

# Climate change and fossil fuels

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# Explaining the climate change

- „How could scientists predict the climate in 100 years when they cannot predict the weather tomorrow?“
- Weather: short time situation (minutes to weeks).
- Climate: atmospheric conditions over a long period of time (years to centuries).
- Consequences for prediction – climate undergoes more gradual change (than weather) and is easier to predict.

# 1) The planet's temperature is rising

- Over the past 130 years the global average temperature has increased by  $0,8^{\circ}\text{C}$  (more than half of that in last 35 years).
- Ancient ice samples (from Antarctica and other places) – their layers are dated and gas bubbles inside are analysed.
  - $\text{CO}_2$  concentration is measured by infrared spectroscopy or mass spectrometry.
  - Isotope ratios of water molecules are measured to determine historical temperatures ( $^{16}\text{O}$  and  $^{18}\text{O}$ ).



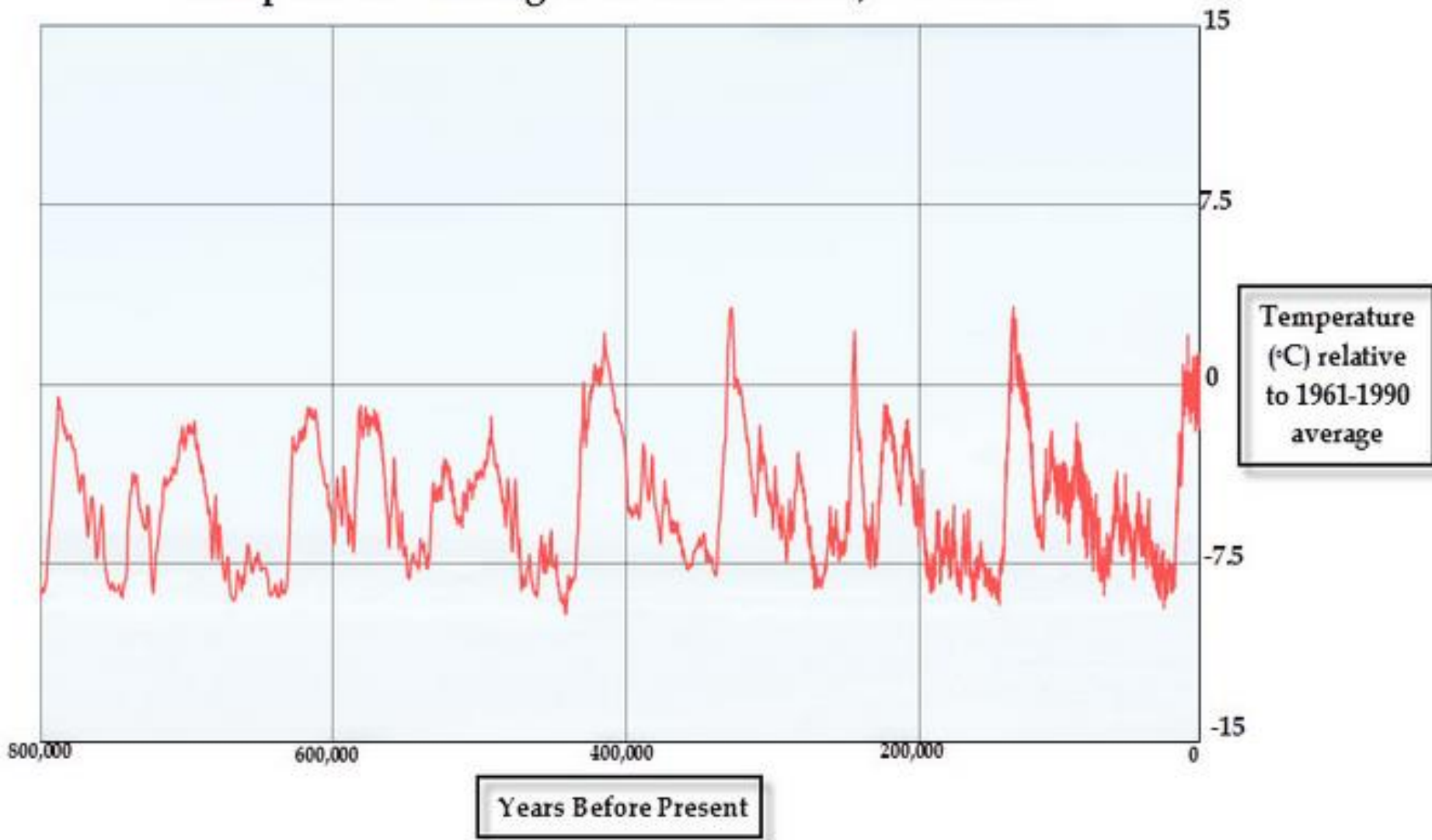




# The planet's temperature is rising

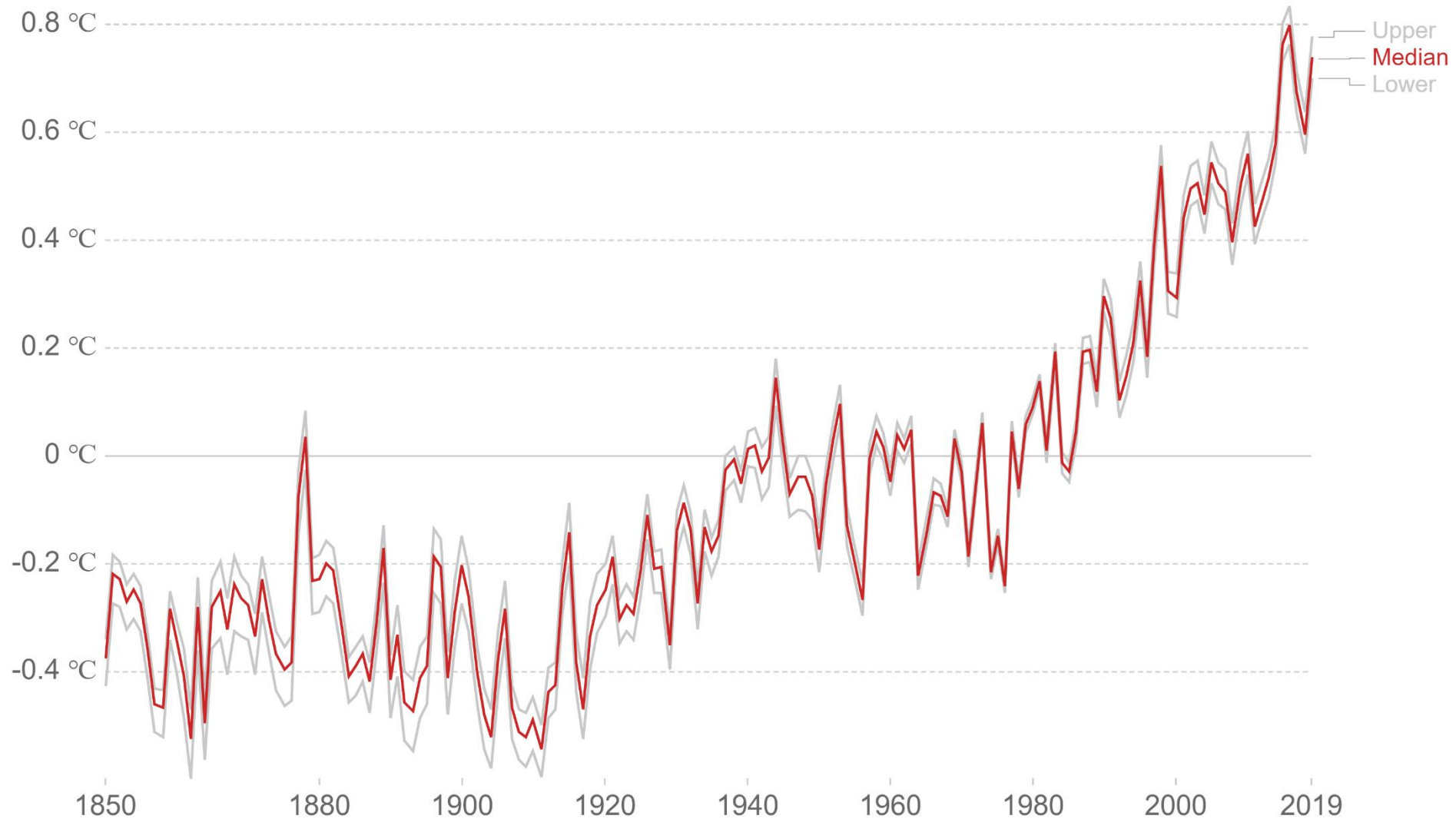
- Earth's climate has always fluctuated. The cooler period – ice ages or glacial periods, the warmer period – interglacial periods.
  - Orbital variations (Milankovitch cycles).
  - Solar output.
  - Volcanic activity.
  - Plate tectonics.
  - And some others.
- The rate of change has become more dramatic since the Industrial Revolution = anthropogenic origins.
  - Problems with adaptation – the change is too fast.

