



Global Carbon Budget

2021

Acknowledgements

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

Atmospheric CO₂ datasets

NOAA/ESRL (Dlugokencky and Tans 2021)
Scripps (Keeling et al. 1976)

Fossil CO₂ emissions

Andrew and Peters, 2021
CDIAC (Gilfillan and Marland, 2021)
UNFCCC, 2021a
BP, 2021

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

fCO₂ 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 SOCATv2021

Full references provided in [Friedlingstein et al 2021](#)

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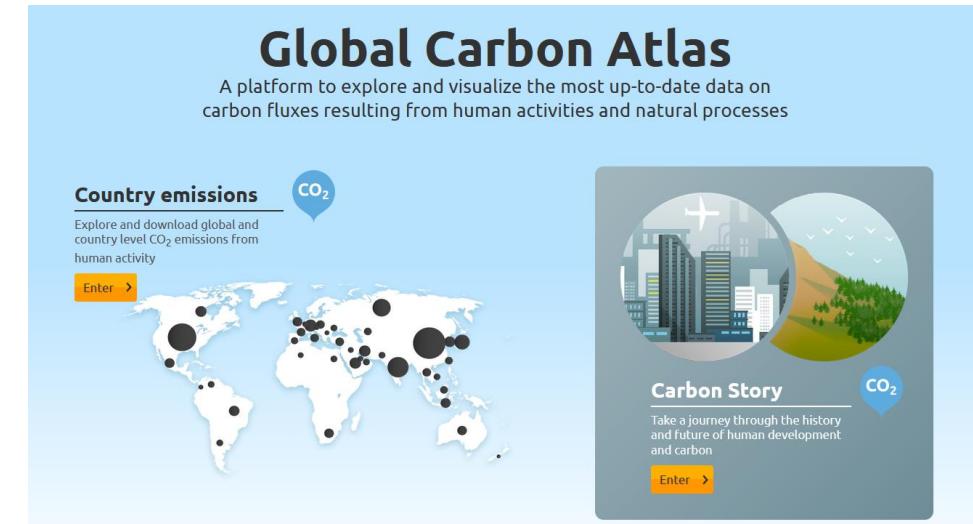
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Data Access and Additional Resources



The screenshot shows the homepage of the Global Carbon Budget 2021. At the top, there's a navigation bar with links to HOME, CARBON ATLAS, CARBON BUDGET, CH₄ BUDGET, N₂O BUDGET, RECCAP, URBANIZATION, and SEARCH. Below the navigation is a sidebar with links to Translate this site, Select Language (dropdown), About GCP, Activities, Meetings, Publications, Science, Research Programs, Carbon Neutral, Internet Resources, Site Map, and Contact Us. The main content area features a large image of Earth with the title "Global Carbon Budget" and a box for "Carbon Budget 2021". The box contains the text "An annual update of the global carbon budget and trends" and "Published 4 November 2021". Below this are two tables: "HIGHLIGHTS" and "Governance". The "HIGHLIGHTS" table includes links to Publications (Papers, Contributors and how to cite Budget 2021), Infographics (Infographics supporting Budget 2021), and Data (Powerpoint and figures on Budget 2021). The "Governance" table includes links to Images (Images available for media coverage) and Visualisations (Visualisations of the carbon cycle). At the bottom of the content area is a link to "Archive Data from previous carbon budgets". On the right side, there's a "Media" section with "Highlights" (link to 'Carbon Budget 2021' compact format), "Press Releases" (link to releases from various research institutions), and a "See also" section with a link to the "GLOBAL CARBON ATLAS". The footer contains copyright information: "© GCP 2001-2021 | Global Carbon Project | info@globalcarbonproject.org | Disclaimer".

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

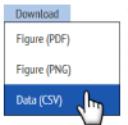


The screenshot shows the homepage of the Global Carbon Atlas. The title "Global Carbon Atlas" is at the top, followed by the subtitle "A platform to explore and visualize the most up-to-date data on carbon fluxes resulting from human activities and natural processes". Below this are two main sections: "Country emissions" and "Carbon Story". The "Country emissions" section features a world map with black dots representing CO₂ emissions and an "Enter" button. The "Carbon Story" section features a circular graphic showing a city skyline and a forest, with an "Enter" button. Both sections have a blue CO₂ icon.

More information, data sources and data files:
www.globalcarbonatlas.org
 (co-funded in part by BNP Paribas Foundation)
 Contact: philippe.ciais@lsce.ipsl.fr

Download of figures and data

Global Carbon Budget



To download figures or data, use the Download menu to the upper right of each figure. The precision provided in the data files is not indicative of certainty. For example, the data file says that global emissions in 2018 were 36.444 GtCO₂, but this should be quoted as 36.4 GtCO₂. CSV data files have been prepared for many but not all figures on this page.

Slide 07

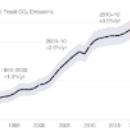
Perturbation of the carbon cycle



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Slide 09

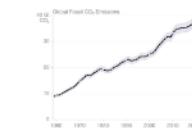
Global fossil fuel and cement emissions



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Slide 10

Global fossil fuel and cement emissions



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Slide 11

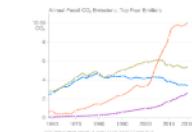
Emissions of the top four emitters



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Slide 12

Emissions of the top four emitters



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Slide 13

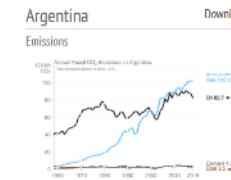
Per-capita emissions of the top four emitters



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Additional country figures

Argentina



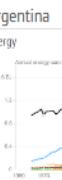
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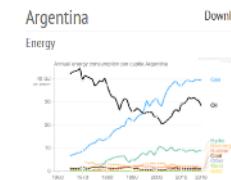
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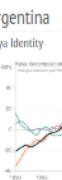
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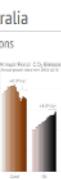
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Australia



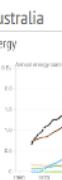
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Australia



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Australia



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Figures and data for most slides available from tinyurl.com/GCB21figs

All the data is shown in billion tonnes CO₂ (GtCO₂)

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

1 kg carbon (C) = 3.664 kg carbon dioxide (CO₂)

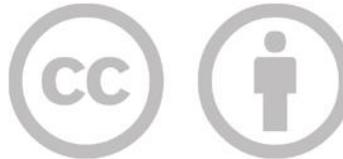
1 GtC = 3.664 billion tonnes CO₂ = 3.664 GtCO₂

(Figures in units of GtC and GtCO₂ are available from <http://globalcarbonbudget.org/carbonbudget>)

Most figures in this presentation are available for download as PNG, PDF and SVG files
from tinyurl.com/GCB21figs along with the data required to produce them.

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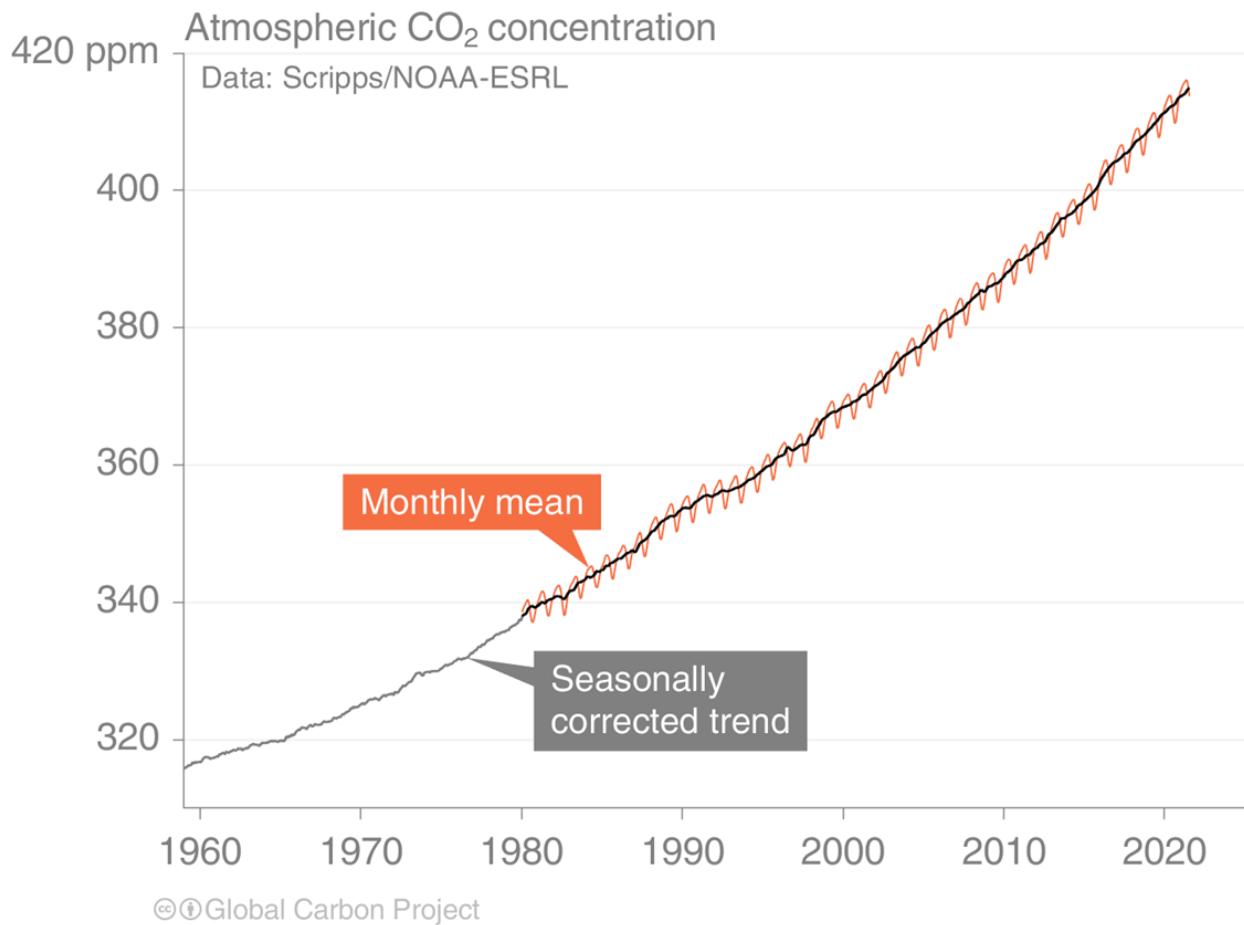
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Atmospheric CO₂ concentration

The global CO₂ concentration increased from ~277 ppm in 1750 to 415 ppm in 2021 (up 49%)

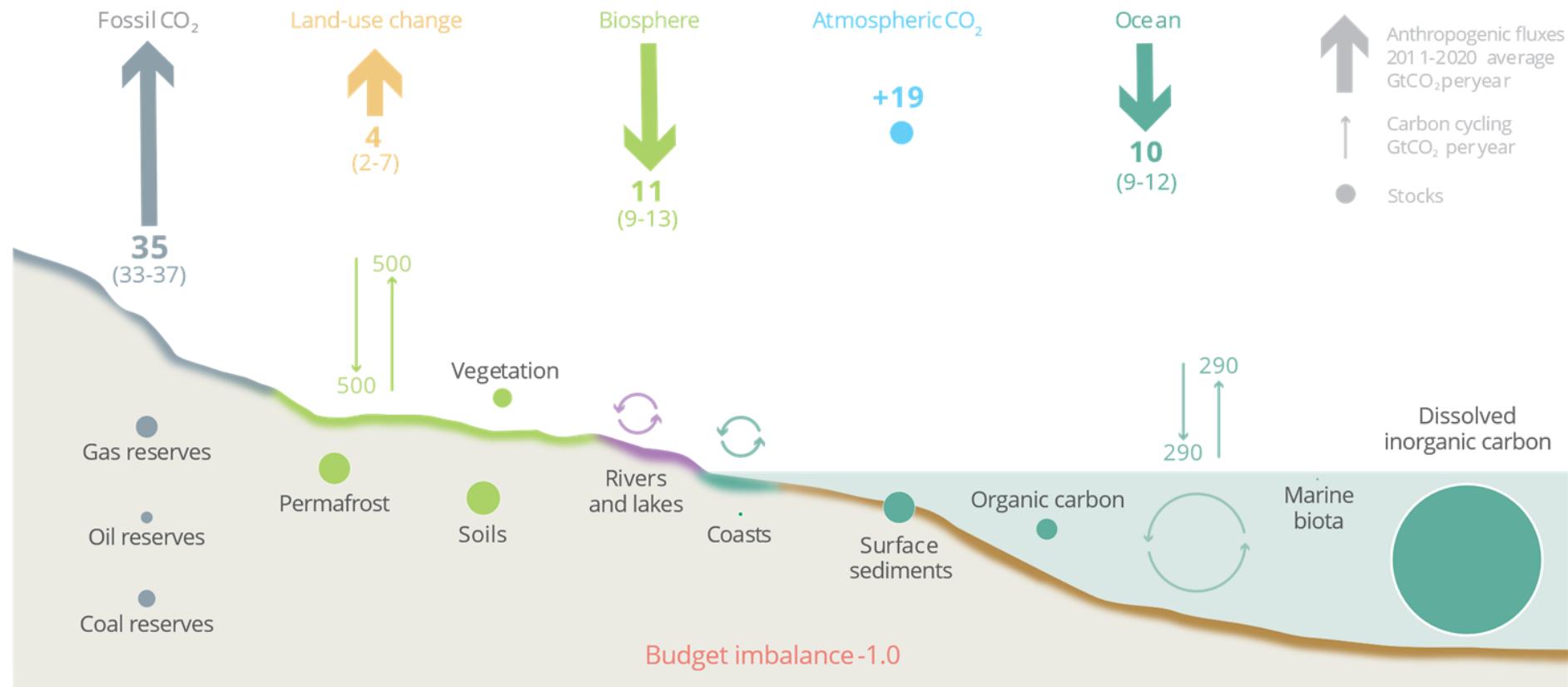


Globally averaged surface atmospheric CO₂ concentration. Data from: NOAA-ESRL after 1980;
the Scripps Institution of Oceanography before 1980

Source: [NOAA-ESRL](#); [Scripps Institution of Oceanography](#); [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Anthropogenic perturbation of the global carbon cycle

Perturbation of the global carbon cycle caused by anthropogenic activities,
global annual average for the decade 2011–2020 (GtCO₂/yr)



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

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

Key Highlights in 2021

Summary of fossil CO₂ emissions in 2020 and 2021

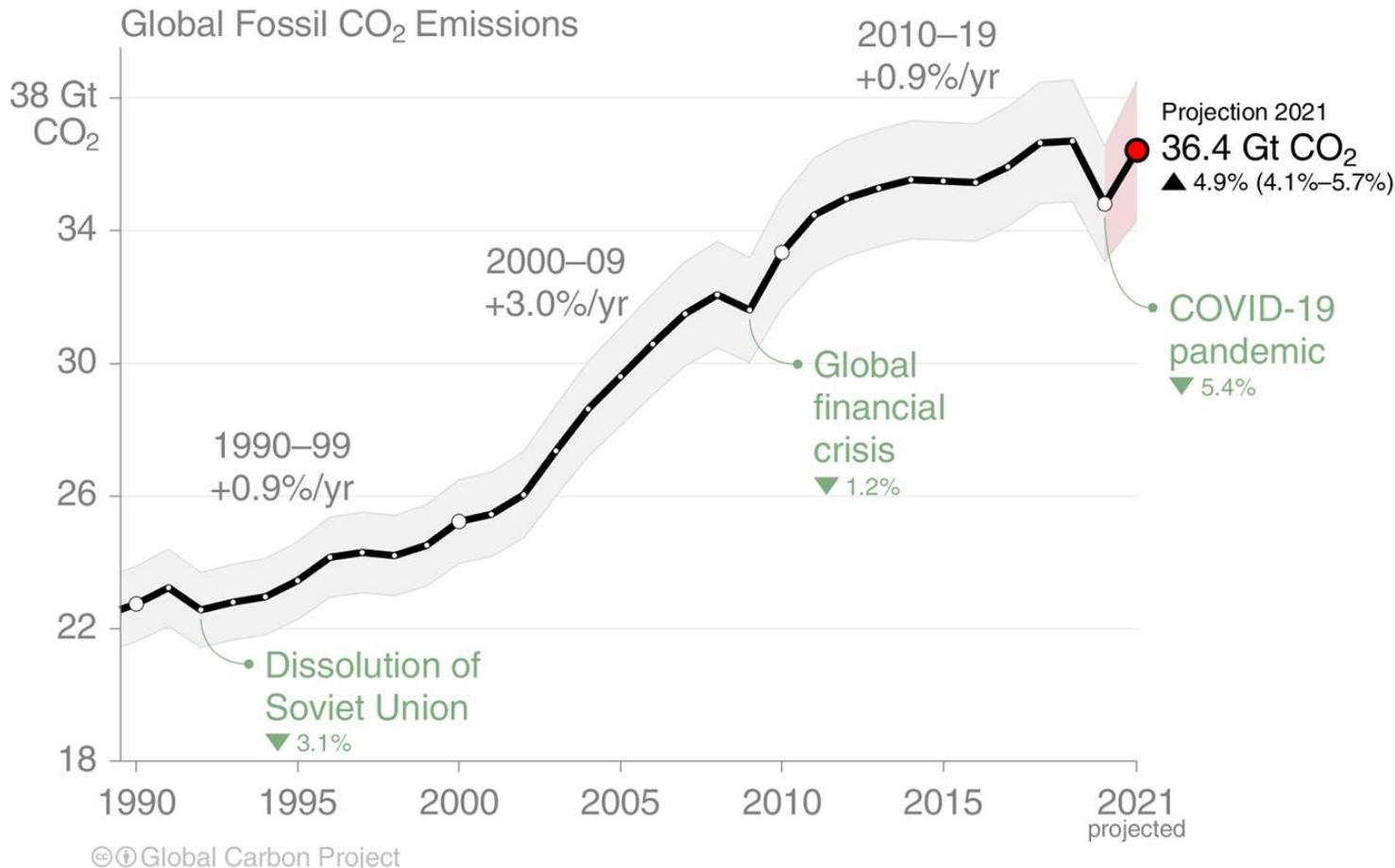
Region / Country	2020 emissions (billion tonnes/yr)	2020 growth (percent)	2021 projected emissions growth (percent)	2021 projected emissions (billion tonnes/yr)
China	10.7	1.4%	4.0%	11.1
USA	4.7	-10.6%	7.6%	5.1
EU27	2.6	-10.9%	7.6%	2.8
India	2.4	-7.3%	12.6%	2.7
All others (incl. IAS*)	14.4	-7.0%	2.9%	14.8
World (incl. IAS*)	34.8	-5.4%	4.9%	36.4

*IAS: Emissions from use of international aviation and maritime shipping bunker fuels are not usually included in national totals

Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Global Fossil CO₂ Emissions

Global fossil CO₂ emissions: 34.8 ± 2 GtCO₂ in 2020, 53% over 1990
● Projection for 2021: 36.4 ± 2 GtCO₂, 4.9% [4.1%–5.7%] higher than 2020

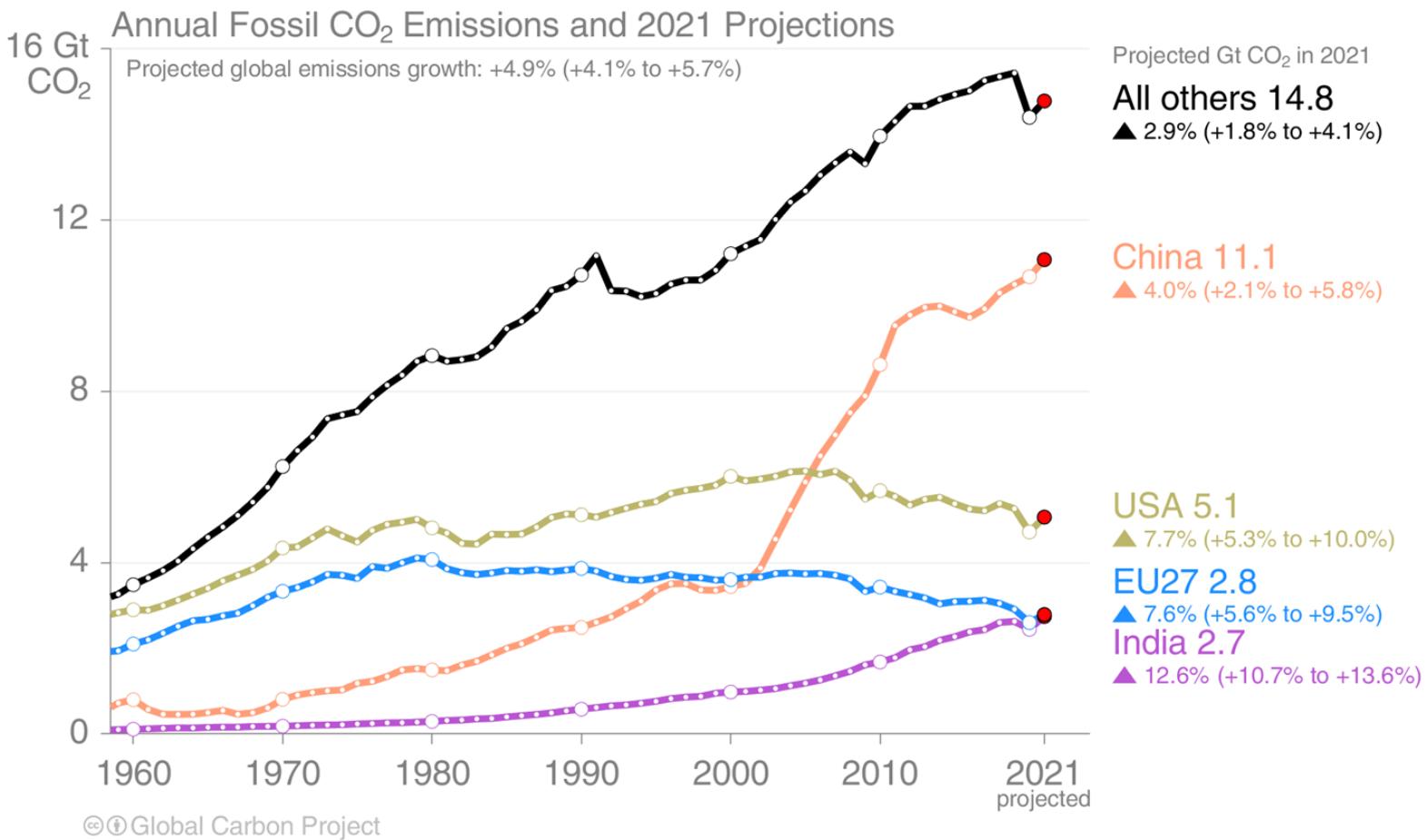


Uncertainty is $\pm 5\%$ for one standard deviation (IPCC “likely” range)

The 2021 projection is based on preliminary data and modelling.
Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Emissions Projections for 2021

Global fossil CO₂ emissions are projected to increase by 4.9% [4.1%–5.7%] in 2021



The 2021 projections are based on preliminary data and modelling.

Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Fossil CO₂ emissions growth: 2019–2021

Emissions are expected to increase in most countries in 2021, with the largest increase in China, USA, and India

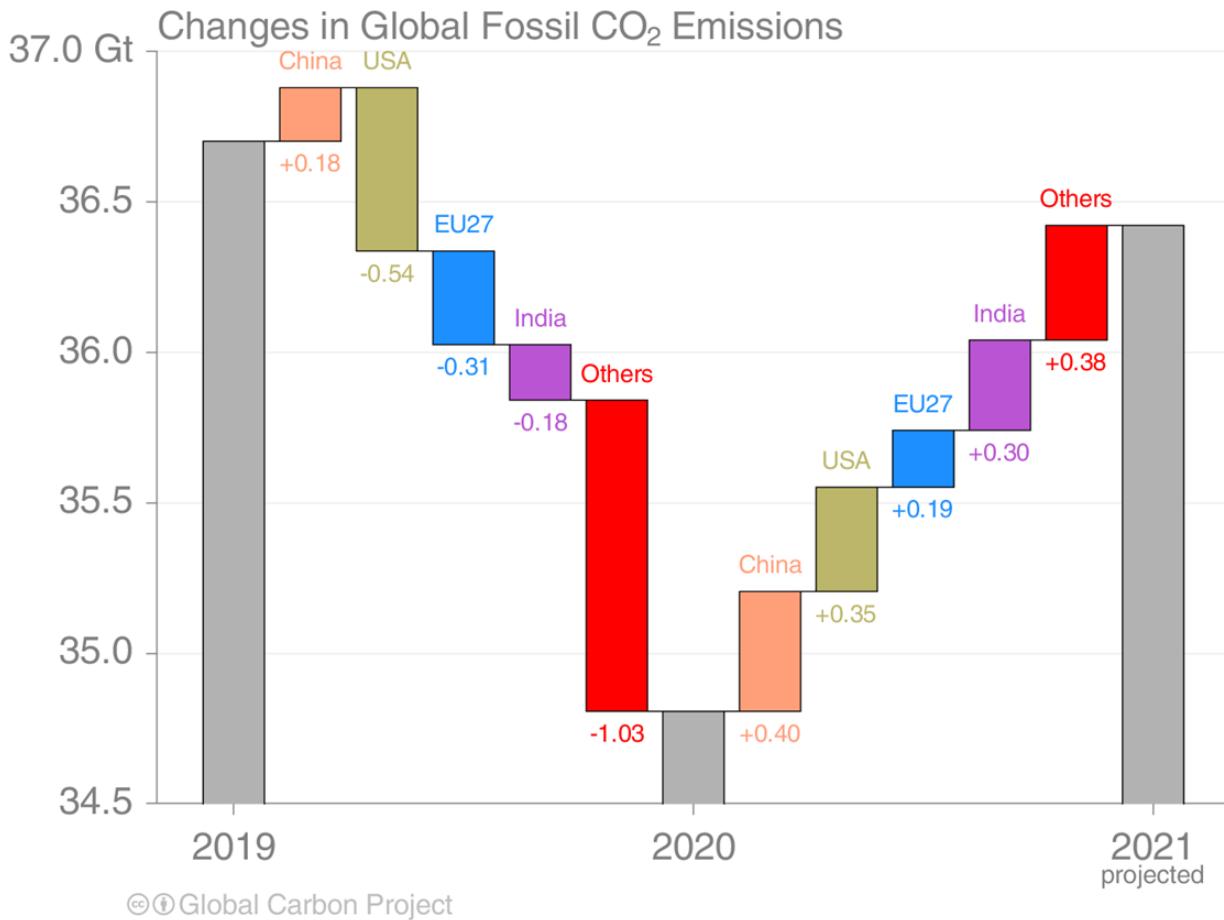
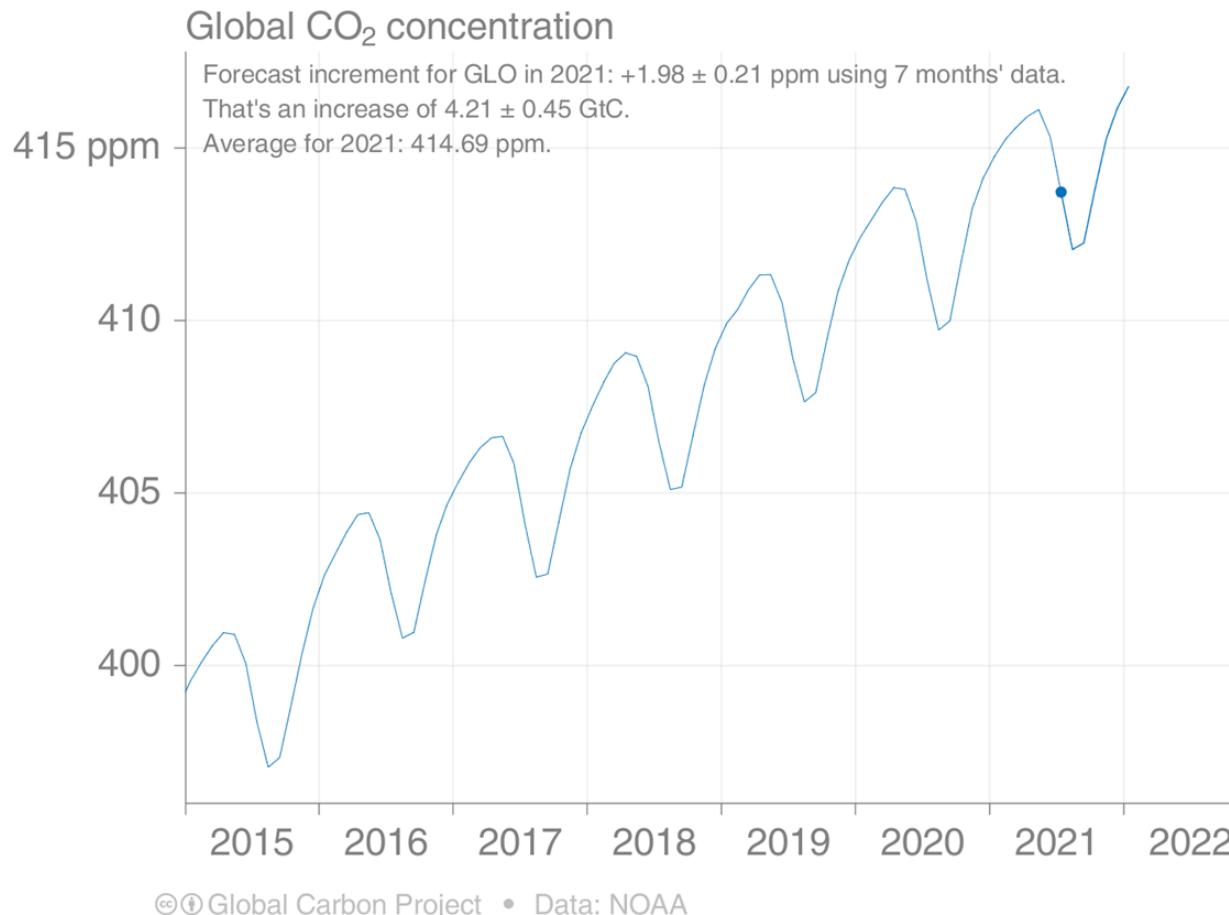


Figure shows the top four countries contributing to emissions changes
Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

