

# Lecture 01

## Course

### introduction, the climate crisis, and civil engineering

Andrew Sonta

CIVIL-239: Engineering a sustainable  
built environment

10 September 2025



# Andrew Sonta

Tenure-Track Assistant  
Professor  
September 2022 – present

EPFL Fribourg

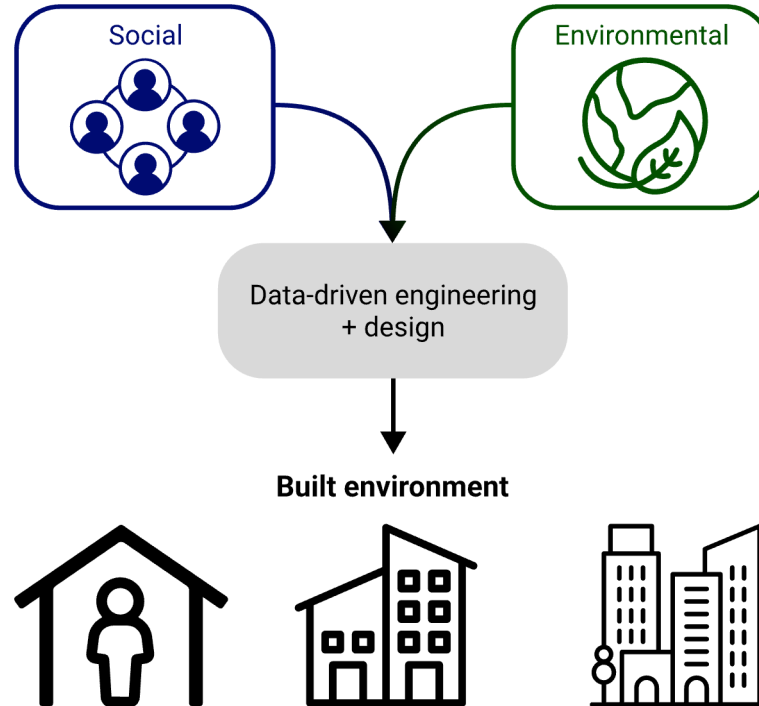


Previously:

- Postdoc, Columbia University, Data Science Institute
- PhD, Stanford University, Civil and Environmental Engineering

# ETHOS Lab

Engineering and Technology for Human Oriented Sustainability



**Research vision**  
Using **data**, **engineering**, and **design** to create interventions in the built environment that integrate our **social** and **environmental** goals.

## Some current projects

- Occupant-centric building design and management
- Socio-environmental analysis of urban form

# **Respect and Diversity at ENAC**

# What is harassment?

## Psychological harassment or mobbing

- Mobbing is an **unethical** et **destructive** behaviour in a situation or toward a person

## Sexual harassment

- Sexual or sexist harassment **any comment or act of a sexual nature** or based on sexual identification toward a person **who does not want it** and **which affects their dignity**

**At EPFL: Zero tolerance!**

# What to do in these situations



@ EPFL

- If you witness inappropriate behaviours, **show you don't approve!**  
Also, inform your coach, class representative of section
- If you are a victim, only if you feel comfortable doing it, **clarify the situation** and communicate to the person the behaviour that make you feel **harassed**
- **Rapidly communicate** to a person of trust or contact the support network (Trust and Support Network):  
<https://www.epfl.ch/campus/community/trust-and-support-network/>
- Feel free to contact me or anyone at the **Diversity Office at ENAC**  
(<https://www.epfl.ch/schools/enac/about/diversity-office/>)

# What is the ENAC Diversity Office?

- **Group that gathers representatives of all ENAC components:**
  - Students
  - Researchers
  - Administrative, scientific and technical staff
  - Professors and teachers
- **Work together to develop proactive measures to:**
  - Identify and eliminate bias and other barriers to inclusion
  - Raise awareness and promote responsible behaviour

# Diversity Office at ENAC

Diversity is a core driver for the success of our faculty.

We believe that diversity is essential to achieving excellence in education, research and innovation.



*“As the dean of ENAC, one of my top priorities is to make our school a place where everyone can live up to their full potential, regardless of their gender, nationality, ethnic origin, sexual orientation, religion, disability or any other distinguishing feature. I want ENAC to be a vibrant, welcoming community where diversity is a key engine not just for learning and studying, but also creating, inventing, building and developing talent and know-how.”*

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– Katrin Beyer, Dean of ENAC

# Course information (also in PDF on Moodle)

- Lectures: 10:15-12:00, INR 219
- Exercises: 12:15-13:00, INR 219
  - This is time for you to work on the course assignments
  - Course assistants will be present
  - Note: we will not be using GC B330 as indicated on ISA
- Course assistants:
  - Axel Cebille, civil engineering master student
  - Pedro Savini, civil engineering master student

# Course content

- Sustainability in the built environment
  - Sustainability, energy, carbon emissions, social and economic aspects
- Engineering lens
  - Approaches to sustainability in civil engineering
  - Specific **tools** for enacting sustainability in civil engineering
- Topics
  - Energy supply and demand
  - Mobility and sustainability
  - Materials and structures
  - Natural systems
  - Sustainability in the civil engineering profession

# Course assessment

- Graded exercises (20%)
  - On your own time, but you should also work on these during the exercise hour (12:15-13:00 on Tuesdays) when course assistants are present
  - The work must be done individually, but you may discuss with your fellow students
  - Write down on your submission who you discussed with
  - See course information sheet for policy on Generative AI!
- Midterm exam (30%)
- Final exam, during exam session (50%)

# Generative AI policy

- Generative AI tools (such as ChatGPT) can be valuable aids for reflection, studying, and generating ideas
- They also carry limitations and risks, so their use in this course is restricted to specific, responsible practices:
  - **Study aid only** — do not generate content for assignments
  - Only use with **proper citation** and acknowledgement
  - You are **responsible** for the output, no one else
  - ChatGPT can be a good resource, but it can also **limit learning**
- **See course information sheet for full policy**

# ChatGPT

What is one third of a decade?

A decade is **10 years**.

One third of 10 years =  $10 \div 3 = 3.333\dots$  years,  
which is **3 years and 4 months** (approximately).

What is half a decade?

Half a decade is **5 years  $\div 2 = 2.5$  years**.

So half a decade is two and a half years.

So half a decade is shorter than one third of a decade?

No — it's the other way around.

- **Half a decade = 2.5 years**
- **One third of a decade  $\approx 3.33$  years**

So **one third of a decade is longer than half a decade**.

Week	Date	Course Content	Engineering knowledge and tools	Due
<b>Course introduction</b>				
1	10-Sep	The climate crisis What is sustainability? Sustainability in civil engineering	The role of the built environment in sustainability	
2	17-Sep	Sustainability indicators New economic thinking	The importance of data	
<b>Buildings and energy</b>				
3	24-Sep	Energy demand: buildings and infrastructure	How design impacts energy demand; Energy and load calcs	Assignment 1
4	1-Oct	Energy supply: Renewables, the grid, and grid integration	Interface between the built environment and energy systems; time-series data analysis	
<b>Mobility and sustainability</b>				
5	8-Oct	Transportation systems	Link between transportation and energy; systems thinking	Assignment 2
6	15-Oct	Sustainable urban design and active mobility Social systems	System dynamics	
7	22-Oct	No Class - Fall Break		
8	29-Oct	<b>Midterm exam – CE 11</b>		Assignment 3

<b>Materials, structures, and life-cycle assessment</b>				
9	5-Nov	Life-cycle assessment	Environmental LCA	
10	12-Nov	<b>Guest lecture:</b> Embodied carbon emissions and materials	The phases of infrastructure life cycles	
<b>Civil engineering and natural systems</b>				
11	19-Nov	<b>Guest lecture:</b> Assigning value to natural systems	Sustainability in natural systems; Engineering and sustainability economics	
12	26-Nov	Engineering with natural systems; geotechnical engineering, water resources engineering	Multi-criteria decision-making, resilience, sensitivity analysis, nature-based solutions	Assignment 4
<b>Sustainability in the civil engineering profession</b>				
13	3-Dec	Safety and reliability in civil engineering	Load combinations, safety and reliability, safety factors	
14	10-Dec	<b>Guest lecture:</b> Sustainable engineering in the industry	Practical issues	
15	17-Dec	Course wrap up Class debate		Assignment 5
-	TBD	<b><i>Final written exam</i></b>		

# Today's outline

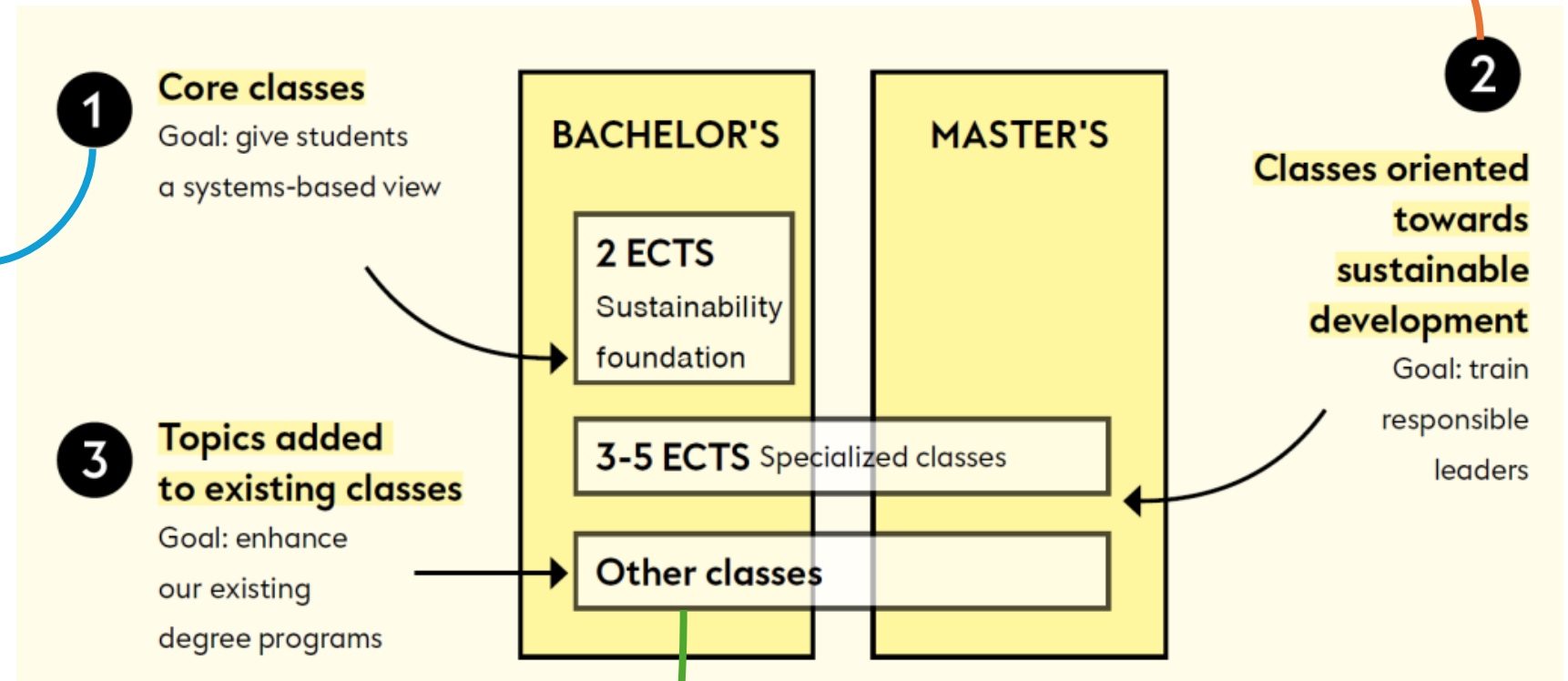
- Sustainability in the curriculum at EPFL
- Sustainability in civil engineering: overview of the topics in the course
- The climate crisis
- Definitions of sustainability
- Why civil and environmental engineering is uniquely concerned with sustainability

# Teach4Sustainability

This is the purpose of CIVIL-239

## ENV-101:

- Climate crisis
- Planetary boundaries
- Definitions of sustainability
- Technological aspects
- Social and political aspects
- Systems thinking



For some of you: Global Issues courses on sustainability

- Energy and innovation
- Climate change
- Food and sustainability
- ...

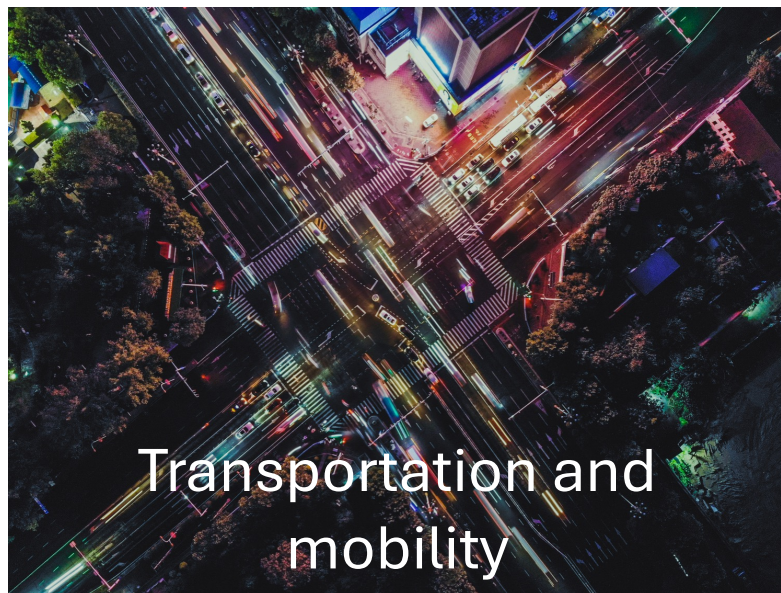
# Sustainability in civil engineering

# What is civil engineering at its core?

- American Society of Civil Engineers definition: Civil engineers **design, build, and maintain** the foundation for our modern **society** – our buildings, roads and bridges, drinking water and energy systems, sea ports and airports, and the infrastructure for a cleaner environment, to name just a few.

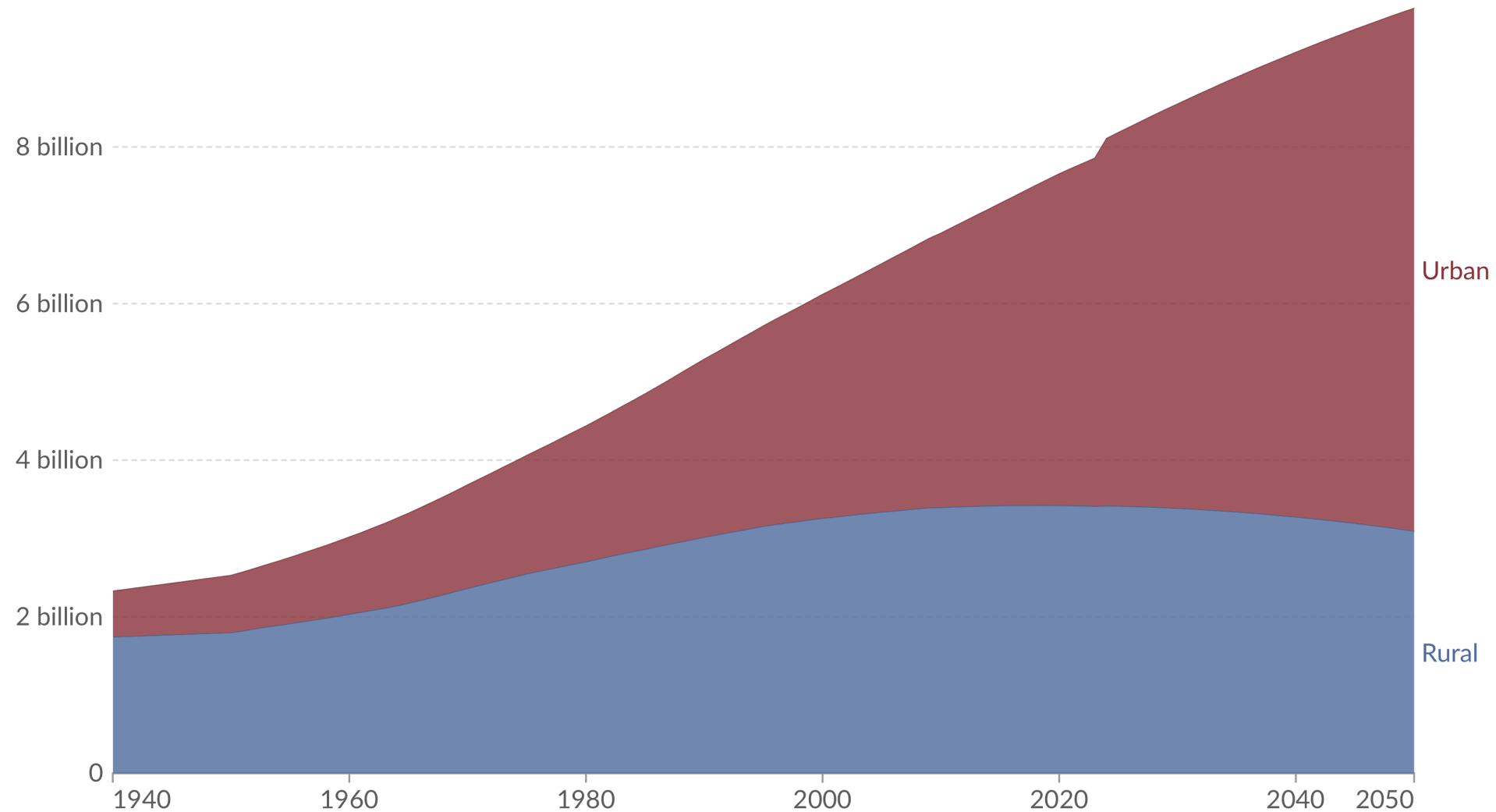


# Subdisciplines of civil engineering



# Urban and rural population projected to 2050, World, 1940 to 2050

Total urban and rural population, given as estimates to 2023, and UN projections to 2050. Projections are based on the UN World Urbanization Prospects and its median fertility scenario.



**Data source:** United Nations, Department of Economic and Social Affairs, Population Division (2018); HYDE (2023)  
OurWorldInData.org/urbanization | CC BY

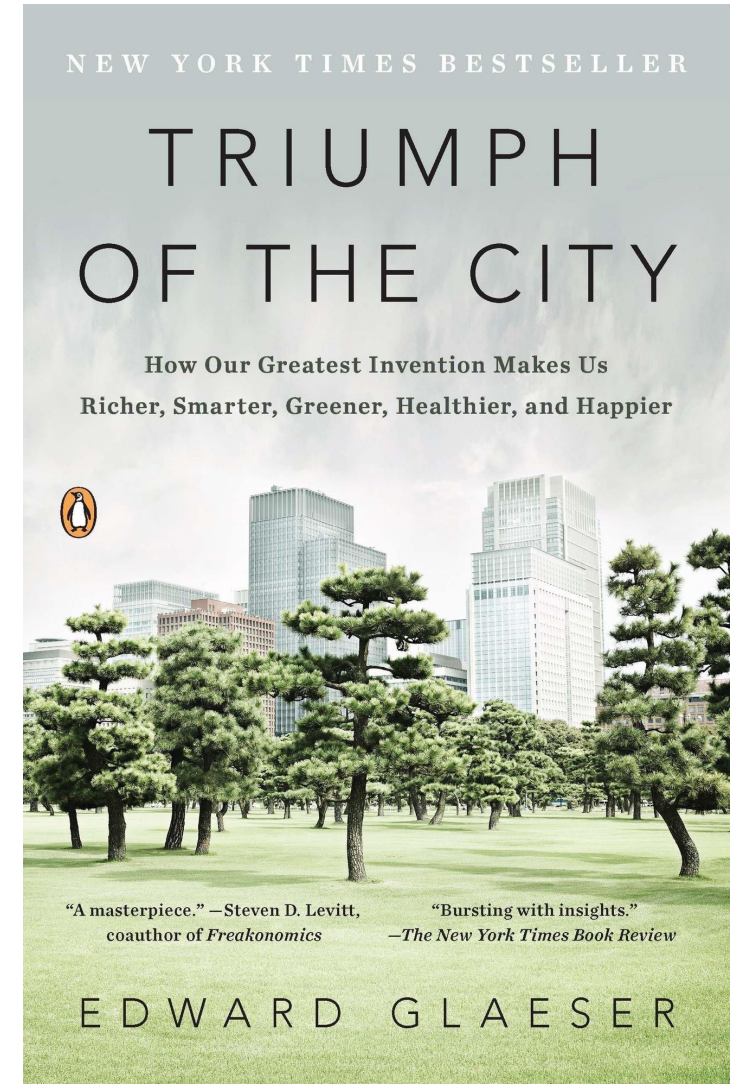
# Why do cities grow?