# Temperature Changes in the Past 800,000 Years



# Average temperature anomaly, Global

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



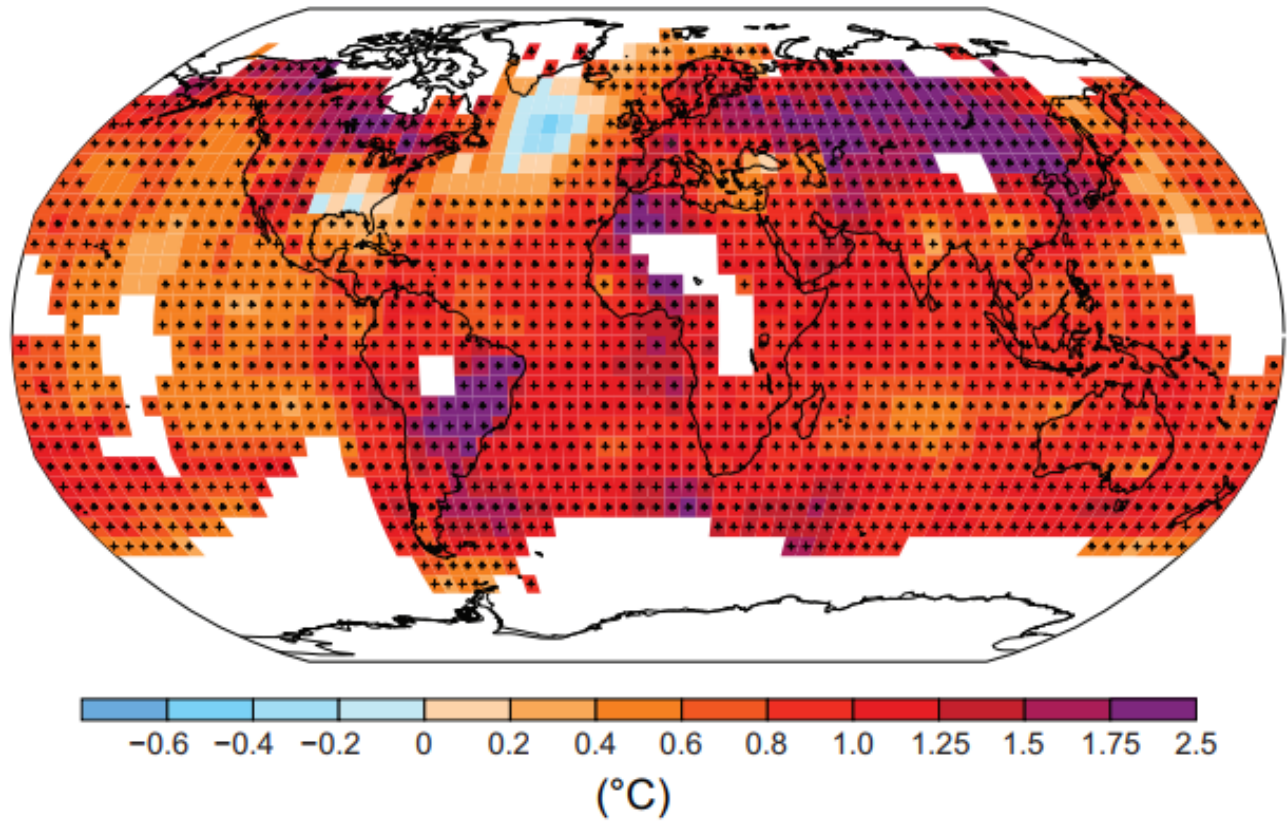
Source: Hadley Centre (HadCRUT4)

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

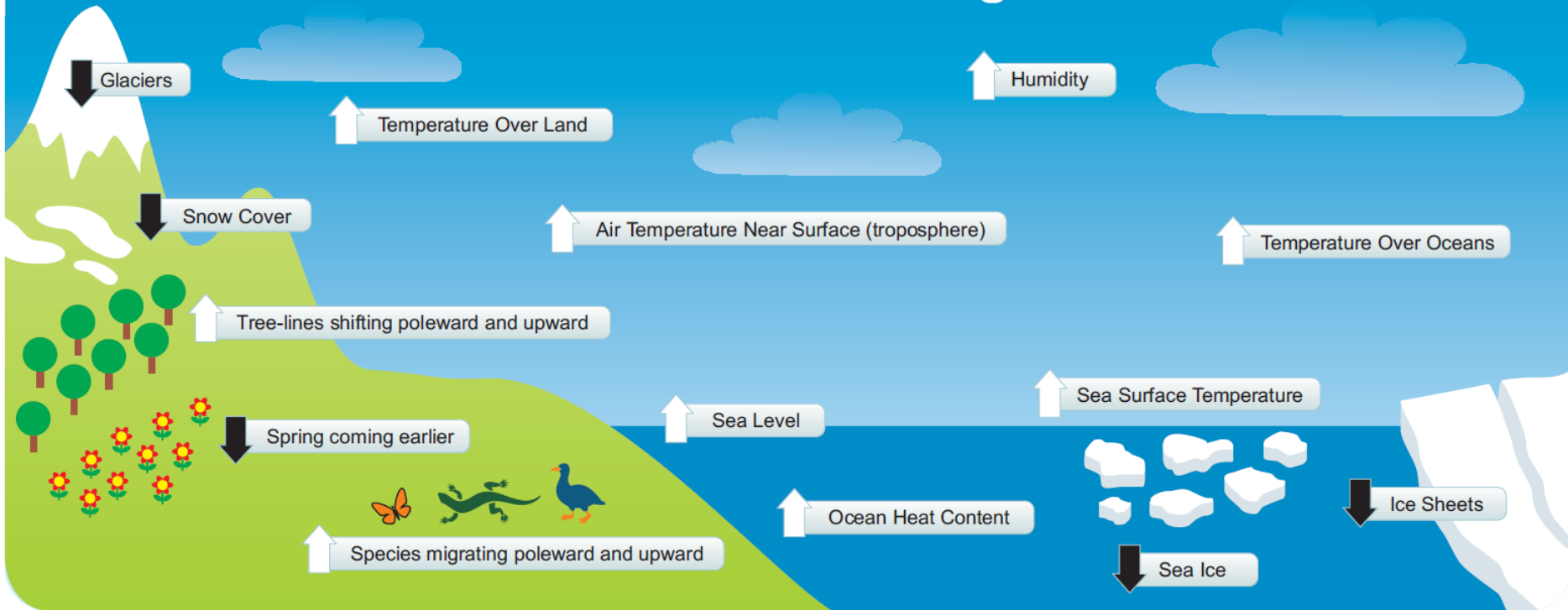
Note: The red line represents the median average temperature change, and grey lines represent the upper and lower 95% confidence intervals.