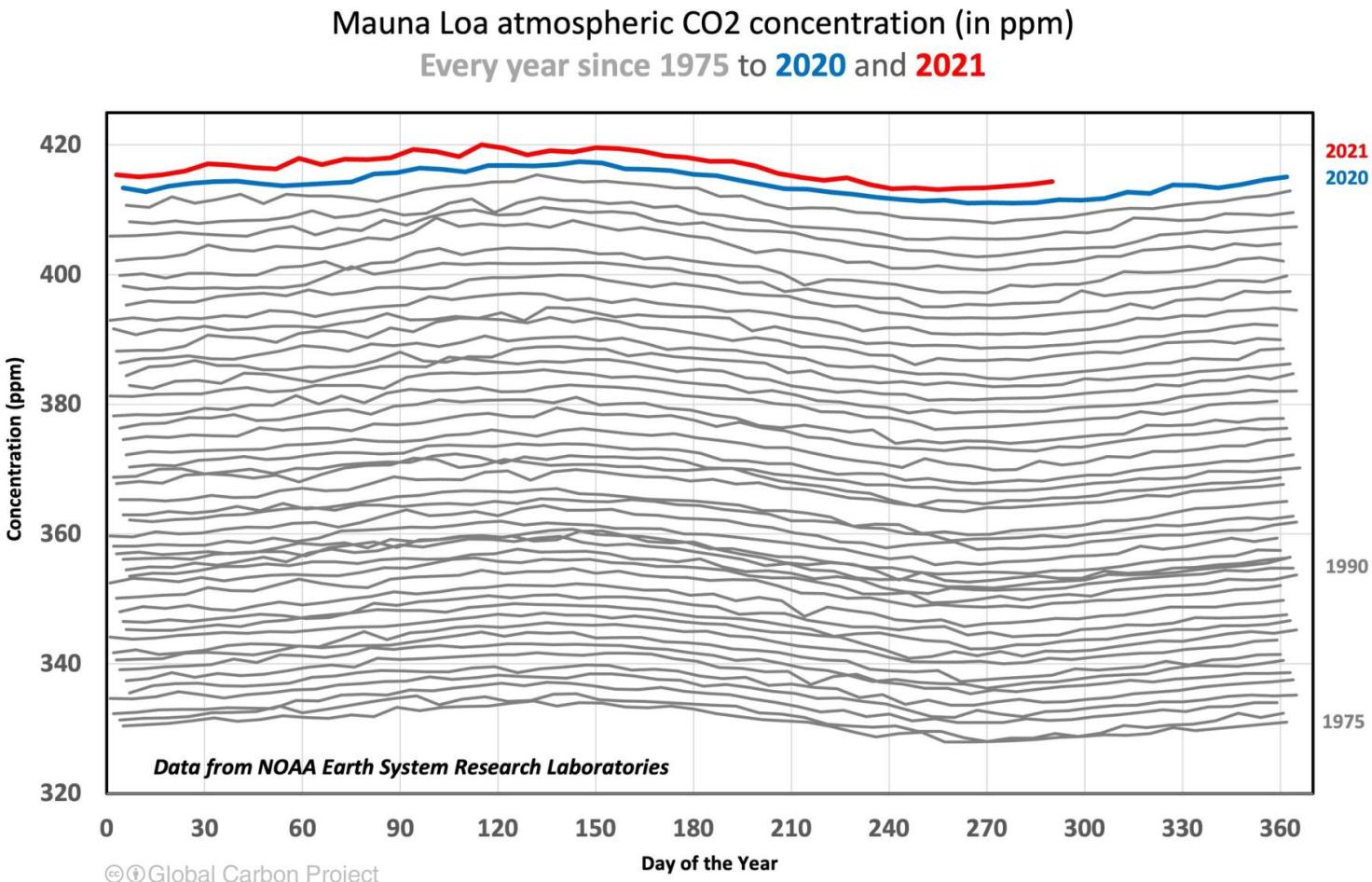
Forecast of global atmospheric CO₂ concentration

The global atmospheric CO₂ concentration is forecast to average 415 parts per million (ppm) in 2021, increasing by 2.0 ppm



Mauna Loa atmospheric CO₂

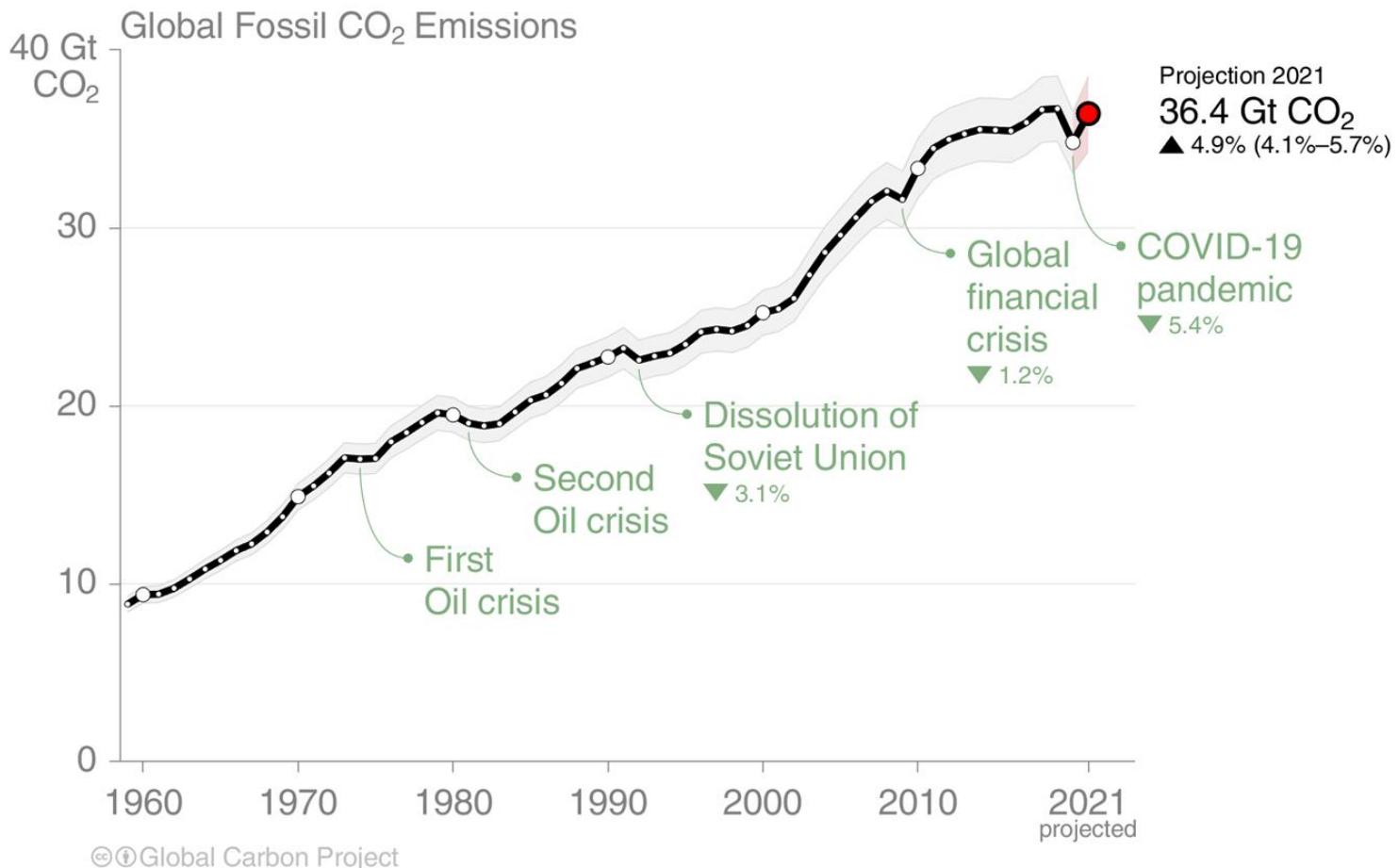
Atmospheric CO₂ concentration increased every single year, including in 2020, despite the drop in fossil fuel emissions, because of continued emissions



Fossil CO₂ Emissions by country

Global Fossil CO₂ Emissions

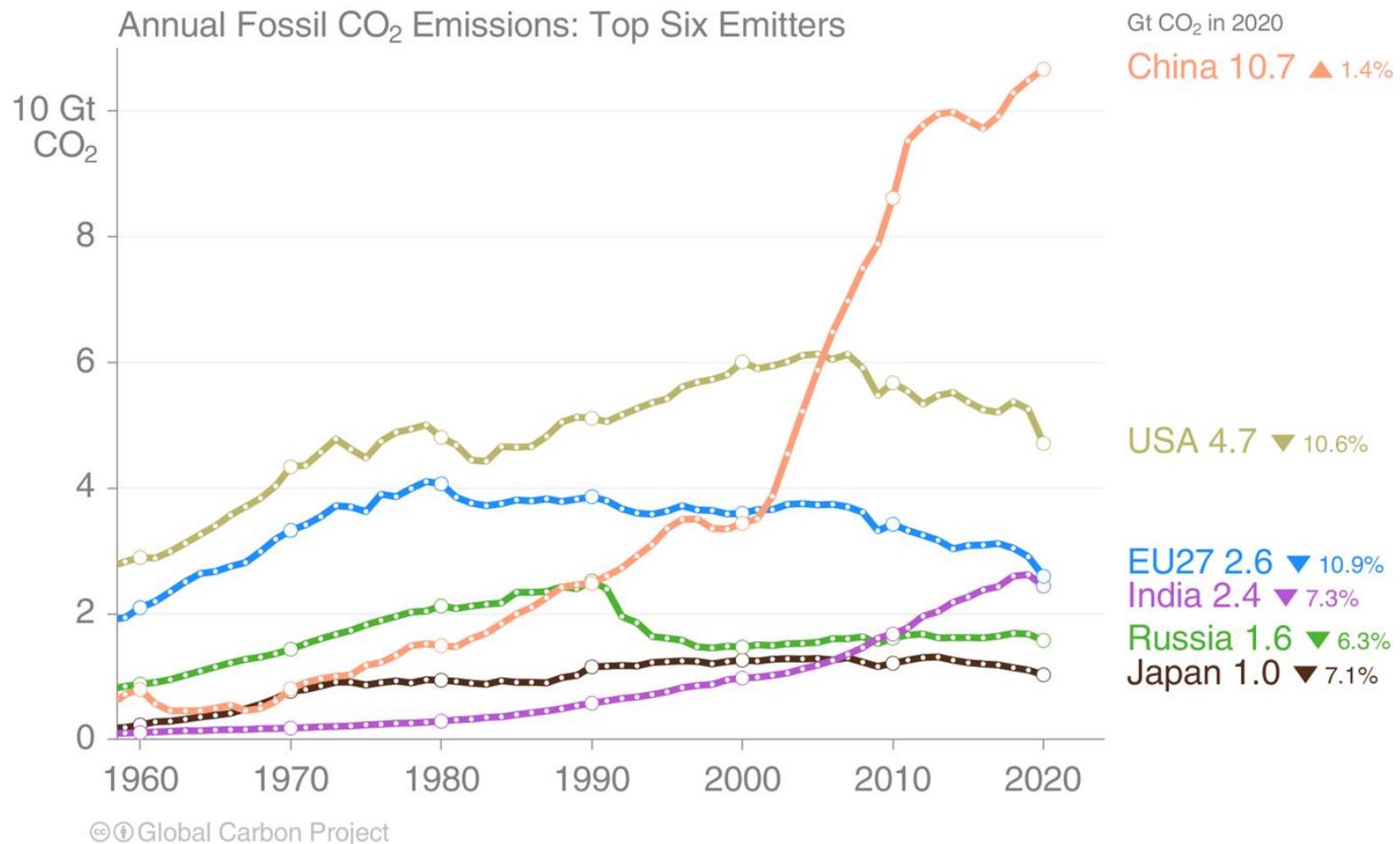
Global fossil CO₂ emissions have risen steadily over the last decades.
Emissions in 2021 are set to rebound towards their pre-COVID-19 levels after an unprecedented drop in 2020.



The 2021 projection is based on preliminary data and modelling.
Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Top emitters: Fossil CO₂ Emissions to 2020

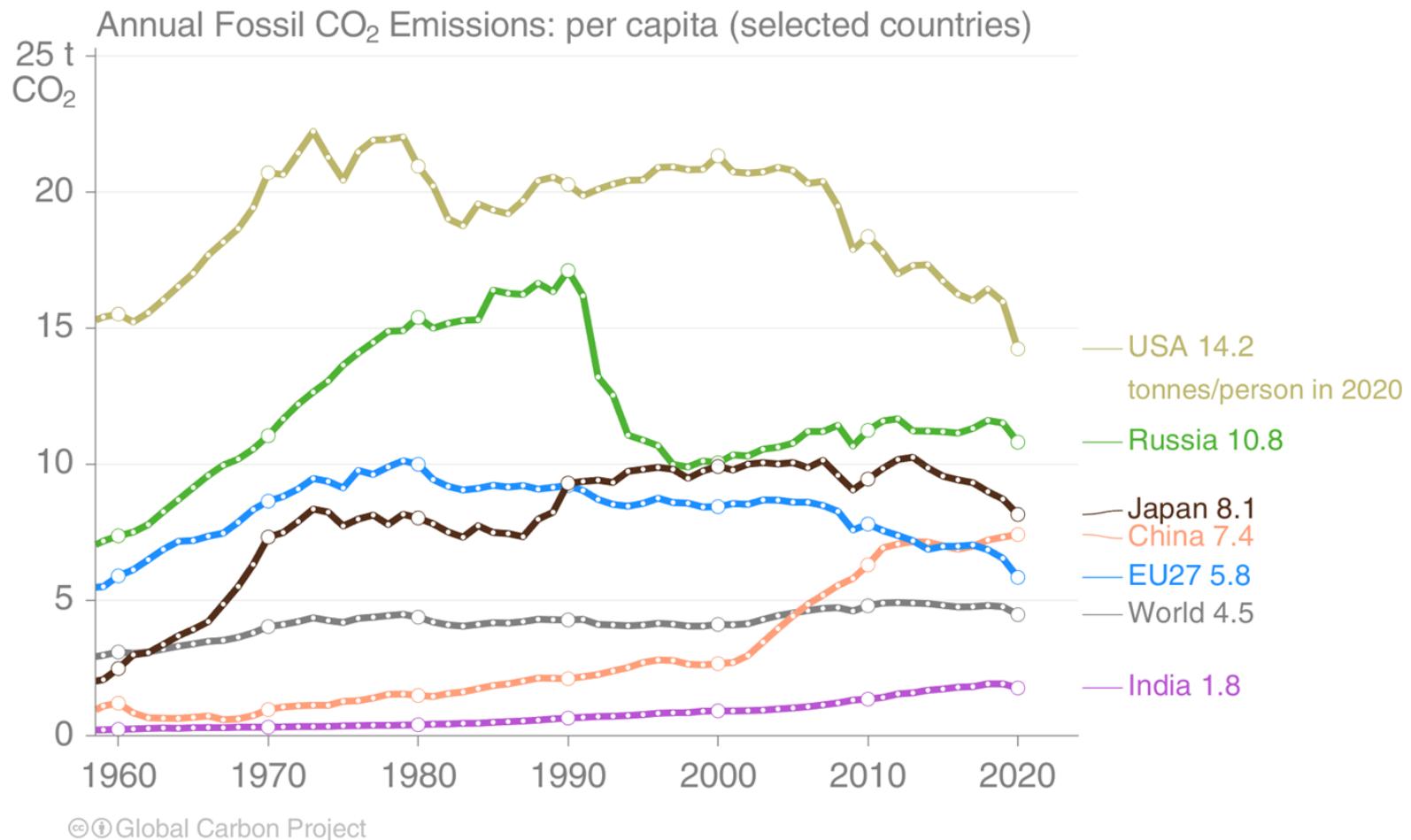
The top six emitters in 2020 covered 66% of global emissions
 China 31%, United States 14%, EU27 7%, India 7%, Russia 5%, and Japan 3%



International aviation and maritime shipping (bunker fuels) contributed 2.9% of global emissions in 2020.
 Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

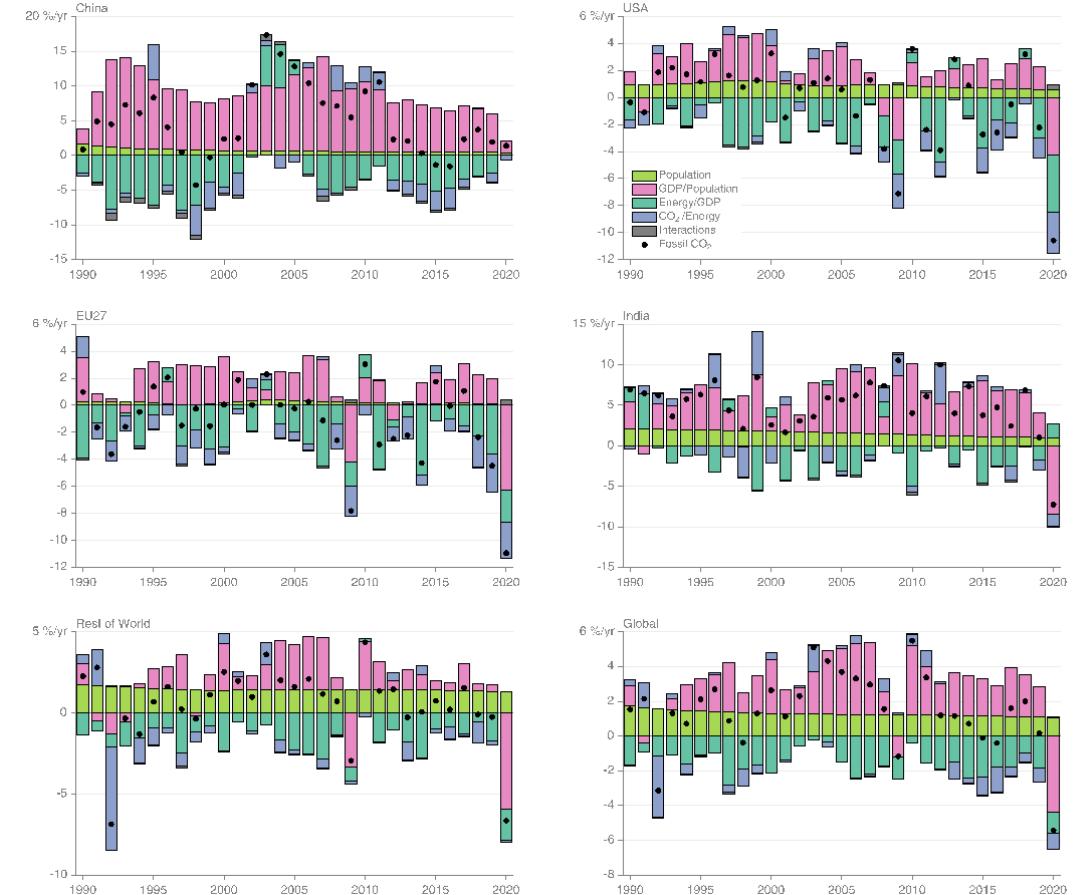
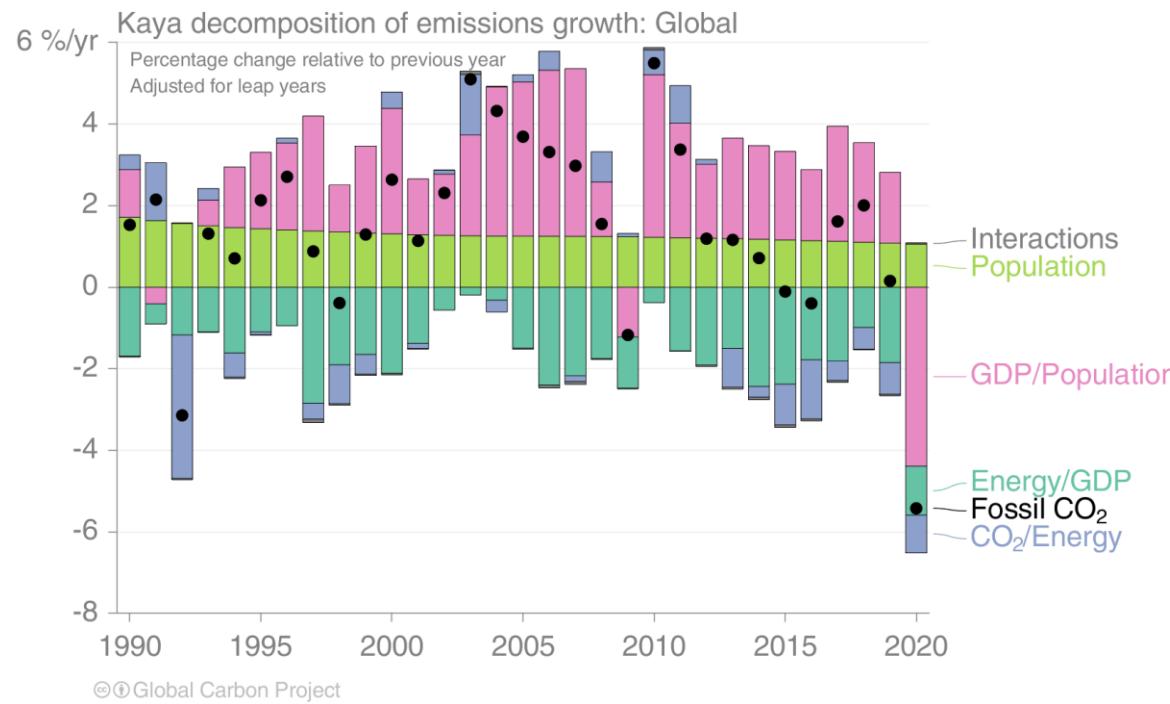
Top emitters: Fossil CO₂ Emissions per capita to 2020

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



Fossil Fuel 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 is a clear outlier with a severe decline in GDP.



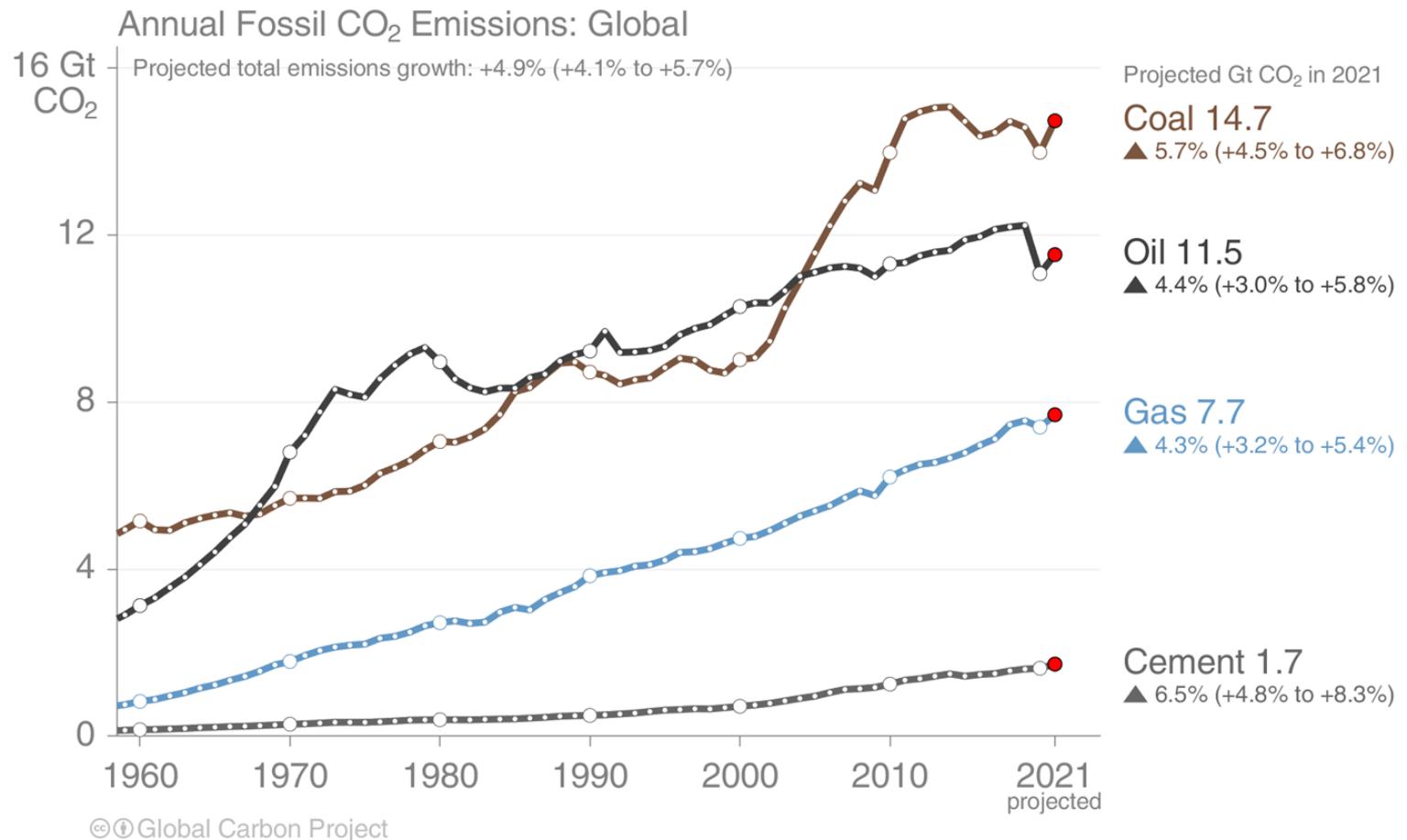
Key statistics for emissions in 2020

Region/Country	Emissions 2020				
	Per capita tCO ₂ per person	Total GtCO ₂	Total %	Growth 2019–20 GtCO ₂	Growth 2019–20 %
Global (including bunkers)	4.5	34.81	100	-1.895	-5.4
OECD Countries					
OECD	8.4	11.05	31.7	-1.185	-9.9
USA	14.2	4.71	13.5	-0.543	-10.6
OECD Europe	5.8	2.86	8.2	-0.347	-11.1
Japan	8.1	1.03	3.0	-0.075	-7.1
South Korea	11.7	0.60	1.7	-0.050	-8.0
Canada	14.2	0.54	1.5	-0.047	-8.2
Non-OECD Countries					
Non-OECD	3.5	22.76	65.4	-0.457	-2.2
China	7.4	10.67	30.6	0.178	1.4
India	1.8	2.44	7.0	-0.184	-7.3
Russia	10.8	1.58	4.5	-0.102	-6.3
Iran	8.9	0.75	2.1	0.012	1.3
Indonesia	18.0	0.63	1.8	0.003	0.2
International Bunkers					
Bunkers	-	1.00	2.9	-0.254	-20.2

Fossil CO₂ Emissions by source

Fossil CO₂ Emissions by source

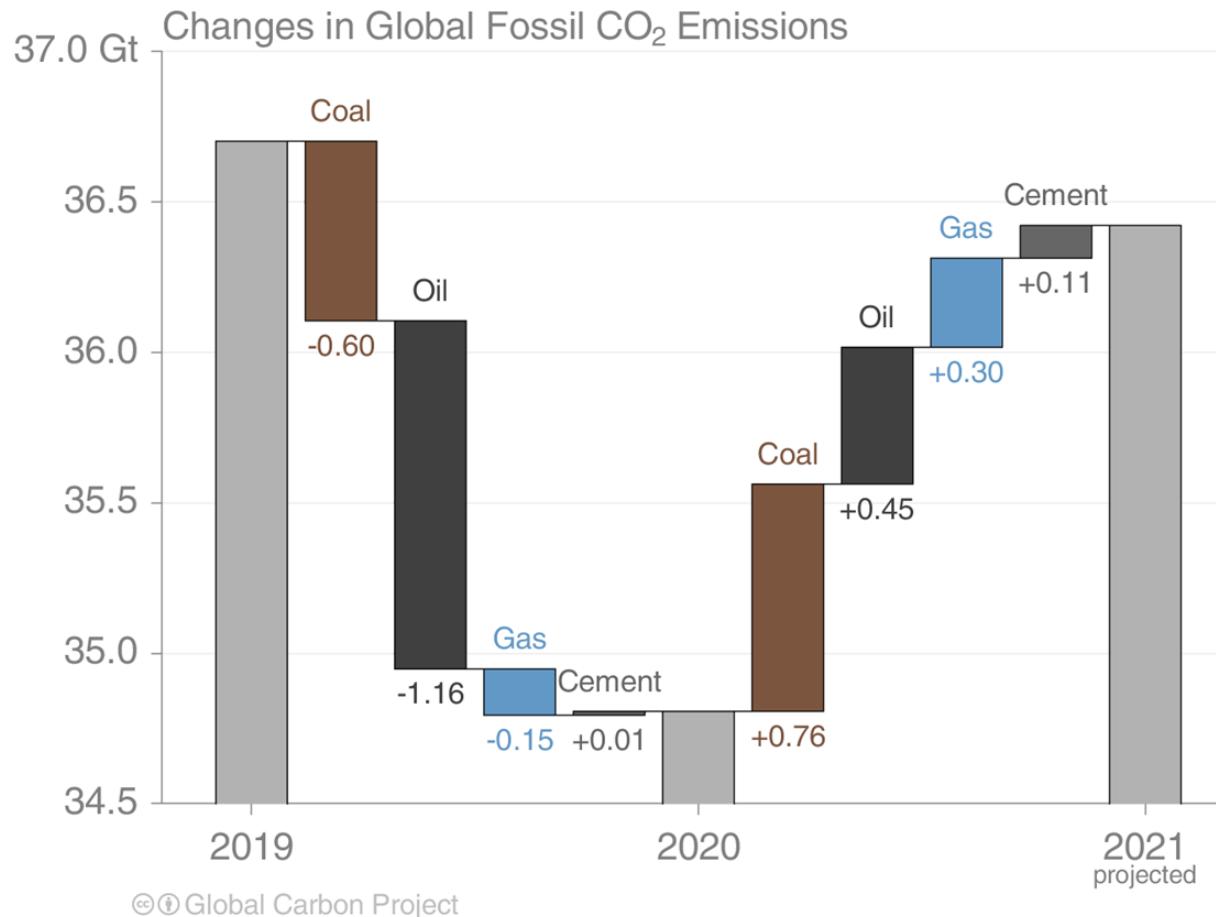
Share of global fossil CO₂ emissions in 2020: coal (40%), oil (32%), gas (21%), cement (5%), flaring and others (2%, not shown)
 Projection by fuel type is based on monthly data (GCP analysis)



Fossil CO₂ emissions growth: 2019–2021

Global emissions in 2020 dropped across all categories.

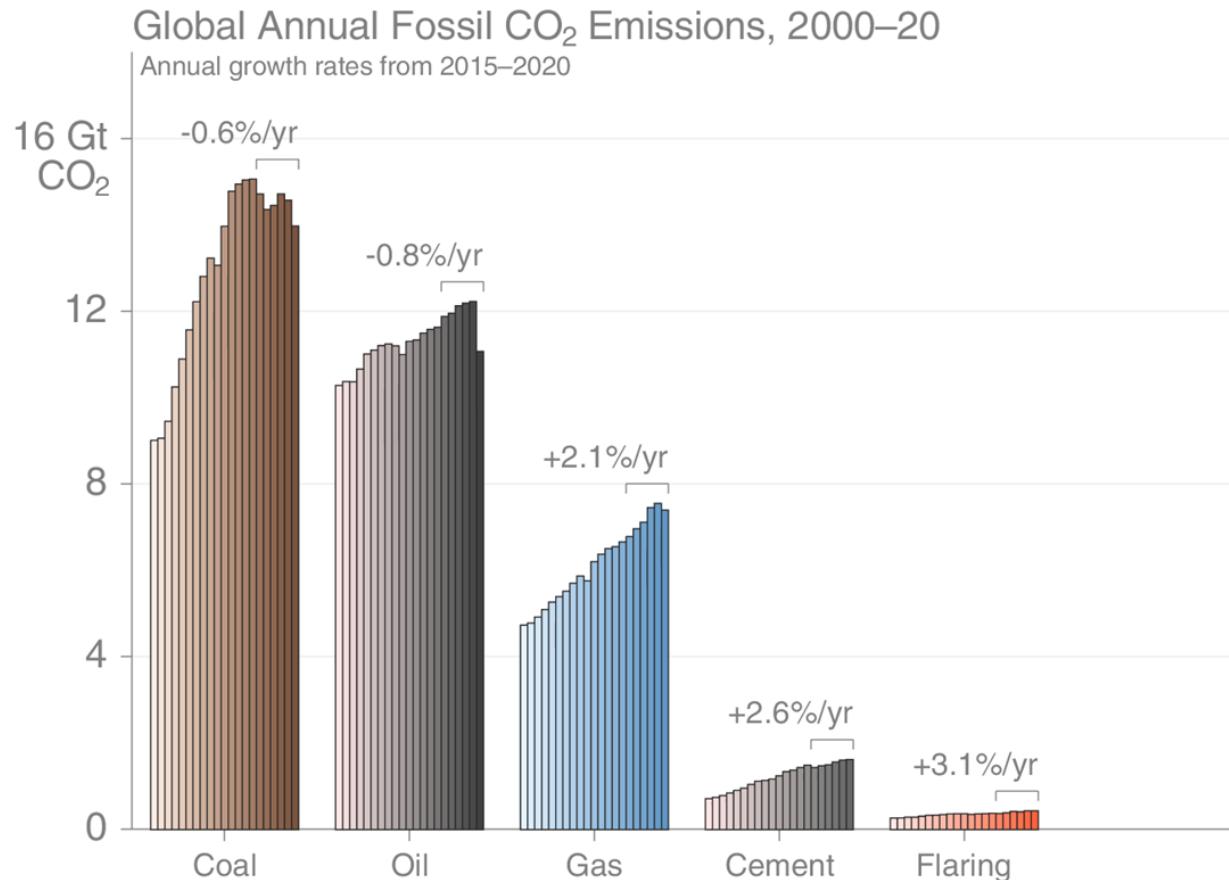
In 2021 coal and natural gas have more than recovered this loss, while oil still lags with from subdued transportation.



