Global Carbon Budget

2021

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

Published on 4 November 2021
PowerPoint version 1.0

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 2021)
Scripps (Keeling et al. 1976)

Fossil CO_2 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

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 SOCATv2021

Full references provided in Friedlingstein et al 2021

Contributors 94 people | 70 organisations | 18 countries

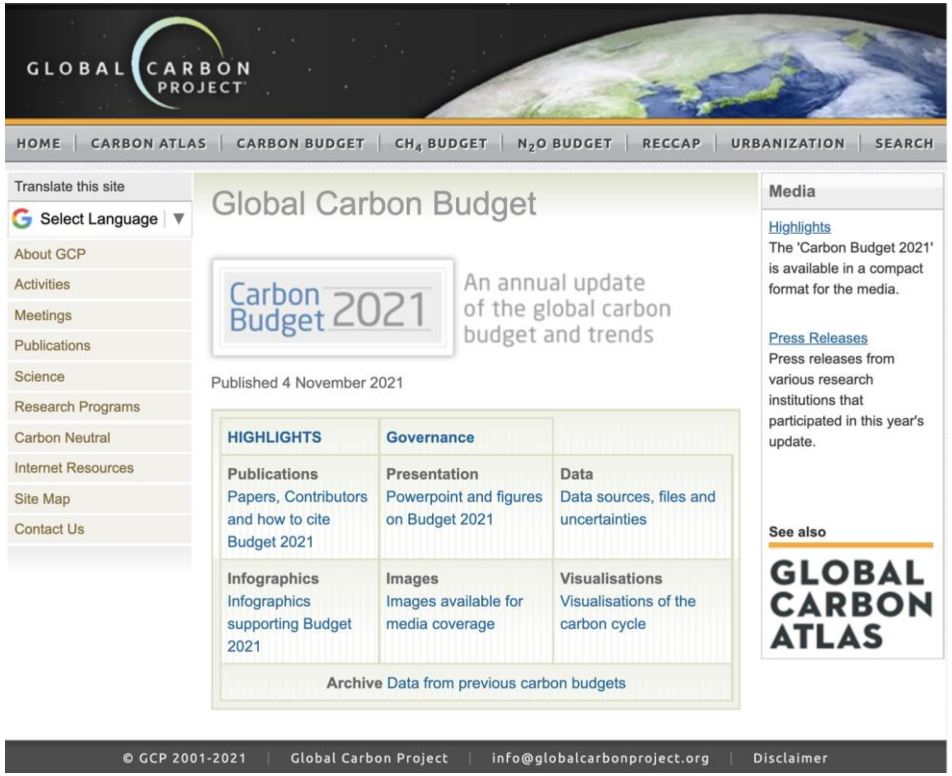
P Friedlingstein UK | **MW Jones** UK | **M O'Sullivan** UK | **RM Andrew** Norway | **DCE Bakker** UK
J Hauck Germany | **Le Quéré** UK | **GP Peters** Norway | **W Peters** Netherlands | **J Pongratz** Germany
S Sitch UK | **JG Canadell** Australia | **P Ciais** France | **RB Jackson** USA

