GLOBAL CARBON project

GLOBAL CARBON BUDGET 2022

The GCP is a Global Research Project of futurearth Research. Innovation. Sustainability. and a Research Partner of WCRP World Climate Research Programme

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Acknowledgements

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

Atmospheric CO_2 datasets
NOAA/ESRL (Dlugokencky and Tans 2022)
Scripps (Keeling et al. 1976)

Fossil CO_2 emissions
Andrew and Peters, 2022
CDIAC (Gilfillan and Marland, 2021)
UNFCCC, 2022
BP, 2022

Consumption Emissions
Peters et al. 2011
GTAP (Narayanan et al. 2015)

Land-Use Change
Houghton and Nassikas 2017
BLUE (Hansis et al. 2015)
OSCAR (Gasser et al. 2020)
GFED4 (van der Werf et al. 2017)
FAO-FRA and FAOSTAT
HYDE (Klein Goldewijk et al. 2017)
LUH2 (Hurtt et al. 2020)

Atmospheric inversions
CarbonTracker Europe | Jena CarboScope | CAMS | UoE In situ | NISMON-CO2 | CMS-Flux

Land models
CABLE-POP | CLASSIC | CLM5.0 | DLEM | IBIS | ISAM | ISBA-CTRIP | JSBACH | JULES-ES | LPJ-GUESS | LPJ | LPX-Bern | OCN | ORCHIDEEv3 | SDGVM | VISIT | YIBs
Climate forcing CRU (Harris et al. 2014) | JRA-55 (Kobayashi et al. 2015)

Ocean models
CESM-ETHZ | FESOM-2.1-REcoM2 | MICOM-HAMOCC (NorESM-OCv1.2) | MOM6-COBALT (Princeton) | MPIOM-HAMOCC6 | NEMO3.6-PISCESv2-gas (CNRM) | NEMO-PISCES (IPSL) | NEMO-PlankTOM12

fCO_2 based ocean flux products
CMEMS-LSCE-FFNNv2 |CSIR-ML6 | Jena- MLS | JMA-MLR | NIES-NN | MPI-SOMFFN | OS-ETHZ-GRaCER | Watson et al.

Surface Ocean CO2 Atlas SOCATv2022

Full references provided in Friedlingstein et al 2022

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PP Tans USA | **X Tian** China | **H Tian** USA | **B Tilbrook** Australia | **H Tsujino** Japan | **F Tubiello** Italy |
GR van der Werf Netherlands | **AP Walker** USA | **R Wanninkhof** USA | **C Whitehead** USA |
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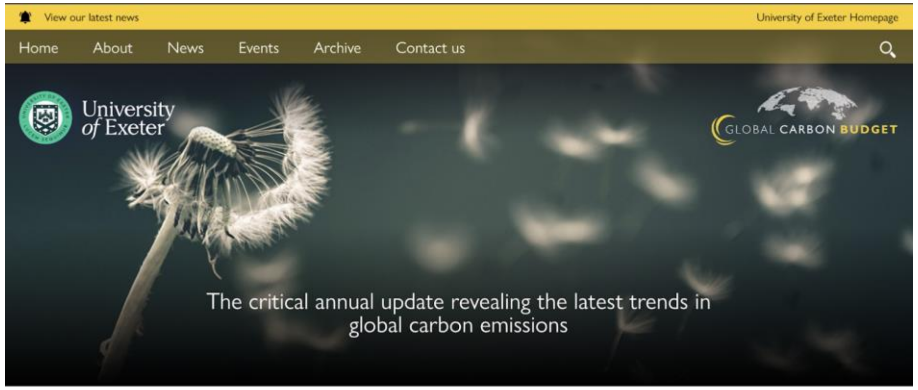
Data Access and Additional Resources

More information, data sources and data files:
http://www.globalcarbonproject.org/carbonbudget
Contact: Pep.Canadell@csiro.au

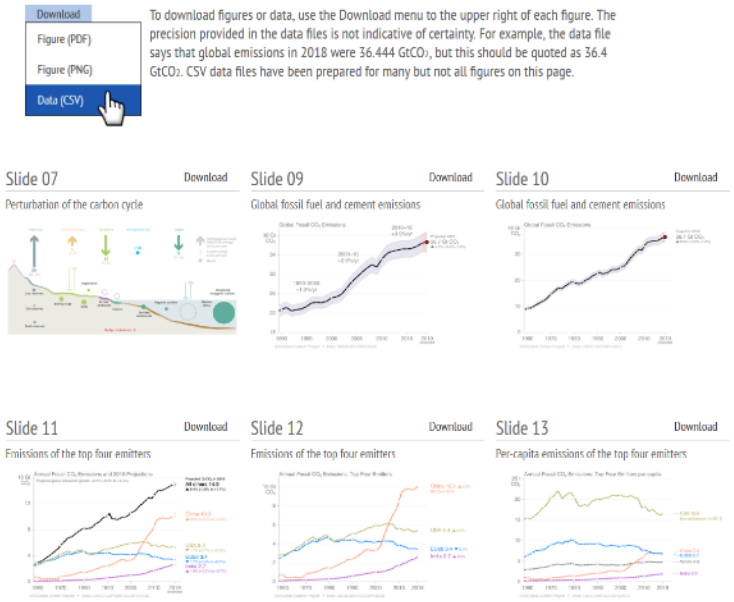


More information, data sources and data files:
https://globalcarbonbudget.org/carbonbudget

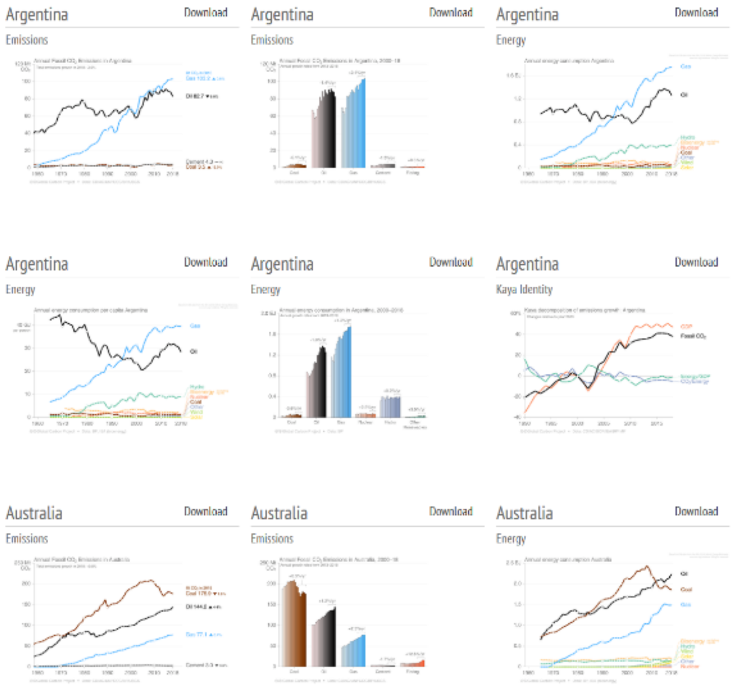
More information, data sources and data files:
www.globalcarbonatlas.org
(co-funded in part by BNP Paribas Foundation)

Download of figures and data

Global Carbon Budget



Additional country figures



Figures and data for most slides available from tinyurl.com/GCB22figs
and from https://globalcarbonbudget.org/carbonbudget

All the data is shown in billion tonnes CO_2 ($GtCO_2$)

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

1 kg carbon (C) = 3.664 kg carbon dioxide (CO_2)

1 GtC = 3.664 billion tonnes CO_2 = 3.664 $GtCO_2$

(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/GCB22figs along with the data required to produce them.

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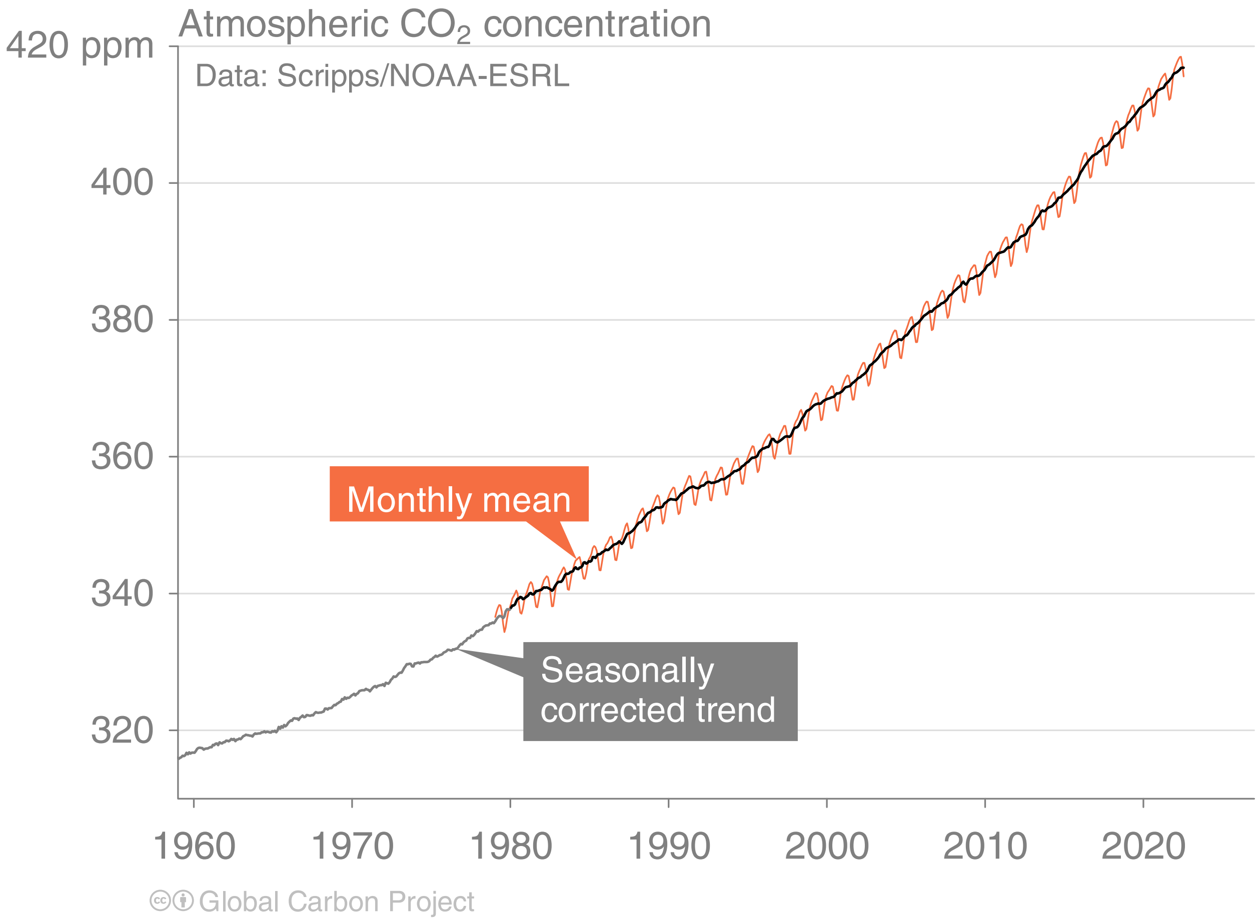
Atmospheric CO_2 concentration

The global CO_2 concentration increased from ~277 ppm in 1750 to 417.2 ppm in 2022 (up 51%)

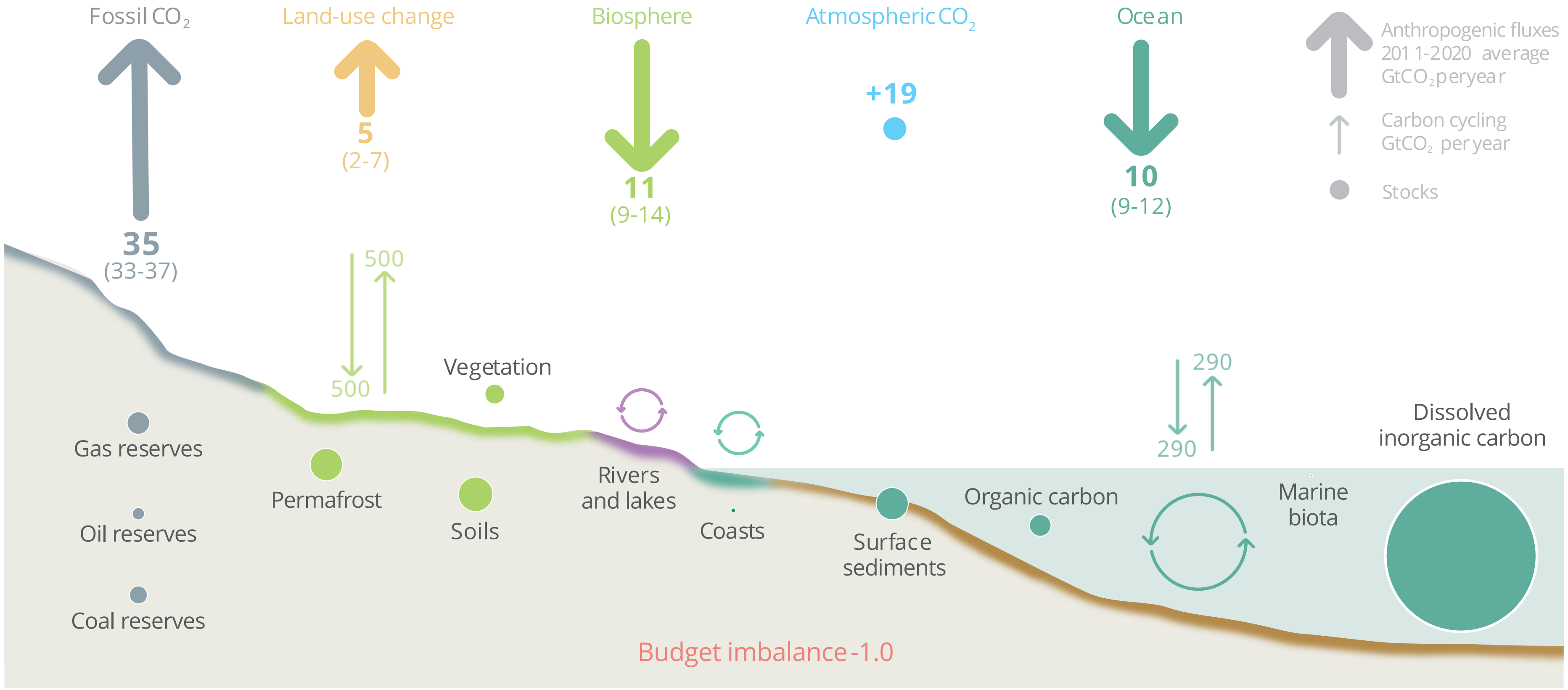


Globally averaged surface atmospheric CO_2 concentration. Data from: NOAA-ESRL after 1980;
the Scripps Institution of Oceanography before 1980

Source: NOAA-ESRL; Scripps Institution of Oceanography; Friedlingstein et al 2022; Global Carbon Project 2022

Anthropogenic perturbation of the global carbon cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, global annual average for the decade 2012–2021 ($GtCO_2$/yr)



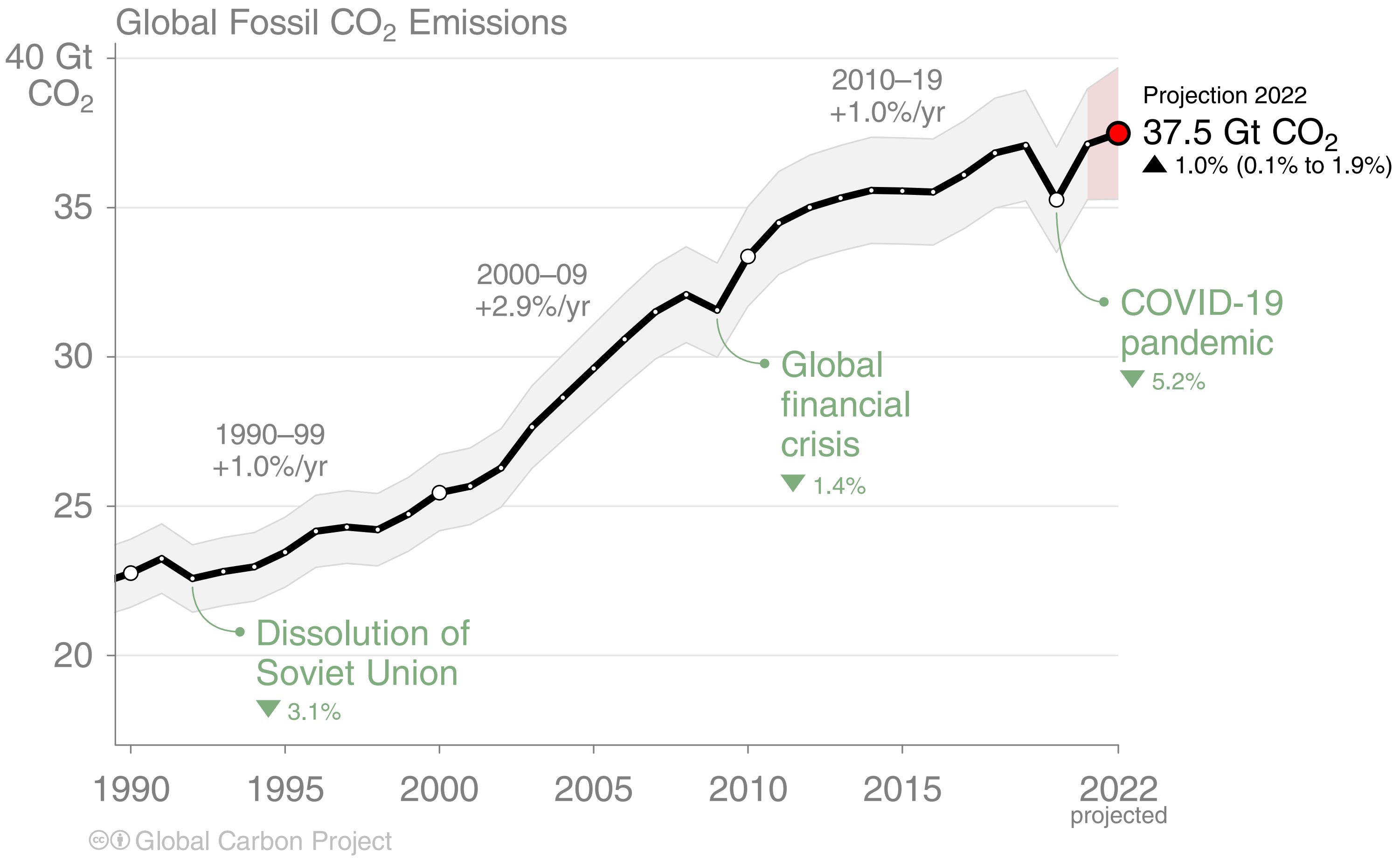
The budget imbalance is the difference between the estimated emissions and sinks.
Source: NOAA-ESRL; Friedlingstein et al 2022; Canadell et al 2021 (IPCC AR6 WG1 Chapter 5); Global Carbon Project 2022

Key Highlights in 2022

Global Fossil CO_2 Emissions

Global fossil CO_2 emissions: 37.1 ± 2 $GtCO_2$ in 2021, 63% over 1990

Projection for 2022: 37.5 ± 2 $GtCO_2$, 1.0% [0.1% to +1.9%] higher than 2021



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

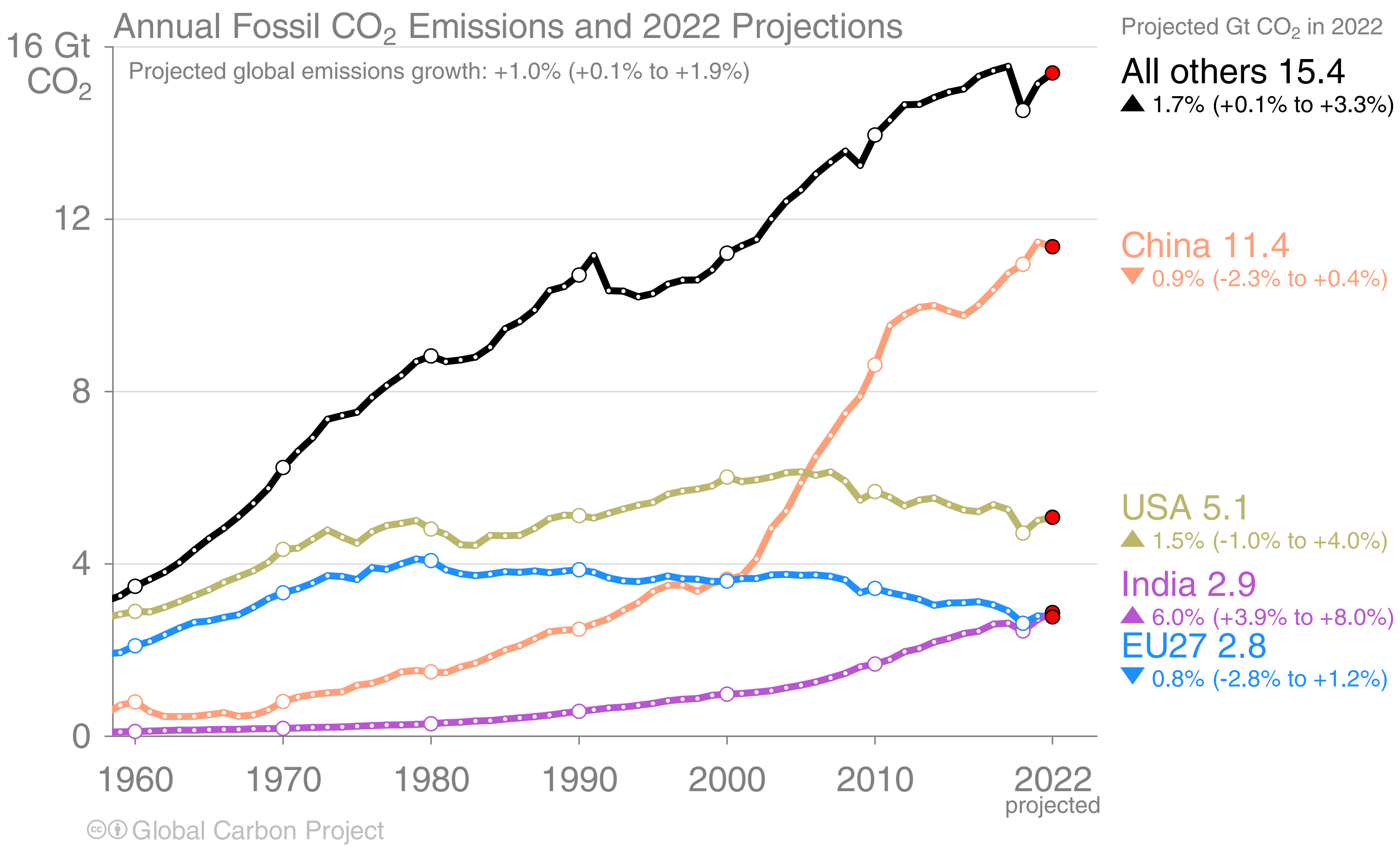
When including cement carbonation, the 2021 and 2022 estimates amount to 36.3 ± 2 $GtCO_2$ and 36.6 ± 2 $GtCO_2$ respectively

The 2022 projection is based on preliminary data and modelling.

Source: Friedlingstein et al 2022; Global Carbon Project 2022

Emissions Projections for 2022

Global fossil CO_2 emissions are projected to increase by 1.0% [0.1% to 1.9%] in 2022



The 2022 projections are based on preliminary data and modelling.
Source: Friedlingstein et al 2022; Global Carbon Project 2022

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Fossil CO_2 emissions growth: 2020–2022

Emissions are expected to decrease in China and the EU in 2022, and increase in USA, India and the combined rest of the world (Others)

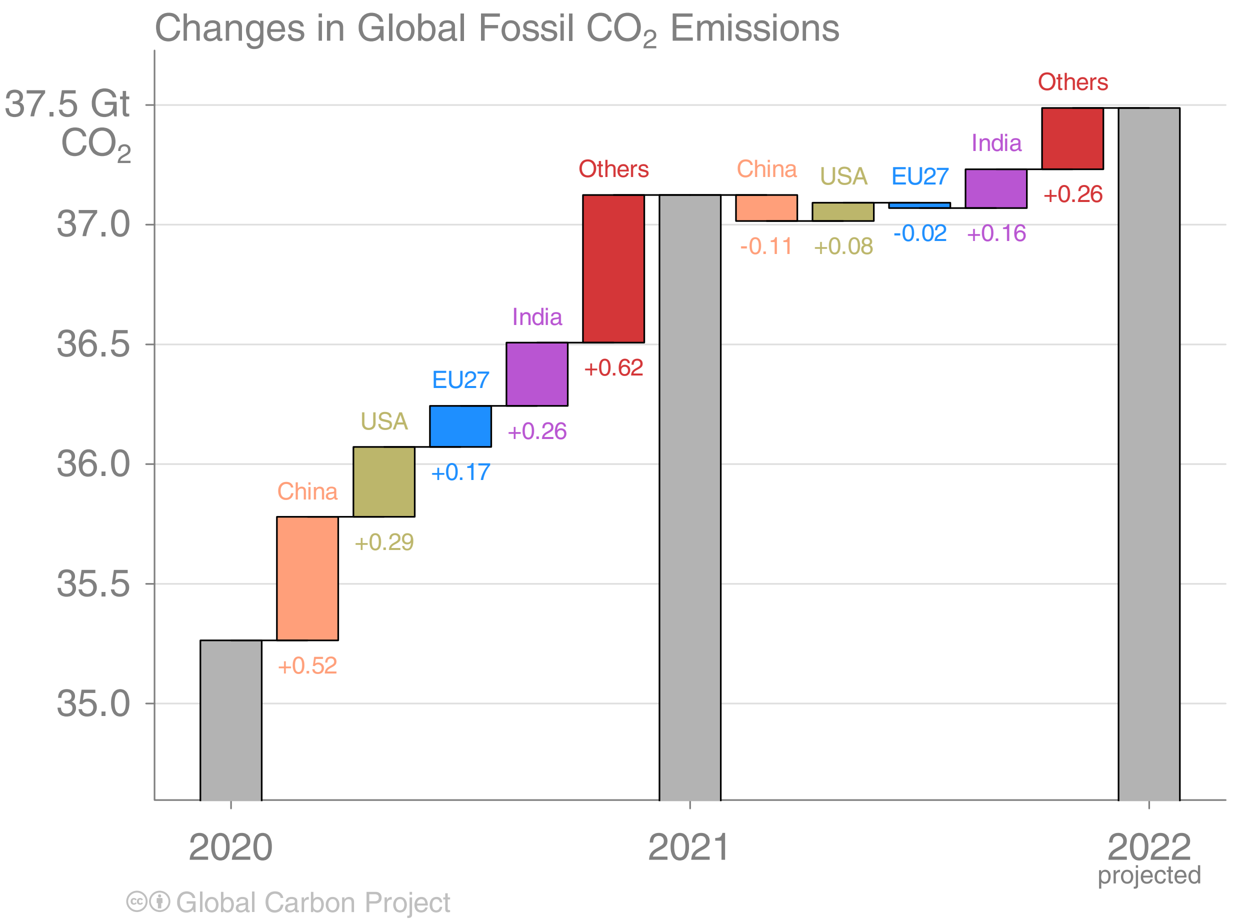


Figure shows the top four countries contributing to emissions changes
International shipping and aviation are included in “Others”
Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

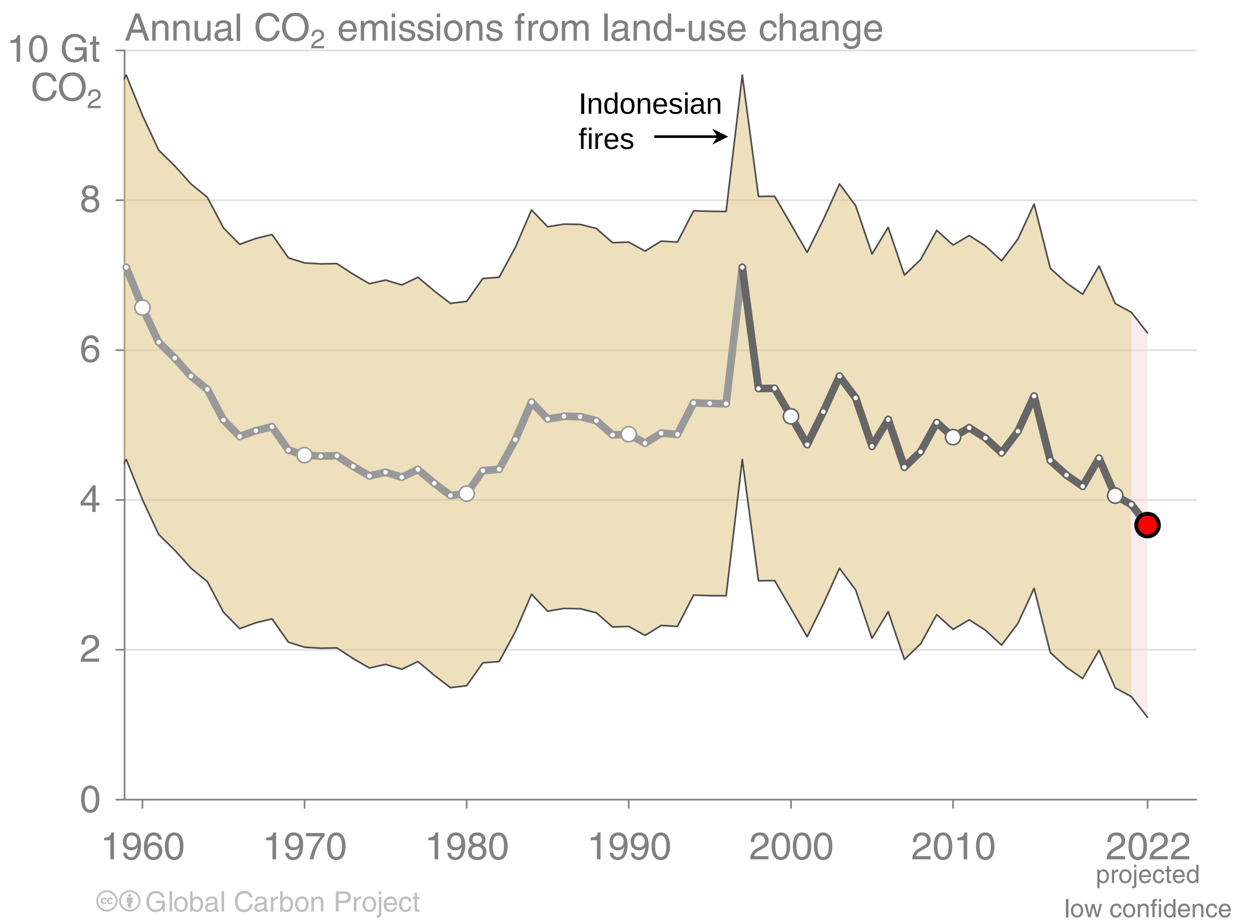
Summary of fossil CO_2 emissions in 2021 and 2022

Region / Country	2021 emissions (billion tonnes/yr)	2021 growth (percent)	2022 projected emissions growth (percent)	2022 projected emissions (billion tonnes/yr)
China	11.5	+5.0%	-0.9%	11.4
USA	5.0	+6.5%	+1.5%	5.1
EU27	2.8	+6.8%	-0.8%	2.8
India	2.7	+11.1%	+6.0%	2.9
All others (incl. IAS*)	15.1	+4.5%	+1.7%	15.4
World (incl. IAS*)	37.1	+5.6%	+1.0%	37.5
World (incl. IAS* and cement carbonation)	36.3	+5.6%	+1.0%	36.6

*IAS: 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 2022; Global Carbon Project 2022

Land-use change emissions

Land-use change emissions are 4.5 ± 2.6 $GtCO_2$ per year for 2012-2021, and show a negative trend in the last two decades, but estimates are still highly uncertain. ● Projection for 2022: 3.9 ± 2.6 $GtCO_2$

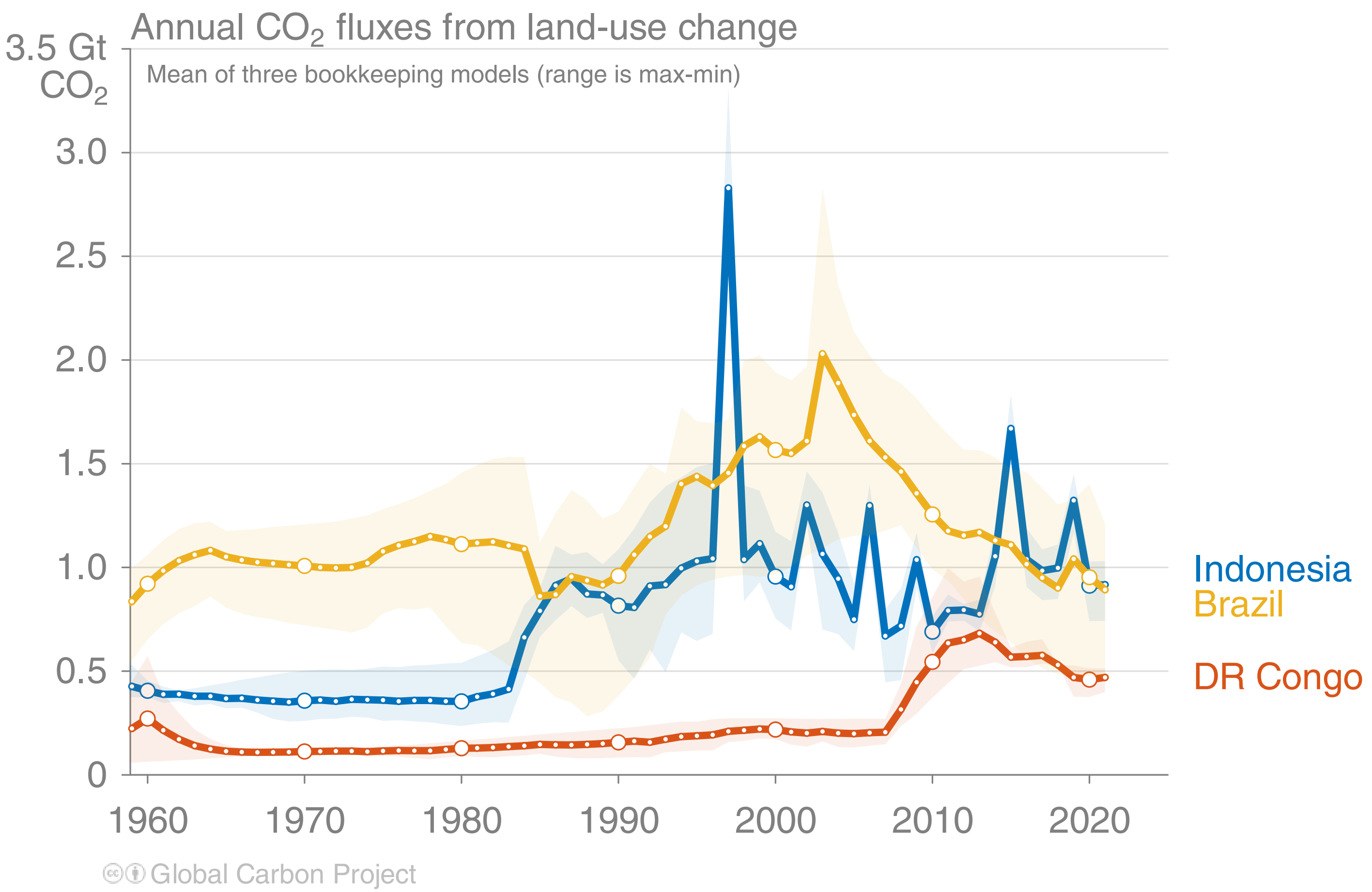


Estimates from three bookkeeping models

Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Land-use change emissions

Combined land-use change emissions from Brazil, the Democratic Republic of the Congo, and Indonesia make up over 50% of the global net land-use change emissions



