



GLOBAL CARBON **BUDGET**  
2024

The work presented here has been possible thanks to the enormous observational and modelling efforts of the institutions and networks below

## Atmospheric CO<sub>2</sub> datasets

NOAA/GML (Lan et al., 2024)  
Scripps (Keeling et al., 1976)

## Atmospheric O<sub>2</sub> datasets

Scripps (Keeling 2024)

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

Andrew and Peters, 2024  
CDIAC-FF (Hefner and Marland, 2024)  
UNFCCC 2024  
Energy Institute 2024

## Consumption emissions

Peters et al., 2011  
GTAP (Narayanan et al., 2015)

## Land-use change

Houghton and Castanho 2023  
BLUE (Hansis et al., 2015)  
OSCAR (Gasser et al., 2020)  
LUCE (Qin et al., 2024)  
GFED4 (van der Werf et al., 2017)  
FAO-FRA and FAOSTAT  
HYDE (Klein Goldewijk et al., 2017)  
LUH2 (Hurtt et al., 2020)  
MapBiomas (Souza et al., 2020)

## Land models

CABLE-POP | CLASSIC | CLM6.0 | DLEM | eDV3 | ELM | IBIS | ISAM | ISBA-CTRIP | JSBACH | JULES-ES | LPJ-GUESS | LPJmI | LPJ-wsl | LPX-Bern | OCN | ORCHIDEEv3 | SDGVM | VISIT | CARDAMOM

**Climate forcing** CRU (Harris et al., 2014) | JRA-55 (Kobayashi et al., 2015)

## Ocean models

NEMO-PlankTOM12 | NEMO4.2-PISCES (IPSL) | MICOM-HAMOCC (NorESM1-OCv1.2) | MPIOM-HAMOCC6 | NEMO3.6-PISCESv2-gas (CNRM) | FESOM2.1-REcoM3 | MOM6-COBALT (Princeton) | CESM-ETHZ | MRI-ESM2-3 | ACCESS (CSIRO)

## fCO<sub>2</sub> based ocean flux products

VLIZ-SOMFFN | Jena-MLS | CMEMS-LSCE-FFNNv2 | UExp-FNN-U | NIES-ML3 | JMA-MLR | OceanSODA-ETHZv2 | LDEO-HPD CSIR-ML6

**Surface Ocean CO<sub>2</sub> Atlas** SOCATv2024

## Atmospheric inversions

Jena CarboScope | CAMS | CarbonTracker Europe (CTE) | NISMON-CO<sub>2</sub> | CT-NOAA | CMS-Flux | CAMS-Satellite | GONGGA | COLA | GCASv2 | UoE in-situ | IAPCAS | MIROC4-ACTM | NTFVAR

## Earth system models

CanESM5 | EC-Earth3-CC | IPSL-CM6A-CO2-LR | MIROC-ES2L | MPI-ESM1-2-LRCan

Full references provided in [Friedlingstein et al 2024](#)

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L Resplandy | A Roobaert | C Rödenbeck | J Schwinger | TL Smallman | S Smith  
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More information, data sources and data files:  
<https://globalcarbonbudget.org/carbonbudget>



More information, data sources and data files:  
[www.globalcarbonatlas.org](http://www.globalcarbonatlas.org)  
(co-funded in part by BNP Paribas Foundation)

## Global Carbon Budget



## Additional country figures



Figures and data for most slides available from [tinyurl.com/GCB24figs](https://tinyurl.com/GCB24figs) and from <https://globalcarbonbudget.org/carbonbudget>

All the data is shown in billion tonnes CO<sub>2</sub> (GtCO<sub>2</sub>)

1 Gigatonne (Gt) = 1 billion tonnes =  $1 \times 10^{15}$ g = 1 Petagram (Pg)

1 kg carbon (C) = 3.664 kg carbon dioxide (CO<sub>2</sub>)

1 GtC = 3.664 billion tonnes CO<sub>2</sub> = 3.664 GtCO<sub>2</sub>

(Figures are available from <https://globalcarbonbudget.org/carbonbudget>)

Most figures in this presentation are available for download as PNG, PDF and SVG files from [tinyurl.com/GCB24figs](https://tinyurl.com/GCB24figs) along with the data required to produce them.

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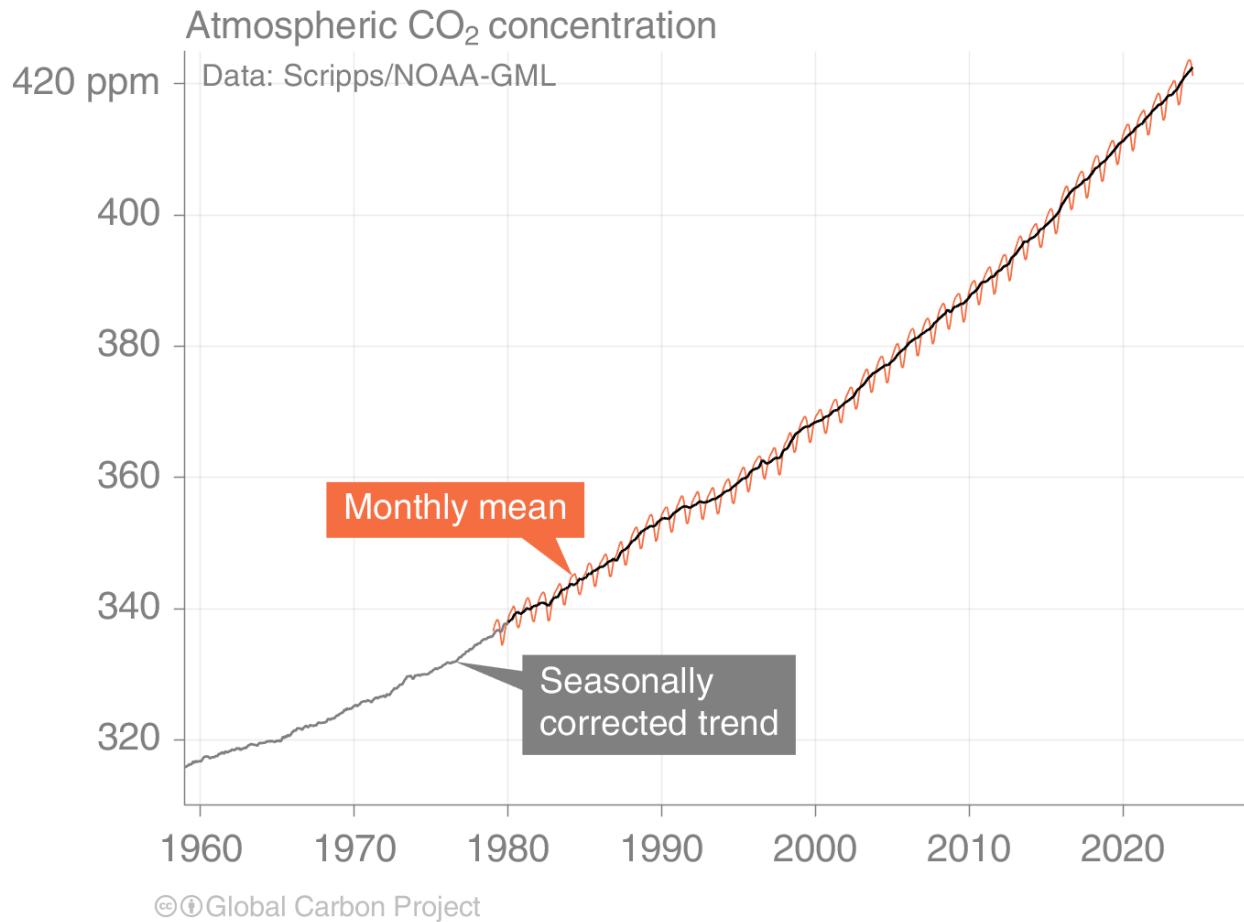
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# Atmospheric CO<sub>2</sub> concentration

The global CO<sub>2</sub> concentration increased from ~277 ppm in 1750 to 422.5 ppm in 2024 (up 52%)



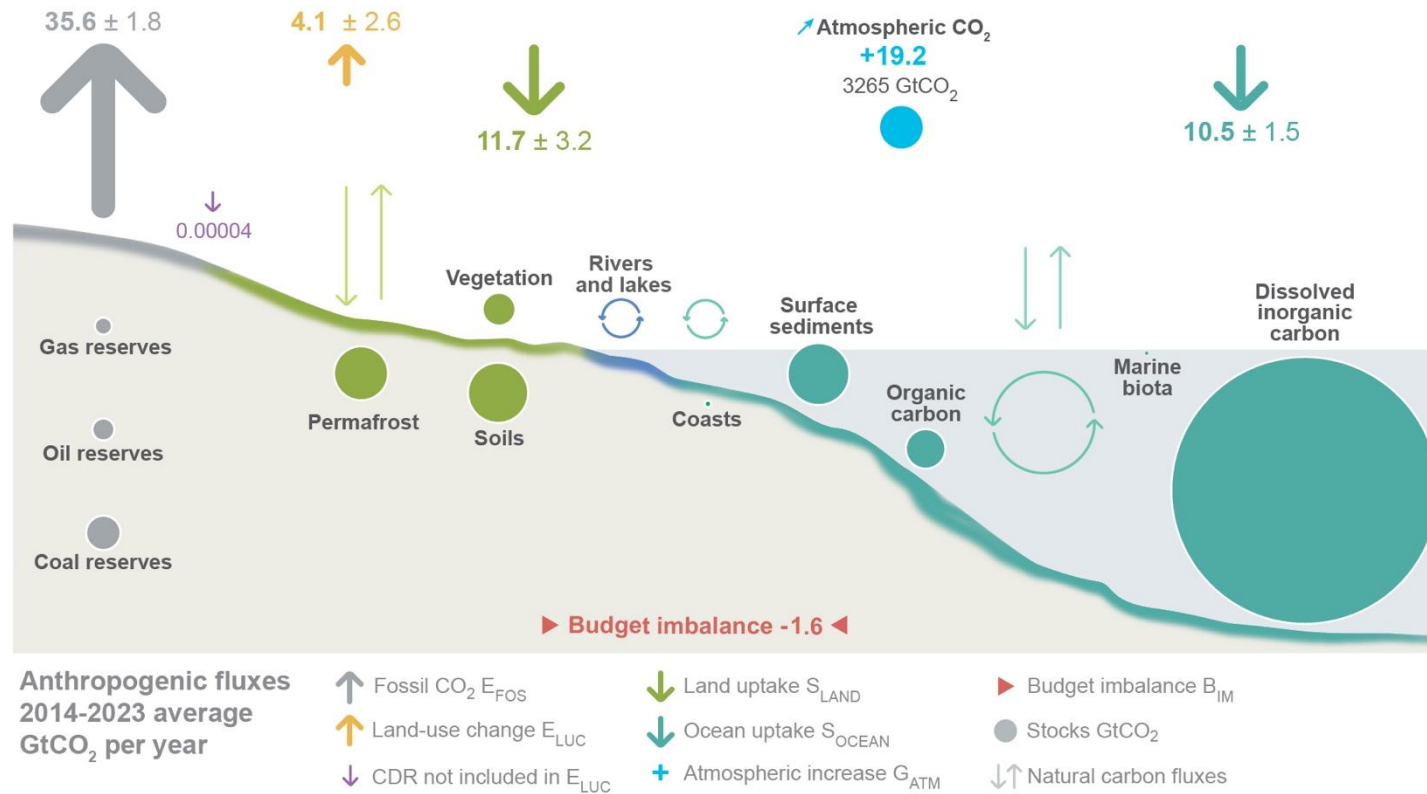
Globally averaged surface atmospheric CO<sub>2</sub> concentration. Data from: NOAA-GML after 1980; the Scripps Institution of Oceanography before 1980

Source: [NOAA-GML](#); [Scripps Institution of Oceanography](#); [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Anthropogenic perturbation of the global carbon cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, global annual average for the decade 2014–2023 (GtCO<sub>2</sub>/yr)

## The global carbon cycle



CDR here refers to Carbon Dioxide Removal besides those associated with land-use that are accounted for in the Land-use change estimate.

The budget imbalance is the difference between the estimated emissions and sinks.

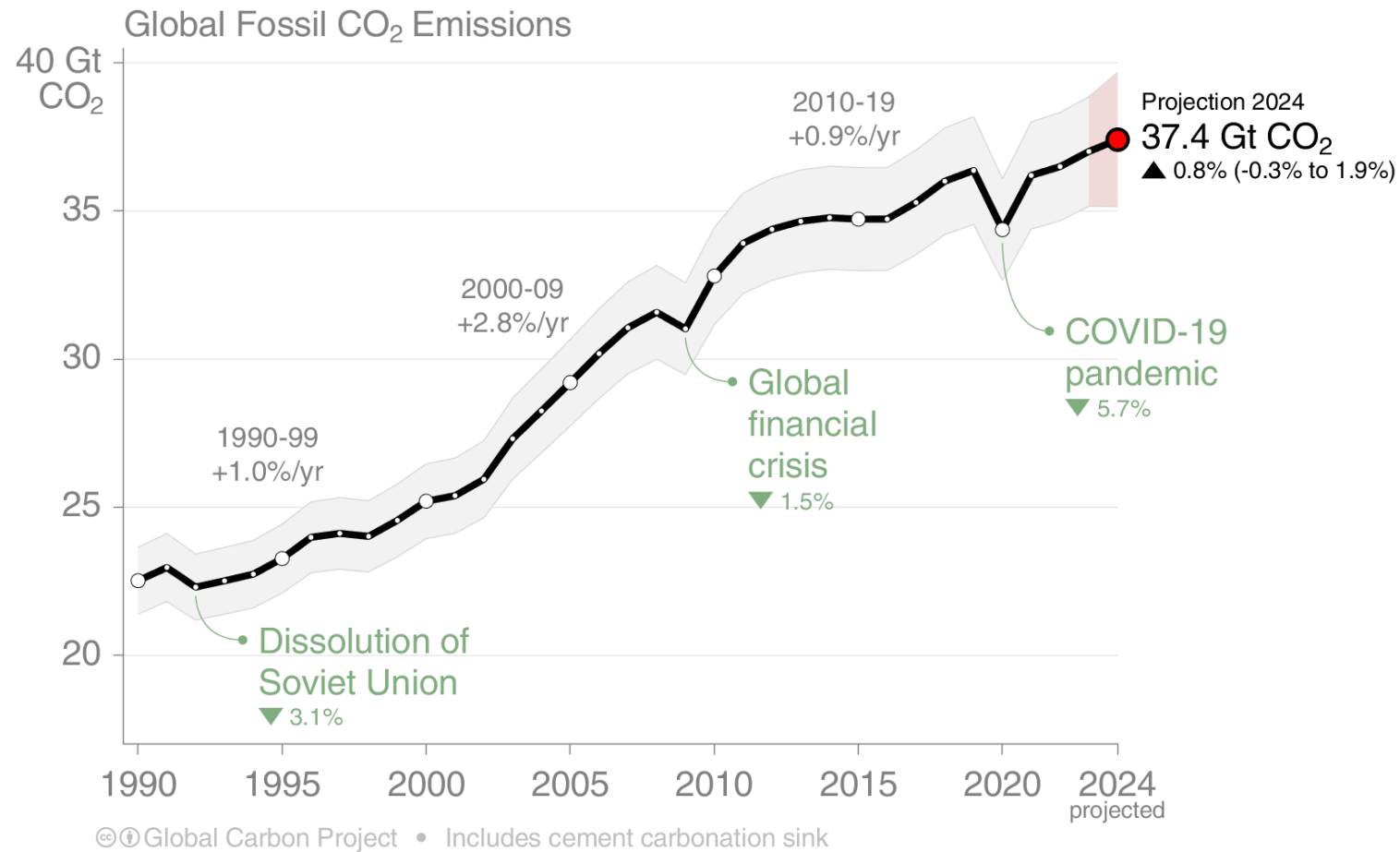
Source: [NOAA-GML](#); [Friedlingstein et al 2024](#); [Canadell et al 2021 \(IPCC AR6 WG1 Chapter 5\)](#); [Global Carbon Project 2024](#)

# Key Highlights in 2024

# Global Fossil CO<sub>2</sub> Emissions

Global fossil CO<sub>2</sub> emissions: 37.0 ± 2 GtCO<sub>2</sub> in 2023, 66% over 1990

● Projection for 2024: 37.4 ± 2 GtCO<sub>2</sub>, 0.8% [-0.3% to +1.9%] higher than 2023



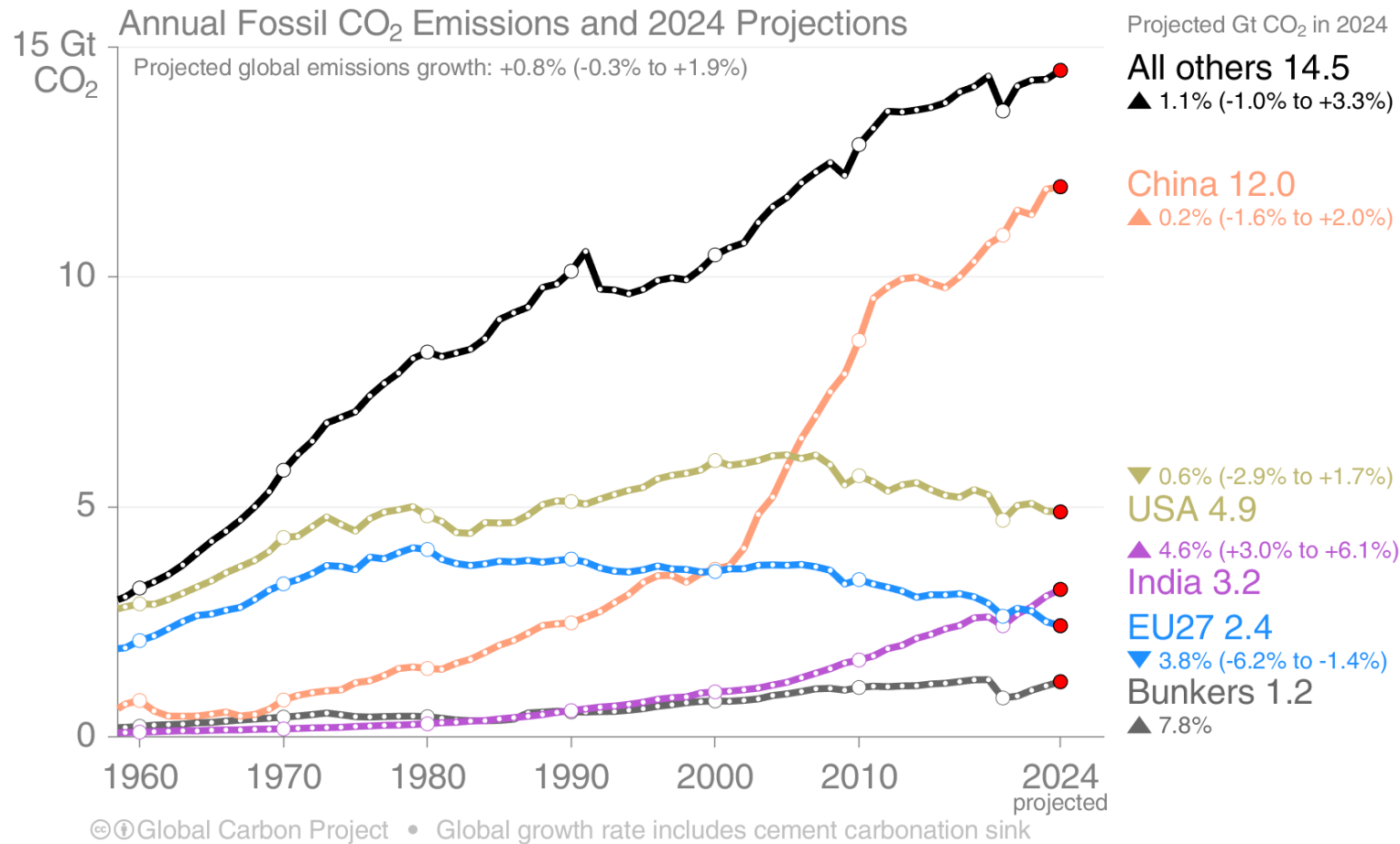
Uncertainty is ±5% for one standard deviation (IPCC “likely” range)

The 2024 projection is based on preliminary data and modelling. The global total includes a cement carbonation sink of 0.8 GtCO<sub>2</sub>.

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Emissions Projections for 2024

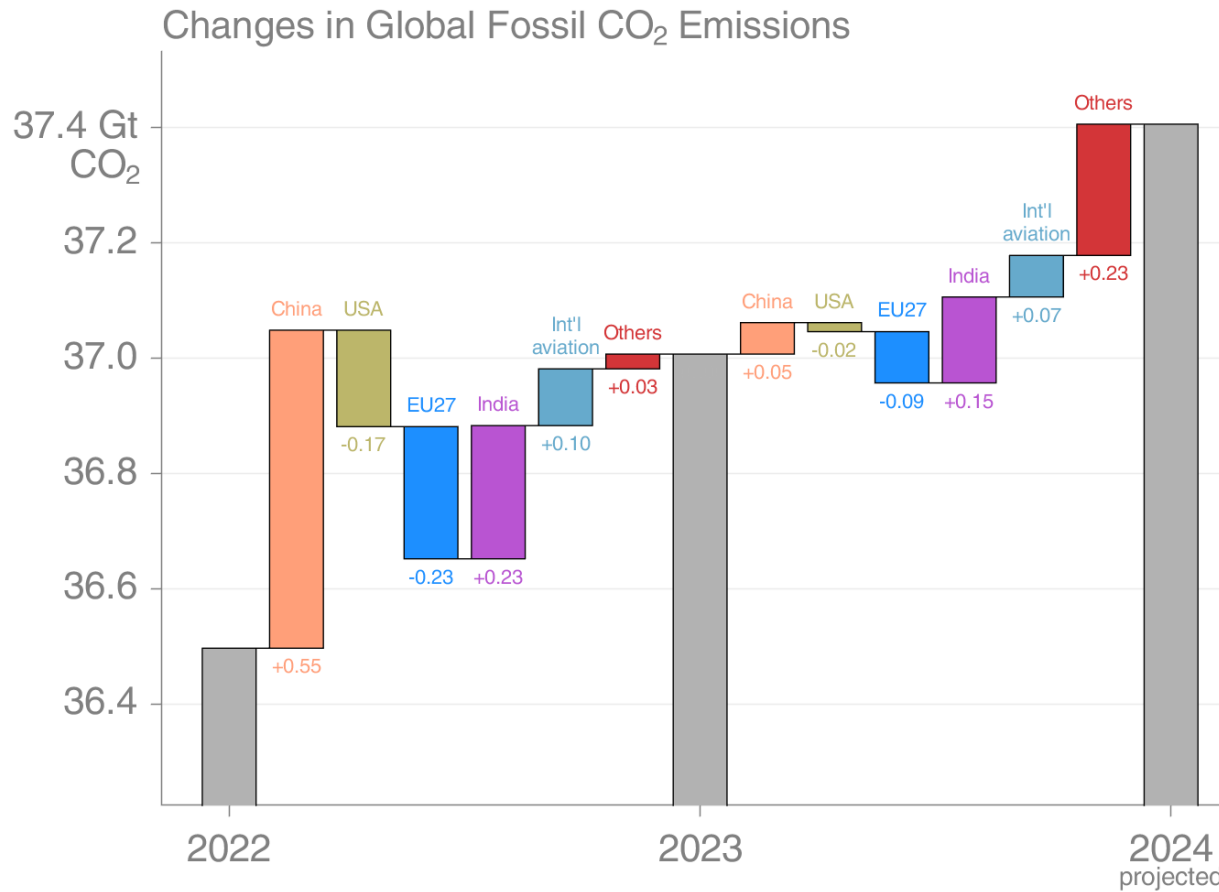
There are sharp contrasts between the projected emissions changes for the top emitters



The 2024 projections are based on preliminary data and modelling.  
 'Bunkers' are fossil fuels used for international shipping and aviation  
 Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Fossil CO<sub>2</sub> emissions growth: 2022–2024

Emissions are expected to increase in India, international aviation and the combined rest of the world (Others) in 2024, decline in USA and the EU, and increase marginally in China



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The 2024 projections are based on preliminary data and modelling.  
 Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

## Summary of fossil CO<sub>2</sub> emissions in 2023 and 2024

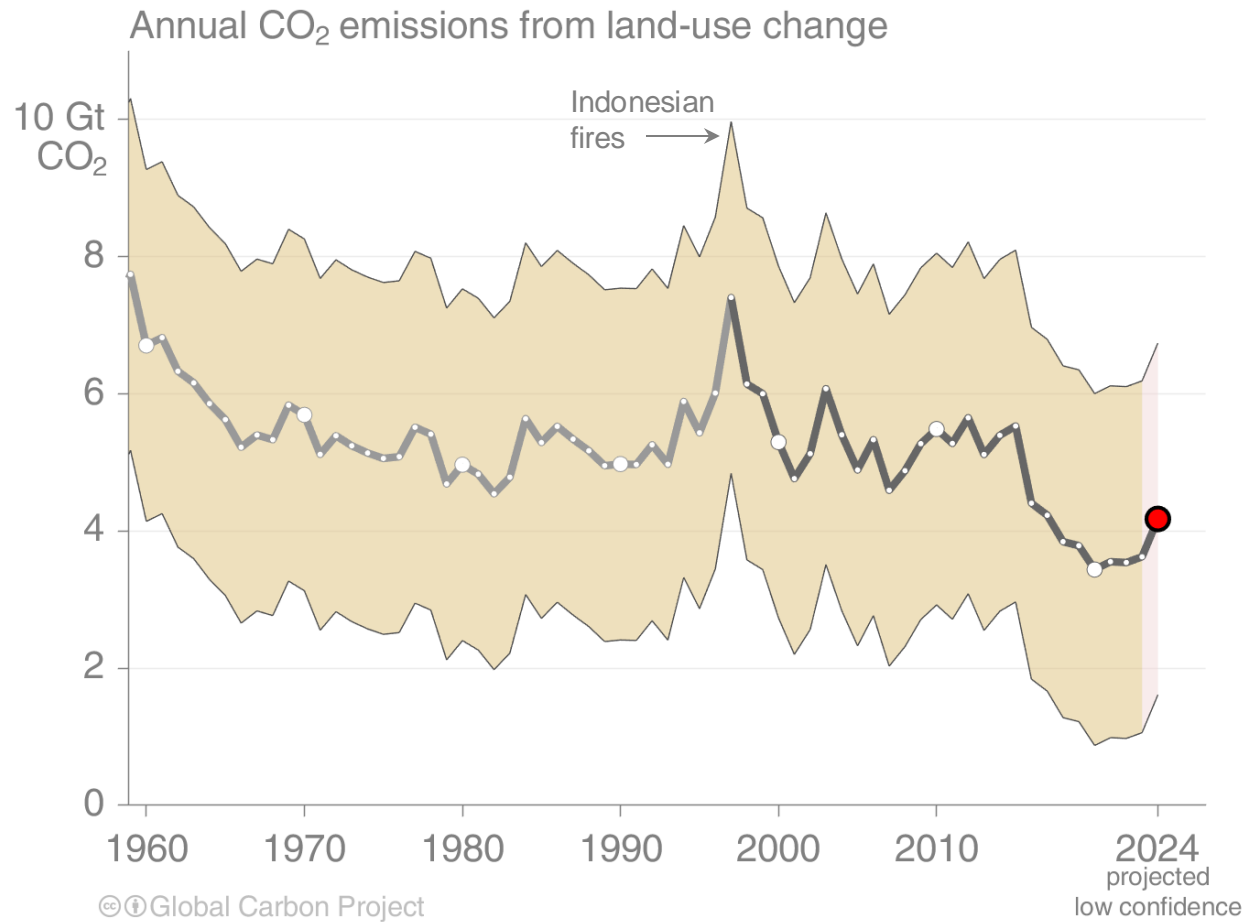
Region / Country	2023 emissions (billion tonnes/yr)	2023 growth (percent)	2024 projected emissions growth (percent)	2024 projected emissions (billion tonnes/yr)
China	11.9	+4.9%	+0.20%	11.9
USA	4.9	-3.3%	-0.6%	4.9
India	3.1	+8.2%	+4.6%	3.1
EU27	2.5	-8.4%	-3.8%	2.6
International bunkers*	1.1	+9.4%	+7.8%	1.2
All others	14.3	+0.1%	+1.1	14.5
World	37.8	+1.3%	+0.7%	38.2
World (incl. cement carbonation)	37.0	+1.4%	+0.8%	37.4

\*Emissions from use of international aviation and maritime shipping bunker fuels are not usually included in national totals. Cement carbonation sink only included in global (World) estimate.

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Land-use change emissions

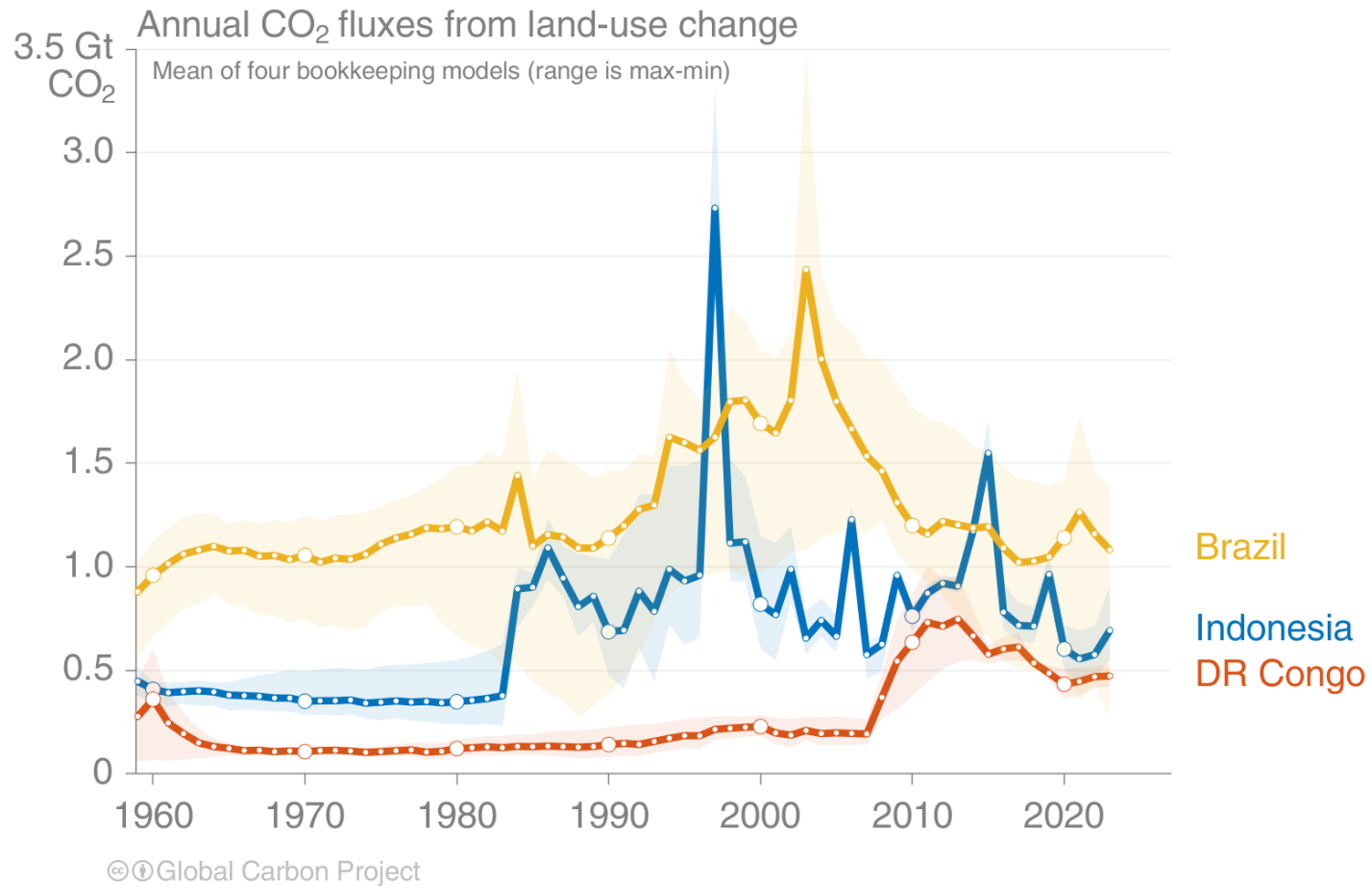
Land-use change emissions are  $4.1 \pm 2.6$  GtCO<sub>2</sub> per year for 2014–2023, and show a negative trend in the last two decades, but estimates are still highly uncertain. ● Projection for 2024:  $4.2 \pm 2.6$  GtCO<sub>2</sub>



Estimates from four bookkeeping models  
 Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Land-use change emissions

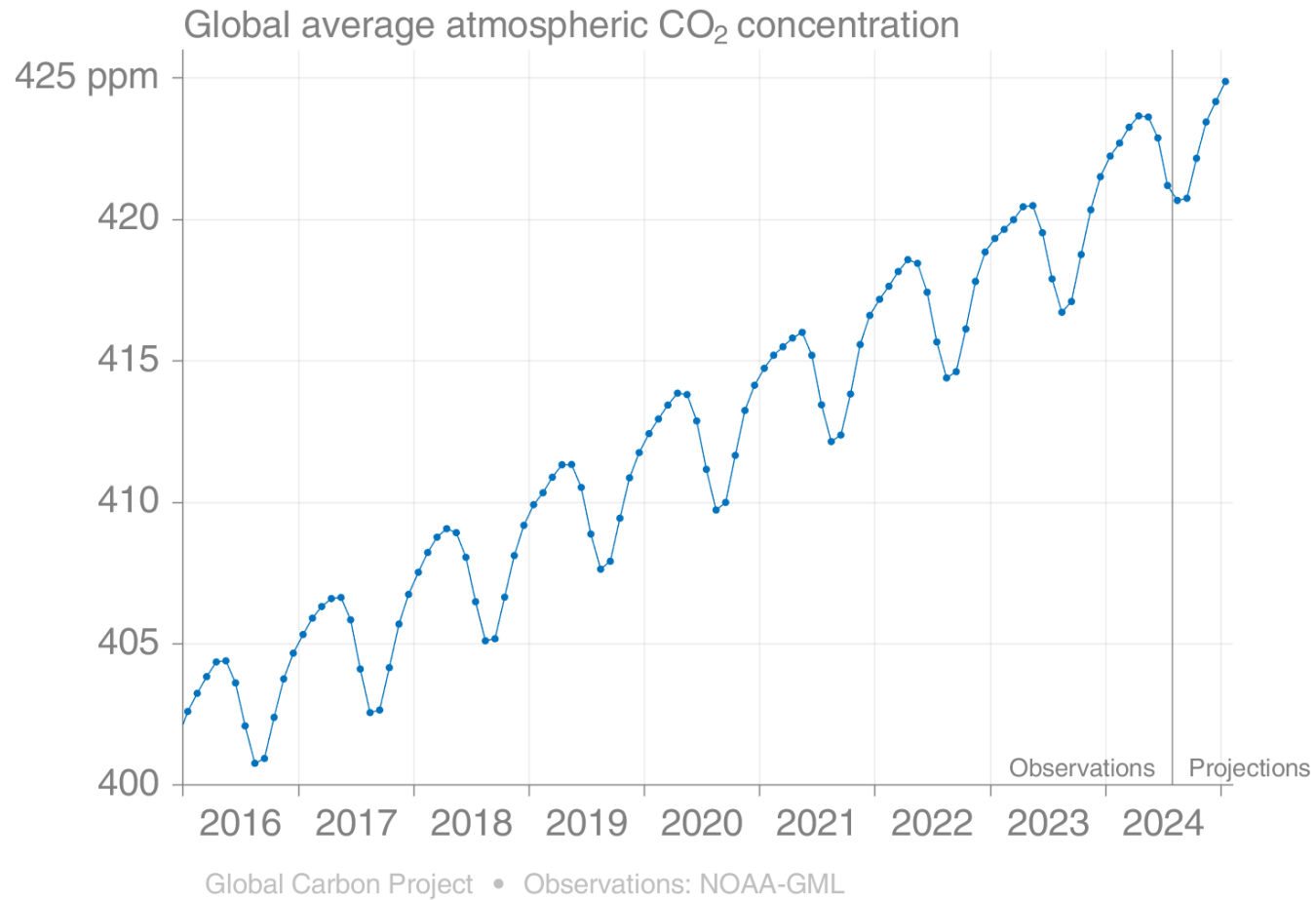
Combined land-use change emissions from Brazil, Indonesia, and the Democratic Republic of the Congo make up 60% of the global net land-use change emissions



Estimates from four bookkeeping models  
Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

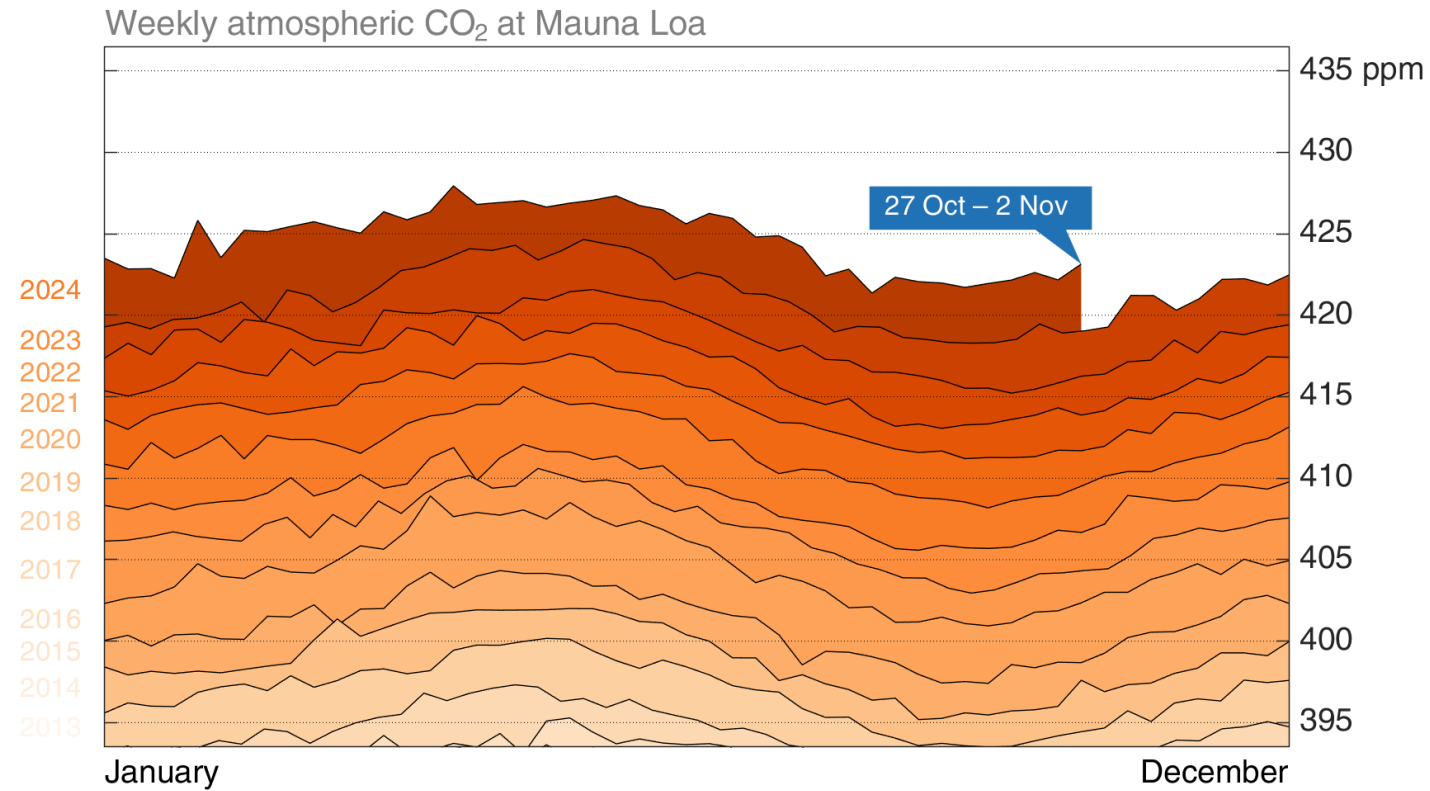
# Forecast of global atmospheric CO<sub>2</sub> concentration

The global atmospheric CO<sub>2</sub> concentration is forecast to average 422.5 parts per million (ppm) in 2024, increasing by 2.8 ppm.