Simone R. Alin USA | **Peter Anthoni** USA | **Nicholas R. Bates** Bermuda | **Meike Becker** Norway | **Nicolas Bellouin** UK | **Laurent Bopp** France | **Thi Tuyet Trang Chau** France | **Frédéric Chevallier** France | **Louise P. Chini** USA | **Margot Cronin** Ireland | **Kim I. Currie** New Zealand | **Bertrand Decharme** France | **Laique M. Djeutchouang** South Africa | **Xinyu Dou** China | **Wiley Evans** Canada | **Richard A. Feely** USA | **Liang Feng** UK | **Thomas Gasser** Austria | **Dennis Gilfillan** USA | **Thanos Gkritzalis** Belgium | **Giacomo Grassi** Italy | **Luke Gregor** Switzerland | **Nicolas Gruber** Switzerland | **Özgür Gürses** Germany | **Ian Harris** UK| **Richard A. Houghton** USA | **George Hurtt** USA | **Yosuke Iida** Japan | **Tatiana Ilyina** Germany | **Ingrid T. Luijkx** Netherlands | **Atul K. Jain** USA | **Steve D. Jones** UK | **Etsushi Kato** Japan | **Daniel Kennedy** USA | **Kees Klein Goldewijk** Netherlands | **Jürgen Knauer** Australia | **Jan Ivar Korsbakken** Norway | **Arne Körtzinger** Germany | **Peter Landschützer** Germany | **Siv K. Lauvset** Norway | **Nathalie Lefèvre** France | **Sebastian Lienert** Switzerland | **Zhu Liu** China | **Danica Lombardozzi** USA | **Gregg Marland** USA | **Nicolas Metzl** France | **David R. Munro** USA | **Junjie Liu** USA | **Gregg Marland** USA | **Patrick C. McGuire** UK | **Joe R. Melton** Canada | **David R. Munro** USA | **Julia E. M. S. Nabel** Germany | **Shin-ichiro Nakaoka** Japan | **Yosuke Niwa** Japan | **Tsuneo Ono** Japan | **Denis Pierrot** USA | **Benjamin Poulter** USA | **Gregor Rehder** Germany | **Laure Resplandy** USA | **Eddy Robertson** UK | **Christian Rödenbeck** Germany | **Thais M Rosan** UK | **Jörg Schwinger** Norway | **Clemens Schwingshackl** Germany | **Roland Séférian** France | **Adrienne J. Sutton** USA | **Colm Sweeney** USA | **Toste Tanhua** Germany | **Pieter P. Tans** USA | **Hanqin Tian** USA | **Bronte Tilbrook** Australia | **Francesco Tubiello** Italy | **Guido R. van der Werf** Netherlands | **Nicolas Vuichard** France | **Chisato Wada** Japan | **Rik Wanninkhof** USA | **Andrew J. Watson** UK | **David Willis** UK | **Andrew J. Wiltshire** UK | **Wenping Yuan** China | **Chao Yue** France | **Xu Yue** China | **Sönke Zaehle** Germany | **Jiye Zeng** Japan

Atlas Team Members at LSCE, France
P Ciais | **A Peregon** | **P Brockmann**

Communications Team
Davies | **A Morrison** | **C Bartman** | **N Hawtin** | **K Mansell**

Data Access and Additional Resources

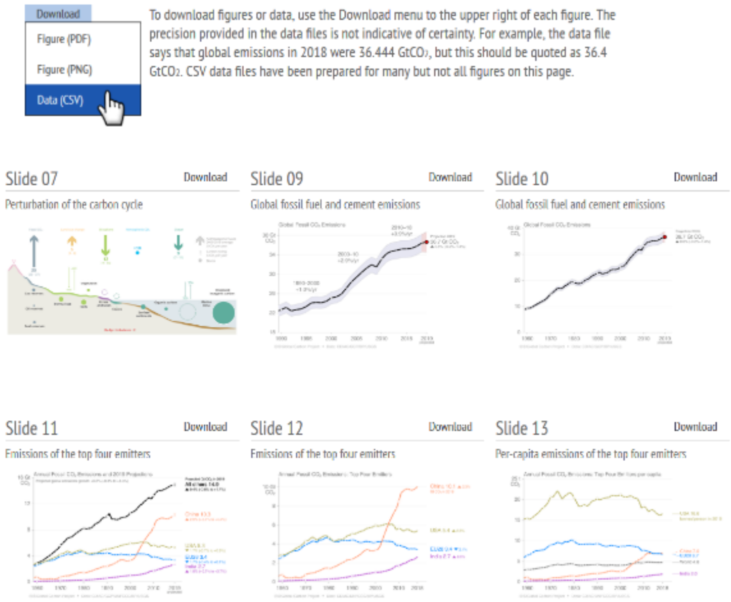


More information, data sources and data files:
http://www.globalcarbonproject.org/carbonbudget
Contact: Pep.Canadell@csiro.au