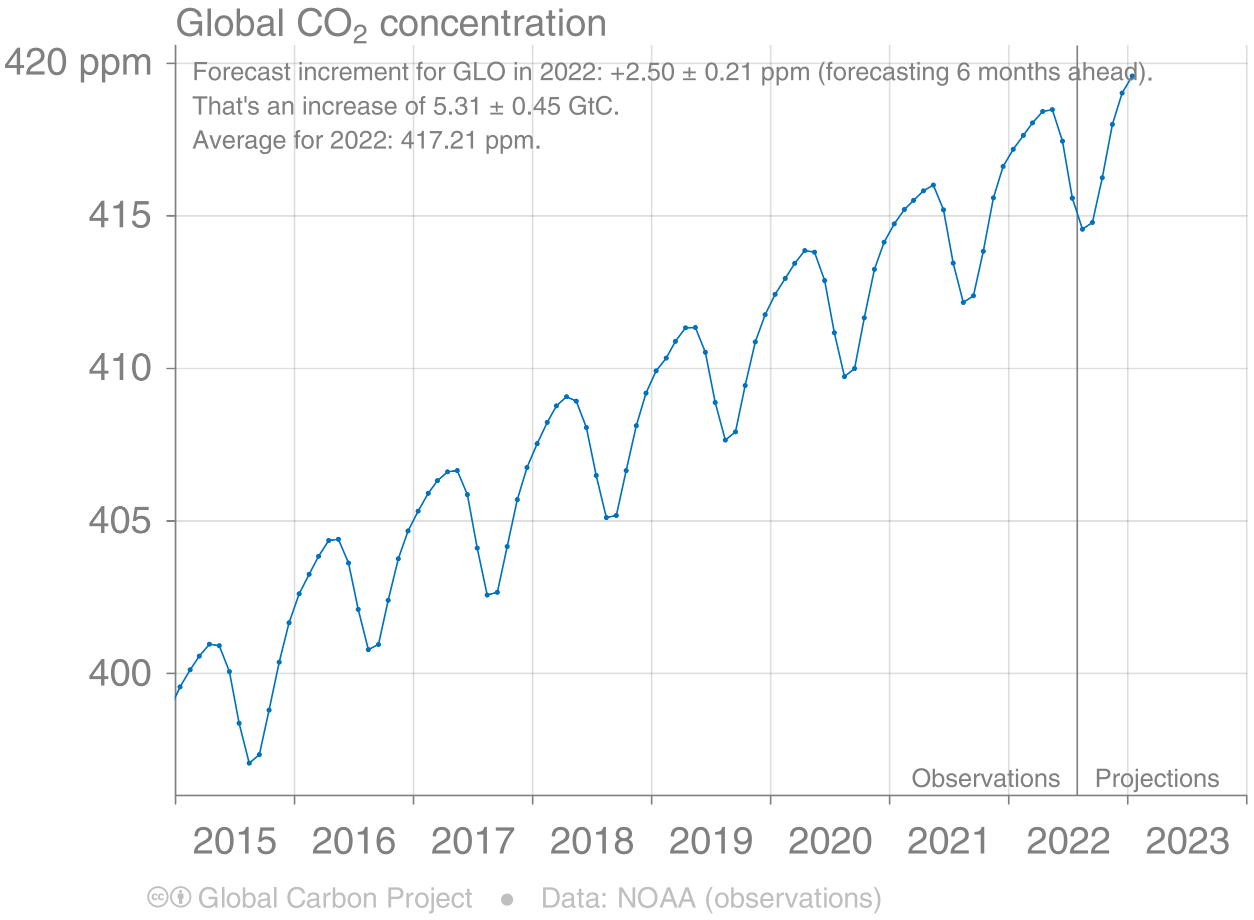
The peak in Indonesia in 1997 was the Indonesian peat fires

Estimates from three bookkeeping models

Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Forecast of global atmospheric CO_2 concentration

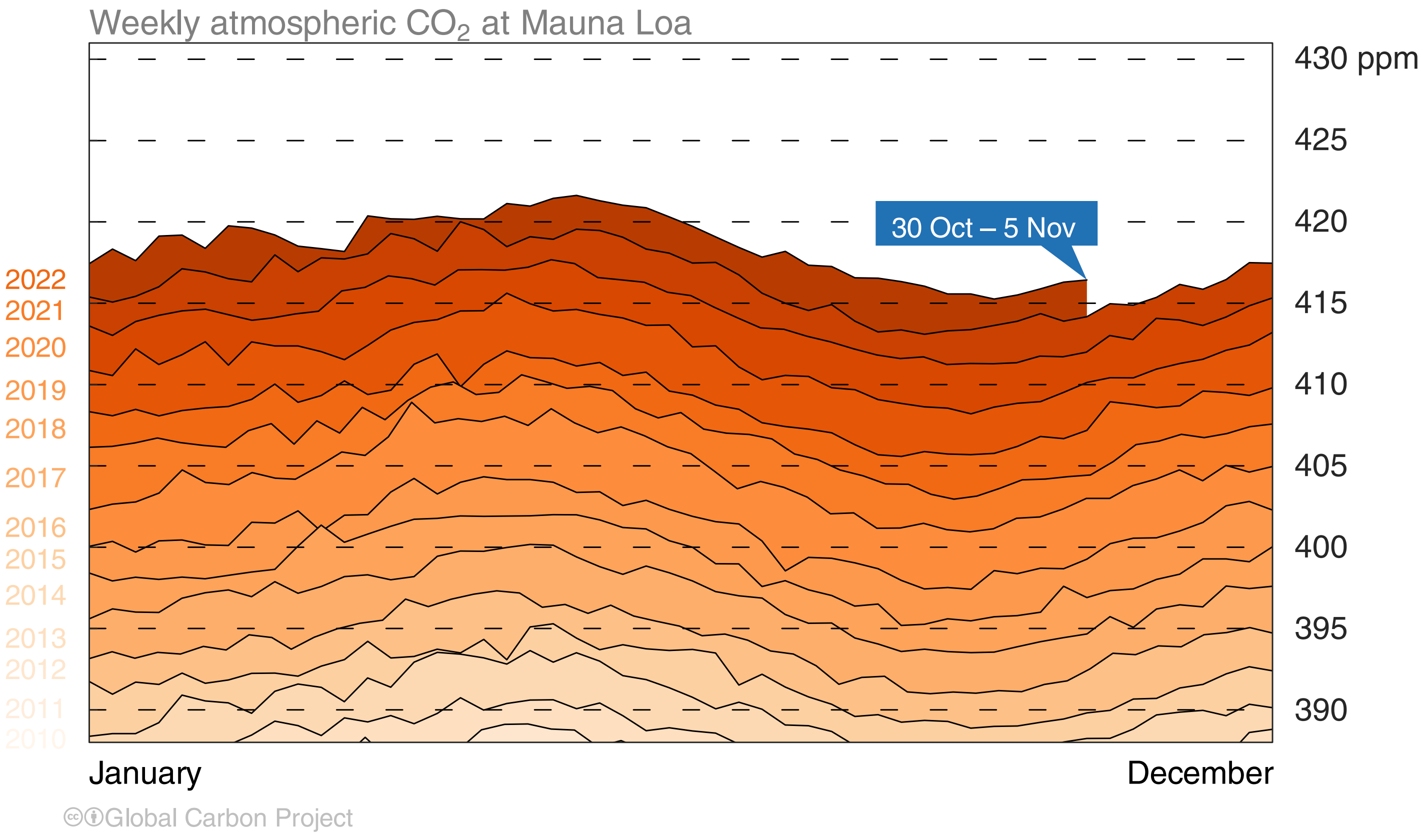
The global atmospheric CO_2 concentration is forecast to average 417 parts per million (ppm) in 2022, increasing by 2.5 ppm



Source: Friedlingstein et al 2022; Global Carbon Budget 2022

Mauna Loa atmospheric CO_2

Atmospheric CO_2 concentration has increased every single year,
including in 2020, despite the drop in fossil CO_2 emissions, because of continued emissions

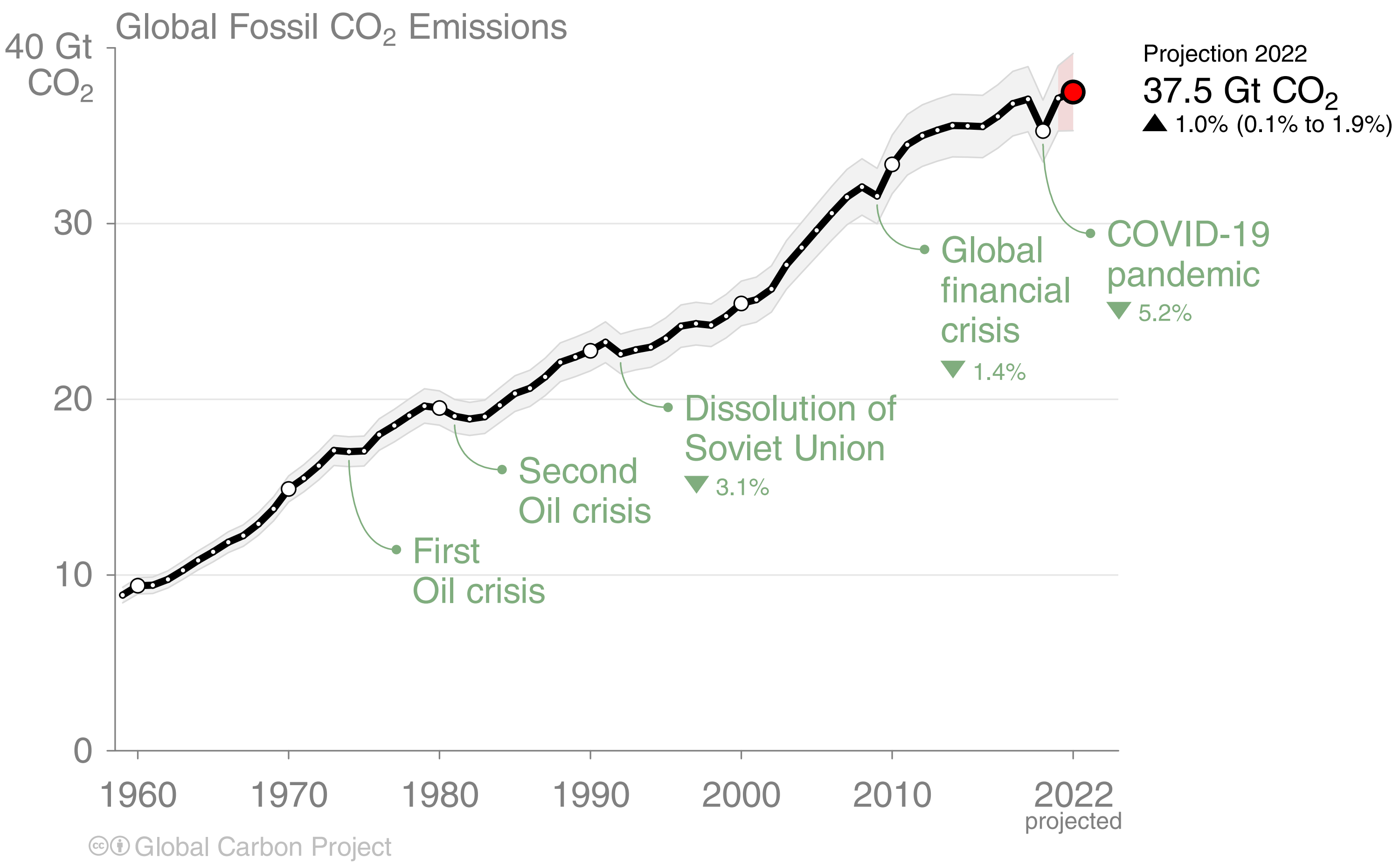


Source: Tans and Keeling (2020); Friedlingstein et al 2022; Global Carbon Budget 2022

Global Fossil CO_2 Emissions

Global Fossil CO_2 Emissions

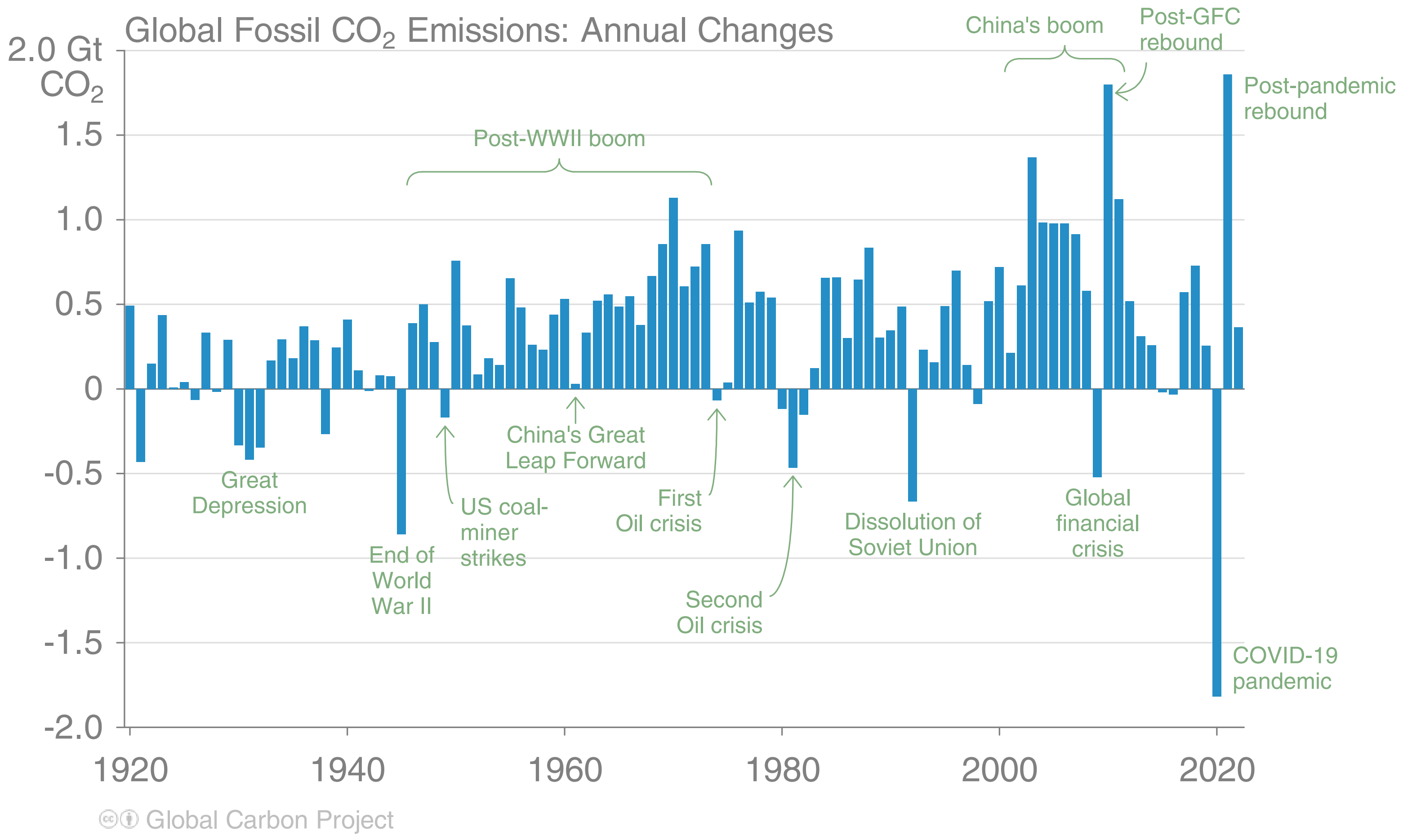
Global fossil CO_2 emissions have risen steadily over the last decades.
Emissions are set to grow again in 2022.



When including cement carbonation, the 2022 estimate is 36.6 ± 2 $GtCO_2$.
The 2022 projection is based on preliminary data and modelling.
Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Global Fossil CO_2 Emissions

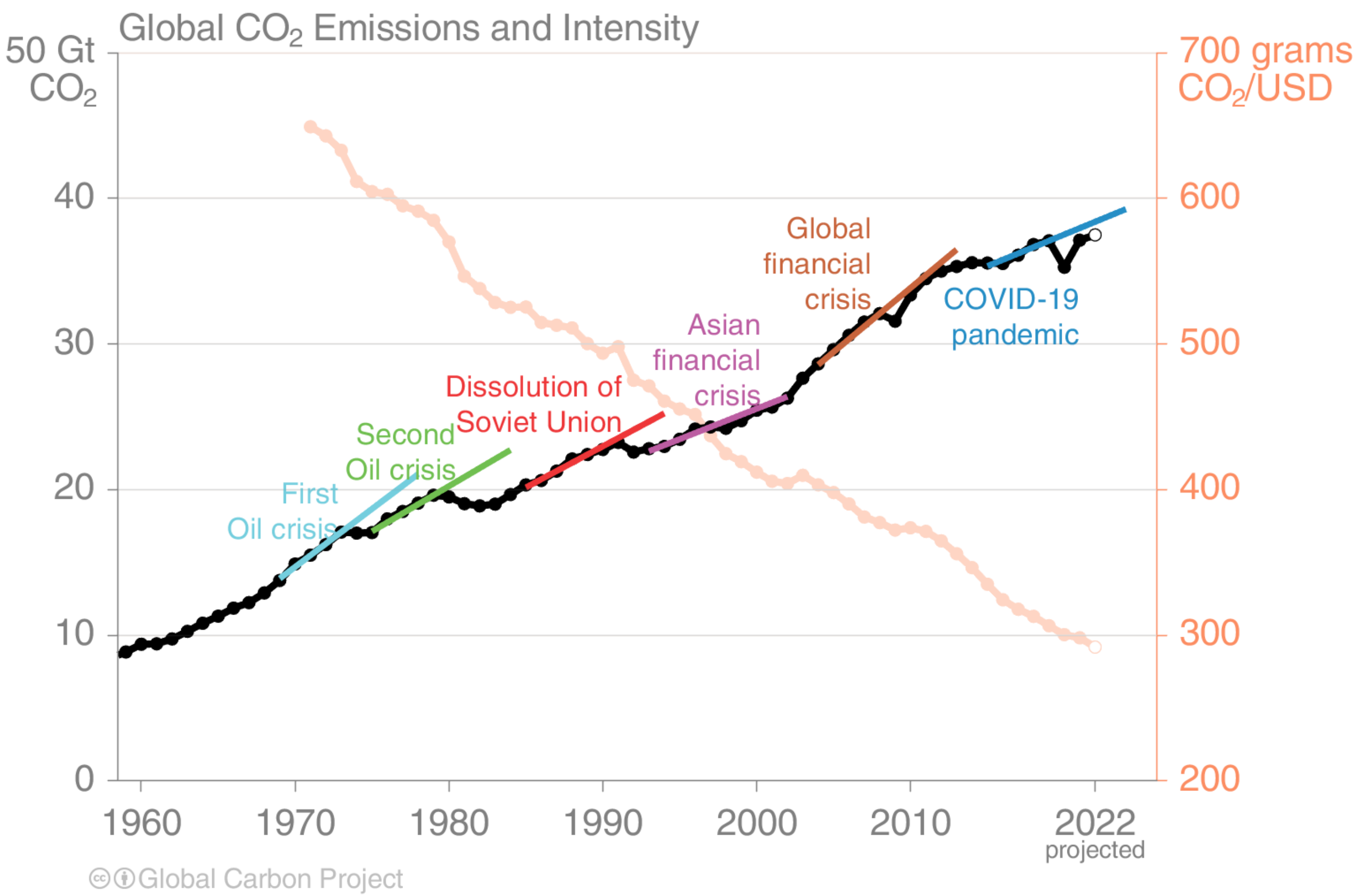
For the last 100 years, it has generally taken a crisis to drive global emissions reductions.
To stabilise temperatures, intentional, planned, sustained global reductions must begin.



The 2022 projection is based on preliminary data and modelling.
Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Fossil CO_2 emission intensity

Global CO_2 emissions growth has generally resumed quickly from global crises.
Emission intensity has steadily declined but not sufficiently to offset economic growth.



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 2010 US dollars.
Source: Friedlingstein et al 2022; Global Carbon Project 2022

Fossil CO_2 Emissions by country

Top emitters: Fossil CO_2 Emissions to 2021

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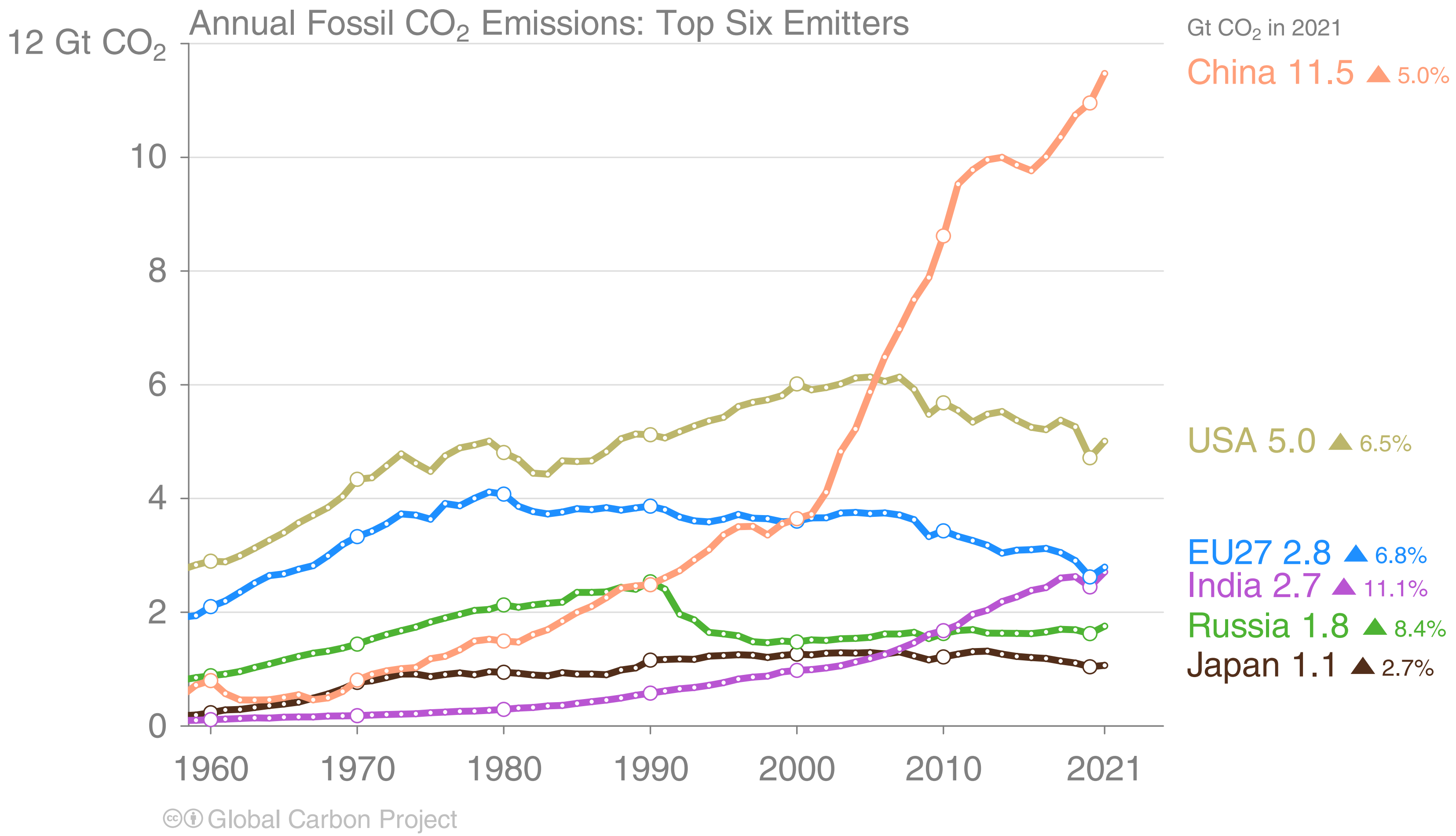
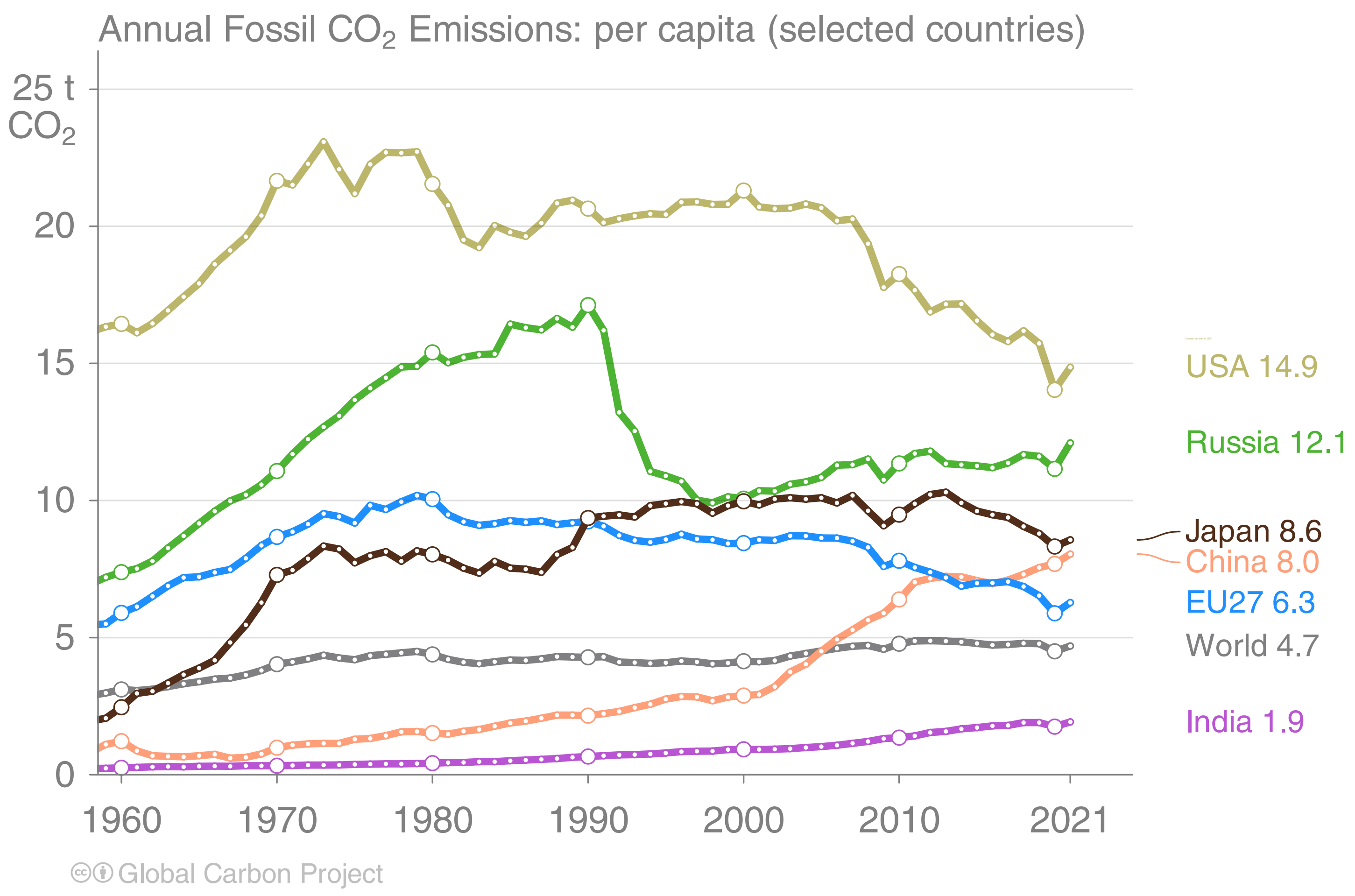
The top six emitters in 2021 covered 67% of global emissions
China 31%, United States 14%, EU27 8%, India 7%, Russia 5%, and Japan 3%



International aviation and maritime shipping (bunker fuels) contributed 2.8% of global emissions in 2021.
Source: Friedlingstein et al 2022; Global Carbon Project 2022

Top emitters: Fossil CO_2 Emissions per capita to 2021

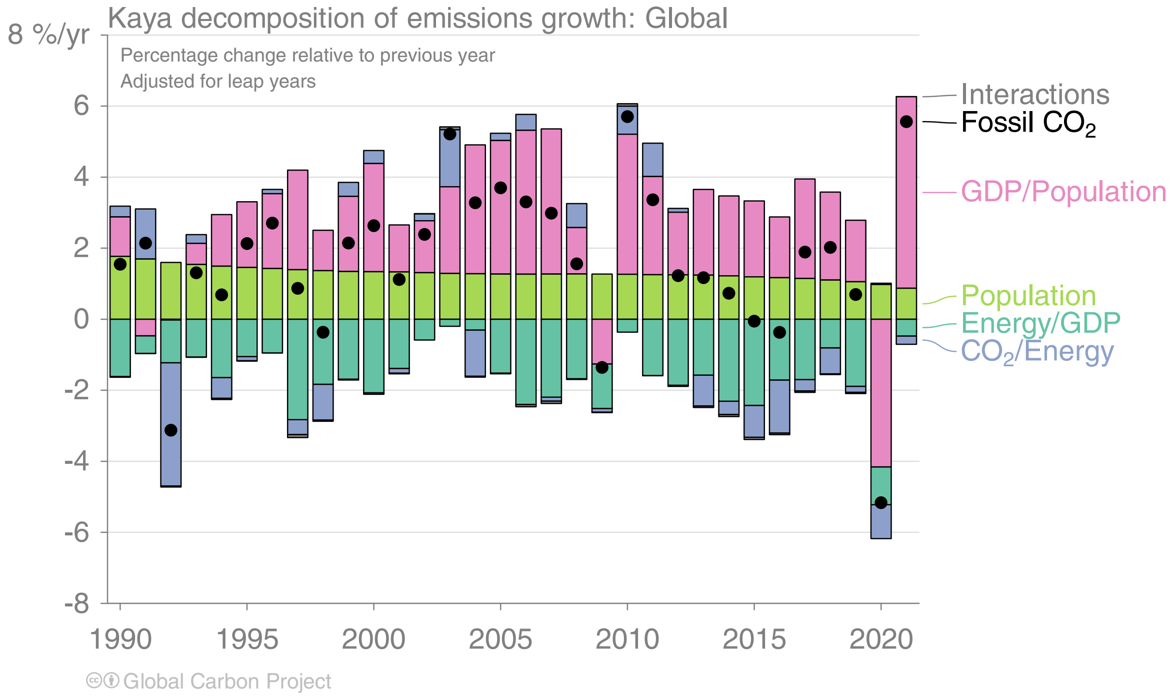
Countries have a broad range of per capita emissions reflecting their national circumstances

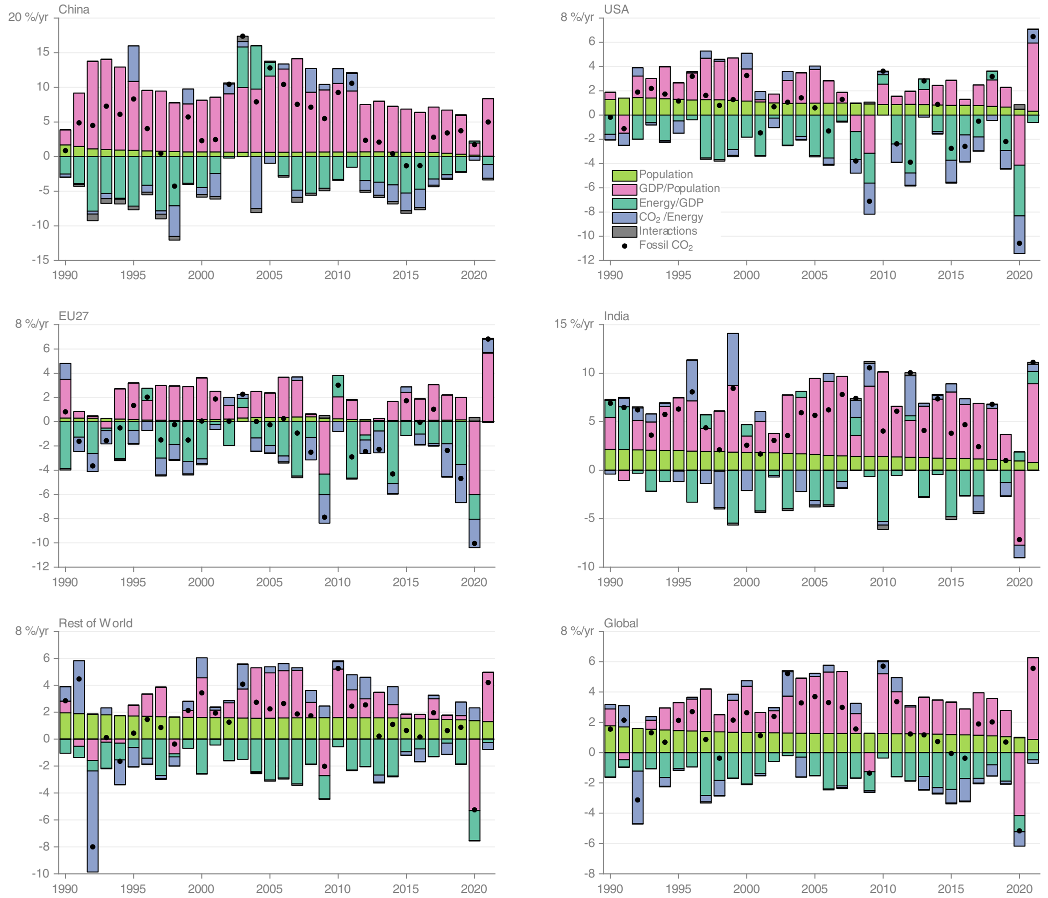


Source: Friedlingstein et al 2022; Global Carbon Project 2022

Fossil CO_2 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 severe decline in GDP.

