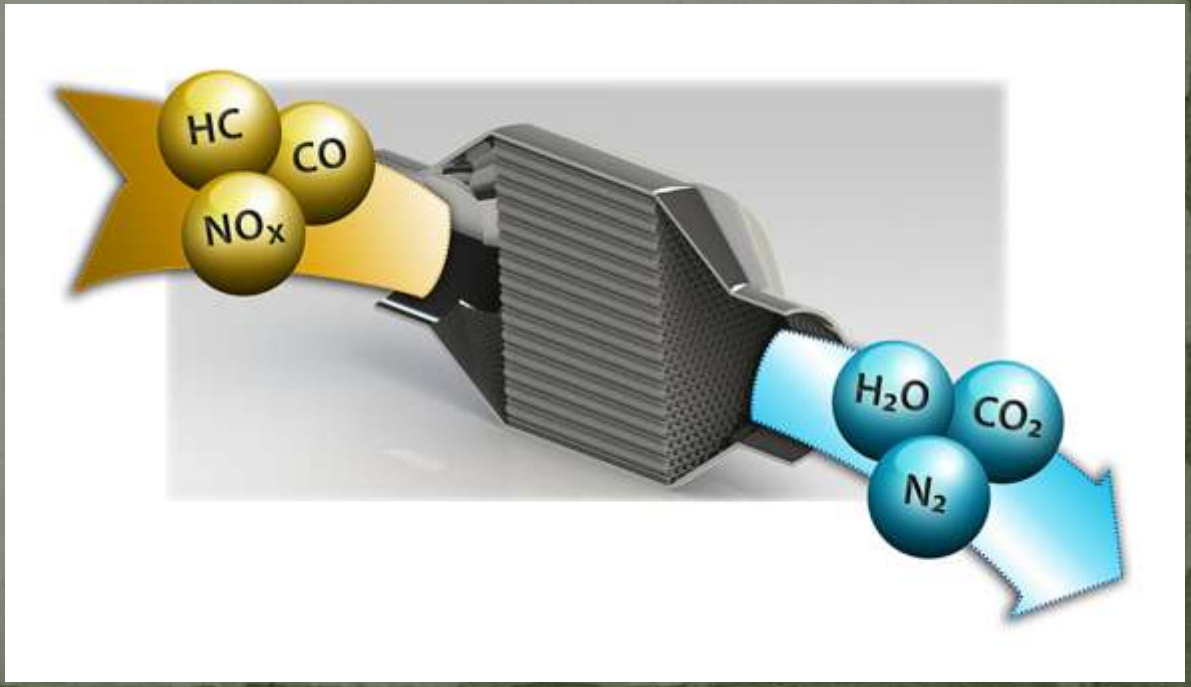
Darkness

In absense of conditions...
it is the end of the reactions.

Smog can appear or moderate.

Solutions of the problem: Reduction of emission (NOx, CO)

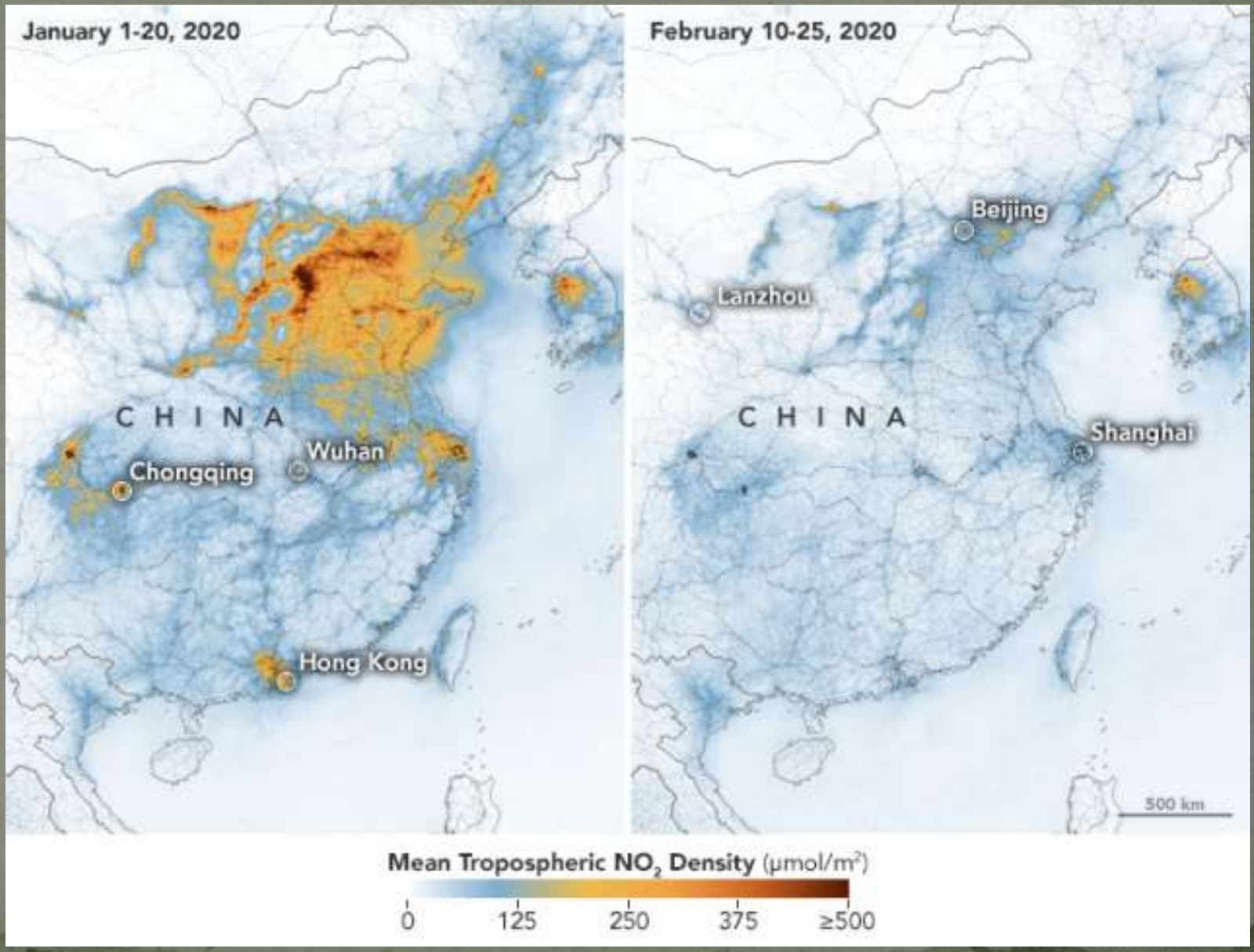
- Catalytic converters in automobiles
- Reduction of traffic
- Reduction of industrial emission



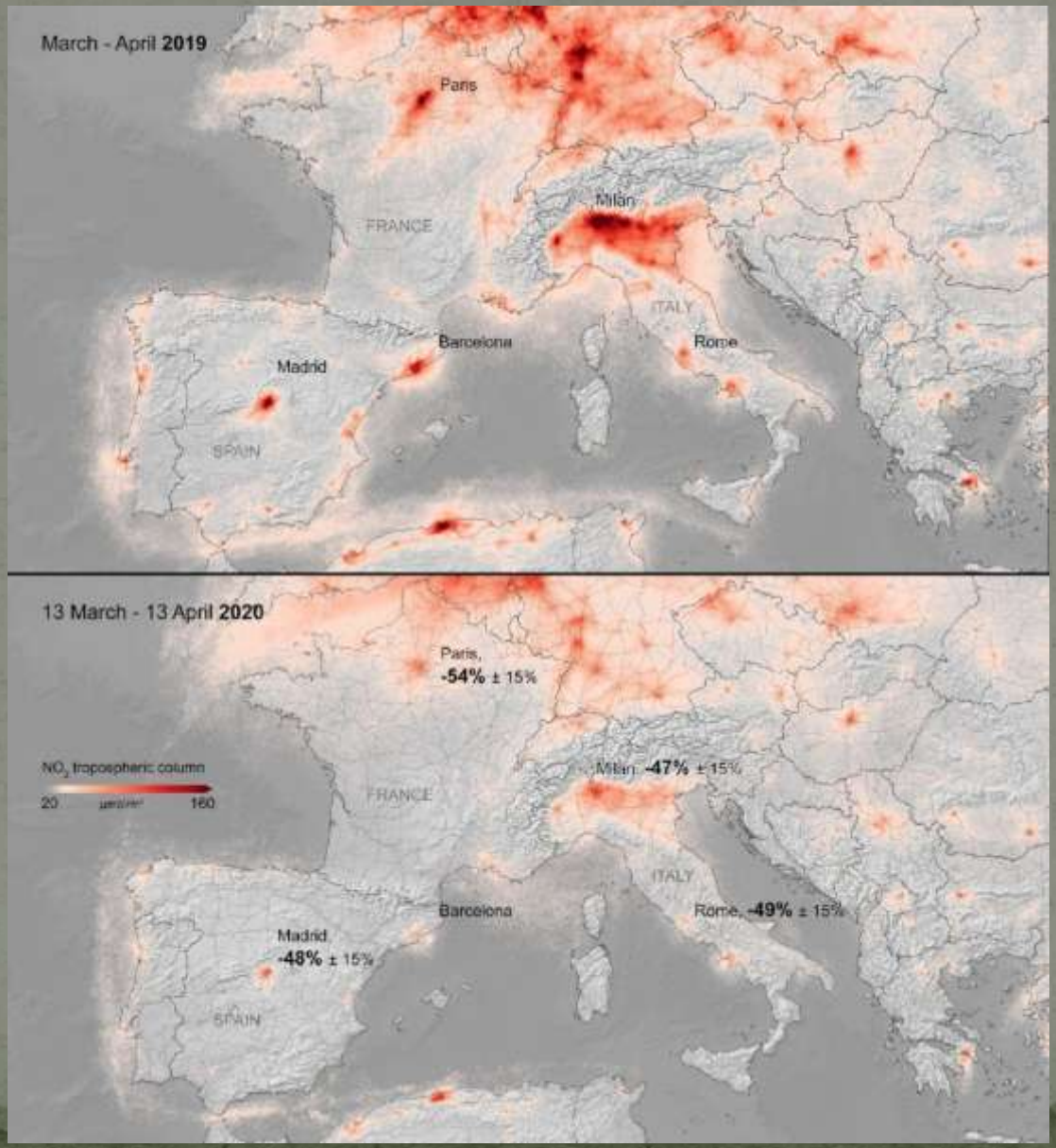
Effects of COVID-19 lockdowns

India 2020:
The Himalayas can be seen for the first time in 'decades,' as the lockdown eases air pollution.

Effects of CoVID-19 lockdowns

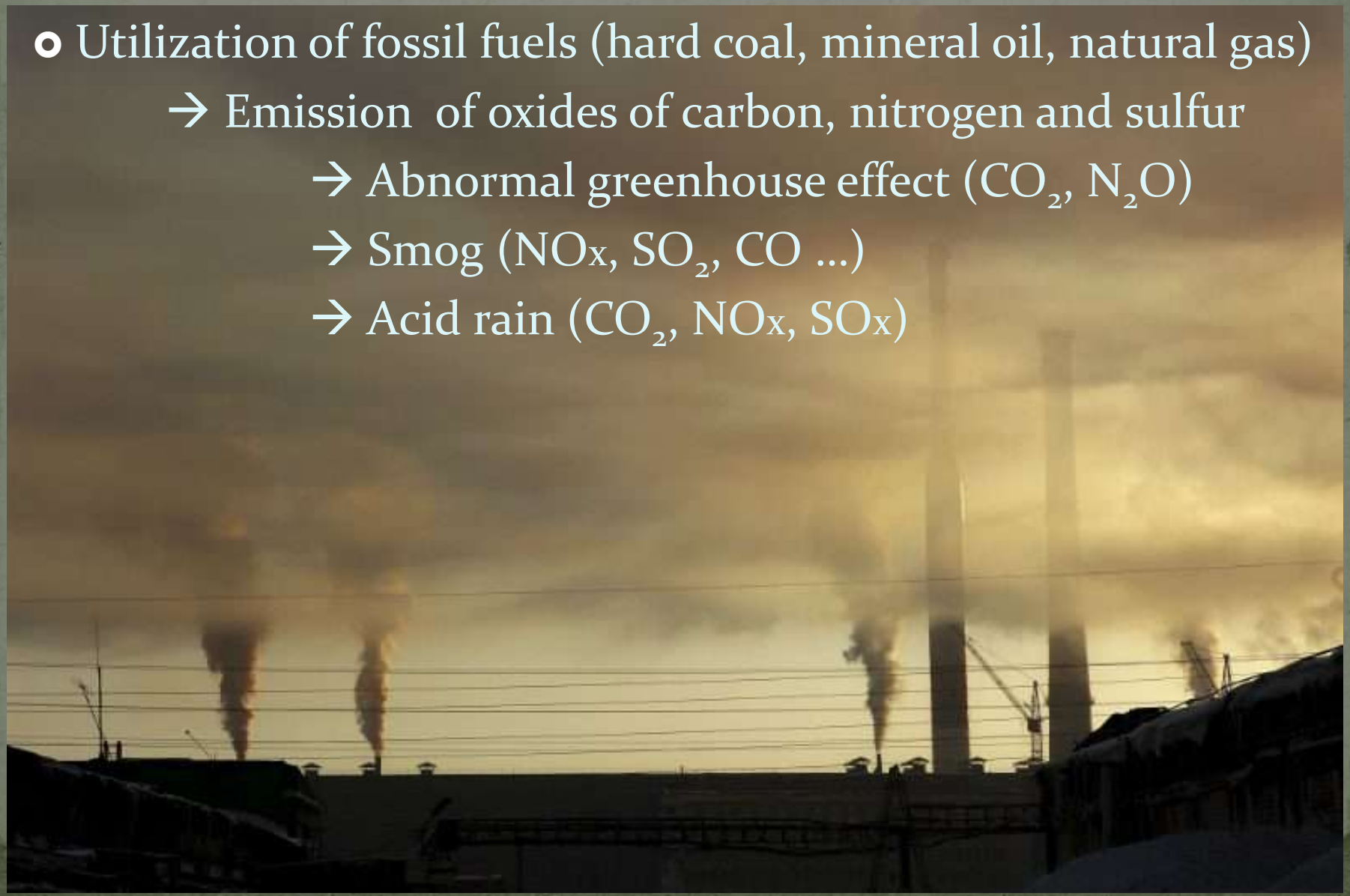


Effects of CoVID-19 lockdowns



Global effects

- Utilization of fossil fuels (hard coal, mineral oil, natural gas)
  - → Emission of oxides of carbon, nitrogen and sulfur
    - → Abnormal greenhouse effect (CO_2, N_2O)
    - → Smog (NO_x, SO_2, CO ...)
    - → Acid rain (CO_2, NO_x, SO_x)



Where does acid rain come from?

- Discovery: 1963 - Gene Likens:

Samples of rain ← large-scale pollution

$SO_2 \rightarrow SO_3 \rightarrow H_2SO_4$

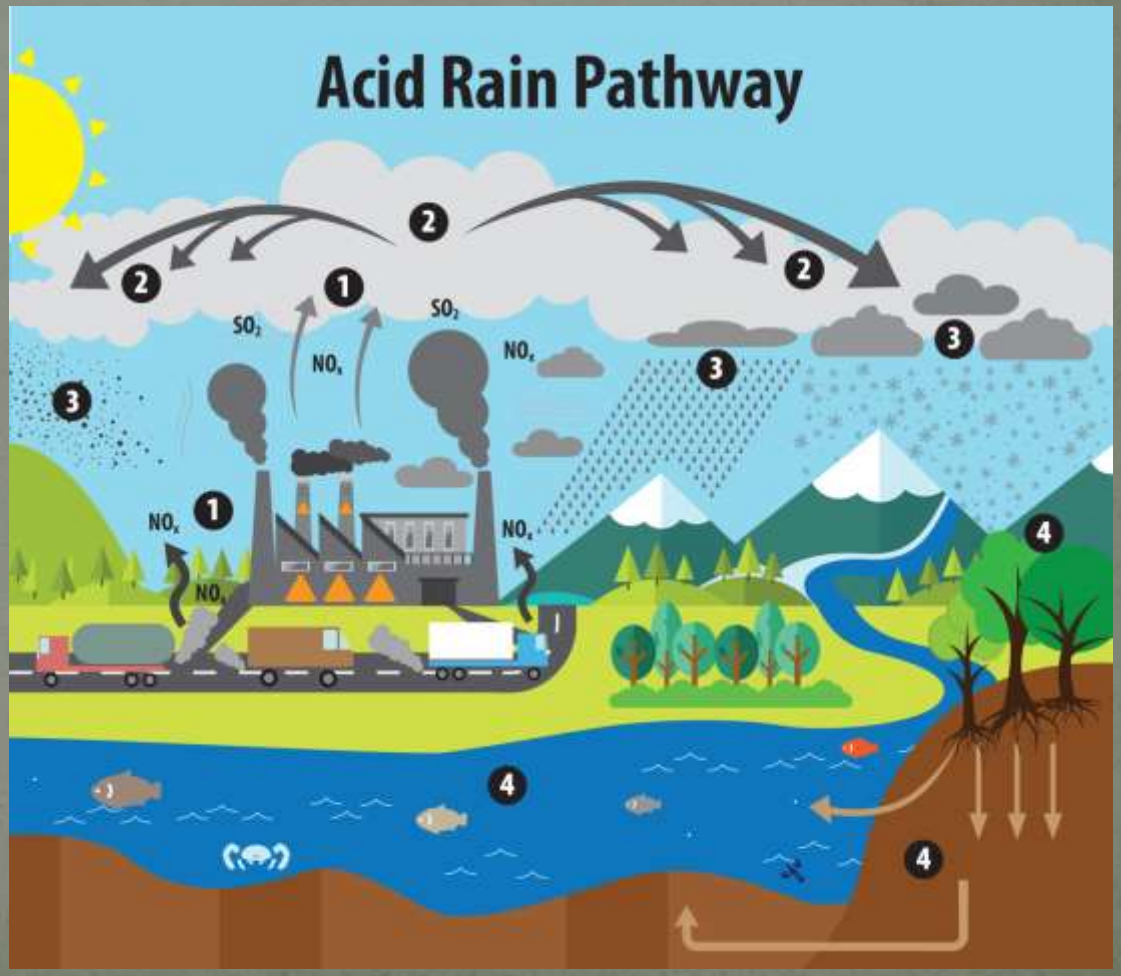
Sulfur dioxide → sulfuric acid

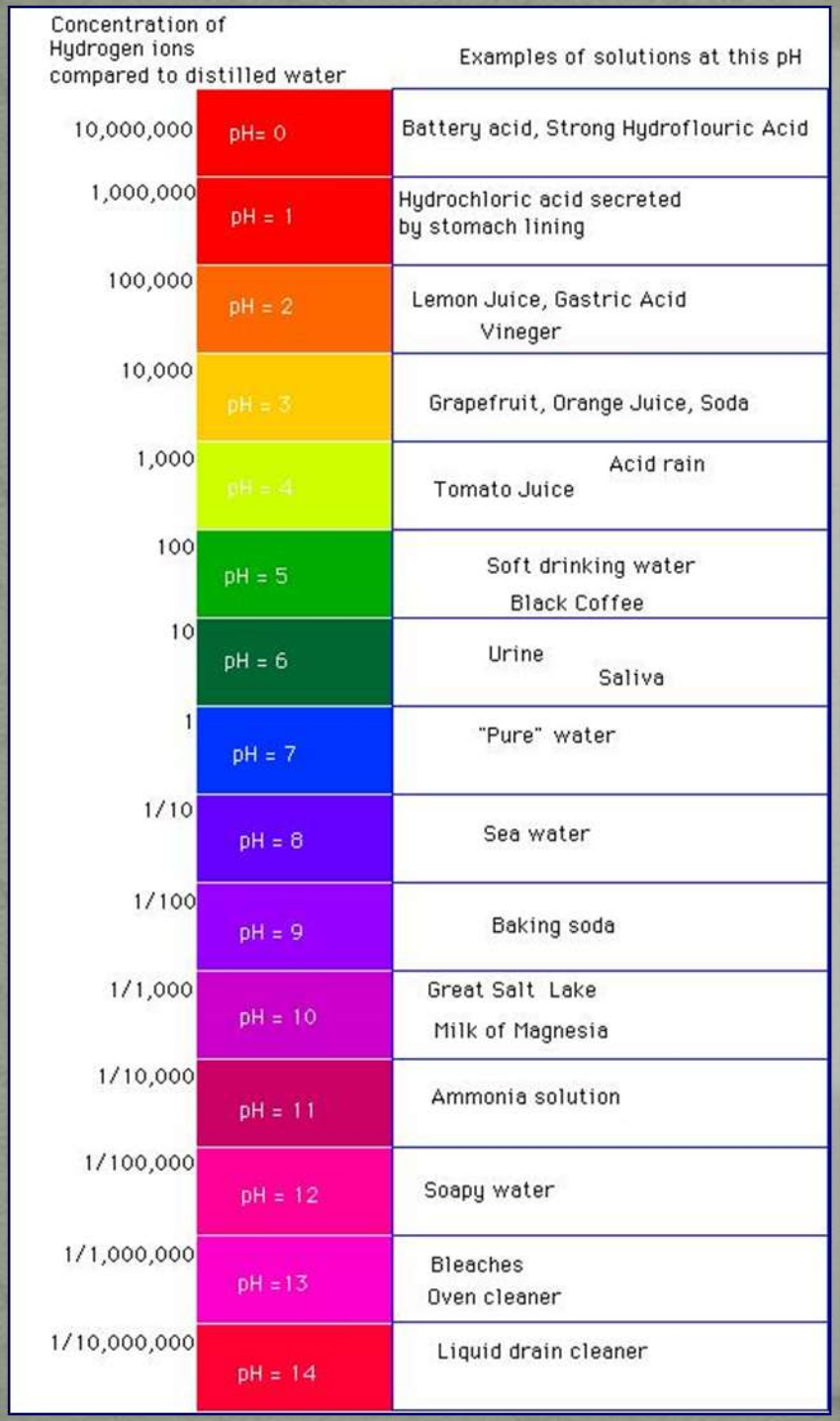
$2NO_2 + H_2O = HNO_3 + HNO_2$

Nitrogen dioxide → nitric acid + nitrous acid

$CO_2 + H_2O = H_2CO_3$

Carbon dioxide → carbonic acid





Definition

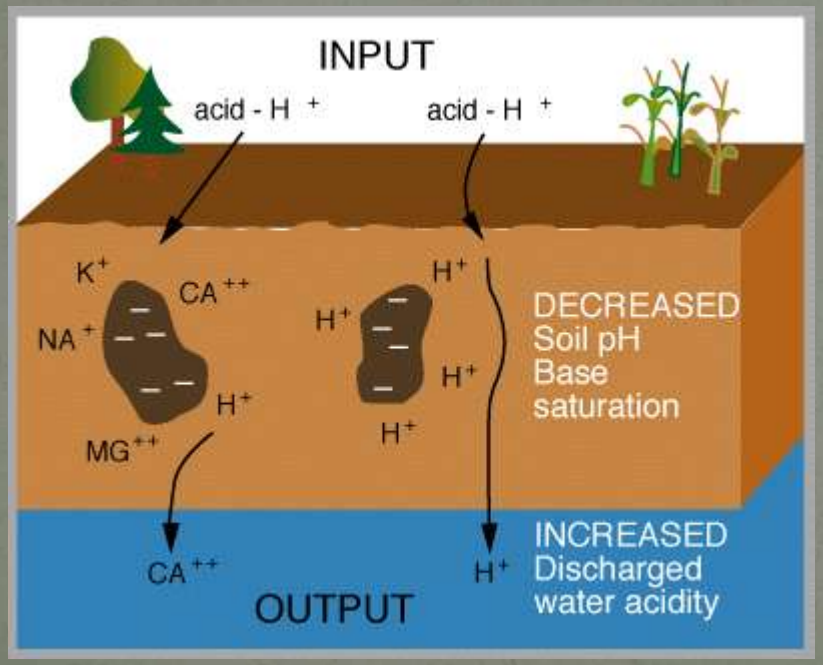
- Normal rain: 5.0 < pH < 6.5
- Acid rain: pH < 5.0
- Acid rain, or acid deposition, is a broad term that includes any form of precipitation with acidic components,

such as sulfuric or nitric acid that fall to the ground from the atmosphere in wet or dry forms. This can include rain, snow, fog, hail or even dust that is acidic.

Regional effects of acid rain

- Decreased pH in soil
  - Rainout of essential metals

  (They would be required for plants)
  - Increased solubility of toxic metals



Regional effects of acid rain

- Direct effect on plant's metasbolism
- Animals and humans:
  - Respiratory diseases

Regional effects of acid rain

- Dead or dying trees are a common sight in areas effected by acid rain. Acid rain leaches aluminum from the soil. That aluminum may be harmful to plants as well as animals.
- Acid rain also removes minerals and nutrients from the soil that trees need to grow.
- At high elevations, acidic fog and clouds might strip nutrients from trees' foliage, leaving them with brown or dead leaves and needles. The trees are then less able to absorb sunlight, which makes them weak and less able to withstand freezing temperatures.

Regional effects of acid rain

- Wetlands (streams, lakes, marshes):
  - the young of most species are more sensitive to environmental conditions than adults (lower pH, high concentration of toxic metals).
  - At pH 5, most fish eggs cannot hatch.
  - At lower pH levels, some adult fish die.
  - (Even if a species of fish or animal can tolerate moderately acidic water, the animals or plants it eats might not.)