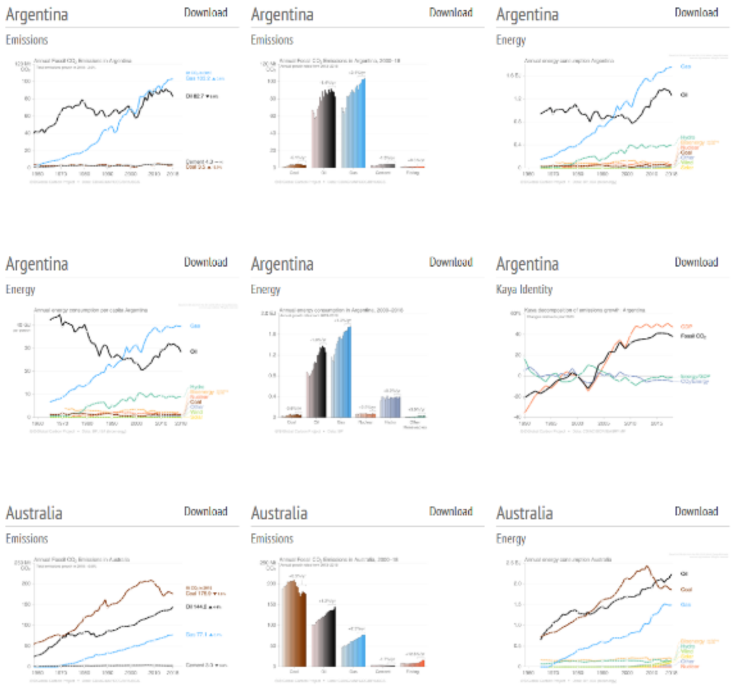
More information, data sources and data files:
www.globalcarbonatlas.org
(co-funded in part by BNP Paribas Foundation)
Contact: philippe.ciais@lsce.ipsl.fr

Download of figures and data

Global Carbon Budget



Additional country figures



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

GLOBAL CARBON PROJECT

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 in units of GtC and $GtCO_2$ 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.

Disclaimer

The Global Carbon Budget and the information presented here are intended for those interested in learning about the carbon cycle, and how human activities are changing it. The information contained herein is provided as a public service, with the understanding that the Global Carbon Project team make no warranties, either expressed or implied, concerning the accuracy, completeness, reliability, or suitability of the information.

License

Global Carbon Project

Our intention is that these figures and data are used. That's why they're released under the *Creative Commons Attribution 4.0 International license*. Simply put, you may freely copy and modify these figures and data, and use them in both commercial and non-commercial works, as long as you give credit to the Global Carbon Project.