“Cities magnify humanity’s strengths”

-Edward Glaeser, Professor of Economics, Harvard

*“They spur **innovation** by facilitating face-to-face interaction, they attract talent and sharpen it through competition, they encourage entrepreneurship, and they allow for social and economic mobility.”*

-Diana Silver, Asst. Professor of Public Health, NYU (review of Triumph of a City in NY-Times)



# Our visual understanding of Earth



Landscapes  
since ~start  
of civilization



City panoramas  
(e.g. view from Tour Eiffel)  
since ~1800-1900



Views from airplanes  
since ~1920

# Earthrise

- Photo taken December 24, 1968, during Apollo 8 mission to the Moon
- First color picture of the entire Earth
- Widely credited with propelling the environmental movement



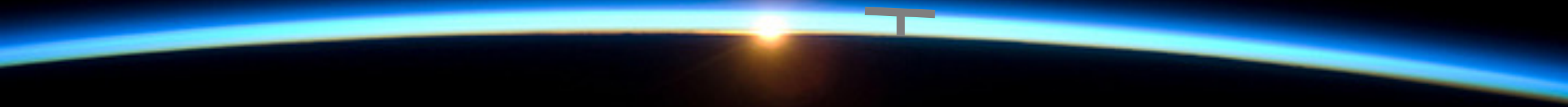
# The Blue Marble

- Photo taken December 7, 1972, during Apollo 17 mission to the Moon



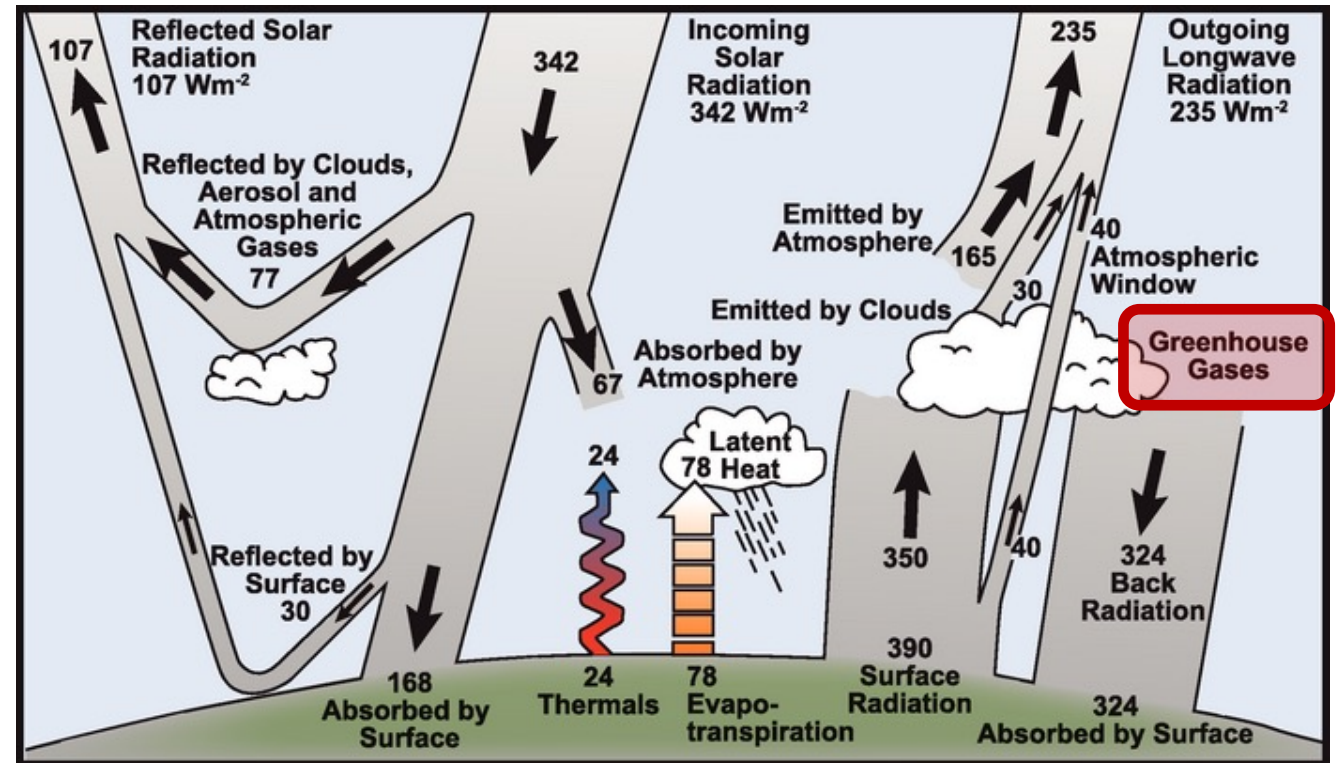
# THE THIN BLUE LINE

Kármán Line: Edge of space  
100km above sea level

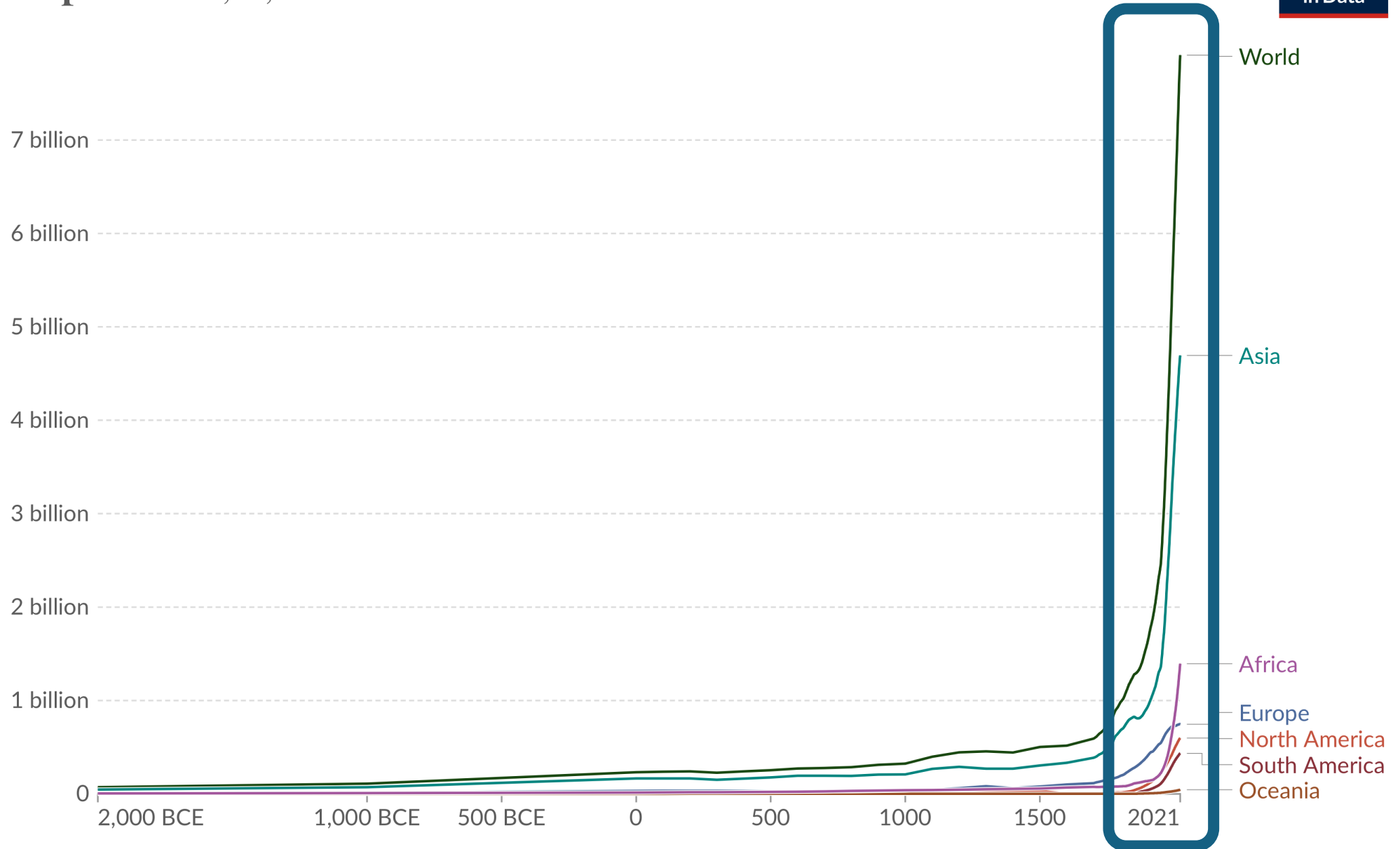


# A delicate balance

- The Earth's temperature is the result of radiative balance
- The sun emits  $3.9 \times 10^{26}$  W, and the Earth receives  $\sim 340$  W/m<sup>2</sup> on average
- The Earth emits radiation in the infrared spectrum
- Without the greenhouse effect, the surface of the Earth would be  $-18^{\circ}\text{C}$  on average, instead of the observed  $15^{\circ}\text{C}$



# Population, 2,000 BCE to 2021



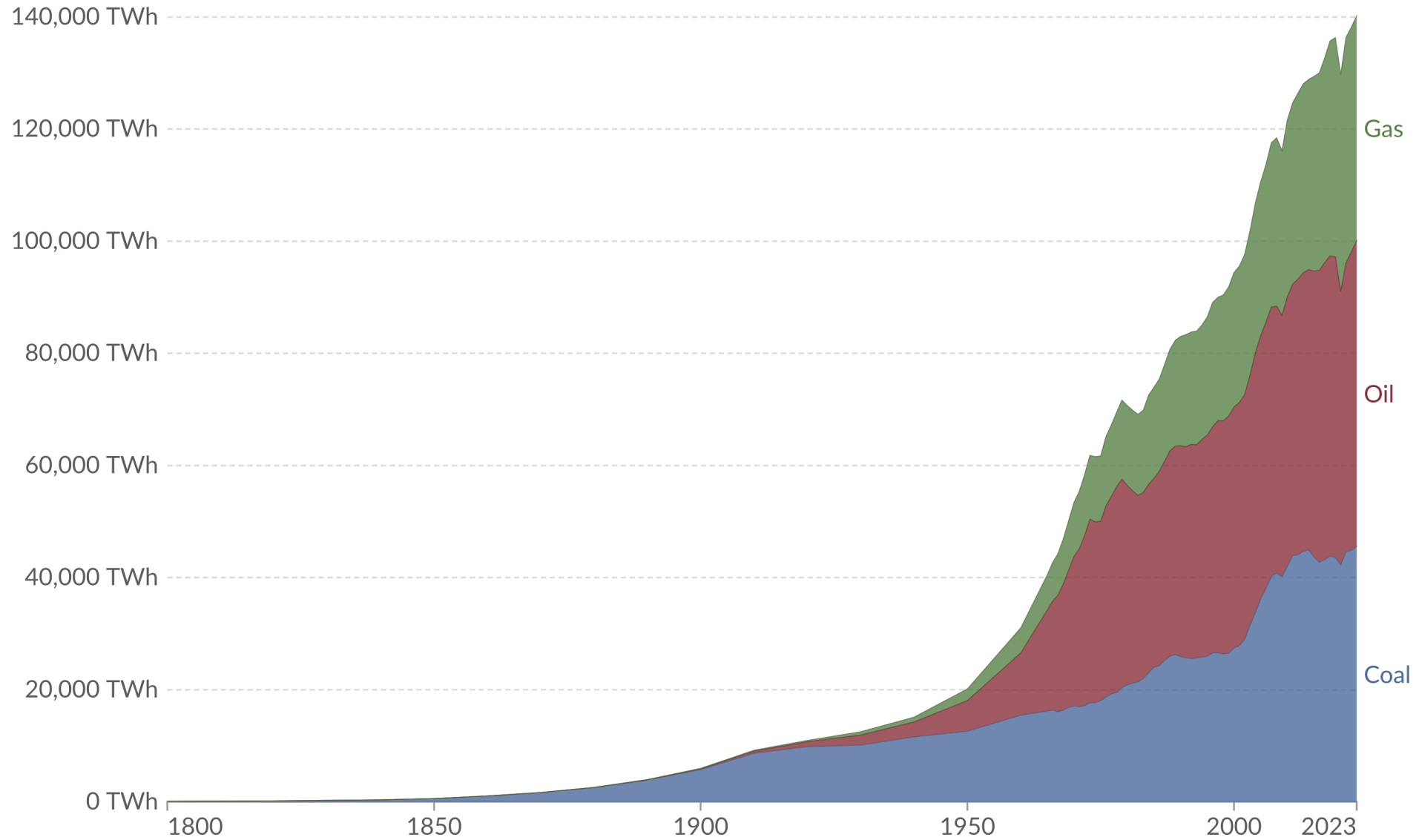
Data source: HYDE (2017); Gapminder (2022); UN (2022)

Note: Historical country data is shown based on today's geographical borders.

OurWorldInData.org/population-growth | CC BY

# Global fossil fuel consumption

Measured in terawatt-hours<sup>1</sup> of primary energy<sup>2</sup> consumption.

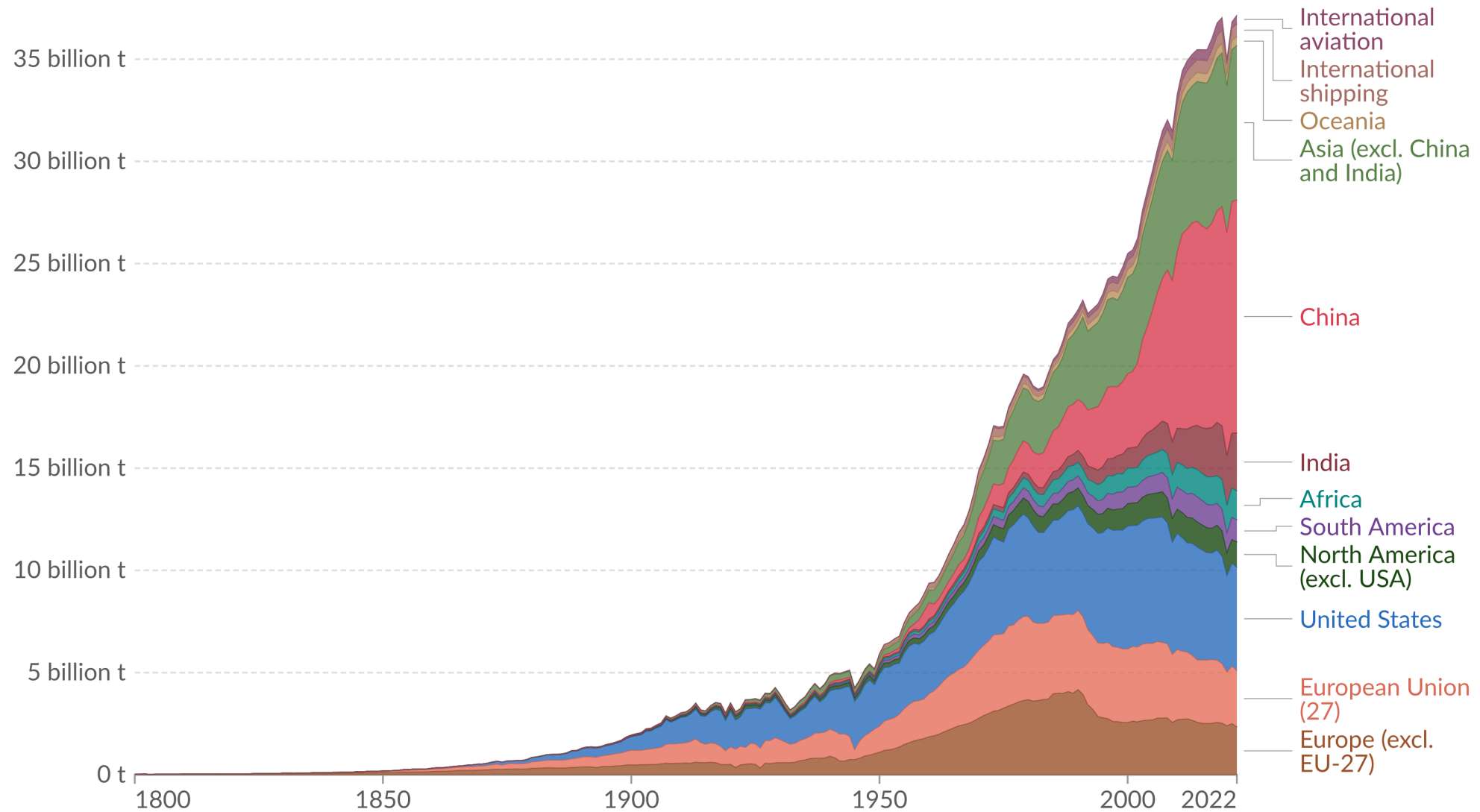


Data source: Energy Institute - Statistical Review of World Energy (2024); Smil (2017)

OurWorldInData.org/fossil-fuels | CC BY

# Annual CO<sub>2</sub> emissions by world region

Emissions from fossil fuels and industry<sup>1</sup> are included, but not land-use change emissions. International aviation and shipping are included as separate entities, as they are not included in any country's emissions.

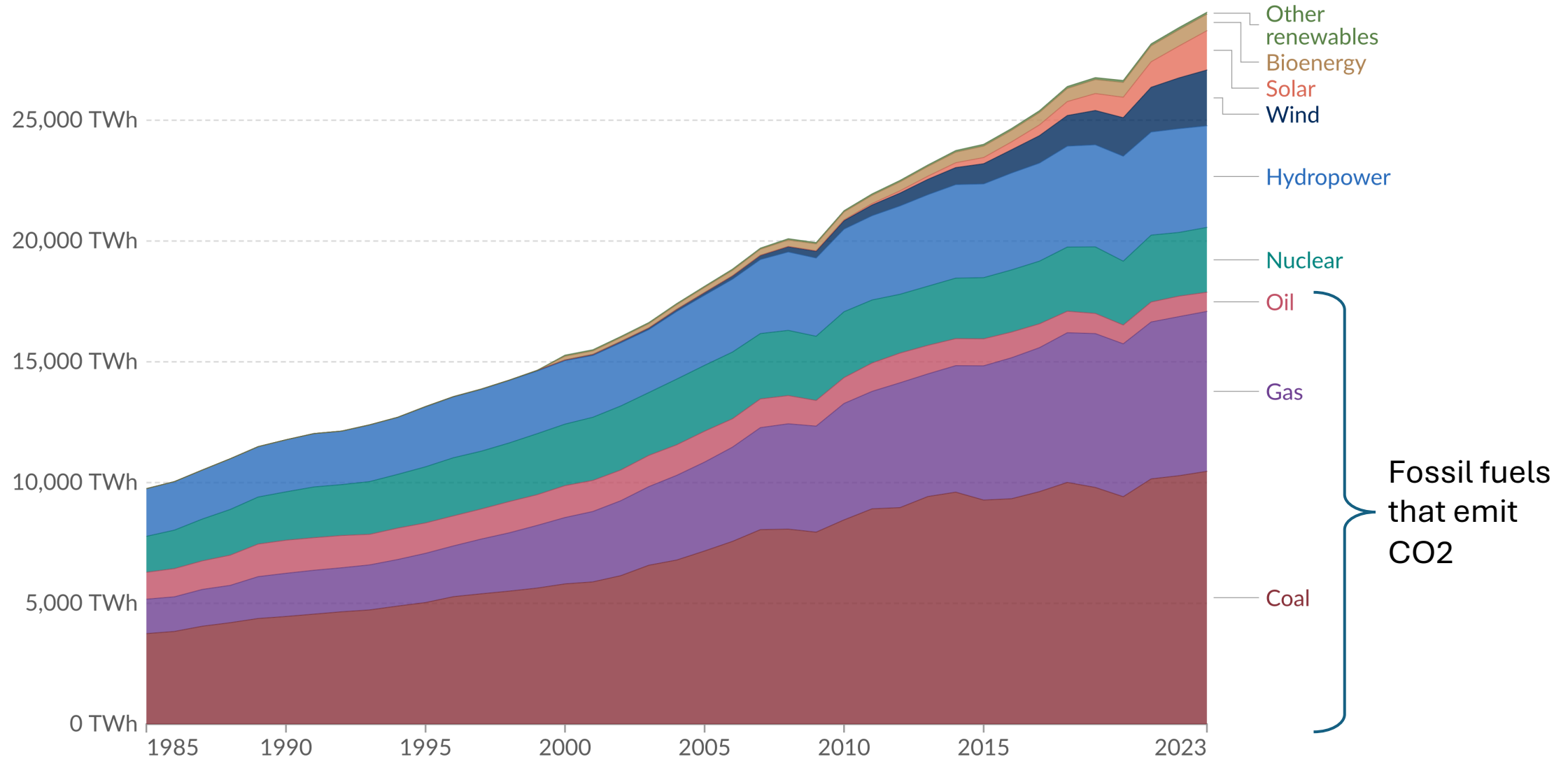


Data source: Global Carbon Budget (2023)

OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

# Electricity production by source, World

Measured in terawatt-hours<sup>1</sup>.



Data source: Ember (2024); Energy Institute - Statistical Review of World Energy (2024)

OurWorldInData.org/energy | CC BY

Note: "Other renewables" include waste, geothermal, wave, and tidal.