# Mauna Loa atmospheric CO<sub>2</sub>

Atmospheric CO<sub>2</sub> concentration has increased every single year, including in 2020 – despite the drop in fossil CO<sub>2</sub> emissions – because of continued emissions

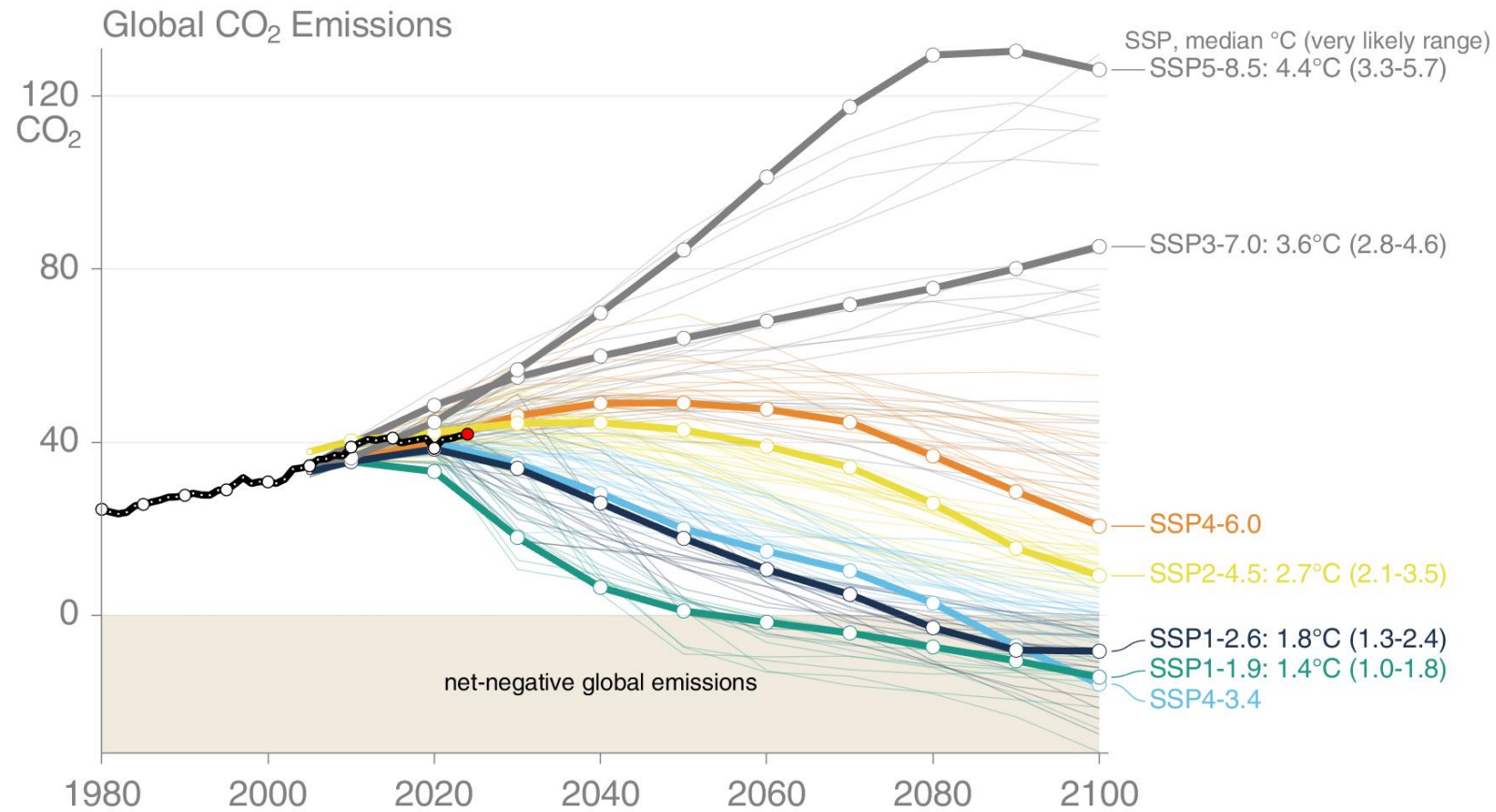


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Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Shared Socioeconomic Pathways (SSPs)

The SSPs were designed to span the range of potential outcomes. Total CO<sub>2</sub> emissions are currently tracking in the middle of the range. The temperature outcomes are based on assessed scenarios in IPCC AR6 Working Group I.



© Global Carbon Project • Data: Riahi et al (2017), Rogelj et al (2018), SSP Database (version 2)

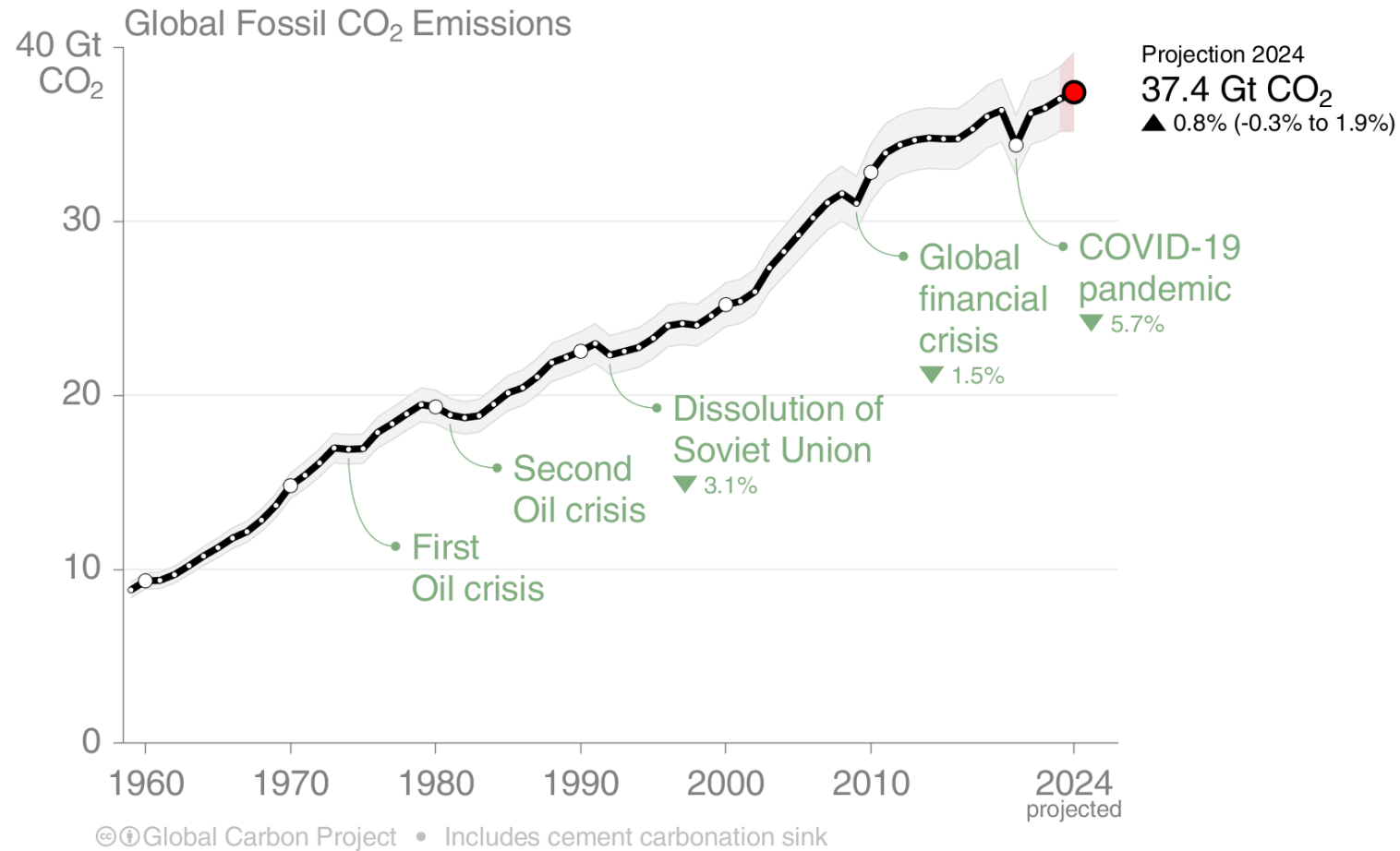
This set of quantified SSPs are based on the output of six Integrated Assessment Models (AIM/CGE, GCAM, IMAGE, MESSAGE, REMIND, WITCH).  
Net emissions include those from land-use change and bioenergy with CCS.

Source: [Riahi et al. 2016](#); [Rogelj et al. 2018](#); [IIASA SSP Database](#); [IAMC](#); [Global Carbon Project 2024](#)

# Global fossil CO<sub>2</sub> emissions

# Global fossil CO<sub>2</sub> emissions

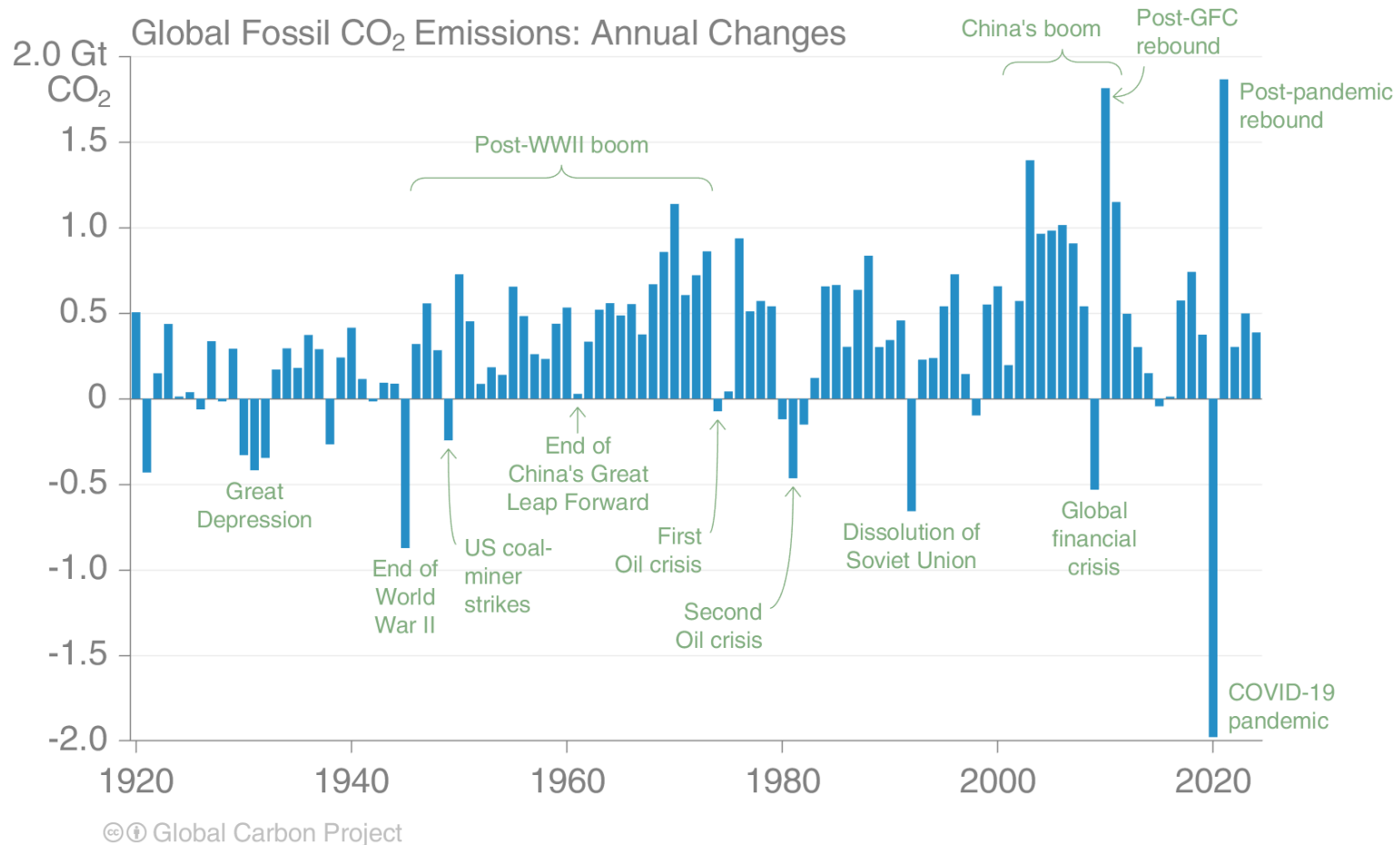
Global fossil CO<sub>2</sub> emissions have risen steadily over the last decades. Emissions are set to grow again in 2024.



The 2024 projection is based on preliminary data and modelling.  
 Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Global fossil CO<sub>2</sub> emissions

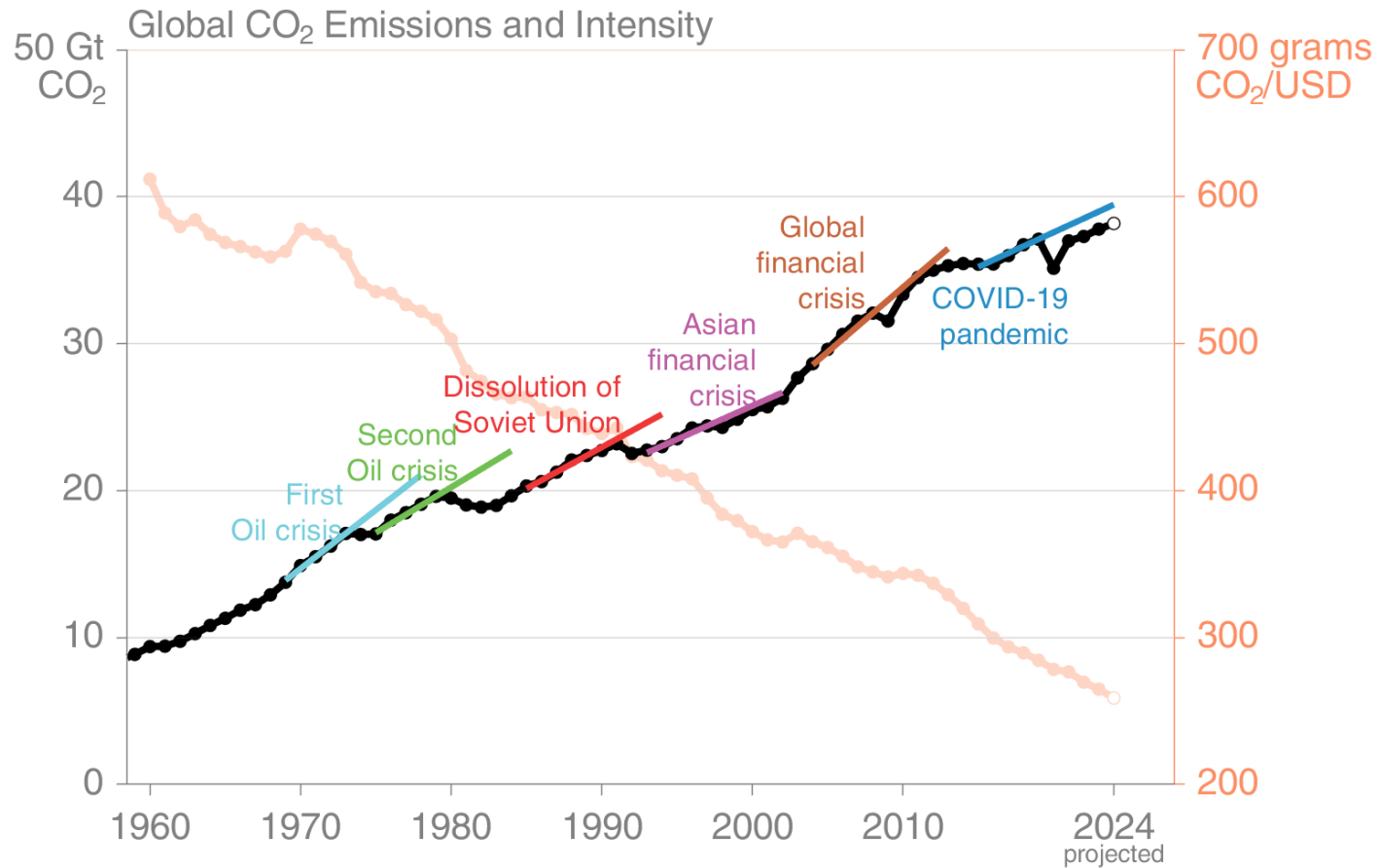
For the last 100 years, it has generally taken a crisis to drive global emissions reductions. To stabilise temperatures, intentional, planned, sustained global reductions must begin.



The 2024 projection is based on preliminary data and modelling.  
 Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Fossil CO<sub>2</sub> emission intensity

Global CO<sub>2</sub> emissions growth has generally resumed quickly from global crises. Emission intensity has steadily declined but not sufficiently to offset economic growth.



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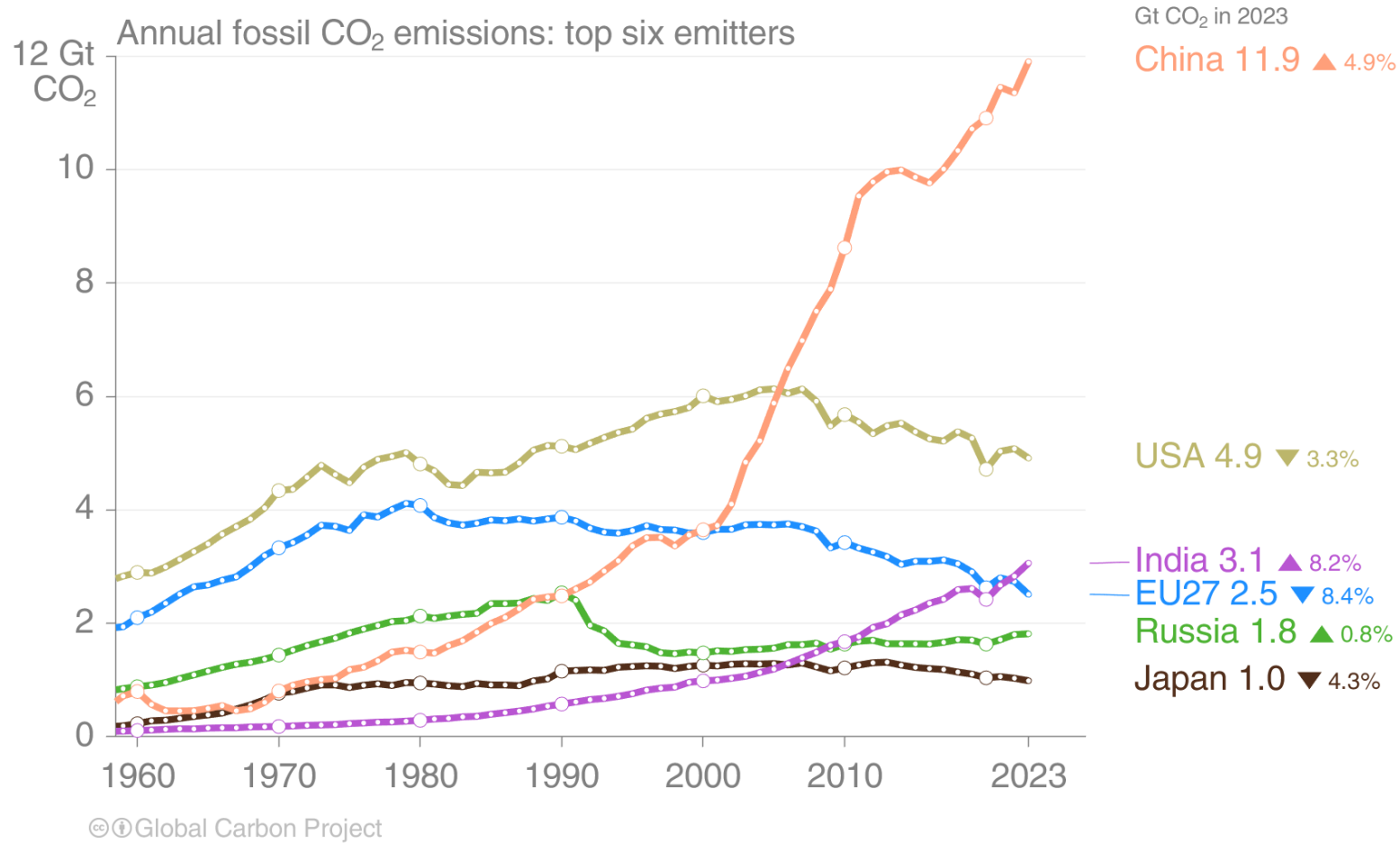
Each trend line is based on the five years before the crisis and extended to five years after. Economic activity is measured in purchasing power parity (PPP) terms in 2017 US dollars.

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Fossil CO<sub>2</sub> emissions by country

# Top emitters: Fossil CO<sub>2</sub> emissions to 2023

The top six emitters in 2023 covered 68% of global emissions  
 China 32%, United States 13%, India 8%, EU 7%, Russia 5%, and Japan 3%

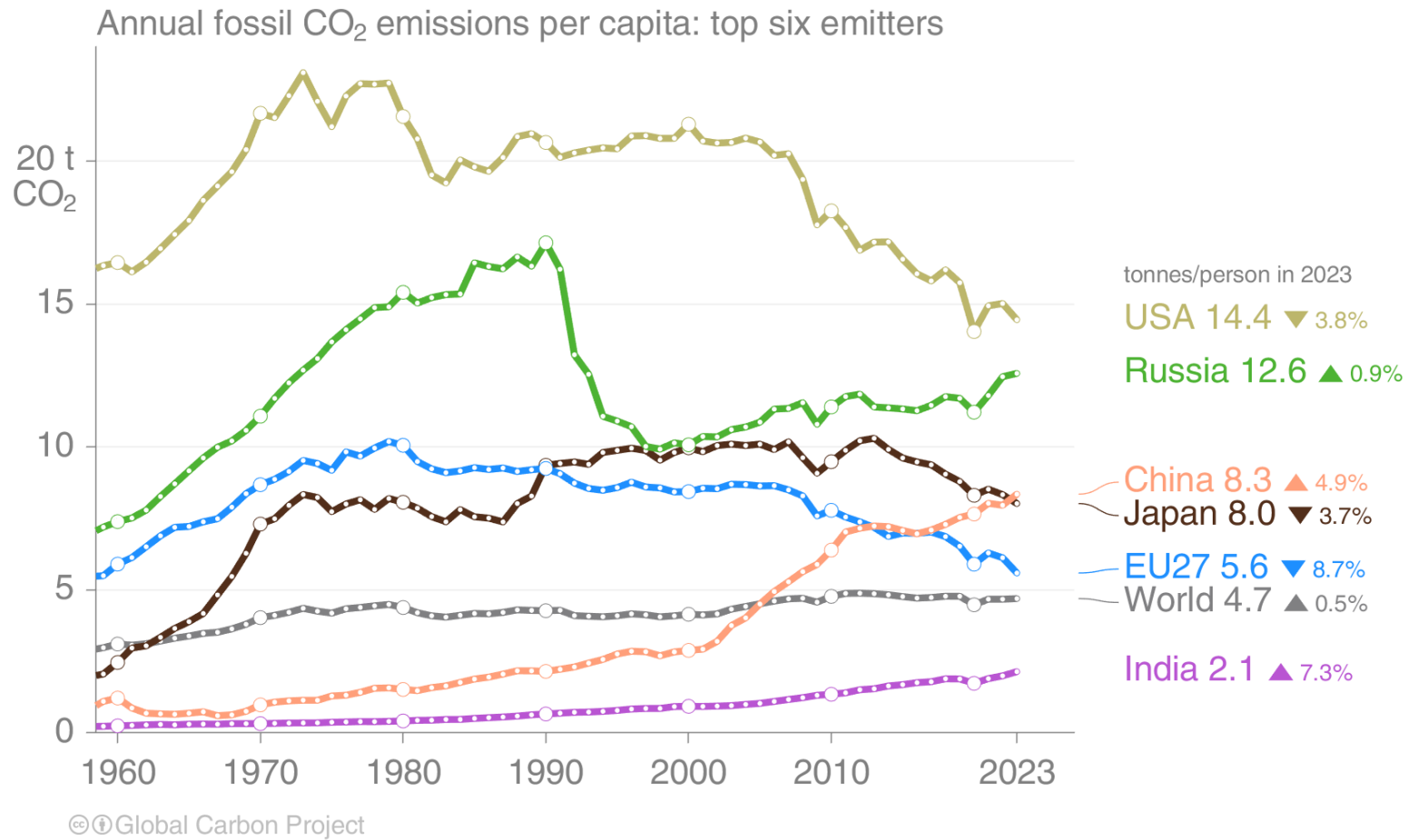


International aviation and maritime shipping (bunker fuels) contributed 3.0% of global emissions in 2023.

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Top emitters: Fossil CO<sub>2</sub> emissions per capita to 2023

Countries have a broad range of per capita emissions reflecting their national circumstances

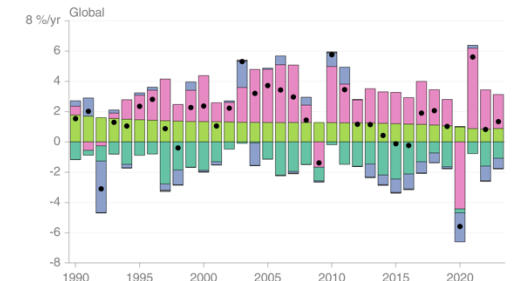
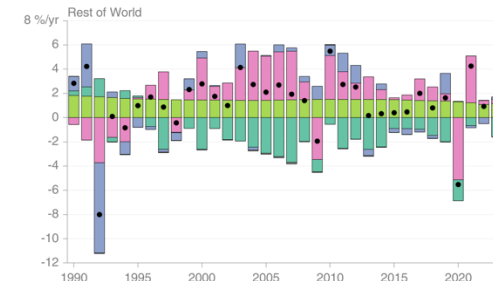
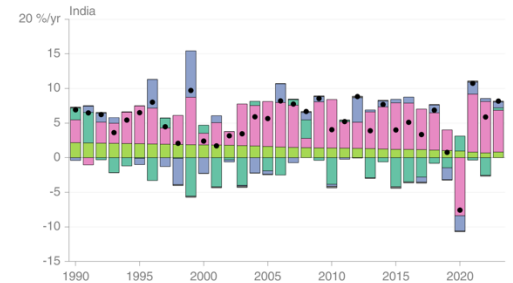
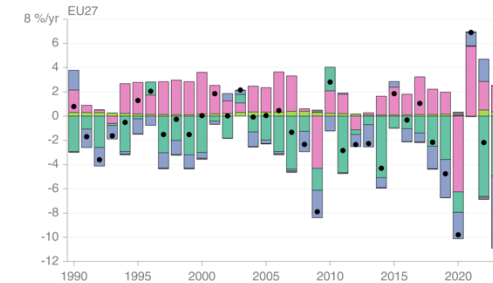
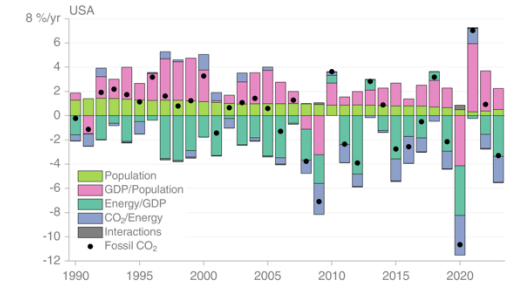
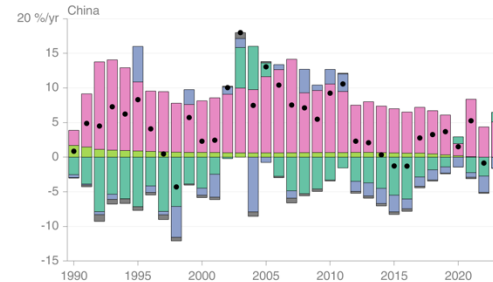
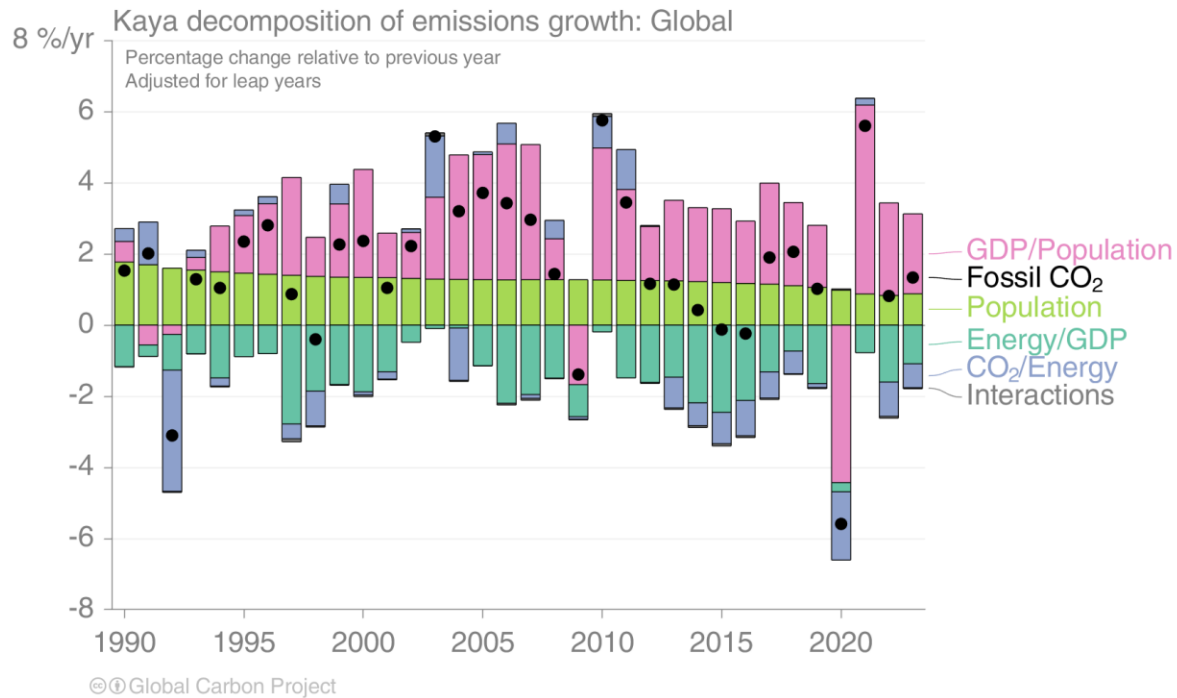


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Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

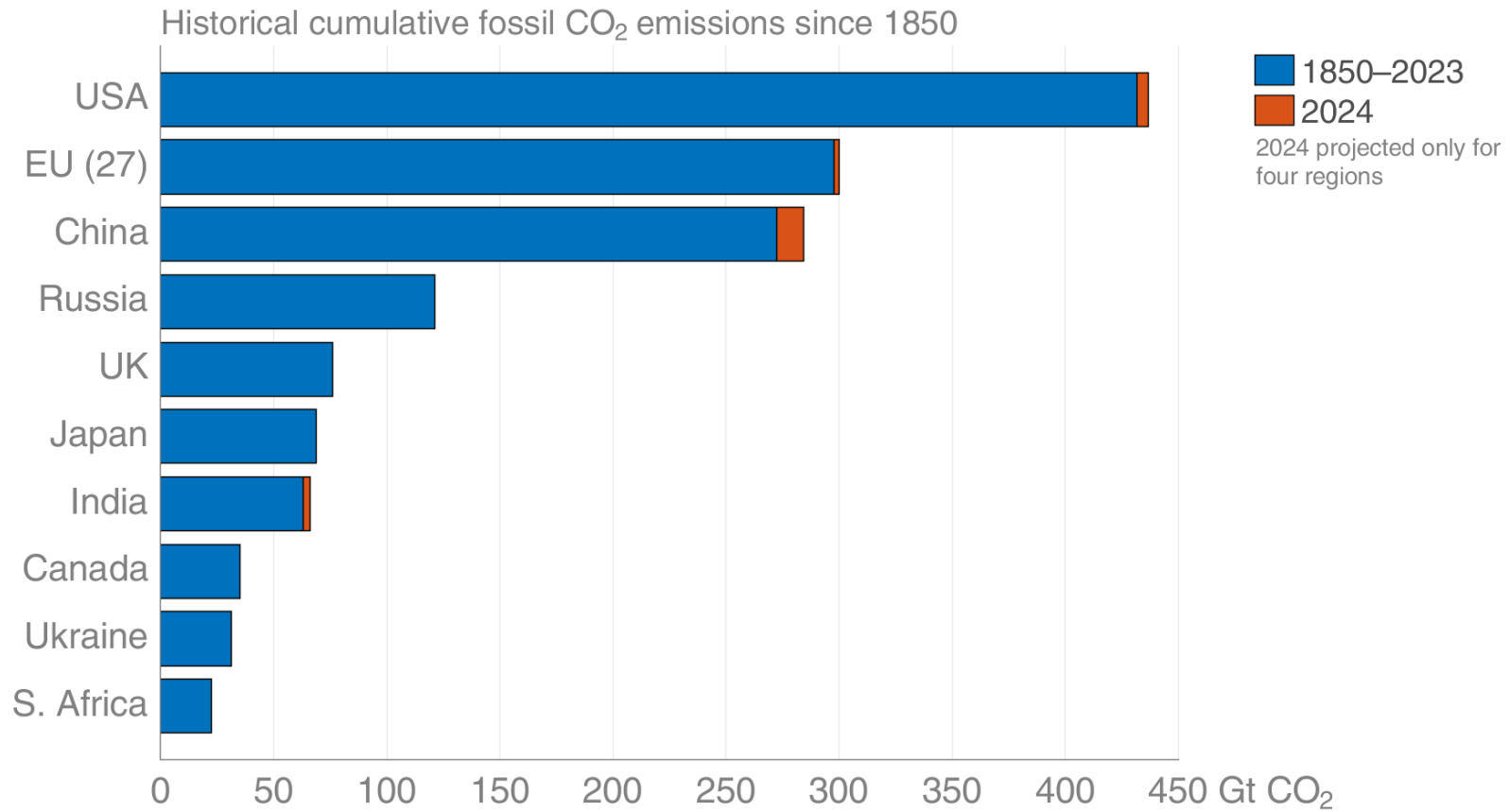
# Fossil CO<sub>2</sub> emissions — Kaya decomposition

Globally, decarbonisation and declines in energy per GDP are largely responsible for the reduced growth rate in emissions over the last decade. 2020 was a clear outlier with a sharp decline in GDP.