# Observed change in surface temperature 1901 - 2012



# Indicators of a Warming World



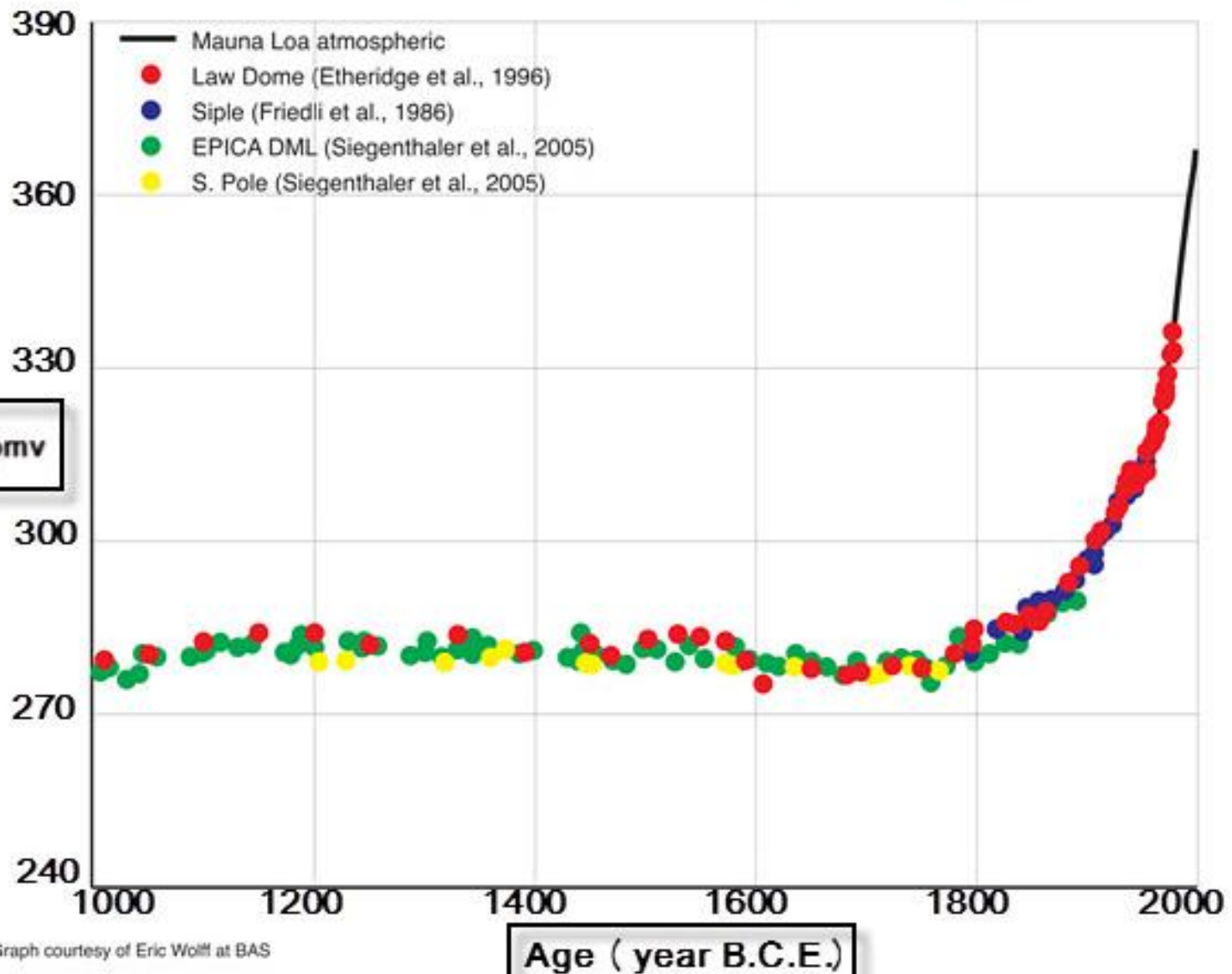
Parmesan & Yohe 2003<sup>32</sup>, NOAA<sup>34</sup>

## 2) CO<sub>2</sub> level is increasing (also methane and nitrous oxide)

- CO<sub>2</sub> concentration increased by 40% since pre-industrial time. The ocean absorbed about 30% of this increase, causing ocean acidification.
- Also methane (150% increase) and nitrous oxide (20%).

# Rates of Change in the Past 250 Years

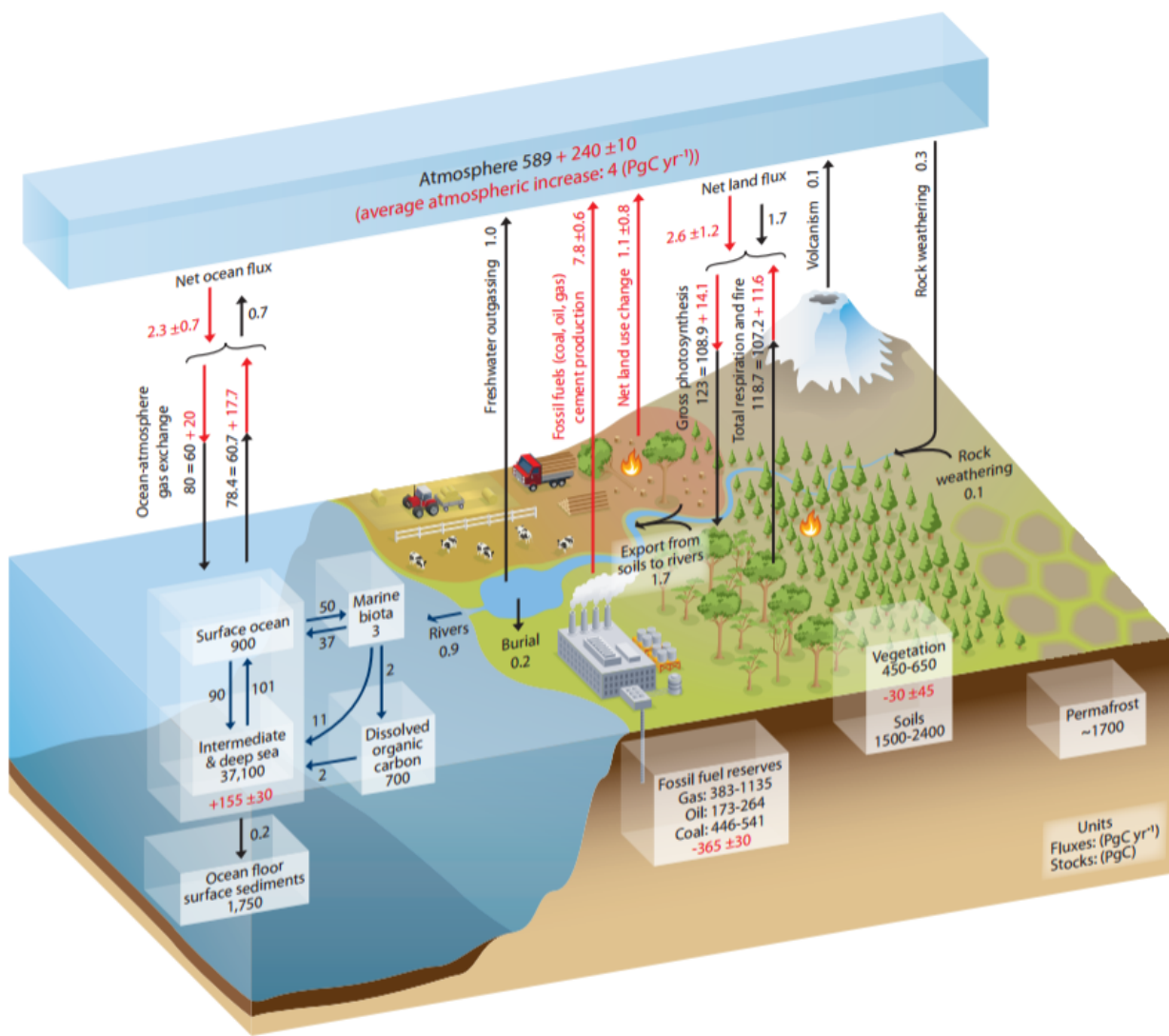
## CO<sub>2</sub> Concentrations in the Past 1000 Years



### 3) We are responsible for the increase in CO<sub>2</sub>

- Human CO<sub>2</sub> emissions (20 billion tons/y) are small compared to natural emission (776 billion tons/y).
- But natural absorptions (788 billion tons/y) roughly balance natural emissions.
- Carbon 12 isotope to carbon 13 isotope ratio increases.