THAWING PERMAFROST

AIR TRANSPORT

COAL MINING

OIL PRODUCTION

COAL PLANTS

FERTILIZATION

INDUSTRIAL PROCESSES

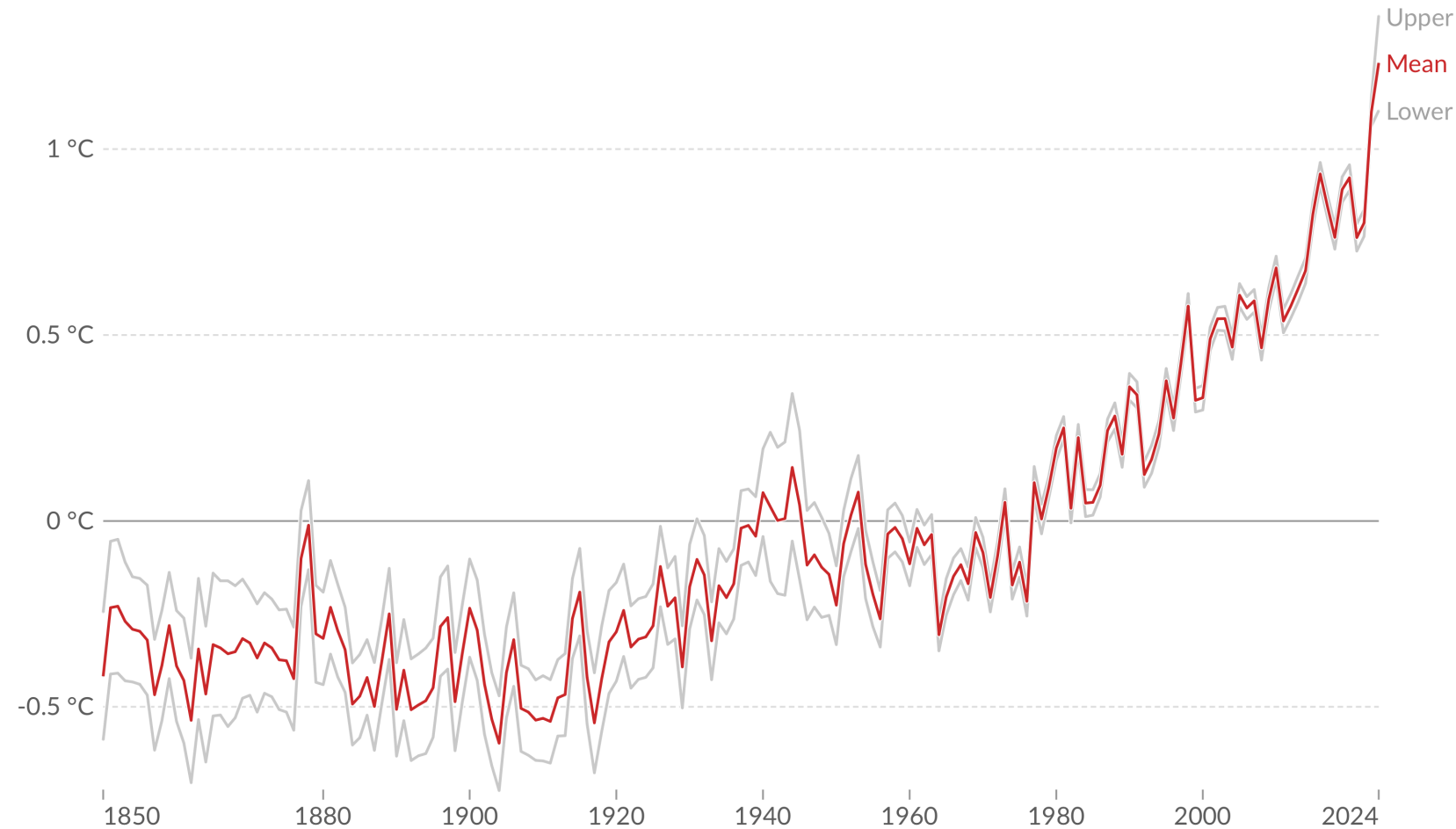
LAND TRANSPORT

LANDFILLS

# Average temperature anomaly, Global

Global average land-sea temperature anomaly relative to the 1961-1990 average temperature.

Our World  
in Data



But Andrew, there are natural cycles that cause Earth's CO<sub>2</sub> concentrations to vary over time. How do we know this is an urgent issue?

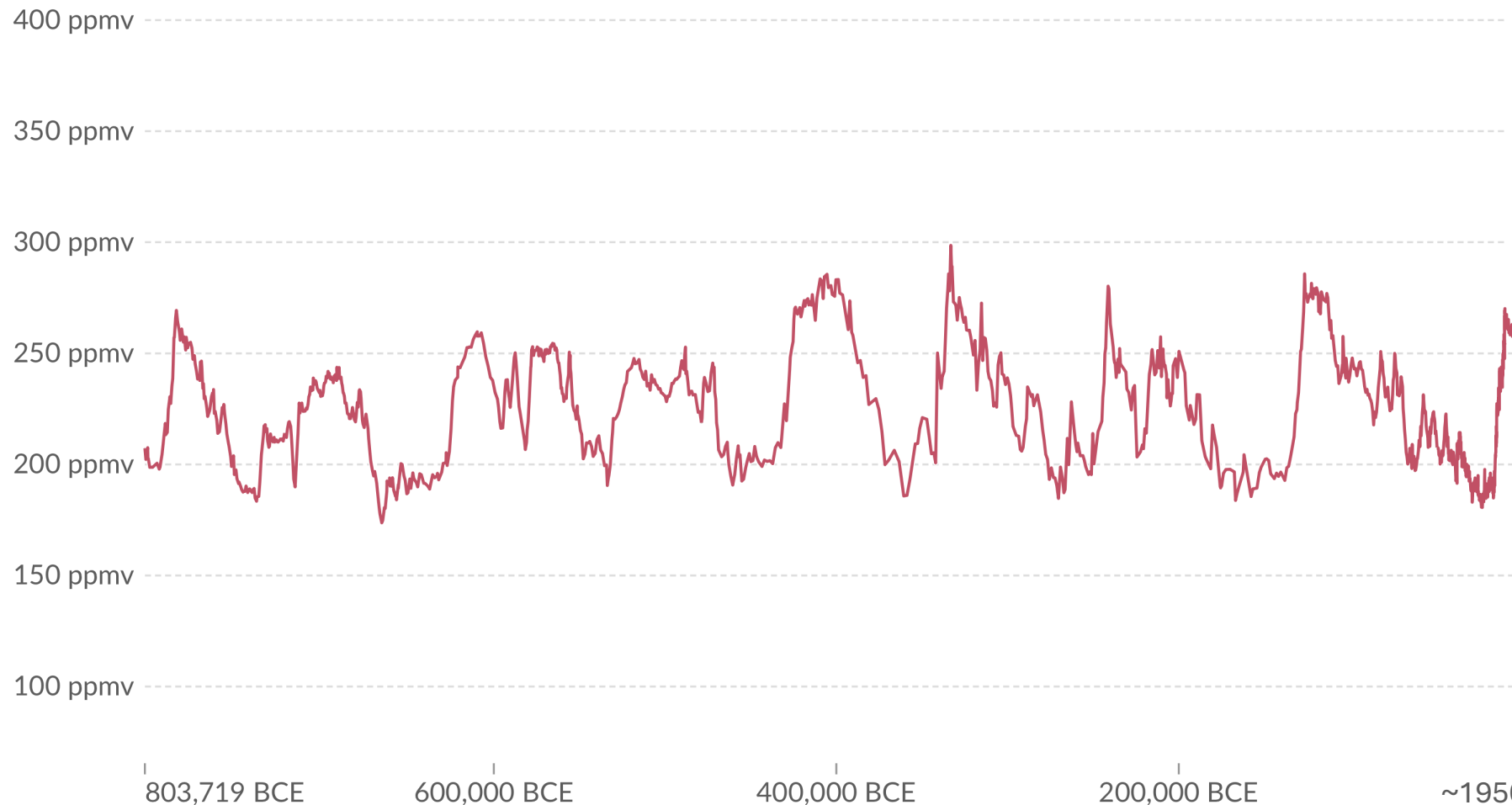
Data source: Met Office Hadley Centre (2024)

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Note: The gray lines represent the upper and lower bounds of the 95% confidence intervals.

# Carbon dioxide concentrations in the atmosphere

Atmospheric carbon dioxide (CO<sub>2</sub>) concentration is measured in parts per million (ppm). Long-term trends in CO<sub>2</sub> concentrations can be measured at high-resolution using preserved air samples from ice cores.



**Data source:** NOAA Global Monitoring Laboratory - Trends in Atmospheric Carbon Dioxide (2024); EPA based on various sources (2022)

[OurWorldInData.org/climate-change](https://OurWorldInData.org/climate-change) | CC BY

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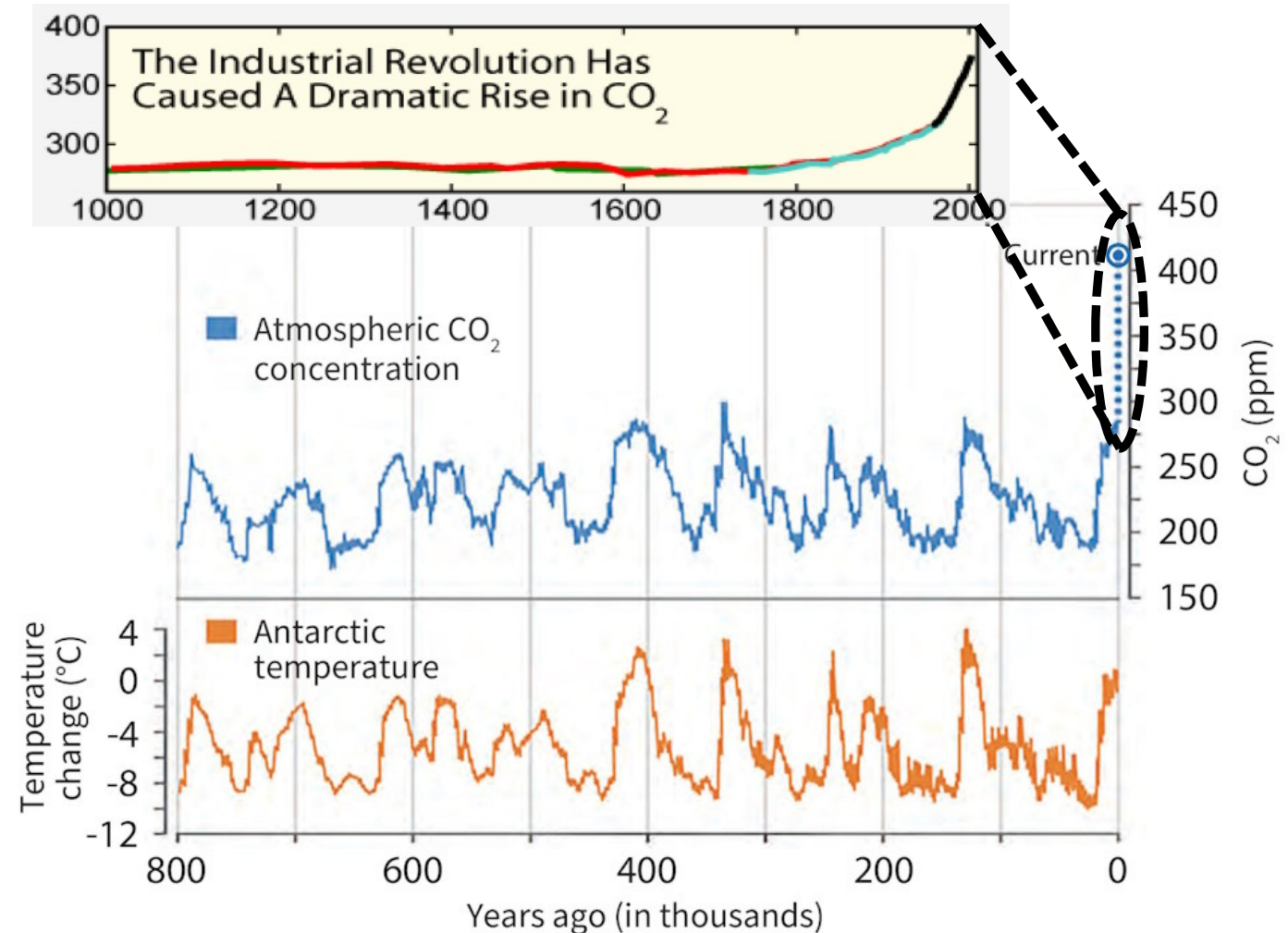


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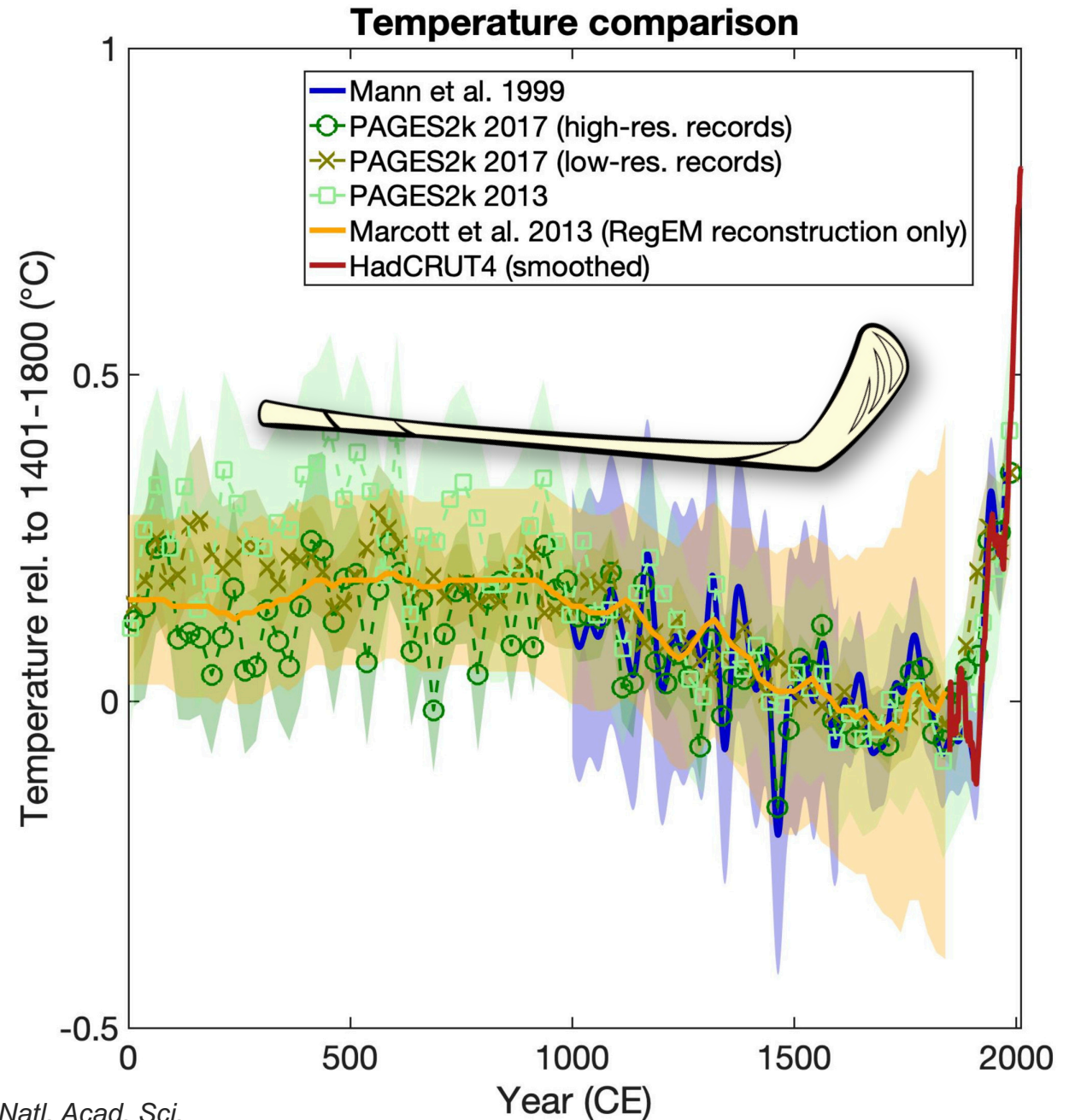
# Unprecedented impact of human activity

- “The cyclical pattern of temperature variations constitutes the ice age/interglacial cycles...
- During these cycles, changes in CO<sub>2</sub> concentrations (in blue) track closely with changes in temperature (in orange)...
- As the record shows, the recent increase in atmospheric CO<sub>2</sub> concentration is unprecedented in the past 800,000 years.”



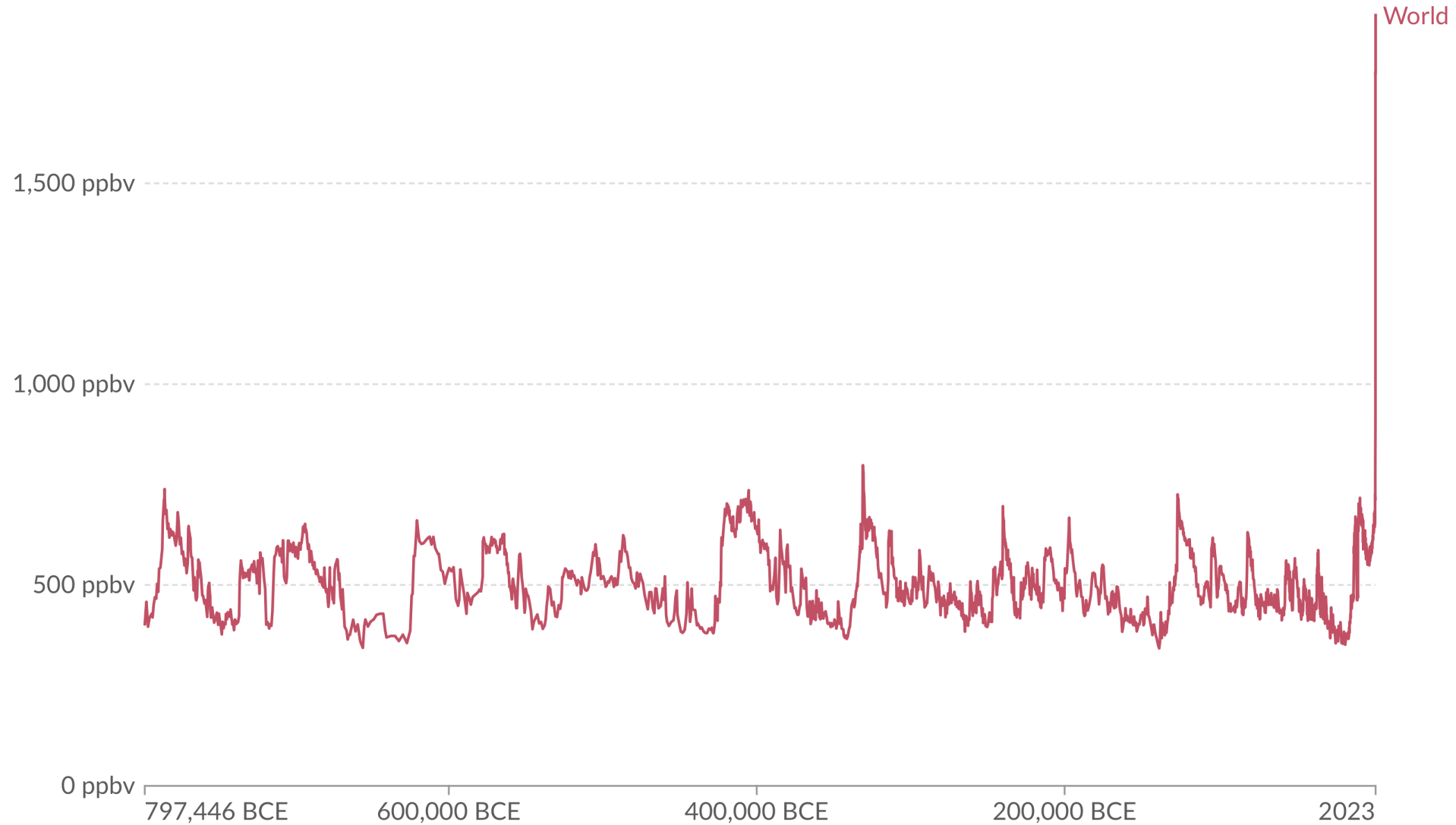
# The original “hockey stick graph” (with newer data)

The key message behind the “hockey stick graph” is that, while historical variations in global temperatures are normal, the rate of change after the industrial revolution is unprecedented.



# Methane concentration in the atmosphere

Measured in parts per billion.