Regional effects of acid rain

- Wetlands (streams, lakes, marshes):
  - „Dead lakes”: blue and clear
    because of absense of plankton

Effects on built environment

- Limestone:

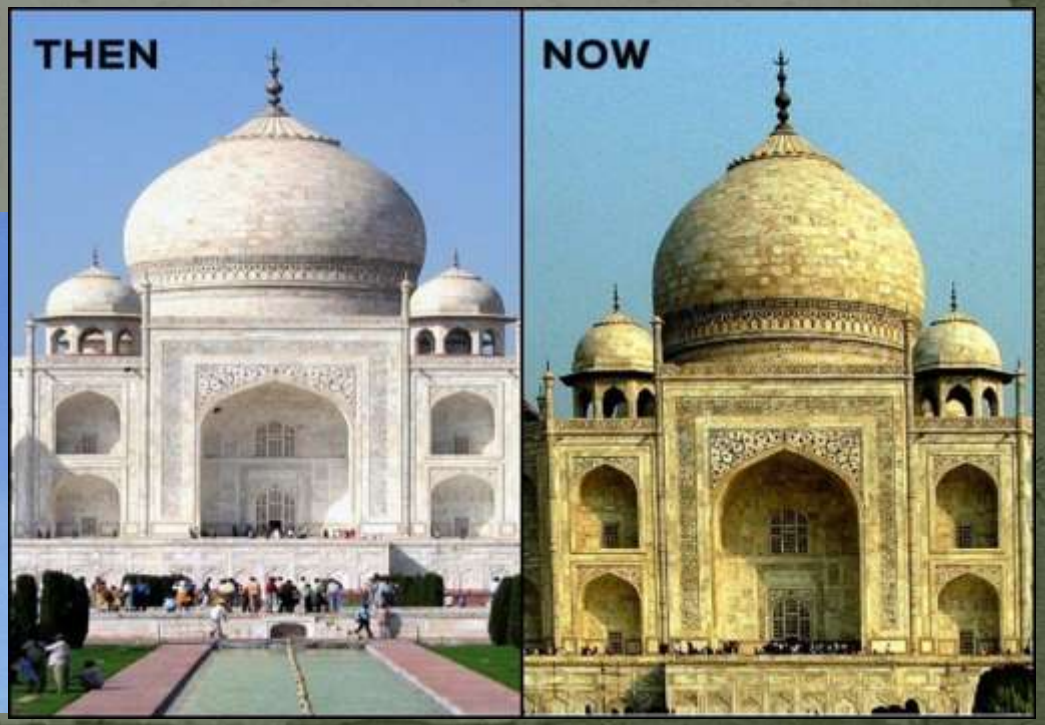
$CaCO_3 + H_2SO_4 \rightarrow Ca^{2+} + SO_4^{2-} + H_2O + CO_2$

- Sandstone:

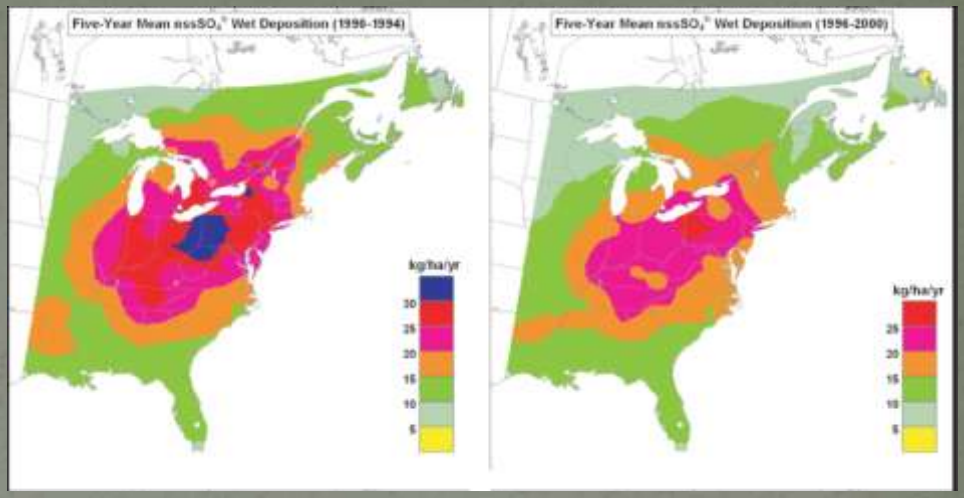
$Fe_2O_3 + 3\ H_2SO_4 \rightarrow 2\ Fe^{3+} + 3\ SO_4^{2-} + 3\ H_2O$

- Metals (corrosive effect):

$Me + 2\ H^+ \rightarrow Me^{2+} + H_2$



Interventions



- North America:
  - Interventions after 27 years after discovery!
  - It was succeeded to stop acid rain!

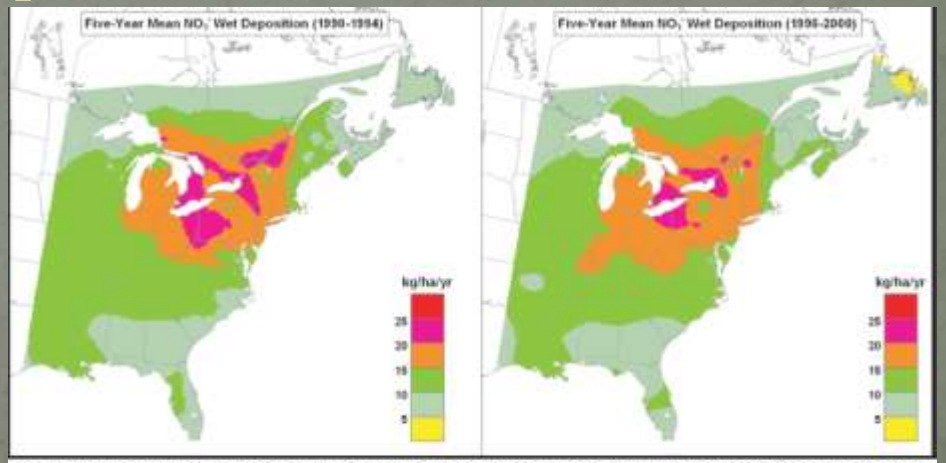
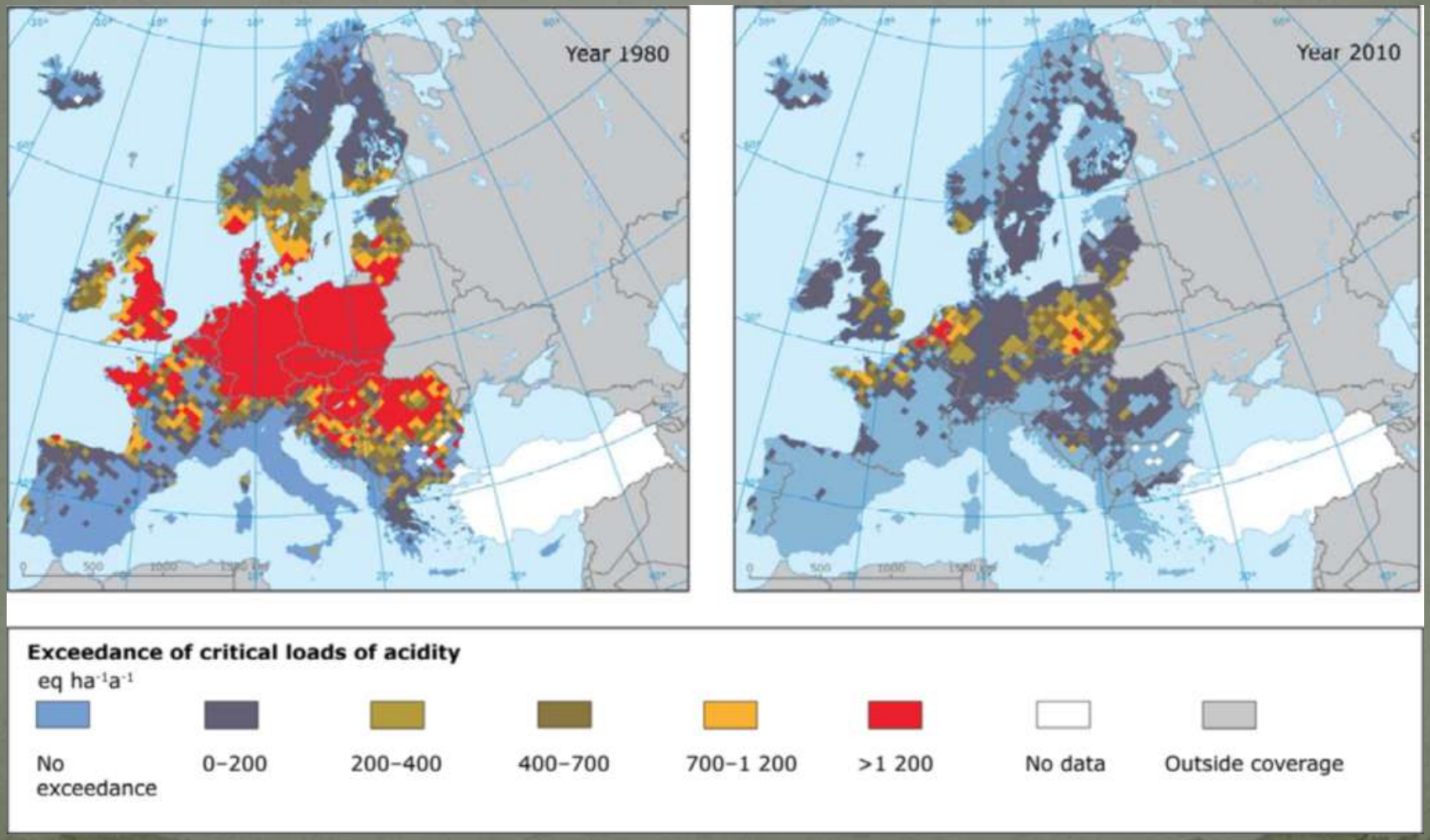


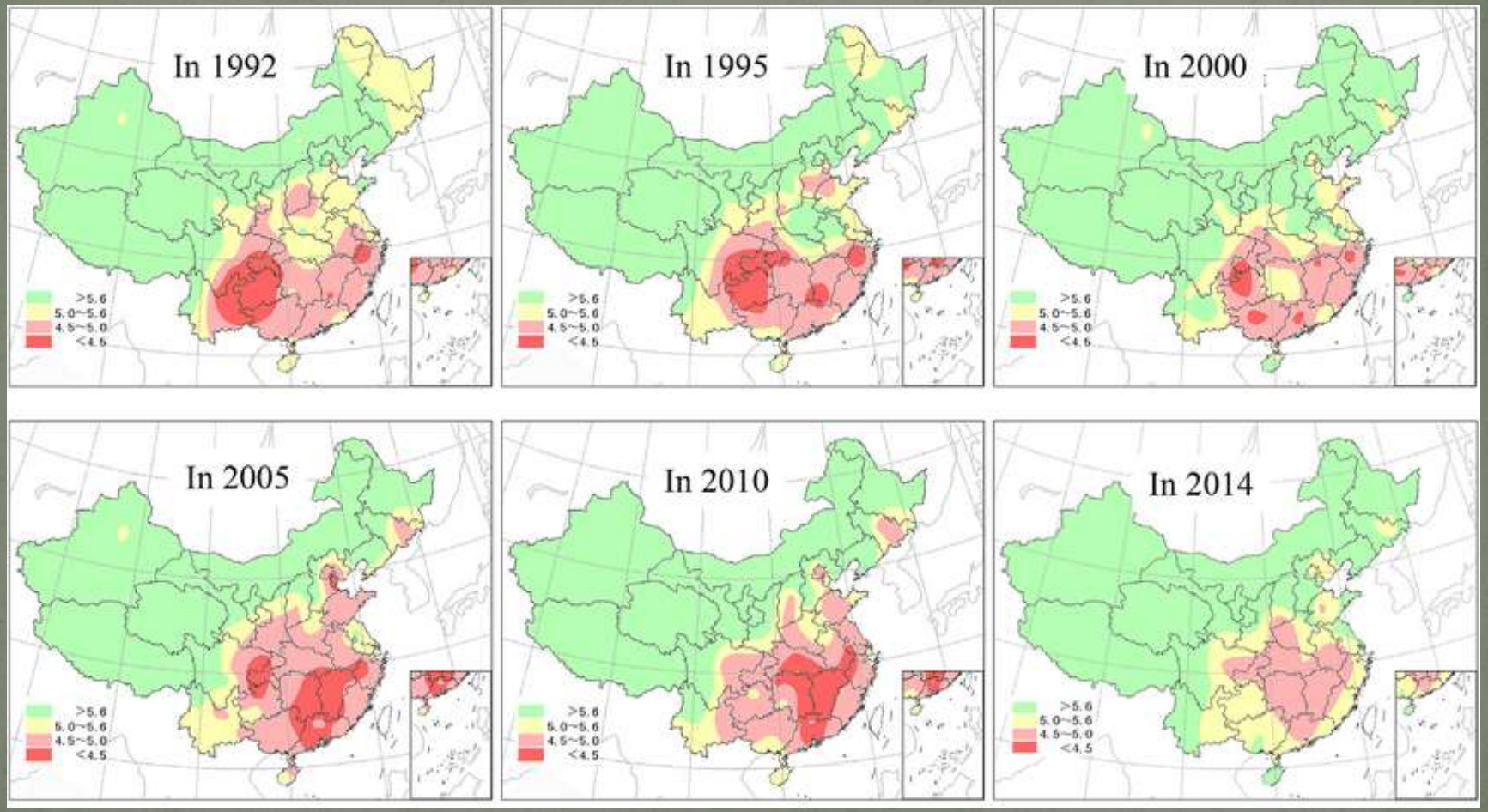
Figure 3. Five-year mean patterns of wet non-sea-salt-sulfate ($nssSO_4^{2-}$) and wet nitrate deposition for the periods 1990-1994 and 1996-2000.

Source: Figures 9 through 12 of Canada - United States Air Quality Agreement: 2002 Progress Report. http://www.epa.gov/airmarkets/progsregs/usca/docs/annex02.pdf, and Jeffries *et al.* 2003

Acid Rain in Europe



Asia:
Acid rain is a growing problem!



Acid rain → landslide?

Questions

- What was the most important invention of the industrial revolution?
- What was the main energy source after industrial revolution? What were the consequences of its use?
- What are the main roles of the atmosphere?
- What are the differences between sulfurous and photochemical smog?
- What are the global consequences of emission of NO_x?
- How can we reduce this emission?
- Which gases can form acids in the rain?
- What are the effects of acid rain?

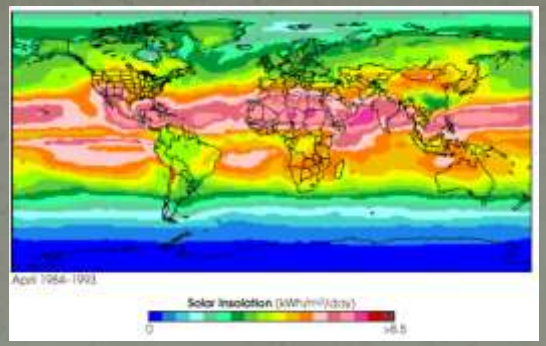
Emission of carbon dioxide and the climate crisis

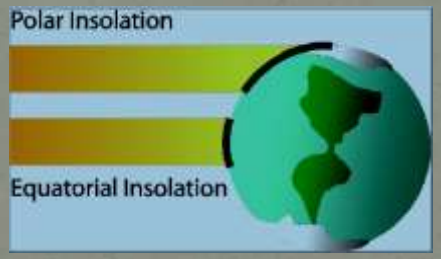
- Weather: describes the short term state of the atmosphere. This includes such conditions as wind, air pressure, precipitation, humidity and temperature.

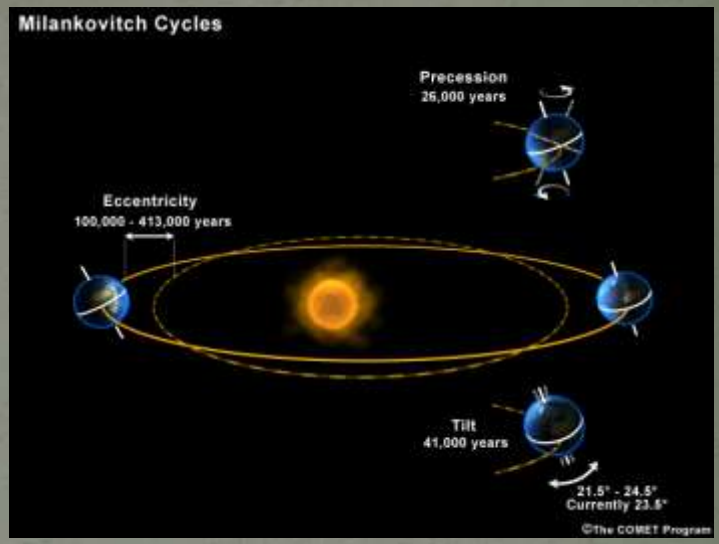
- Climate describes the typical, or average, atmospheric conditions.

What controls the climate?

- Insolation





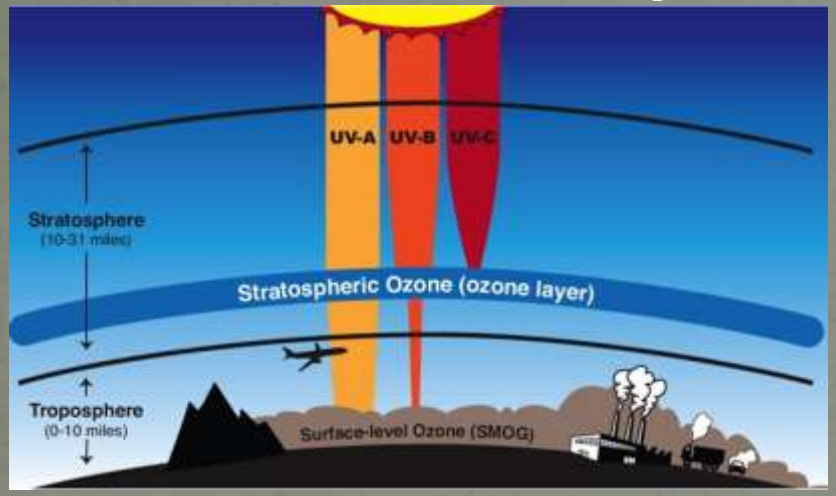


- Albedo

- Greenhouse gases of the atmosphere

The roles of the atmosphere

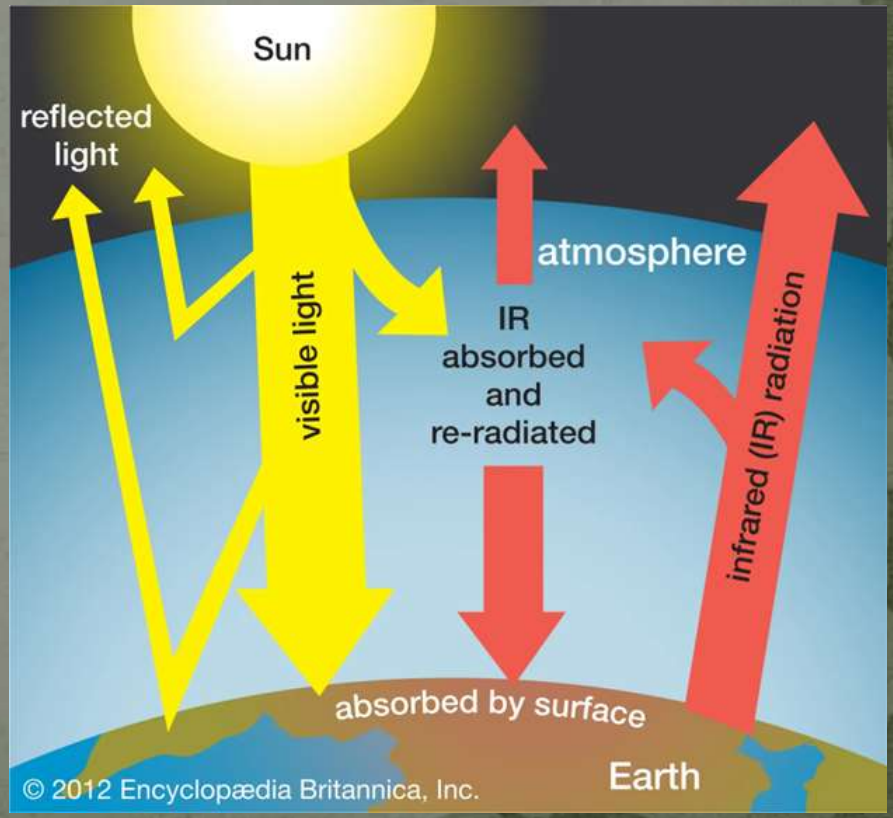
- Ozone layer → Protection from harmful radiation (X-ray, UV)

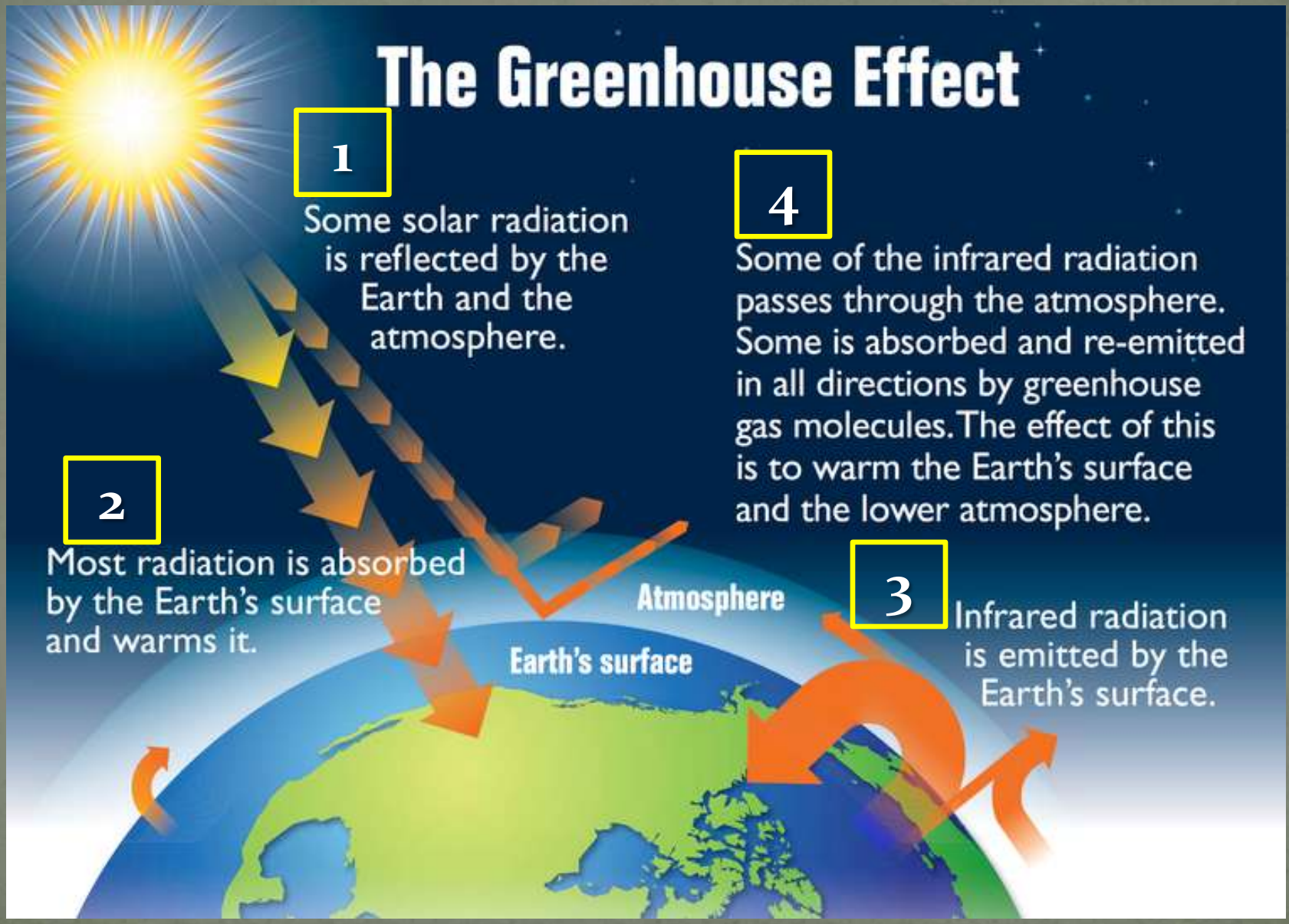


- Greenhouse gases in normal level → Advantageous greenhouse effect

(It warms the planet to its comfortable average of 15 degrees Celsius)

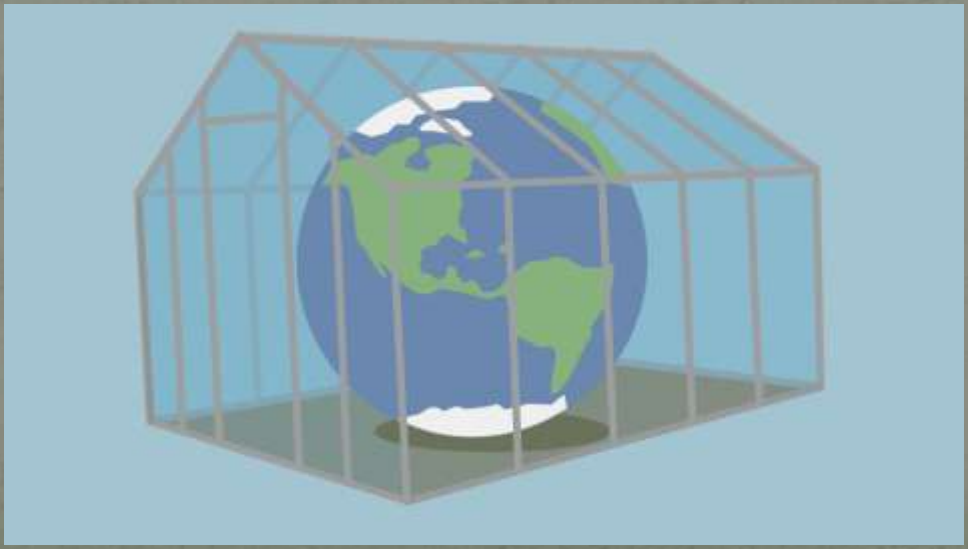
- Oxigen content → Breathing




The Greenhouse Effect
1
Some solar radiation is reflected by the Earth and the atmosphere.
2
Most radiation is absorbed by the Earth's surface and warms it.
3
Infrared radiation is emitted by the Earth's surface.
4
Some of the infrared radiation passes through the atmosphere. Some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Atmosphere
Earth's surface

Greenhouse Effect

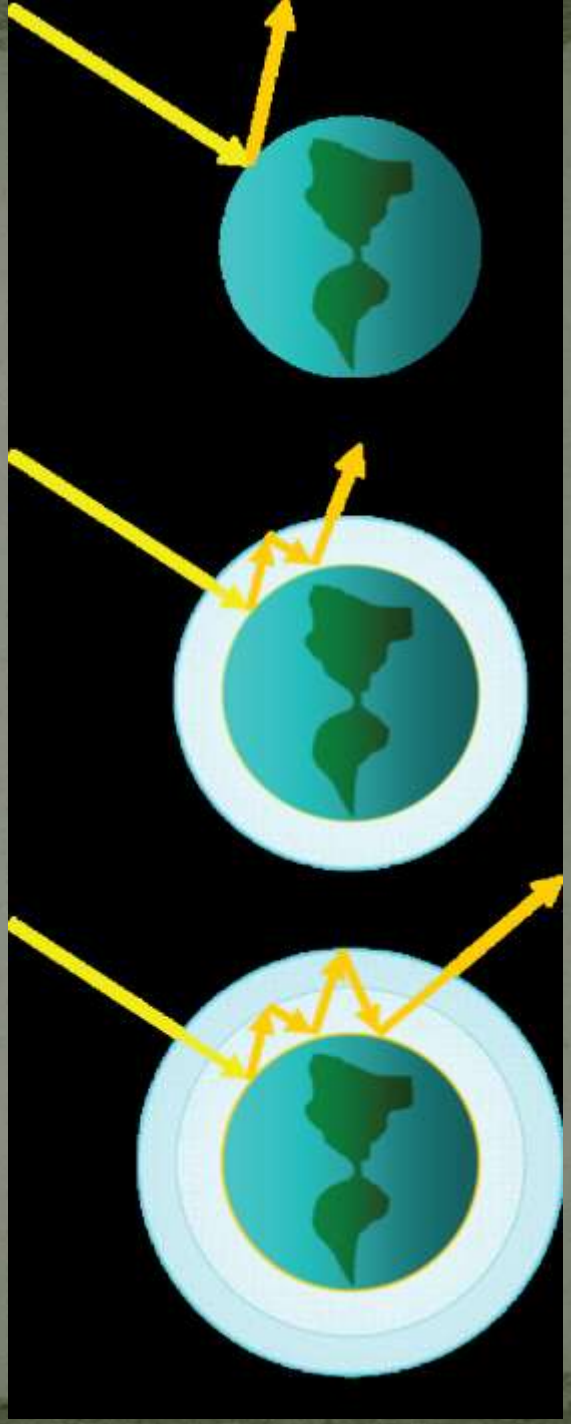
The greenhouse effect is a process that occurs when gases in Earth's atmosphere trap the Sun's heat. This process makes Earth much warmer than it would be without an atmosphere. The greenhouse effect is one of the things that makes Earth a comfortable place to live.

