www.emu.ee

Climate Policy, Objectives, and Options, Impact to Climate Change

ERASMUS ClimEd Blended Learning for Climate Change
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MSc Peep Mardiste
peep.mardiste@ut.ee

lecturer, Estonian University of Life Sciences
consultant, environment & climate change

Plan for the lecture

1. Terminology
2. Trends and causes of climate change
3. Impacts of climate change
4. Climate policy options

1. Terminology

Weather or climate?

- **Weather**: **state of the atmosphere at a particular place and time** (as regards heat, cloudiness, dryness, sunshine, wind, rain, etc.)

- **Climate**: **long-term weather pattern and rhythm at a particular place** (described by air temperature, humidity and pressure, wind regime, precipitation and other indicators, characterizing the state of the atmosphere), typically averaged over 30 years)

- **Climate change**: **long-term change in the average weather patterns** that have come to define Earth's local, regional and global climates

Weather

https://www.meteo.gov.ua

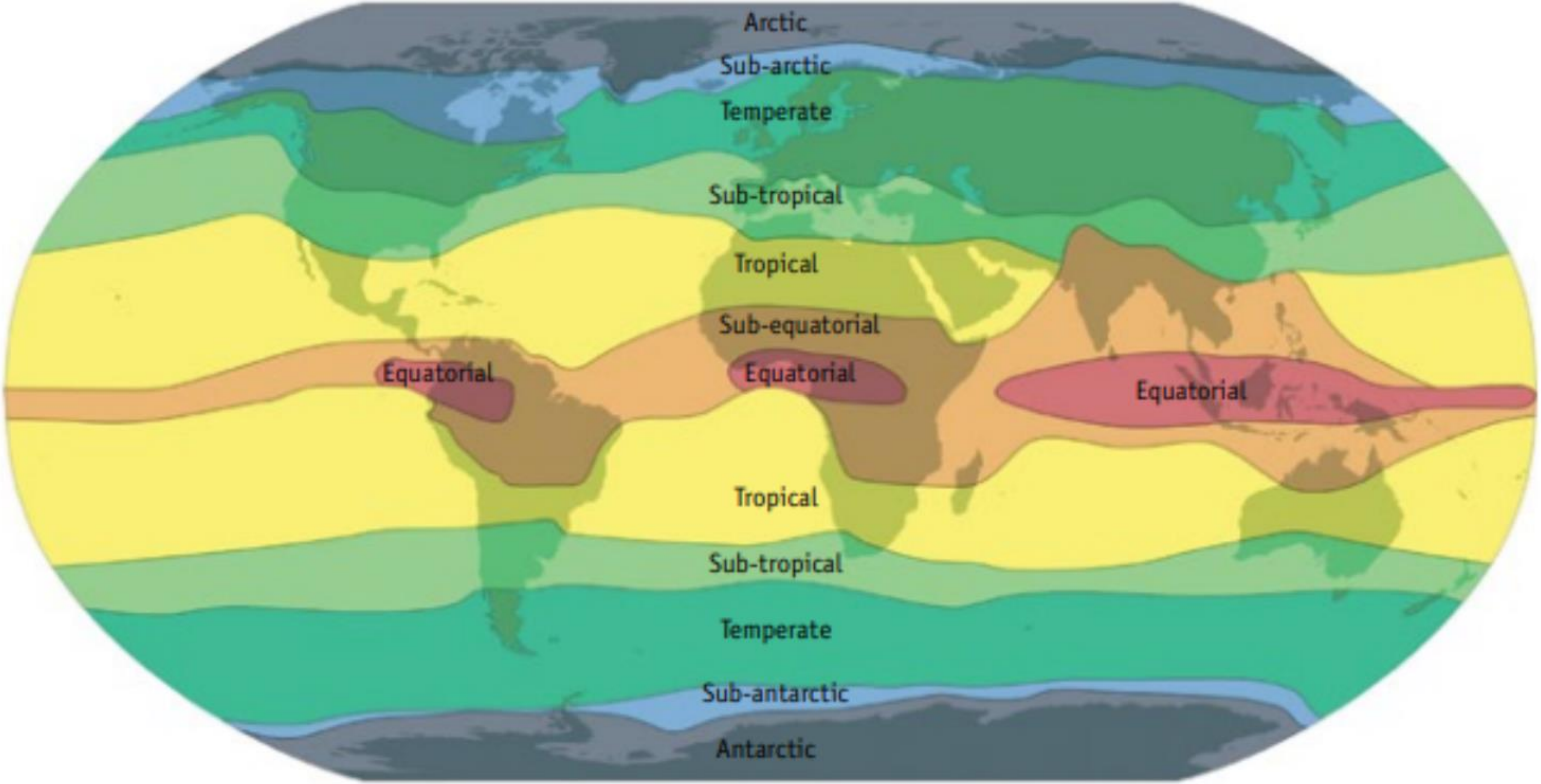
Climate

Average air temperature (°C) 1991-2020

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Jõgeva	-4,5	-5,1	-1,3	5,1	10,9	15,0	17,5	16,0	11,3	5,6	0,9	-2,3	**5,8**
Jõhvi	-4,6	-5,2	-1,7	4,5	10,3	14,6	17,4	15,9	11,2	5,5	0,6	-2,5	**5,5**
Kihnu	-1,7	-2,9	-0,5	4,5	10,5	14,9	18,3	18,0	13,8	8,3	3,8	0,8	**7,3**
Kunda	-3,3	-4,0	-0,8	4,4	9,8	14,4	17,5	16,5	12,2	6,7	1,9	-1,1	**6,2**
Kuusiku	-3,8	-4,4	-1,1	4,9	10,6	14,7	17,4	16,0	11,3	5,7	1,4	-1,8	**5,9**
Lääne-Nigula	-3,0	-3,6	-0,6	5,1	10,7	14,6	17,6	16,4	11,8	6,4	2,1	-0,8	**6,4**
Pakri	-2,1	-2,9	-0,2	4,3	9,3	13,9	17,5	17,1	12,9	7,5	2,9	0,0	**6,7**
Pärnu	-3,0	-3,7	-0,5	5,4	11,4	15,4	18,3	17,2	12,5	6,8	2,2	-0,9	**6,8**
Ristna	-0,5	-1,6	0,3	4,1	9,0	13,5	17,5	17,3	13,3	8,3	4,2	1,6	**7,2**
Sõrve	-0,5	-1,4	0,4	4,4	9,6	14,2	17,5	17,6	13,9	8,7	4,7	1,6	**7,5**
Tallinn-Harku	-2,9	-3,6	-0,6	4,8	10,2	14,5	17,6	16,5	12,0	6,5	2,0	-0,9	**6,4**
Tartu-Tõravere	-4,1	-4,4	-0,5	5,9	11,5	15,5	18,0	16,7	11,8	6,0	1,2	-2,1	**6,3**

https://www.ilmateenistus.ee/kliima/kliimanormid/ohutemperatuur/?lang=en

Climate zones



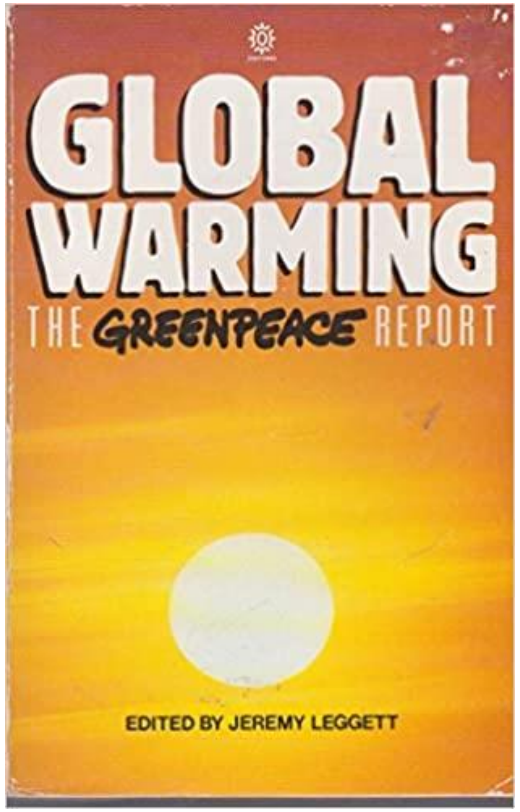
https://www.envir.ee/kliima/kliimamuutused

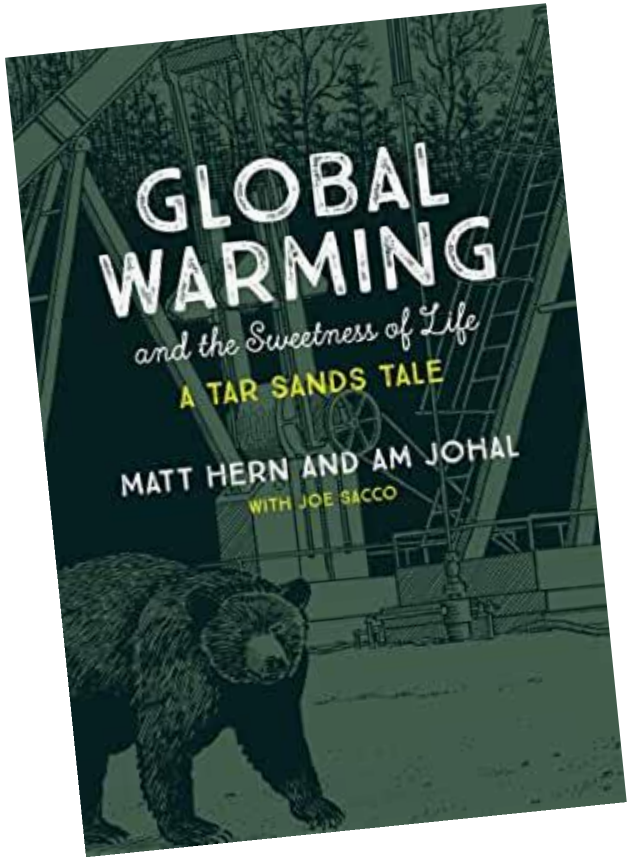
Climate change Climate change refers to a change in the state of the *climate* that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external *forcings* such as modulations of the solar cycles, volcanic eruptions and persistent *anthropogenic* changes in the composition of the *atmosphere* or in *land use.* Note that the *Framework Convention on Climate Change (UNFCCC)*, in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes. See also *Climate variability*, *Global warming*, *Ocean acidification (OA)* and *Detection and attribution*.

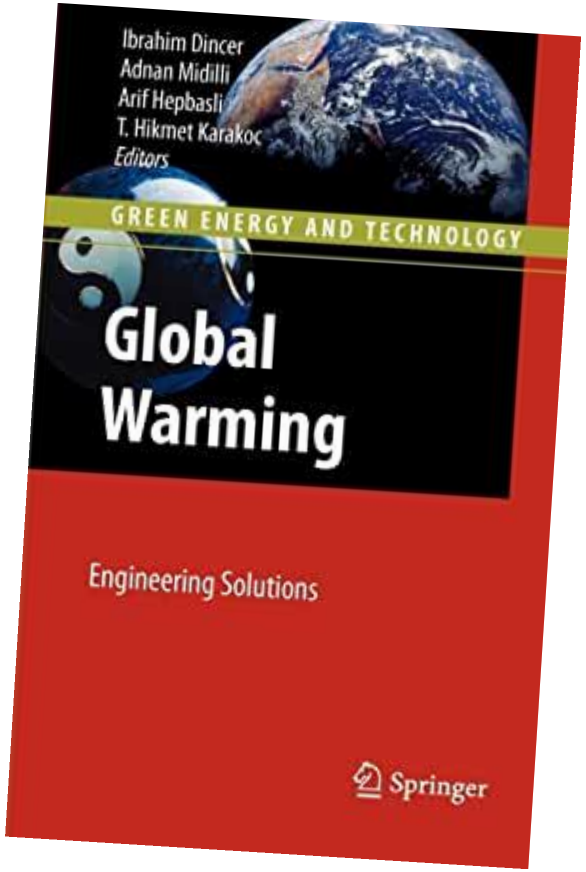
International Panel for Climate Change (IPCC) 2018 glossary (https://apps.ipcc.ch/glossary)

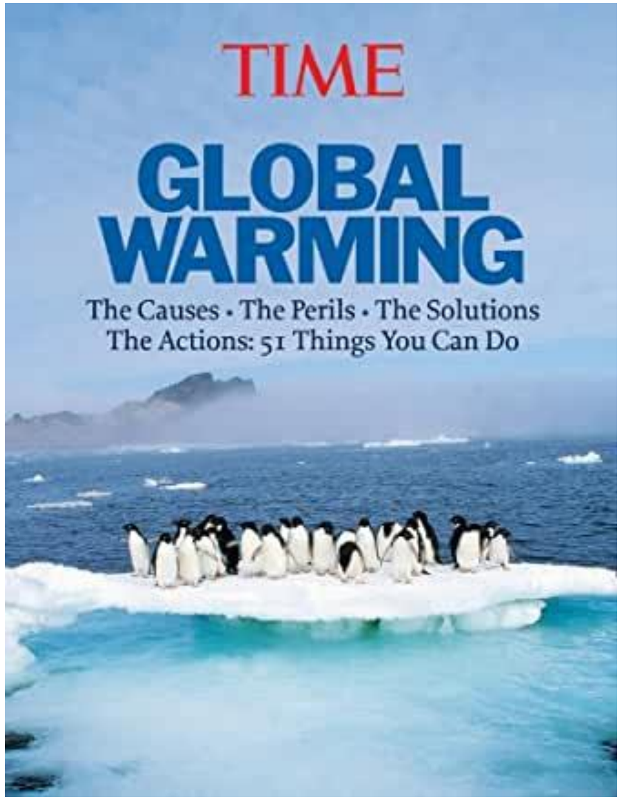
Warming or change?

- In 1980s/1990s, ‘global warming’ (*глобальне потепління*) widely used
- Today ‘climate change’ (*зміна клімату*) used as more precise (not necessarily causing warming everywhere)









2. Trends and causes of climate change

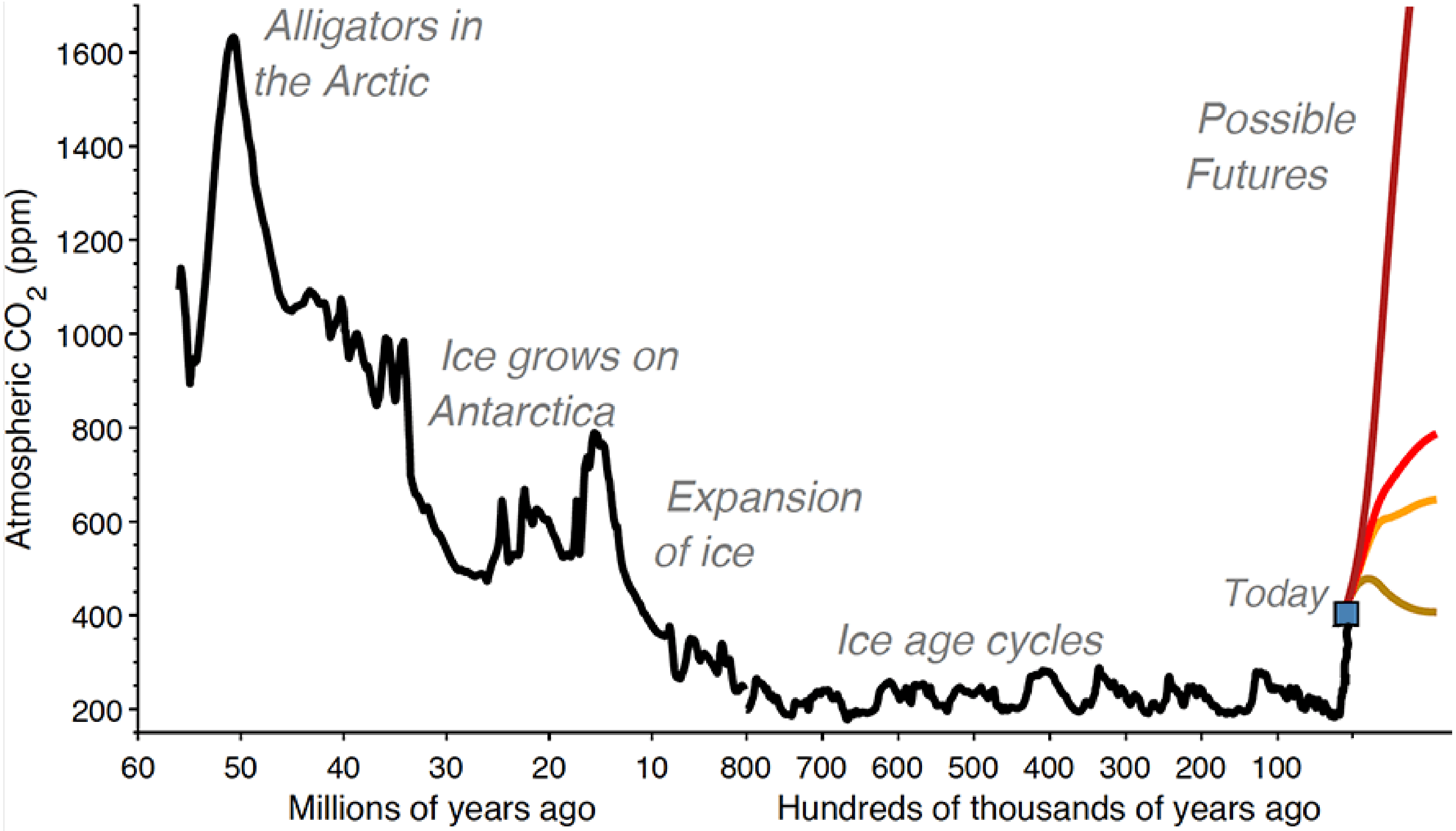
Trends

Historical climate

- climate keeps changing, it's a natural process
- during Cryogen era (850-630 million years ago) entire Earth glaciated 2 times ("snowball Earth"), there were few greenhouse gases
- it has been very warm a very long time ago (50 million years ago CO_2 concentration was 0.17%,[1] average temperature 15°C warmer and alligators in the Arctic)
- today's CO_2 concentration (0.04%) last occurred at approx. 3 million years ago
- CO_2 concentration has been stable during last 1 million years (0.018%...0.03%)
- with human activity, the concentration of CO_2 has increased dramatically during the last 150 years (0.028% > 0.042%)...
- ... and we have postponed the next ice age by at least 50,000 years

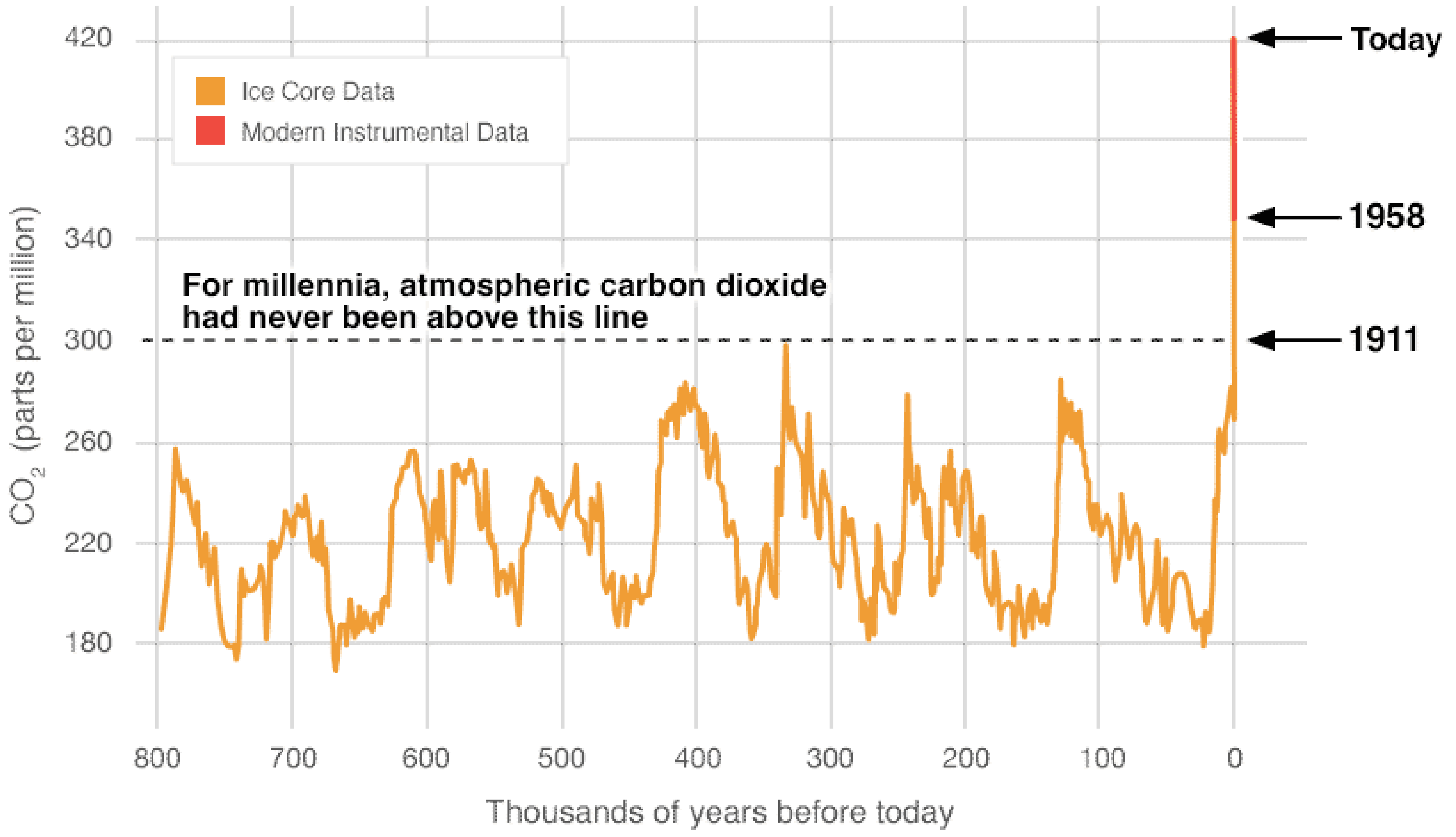
[1] more correct: 1700 ppm *(part per million)*

Carbon concentration in atmosphere (~temperature)



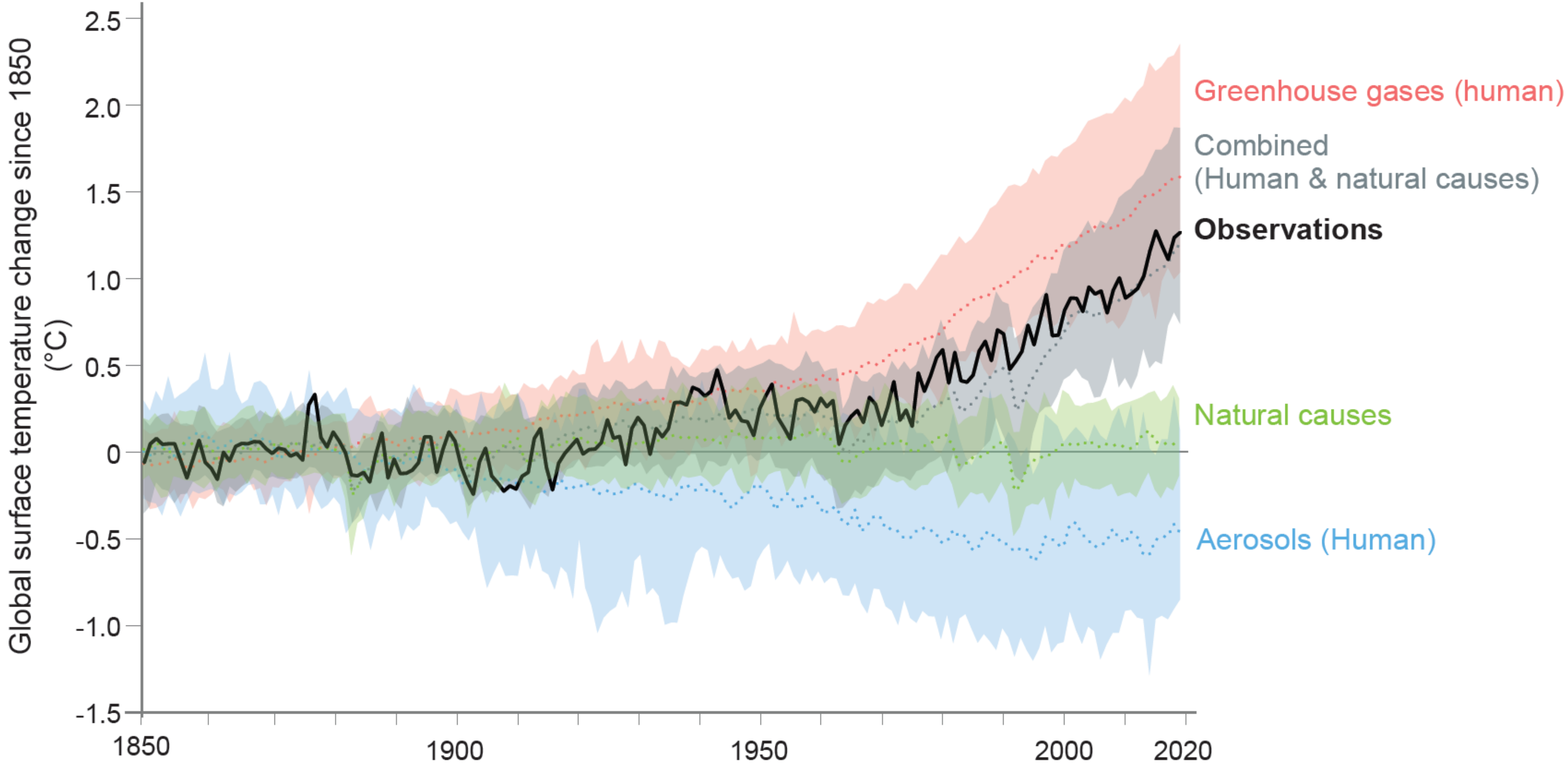
Based on https://today.tamu.edu/2021/06/14/ancient-deepsea-shells-reveal-66-million-years-of-carbon-dioxide-levels

Carbon concentration in atmosphere (~temperature)



https://climate.nasa.gov/vital-signs/carbon-dioxide/?intent=121

Role of athropogenic vs natural causes



https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter03.pdf

Global agreement about limiting climate change

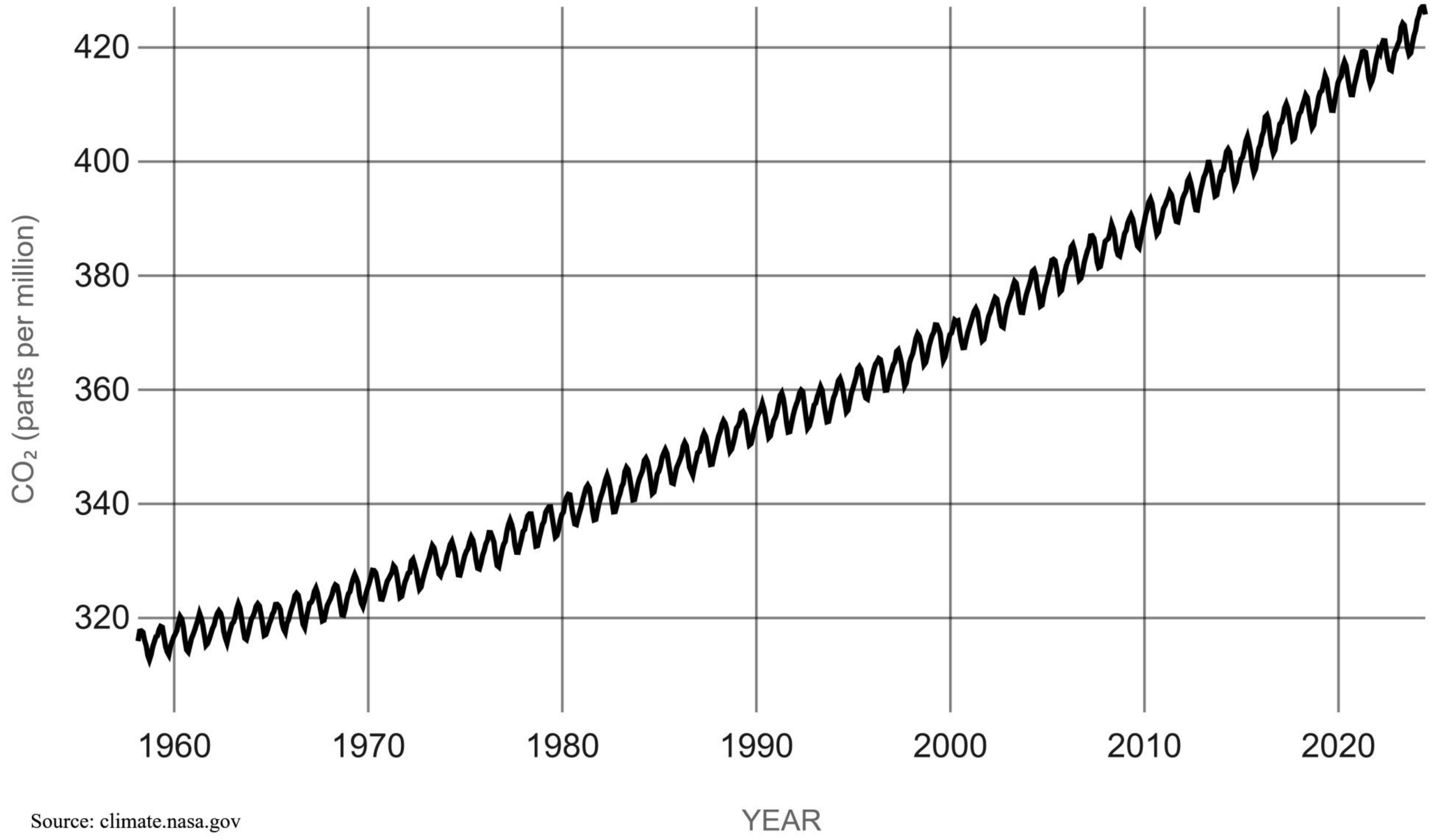
- 1992 UN climate covention (UNFCCC)

Objective: "<u>stabilization of greenhouse gas concentrations</u> in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

- 2015 Paris Agreement

Overarching goal to "hold the increase in the global average temperature to <u>well below 2°C</u> above pre-industrial levels" and <u>pursue efforts</u> to limit the temperature increase to <u>1.5°C</u> above pre-industrial levels."