**Data source:** NOAA Global Monitoring Laboratory - Trends in Atmospheric Methane (2024); EPA based on various sources (2022)  
OurWorldInData.org/climate-change | CC BY

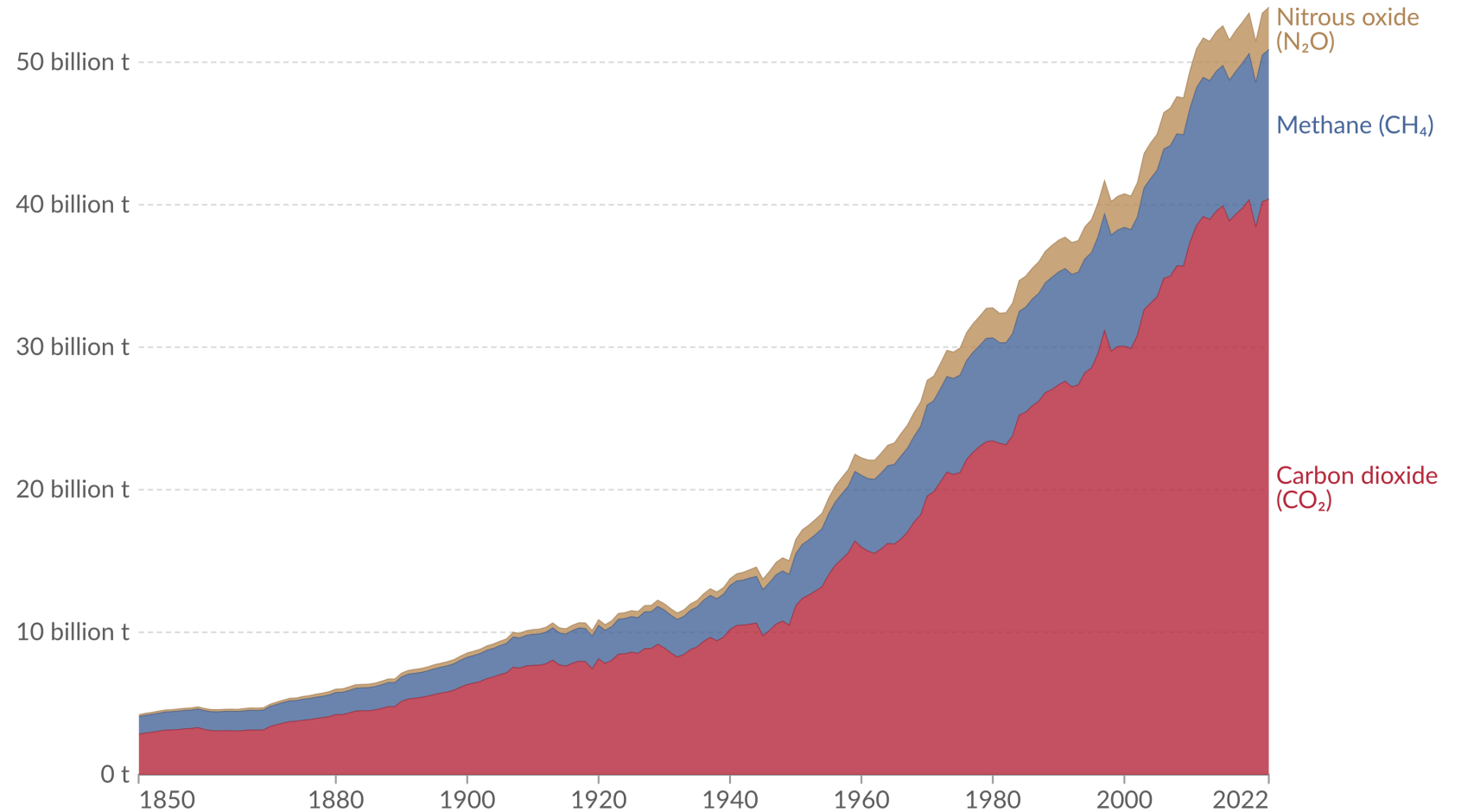
## Measured in CO<sub>2</sub>e (carbon dioxide equivalents)

Example: Methane is ~28x more effective in trapping heat compared to carbon dioxide over a 100-year period, so the raw amount of methane emitted is ~1/28 of what is shown.

## Greenhouse gas emissions by gas, World, 1850 to 2022

Our World  
in Data

Greenhouse gas emissions<sup>1</sup> from all sources, including agriculture and land-use change. They are measured in tonnes of carbon dioxide-equivalents<sup>2</sup> over a 100-year timescale.



Data source: Jones et al. (2024)

OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

# Greenhouse gas (GHG)

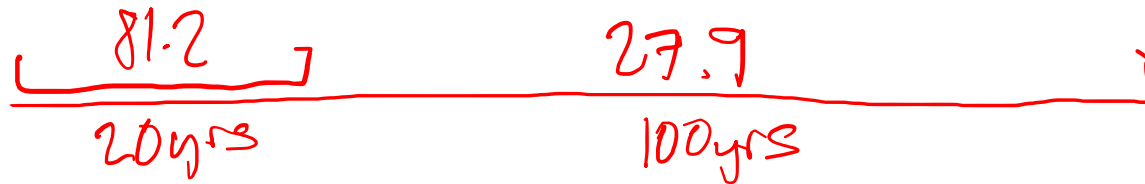
- Group of gases that contribute to global warming and climate change by trapping heat in the atmosphere
- The Kyoto Protocol (1997 UN agreement) covers seven GHGs<sup>1</sup>:
  - **carbon dioxide (CO<sub>2</sub>)**
  - **methane (CH<sub>4</sub>)**
  - nitrous oxide (N<sub>2</sub>O)
  - hydrofluorocarbons (HFCs)
  - perfluorocarbons (PFCs)
  - sulphur hexafluoride (SF<sub>6</sub>)
  - nitrogen trifluoride (NF<sub>3</sub>)

<sup>1</sup> Source: European Union

# Accounting for different greenhouse gases

- **Global Warming Potential (GWP)**

- Measure of how much heat a GHG traps, taking account of how long it remains active in the atmosphere (atmospheric lifetime), relative to CO<sub>2</sub>
- GWP is defined for a specific time period (e.g., 20 years, 100 years)
- CO<sub>2</sub> has a GWP over 100 years of 1
  - This is the definition of the baseline
- Methane (CH<sub>4</sub>) has the following GWPs:
  - 20 years: 81.2
  - 100 years: 27.9
  - 500 years: 7.95



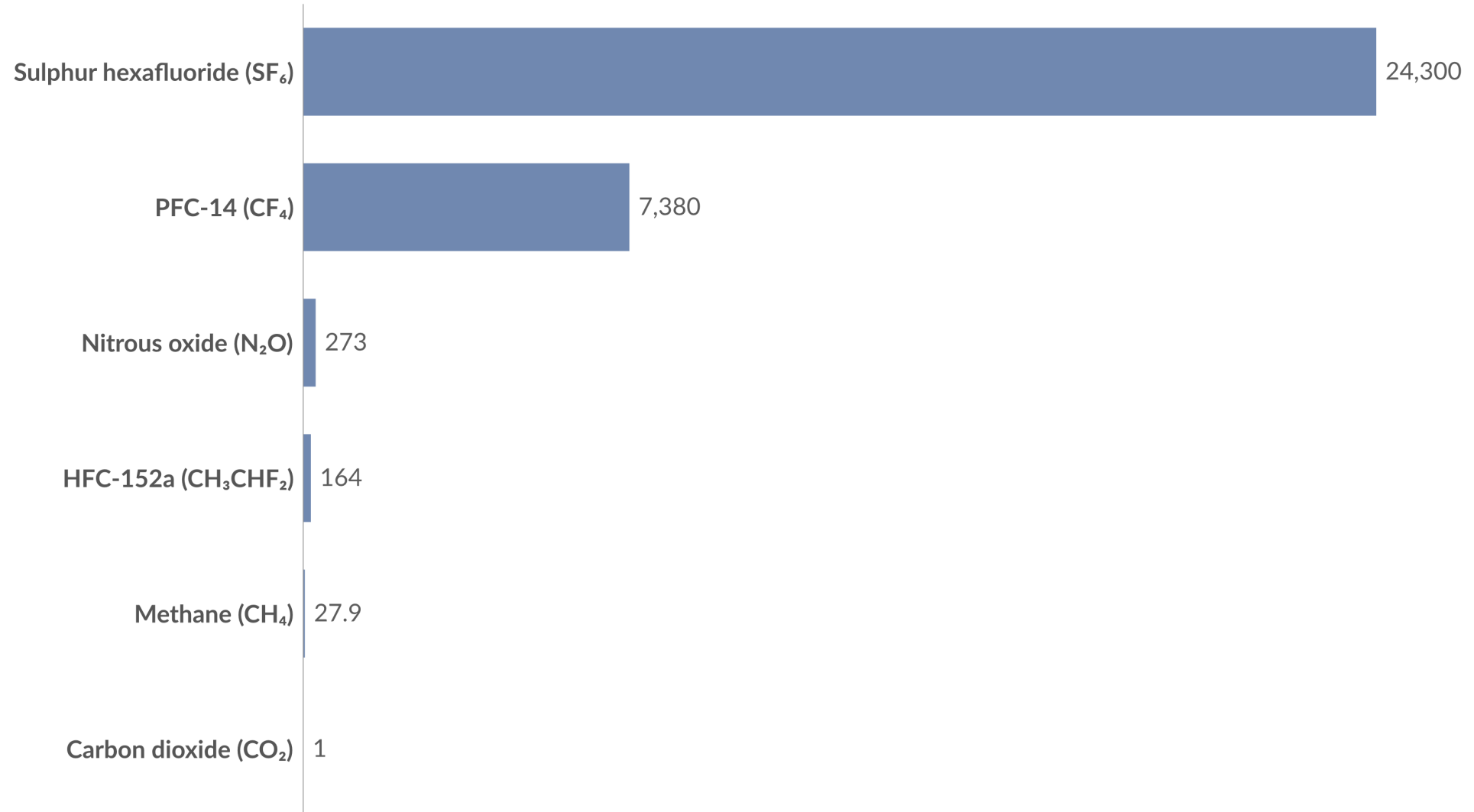
- **Carbon dioxide equivalent (CO<sub>2</sub>e or CO<sub>2</sub>eq)**

- Defined as GWP times mass of gas
- What is 1g of CH<sub>4</sub> in CO<sub>2</sub>e (100 years)?

# Global warming potential of greenhouse gases relative to CO<sub>2</sub>

Our World  
in Data

Global warming potential<sup>1</sup> measures the relative warming impact of one unit mass of a greenhouse gas relative to carbon dioxide over a 100-year timescale.



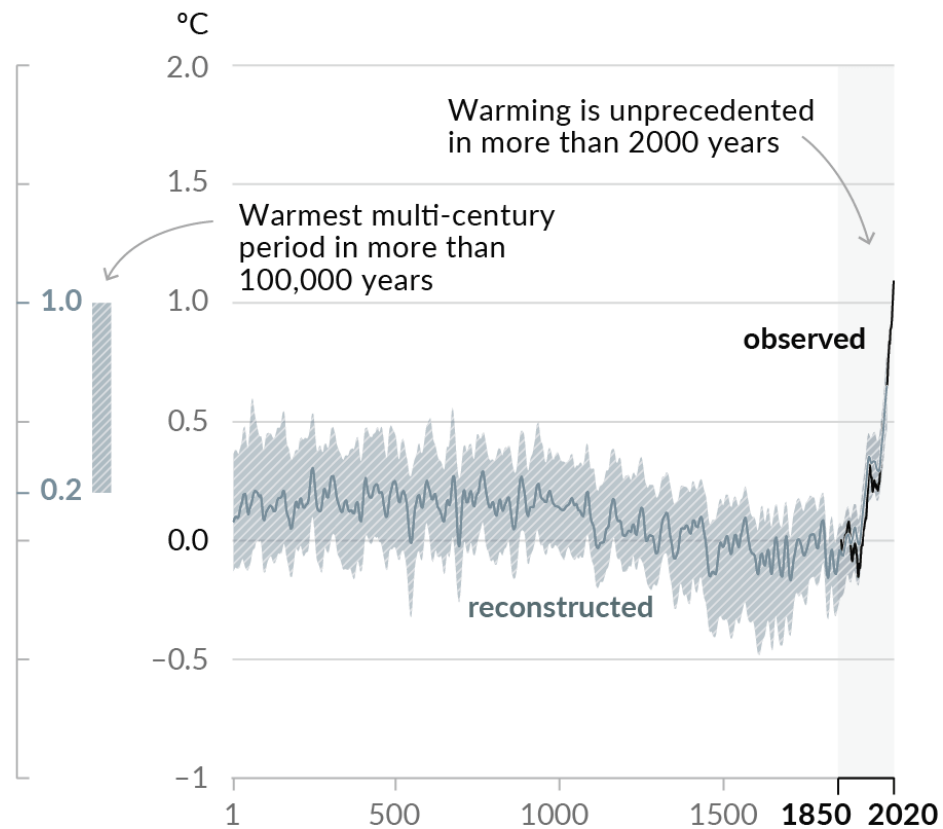
Data source: IPCC (2021)

OurWorldinData.org/co2-and-greenhouse-gas-emissions | CC BY

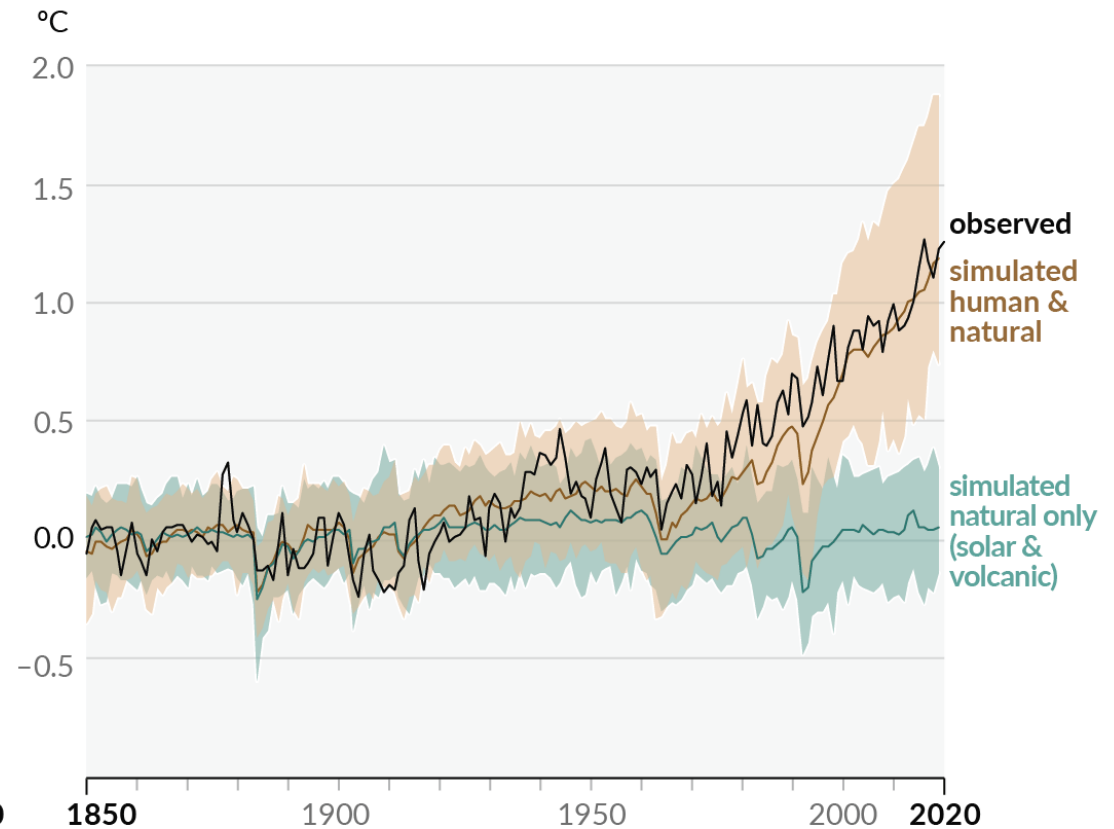
# Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

## Changes in global surface temperature relative to 1850–1900

(a) Change in global surface temperature (decadal average) as **reconstructed** (1–2000) and **observed** (1850–2020)



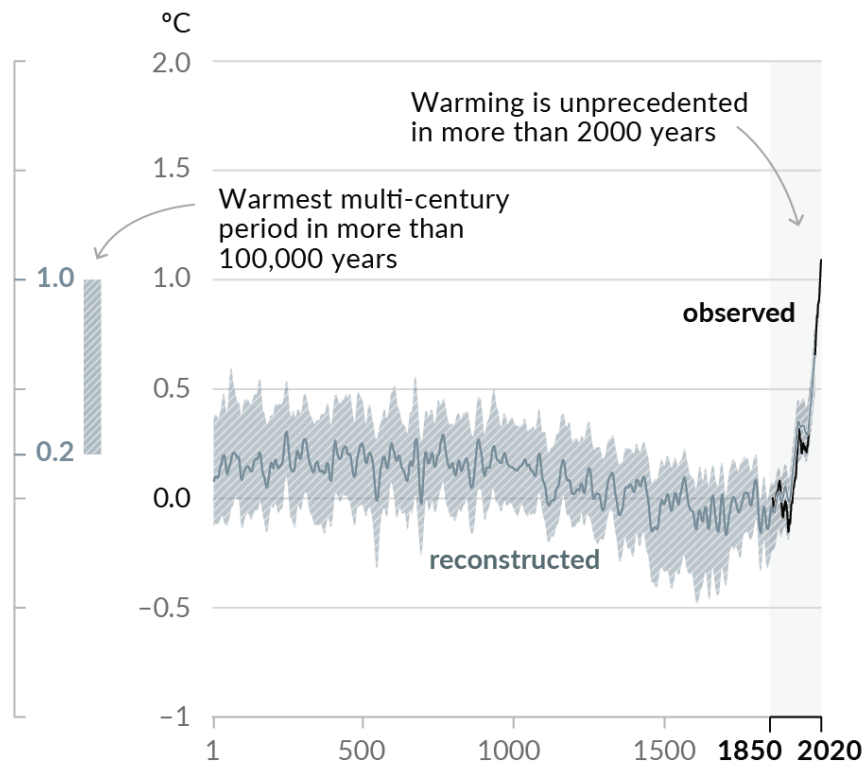
(b) Change in global surface temperature (annual average) as **observed** and simulated using **human & natural** and **only natural** factors (both 1850–2020)



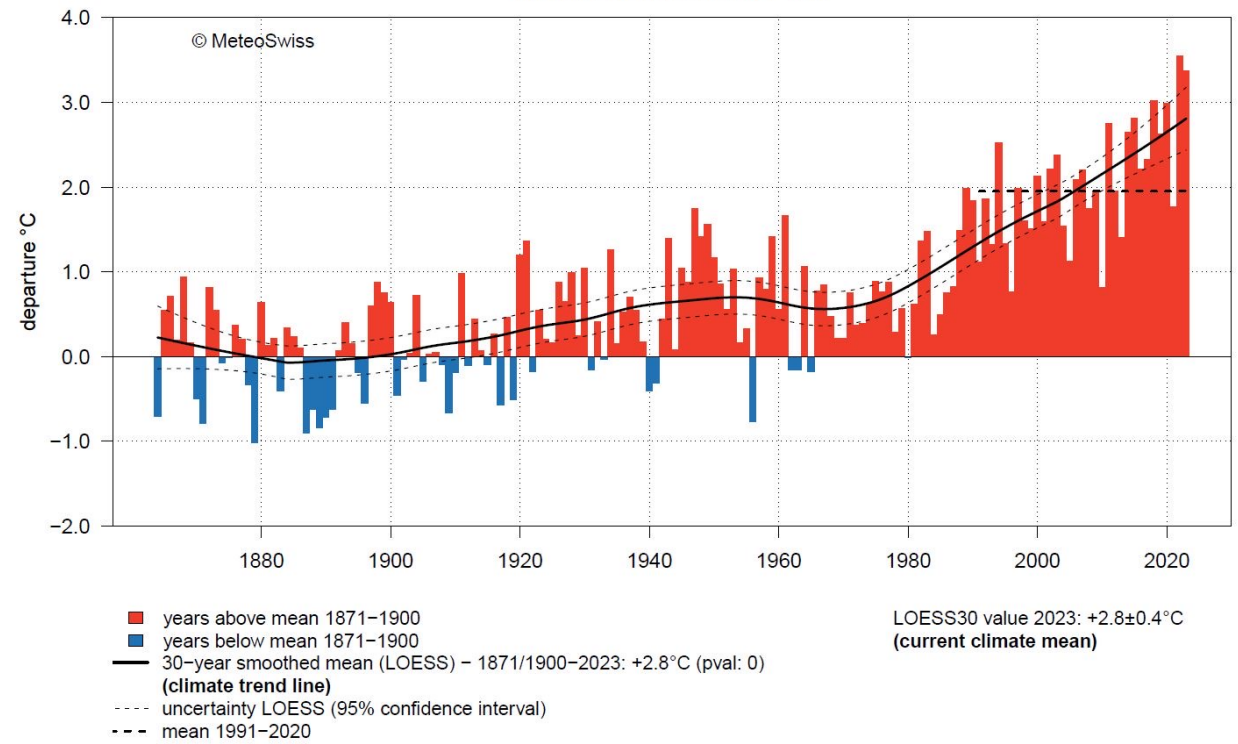
# Warming is about 2x faster in Switzerland