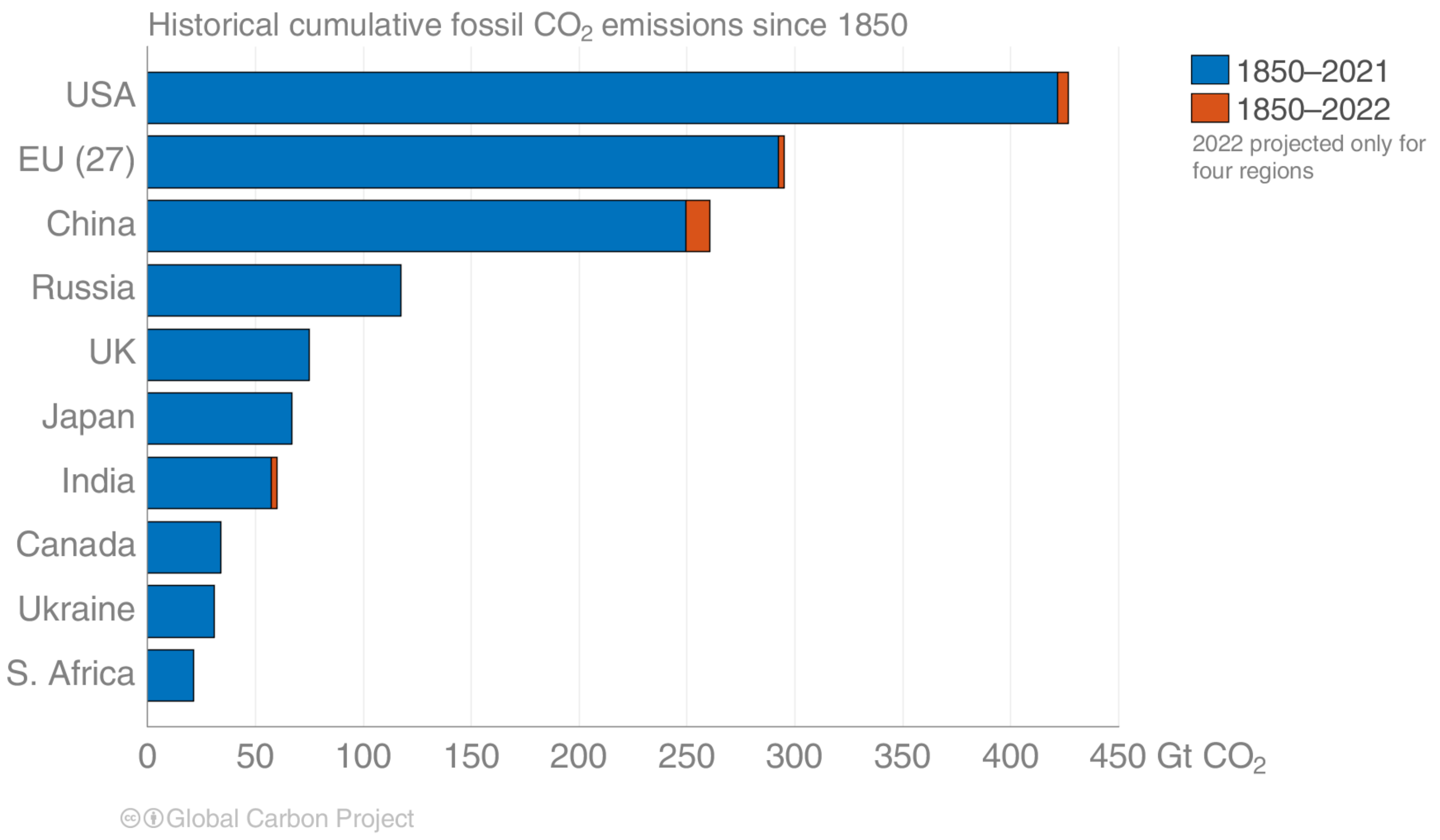




Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Historical cumulative fossil CO_2 emissions

The USA and EU have the highest accumulated fossil CO_2 emissions since 1850, but China is not far behind.

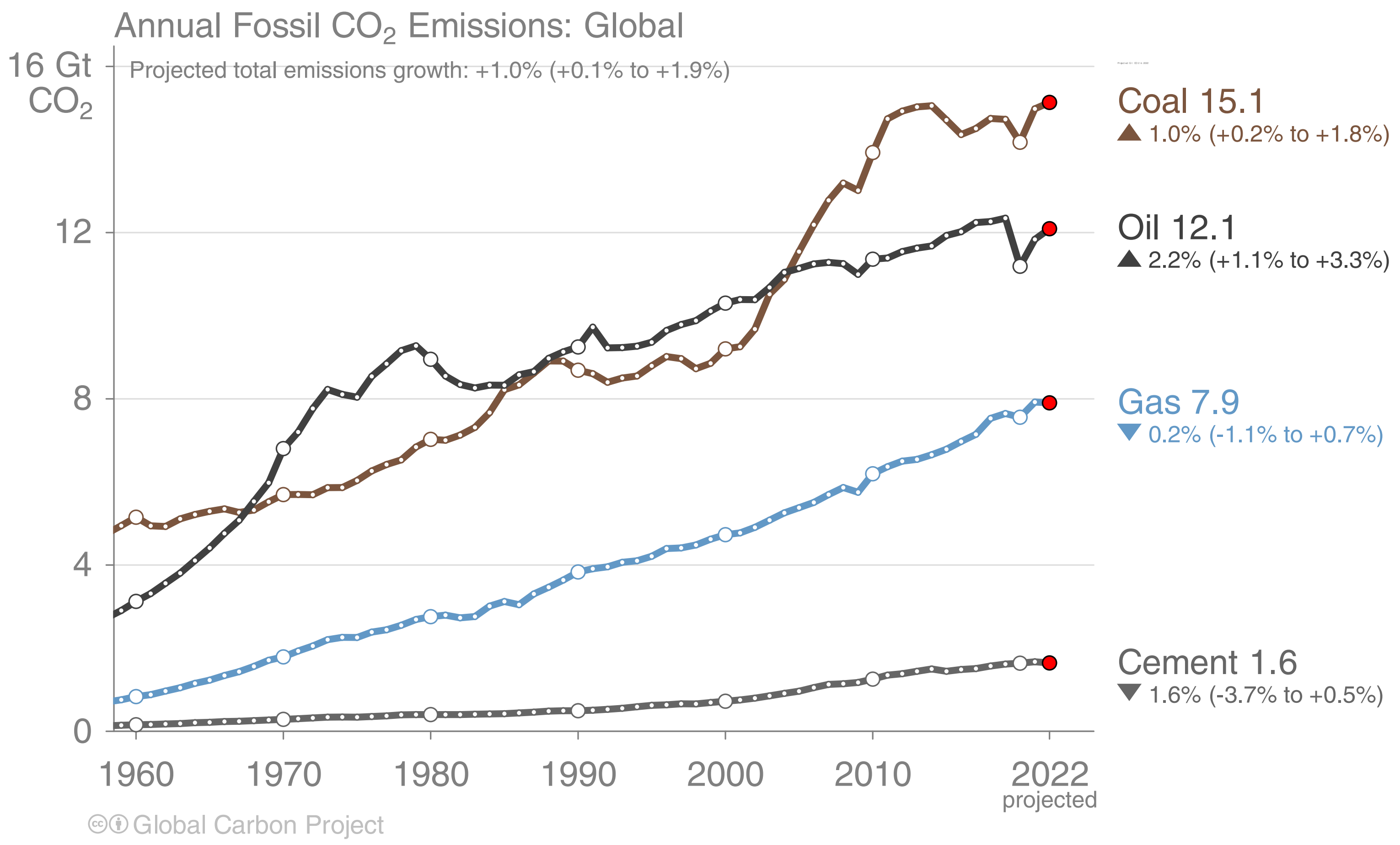


Calculated using territorial emissions.
Source: Friedlingstein et al 2022; Global Carbon Project 2022

Fossil CO_2 Emissions by source

Fossil CO_2 Emissions by source

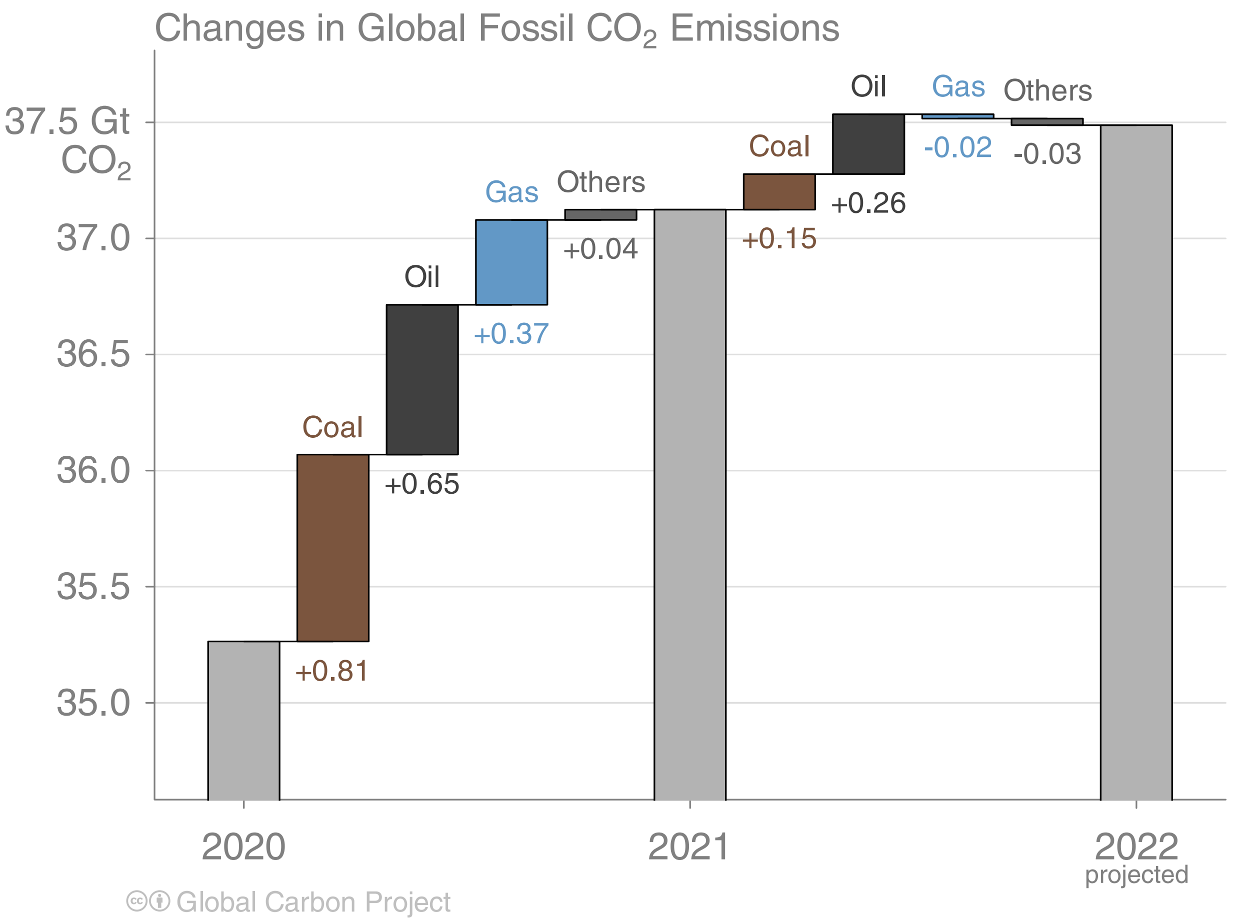
Share of global fossil CO2 emissions in 2021: coal (40%), oil (32%), gas (21%), cement (5%), flaring and others (2%, not shown)
Projection by fuel type is based on monthly data (GCP analysis)



Source: [Friedlingstein et al 2022]; [Global Carbon Project 2022]

Fossil CO_2 emissions growth: 2020–2022

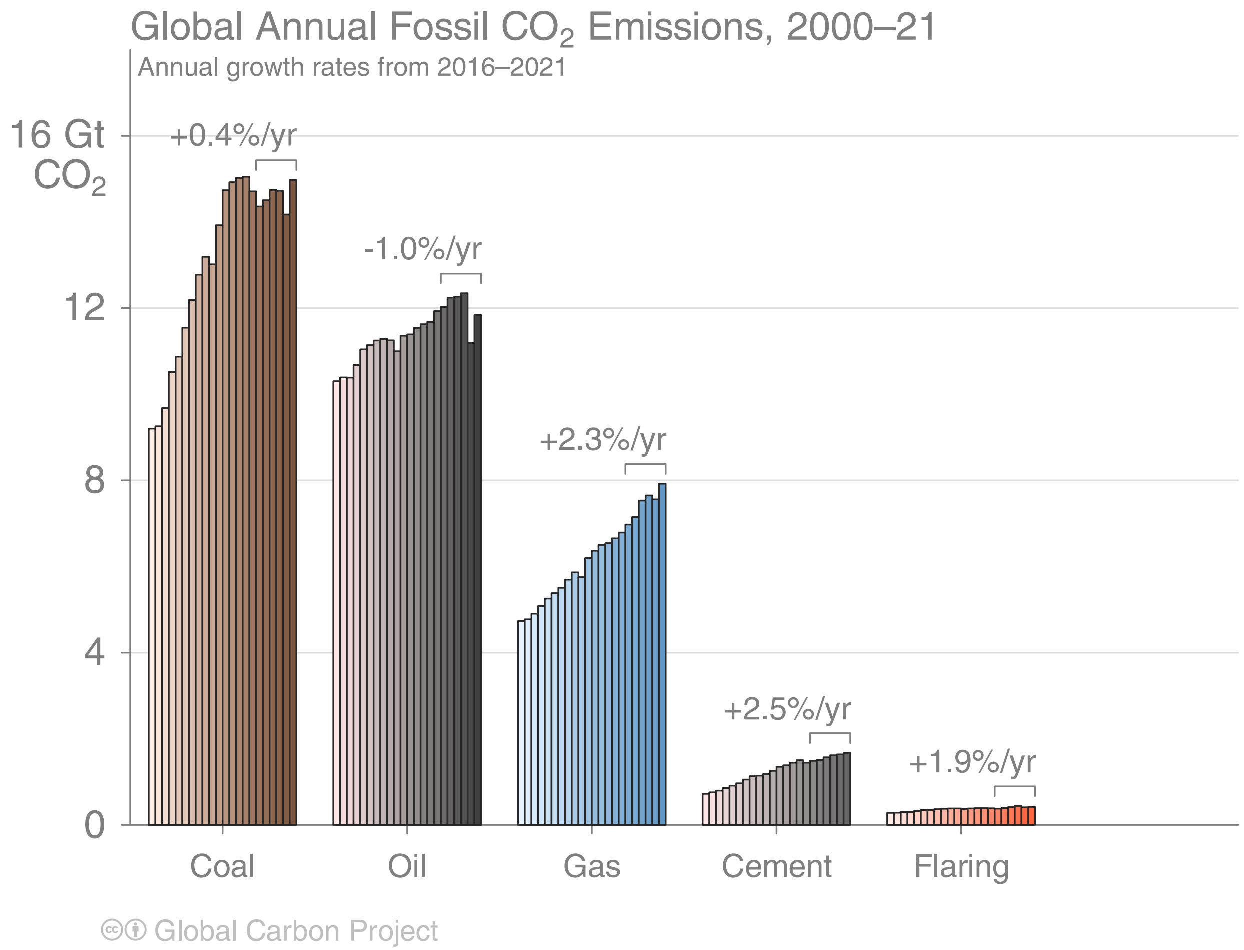
Global emissions in 2021 rebounded strongly from their 2020 drop across all categories.
In 2022 oil continues to recover, natural gas is down because of supply constraints, and coal is up.



Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Fossil CO_2 Emissions by source

Emissions by category from 2000 to 2021, with growth rates indicated for the more recent period of 2016 to 2021
Coal use has declined since 2014, and both coal and oil declined sharply in the pandemic year 2020



Source: [CDIAC](); [Global Carbon Project 2022]()

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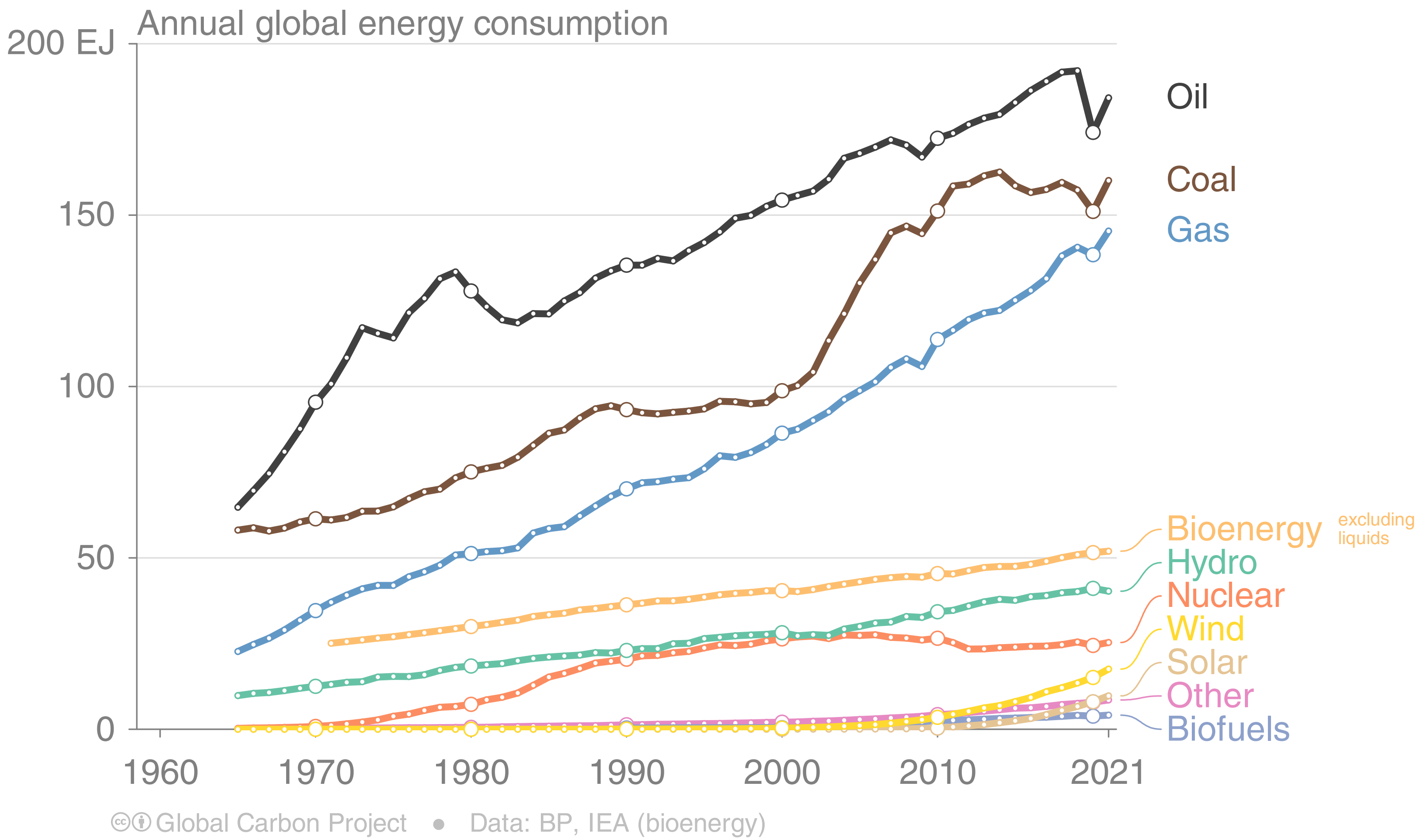
Energy use by source

Consumption of energy from fossil sources bounced back in 2021, but oil is still subdued.
Renewable energy continued to grow, but needs to grow even faster to replace fossil energy consumption.

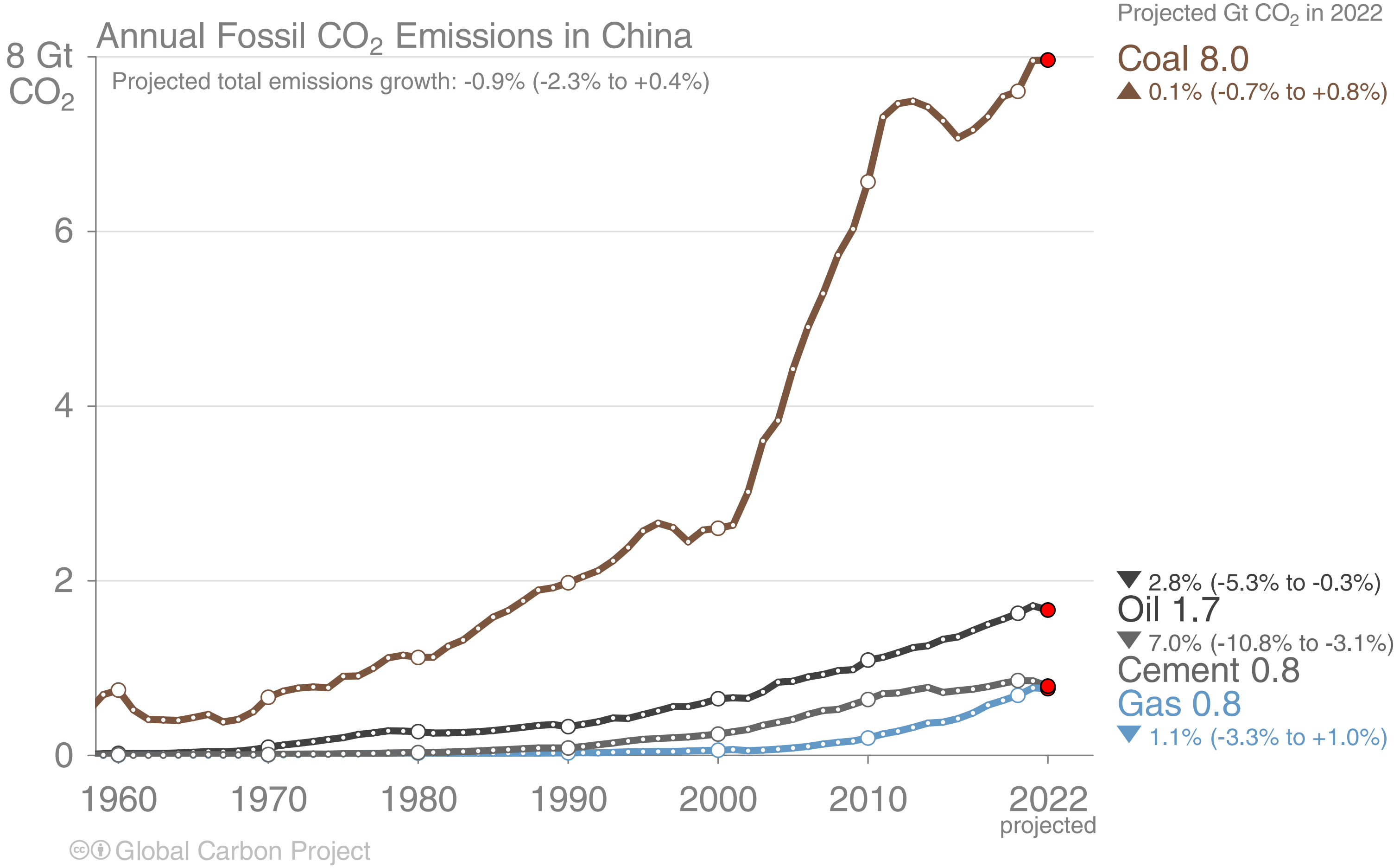


This figure shows “primary energy” using the BP substitution method
(non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)
Source: [BP 2022](); [Global Carbon Project 2022]()

Fossil CO_2 Emission by source for top emitters

Fossil CO_2 Emissions in China

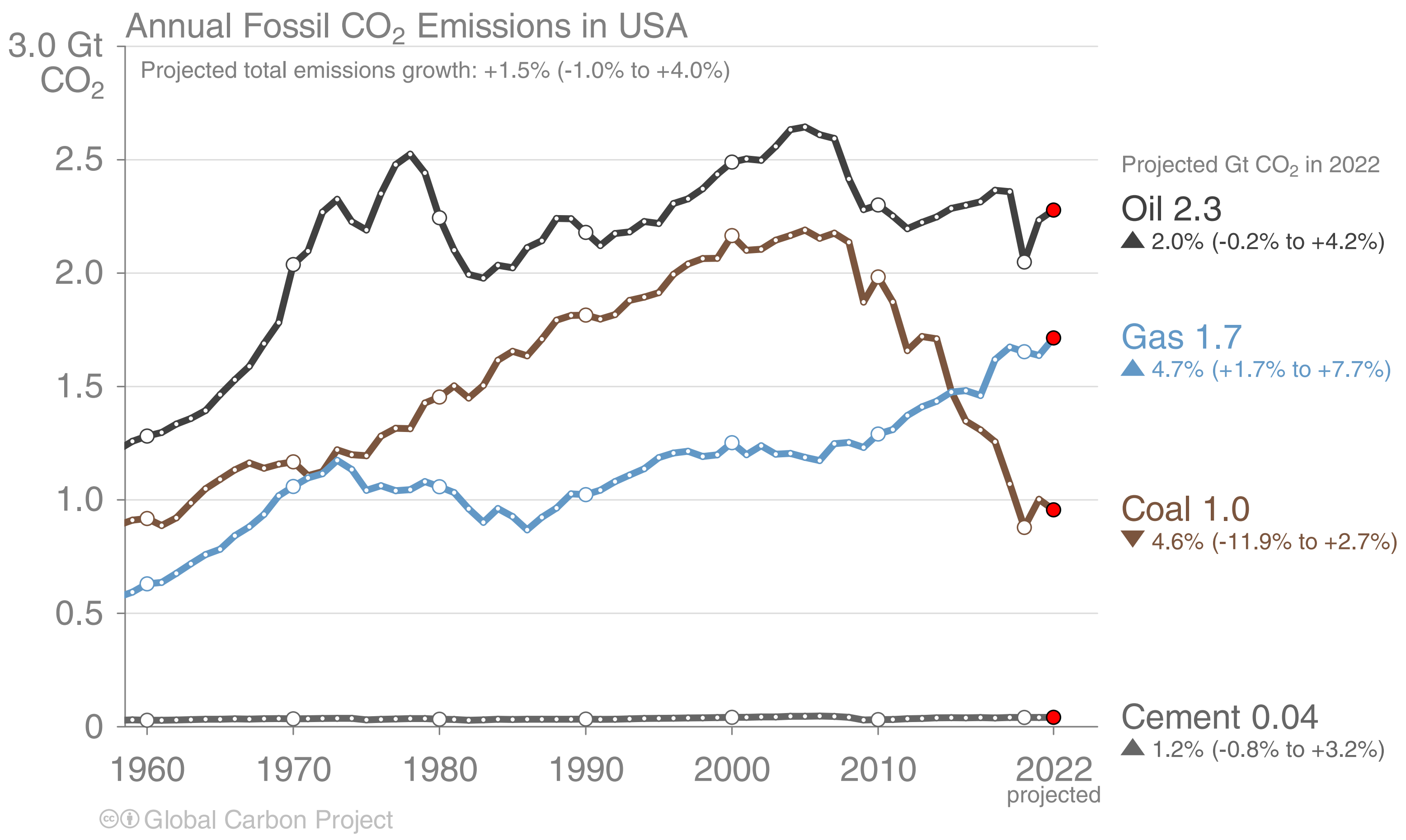
Annual emissions in China are expected to be about the same in 2022 as in 2021, as COVID-19 lockdowns continue and the property market is slowing sharply



Source: Friedlingstein et al 2022; Global Carbon Project 2022

Fossil CO_2 Emissions in USA

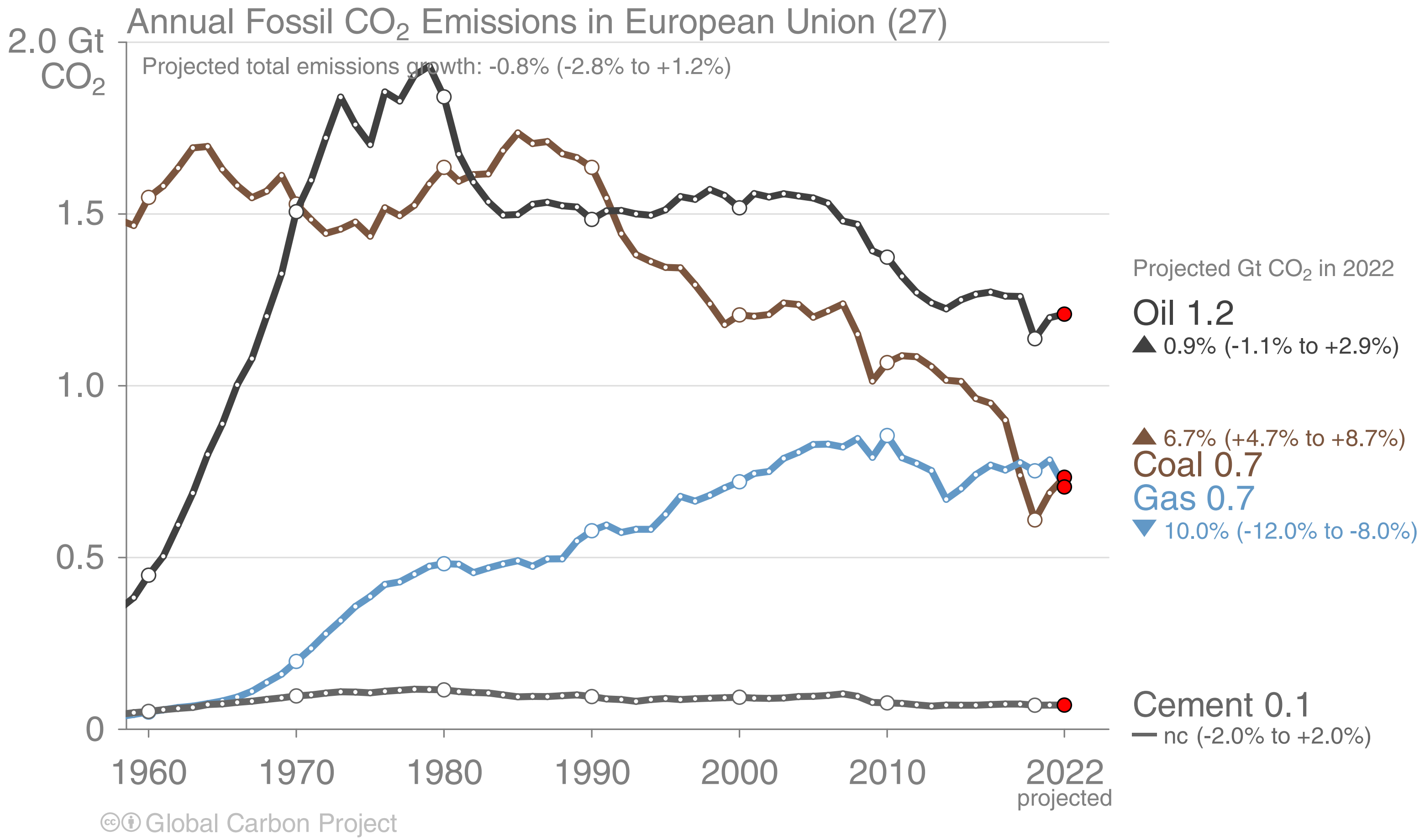
The USA's emissions from coal are expected to drop again in 2022, as the transition to natural gas continues.
Emissions from oil are still below 2019's level.



Source: EIA 2022; Friedlingstein et al 2022; Global Carbon Project 2022

Fossil CO_2 Emissions in the European Union

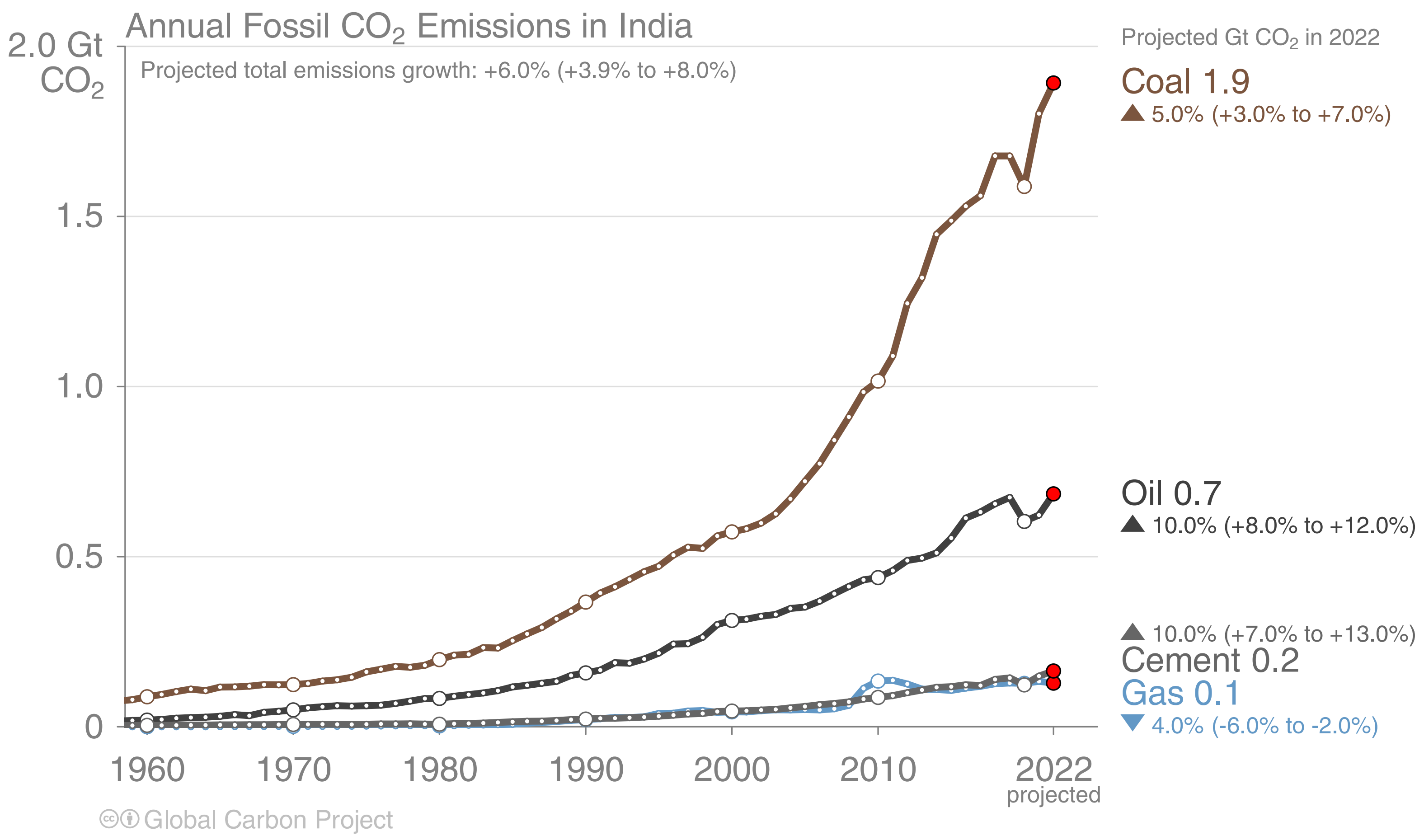
The EU's emissions from natural gas have dropped sharply in 2022 due to supply constraints. Use of coal has increased to fill the gap, but this is expected to be temporary. Oil continued to recover from the pandemic, albeit slowly.