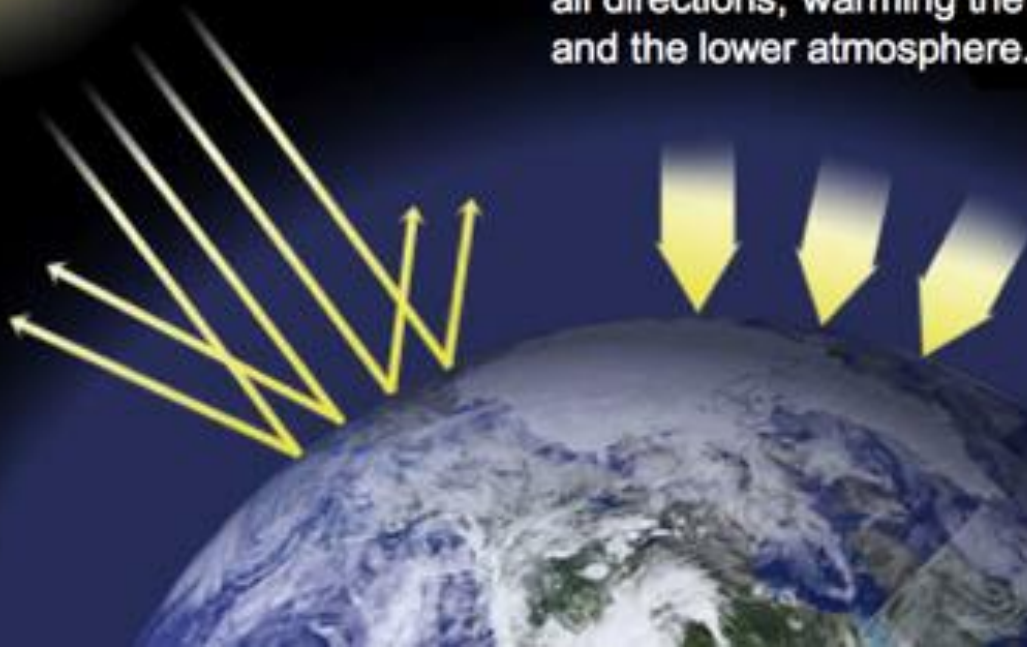
Global carbon cycle. Numbers represent reservoir mass (carbon stocks) and annual carbon exchange fluxes. Black numbers and arrows indicate reservoir mass and exchange fluxes estimated for the time prior to the Industrial Era (about 1750). Red indicate annual anthropogenic fluxes averaged over the 2000-2009.

## 4) Increased CO<sub>2</sub> is the primary driver of greenhouse effect

- Inbound solar radiation has short wavelengths and high energy contents. This radiation passes through the atmosphere. Some energy is absorbed by the ground (warming it up). Some energy is reflected back to the space.
- That reflected radiation has lower energy levels and longer wavelengths. 80% of the outgoing radiation is trapped in the lower troposphere.
- Energy trapped in the troposphere warms the surface.
- More GHGs in the atmosphere trap more outbound solar radiation, thus warming the planet – anthropogenic climate change.

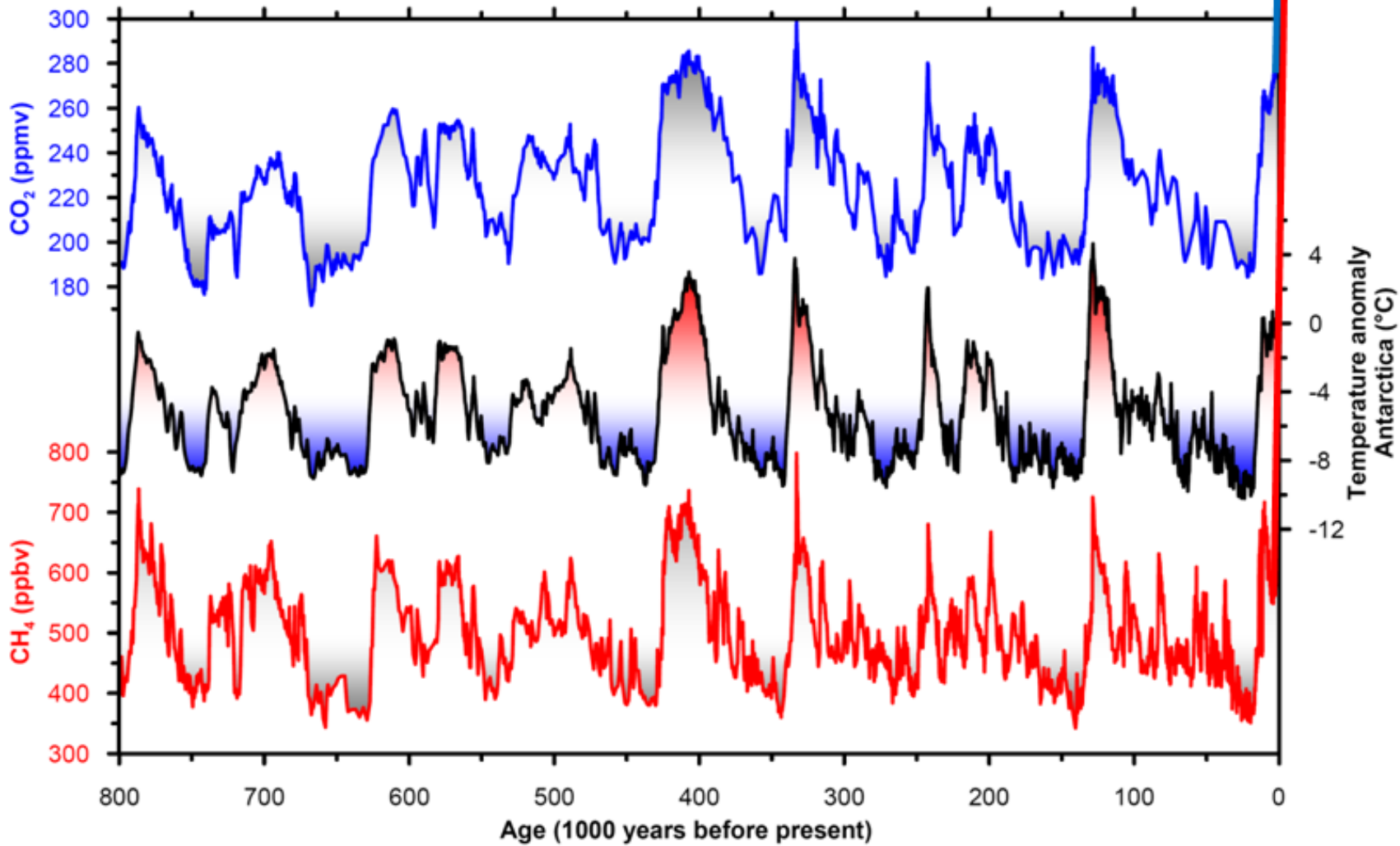
Sunlight passes through the atmosphere and warms the Earth's surface. This heat is radiated back toward space.

Most of the outgoing heat is absorbed by greenhouse gas molecules and re-emitted in all directions, warming the surface of the Earth and the lower atmosphere.



## 4) Increased CO<sub>2</sub> is the primary driver of greenhouse effect

- CO<sub>2</sub> traps infrared radiation (thermal radiation). Proven by laboratory experiments and satellites (satellite data from 1970; direct experimental evidence) that find less heat escaping out to space over the last few decades.



1790 ppb

386 ppm



# Climate change uncertainty

- Positive/negative feedbacks – examining different period throughout Earth's history shows that feedbacks amplify or diminish any initial warming.
- Positive feedback
  - Warming keeps more water in the air and more vapour traps more heat.
  - Warming releases carbon (methane) in the arctic – from thawing permafrost. Or from hydrates (water ice containing methane in its structure).
  - Drying rainforest, forest fires. Desertification.
  - Albedo feedback.
- Negative feedback
  - More water vapour causes more clouds, reflecting sunlight.
  - Increase in the overall amount of greenery – increased plants photosynthesis

# Permafrost example

- About 700 – 800 Gt of CO<sub>2</sub> in the atmosphere. Up to 1700 Gt in permafrost in Siberia, Canada...
- Higher temperature leads to faster thawing which leads to faster releasing of CO<sub>2</sub>, which leads to increase in the temperature....
- With about 3°C expected average temperature increase (= 6°C in arctic, due to the uneven distribution) about 30 – 85% of near-surface permafrost is to melt.
- According to the UNEP, by 2100 about 43-135Gt of CO<sub>2</sub> may be released, by 2020 something between 246-415Gt.
- Unreliable data about deeper layers of permafrost.
- Plus methane.