## Changes in global surface temperature relative to 1850–1900

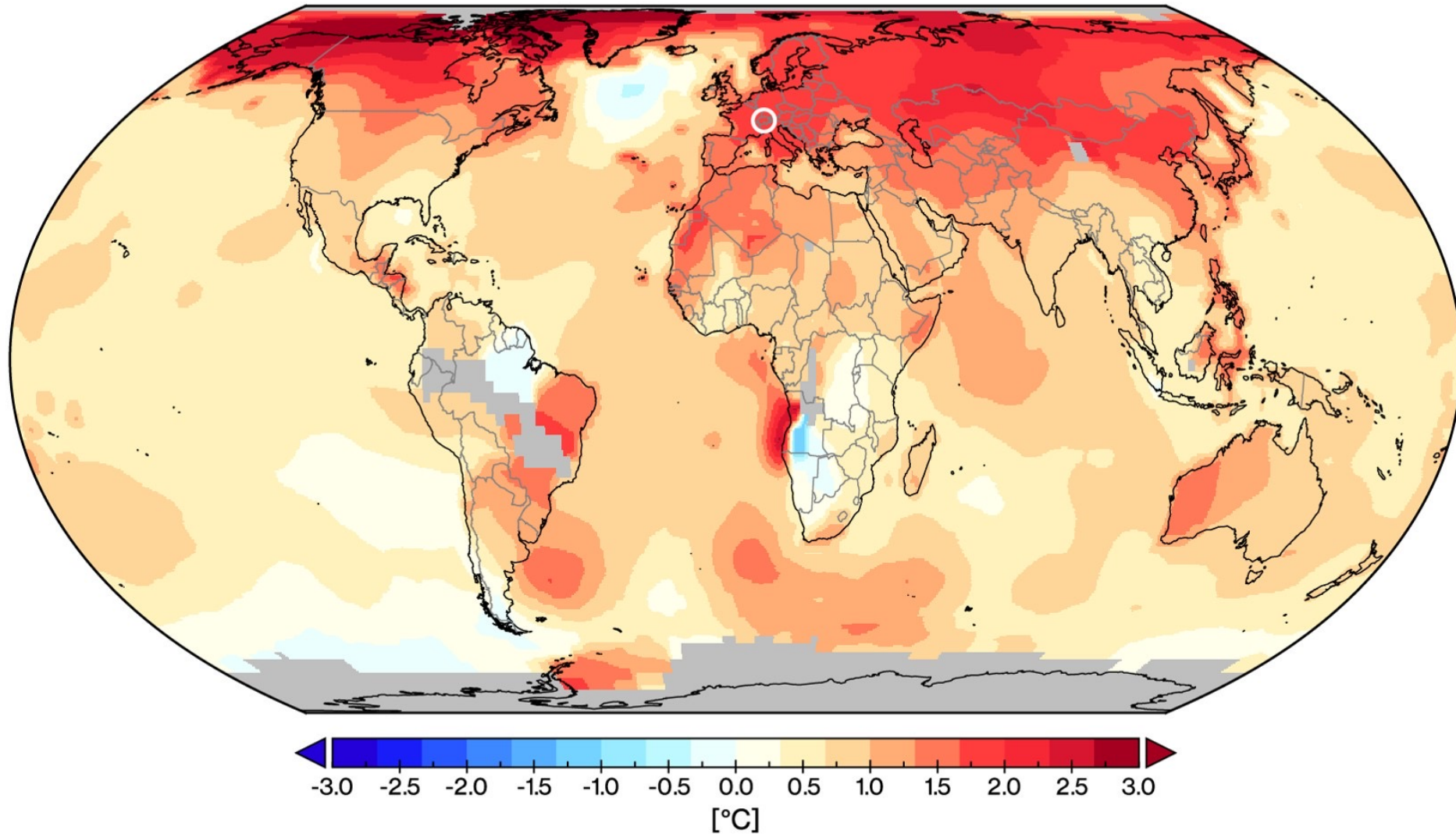
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Annual temperature – Switzerland – 1864–2023  
departure from the mean 1871–1900



Observed warming of the earth. Difference between 30-year mean values from 1881-1910 and 1991-2020. Data: GISTEMP, NASA



# Climate crisis summary

- All scientists agree that human activities and greenhouse gas emissions (primarily CO<sub>2</sub>) are responsible for the current temperature increases
- Climate models agree about the effects, trends, and causes of climate change
- Global average temperatures have risen by 1.2°C compared to the pre-industrial average
- Current atmospheric CO<sub>2</sub> concentrations (>420 ppm) are the highest in 800,000 years
- With current policies, expected warming will be in the range of 2.5-2.9°C (best case), or 3-5°C (worst case)

# Global greenhouse gas emissions and warming scenarios

- Each pathway comes with uncertainty, marked by the shading from low to high emissions under each scenario.
- Warming refers to the expected global temperature rise by 2100, relative to pre-industrial temperatures.

Annual global greenhouse gas emissions  
in gigatonnes of carbon dioxide-equivalents

150 Gt

100 Gt

50 Gt

Greenhouse gas emissions  
up to the present

0

1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100

**No climate policies**

4.1 – 4.8 °C

→ expected emissions in a baseline scenario if countries had not implemented climate reduction policies.

**Current policies**

2.5 – 2.9 °C

→ emissions with current climate policies in place result in warming of 2.5 to 2.9°C by 2100.

**Pledges & targets (2.1 °C)**

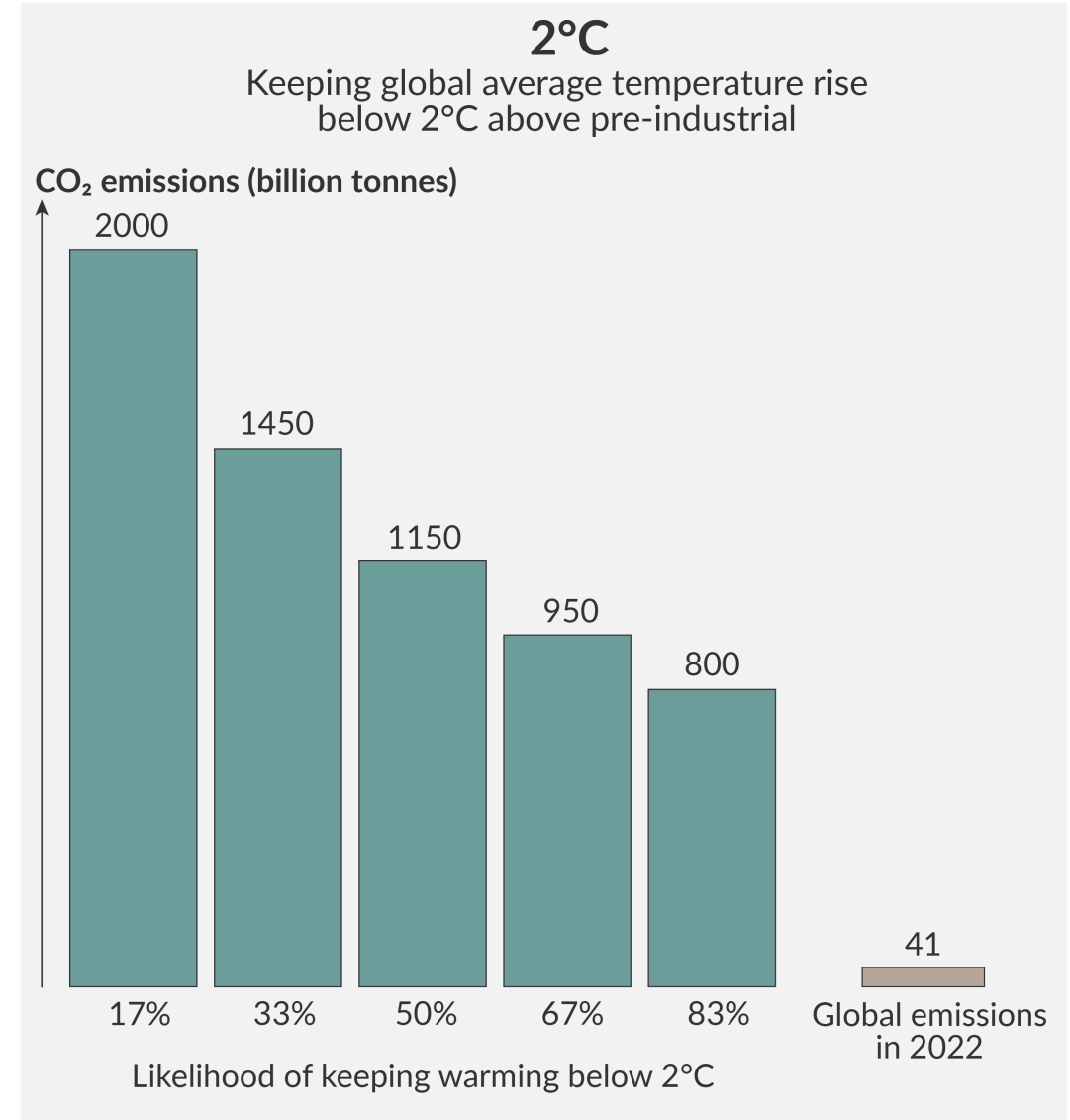
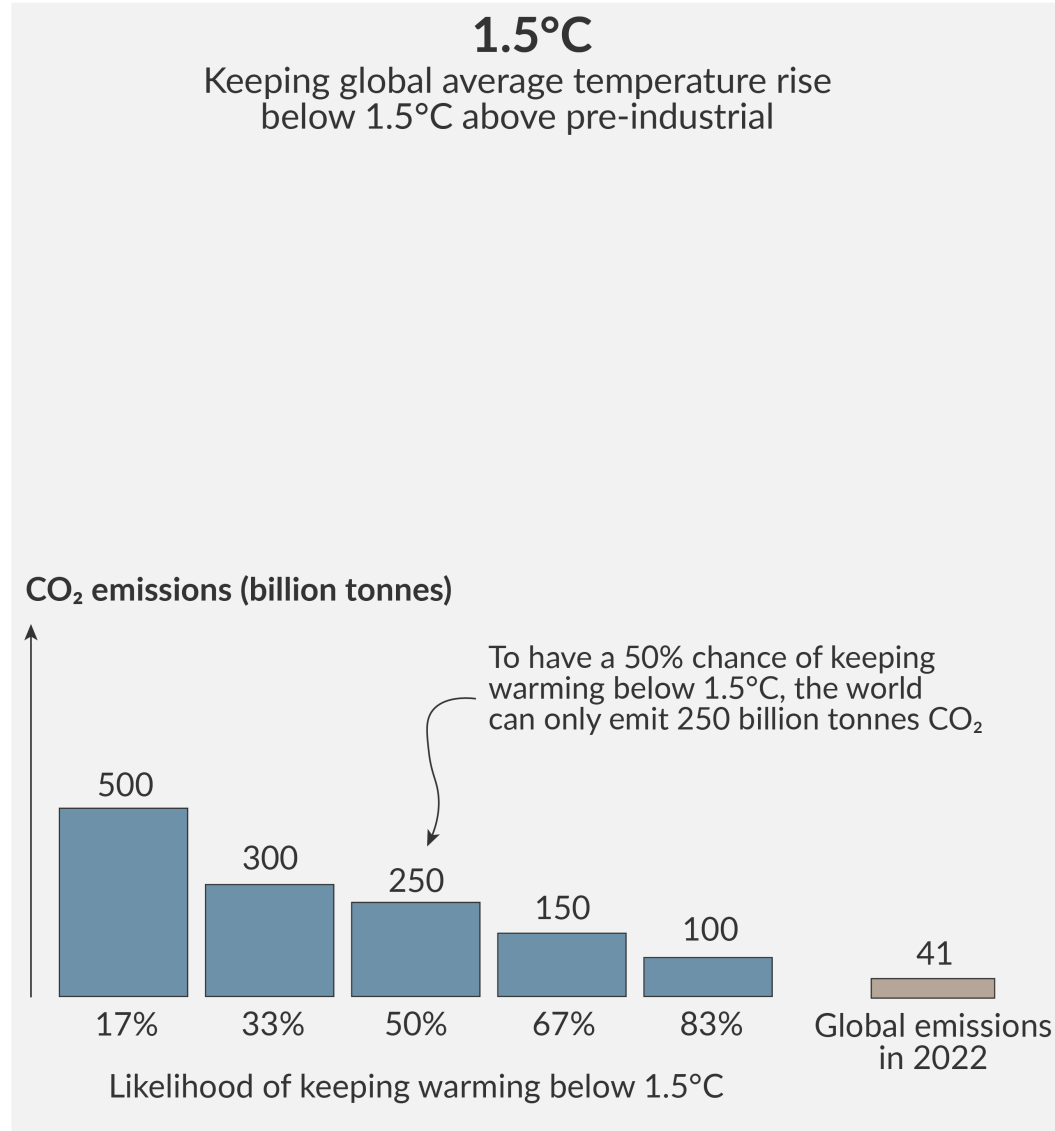
→ emissions if all countries delivered on reduction pledges result in warming of 2.1°C by 2100.

**2°C pathways**

**1.5°C pathways**

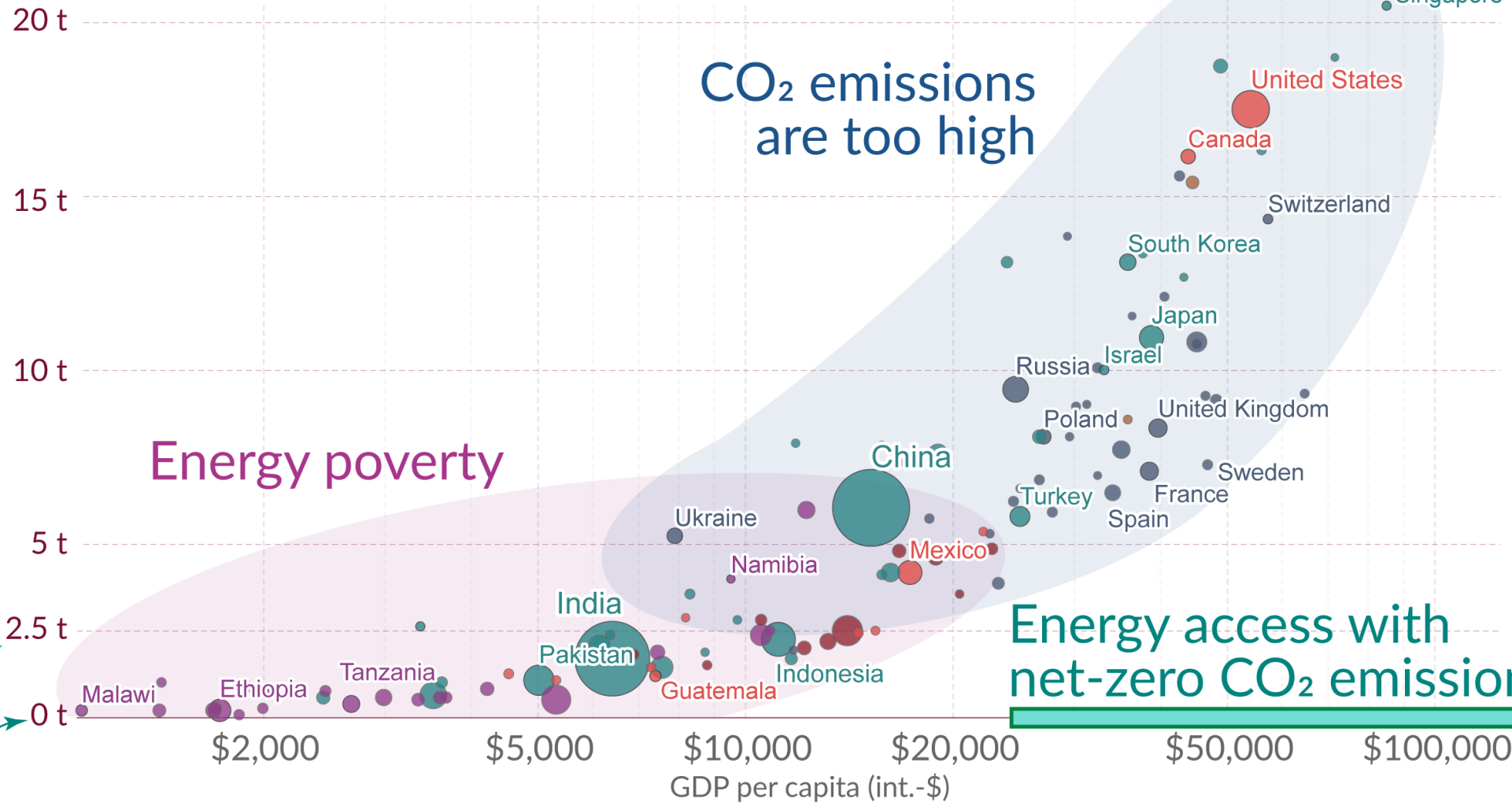
# Carbon budget to keep global warming below 1.5°C and 2°C

How much total CO<sub>2</sub> can be emitted to keep global average temperature rise below 1.5C and 2C, compared to pre-industrial temperatures. This is remaining budget from the start of 2023. Current annual emissions from fossil fuels, industry and land use are shown for context.



# CO<sub>2</sub> emissions per capita vs GDP per capita

Per capita consumption-based CO<sub>2</sub> emissions



To end climate change the long-run goal is that net-emissions decline to zero.  
Bringing emissions down to 2.4 tonnes per person would mean we have halved emissions from their current level (4.8t), a big milestone.

Data: Global Carbon Project, UN Population, and World Bank.

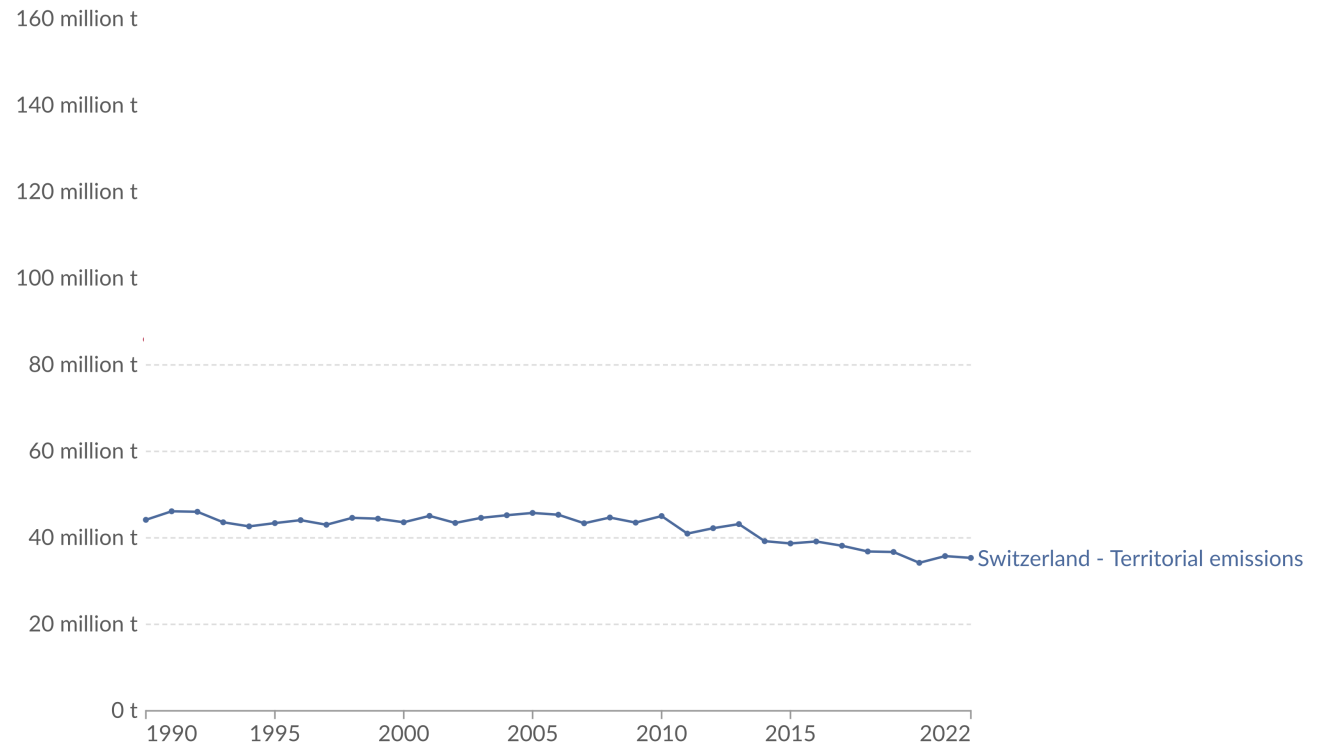
# Swiss CO<sub>2</sub> emissions

- 20% reduction in national CO<sub>2</sub> emissions since 1990

## Territorial and consumption-based CO<sub>2</sub> emissions, Switzerland

Consumption-based emissions<sup>1</sup> include those from fossil fuels and industry<sup>2</sup>. Land-use change emissions are not included.