Source: Friedlingstein et al 2022; Global Carbon Project 2022

Fossil CO_2 Emissions in India

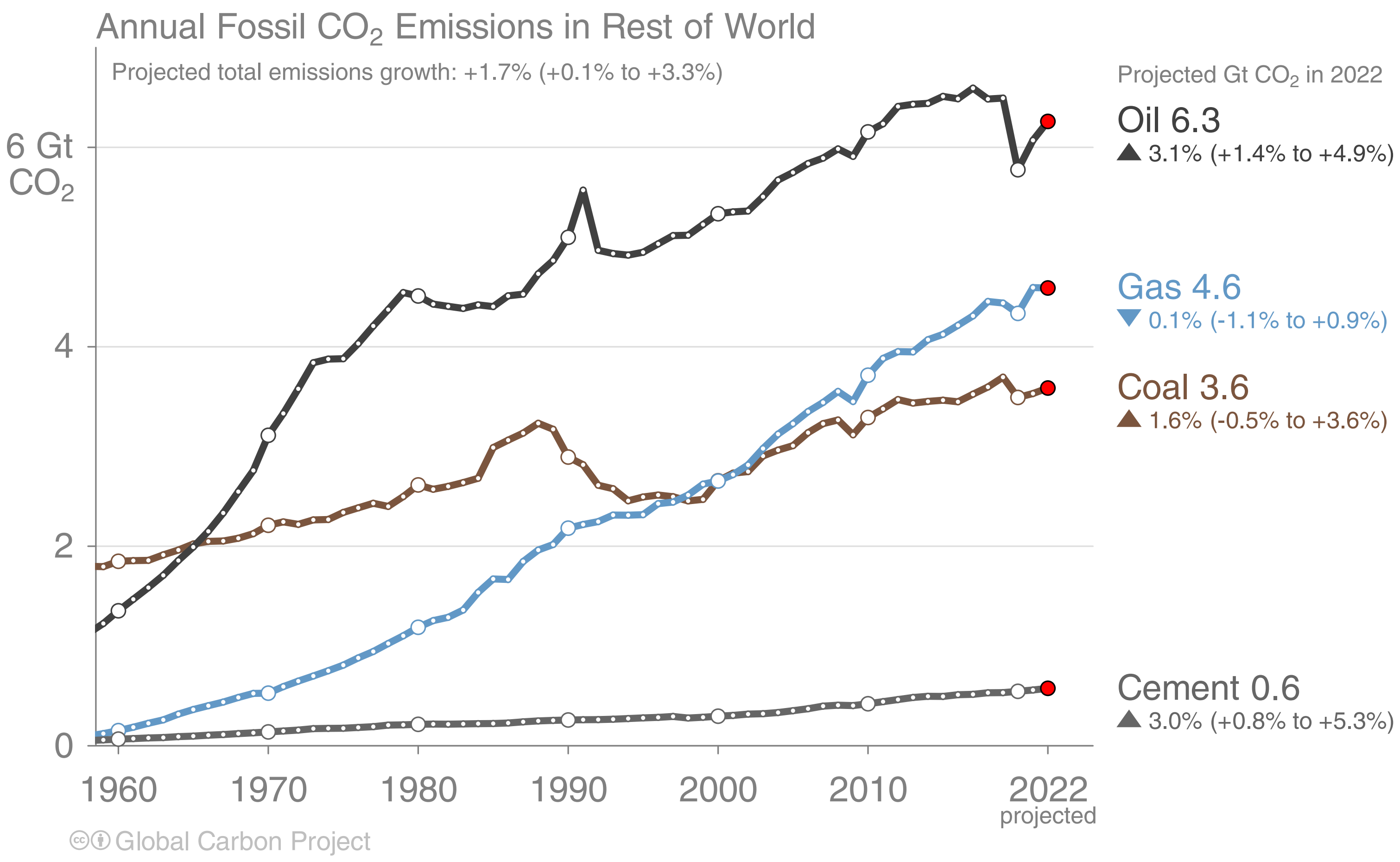
India's emissions continue to grow sharply in 2022, with coal returning to its pre-pandemic trend. Natural gas supplies are constrained, but these form a very small share of India's energy supply.



Source: Friedlingstein et al 2022; Global Carbon Project 2022

Fossil CO_2 Emissions in Rest of World

In the Rest of the World, emissions from coal grow slightly while natural gas declines on high prices.
Oil, which here includes internationship transport, remains below 2019 levels.

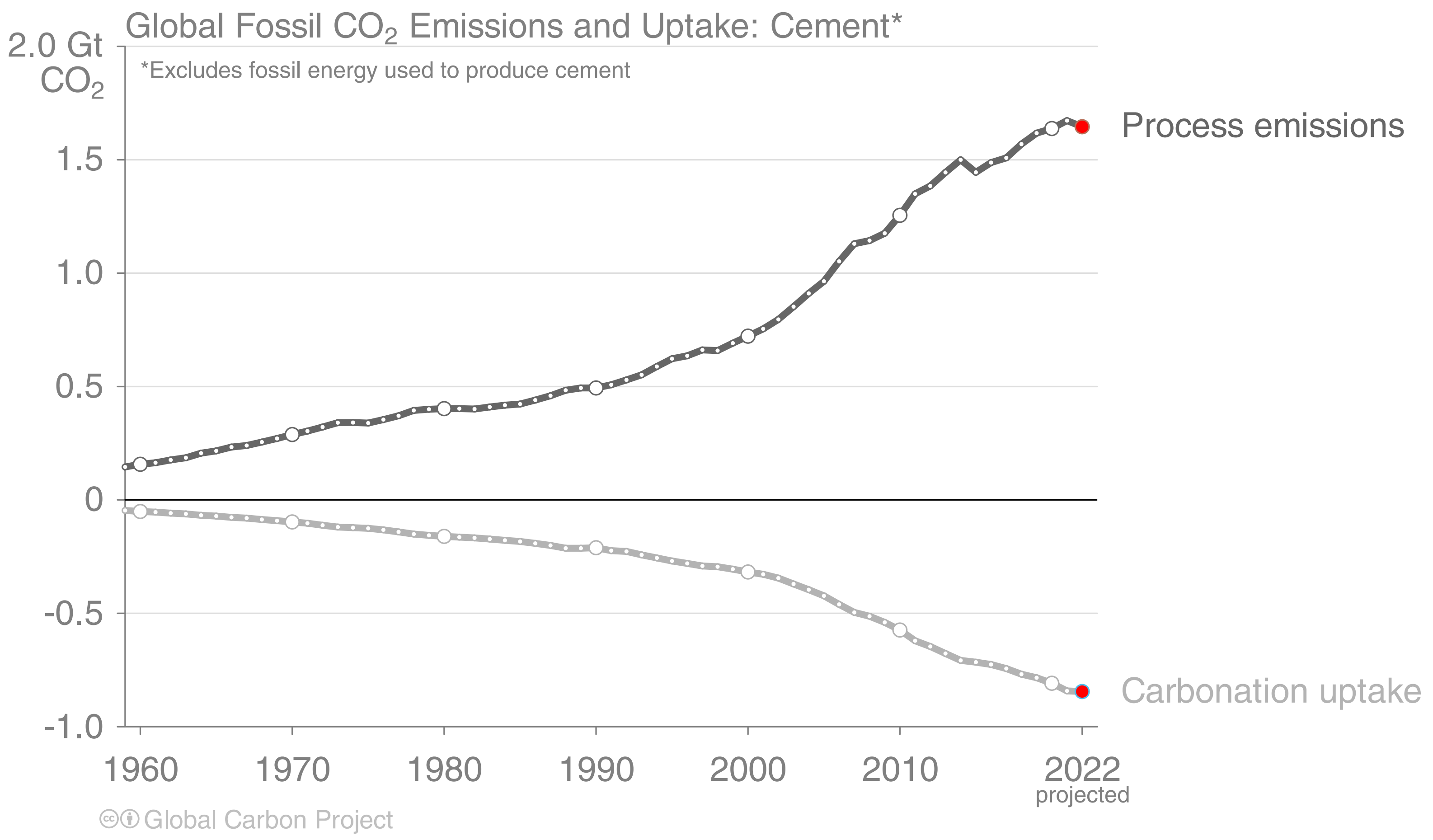


The Rest of the World is the global total less China, US, EU, and India. It also includes international aviation and maritime shipping.
Source: Friedlingstein et al 2022; Global Carbon Project 2022

Cement carbonation sink

Cement carbonation sink

The production of cement results in ‘process’ emissions of CO_2 from the chemical reaction.
During its lifetime, cement slowly re-absorbs CO_2 from the atmosphere.



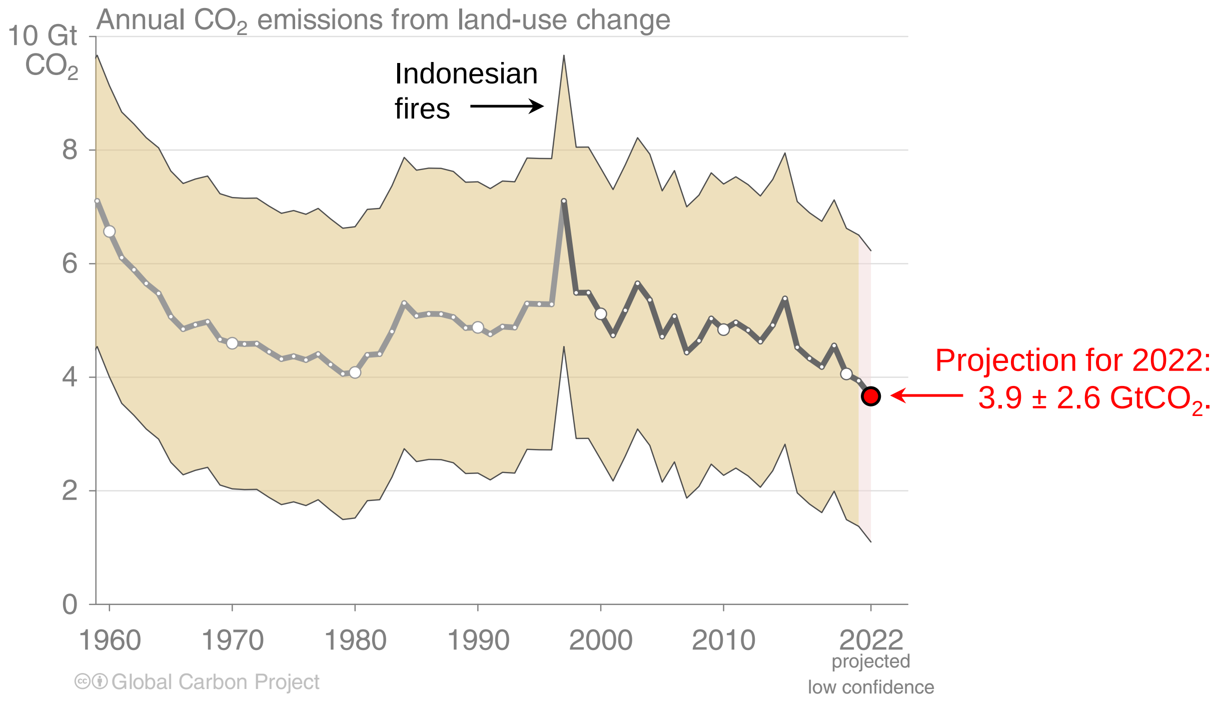
Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

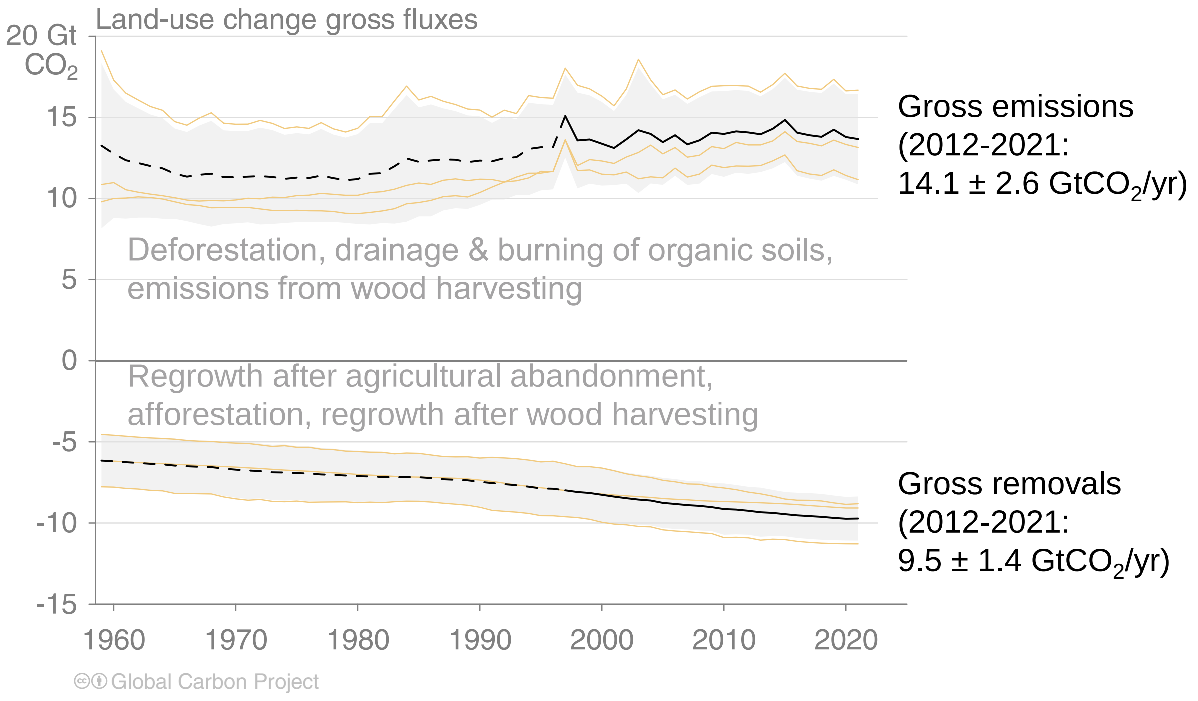
Land-use Change Emissions

Land-use change emissions

Land-use change emissions are 4.5 ± 2.6 $GtCO_2$ per year for 2012-2021, and show a negative trend in the last two decades, but estimates are still highly uncertain.

Net land-use emissions are the difference between CO_2 emissions and CO_2 removals



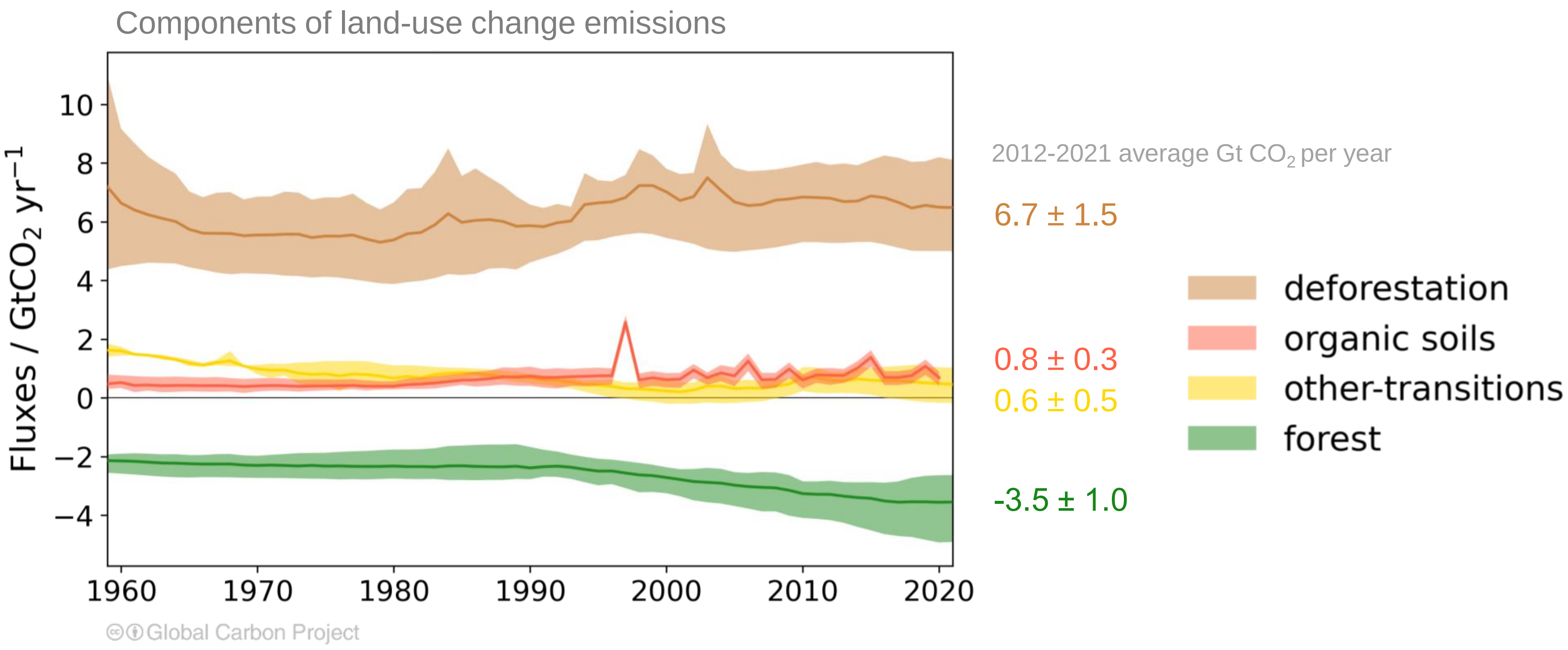


Estimates from three bookkeeping models

Source: Friedlingstein et al 2022; Global Carbon Project 2022

Drivers of land-use change emissions

Deforestation is the main driver of land-use emissions (remaining high at 6.7 ± 1.5 GtCO_2 per year for 2012-2021). Forest fluxes from re/afforestation and wood harvest emissions and removals counterbalance approximately half of these emissions (-3.5 ± 1.0 GtCO_2 per year).



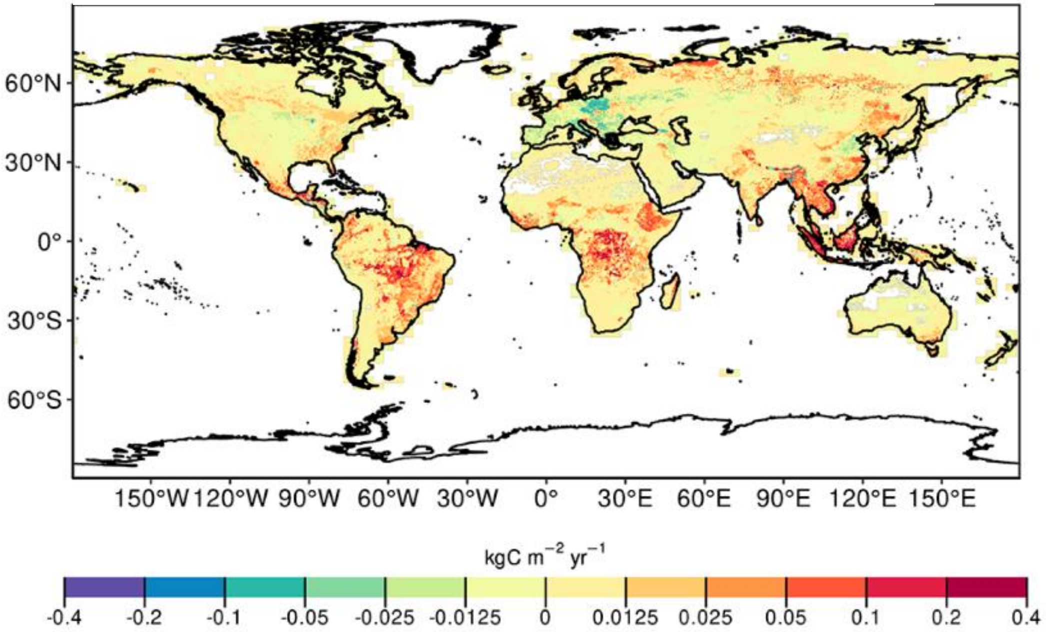
Estimates from three bookkeeping models

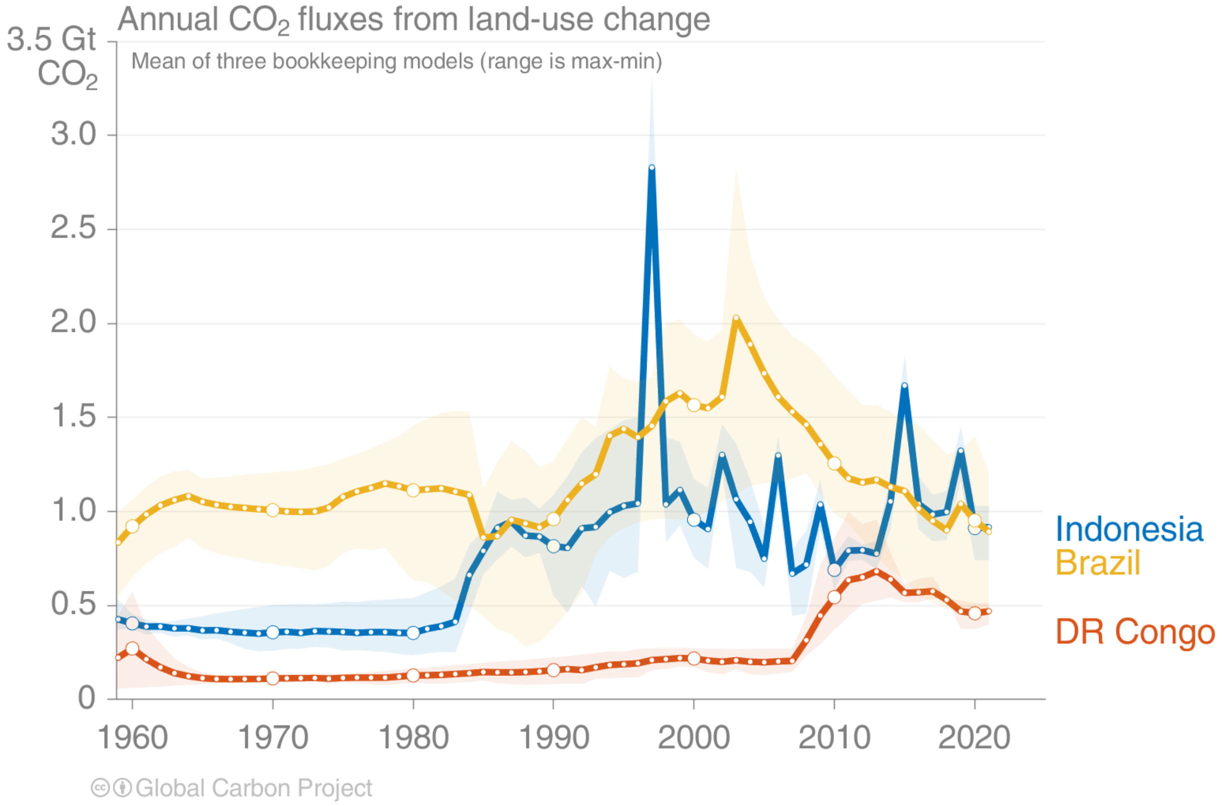
Source: Friedlingstein et al 2022; Global Carbon Project 2022

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 2012-2021 – Indonesia, Brazil and the Democratic Republic of the Congo – contribute 58% of the global net land-use emissions.





Estimates from the spatially explicit bookkeeping model BLUE (excluding emissions from organic soils)

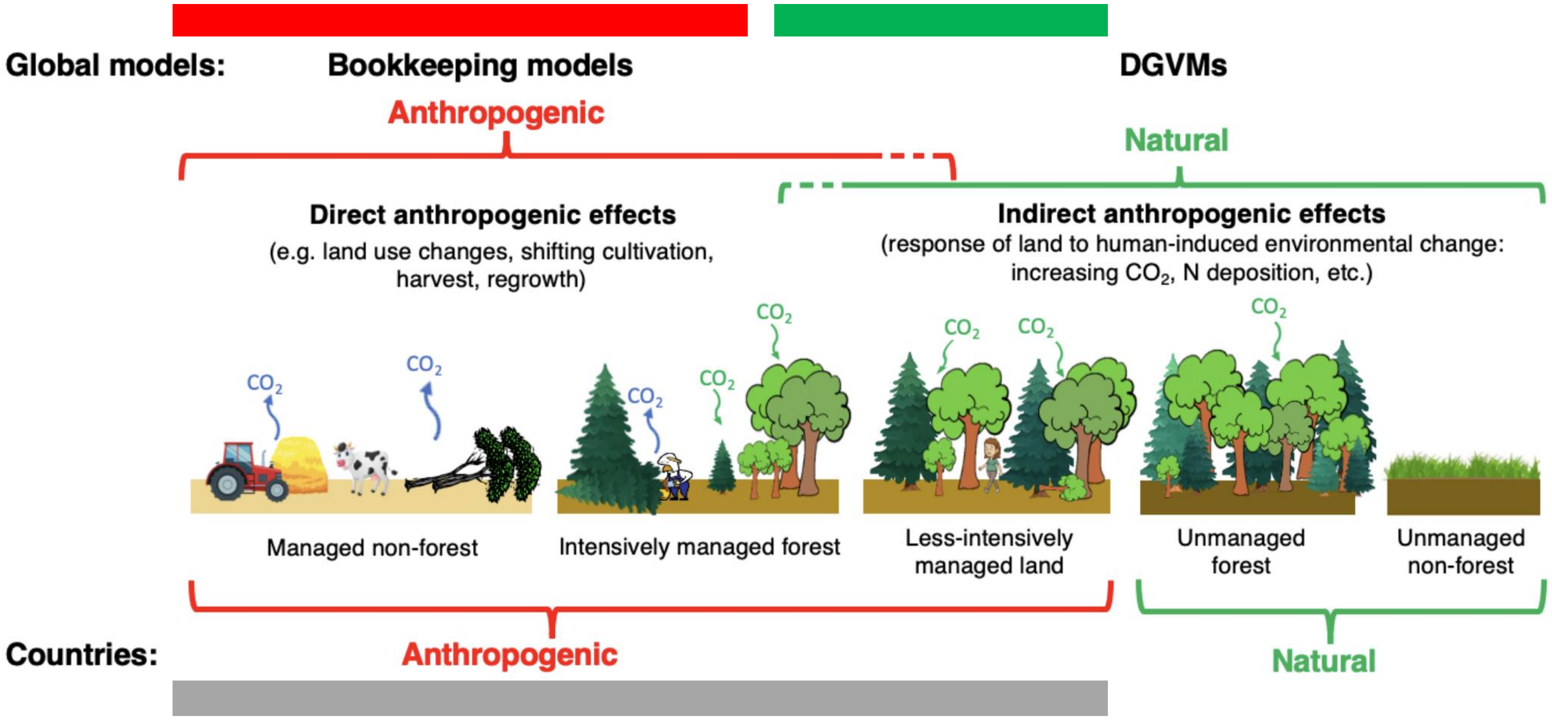
The peak in Indonesia in 1997 was the Indonesian peat fires. Estimates from three bookkeeping models

Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

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

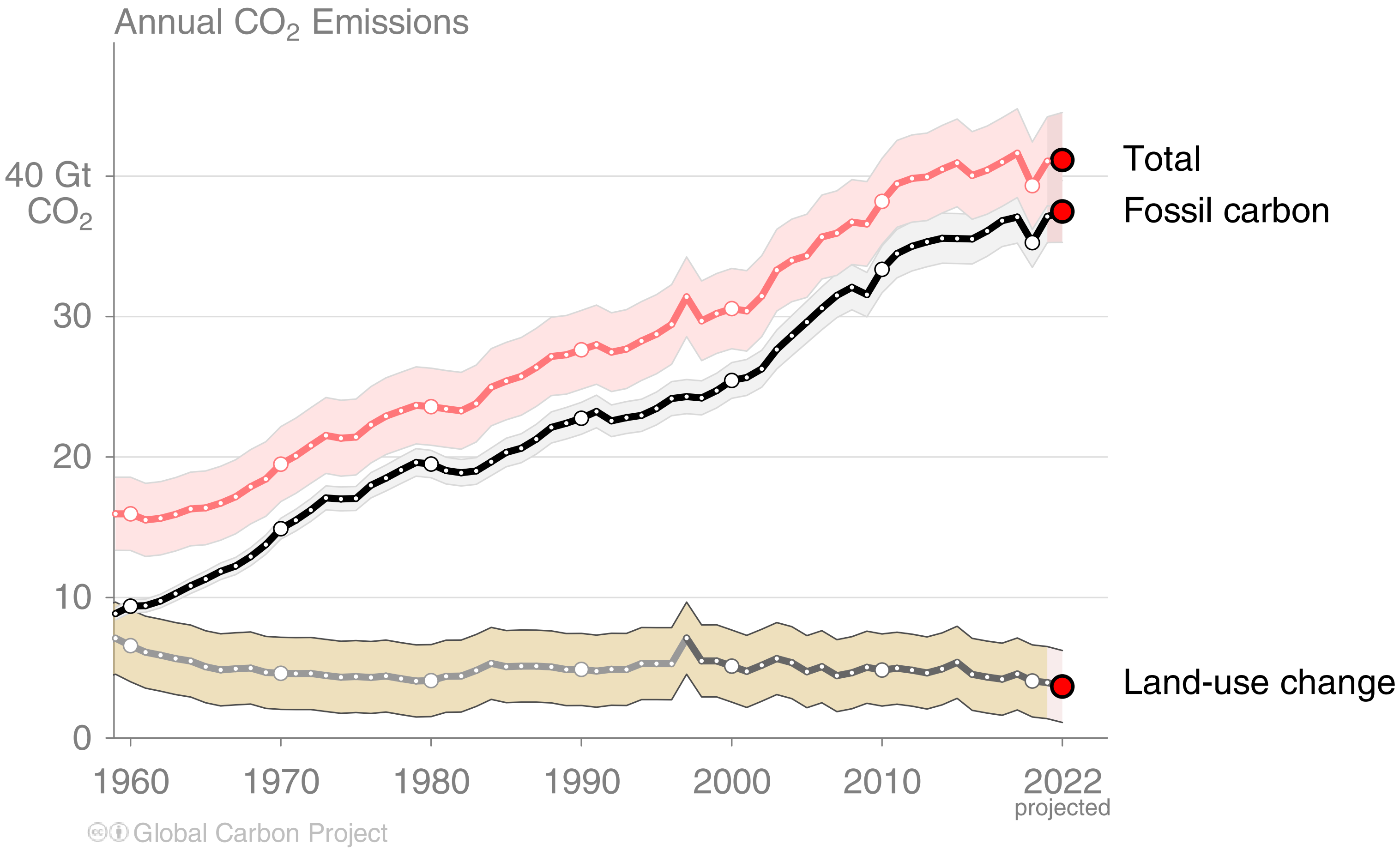
When natural fluxes on managed forests (-6.6 $GtCO_2$ per year for 2012-2021) are added to land-use emissions (4.5 $GtCO_2$ per year), the GCB2022 estimates (-2.1 $GtCO_2$ per year) are very similar to the country-reported data (-2.0 $GtCO_2$ per year), linking the anthropogenic carbon budget estimates of land CO_2 fluxes directly to the Global Stocktake as part of UNFCCC Paris Agreement.



Source: Friedlingstein et al 2022; Global Carbon Project 2022
Figure from Grassi et al., ESSDD 2022

Total global emissions

Total global emissions: 41.1 ± 3.3 $GtCO_2$ in 2021, 49% over 1990
Percentage land-use change: 41% in 1960, 11% averaged 2012–2021



Land-use change estimates from three bookkeeping models, using fire-based variability from 1997
Source: [Friedlingstein et al 2022]; [Global Carbon Project 2022]

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Closing the Global Carbon Budget

Fate of anthropogenic CO_2 emissions (2012–2021)

Sources = Sinks

35.2 $GtCO_2$/yr

89%

11%

4.5 $GtCO_2$/yr

19.1 $GtCO_2$/yr

48%

29%

11.4 $GtCO_2$/yr

26%

10.5 $GtCO_2$/yr

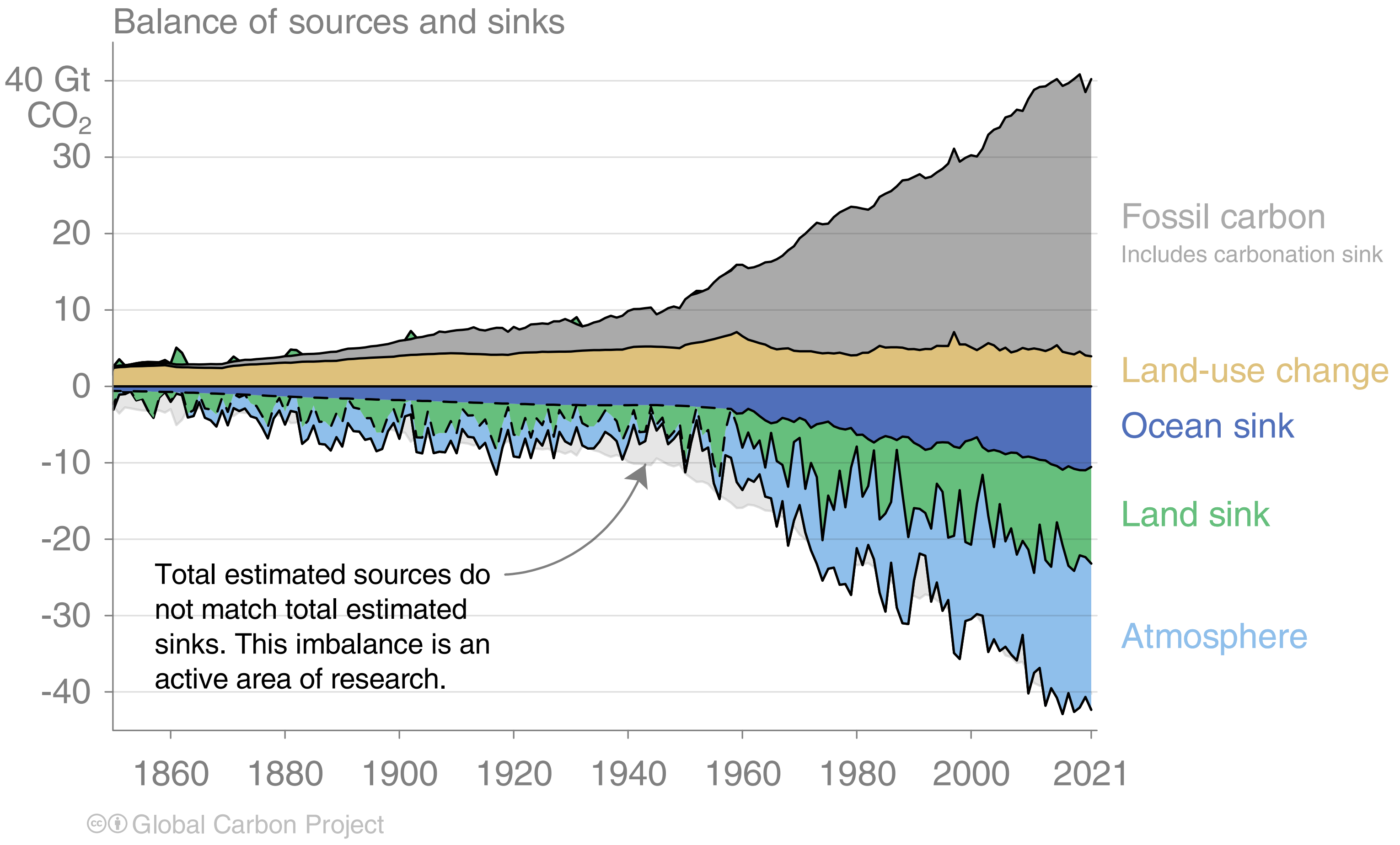
Budget Imbalance:
(the difference between estimated sources & sinks)