Stabilisation of concentration? No ☹



Source: climate.nasa.gov

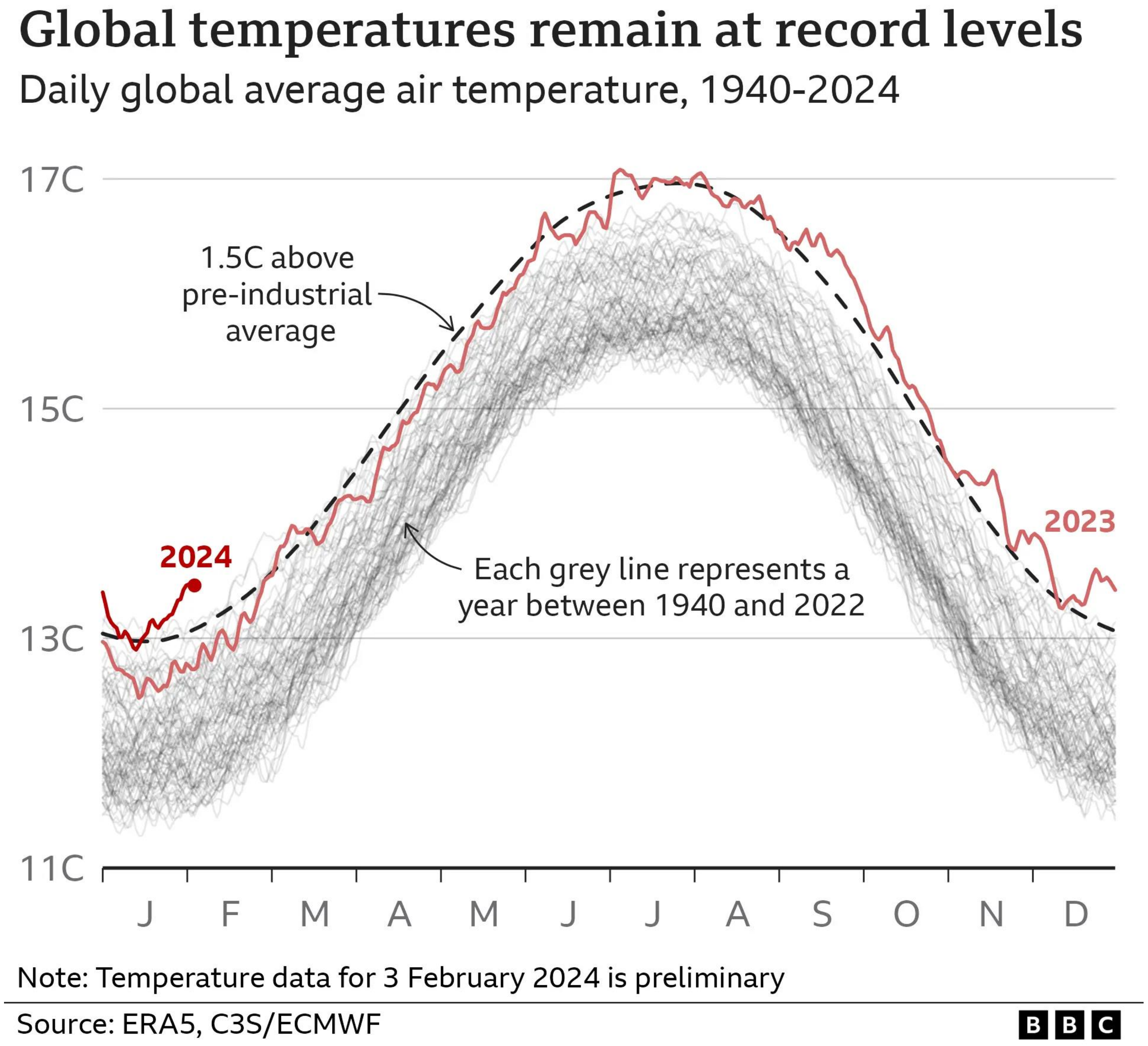
https://climate.nasa.gov/vital-signs/carbon-dioxide/?intent=121

Stay below 1.5°C temperature raise? No ☹

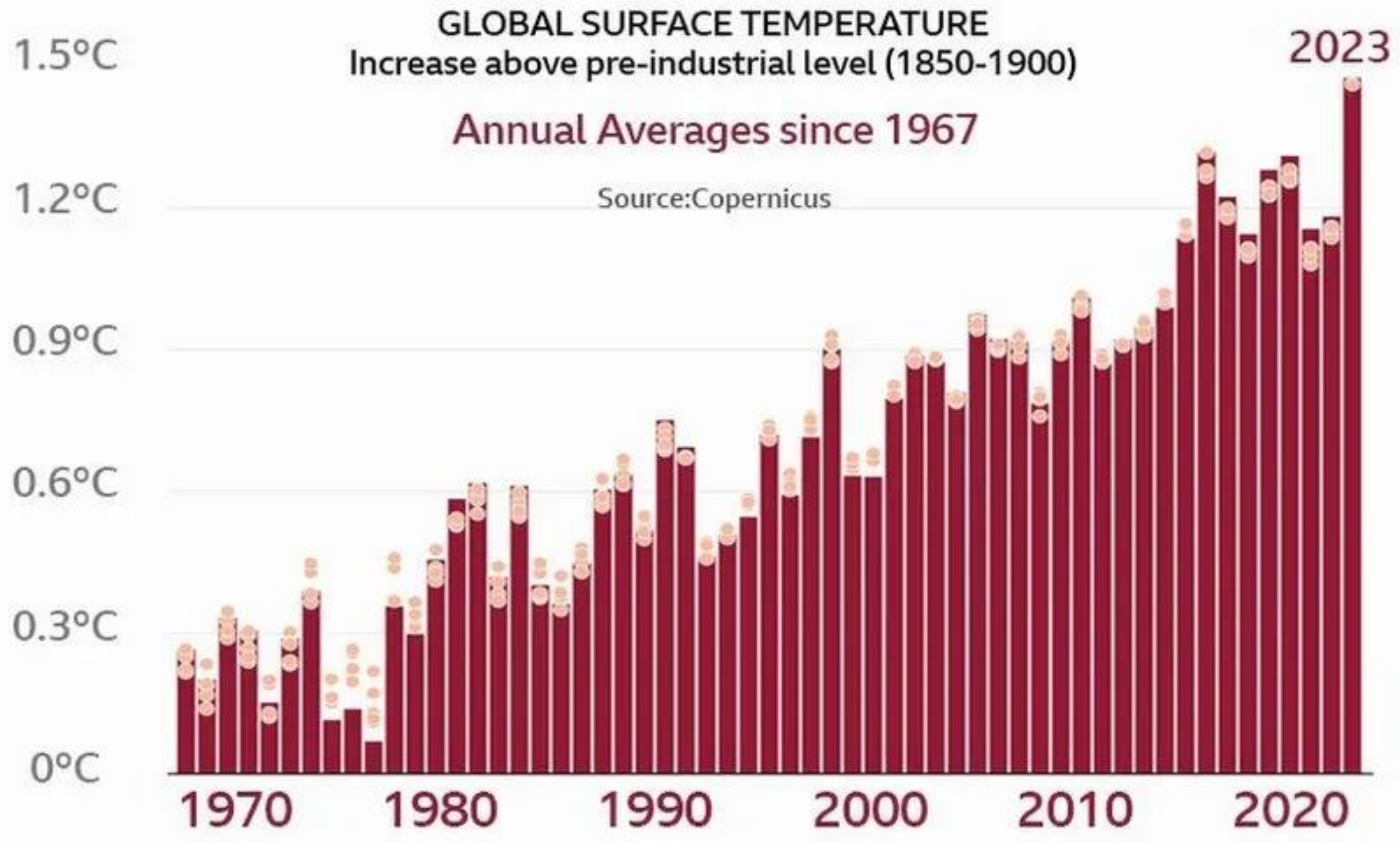
- 1.1°C warming has already taken place by now compared to the time before the industrial revolution
- staying within 1.5°C limits is completely unrealistic based on today's global agreements

\- 2022 UN Environment (UNEP) "*no credible pathway to 1.5°C in place*"

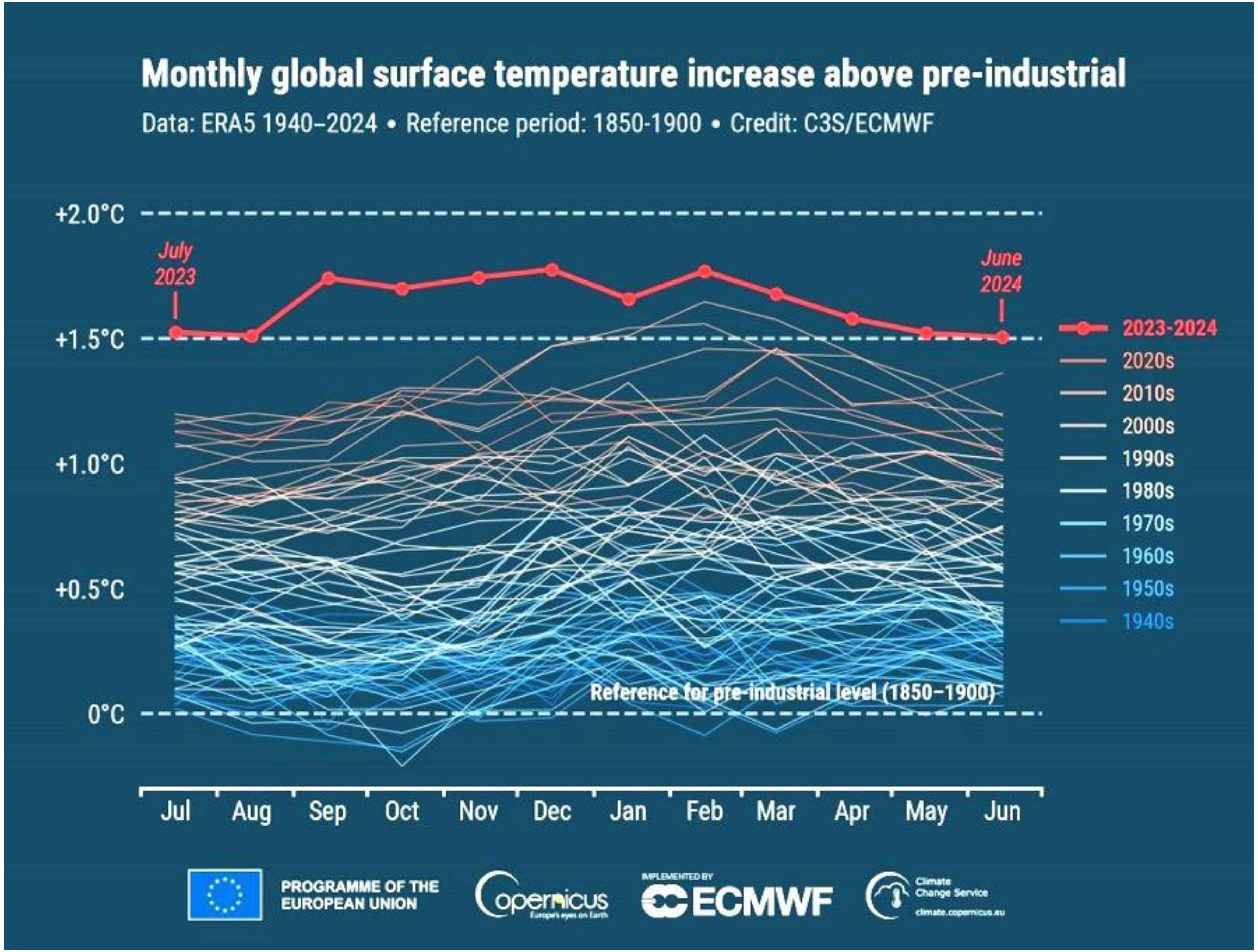
- current global agreements implementation leads increase of 2.7°C



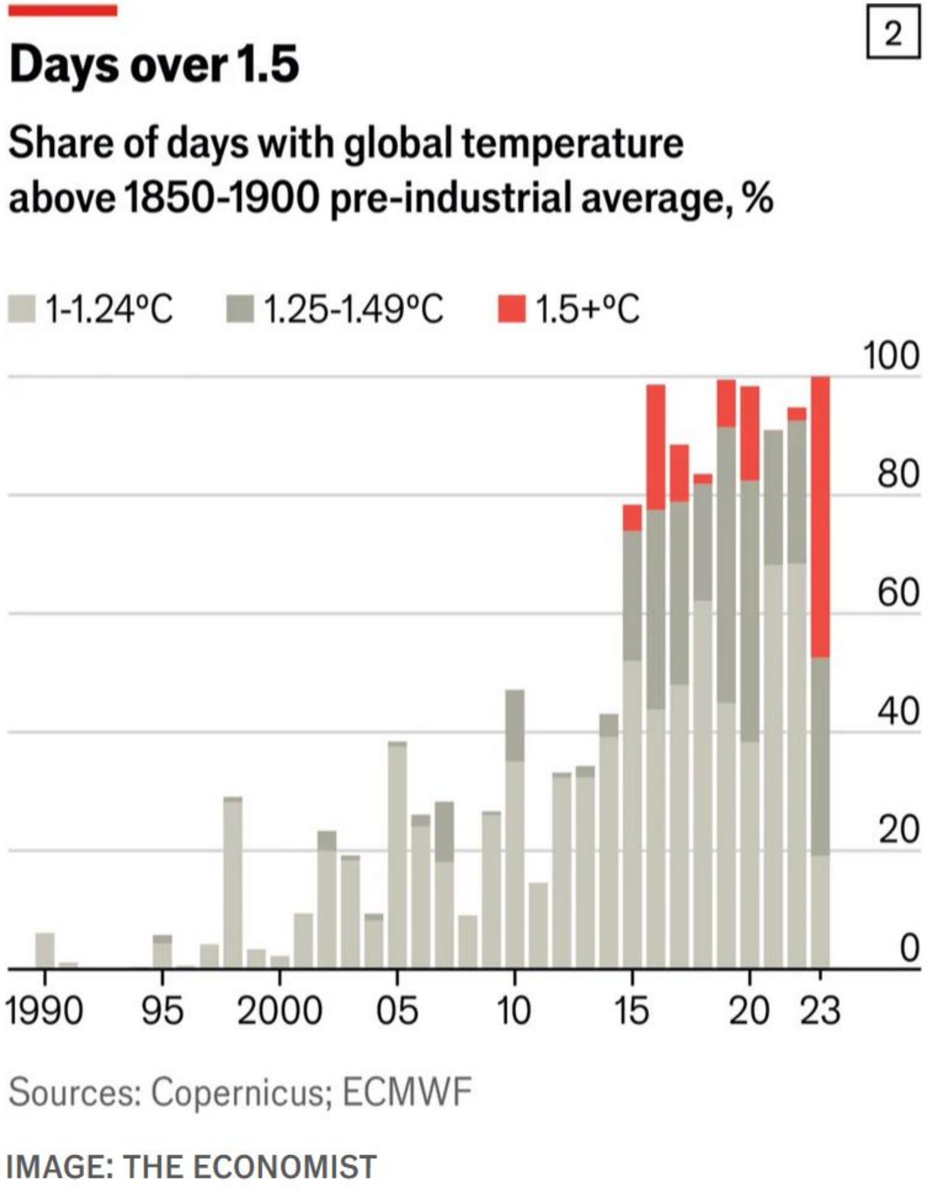
https://www.bbc.com/news/science-environment-68110310



https://www.bbc.com/weather/features/67761183



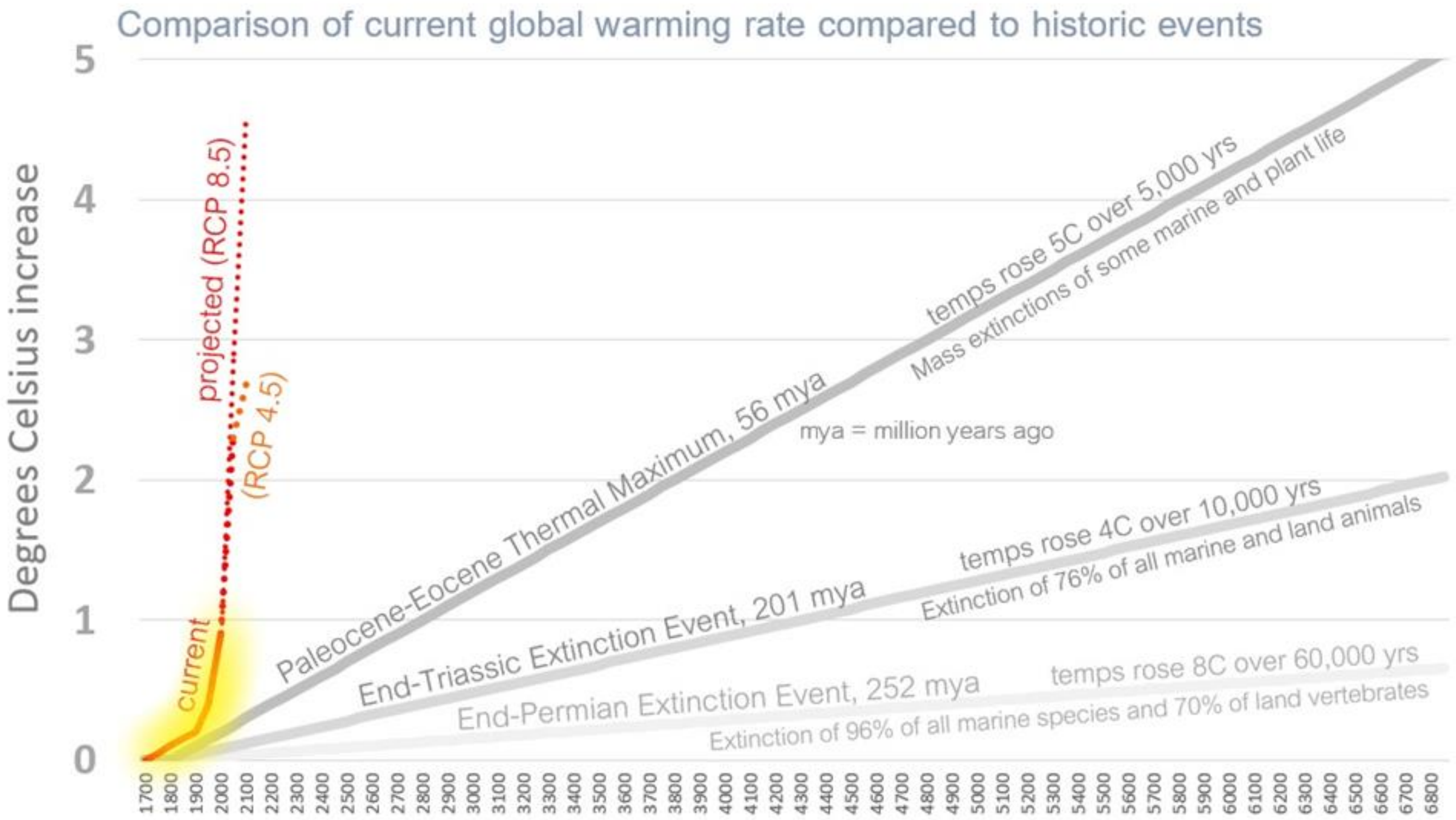
https://pulse.climate.copernicus.eu



The second difficulty is defining how the "global average temperature" is to be measured, and the timeframe for doing so. Is the average calculated over a day? A year? Several years? Temperatures have been exceeding the 1.5°C threshold over single days for roughly a decade (see chart 2) and their seasonal fluctuations make single days a poor indicator of long-term warming.

https://www.economist.com/the-economist-explains/2024/02/09/how-to-know-when-the-world-has-passed-15degc-of-global-warming

Fast speed of (climate) change is major problem



thecottonwoodpost.net/2019/12/10/modern-climate-change-is-10x-faster-than-historic-global-warming-mass-extinction-events

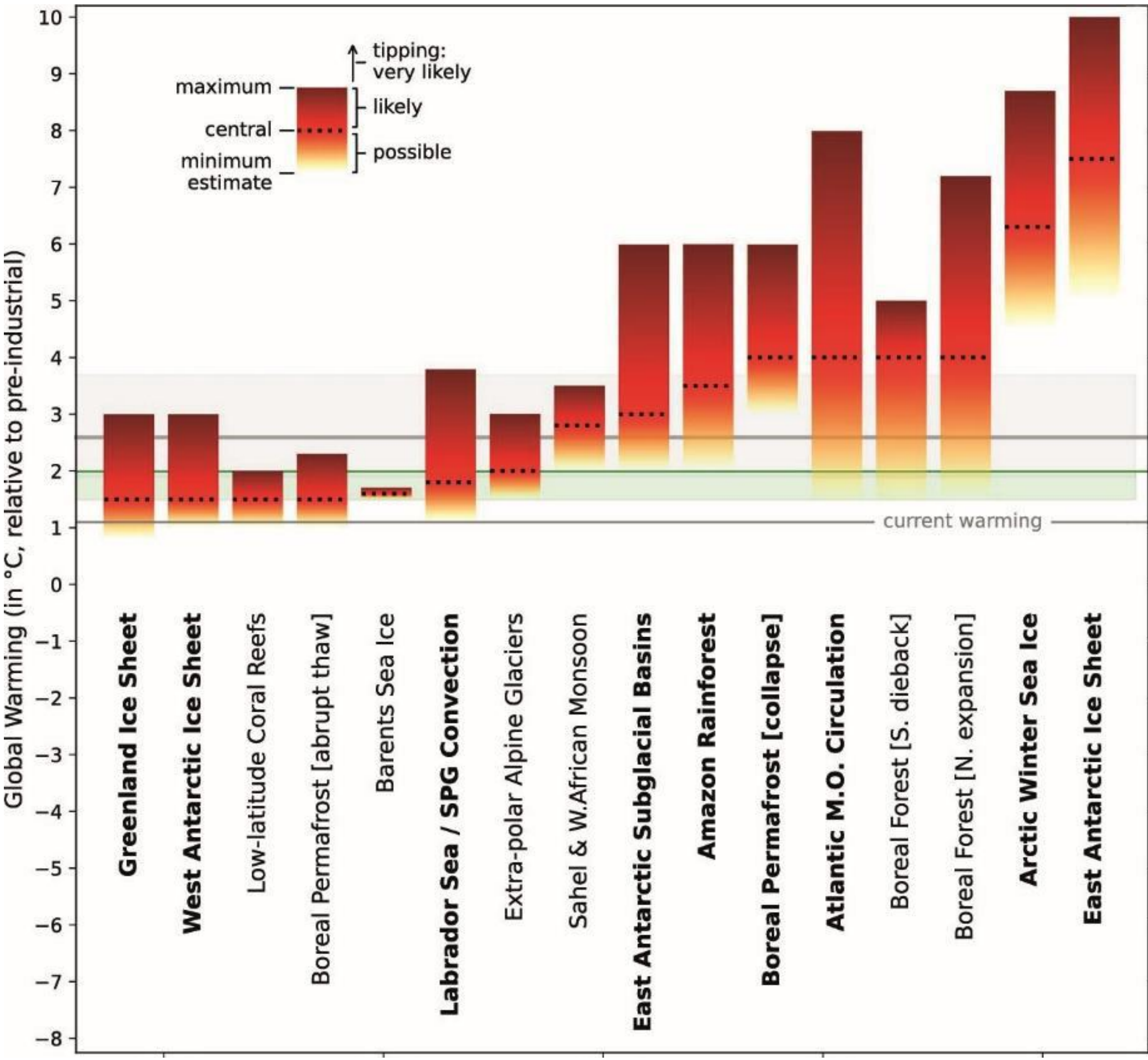
Tipping points, 1/4

- Somewhere between 1.5…2°C of global average temperature rise is probably a ***tipping point*** (point of no return)
- A tipping point is a critical threshold beyond which a system reorganises, often abruptly and/or irreversibly
- More than 25 Earth system tipping points have been identified from evidence of past changes, observational records and computer models (see https://global-tipping-points.org)
- Tipping one system can cause another tipping point to be passed, leading to potentially catastrophic impacts (‘tipping cascade’)
- Timeframes may become short enough to defy the ability and capacity of human societies to adapt, leading to severe effects on human and natural systems

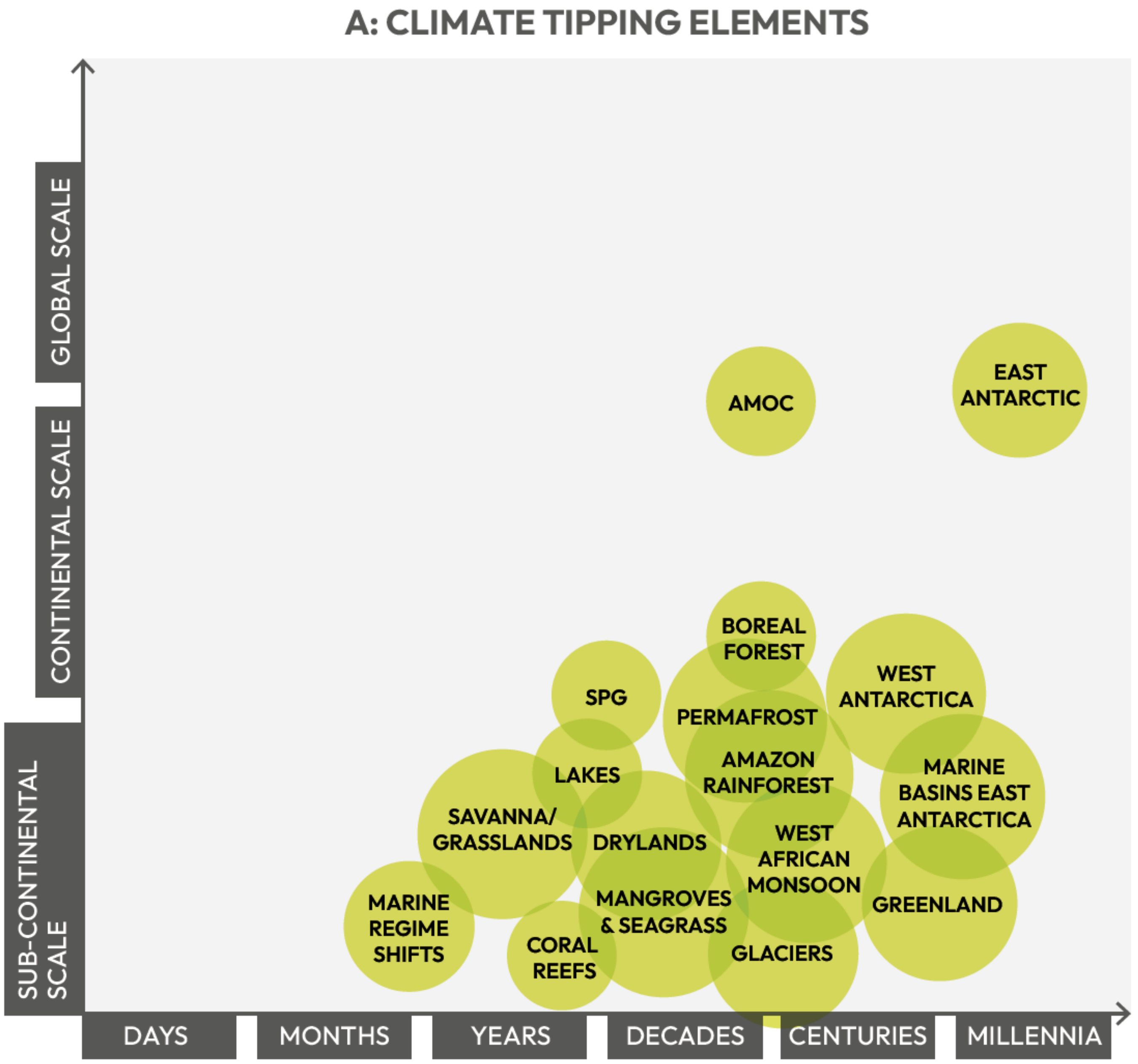
Tipping points, 2/4

Link between levels of warming (from pre-industrial levels) and some **global** and regional tipping elements

OECD 2022 (https://www.oecd.org/en/publications/climate-tipping-points_abc5a69e-en.html)



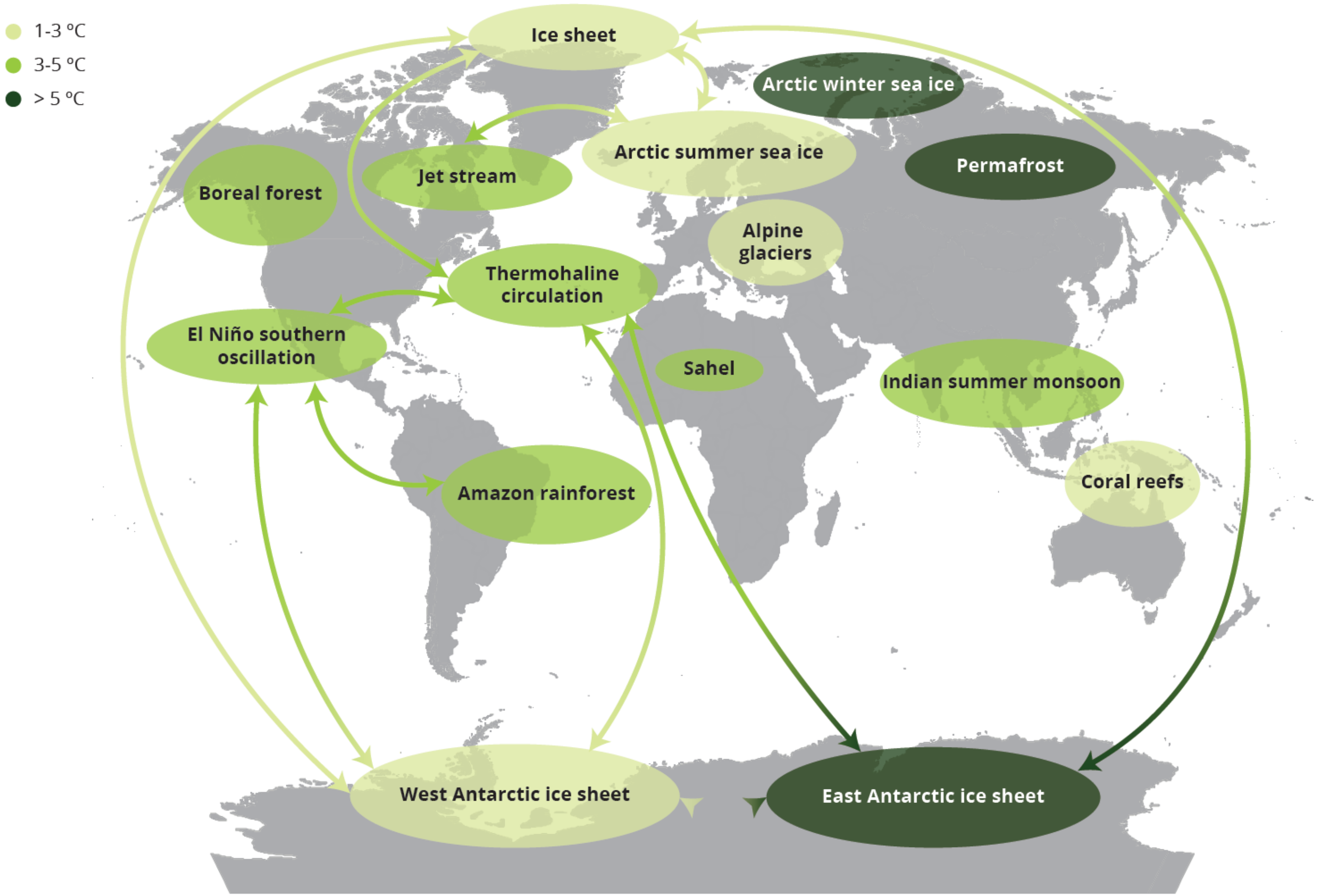
Tipping points, 3/4



Global Tipping Points Report 2023 (https://global-tipping-points.org/section1/1-earth-system-tipping-points)

Tipping points, 4/4

FIGURE 1.3 **Potential tipping elements and cascades according to estimated thresholds in global average surface temperature**



Source: Steffen et al. (2018).

The European Environment 2020 (https://www.eea.europa.eu/soer/publications/soer-2020)

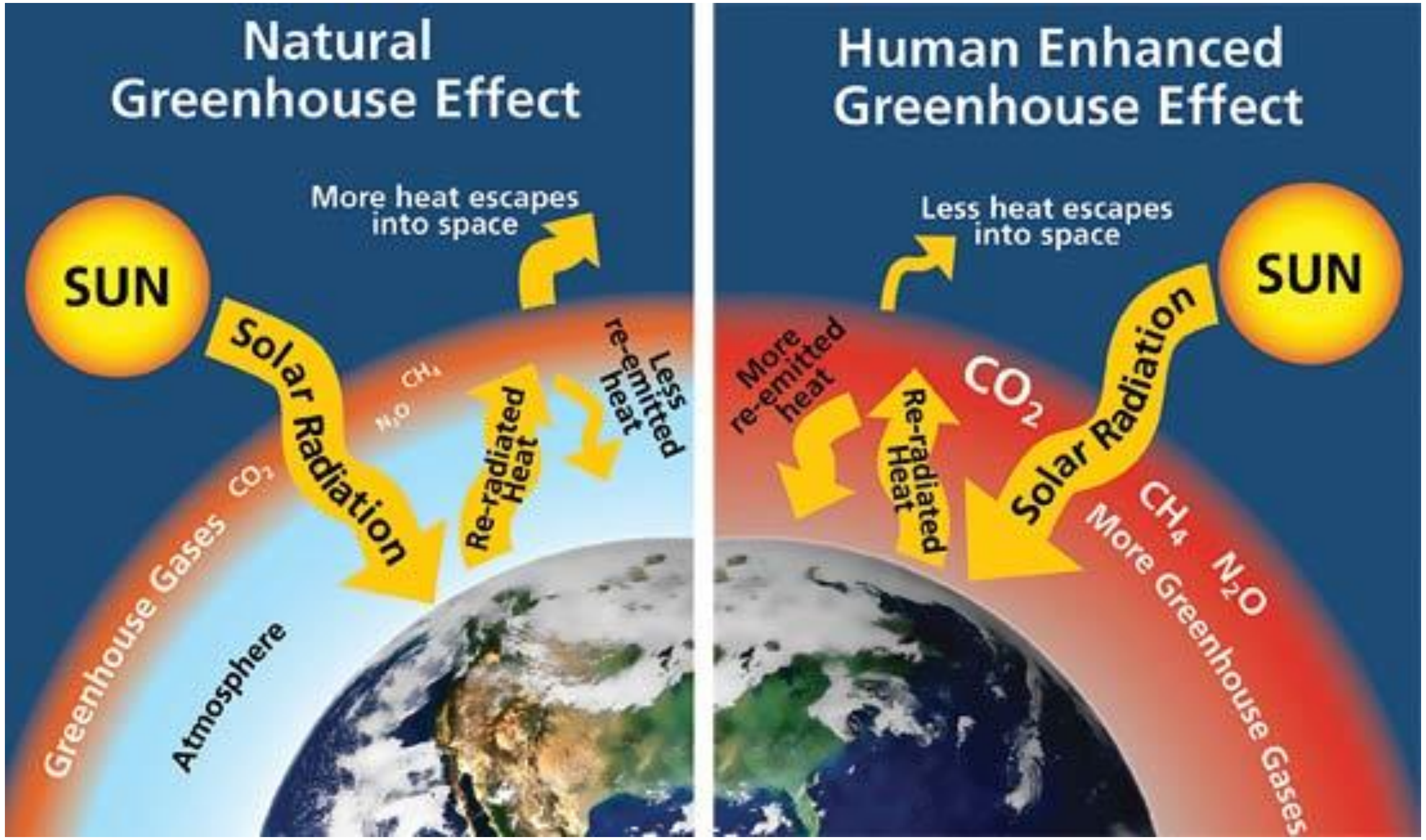
Causes

Greenhouse effect

- Carbon (and other greenhouse gases) makes a „cover,“ which keeps heat inside atmosphere.
- Even tiny change of carbon share causes big changes in Earth climate

1850 – 0,028%

2023 – 0,042%



https://archive.ipcc.ch/ipccreports/tar/wg1/016.htm
https://www.co2.earth/daily-co2
https://www.c2es.org/content/changes-in-climate

Causes of climate change

- Natural:

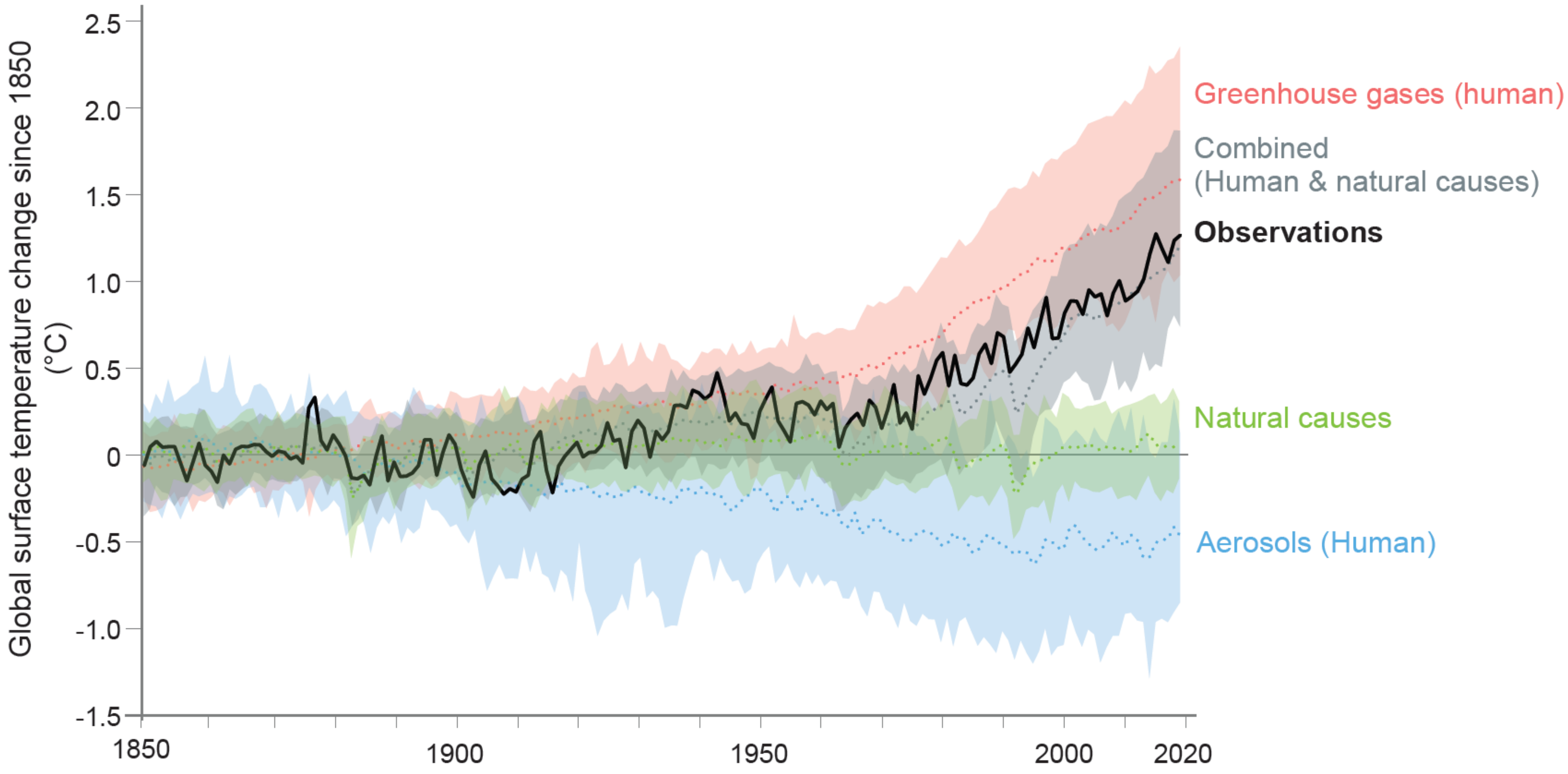
- cyclic changes in the Earth's orbit
- changes in solar activity
- volcanic activity
- leaks of natural gas

- Anthropogenic:

- energy production by burning fossil fuels (coal, oil, gas)
- transport (by using of fossil fuels)
- agriculture (livestock breeding, use of nitrogen-containing fertilizers)
- deforestation (carbon release)
- drainage of wetlands (release of carbon and N_2O)

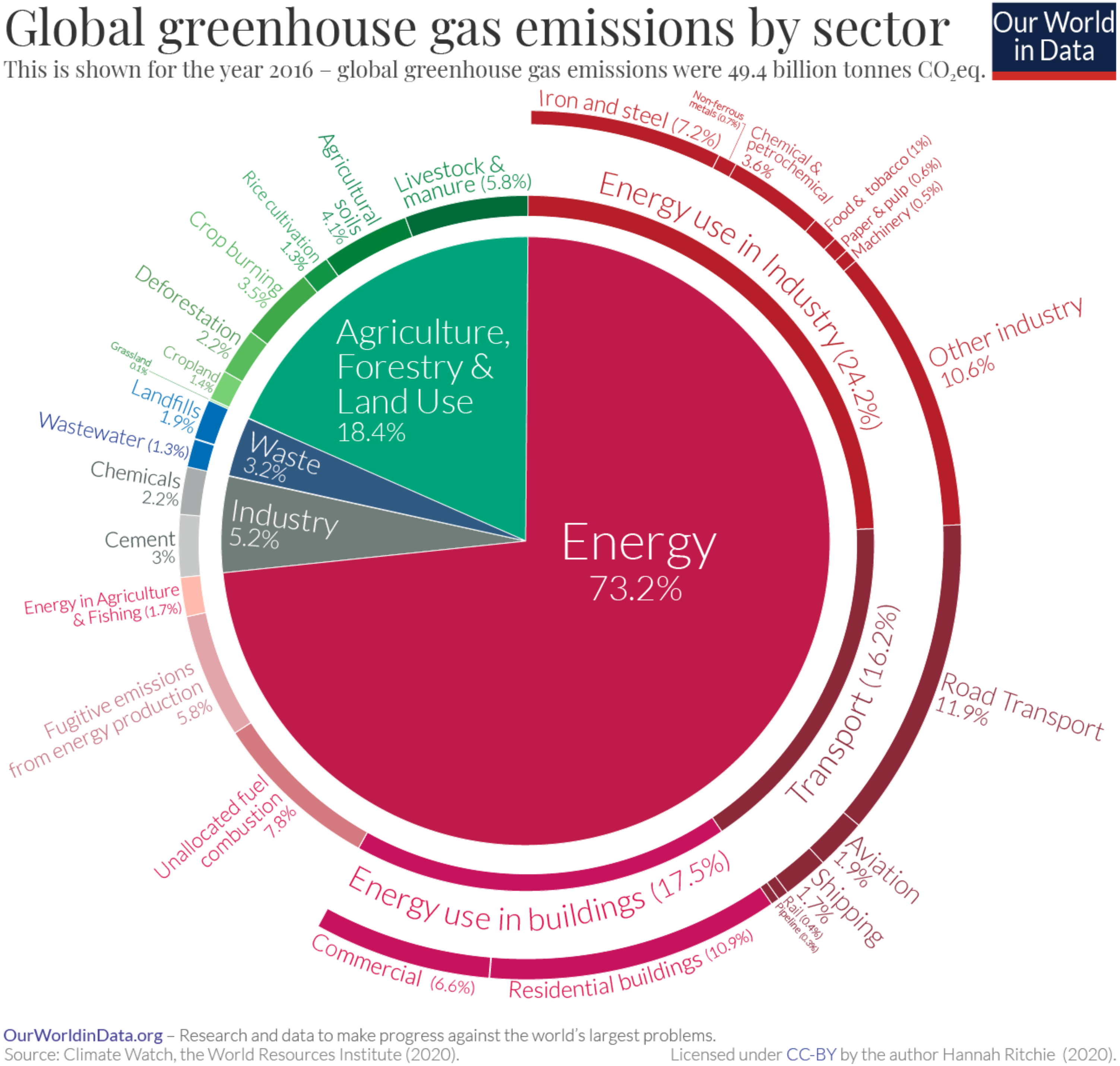
- release of carbon/methane from oceans and from melting permafrost (natural processes, but triggered by anthropogenic climate warming)

Role of athropogenic vs natural causes

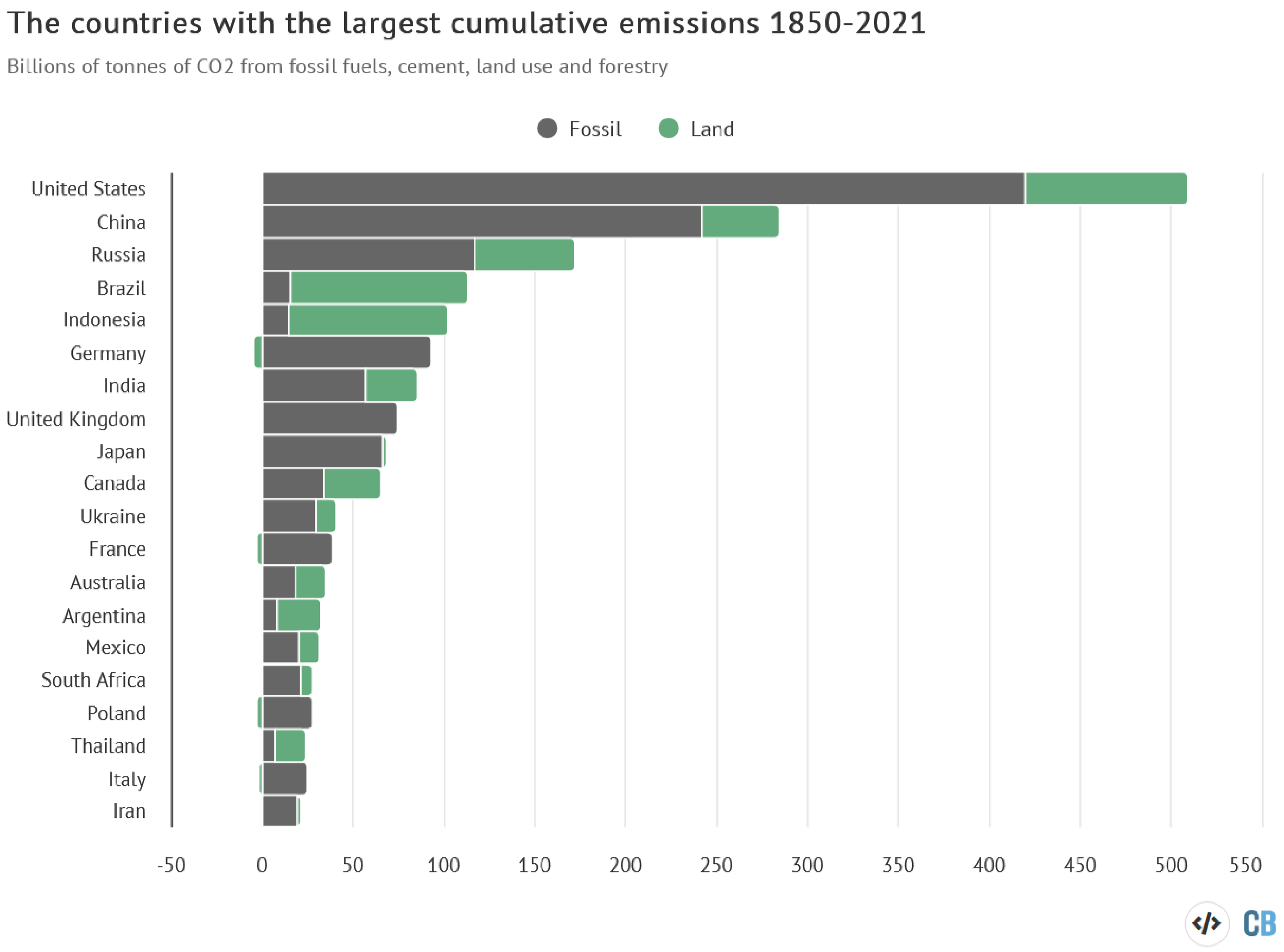


https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter03.pdf

Anthropogenic causes of climate change



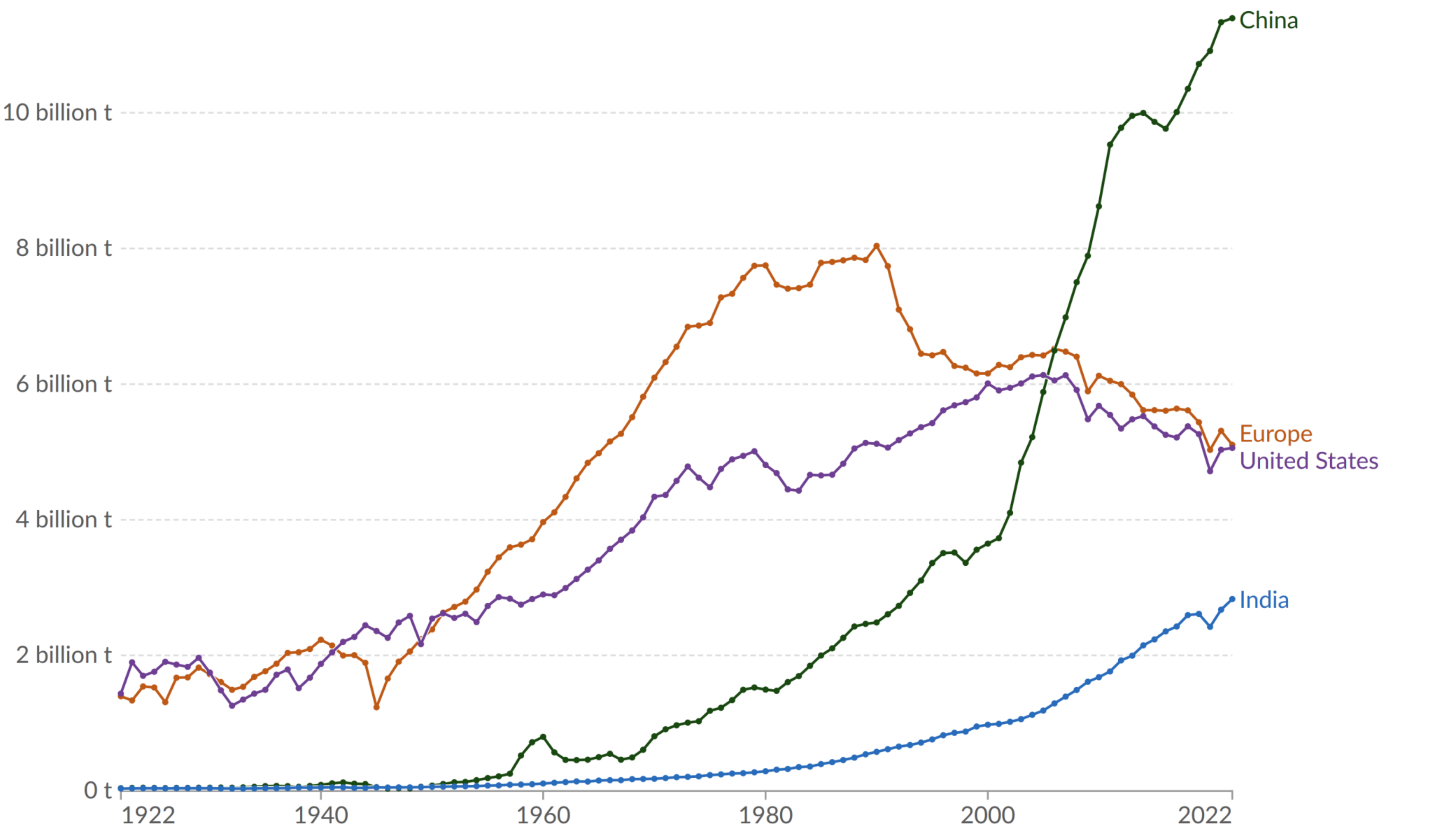
https://ourworldindata.org/emissions-by-sector



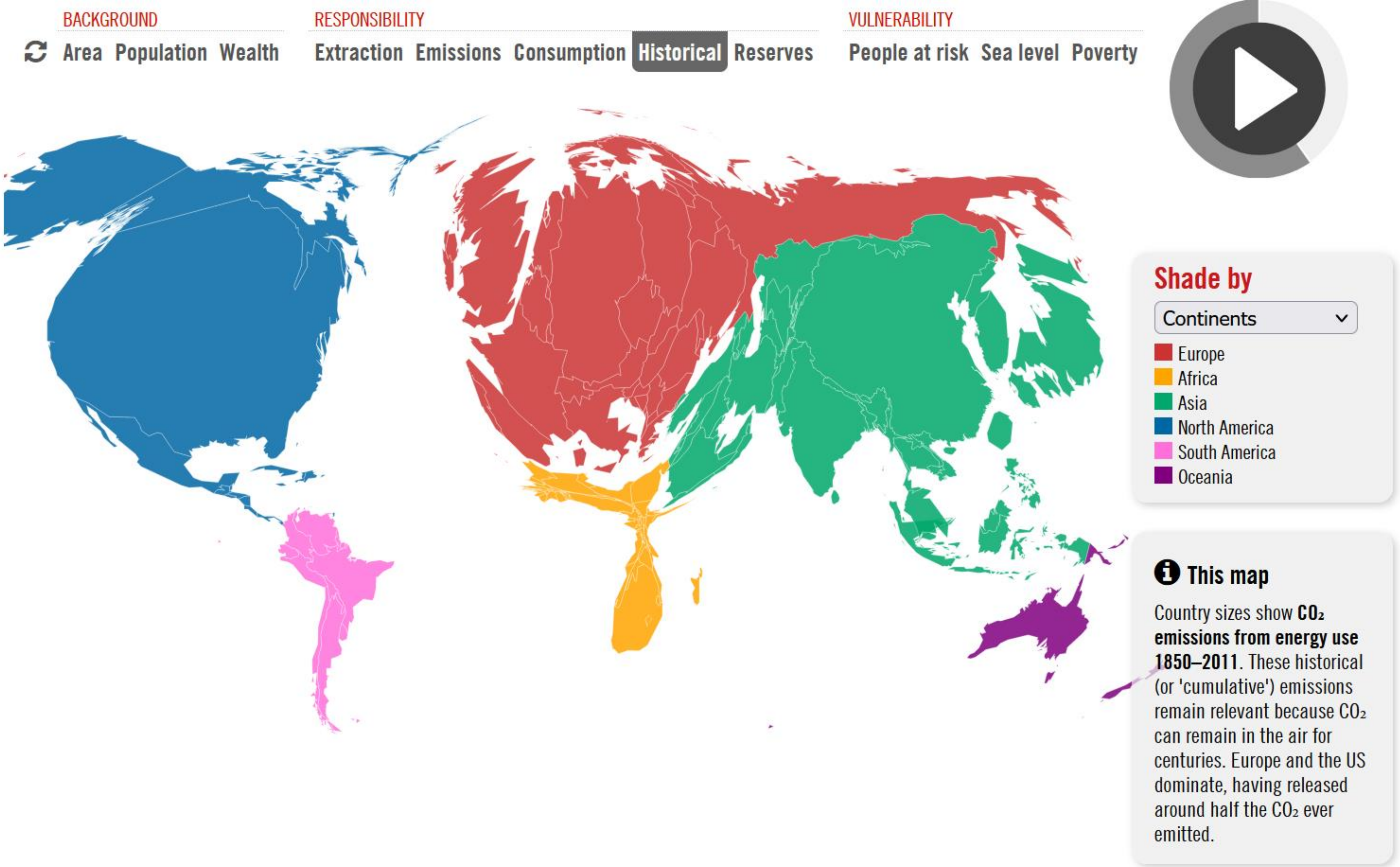
https://www.carbonbrief.org/analysis-which-countries-are-historically-responsible-for-climate-change

Annual CO_2 emissions

Carbon dioxide (CO_2) emissions from fossil fuels and industry[1]. Land-use change is not included.



https://ourworldindata.org/co2-emissions



https://www.theguardian.com/news/datablog/interactive/2012/mar/29/carbon-map-infographic-world

3. Impacts of climate change

Impacts of climate change to nature

- shift of climatic zones, change of ecosystems, extinction of certain species
- decrease of ice cover (Greenland & Antarctica, polar sea, glaciers, permafrost)
- sea level rise, warming of seawater, acidification, changes in currents
- forest fires
- deterioration of soil quality
- ...

Impacts of climate change to human society

- Instability and damage from increased frequency of extreme weather events (hurricanes, storms, droughts, floods, flash floods, etc.)
- Challenges caused by general warming:

- large territories become uninhabitable (urban & rural)
- problems in agriculture, fishing = food shortage
- lack of freshwater
- spread of diseases
- changes in the economy, tourism
- increased migration (climate refugees), deepening inequality
- armed conflicts
- ...

Impacts to nature: climatic zones, habitats, 1/3

- **Species (incl. humans) and habitats are moving towards the poles, in mountains snow line rises higher**
- Pace of shift of climate zones varies, the order of magnitude in continental Europe is 30*...100** km per 10 years towards North and East (with pace accelerating)
- The border of species range in Europe shifts approx. 6 km in 10 years on the land (1-28 km in 10 years in the sea)
- In the mountains, the limit of vegetation is shifting higher by approx. 60 m in 10 years***

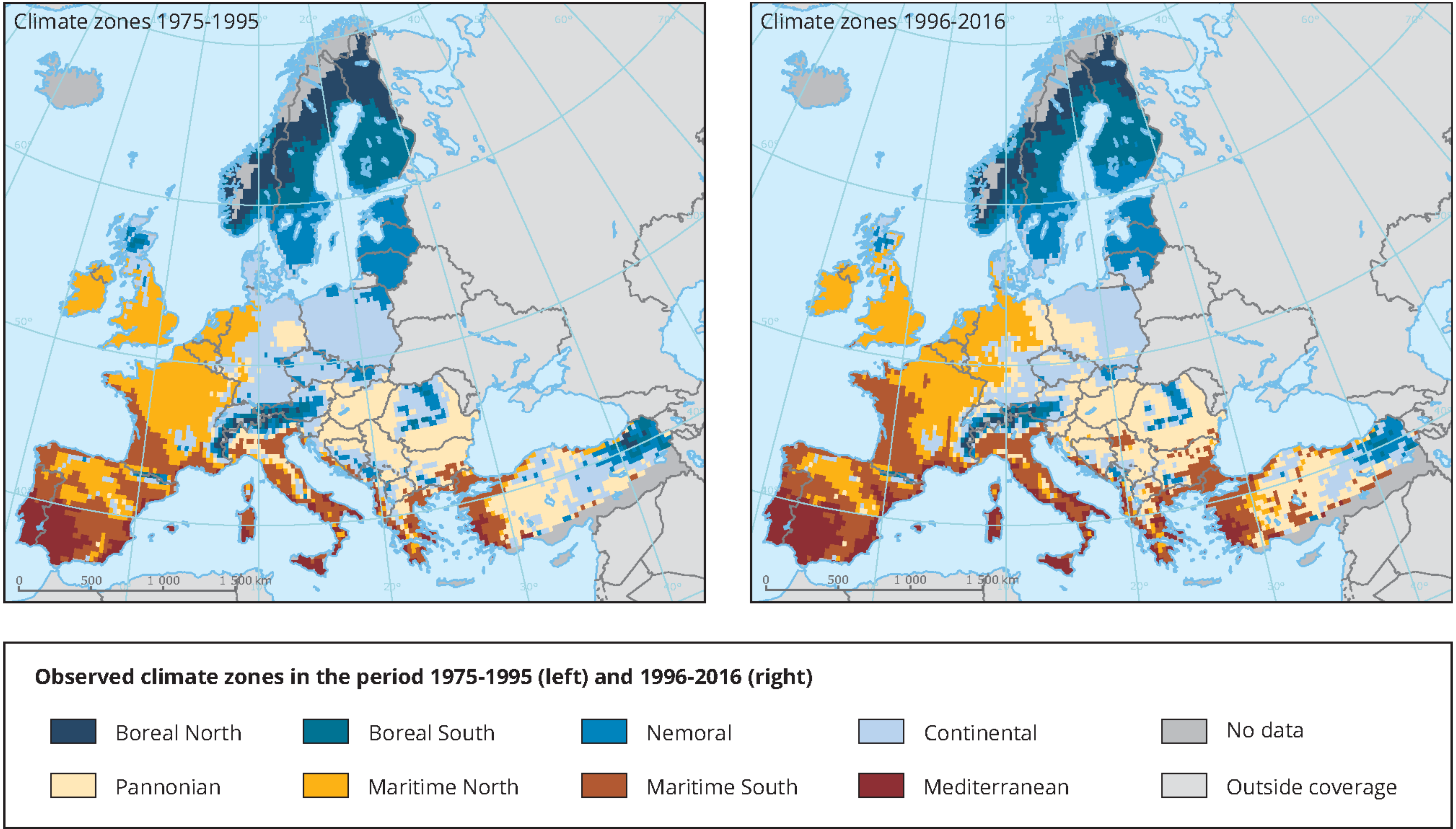
* https://www.science.org/doi/10.1126/science.1210288

** https://doi.org/10.1029/2019EF001178

*** https://doi.org/10.1371/journal.pclm.0000071

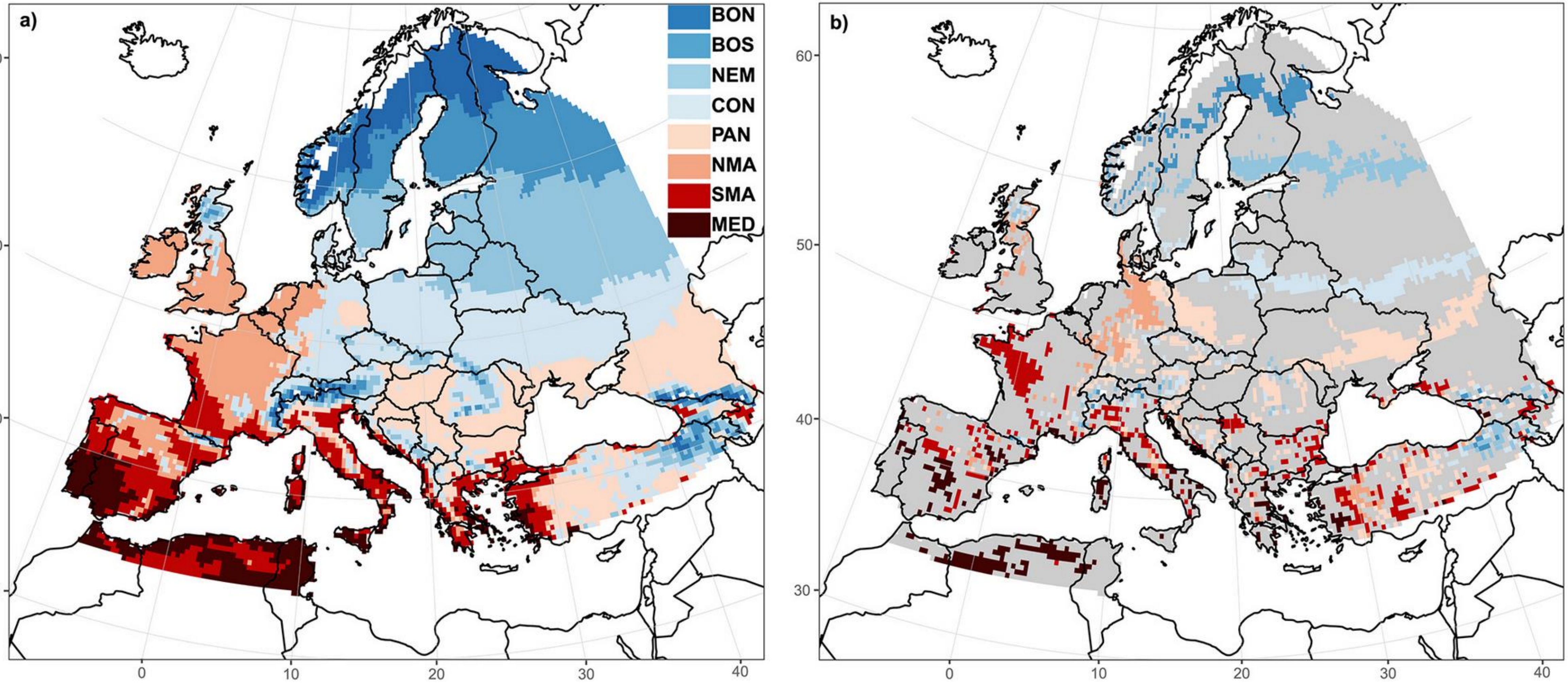
Impacts to nature: climatic zones, habitats, 2/3

Change of agro-climatic zones in Europe
1975-1995 vs 1996-2016 (EEA 2019)



Impacts to nature: climatic zones, habitats, 3/3

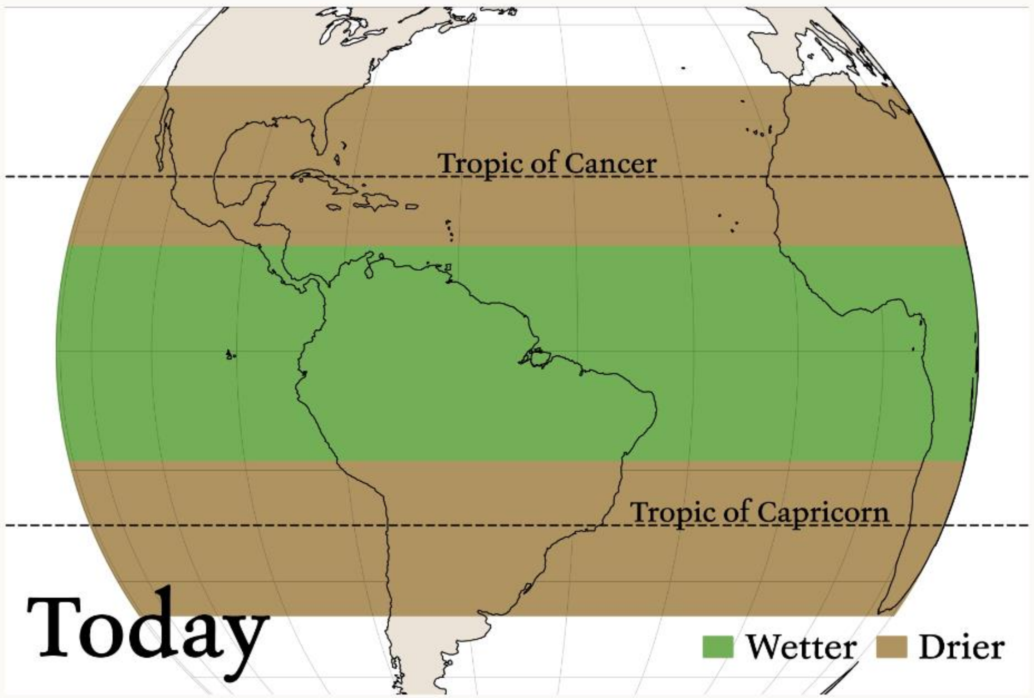
Change of agro-climatic zones in Europe 1975-1995 vs 1996-2016 (grey – no change)



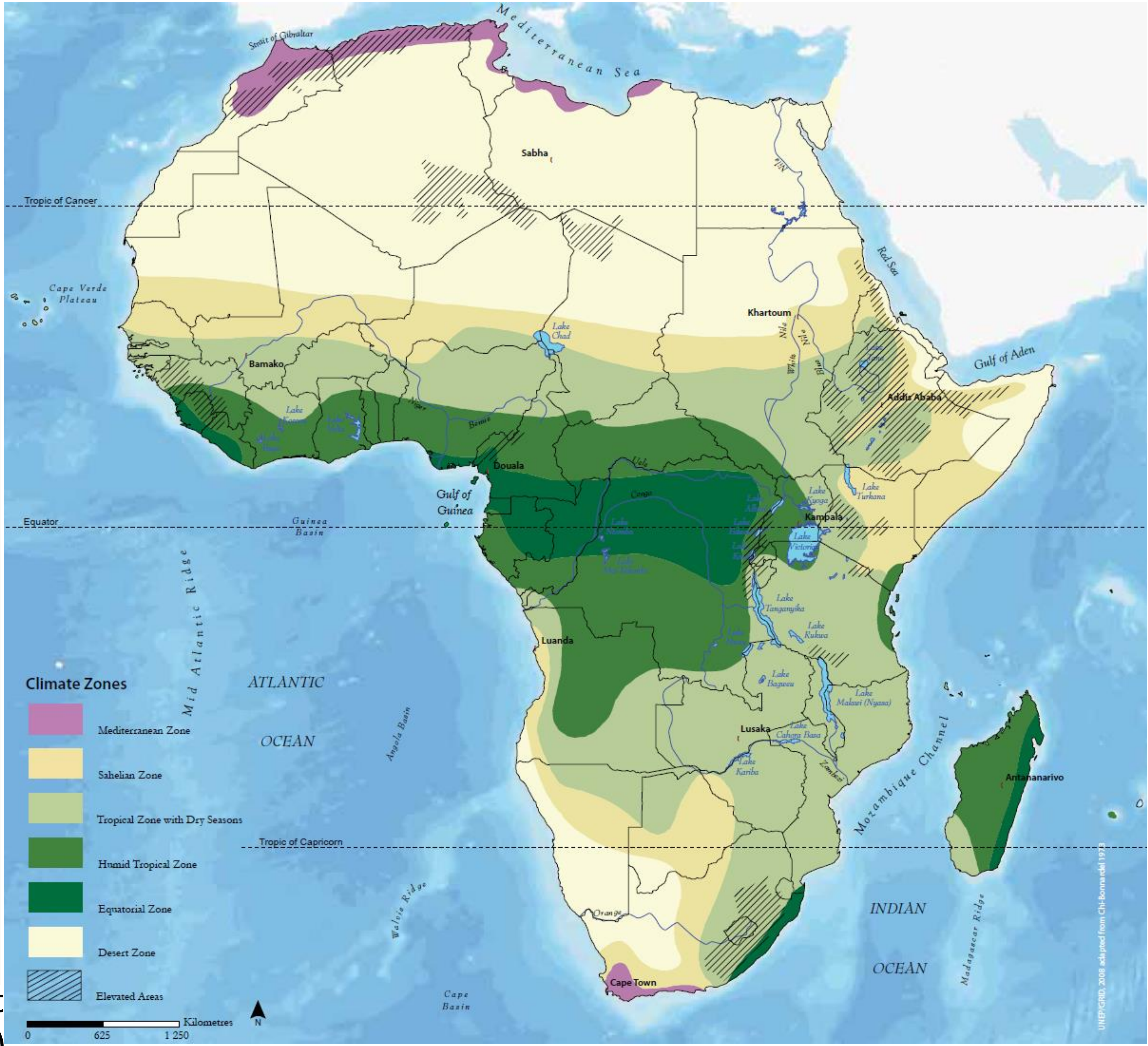
https://doi.org/10.1029/2019EF001178

"*Tropic squeeze*"

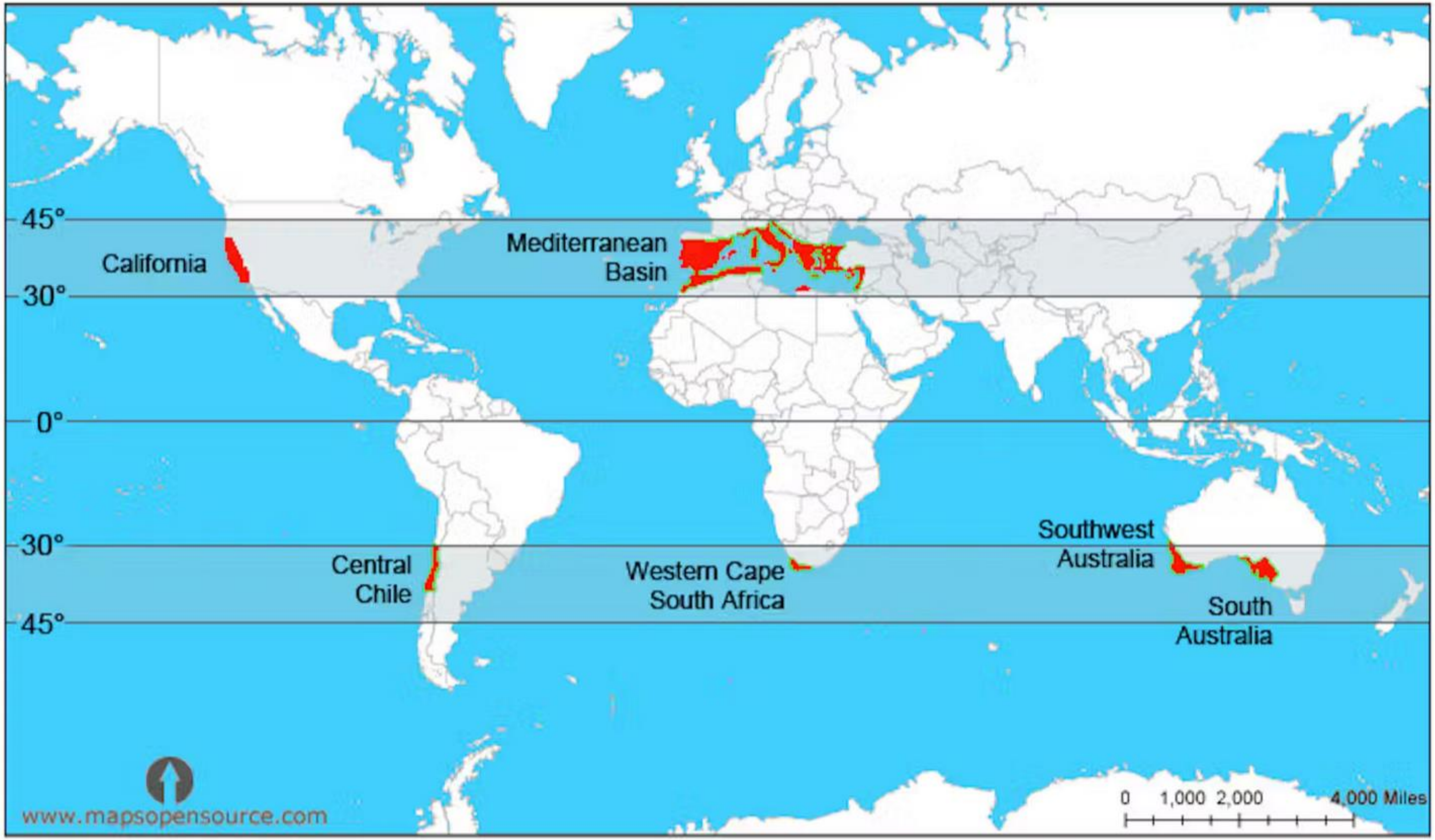
- The tropical zone is expanding, at the pace of about 1 degree of latitude (110 km) in 30 years



The tropics are expanding by half a degree per decade. SOURCE: STATEN ET AL., NATURE CLIMATE CHANGE, 2018. GRAPHIC BY KATIE PEEK.