Fossil CO₂ Emissions by source

Emissions by category from 2000 to 2020, with growth rates indicated for the more recent period of 2015 to 2020

Coal use has declined since 2014, and both coal and oil declined sharply in the pandemic year 2020



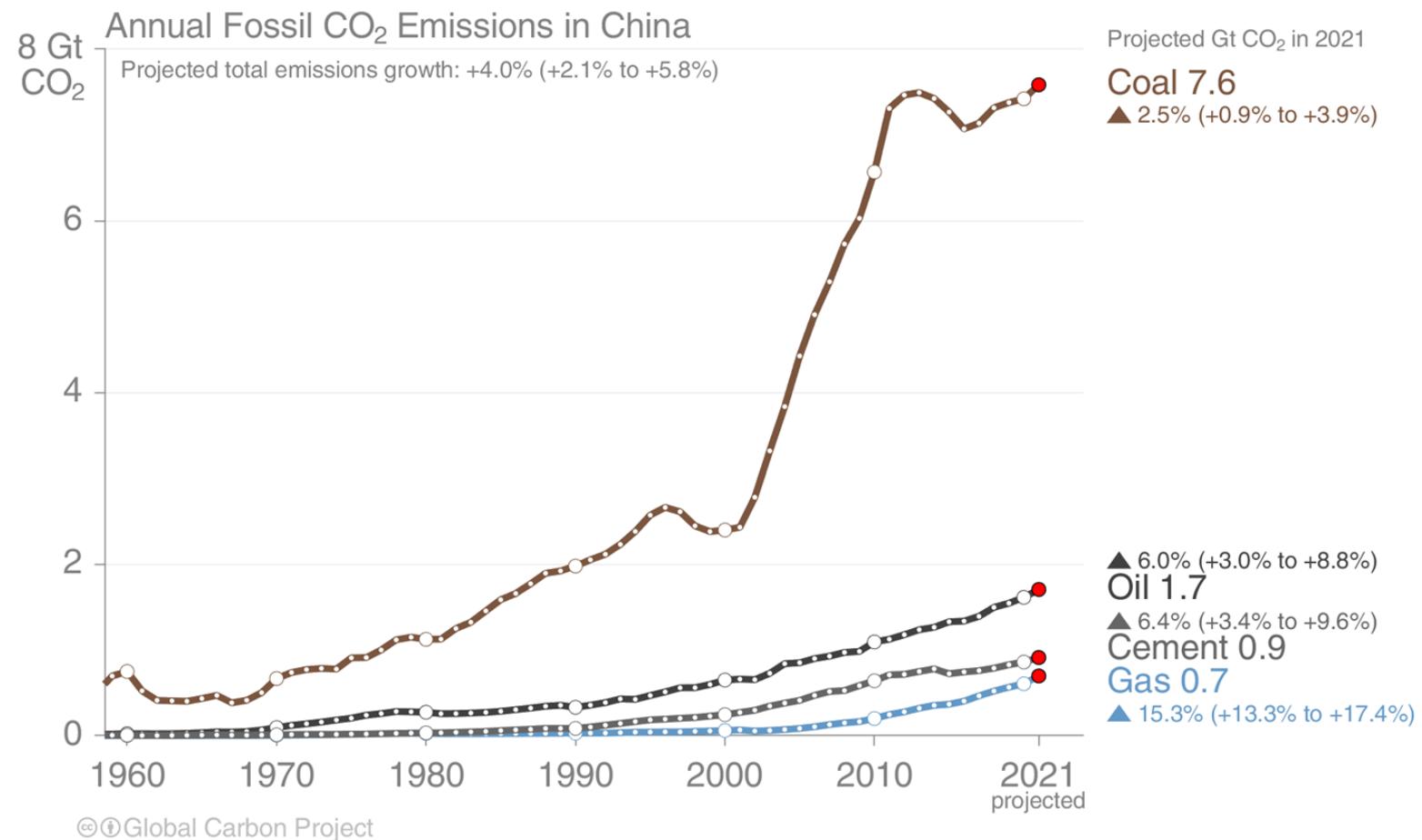
© Global Carbon Project

Source: [CDIAC](#); [Global Carbon Project 2021](#)

Fossil CO₂ Emission by source for top emitters

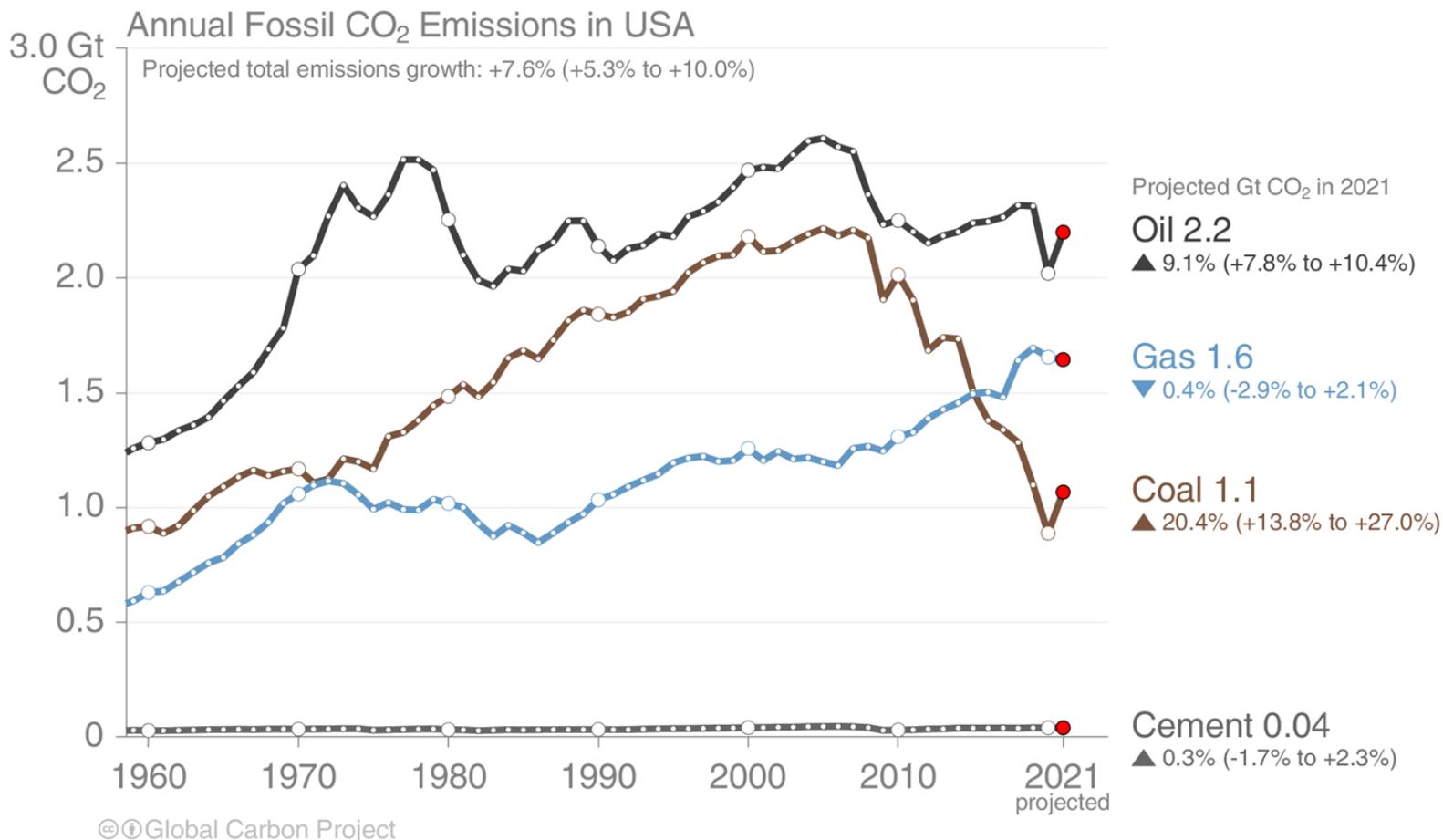
Fossil CO₂ Emissions in China

Annual emissions in China are expected to reach another record high in 2021, with substantial industrial growth



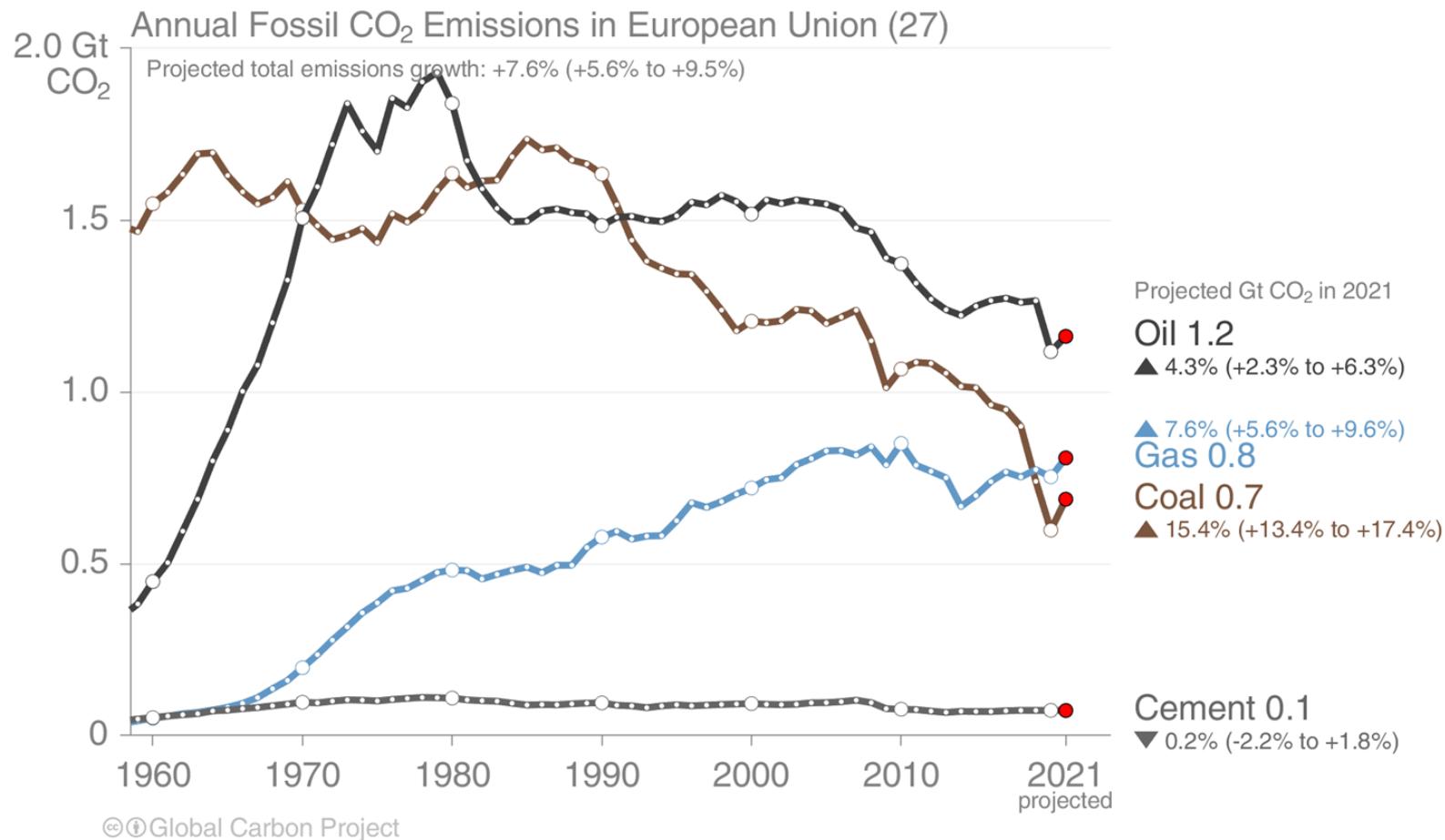
Fossil CO₂ Emissions in USA

The USA's emissions from coal are expected to bounce back in 2021, partly as a result of supply constraints on natural gas.
 Emissions from oil do not return to 2019's level.



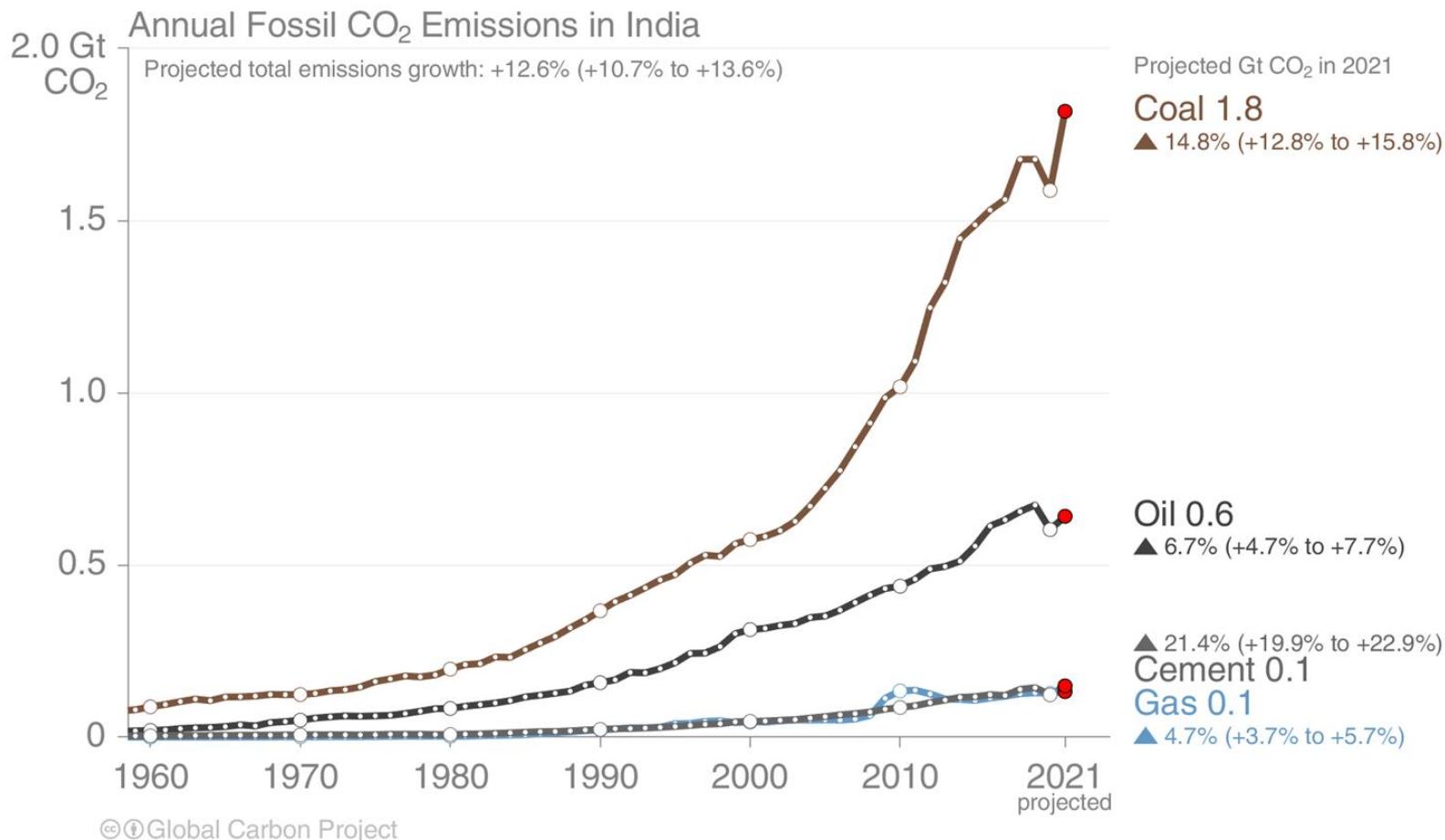
Fossil CO₂ Emissions in the European Union

In the first half of 2021 EU coal power generation was strong due partly to very low generation from wind power, but the 2021 total is expected to remain below 2019's level and continue to decline.



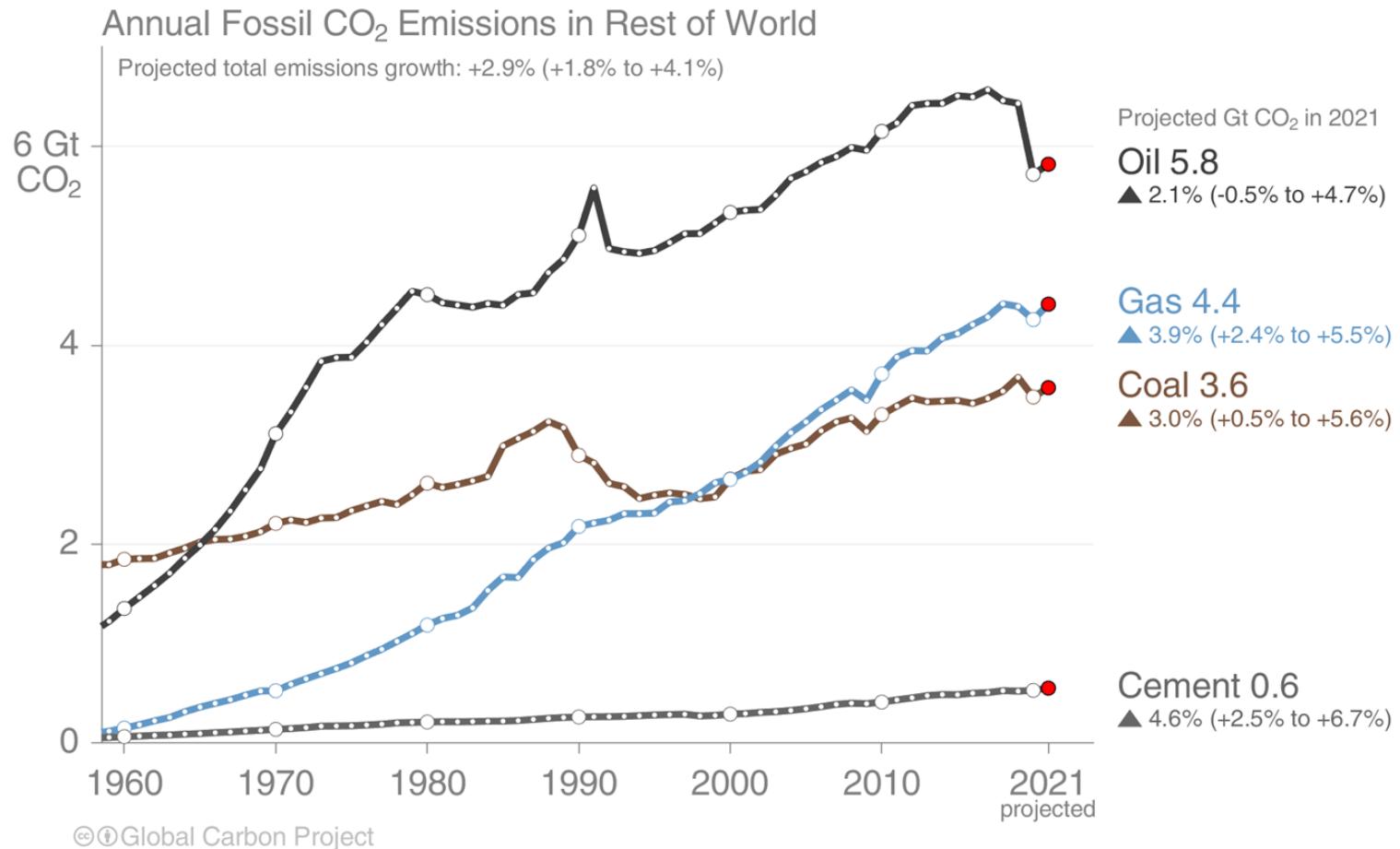
Fossil CO₂ Emissions in India

India's emissions are expected to jump sharply in 2021, returning to a strongly growing trend driven largely by use of coal in power generation.



Fossil CO₂ Emissions in Rest of World

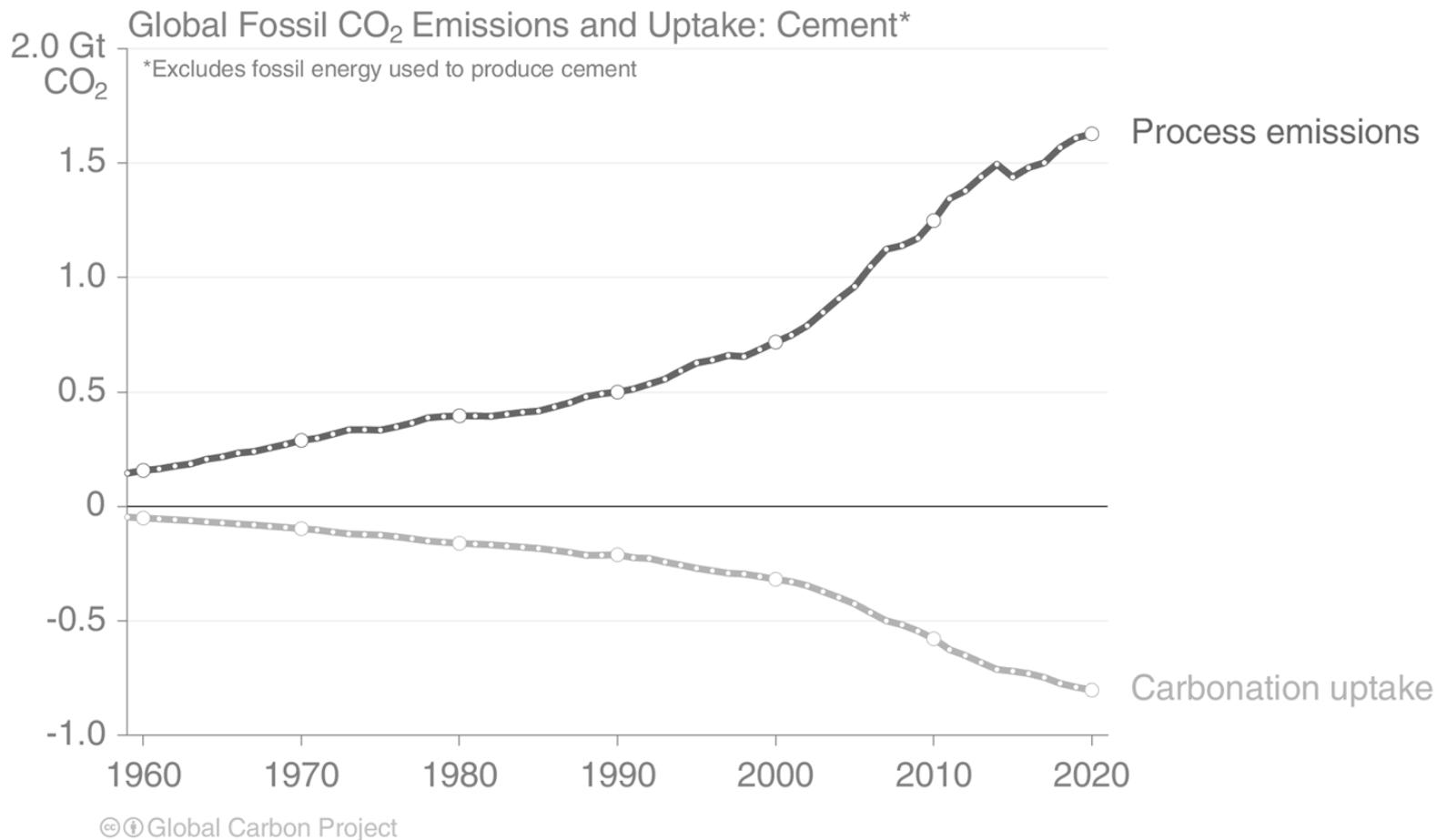
In the Rest of the World, emissions from coal and natural gas are expected to recover most of their losses in 2020. Oil, which here includes international shipping transport, remains subdued.



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 2021](#); [Global Carbon Project 2021](#)

Cement carbonation sink

The production of cement results in ‘process’ emissions of CO₂ from the chemical reaction
During its lifetime, cement slowly absorbs CO₂ from the atmosphere

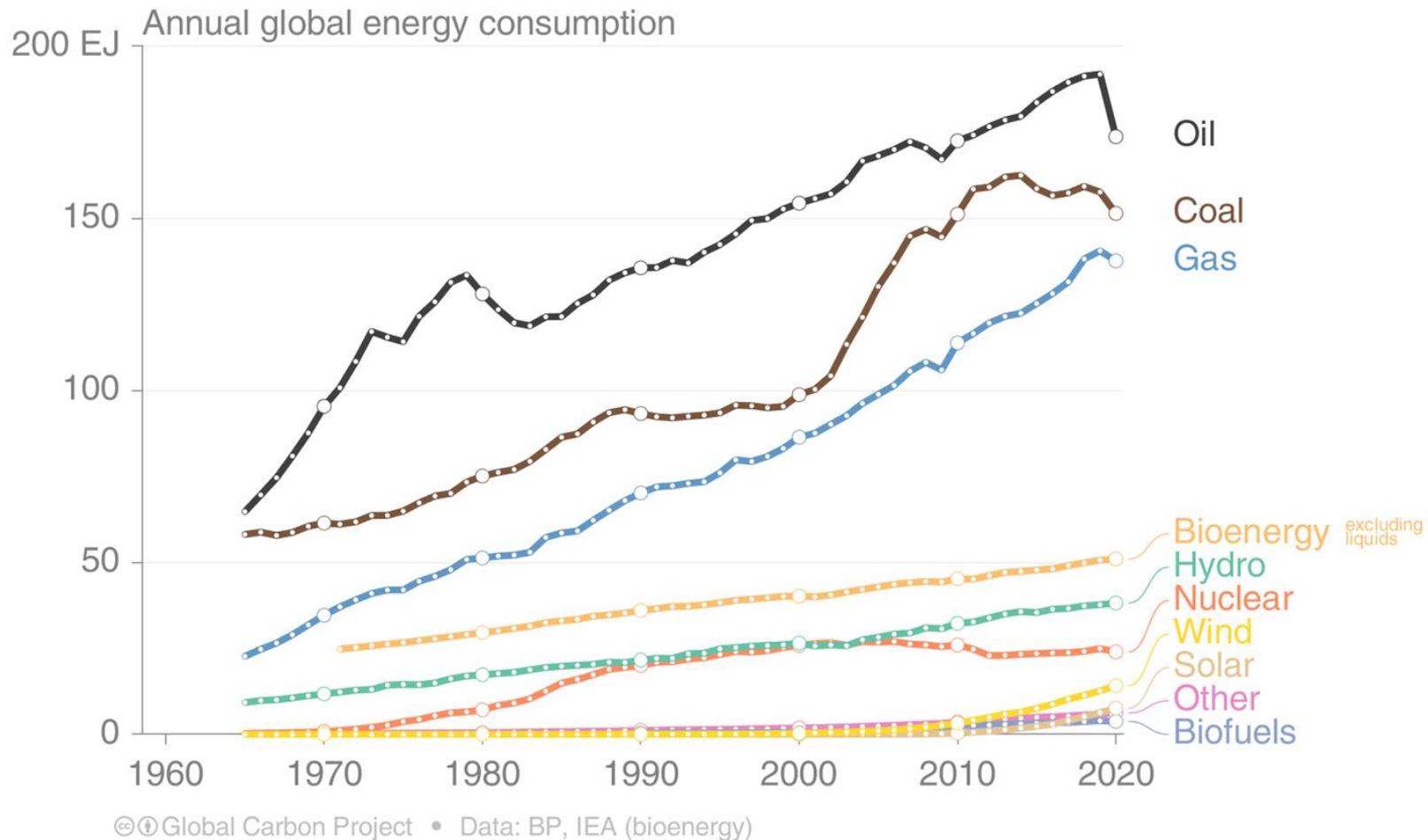


Energy use by source

Energy use by source

Consumption of energy from fossil sources declined in 2020.

Renewable energy continued to grow, but needs to grow even faster to replace fossil energy consumption.