# Historical cumulative fossil CO<sub>2</sub> emissions

The USA and EU have the highest accumulated fossil CO<sub>2</sub> emissions since 1850, but China is a close third.



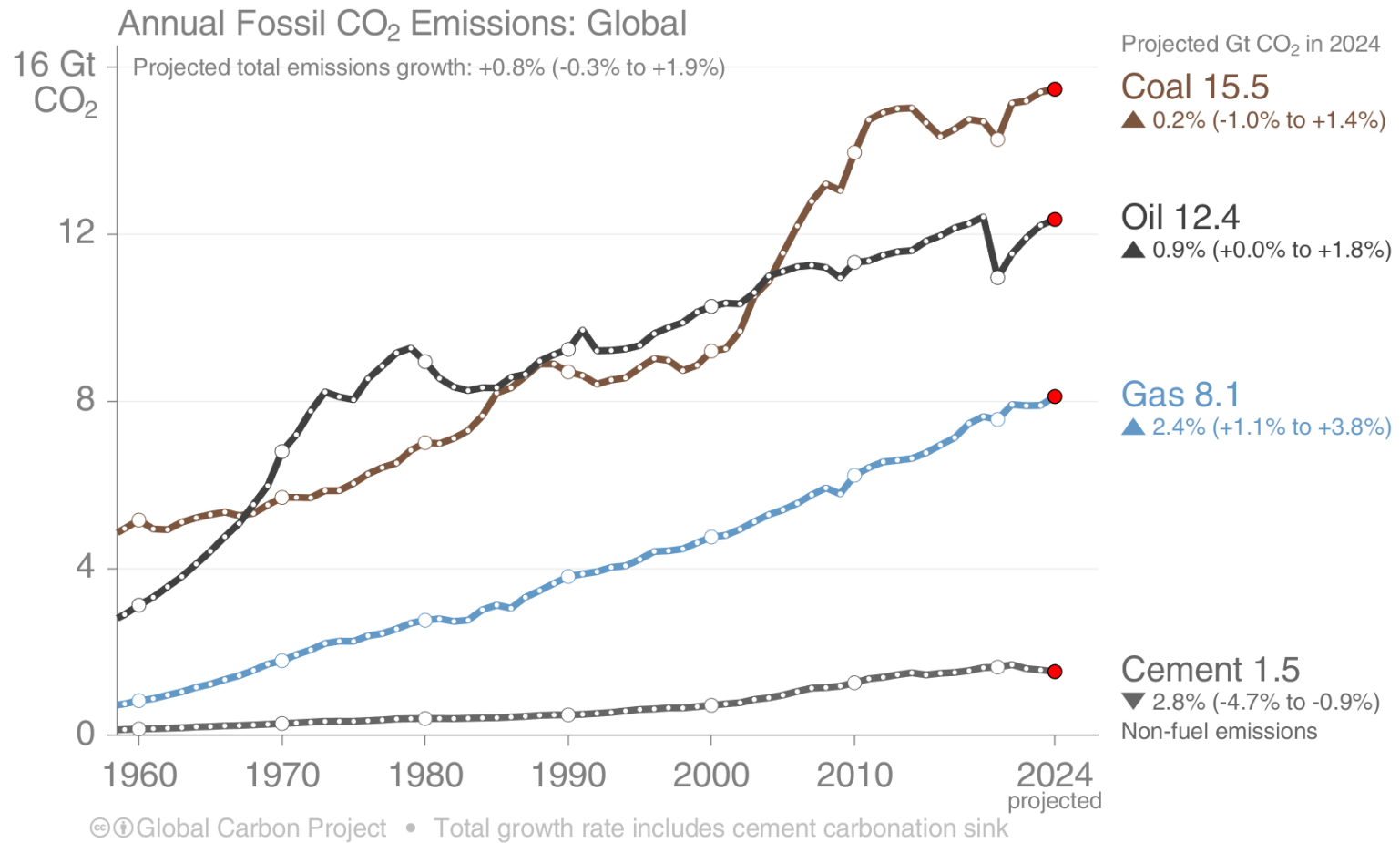
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Calculated using territorial emissions.  
 Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Fossil CO<sub>2</sub> emissions by source

# Fossil CO<sub>2</sub> emissions by source

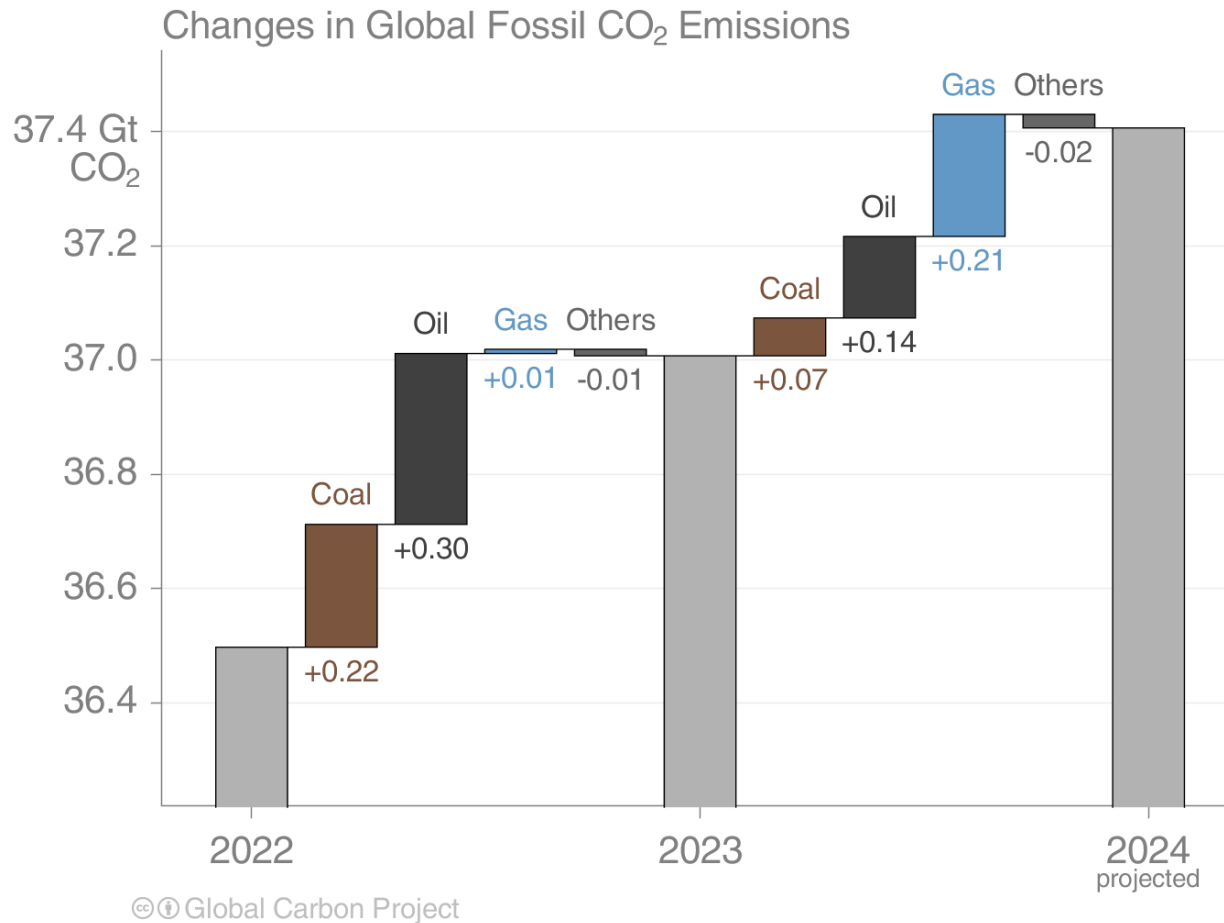
Share of global fossil CO<sub>2</sub> emissions in 2024: coal (41%), oil (32%), gas (21%), cement (4%), flaring and others (2%, not shown)



The 2024 projection is based on preliminary data and modelling.  
 Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

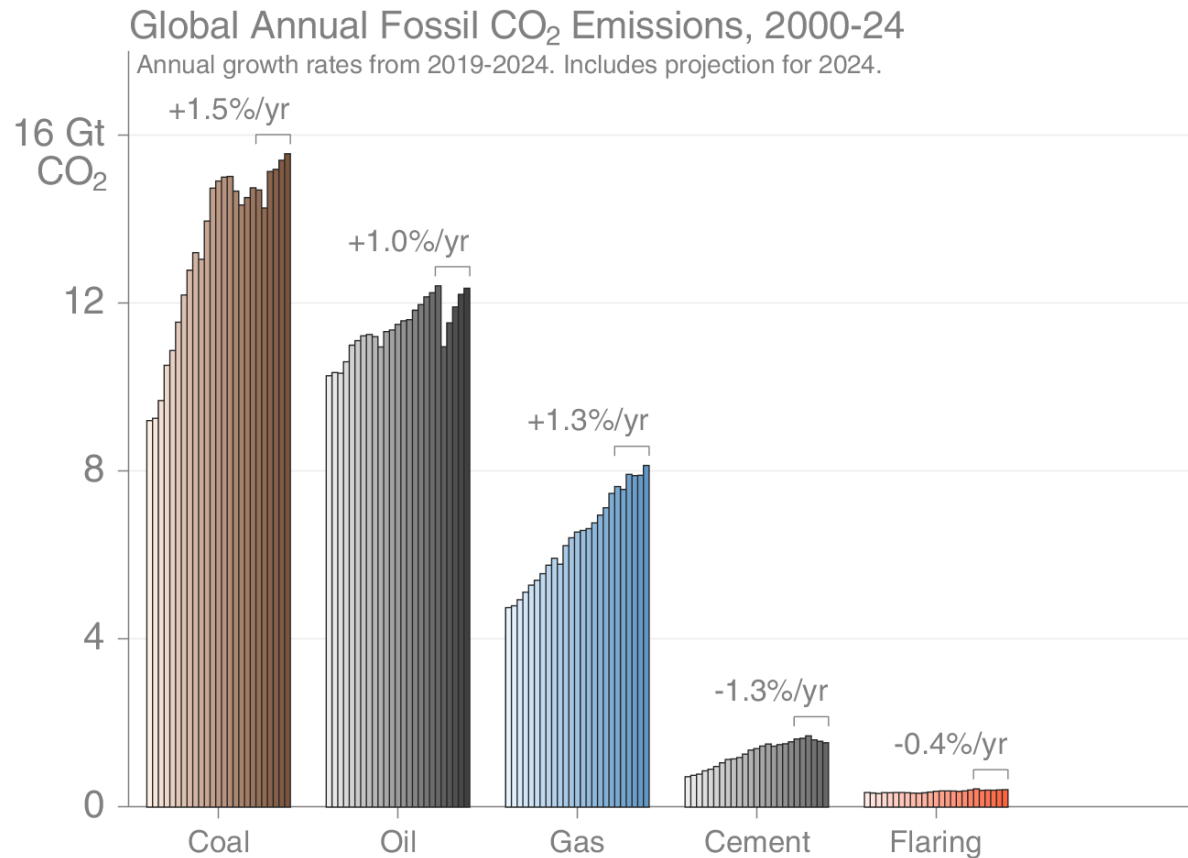
# Fossil CO<sub>2</sub> emissions growth: 2022–2024

Global emissions from oil continued to rebound in both 2023 and 2024 with recovery of aviation. In 2023 natural gas grew slowly because of supply constraints but returns to growth in 2024. Coal continues to climb.



# Fossil CO<sub>2</sub> emissions by source

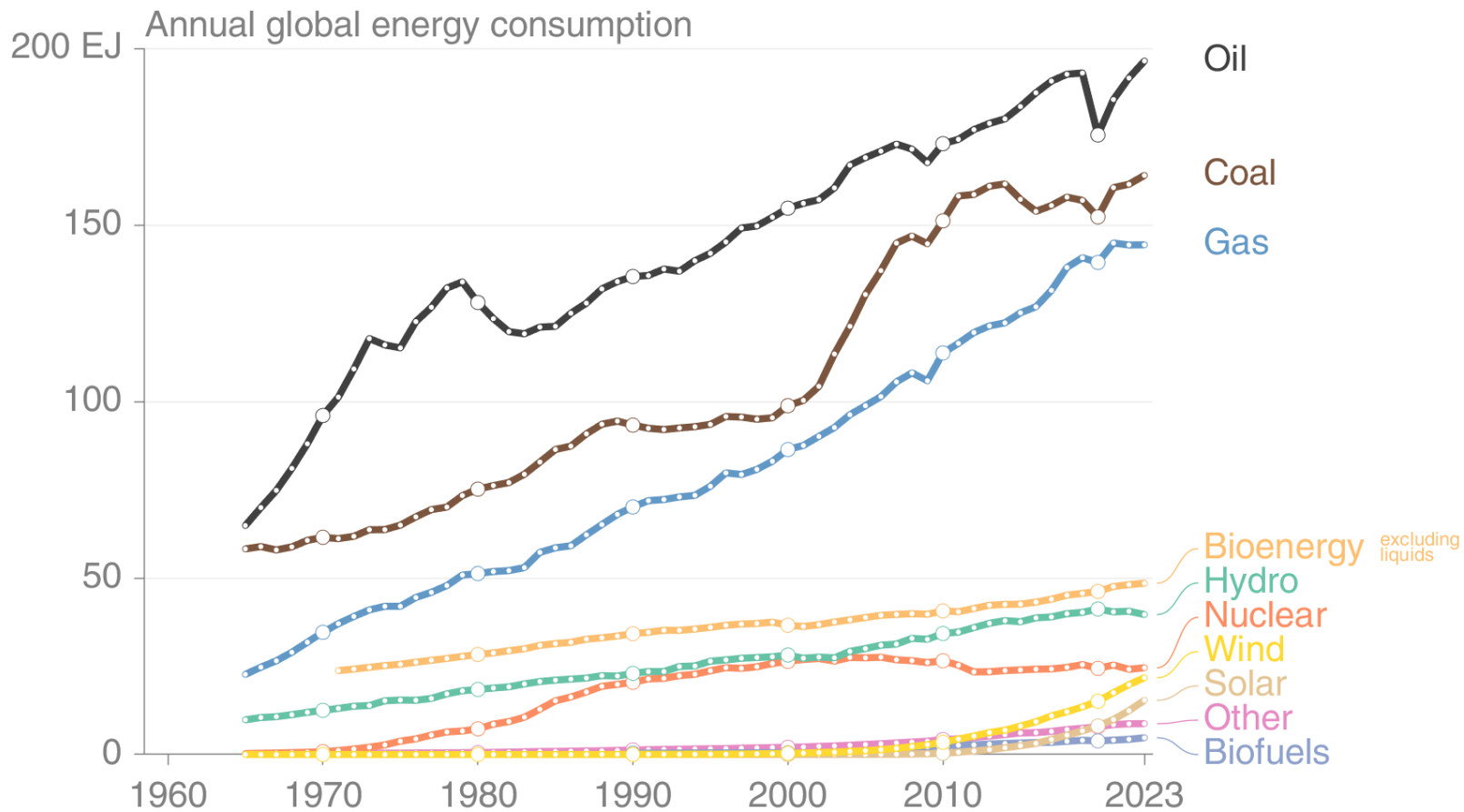
Emissions by category from 2000 to 2024, with growth rates indicated for the more recent period of 2019 to 2024  
 Coal use has returned to growth, and both coal and oil declined sharply in the pandemic year 2020



© Global Carbon Project

# Energy use by source

Consumption of natural gas was flat in 2023, but oil exceeded its pre-pandemic level. Renewable energy continued to grow, but needs to grow even faster to replace fossil energy consumption.



© Global Carbon Project • Data: Energy Institute, IEA (bioenergy)

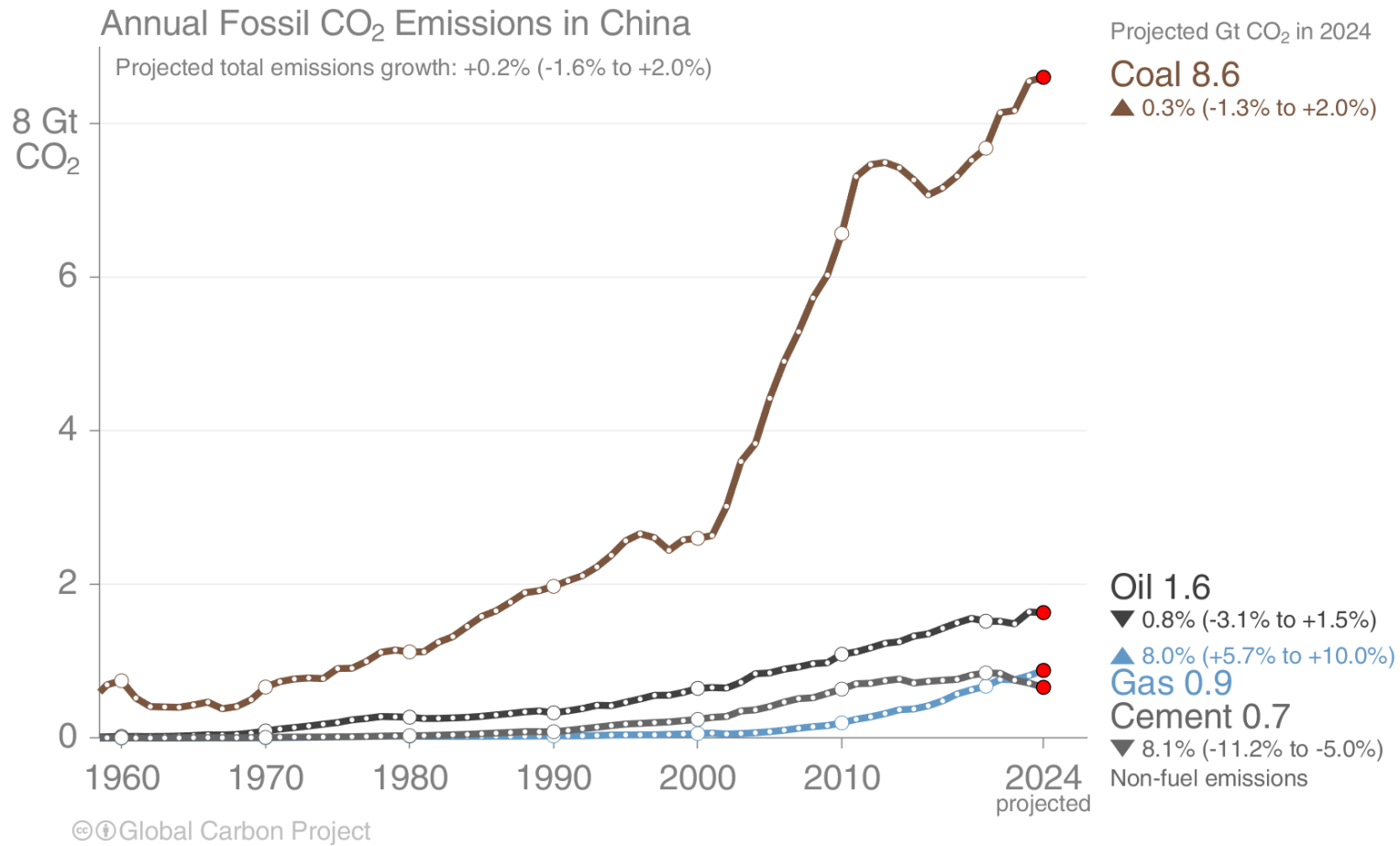
This figure shows “primary energy” using the substitution method (non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)

Source: [Energy Institute 2024](#); [Global Carbon Project 2024](#)

# Fossil CO<sub>2</sub> emission by source for top emitters

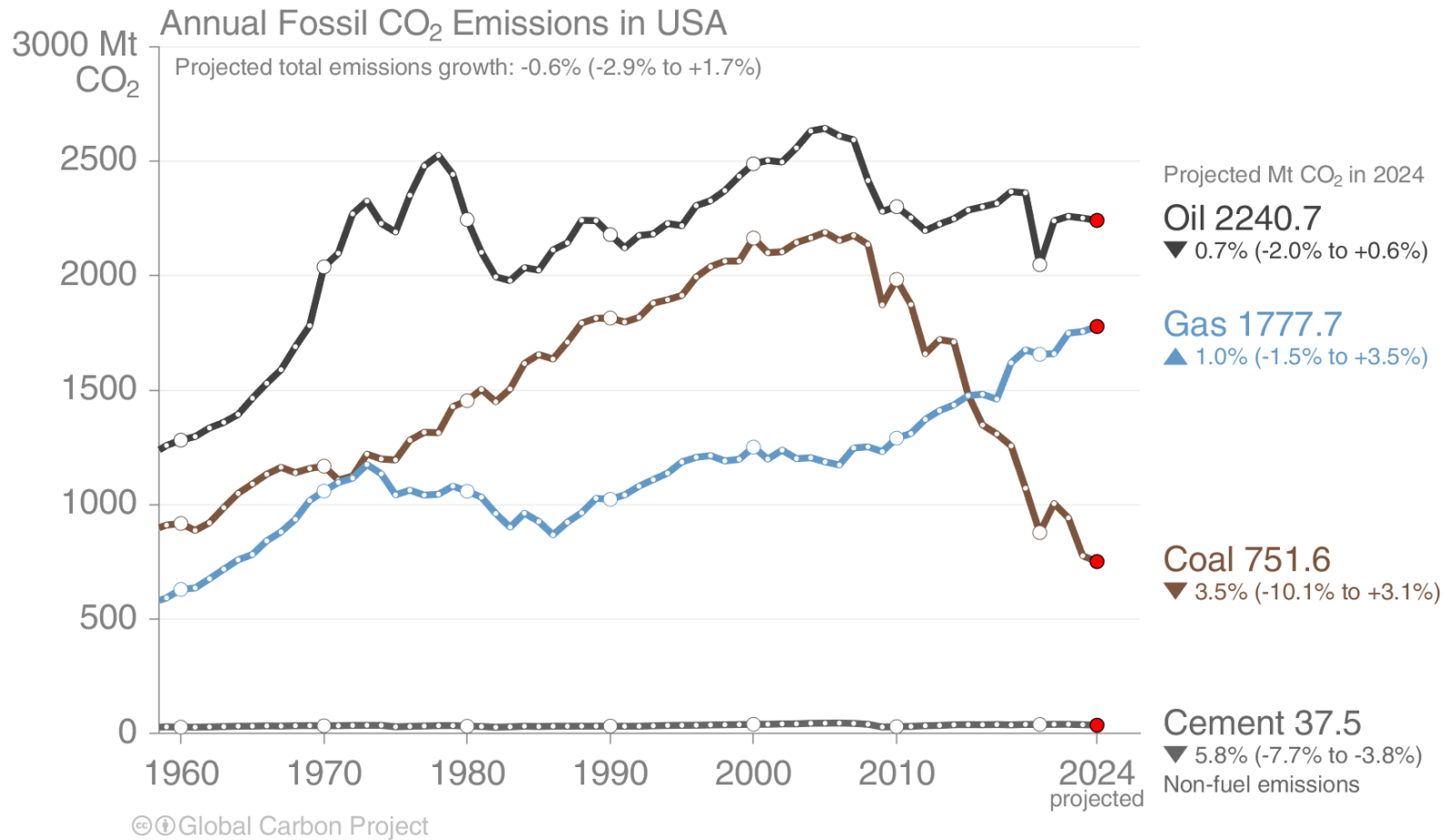
# Fossil CO<sub>2</sub> emissions in China

China's coal and oil consumption levelled off in 2024, while emissions from gas continue to grow strongly



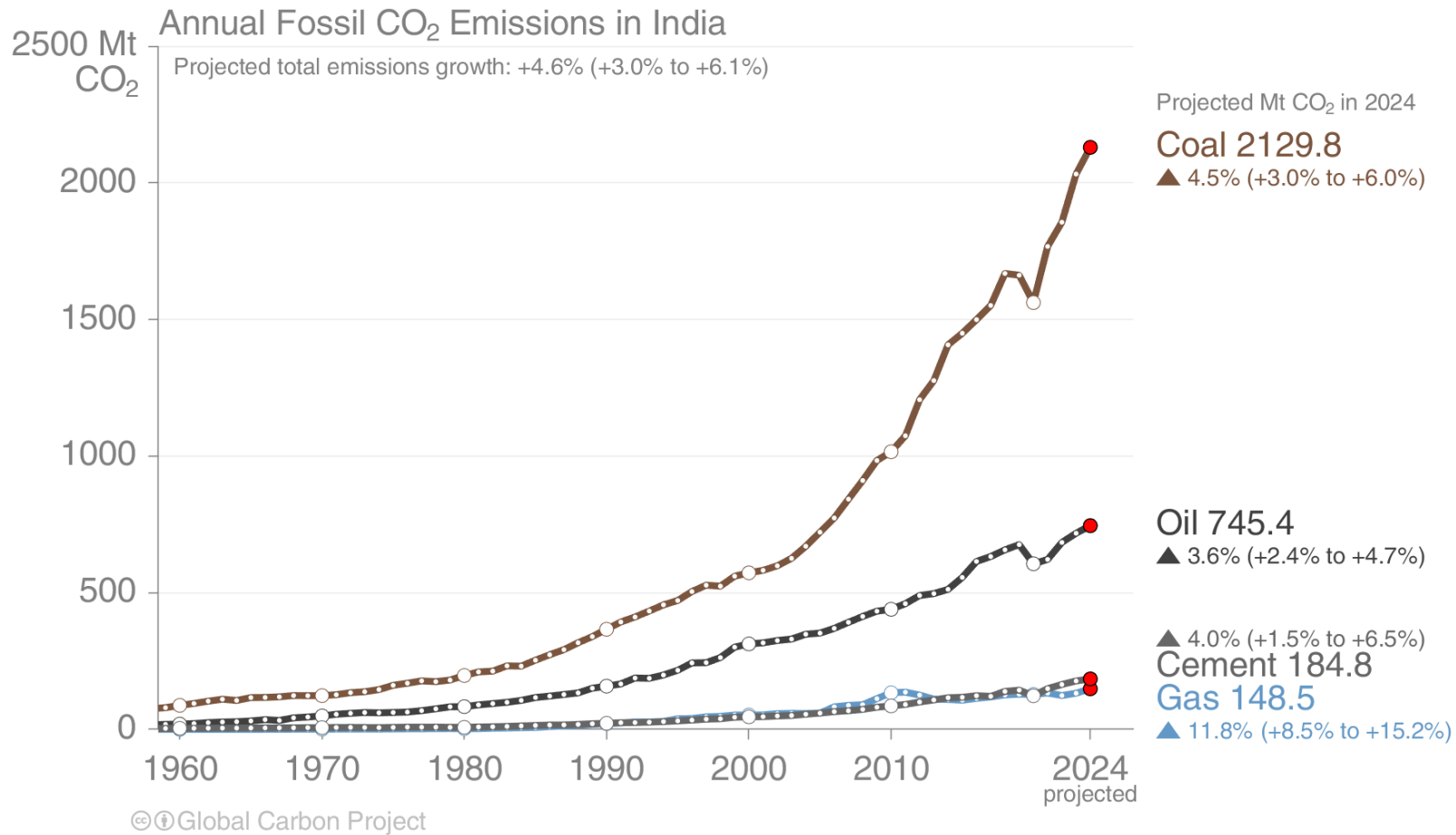
# Fossil CO<sub>2</sub> emissions in USA

The USA's emissions from coal continued their long decline in 2024, to their lowest level since 1902, as the transition to natural gas and growth in renewables continue. Emissions from oil are still below 2019's level.



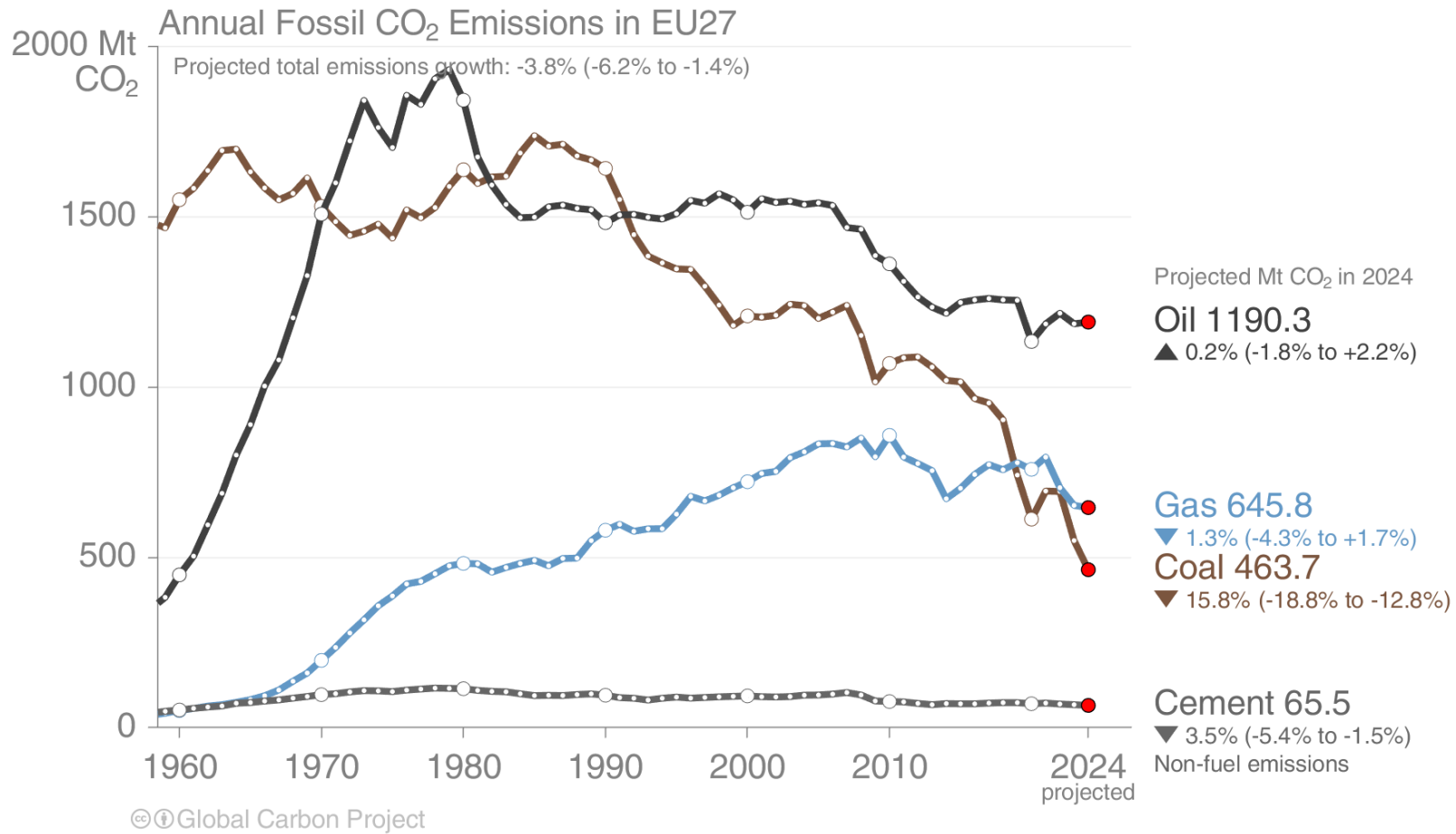
# Fossil CO<sub>2</sub> emissions in India

India's emissions continue to grow strongly in 2024. Increases in solar and wind capacity were far from sufficient to meet a large increase in power demand as the economy grows strongly.