UNEP, 2008. Africa: Atlas of Our Changing Environment (https://wedocs.unep.org/handle/20.500.11822/7717)



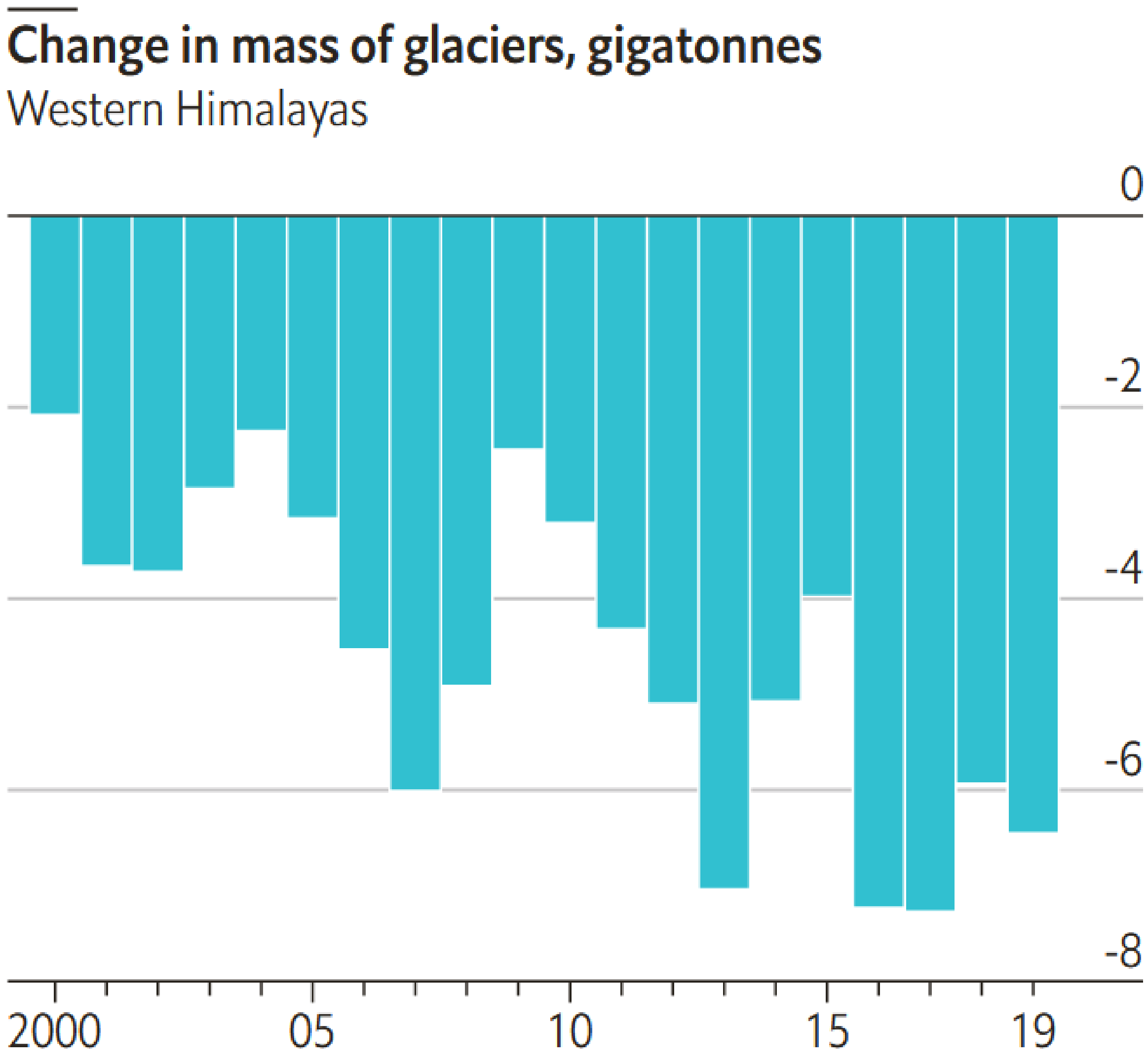
The Mediterranean climates of the world are experiencing drying and warming as the edge of dry subtropical zone - located near 30N and 30S shifts poleward. Steve Turton

https://theconversation.com/africa-should-be-worried-about-the-expanding-tropics-69375

Impacts to nature: melting of continental ice, 1/3

- Areas covered in ice and snow help to cool the planet (they do not absorb heat like darker areas - land and sea)
- 10% of land is covered by continental ice (90% of it in Antarctica)
- The increase in average temperature reduces the volume of ice/snow
- If all the continental ice would melt, global sea level would rise by 60 m
- Continued melting of the Antarctic ice sheet will raise global sea levels by up to 28 cm by 2100 (IPCC)
- The predicted 3.3% melting of the Greenland ice sheet by the year 2100 (110 trillion tons) will raise the global sea level by 27 cm
- Greenland's ice cover currently melts about 280 billion tons per year, in Antarctica 150 billion tons of ice per year
- Greenland's ice is currently melting 6-7 times faster than 25 years ago

Impacts to nature: melting of continental ice, 3/3

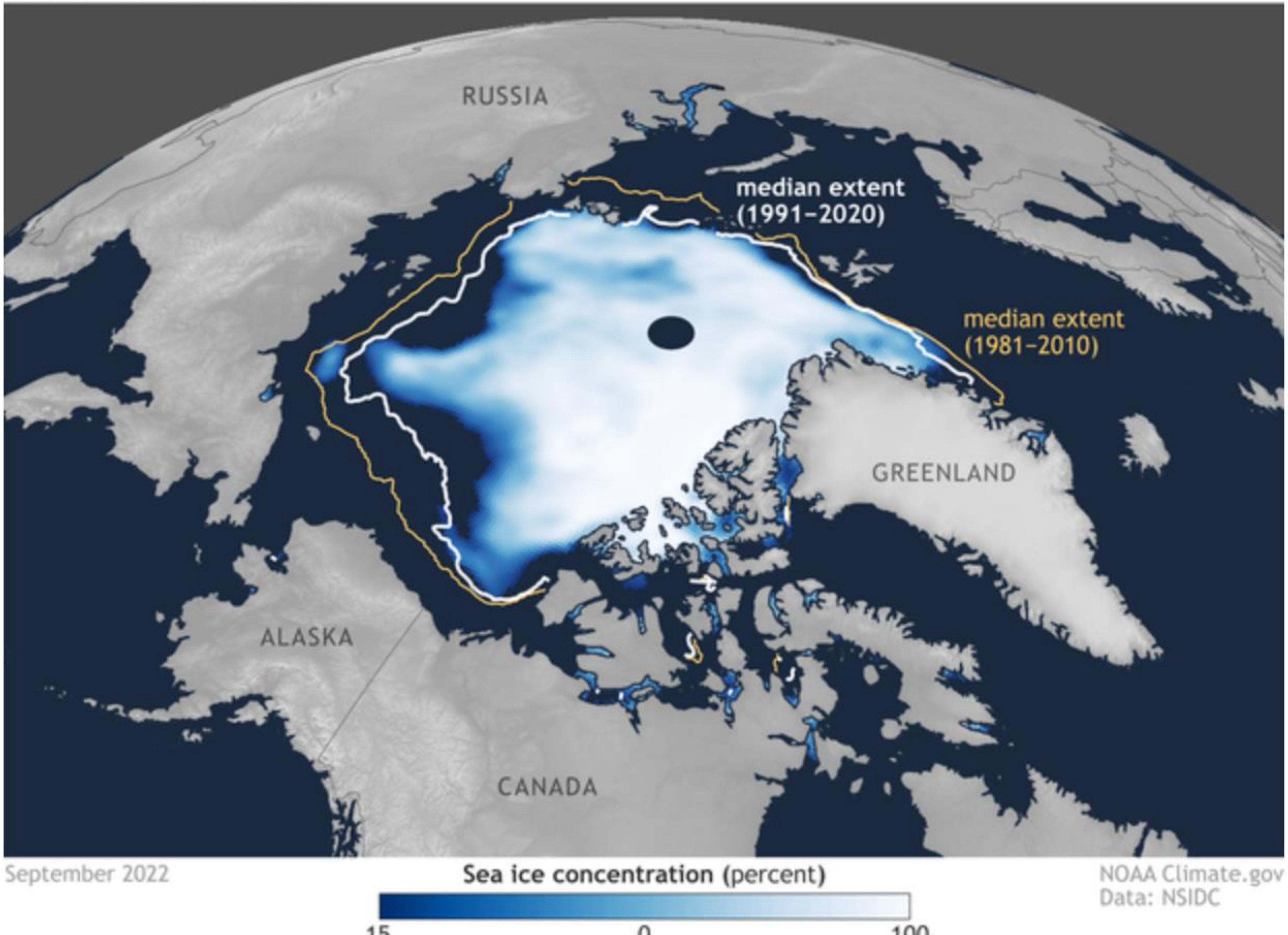


Economist 17-23 September 2022

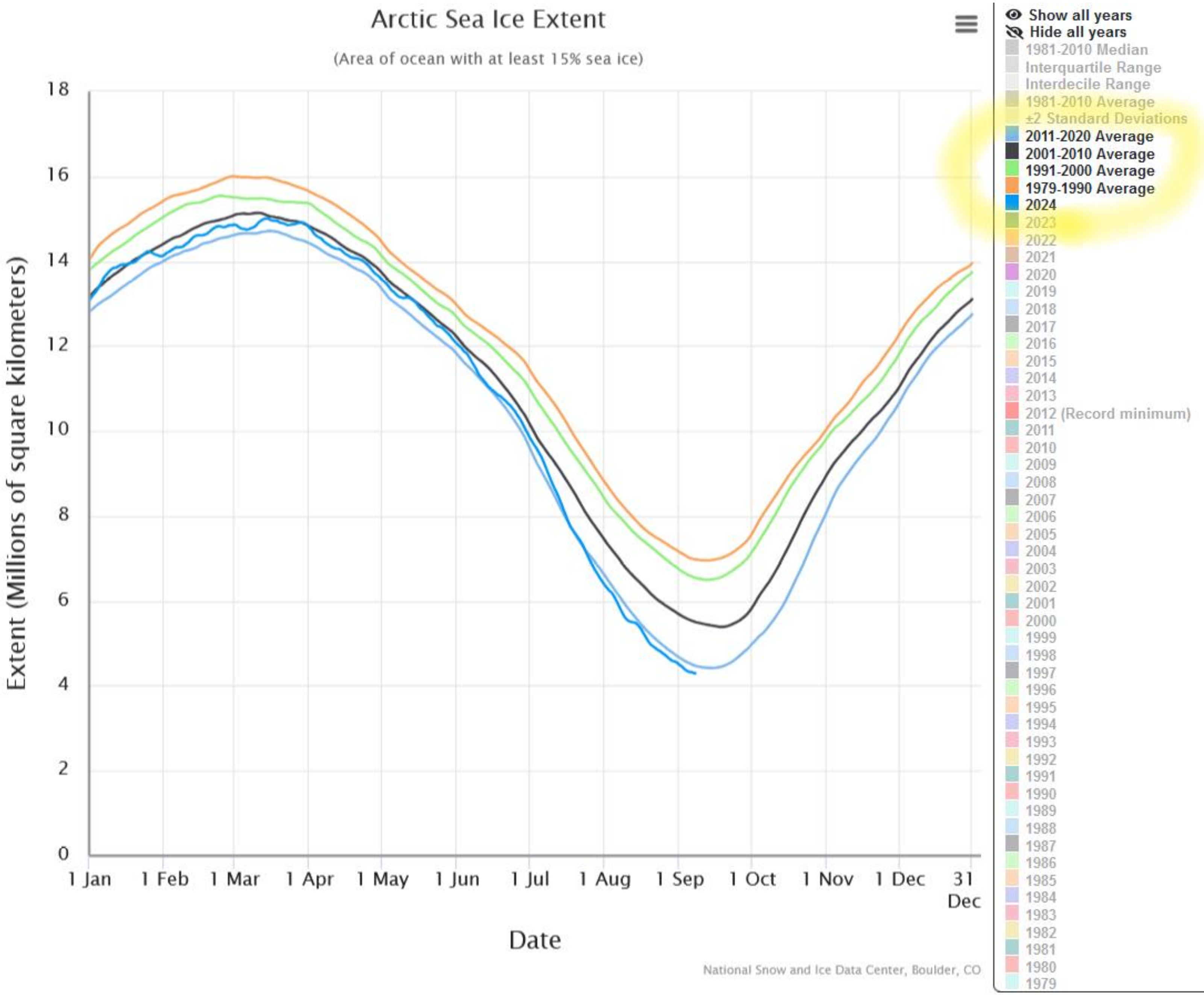
Impacts to nature: polar seas, 1/3

- Arctic sea is covered by ice (with smallest extent at the end of Summer, in September)
- the Arctics is one of the fastest warming areas due to climate change
- 12% of the Arctic ice cover will disappear in 10 years
- the ice sheet in the sea is thinning (has melted 2/3 thinner)
- the proportion of old ice decreases
- ice cover grows and melts faster (today 70% of ice is seasonal)

2022 summer minimum



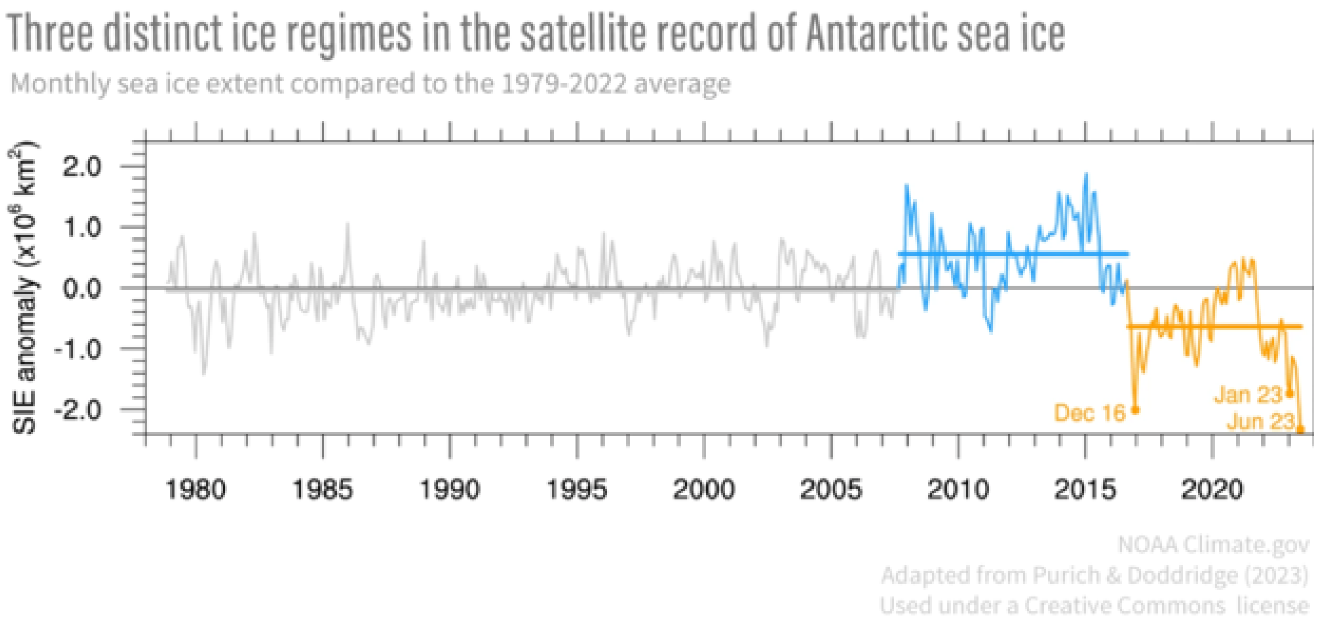
Impacts to nature: polar seas, 2/3



Arctic sea-ice extent (million km2, 1979-2024)

https://nsidc.org/sea-ice-today/sea-ice-tools/charctic-interactive-sea-ice-graph

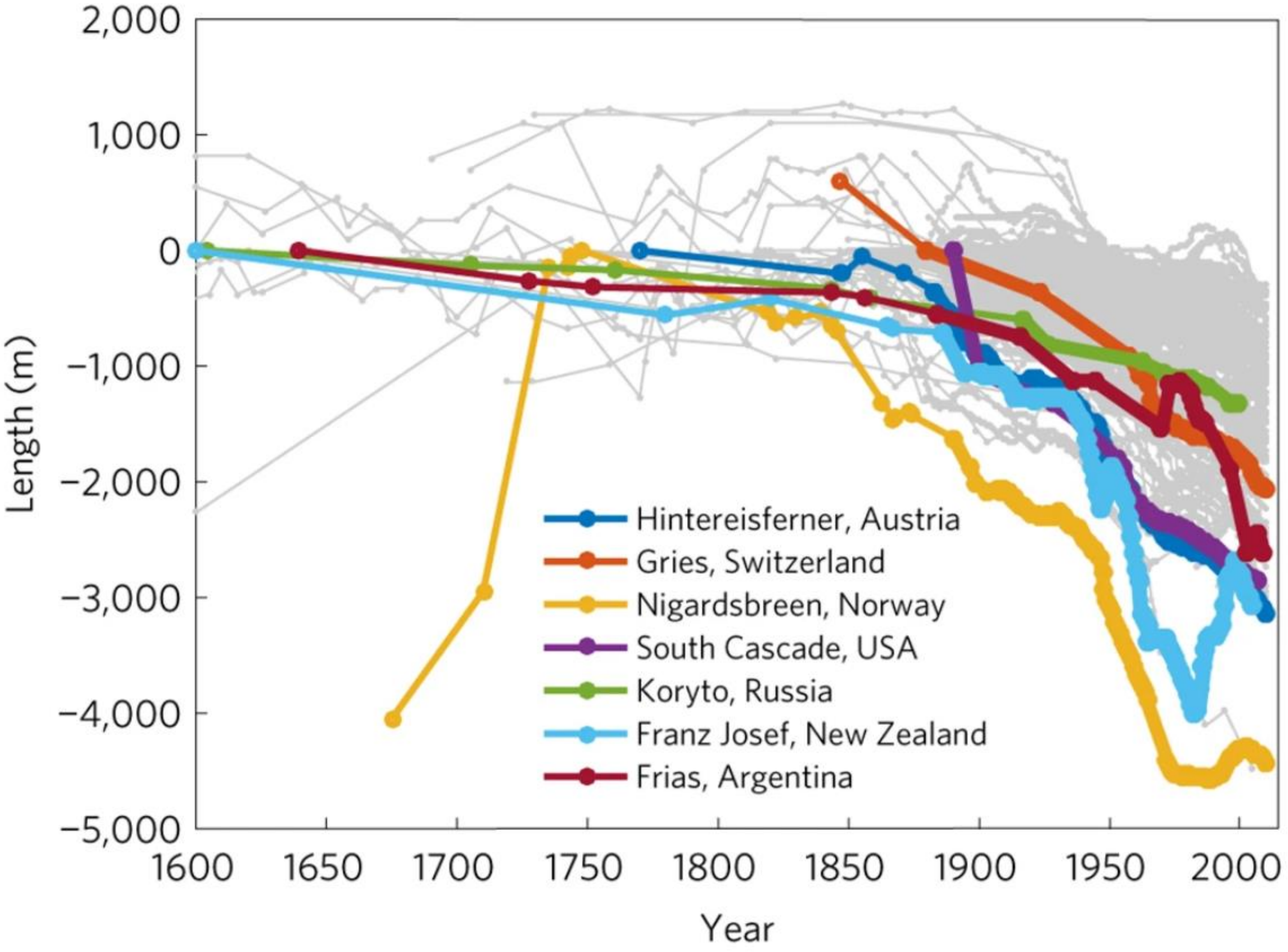
Impacts to nature: polar seas, 3/3



- https://www.climate.gov/news-features/event-tracker/antarctic-sea-ice-summer-minimum-ties-second-lowest-record-2024
- https://www.bbc.com/news/science-environment-66724246

Impacts to nature: lack of freshwater, 1/3

- Glaciers retreat:
- In short run, mountain rivers are abundant in water
- In long run, mountain rivers are water scarce or dry (as are villages, cities and countries downstream)

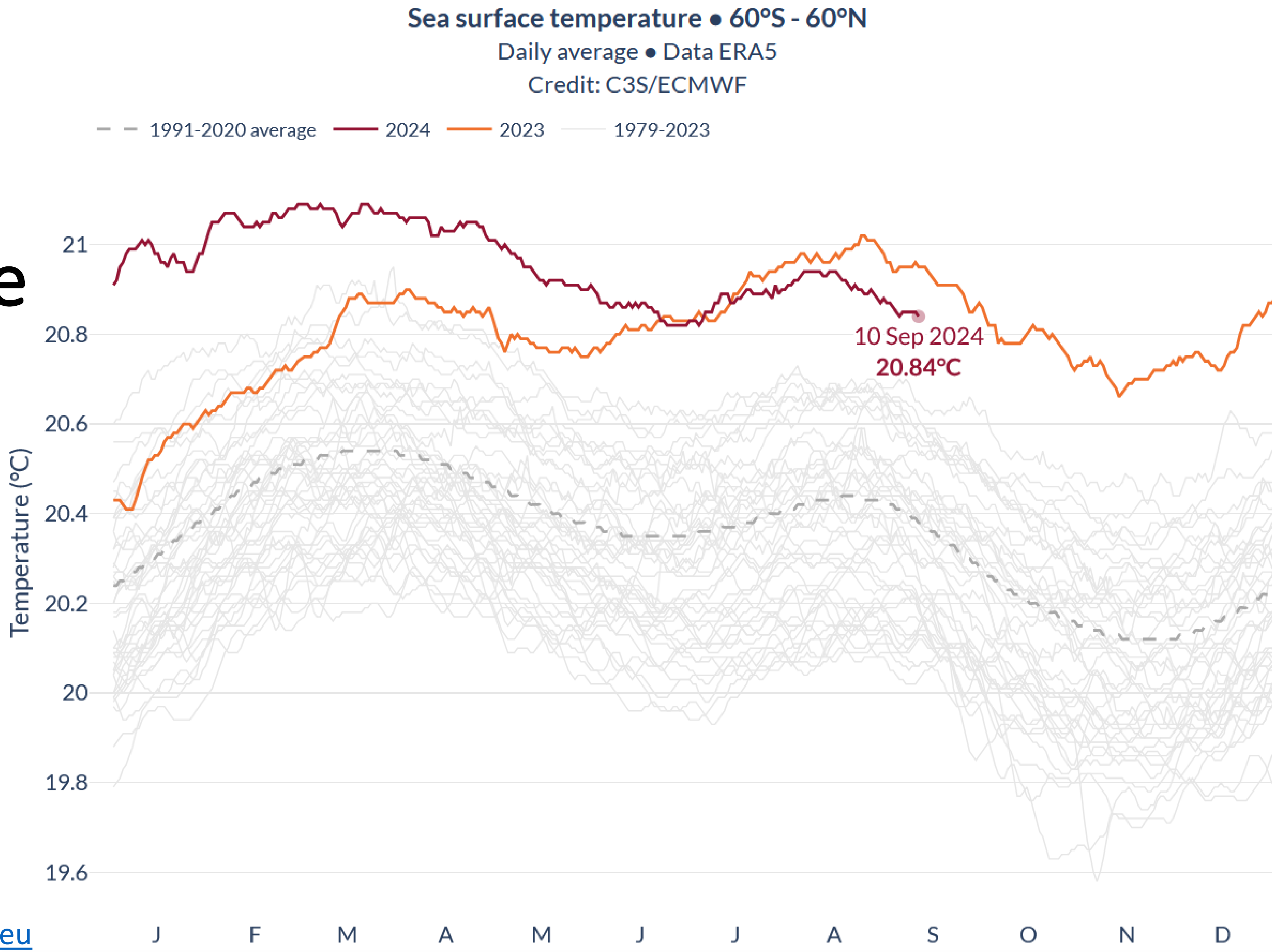


Glacial retreat
(www.nature.com/articles/ngeo2863)

Impacts to nature: lack of freshwater, 2/3

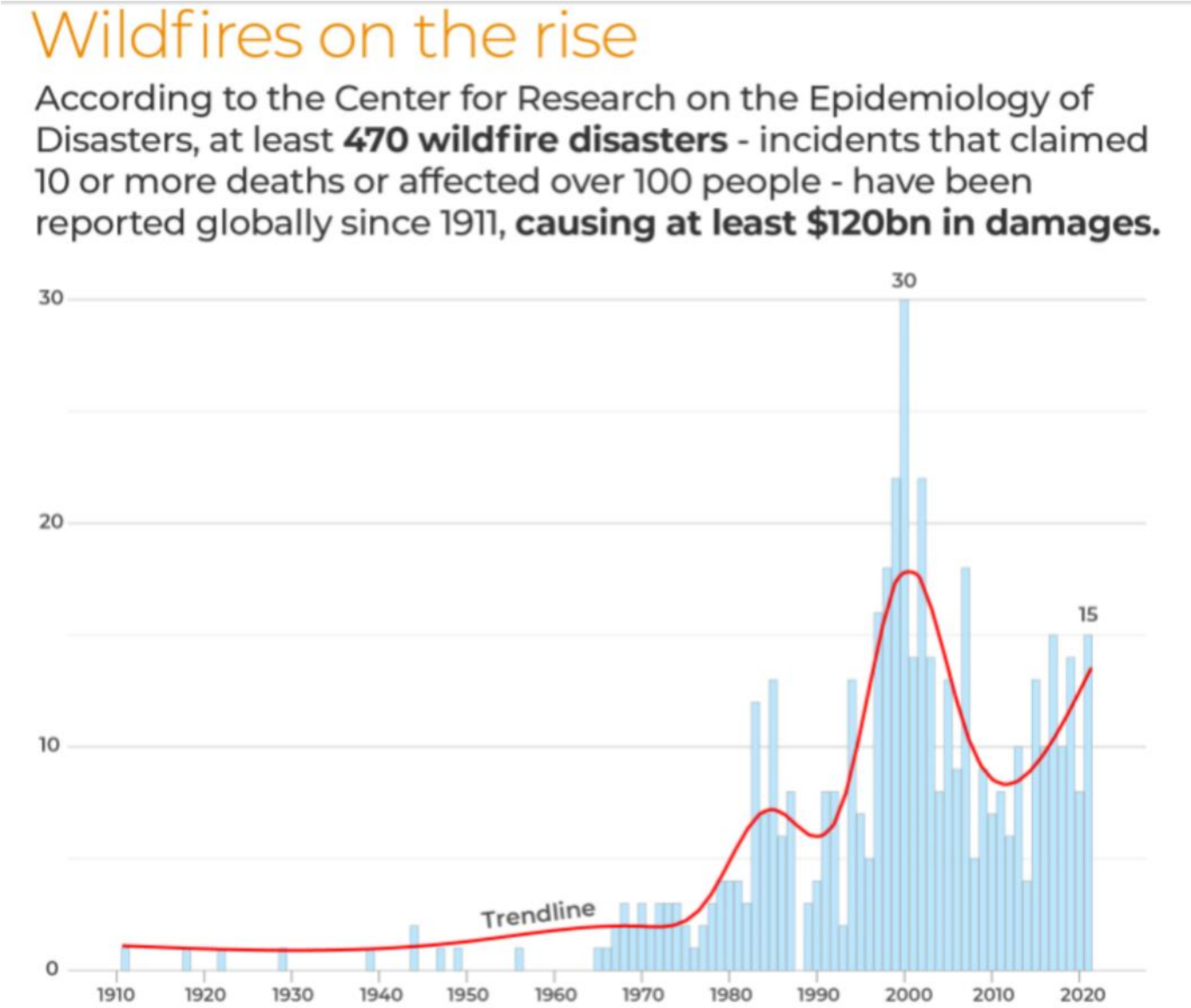
Impacts to nature: lack of freshwater, 3/3

Impacts to nature: sea temperature



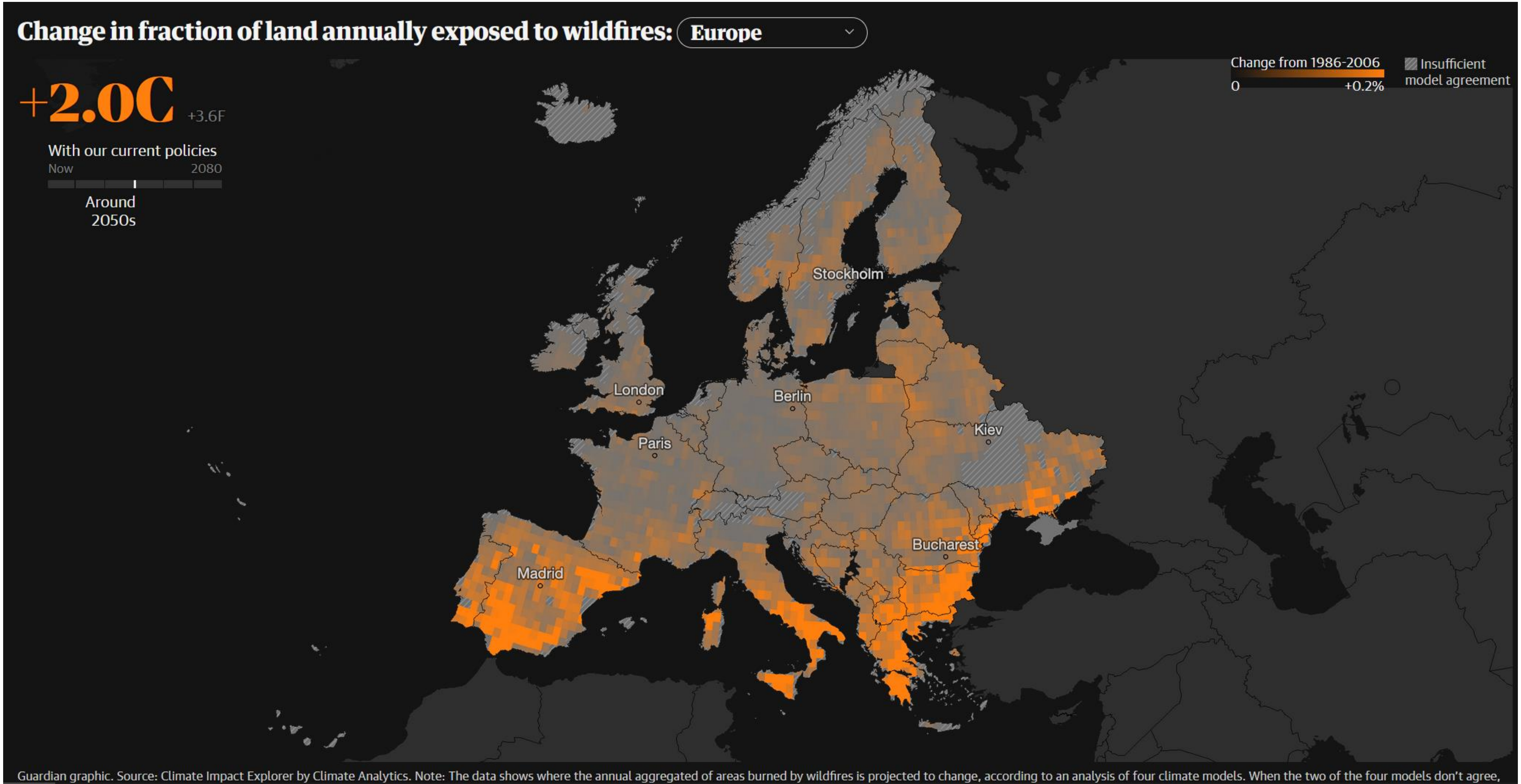
https://pulse.climate.copernicus.eu

Impacts to nature: wildfires, 1/2



https://www.aljazeera.com/news/2021/8/19/mapping-wildfires-around-the-world-interactive

Impacts to nature: wildfires, 2/2



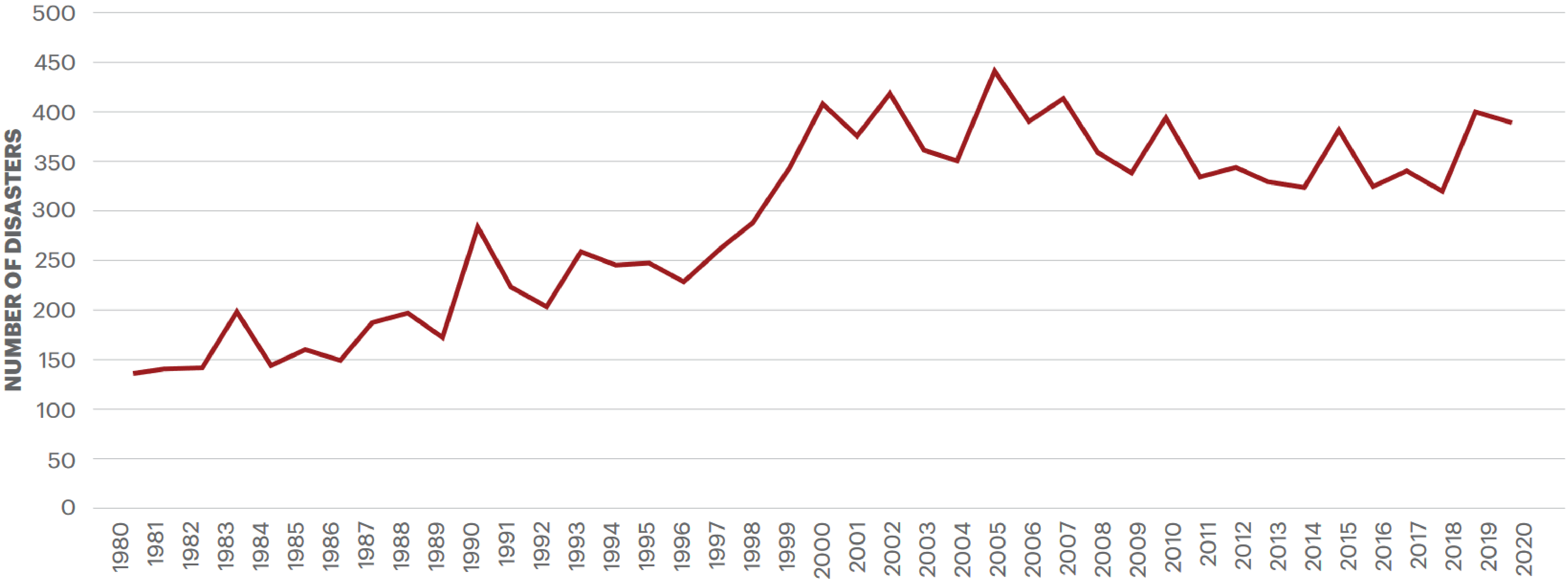
Impacts to human society, 1/3

- Frequency and increasing power of extreme weather events is a major problem (with unpredictability)
- Rapid speed of changes a problem (difficult to adapt)
- Problems visible and understandable: extreme weather events more frequent: floods, storms, heat waves, flash floods, ...
- Problems less visible but certain: warming with its consequences

- frequent heat waves
- spread of diseases/pathogens (malaria, dengue fever, ticks, viruses...)
- rising sea level
- impacts to land use, agriculture
- ...

Trend in natural disasters, 1980–2020

Since 2000, the number of disasters has plateaued between 300 and 450 disasters annually.