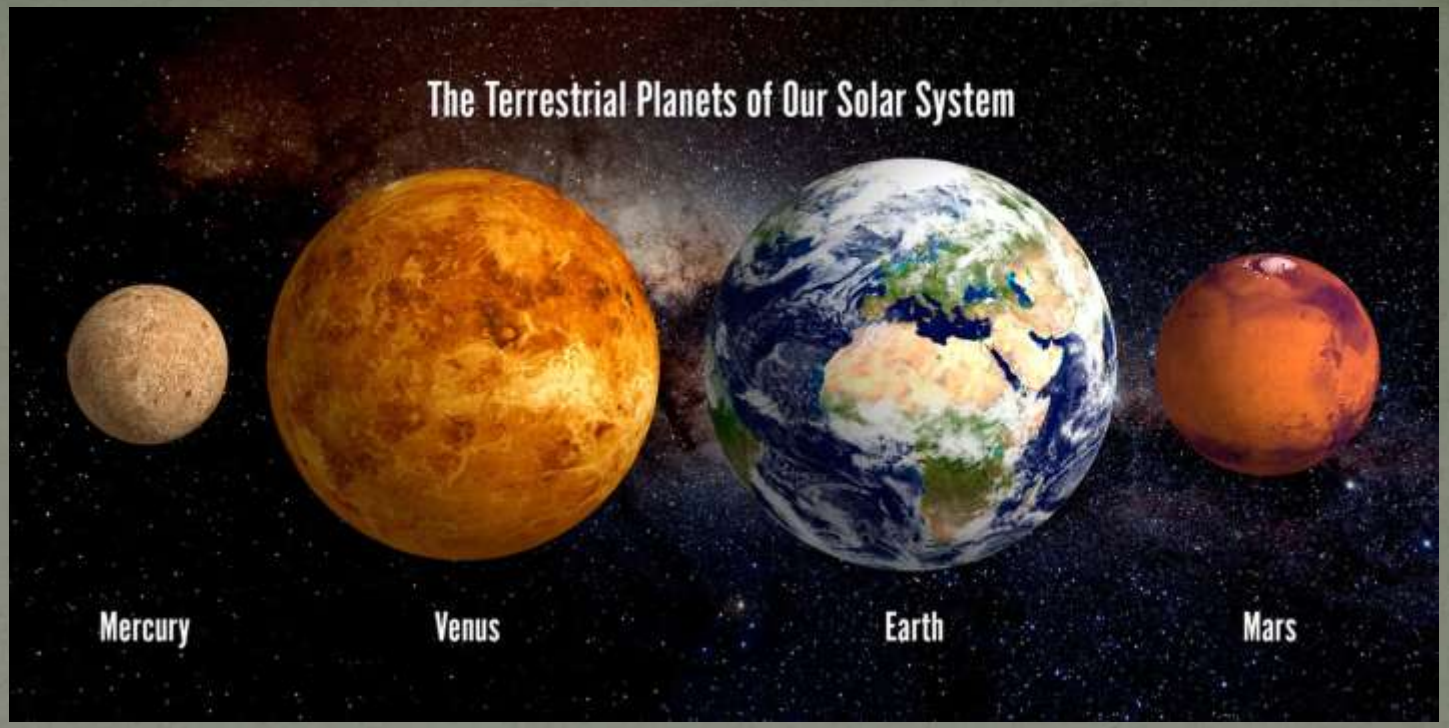


(Top) Visible light radiation emitted by the sun (yellow arrows) strikes the Earth and reflects as infrared radiation (orange arrow)

(middle) an atmosphere reflects some of the infrared radiation back towardthe planet

(bottom) a thickened atmosphere reflects greater amounts of infrared radiation.

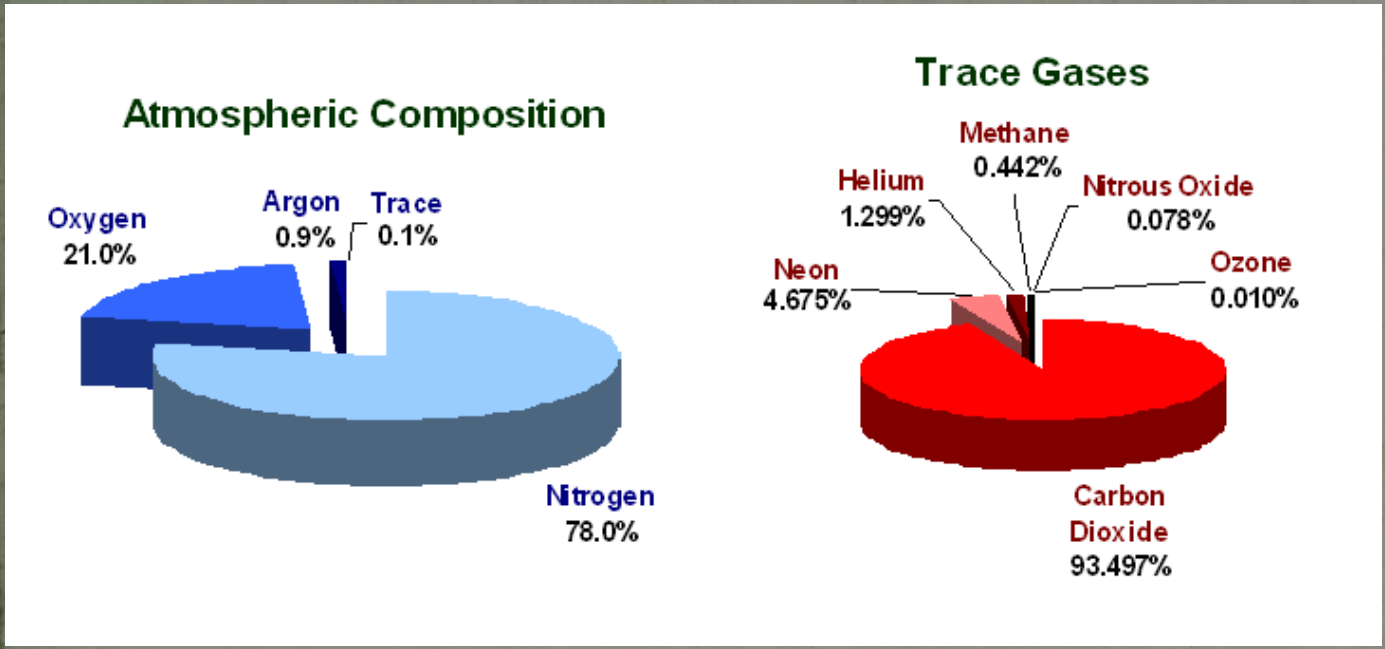




- Venus ~ 480 °C (large gas content)
- Mars: permanent cold (very thin atmosphere)
- Earth: ~ 15 °C
  (without greenhouse gases: -18 °C)

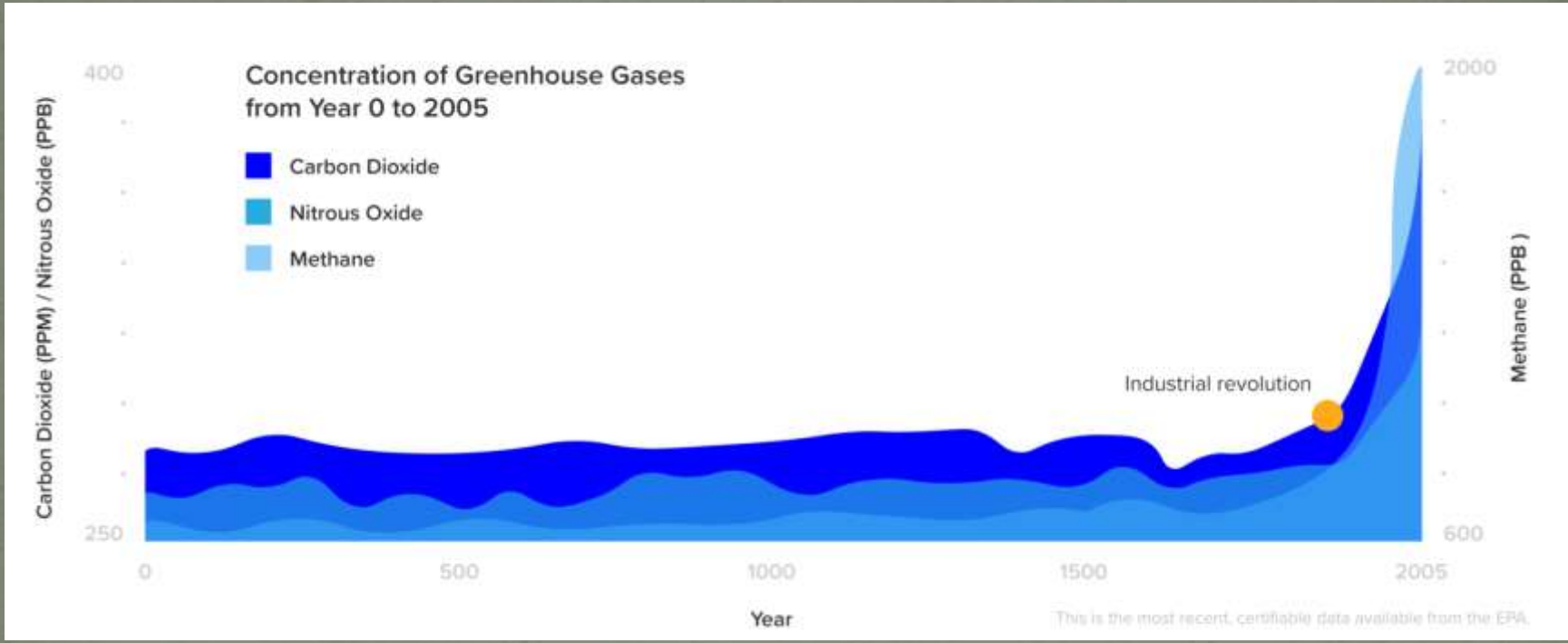
Global problems in the atmosphere

Composition of the atmosphere



- Carbon dioxie ↑
- Carbon monoxide ↑
- Oxides of nitrogen ↑
- Halogenated hydrocarbons ↑
- Oxides of sulfur ↑
- Methane ↑

Starting point: Industrial Revolution



Changes of Greenhouse Gases

	CO_2	CH_4	N_2O	CFC-11	CFC-12
Concentration before industrialization	278 ppm	700 ppb	275 ppb	0	0
Current concentration (2022)	>421 ppm	1900 ppb	330 ppb	225 ppt	493 ppt
Efficiency potential	1	25	310	3800	8100
Residence time in the atmosphere (year)	50-200	12	114	45	100

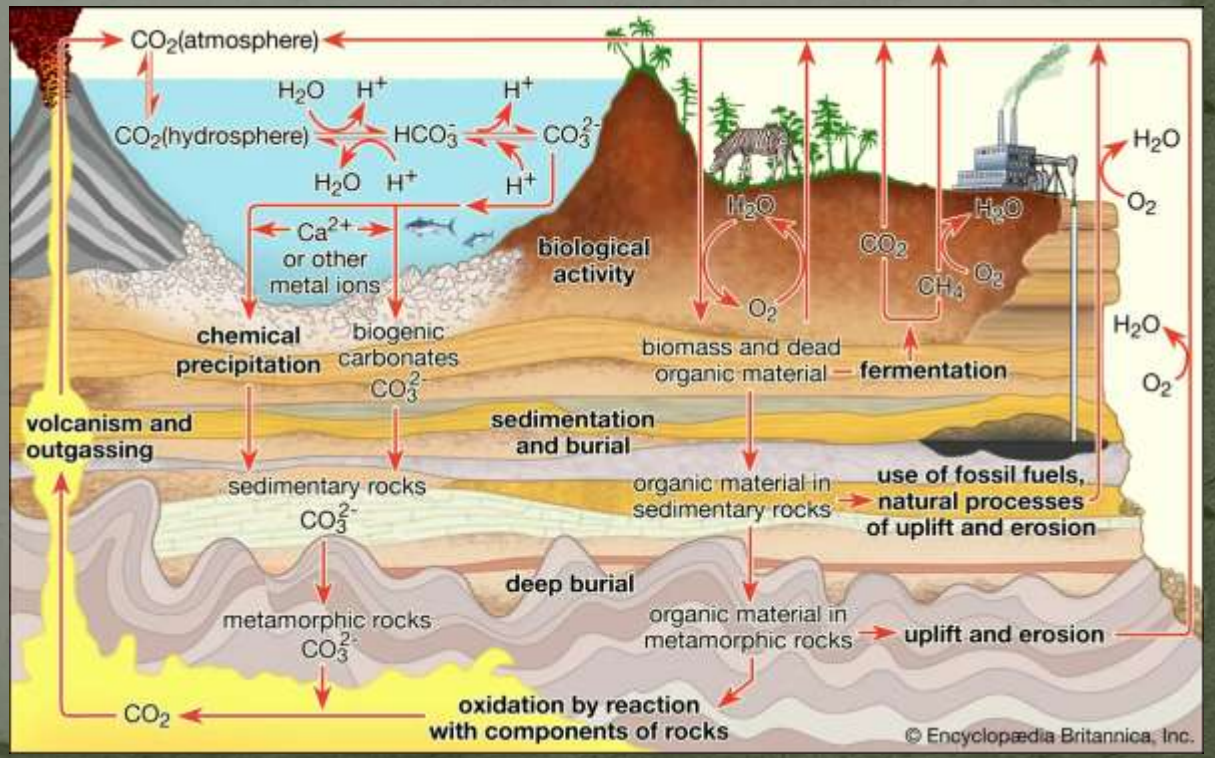
1 ppm = 1000 ppb = 1.000.000 ppt

Greenhouse Gases: Water vapor

- It has a most significant effect (13 trillion tons!)
- Human influence the amount of vapor isn't significant, but we're trying to change it:
  - Transformation of Earth's surface and vegetation
  - Irrigation
  - Decrease of surfaces covered by ice

Greenhouse Gases: carbon dioxide

- Efficiency potential: 1 unit
- Residence time in the atmosphere: 50-200 years!
- Sources:
  - Respiration (natural)
  - Decomposition of organic materials (natural)
  - Human activity (artificial)



Greenhouse Gases: carbon dioxide

- Human activity
  - Burning of fossil fuels (20 billion tons)
  - Burning the forests (4-7 billion tons)
  - Decrease of carbon dioxide fixation because of the missing forests
  - Use of limestone
- Starting point: Industrial Revolution

- Demand for clothing (textile industry)
- Increasing demand in military industry

Discovery of steam engine

Increasing use of hard coal

Machine manufacturing

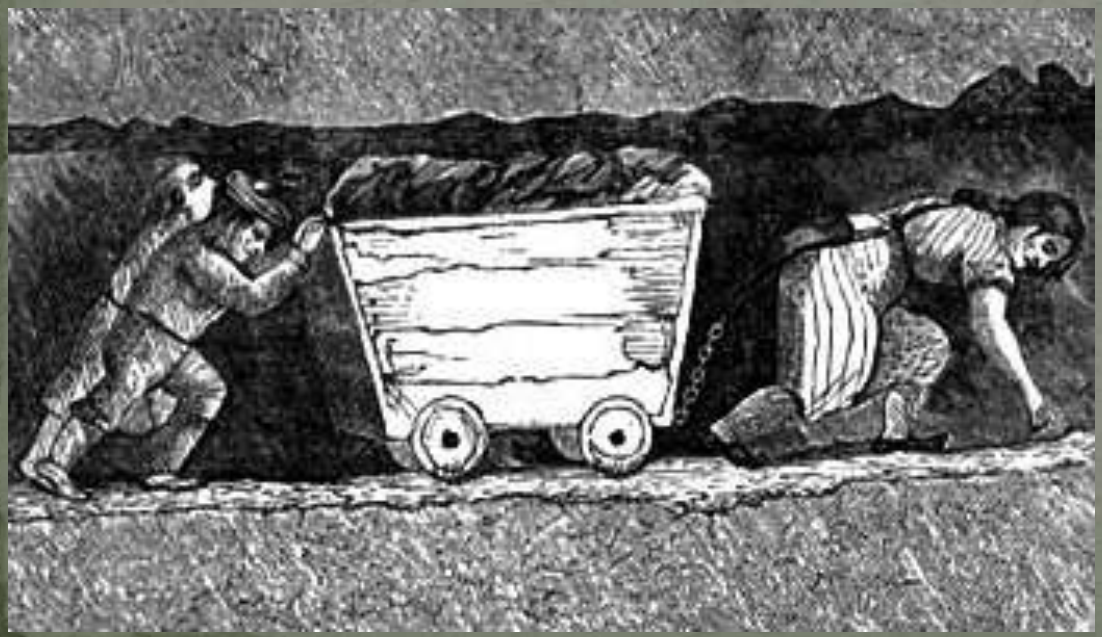
- Mining
- Metallurgy
- Metalworking

- Agricultural machines
- Vehicles

Increasing use of coal after Industrial Revolution

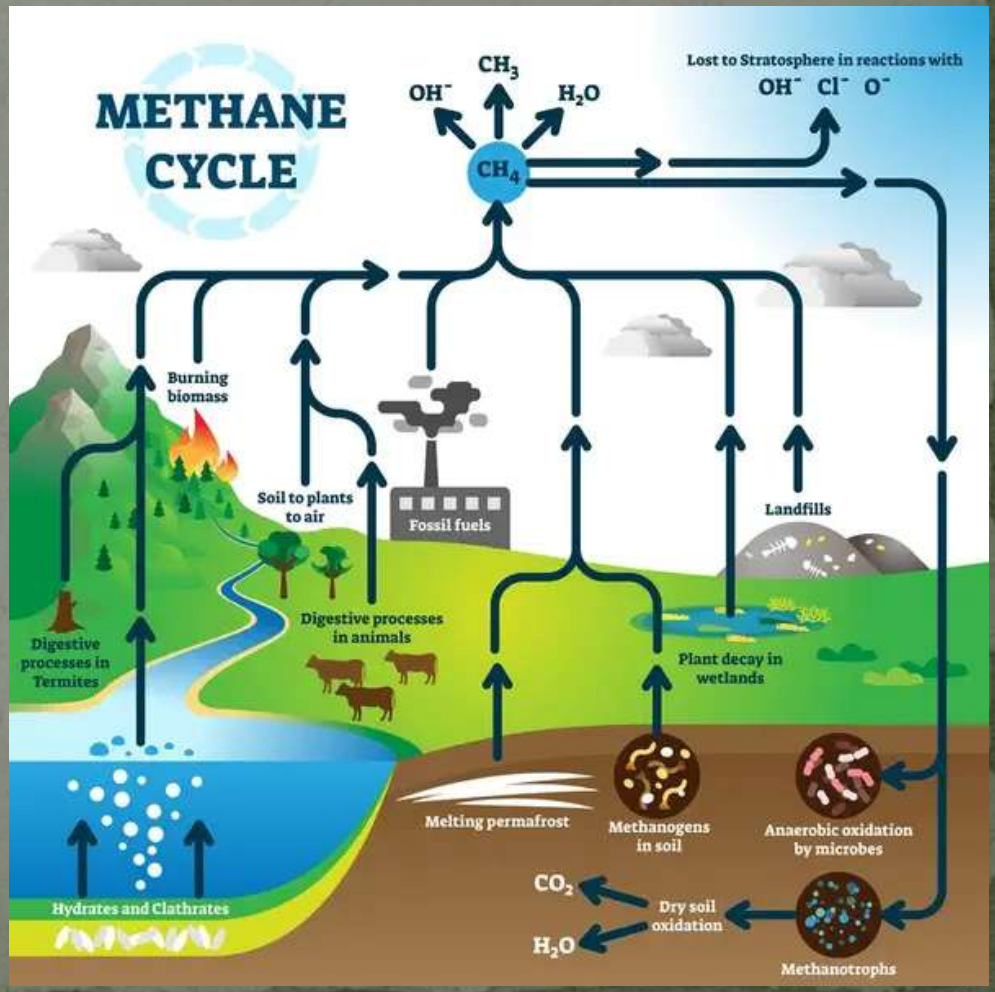
- Major fuel
- Propellant of vehicles
- Raw materials of chemical industry
- Increasing CO_2-emission

STARTING POINT OF GLOBAL AIR POLLUTION



Greenhouse Gases: Methane

- Efficiency potential: 250 unit!
- Residence time in the atmosphere: 12 years
- Sources:
  - Decomposition (natural)
  - Fermentation (natural)
  - Human activities (artificial)



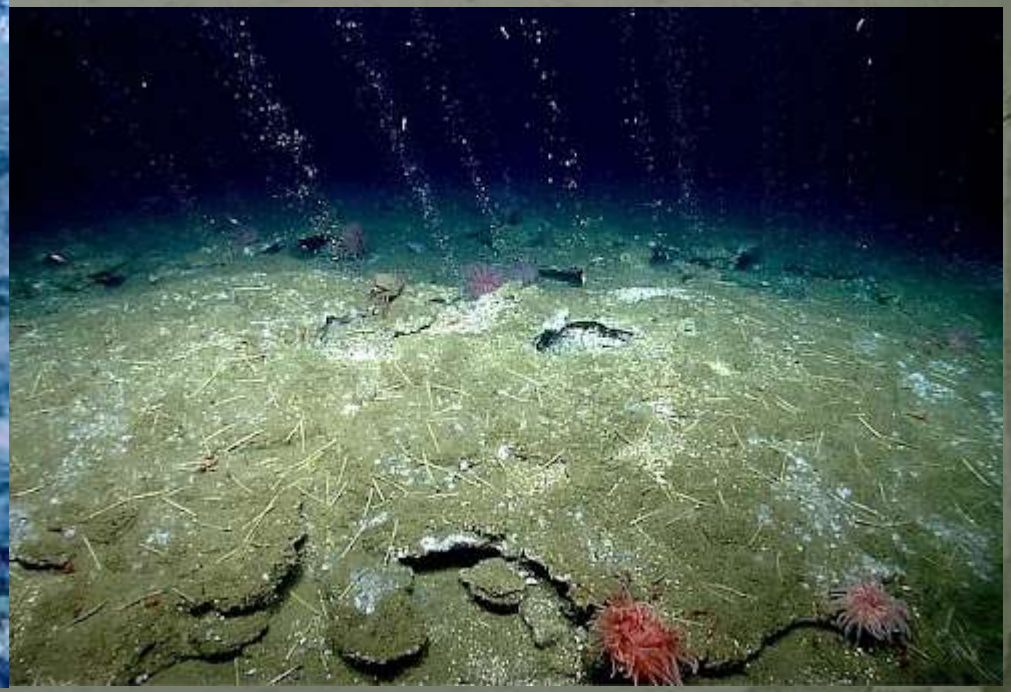
Greenhouse Gases: Methane

- Human activities
  - Rice production
  - Mining
  - Industry
  - Animal husbandry

  (cows 300 litre methane/day)

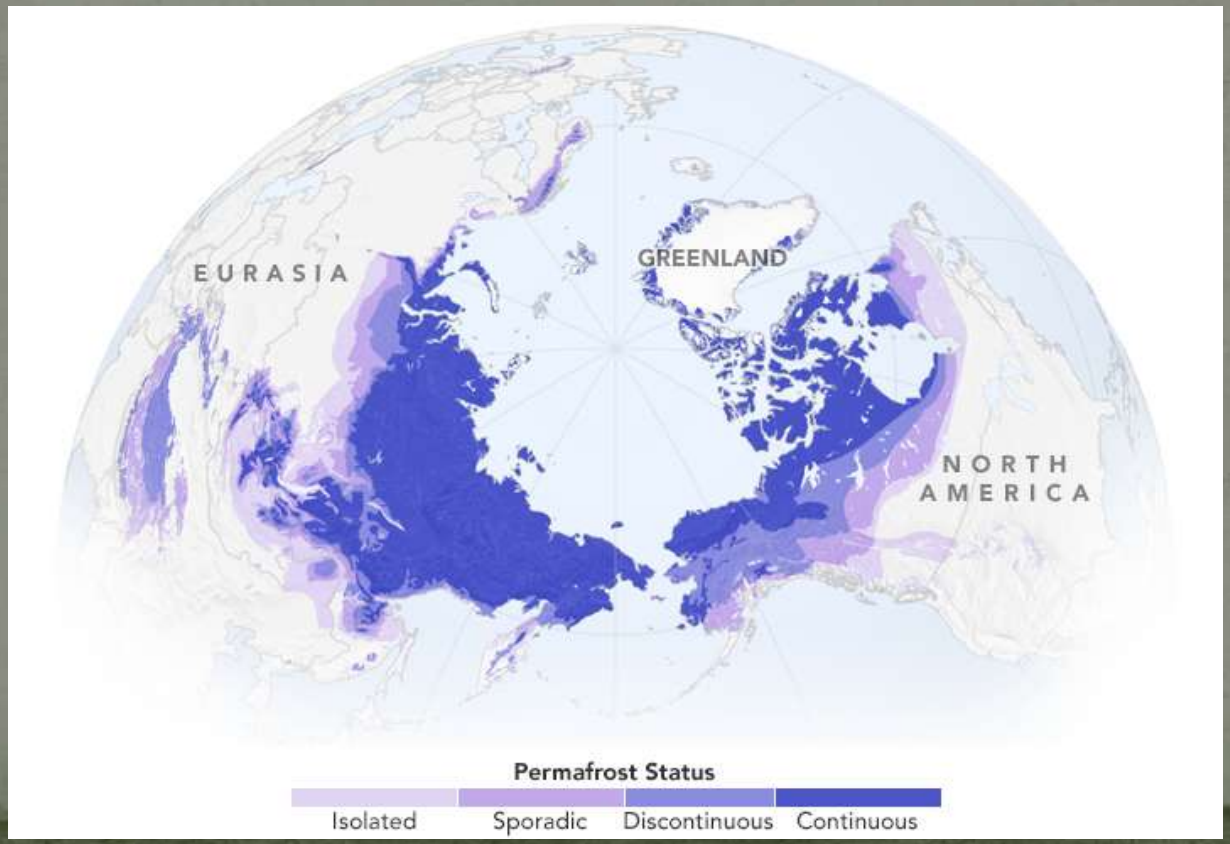
Liberation of methane because of global warming

- From the soil of arctic areas
- From the oceans



Permafrost melting

Permafrost: a thick subsurface layer of soil that remains below freezing point throughout the year, occurring chiefly in polar regions.