# Summary

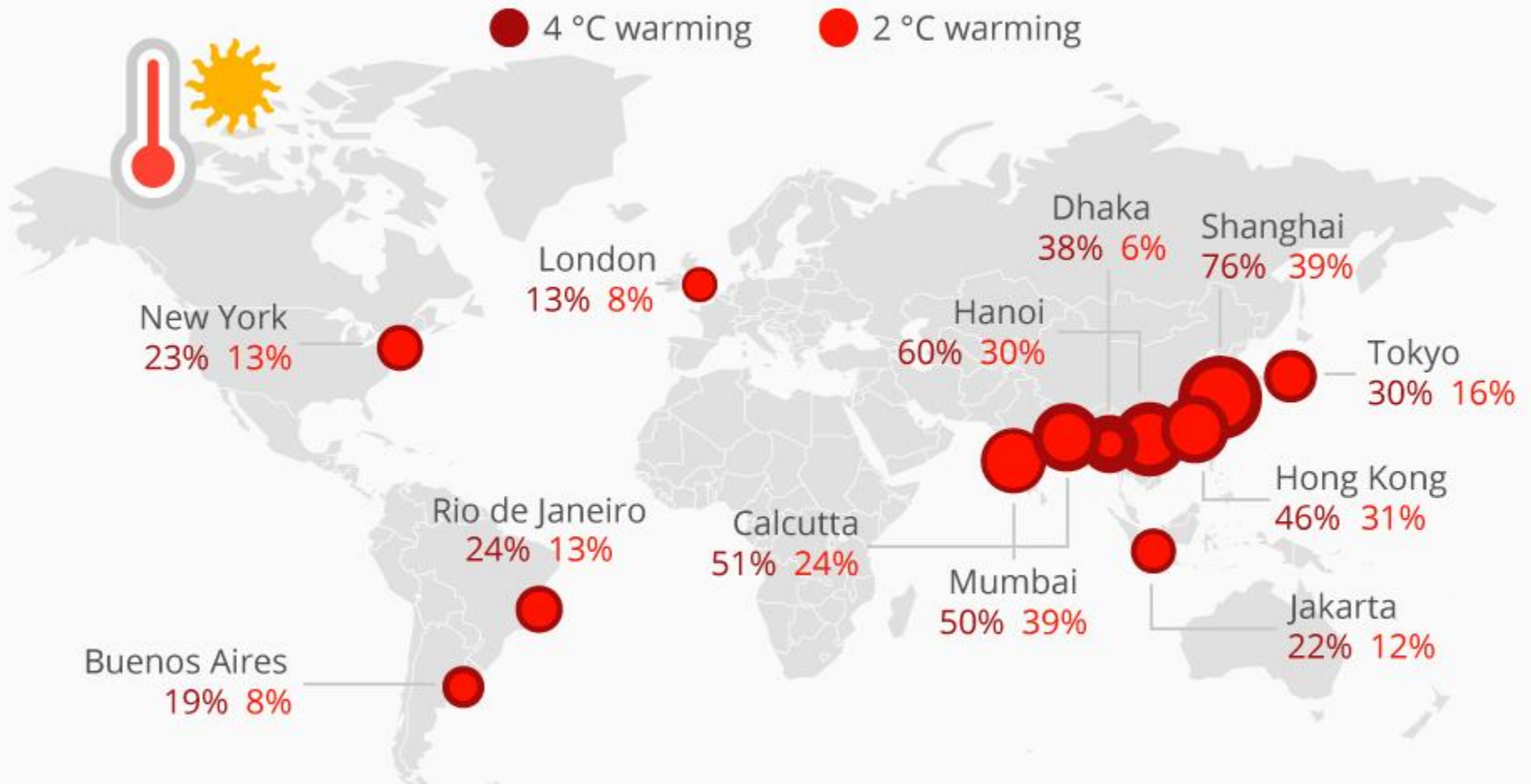
- Earth's climate has undergone changes over long periods of time (several ice ages, period of warming).
- Previous changes were dramatic but gradual (thousands of years).
- Today's change is extremely fast and the pace is increasing. Until 250 years ago the highest rate of temperature increase recorded was approximately  $0,003^{\circ}\text{C}/\text{y}$ . For the last ten years, it is  $0,017^{\circ}\text{C}$
- Global warming vs. climate change. The first suggests that Earth's climate is warming on average, but it is not fully true. Factors such as precipitation and evaporation are also changing. And these changes often affect climate patterns elsewhere in the world.

# Climate change impacts

- Melting ice
  - World's glaciers are melting faster than are replenished.
  - 1/3 of North Pole's ice sheets melted since 90s.
- Accelerated sea level rise, increase coastal flooding.
  - 20 cm in the last century (40% thermal expansivity, 60% melting of the land ice).
  - Actual rate 3mm/y.
  - Problem for low-lying communities (such as Bangladesh).
  - Problem from some smaller islands (such as Kiribati in the Pacific, no more than 2m above sea level at the highest point)
- Extreme weather events (heat waves, coastal flooding, extreme precipitation events, more severe droughts).

# The cities most threatened by rising sea levels

Percentage of population affected by rising sea levels in selected cities in 2010



\* only urban agglomerations with total 2010 populations exceeding 10 million are included in this analysis



@StatistaCharts

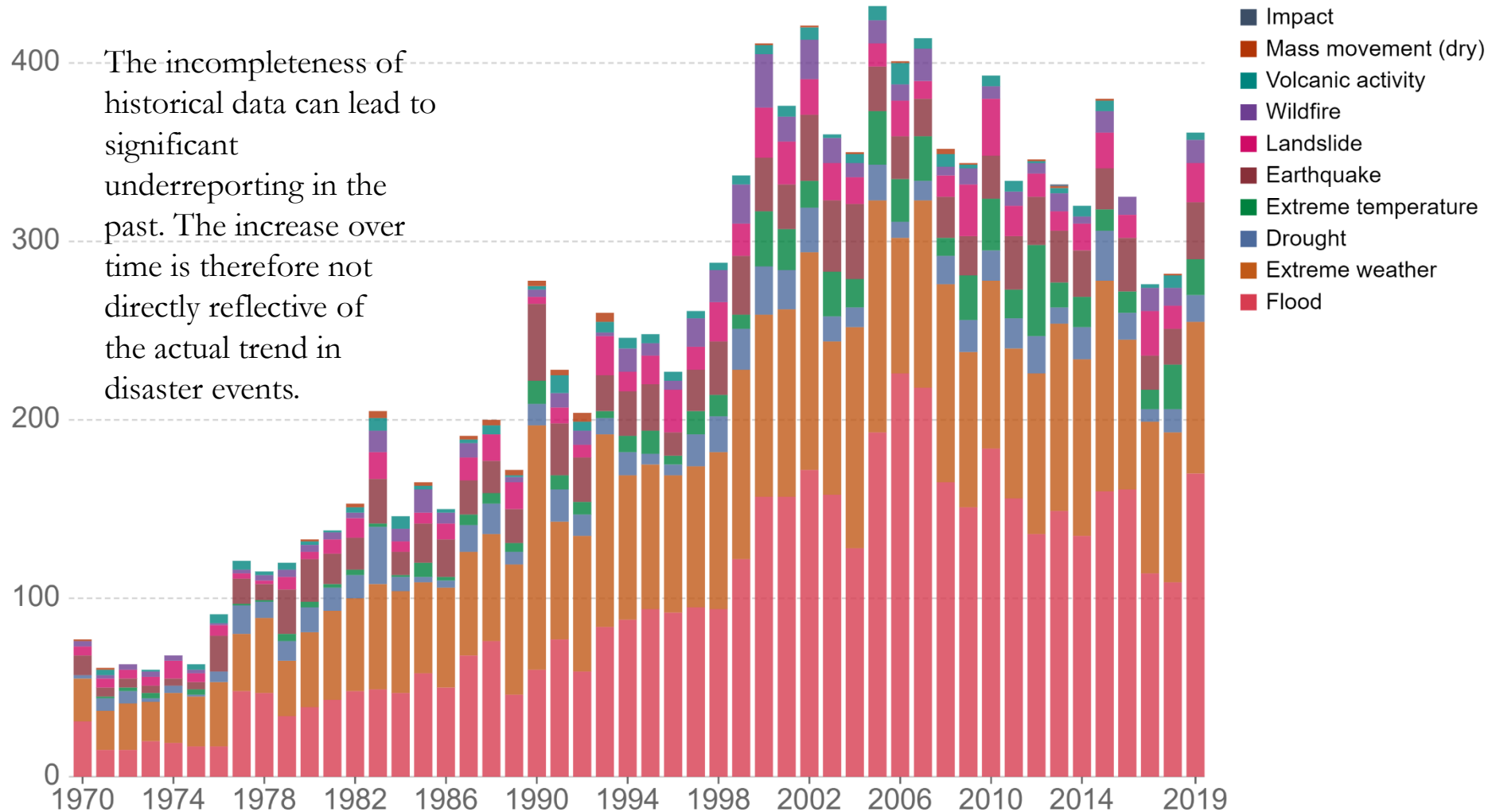
Source: Climate Central

statista



# Global reported natural disasters by type, 1970 to 2019

The annual reported number of natural disasters, categorised by type. This includes both weather and non-weather related disasters.