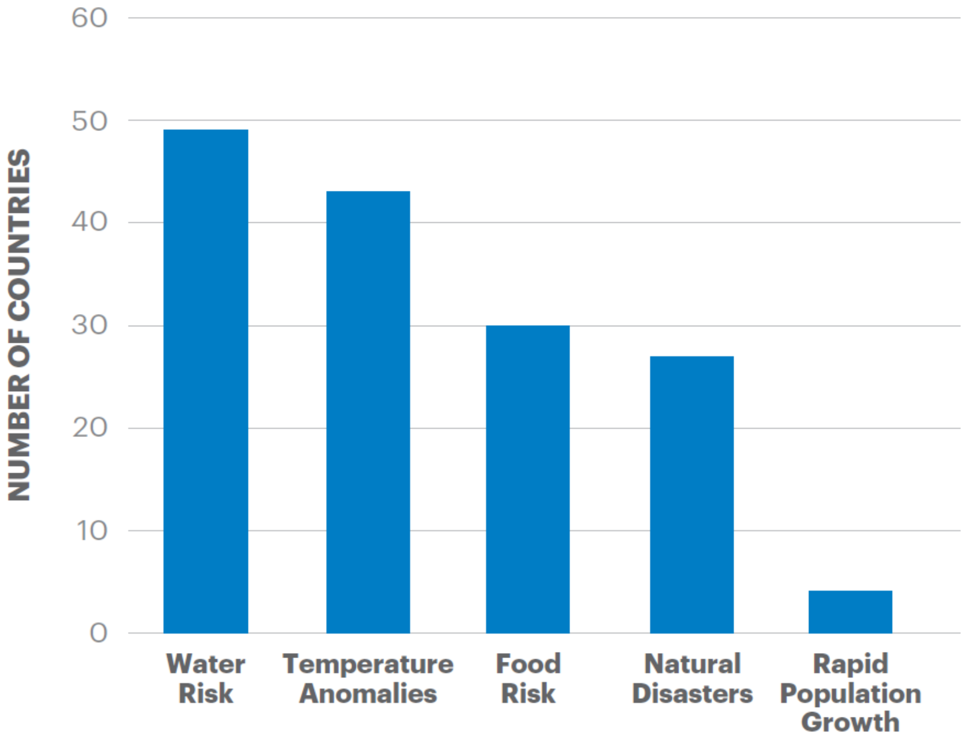
Source: EM-DAT; IEP

Ecological Threat Report 2021 (www.visionofhumanity.org/wp-content/uploads/2021/10/ETR-2021-web-131021.pdf)

Impacts to human society, 2/3

The frequency of the maximum catastrophic threat type, high or extremely high threat, number of countries, 2021

Water risk is the most common maximum threat. Forty-nine countries score high and extremely high for *water risk* as well as it being the highest scoring indicator of the country.



Source: IEP

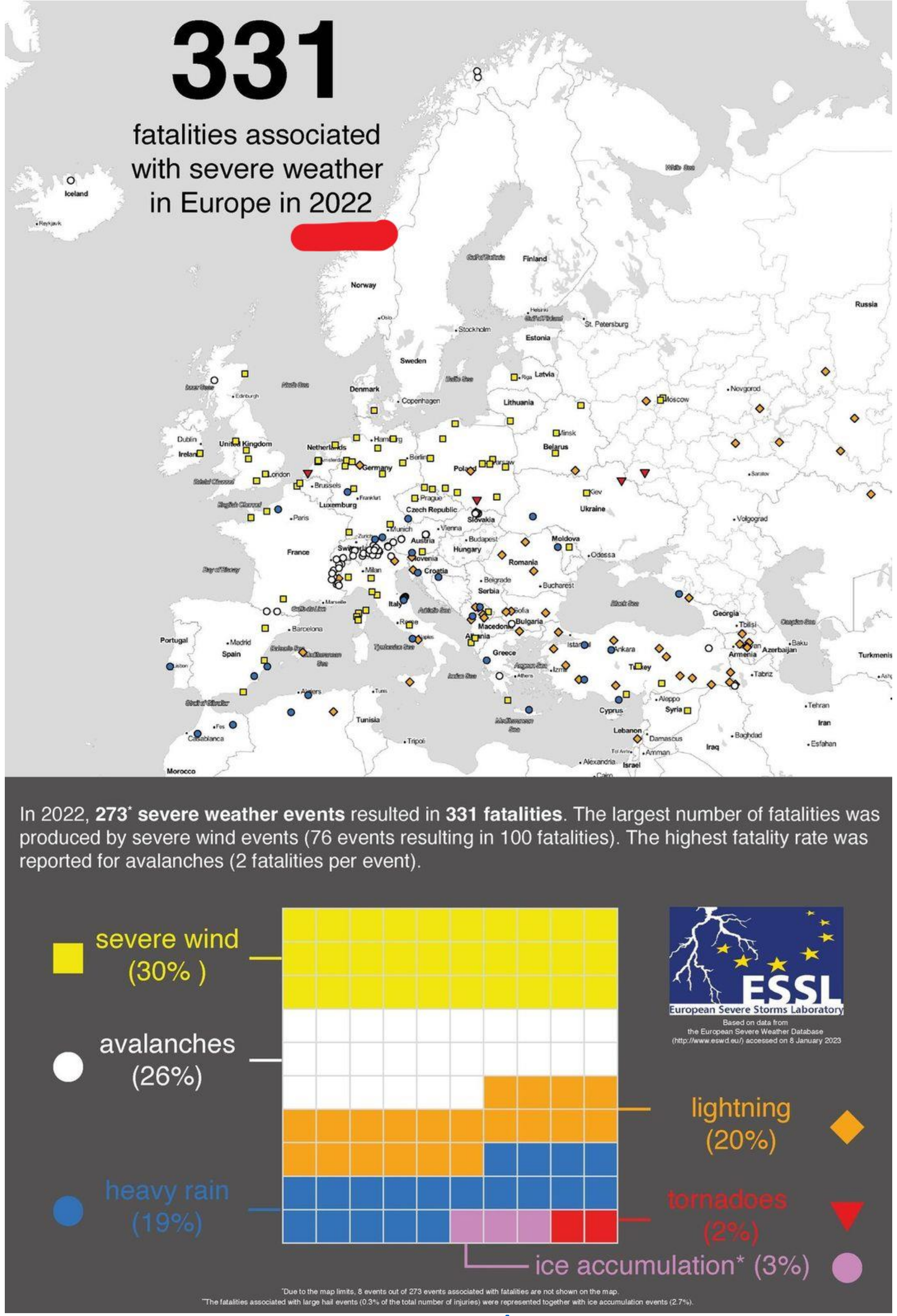
Average ETR score, by region, 2021

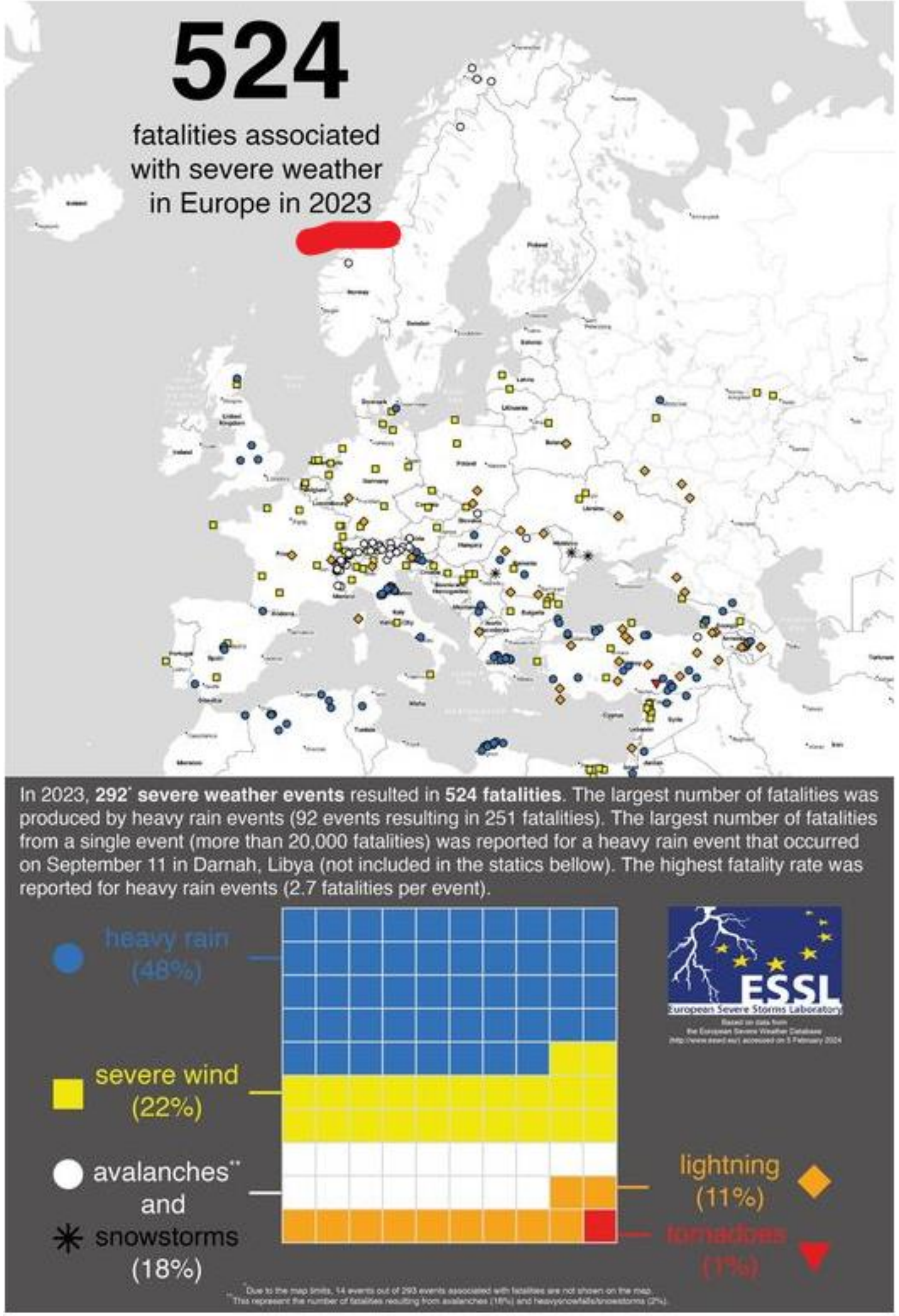
South Asia and sub-Saharan Africa countries have the highest average ETR score.

Source: IEP

Ecological Threat Report 2021 (www.visionofhumanity.org/wp-content/uploads/2021/10/ETR-2021-web-131021.pdf)

Impacts to human society, 3/3



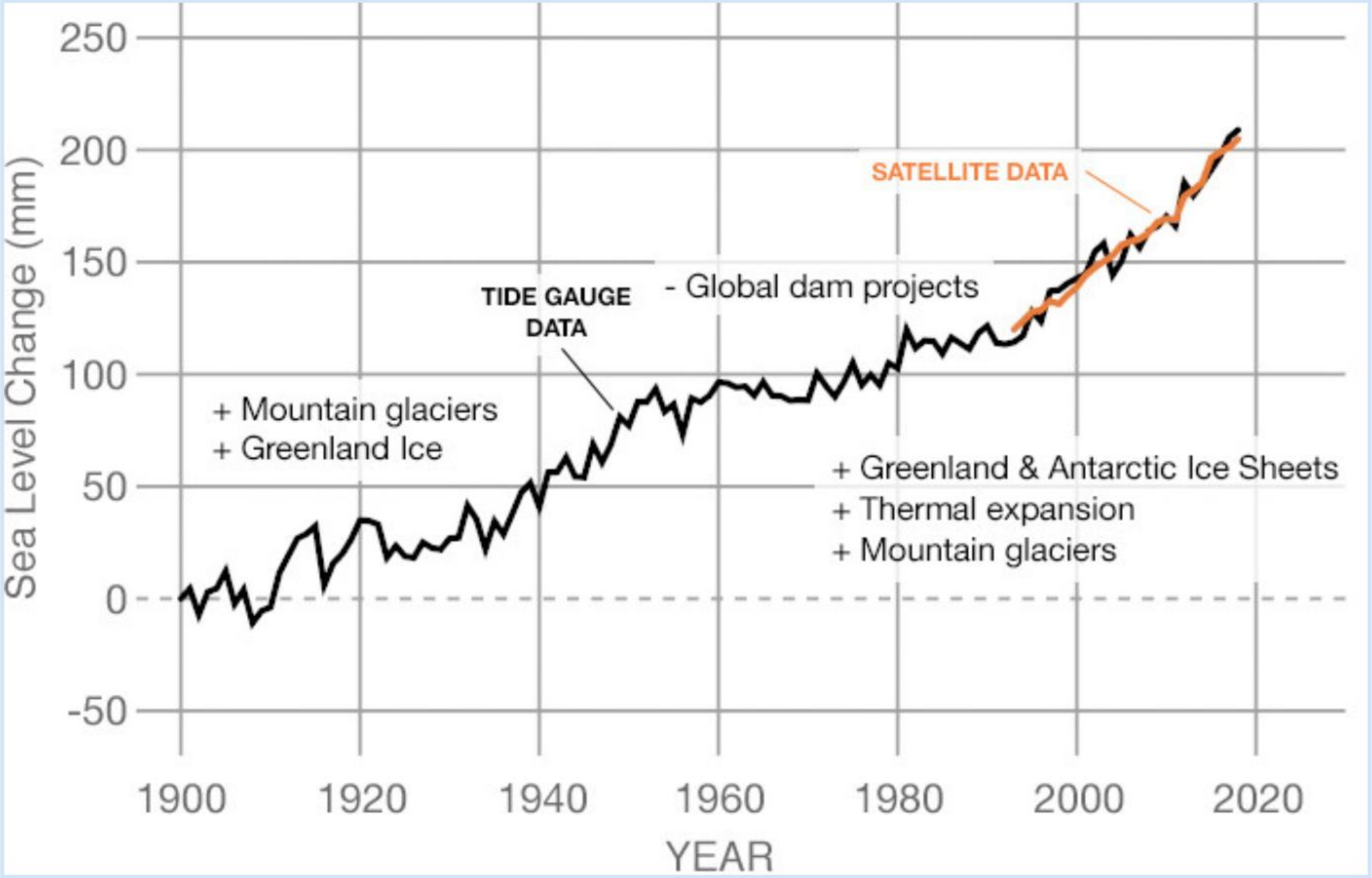


https://www.facebook.com/European.Severe.Storms.Laboratory

Impacts to human society: sea level rise, 1/4

- Sea level rise due to climate change:
- more water (melting of continental ice and glaciers)
- water expands as it heats up (thermal expansion)
- In the 20th century, global sea level has risen by an average of 1.4 mm per year
- Rise of the water level is accelerating, with an average rise of 3.6 mm/year in the last decade
- 1 cm of water level rise ~ 1 meter of average shoreline movement
- Since 1880, the water level has increased by 21...23 cm
- By the year 2100, the global sea level will be about 0.43-0.84 m higher (IPCC)

Impacts to human society: sea level rise, 2/4



Satellites have been capturing rising sea level data since the early 1990s. Image: NASA

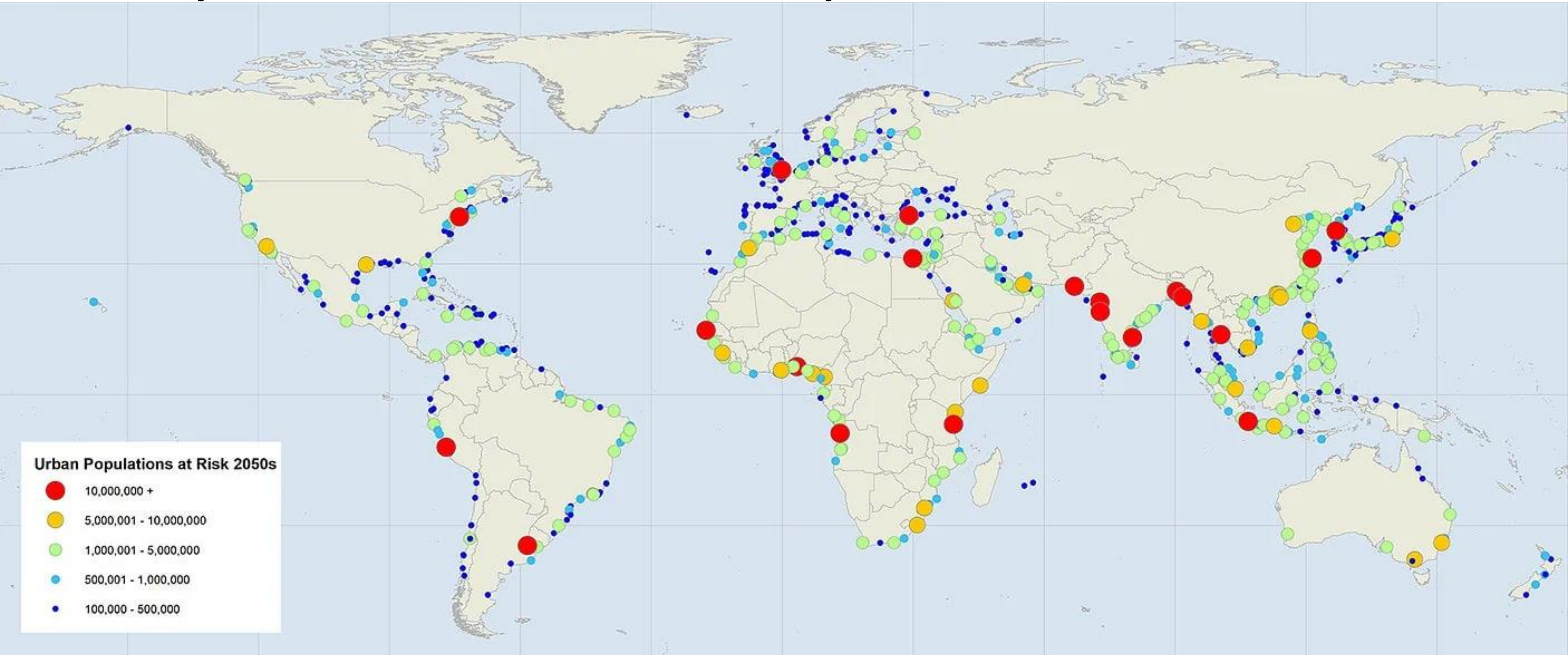
https://www.weforum.org/agenda/2022/09/rising-sea-levels-global-threat

Impacts to human society: sea level rise, 3/4

- Currently, about 110 million people live below sea level (behind the coastal defense walls), if the water level were to rise by 2 meters, 240 million people would live below sea level
- If the water level rises by 0.5 meters by 2050, 800 million people worldwide in 570 cities will be at risk, equally in

- Global South (Bangkok, Shanghai, Guangzhou, Mumbai, Kolkata, Jakarta, Dar es Salaam, Buenos Aires etc.) and
- Global North (New York/Manhattan, Miami, Venice, Hamburg, London etc.)

Impacts to human society: sea level rise, 4/4



https://www.c40.org/what-we-do/scaling-up-climate-action/adaptation-water/the-future-we-dont-want/sea-level-rise

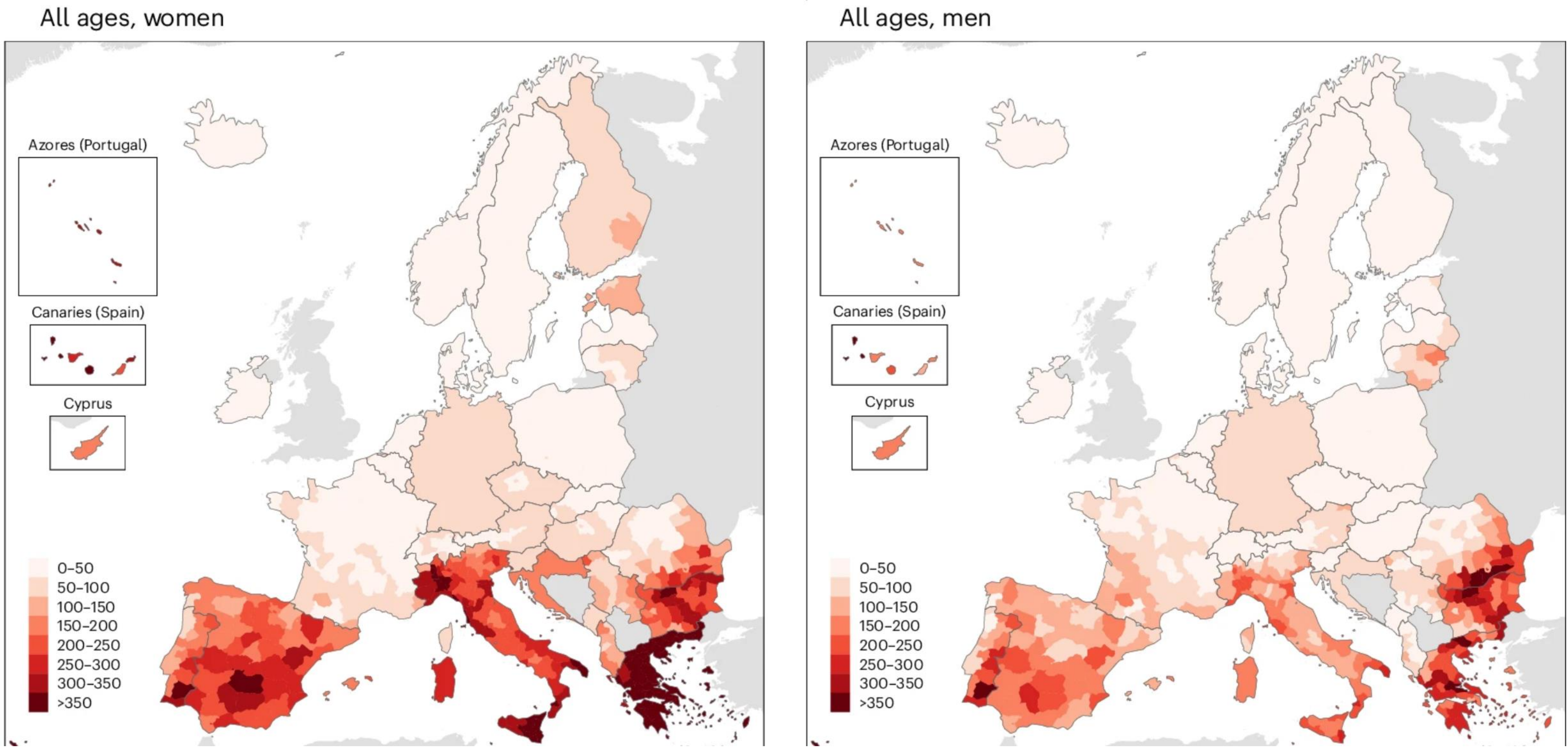
Impacts to human society: health risks

- Climate change will result in more intense, more frequent, and longer lasting heat waves
- There is strong positive association between extreme warm temperatures and mortality
- In Europe, around 40,000 people die annually because of heat waves:

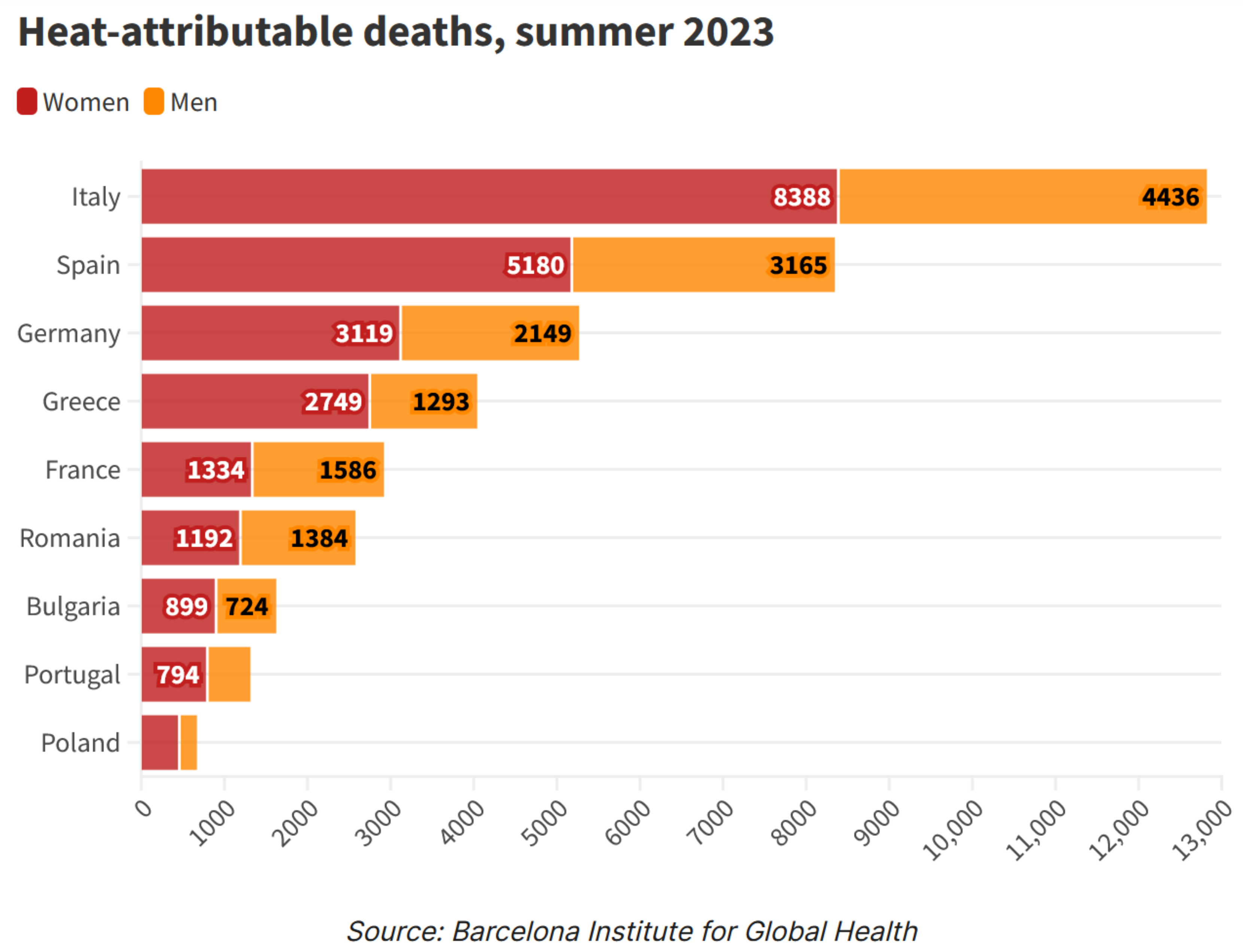
- in 2022, 61,000 deaths
- in 2023, 47,000 deaths

- 3x increase of heat deaths in Europe by 2100 if average temperatures raise by 3°C...4°C
- Heat deaths numbers rising disproportionately in southern European countries such as Italy, Greece and Spain

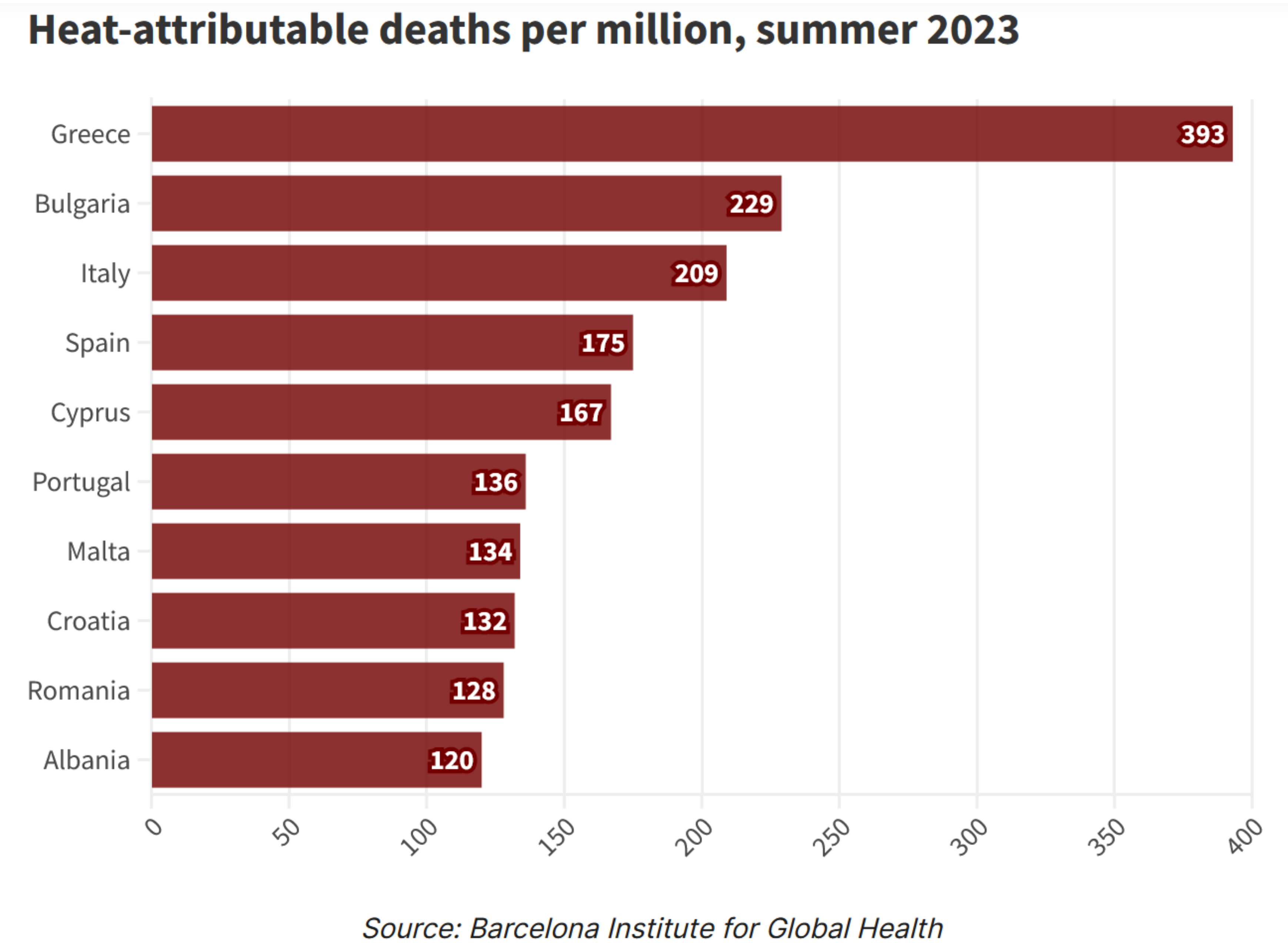
NB! Europe is the coolest inhabited continent



Heat-related mortality in European regions in 2023 (deaths per 1 million people)
Gallo, E. et al, 2024 (https://www.nature.com/articles/s41591-024-03186-1)



https://www.euronews.com/green/2024/08/12/italy-spain-germany-the-european-countries-where-the-most-people-died-from-heat-last-summer



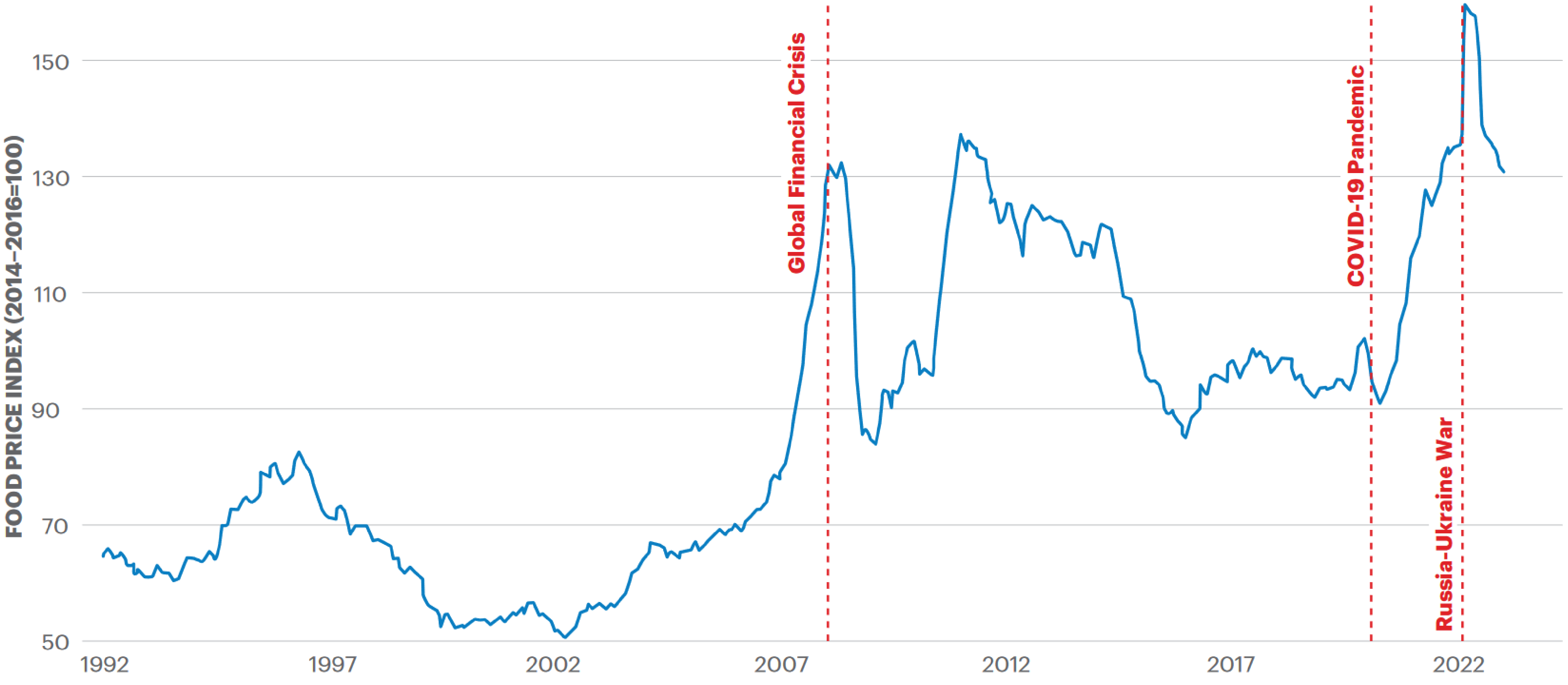
https://www.euronews.com/green/2024/08/12/italy-spain-germany-the-european-countries-where-the-most-people-died-from-heat-last-summer

Impacts to human society: food security

- 8.9% of the global population (663 millions) is starving (…500m is overweight)
- To feed the global population, food production shall increase by 60% by 2050 (FAO)...
- ... but climate change reduces crop yields globally, extreme events such as droughts and flash floods destroy yields
- Climate change accelerates desertification (and loss of farmland)
- In the short to medium term, areas more favourable for agriculture will "move" towards the poles (generally into more developed countries, including Estonia)

Monthly Food Price Indices (2014–2016=100), 1992–2023

Food Price Indices increase in times of international crisis.