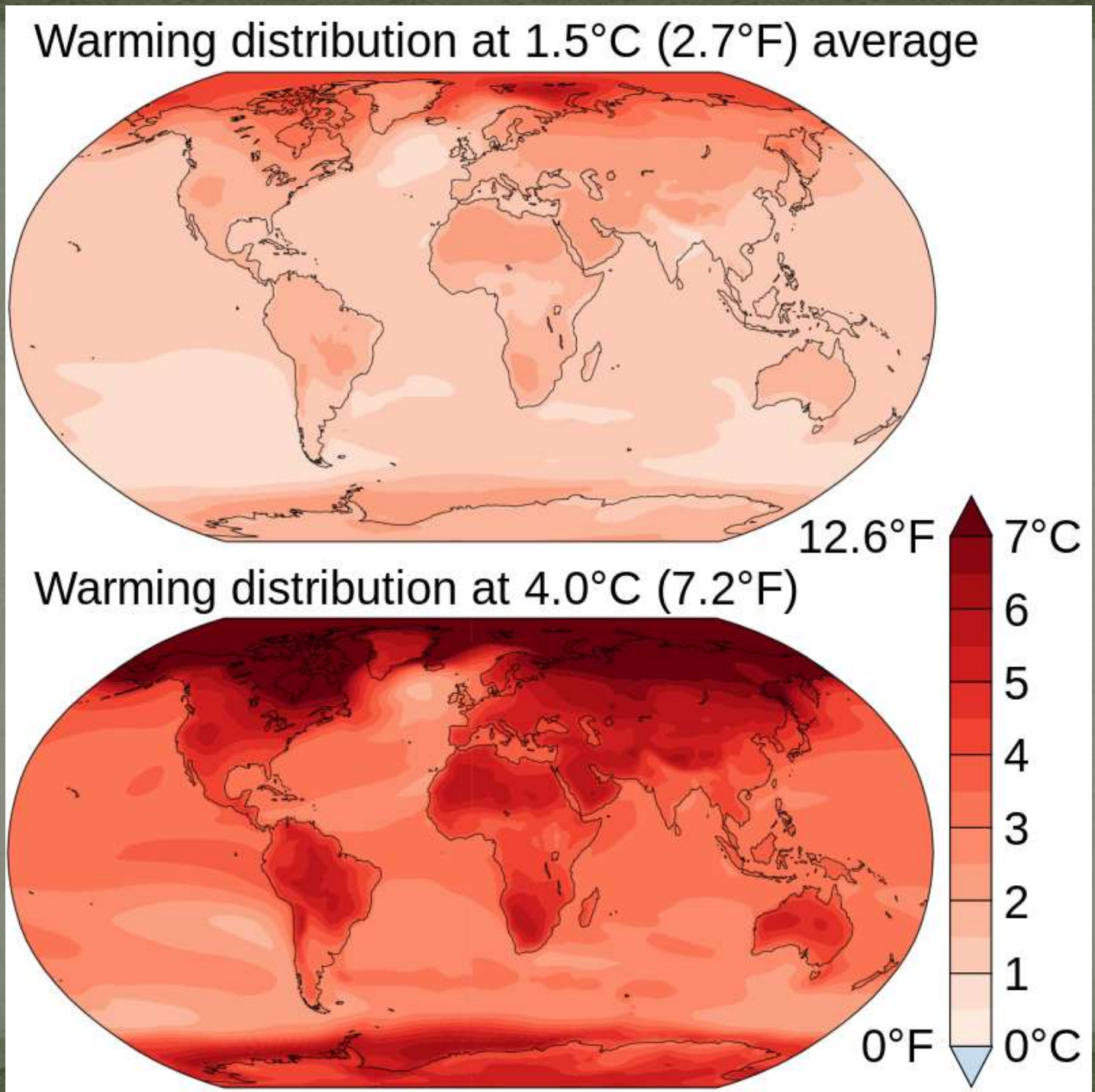
Permafrost melting because of global warming

- „Drunken forests”: Thawing makes trees bend and snap, leading to widespread tree mortality.

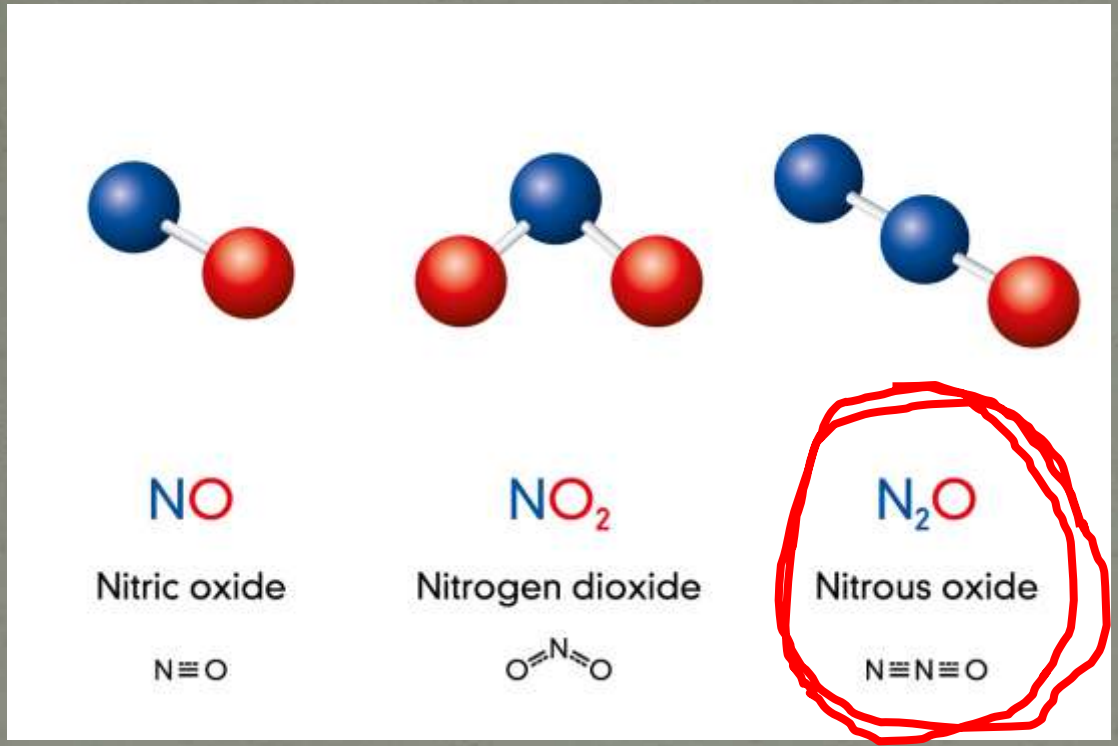
Permafrost melting because of global warming

- Methane emission from melted soil:
  - explosions (gas emission craters)
  - thermokarst lakes

- A gas emission crater is recent arctic phenomenon where melting permafrost releases enormous volumes of trapped gas in an explosive event. (wikipedia)


Warming distribution at 1.5°C (2.7°F) average
12.6°F
7°C
6
5
4
3
2
1
0°C
Warming distribution at 4.0°C (7.2°F)
0°F

Greenhouse Gases: nitrous oxide



- Efficiency potential: 310 unit!
- Residence time in the atmosphere: 114 years

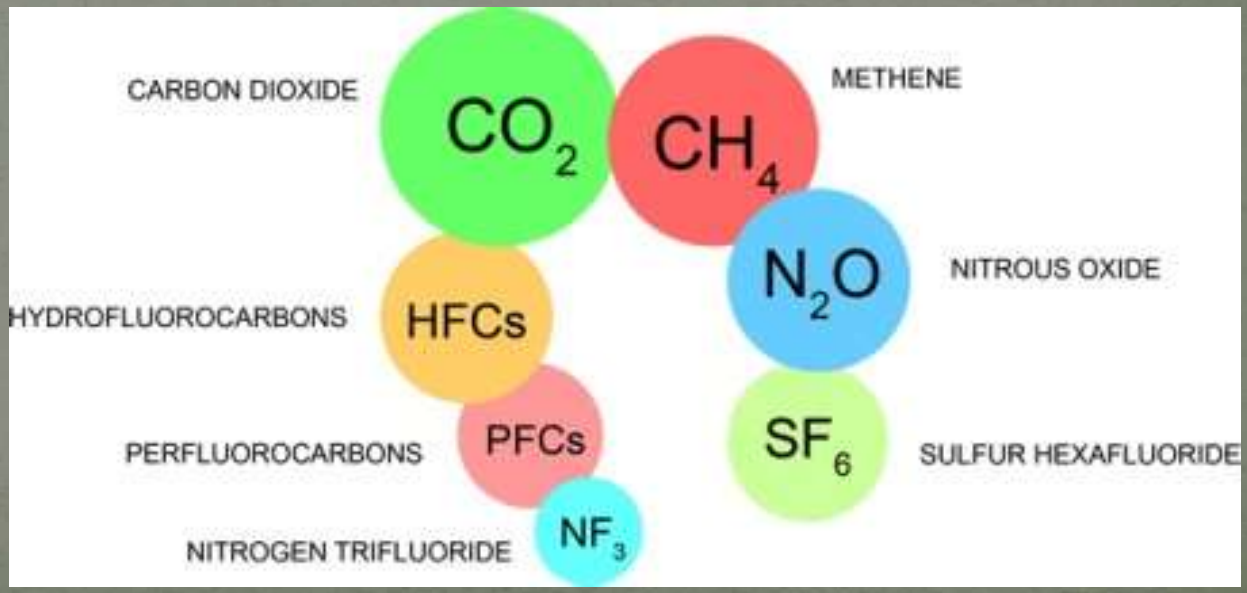
Greenhouse Gases: nitrous oxide

Sources:

- Transport
- Burning of fossil fuels
- Combustion of biomass
- Fertilizers in agriculture

Other greenhouse gases

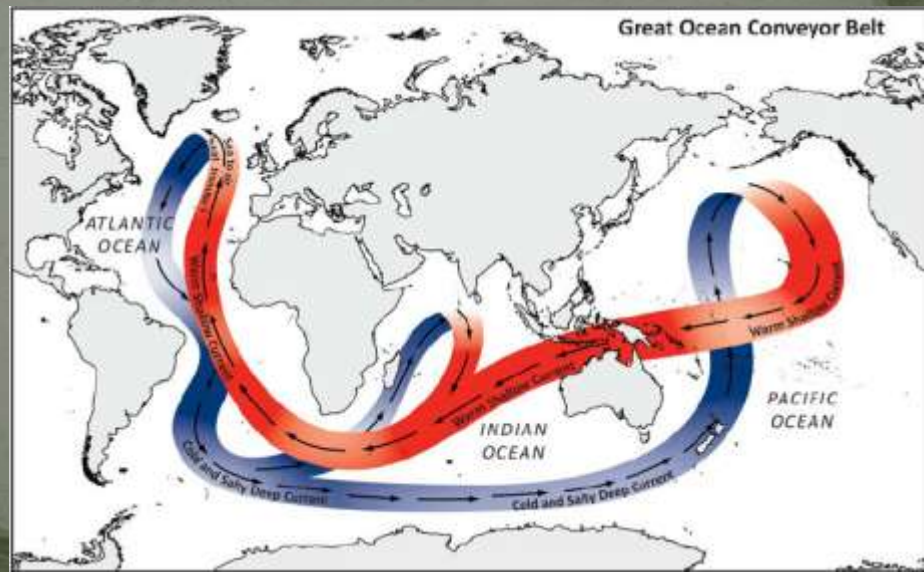
- Halogenated hydrocarbons = CFCs
(e.g. chloro-fluorocarbons, hydrofluorocarbons)
- Sulfur hexafluoride
- Ozone (tropospheric)
- Carbon monoxide



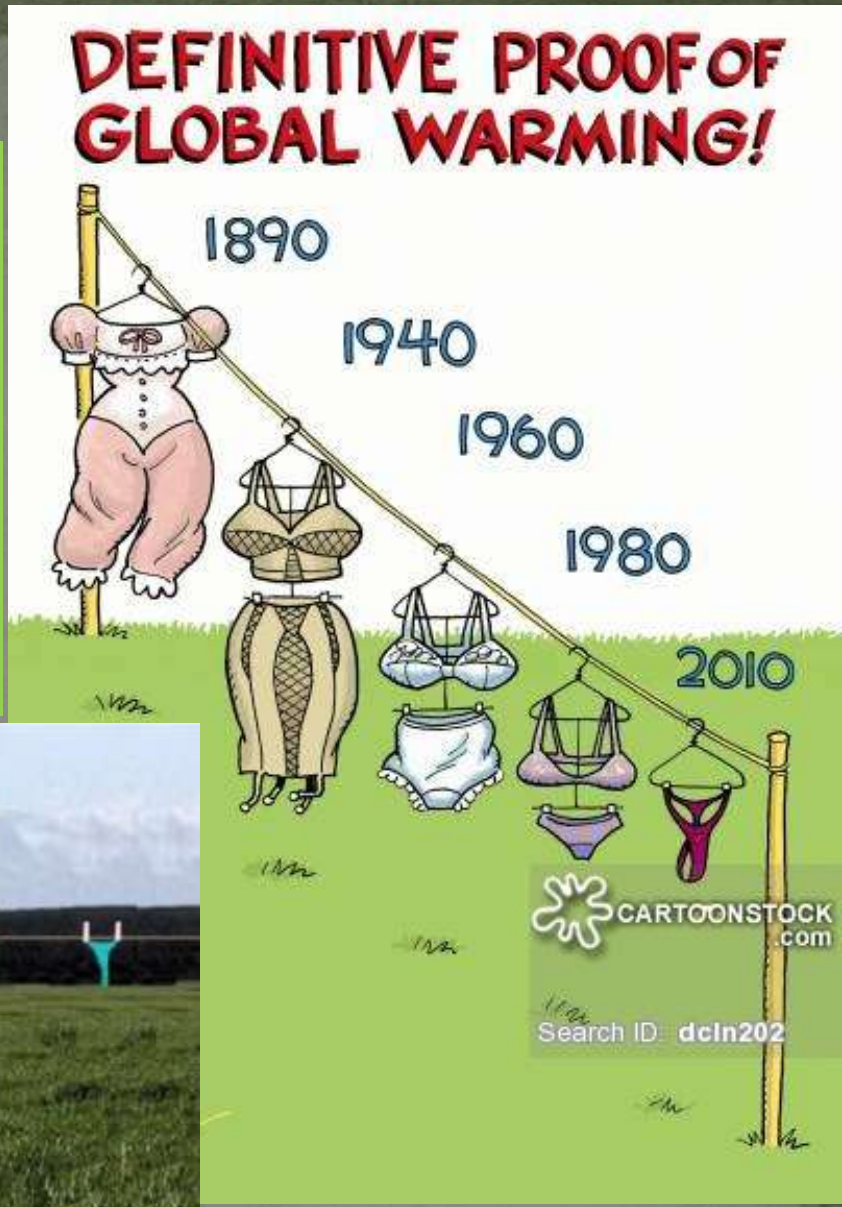
Effects of global warming

- Warming of the atmosphere
- Changes of the surfaces covered by ice
- Desertification
- Extreme weather, more frequent natural disasters
- Weakening of ocean conveyor belt

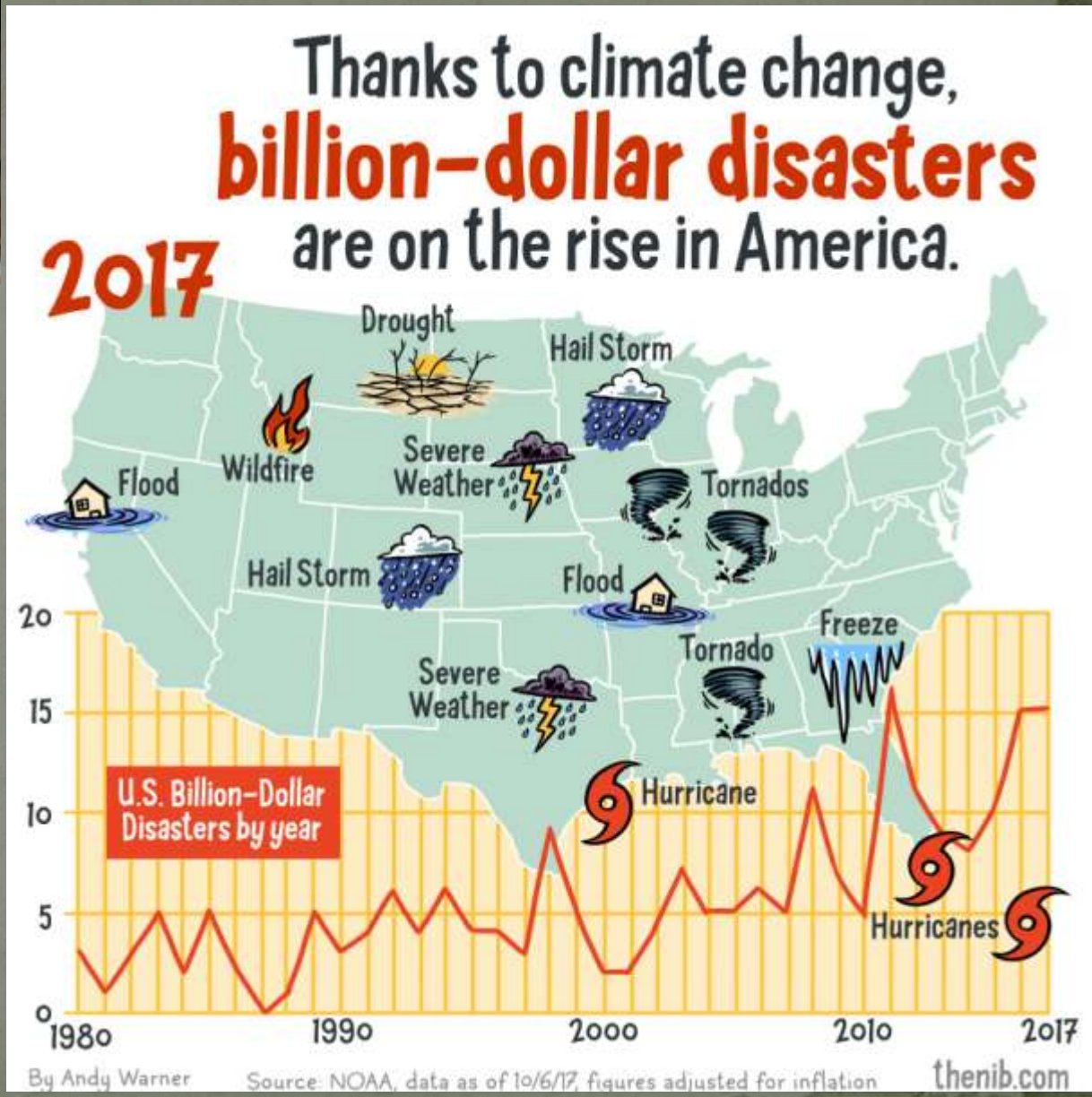
- Climate change



Climate change – is not a joke

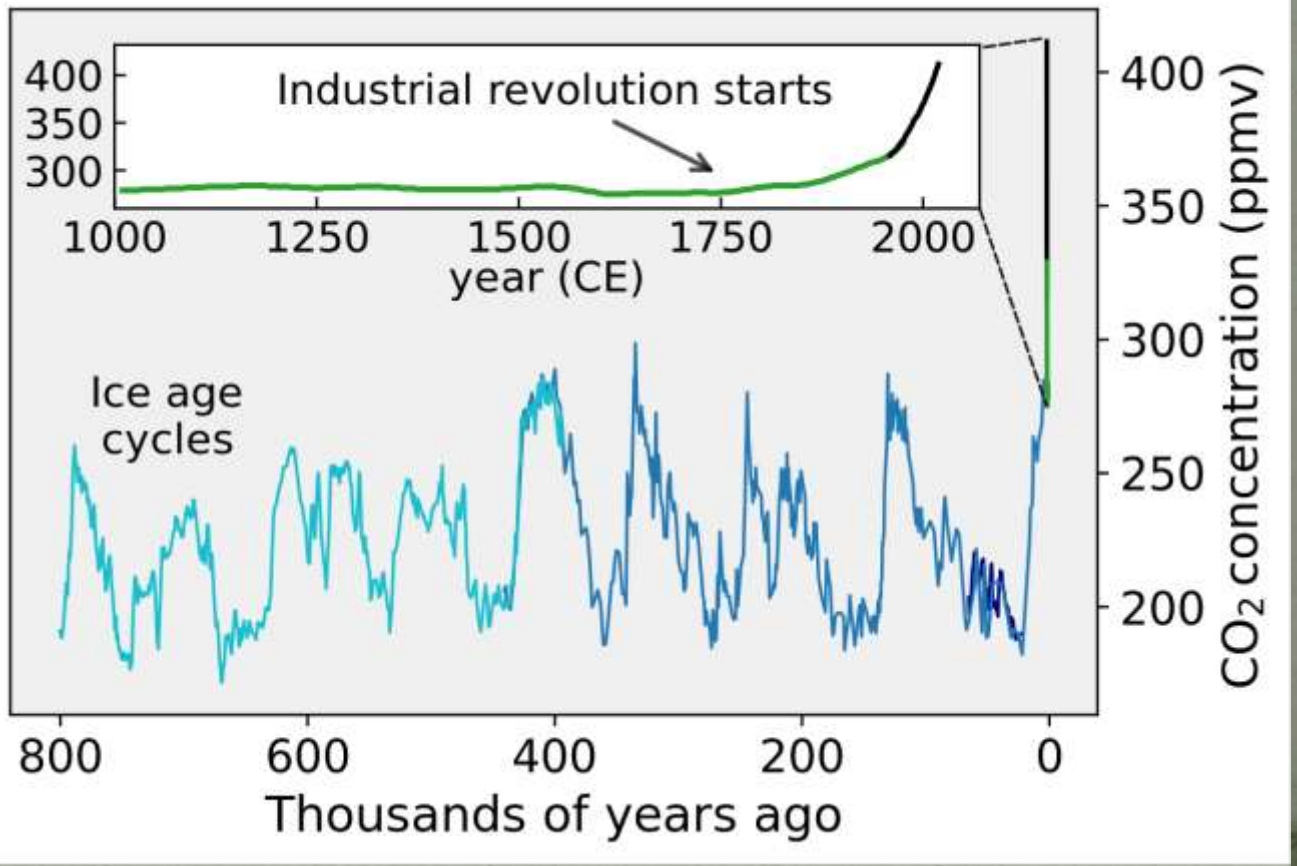


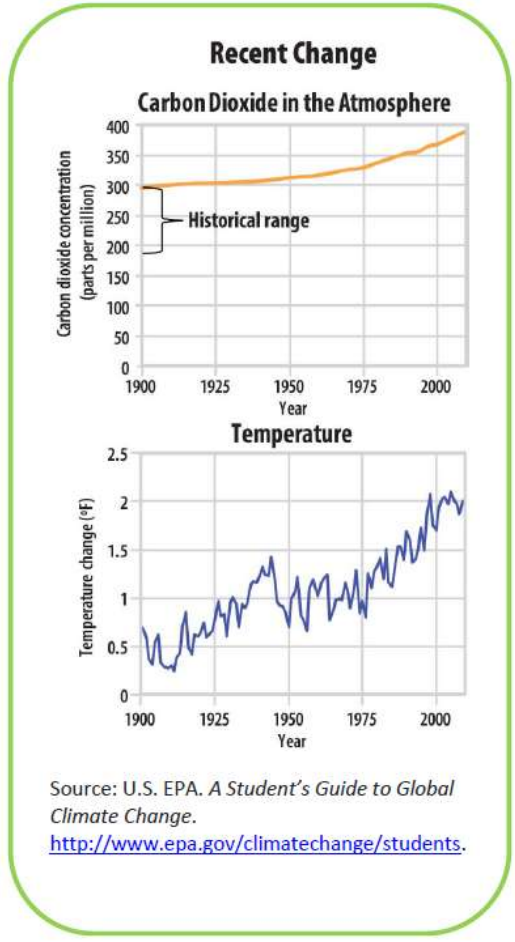
Increasing costs



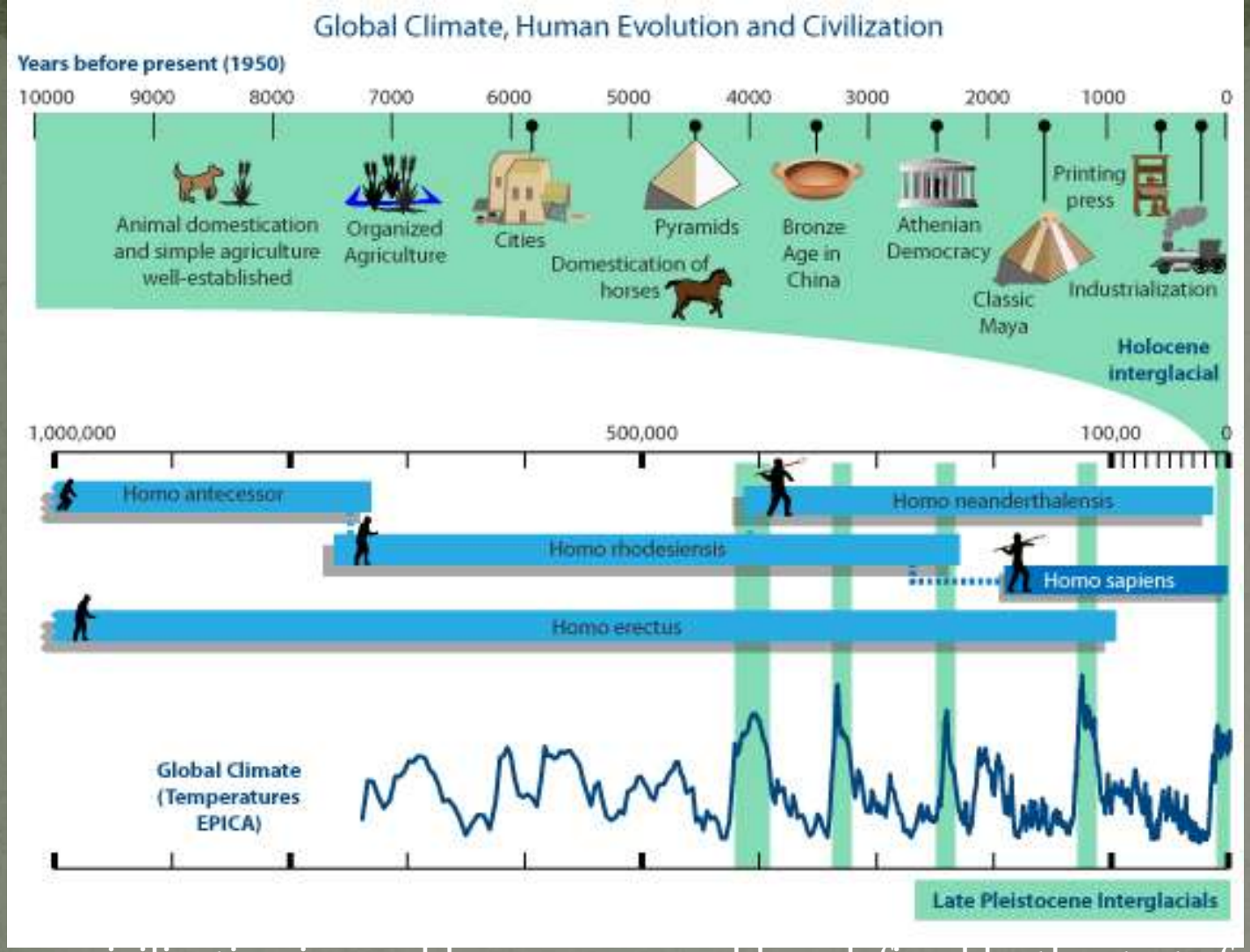
- Ice samples from Antarctica and Greenland > data of concentration of CO_2 CH_4, temperature (ratio of hydrogen/deuterium) let to know the history for 800 000 years!
- Very close relation between level of CO_2 CH_4 and temperature
- In 2022, level of CO_2 reached the 421 ppm!

1.5. ábra. Antarktiszi jégfuratminta a Dome C kutatóállomásról. (Fotó: Laurent Augusti CNRS/LGGE, Grenoble, France)





Source: U.S. EPA. *A Student's Guide to Global Climate Change*. http://www.epa.gov/climatechange/students.