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Data source: Global Carbon Budget (2023)

OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

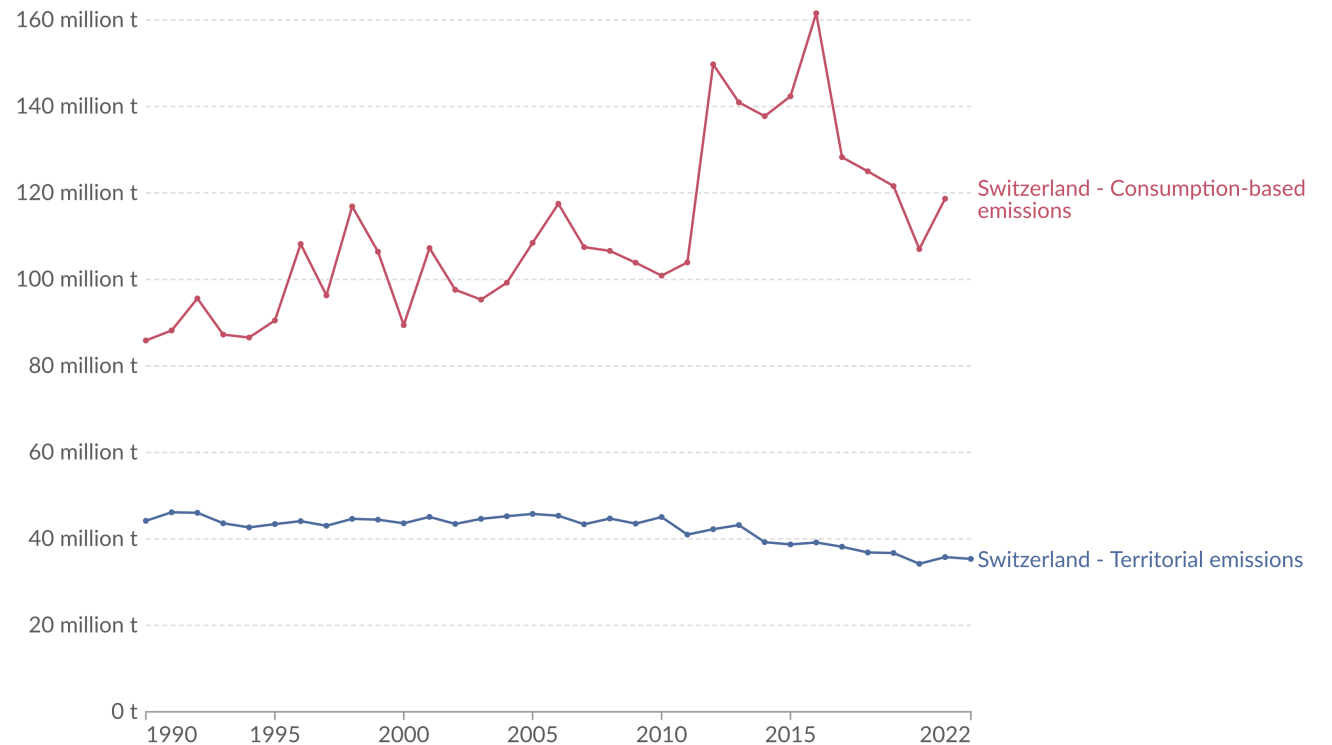
# Swiss CO<sub>2</sub> emissions

- 20% reduction in national CO<sub>2</sub> emissions since 1990
- But there is growth (with variability) in emissions when trade flows are integrated
- “Imported CO<sub>2</sub>” = ~3x CO<sub>2</sub> produced
  - Example: 3x more air transport than the European average

## Territorial and consumption-based CO<sub>2</sub> emissions, Switzerland

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in Data

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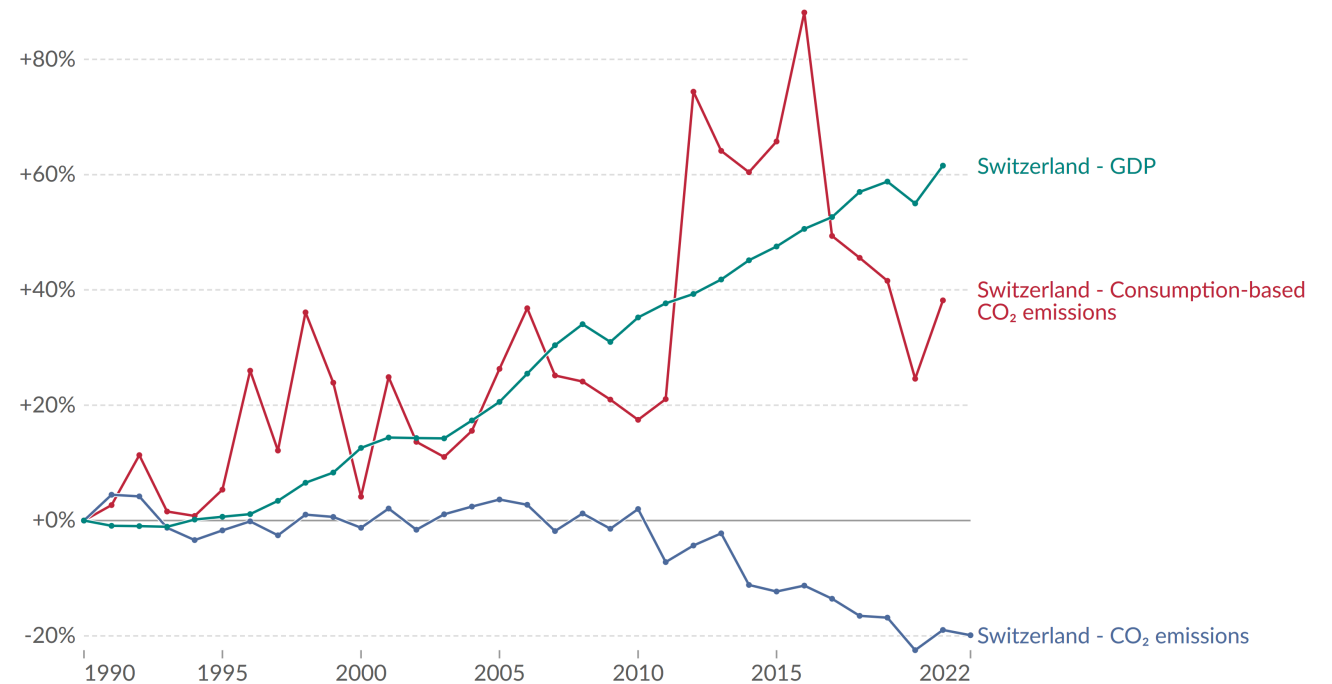
OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

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- But there is growth (with variability) in emissions when trade flows are integrated
- “Imported CO<sub>2</sub>” = ~3x CO<sub>2</sub> produced
  - Example: 3x more air transport than the European average

## Change in CO<sub>2</sub> emissions and GDP, Switzerland

Consumption-based emissions<sup>1</sup> are national emissions that have been adjusted for trade. This measures fossil fuel and industry emissions<sup>2</sup>. Land-use change is not included.



Data source: World Bank (2023); Global Carbon Budget (2023)

Note: Gross Domestic Product (GDP) figures are adjusted for inflation.

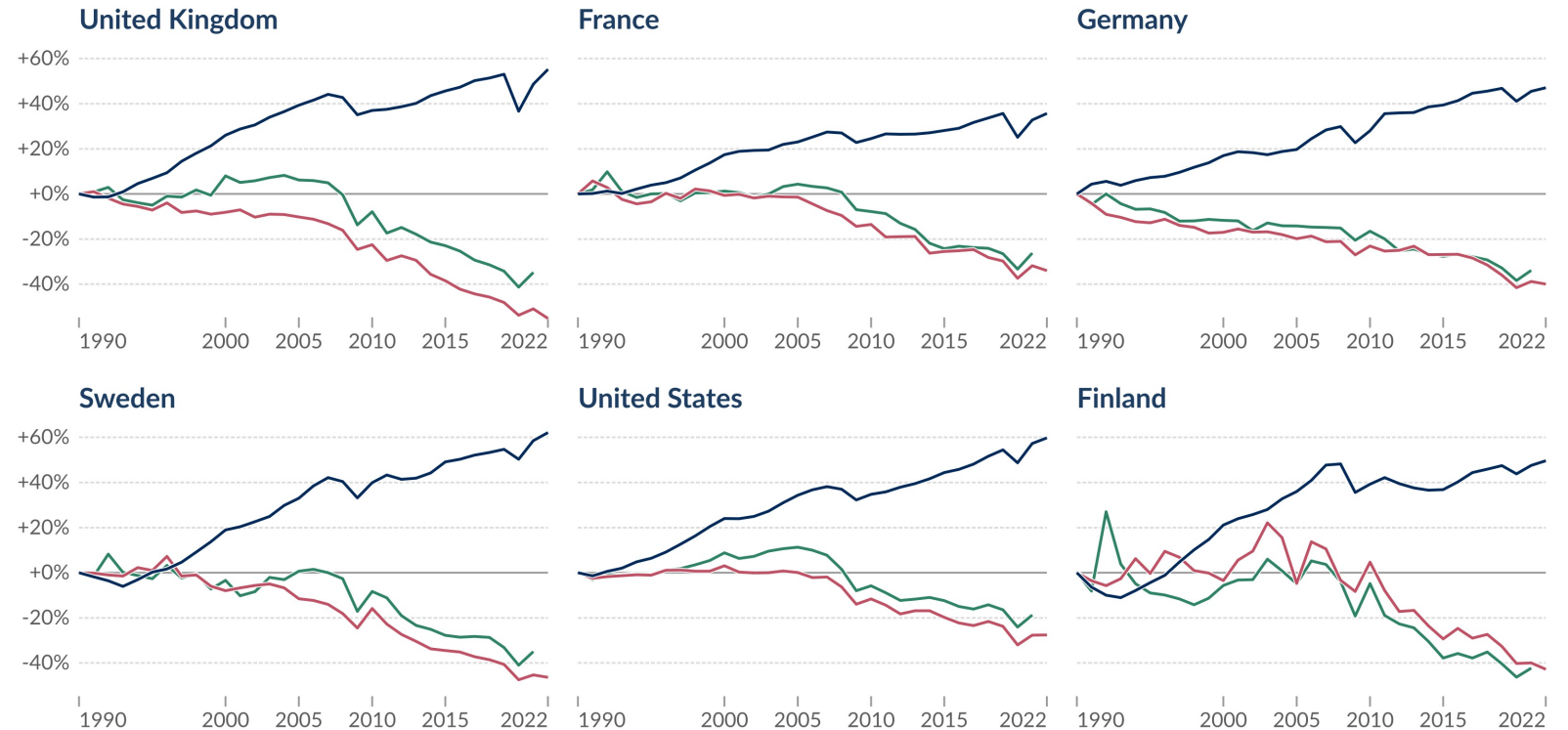
[OurWorldInData.org/co2-and-greenhouse-gas-emissions](https://OurWorldInData.org/co2-and-greenhouse-gas-emissions) | CC BY

## Change in per capita CO<sub>2</sub> emissions and GDP

Consumption-based emissions<sup>1</sup> include those from fossil fuels and industry<sup>2</sup>. Land-use change emissions are not included.

■ GDP per capita ■ CO<sub>2</sub> emissions per capita ■ Consumption-based CO<sub>2</sub> emissions per capita

Some countries  
(not many) have  
been able to  
**decouple**  
economic growth  
from both territorial  
carbon emissions  
and consumption-  
based carbon  
emissions



Data source: World Bank (2023); Global Carbon Budget (2023); Population based on various sources (2023)

Note: GDP figures are adjusted for inflation.

[OurWorldInData.org/co2-and-greenhouse-gas-emissions](https://OurWorldInData.org/co2-and-greenhouse-gas-emissions) | CC BY

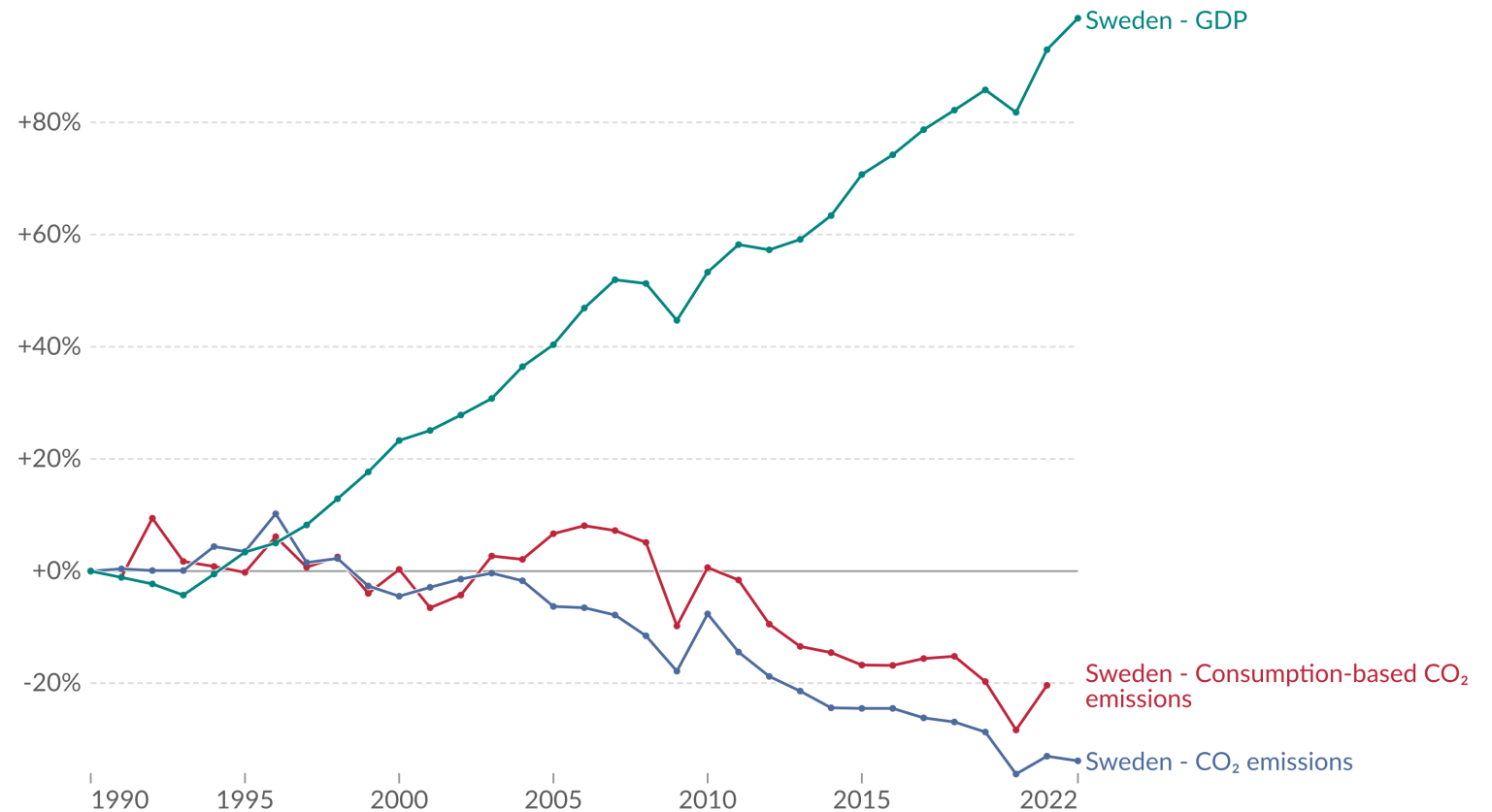


## Some elements from Sweden

- Growing carbon tax since 1991
- Increasing renewables production
- Improving energy efficiency
- Promoting sustainable transportation
- Encouraging sustainable production and consumption

## Change in CO<sub>2</sub> emissions and GDP, Sweden

Consumption-based emissions<sup>1</sup> are national emissions that have been adjusted for trade. This measures fossil fuel and industry emissions<sup>2</sup>. Land-use change is not included.



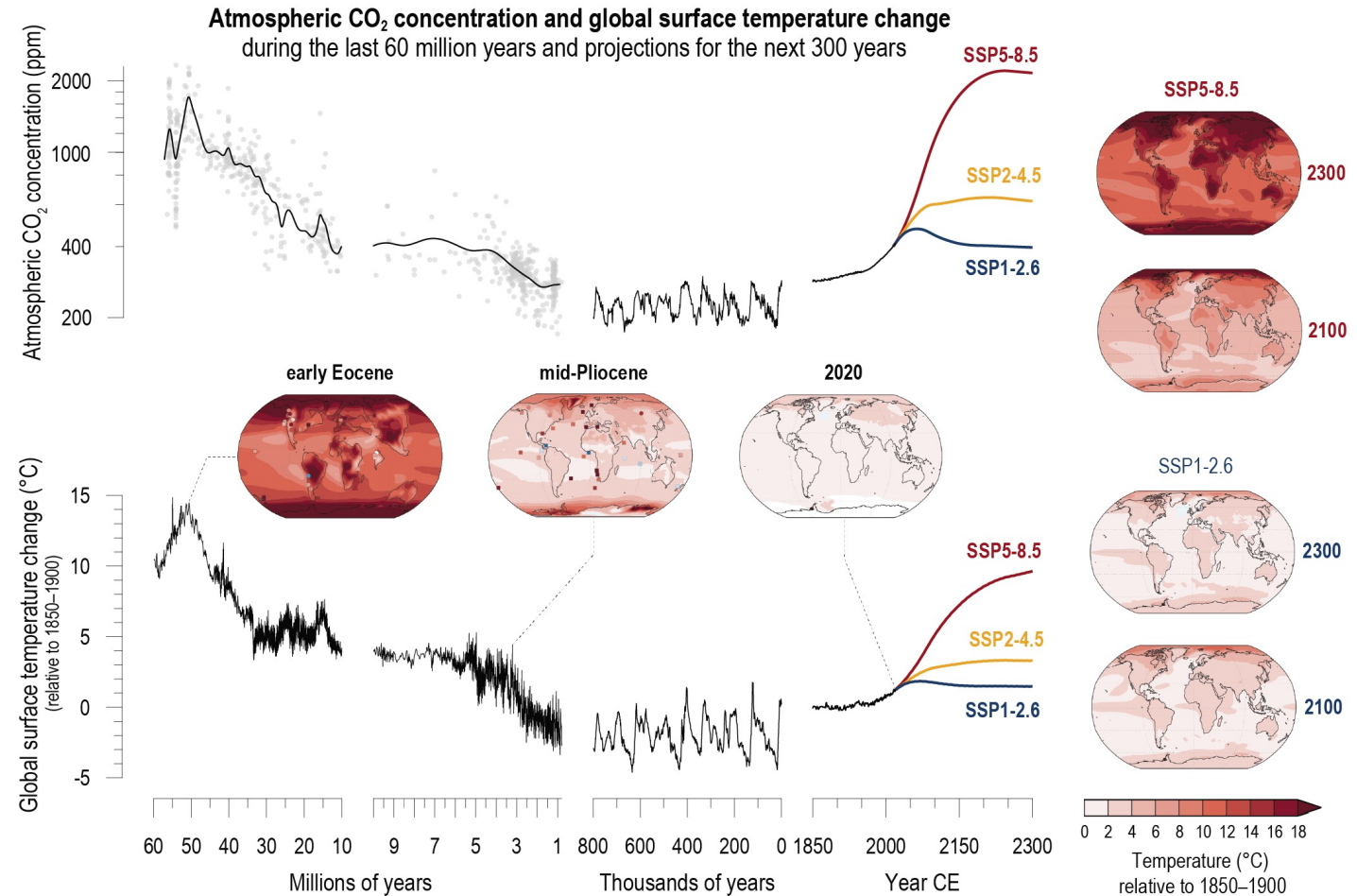
Data source: World Bank (2023); Global Carbon Budget (2023)

OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

Note: Gross Domestic Product (GDP) figures are adjusted for inflation.

# Is it a problem?

- Let's take a 60-million-year perspective compared to future scenarios
- Middle scenario: climate of the mid Pliocene (~3-5 million years ago)
- High scenario: climate of the early Eocene (~50 million years ago)



Ok, so the earth is warming, but 2° doesn't sound like very much!