3%
-1.2 $GtCO_2$/yr

Source: Friedlingstein et al 2022; Global Carbon Project 2022

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



Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

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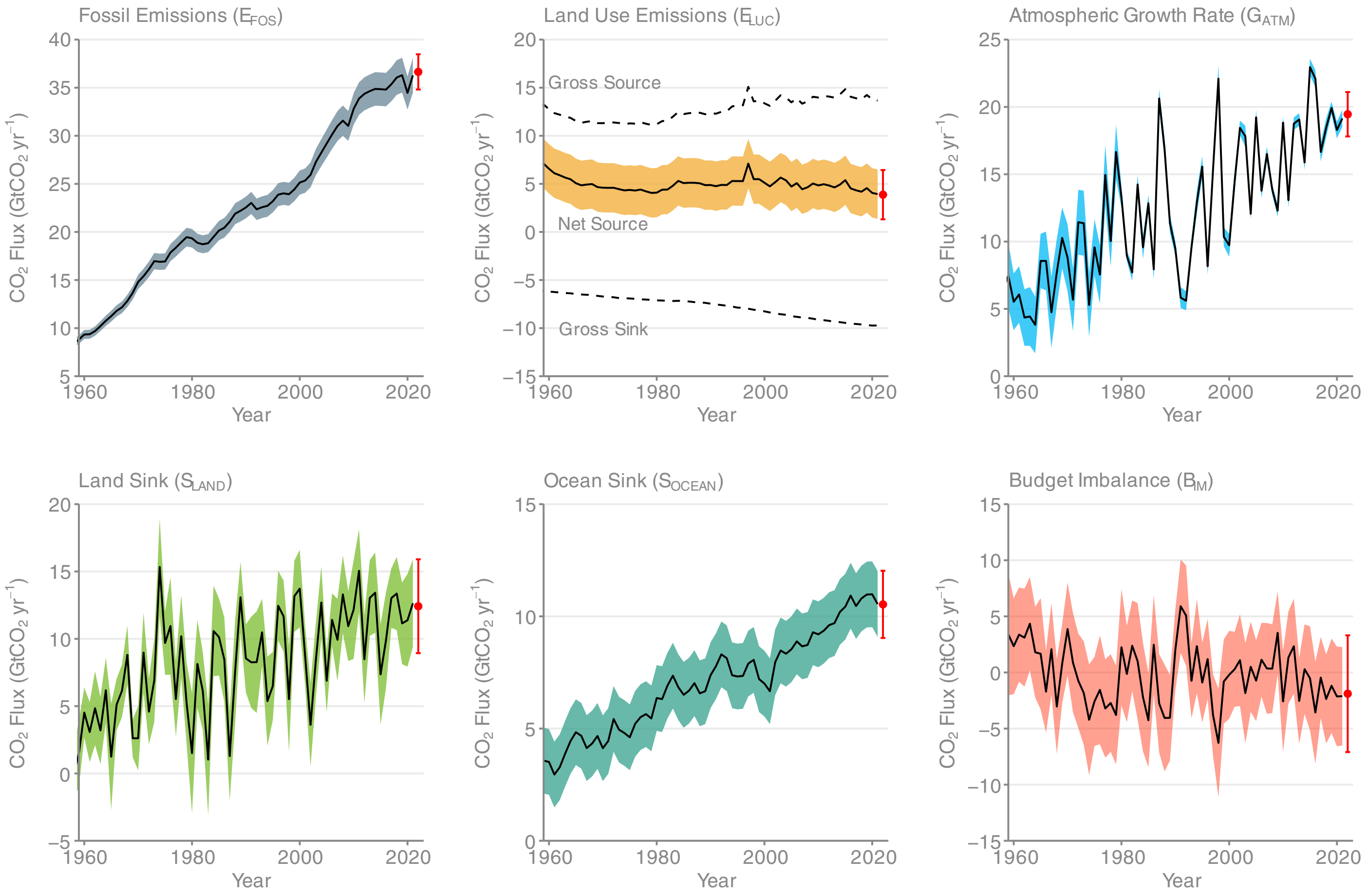
Changes in the budget over time

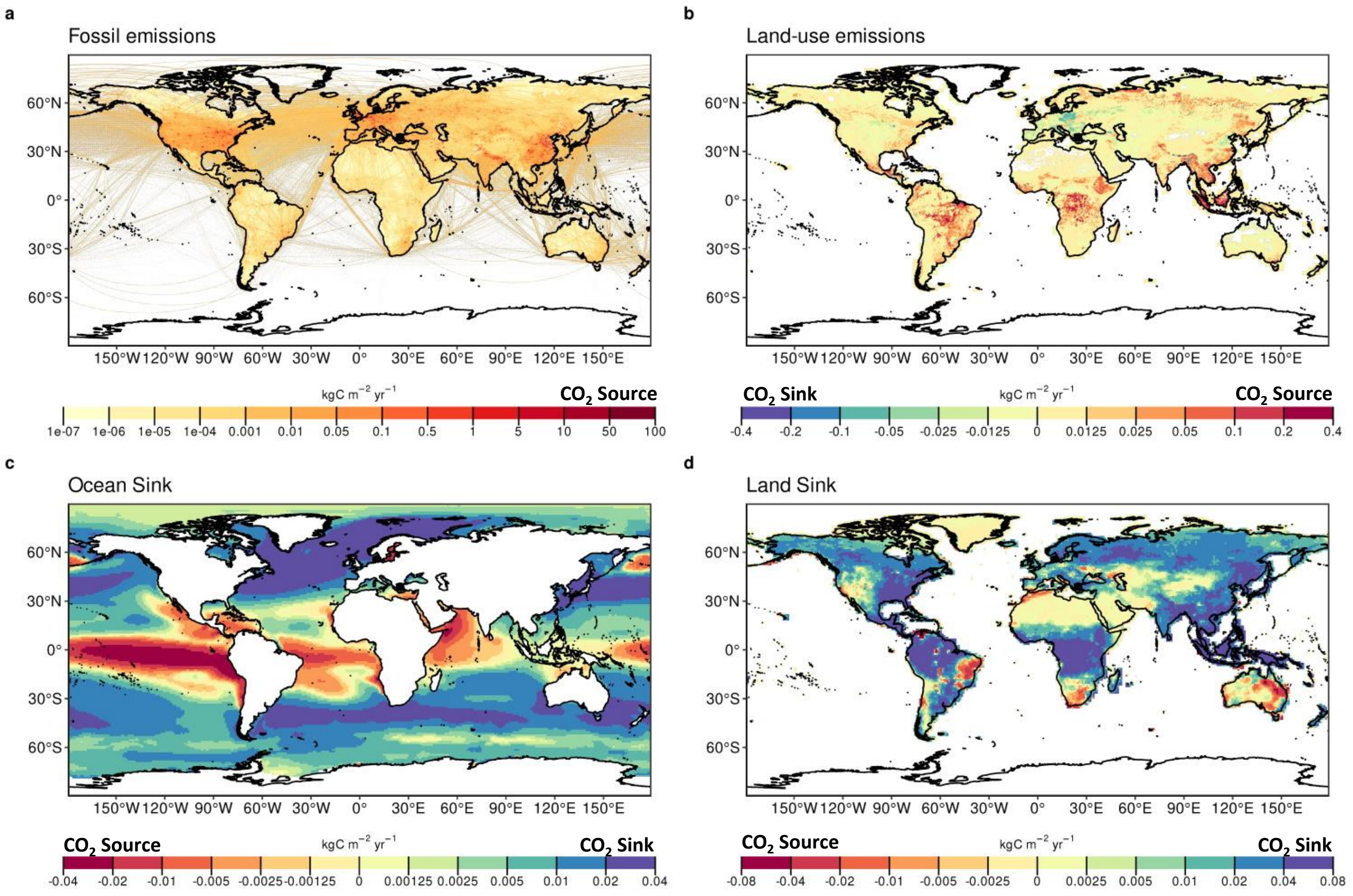
The sinks have continued to grow with increasing emissions, but climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere



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 2022; Global Carbon Project 2022

Global carbon budget

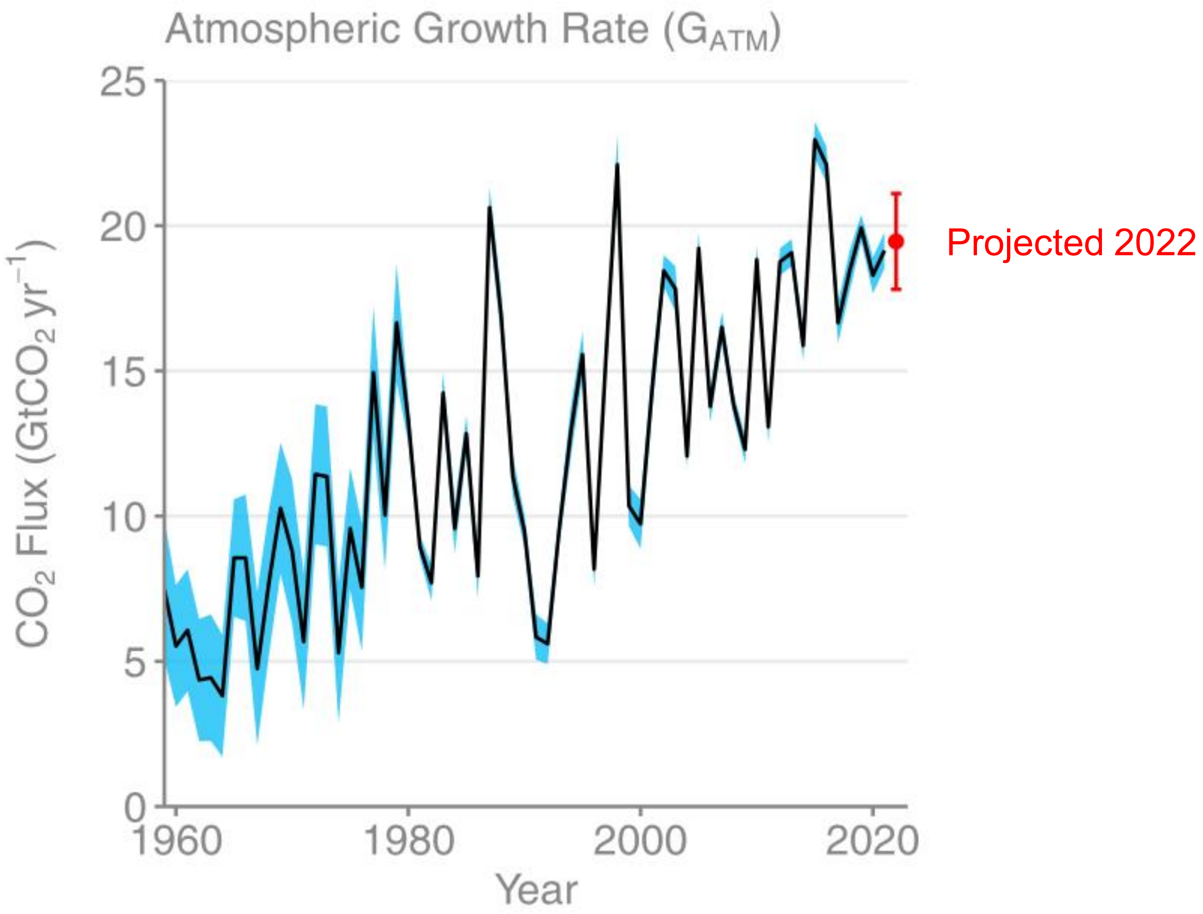
Fossil emissions dominate in the Northern Hemisphere, while land-use emissions are important in the tropics.
The North Atlantic and Southern Ocean are carbon sinks while the tropical ocean is a source of CO_2.
Tropical, temperate and boreal forest are the main terrestrial carbon sinks



Source: [Friedlingstein et al 2022](); [Global Carbon Budget 2022]()

Atmospheric concentration

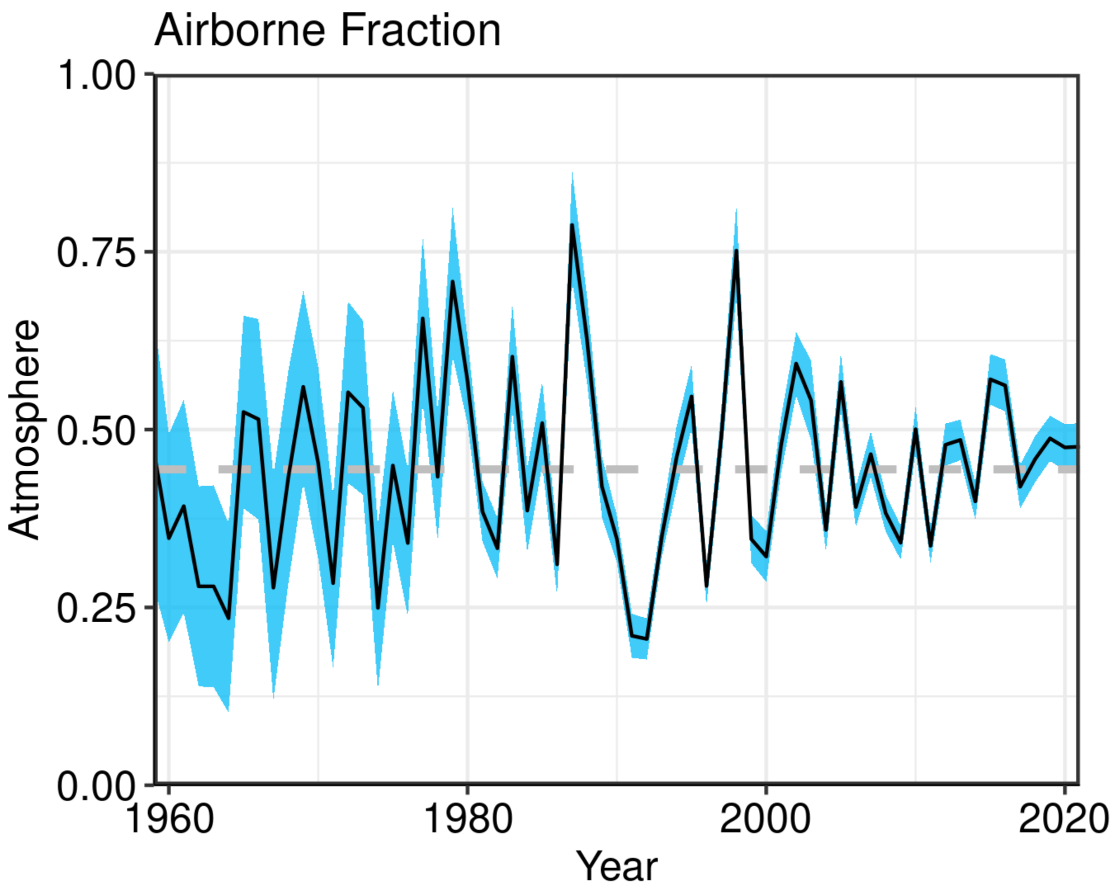
The atmospheric concentration growth rate has increased steadily.
The high growth in 1987, 1998, & 2015–16 reflect a strong El Niño, which weakens the land sink.



Source: NOAA-ESRL; Friedlingstein et al 2022; Global Carbon Project 2022

Airborne Fraction

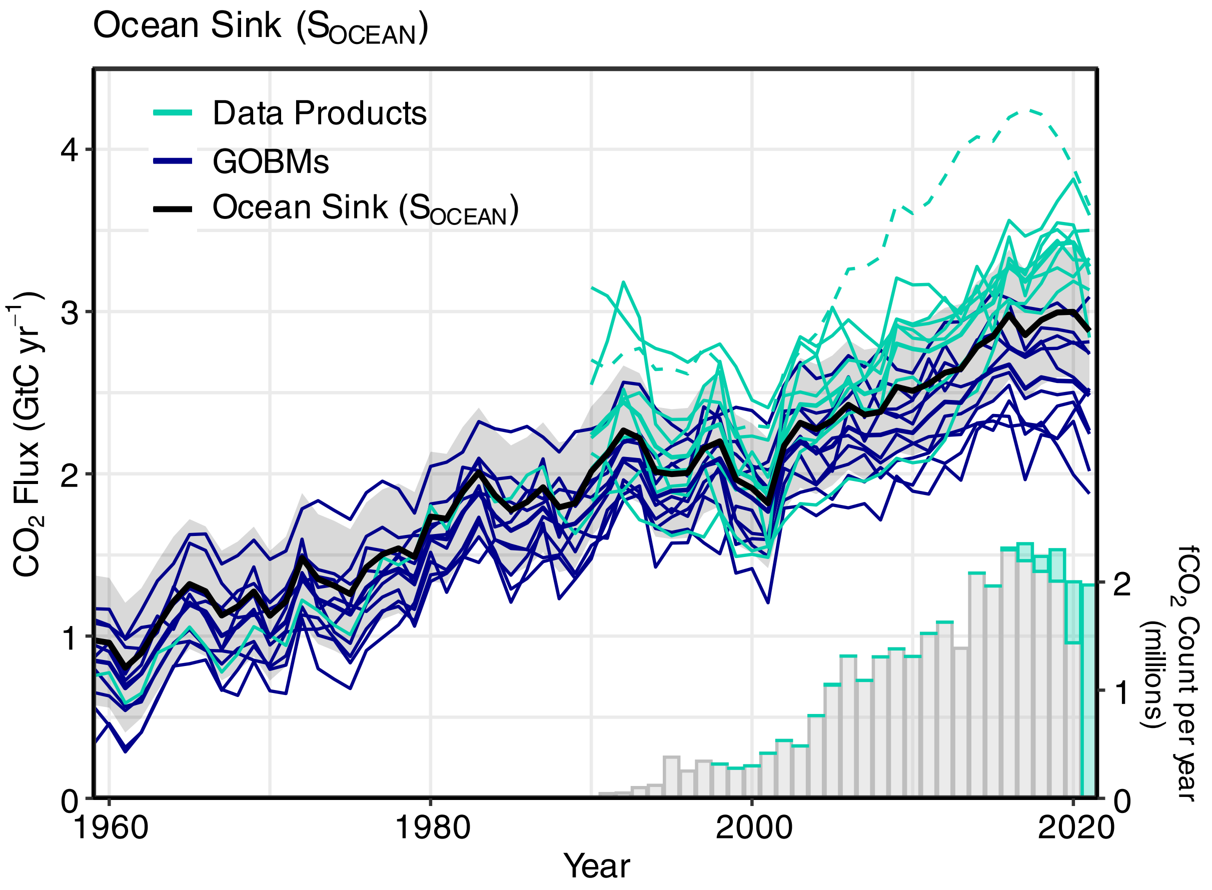
The airborne fraction is the proportion of the total annual CO_2 emissions that remains in the atmosphere.
The rest of the CO_2 emissions are removed by the land and ocean sinks.
Around 45% of CO_2 emissions remain in the atmosphere despite sustained growth in CO_2 emissions.



Source: NOAA-ESRL; Global Carbon Project 2022

Ocean sink

The ocean carbon sink, estimated by Global Ocean Biogeochemical Models and observation-based data products, continues to increase 10.5 ± 1.5 $GtCO_2$/yr for 2012–2021 and 10.6 ± 1.5 $GtCO_2$/yr in 2021

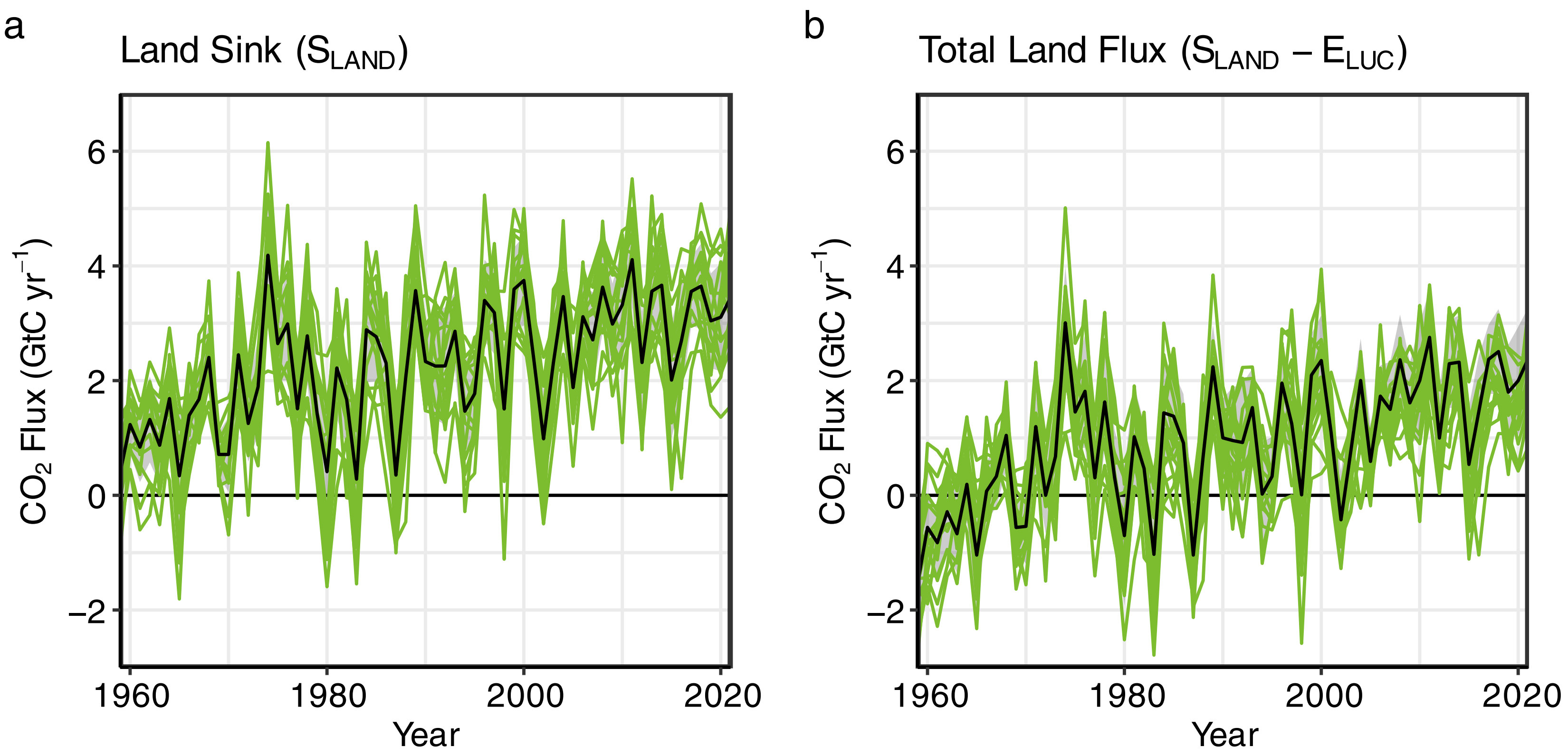


Note
Data are in GtC as in the ESSD publication. Multiply by 3.664 to convert to $GtCO_2$

Source: SOCATv7; Bakker et al 2016; Friedlingstein et al 2022; Global Carbon Project 2022

Terrestrial sink

The land carbon sink, estimated by Dynamic Global Vegetation Models, was 11.4 ± 2.3 $GtCO_2$/yr during 2012–2021 and 12.6 ± 3.3 $GtCO_2$/yr in 2021.
The total CO_2 fluxes on land (including land-use change) are also constrained by atmospheric inversions.

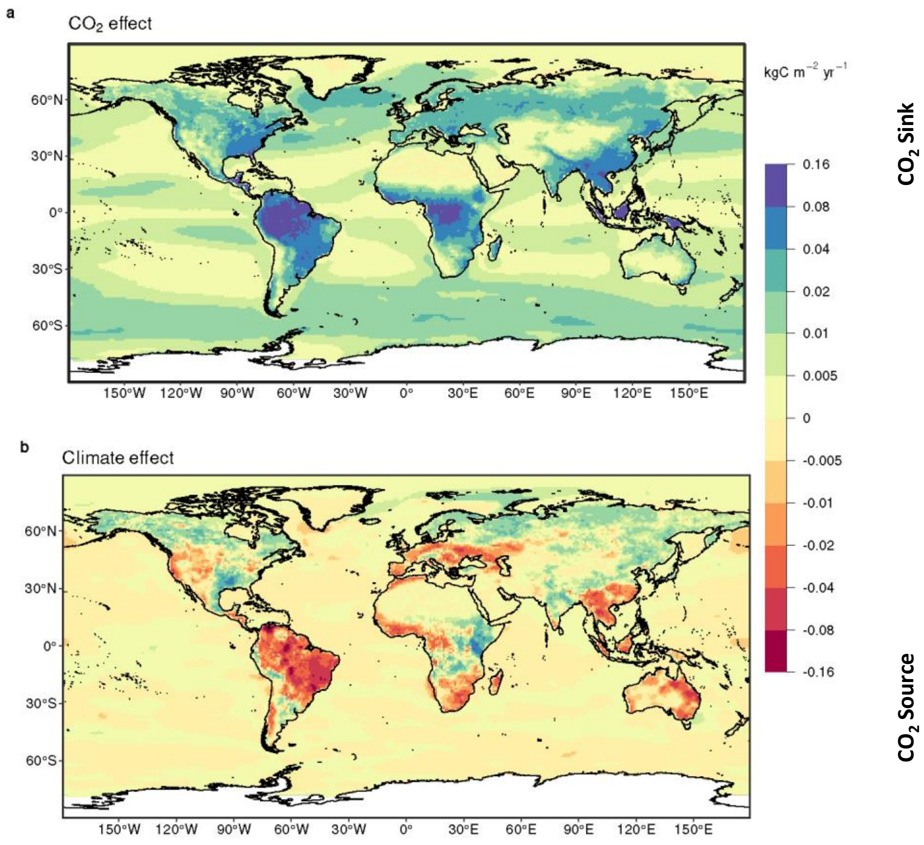


Note
Data are in GtC as in the ESSD publication. Multiply by 3.664 to convert to $GtCO_2$

Source: Friedlingstein et al 2022; Global Carbon Project 2022

Land and ocean sinks — Effects of CO_2 vs climate change

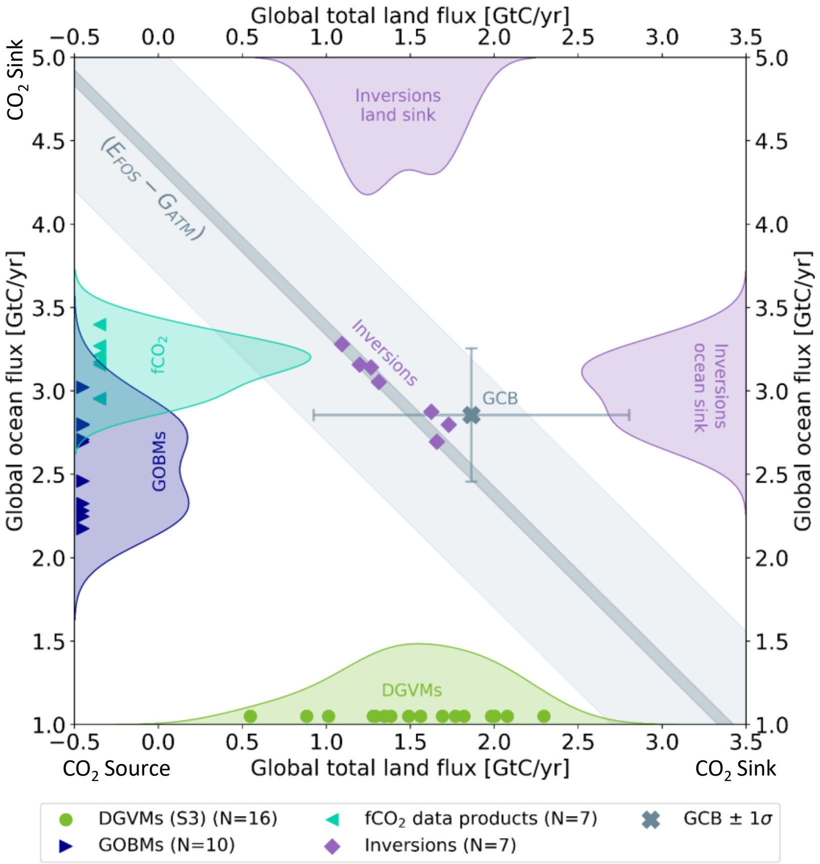
Process models suggest that increasing atmospheric CO_2 drives the land and ocean sinks while climate change reduces the carbon sinks; the climate effect is largest in tropical and semi-arid land ecosystems.
Globally during the 2012-2021 decade, climate change reduced the land sink by ~17% and the ocean sink by ~4%



Source: Friedlingstein et al 2022; Global Carbon Budget 2022

Land and ocean sinks — Estimates from atmospheric inversions

Atmospheric CO_2 inversions allow to estimate the land and ocean carbon fluxes, independently from the land and ocean process-based models estimates, confirming the global carbon budget estimates of the land and ocean partitioning of anthropogenic CO_2

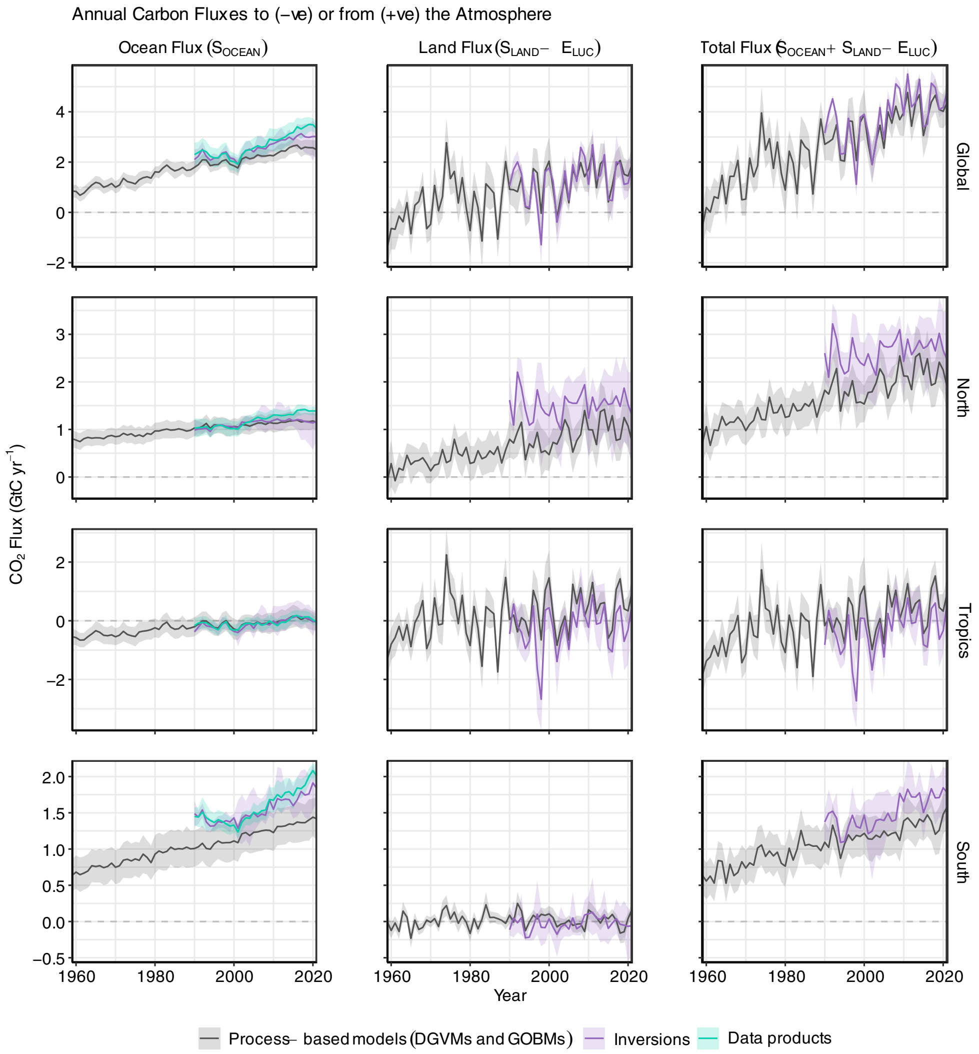


Note
Data are in GtC as in the ESSD publication. Multiply by 3.664 to convert to $GtCO_2$

Source: Friedlingstein et al 2022; Global Carbon Budget 2022

Total land and ocean fluxes

Total land and ocean fluxes show more interannual variability in the tropics

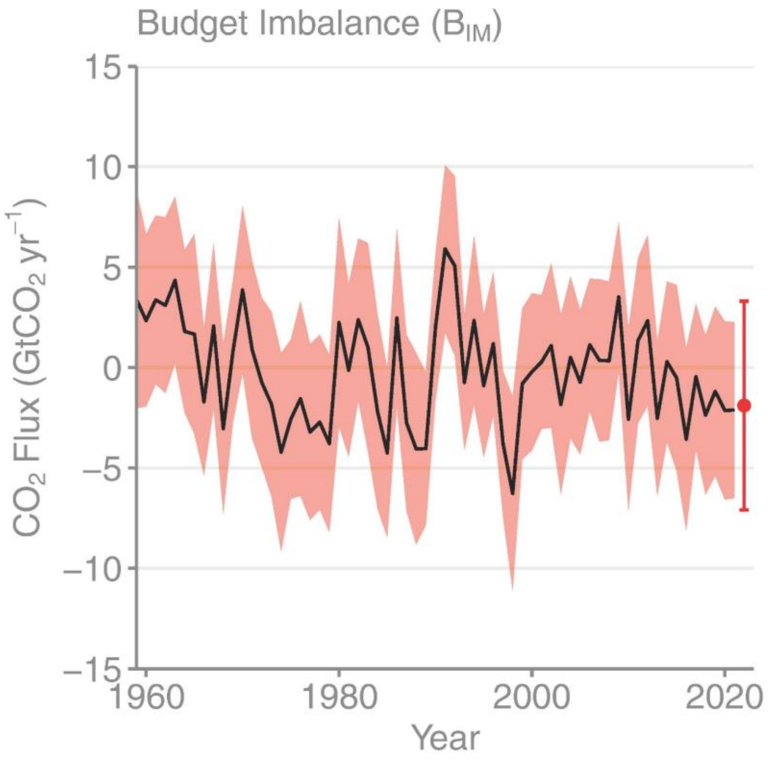


Source: Friedlingstein et al 2022; Global Carbon Project 2022

Note
Data are in GtC as in the ESSD publication. Multiply by 3.664 to convert to $GtCO_2$

Remaining carbon budget imbalance

Large and unexplained variability in the global carbon balance caused by uncertainty and understanding hinder independent verification of reported CO_2 emissions



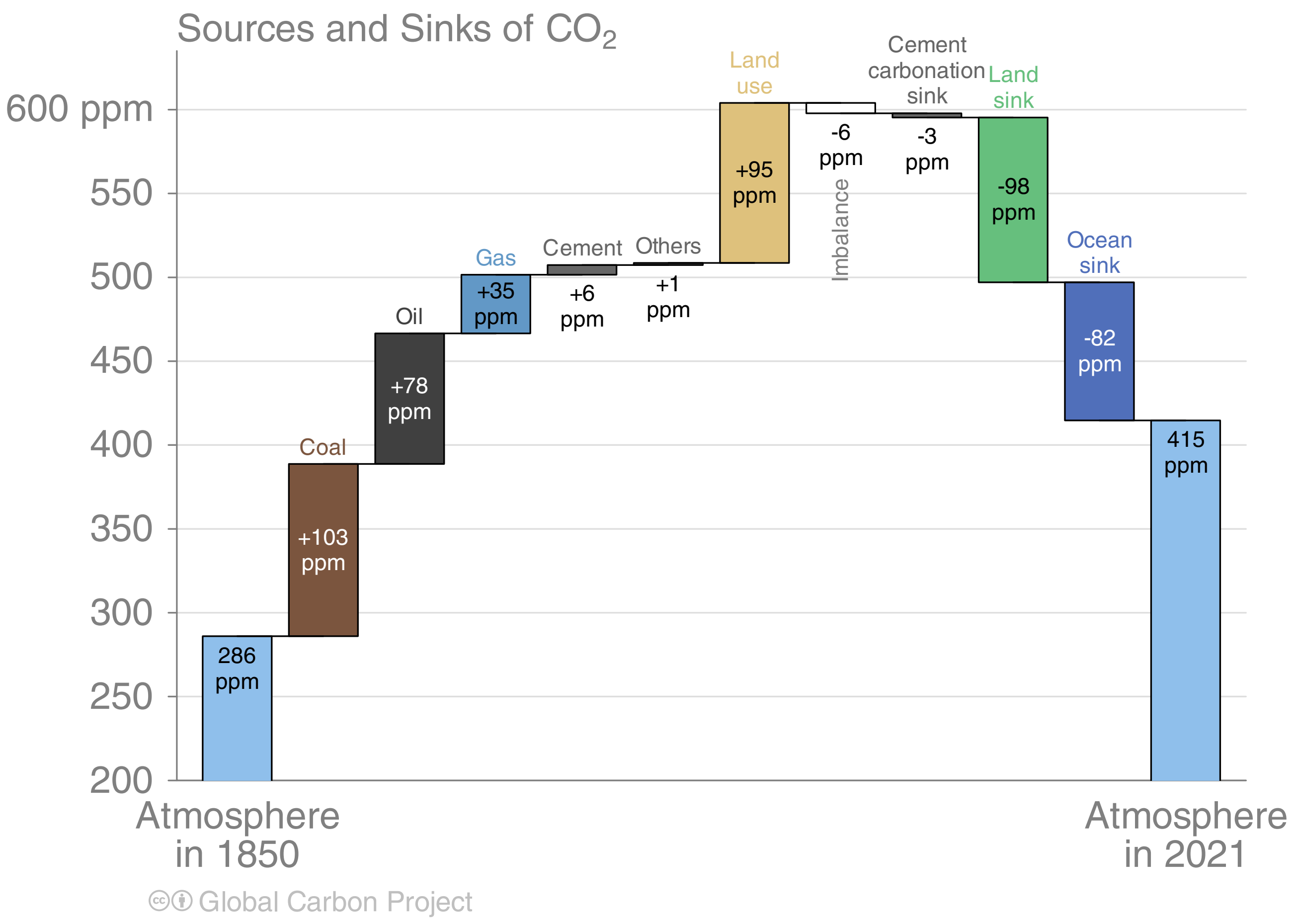
positive values mean overestimated emissions and/or underestimated sinks