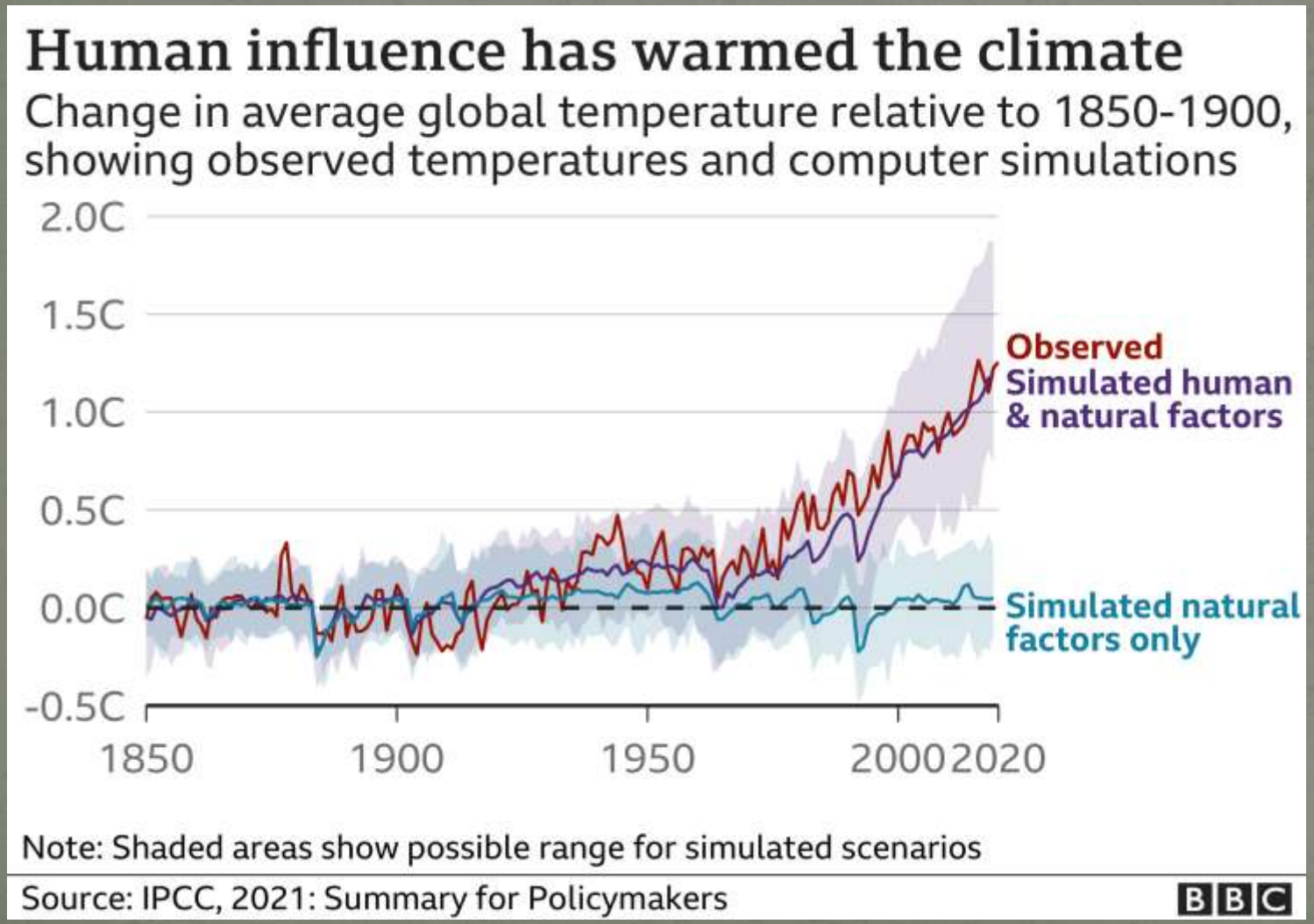


Human civilization is roughly 12,000 years old, as defined by the start of permanent settlements and agriculture.

Agriculture became established as the glaciers retreated from the last ice age.

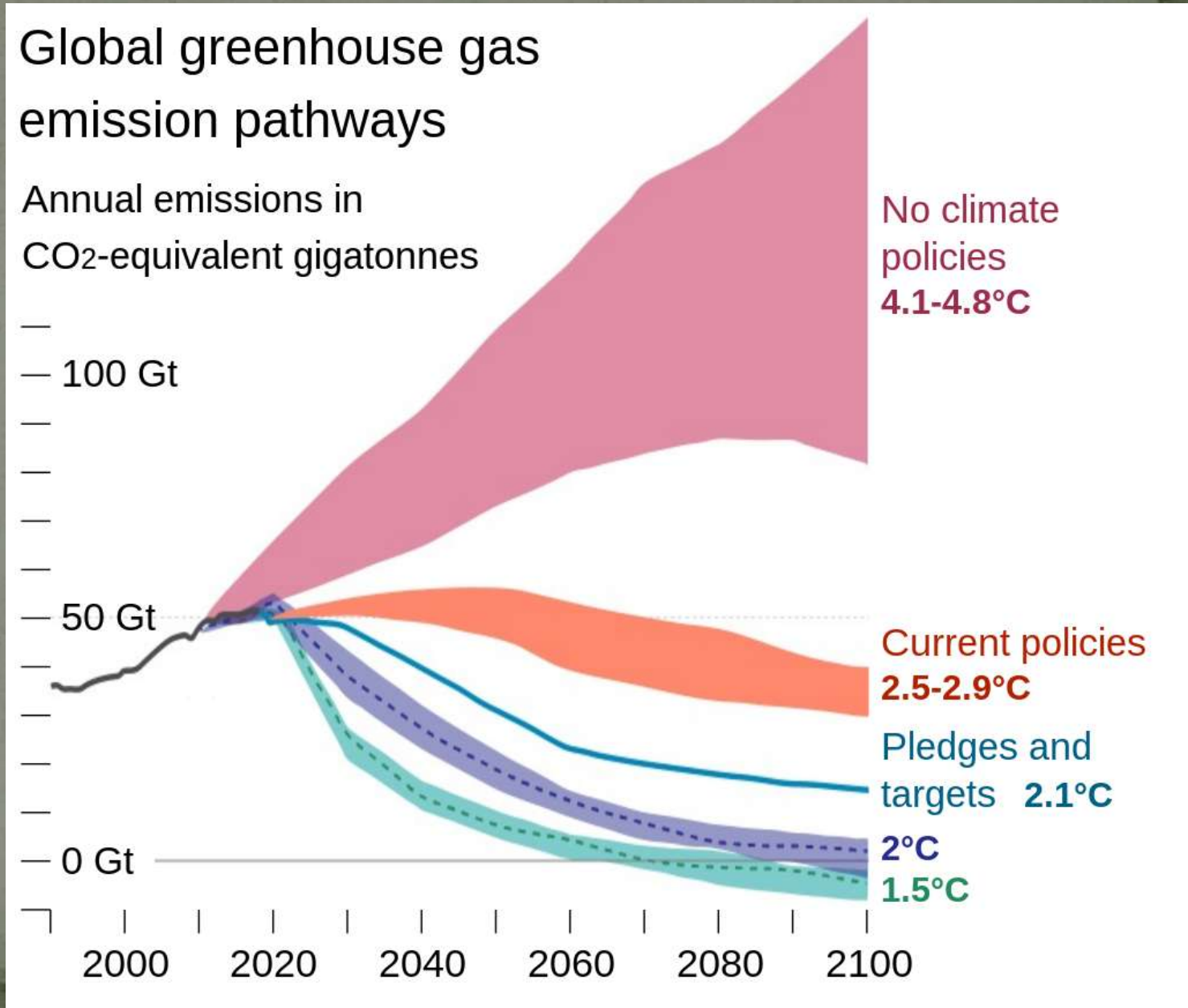
Modern society has developed entirely in our current geological epoch, the Holocene. **Global temperatures haven't varied by more than ±1 °C since**.

1. Warming of the atmosphere

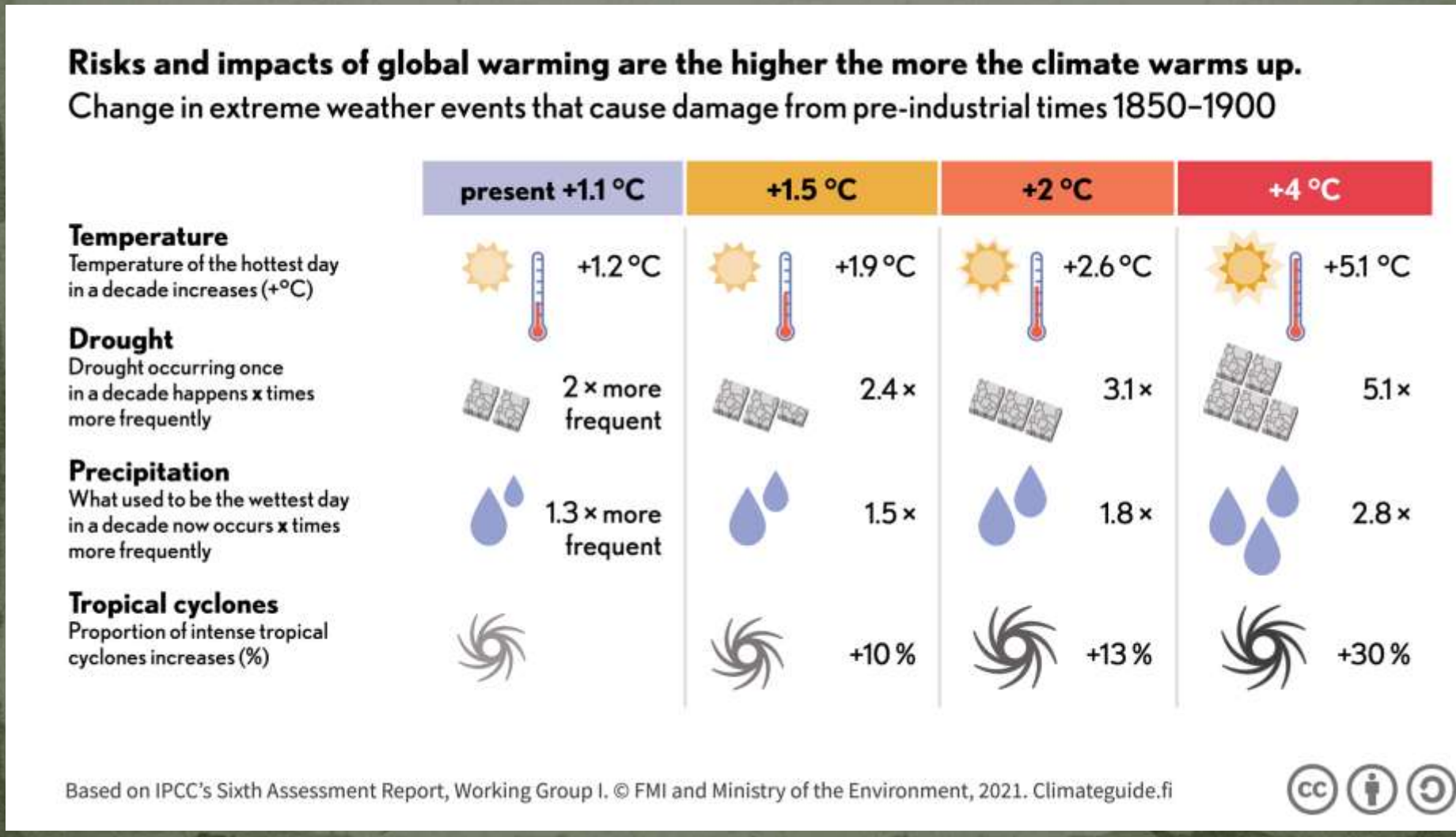


IPCC The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations. Its job is to advance scientific knowledge about climate change caused by human activities

scenarios

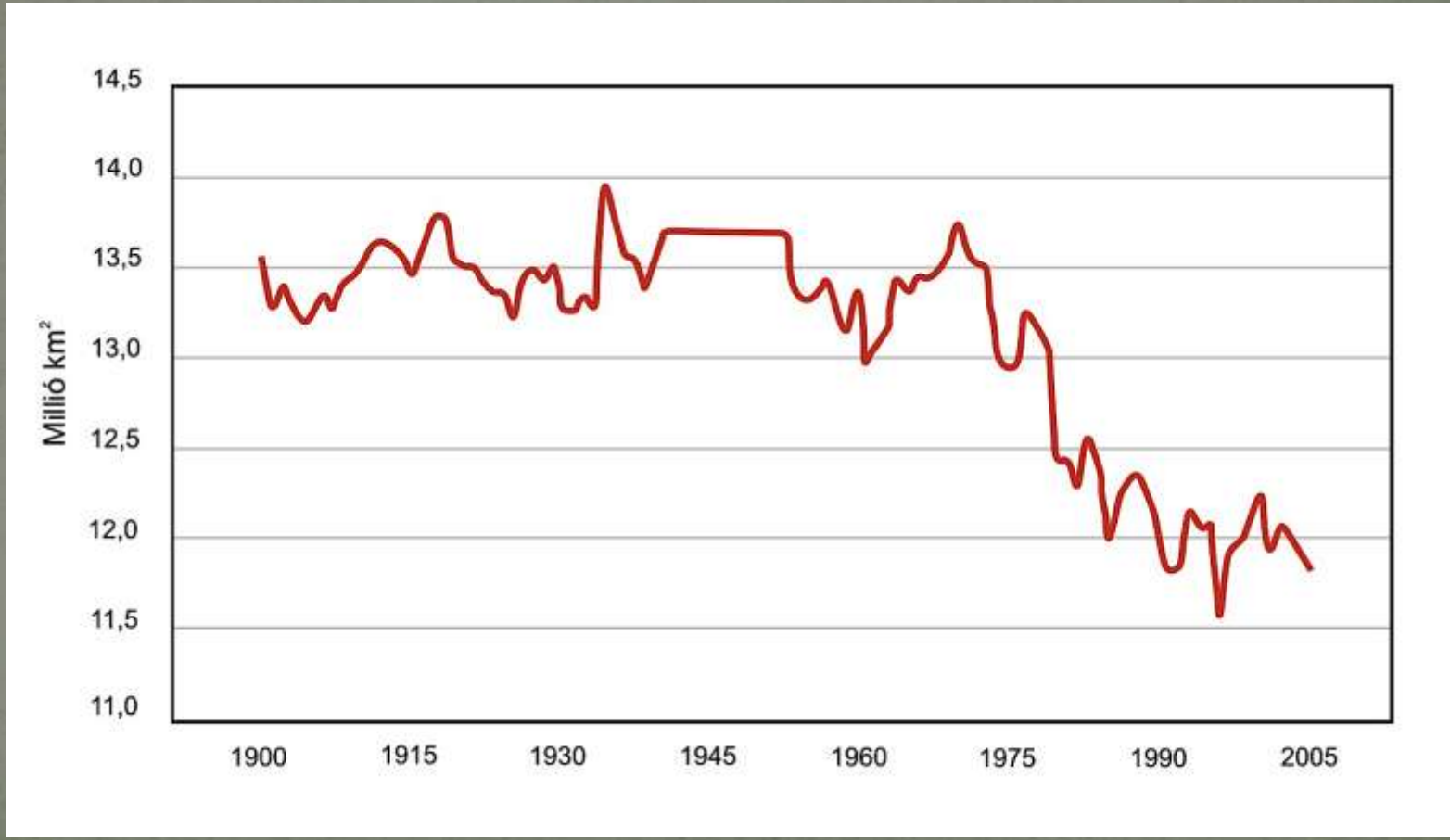


1. Warming of the atmosphere



2. Changes of the surfaces covered by ice

- North Pole



Is Northwest Passage viable?

New York Times, Aug. 19, 2000:
Ages-Old Icecap at North Pole Is Now Liquid, Scientists Find

„The North Pole is melting.
The thick ice that has for ages covered the Arctic Ocean at the pole has turned to water, recent visitors there reported yesterday. At least for the time being, an ice-free patch of ocean about a mile wide has opened at the very top of the world, something that has presumably never before been seen by humans and is more evidence that global warming may be real and already affecting climate.
The last time scientists can be certain the pole was awash in water was more than 50 million years ago."

New York Times, Aug. 19, 2000:

Ages-Old Icecap at North Pole Is Now Liquid, Scientists Find

"It was totally unexpected," said Dr. James J. McCarthy, an oceanographer, director of the Museum of Comparative Zoology at Harvard University and the co-leader of a group working for the Intergovernmental Panel on Climate Change, which is sponsored by the United Nations. The panel is studying the potential environmental and economic consequences of marked climate change.

Dr. McCarthy was a lecturer on a tourist cruise in the Arctic aboard a Russian icebreaker earlier this month. On a similar cruise six years ago, he recalled, the icebreaker plowed through an icecap six to nine feet thick at the North Pole.

This time, ice was generally so thin that sunlight could penetrate and support concentrations of plankton growing under the ice. Dr. McCarthy said the icebreaker's Russian captain, who has made the voyage 10 times in recent years, said he had never before encountered open water at the pole.

New York Times, Aug. 19, 2000:
Ages-Old Icecap at North Pole Is Now Liquid, Scientists Find

„Another lecturer, Dr. Malcolm C. McKenna, a paleontologist at the American Museum of Natural History, said the ship, the Yamal, crunched through miles of unusually thin ice and intermittent open water on the approach from Spitsbergen, Norway, to the pole. When the ship reached the pole -- which Dr. McKenna and his wife, Priscilla, confirmed with a handheld Global Positioning System navigation device -- water lapped its bow.

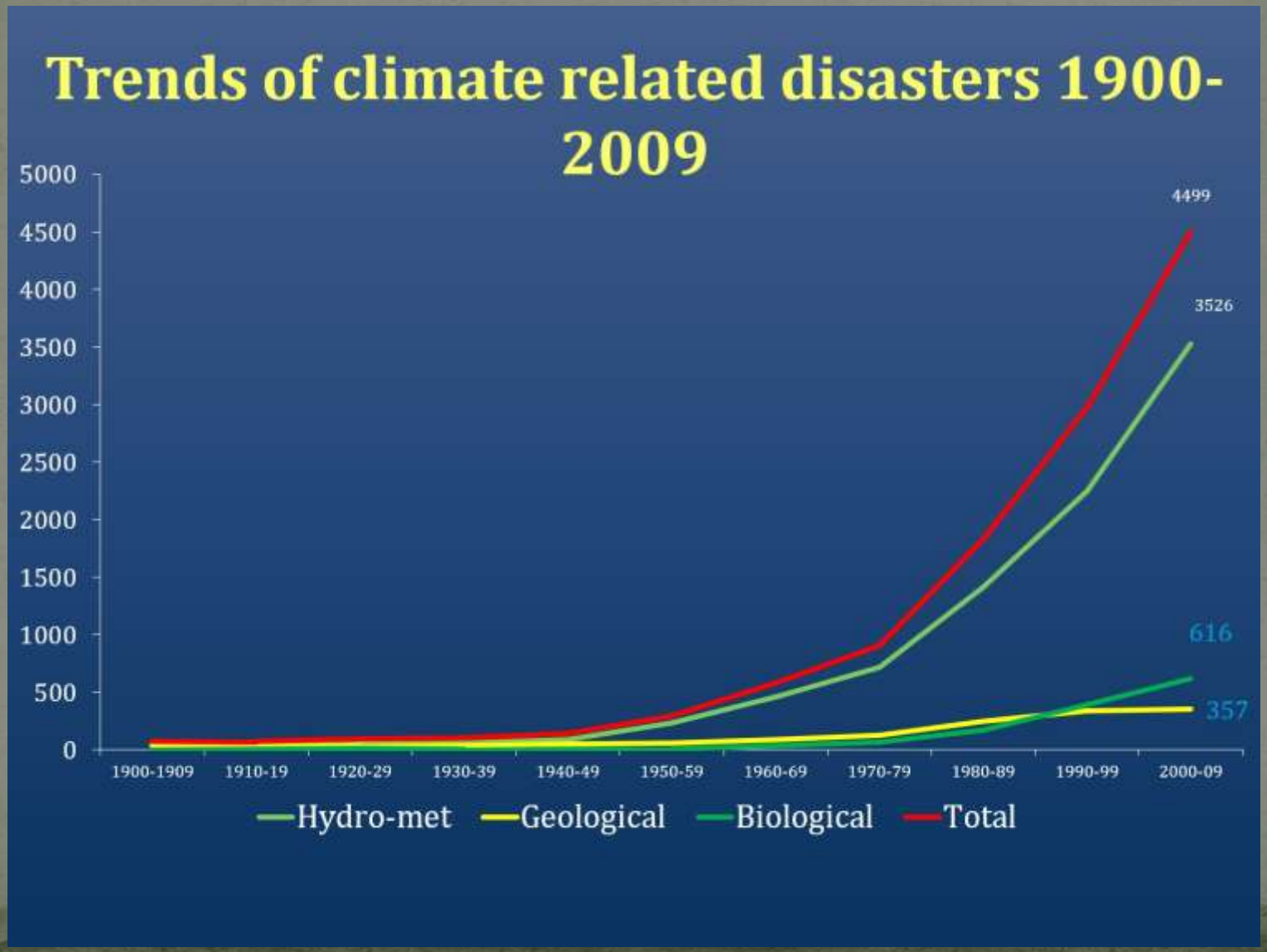
"I don't know if anybody in history ever got to 90 degrees north to be greeted by water, not ice," Dr. McKenna said in an interview. He instantly snapped pictures to document the phenomenon in photographs.

The Yamal eventually had to steam six miles away to find ice thick enough for the 100 passengers to get out and be able to say they had stood on the North Pole, or close to it. They saw ivory gulls flying overhead, the first time ornithologists said they had ever been sighted at the pole."

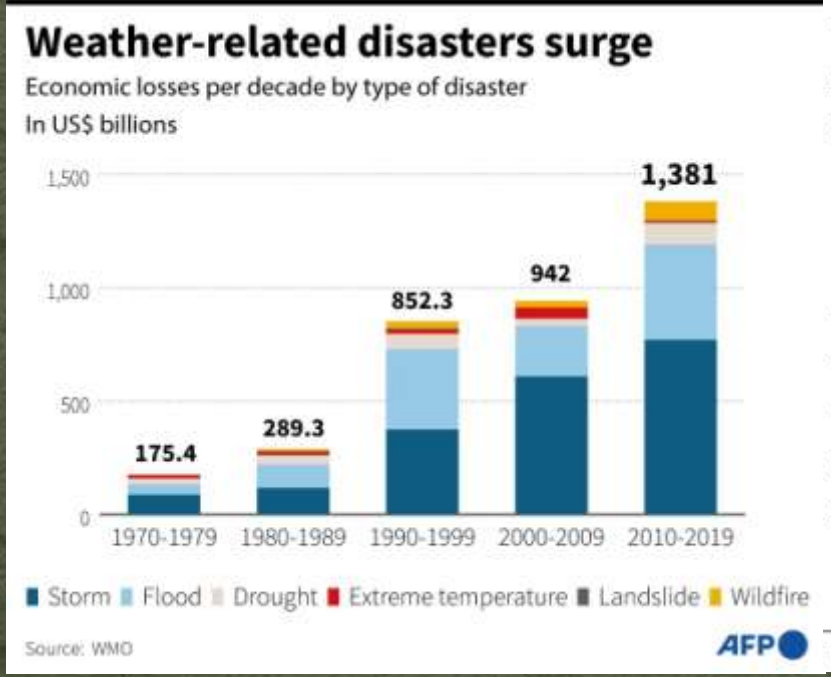
3. Desertification

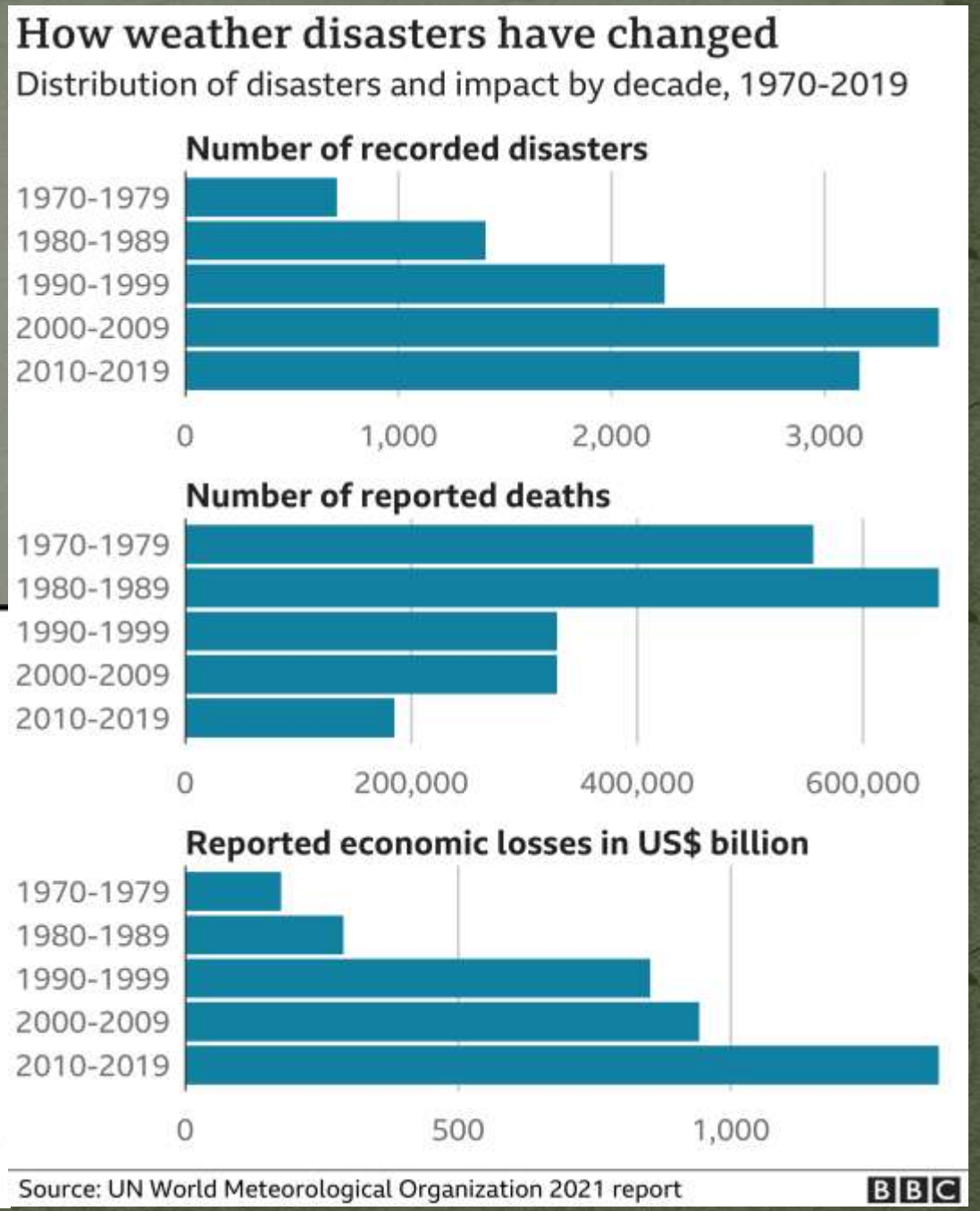
- Less precipitation
- Warming of the atmosphere
- Poor vegetation, ecological instability
- Human activities
  - Growth of population
  - Demand of food ↑
  - Live-stock ↑ (overgrazing)
  - Erosion
  - Deforestation
  - Wars
  - Escalating use of water

4. More frequent natural disasters



4. More frequent natural disasters





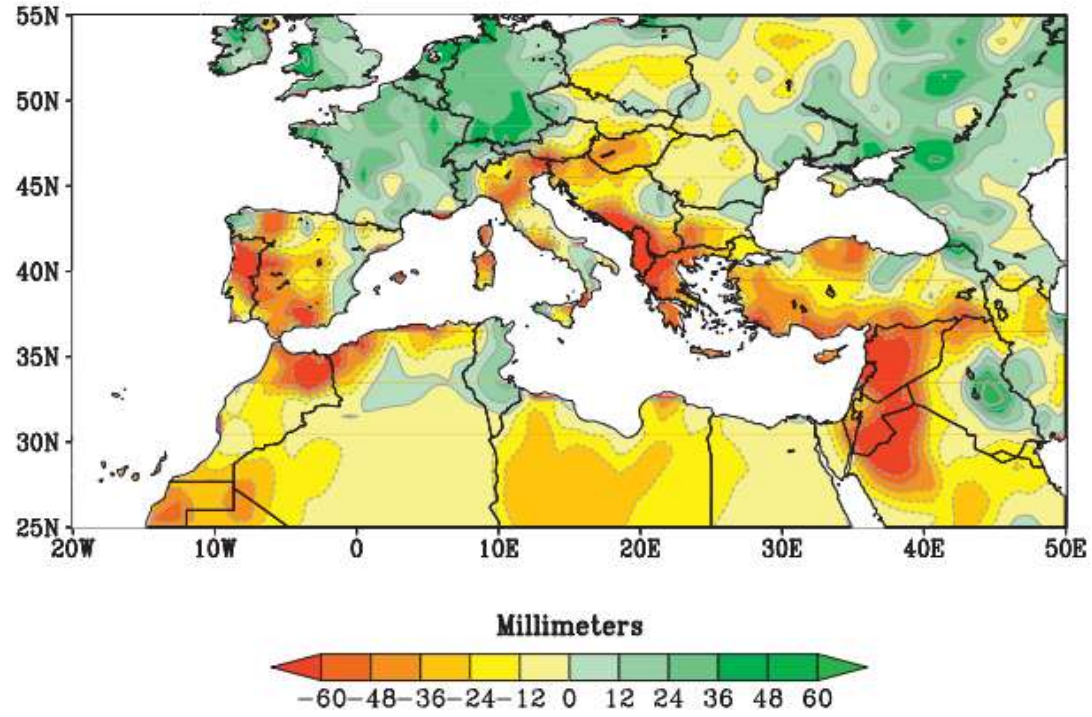
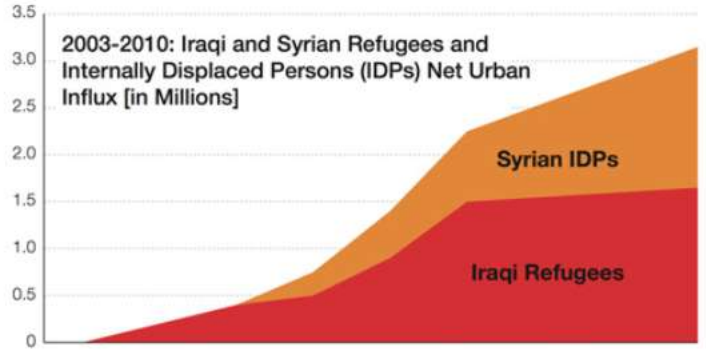
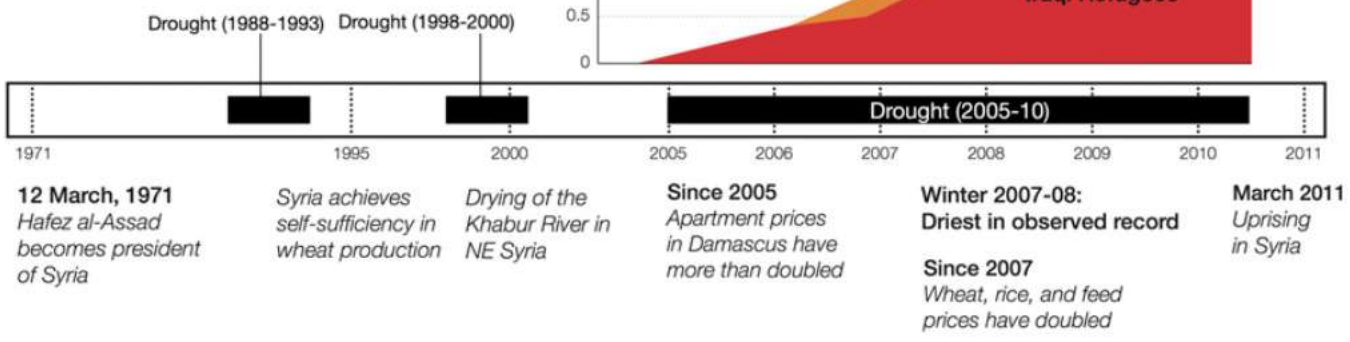


FIG. 1. (top) Observed time series of Mediterranean (30°–45°N; 10°W–40°E) cold season (November–April) precipitation for the period 1902–2010 and (bottom) the observed change in cold season precipitation for the period 1971–2010 minus 1902–70. Anomalies (mm) are relative to the 1902–2010 period. Solid curve is the smoothed precipitation time series using a nine-point Gaussian filter. Data are from the GPCC.