Source: FAO; IEP Calculations

Ecological Threat Report 2023 (https://www.economicsandpeace.org/wp-content/uploads/2023/12/ETR-2023-web.pdf)

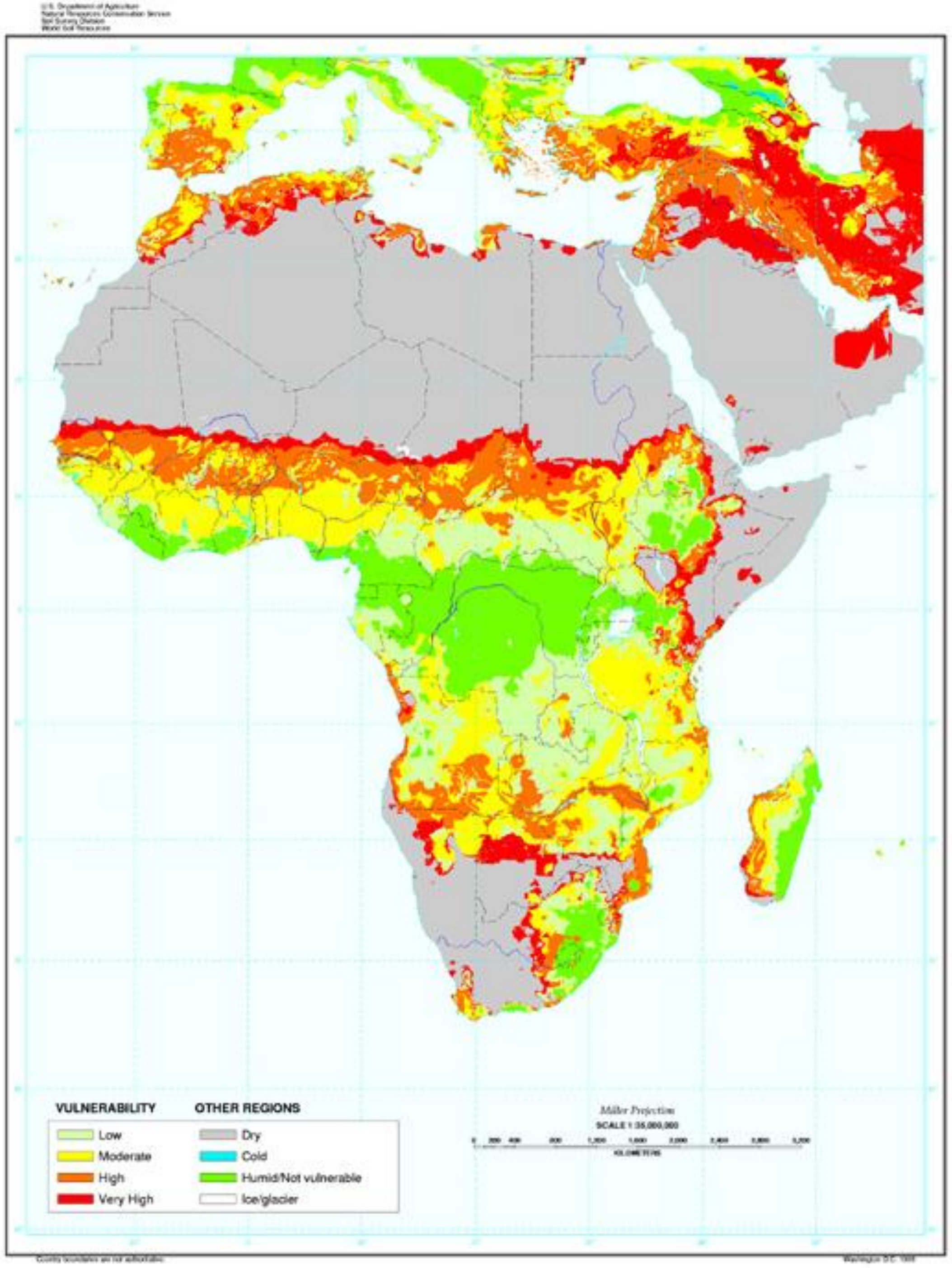
Impacts to human society: food security / desertification, 1/2

- Arid and semi-arid areas cover 1/3 of the land
- Through the process of desertification, the coverage with plants decreases, the nutrient content of the soil decreases and danger of erosion increases
- Desertification is in itself a natural phenomenon, for humans the problem is over 10% drop in production due to dryness:

- production decline 10%-25%: moderate desertification
- production decline 25%-50%: severe desertification
- production drop of more than 50%: particularly severe desertification

- Over the past 50 years, an area of the size of Brazil has been desertified
- Desertification threatens a quarter of the land area

Impacts to human society: food security / desertification, 2/2

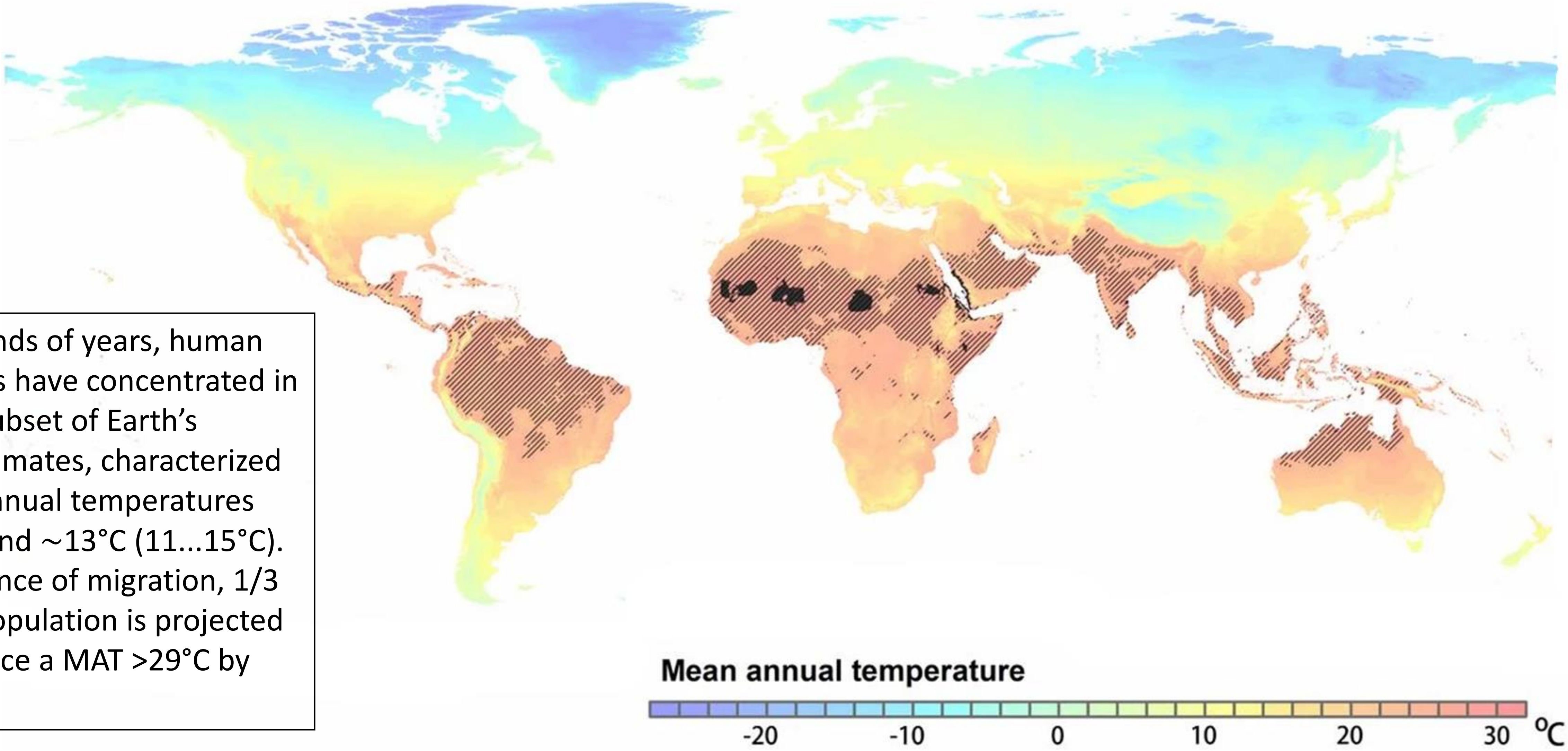


Impacts to human society: climate refugees, 1/2

- Environmental refugee – forced to leave home due to, for example, a volcanic eruption and climate refugee
- Neither is an official status, the 1951 Geneva Refugee Convention does not address environmental or climate refugees (refugee status based on race, religion, nationality, social affiliation or religious belief)
- There is need to define the status of environmental and climate refugees so that they can be better supported (the number of environmental refugees is greater than the number of political or war refugees). There is an UNHCR proposal (www.refworld.org/docid/5f75f2734.html), but no agreement), but no agreement so far
- Already now, extraordinary weather conditions and rising sea levels force approx. 20 million people per year to relocate within their country
- 0.2…1 billion environmental refugees predicted by year 2050

Impacts to human society: climate refugees, 2/2

For thousands of years, human populations have concentrated in a narrow subset of Earth's available climates, characterized by mean annual temperatures (MAT) around ~13°C (11...15°C). In the absence of migration, 1/3 of global population is projected to experience a MAT >29°C by 2070.



Projection of uninhabitable areas (mean annual temperature >29 °C) in 2070 (shaded) vs today (black) according to RCP8.5 climate scenario (www.pnas.org/doi/10.1073/pnas.1910114117)

Impacts to human society: economy, 1/2

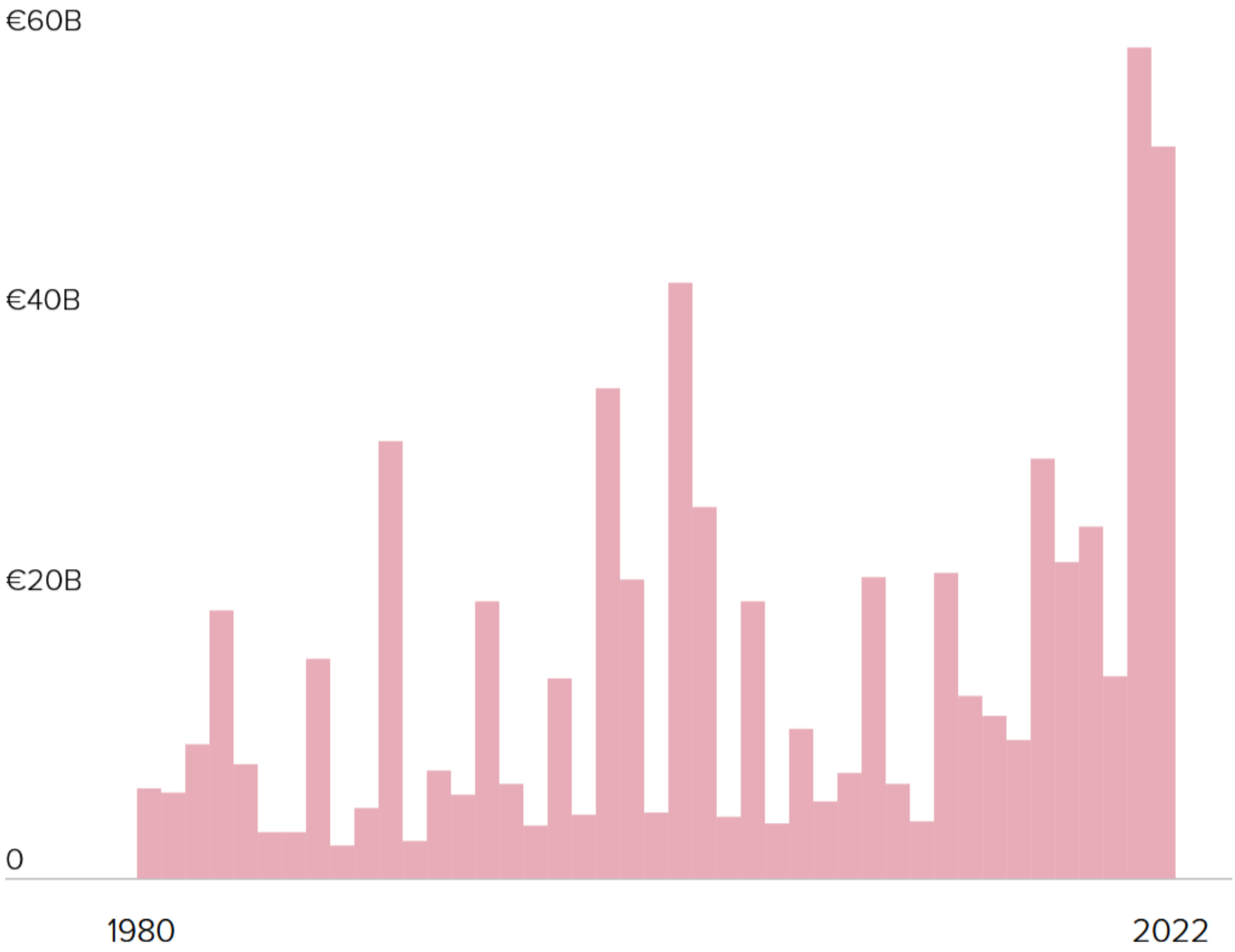
- Climate change as biggest <u>market failure</u> in human history – massive external costs are left to society
- Due to climate change, some 5% of global Gross Domestic Product (GDP) is lost annually forever. Loss can reach up to 20% if all indirect risks materialize (2006, sir Nicholas Stern)

- Global losses caused by heatwaves in 1992-2013 (human health, agricultural yields, etc.) are 16 trillion USD (in rich countries -1.5% GDP, in poor ones -6.7% GDP) (Callahan, Mankin, 2022)
- Global cost of uncontrolled climate change 178 trillion USD over the next 50 years (Deloitte)
- Uncontrolled climate change can reduce the GDP in the EU by 10%, more expensive than the cost of the Green Transition (European Central Bank)

Impacts to human society: economy, 2/2

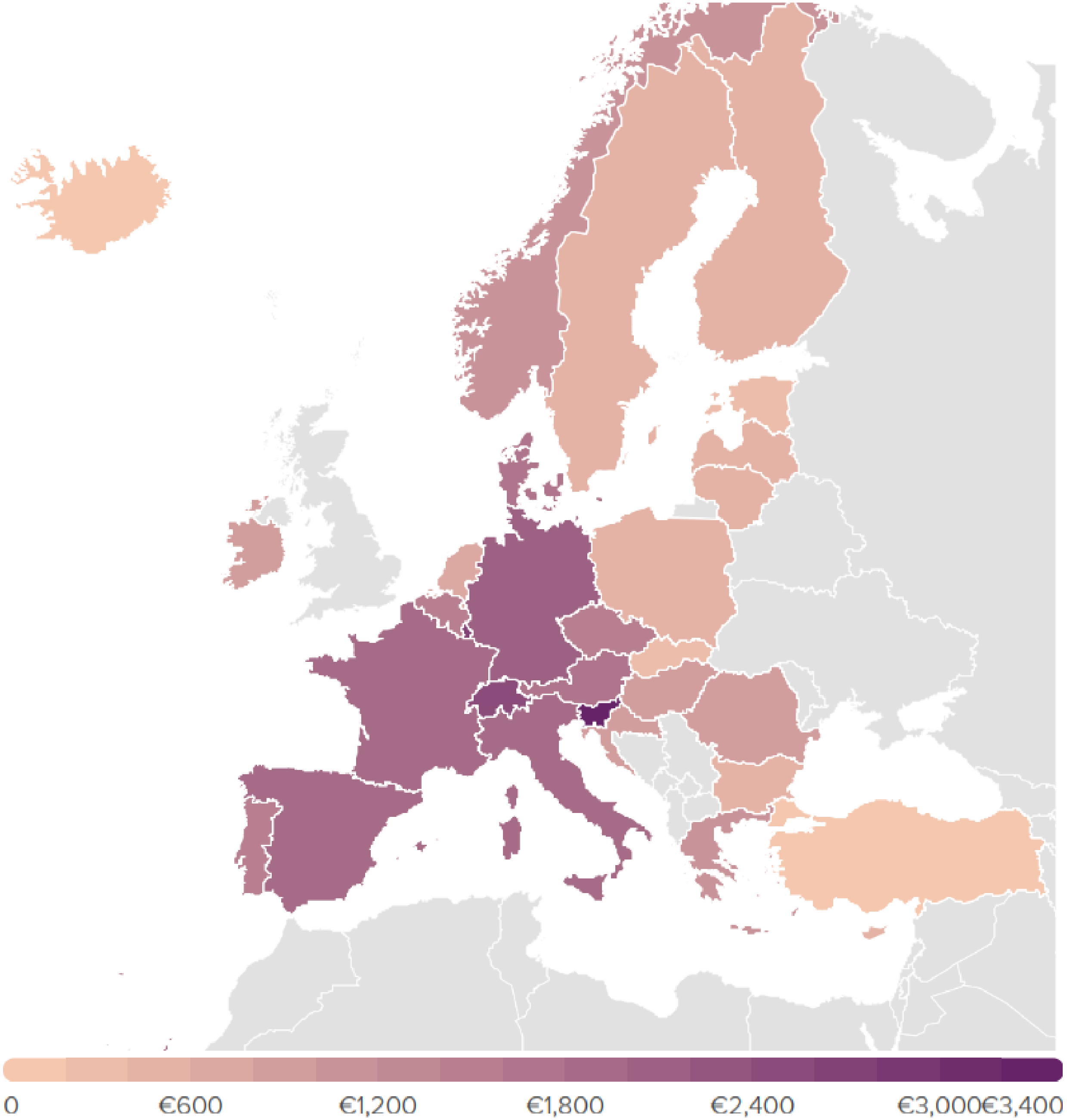
- Most countries will loose in result of climate change
- In some countries and for some time, economic situation improves (such as agriculture in Northern parts of temperate zone in Northern hemisphere)
- Some trade routes shorten (melted ice in Arctic Ocean)
- Some parts of economy flourish (renewable energy, energy storage, green transition)
- Some parts of economy disappears (fossil fuels)
- Tourism destinations change (people abandon destinations which become too hot and move to cooler locations, including Baltic Sea)
- In mountains, (except on glaciers and higher altitudes) winter sports will be replaced by hiking, biking. In Alps, snow cover has reduced 8.4% per 10 years during 1971-2019
- Less cross country skiing in Estonia, loss of ice roads :(

In the EU, financial damage* from extreme weather and climate events totaled €650 billion (over $710 billion in current prices) between 1980 and 2022, with a worsening trend observed in recent years.



Politico 2023 (https://www.politico.eu/article/cop28-global-warming-climate-crisis-pollution-eu-us-uk)
Financial damage from extreme weather and climate events in EU

Cost of extreme weather and climate events per capita between 1980 and 2022 in European countries, in euros.



Politico 2023 (https://www.politico.eu/article/cop28-global-warming-climate-crisis-pollution-eu-us-uk)

Financial damage from extreme weather and climate events in EU

Impacts to human society: economy / tourism

FUTURE PLANET

FUTURE PLANET

Are ski trips coming to an end?

4. Climate policy options

Choices in climate policy

- Goal – to stabilize the level of greenhouse gases in such a time frame that ecosystems can adapt, food production is not threatened and sustainable economic development is possible (IPCC 2014)
- Two types of activities needed (in parallel):

- mitigation (try to save the situation as much as possible)
    - reduction of emissions of greenhouse gases to a minimum
    - removal of existing carbon from atmosphere and long-term storage
- adaptation (learn how to survive in new harsh climate conditions)

Mitigation / reduction of emissions

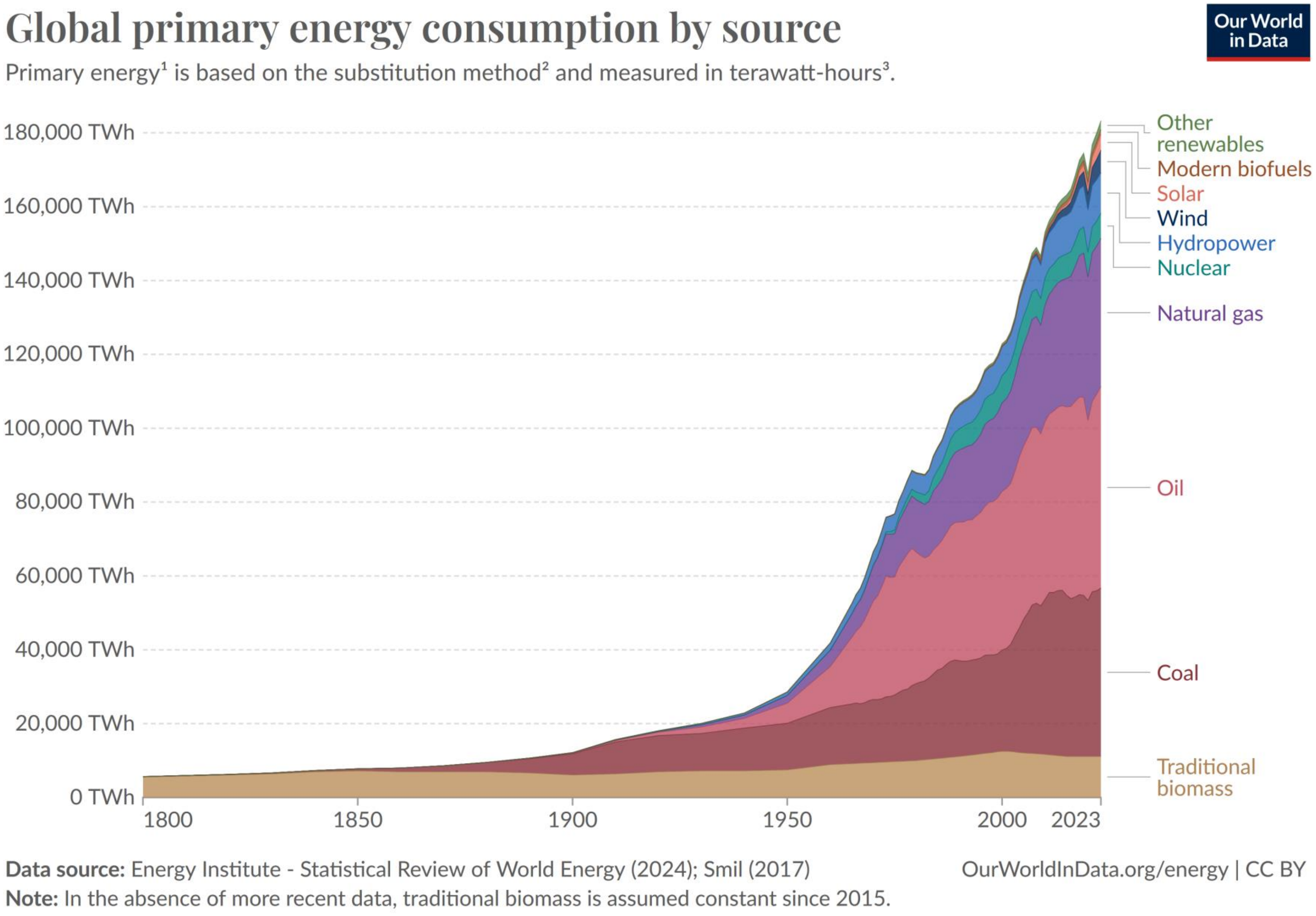
Mitigation / reduction of emissions, 1/8

- Reduction of greenhouse gas (GHG) emissions:

- replacement of fossil fuels with renewable energy + energy storage (incl. green hydrogen) + develop international energy networks + apply energy saving
- changes in land use (limits to deforestation and to draining of wetlands)

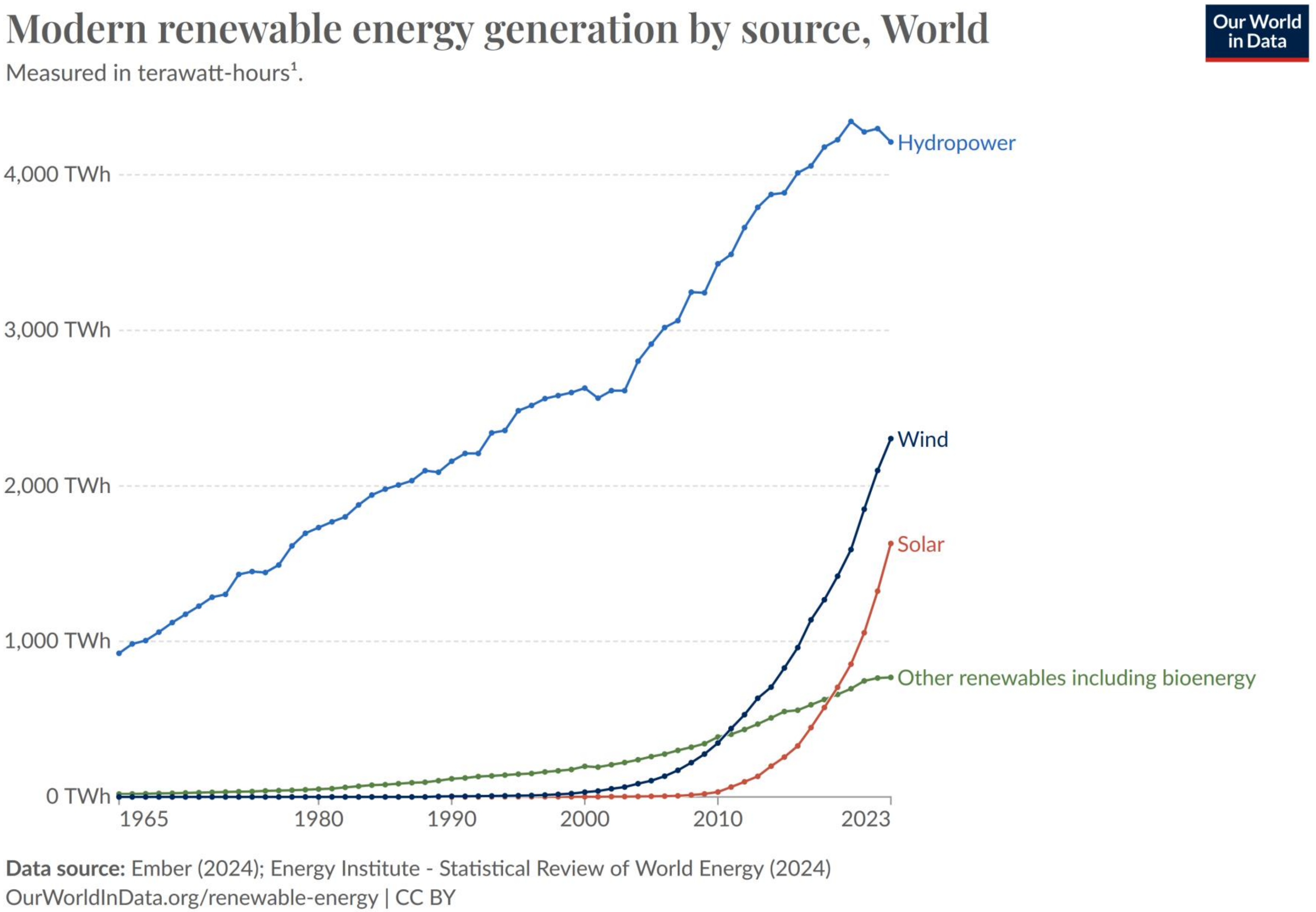
Mitigation / reduction of emissions, 2/8

- Share of fossil fuels is still big (its replacement is enormous challenge)



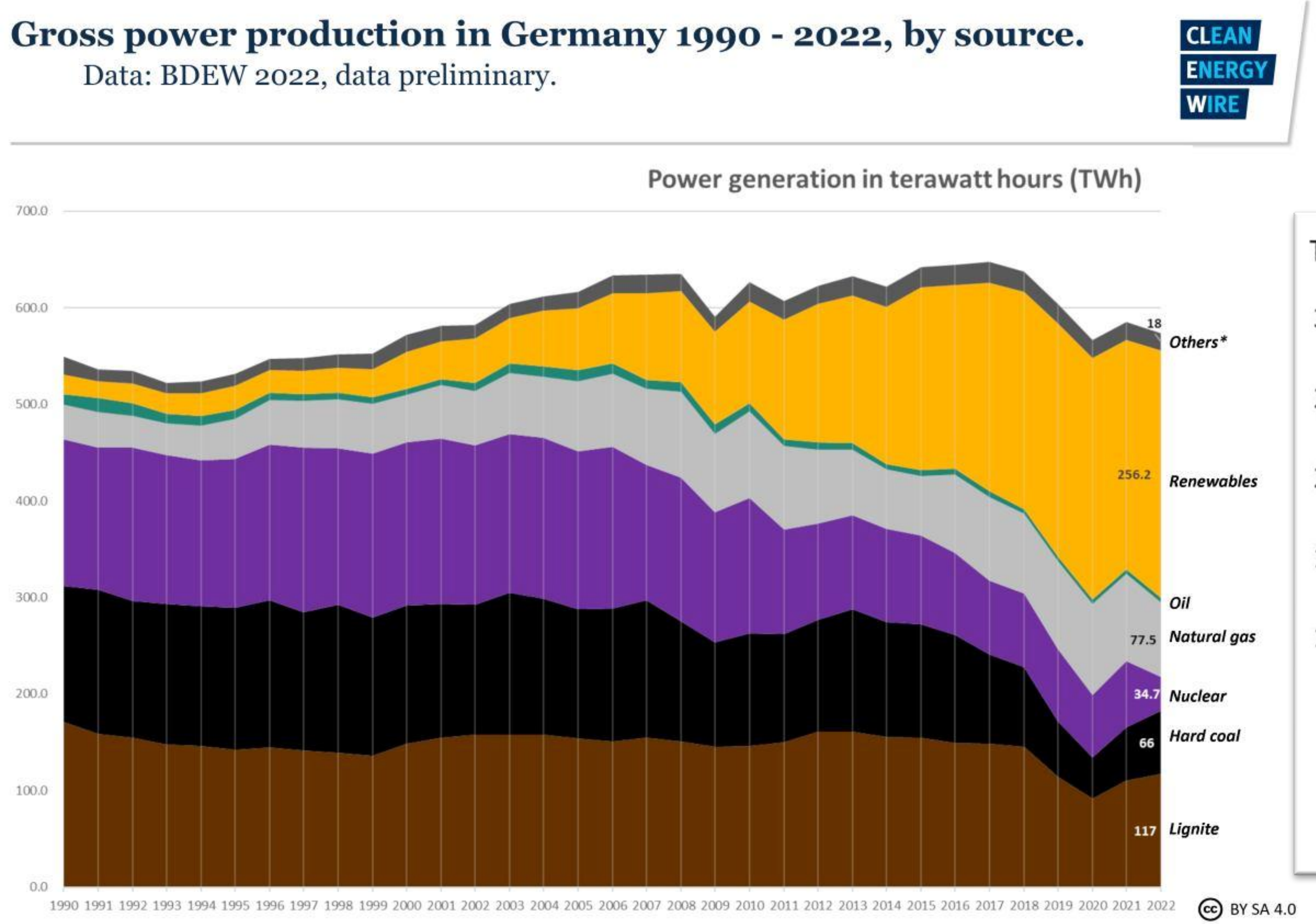
Mitigation / reduction of emissions, 3/8

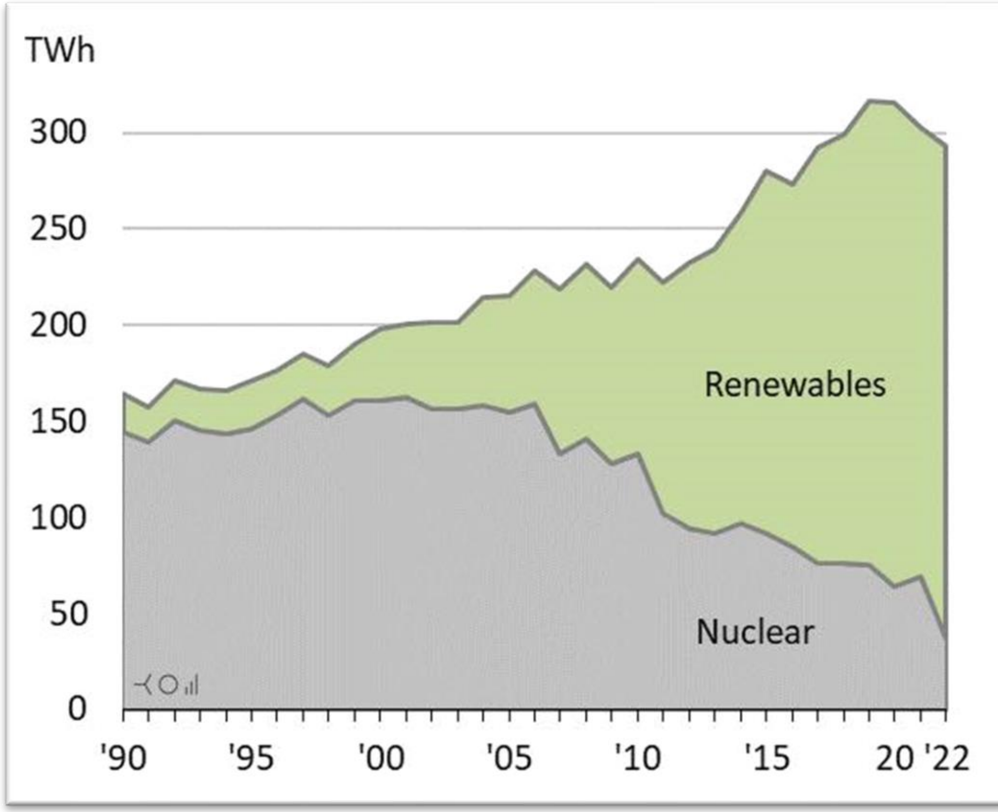
- Renewable energy develops fast



Mitigation / reduction of emissions, 4/8

- In some countries, switch to renewables is smooth (see Germany)



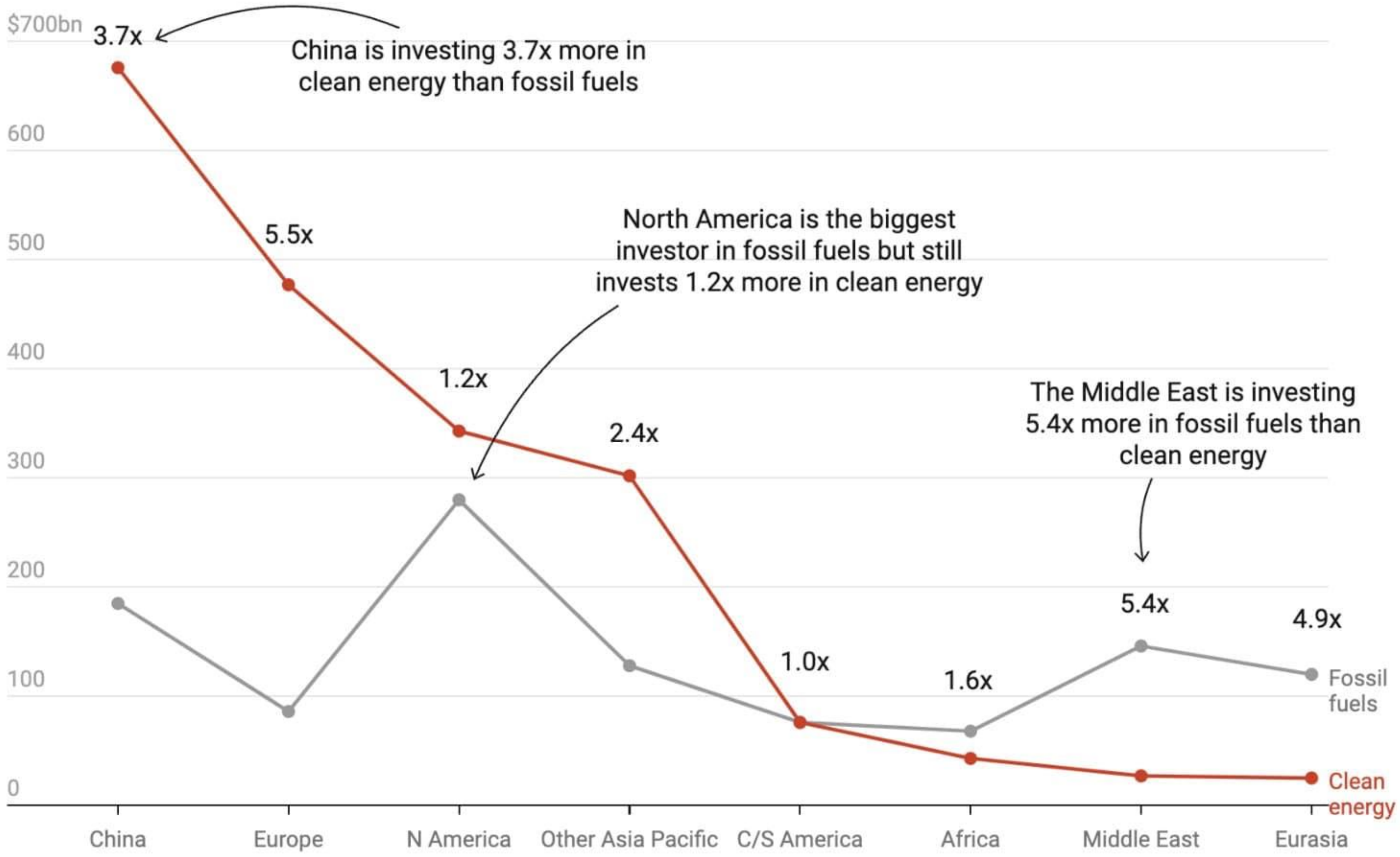


2022 installed renewable capacity and 2030 needed capacity to reach 1.5°C target

https://www.politico.eu/article/cop28-renewable-energy-efficiency-targets-data-paris-agreement-climate-change-global-warming