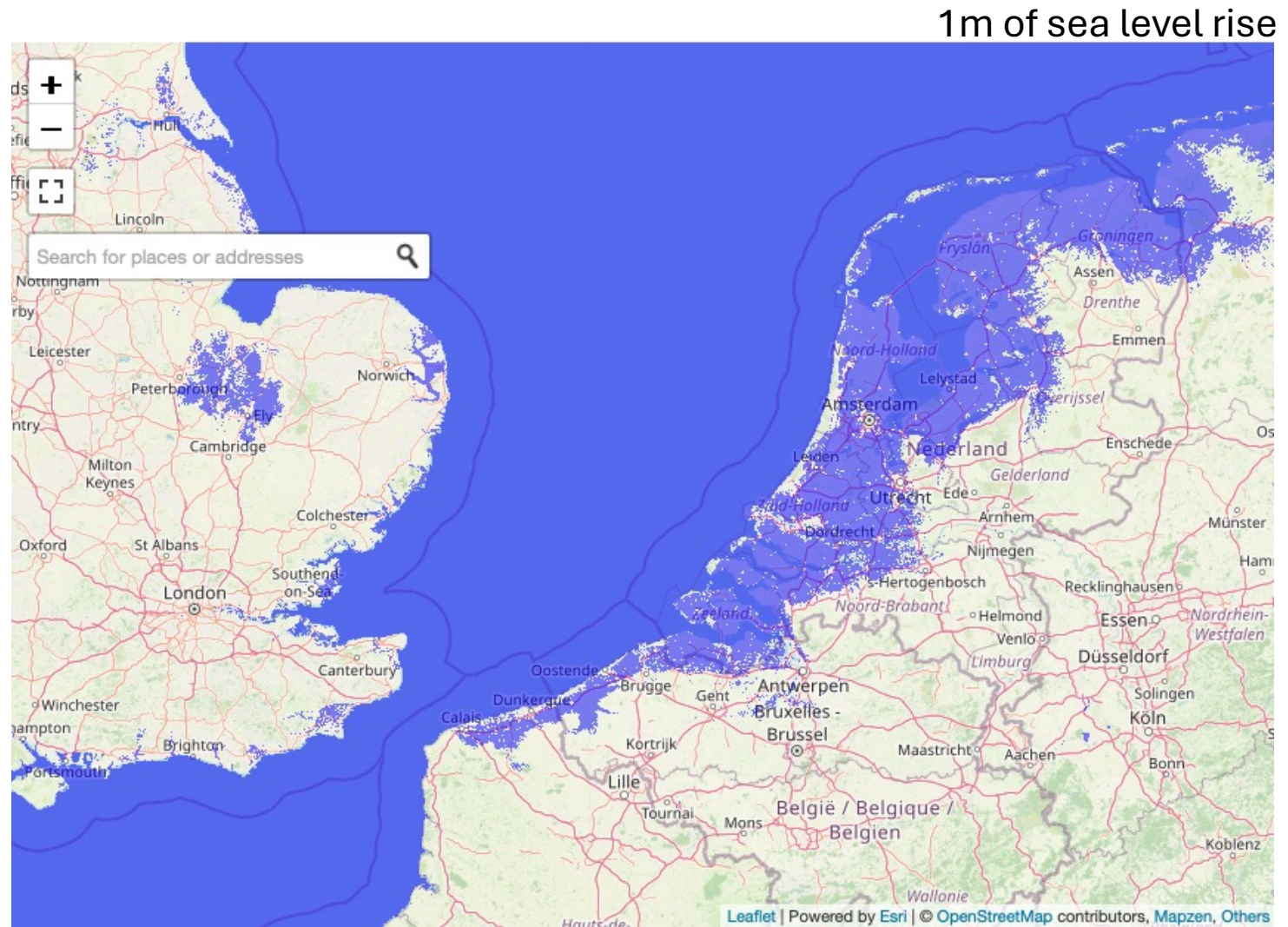


# Impacts from climate change

- Sea level rise and coastal erosion
- Extreme weather
  - Heat waves
  - Fires
  - Storms
  - Droughts
- Agricultural impacts
- Loss of biodiversity
- Local pollution
- It is affecting the planet and the people
- Global warming, **climate change**, or **climate crisis**?

# Sea level rise

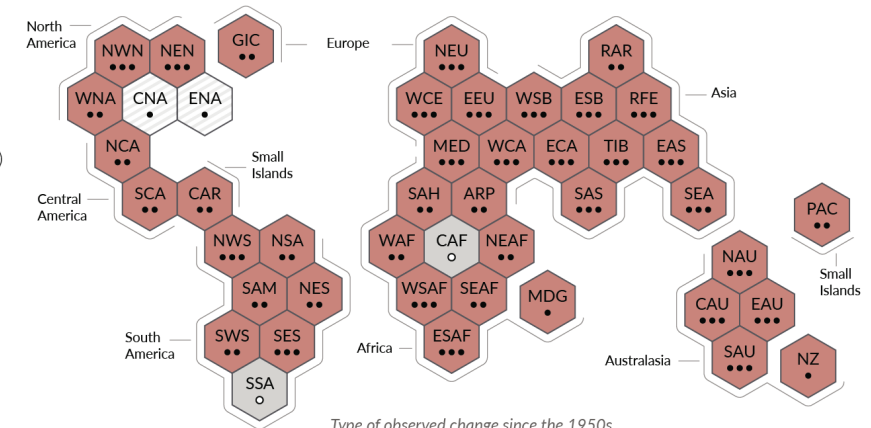
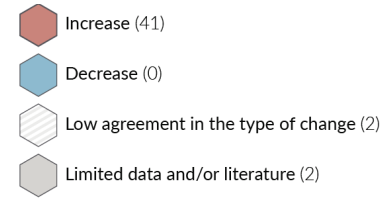
- Due to melting ice on land and expanding water
- Even more impactful with storm surges
- IPCC estimates 0.29-0.59m for a low emissions scenario, 0.61-1.10m for a high emissions scenario



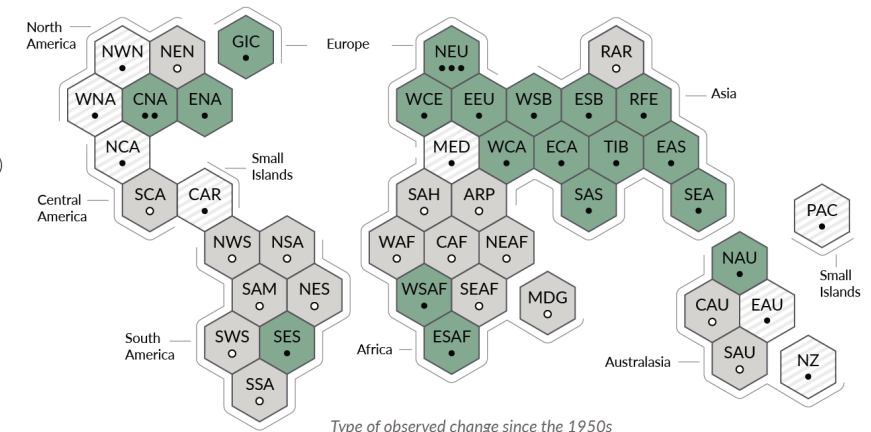
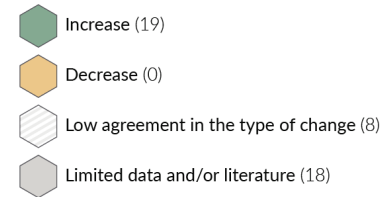
# Acute weather impacts

- The frequency and strength of heat waves, extreme (acute) rainstorms, and droughts are all increasing

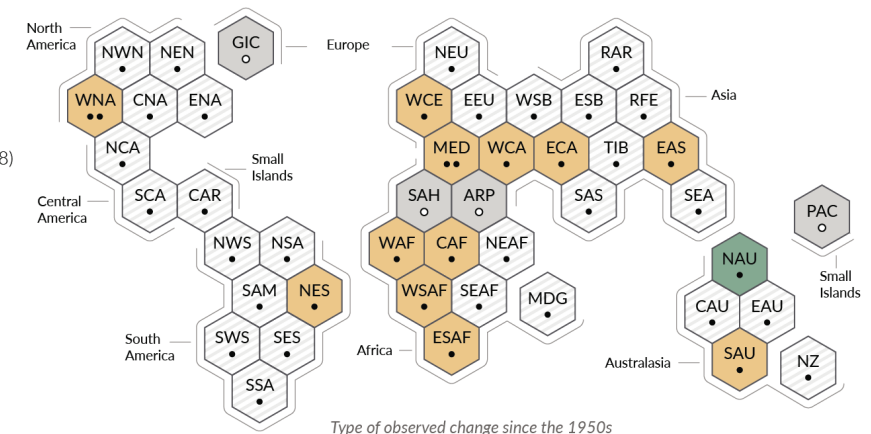
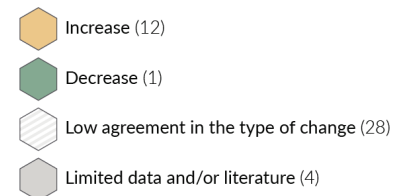
## Extreme heat



## Extreme rain

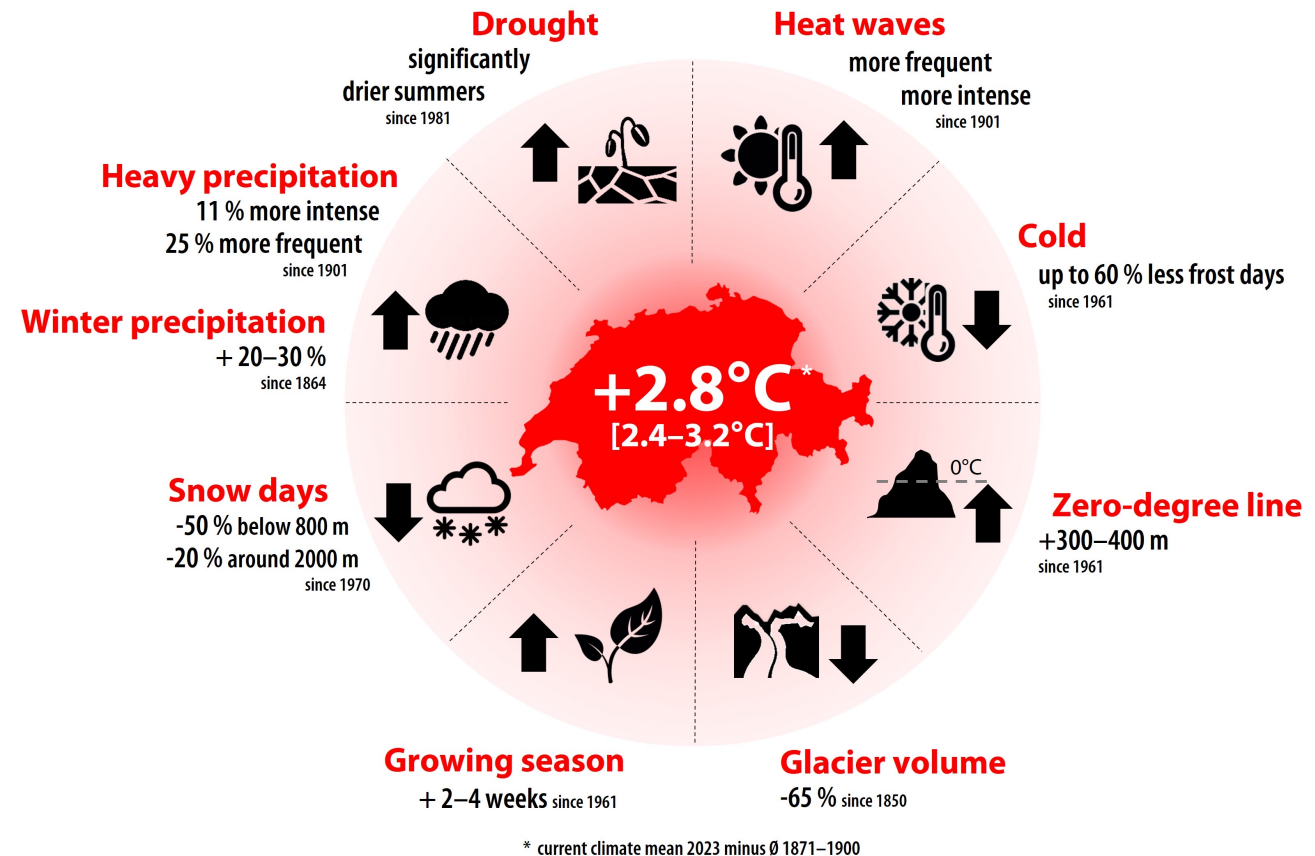


## Drought



# Impacts from climate change in Switzerland

- Some very specific impacts in alpine regions



# A summary of CO2 emission mitigation strategies

- Switching to renewable energies – a huge number of solar panels, wind turbines, and batteries are required
- Reducing energy demand – e.g., in buildings, transportation
- Electrification – shifting away from fossil fuels in heating and transportation
- Less emissions from agriculture – especially eating less meat
- Carbon capture and storage? – lots of debate here
- **For first assignment: explore [En-ROADS Climate Solutions Simulator](#) from MIT**



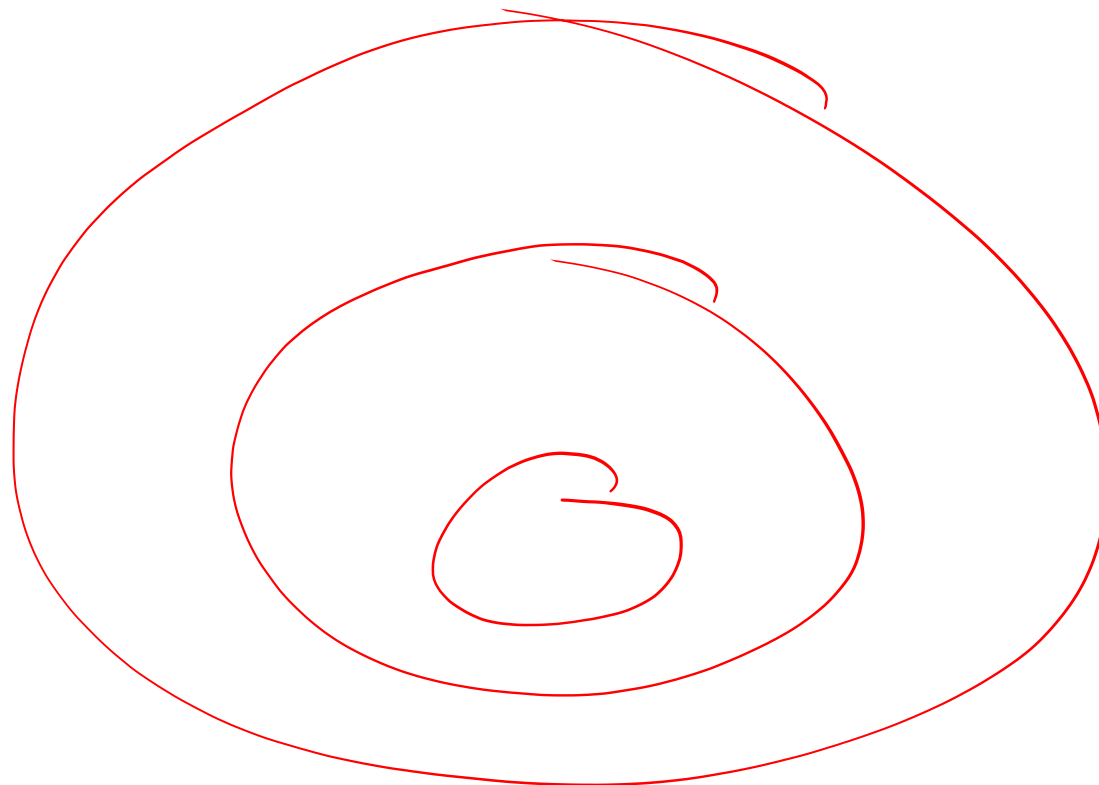
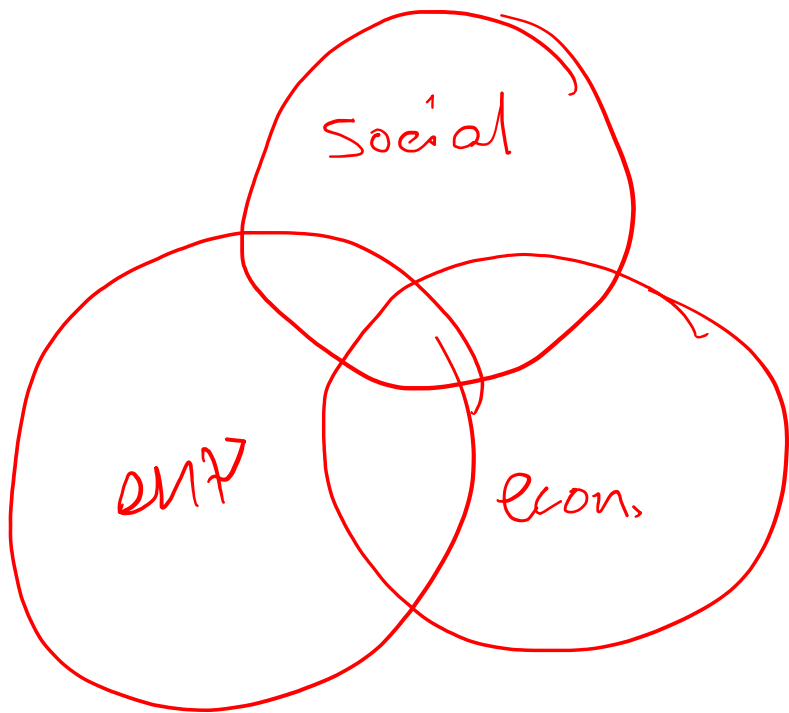
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## What is **sustainability**?

- We have seen the stark realities of human activity on the climate
- How can we conceptualize solving the problem?
- How do we consider the various systems at play?
  - Earth and environment
  - Human society and our well-being

# How do you define sustainability?

- Break into small groups of 2-3
  - Discuss the question: “what is the definition of sustainability”
  - Write down your definition
  - Be prepared to share back with the class
- Take inspiration from ENV-101 last year, as well as other knowledge you may have
- I will post summary slides of definitions to know after class on Moodle



# Early definition of sustainability

- The World Commission on Environment and Development, now known as the **Brundtland Commission**, was founded as a sub-organization of the United Nations in 1983 and published an influential report in 1987
  - **“Sustainable development is development**
  - **that meets the needs of the present**
  - **without compromising the ability**
  - **of future generations to meet their own needs”**



Gro Harlem Brundtland,  
first head of the commission

# Weak and strong sustainability

- Weak sustainability

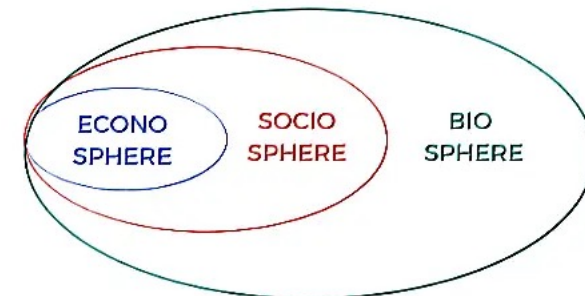
- Claims that human and manufactured capital can replace natural capital
- If we degrade the natural environment, we can make up for lost capital through technological innovation
- Based on the work of Robert Solow, MIT economist and Nobel Prize winner, who argued that sustainability does not require saving specific natural resources



- Strong sustainability:

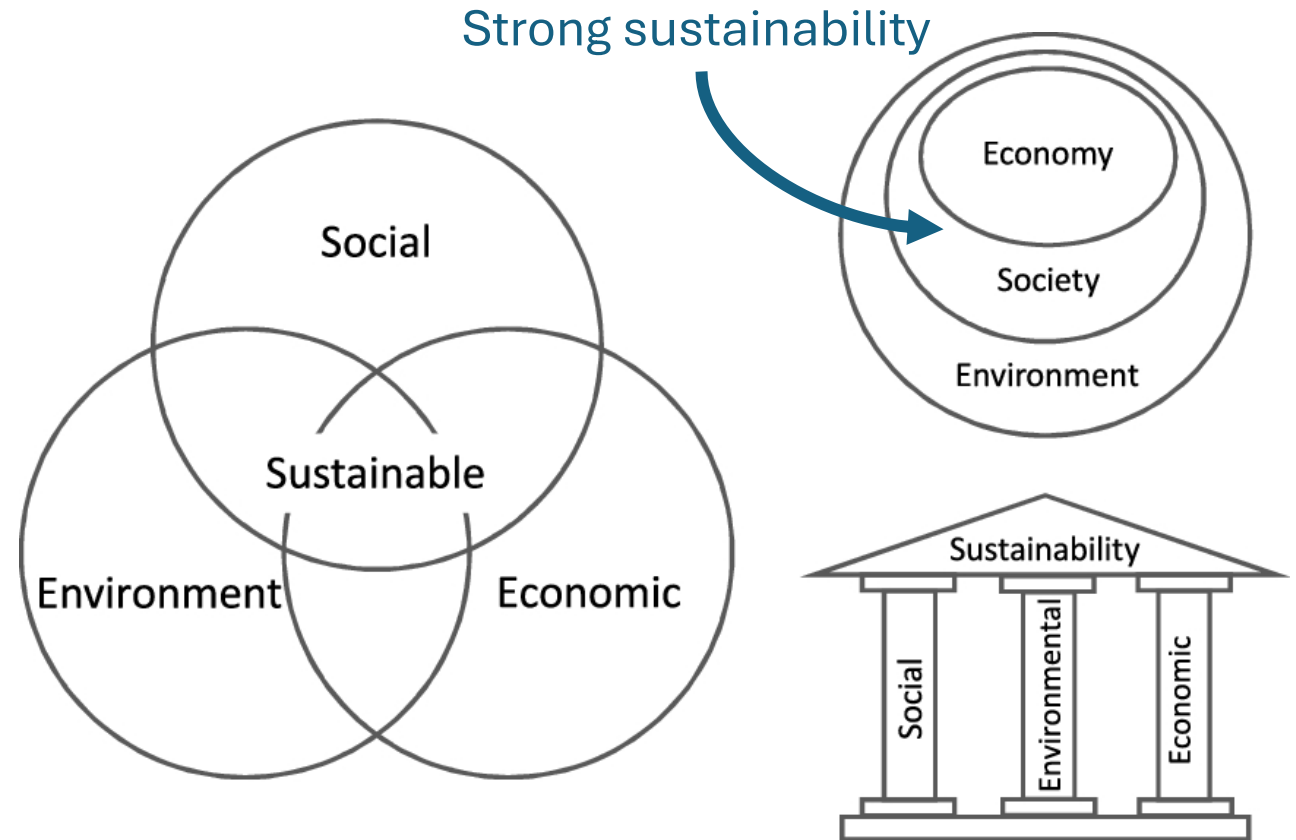
- Claims that human and manufactured capital are not interchangeable with natural capital
- Destruction of natural capital cannot be reversed
- We derive human/manufactured capital from natural capital
- It is critical to preserve our natural resources