Increasing tension in human societies – increase of migration





Questions

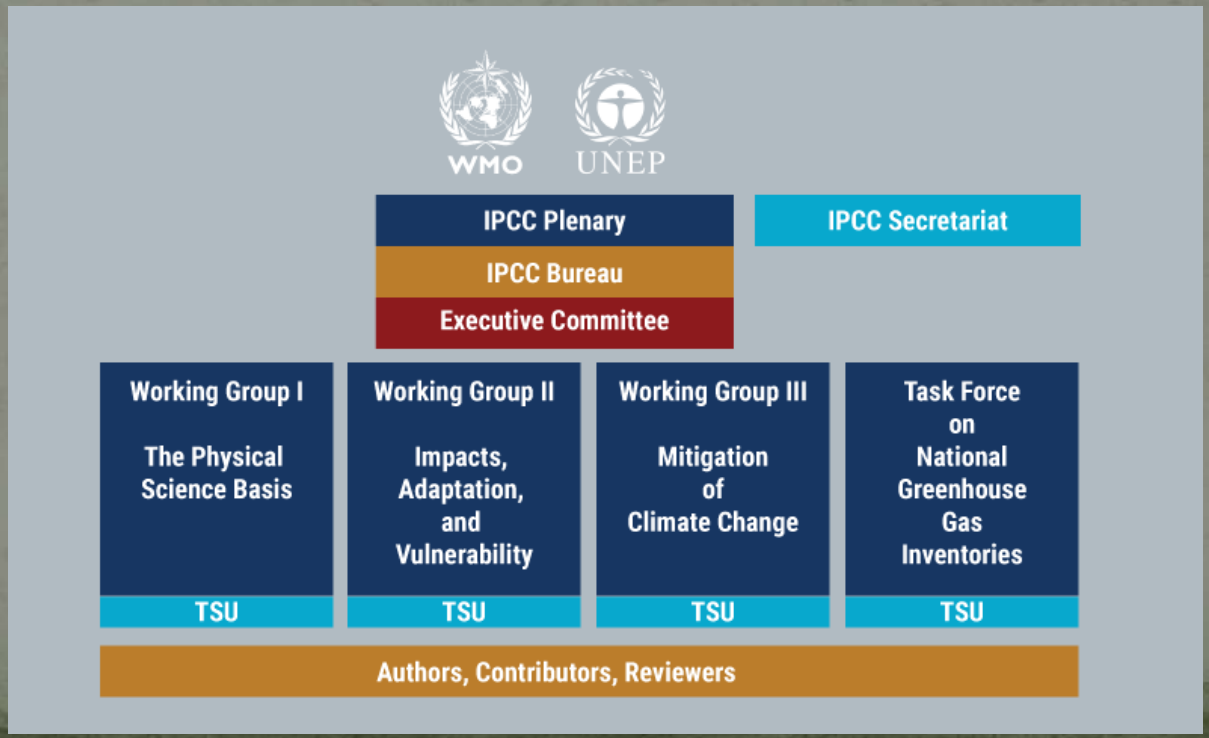
- What is the consequence of the presence of greenhouse gases?
- What was the starting point of the emission of greenhouse gases?
- What are the main causatives of abnormal greenhouse effect?
- What are the differences between greenhouse gases?
- What are the sources of greenhosue gases?
- What are the effects of global warming?

Climate Protection and Renewable Energy Sources

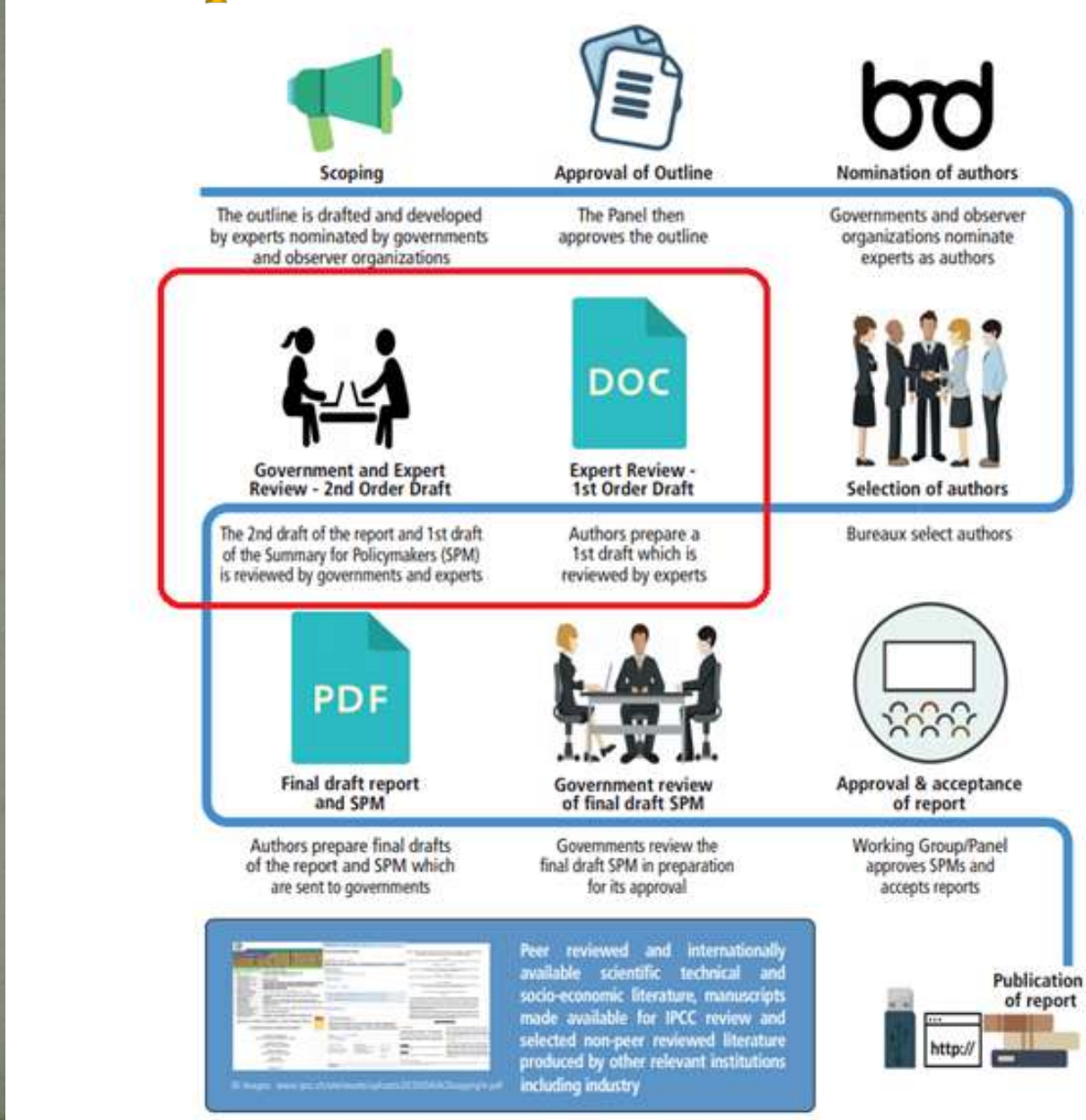
- Created in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP)
- The IPCC is an organization of governments that are members of the United Nations or WMO. The IPCC currently has 195 members.

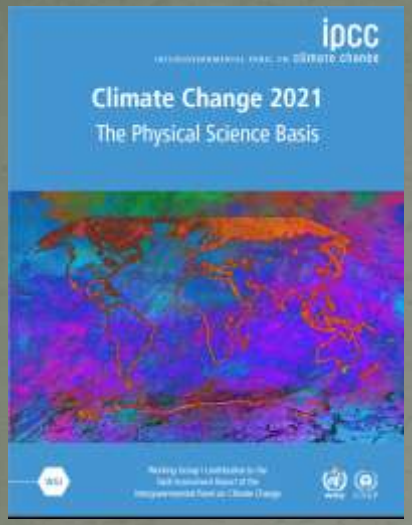
- The objective of the IPCC is …
  - …to provide governments at all levels with scientific information that they can use to develop climate policies.
  - …to provide a comprehensive summary of what is known about the drivers of climate change, its impacts and future risks, and how adaptation and mitigation can reduce those risks.

- **Working Groups**
  - Working Group I deals with The Physical Science Basis of Climate Change,
  - Working Group II with Climate Change Impacts, Adaptation and Vulnerability
  - and Working Group III with Mitigation of Climate Change.
- **Task Forces:** The main objective of the Task Force on National Greenhouse Gas Inventories is to develop and refine a methodology for the calculation and reporting of national greenhouse gas emissions and removals.
- **Technical Support Units**
- **Bureau**
- **Panel**



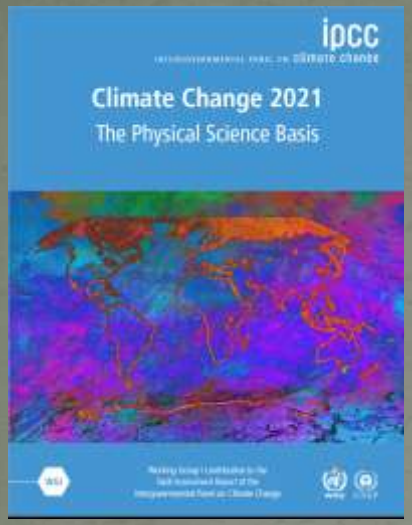
IPCC Report Preparation Process





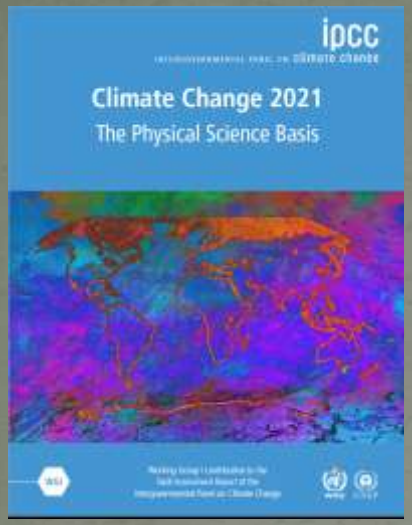
The Sixth Assessment Report (2021)

- **A.1** Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850–1900 in 2011–2020. Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals.



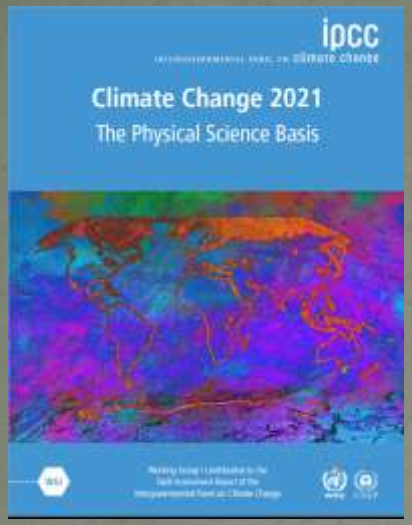
The Sixth Assessment Report (2021)

- **A.2** Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people (high confidence). Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected.



The Sixth Assessment Report (2021)

- **A.4** Policies and laws addressing mitigation have consistently expanded since „Assessment Report 5". „Global Greenhouse Gas emissions" in 2030 implied by nationally determined contributions (NDCs) announced by October 2021 make it likely that warming will exceed 1.5°C during the 21st century and make it harder to limit warming below 2°C. There are gaps between projected emissions from implemented policies and those from NDCs and finance flows fall short of the levels needed to meet climate goals across all sectors and regions.



The Sixth Assessment Report (2021)

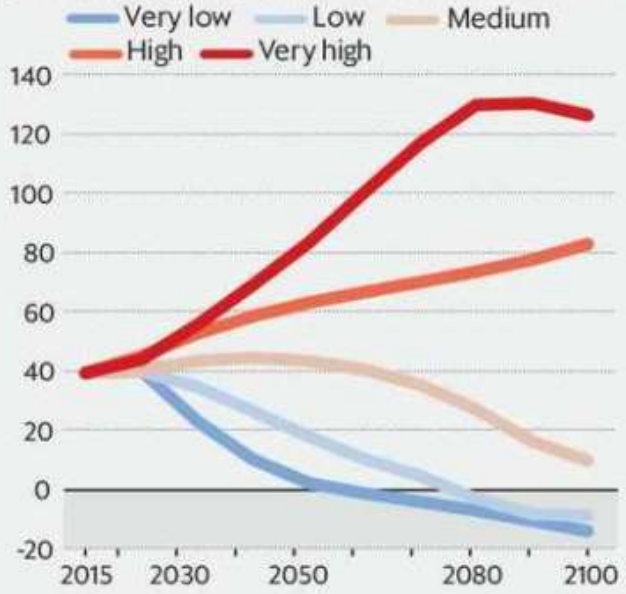
- **A.5** Limiting human-caused global warming requires net zero CO_2 emissions. Cumulative carbon emissions until the time of reaching net-zero CO_2 emissions and the level of greenhouse gas emission reductions this decade largely determine whether warming can be limited to 1.5°C or 2°C. Projected CO_2 emissions from existing fossil fuel infrastructure without additional abatement would exceed the remaining carbon budget for 1.5°C (50%).

A look at the change in emission levels and rise in global temperatures as projected by the intergovernmental panel:

Target zero

It's possible to reach net zero carbon by 2060 at very low emission levels. But at higher levels, it may not be possible to reach that goal in this century, the IPCC says.

Projected carbon dioxide level (bn tonnes/year) at various emission levels



DATA BY **TANAY SUKUMAR/MINT**

Projected rise in global temperature

(relative to 1850-1900) (in °C)

> Today's report is 'Code Red' for humanity ... it must sound a death knell for coal, fossil fuels before they destroy the planet
>
> **Antonio Guterres**
> UN secretary general

Likely rise in global mean sea level (in metres)

by 2100 (relative to 1995-2014)

Figures are midpoint estimates

Source: IPCC

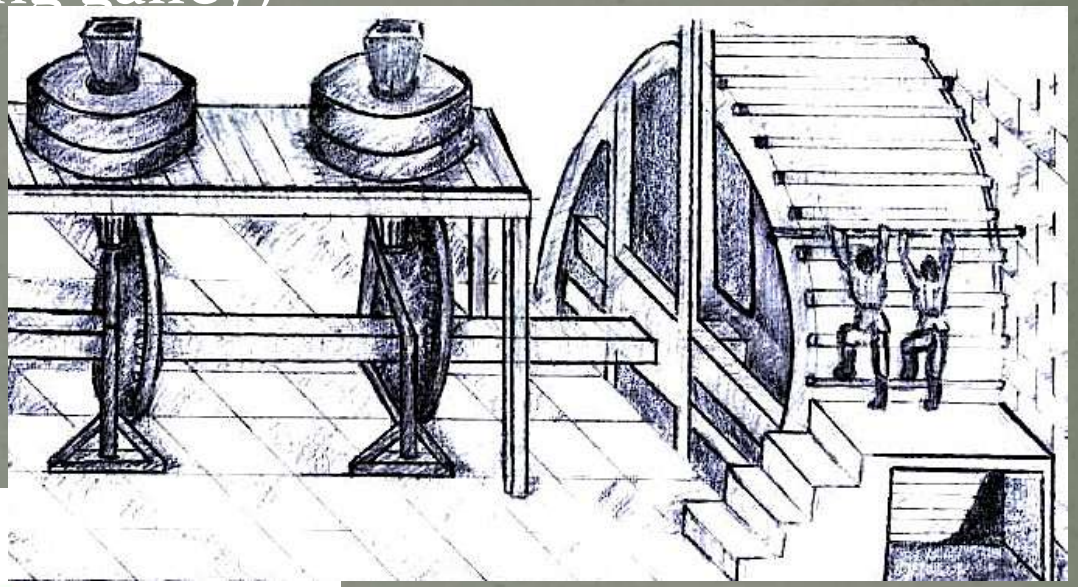
Projection for South Asia in 21st century:
Heatwaves and **humid heat stress** to be more intense and frequent. Annual and summer **monsoon precipitation** to rise

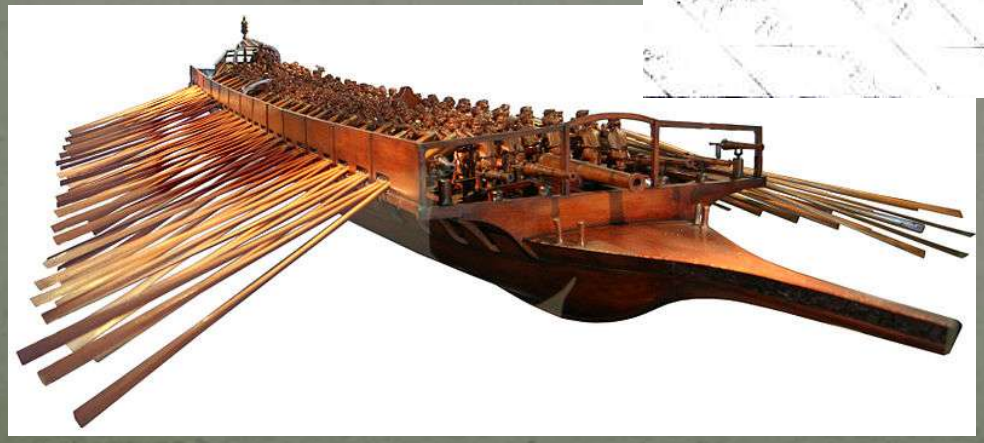
Net Zero
Carbon Emission by 2050?

Renewable Energy Sources

Antecedents in Ancient Times

- Force of muscles / animal or human
  (treadmills, rowing galley)

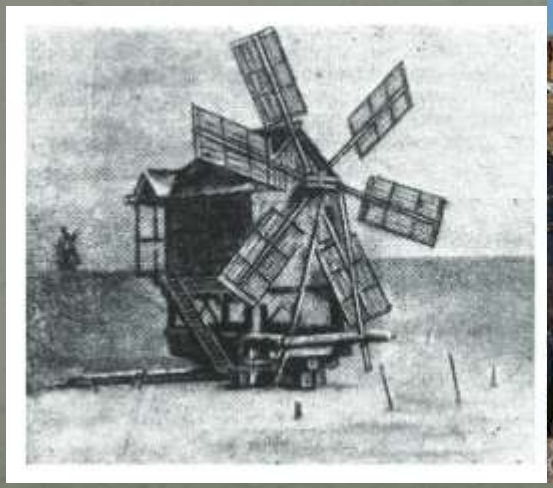




Energy Sources in Ancient Times

- Wind power
  - Sailing boats
  - Wind mills

  (from Egypt, BC 1200)
  - Wind wheels



Ancient wind mills in Nashtifan,Iran

Antecedents in Medieval Era

- Hydropower
  - Water wheels

  (ancient Greek invention)
  - Water mills
  - Ebb/flow force power,

    tidal mills (7th century)

Dürer: The Wire-drawing mill

Albertini: Medieval sawmill with hydraulic power

Medieval paper mill in Vetrní

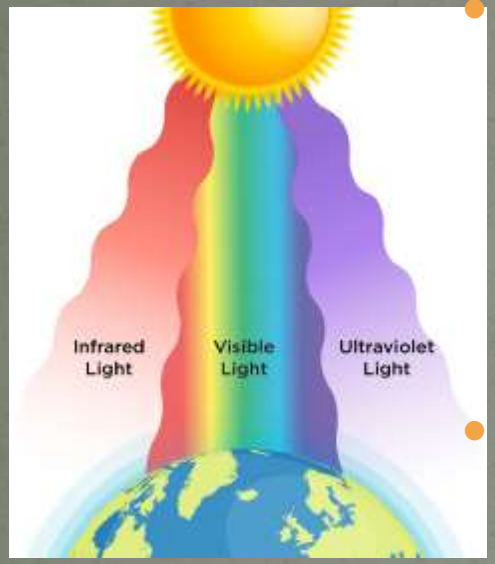
Water driven silk throwing mill at Tring (19th century)

Renewable Energy Sources in our days

Solar Energy

- Solar energy is any type of energy generated by the sun.
- Solar energy is created by nuclear fusion that takes place in the sun. Fusion occurs when protons of hydrogen atoms violently collide in the sun's core and fuse to create a helium atom.
- Solar energy is constantly flowing away from the sun and throughout the solar system. Solar energy warms the Earth, causes wind and weather, and sustains plant and animal life.

Solar Energy



- The Sun is an extremely powerful energy source, and sunlight is by far the largest source of energy received by Earth, but its intensity at Earth's surface is actually quite low. This is essentially because of the enormous radial spreading of radiation from the distant Sun.
- A relatively minor additional loss is due to Earth's atmosphere and clouds, which absorb or scatter as much as 54 percent of the incoming sunlight.
- The sunlight that reaches the ground consists of nearly 50 percent visible light, 45 percent infrared radiation, and smaller amounts of ultraviolet and other forms of electromagnetic radiation.

Types of Solar Energy

- **Passive Solar Technology:** It is often involved in the design of a building. For example, in the planning stage of construction, the engineer or architect may align the building with the sun's daily path to receive desirable amounts of sunlight. This method takes into account the latitude, altitude, and typical cloud cover of a specific area.

Types of Solar Energy

- **Active Solar Technologies:**
  - **Concentrated Solar Energy / CSE:** A solar collector is a device that collects and/or concentrates solar radiation from the Sun. These devices are primarily used for active solar heating and allow for the heating of water for personal use.
  - **Photovoltatics / PV :** A photovoltaic system is composed of one or more solar panels combined with an inverter and other electrical and mechanical hardware that use energy from the Sun to generate electricity.

Advantages of Solar Energy

- **Renewable:** Solar energy is a fully renewable energy resource
- **No Fuel Costs:** There are no fuel costs associated with solar energy, which will save money
- **Environmentally Friendly:** Unlike with other energy sources, such as fossil fuels, solar energy doesn't release any harmful natural gases or hazardous by-products

Advantages of Solar Energy

- **Lifetime:** 15-20 years
- On-time investment
- Minimal operating expense
- Economic energy source for off-grid consumers in remote locations

Disadvantages of Solar Energy

- **Reliability:** Solar energy is dependent on the weather and how many hours of sunlight there are. This means that it is better suited to some parts of the world than others.
- **Cost:** Although the costs are reducing, solar energy technology such as solar panels can be expensive to install.

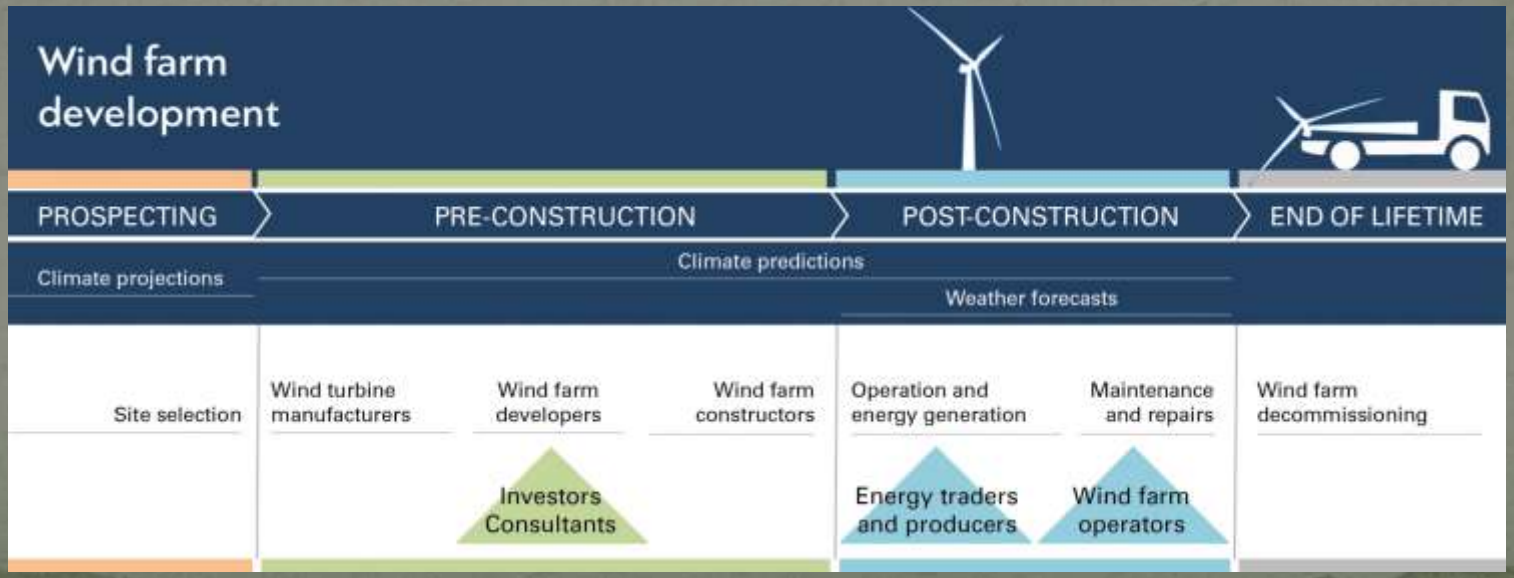
Wind Power

- Wind power or wind energy describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water), or can be converted into electricity by a generator.