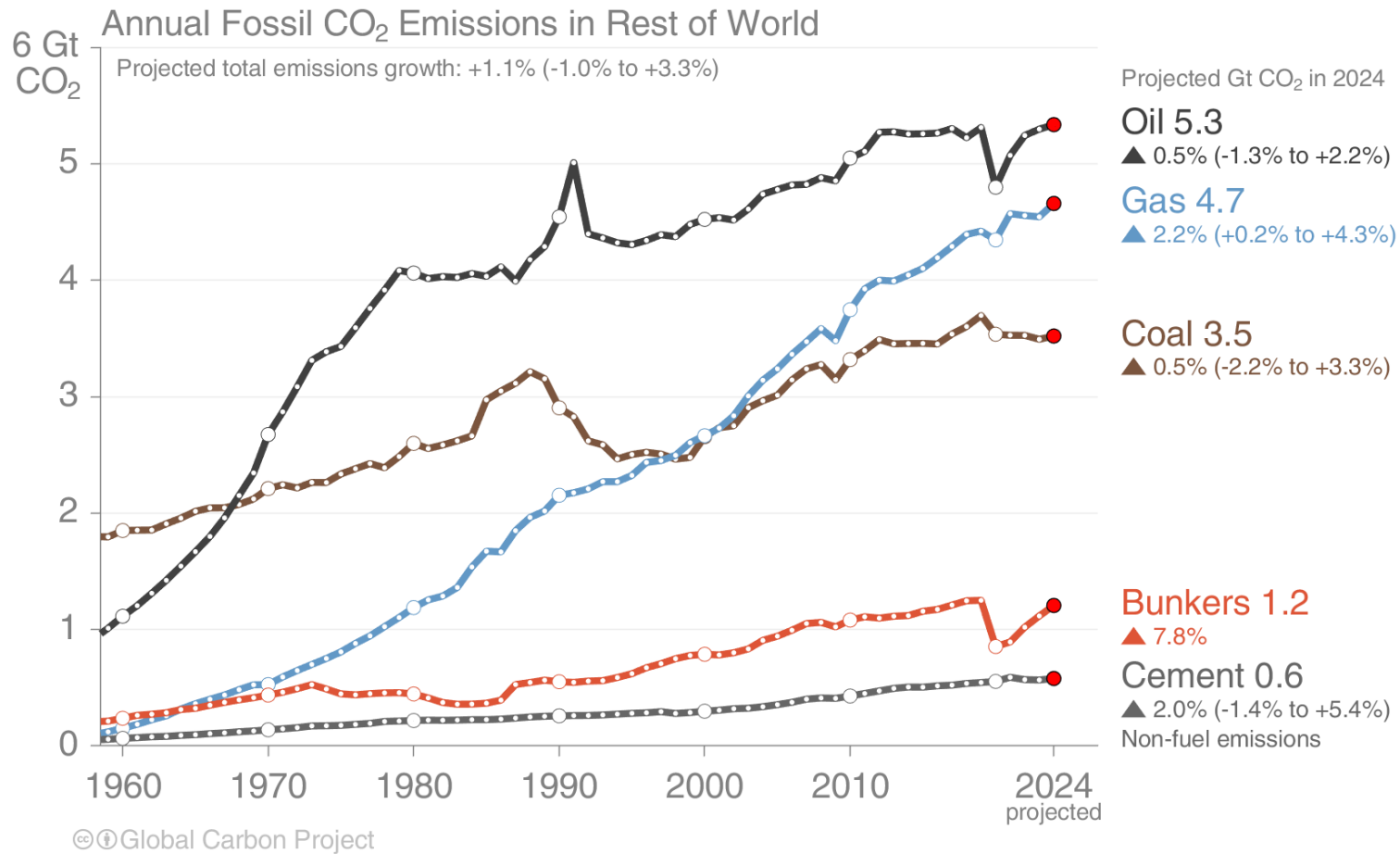
# Fossil CO<sub>2</sub> emissions in the European Union

The EU's emissions from coal continue to fall strongly in 2024, a result of strong growth in renewables but also economic headwinds caused by high energy costs.



# Fossil CO<sub>2</sub> emissions in Rest of World

In the rest of the world, emissions from coal and oil grow slightly while natural gas jumps again. Oil in international aviation grew strongly again, nearing pre-pandemic levels.



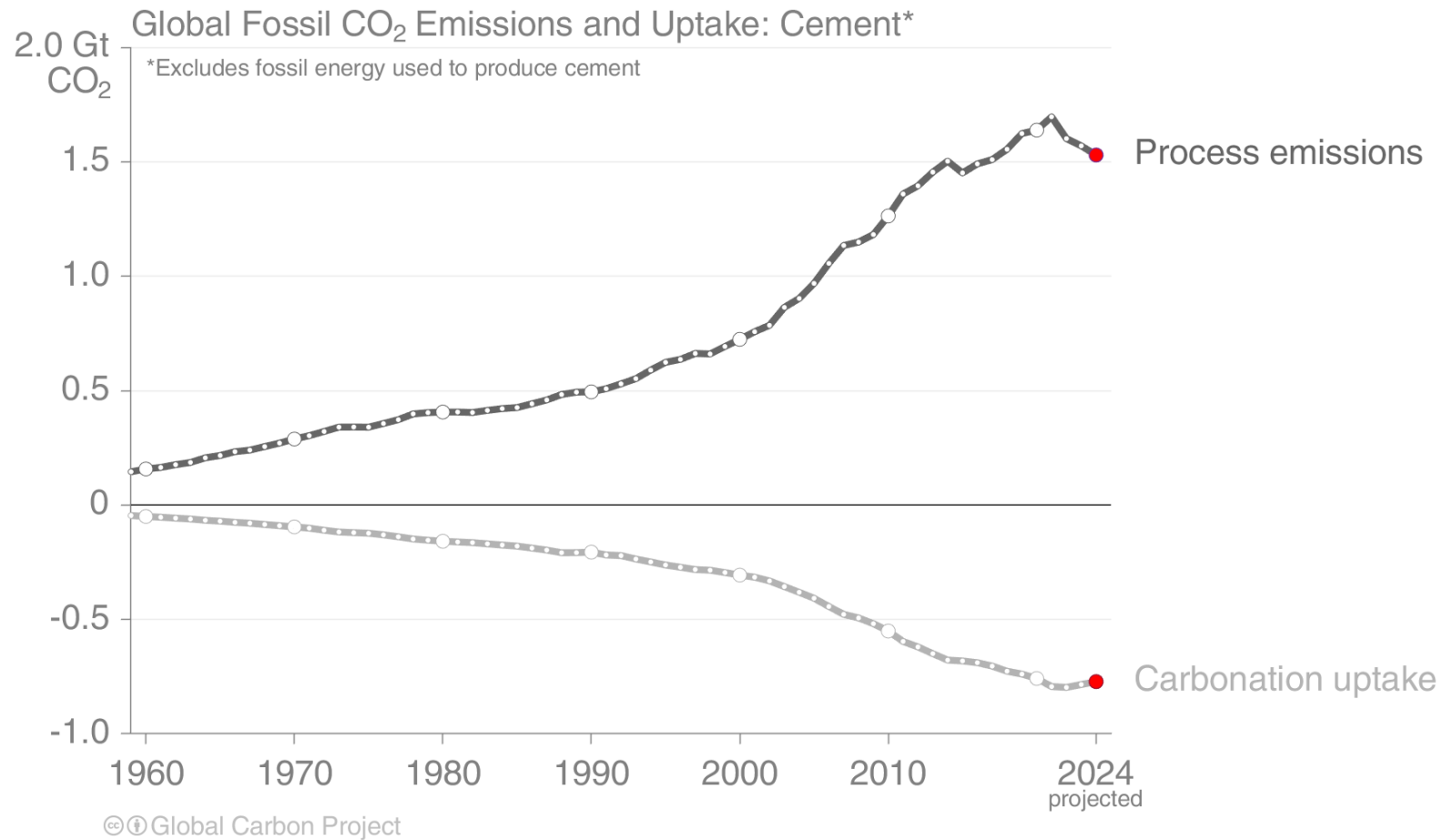
The Rest of the World is the global total less China, US, EU, and India.

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Cement carbonation sink

# Cement carbonation sink

The production of cement results in ‘process’ emissions of CO<sub>2</sub> from the chemical decomposition of carbonates. During its lifetime, cement re-absorbs some CO<sub>2</sub> from the atmosphere.

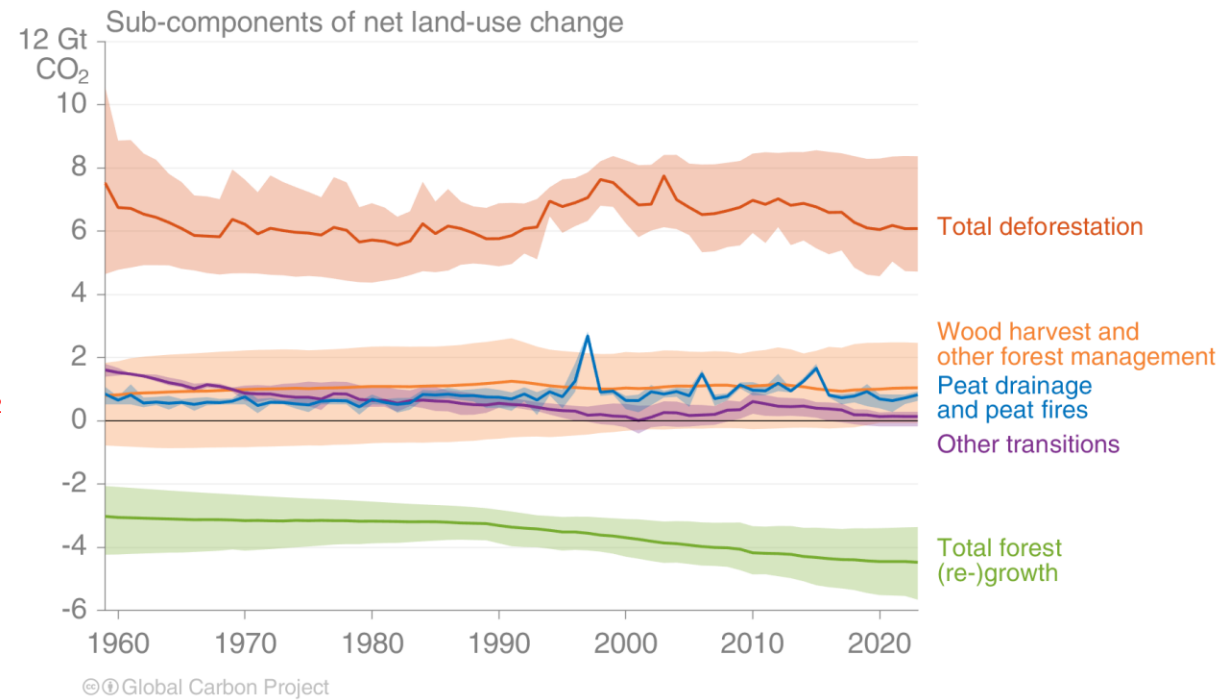
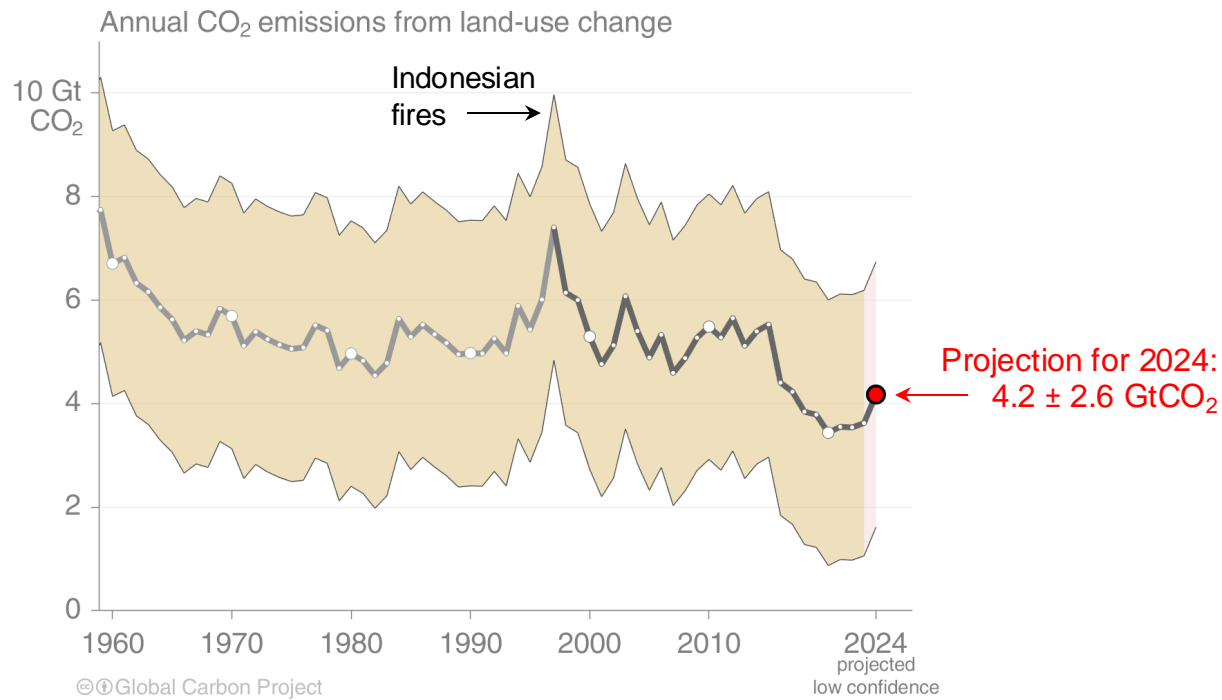


# Land-use change emissions

# Land-use change emissions

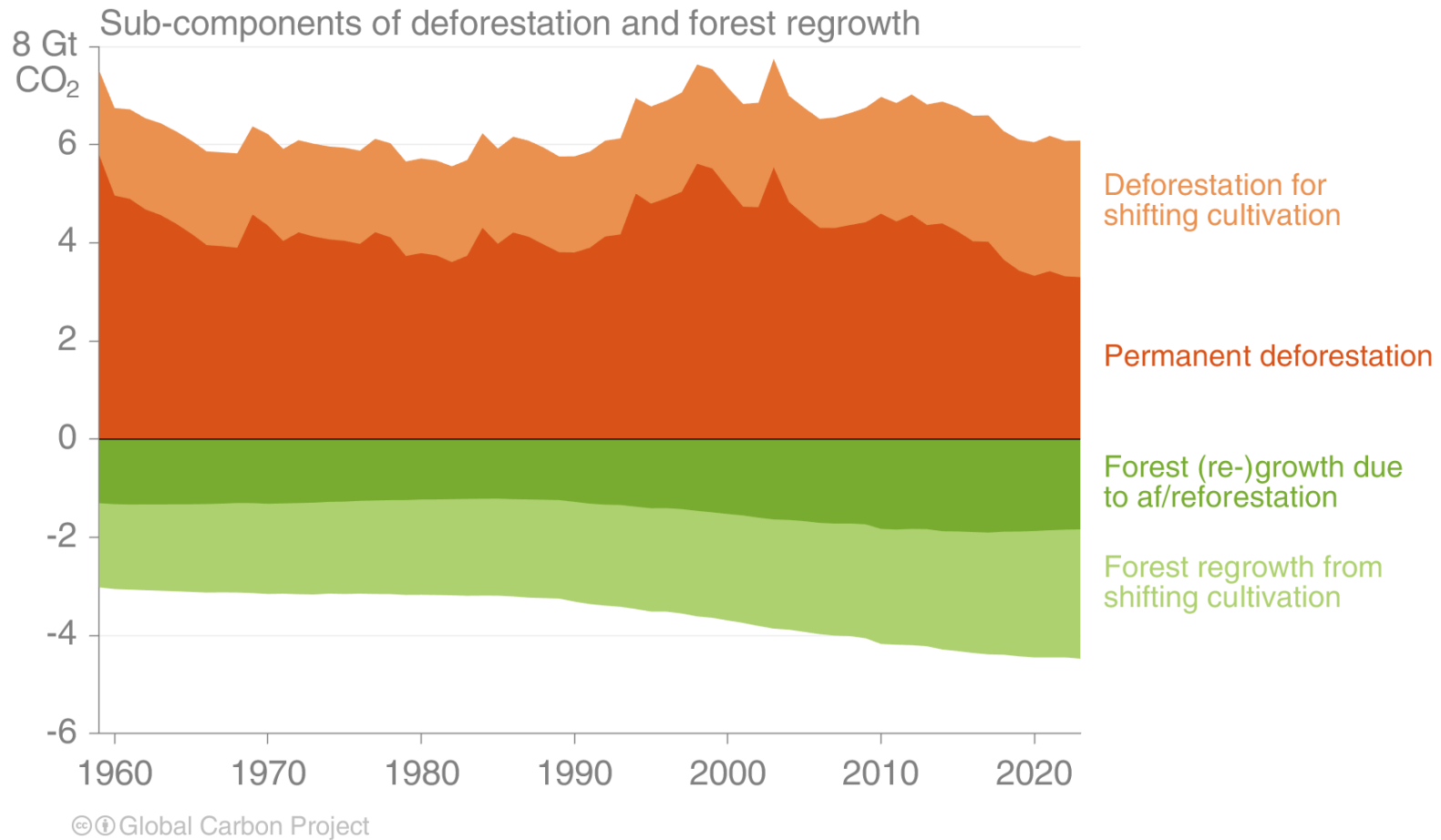
Land-use change emissions were  $4.1 \pm 2.6$  GtCO<sub>2</sub> per year for 2014–2023, and show a negative trend in the last two decades, but estimates are still highly uncertain.

Net land-use emissions are the result of multiple anthropogenic activities on land that lead to CO<sub>2</sub> emissions or removals



# Land-use change emissions

Annual emissions from permanent deforestation declined over 2014–2023 but remain high at around 3.7 GtCO<sub>2</sub>. Carbon dioxide removals through permanent af/reforestation are 1.9 GtCO<sub>2</sub> per year over the same period.

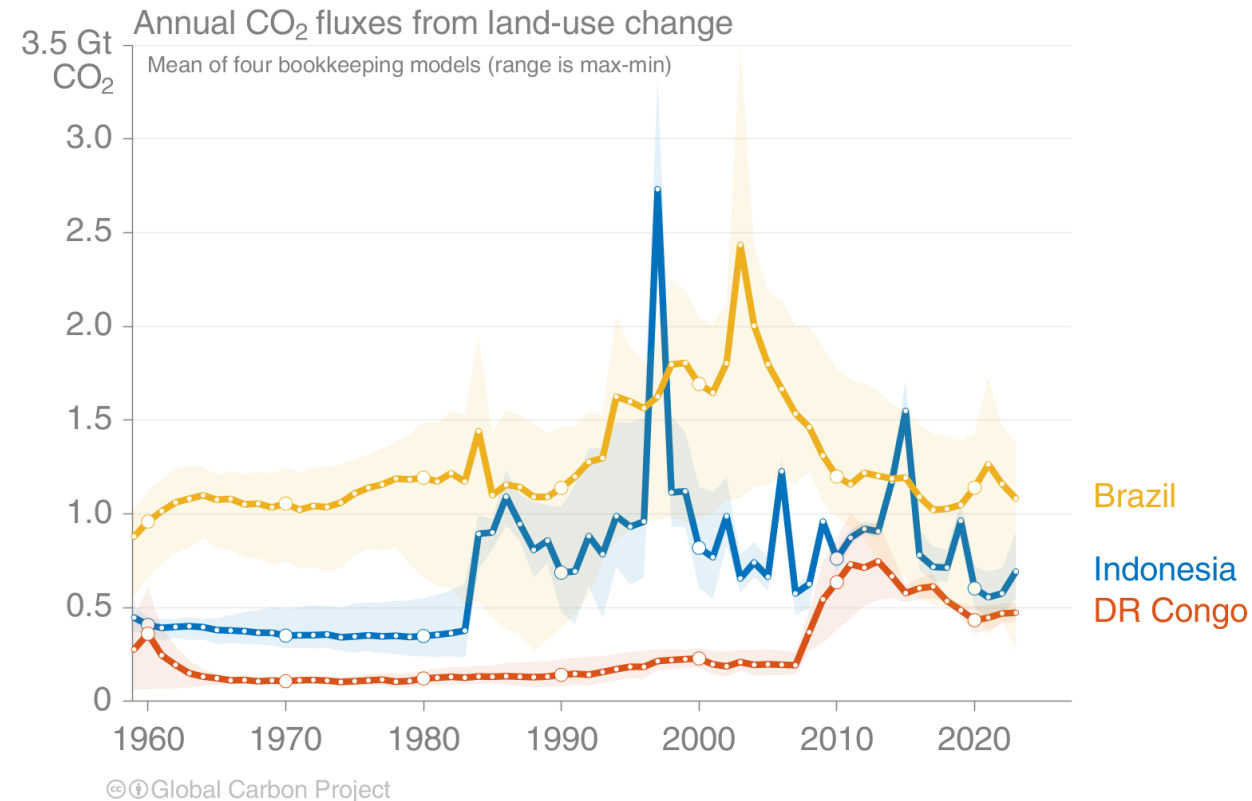
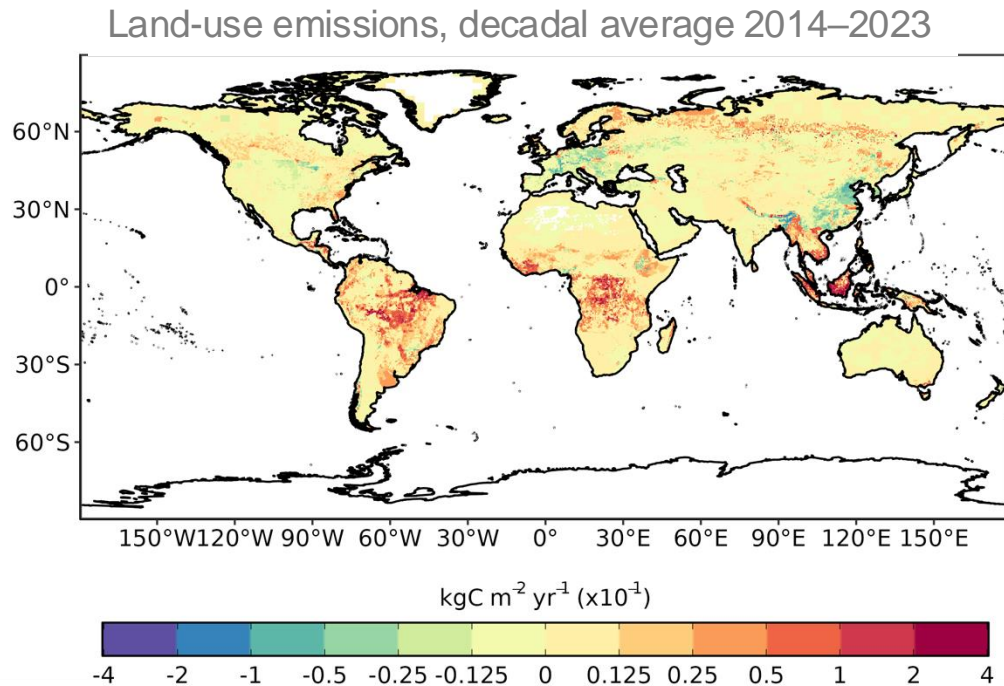


Estimates from four bookkeeping models  
 Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Regional patterns of land-use change emissions

Land-use emissions are high in the tropics, driven largely by deforestation. Net sinks occur in regions of re/afforestation such as parts of Europe and China.

The top three emitters over 2014–2023 – Brazil, Indonesia, and the Democratic Republic of the Congo – contribute 60% of the global net land-use emissions.

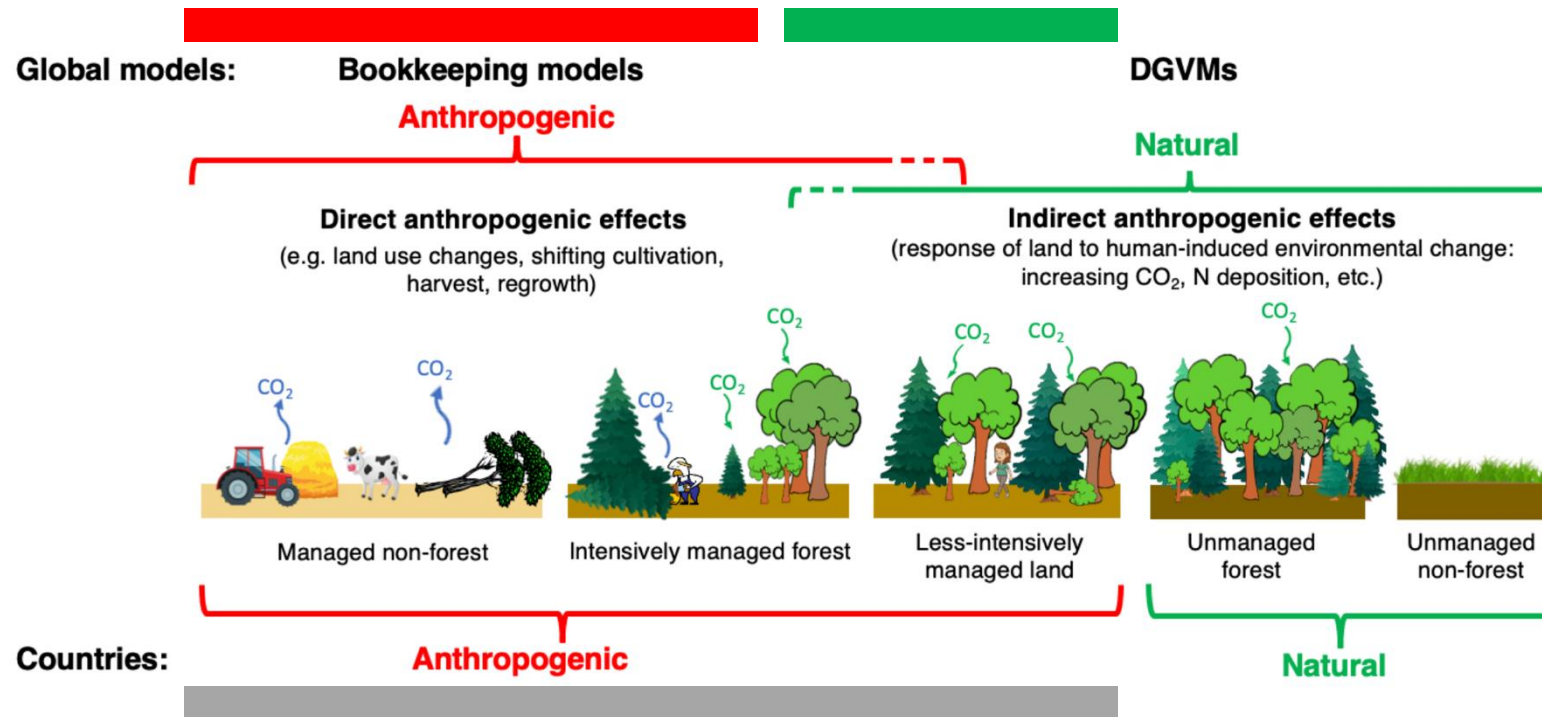


The peak in Indonesia in 1997 was the Indonesian peat fires.

# Linking global models to country reports

## Mapping of global carbon cycle model land flux definitions to the definition of the LULUCF net flux used in national Greenhouse Gas Inventories (NGHGI) reported to UNFCCC

When natural fluxes on managed forests (-6.7 GtCO<sub>2</sub> per year for 2014–2023) are added to land-use emissions (4.1 GtCO<sub>2</sub> per year), the GCB2024 estimates (-2.6 GtCO<sub>2</sub> per year) are very similar to the country-reported data (-2.8 GtCO<sub>2</sub> per year), linking the anthropogenic carbon budget estimates of land CO<sub>2</sub> fluxes directly to the Global Stocktake as part of UNFCCC Paris Agreement.

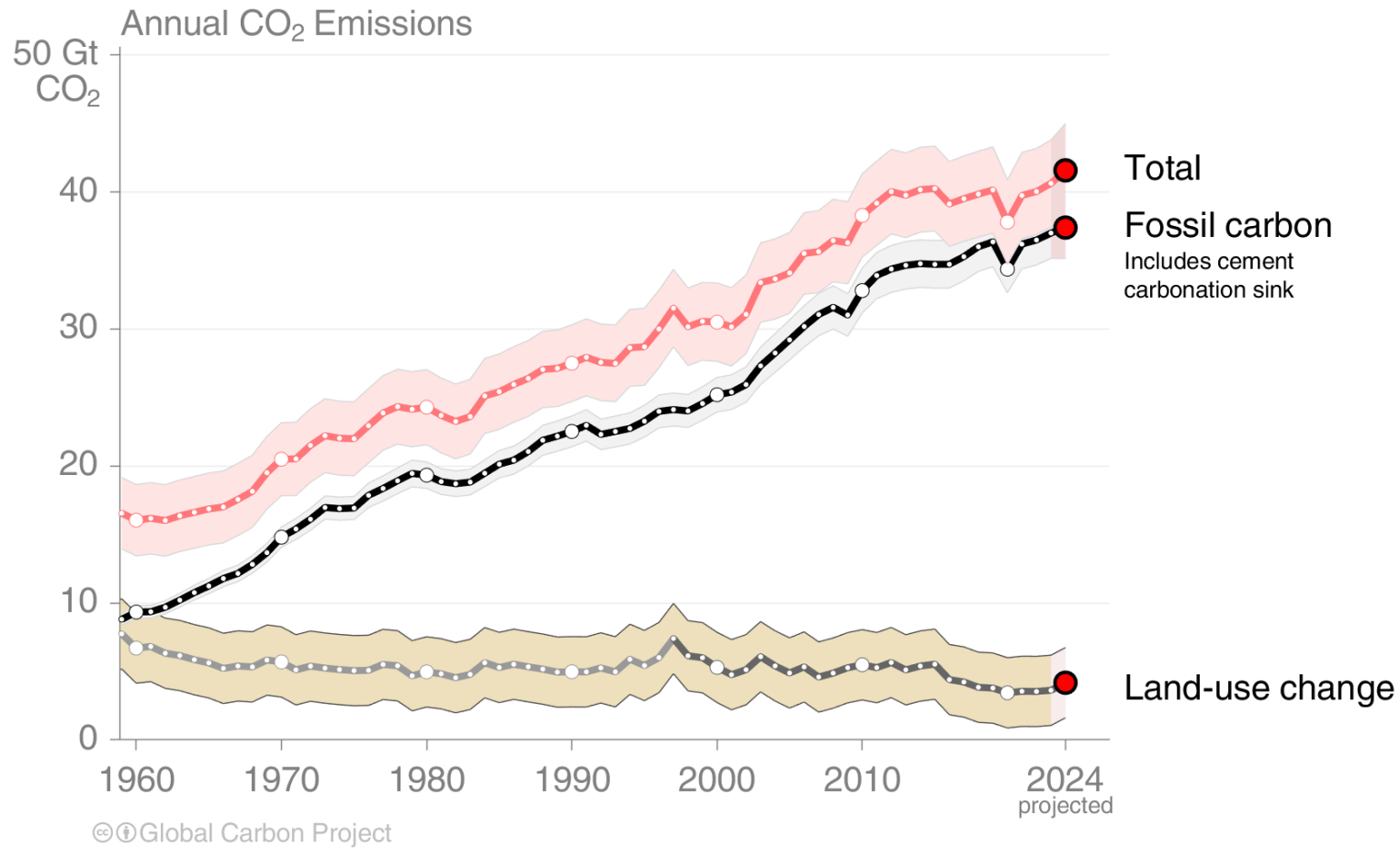


Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

Figure from [Grassi et al., ESSD 2023](#)

# Total global emissions

Total global emissions, projected to reach  $41.6 \pm 3.2$  GtCO<sub>2</sub> in 2024, 51% over 1990  
 Percentage land-use change: 42% in 1960, 10% averaged 2014–2023



Land-use change estimates from four bookkeeping models, using fire-based variability from 1997  
 Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Carbon Dioxide Removal

Equivalent to ~5% of annual Fossil CO<sub>2</sub> emissions



1.9 GtCO<sub>2</sub> per year

Equivalent to ~1 millionth of annual Fossil CO<sub>2</sub> emissions



0.004 MtCO<sub>2</sub> per year

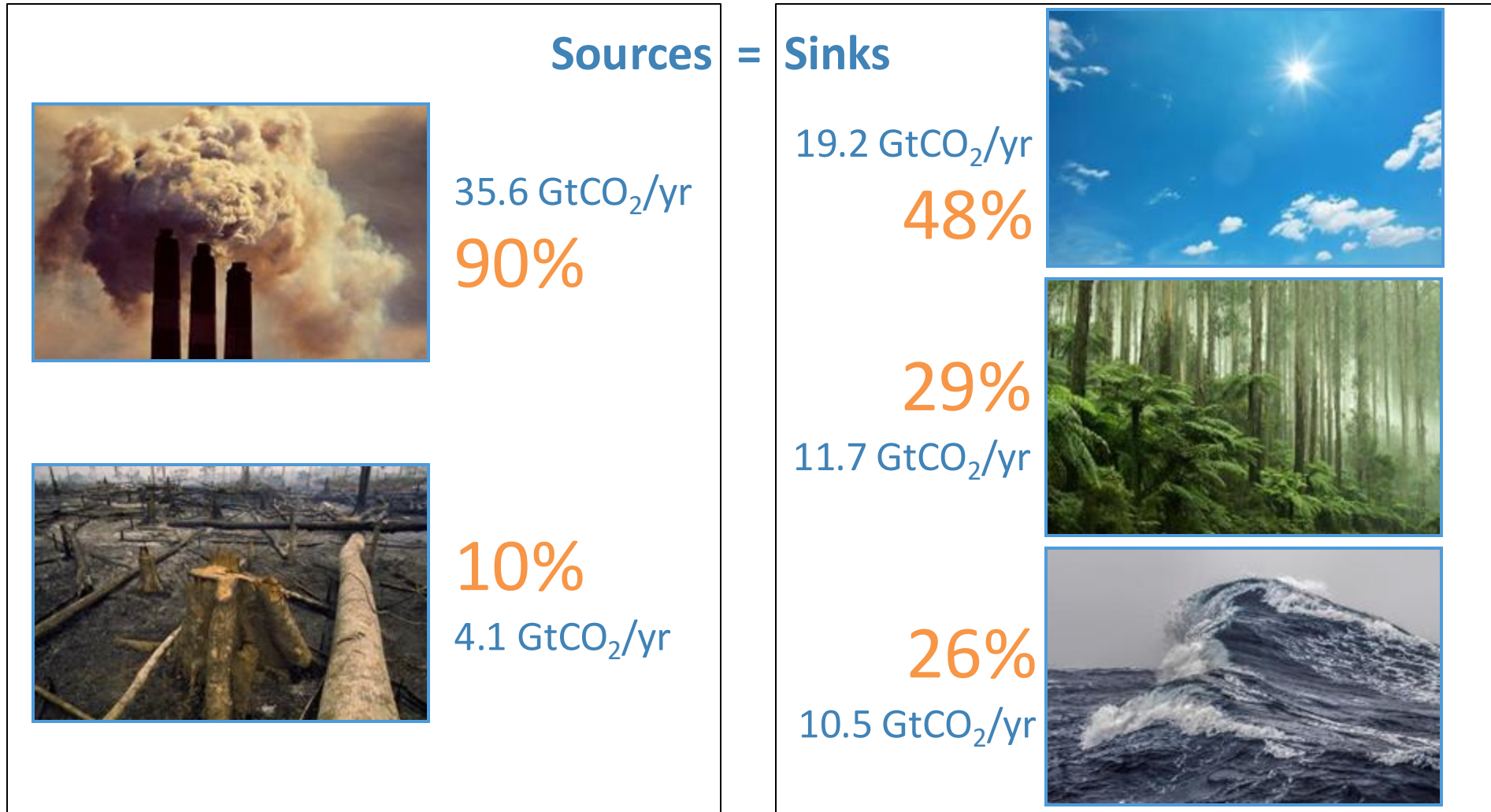


0.03 MtCO<sub>2</sub> per year

Vegetation-based CDR estimates from GCB2024  
CDR not based on vegetation from the State of CDR report (2024)