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 2022; Global Carbon Project 2022

Global carbon budget

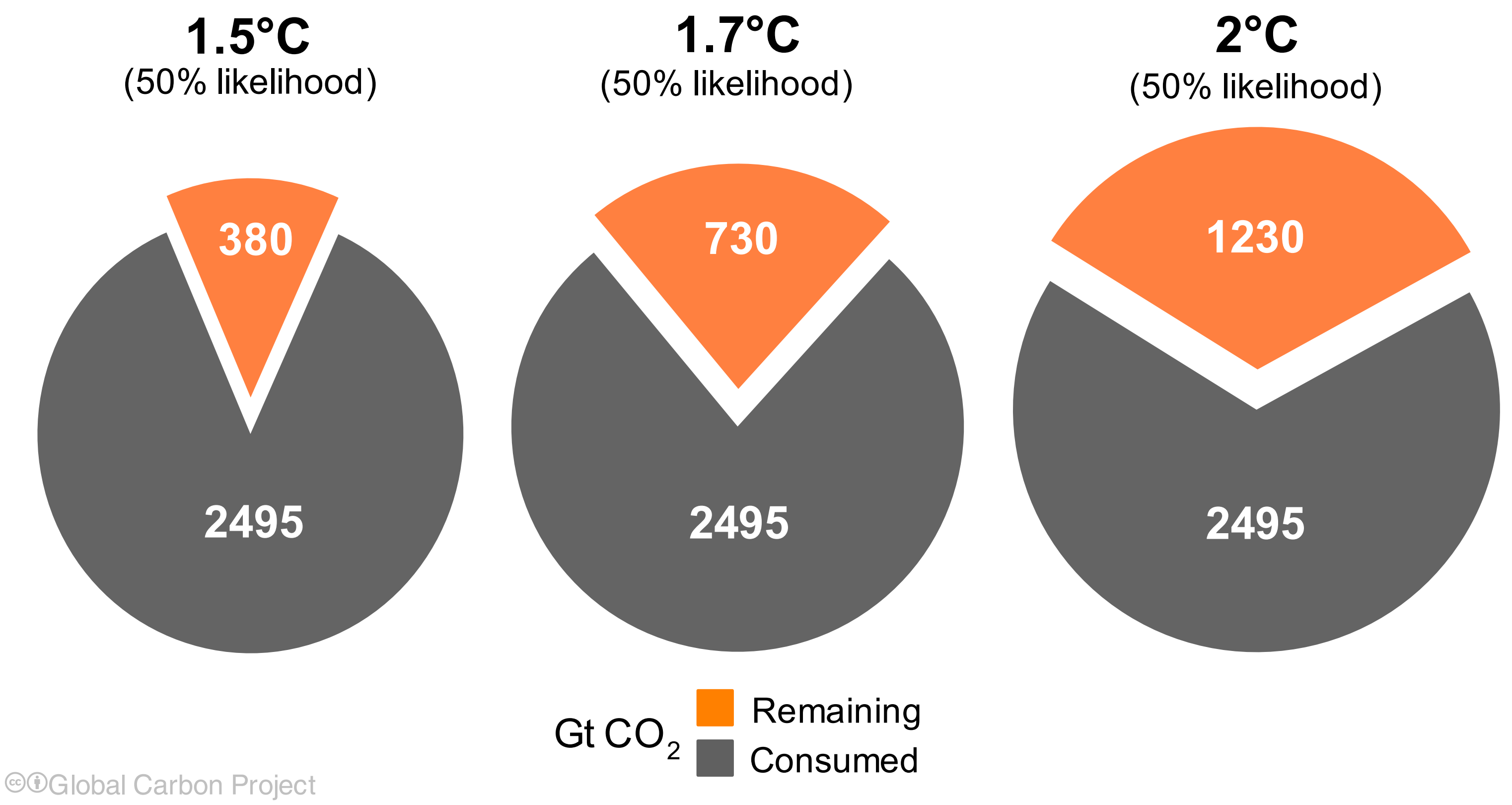
The cumulative contributions to the global carbon budget from 1850
The carbon imbalance represents the gap in our current understanding of sources & sinks



Source: Friedlingstein et al 2022; Global Carbon Project 2022

Remaining carbon budget

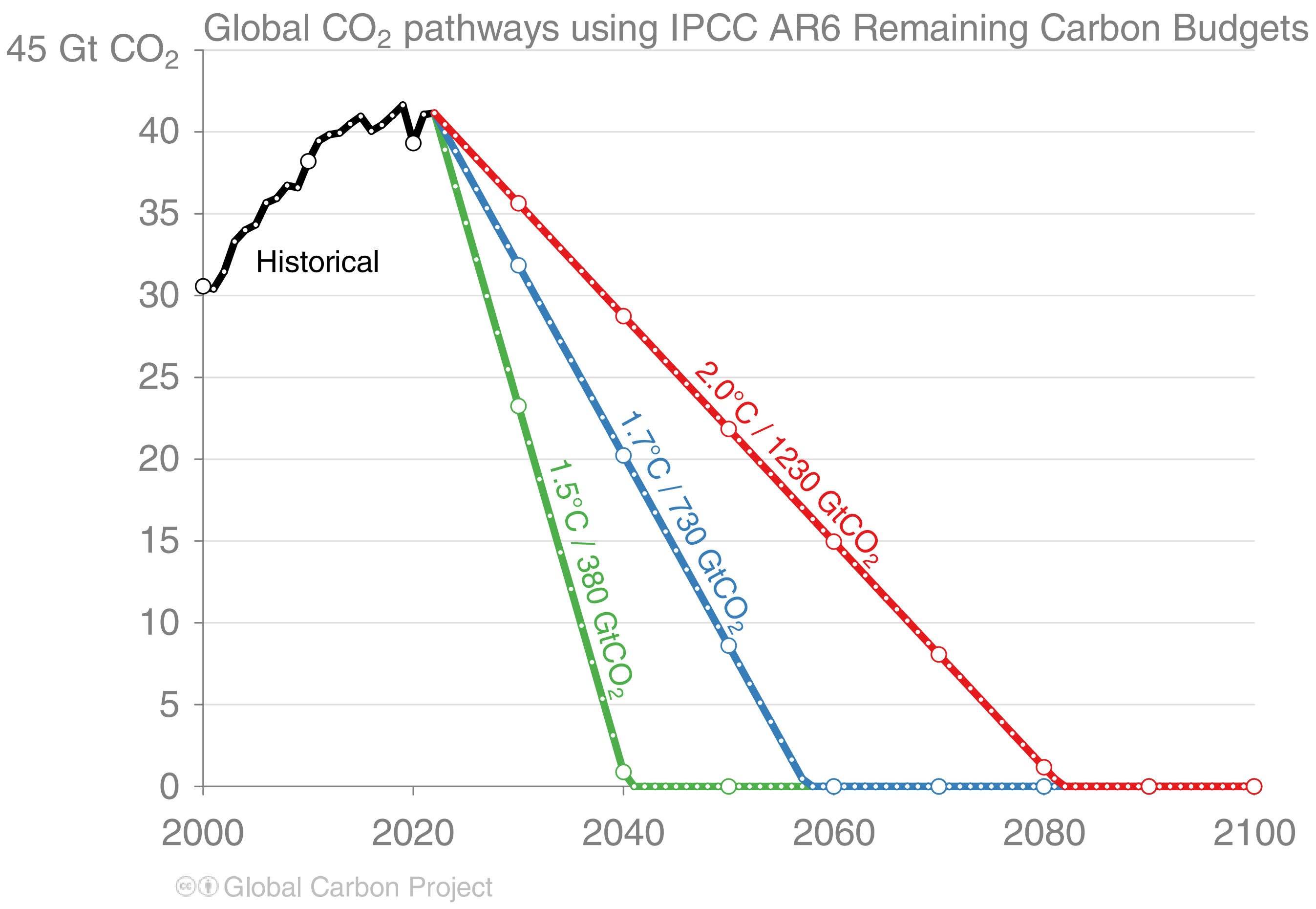
The remaining carbon budget to limit global warming to 1.5°C , 1.7°C and 2°C is
380 GtCO_2, 730 GtCO_2, and 1230 GtCO_2 respectively, equivalent to 9, 18 and 30 years from 2023.
2610 GtCO_2 have been emitted since 1750



The remaining carbon budgets are updated from IPCC AR6 WG1 Chapter 5 by removing additional historical emissions since 1 January 2020.
Quantities are subject to additional uncertainties e.g., future mitigation choices of non-CO_2 emissions
Source: IPCC AR6 WG1; Friedlingstein et al 2022; Global Carbon Budget 2022

Remaining carbon budget

Global CO_2 emissions must reach zero to limit global warming



Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

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Acknowledgements

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Acknowledgements

The work presented in the **Global Carbon Budget 2022** has been possible thanks to the contributions of **hundreds of people** involved in observational networks, modeling, and synthesis efforts.

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We also want thank the EU/H2020 projects 4C (821003) and VERIFY (776810) that supported this coordinated effort as well as each of the many funding agencies that supported the individual components of this release. A full list in provided in Table A9 of Friedlingstein et al. 2022.

https://essd.copernicus.org/articles/14/4811/2022/

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.

futurearth Research. Innovation. Sustainability.

WCRP World Climate Research Programme

European Commission

4C Climate-Carbon Interactions in the Current Century

VERIFY

CSIRO

NIES National Institute for Environmental Studies, Japan

U.S. Carbon Cycle Science Program — Land • Ocean • Atmosphere • Society

CICERO Center for International Climate Research

University of Exeter

UEA University of East Anglia

Stanford University

LSCE

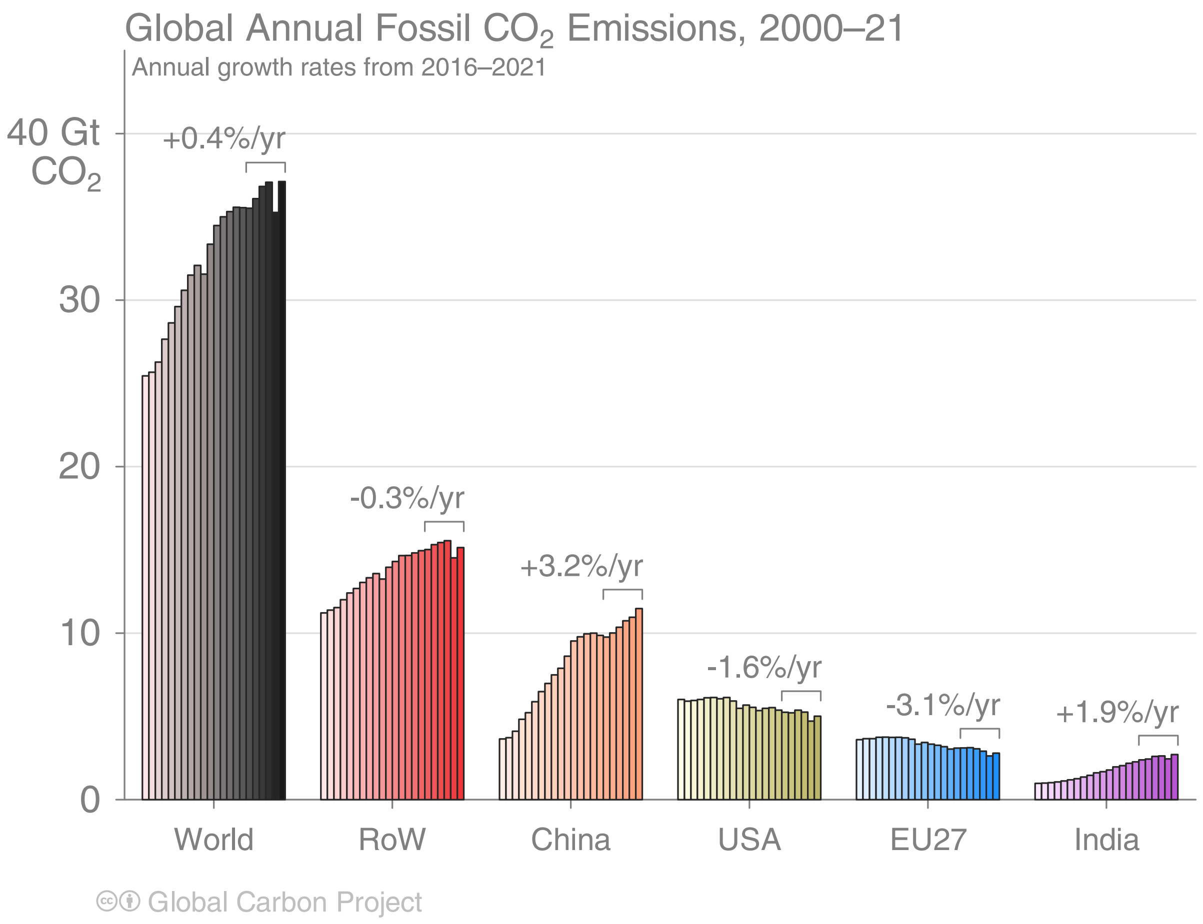
FONDATION BNP PARIBAS

Additional Figures

Additional Figures
Fossil CO_2

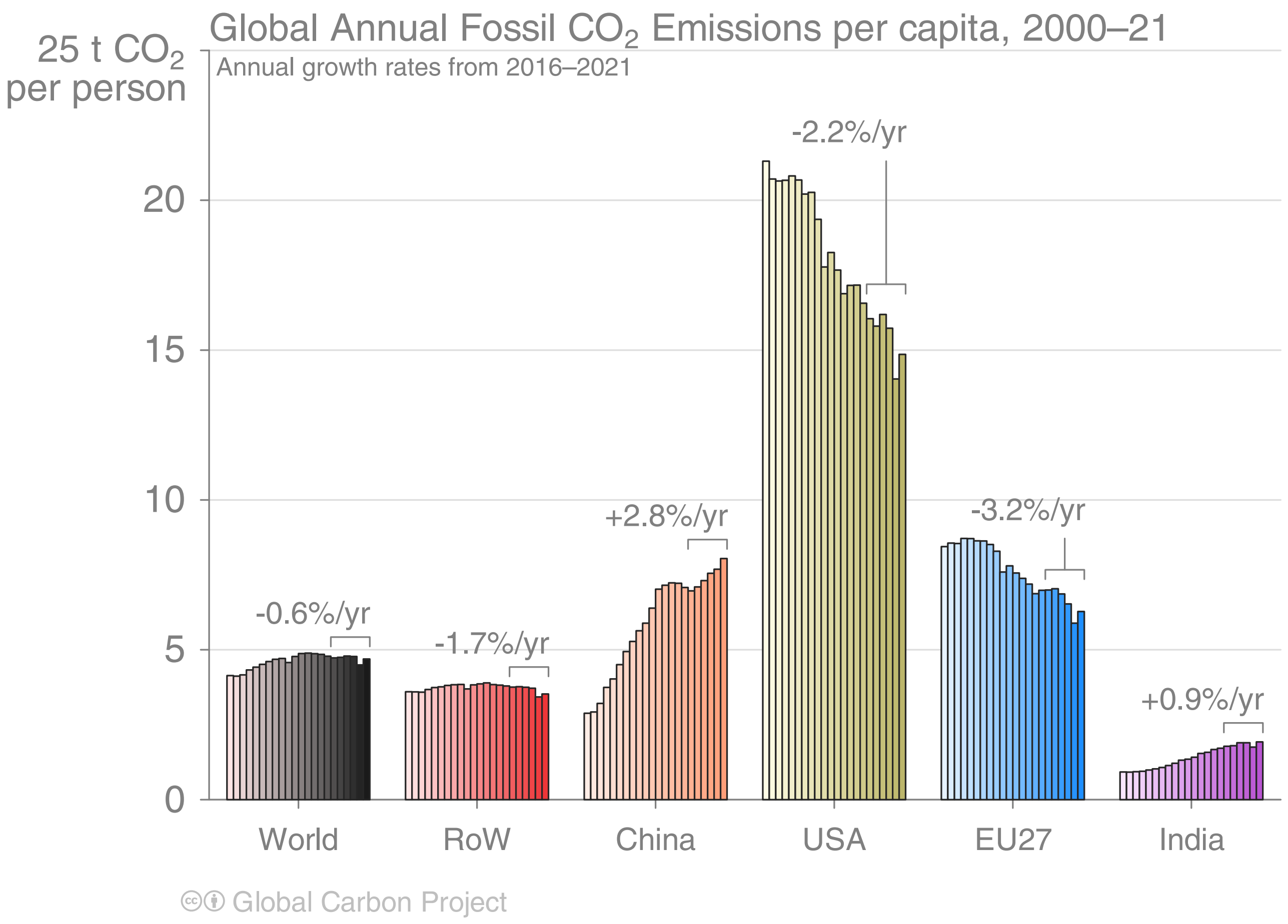
Top emitters: Fossil CO_2 Emissions

Emissions by country from 2000 to 2021, with the growth rates indicated for the more recent period of 2016 to 2021



Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

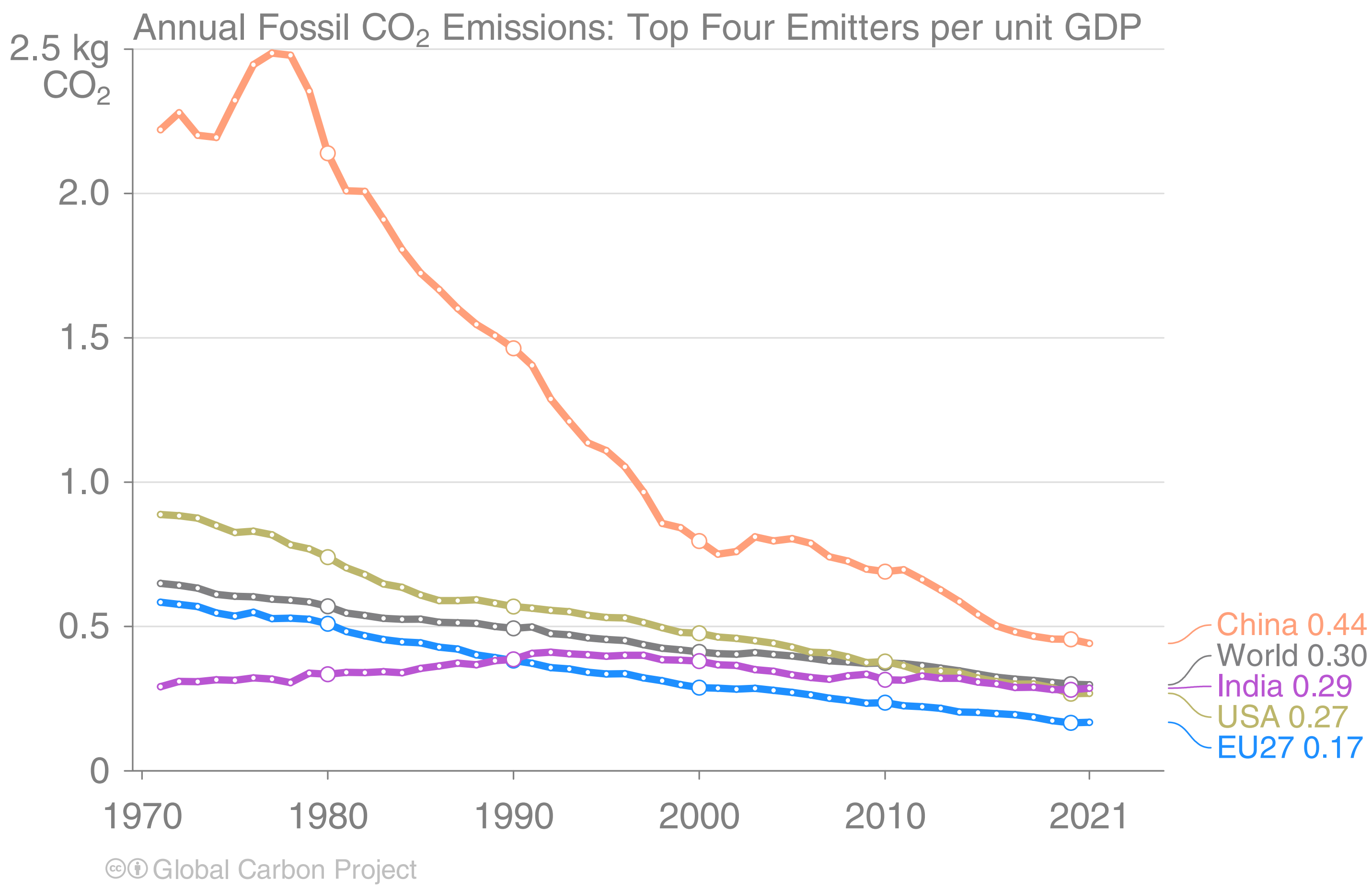
Per capita CO_2 emissions



Source: Friedlingstein et al 2022; Global Carbon Project 2022

Top emitters: Fossil CO_2 Emission Intensity

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

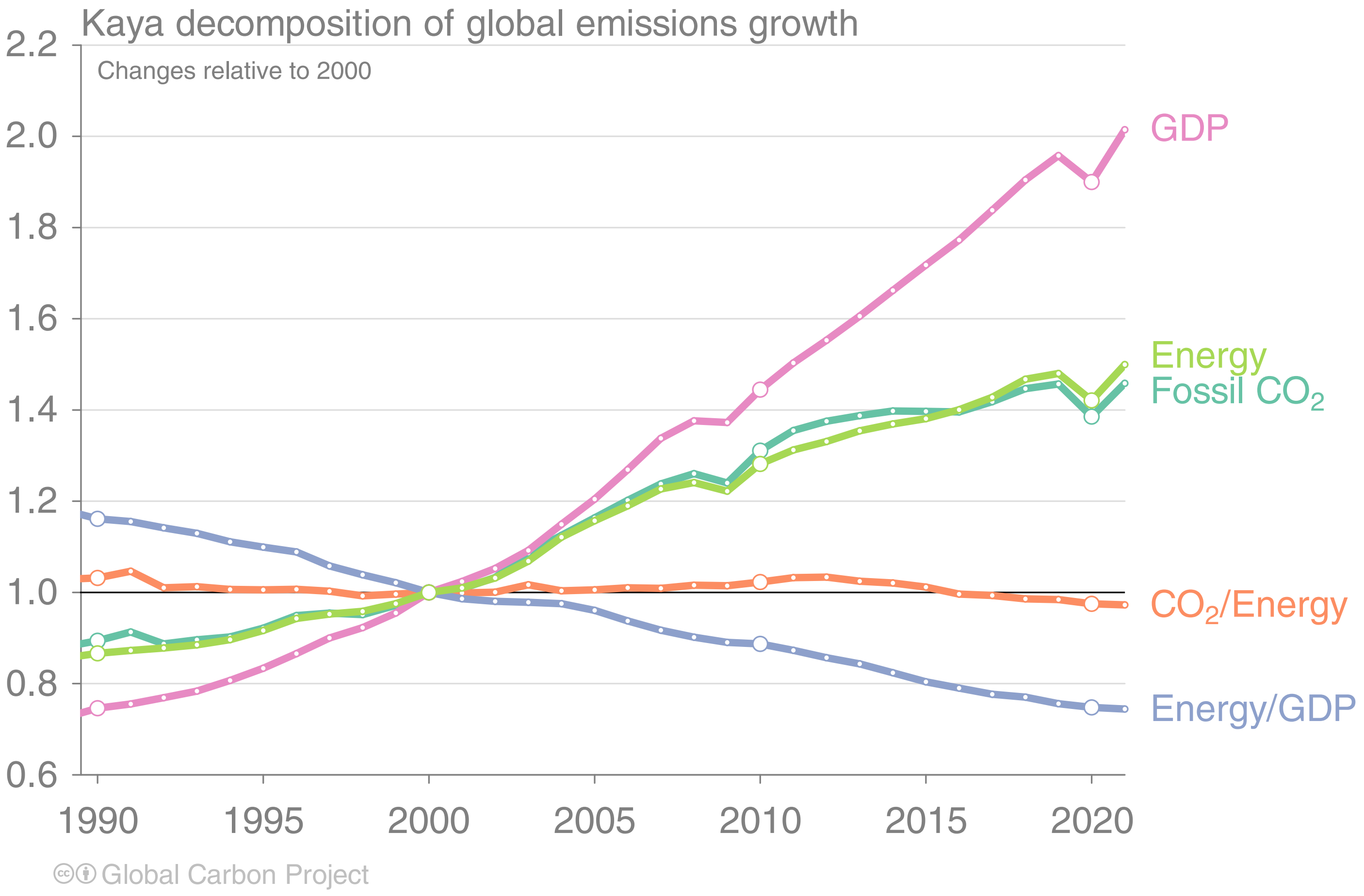


GDP is measured in purchasing power parity (PPP) terms in 2010 US dollars.

Source: Friedlingstein et al 2022; Global Carbon Project 2022

Kaya decomposition

The Kaya decomposition illustrates that relative decoupling of economic growth from CO_2 emissions is driven by improved energy intensity (Energy/GDP) &, recently, carbon intensity of energy (CO_2/Energy)

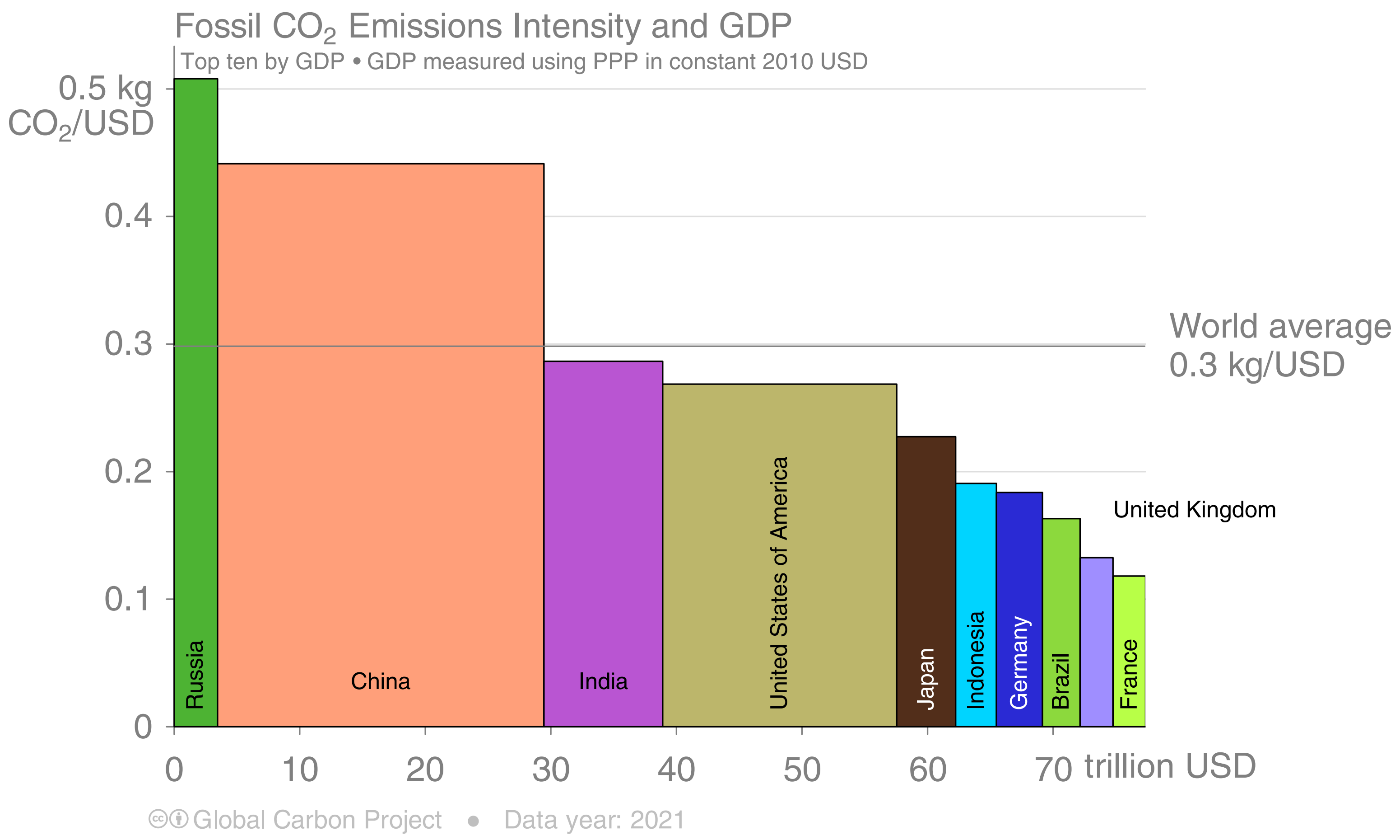


GDP: Gross Domestic Product (economic activity)

Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Fossil CO_2 emission intensity

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

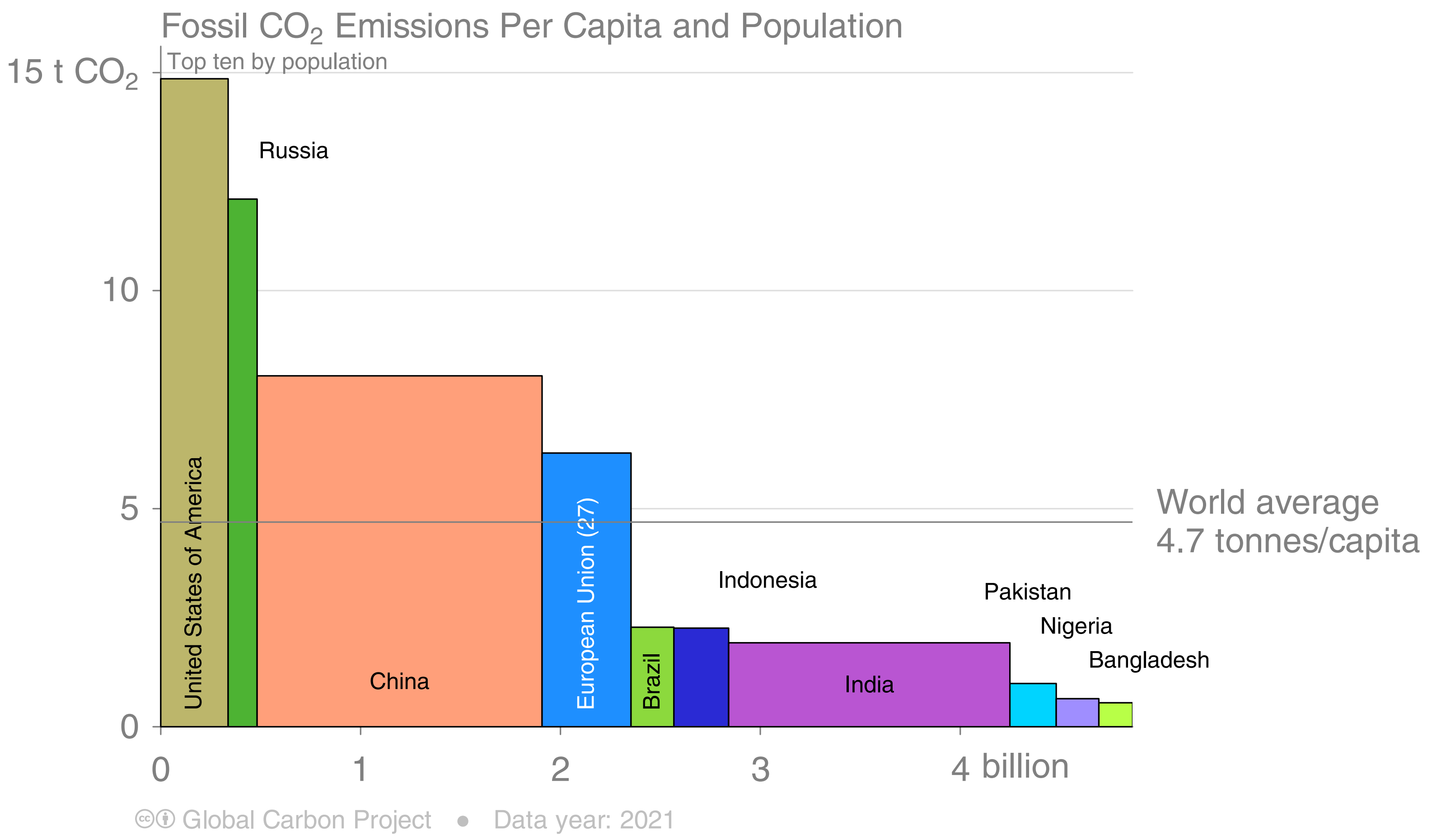


Emission intensity: Fossil CO_2 emissions divided by Gross Domestic Product (GDP)