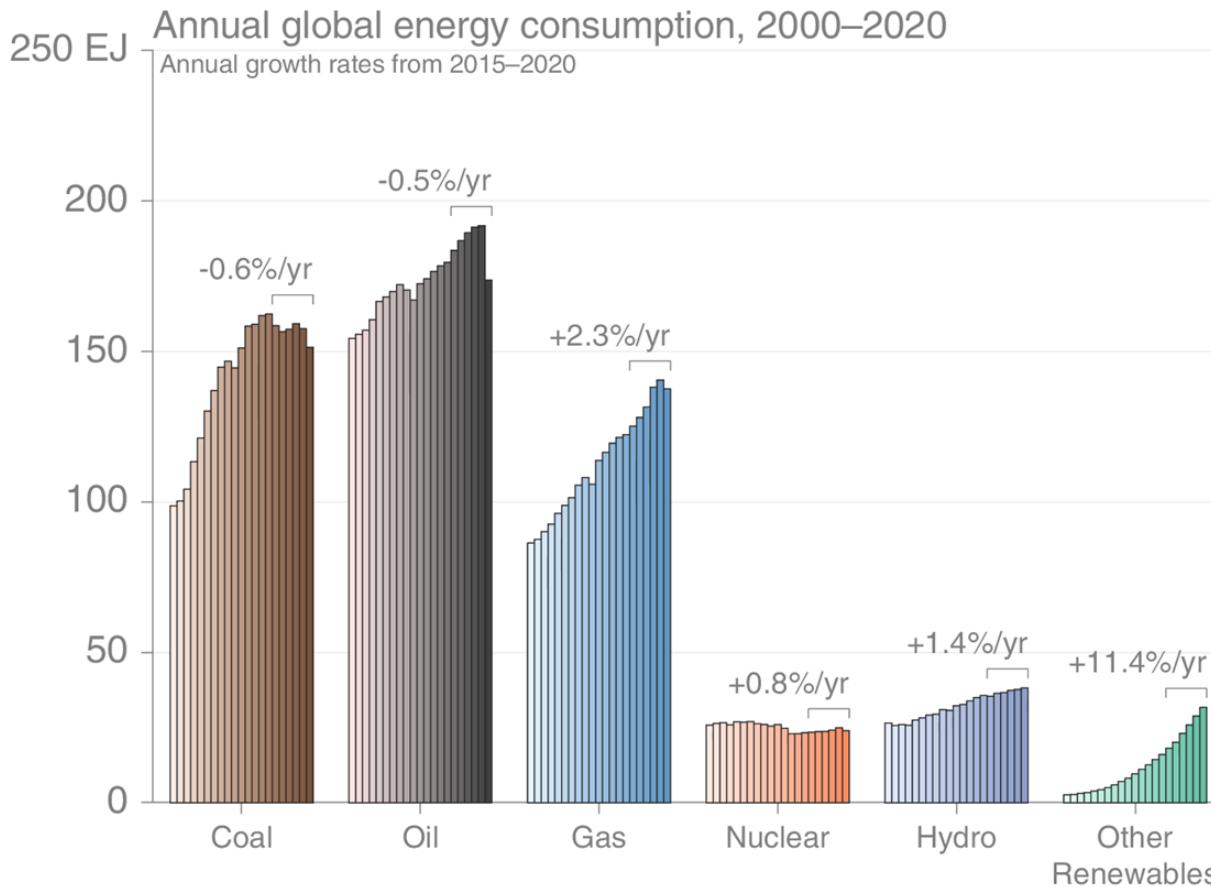


This figure shows “primary energy” using the BP substitution method
(non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)

Source: [BP 2021](#); [Global Carbon Project 2021](#)

Energy use by source

Energy consumption by fuel source from 2000 to 2020, with growth rates indicated for the more recent period of 2015 to 2020



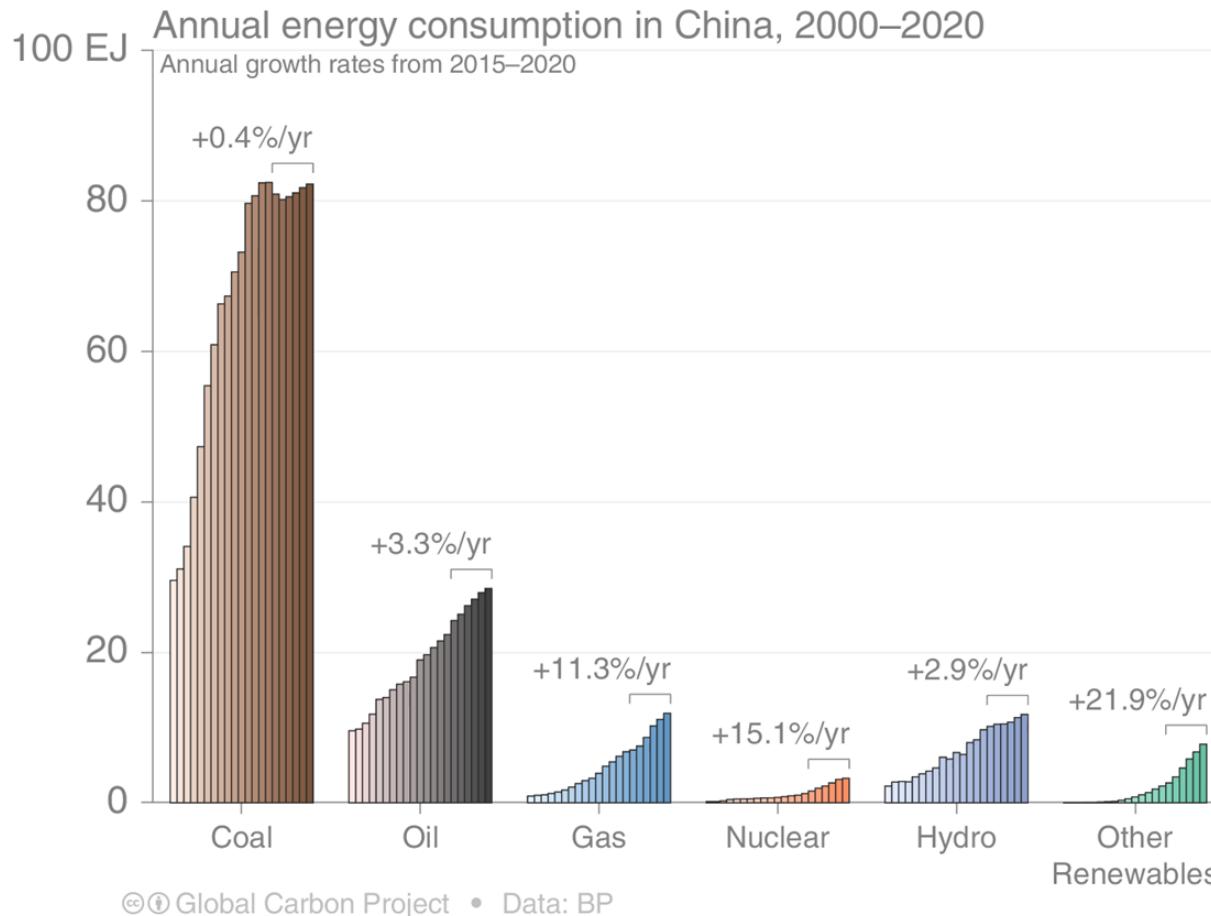
CC BY Global Carbon Project • Data: BP

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 2020](#); [Global Carbon Project 2021](#)

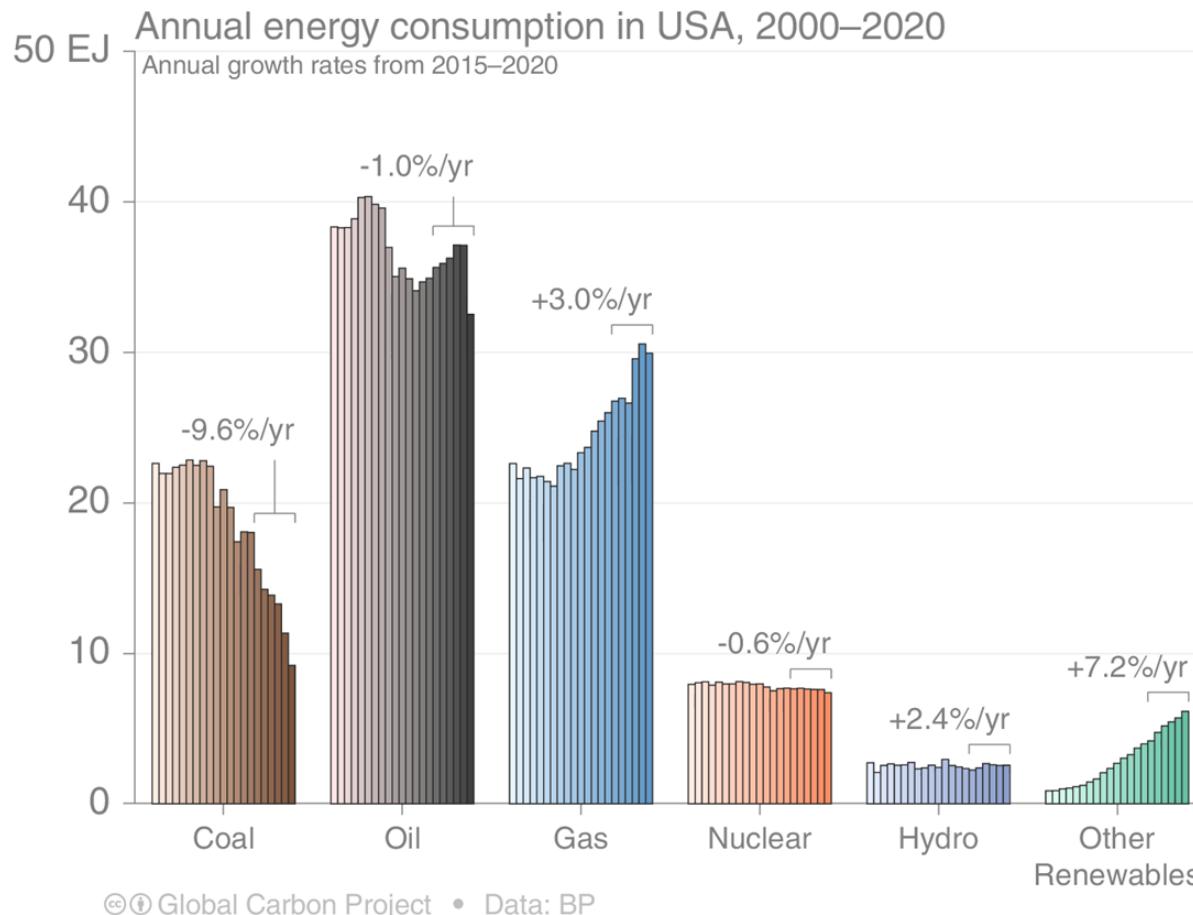
Energy use in China

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



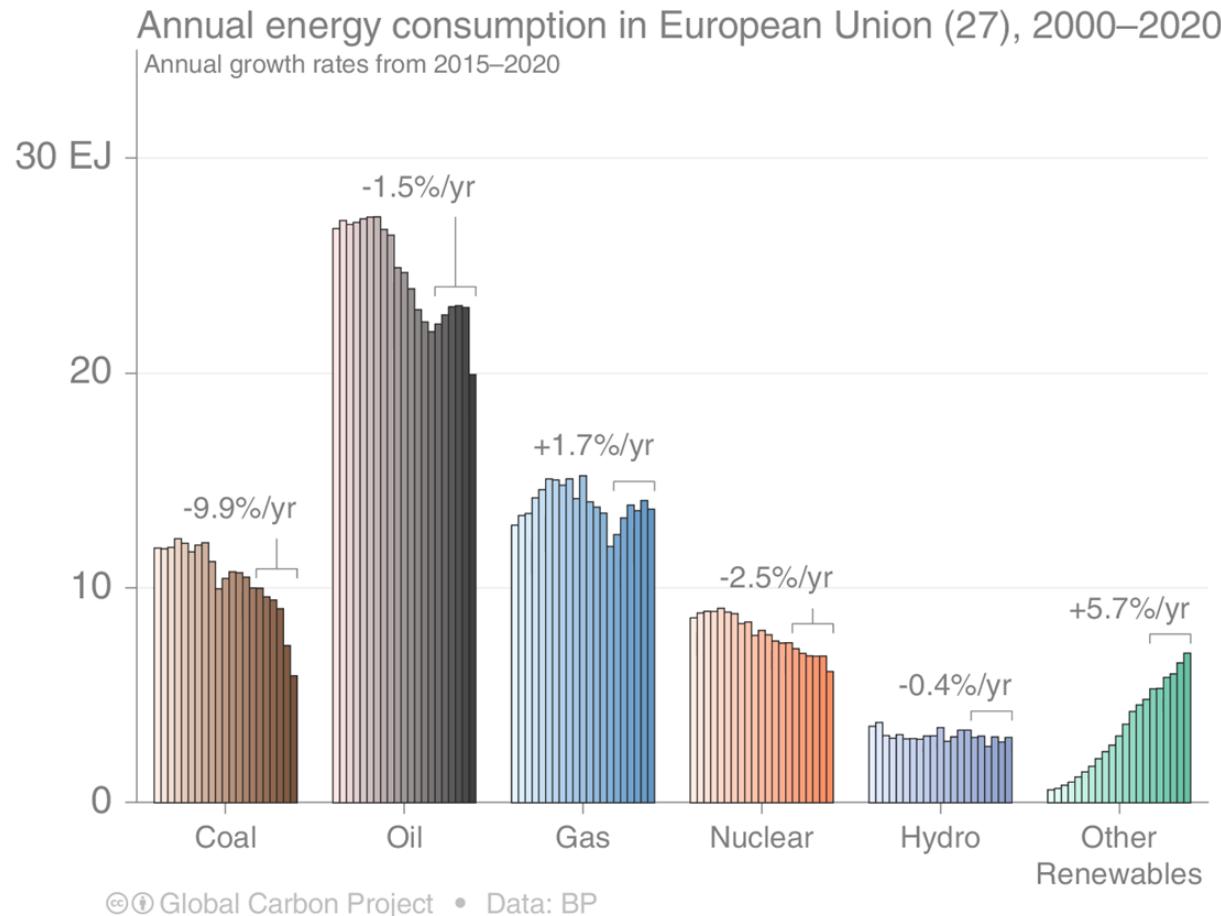
Energy use in USA

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.



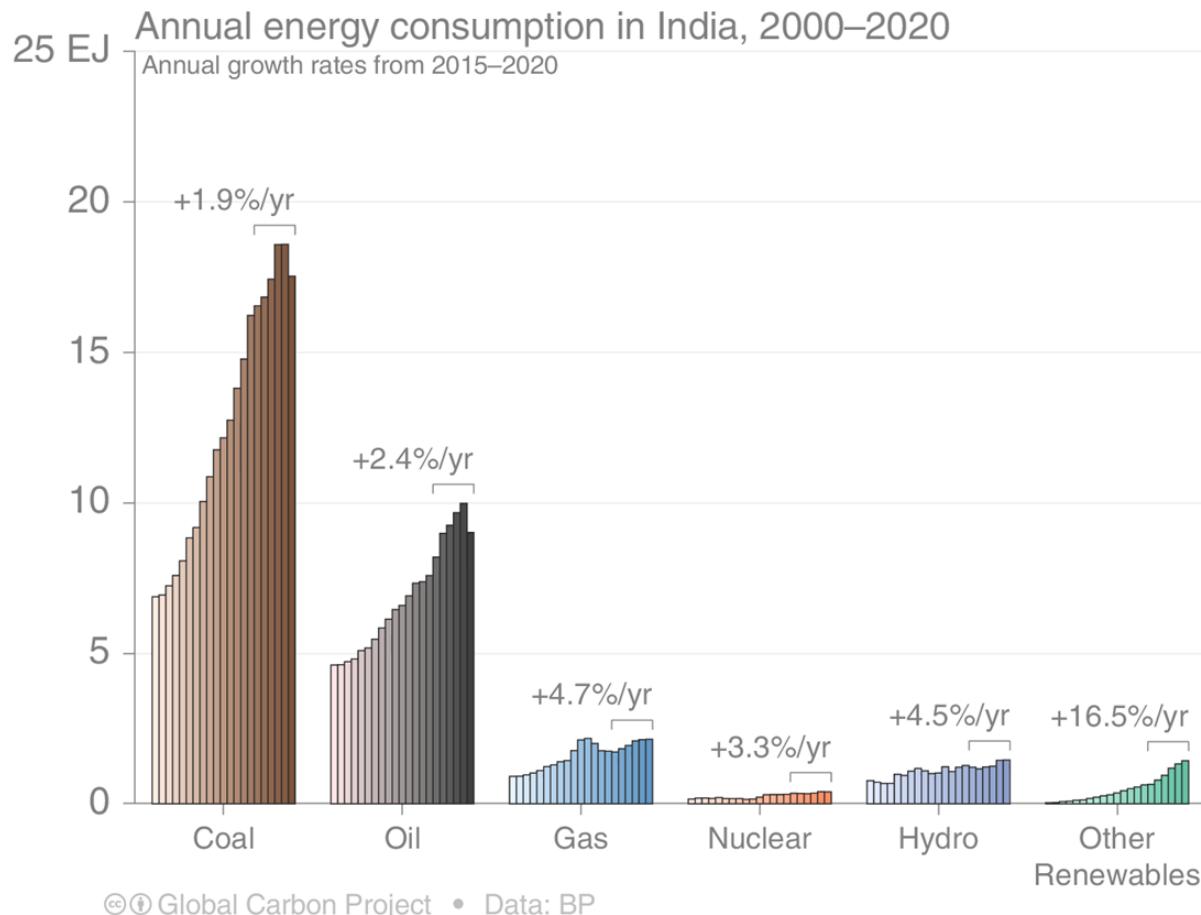
Energy use in the European Union

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.



Energy use in India

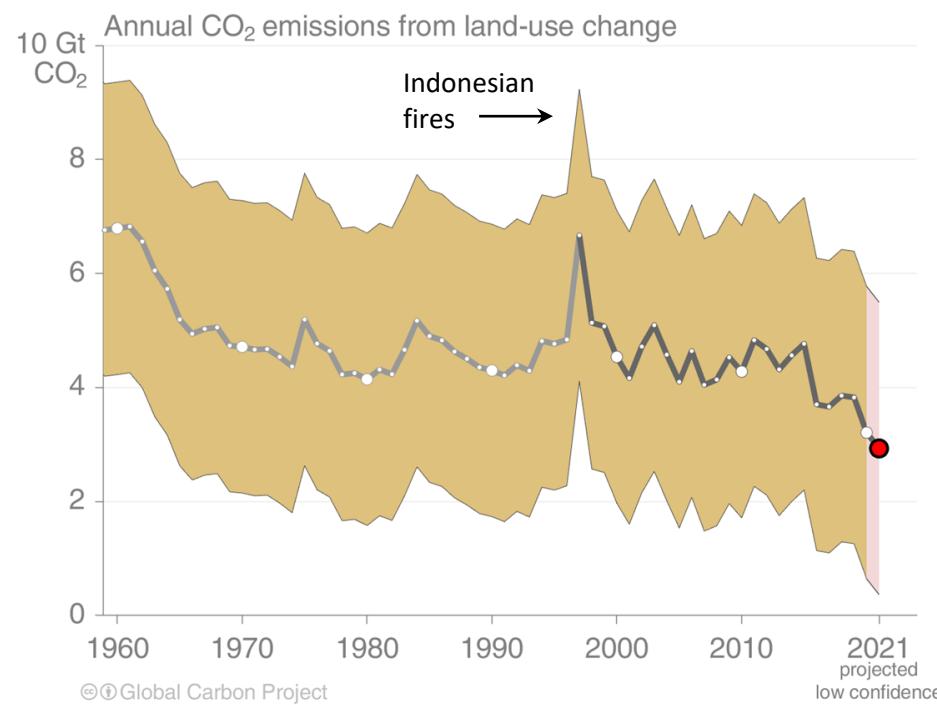
Pandemic year 2020 has interrupted India's strong growth in energy consumption.
Consumption of coal and oil dominate.



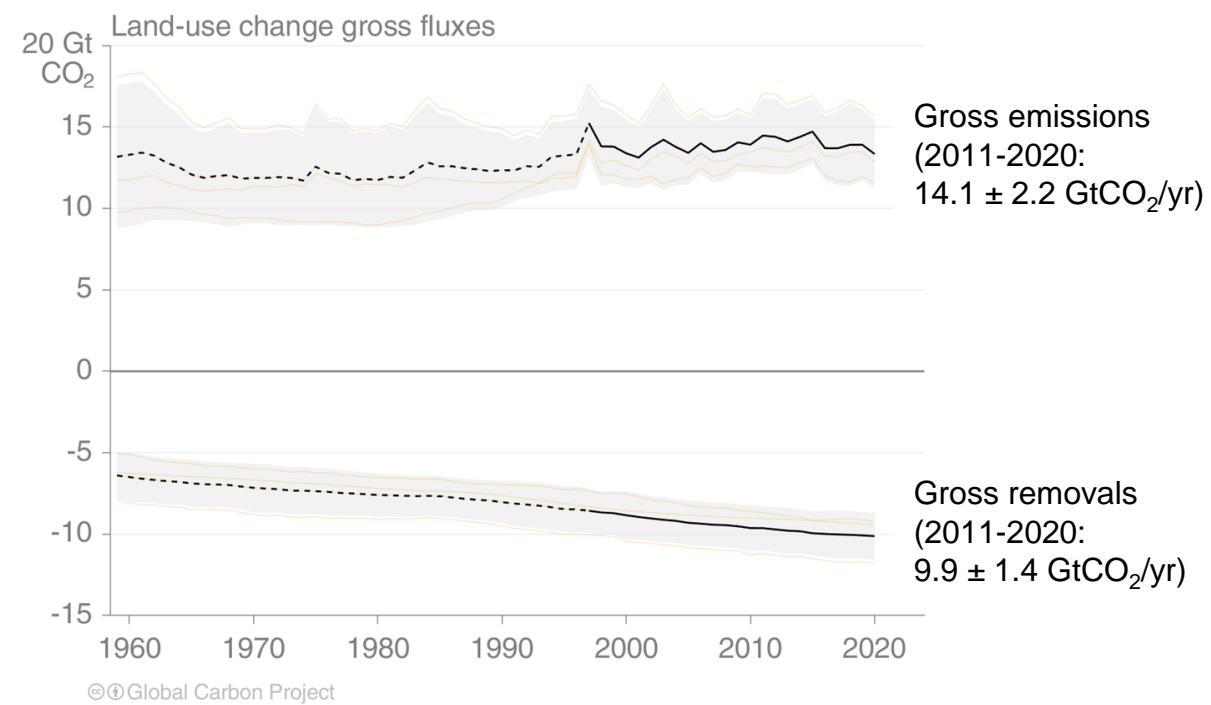
Land-use Change Emissions

Land-use change emissions

Land-use change emissions are $4.1 \pm 2.6 \text{ GtCO}_2$ for 2011-2020, and show a negative trend in the last two decades, but estimates are still highly uncertain.



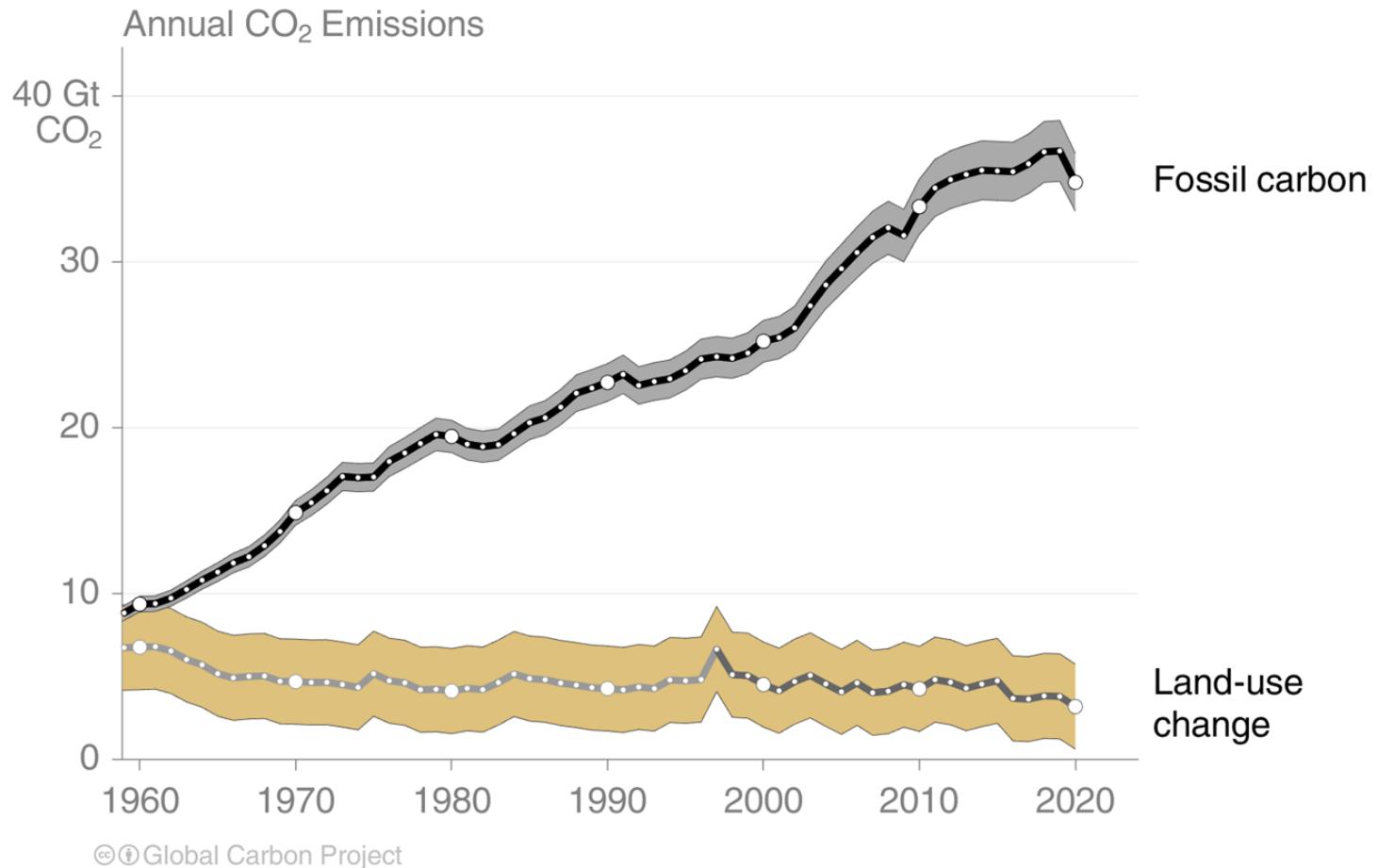
Net land-use emissions are the difference between CO₂ emissions, primarily from deforestation, and CO₂ removals, primarily from abandonment of agricultural land



Total global emissions

Total global emissions: $38.0 \pm 3.1 \text{ GtCO}_2$ in 2020, 40% over 1990

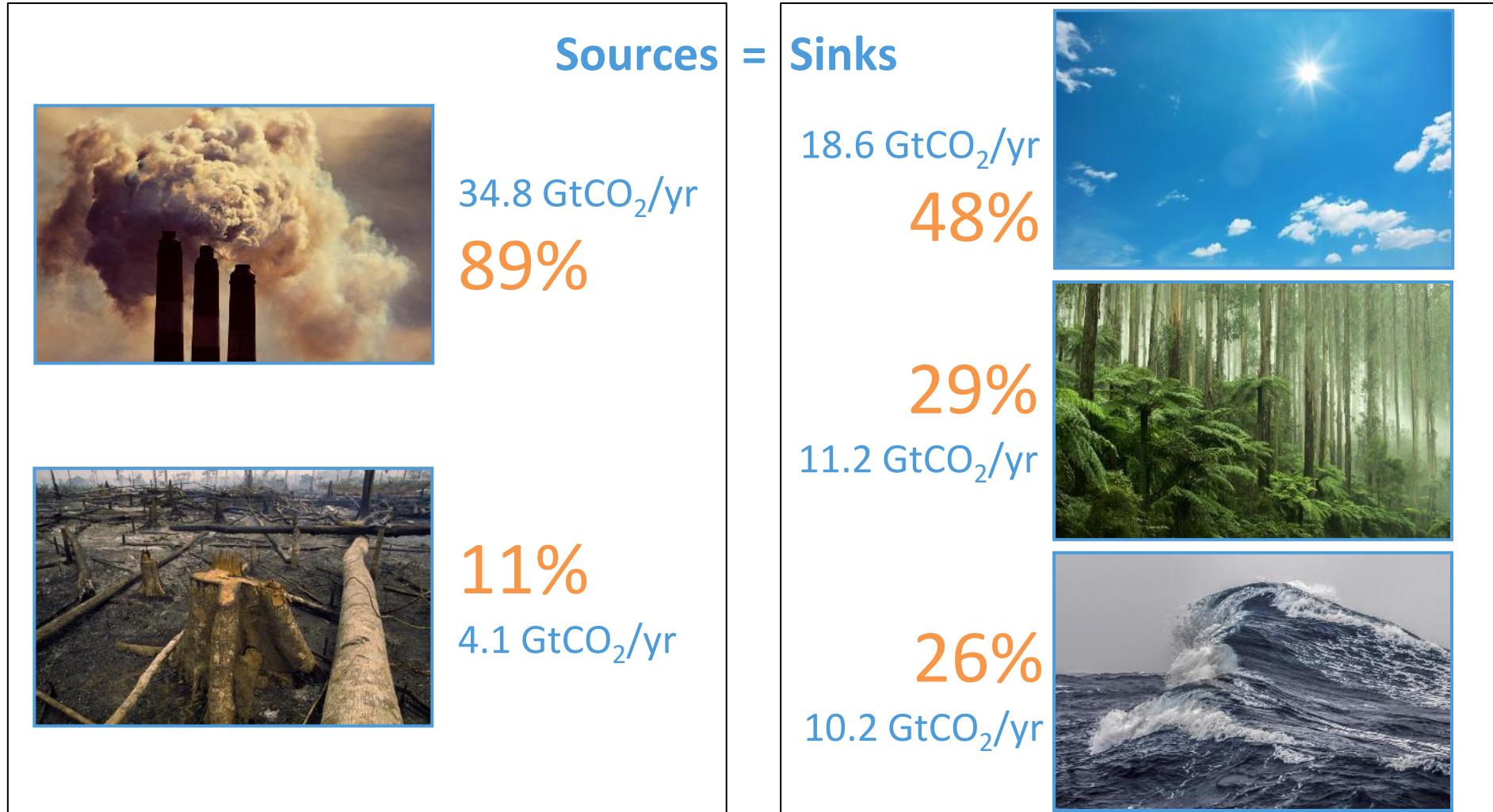
Percentage land-use change: 42% in 1960, 10% averaged 2011–2020



Land-use change estimates from three bookkeeping models, using fire-based variability from 1997
Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Closing the Global Carbon Budget

Fate of anthropogenic CO₂ emissions (2011–2020)

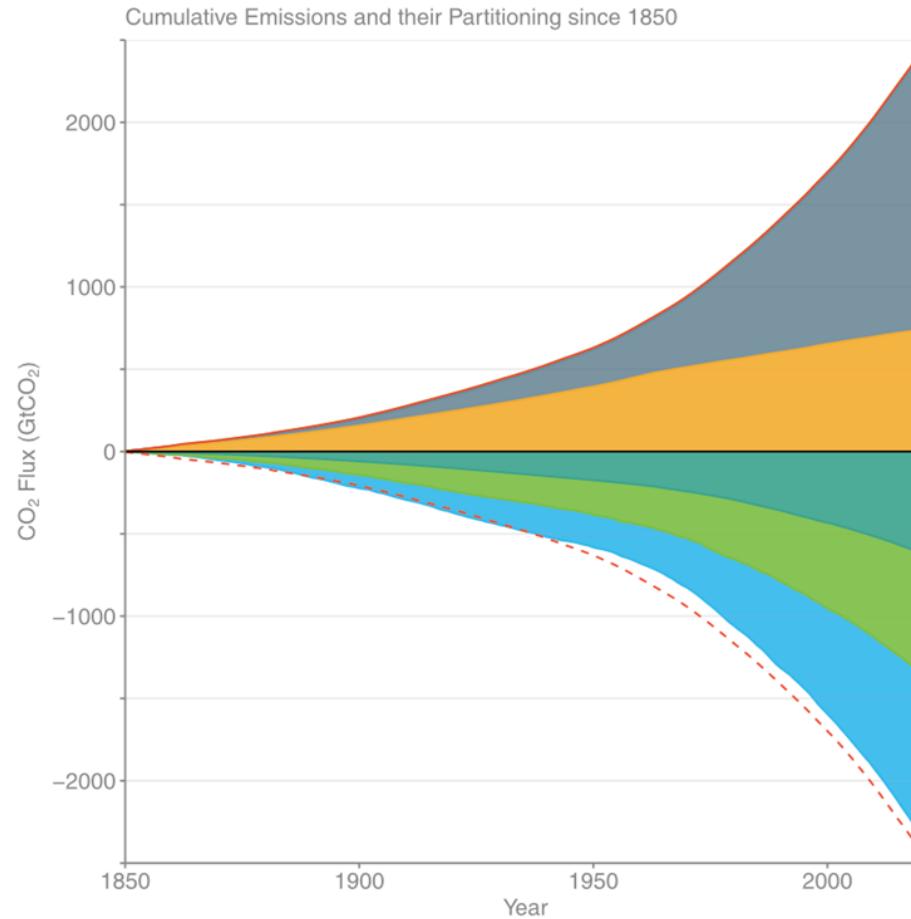
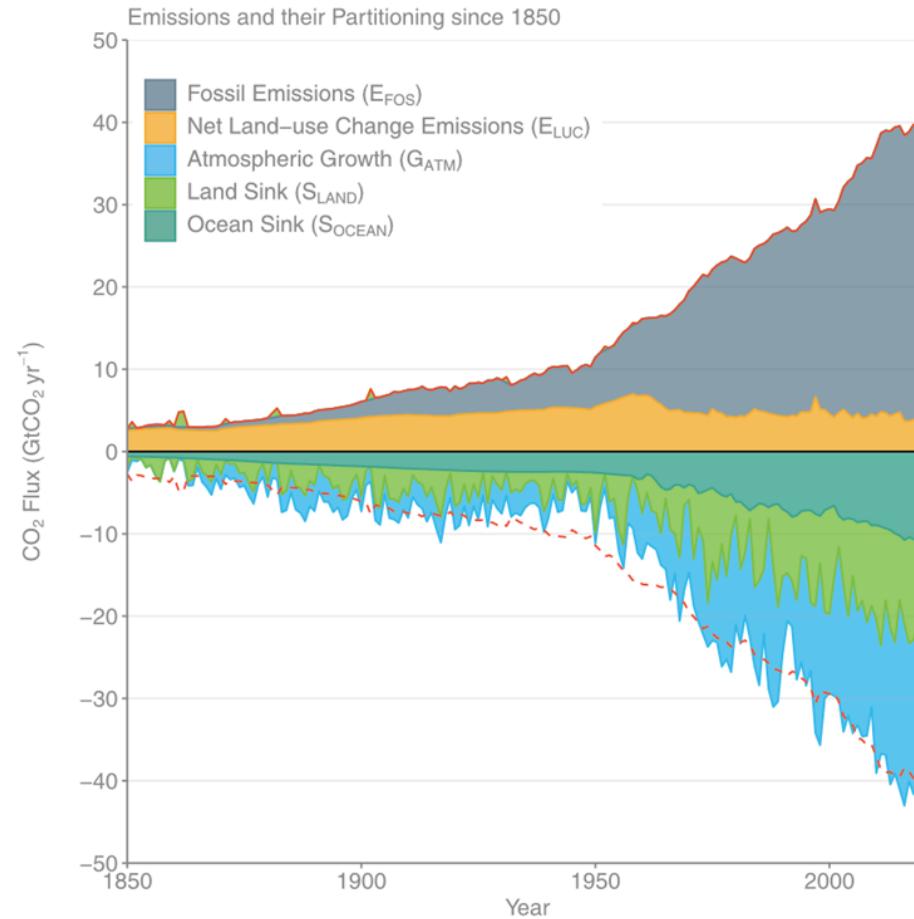