# Closing the Global Carbon Budget

# Fate of anthropogenic CO<sub>2</sub> emissions (2014–2023)

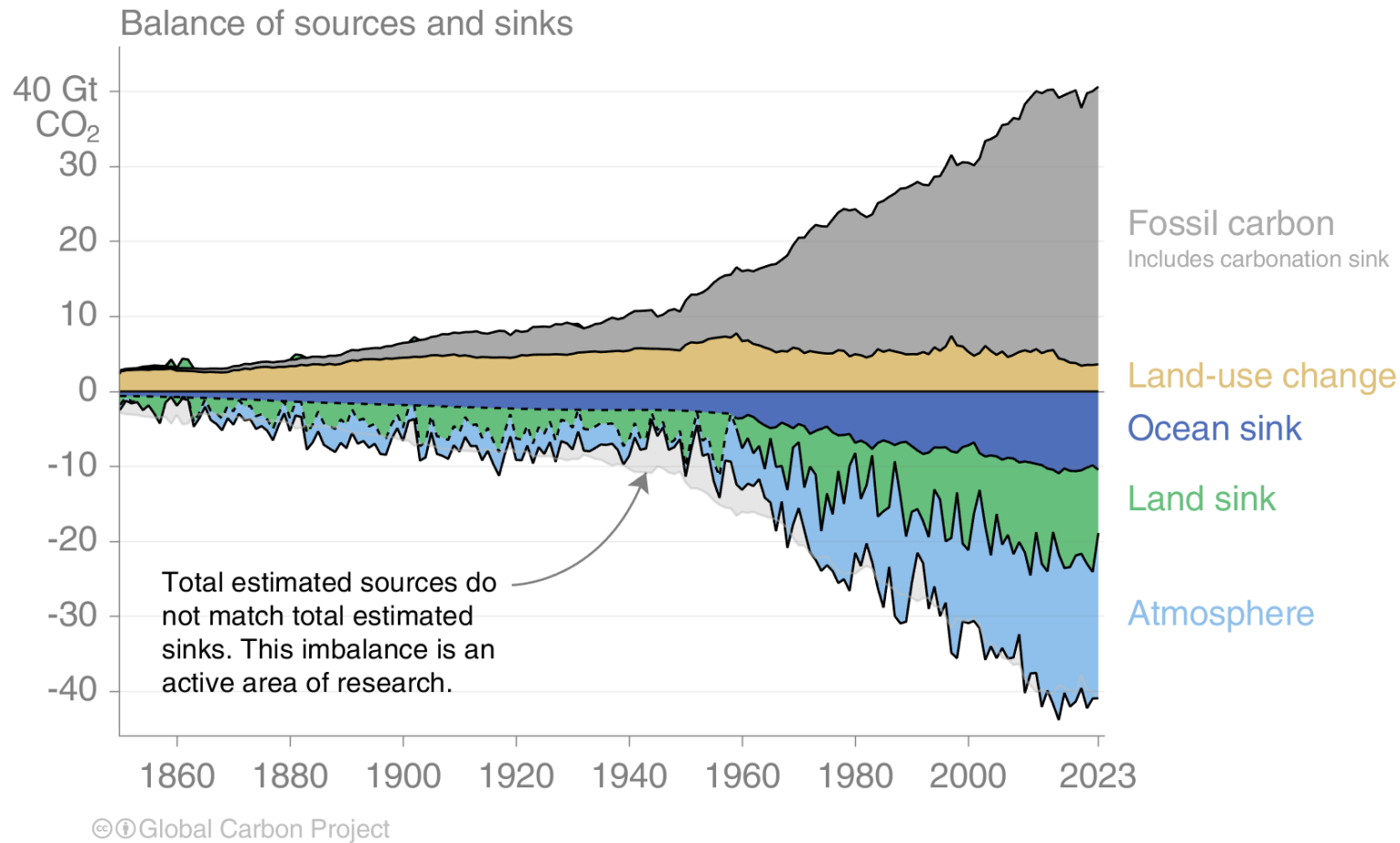


**Budget Imbalance:**  
(the difference between estimated sources & sinks)

**4%**  
-1.6 GtCO<sub>2</sub>/yr

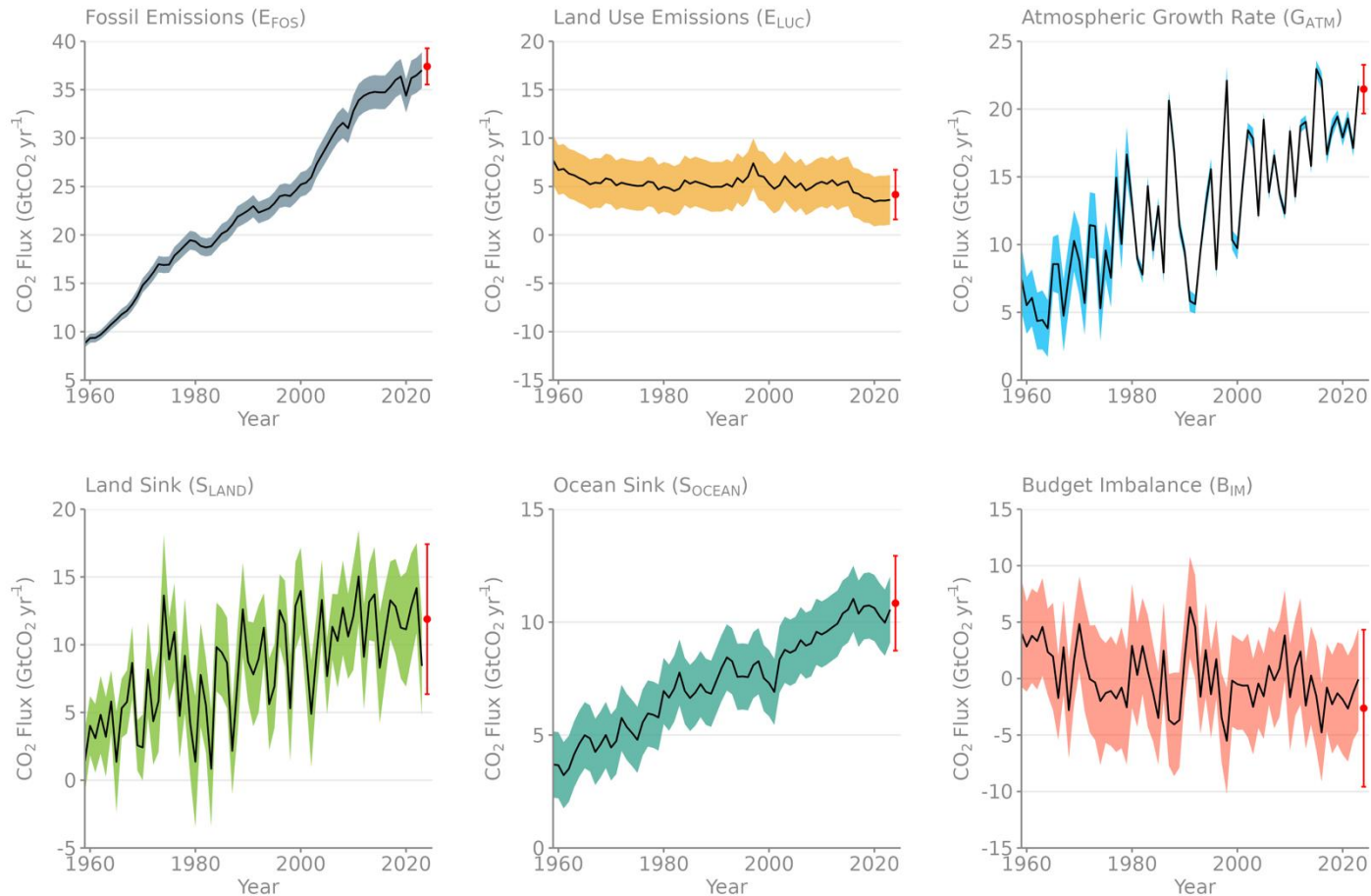
# Global carbon budget

Carbon emissions are partitioned among the atmosphere and carbon sinks on land and in the ocean  
 The “imbalance” between total emissions and total sinks is an active area of research



# Changes in the budget over time

The sinks have continued to grow with increasing emissions, but climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO<sub>2</sub> in the atmosphere

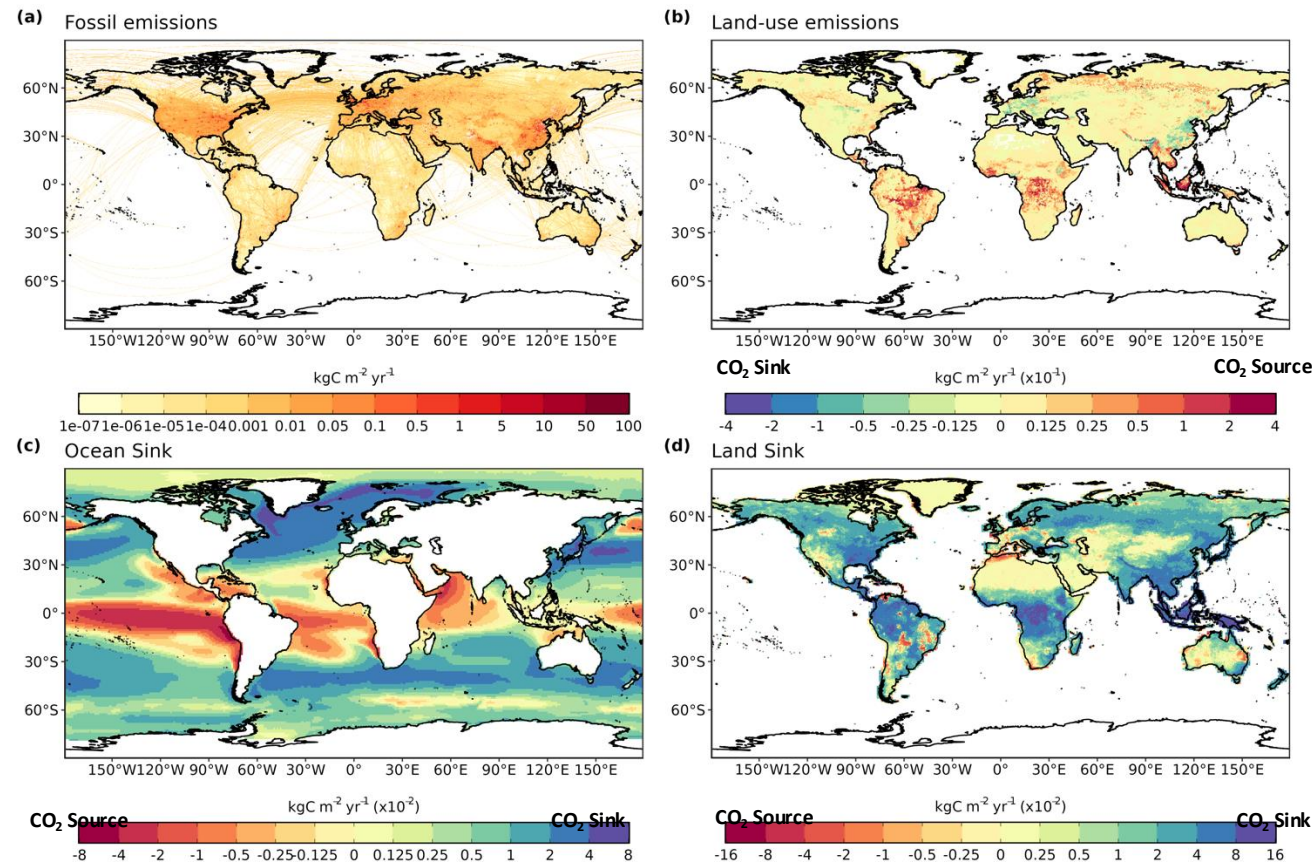


The budget imbalance is the total emissions minus the estimated growth in the atmosphere, land and ocean. It reflects the limits of our understanding of the carbon cycle.

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

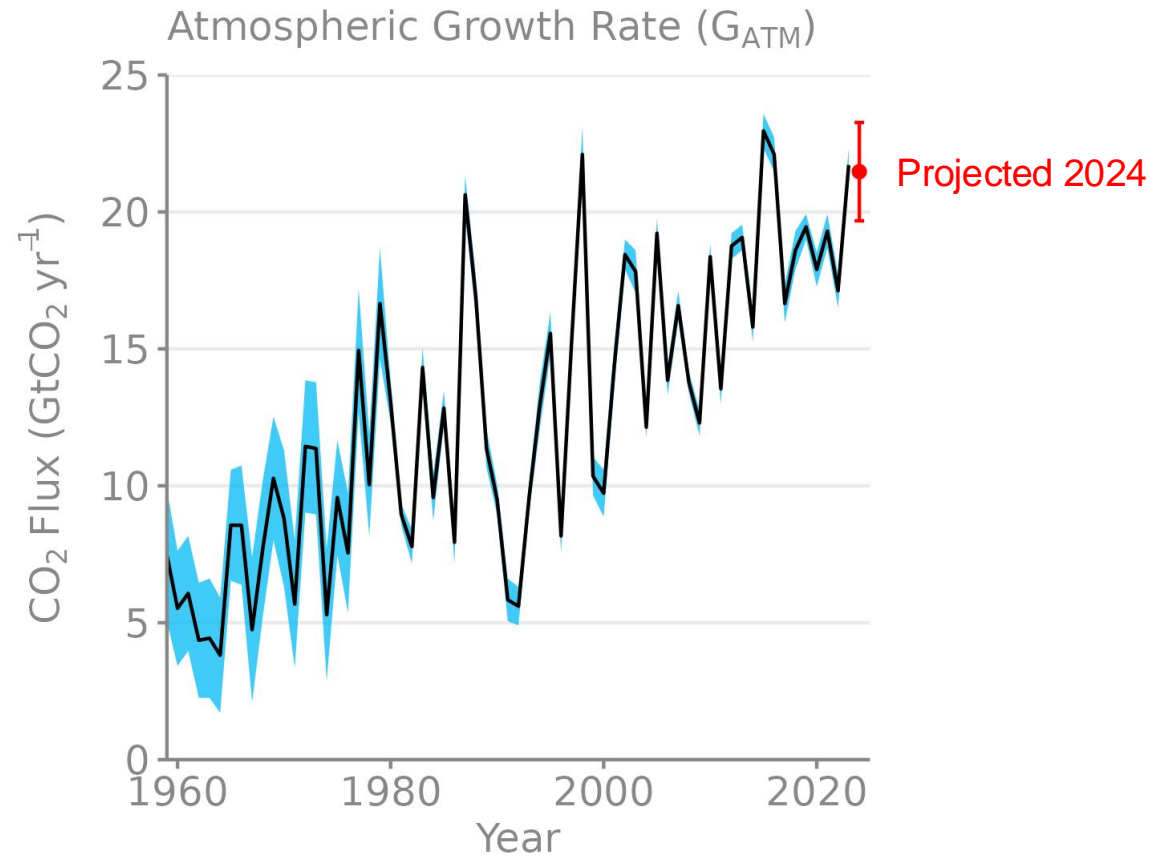
# Global carbon budget

Fossil emissions dominate in the Northern Hemisphere, while land-use emissions are important in the tropics. The North Atlantic and Southern Ocean are carbon sinks while the tropical ocean is a source of CO<sub>2</sub>. Tropical, temperate and boreal forest are the main terrestrial carbon sinks



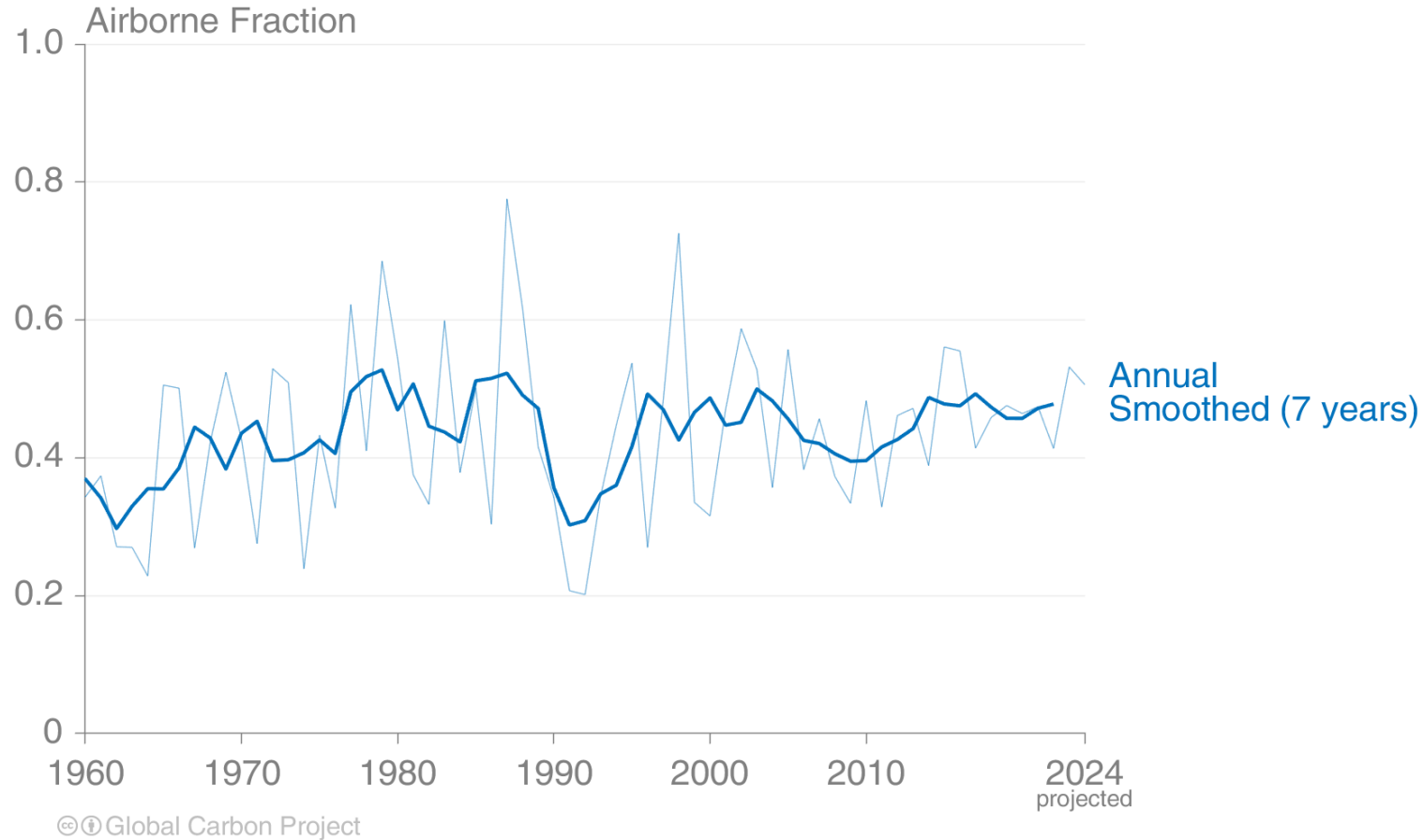
# Atmospheric concentration

The atmospheric concentration growth rate has increased steadily.  
 The high growth in 1987, 1998, & 2015–16 reflect a strong El Niño, which weakens the land sink.



# Airborne Fraction

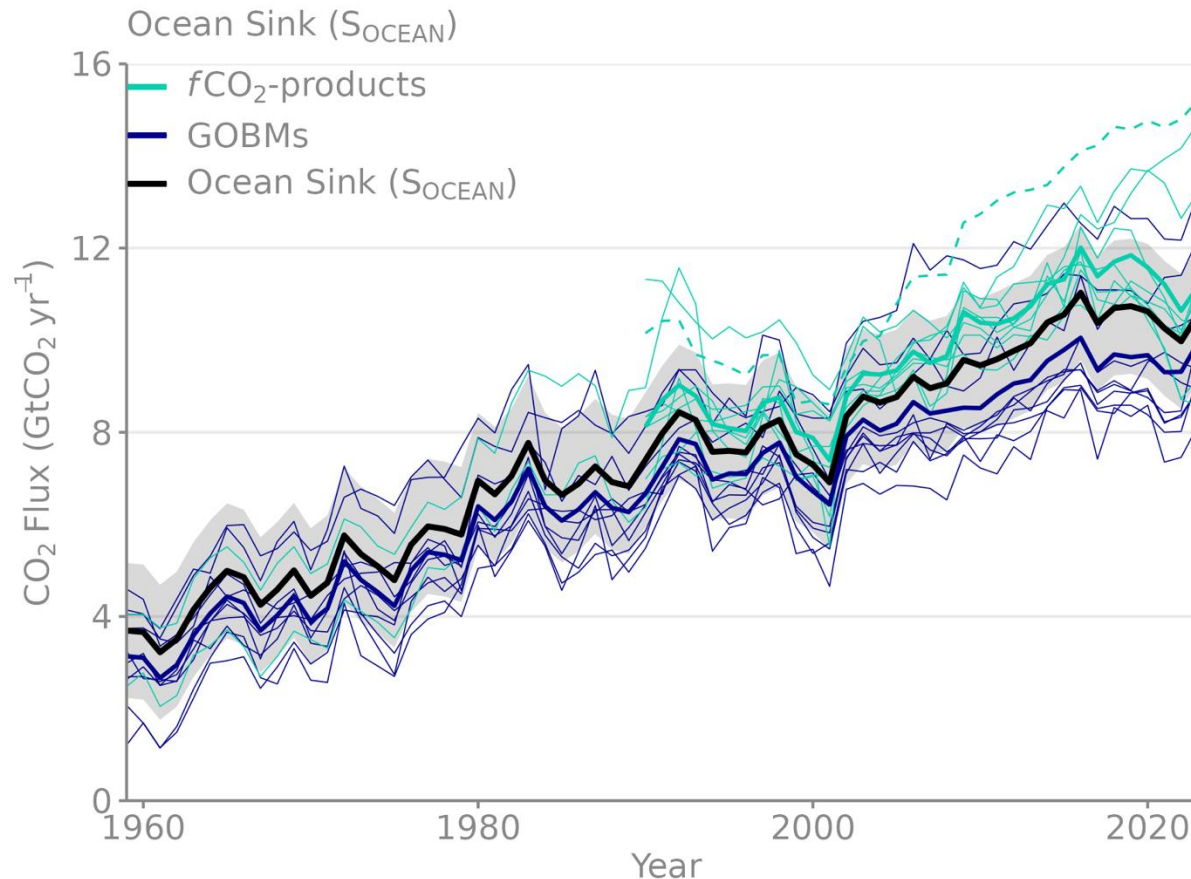
The airborne fraction is the proportion of the total annual CO<sub>2</sub> emissions that remains in the atmosphere.  
 The rest of the CO<sub>2</sub> emissions are removed by the land and ocean sinks.  
 Around 45% of CO<sub>2</sub> emissions remain in the atmosphere despite sustained growth in CO<sub>2</sub> emissions.



# Ocean sink

The ocean carbon sink, estimated by Global Ocean Biogeochemical Models and observation-based data products, amounts to  $10.5 \pm 1.5$  GtCO<sub>2</sub>/yr for 2014–2023 and  $10.6 \pm 1.5$  GtCO<sub>2</sub>/yr in 2023.

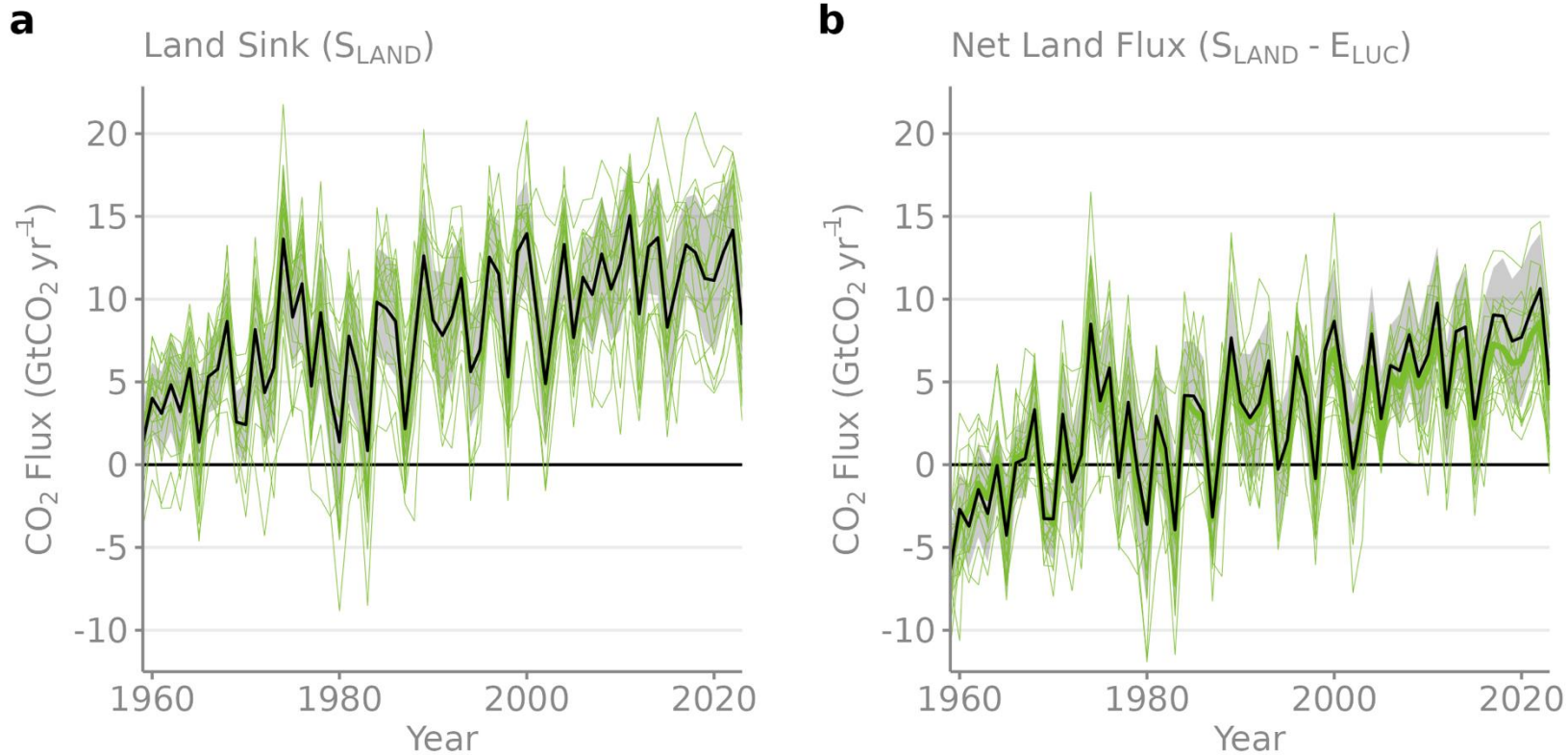
The ocean sink increased in 2023, in line with the expected sink response to the 2023 El Niño conditions. This is after no growth since 2019 due to a triple La Niña event during 2020–2022.



# Terrestrial sink

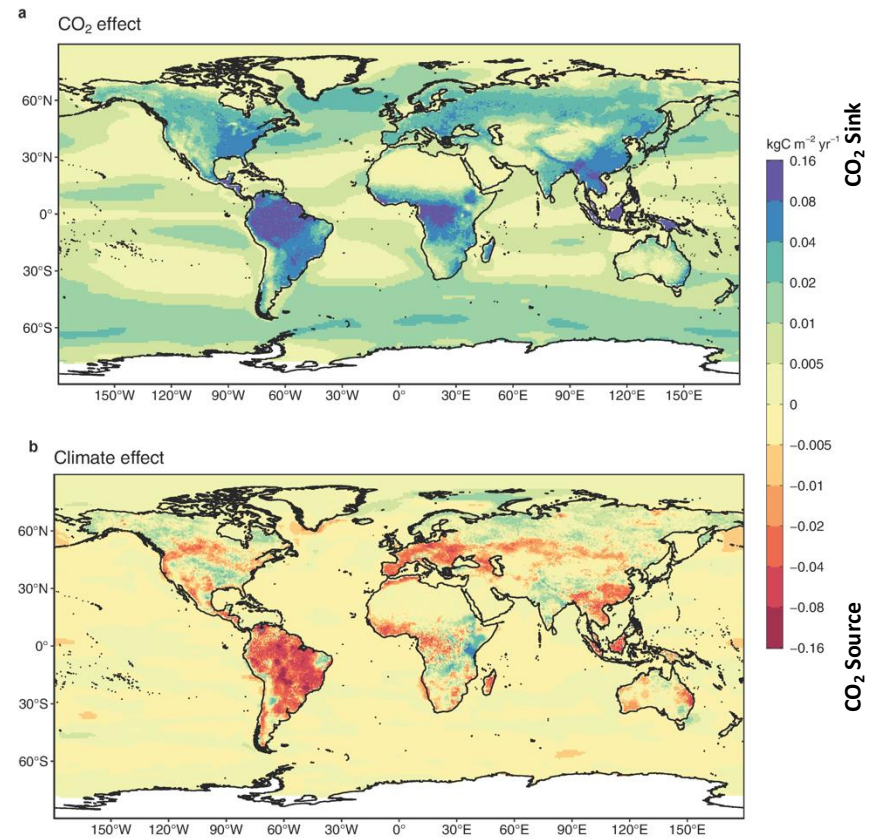
The land carbon sink, estimated by Dynamic Global Vegetation Models, was  $11.7 \pm 3.2$  GtCO<sub>2</sub>/yr during 2014–2023. The effects of El Niño that developed in late 2023 and early 2024 reduced the land CO<sub>2</sub> sink to 8.4 GtCO<sub>2</sub> in 2023, 28% below its decadal mean.

The total CO<sub>2</sub> fluxes on land (including land-use change) are also constrained by atmospheric inversions.



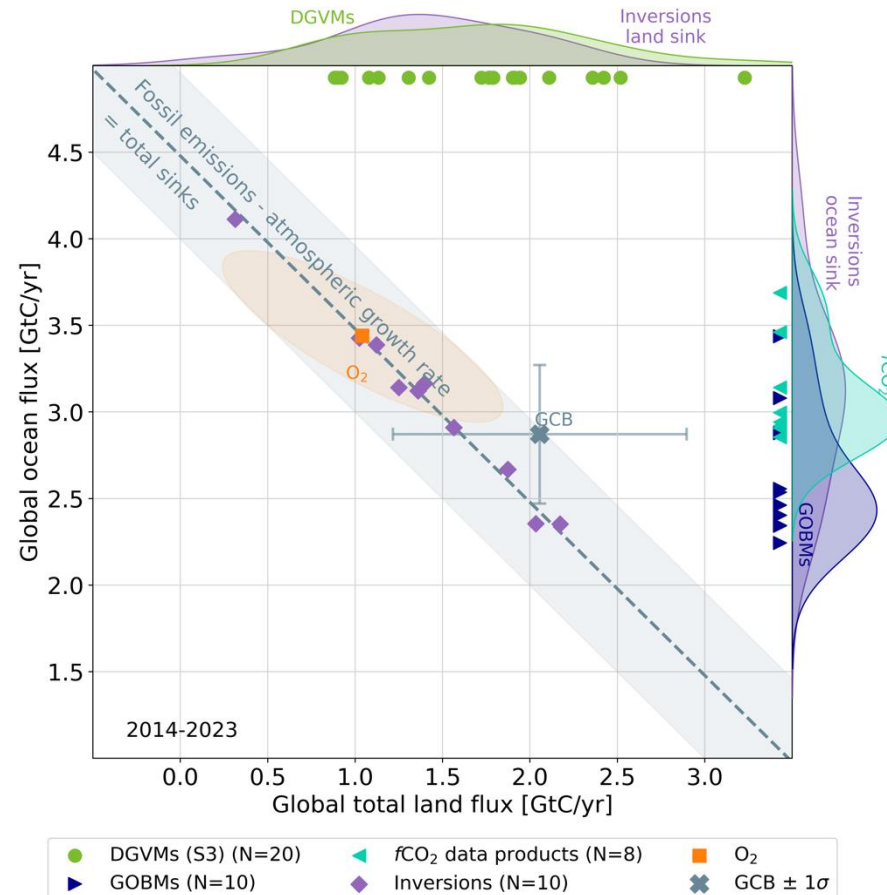
# Land and ocean sinks — Effects of CO<sub>2</sub> vs climate change

Process models suggest that increasing atmospheric CO<sub>2</sub> drives the land and ocean sinks while climate change reduces the carbon sinks; the climate effect is largest in tropical and semi-arid land ecosystems. Globally during 2014–2023, climate change reduced the land sink by ~27% and the ocean sink by 6%.



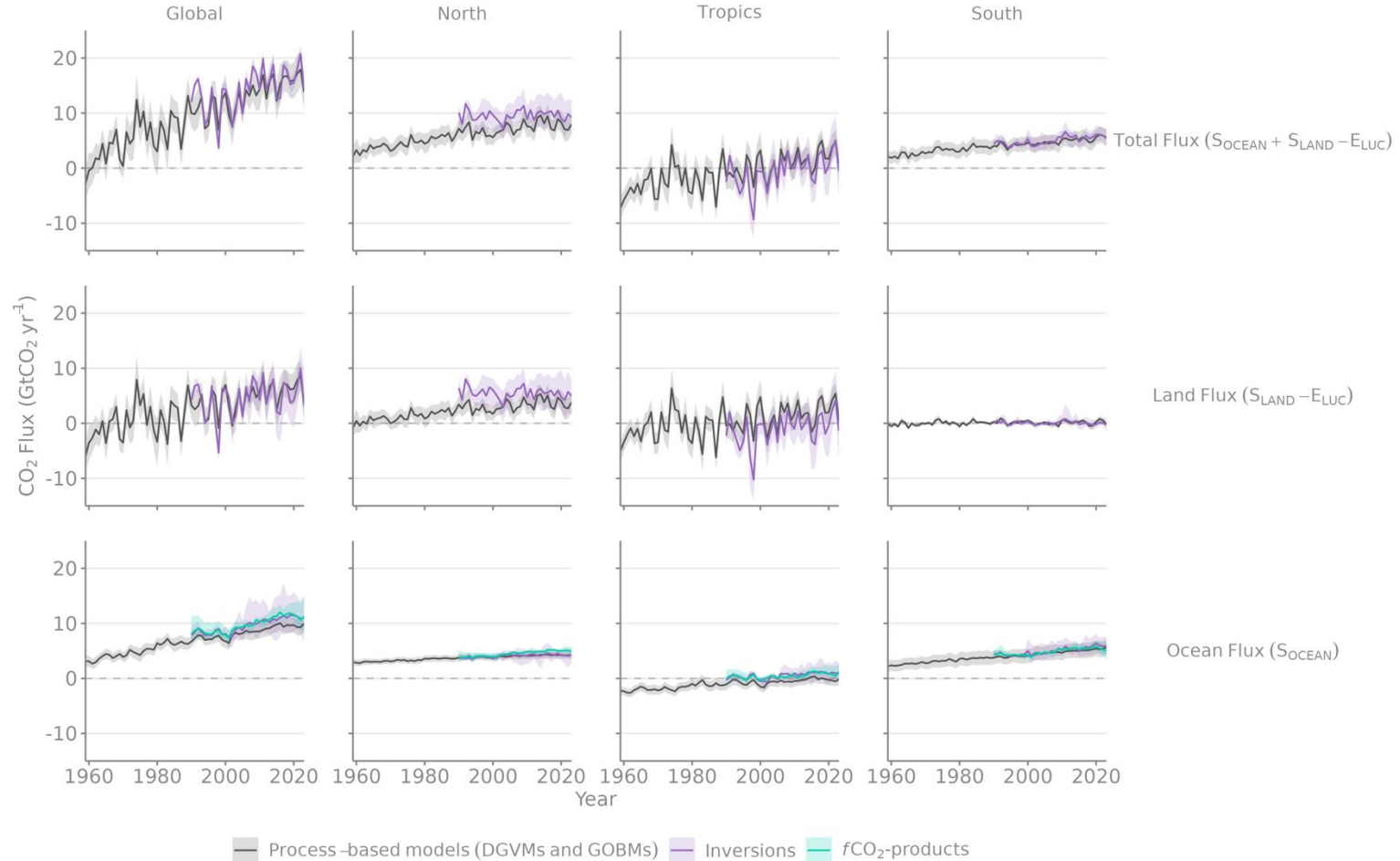
# Land and ocean sinks — Estimates from atmospheric inversions

Both atmospheric CO<sub>2</sub> inversions and atmospheric oxygen allow to estimate the land and ocean carbon fluxes, independently from the land and ocean process-based models, confirming the global carbon budget estimates of the land and ocean partitioning of anthropogenic CO<sub>2</sub>



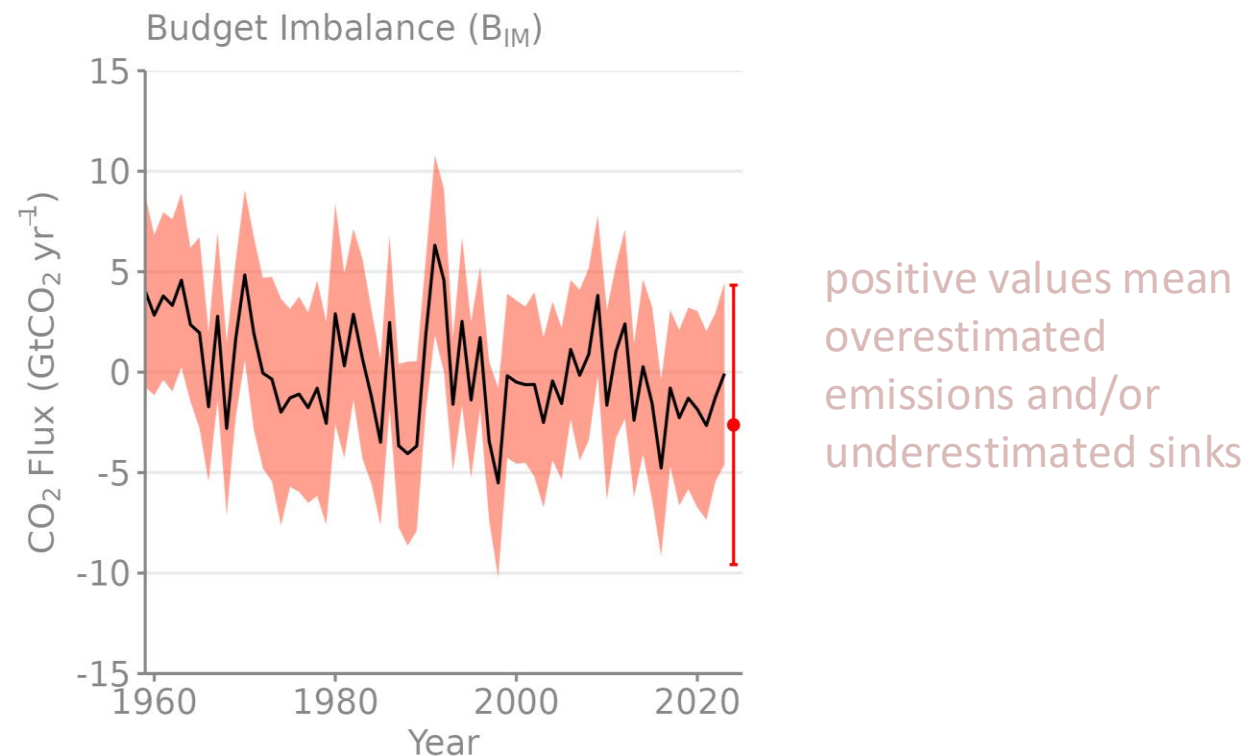
# Total land and ocean fluxes

Bottom-up estimates and top-down atmospheric inversions broadly agree on the land and ocean sinks at large regional scales. The interannual variability in the global total CO<sub>2</sub> flux is largely due to the variability of the land sink in the tropics.