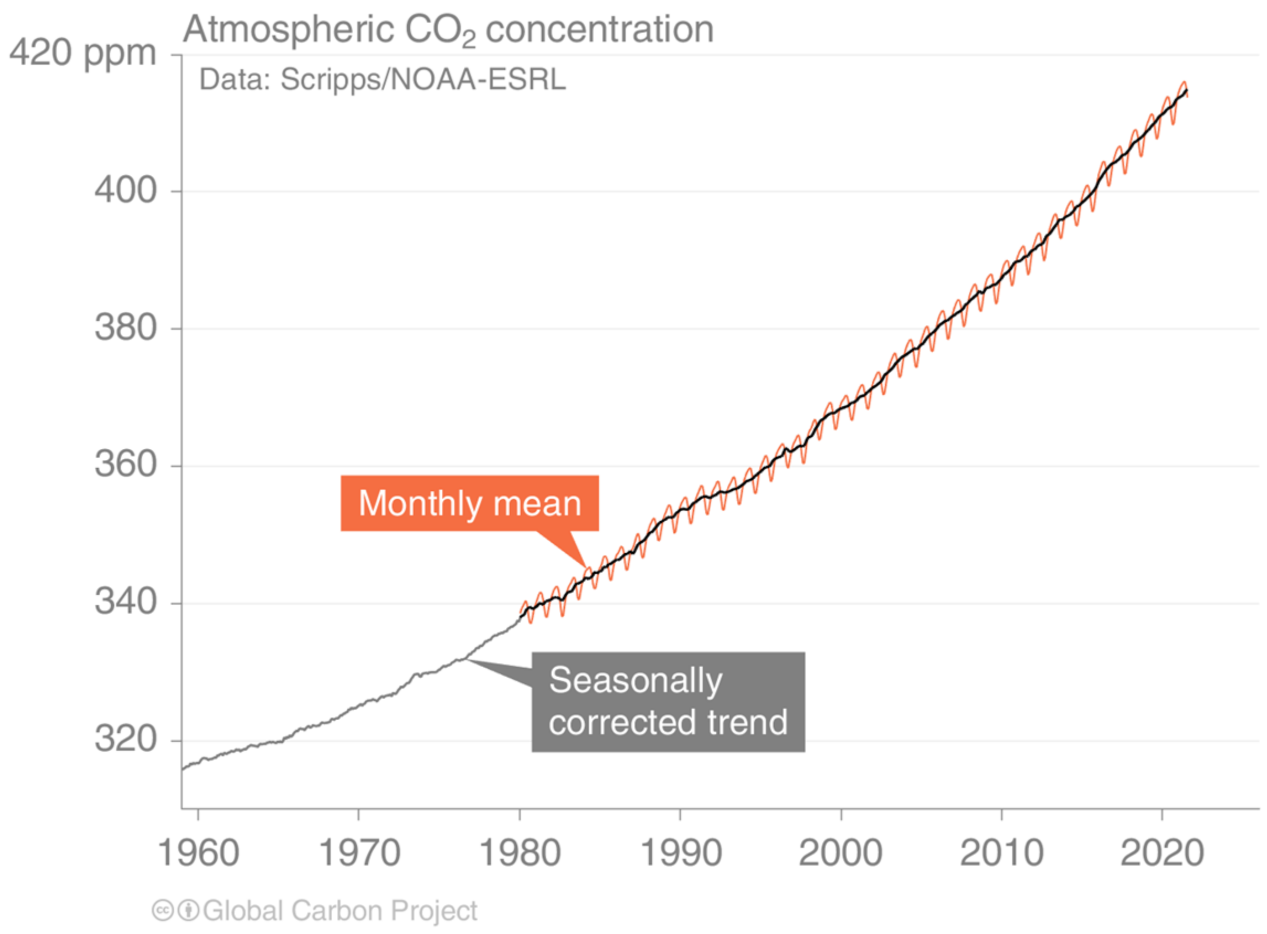
If you're just tweeting a figure or using a figure in a presentation, then it already says at the bottom that it's by the Global Carbon Project, so you're good to go! If you use the data directly or modify the figure then you will need to make sure the attribution is in place.

For details on the license, visit the Creative Commons website.

Suggested citation for use in a book: "Used with permission of the Global Carbon Project under the Creative Commons Attribution 4.0 International license."

Atmospheric CO_2 concentration

The global CO_2 concentration increased from ~277 ppm in 1750 to 415 ppm in 2021 (up 49%)