Budget Imbalance:
(the difference between estimated sources & sinks)

3%
-1.0 GtCO₂/yr

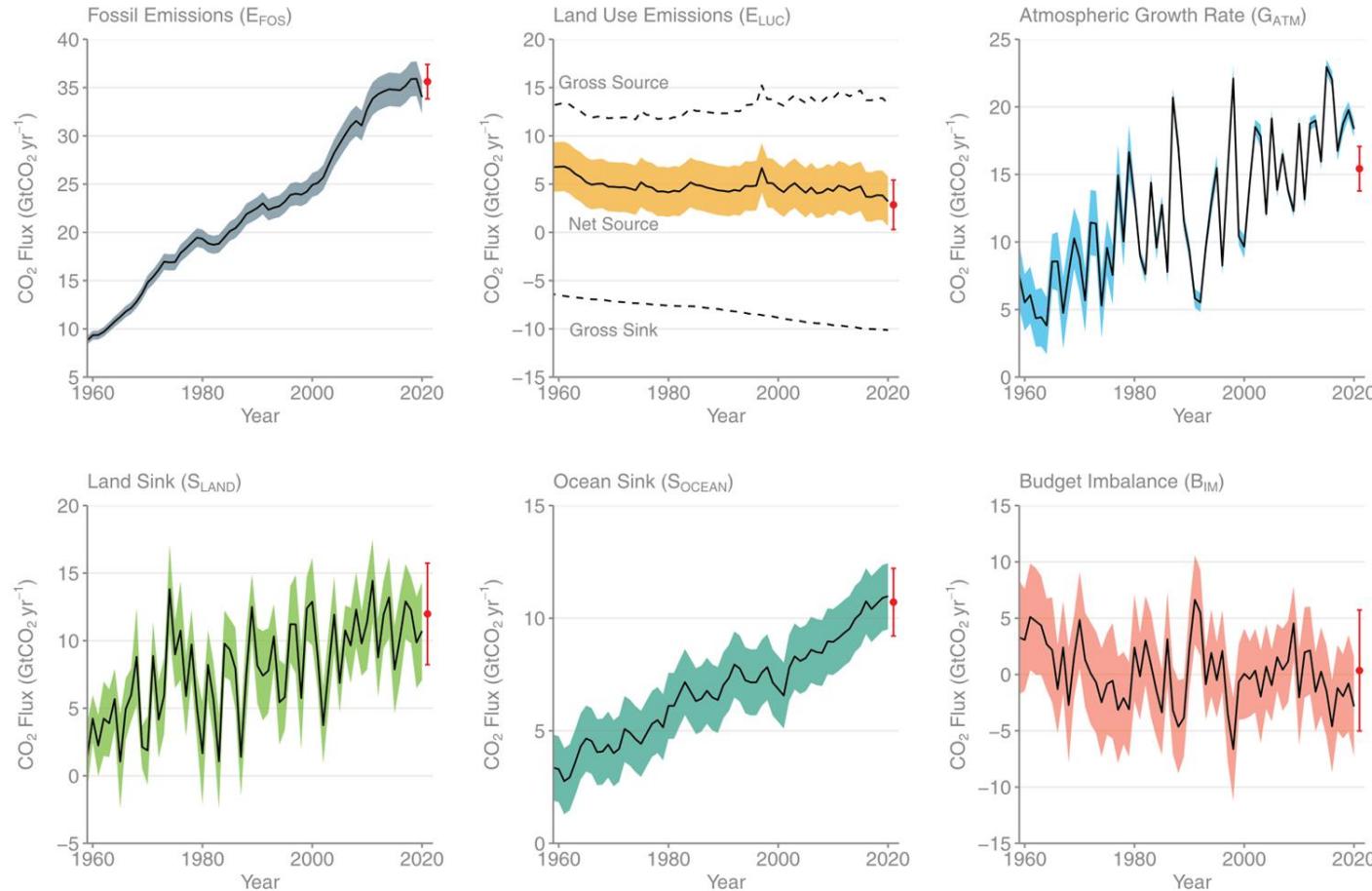
Global carbon budget

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

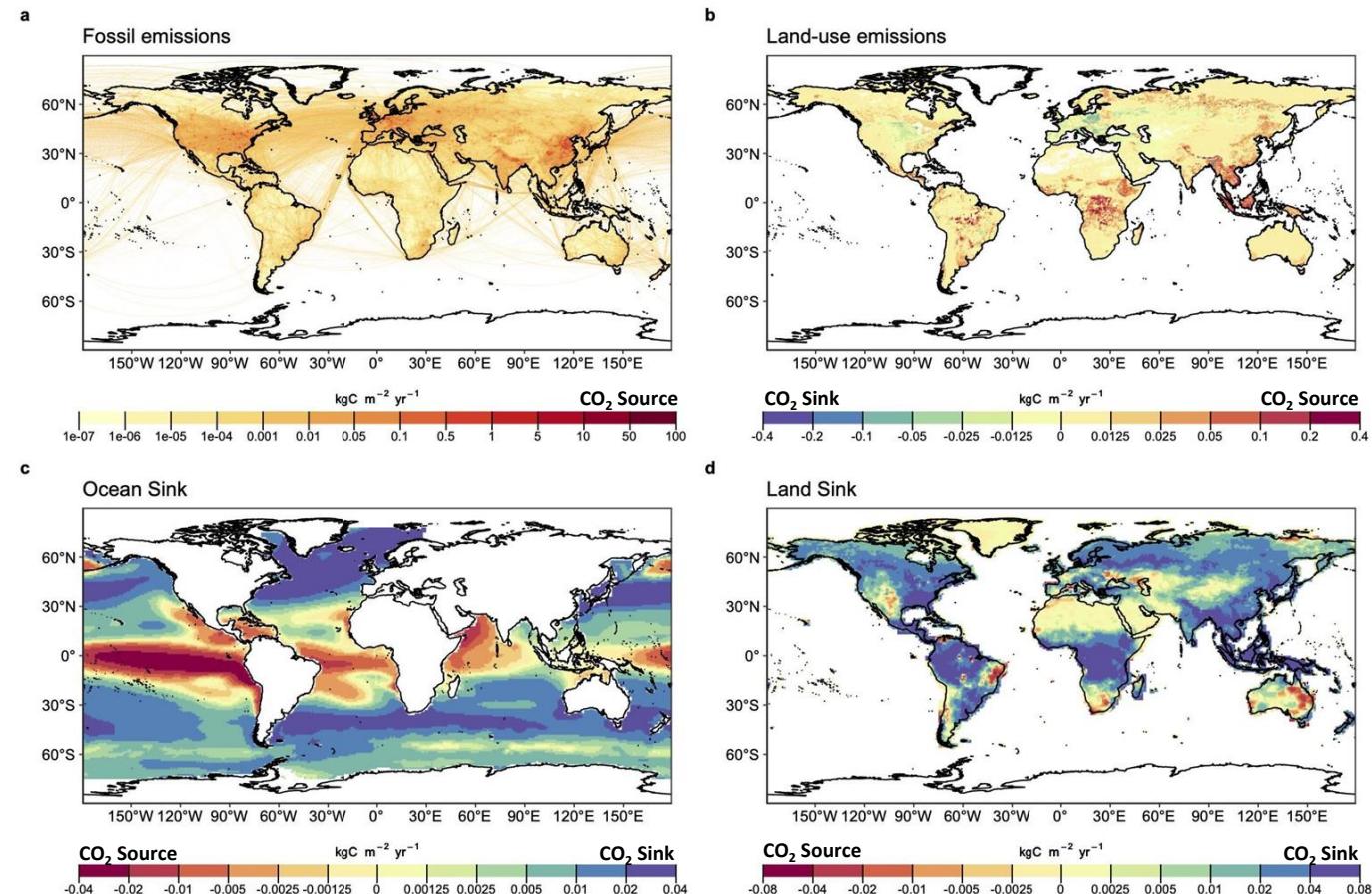
The sinks have continued to grow with increasing emissions, but climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO₂ in the atmosphere



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 2021](#); [Global Carbon Project 2021](#)

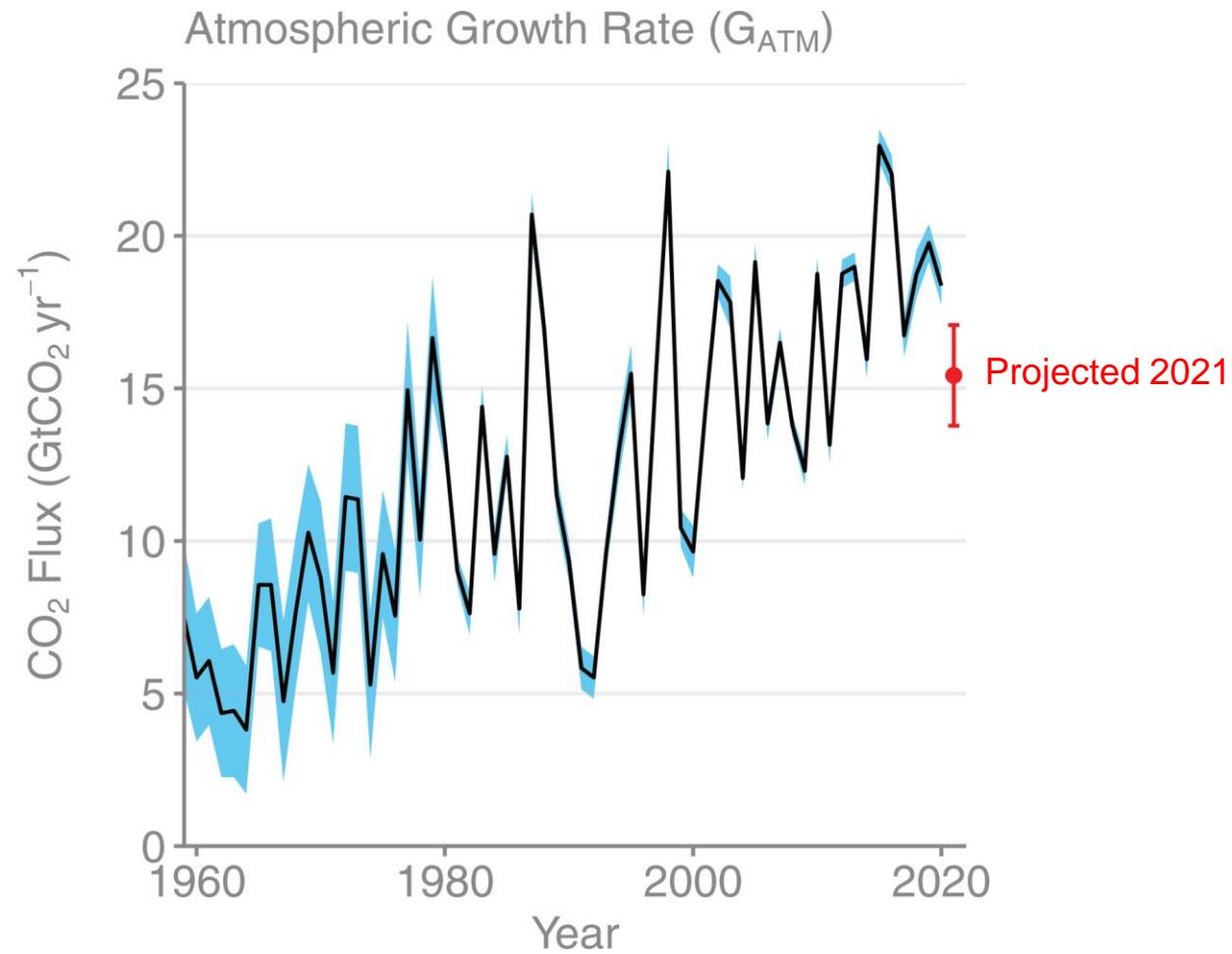
Global carbon budget

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 CO₂.
 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.

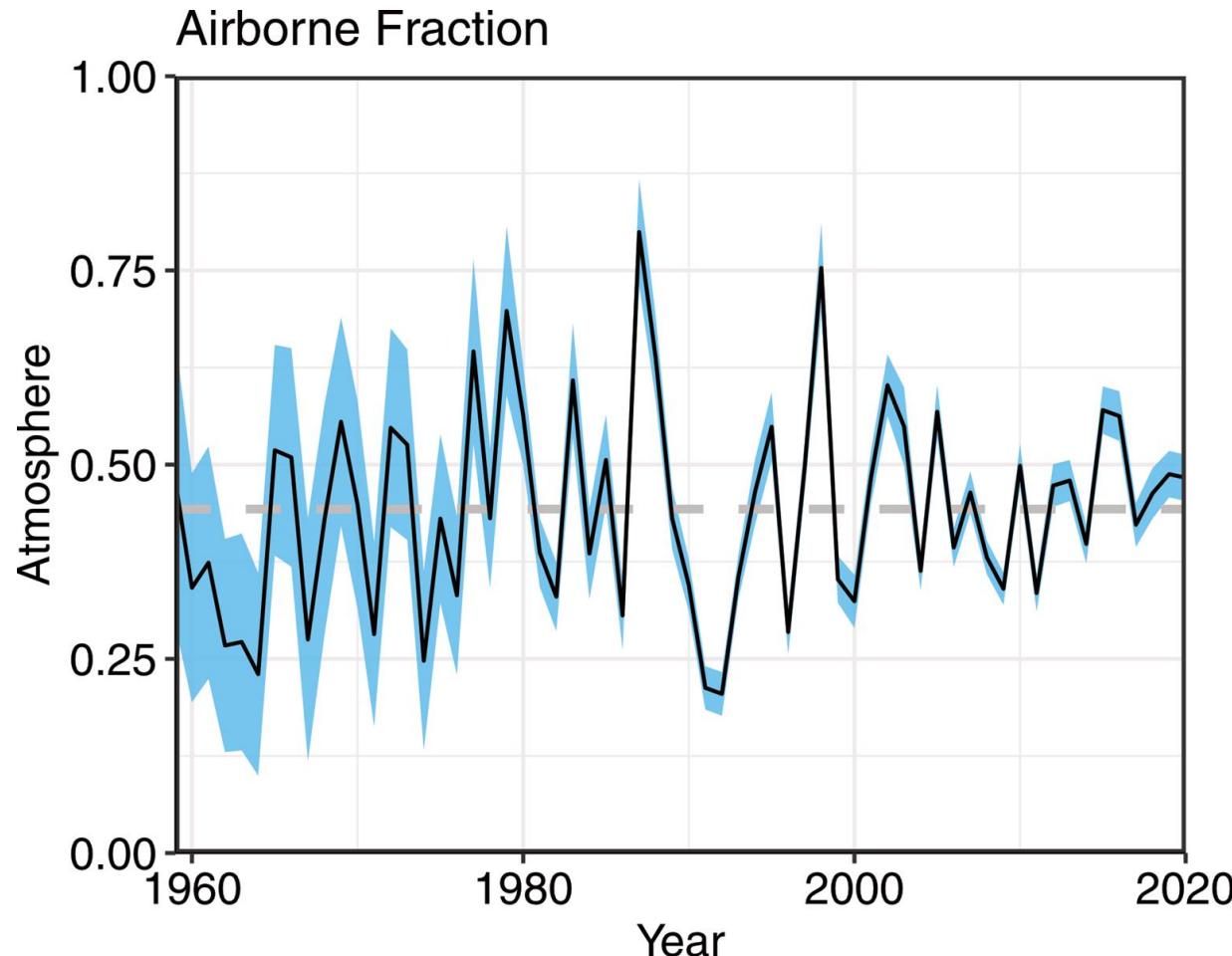


Airborne Fraction

The airborne fraction is the proportion of the total annual CO₂ emissions that remains in the atmosphere.

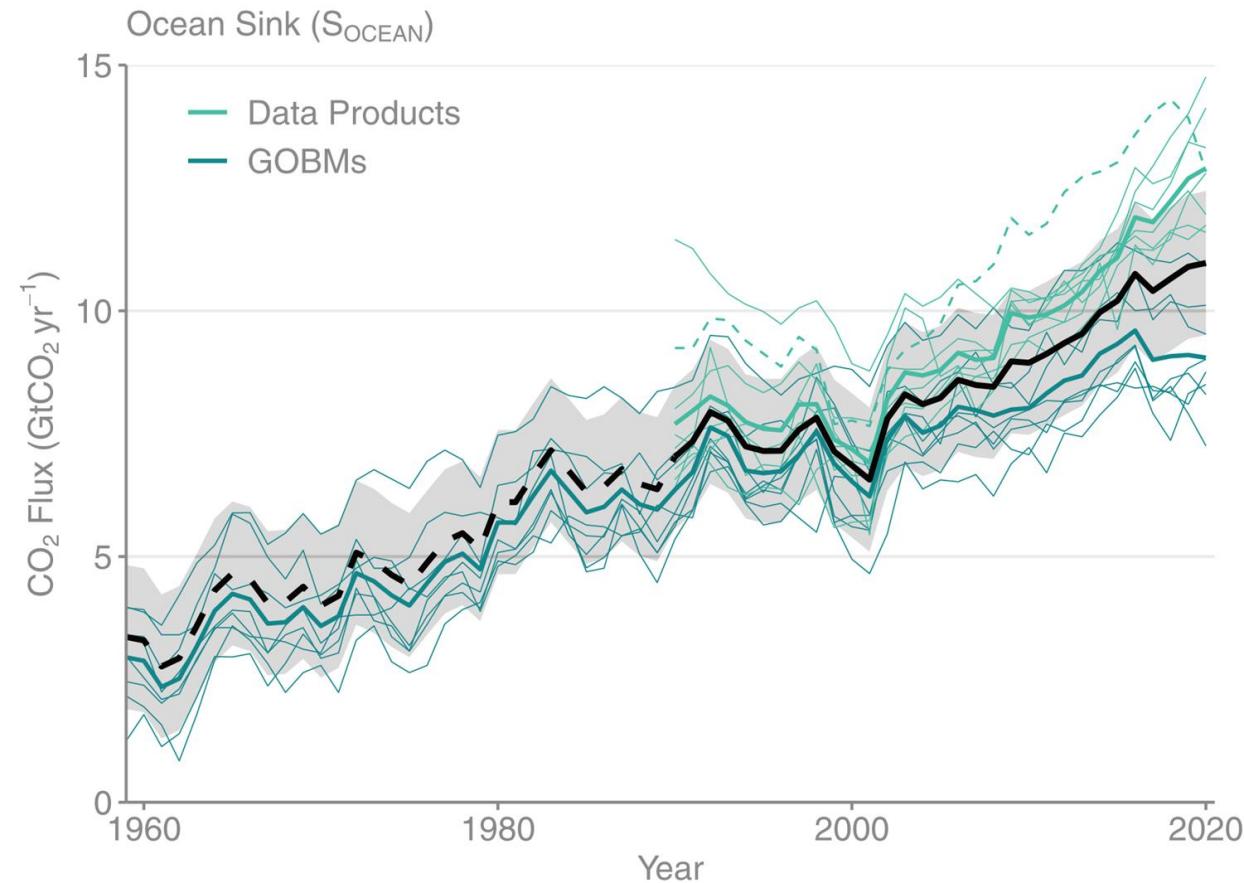
The rest of CO₂ emissions are removed by the land and ocean sinks.

Around 45% of CO₂ emissions remain in the atmosphere despite sustained growth in CO₂ emissions.



Ocean sink

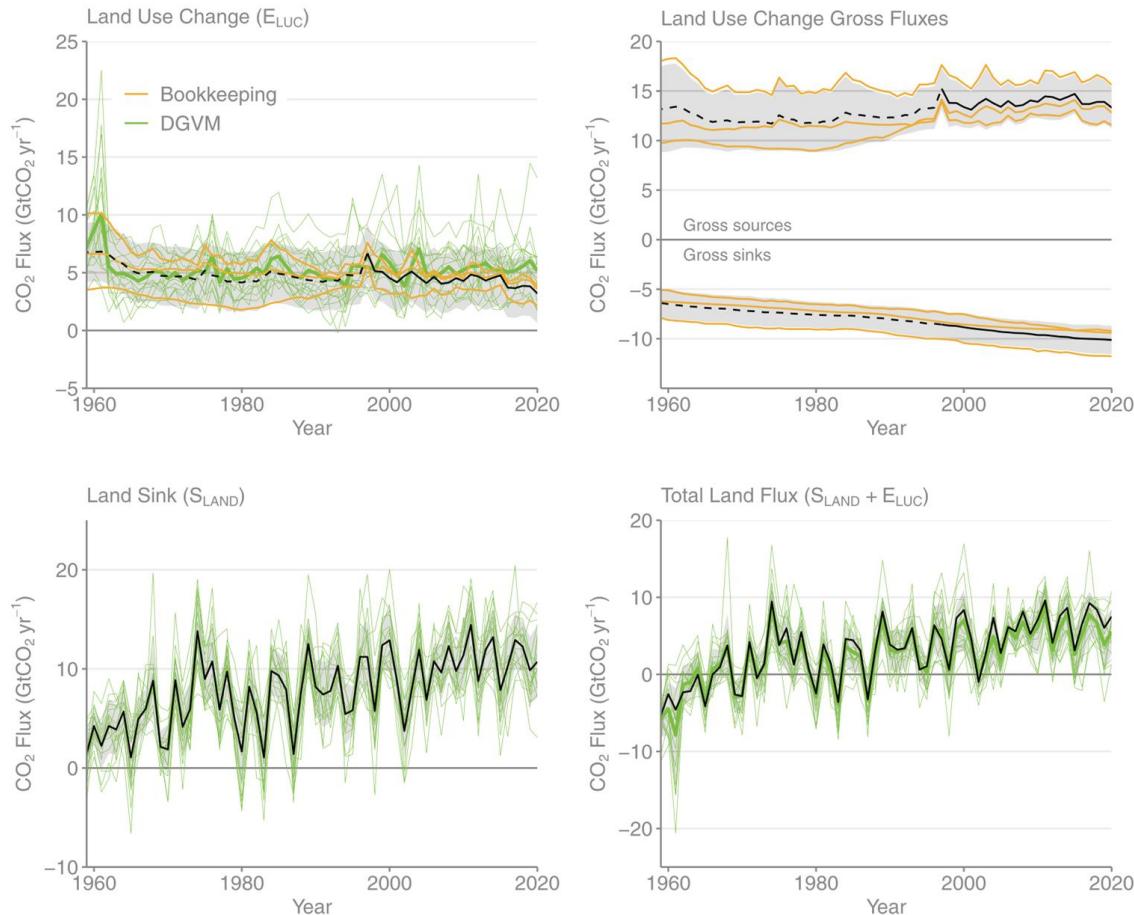
The ocean carbon sink, estimated by Global Ocean Biogeochemical Models and observation-based data products, continues to increase $10.2 \pm 1.5 \text{ GtCO}_2/\text{yr}$ for 2011–2020 and $11.0 \pm 1.5 \text{ GtCO}_2/\text{yr}$ in 2020



Terrestrial sink

The land carbon sink, estimated by Dynamic Global Vegetation Models, was $11.2 \pm 2.2 \text{ GtCO}_2/\text{yr}$ during 2011–2020 and $10.7 \pm 3.6 \text{ GtCO}_2/\text{yr}$ in 2020.

Total CO₂ fluxes on land (including land-use change) are also constrained by atmospheric inversions.

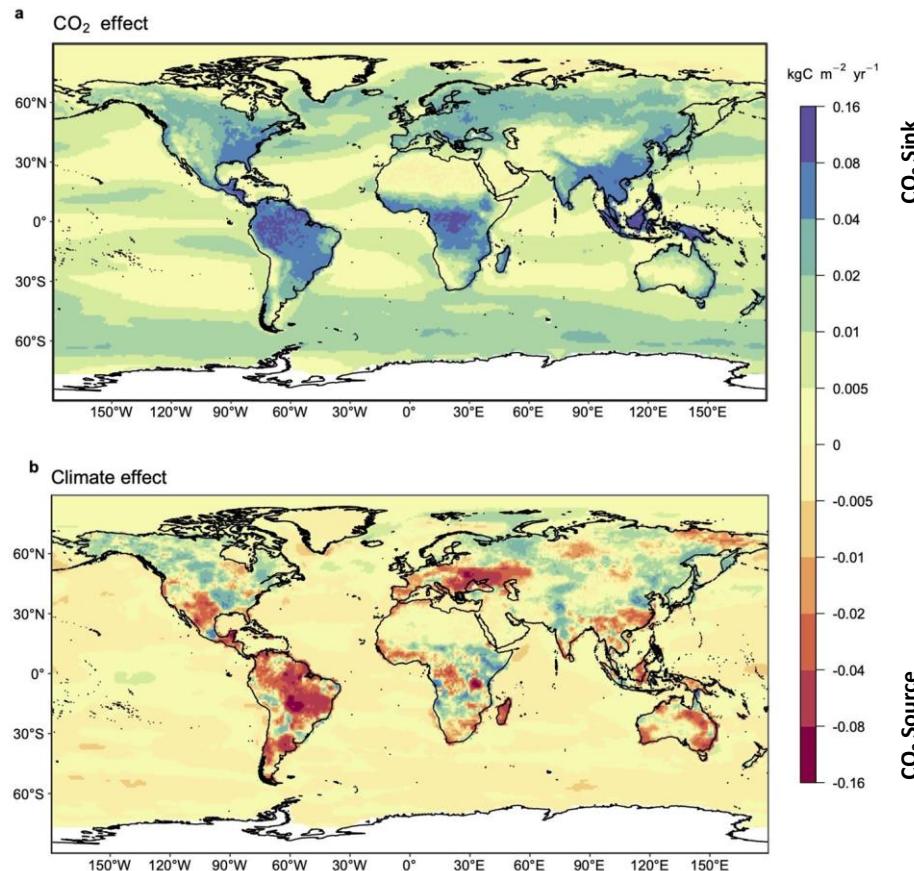


Source: [Friedlingstein et al 2021](#); Global Carbon Project 2021

Land and ocean sinks — Effects of CO₂ vs climate change

Process models suggest that increasing atmospheric CO₂ 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.