# Climate change impacts

- Health impacts - longer and more intense allergy seasons, spread of insect-borne diseases, more frequent heat waves, flooding = costly risks to public health.
- Mosquito-borne diseases - Zika virus, West Nile virus, Chikungunya virus, dengue, and malaria.



# Climate change impacts

- Food problems and water - according to IPCC 1°C = 65 million people starving. Increase of the temperature of more than 2°C = 3 billion people without water supply.
- Between 18-35% of plant and animal species is to extinct by 2050 (ocean acidification – destabilising the whole oceanic food chain). About 1 billion people depend on the ocean for more than 30% of their animal protein.

# Possible Effects of Climate Change

## Eventual Temperature Rise Relative to Pre-Industrial Temperatures

Type of Impact	1°C	2°C	3°C	4°C	5°C
<b>Freshwater Supplies</b>	Small glaciers in the Andes disappear, threatening water supplies for 50 million people	Potential water supply decrease of 20–30% in some regions (Southern Africa and Mediterranean)	Serious droughts in southern Europe every 10 years. 1–4 billion more people suffer water shortages	Potential water supply decrease of 30–50% in southern Africa and Mediterranean	Large glaciers in Himalayas possibly disappear, affecting ¼ of China’s population
<b>Food and Agriculture</b>	Modest increase in yields in temperature regions	Declines in crop yields in tropical regions (5–10% in Africa)	150–550 million more people at risk of hunger. Yields likely to peak at higher latitudes	Yields decline by 15–35% in Africa. Some entire regions out of agricultural production	Increase in ocean acidity possibly reduces fish stocks
<b>Human Health</b>	At least 300,000 die each year from climate-related diseases. Reduction in winter mortality in high latitudes	40–60 million more exposed to malaria in Africa	1–3 million more potentially people die annually from malnutrition	Up to 80 million more people exposed to malaria in Africa	Further disease increase and insubstantial burdens on health care services
<b>Coastal Areas</b>	Increased damage from coastal flooding	Up to 10 million more people exposed to coastal flooding	Up to 170 million more people exposed to coastal flooding	Up to 300 million more people exposed to coastal flooding	Sea-level rise threatens major cities such as New York, Tokyo, and London
<b>Ecosystems</b>	At least 10% of land species facing extinction. Increased wildfire risk	15–40% of species potentially face extinction	20–50% of species potentially face extinction Possible onset of collapse of Amazon forest	Loss of half of Arctic tundra Widespread loss of coral reefs	Significant extinctions across the globe

# Climate refugees

- No legal internationally recognised definition of climate refugee.
- Not covered by UN 1951 Refugee Convention.
- Numbers are increasing. World Bank expects only in the regions of Sub-Saharan Africa, South Asia, and Latin America climate change could force more than 143 million people to move internally by 2050, which eventually be reflected in general migration.
- Problem in numbers and resources?



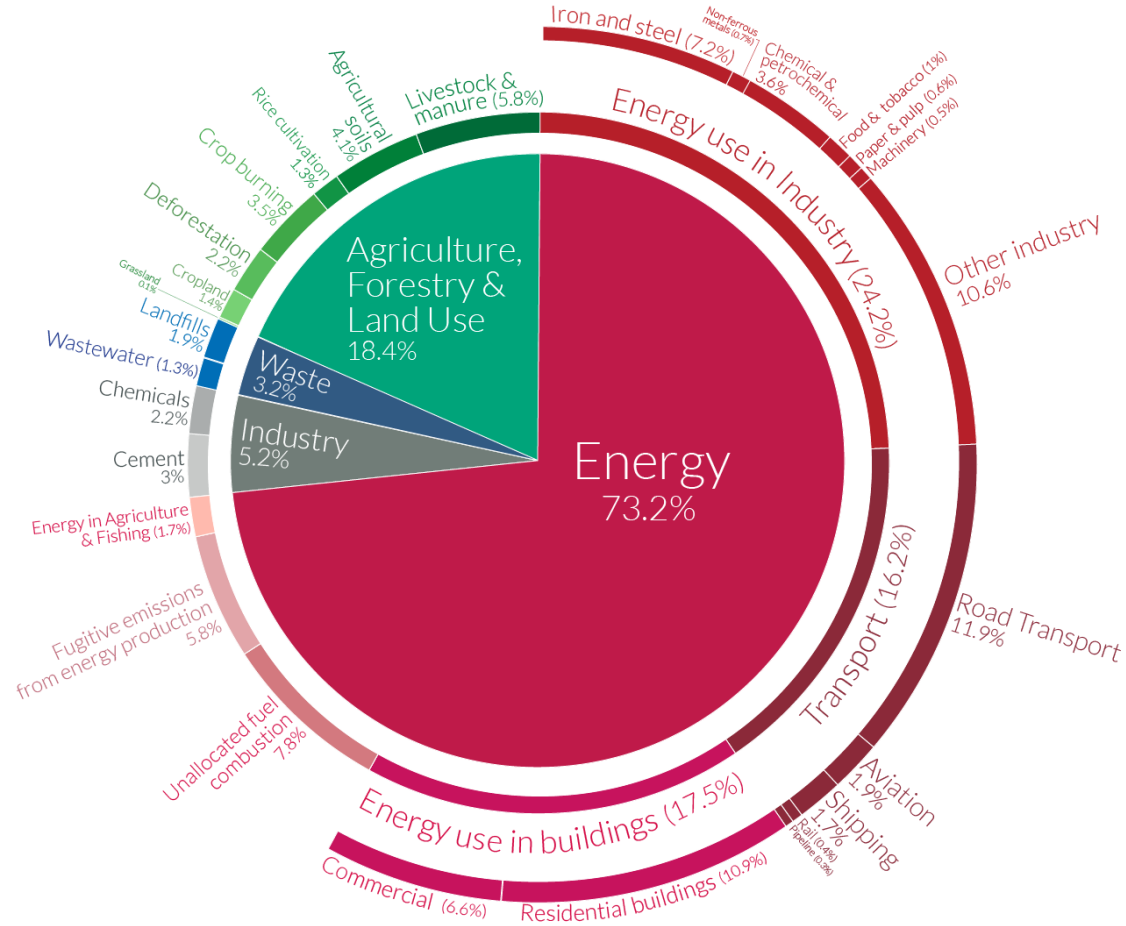
# Expected economic impacts of climate change

	Temperature rise scenario, by mid-century			
	Well-below 2°C increase	2.0°C increase	2.6°C increase	3.2°C increase
	<i>Paris target</i>	<i>The likely range of global temperature gains</i>		<i>Severe case</i>
<b>Simulating for economic loss impacts from rising temperatures in % GDP, relative to a world without climate change (0°C)</b>				
World	-4.2%	-11.0%	-13.9%	-18.1%
OECD	-3.1%	-7.6%	-8.1%	-10.6%
North America	-3.1%	-6.9%	-7.4%	-9.5%
South America	-4.1%	-10.8%	-13.0%	-17.0%
Europe	-2.8%	-7.7%	-8.0%	-10.5%
Middle East & Africa	-4.7%	-14.0%	-21.5%	-27.6%
Asia	-5.5%	-14.9%	-20.4%	-26.5%
Advanced Asia	-3.3%	-9.5%	-11.7%	-15.4%
ASEAN	-4.2%	-17.0%	-29.0%	-37.4%
Oceania	-4.3%	-11.2%	-12.3%	-16.3%