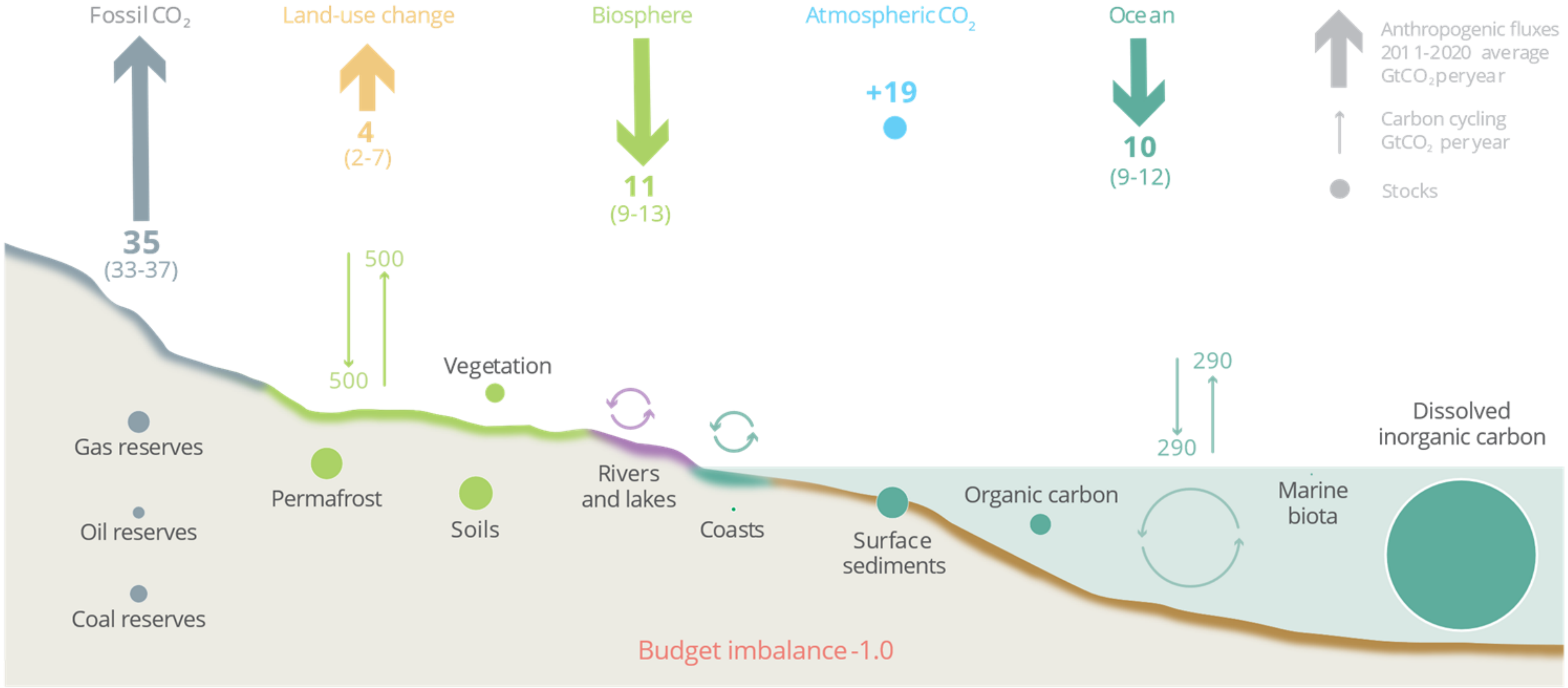


Globally averaged surface atmospheric CO_2 concentration. Data from: NOAA-ESRL after 1980; the Scripps Institution of Oceanography before 1980

Source: NOAA-ESRL; Scripps Institution of Oceanography; Friedlingstein et al 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 ($GtCO_2$/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 CO_2 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