## Remaining carbon budget imbalance

Large and unexplained variability in the global carbon balance caused by uncertainty and understanding hinder independent verification of reported CO<sub>2</sub> emissions

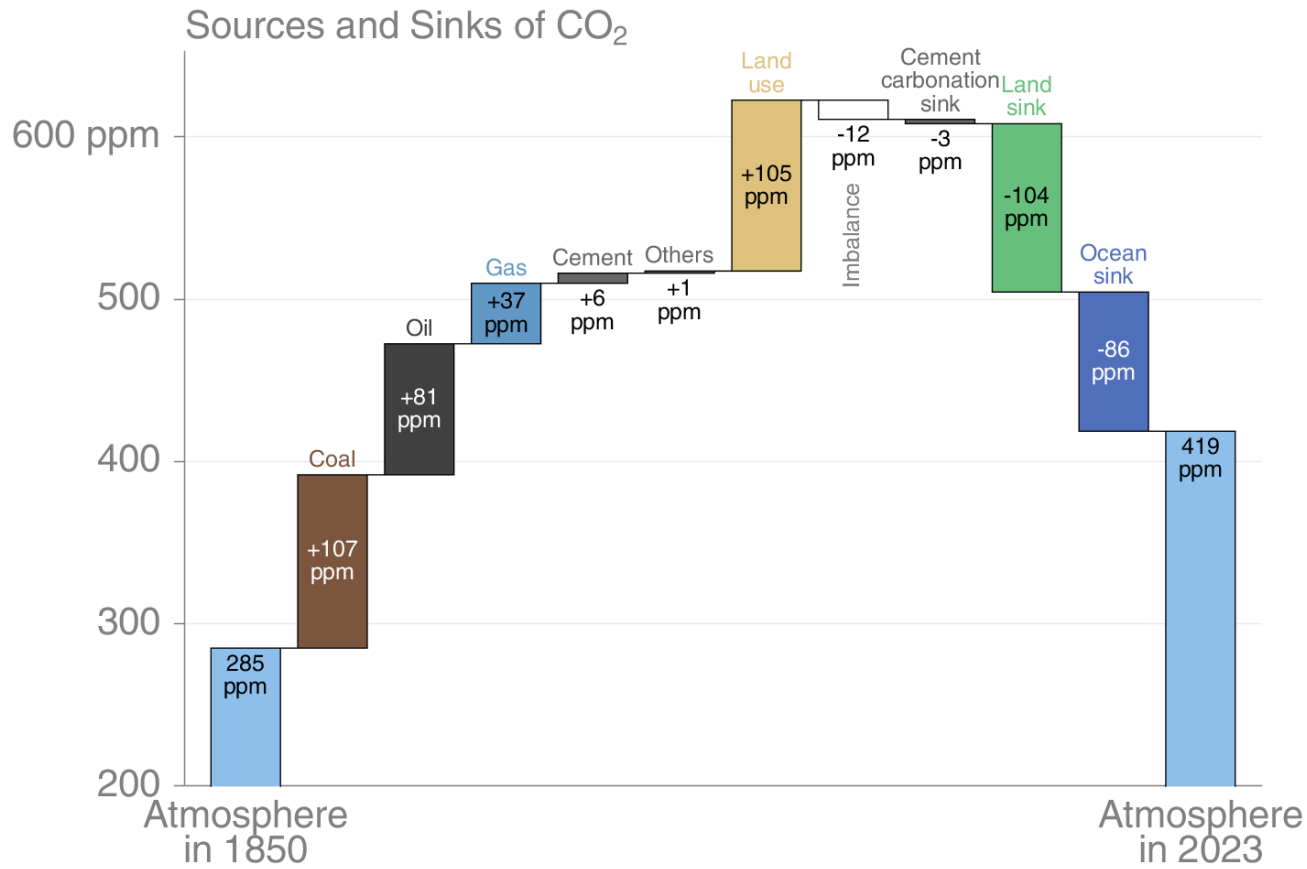


The budget imbalance is the carbon left after adding independent estimates for total emissions, minus the atmospheric growth rate and estimates for the land and ocean carbon sinks using models constrained by observations

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Global carbon budget

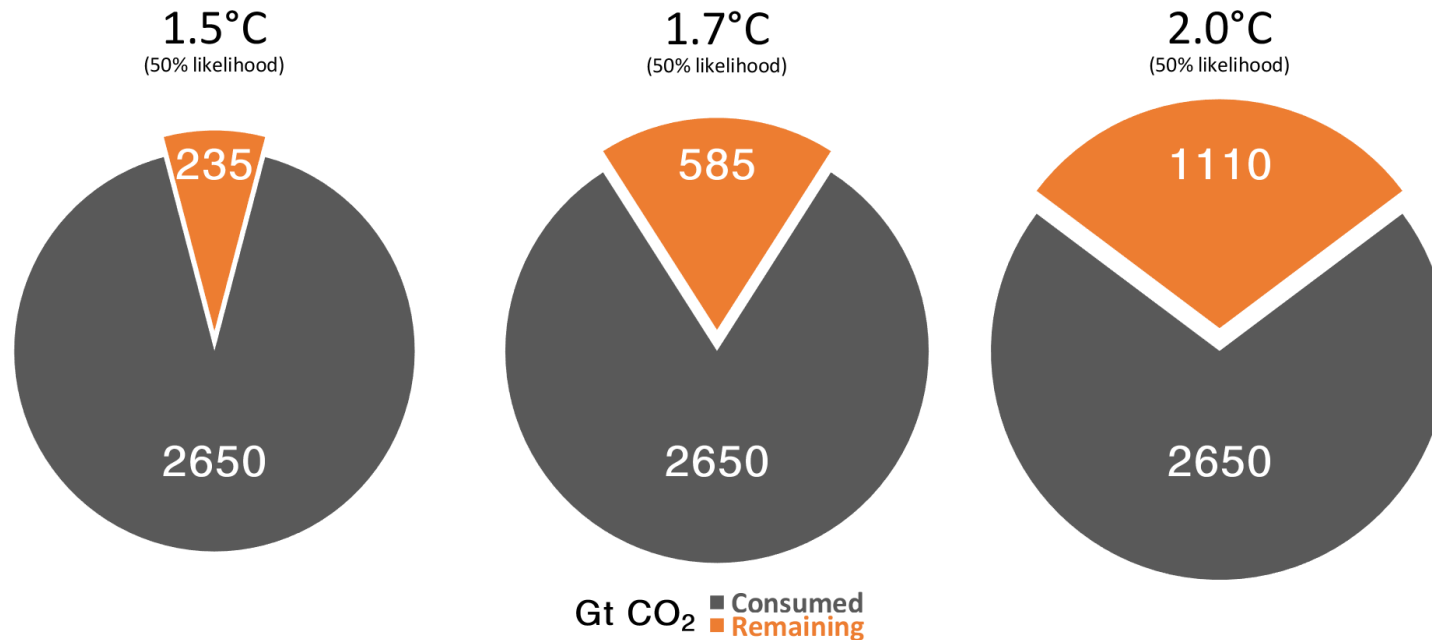
The cumulative contributions to the global carbon budget from 1850  
 The carbon imbalance represents the gap in our current understanding of sources & sinks



© Global Carbon Project

# Remaining carbon budget

The remaining carbon budget to limit global warming to 1.5°C, 1.7°C and 2°C is 235 GtCO<sub>2</sub>, 585 GtCO<sub>2</sub>, and 1110 GtCO<sub>2</sub> respectively, equivalent to 6, 14 and 27 years from 2025. 2650 GtCO<sub>2</sub> have been emitted since 1850

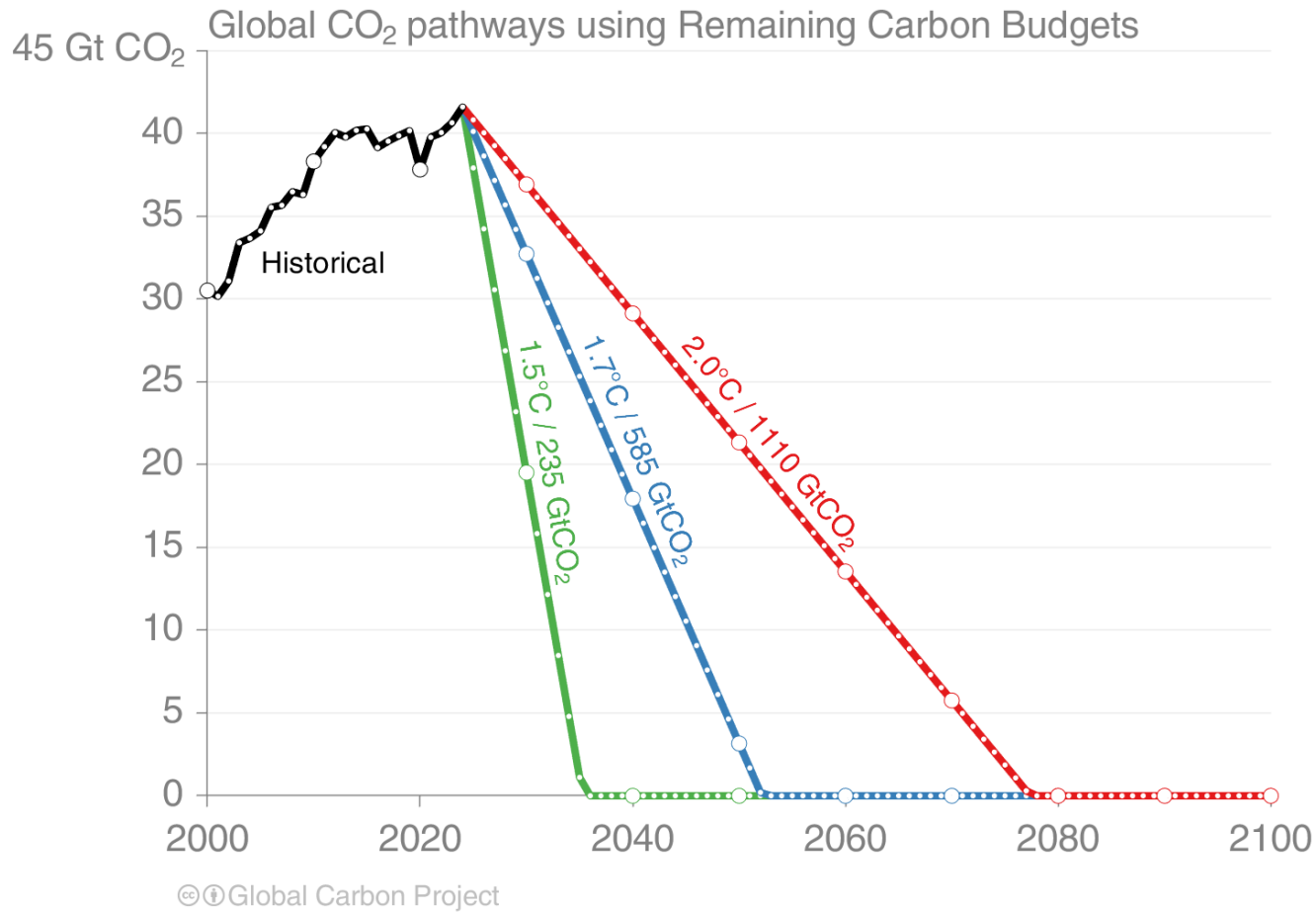


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The remaining carbon budgets are the average of two estimates (IPCC AR6 and Forster et al., 2023), both updated by removing the most recent emissions. Quantities are subject to additional uncertainties e.g., future mitigation choices of non-CO<sub>2</sub> emissions  
 Source: IPCC AR6 WG1; [Forster et al., 2023](#); [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Remaining carbon budget

Global CO<sub>2</sub> emissions must reach zero to limit global warming



# Acknowledgements

# Acknowledgements

The work presented in the **Global Carbon Budget 2024** has been possible thanks to the contributions of **hundreds of people** involved in observational networks, modelling, and synthesis efforts.

We thank the institutions and agencies that provide support for individuals and funding that enable the collaborative effort of bringing all components together in the carbon budget effort.

We thank the sponsors of the GCP and GCP support and liaison offices.

We also want to thank the many funding agencies that supported this coordinated effort and the individual components of this release. A full list is provided in Friedlingstein et al. 2024.

<https://essd.copernicus.org/preprints/essd-2024-519>

We also thanks the Fondation BNP Paribas for supporting the Global Carbon Atlas and the Integrated Carbon Observation System (ICOS) for hosting our data.

This presentation was created by Robbie Andrew and Pierre Friedlingstein with Pep Canadell, Glen Peters and Corinne Le Quéré in support of the international carbon research community.



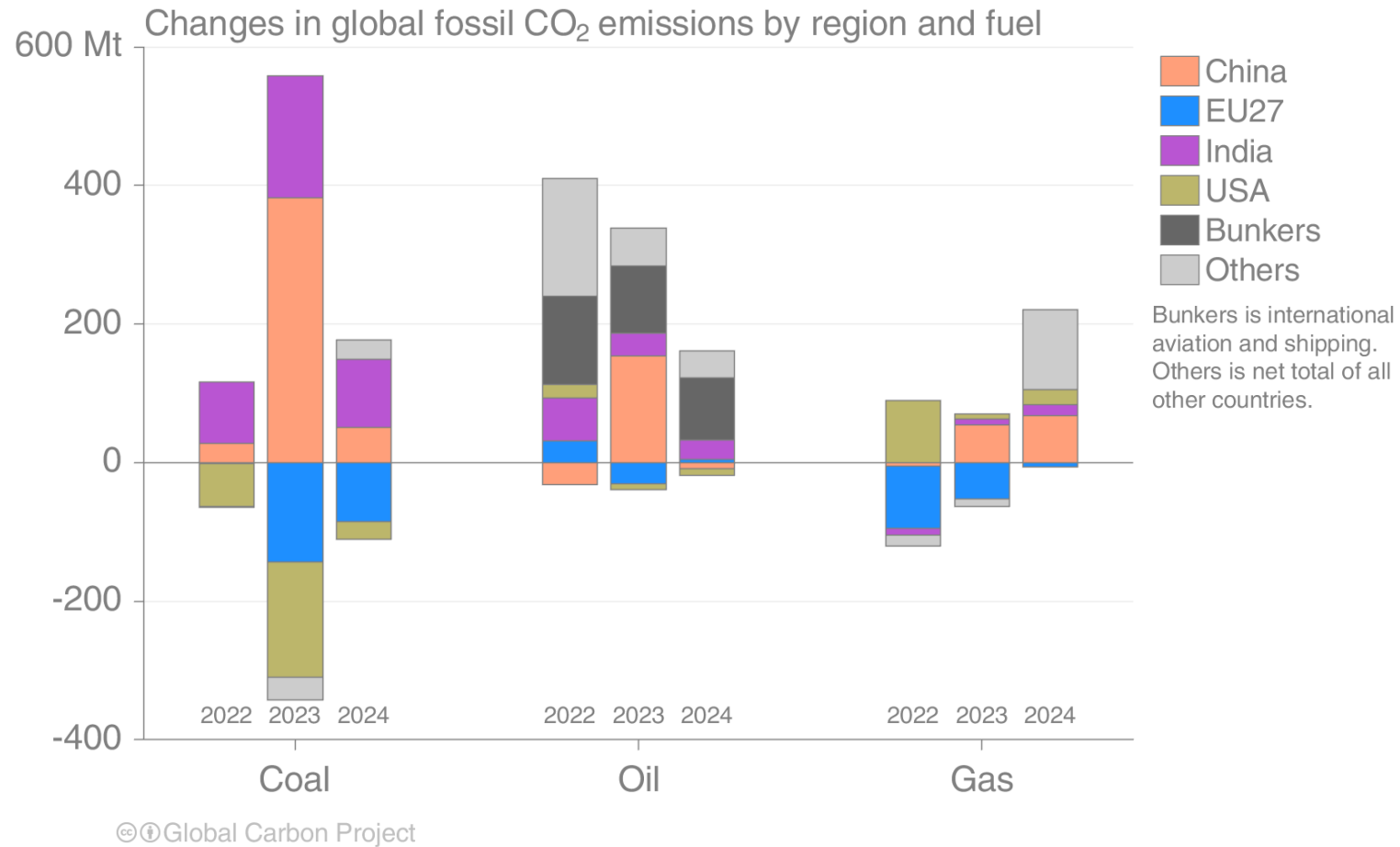
# Additional Figures

# Additional Figures

## Fossil CO<sub>2</sub>

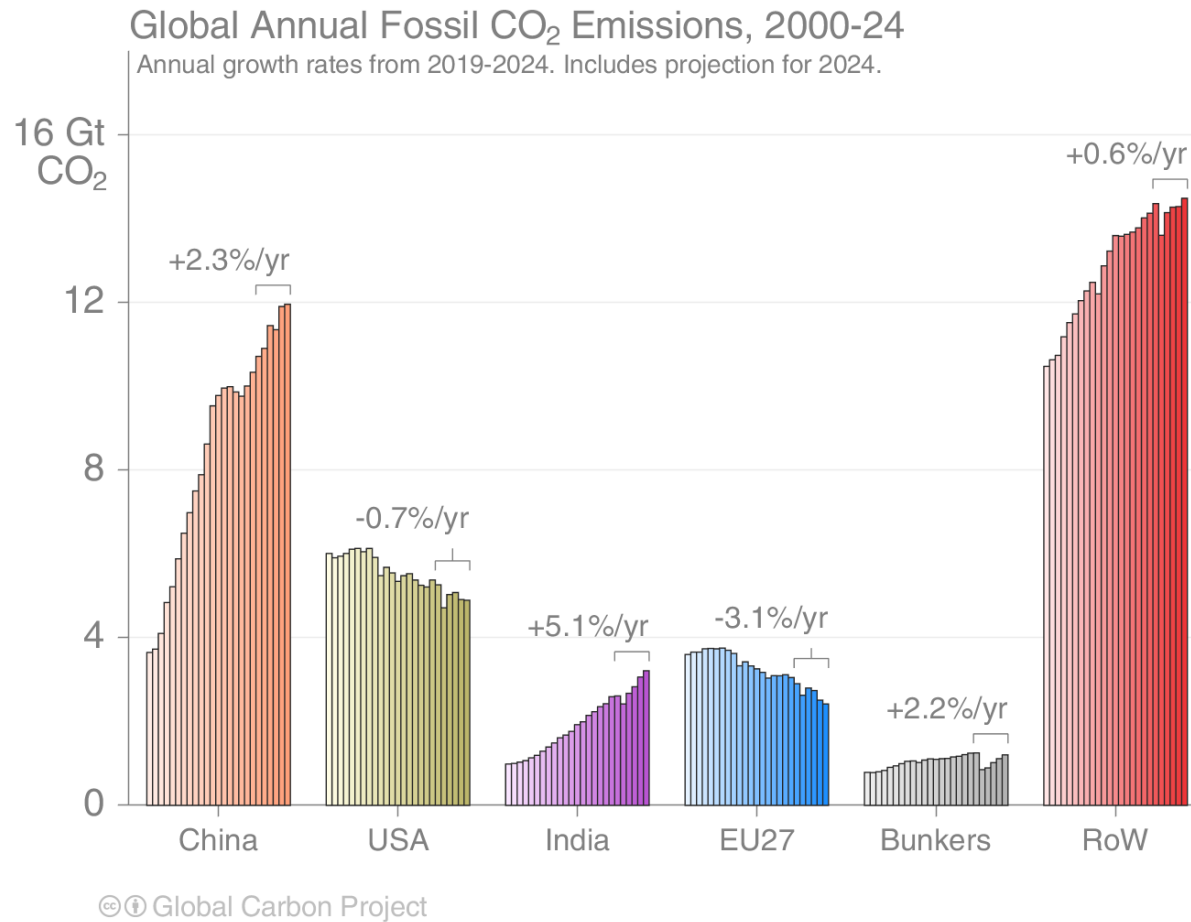
# Emissions changes 2022–2024

Emissions from coal in China and India have been a core reason for global growth. Both 2023 and 2024 were marked by post-pandemic recovery in international aviation (bunkers).

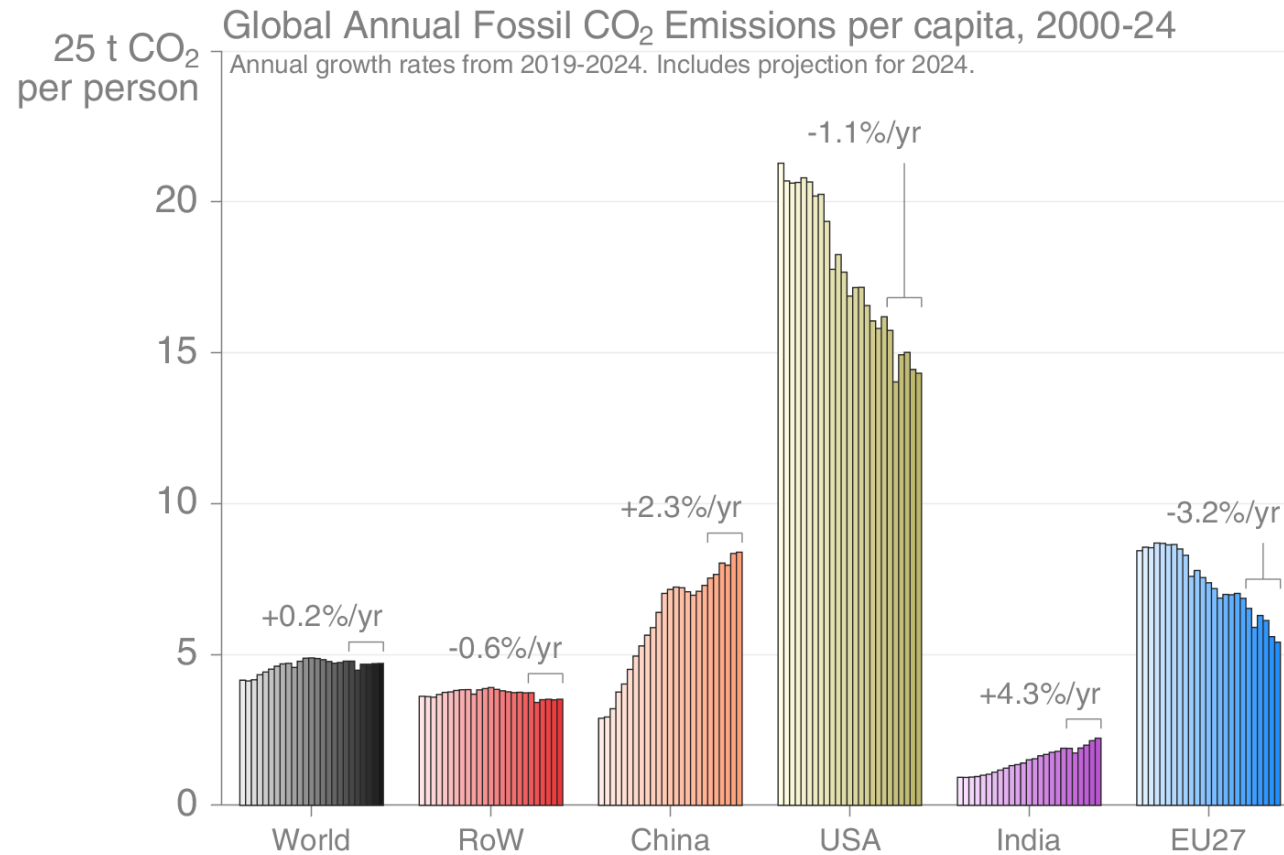


# Top emitters: Fossil CO<sub>2</sub> Emissions

Emissions by country from 2000 to 2024, with the growth rates indicated for the more recent period of 2019 to 2024



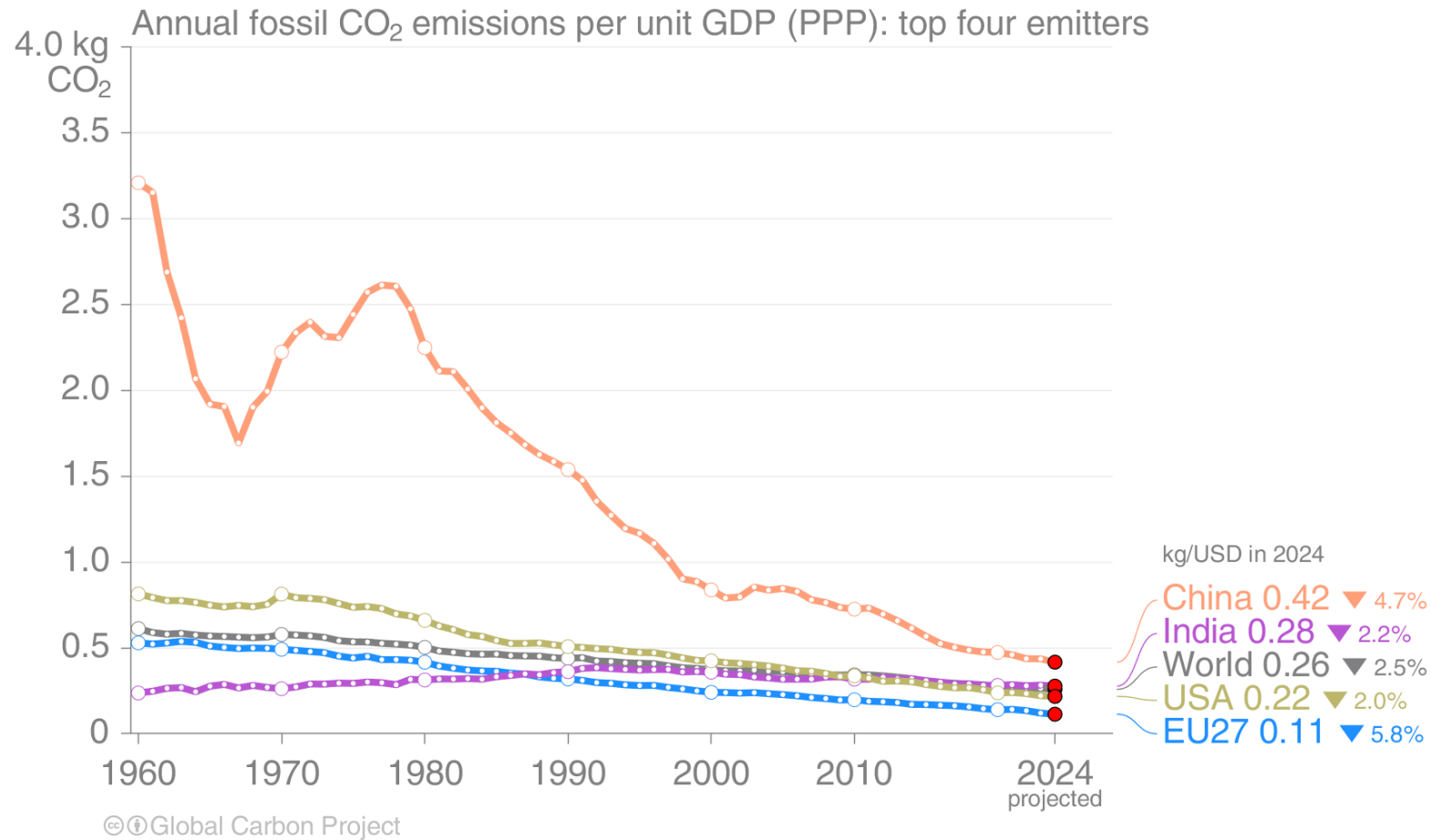
# Per capita CO<sub>2</sub> emissions



© Global Carbon Project

# Top emitters: Fossil CO<sub>2</sub> Emission Intensity

Emission intensity (emission per unit economic output) generally declines over time. In many countries, these declines are insufficient to overcome economic growth.

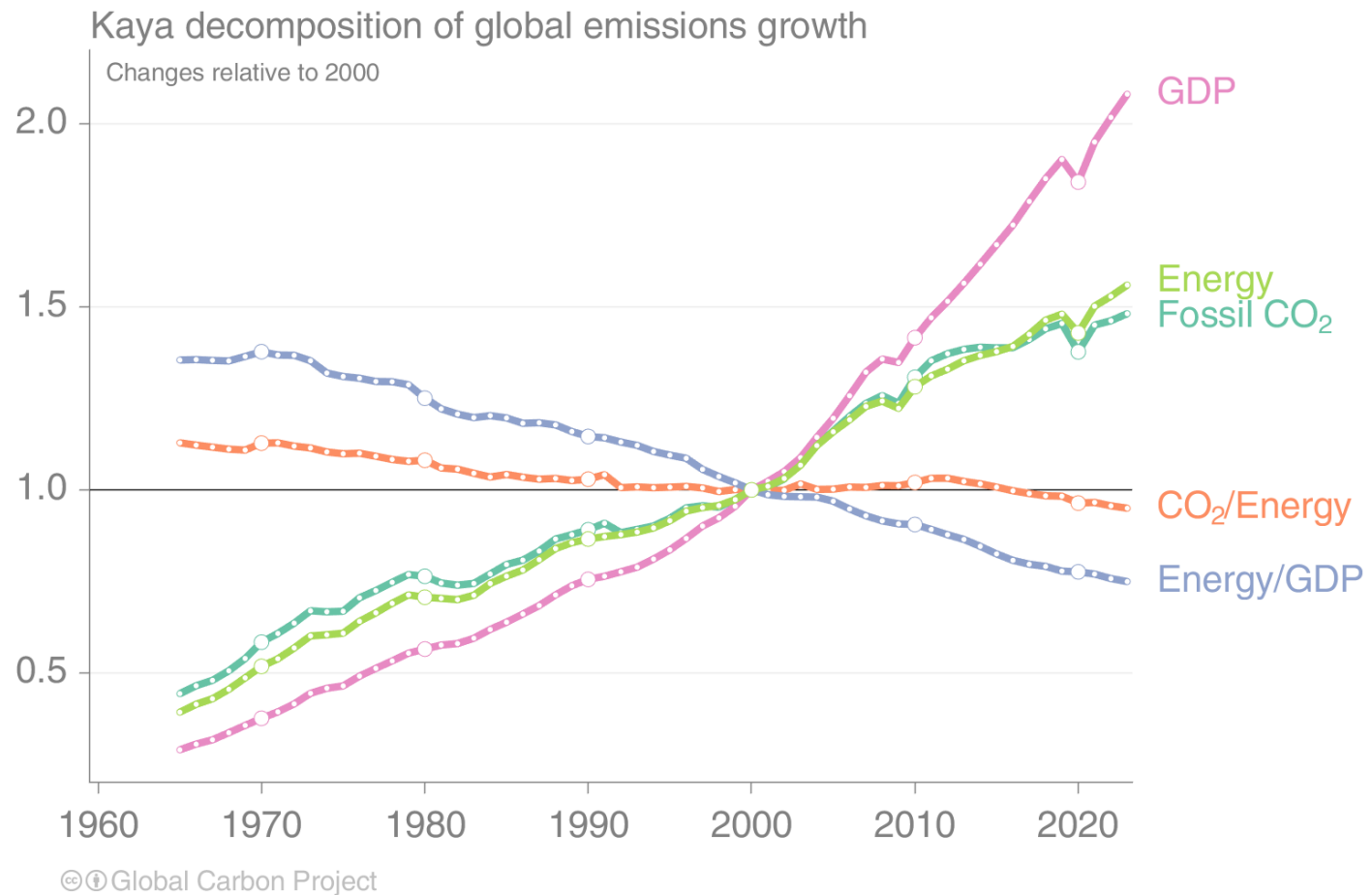


GDP is measured in purchasing power parity (PPP) terms in 2017 US dollars.