China is the world's biggest investor in clean energy in 2024...
...and North America is the biggest for fossil fuels

Investment in energy by country or region in 2024, $bn

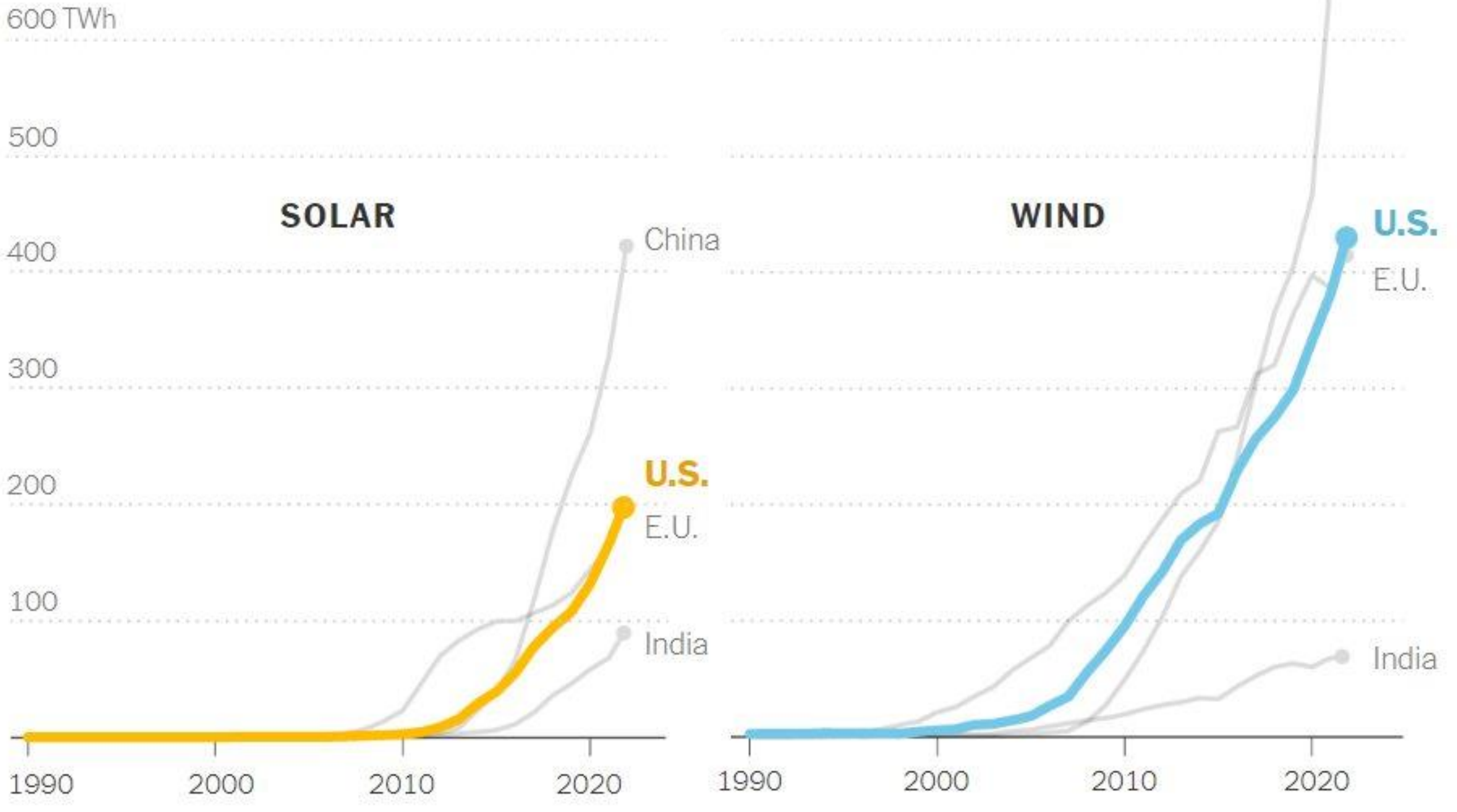


Source: IEA World Energy Investment 2024

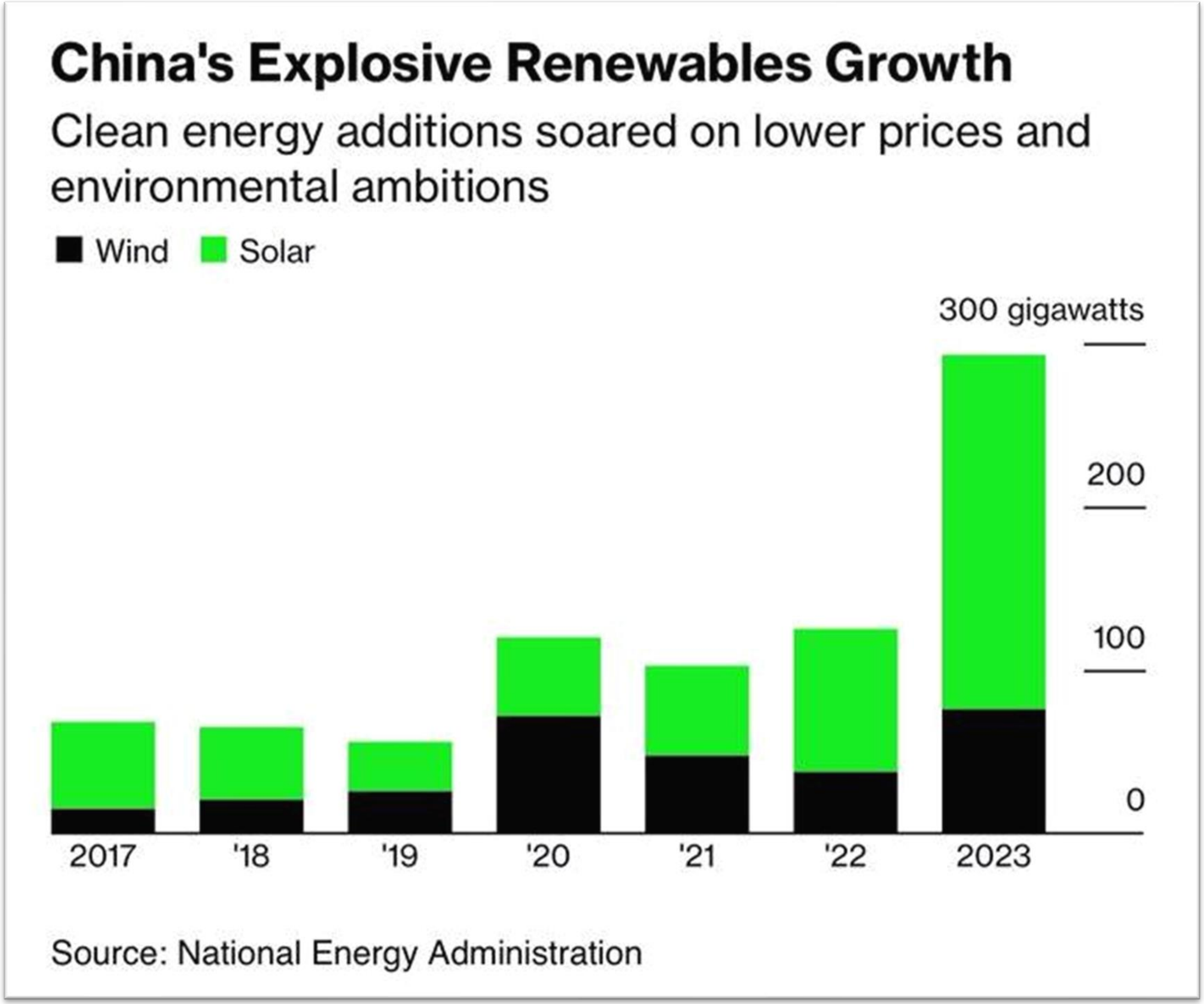
CarbonBrief
CLEAR ON CLIMATE

Solar and Wind Power Have Taken Off

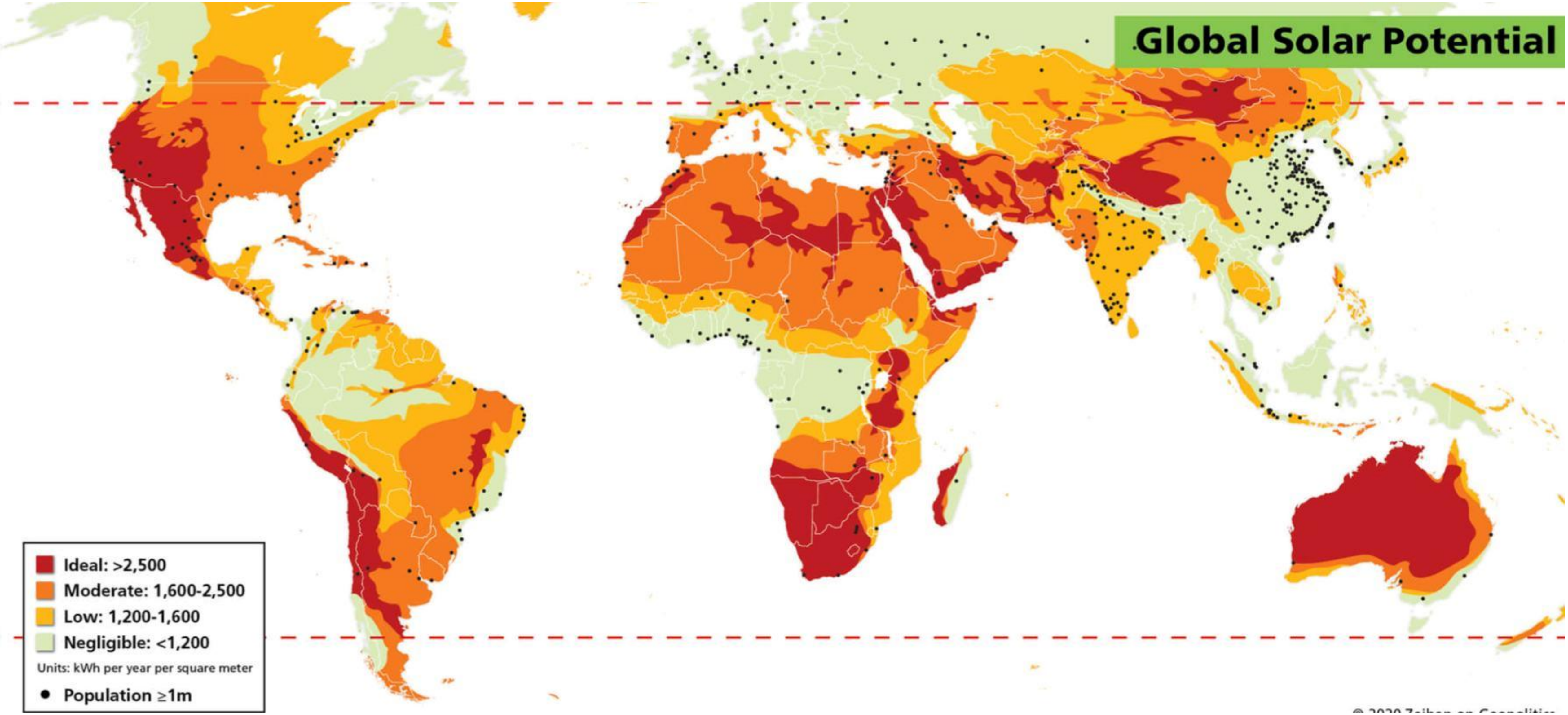
Electricity generation per year, in terawatt hours



Source: The Energy Institute's 2023 Statistical Review of World Energy · Note: Data reflects generation within country borders. · By The New York Times



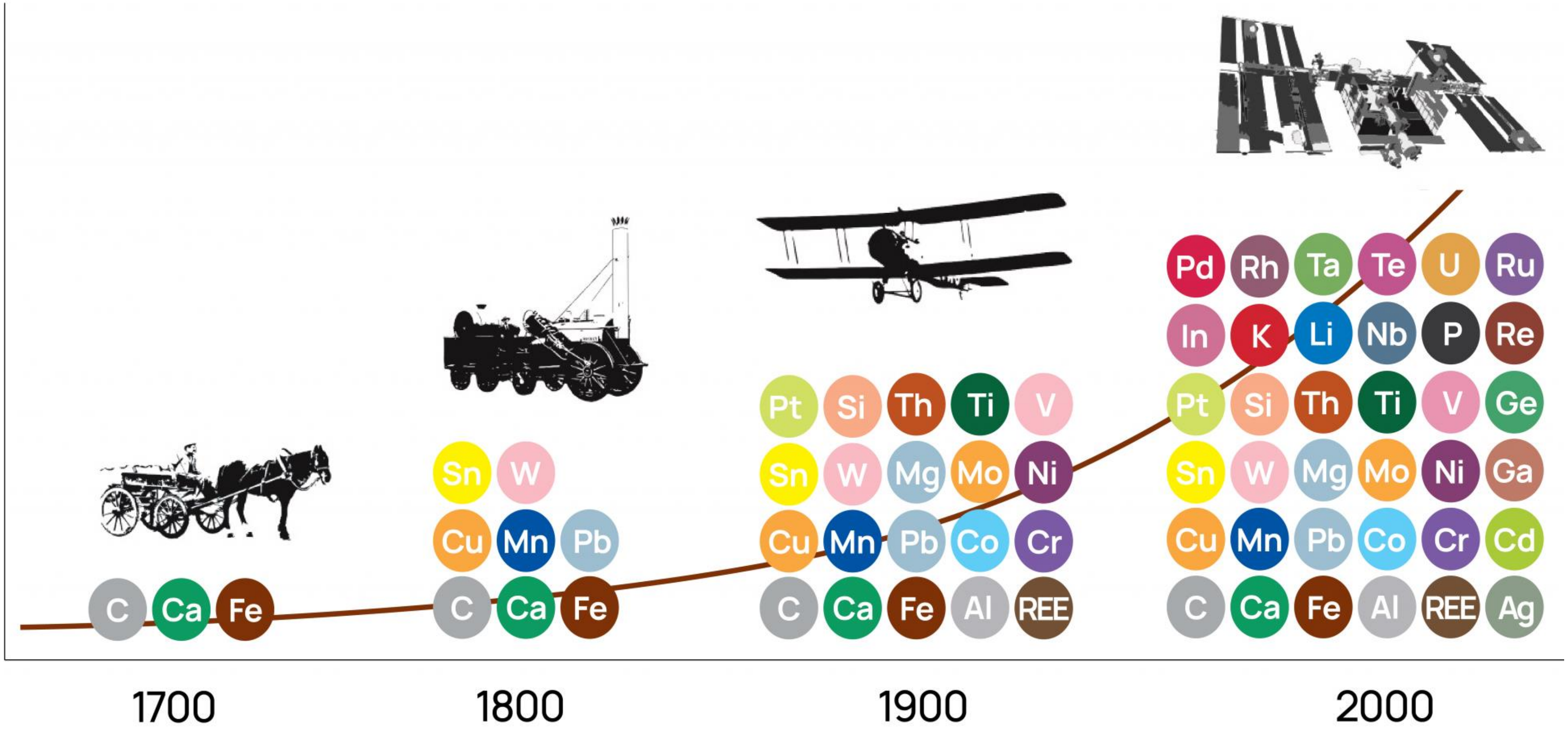
https://x.com/DrSimEvans/status/1798661353361862718 (@DrSimEvans)



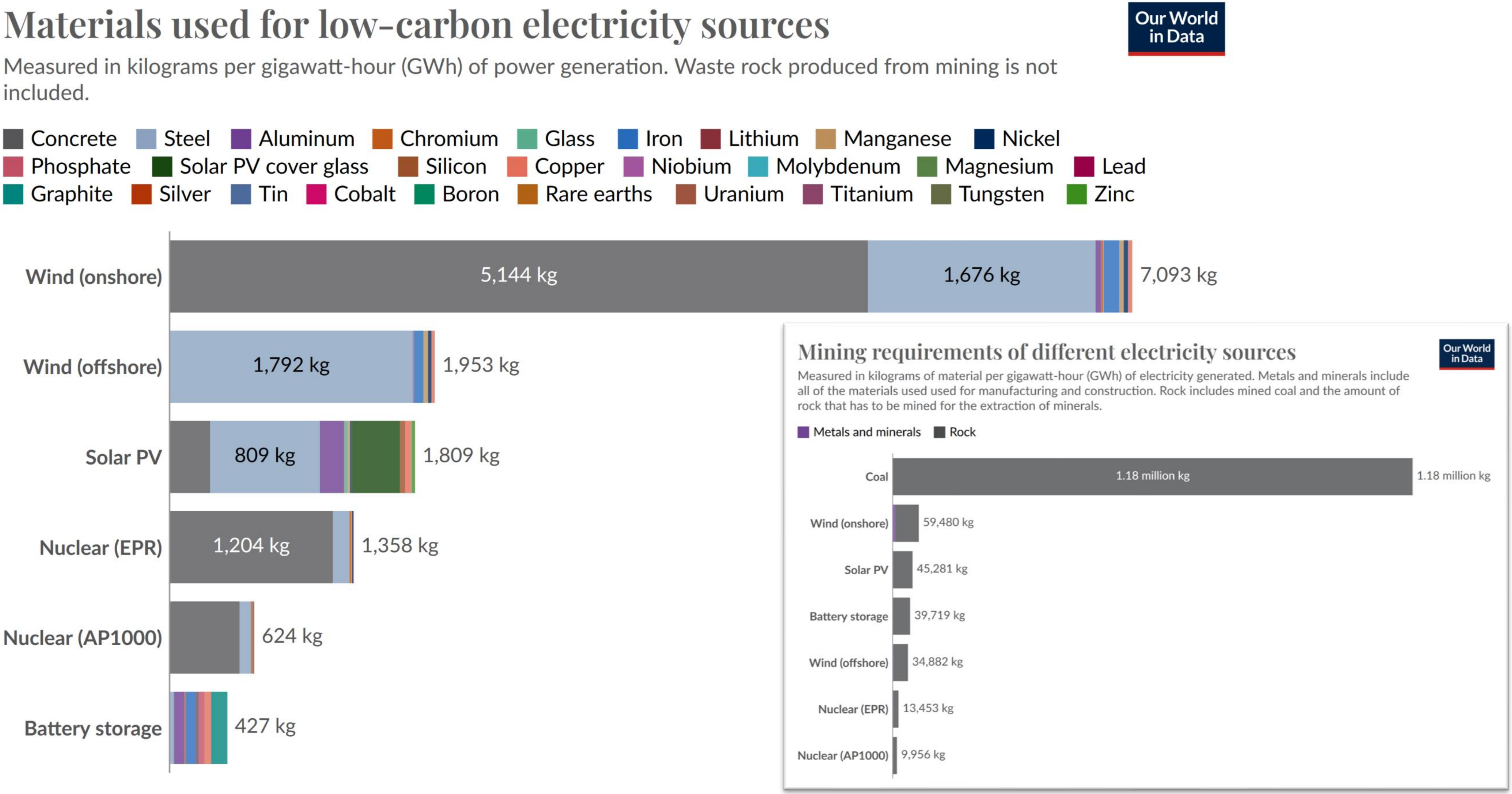
https://globalsolaratlas.info/download/world

Mitigation / reduction of emissions, 5/8

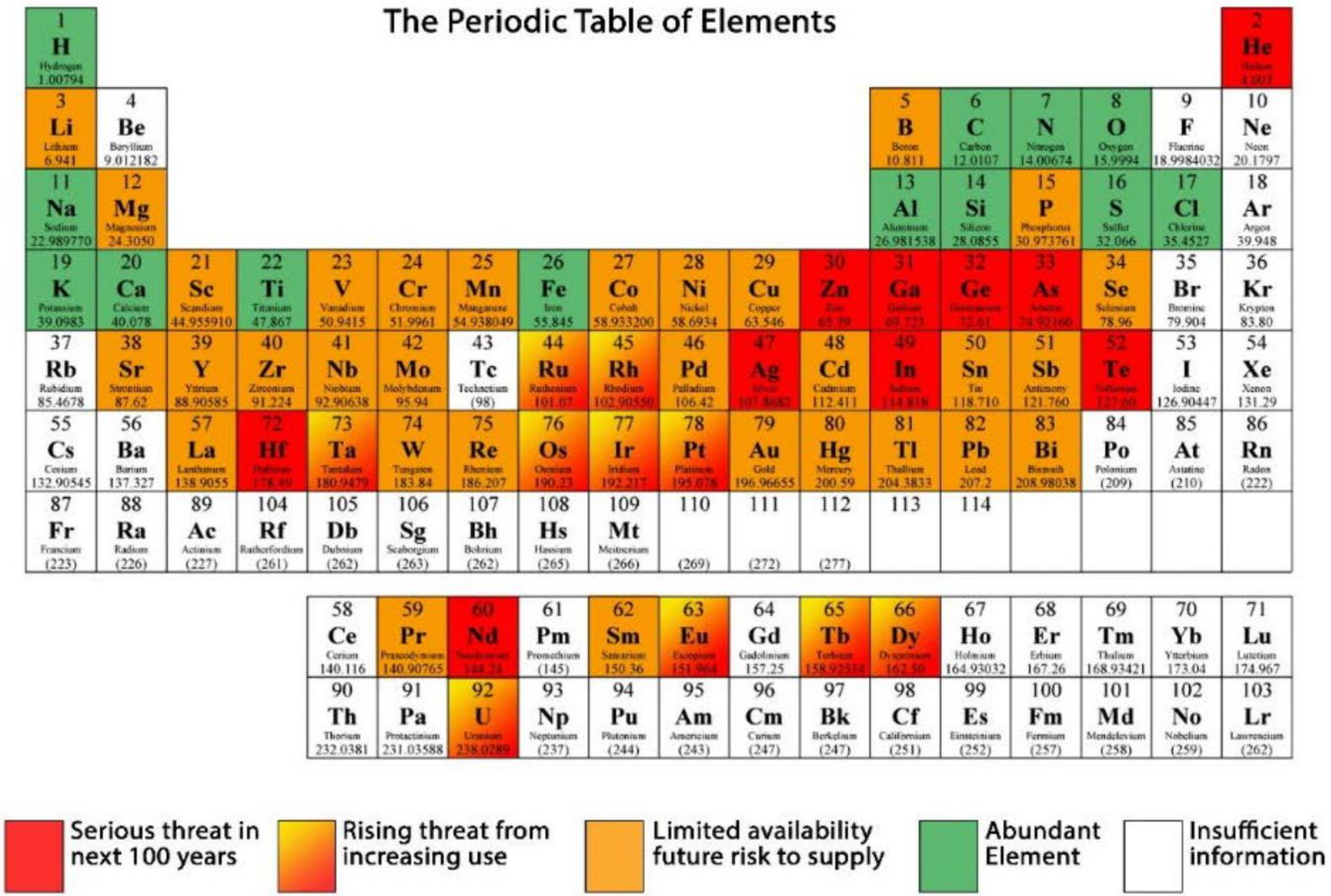
- Renewable energy and energy storage (green transition) need of metals



https://arenguseire.ee/pikksilm/milliseid-maavarasid-vajab-rohepoore



https://ourworldindata.org/low-carbon-technologies-need-far-less-mining-fossil-fuels

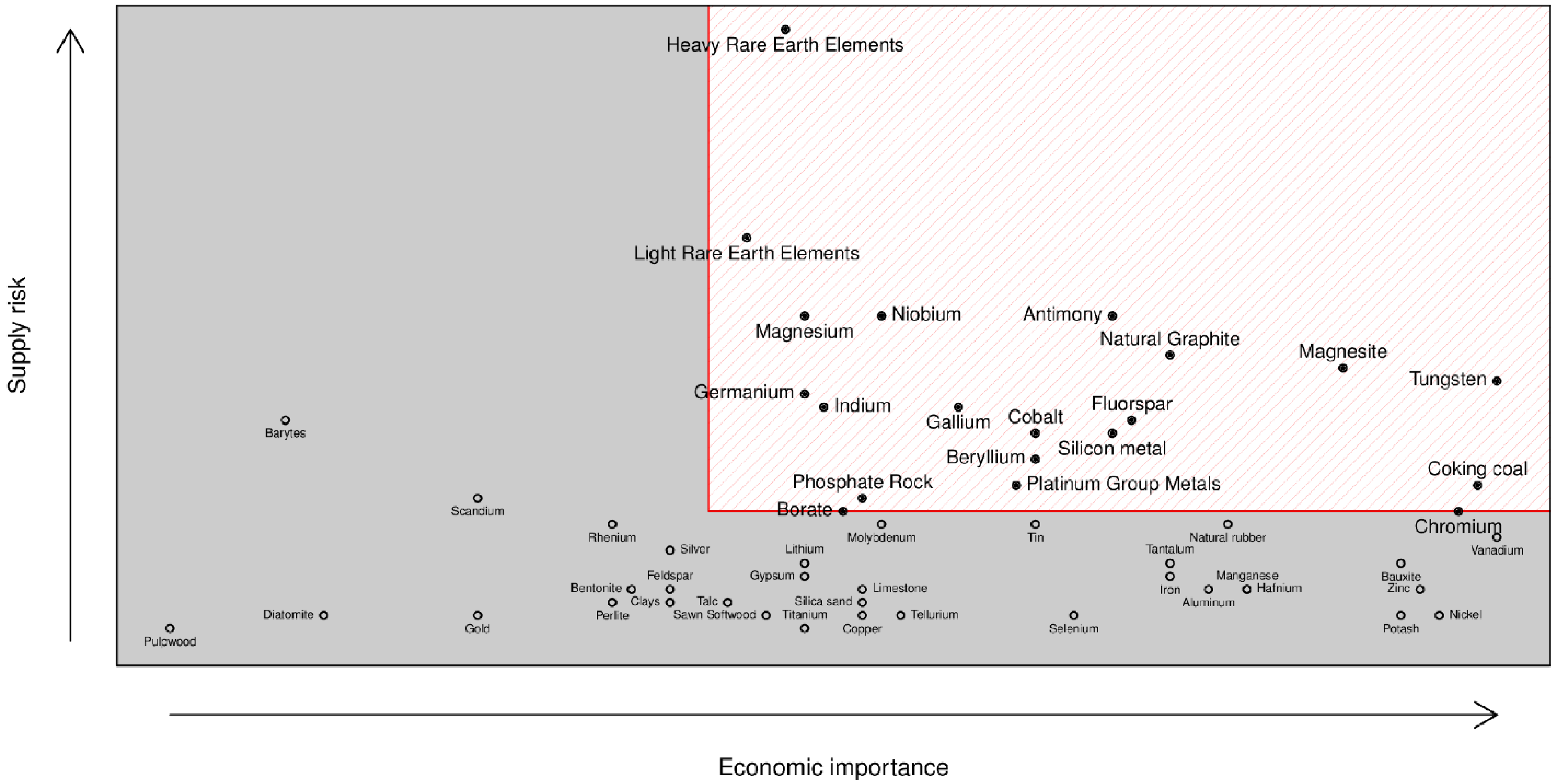


Some primary mining sources for a number of metals have clear supply risks

Simon Michaux 2021 (https://tupa.gtk.fi/raportti/arkisto/16_2021.pdf)

Mitigation / reduction of emissions, 6/8

- Renewable energy and energy storage (green transition) need lot of natural resources (incl. rare-earth elements that have been little mined and used)
- Geopolitics - lot of needed resources are in unstable countries (Russia, China, Congo, ...)
- Human rights – lack of transparency among suppliers (Rwanda/DRC and “blood minerals” and M23 insurgent rebels in Congo)
- Opening of new mines in rich countries is complicated
- Prospects with more stable suppliers: Sweden (newly discovered deposit in Kiruna), Chile, Australia, Portugal, Serbia (lithium) etc.
- “New" metals (lithium, cobalt) are not yet recycled (vs lead, 80% recycled)



Report on critical raw materials in EU 2014 (https://rmis.jrc.ec.europa.eu/uploads/crm-report-on-critical-raw-materials_en.pdf)

Mitigation / reduction of emissions, 7/8

Metal	Element	Total metal required produce one generation of technology units to phase out fossil fuels (tonnes)	Global Metal Production 2019 (tonnes)	Years to produce metal at 2019 rates of production (years)
Copper	Cu	4 575 523 674	24 200 000	189,1
Nickel	Ni	940 578 114	2 350 142	400,2
Lithium	Li	944 150 293	95 170 *	9920,7
Cobalt	Co	218 396 990	126 019	1733,0
Graphite (natural flake)	C	8 973 640 257	1 156 300 ♦	3287,9
Graphite (synthetic)	C		1 573 000 ♦	-
Silicon (Metallurgical)	Si	49 571 460	8 410 000	5,9
Vanadium	V	681 865 986	96 021 *	7101,2
Rare Earth Metals	-			
Neodymium	Nd	965 183	23 900	40,4
Germanium	Ge	4 163 162	143	29113,0
Lanthanum	La	5 970 738	35 800	166,8
Praseodymium	Pr	235 387	7 500	31,4
Dysprosium	Dy	196 207	1 000	196,2
Terbium	Tb	16 771	280	59,9

Simon Michaux 2021

Mitigation / reduction of emissions, 8/8

- Prospects of replacing fossil fuels in transport sector:
- in rich countries, there is a slow transition from fossil cars to electric cars (!!! important to look how the electricity is produced...)
  - 2025 end of sales of fossil cars (cars with an internal combustion engine) in Norway
  - 2035 end of sales of fossil cars in EU
  - 2035 end of sales of fossil cars in California, New York
- a dream of switching road transport from fossils to hydrogen (important that hydrogen is not produced with fossil fuels)
- synthetic and biofuels for airplanes exist, but their market share is close to non-existent
- movement of car free cities/city centres
- ...yet boom of (fossil) car use in global South (developing countries)

Mitigation / carbon removal

Mitigation / carbon removal, 1/6

- To reach global net-zero (and further, net-negative) emissions, carbon removal is needed in addition to the emission reductions
- As developing countries don't have binding commitment to reduce emissions, massive CDR is needed in rich countries
- Carbon Dioxide Removal (CDR) = Negative Emissions Technologies and Practices (NETPs)
- Two types of carbon removal:

- <u>nature-based solutions</u>
- <u>technical solutions</u>

- All CDRs have some side-effects and trade-offs, therefore a combination of many nature-based and technical solutions seems reasonable

Mitigation / carbon removal, 2/6

Examples of nature-based solutions:

- afforestation (planting in new areas) and reforestation (replanting) – storing biomass in carbon sink
- biochar – carbonising of biomass/ organic waste by burning without oxygen (pyrolysis) to get stable solid material (~charcoal) to be used in soils, cement, tar, etc.
- soil carbon sequestration – keeping vegetation to allow photosynthesis
- seaweed cultivation and sinking – storing in deep ocean

- Positive: lower costs, often already existing solutions, can start quickly
- Negative: high risk of carbon leakages (cannot guarantee permanent storage), hard to quantify stored carbon, lack of available land (need to switch)

Mitigation / carbon removal, 3/6

Examples of technical solutions:

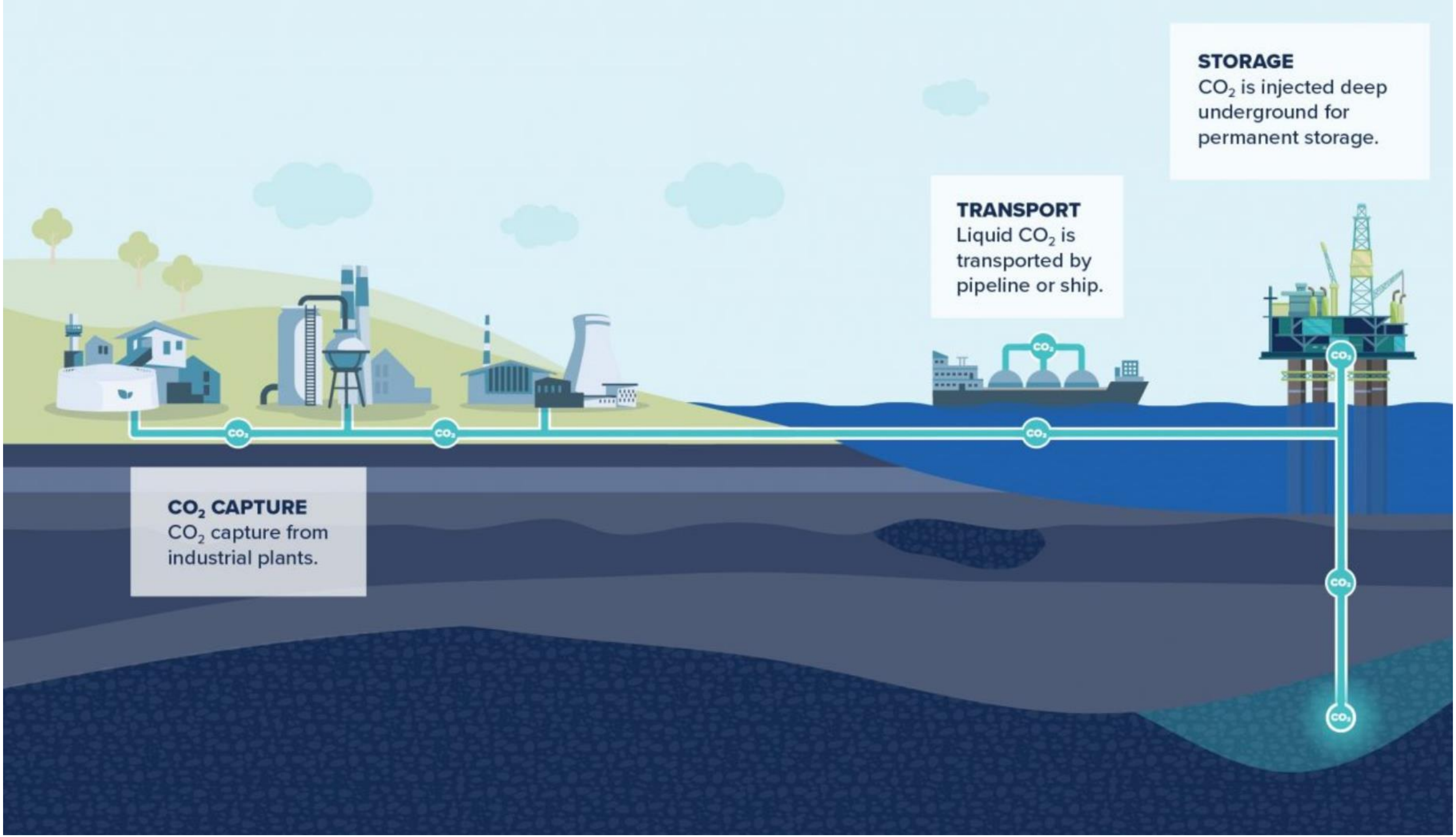
- direct air capture and CO_2 storage (DACCS)
- bioenergy, can be combined with CO_2 capture and storage (BECCS)
- terrestrial enhanced weathering (EW) - application of silicate or carbonate mineral particles in soils which produce bicarbonate ions that flow via groundwater to rivers and to the ocean, or mineralise on land, becoming stable carbonates (~liming of soils)
- ocean-based solutions, such as ocean liming
- solar radiation modification - transporting sulphide aerosols into stratosphere to increase reflection of solar energy back into space