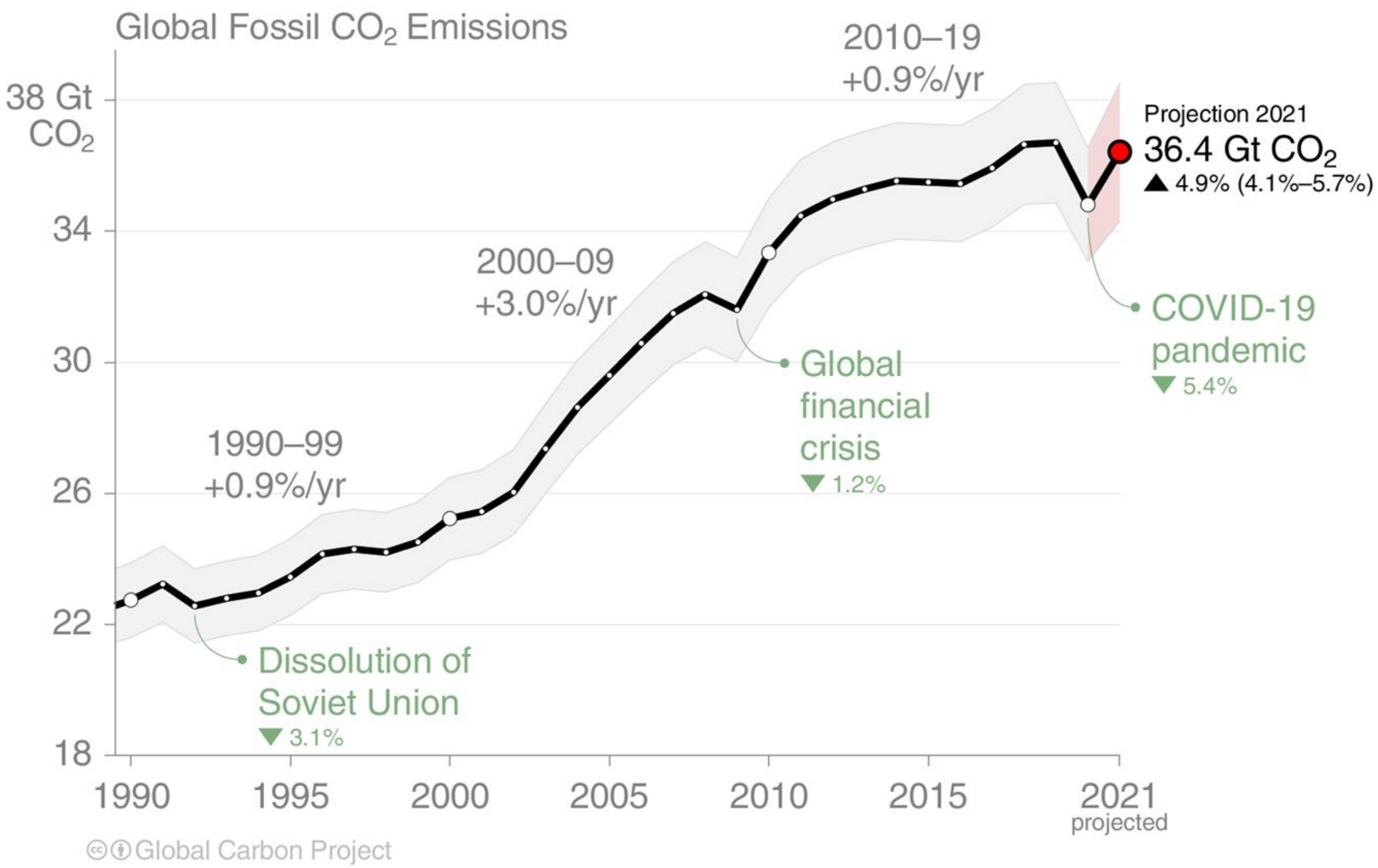
*IAS: Emissions from use of international aviation and maritime shipping bunker fuels are not usually included in national totals