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Kaya decomposition

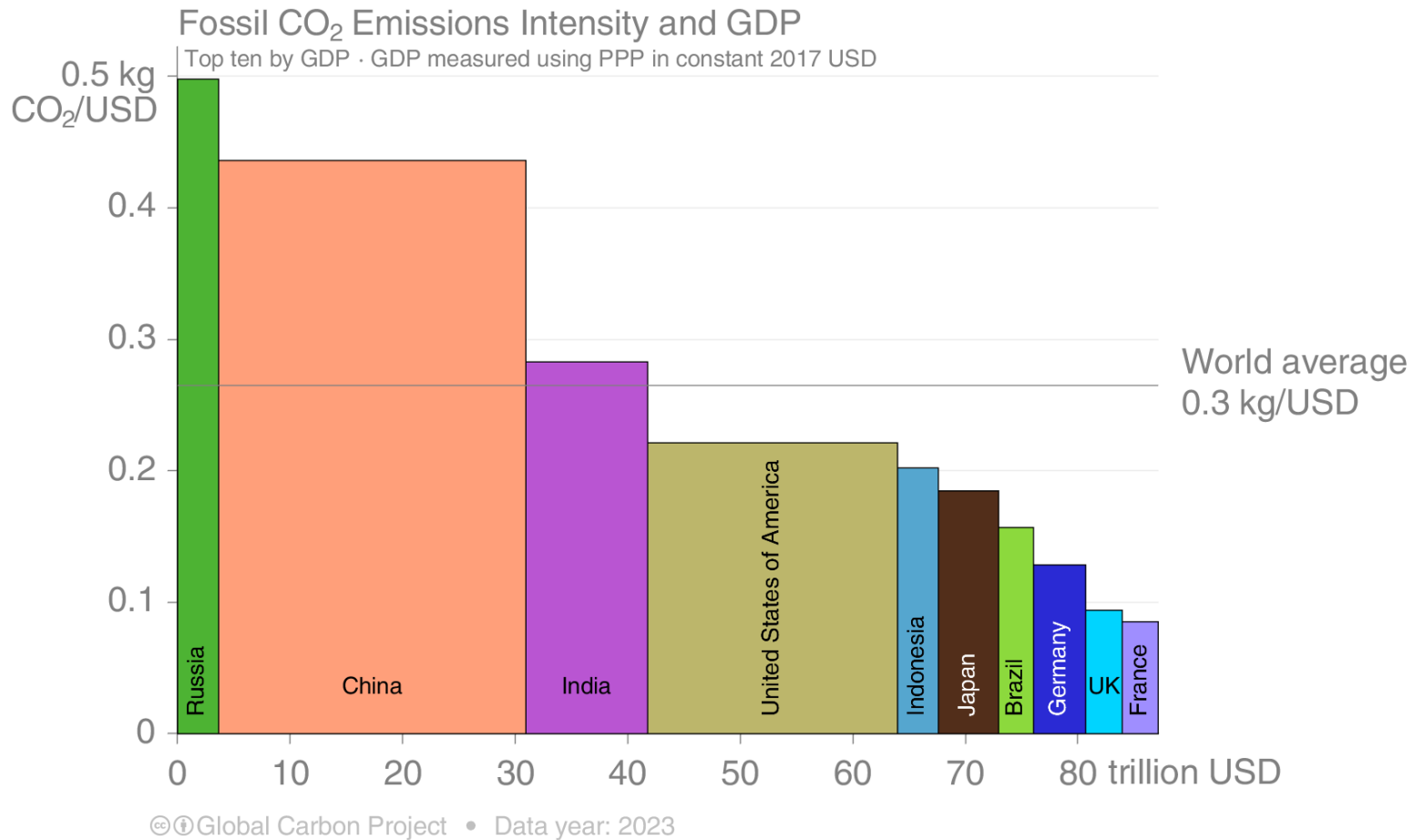
The Kaya decomposition illustrates that relative decoupling of economic growth from CO<sub>2</sub> emissions is driven by improved energy intensity (Energy/GDP) and, recently, carbon intensity of energy (CO<sub>2</sub>/Energy)



GDP: Gross Domestic Product (economic activity)  
Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Fossil CO<sub>2</sub> emission intensity

The 10 largest economies have a wide range of emission intensity of economic activity

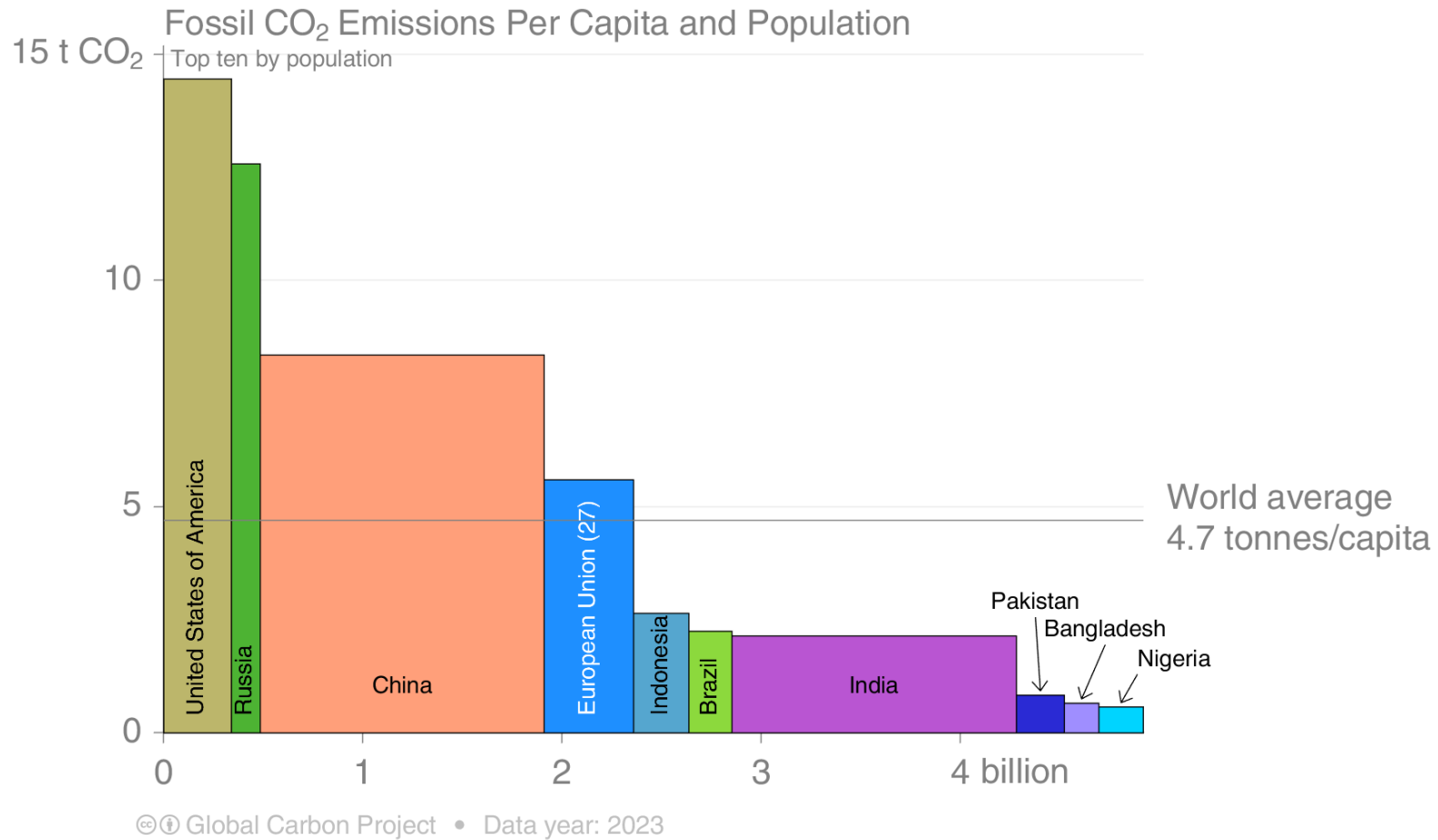


Emission intensity: Fossil CO<sub>2</sub> emissions divided by Gross Domestic Product (GDP)

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Fossil CO<sub>2</sub> Emissions per capita

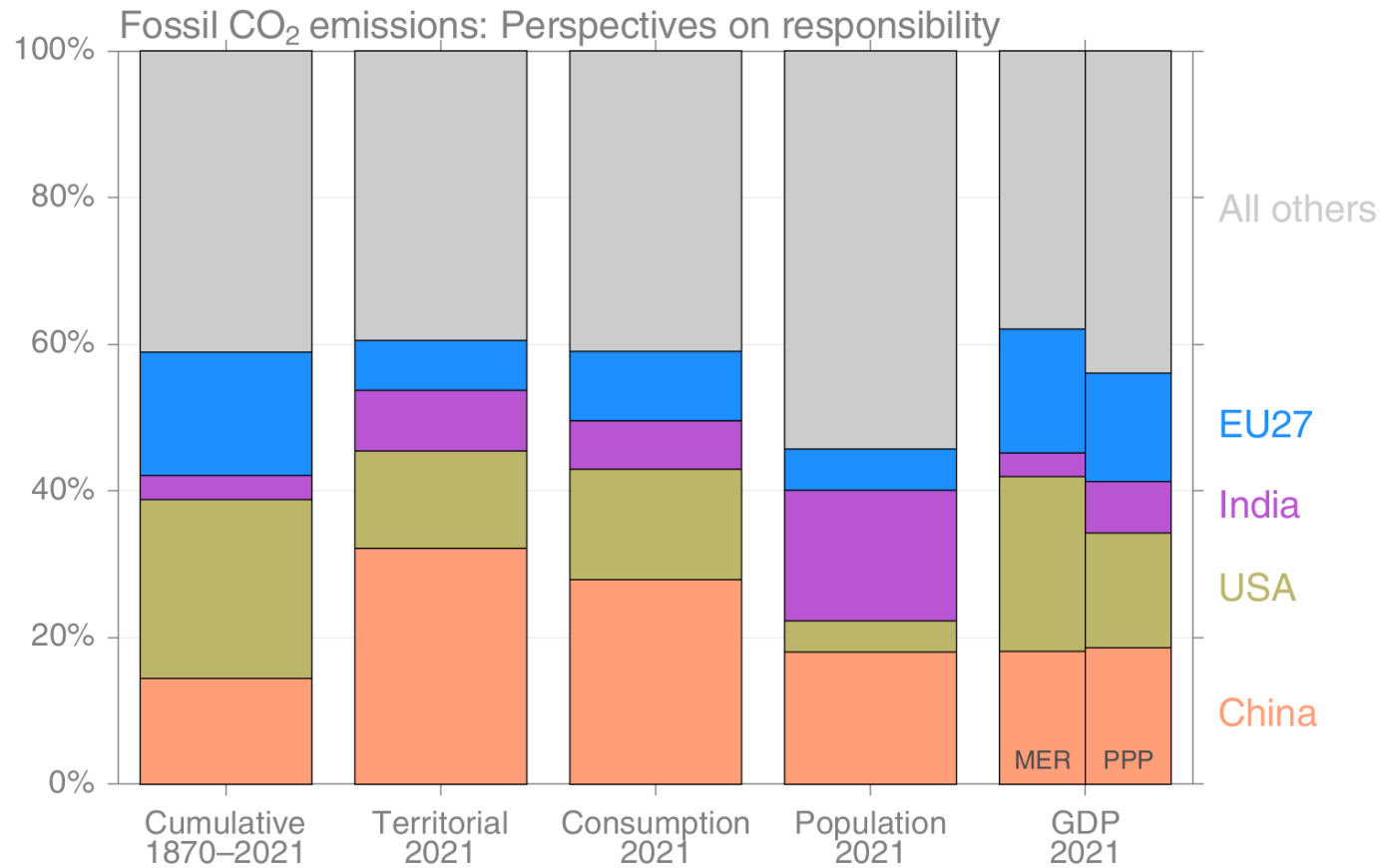
The 10 most populous countries span a wide range of development and emissions per capita



Emission per capita: Fossil CO<sub>2</sub> emissions divided by population  
 Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Alternative rankings of countries

The responsibility of individual countries depends on perspective.  
 Bars indicate fossil CO<sub>2</sub> emissions, population, and GDP.

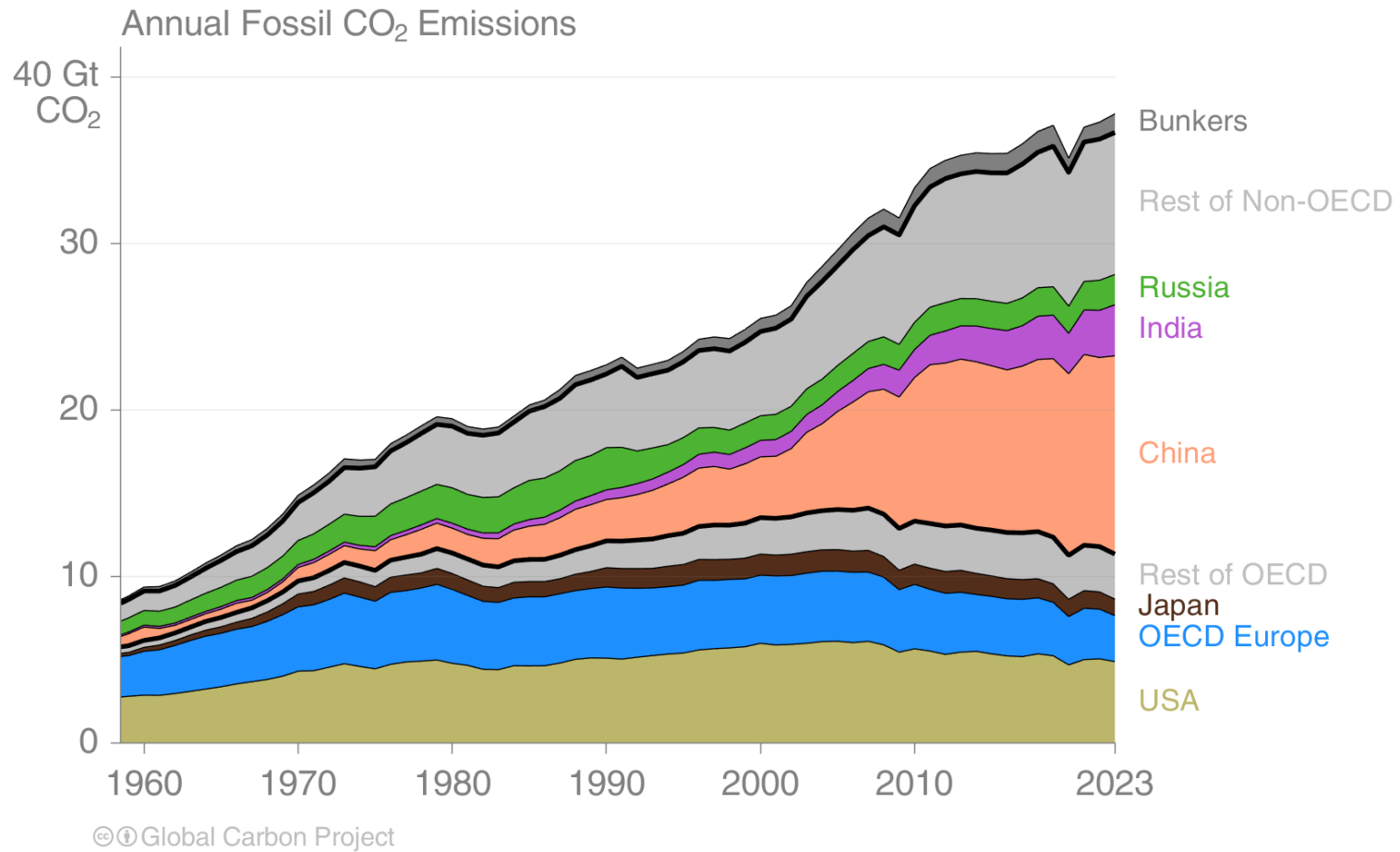


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GDP: Gross Domestic Product in Market Exchange Rates (MER) and Purchasing Power Parity (PPP)

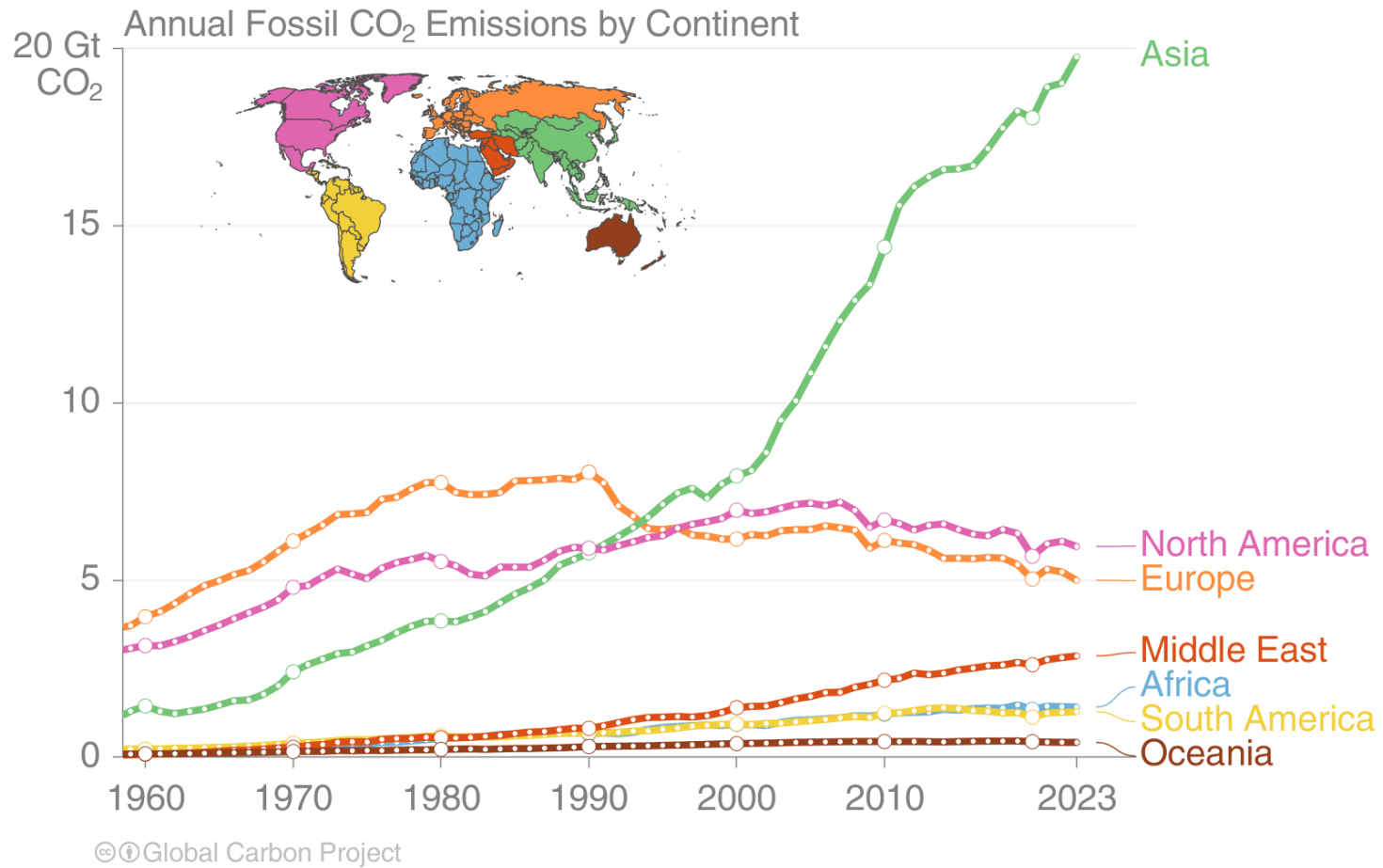
Source: [United Nations](#); [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Breakdown of global fossil CO<sub>2</sub> emissions by country



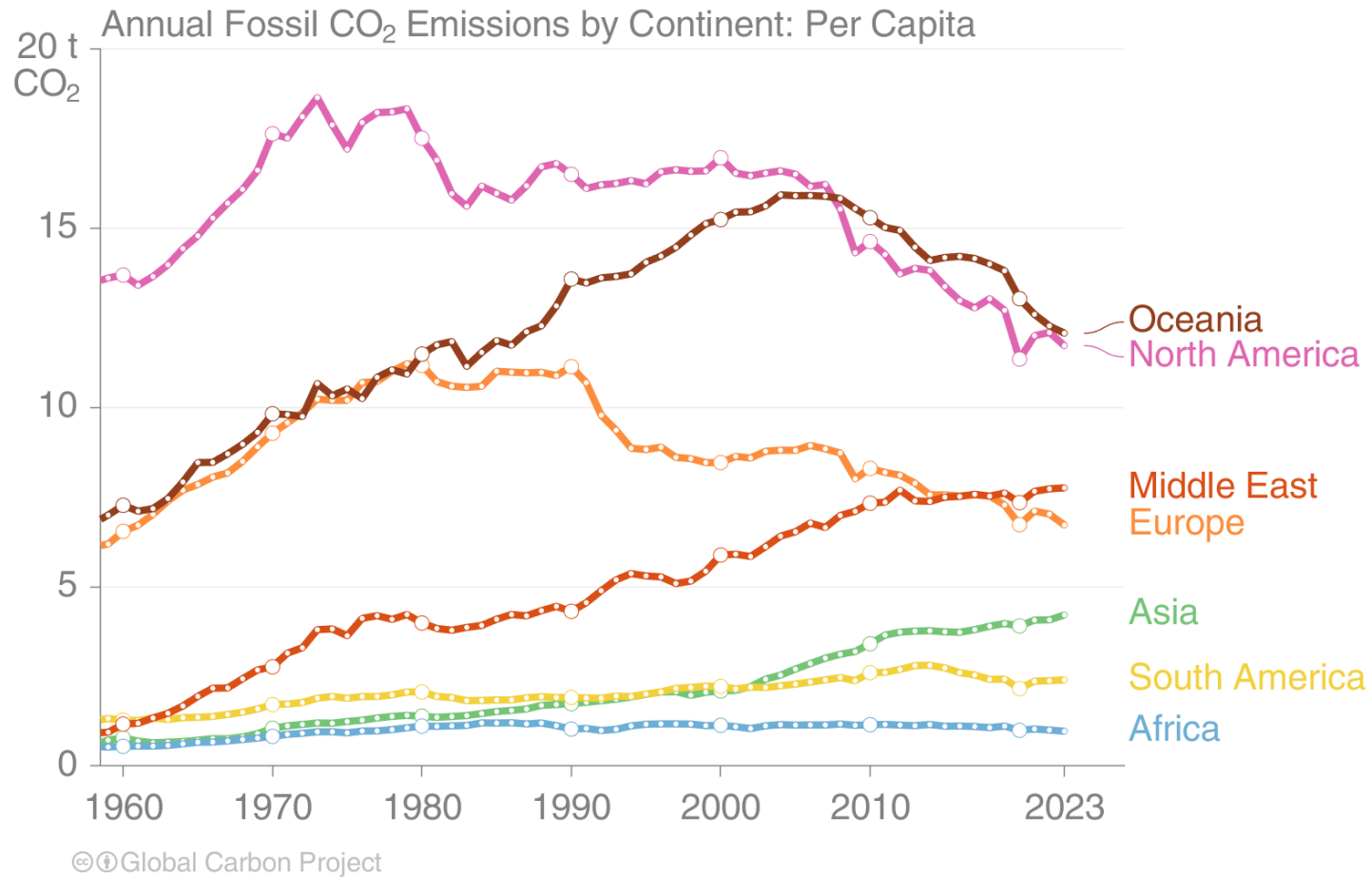
# Fossil CO<sub>2</sub> emissions by continent

Asia dominates global fossil CO<sub>2</sub> emissions, while emissions in North America are of similar size to those in Europe, and the Middle East is growing rapidly.



# Fossil CO<sub>2</sub> emissions by continent: per capita

Oceania and North America have the highest per capita emissions, while the Middle East has recently overtaken Europe. Africa has by far the lowest emissions per capita.



# Additional Figures

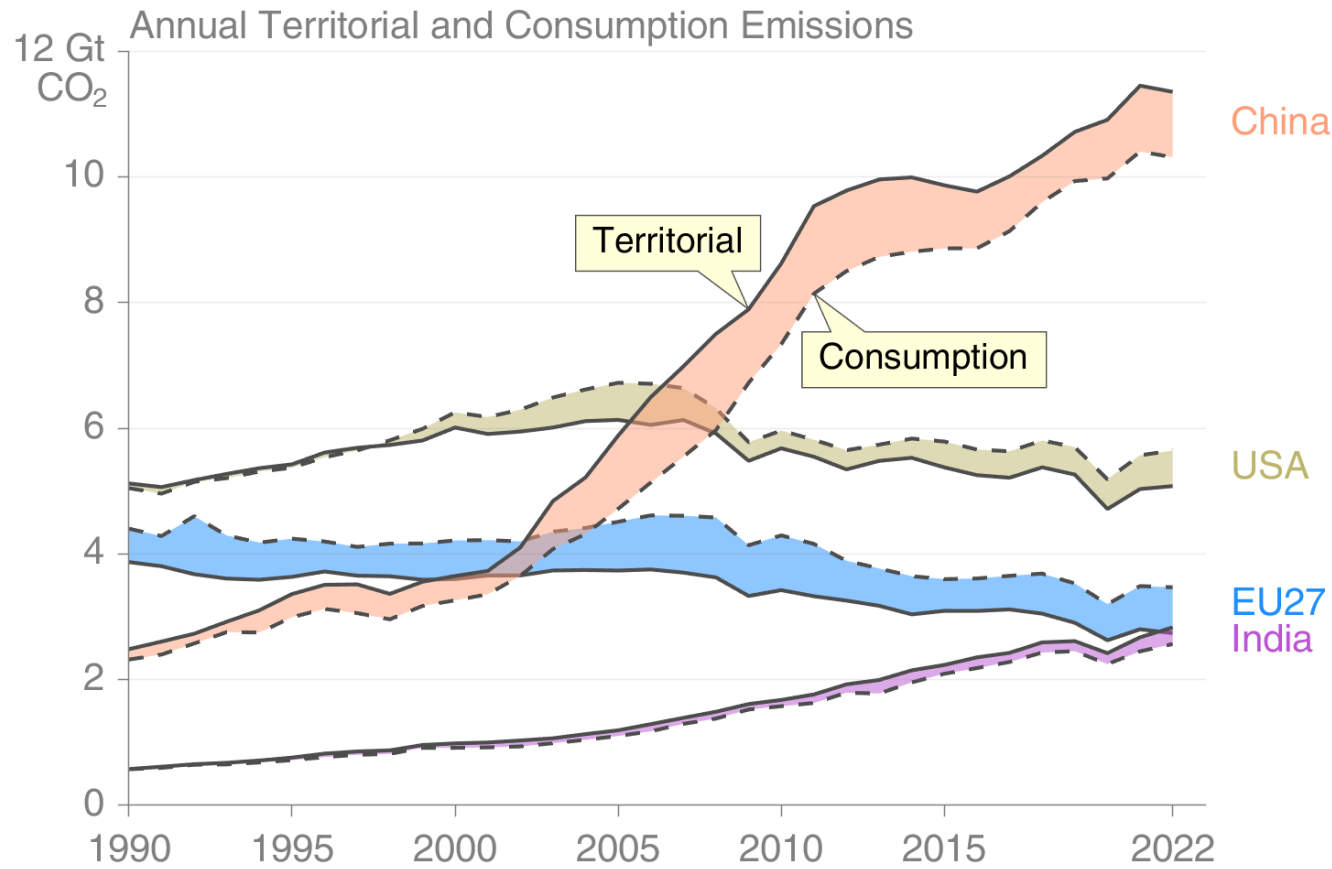
## Consumption-based Emissions

Consumption-based emissions allocate emissions to the location that goods and services are consumed

Consumption-based emissions = Production/Territorial-based emissions minus emissions embodied in exports plus the emissions embodied in imports

# Consumption-based emissions (carbon footprint)

Allocating fossil CO<sub>2</sub> emissions to consumption provides an alternative perspective. USA and EU are net importers of embodied emissions, China and India are net exporters.



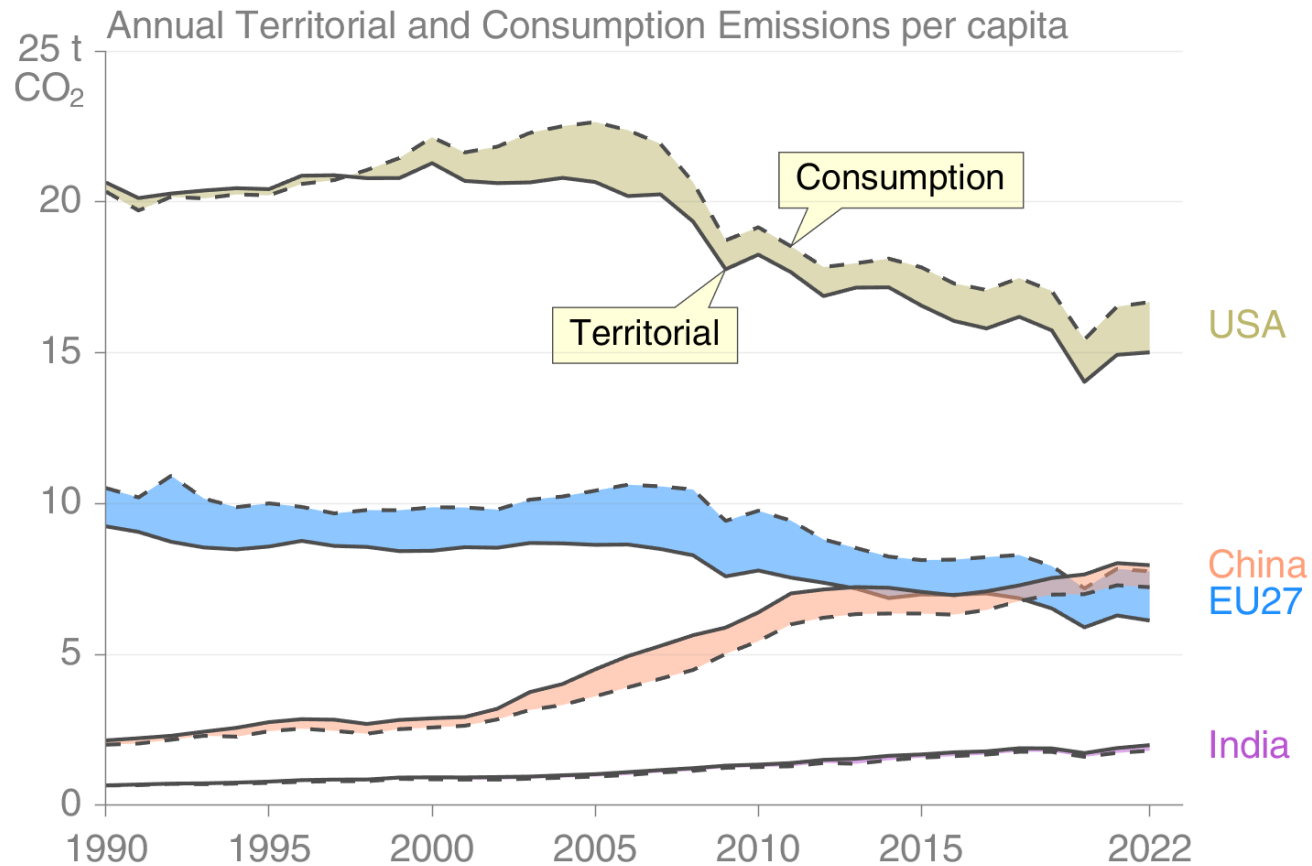
© Global Carbon Project

Consumption-based emissions are calculated by adjusting the standard emissions estimates to account for international trade

Source: [Peters et al 2011](#); [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Consumption-based emissions per person

The differences between fossil CO<sub>2</sub> emissions per capita is larger than the differences between consumption and territorial emissions.



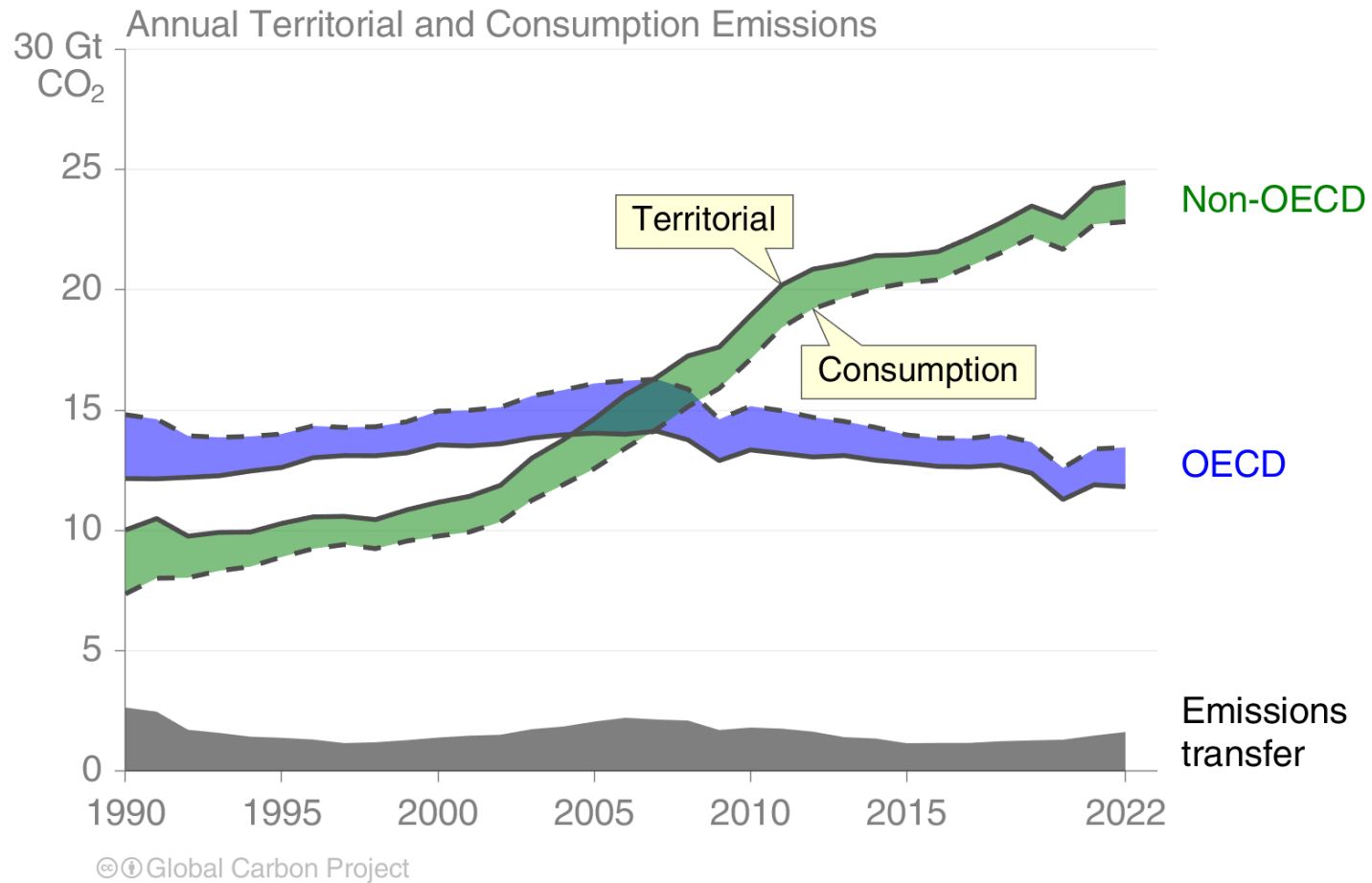
© Global Carbon Project

Consumption-based emissions are calculated by adjusting the standard emissions estimates to account for international trade

Source: [Peters et al 2011](#); [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

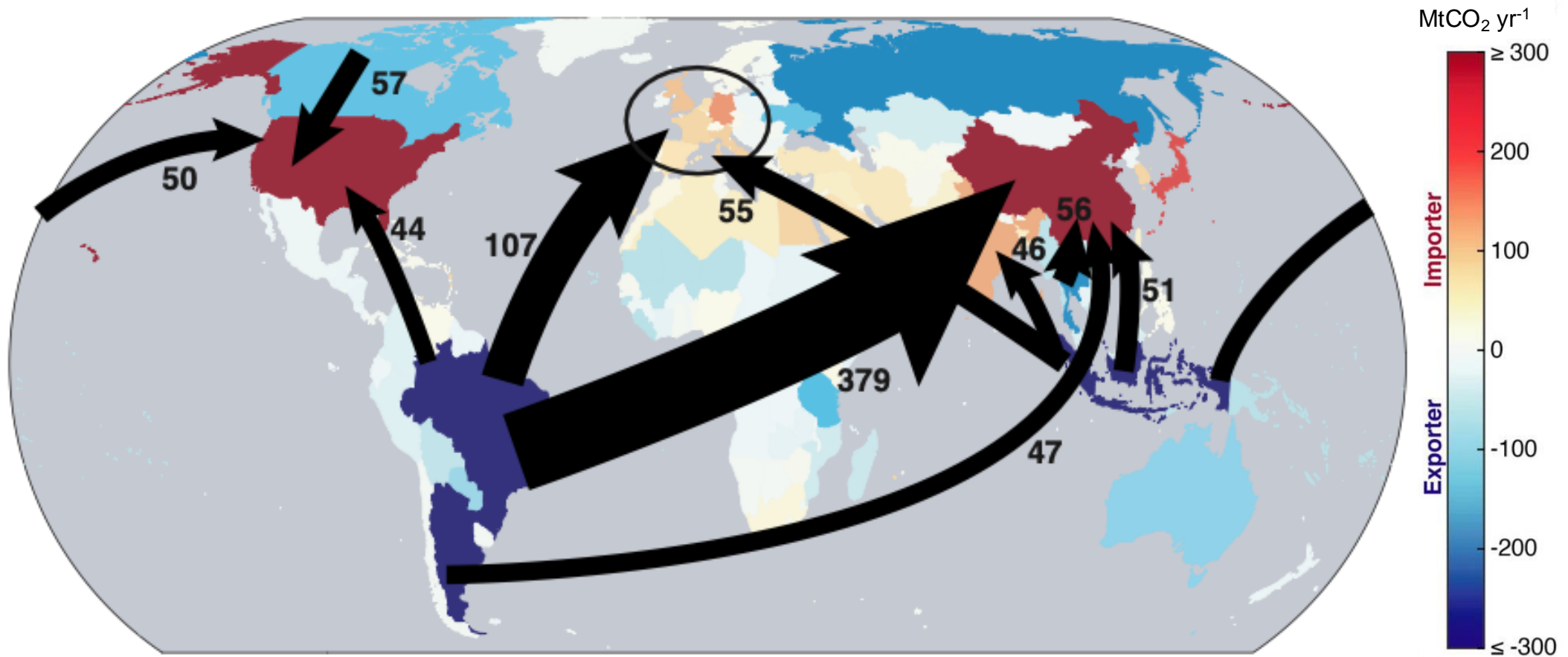
# Consumption-based emissions (carbon footprint)

Transfers of emissions embodied in trade between OECD and non-OECD countries grew slowly during the 2000's, declined to 2015 and have been relatively flat since then.