Wind turbin installation

Before starting the process, wind turbine installers must conduct a detailed study. The study includes:

- Measuring wind speeds for at least three months to determine the project's feasibility.
- Analyzing the topography of the terrain.
- Assessing accessibility.
- Evaluating typical weather conditions.



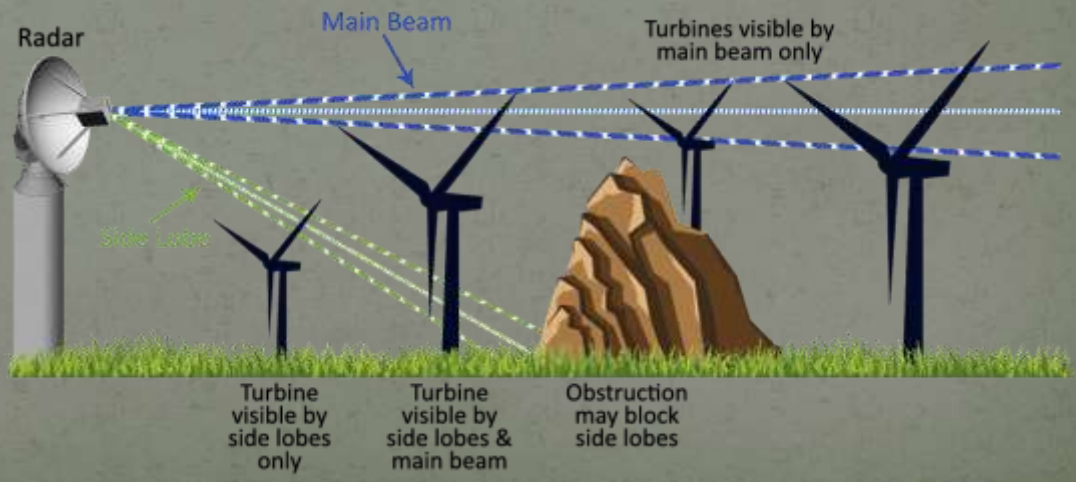
Wind turbin installation

The ‘size’ of a wind turbine is made up of two key elements:

- **the hub-height:** High hub-heights are preferred because this exposes the turbine to higher average wind speeds.
- **the rotor diameter:** Larger rotors are preferred because they capture more wind.

There are a couple of reasons for opting for shorter towers/smaller rotors:

- to avoid microwave transmission links
- or aviation radar interference
- to reduce visual impact

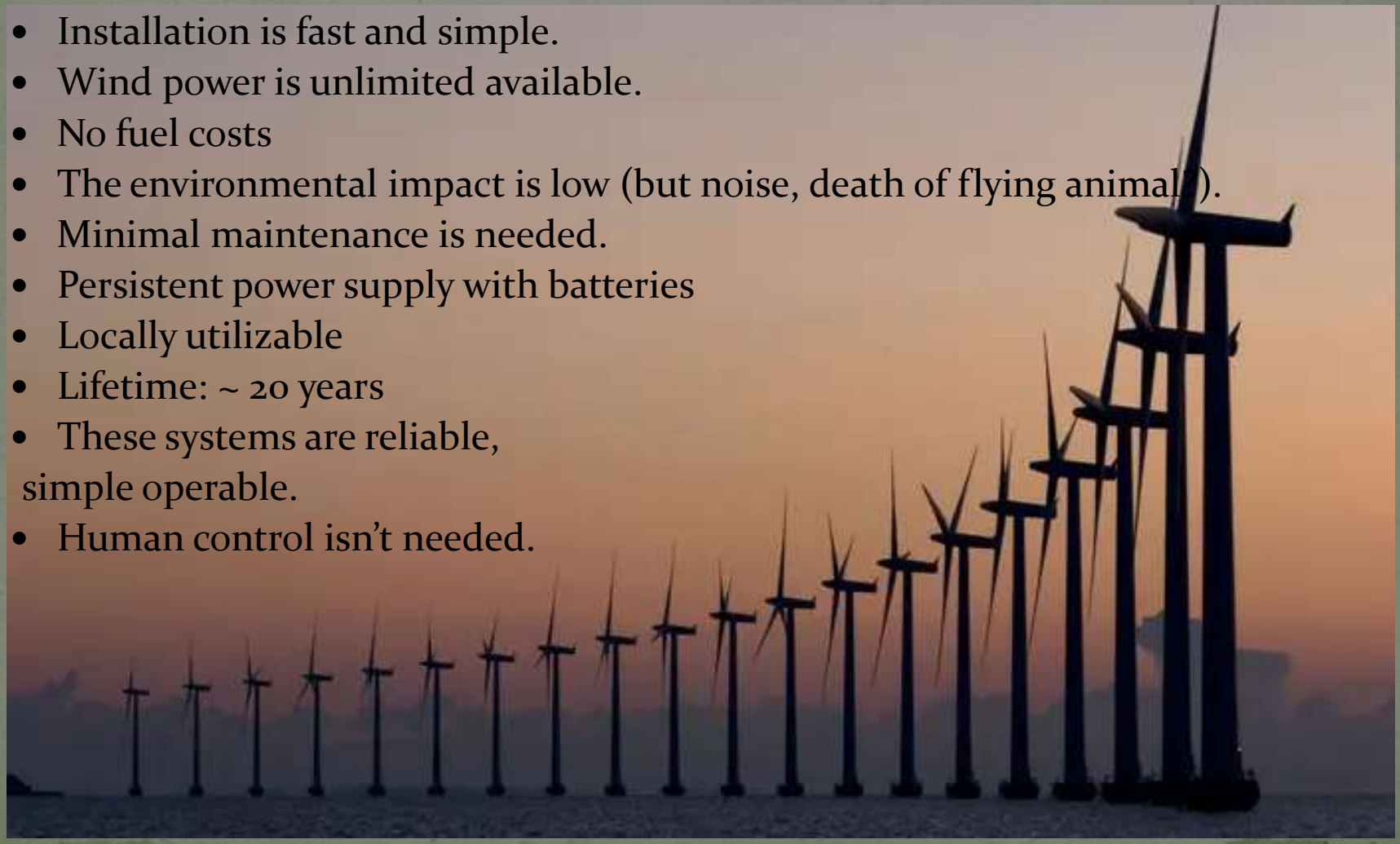


Utilizatition of Wind Power

- **Converting to electricity:** The wind blows the blades of the turbine, which are attached to a rotor. The rotor then spins a generator to create electricity. There are two types of wind turbines: the horizontal-axis wind turbines (HAWTs) and vertical-axis wind turbines (VAWTs).
- **Pumping water:** A typical wind water pumping system includes: the wind rotor, a tower, a mechanical pump, mechanical linkage, a well full of water (or other such water source), and piping to deliver the pumped water. Also there maybe some form of water storage: a large water tank, pond, or reservoirs depending on the application.

- **Aeration for wastewater treatment:** Aeration provides oxygen to bacteria for treating and stabilizing the wastewater. Wind power is an attractive option for driving aerators at suitable sites.

Advantages of Wind Power



- Installation is fast and simple.
- Wind power is unlimited available.
- No fuel costs
- The environmental impact is low (but noise, death of flying animal).
- Minimal maintenance is needed.
- Persistent power supply with batteries
- Locally utilizable
- Lifetime: ~ 20 years
- These systems are reliable, simple operable.
- Human control isn't needed.

Wind Solar Hybrid Projects

A Wind Solar hybrid plant generates power in a continuous pattern:

- with much less variability than a standalone solar plant (generates only during daylight hours)
- or standalone wind plant

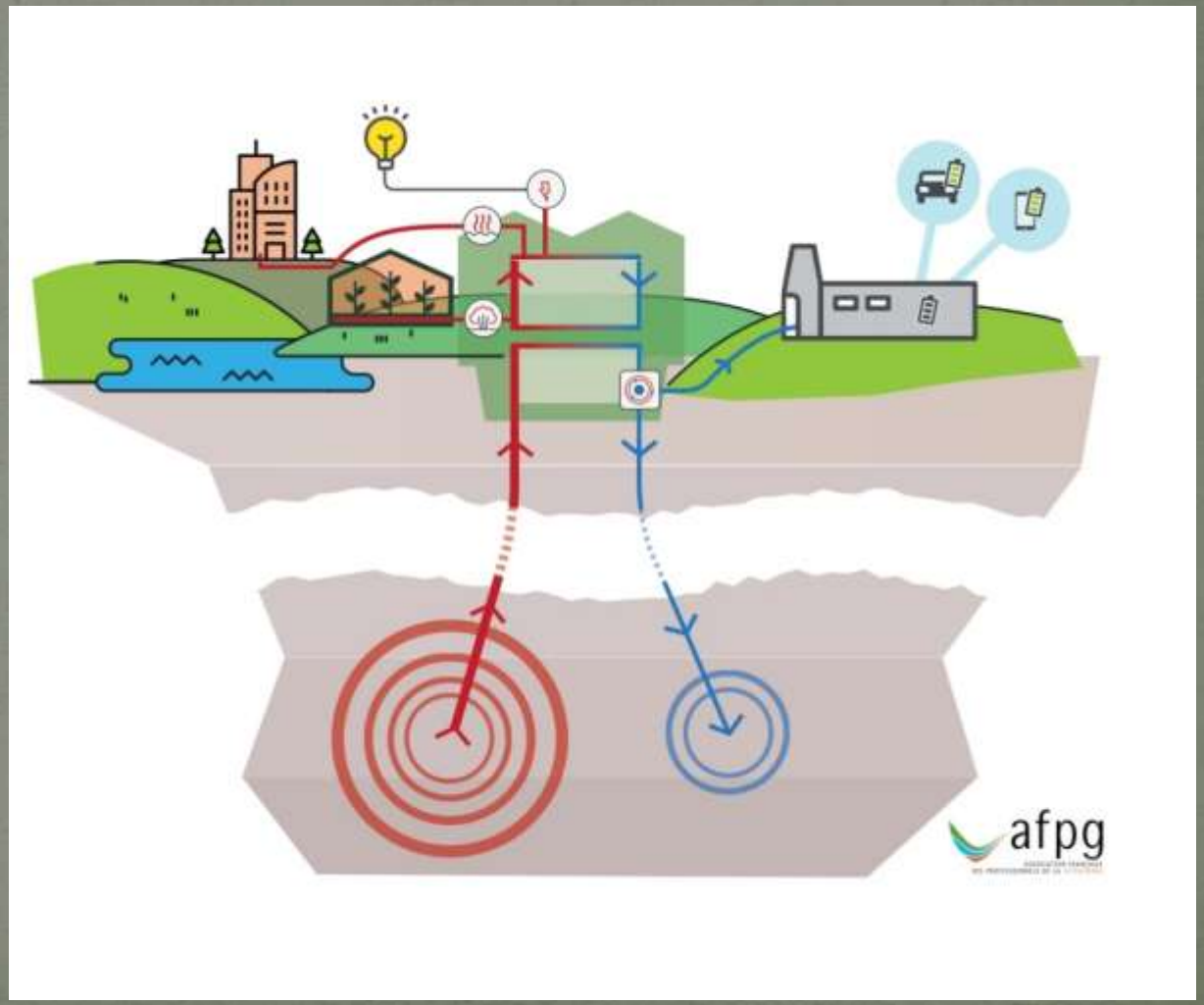
(generates mainly during evening/night).

Geothermal energy

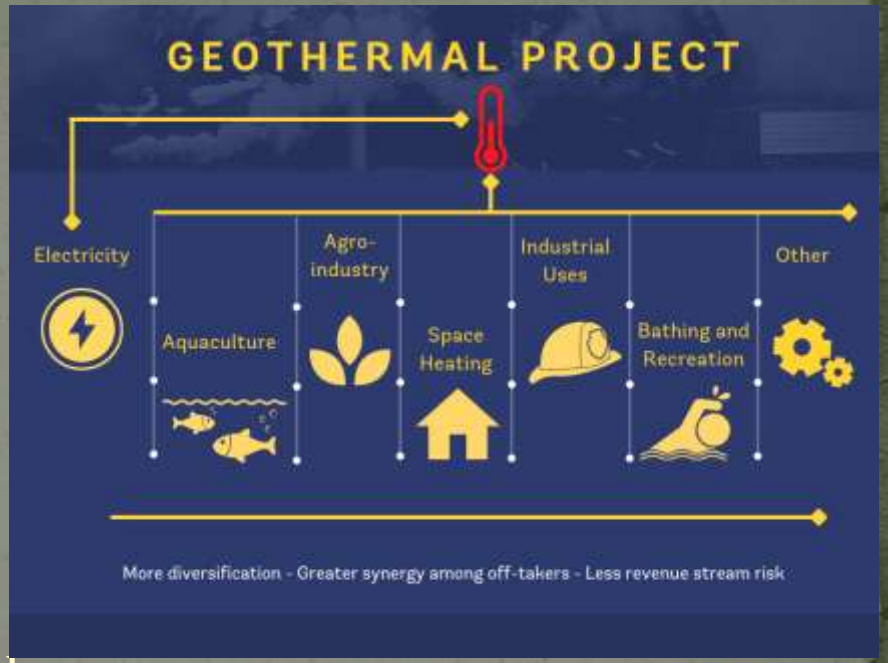
- It comes from heat generated during the original formation of the planet and the radioactive decay of materials.
- This thermal energy is stored in rocks and fluids in the centre of the earth.
- Geothermal resources are reservoirs of hot water that exist or are human made at varying temperatures and depths below the Earth's surface.

Utilization of geothermal energy

- Heating
- Balneology
- Generating electricity



Utilization of geo-thermal energy



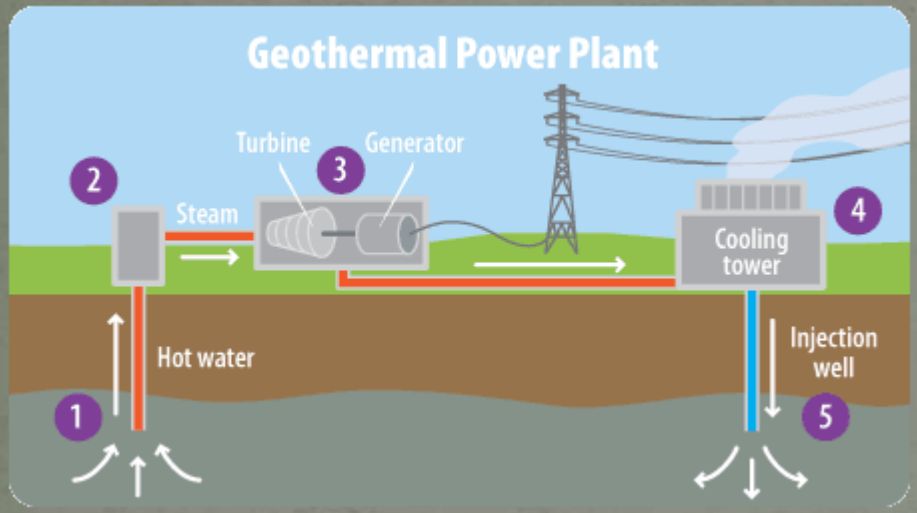
- Heating
  - Heating buildings
  - District heating
  - Warming water for personal use
  - Heating of public baths
  - Heating of greenhouses / polytunnels
  - Drying of crops, fodder and fruits
  - Raising of mushrooms
  - Warming of irrigation water
  - Heating systems of livestock production
  - Temperament of water in fish-farming
  - Industrial/technological warm water demand

Utilization of geo-thermal energy

- Balneology
  - Therapies
  - Health Spa

Utilization of geo-thermal energy

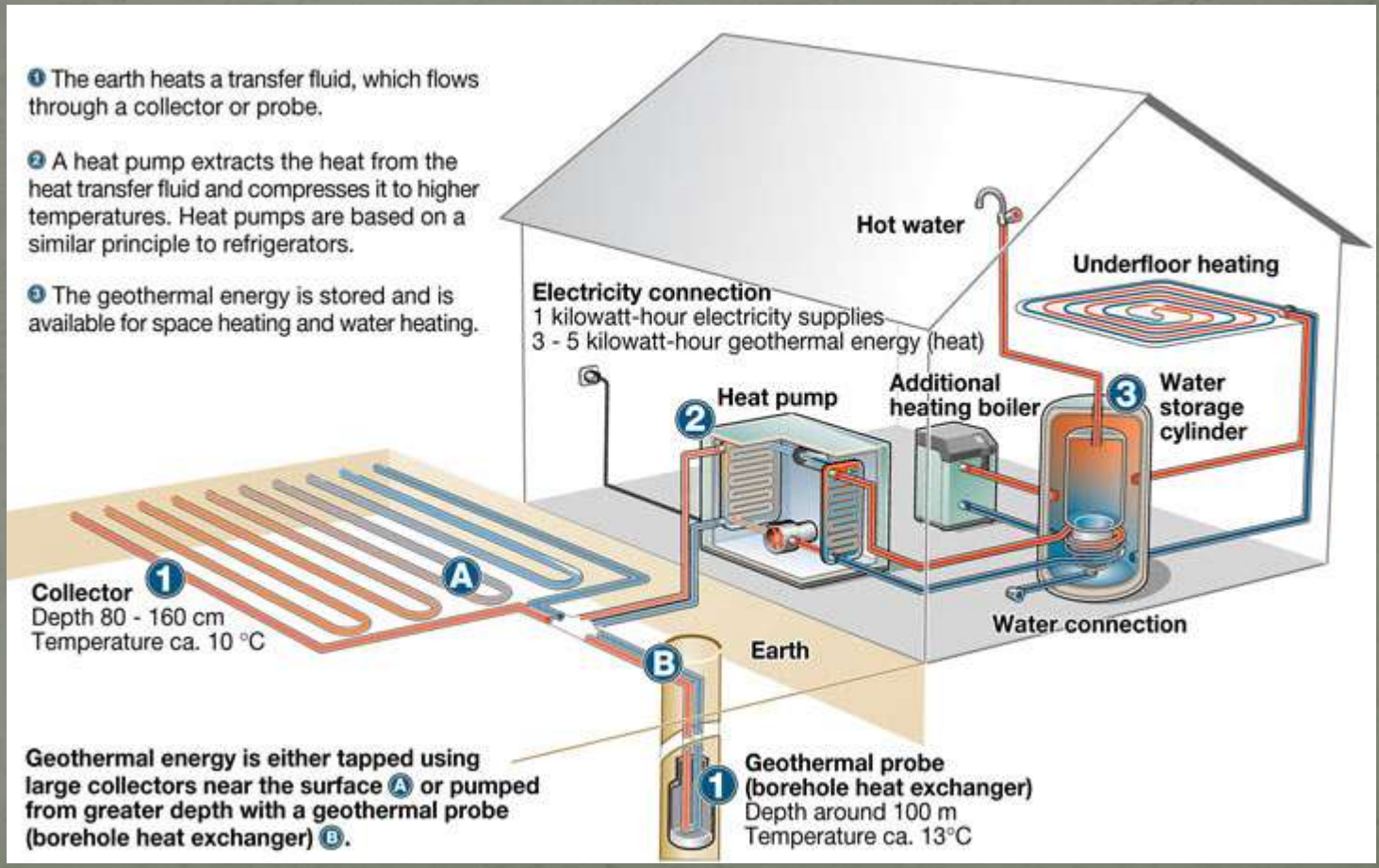
- Generating electricity



1. Hot water is pumped from deep underground through a well under high pressure.
2. When the water reaches the surface, the pressure is dropped, which causes the water to turn into steam.
3. The steam spins a turbine, which is connected to a generator that produces electricity.
4. The steam cools off in a cooling tower and condenses back to water.
5. The cooled water is pumped back into the Earth to begin the process again. (epa.gov)

Utilization of geo-thermal energy

- Technologies: Geothermal Probe



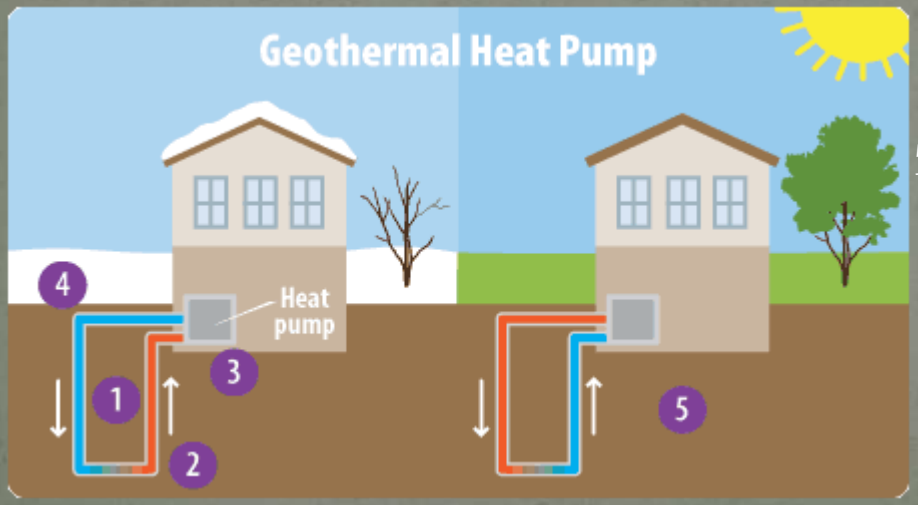
Utilization of geo-thermal energy

- Technologies:

Geothermal Heat Pumps

- Its electricity consumption is low.
- Its investment cost is high.
- Multipurpose:

Heating / Cooling / Warming water



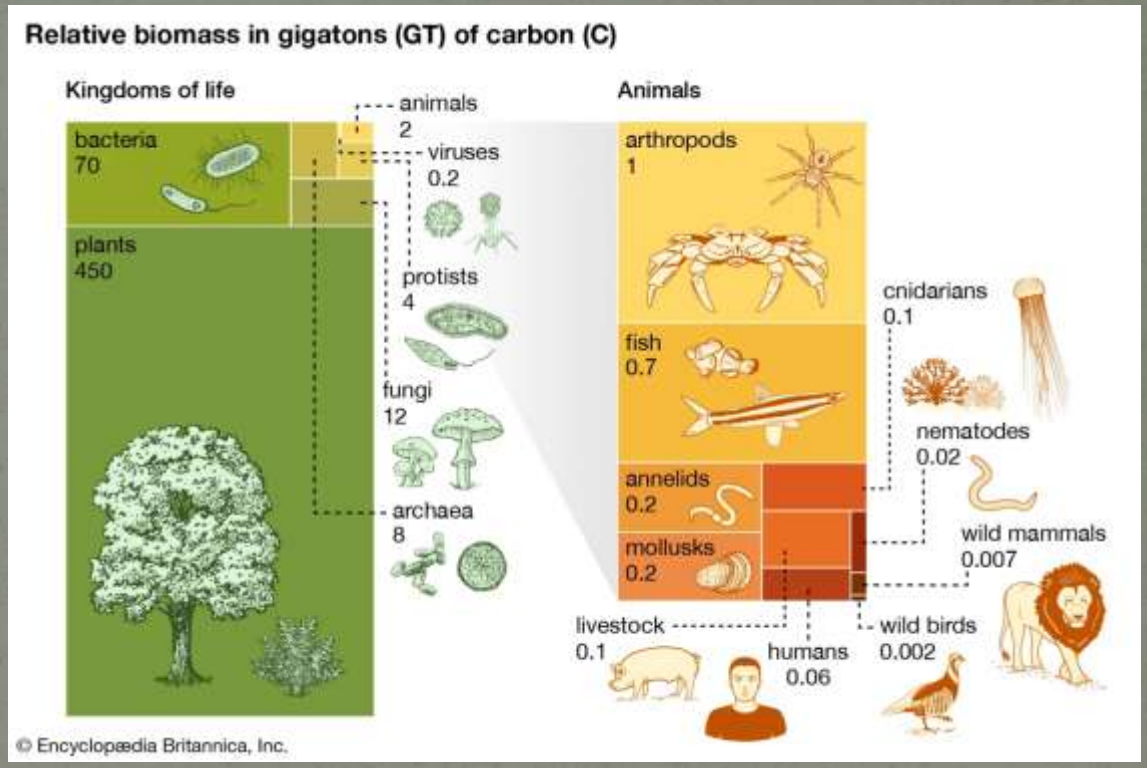
1. Water or a refrigerant moves through a loop of pipes.
2. When the weather is cold, the water or refrigerant heats up as it travels through the part of the loop that's buried underground.
3. Once it gets back above ground, the warmed water or refrigerant transfers heat into the building.
4. The water or refrigerant cools down after its heat is transferred. It is pumped back underground where it heats up once more, starting the process again.
5. On a hot day, the system can run in reverse. The water or refrigerant cools the building and then is pumped underground where extra heat is transferred to the ground around the pipes. (epa.gov)

Advantages of Geothermal Energy

- Persistent availability
- Independent of the weather
- Locally utilizable
- Local air pollution
  is decreased.
- Protection of local
  drinking water sources
- The environmental impact
  is low (if water pumped back) .

Biomass
as renewable energy source

- „The total quantity or weight of organisms in a given area or volume."



- „Organic matter used as a fuel, especially in a power station for the generation of electricity."