Source: Friedlingstein et al 2022; Global Carbon Project 2022

Fossil CO_2 Emissions per capita

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

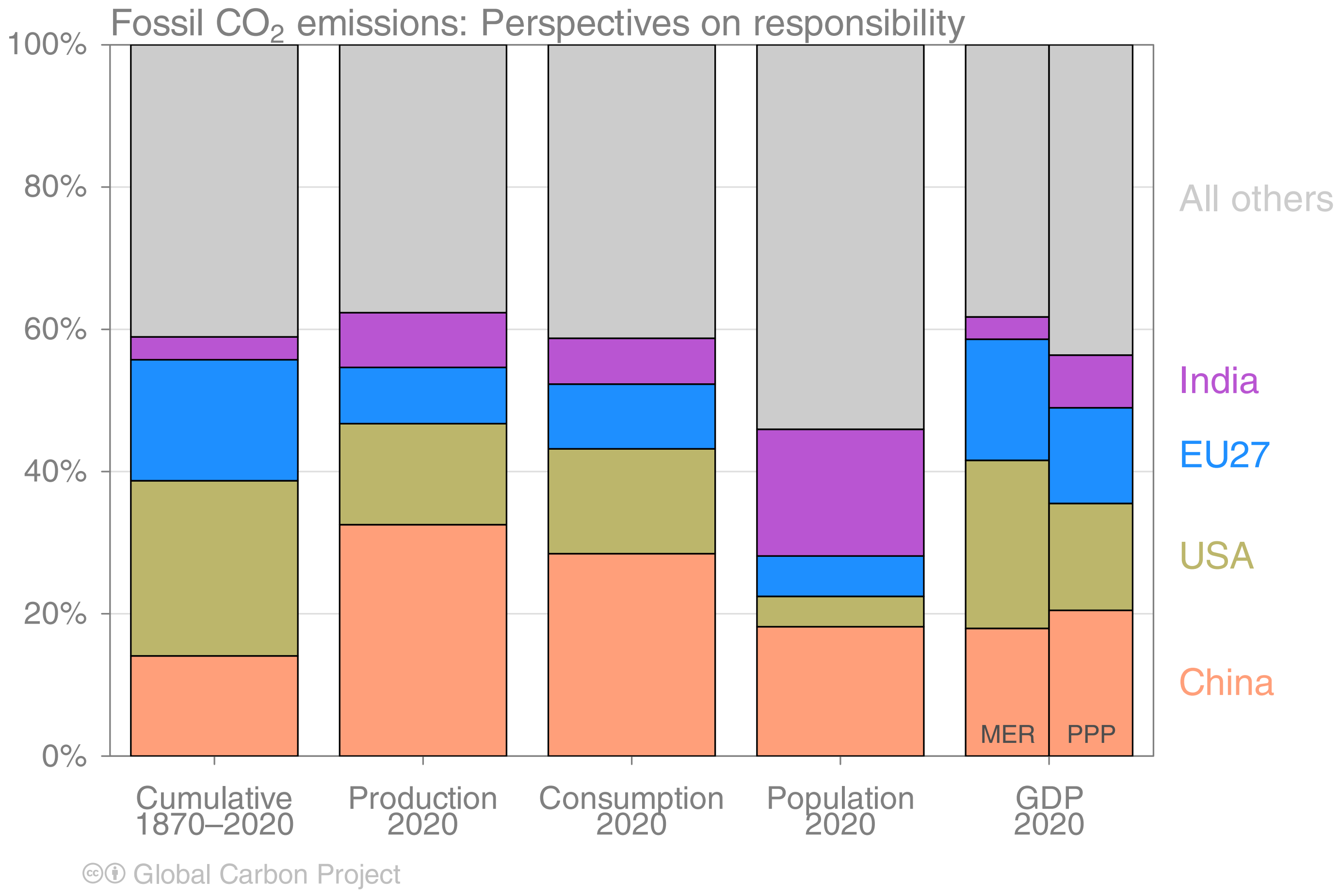


Emission per capita: Fossil CO_2 emissions divided by population

Source: Friedlingstein et al 2022; Global Carbon Project 2022

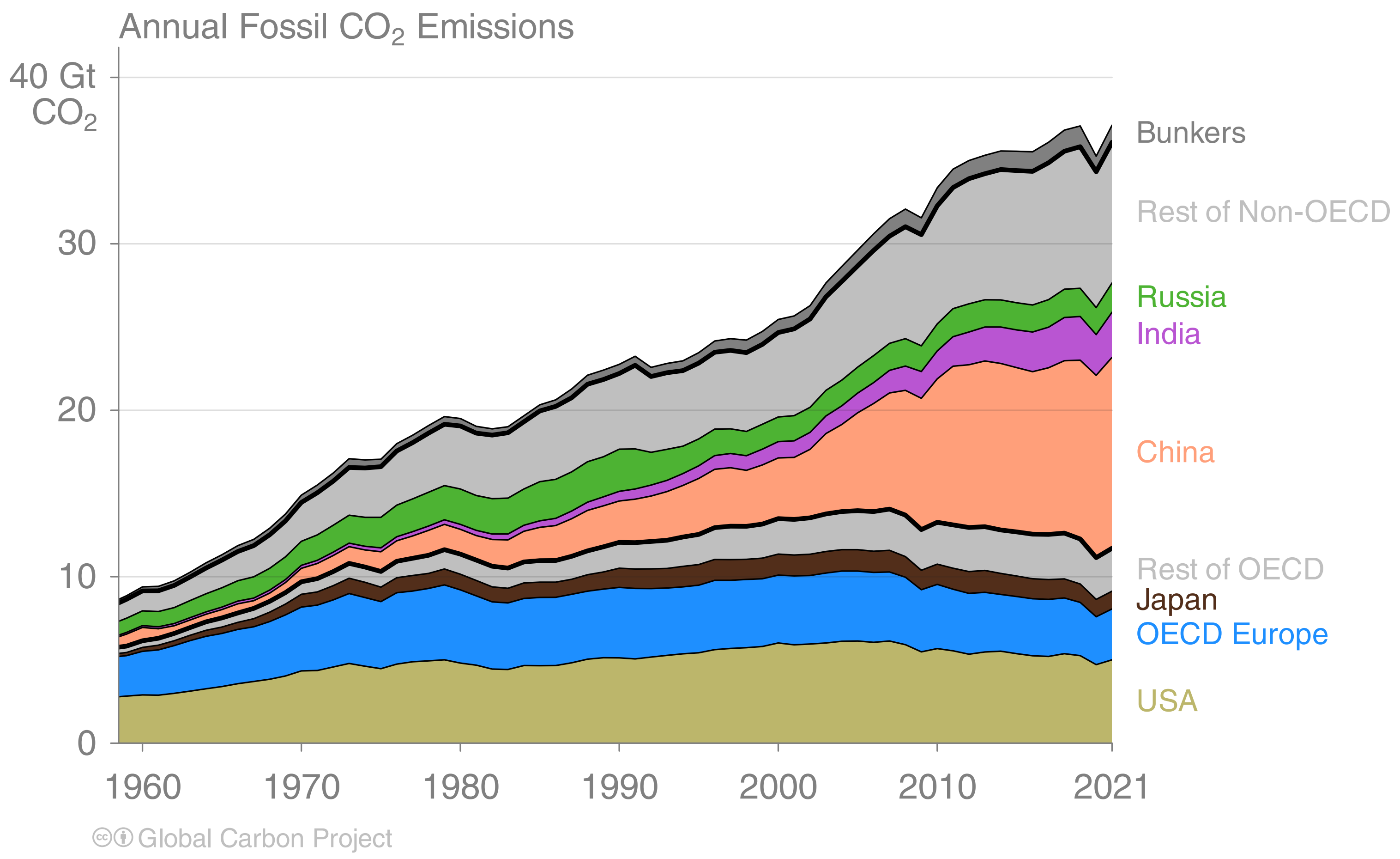
Alternative rankings of countries

The responsibility of individual countries depends on perspective.
Bars indicate fossil CO_2 emissions, population, and GDP.



GDP: Gross Domestic Product in Market Exchange Rates (MER) and Purchasing Power Parity (PPP)
Source: United Nations; Friedlingstein et al 2022; Global Carbon Project 2022

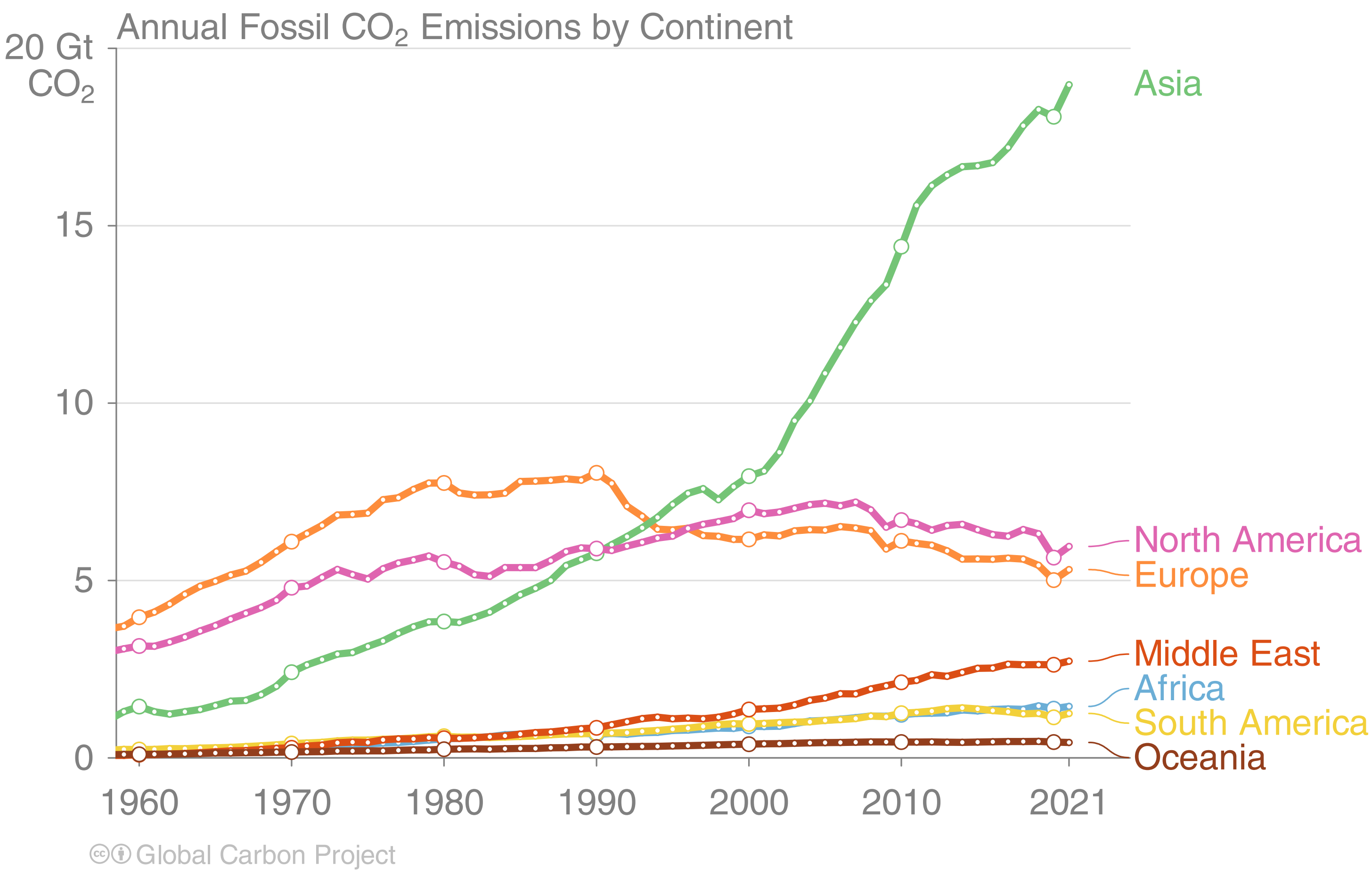
Breakdown of global fossil CO_2 emissions by country



Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Fossil CO_2 emissions by continent

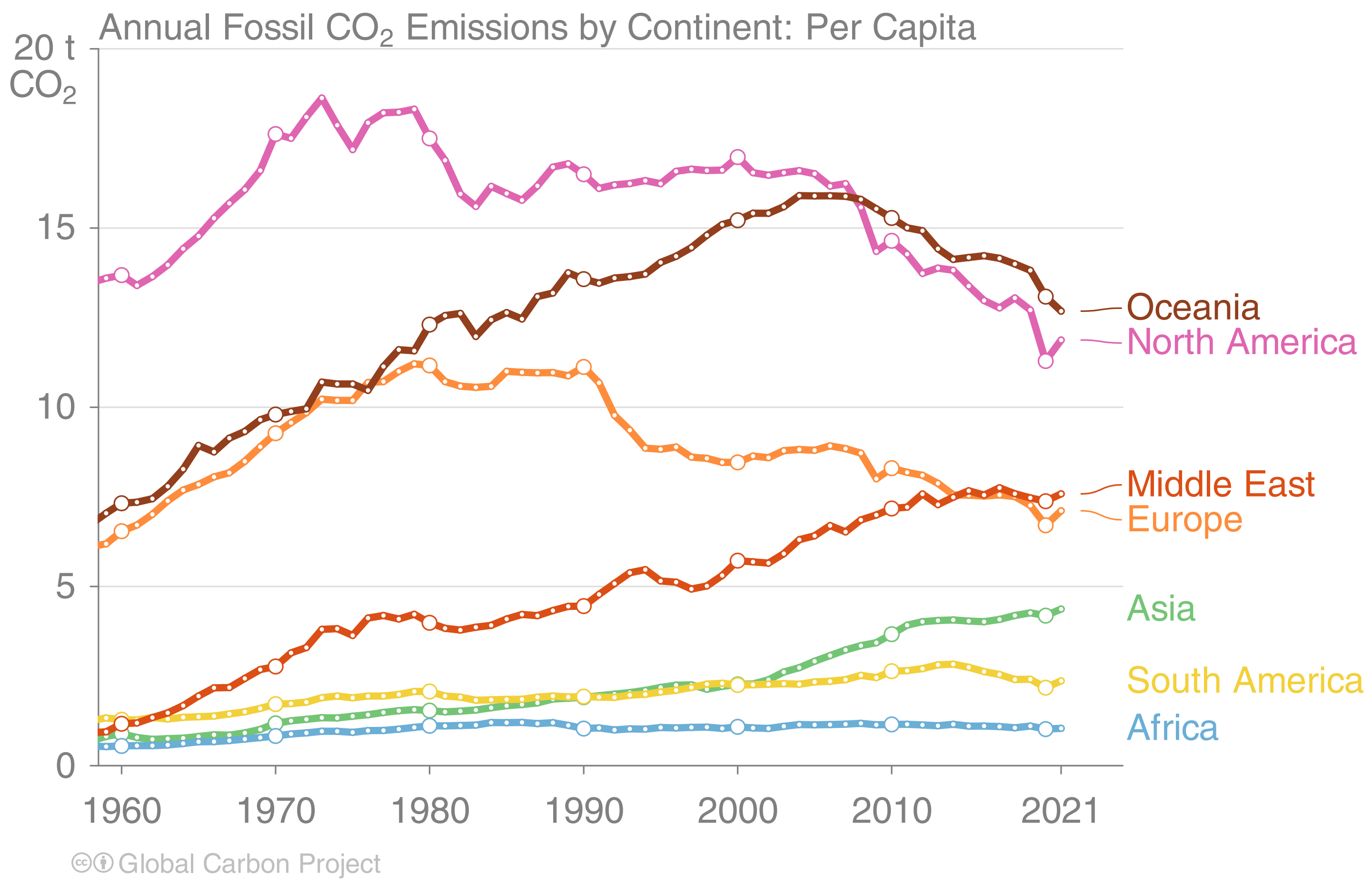
Asia dominates global fossil CO_2 emissions, while emissions in North America are of similar size to those in Europe, and the Middle East is growing rapidly.



Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Fossil CO_2 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.



Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

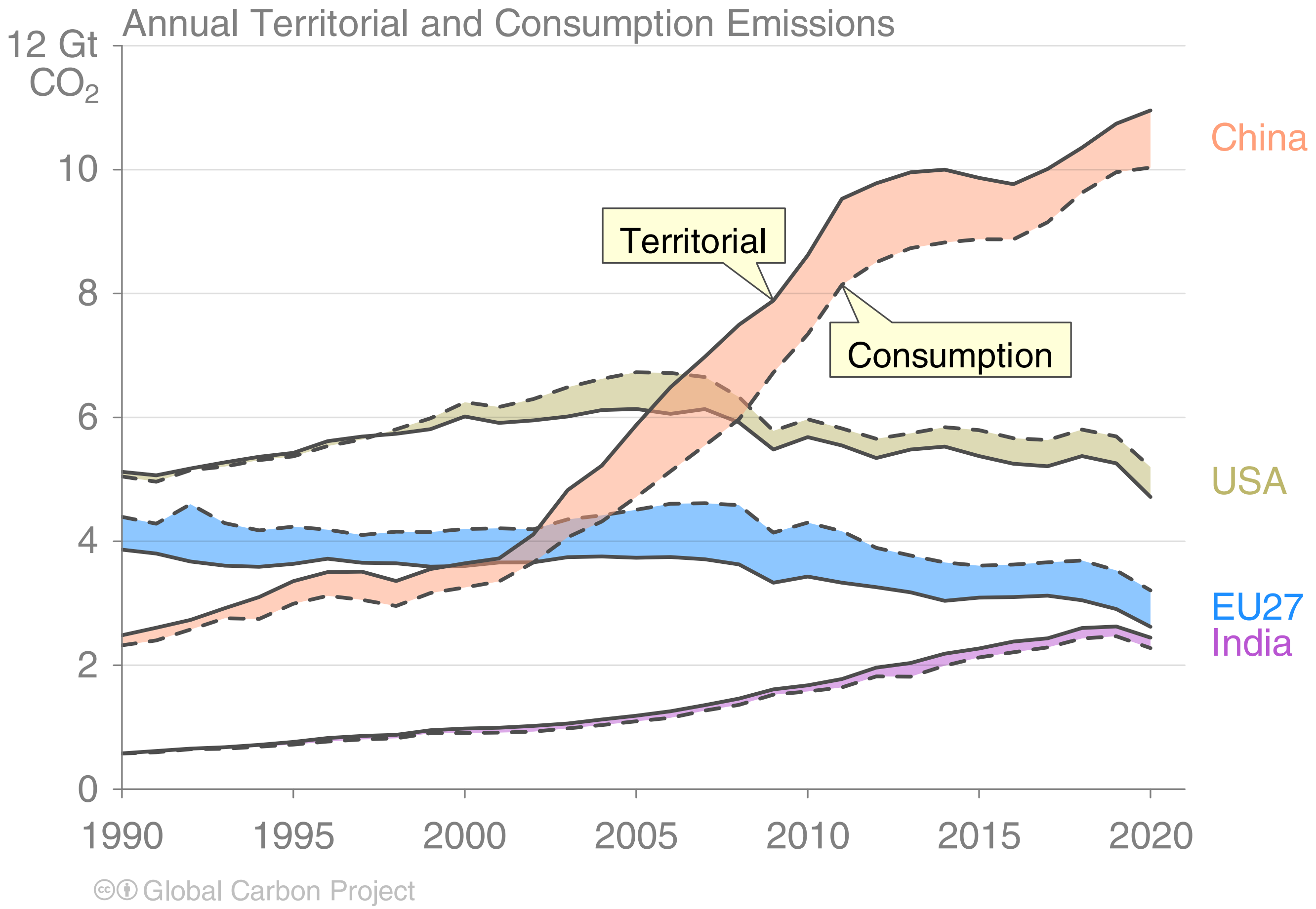
Additional Figures
Consumption-based Emissions

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_2 emissions to consumption provides an alternative perspective.
USA and EU28 are net importers of embodied emissions, China and India are net exporters.

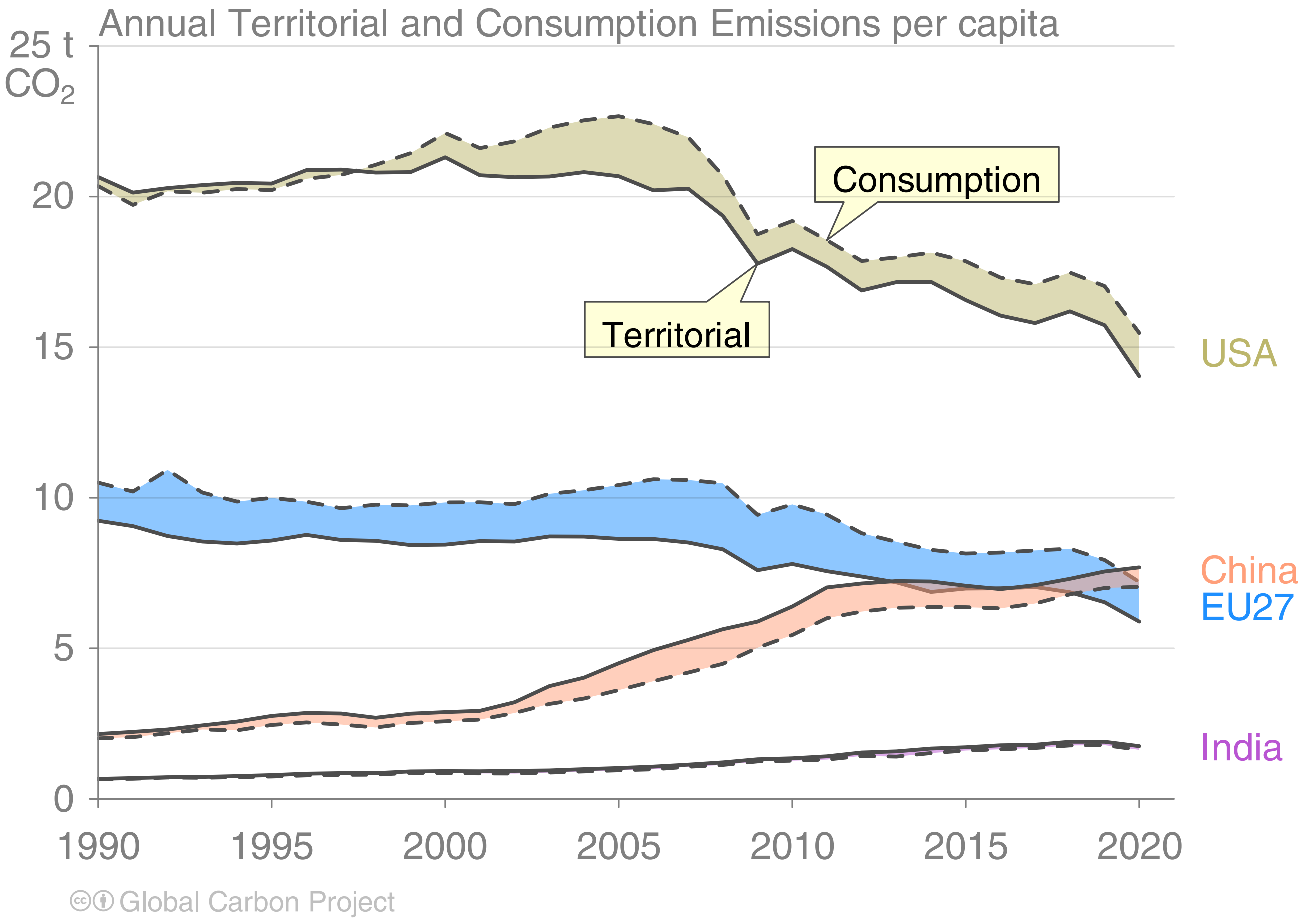


Consumption-based emissions are calculated by adjusting the
standard production-based emissions to account for international trade

Source: Peters et al 2011; Friedlingstein et al 2022; Global Carbon Project 2019

Consumption-based emissions per person

The differences between fossil CO_2 emissions per capita is larger than the differences between consumption and territorial emissions.

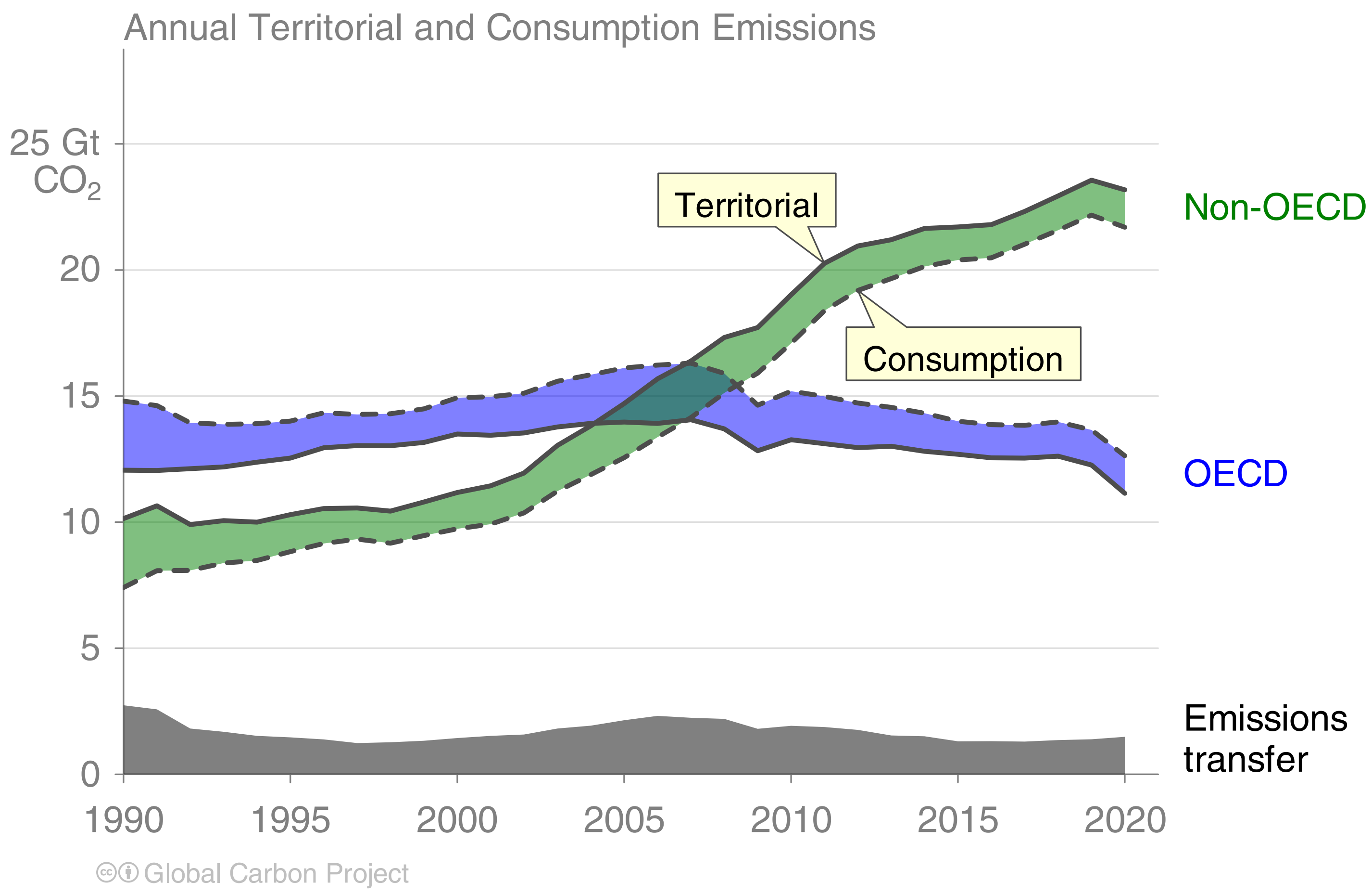


Consumption-based emissions are calculated by adjusting the standard production-based emissions to account for international trade

Source: [Peters et al 2011](); [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Consumption-based emissions (carbon footprint)

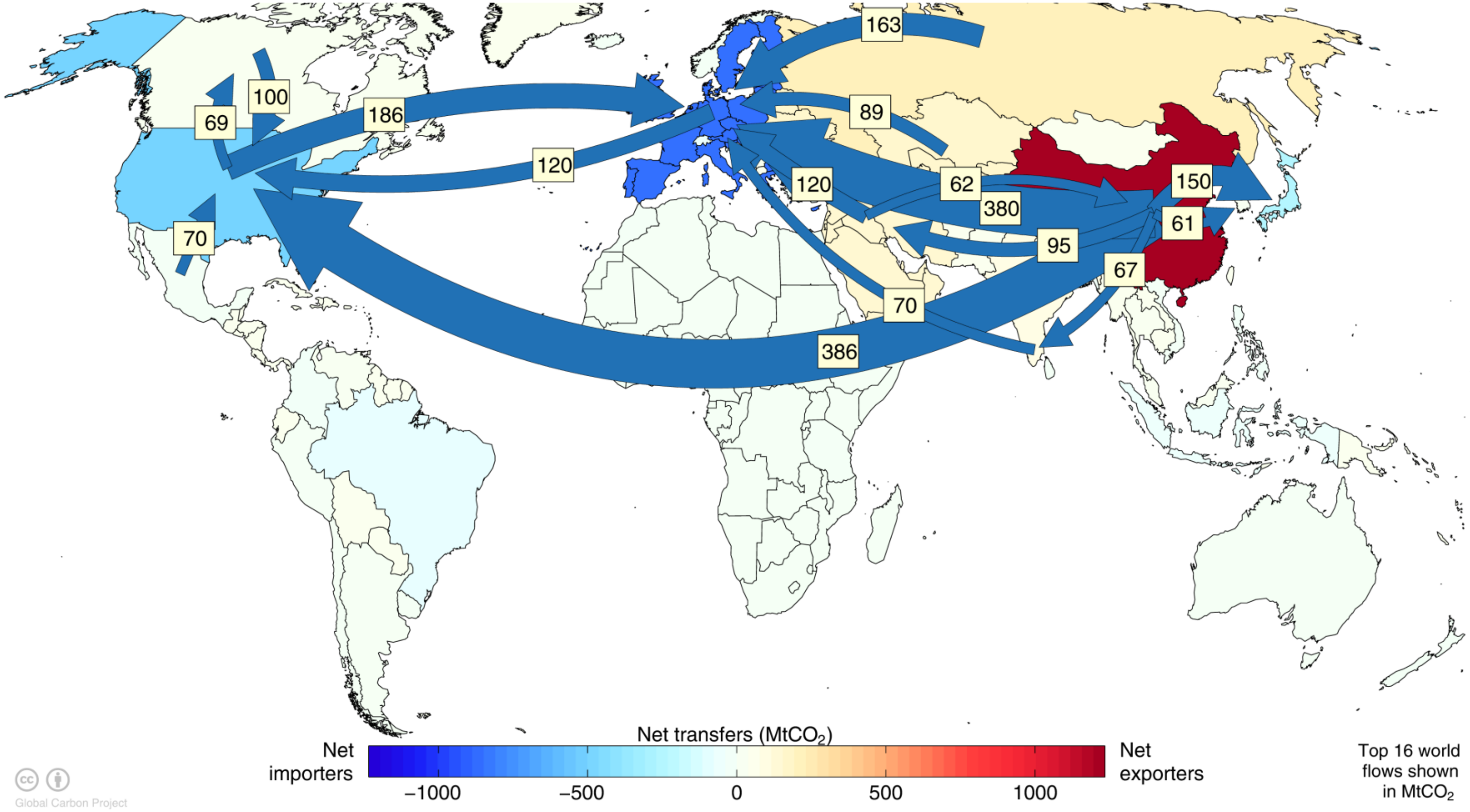
Transfers of emissions embodied in trade between OECD and non-OECD countries grew slowly during the 2000's, but has since slowly declined.



Source: Peters et al 2011; Friedlingstein et al 2022; Global Carbon Project 2022

Major flows from production to consumption (2011) – Fossil CO_2

Flows from location of generation of emissions to location of consumption of goods and services

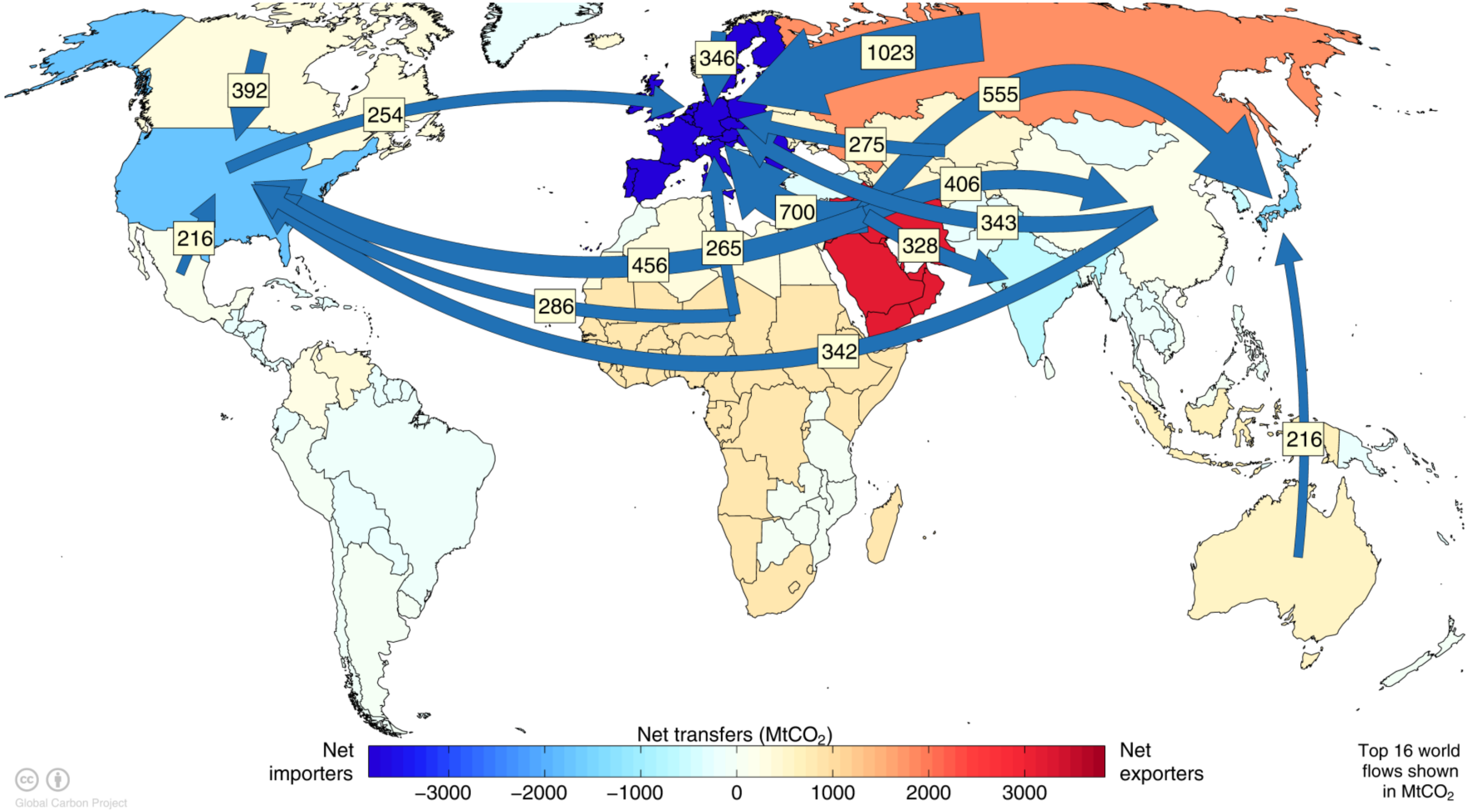


Values for 2011. EU is treated as one region. Units: $MtCO_2$

Source: [Peters et al 2012]

Major flows from extraction to consumption (2011) – Fossil CO_2

Flows from location of fossil fuel extraction to location of consumption of goods and services

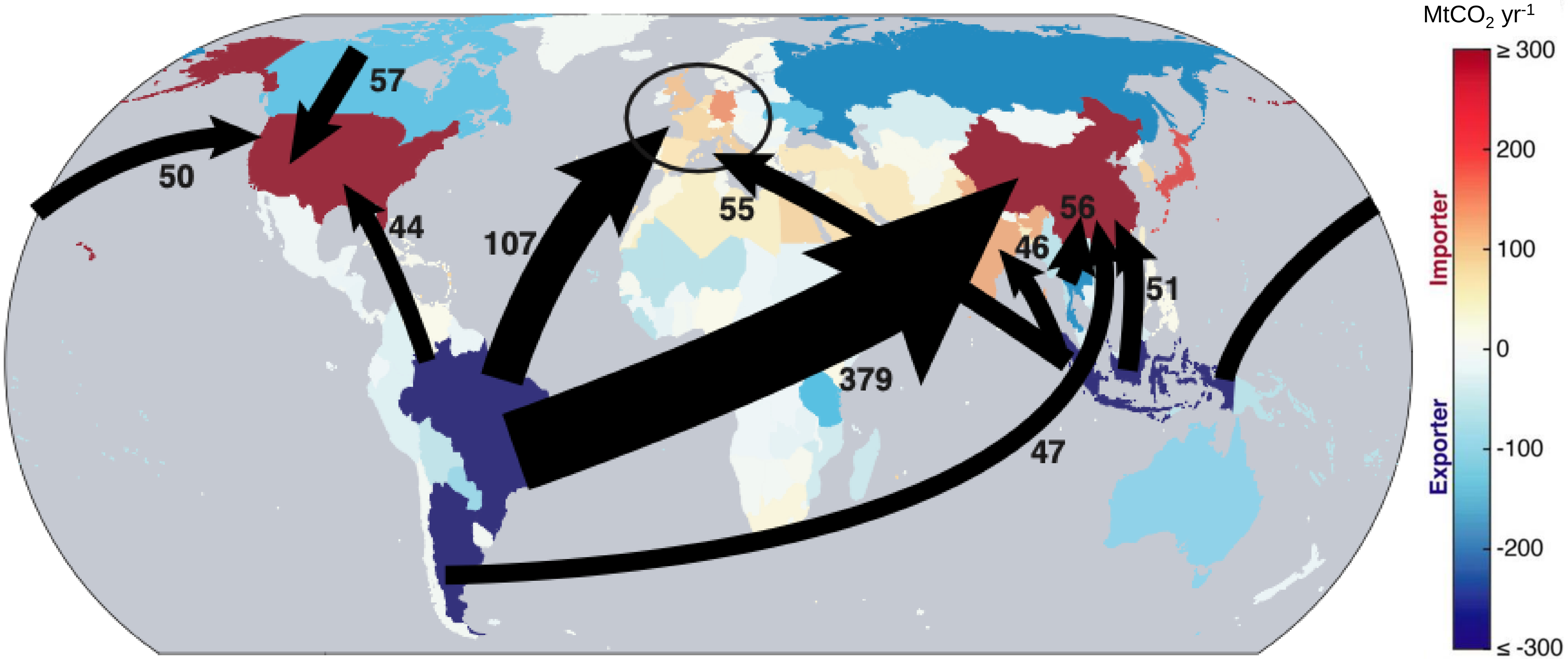


Values for 2011. EU is treated as one region. Units: $MtCO_2$

Source: [Andrew et al 2013]

Major flows from production to consumption (2017) — Land Use Change CO_2

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.