- Positive: long-term geological carbon storage
- Negative: not ready yet, many associated risks

Mitigation / carbon removal, 4/6

- **Carbon Capture and Storage (CCS):**

- an idea that carbon is captured at the "stack end" when coal/shale is burned and re-stored in the soil
- has been tested for over 20 years (9 commercial pilots currently)
- first big pilot currently starting (Greensand in waters of Denmark - 8 million tons of CO_2 annually to be stored in sandstone in depth of 1800 m, to cover 40% of Danish emissions)
- Controversial technology (would allow continued use of fossil fuels – ‘*clean coal*’)



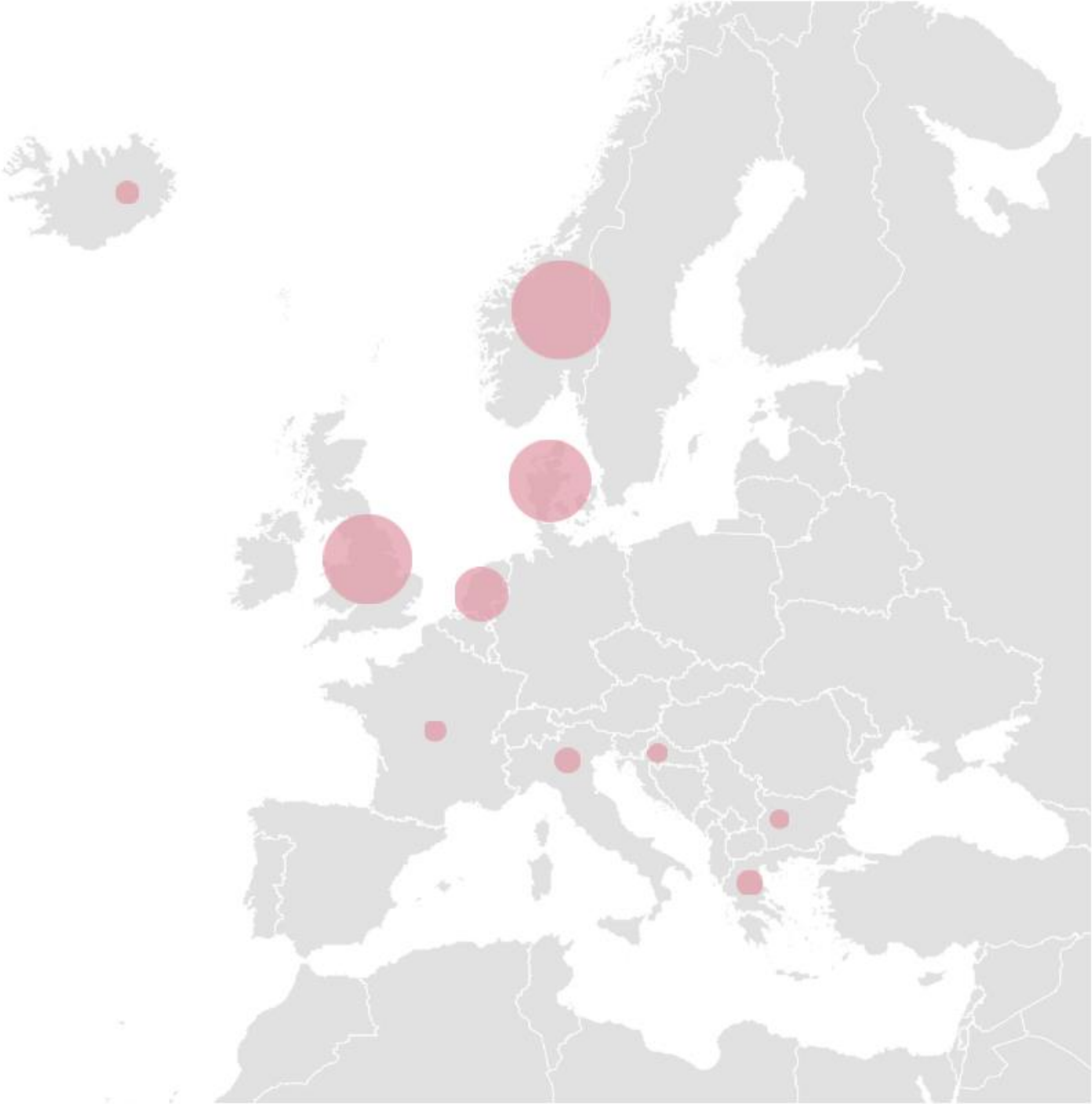
https://www.globalccsinstitute.com/resources/ccs-101-the-basics

Mitigation / carbon removal, 5/6

Lack of storage sites for carbon for the CCS (so far, sites at depleted gas fields in the Netherlands and Denmark dominate the industry)

PLANNED CARBON STORAGE CAPACITY

Projected cumulative capacity* of planned and announced carbon storage projects by 2030, in millions of tons.



https://www.politico.eu/article/europe-is-spending-millions-t

Mitigation / carbon removal, 6/6

- Direct Air Capture, (DAC) of CO_2:
- essentially, large fans that draw air through and trap carbon
- only 18 pilot projects globally (US, Canada, EU)
- 11 further plants in planning stage which would remove total 5.5 Mt CO_2 in 2030 (Estonian annual emission in 2021 was 11.5 Mt CO_2)
- CO_2 capture is too expensive today, does not (yet?) pay off economically (today 600 USD/t, CO_2 market price around 100 USD/t)
- seems like a niche technology
- example of '*climate engineering*'

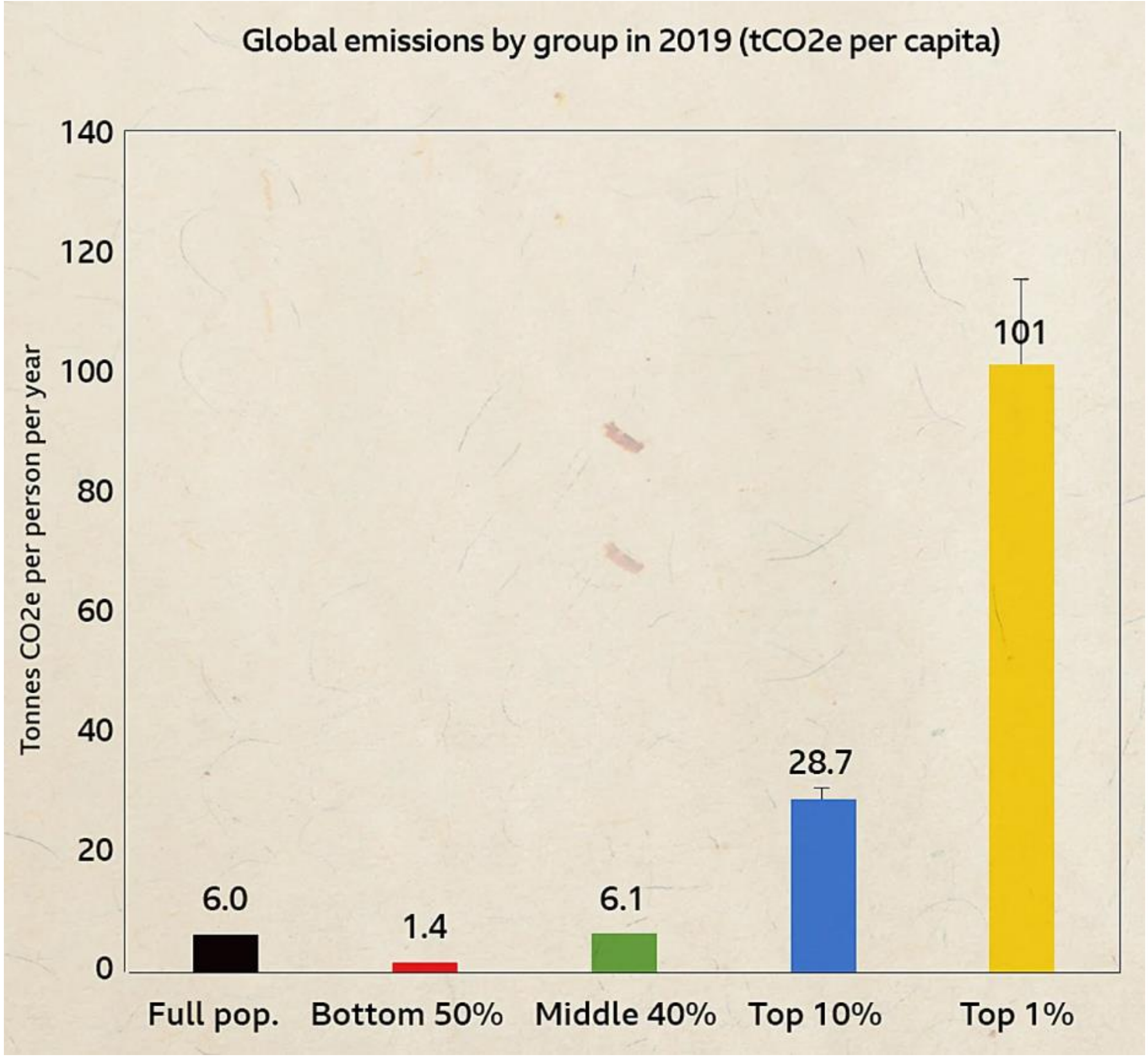
https://www.science.org/content/article/cost-plunges-capturing-carbon-dioxide-air

Adaptation

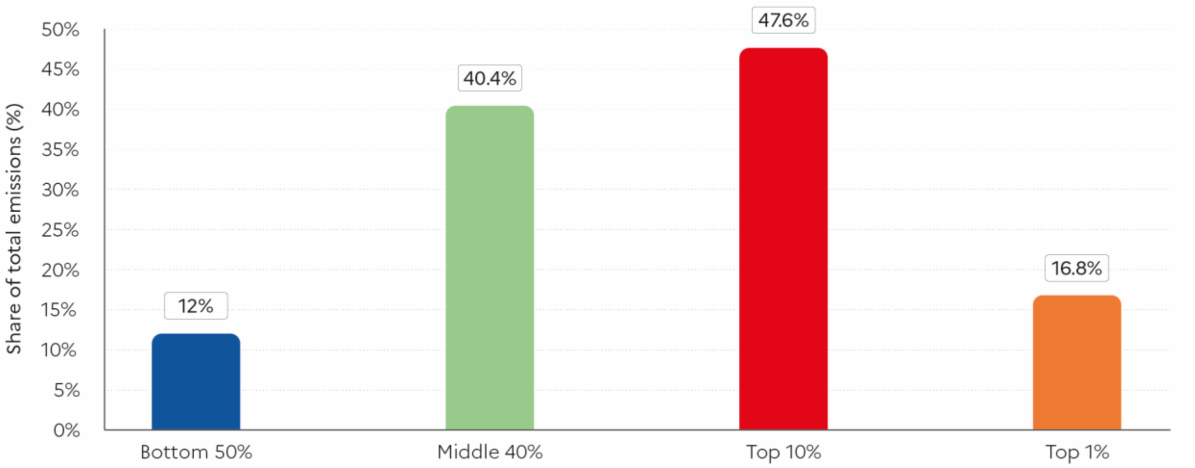
Adaptation (to the changing climate)

- Infrastructure:
- protection from disasters (such as flood prevention)
- overhead electricity cables changed by underground cables
- solutions against heatwaves in cities
- new standards for spatial planning (flash floods, flood prevention) and for construction (passive cooling, vegetation on roofs, reuse of "grey water", etc.)
- warning systems
- Changes in agriculture (choice of crops)
- Choice of crops, resistant to changing weather (and need less watering)
- Changing lifestyle (dietary preferences, transport, etc.)
- Insurance products

Adaptation / change of lifestyle, 1/2



https://www.bbc.com/future/article/20230504-the-people-living-ultra-low-carbon-lifestyles

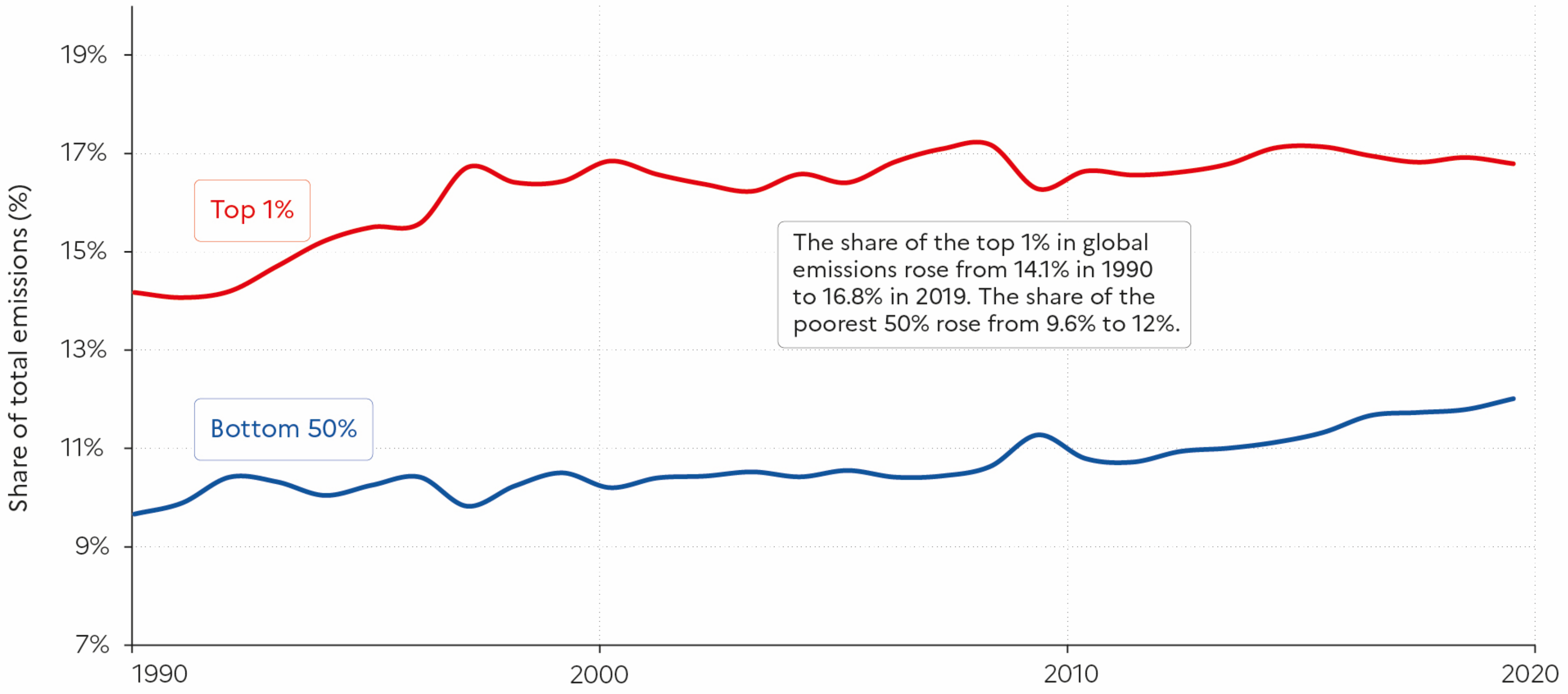


Interpretation: *Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households.* ***Sources and series:*** *wir2022.wid.world/methodology and Chancel (2021).*

https://wir2022.wid.world/chapter-6

Adaptation / change of lifestyle, 1/3

Figure 6.7 *Top 1% and bottom 50% shares in global carbon emissions, 1990-2019*

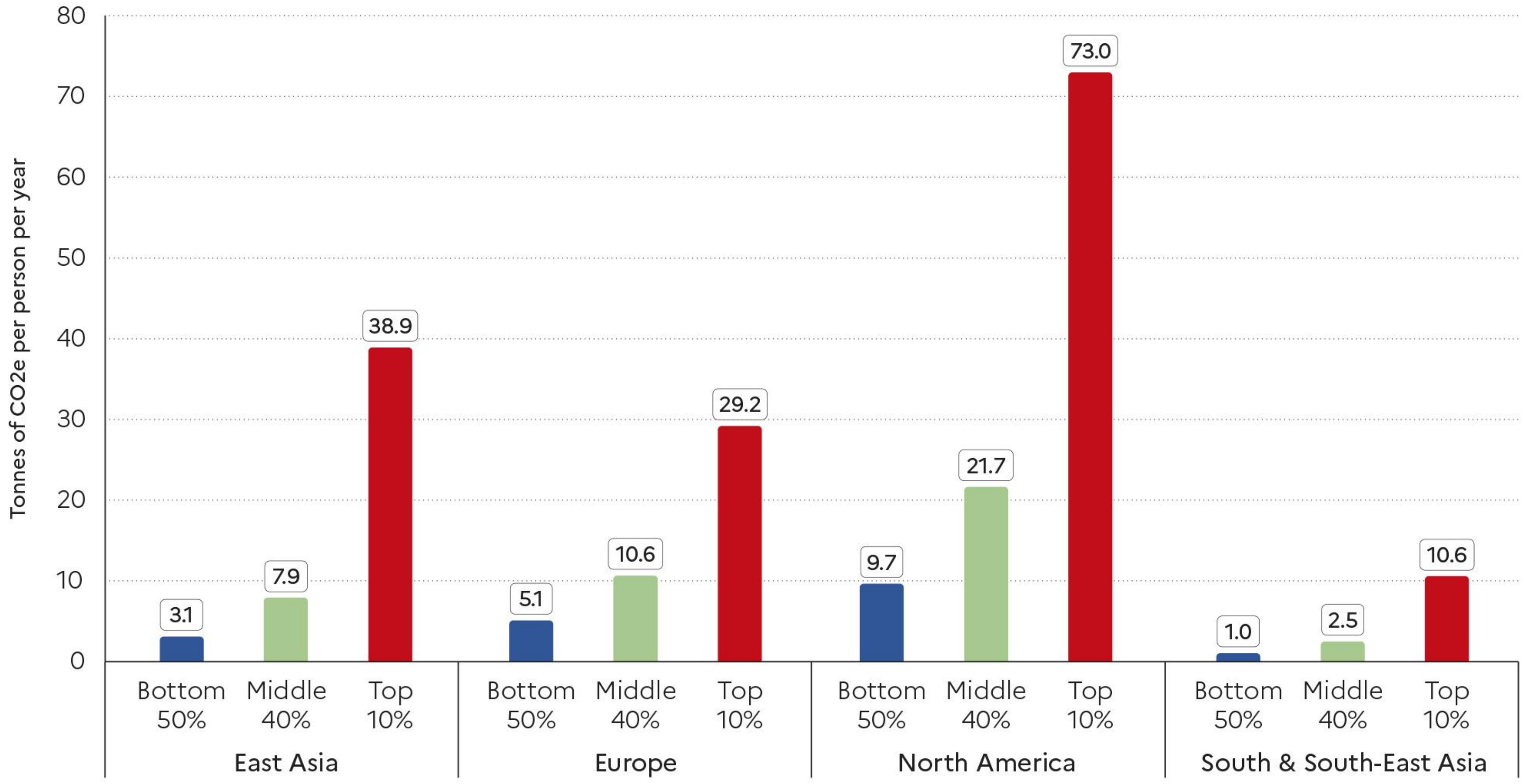


Interpretation: *This figure presents the share of global GHG emissions by the top 1% and bottom 50% of the global population between 1990 and 2019. GHG emissions measured correspond to individual footprints, i.e. they include indirect emissions produced abroad and embedded in individual consumption. Modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households.* ***Sources and series:*** *wir2022.wid.world/methodology and Chancel (2021).*

World Inequality Report 2022 (https://wir2022.wid.world/chapter-6)

Adaptation / change of lifestyle, 2/3

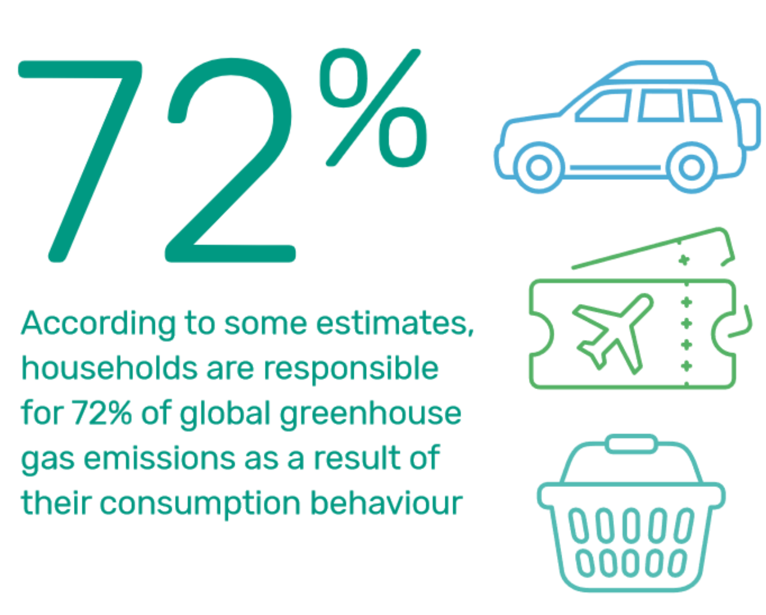
Figure 6.4a *Per capita emissions across the world, 2019*



Interpretation: *Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households.* ***Sources and series:*** *wir2022.wid.world/methodology and Chancel (2021).*

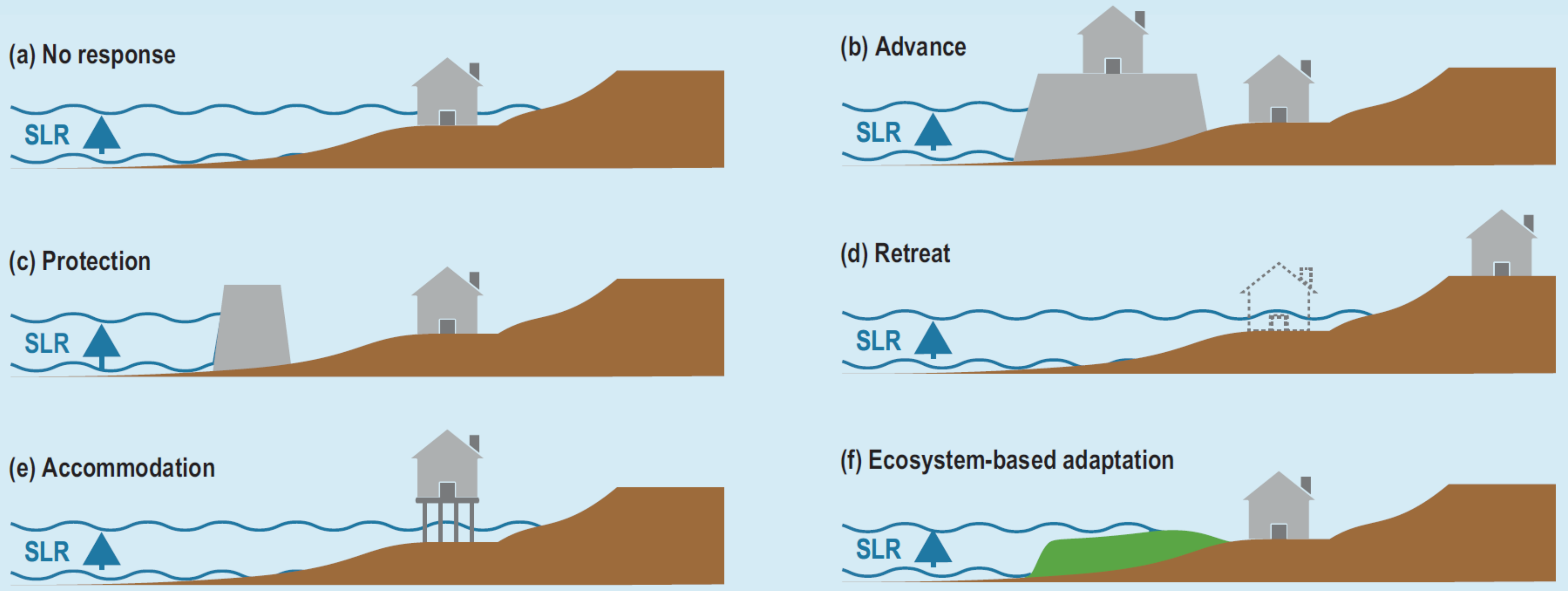
World Inequality Report 2022 (https://wir2022.wid.world/chapter-6)

Adaptation / change of lifestyle, 3/3



- https://www.bbc.com/future/article/20230504-the-people-living-ultra-low-carbon-lifestyles
- https://www.cambridge.org/engage/api-gateway/coe/assets/orp/resource/item/609b92972a6566d64fb44ad9/original/changing-our-ways-the-report-of-the-cambridge-sustainability-commission-on-scaling-behaviour-change.pdf

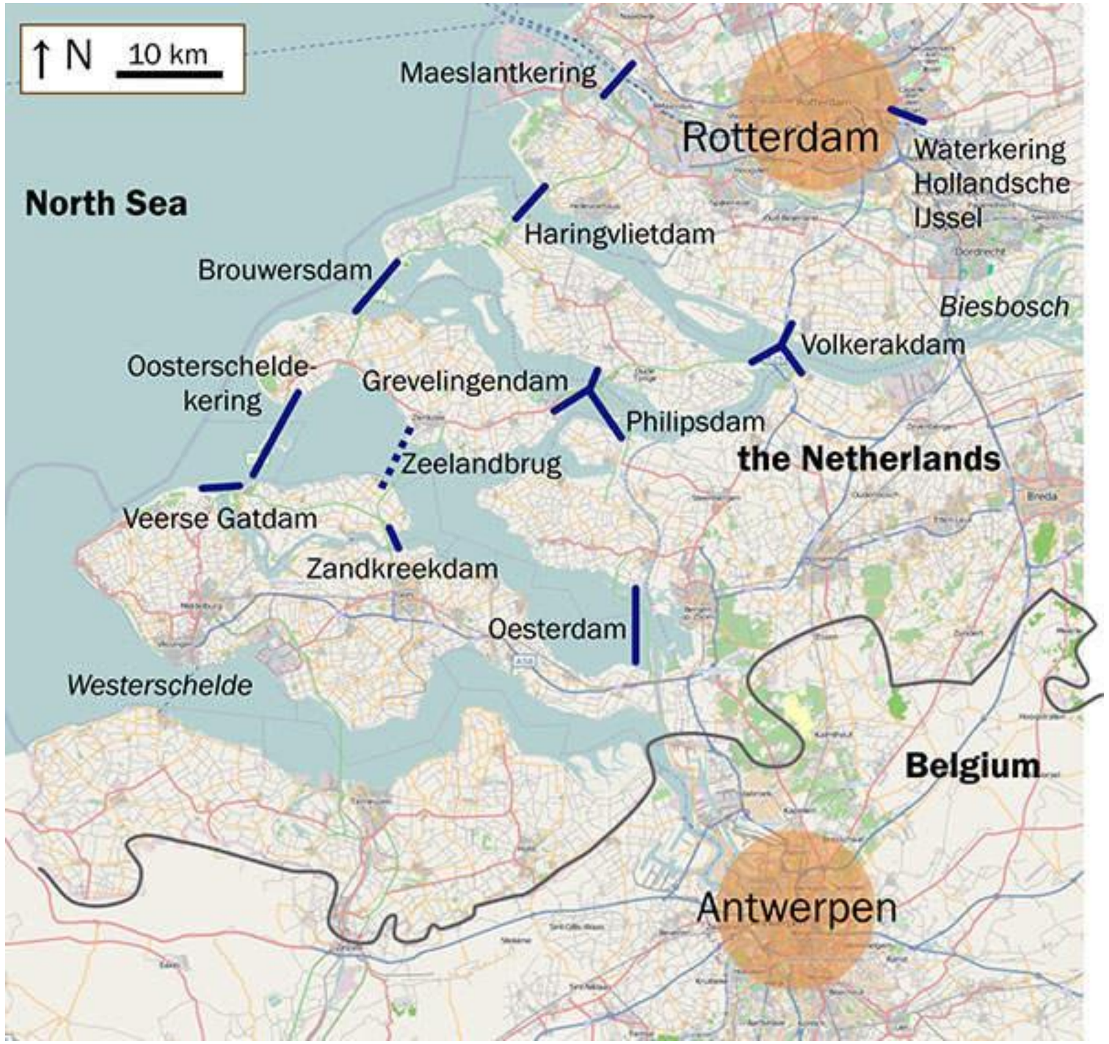
Adaptation, 1/2



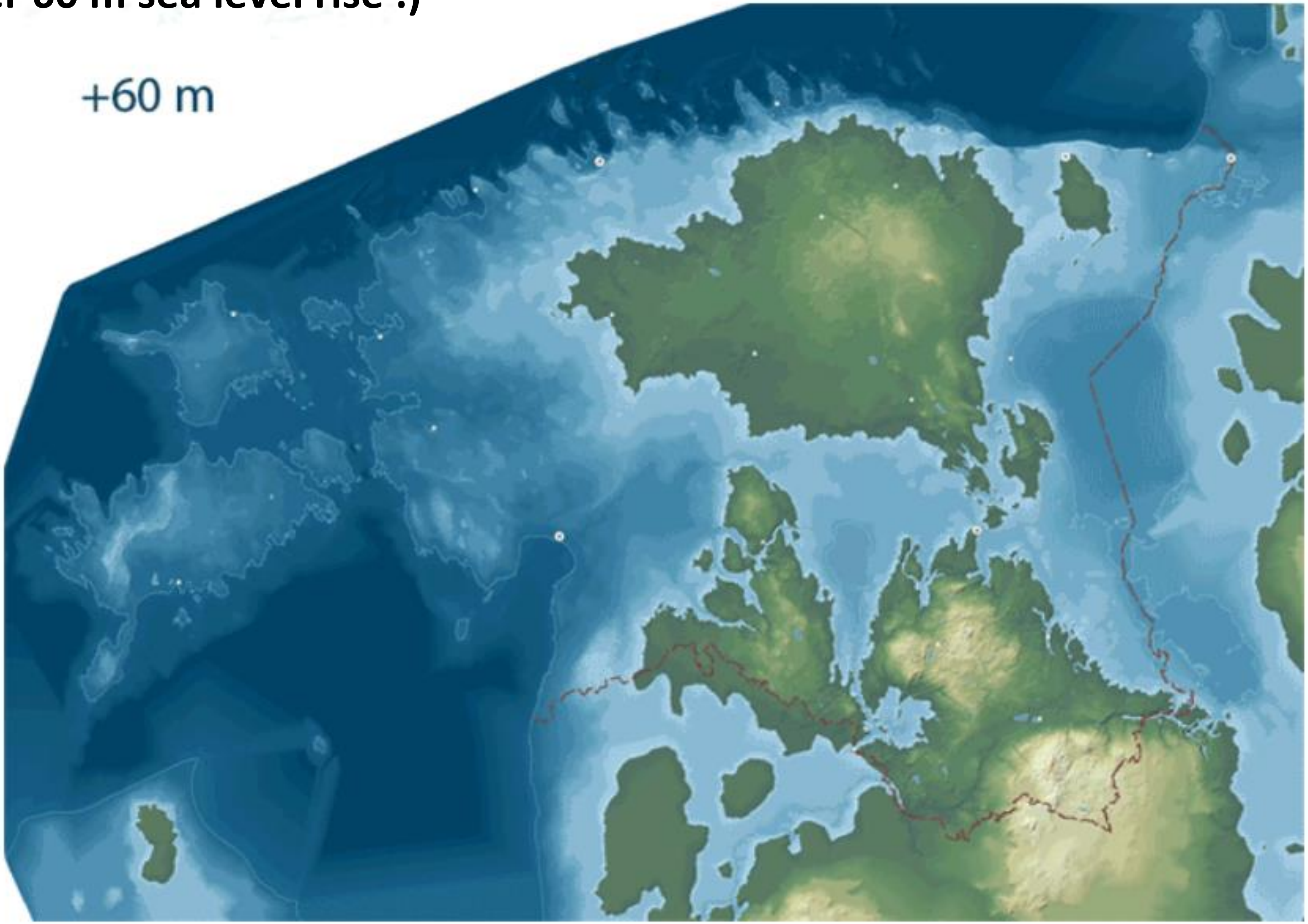
Box 4.3, Figure 1 | Different types of responses to coastal risk and sea level rise (SLR).

https://www.ipcc.ch/site/assets/uploads/sites/3/2022/03/06_SROCC_Ch04_FINAL.pdf

Adaptation, 2/2



Estonia after 60 m sea level rise :)



RA 2009

Some further reading

1. Terminology:

- IPCC climate change glossary (https://apps.ipcc.ch/glossary)

2. Trends and causes of climate change

- IPCC (https://www.ipcc.ch/report/ar6/wg1/resources/climate-change-in-data)
- US Environmental Protection Agency (https://www.epa.gov/climatechange-science/causes-climate-change)
- NASA latest CO2 data (https://climate.nasa.gov/vital-signs/carbon-dioxide)

Some further reading

3. Impacts of climate change

- https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter03.pdf
- https://www.ipcc.ch/sr15/faq/faq-chapter-1
- https://www.nature.com/articles/nature08649
- https://www.nature.com/articles/nature.2013.12838
- https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2019EF001178
- https://www.science.org/doi/10.1126/science.1210288
- https://link.springer.com/article/10.1007/s40641-018-0110-5

Some further reading

1.5°C target

- https://www.ipcc.ch/sr15/faq/faq-chapter-1
- https://www.economist.com/the-economist-explains/2024/02/09/how-to-know-when-the-world-has-passed-15degc-of-global-warming
- https://www.eea.europa.eu/highlights/climate-change-targets-350-ppm-and-the-eu-2-degree-target
- https://mn350.org/understanding350

Tipping points

- https://global-tipping-points.org
- https://www.oecd.org/en/publications/climate-tipping-points_abc5a69e-en.html

Some further reading

4. Climate policy options:

- *Mitigation*

- https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf
- https://www.negemproject.eu
- https://landgap.org
- https://wires.onlinelibrary.wiley.com/doi/10.1002/wcc.754

- *Adaptation*

- https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap15_FINAL.pdf
- https://www.eea.europa.eu/publications/advancing-towards-climate-resilience-in-europe
- https://www.cambridge.org/engage/api-gateway/coe/assets/orp/resource/item/609b92972a6566d64fb44ad9/original/changing-our-ways-the-report-of-the-cambridge-sustainability-commission-on-scaling-behaviour-change.pdf