# 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.



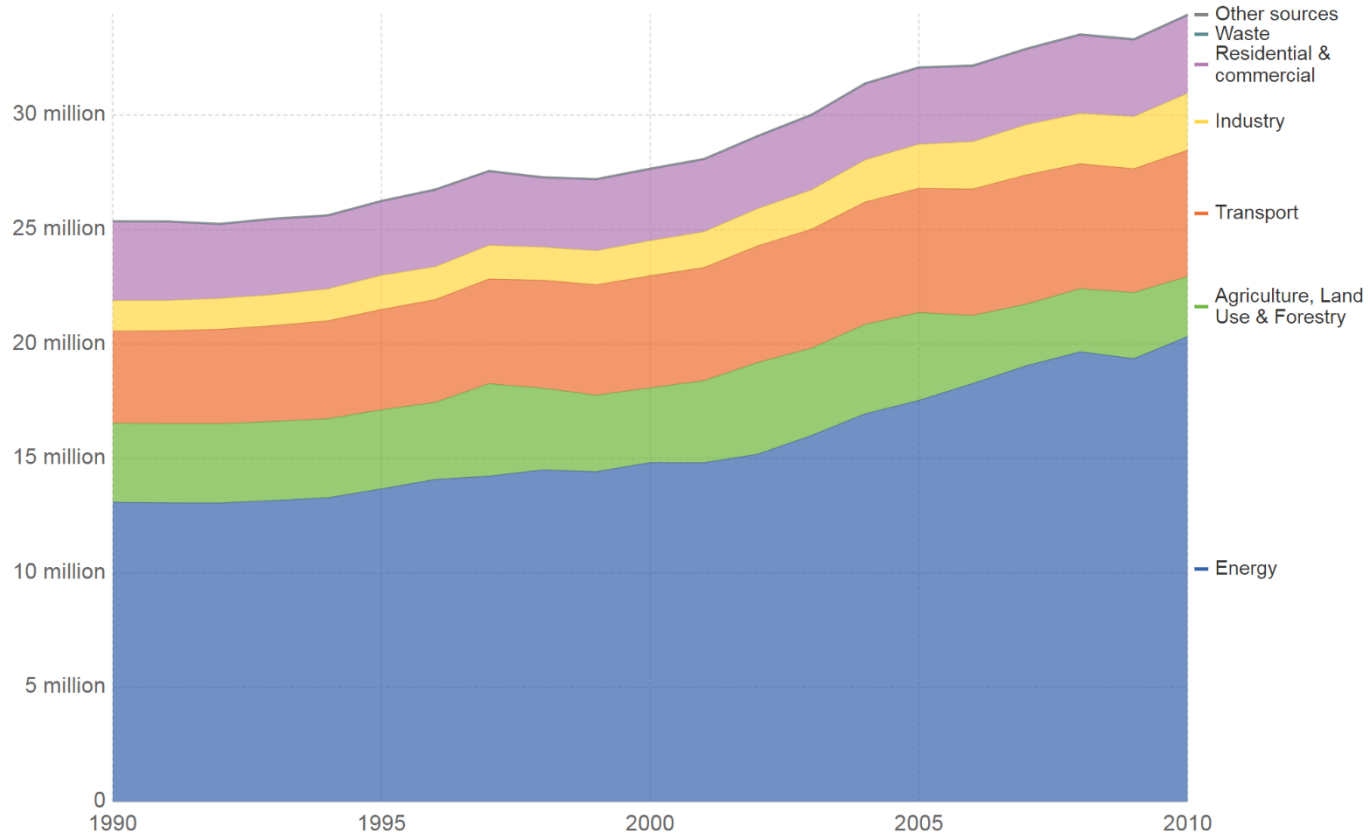
OurWorldinData.org – Research and data to make progress against the world's largest problems.

Source: Climate Watch, the World Resources Institute (2020).

Licensed under CC-BY by the author Hannah Ritchie (2020).

# Global carbon dioxide emissions by sector (Gg CO<sub>2</sub>)

Global carbon dioxide (CO<sub>2</sub>) emissions, measured in gigagrams of CO<sub>2</sub> per year.

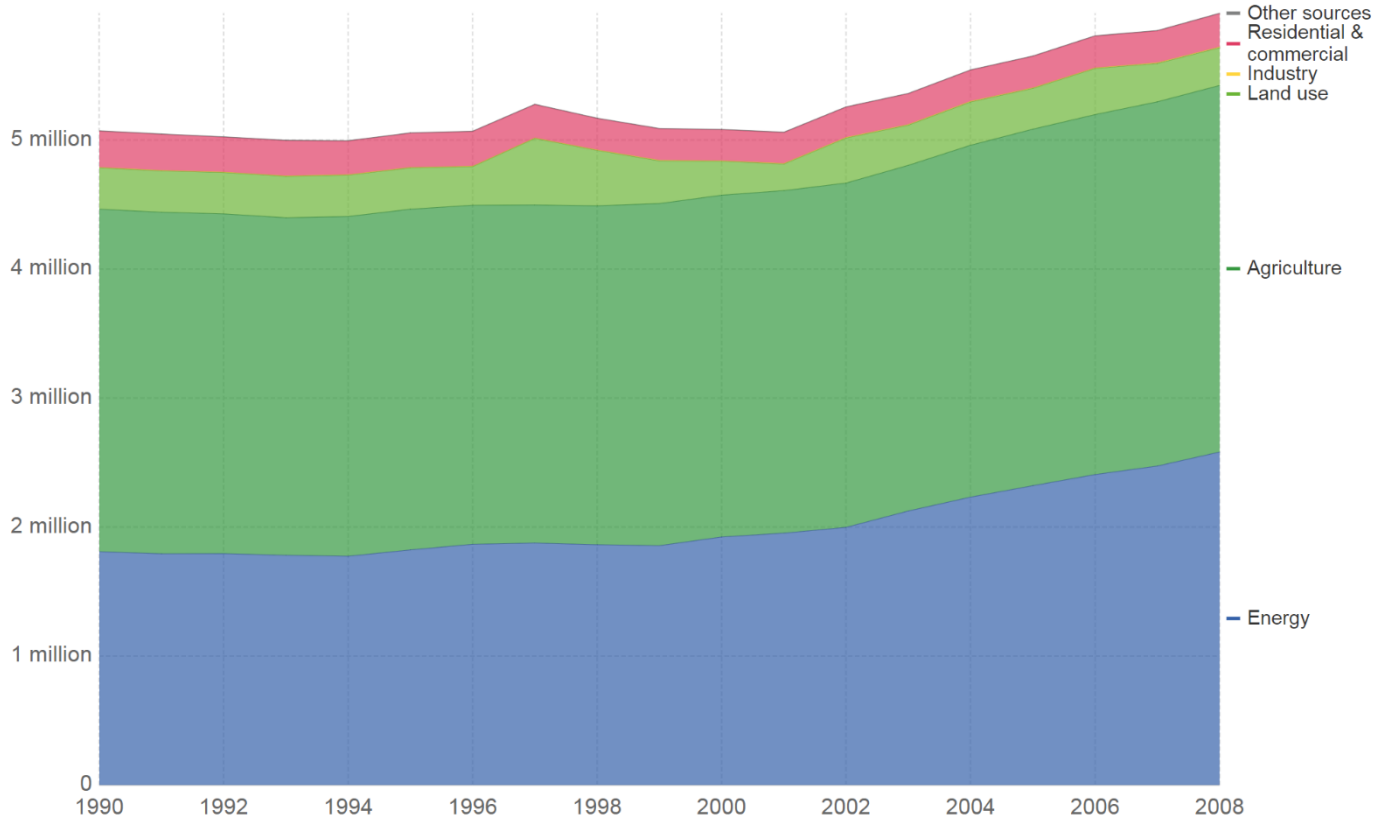


Source: UN Food and Agricultural Organization (FAO)

OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY-SA

## Methane emissions by sector (Gg CO<sub>2</sub>e)

Breakdown of total global methane (CH<sub>4</sub>) emissions by sector, measured in gigagrams of carbon-dioxide equivalents (CO<sub>2</sub>e). Carbon dioxide equivalents measures the total greenhouse gas potential of the full combination of gases, weighted by their relative warming impacts.