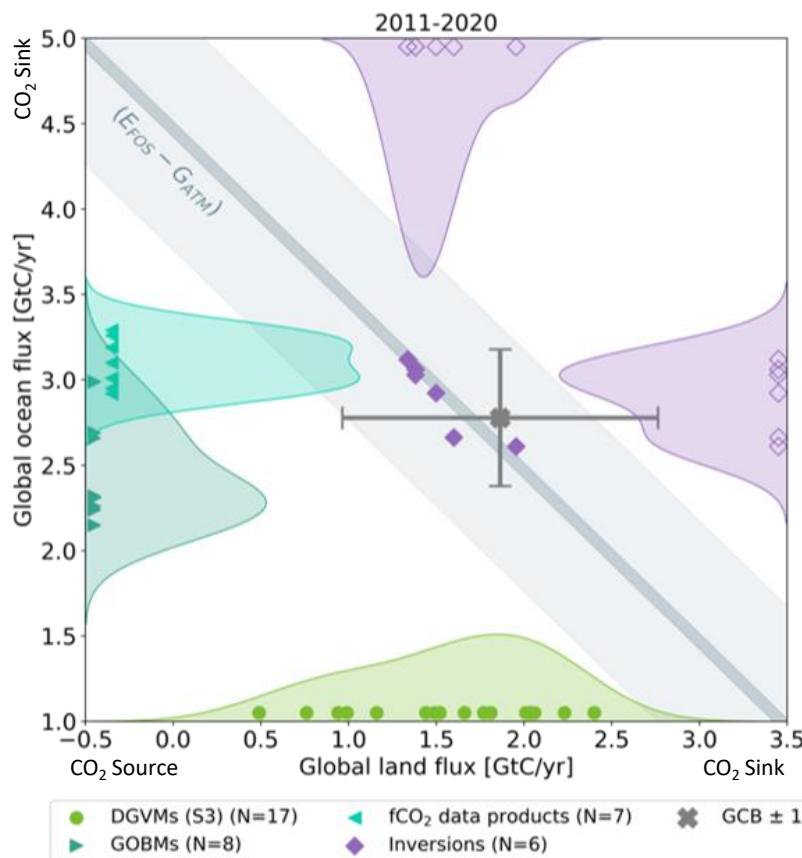
Globally during the 2011-2020 decade, climate change reduced the land sink by ~15% and the ocean sink by ~5%



Source: [Friedlingstein et al 2021](#); [Global Carbon Budget 2021](#)

Land and ocean sinks — Estimates from atmospheric inversions

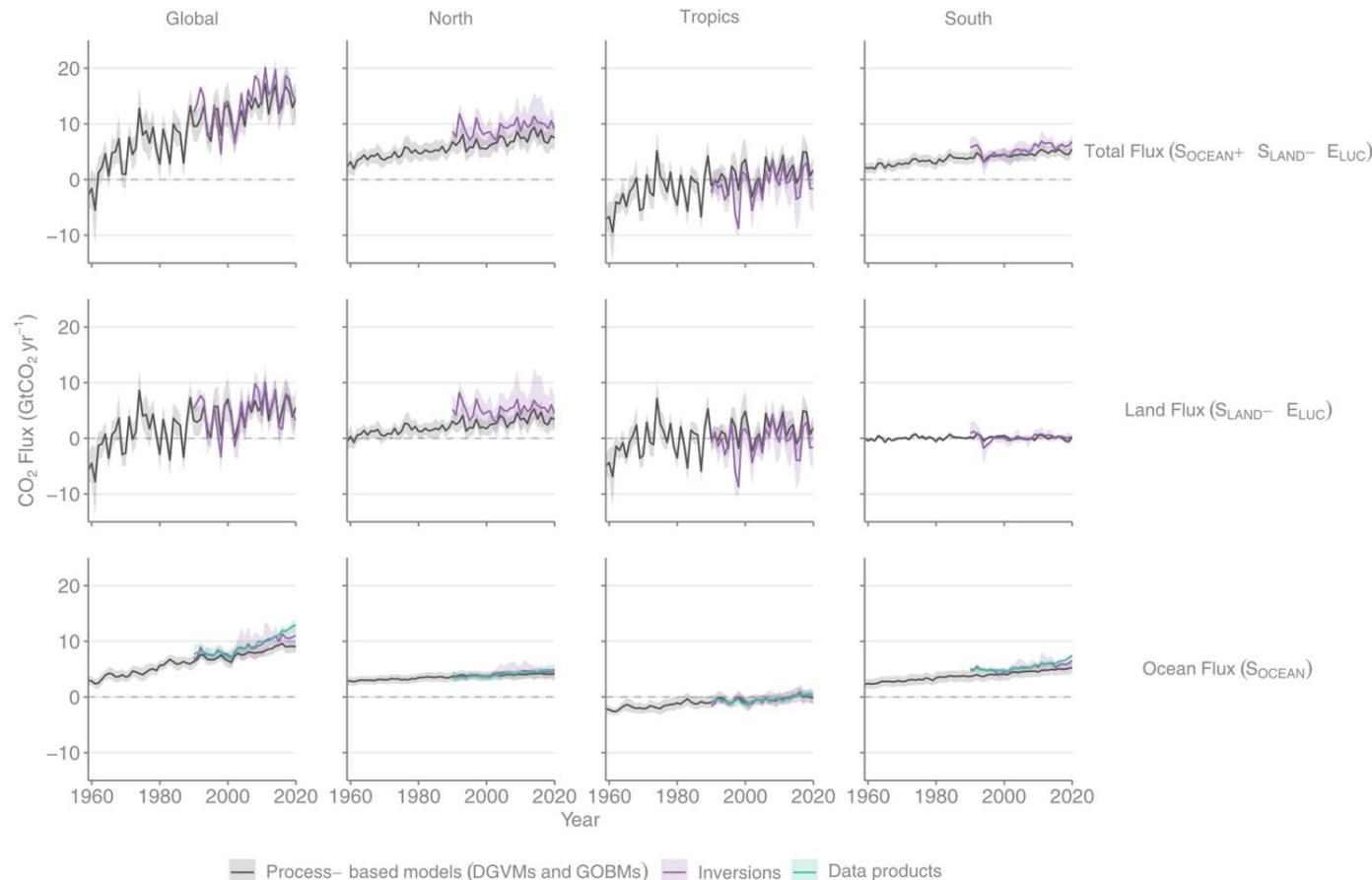
Atmospheric CO₂ inversions allow to estimate the land and ocean carbon fluxes, independently from the land and ocean process-based models estimates, confirming the global carbon budget estimates of the land and ocean partitioning of anthropogenic CO₂



Source: [Friedlingstein et al 2021; Global Carbon Budget 2021](#)

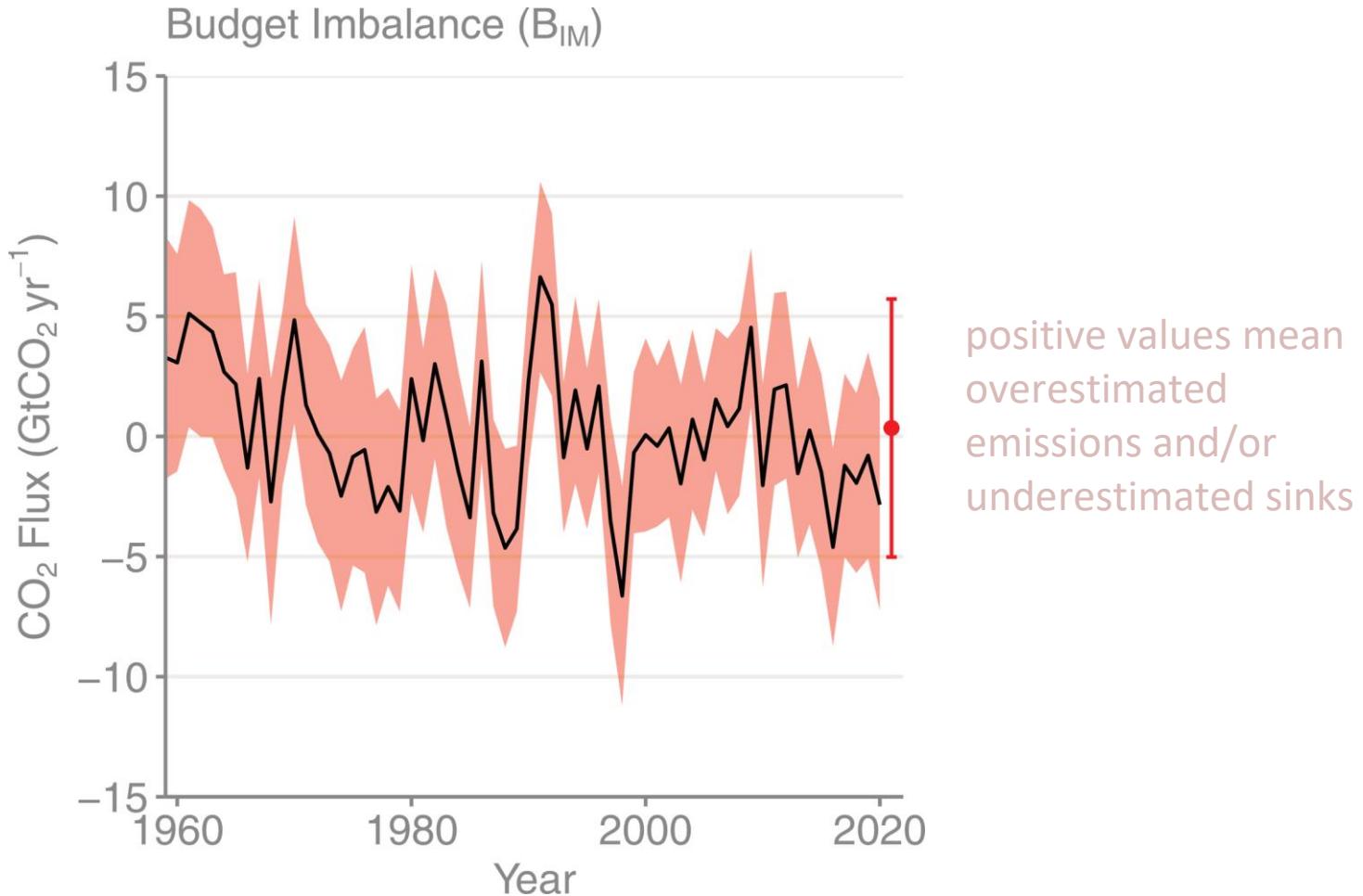
Total land and ocean fluxes

Total land and ocean fluxes show more interannual variability 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 CO₂ emissions

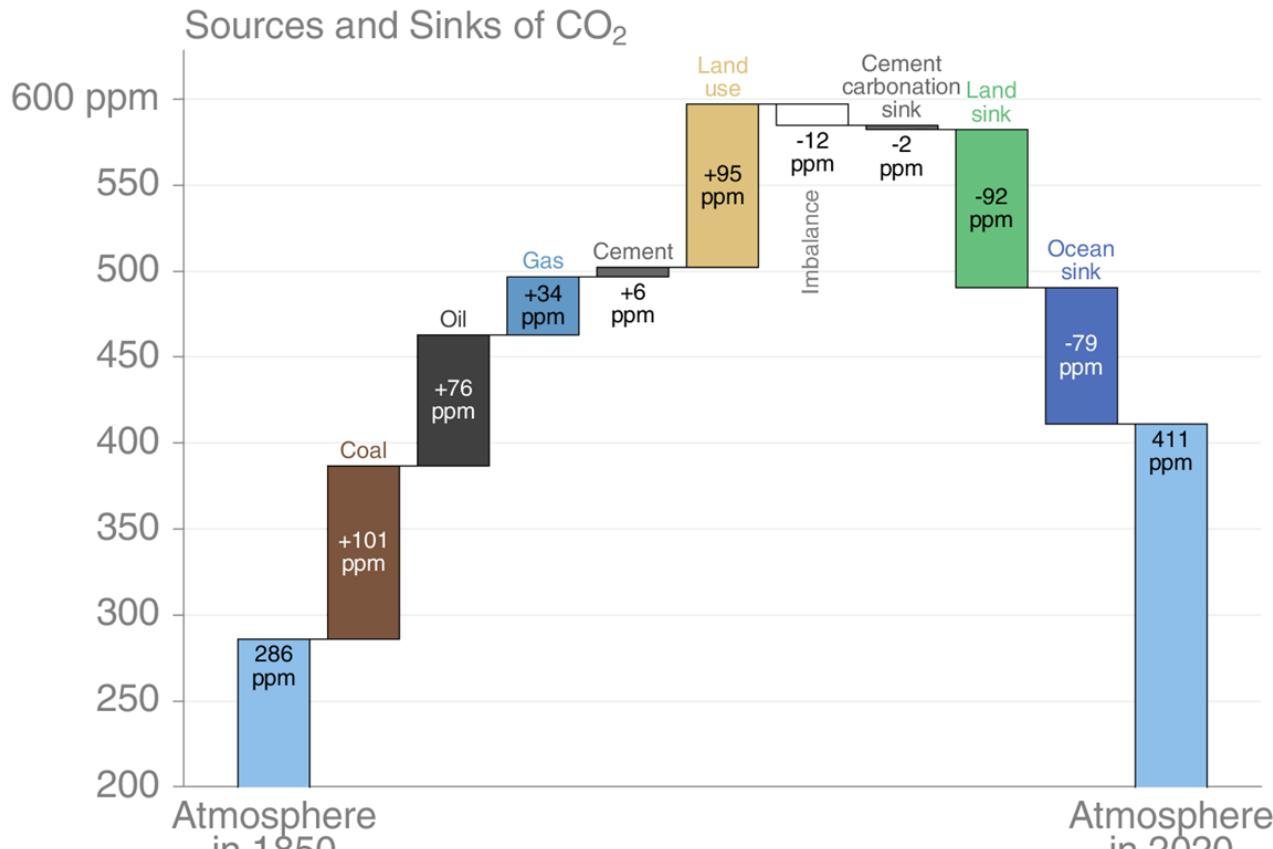


The budget imbalance is the carbon left after adding independent estimates for total emissions, minus the atmospheric growth rate and estimates for the land and ocean carbon sinks using models constrained by observations

Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

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

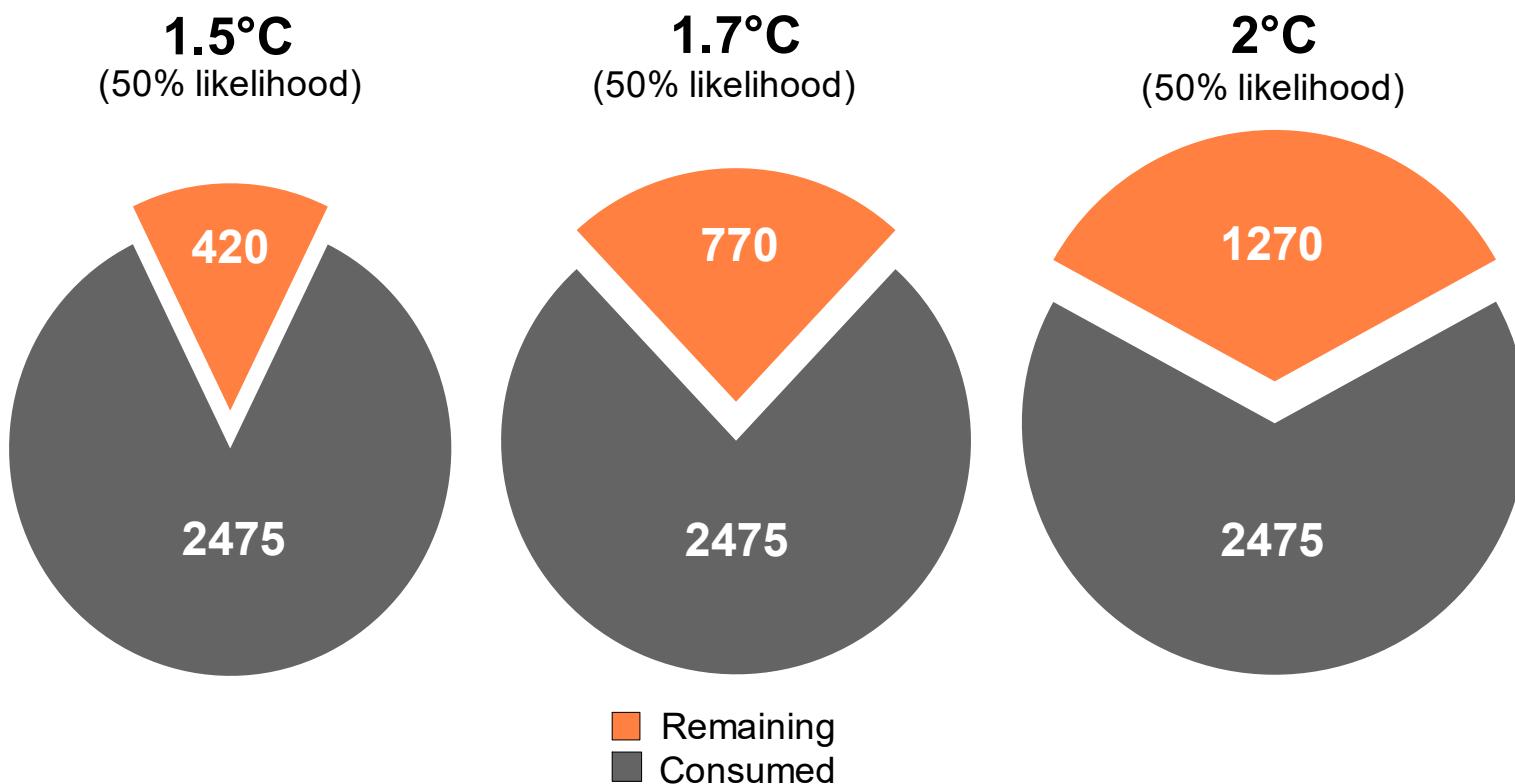


CC BY Global Carbon Project

Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Remaining carbon budget

The remaining carbon budget to limit global warming to 1.5°C, 1.7°C and 2°C is 420 GtCO₂, 770 GtCO₂, and 1270 GtCO₂ respectively, equivalent to 11, 20 and 32 years from 2022. 2475 GtCO₂ have been emitted since 1750



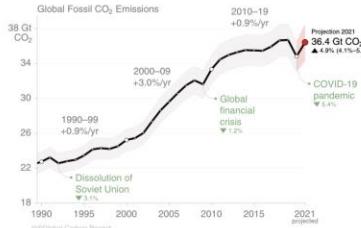
Quantities are subject to [additional] uncertainties e.g., future mitigation choices of non-CO₂ emissions
Source: IPCC AR6 WG1; [Friedlingstein et al 2021](#); [Global Carbon Budget 2021](#)

Infographics

Global Carbon Budget 2021

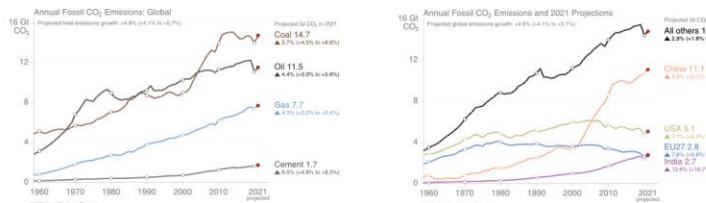
CO₂ emissions rebound towards pre-COVID levels

Global fossil CO₂ emissions in 2021 are set to rebound 4.9% after a record 5.4% drop in 2020.
This follows a decade of strong and growing energy decarbonisation which reduced the growth of emissions.



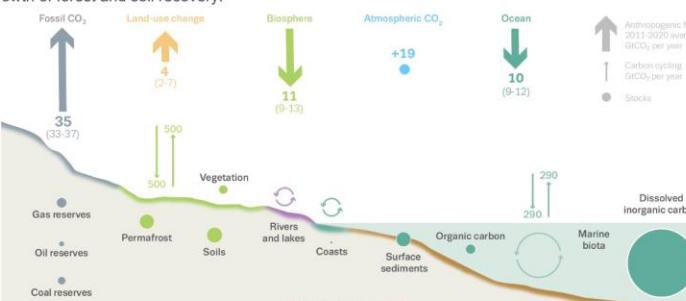
CO₂ emissions cuts of 1.4 billion tonnes are needed each year on average to reach net zero by 2050

Coal and gas use grow more in 2021 than they fell in 2020.
Oil use remains below 2019 levels.



Emissions return to pre-COVID trends in USA, EU27 & India but further growth was sparked in China.

The level of CO₂ continues to increase in the atmosphere, causing climate change.
Emissions from deforestation and other land-use change remain high, partly offset by removals from regrowth of forest and soil recovery.



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Produced by the Global Carbon Project based on Friedlingstein et al. Earth System Science Data (2021). Written and edited by Corinne Le Quere (UEA) and Pierre Friedlingstein (Exeter University) with the Global Carbon Budget team. This infographic is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike license. The original graphics design adapted from a previous version by Nigel Hawtin. Poster created by Natalie Porter (ClimateUEA).



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Acknowledgements

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The work presented in the **Global Carbon Budget 2021** has been possible thanks to the contributions of **hundreds of people** involved in observational networks, modeling, and synthesis efforts.

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<https://essd.copernicus.org/preprints/essd-2021-386/>

We also thank 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.



Research. Innovation. Sustainability.



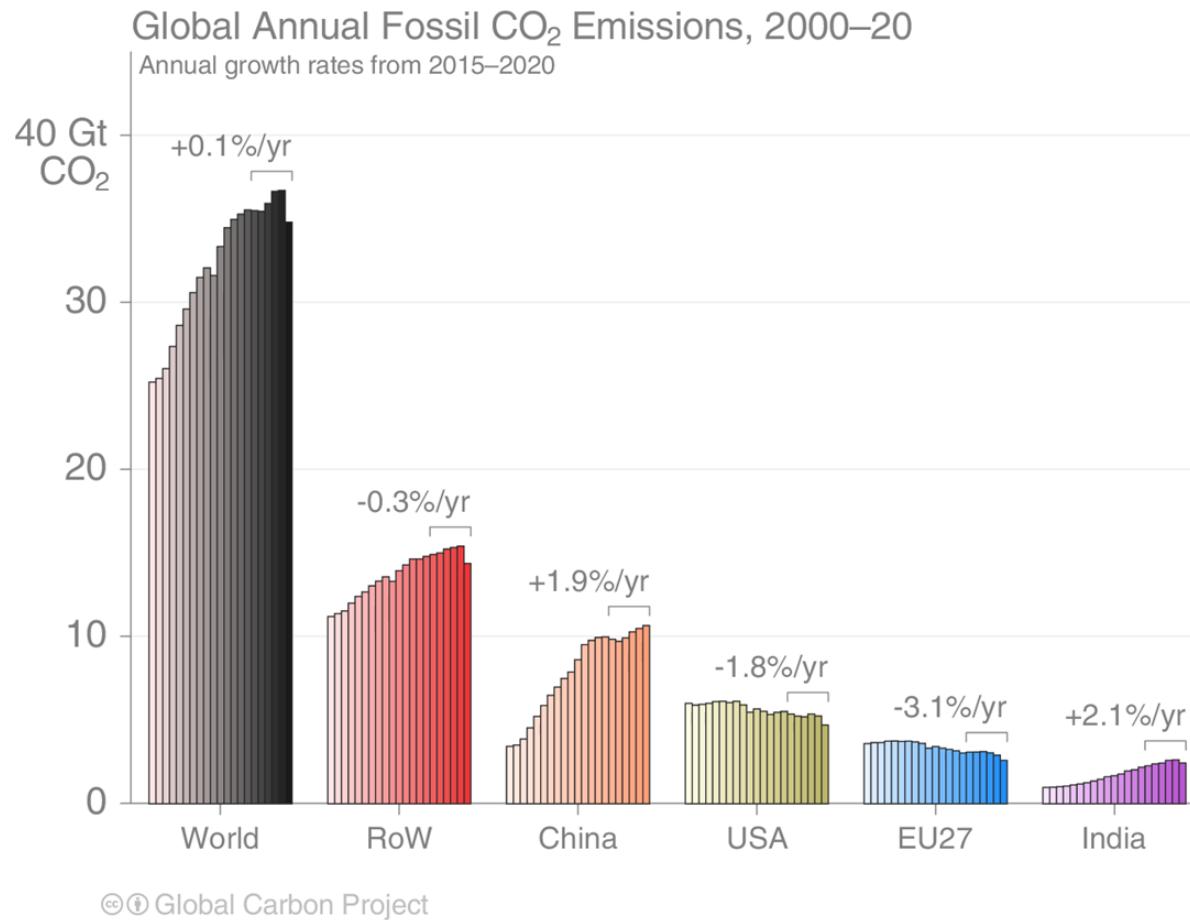
Additional Figures

Additional Figures

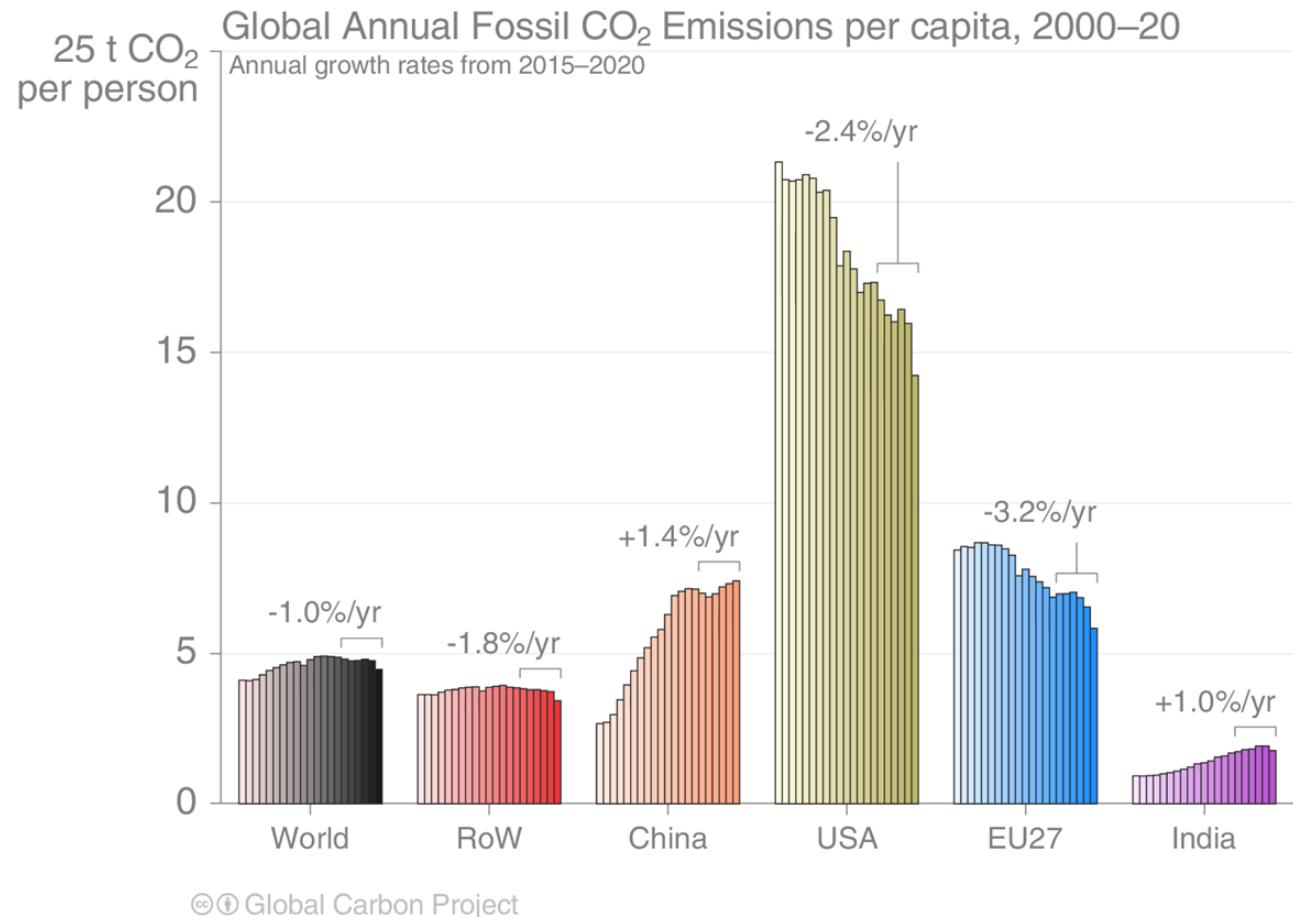
Fossil CO₂

Top emitters: Fossil CO₂ Emissions

Emissions by country from 2000 to 2020, with the growth rates indicated for the more recent period of 2015 to 2020



Per capita CO₂ emissions

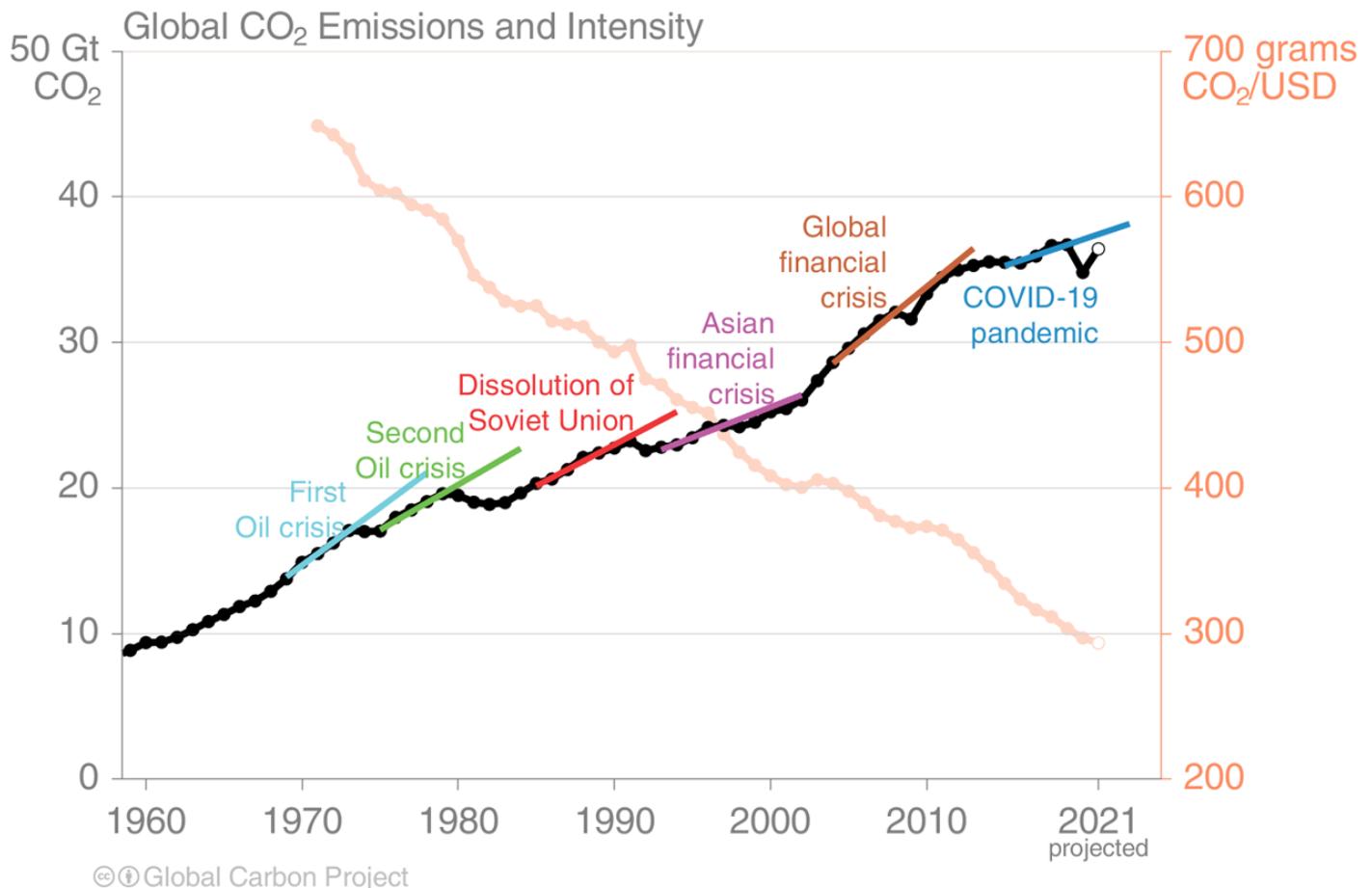


© Global Carbon Project

Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Fossil CO₂ emission intensity

Global CO₂ emissions growth has generally resumed quickly from global crises.
Emission intensity has steadily declined but not sufficiently to offset economic growth.

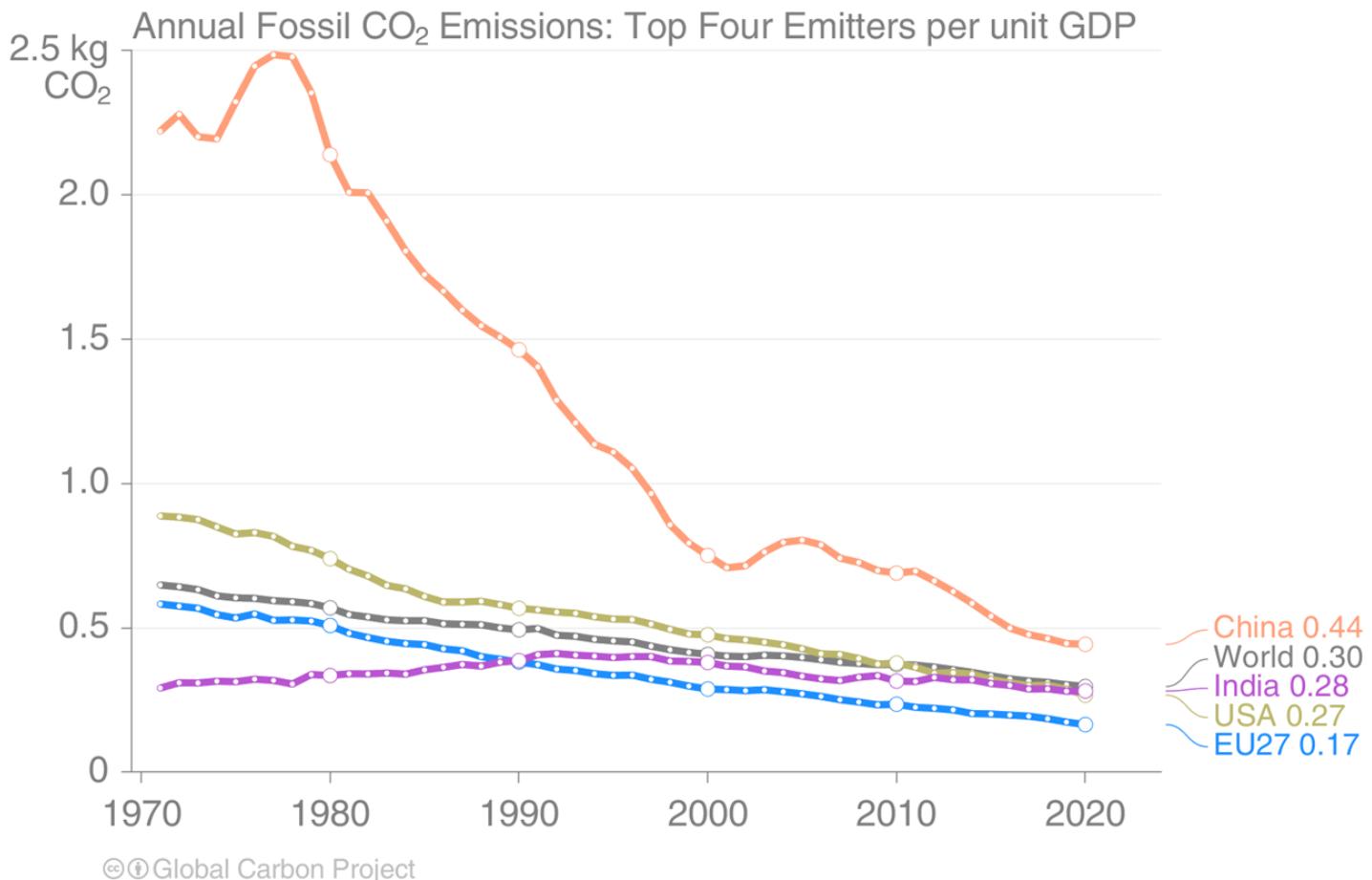


Economic activity is measured in purchasing power parity (PPP) terms in 2010 US dollars.

Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Top emitters: Fossil CO₂ Emission Intensity

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

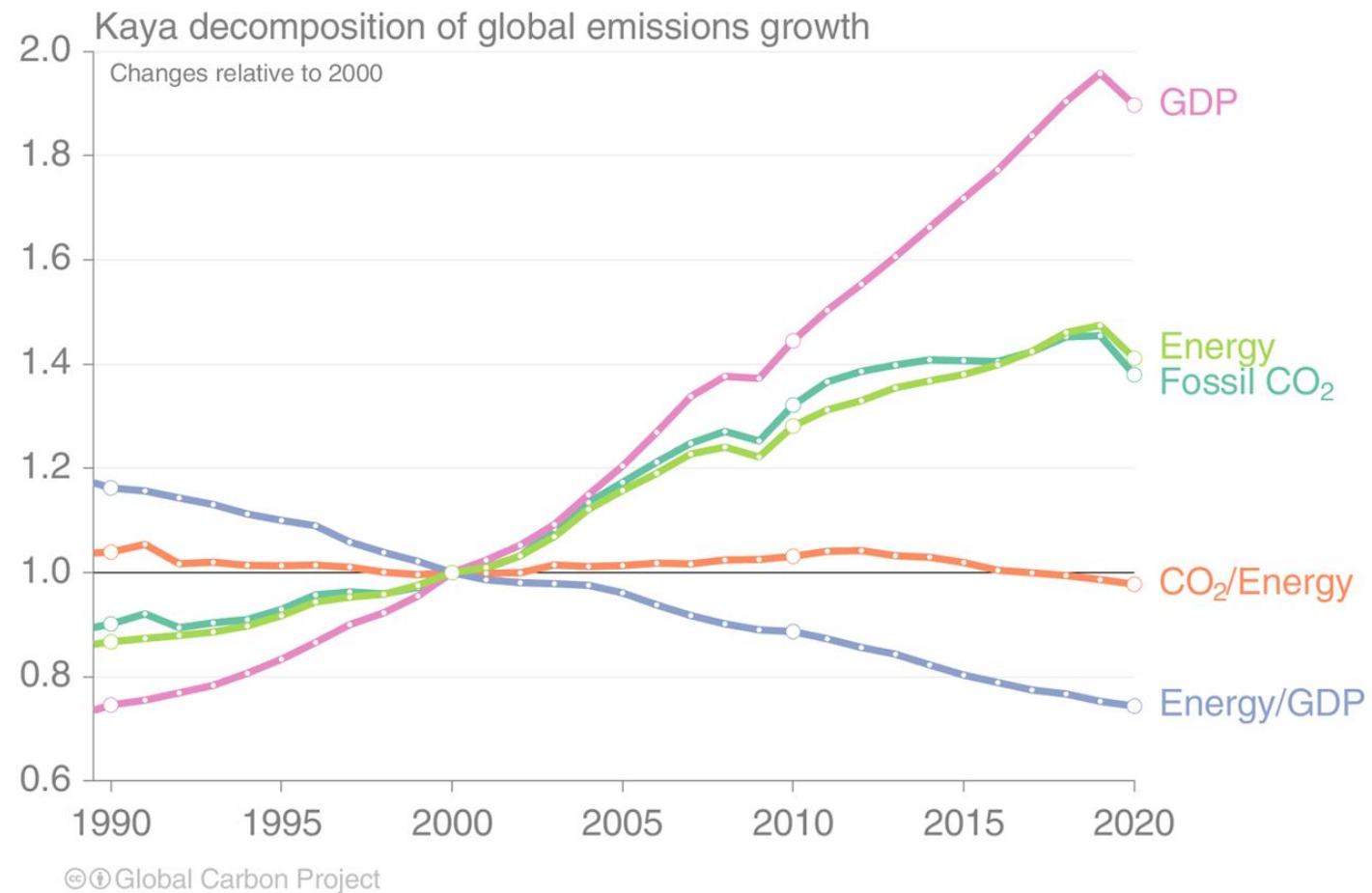


GDP is measured in purchasing power parity (PPP) terms in 2010 US dollars.

Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Kaya decomposition

The Kaya decomposition illustrates that relative decoupling of economic growth from CO₂ emissions is driven by improved energy intensity (Energy/GDP)

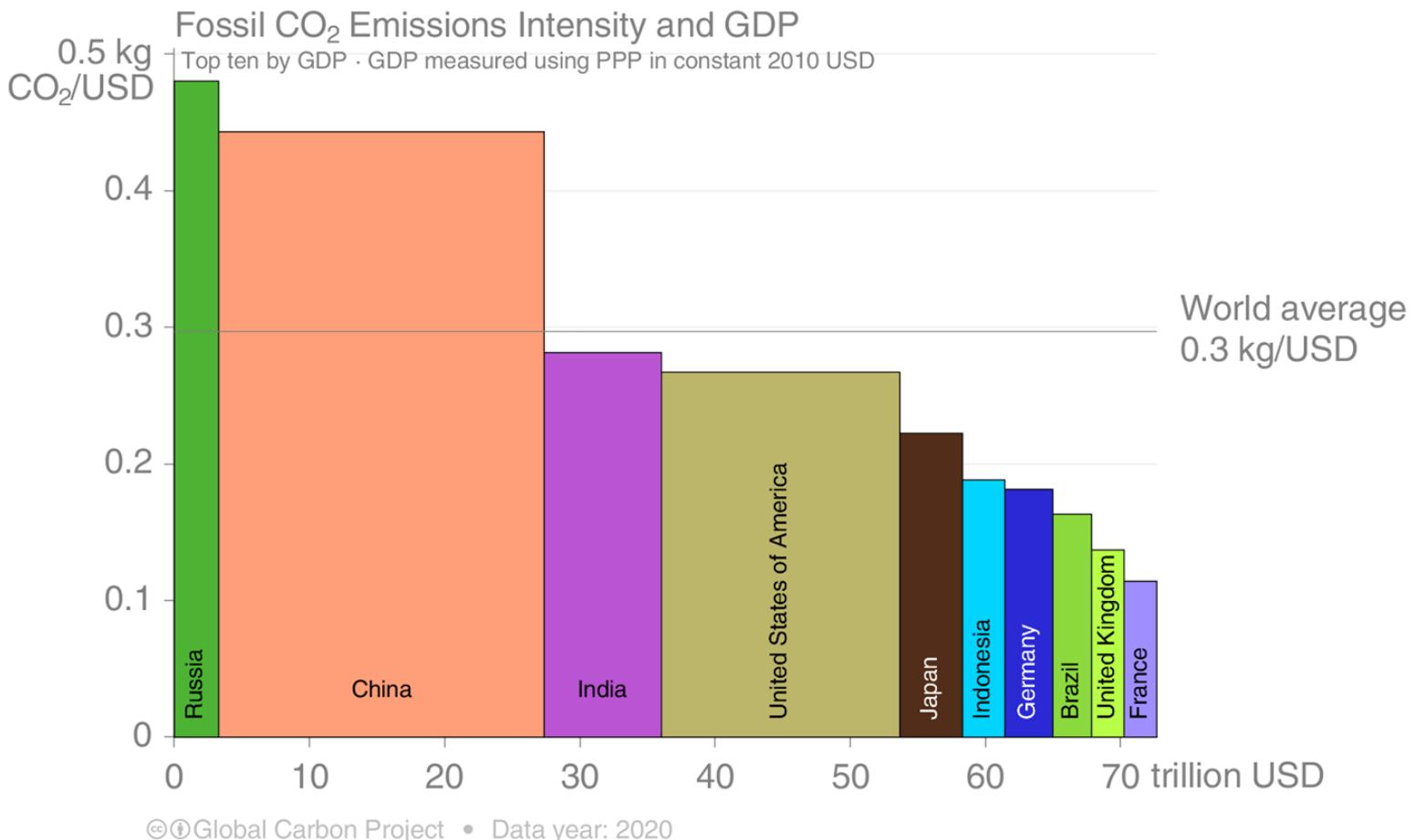


GDP: Gross Domestic Product (economic activity)

Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Fossil CO₂ emission intensity

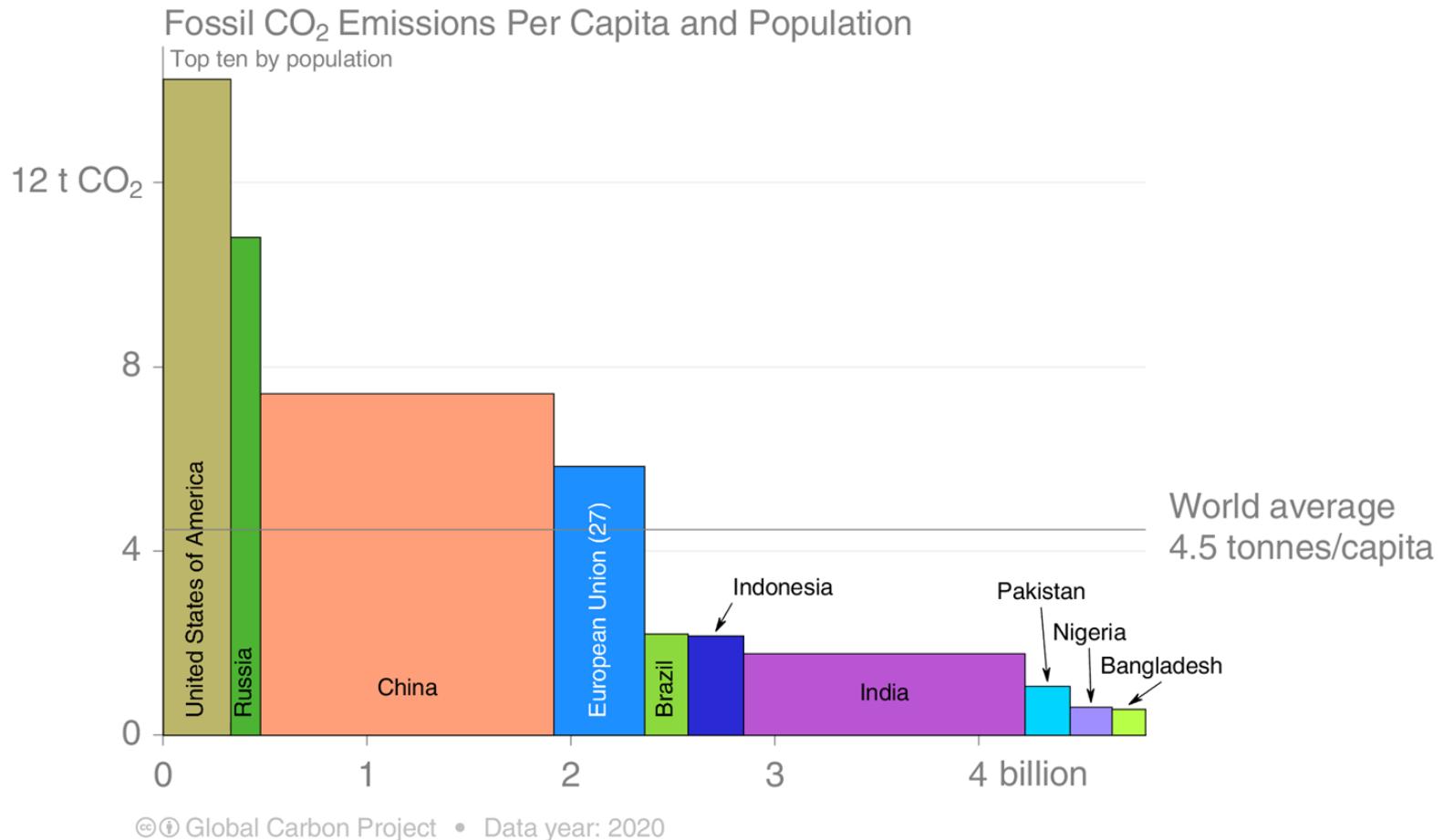
The 10 largest economies have a wide range of emission intensity of economic activity



Emission intensity: Fossil CO₂ emissions divided by Gross Domestic Product (GDP)
Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Fossil CO₂ Emissions per capita

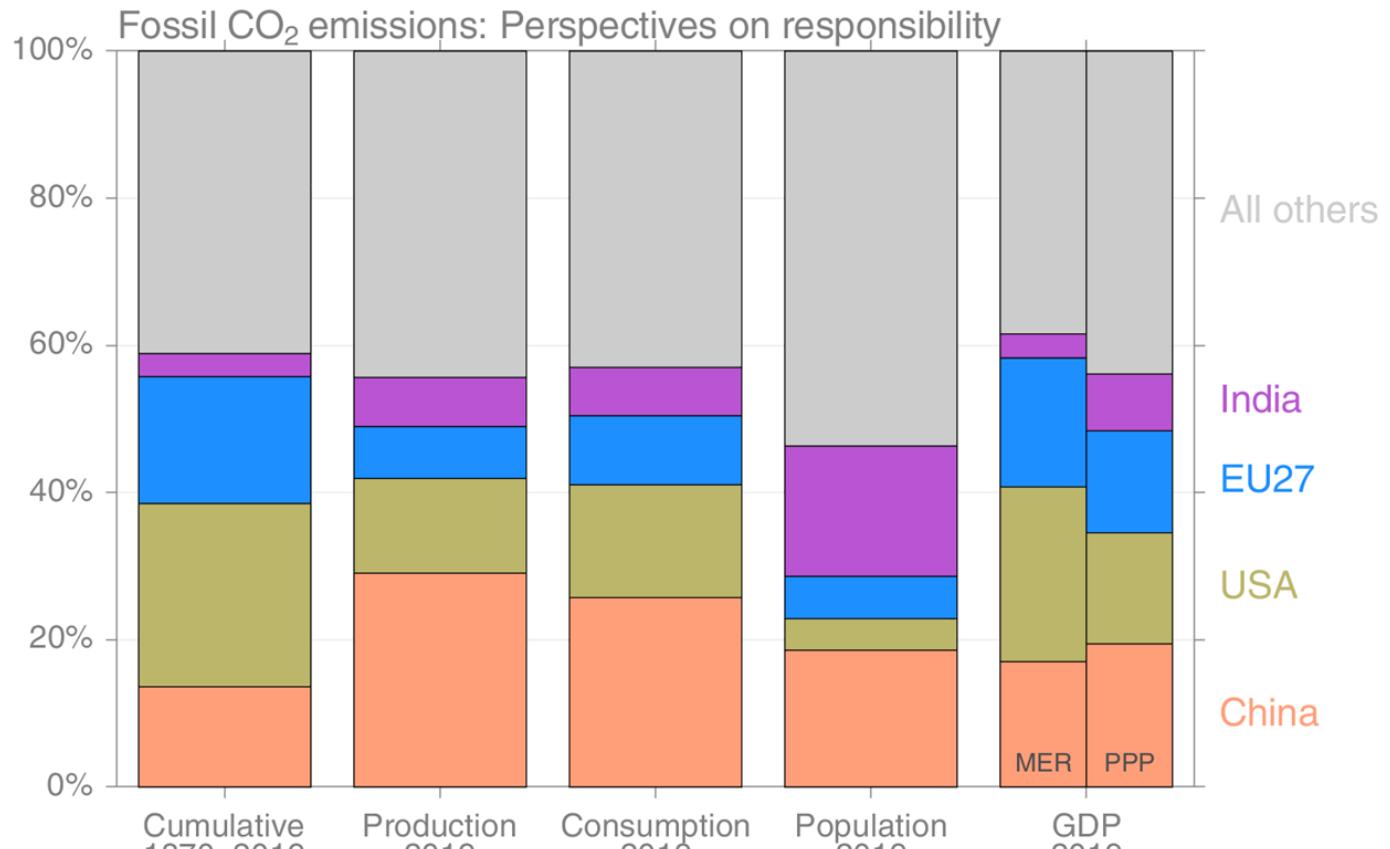
The 10 most populous countries span a wide range of development and emissions per capita



Emission per capita: Fossil CO₂ emissions divided by population
 Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Alternative rankings of countries

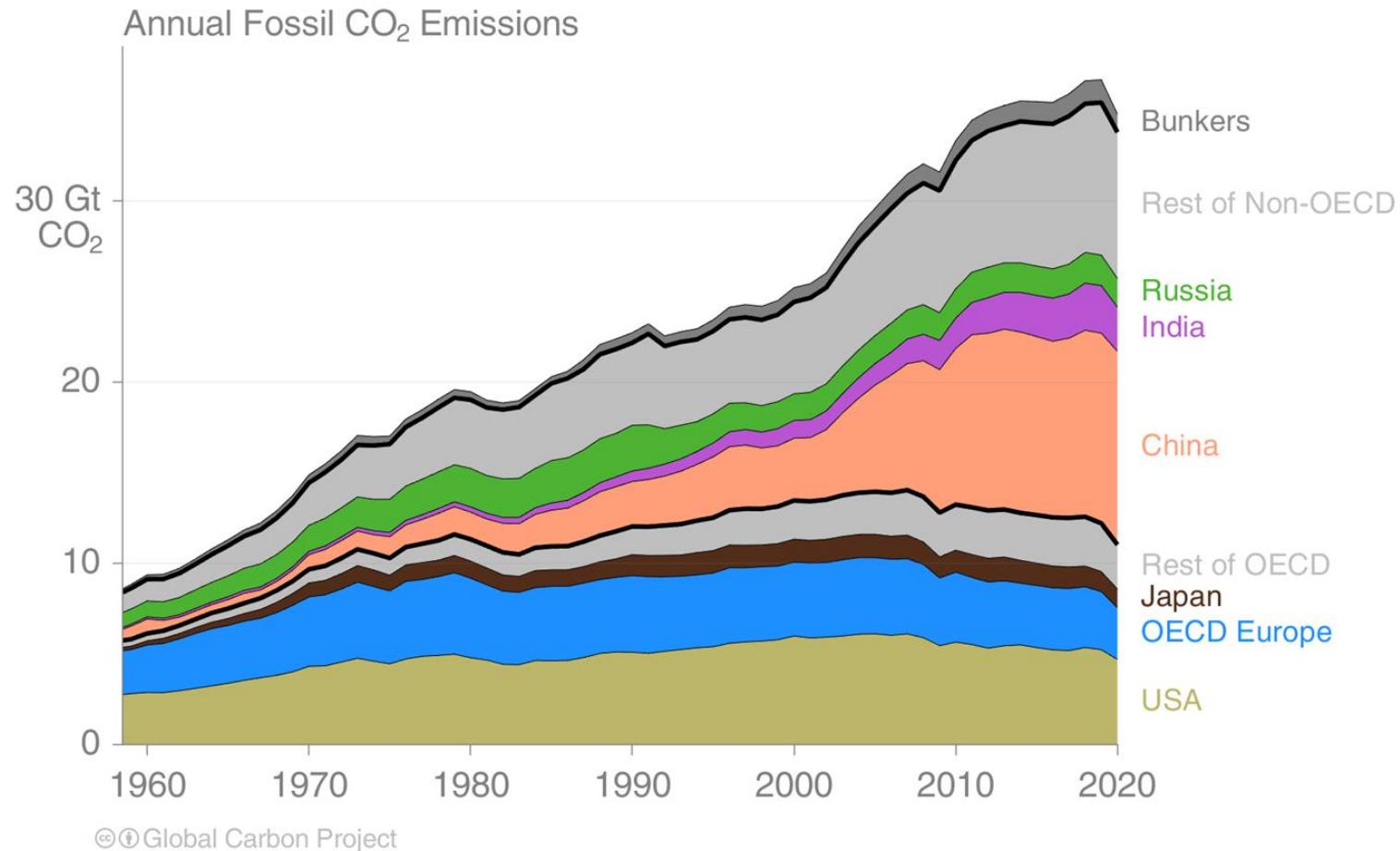
The responsibility of individual countries depends on perspective.
 Bars indicate fossil CO₂ emissions, population, and GDP.



 Global Carbon Project

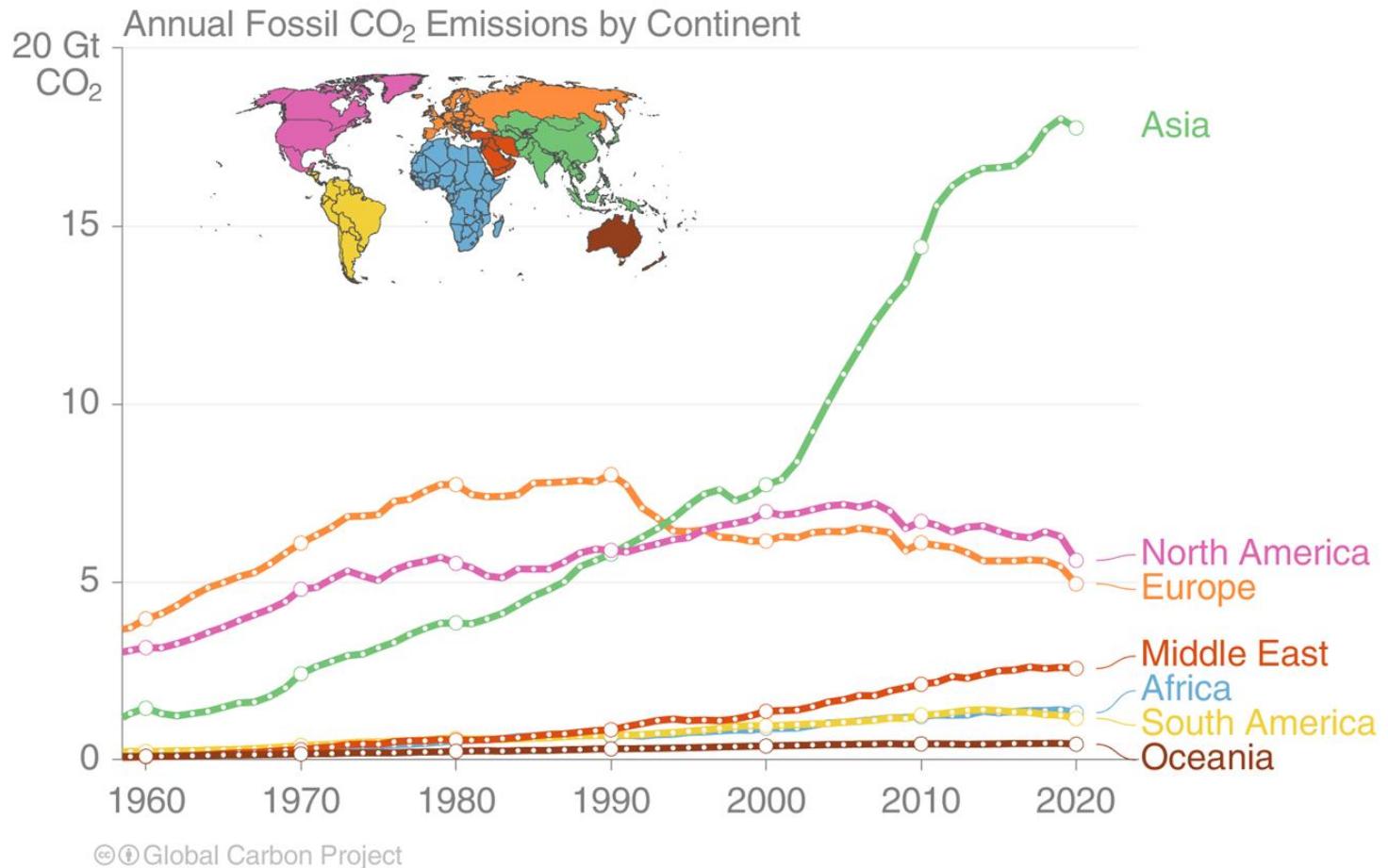
GDP: Gross Domestic Product in Market Exchange Rates (MER) and Purchasing Power Parity (PPP)
 Source: [United Nations](#); [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Breakdown of global fossil CO₂ emissions by country



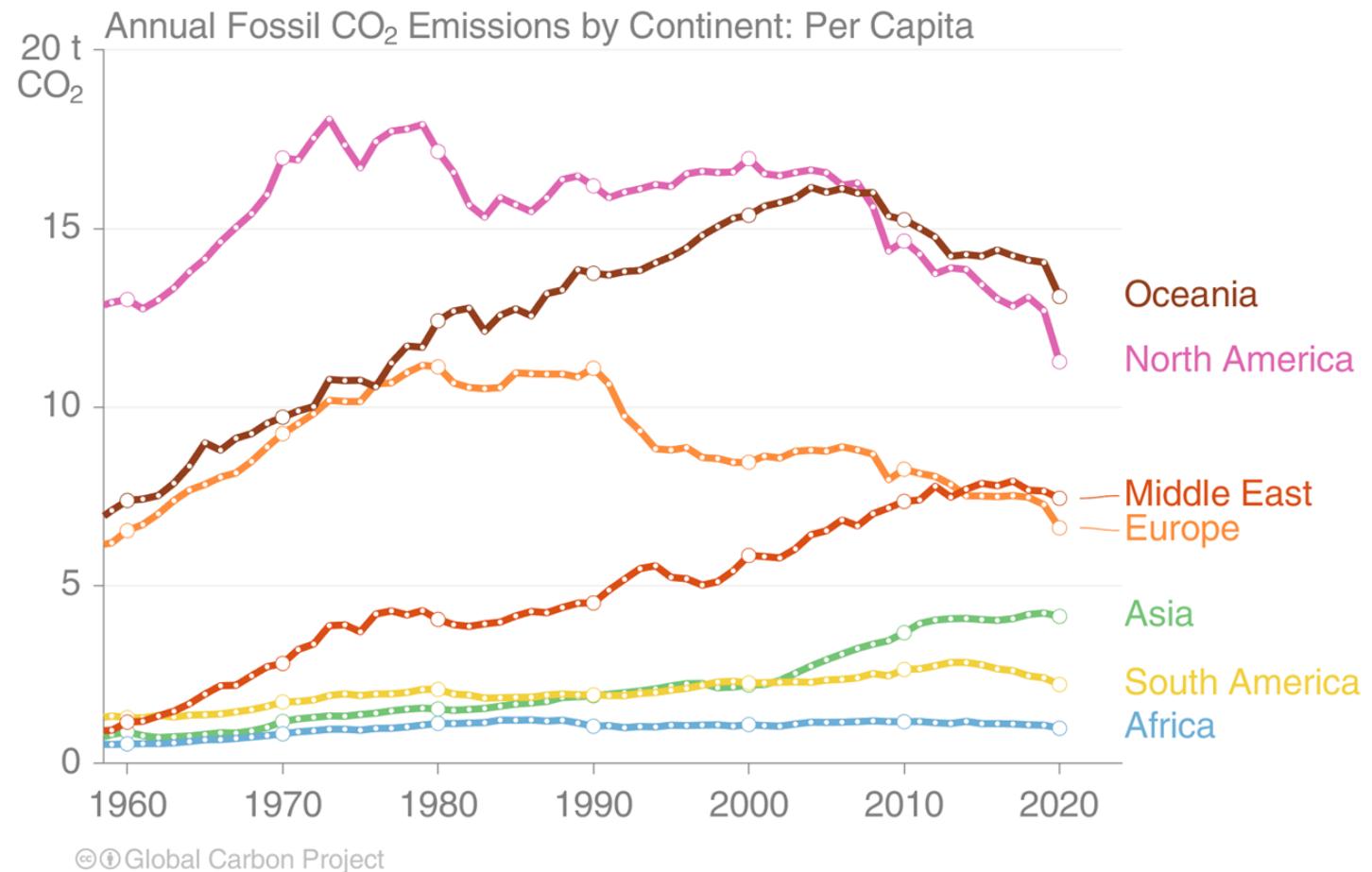
Fossil CO₂ emissions by continent

Asia dominates global fossil CO₂ emissions, while emissions in North America are of similar size to those in Europe, and the Middle East is growing rapidly.