Utilization of Biomass

- Direct utilization: combustion
  - Without pretreatment
  - With pretreatment

- Solid Biomass:
  - Firewood
  - Wood chips
  - Straw
  - Herbs

(e.g. switchgrass, reeds)

  - Pellet

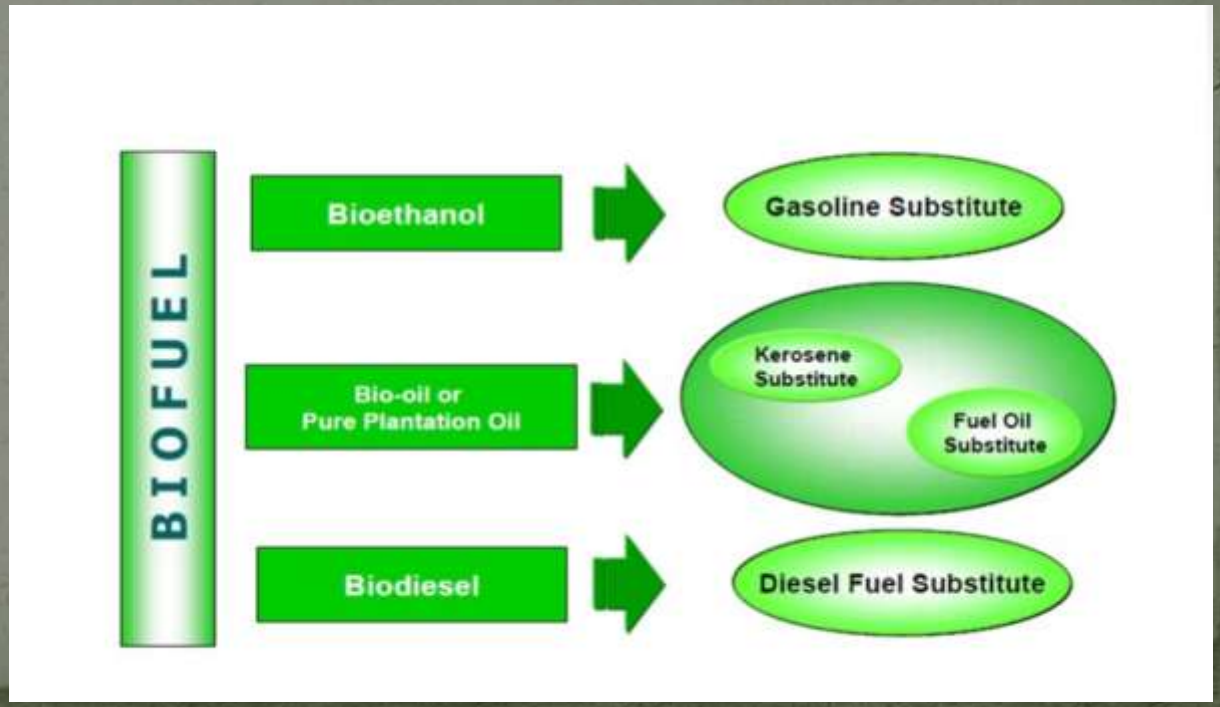
(a compressed feedstock material with or without additives)

  - Bio-Briquette

(compact solid composites of different sizes with the application of pressure)

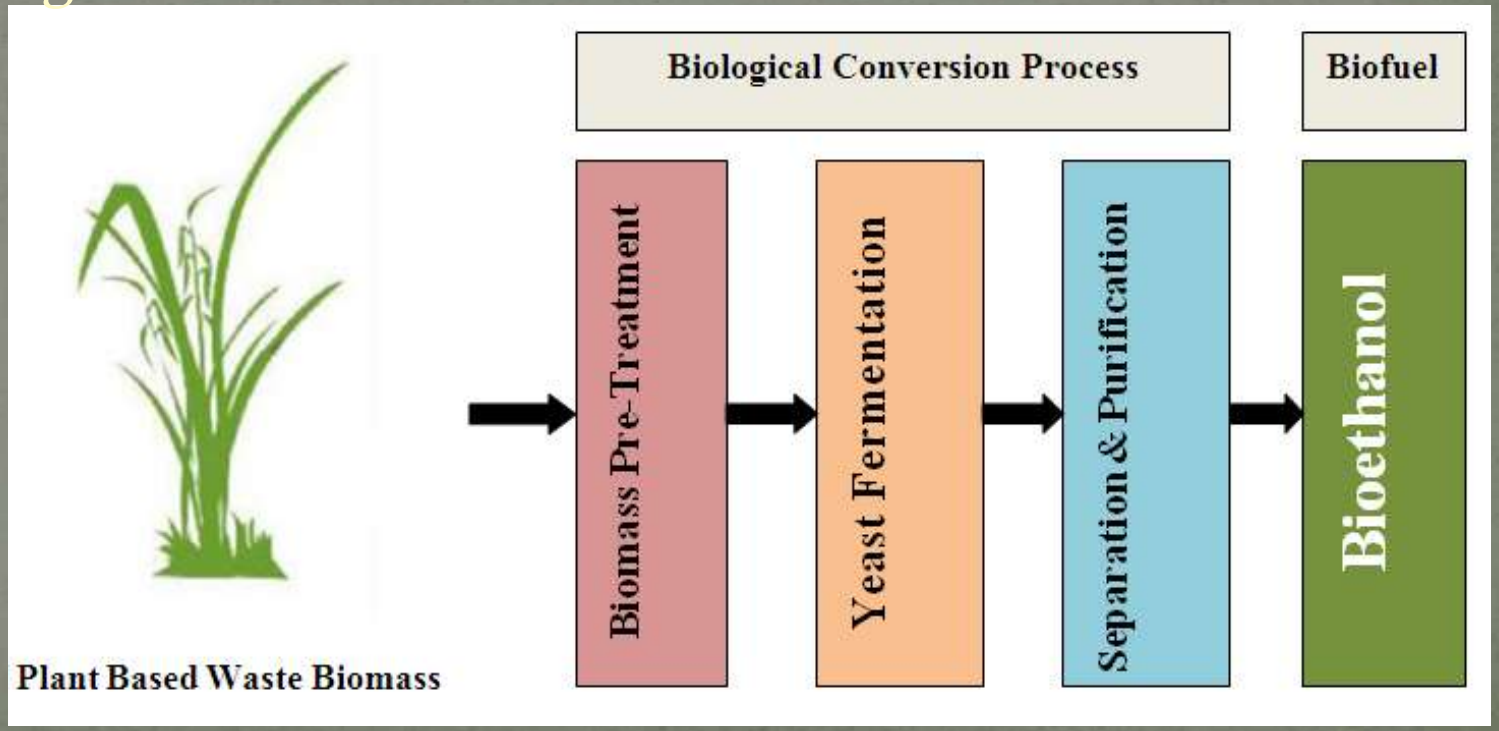
Utilization of Biomass

- Indirect utilization:
  - Chemical modification
    - Liquefaction → liquid fuel
    - Gassing → combustible gas
  - Fermentation → alcohol (as fuel)
  - Esterification of vegetable oils → biodiesel
  - Anaerobic fermentation → biogas

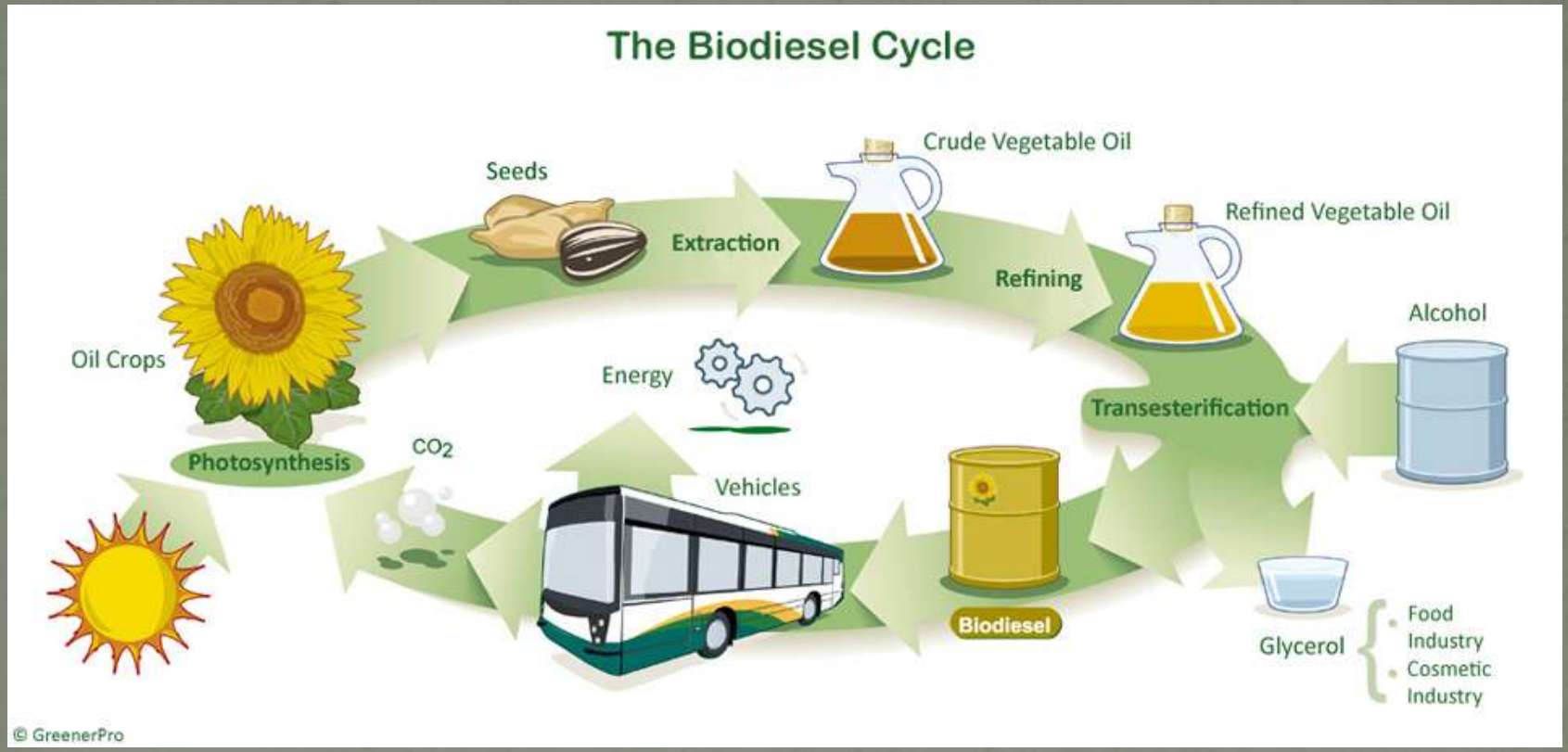


Utilization of Biomass

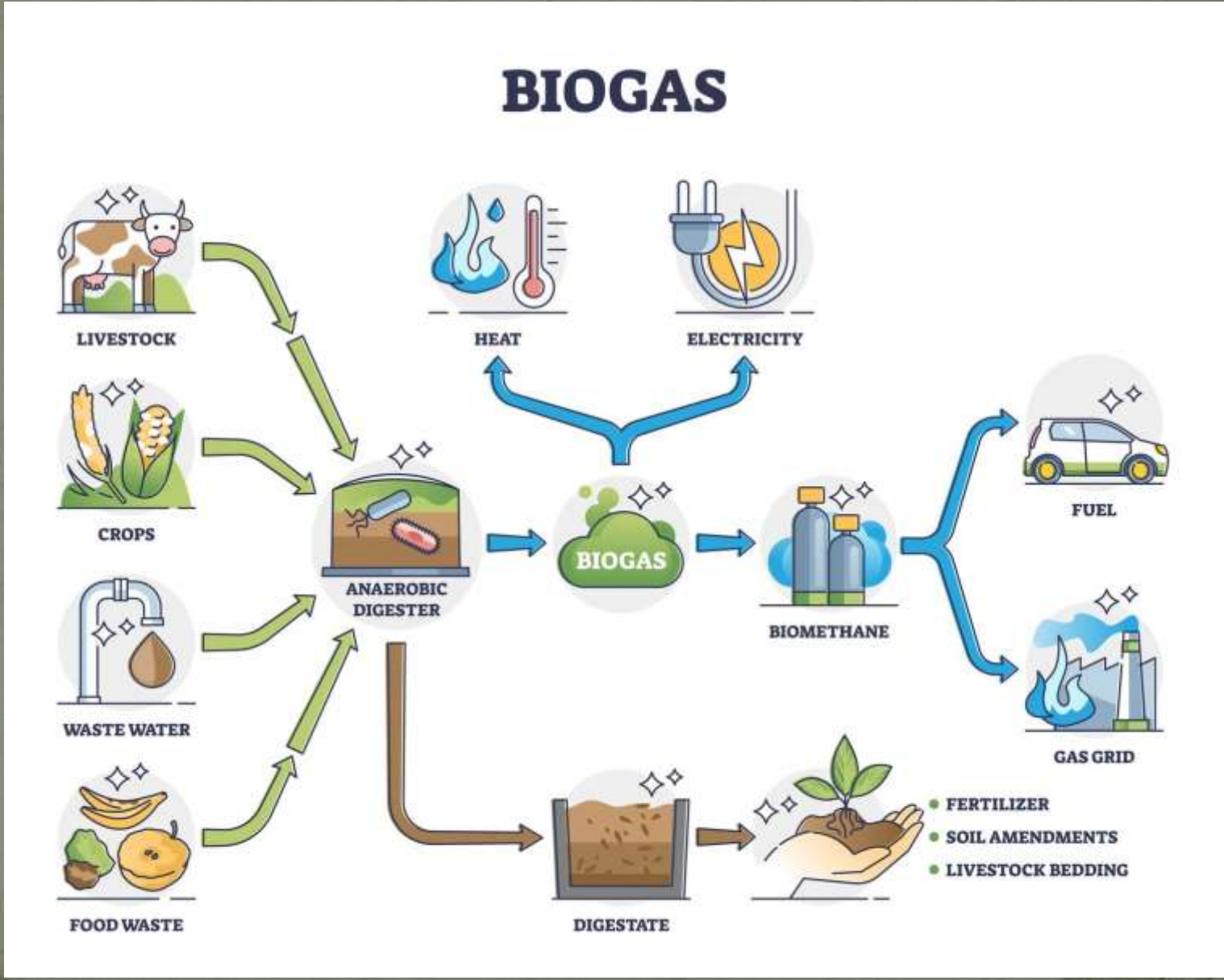
- Liquid Biomass Fuels
  - Bioethanol
  - Biodiesel
- Gaseous Biomass
  - Biogas



Utilization of Biomass



Utilization of Biomass



Energetic Utilization of Biomass

- Generating electricity
- Utilization of agricultural and municipal waste
- Heating (individual or district heating)
- Incineration of hazardous waste
- Fuel production
- Heat production

Advantages of Biomass Energy

- Regrowth is relatively short
- Saving the reserves of mineral resources
- Unused agricultural lands can be used for production of energy herbs
- Rural development

and job creation

- Incineration

of byproducts and waste

Disadvantages of Biomass Energy

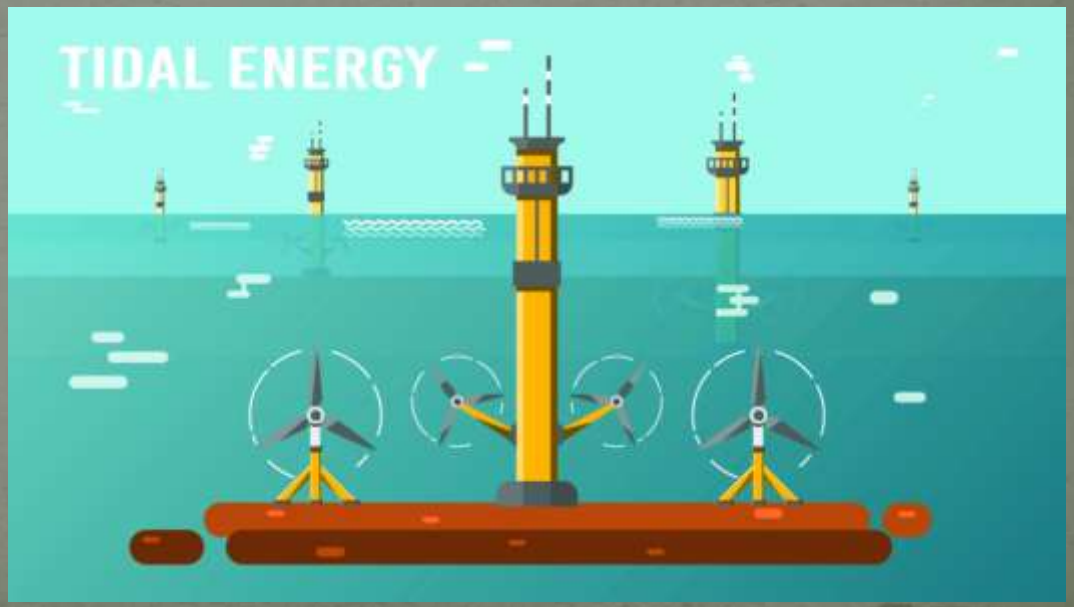
- Environmental impact, such as deforestation and air pollution
- Large-scale cultivation of energy crops for biomass production can lead to land conversion, deforestation, and habitat loss, which can threaten biodiversity and disrupt ecosystems. See: e.g. Oil Palm and Orangutan
- If agricultural land is diverted from food production to growing biomass feedstocks, it could potentially affect food prices by reducing the supply of food crops.

Hydropower

- Electricity produced from generators driven by turbines that convert the potential energy of falling or fast-flowing water into mechanical energy.
  - Water catchments
  - Damned reservoirs
  - Diversions
  - Pumped-storage

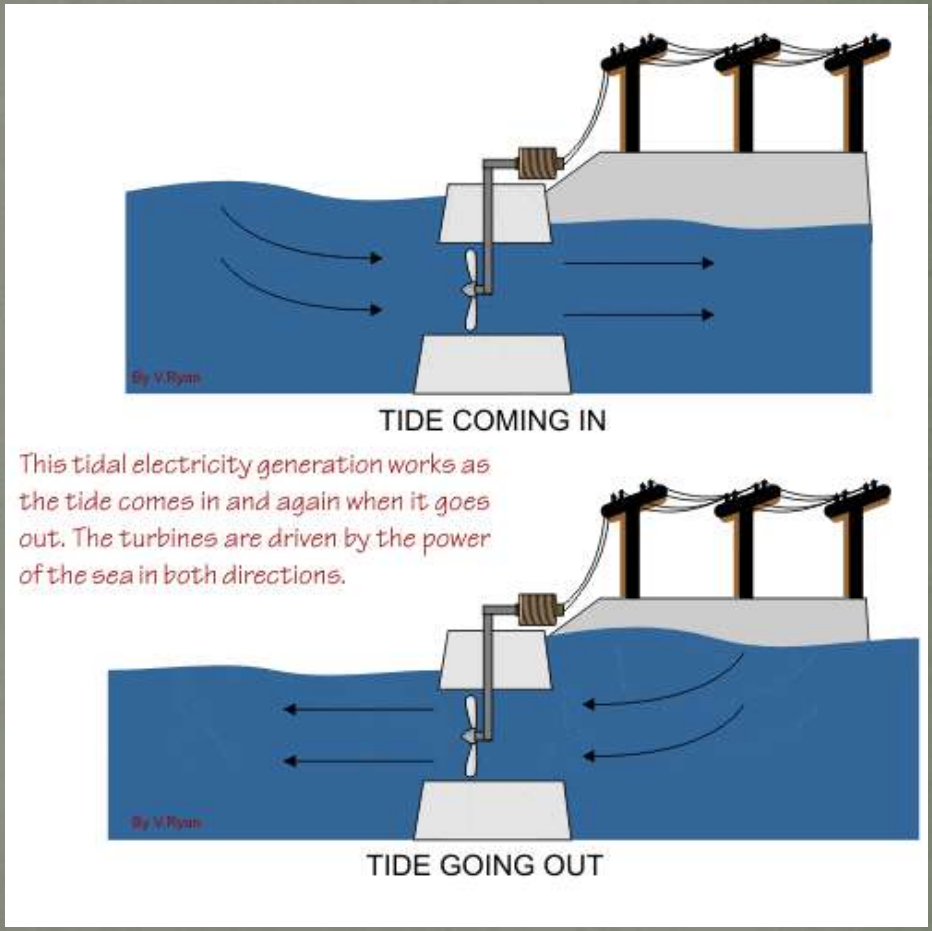
Tidal energy

- Tidal energy is a renewable energy powered by the natural rise and fall of ocean tides and currents. (nationalgeographic) Tides are generated due to gravitational pull of the moon and the Sun.



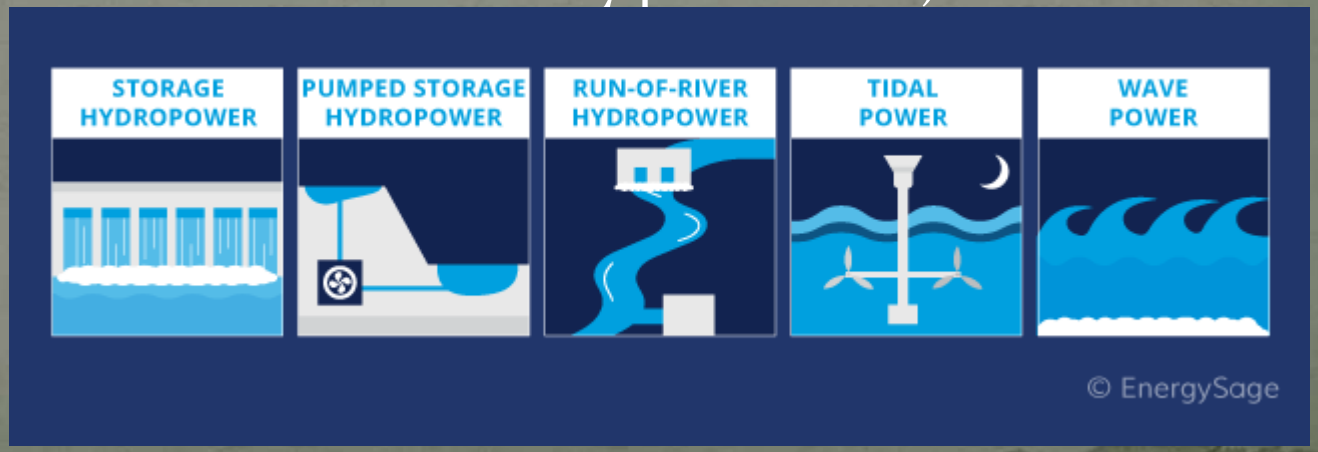
Utilization of Hydro Power

- Hydro Power Plants
  - Generating electricity
- Tidal power Stations
  - Generating electricity
- Barrage
  - Water management
  - Irrigation
  - Shipping
  - Fishing
  - Flood protection
  - Sports, recreation



Advantages of Hydro Power

- Long lifetime (50-100 years)
- Reliable technology
- Emission of greenhouse gases is minimal.
- Flood protection
- Minimal operating expense
- Sustainable
- Water can be stored (contorolled and persistent electricity production)

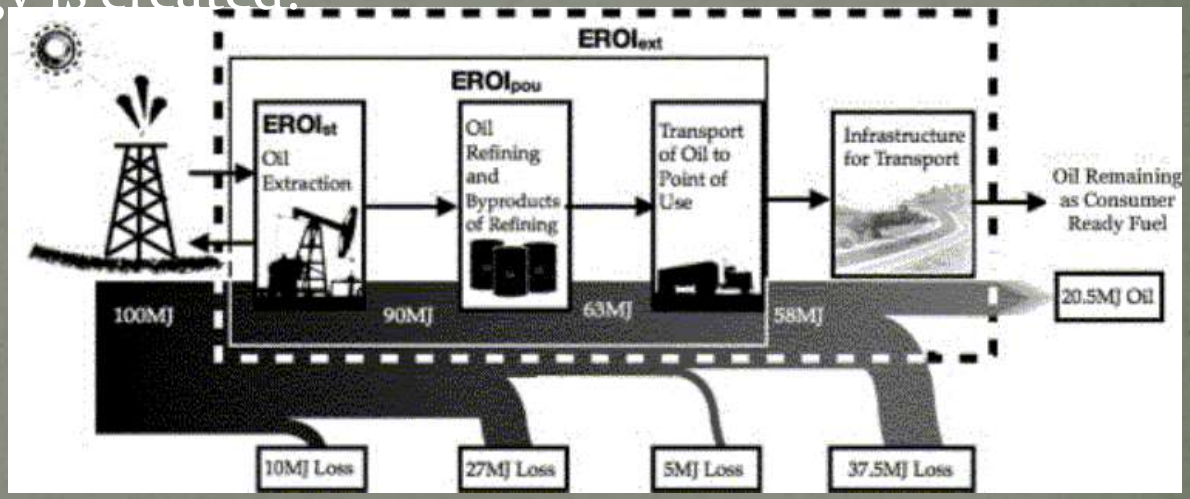


Disadvantages of Hydro Power

- Environmental impact: Large-scale hydropower projects can disrupt river ecosystems, alter natural water flow patterns, and lead to habitat destruction. This can negatively affect fish migration, aquatic biodiversity, and water quality.
- Displacement of communities: The construction of dams and reservoirs for hydropower projects often requires the relocation of communities living in the affected areas. This displacement can lead to social and economic disruptions for local populations, including loss of livelihoods and cultural heritage.
- Risk of dam failure
- Sedimentation: Dams trap sediment flowing in rivers, leading to sedimentation in reservoirs. Over time, this reduces the storage capacity of reservoirs and affects downstream ecosystems, riverbed stability, and water quality.
- Methane emissions: Decomposing organic matter in reservoirs can produce methane, a potent greenhouse gas that contributes to climate change. Large reservoirs created by hydropower projects can be significant sources of methane emissions.
- High initial investment: The construction of hydropower infrastructure, including dams, reservoirs, and power plants, requires substantial upfront investment. This can make hydropower projects economically challenging compared to other energy sources, especially in regions with less developed infrastructure.

Energy Return of Investment (EROI)

- EROI is a ratio for describing a measure of energy produced in relation to the energy used to create it. EROI = Energy Output : Energy Input
- For instance the ratio would illustrate how much energy is used to locate, extract, deliver, and refine crude oil relative to how much useable energy is created.
- EROI of crude oil is changed from 100:1 to 20:1 (1920→2021).



The fossil fuel industry is pushing into resources that are harder to extract.

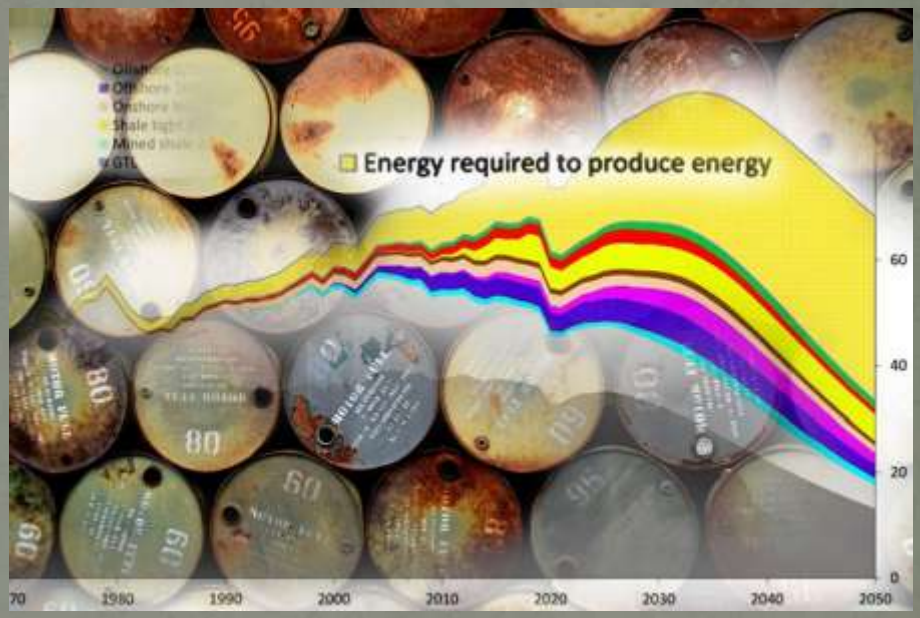
Energy Return of Investment (EROI)

Energy	Average	Optimistic estimation	Pessimistic estimation
Crude oil	19:1		5:1
Hard coal		85:1	50:1
Natural gas	10:1		
Hydro power		267:1	11:1
Nuclear energy		15:1	1.1:1
Wind power (land-based)		58:1	34:1
Wind power (marine)		17.7:1	16.7:1
Photovoltatics		34:1	5:1
Biodiesel (from rapeseed oil)		2.6:1	1.1:1
Oil from tar sand	5:1		
Wave power plants	15:1		
Tidal power stations	6:1		

Energy Return of Investment (EROI)

- Sustainability of industrial civilization:

  EROI should be around 5:1



- Energy Trap:

  Configuration of renewable energy sources is energy-intensive. This energy demand can be satisfied by fossil fuels.

Global Energy Transformation

- Difficulty of Global Energy Transformation
  - Energy Trap
  - Availability of rare metals below a treshold level

  (Importance of recycling in Solar Power Industry)
  - Increased space requirement
  - Landscape Modification

- Global Energy Transformation is a prime necessity
  - In spite of disadvantages
  - Because of Global Warming / Climate Change
  - („Target Zero”)

Net Zero
Carbon Emission by 2050