# Major flows from production to consumption (2017) — Land Use Change CO<sub>2</sub>

Global distribution of land-use change emissions embodied in trade: Arrows show largest flows from location of generation of emissions to location of consumption of agricultural and forestry goods.



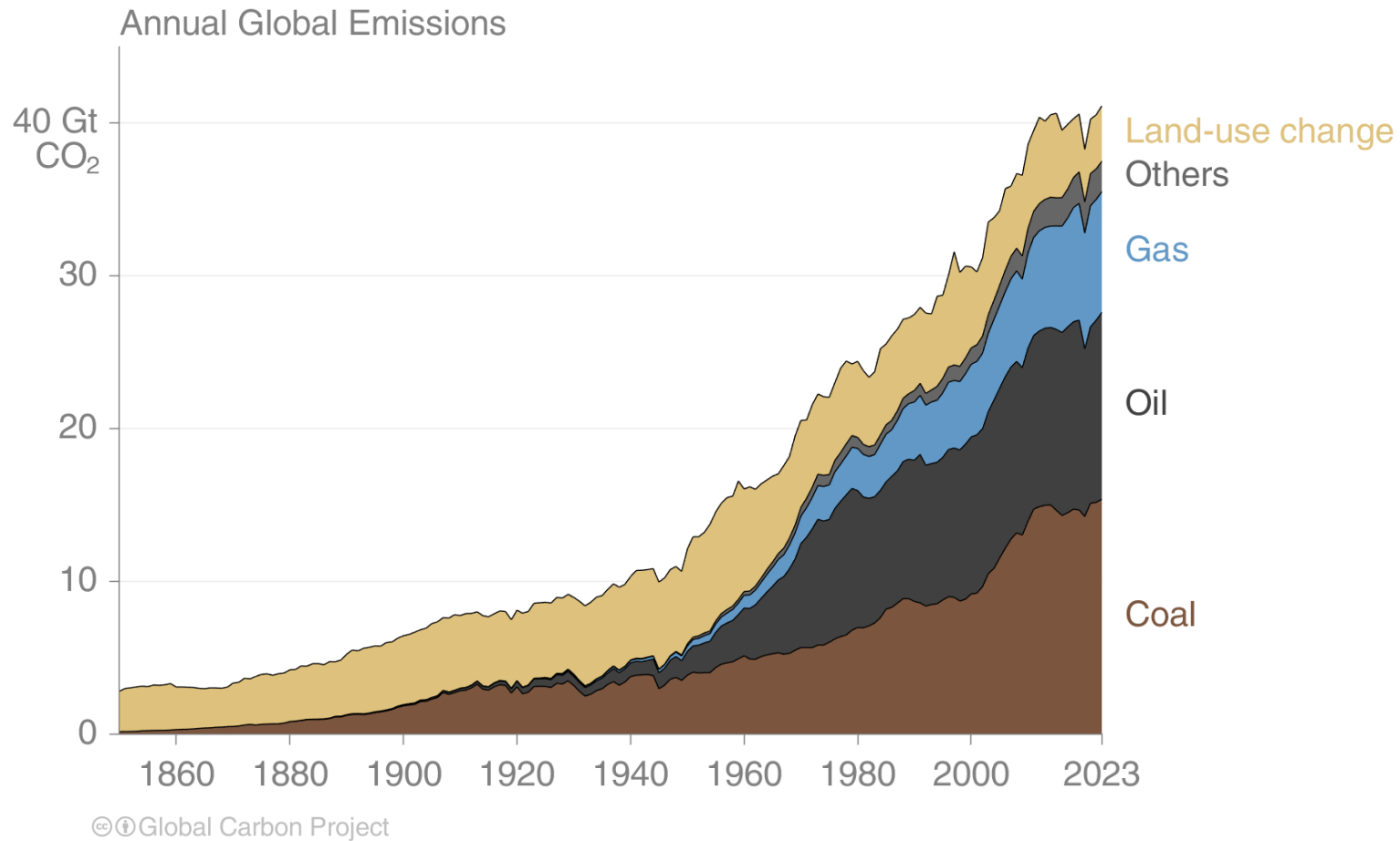
Values for 2017. EU27 is treated as one region. Units: MtCO<sub>2</sub>

Source: [Hong et al 2022](#)

# **Additional Figures Historical Emissions**

# Total global emissions by source

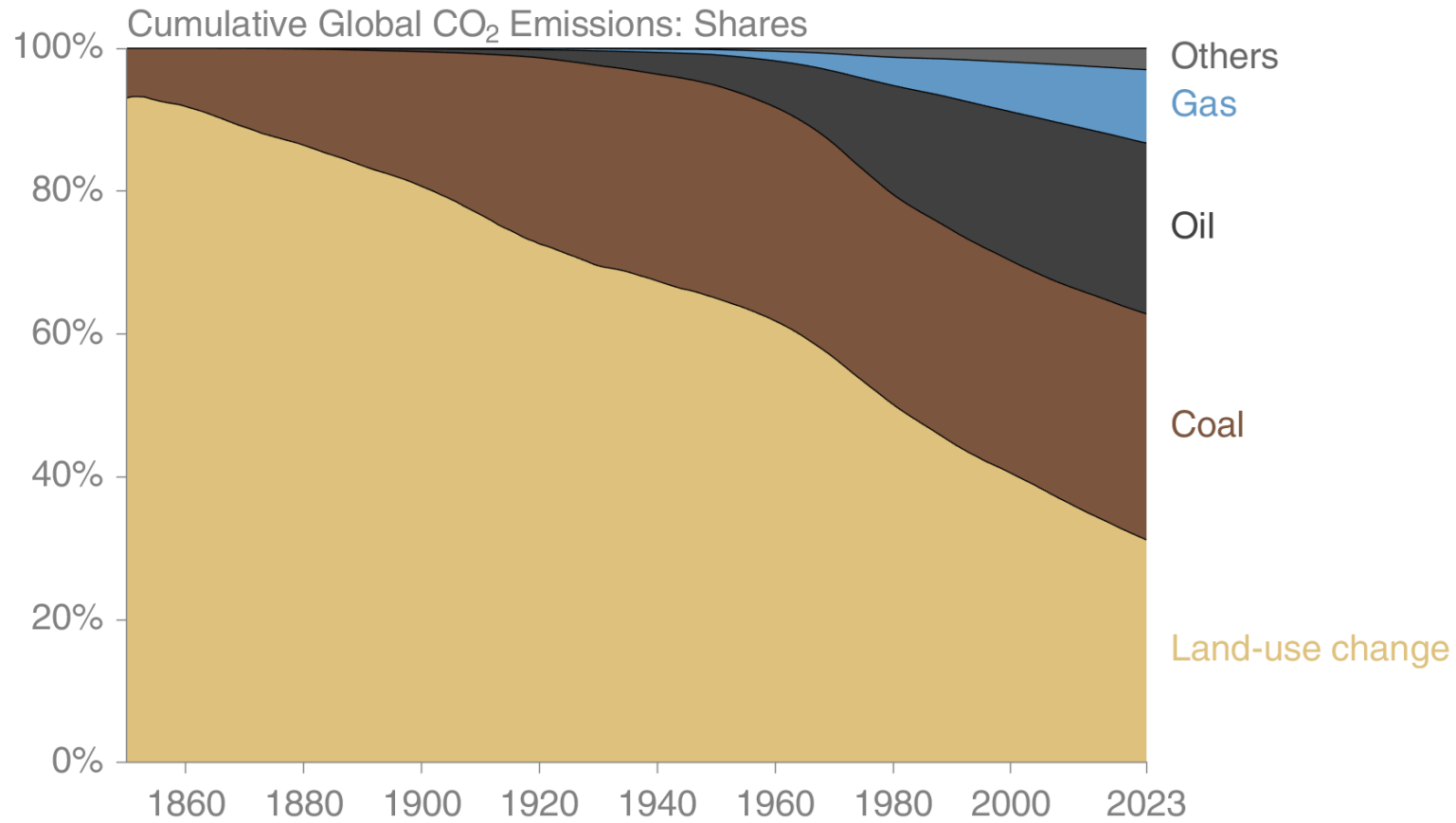
Land-use change was the dominant source of annual CO<sub>2</sub> emissions until around 1950. Fossil CO<sub>2</sub> emissions now dominate global changes.



Others: Emissions from cement production, gas flaring and carbonate decomposition

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Historical cumulative emissions by source

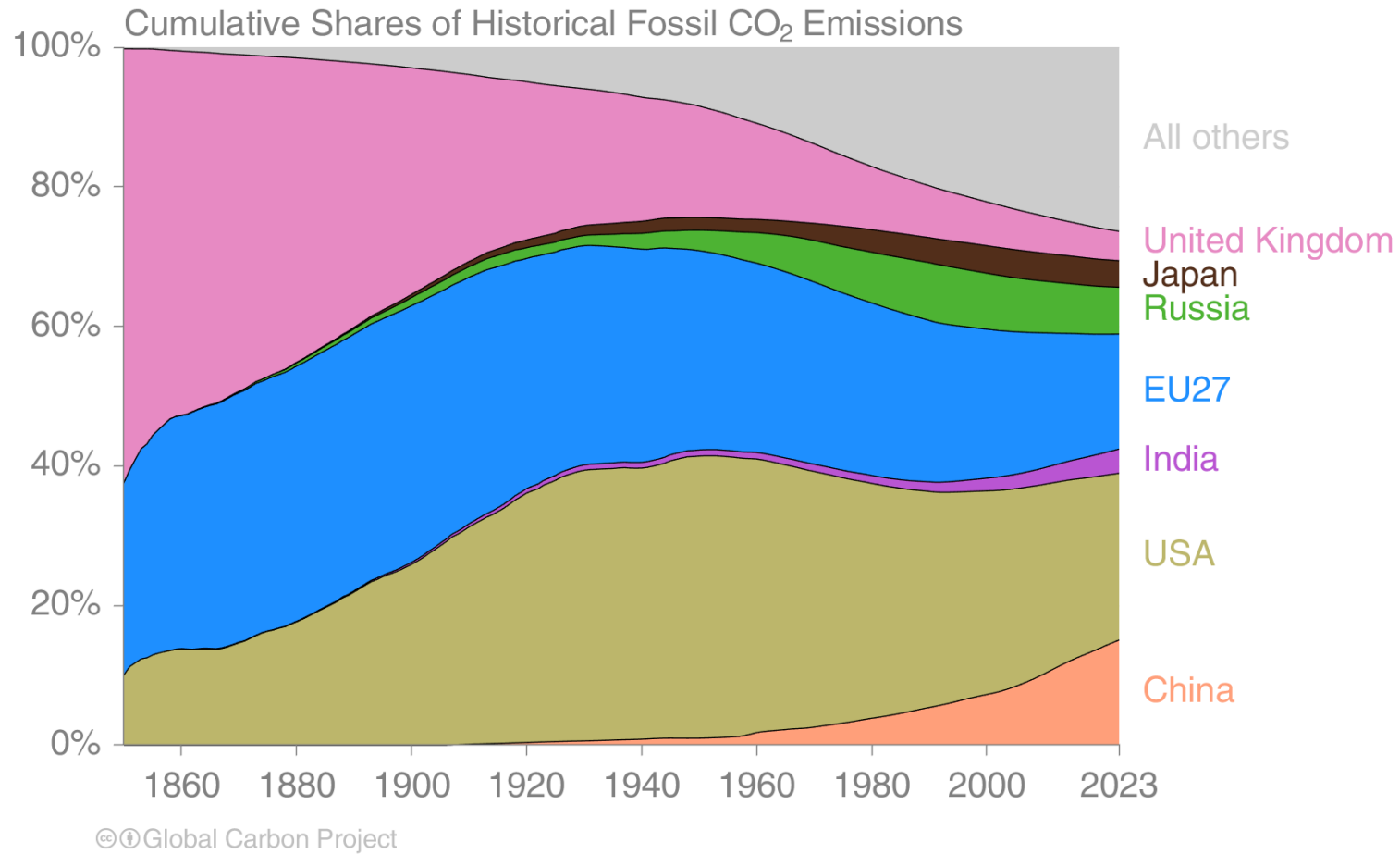


© Global Carbon Project

Others: Emissions from cement production, gas flaring and carbonate decomposition

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Historical cumulative fossil CO<sub>2</sub> emissions by country

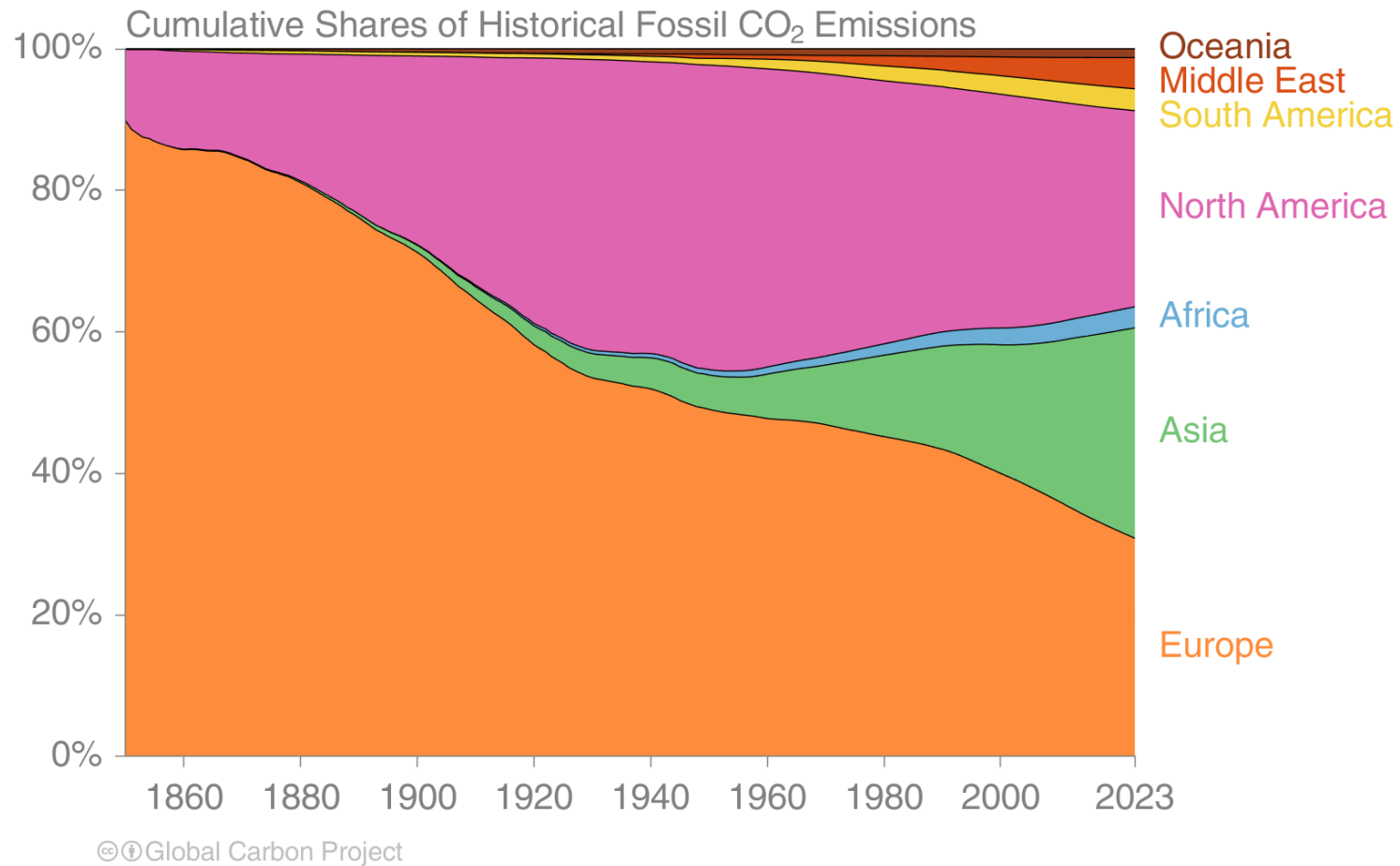


'All others' includes all other countries along with emissions from international aviation and maritime shipping

Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Historical cumulative emissions by continent

Cumulative fossil CO<sub>2</sub> emissions (1850–2023). North America and Europe have contributed the most cumulative emissions, but Asia is growing fast



The figure excludes emissions from international aviation and maritime shipping

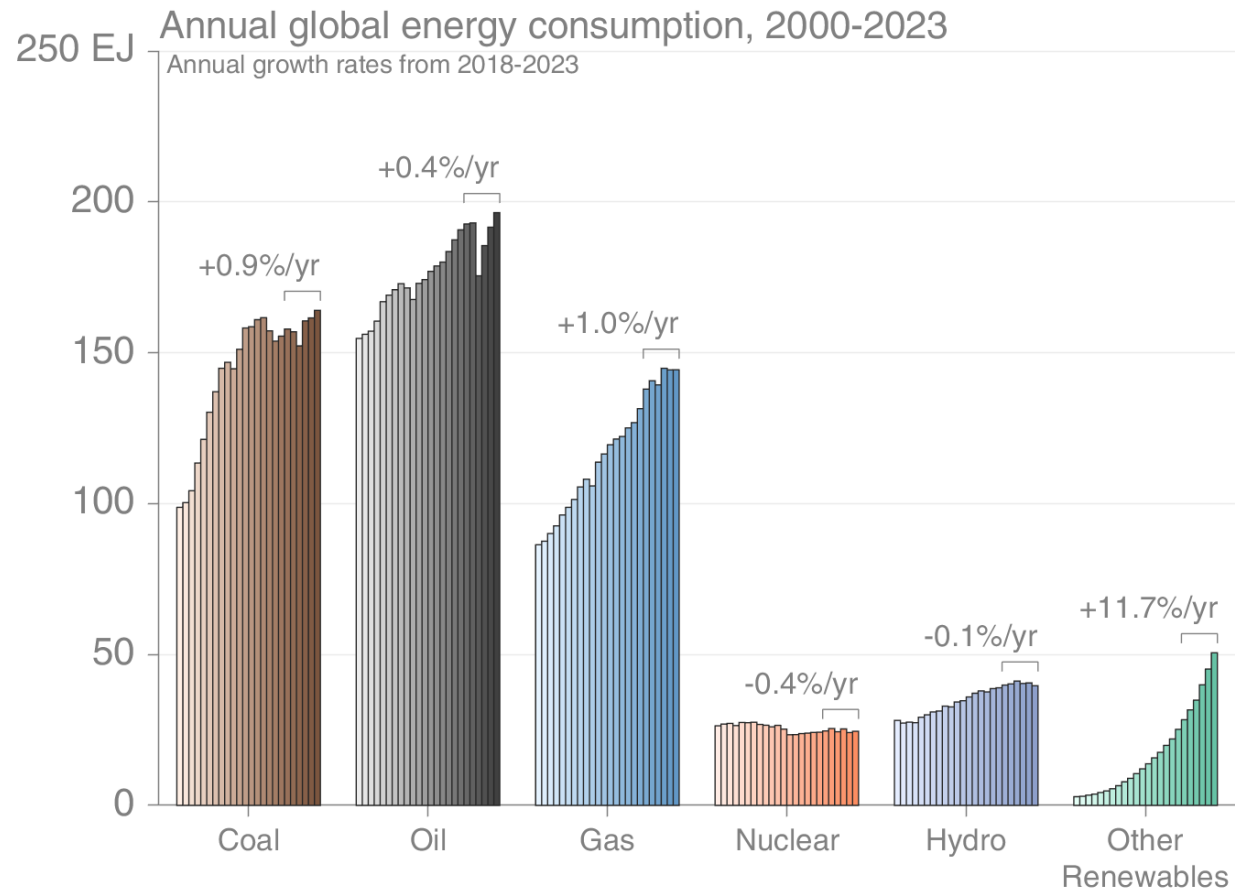
Source: [Friedlingstein et al 2024](#); [Global Carbon Project 2024](#)

# Additional Figures

## Energy Use

# Energy use by source

Energy consumption by fuel source from 2000 to 2023, with growth rates indicated for the more recent period of 2018 to 2023



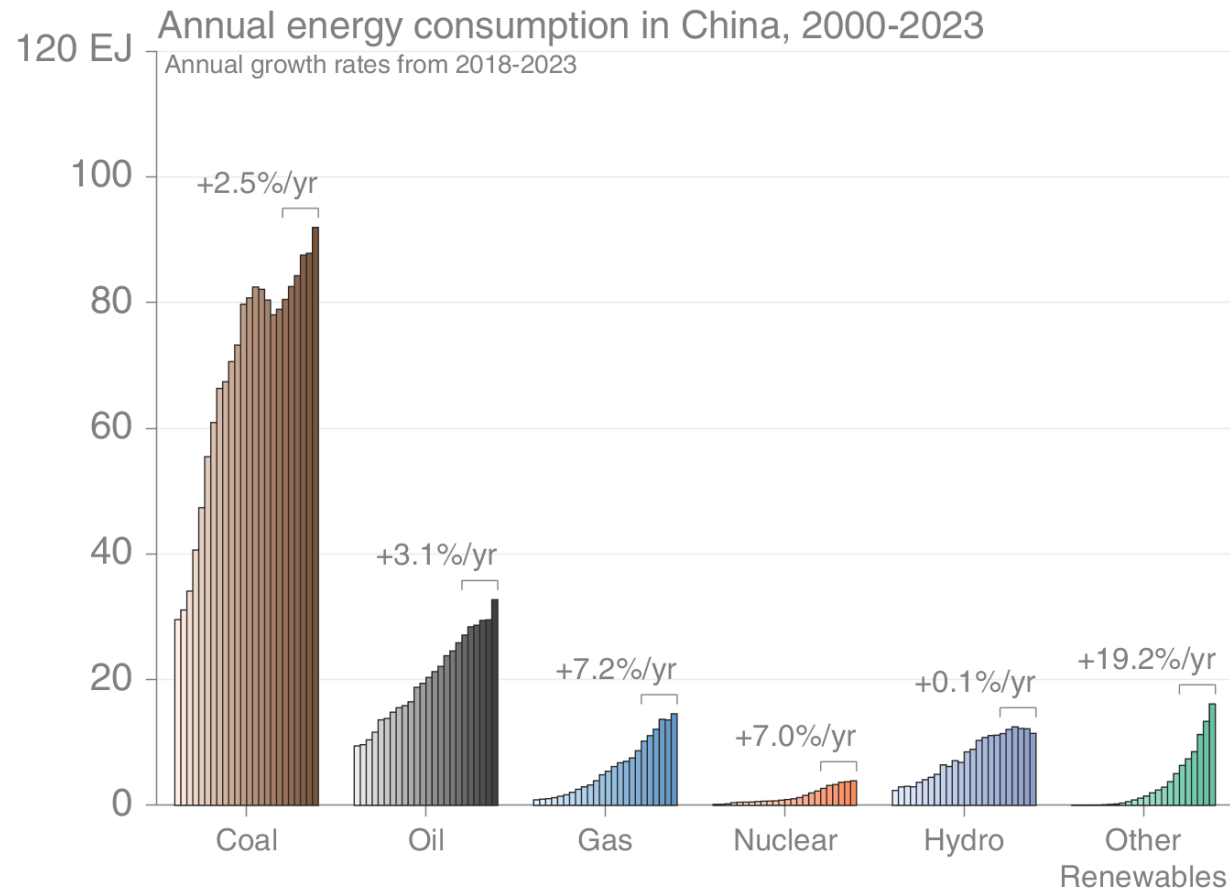
© Global Carbon Project • Data: Energy Institute

This figure shows “primary energy” using the BP substitution method (non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)

Source: [Energy Institute, 2023](#); [Global Carbon Project 2024](#)

# Energy use by source: China

Coal consumption in energy units has returned to peak levels, while consumption of all other energy sources is growing strongly



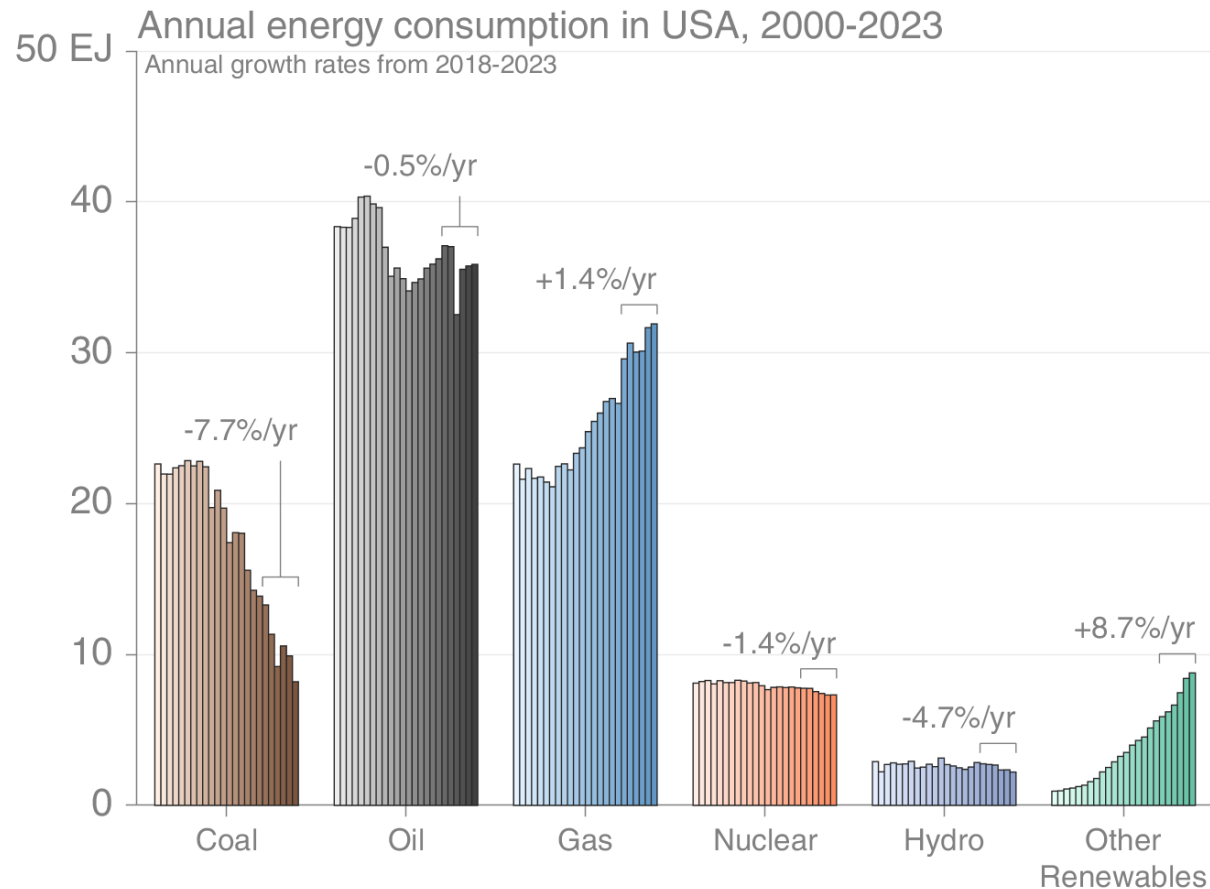
© Global Carbon Project • Data: Energy Institute

This figure shows “primary energy” using the BP substitution method (non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)

Source: [Energy Institute, 2023](#); [Global Carbon Project 2024](#)

# Energy use by source: USA

Coal consumption has declined sharply in recent years with the shale gas boom and strong renewables growth. Output from nuclear power is slowly declining as stations are retired.



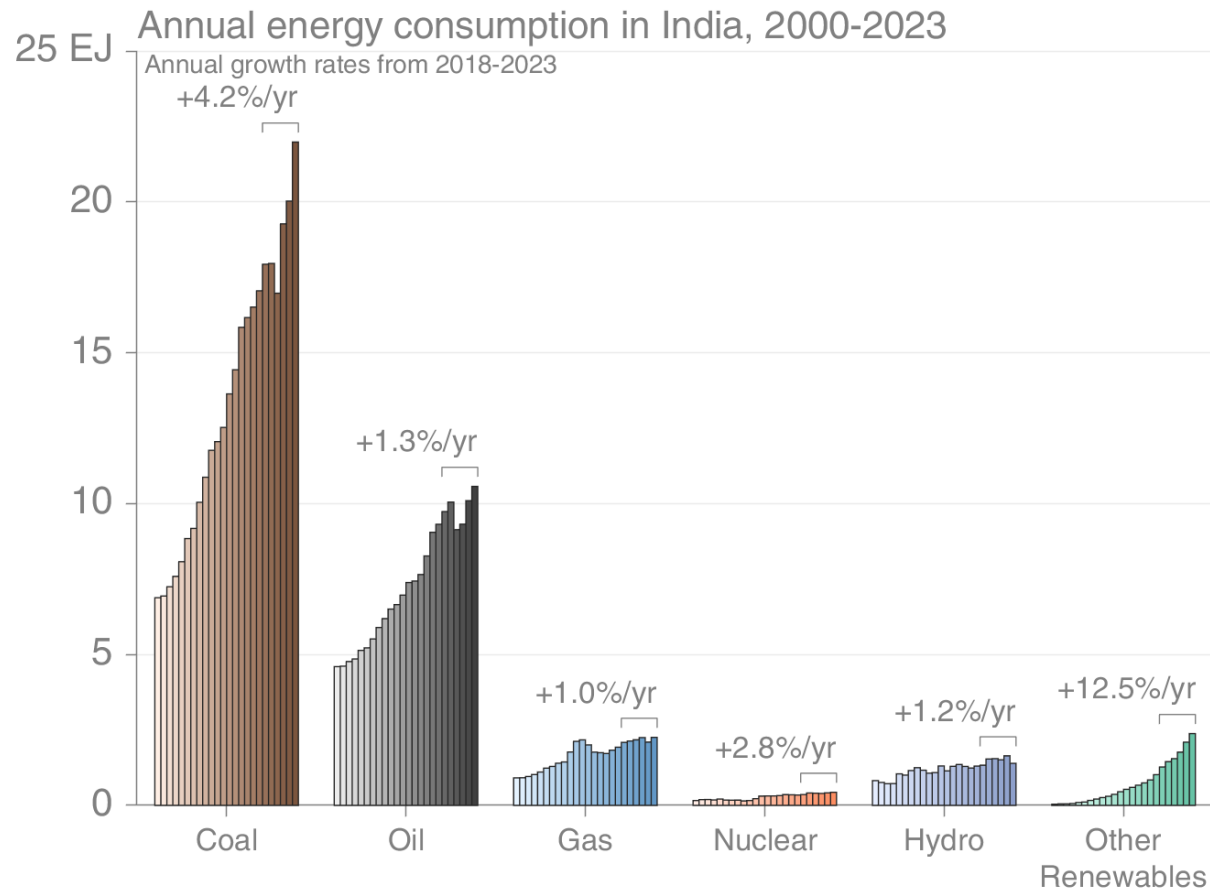
© Global Carbon Project • Data: Energy Institute

This figure shows “primary energy” using the BP substitution method (non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)

Source: [Energy Institute, 2023](#); [Global Carbon Project 2024](#)

# Energy use by source: India

Pandemic year 2020 temporarily interrupted India's strong growth in energy consumption. Consumption of coal and oil dominate.



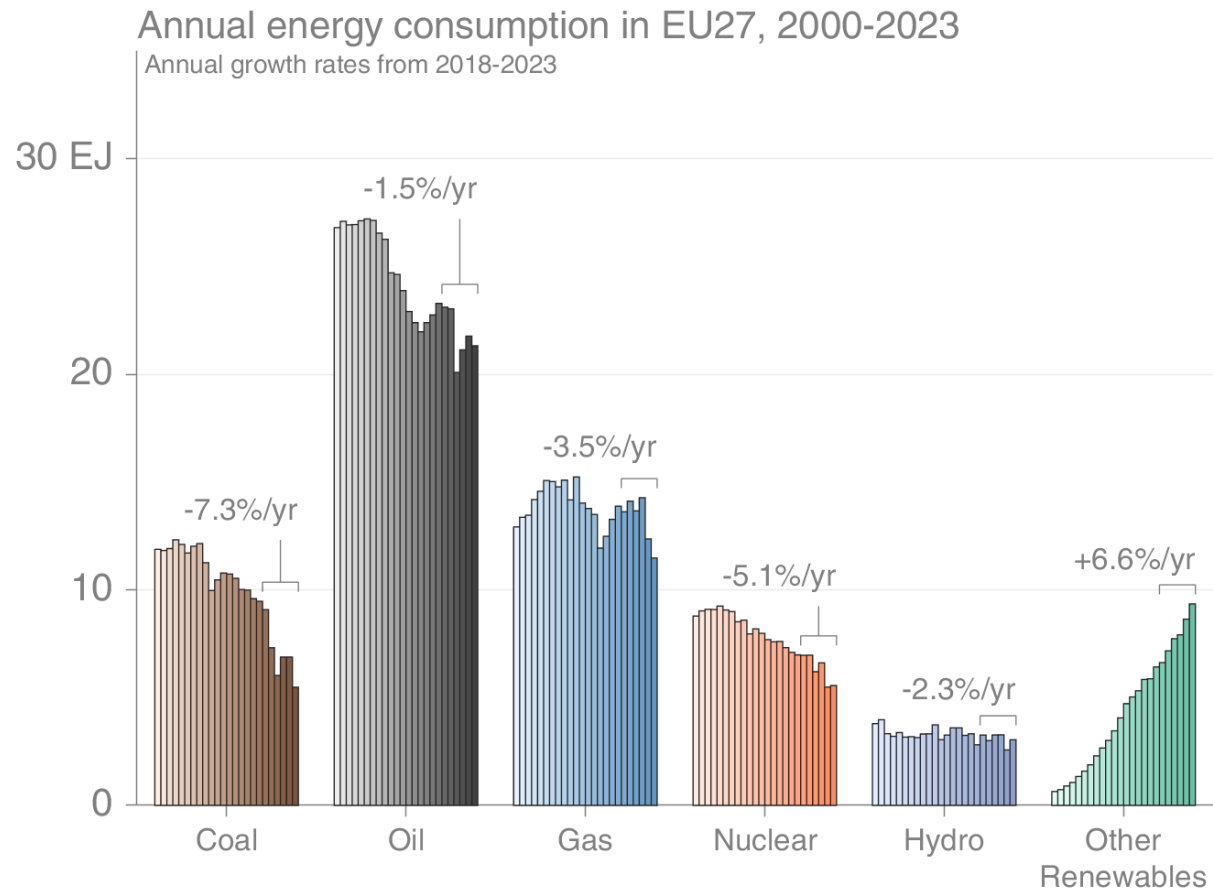
© Global Carbon Project • Data: Energy Institute

This figure shows “primary energy” using the BP substitution method (non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)

Source: [Energy Institute, 2023](#); [Global Carbon Project 2024](#)

# Energy use by source: EU

Consumption of both oil and gas has rebounded in recent years, while coal continues to decline. Renewables are growing strongly, now providing more energy than nuclear power.



© Global Carbon Project • Data: Energy Institute

This figure shows “primary energy” using the BP substitution method (non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)

Source: [Energy Institute, 2023](#); [Global Carbon Project 2024](#)