STRONG SUSTAINABILITY



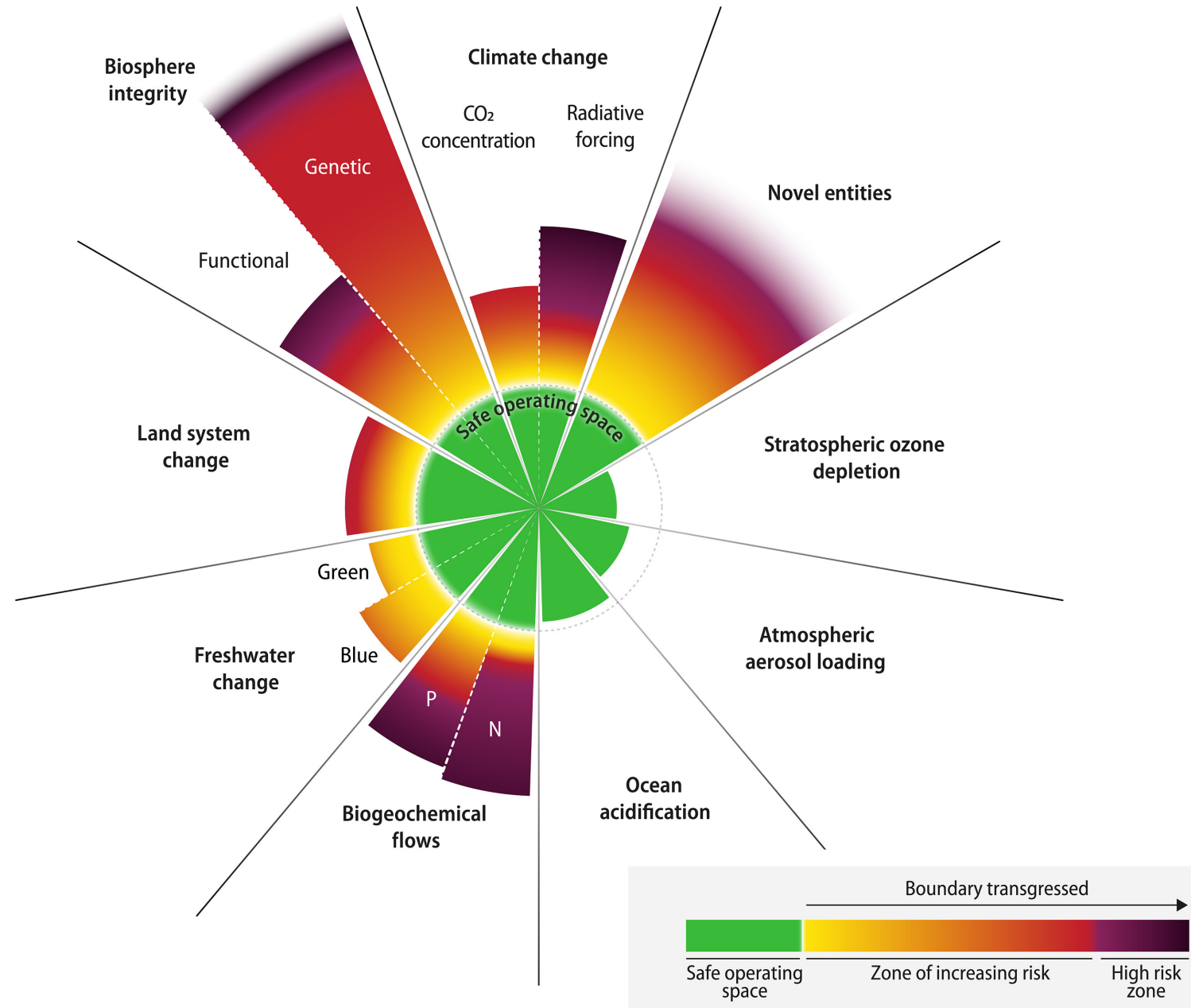
# The three-pillar conception of sustainability

- Three pillars:
  - Environment
  - Social
  - Economic
- Ubiquitous definition of “sustainability,” though the origin has been difficult to identify precisely



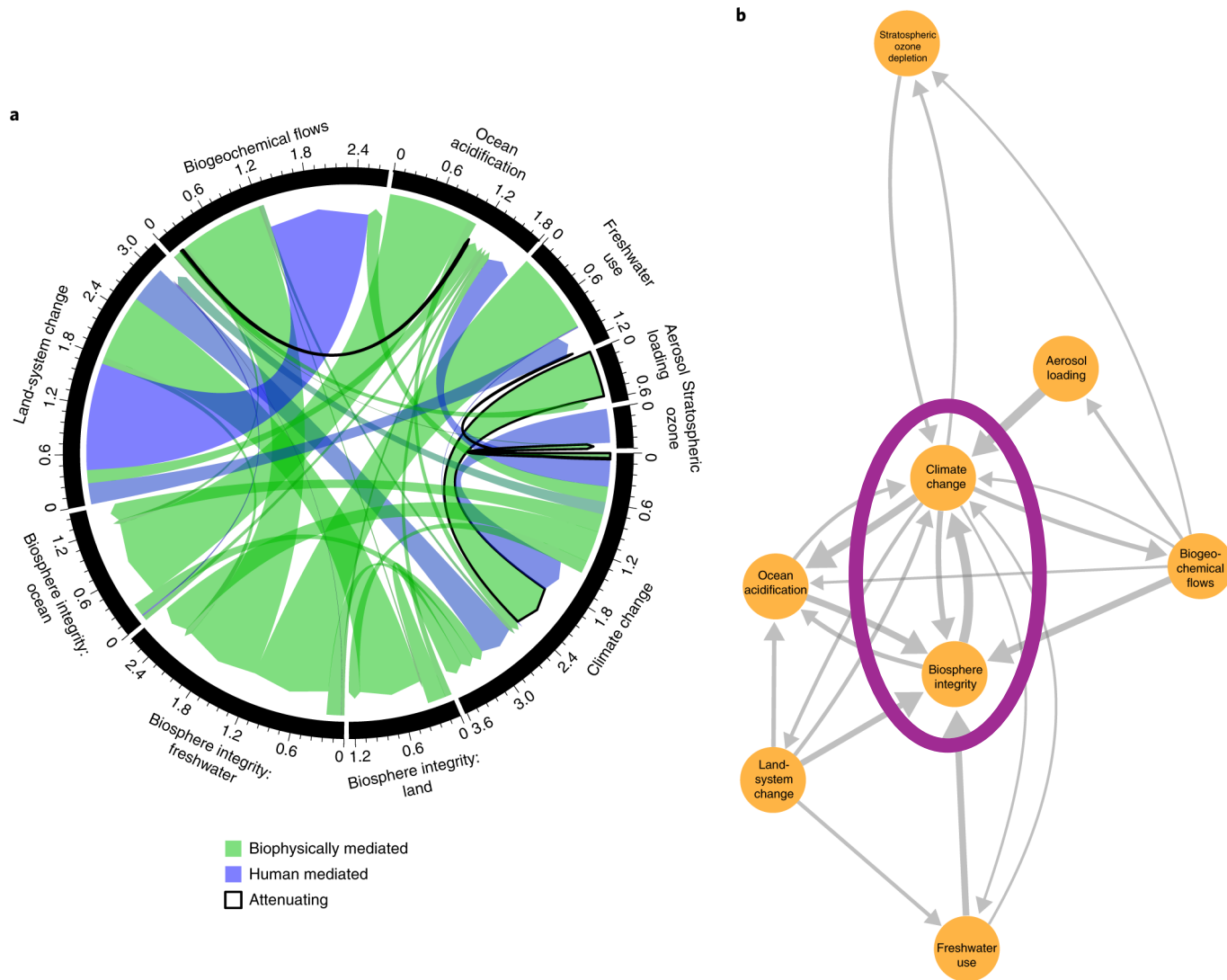
# The Planetary Boundaries

- The framework identifies nine processes that are critical for maintaining the stability and resilience of Earth system as a whole
- All are presently heavily perturbed by human activities
- 2023 update: We have transgressed 6 of 9.



# Planetary boundary interactions

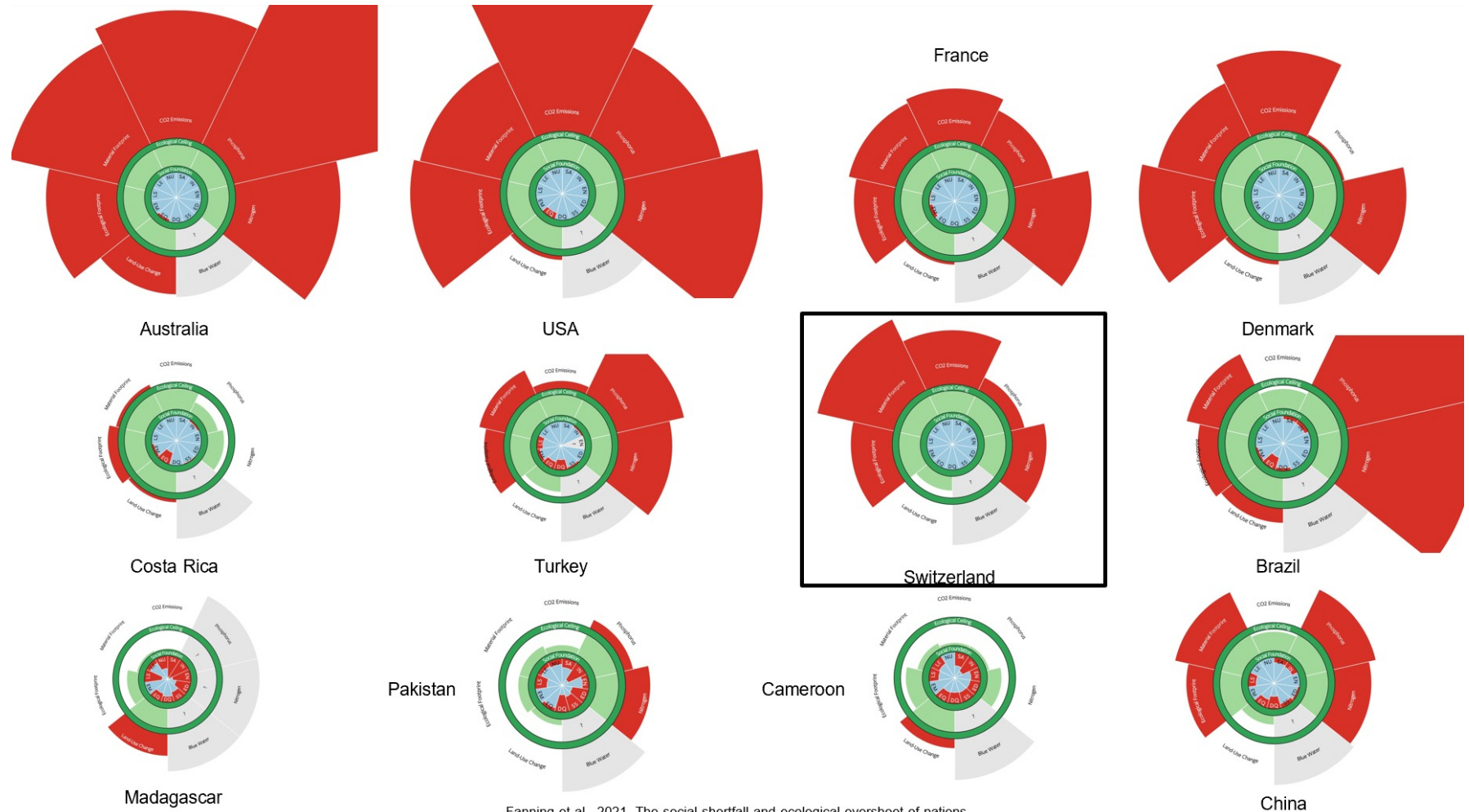
- Planetary boundaries can impact each other
- Climate change and Biosphere integrity are central





# The Doughnut Model

- Current status of different countries



Fanning et al., 2021. The social shortfall and ecological overshoot of nations

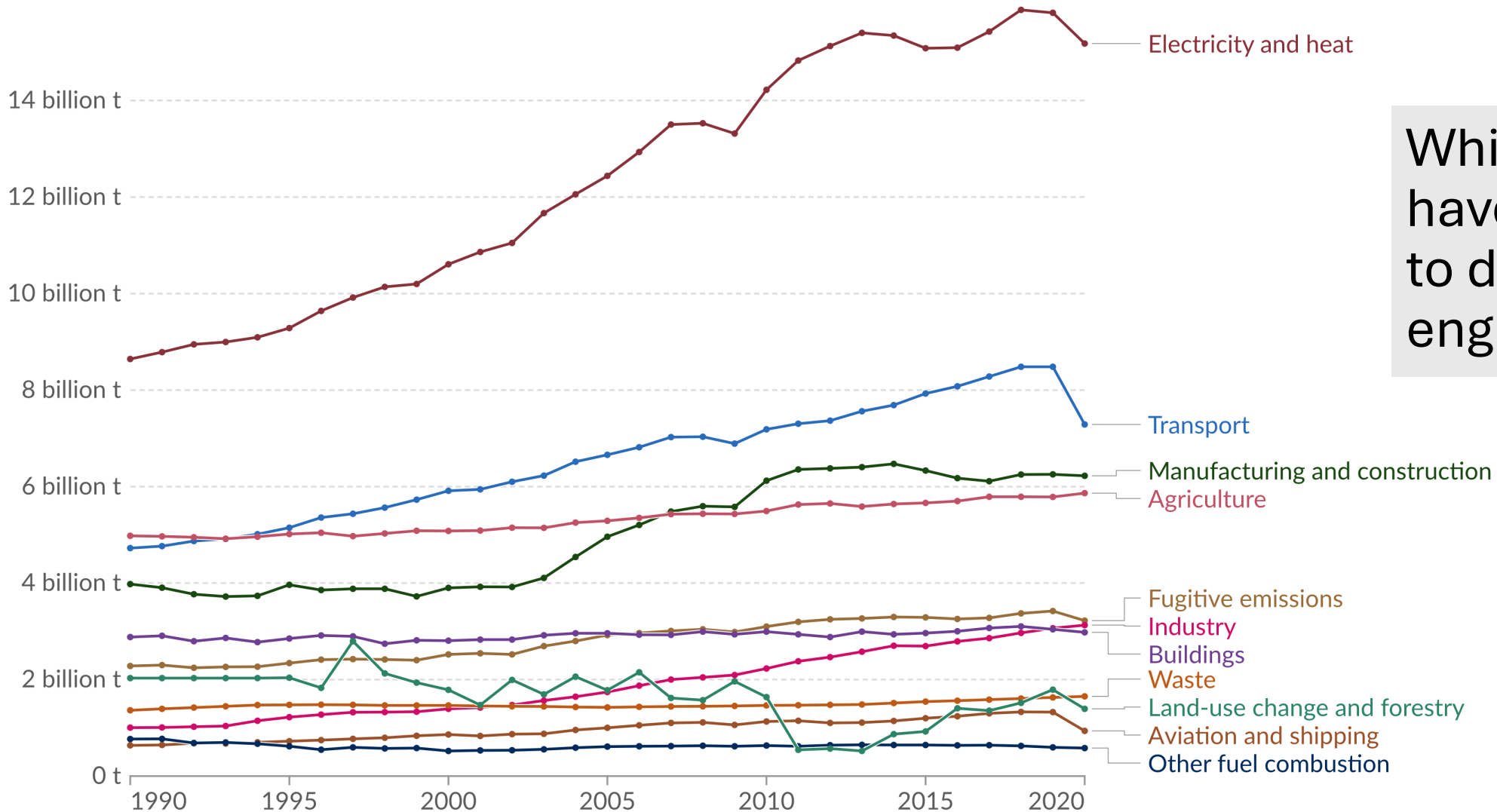
# SUSTAINABLE DEVELOPMENT GOALS



# Sustainability in civil engineering

# Greenhouse gas emissions by sector, World

Greenhouse gas emissions<sup>1</sup> are measured in tonnes of carbon dioxide-equivalents<sup>2</sup> over a 100-year timescale.



Which of these  
have something  
to do with civil  
engineering?

Data source: Climate Watch (2023)

OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

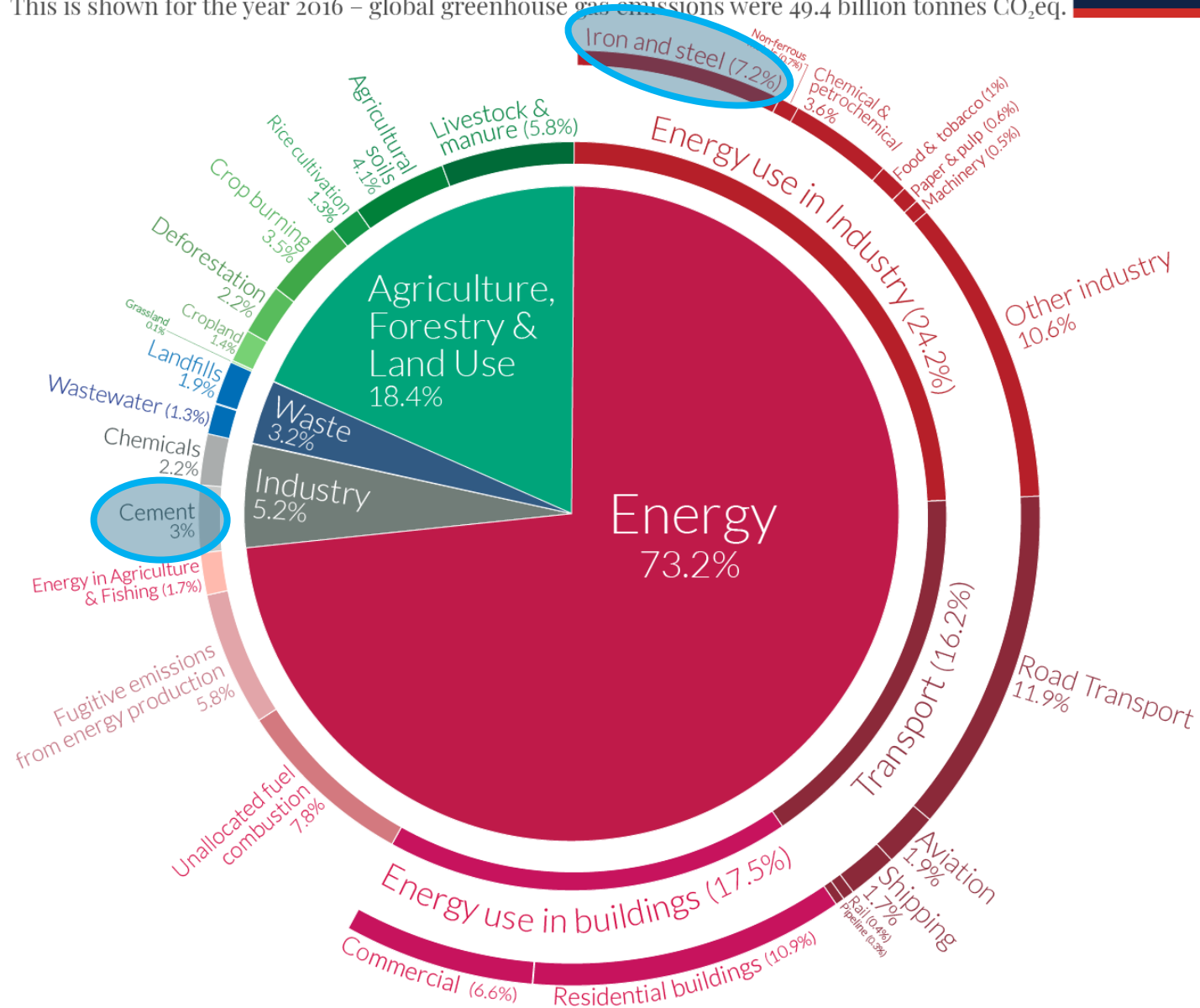
Note: Land-use change emissions can be negative.

# Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO<sub>2</sub>eq.

Another way to visualize  
(but note data is from 2015)

- Direct CO<sub>2</sub> emissions from electricity production ~40% of total
- Cement and steel production



# UN Sustainable Development Goals (SDGs)

## SUSTAINABLE DEVELOPMENT GOALS



Directly related  
to civil  
engineering

# Overview of the topics in this course



Part 1 – Course introduction, the climate crisis, setting the scene



Part 2 – Buildings, energy demand, and energy supply



Part 3 – Mobility and sustainability



Part 4 – Materials, structures, and life-cycle assessment



Part 5 – Natural systems and natural capital



Part 6 – Sustainability in practice (guest lecture from industry)

# What do you expect to learn in this course?

- Email your class delegates by the end of the week: Friday, September 12
  - Answer the question: What do I expect to learn in CIVIL-239 – Engineering a sustainable built environment?
- Class delegates: send me a detailed summary by Tuesday, September 16
- I will address the comments next week in class