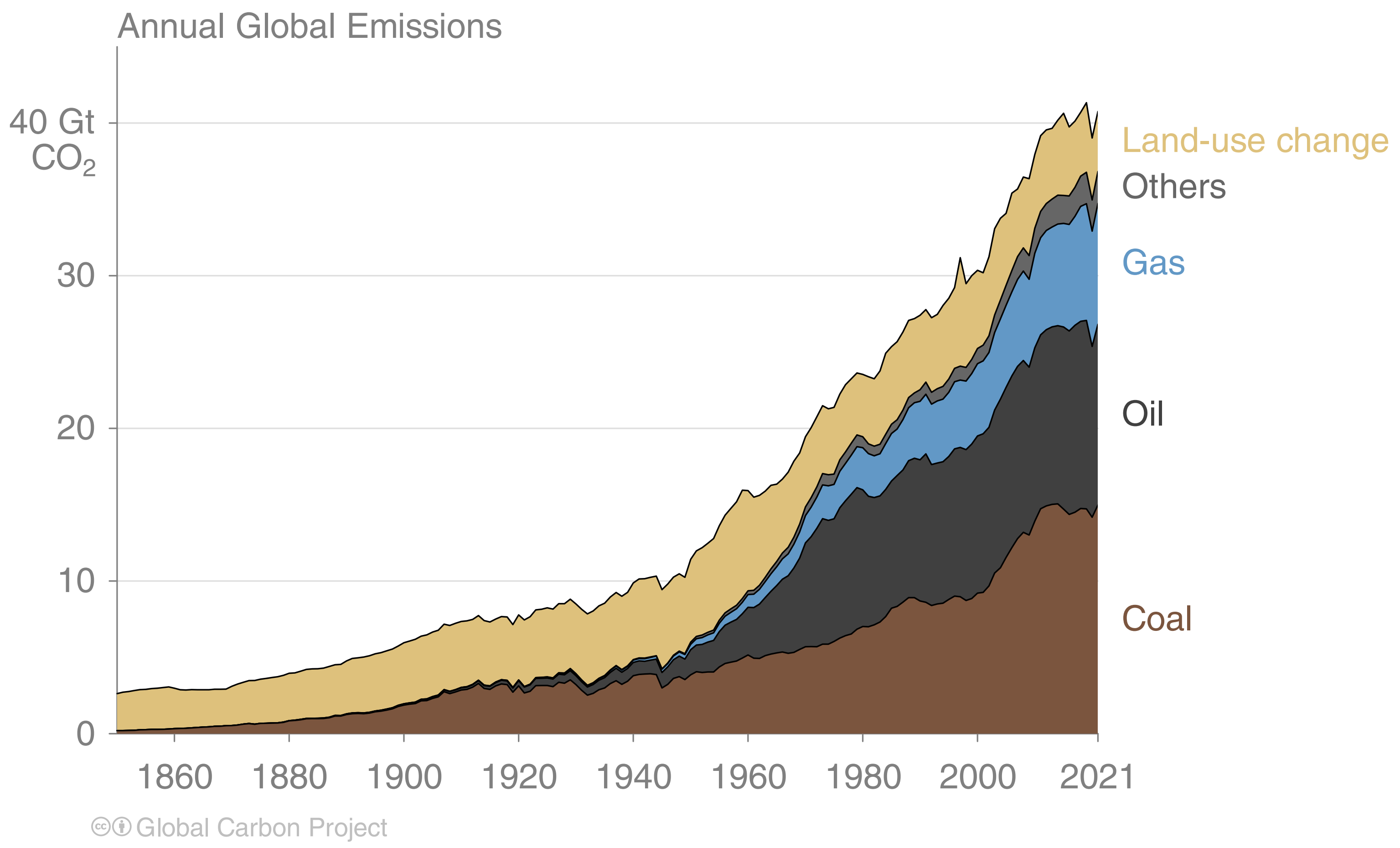
Values for 2017. EU27 is treated as one region. Units: $MtCO_2$

Source: [Hong et al 2022]

Additional Figures
Historical Emissions

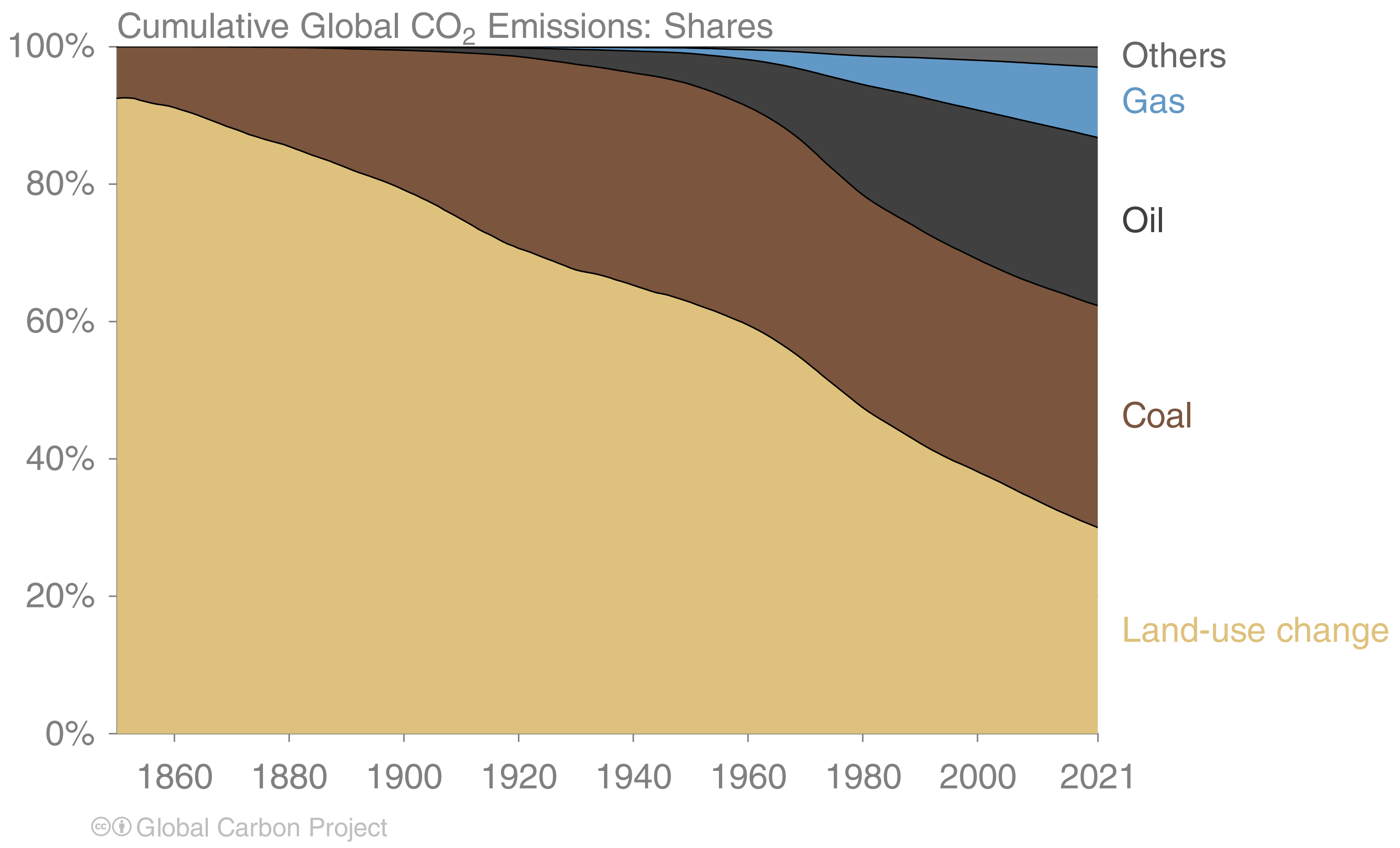
Total global emissions by source

Land-use change was the dominant source of annual CO_2 emissions until around 1950.
Fossil CO_2 emissions now dominate global changes.



Others: Emissions from cement production, gas flaring and carbonate decomposition
Source: Friedlingstein et al 2022; Global Carbon Project 2022

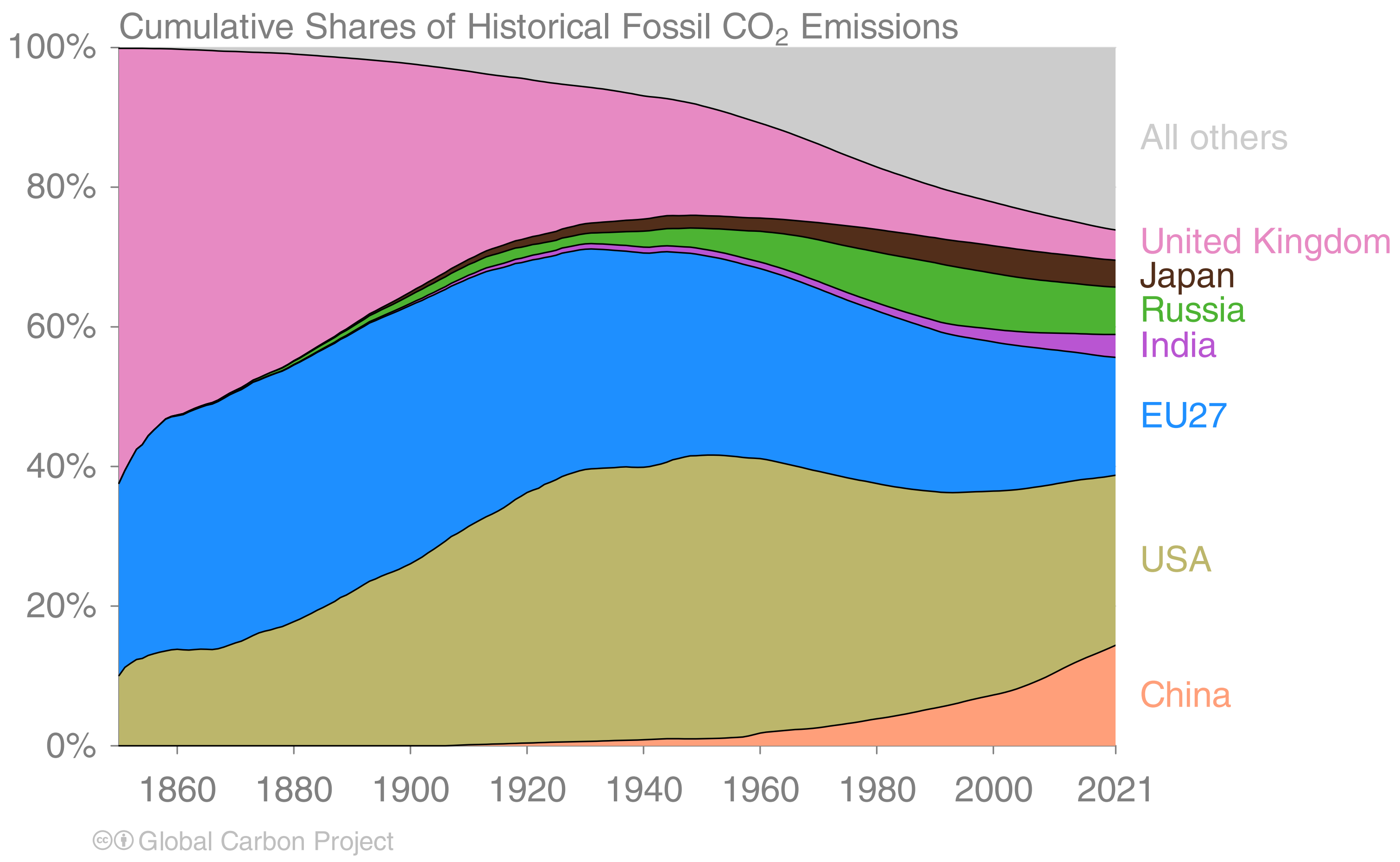
Historical cumulative emissions by source



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

Source: [Friedlingstein et al 2022](); [Global Carbon Project 2022]()

Historical cumulative fossil CO_2 emissions by country

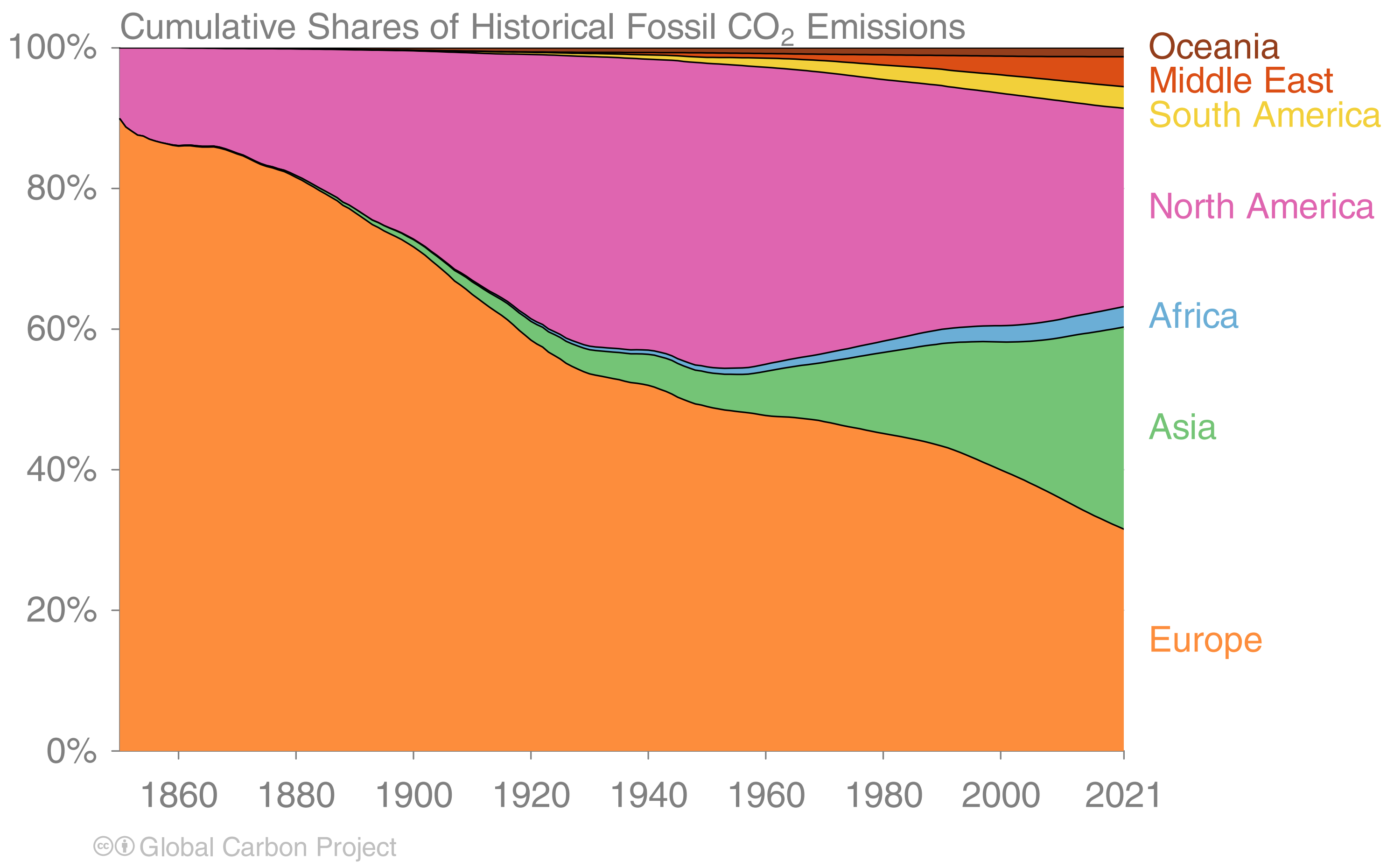


'All others' includes all other countries along with emissions from international aviation and maritime shipping

Source: Friedlingstein et al 2022; Global Carbon Project 2022

Historical cumulative emissions by continent

Cumulative fossil CO_2 emissions (1850–2021). North America and Europe have contributed the most cumulative emissions, but Asia is growing fast



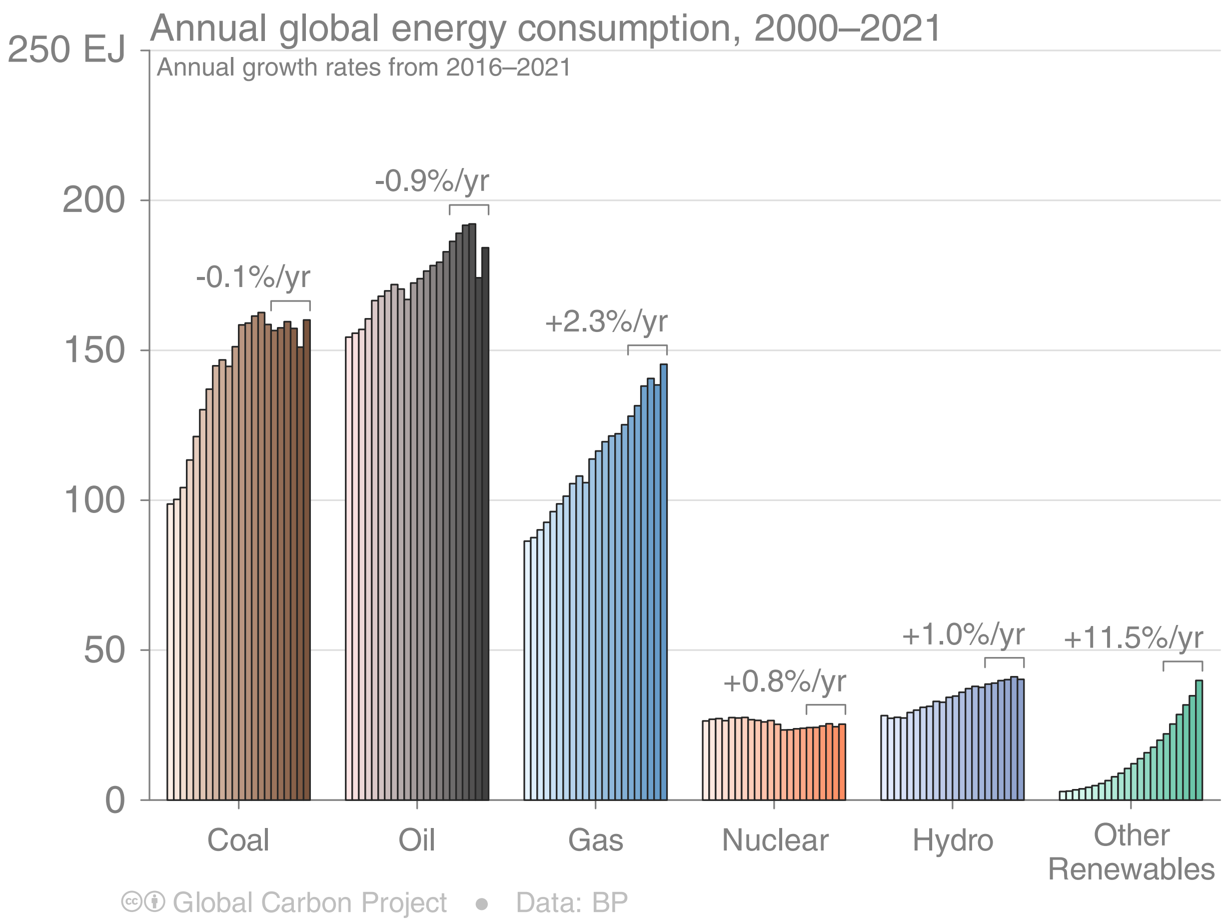
The figure excludes emissions from international aviation and maritime shipping

Source: Friedlingstein et al 2022; Global Carbon Project 2022

Additional Figures
Energy Use

Energy use by source

Energy consumption by fuel source from 2000 to 2021, with growth rates indicated for the more recent period of 2016 to 2021

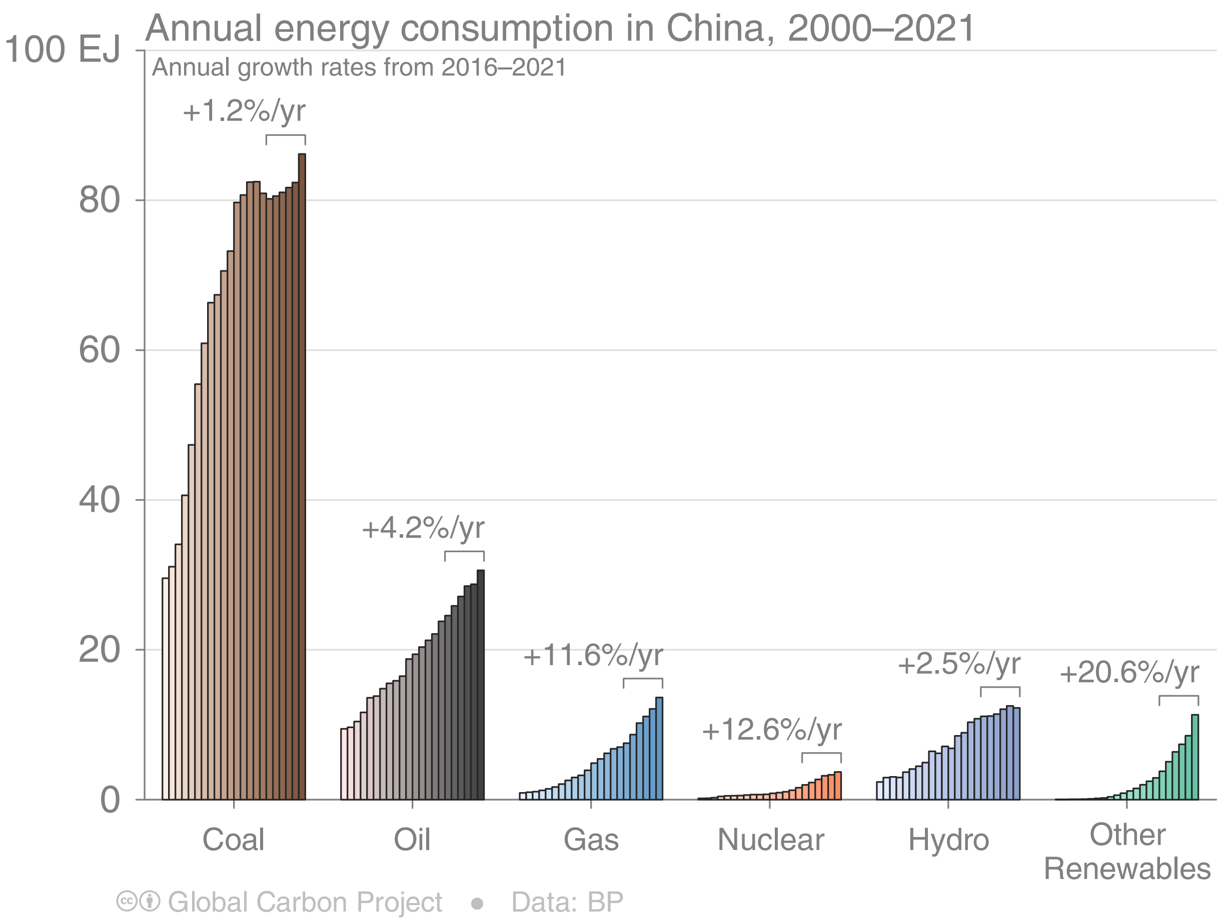


This figure shows "primary energy" using the BP substitution method
(non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)

Source: BP 2022; Global Carbon Project 2022

Energy use in China

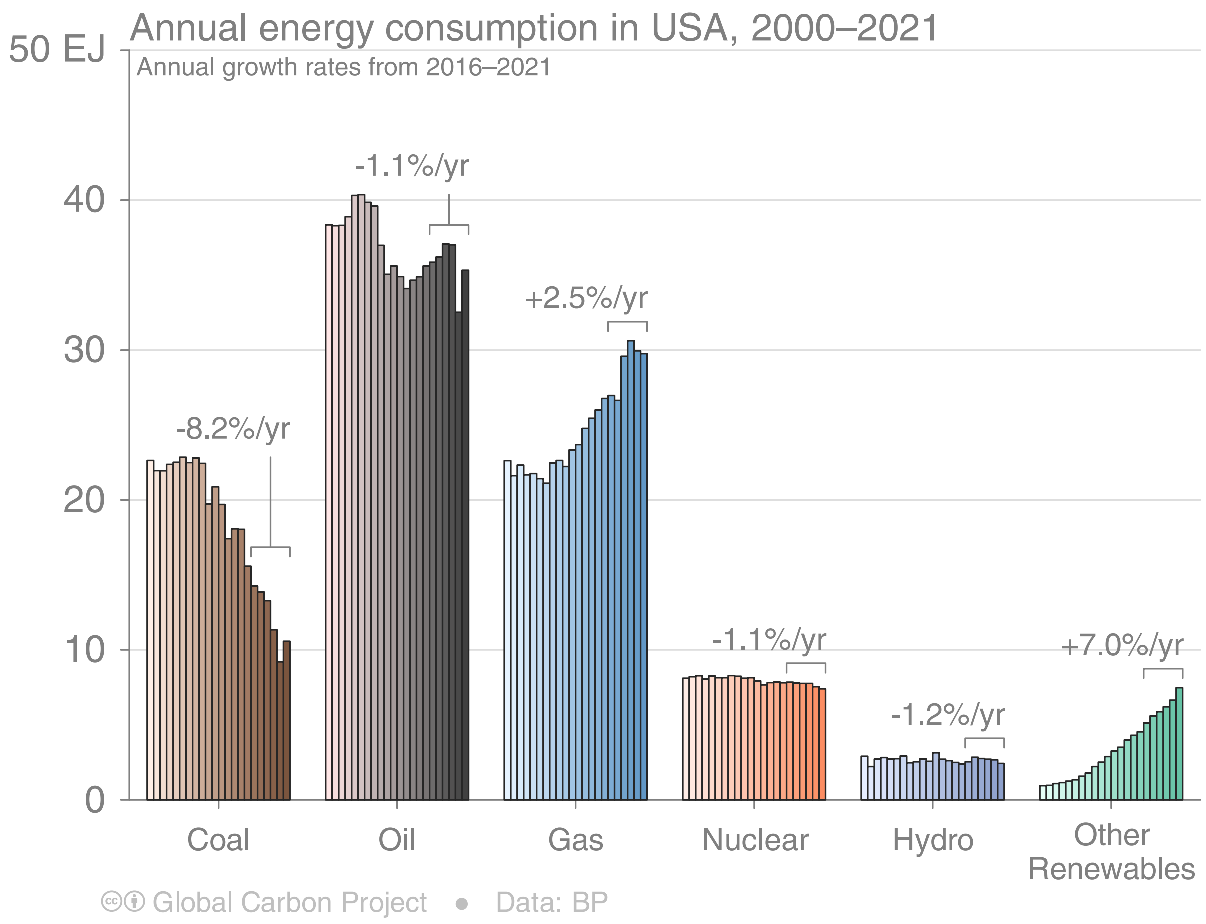
Coal consumption in energy units has returned to peak levels, while consumption of all other energy sources is growing strongly



Source: [BP 2022](); [Global Carbon Project 2022]()

Energy use in USA

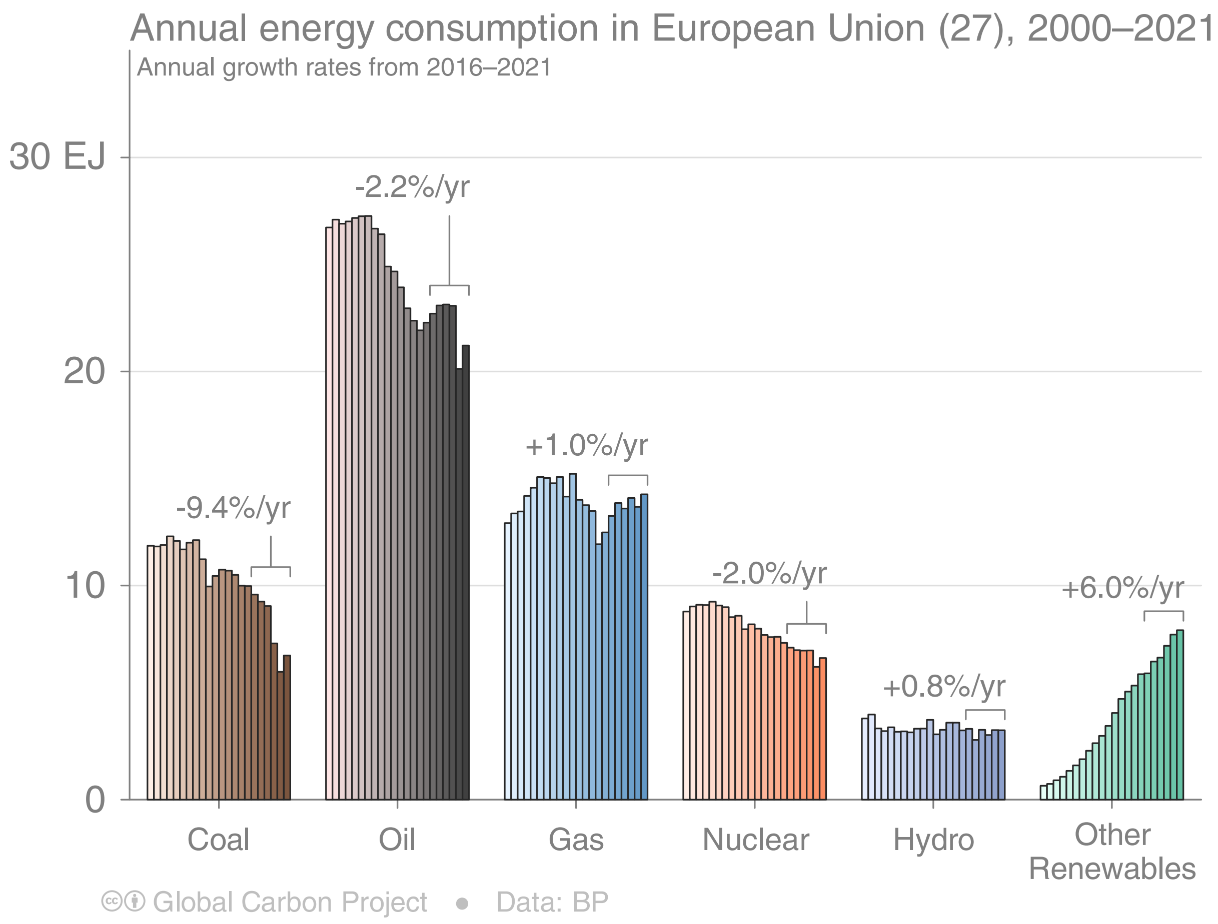
Coal consumption has declined sharply in recent years with the shale gas boom and strong renewables growth. Output from nuclear power is slowly declining as stations are retired.



Source: [BP 2022](); [Global Carbon Project 2022]()

Energy use in the European Union

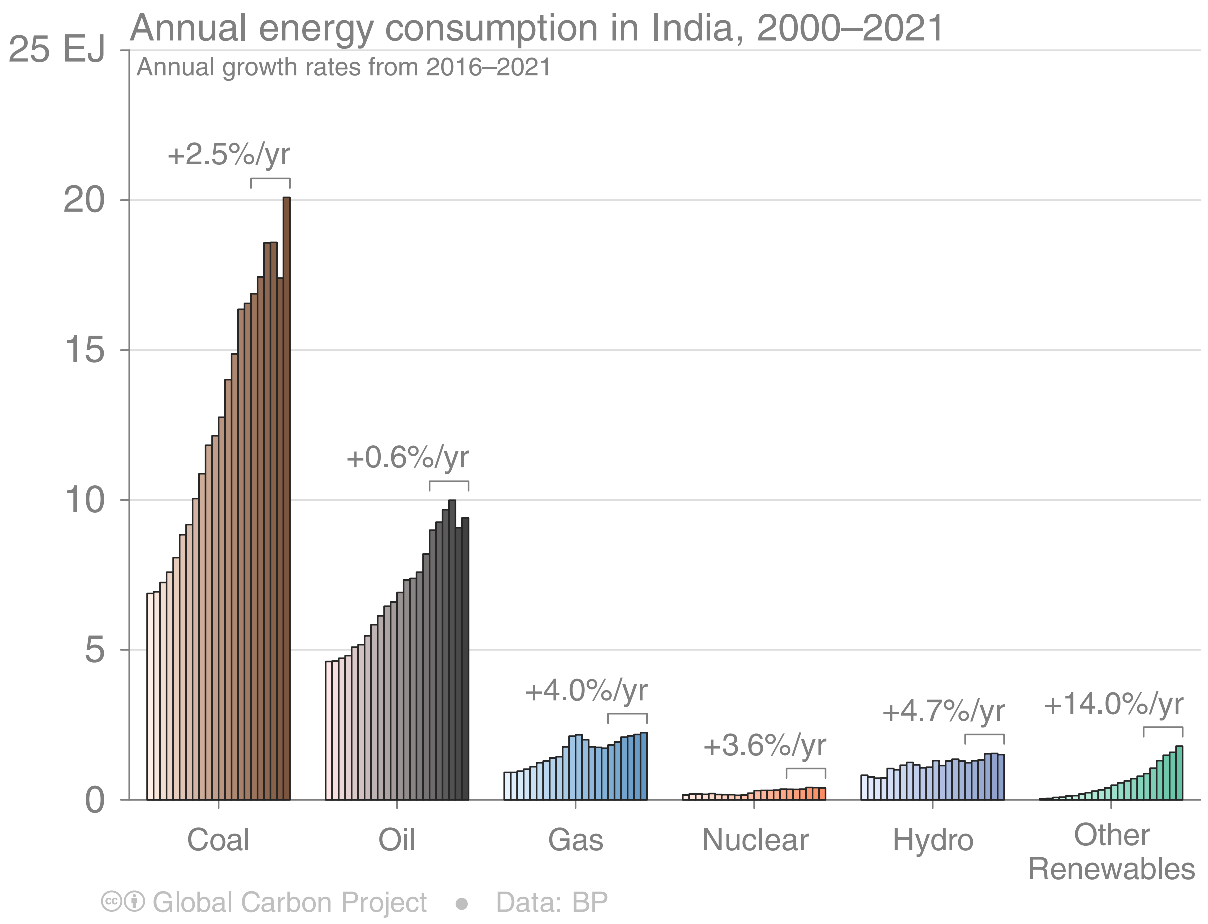
Consumption of both oil and gas has rebounded in recent years, while coal continues to decline.
Renewables are growing strongly, now providing more energy than nuclear power.



Source: [BP 2022](); [Global Carbon Project 2022]()

Energy use in India

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



Source: BP 2022; Global Carbon Project 2022