Fossil CO₂ 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

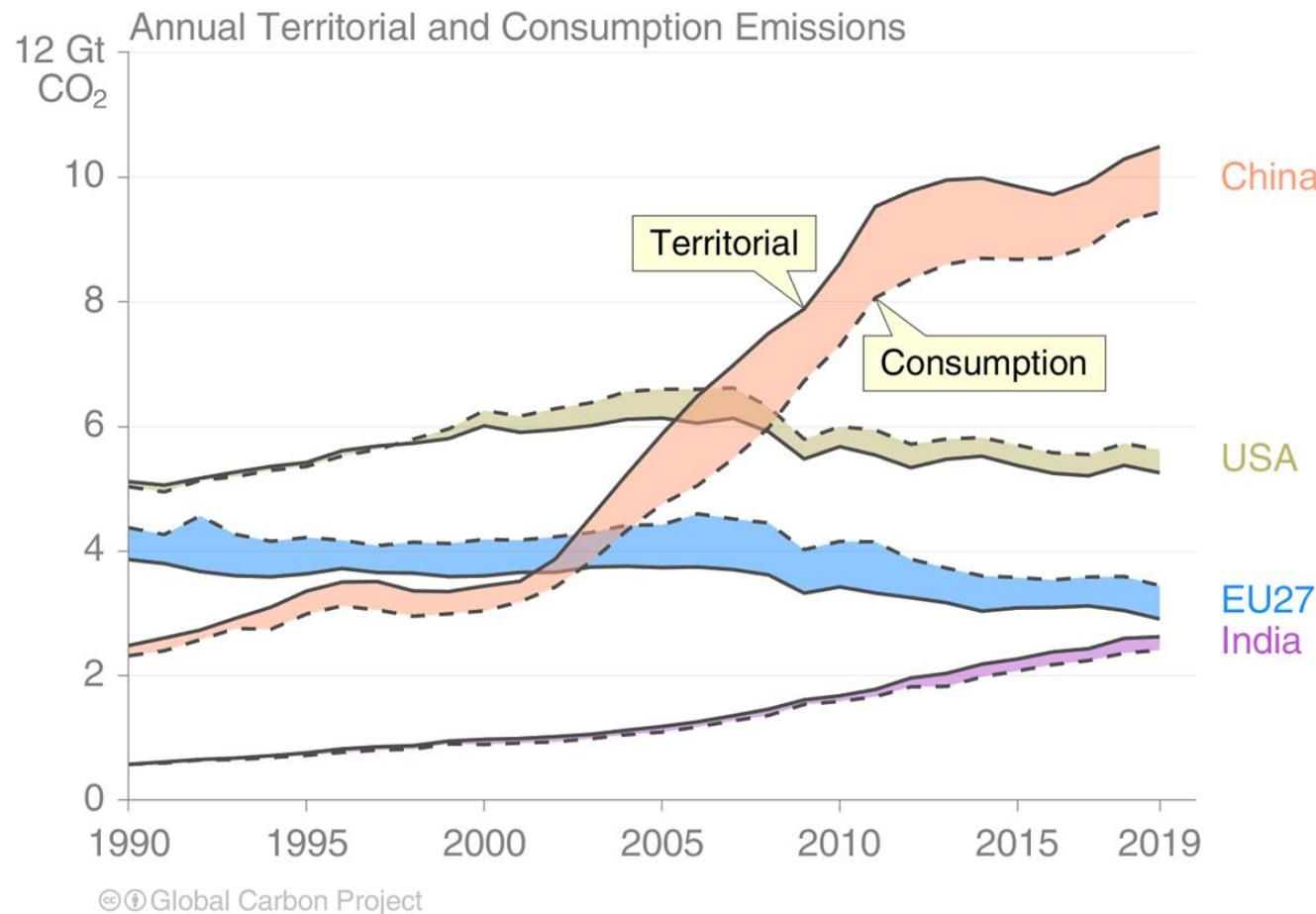
Consumption-based Emissions

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)

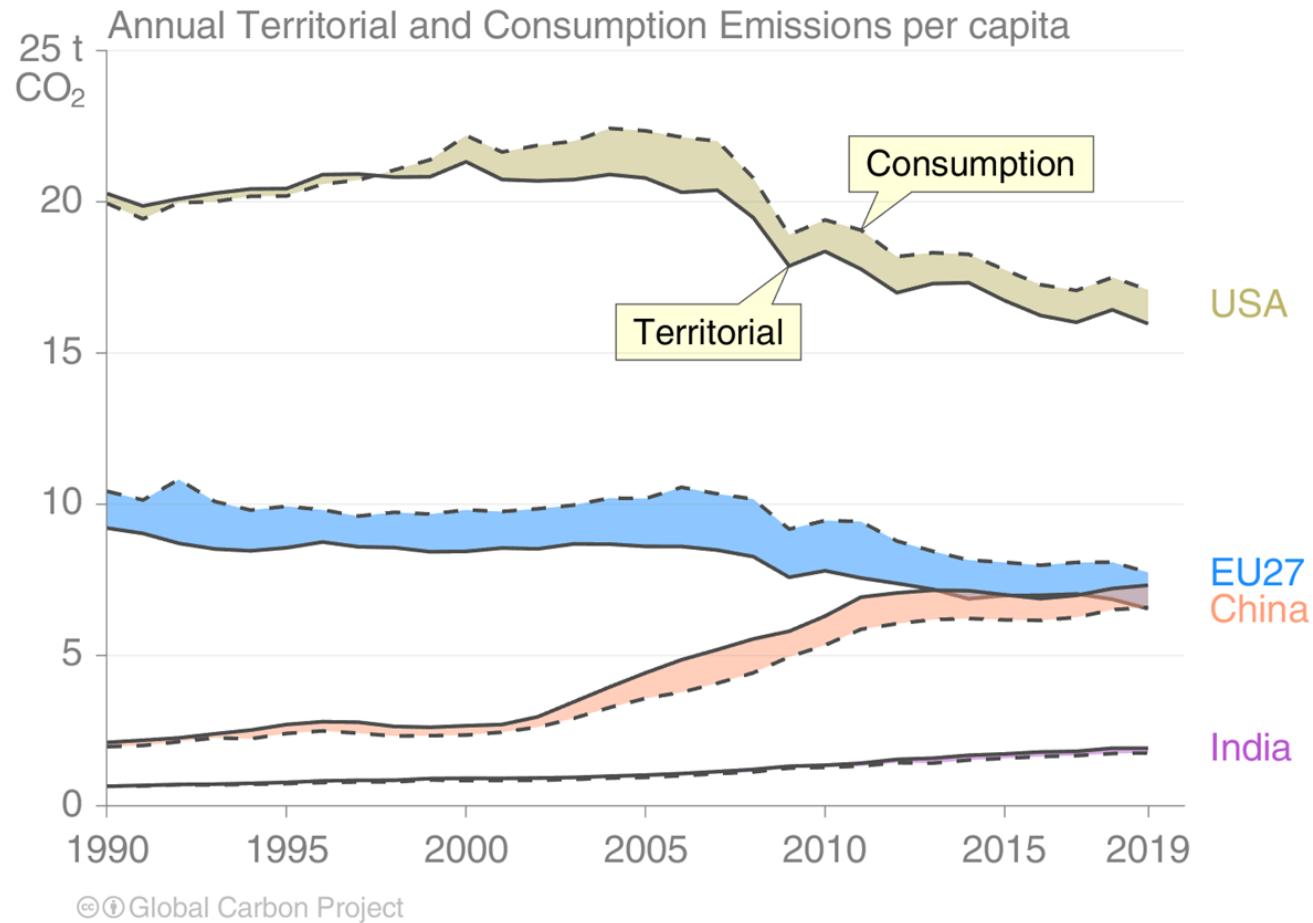
Allocating fossil CO₂ emissions to consumption provides an alternative perspective.
USA and EU28 are net importers of embodied emissions, China and India are net exporters.



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 2021](#); [Global Carbon Project 2019](#)

Consumption-based emissions per person

The differences between fossil CO₂ emissions per capita is larger than the differences between consumption and territorial emissions.

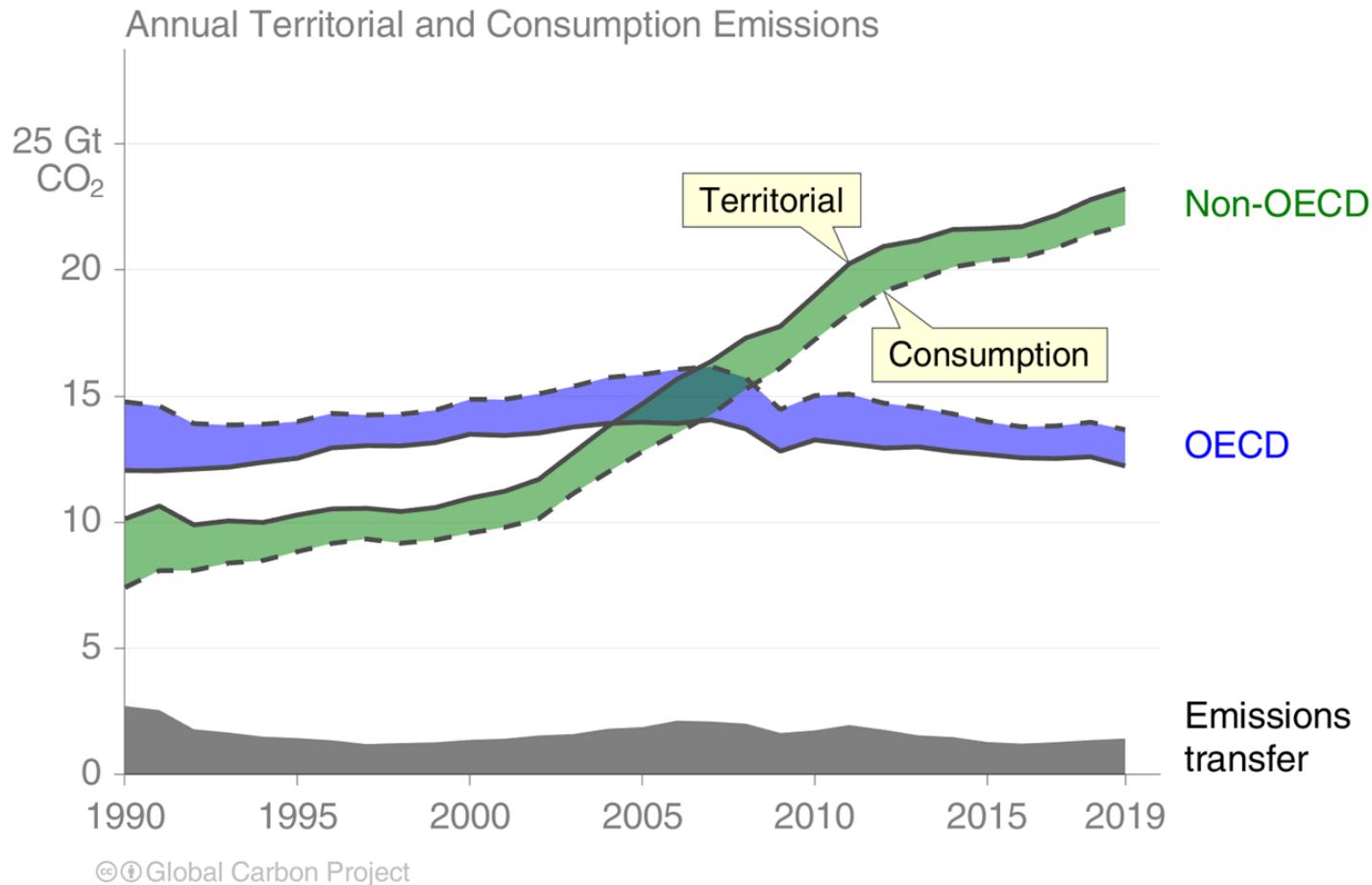


Consumption-based emissions are calculated by adjusting the standard production-based emissions to account for international trade

Source: [Peters et al 2011](#); [Friedlingstein et al 2021](#); [Global Carbon Project 2019](#)

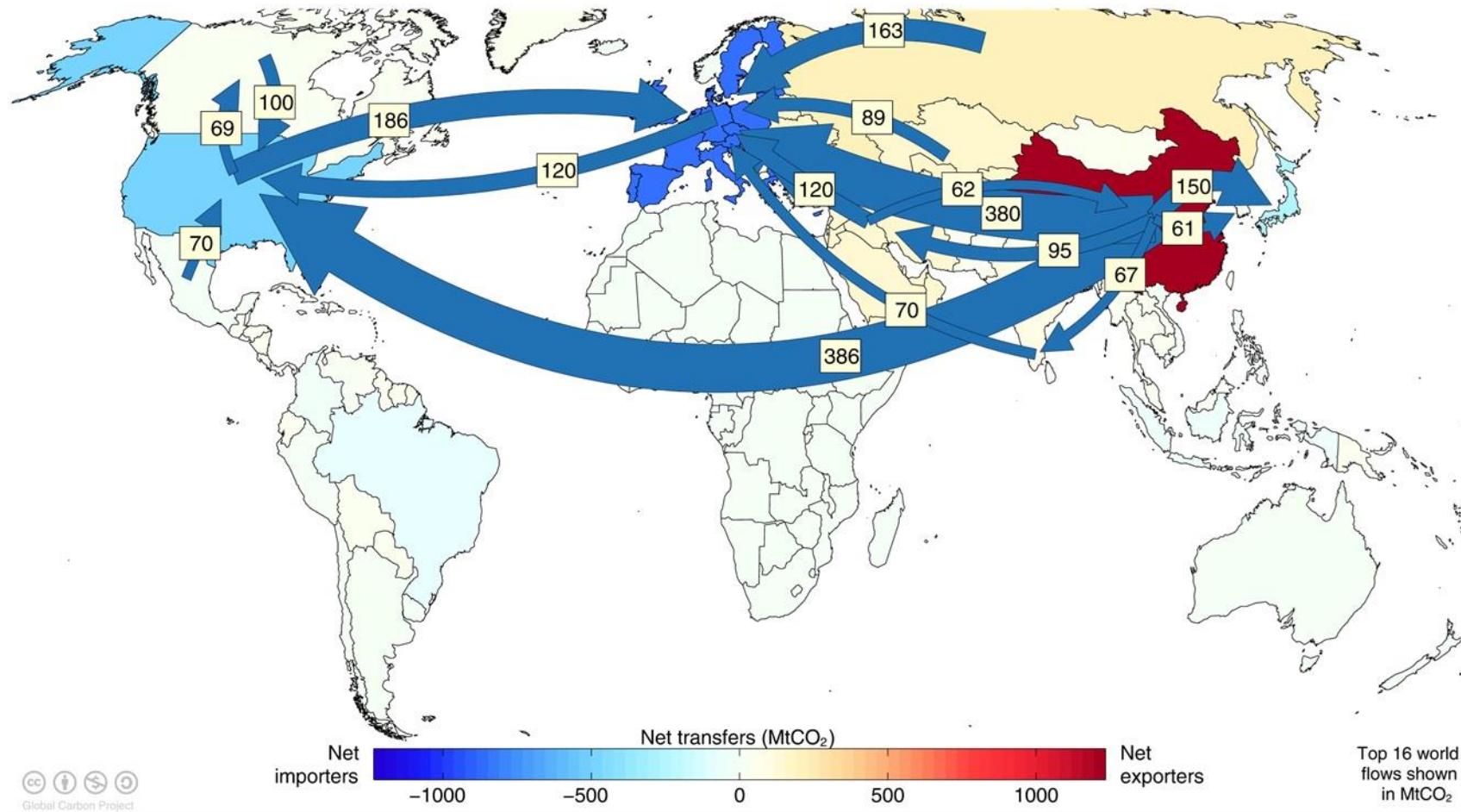
Consumption-based emissions (carbon footprint)

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



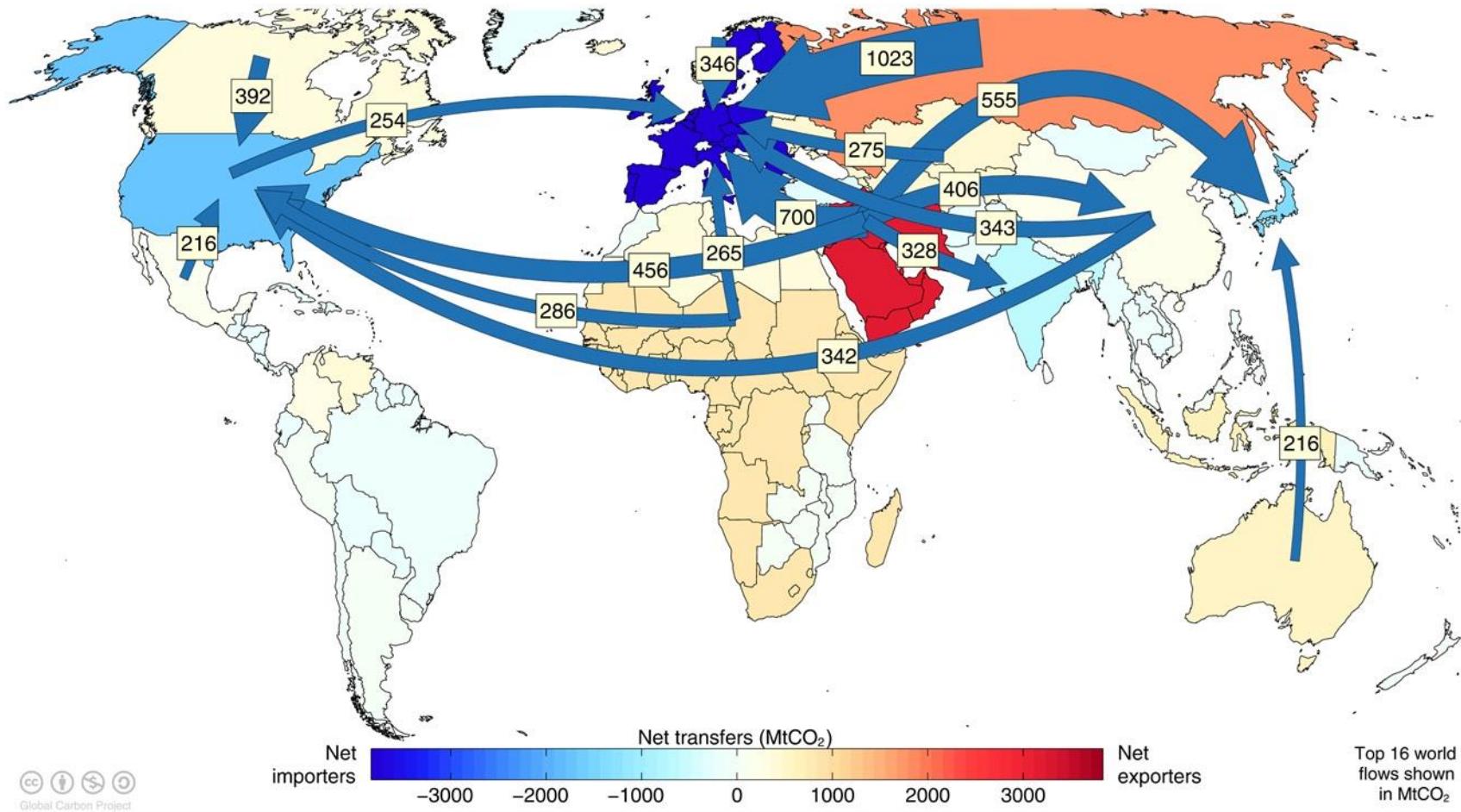
Major flows from production to consumption

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



Major flows from extraction to consumption

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



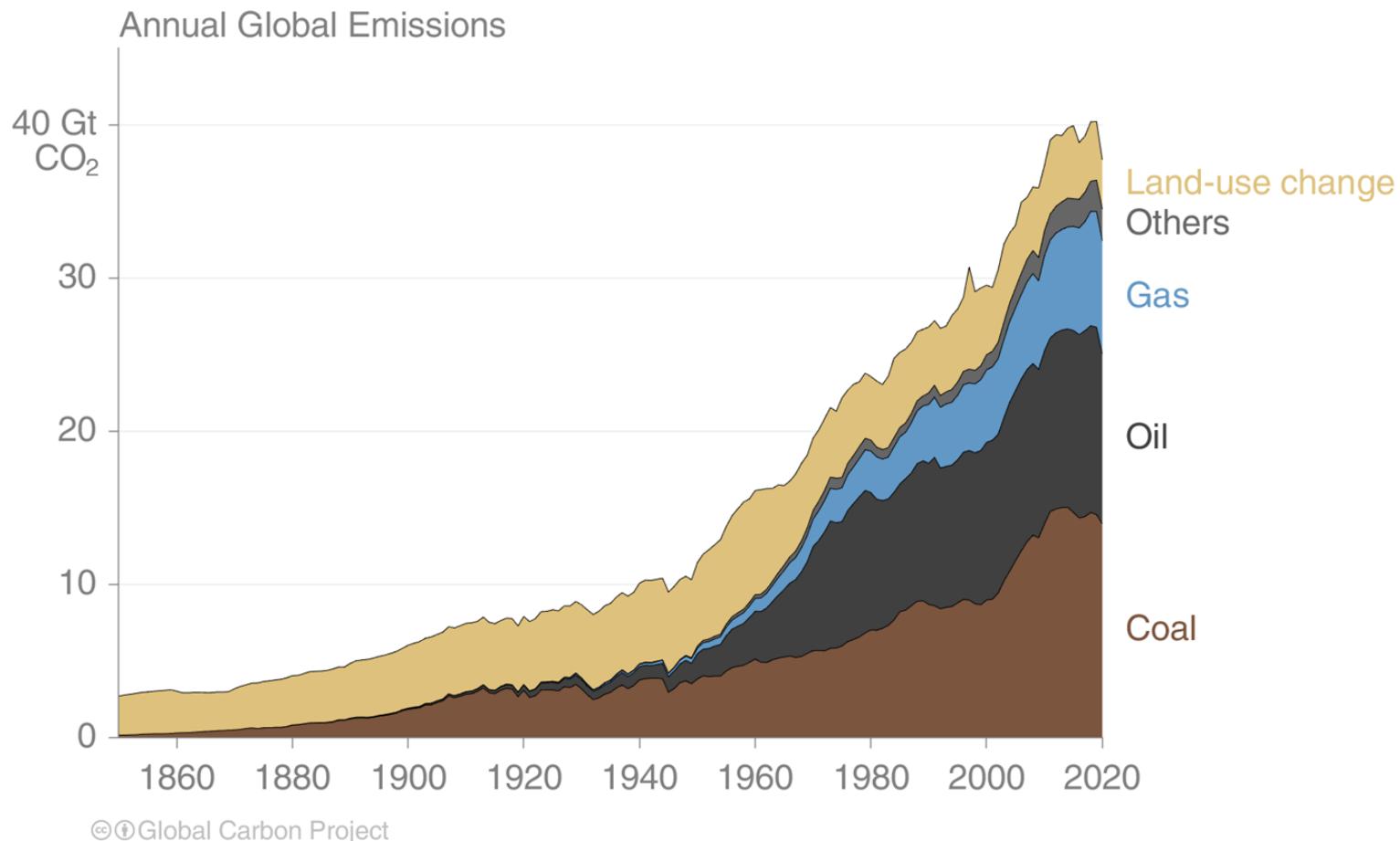
Values for 2011. EU is treated as one region. Units: MtCO_2

Source: [Andrew et al 2013](#)

Additional Figures Historical Emissions

Total global emissions by source

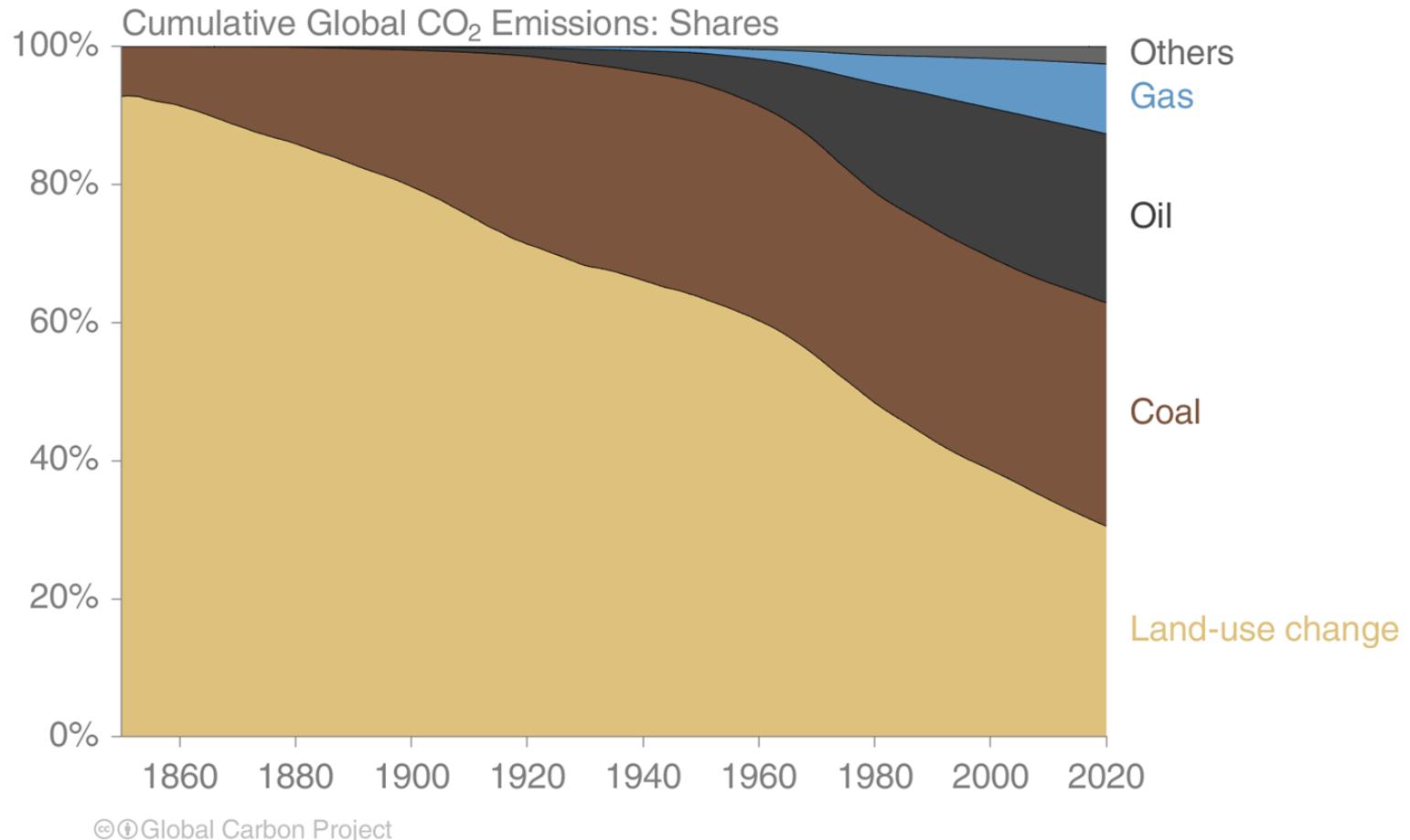
Land-use change was the dominant source of annual CO₂ emissions until around 1950.
Fossil CO₂ emissions now dominate global changes.



Others: Emissions from gas flaring and carbonate decomposition

Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

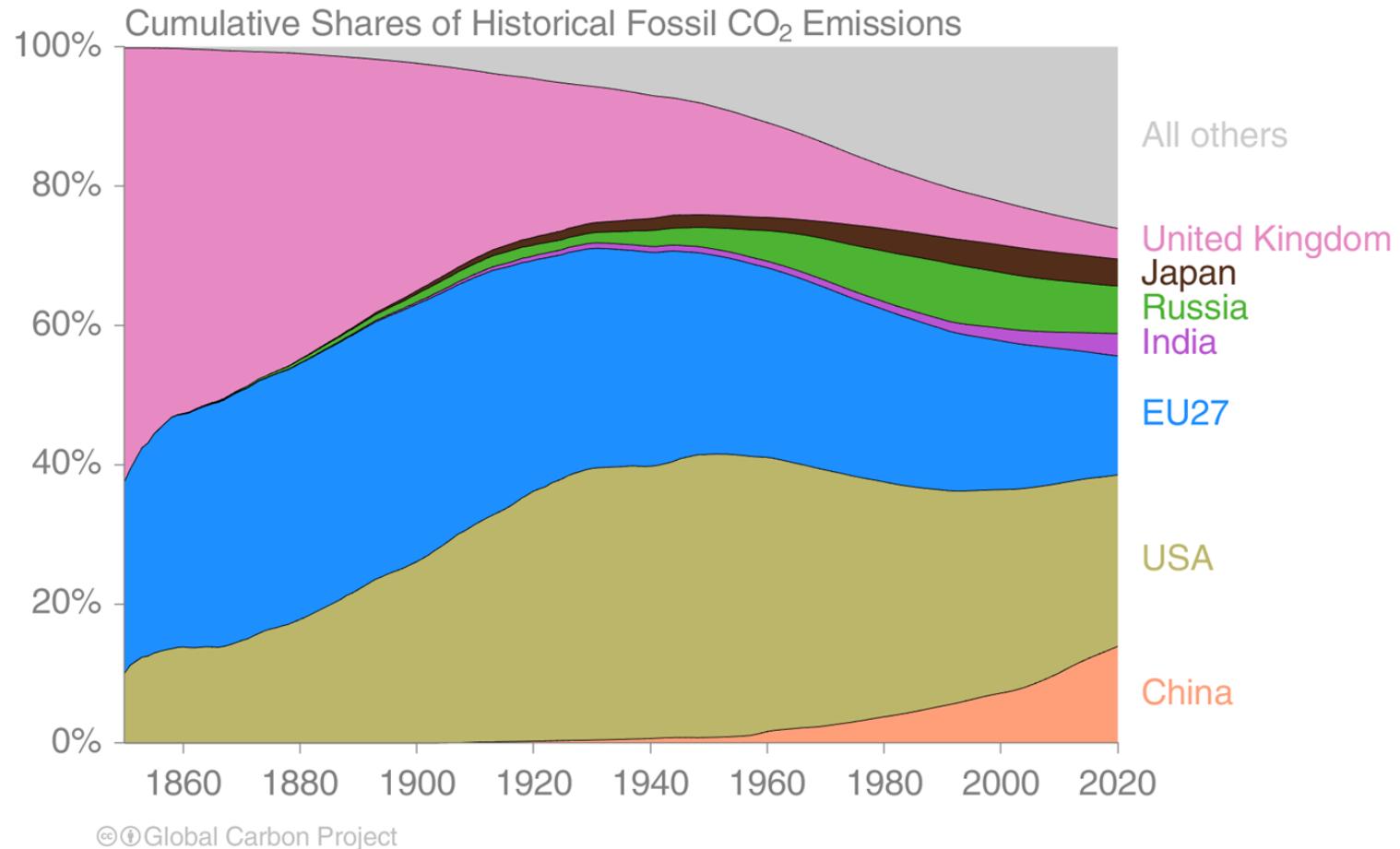
Historical cumulative emissions by source



Others: Emissions from gas flaring and carbonate decomposition

Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

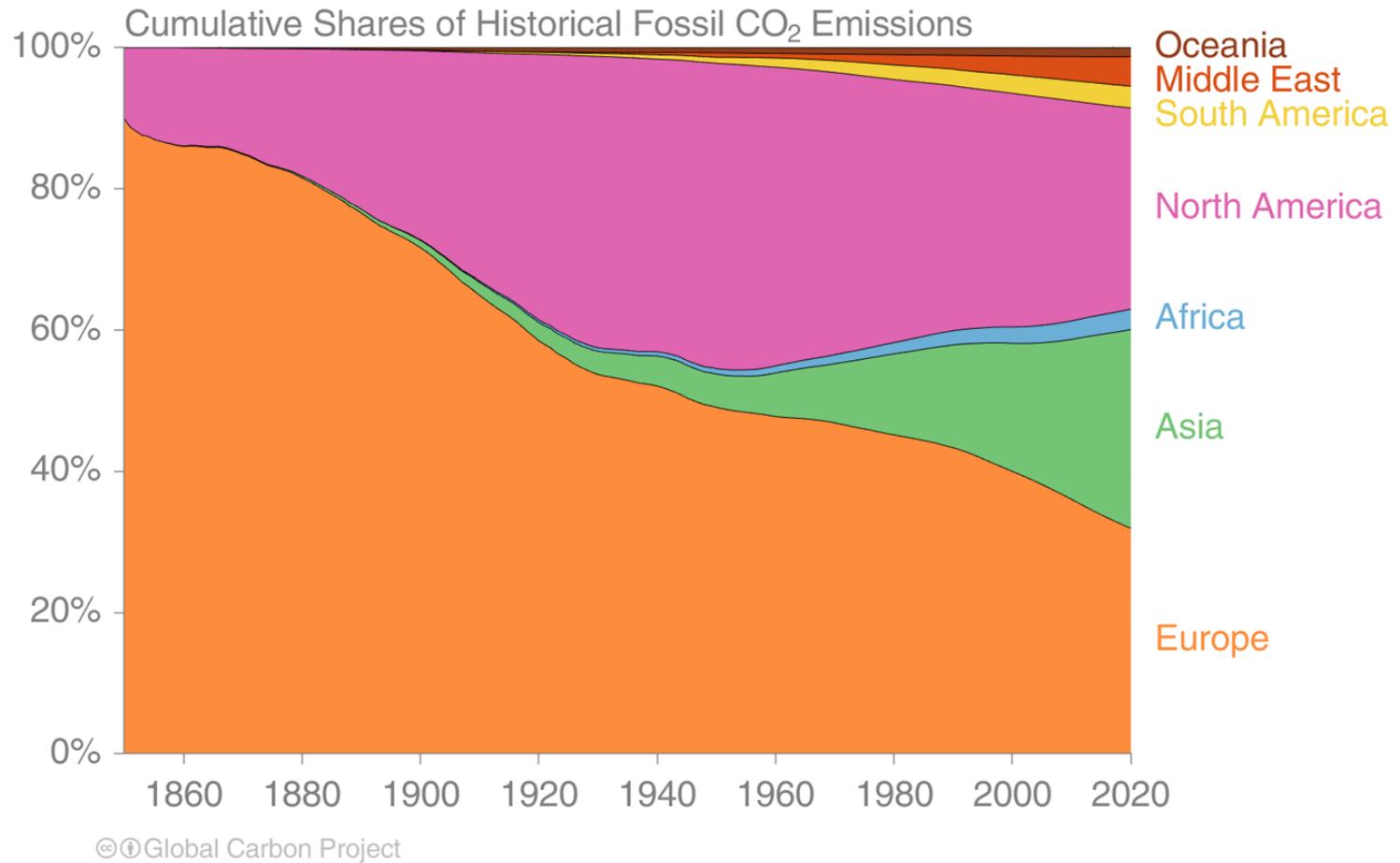
Historical cumulative fossil CO₂ emissions by country



'All others' includes all other countries along with emissions from international aviation and maritime shipping
Source: [Friedlingstein et al 2021](#); [Global Carbon Project 2021](#)

Historical cumulative emissions by continent

Cumulative fossil CO₂ emissions (1850–2020). 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 2021](#); [Global Carbon Project 2021](#)