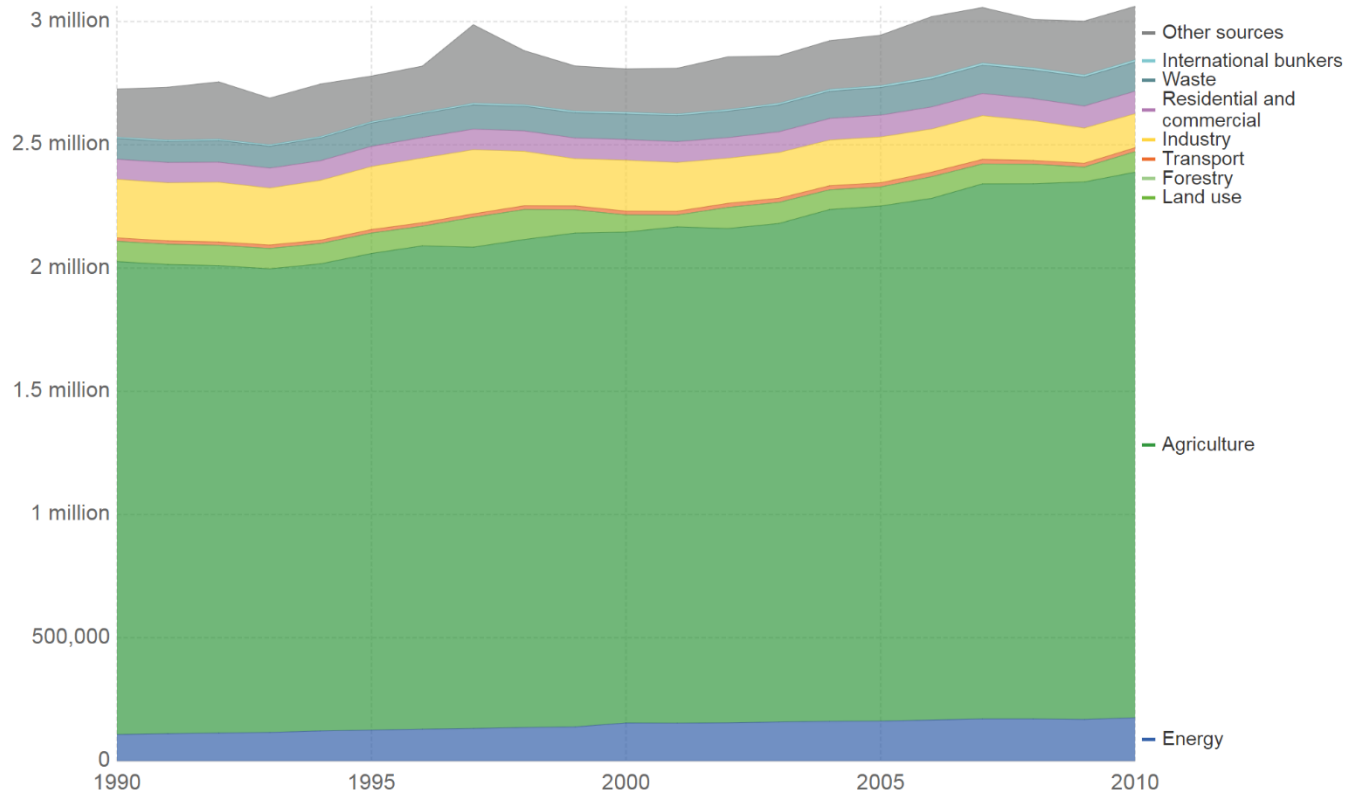


Source: UN Food and Agricultural Organization (FAO)

[OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/](http://OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/) • CC BY-SA

## Nitrous oxide emissions by sector (Gg CO<sub>2</sub>e), World

Breakdown of total global nitrous oxide (N<sub>2</sub>O) emissions by sector, measured in gigagrams of carbon-dioxide equivalents (CO<sub>2</sub>e). Carbon dioxide equivalents measures the total greenhouse gas potential of the full combination of gases, weighted by their relative warming impacts.



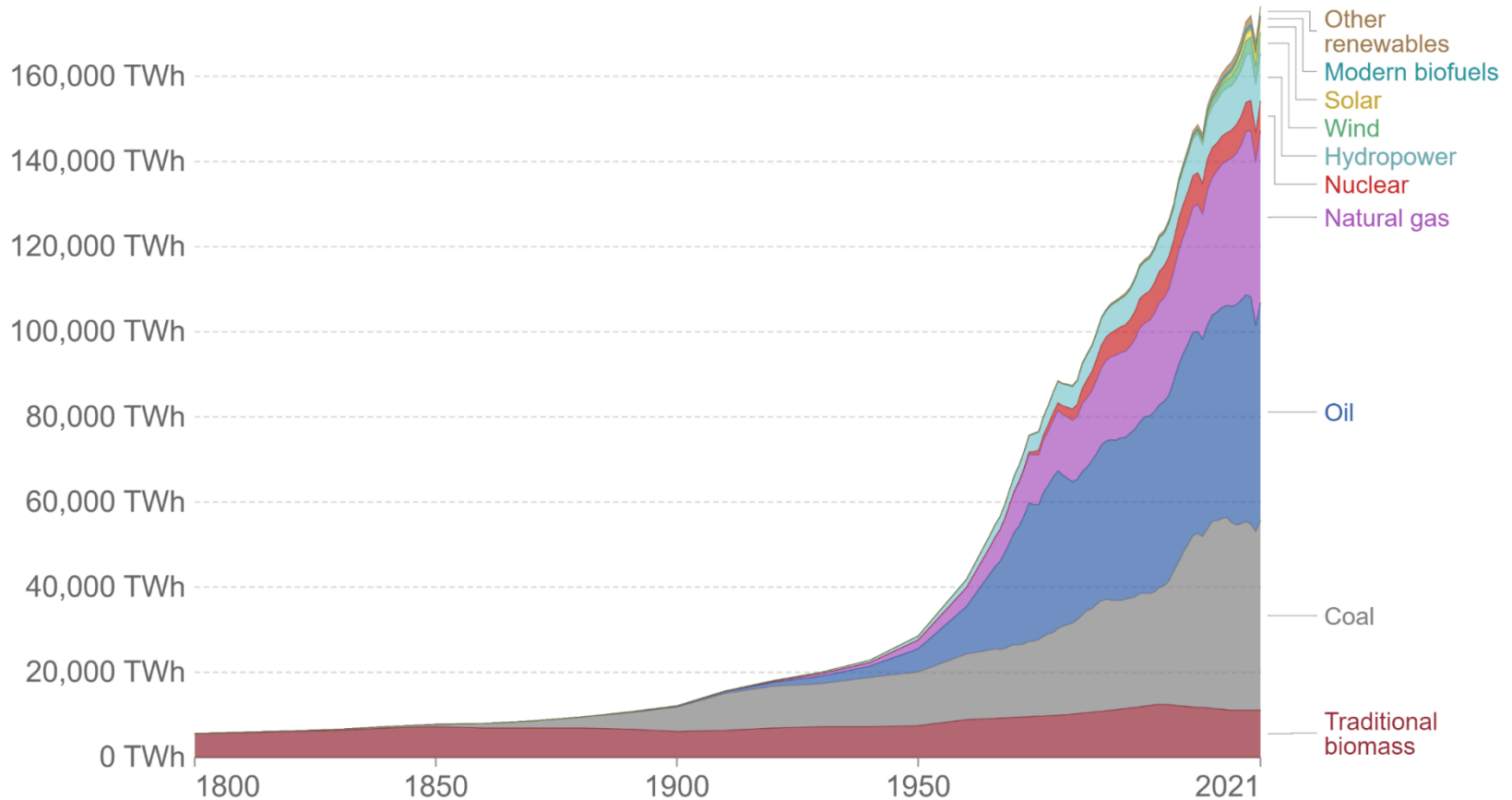
Source: UN Food and Agricultural Organization (FAO)

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# Global primary energy consumption by source



Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.



Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy

OurWorldInData.org/energy • CC BY

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