Source: Friedlingstein et al 2021; Global Carbon Project 2021

Global Fossil CO_2 Emissions

Global fossil CO_2 emissions: 34.8 ± 2 $GtCO_2$ in 2020, 53% over 1990

Projection for 2021: 36.4 ± 2 $GtCO_2$, 4.9% [4.1%–5.7%] higher than 2020

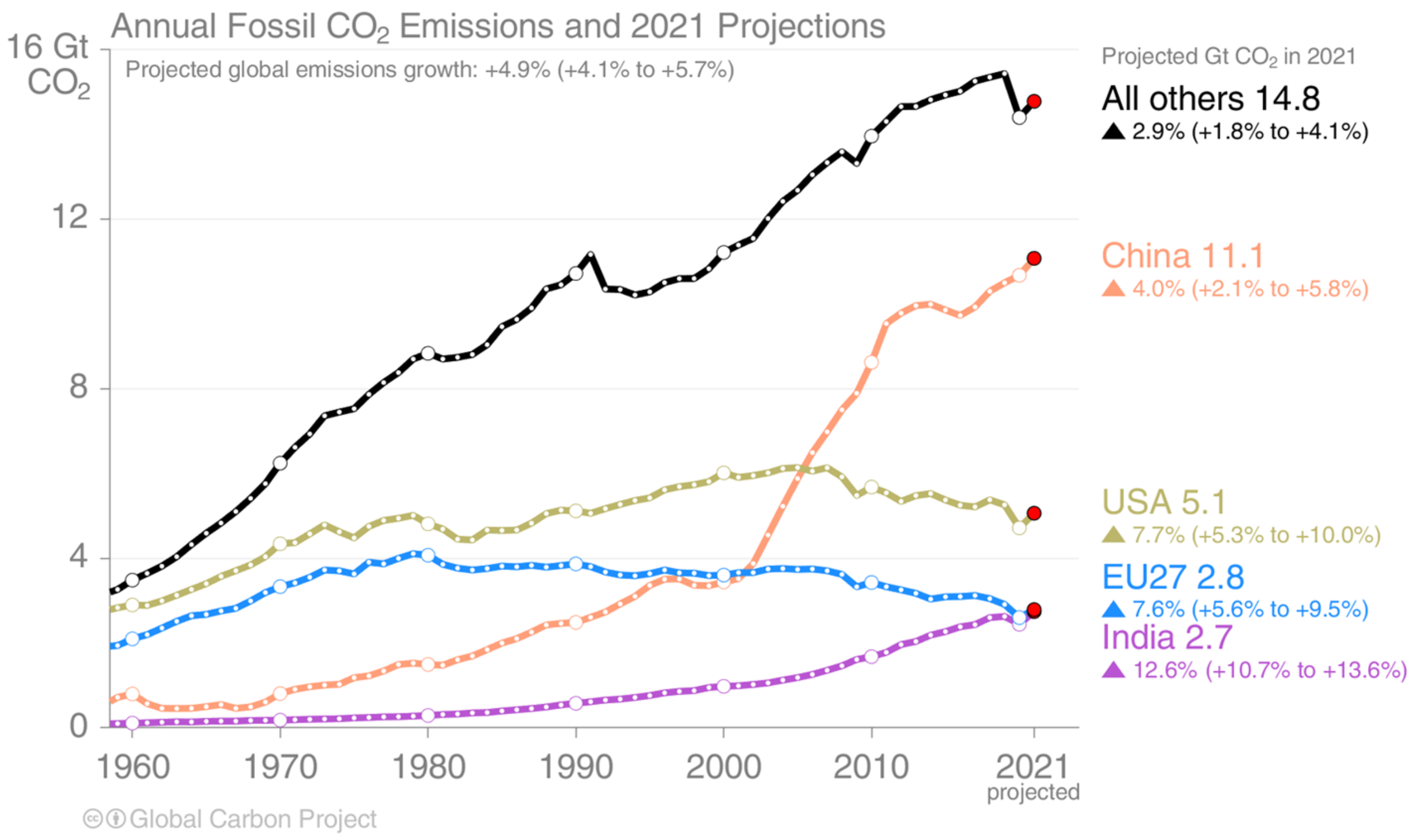


Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

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 CO_2 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 CO_2 emissions growth: 2019–2021

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

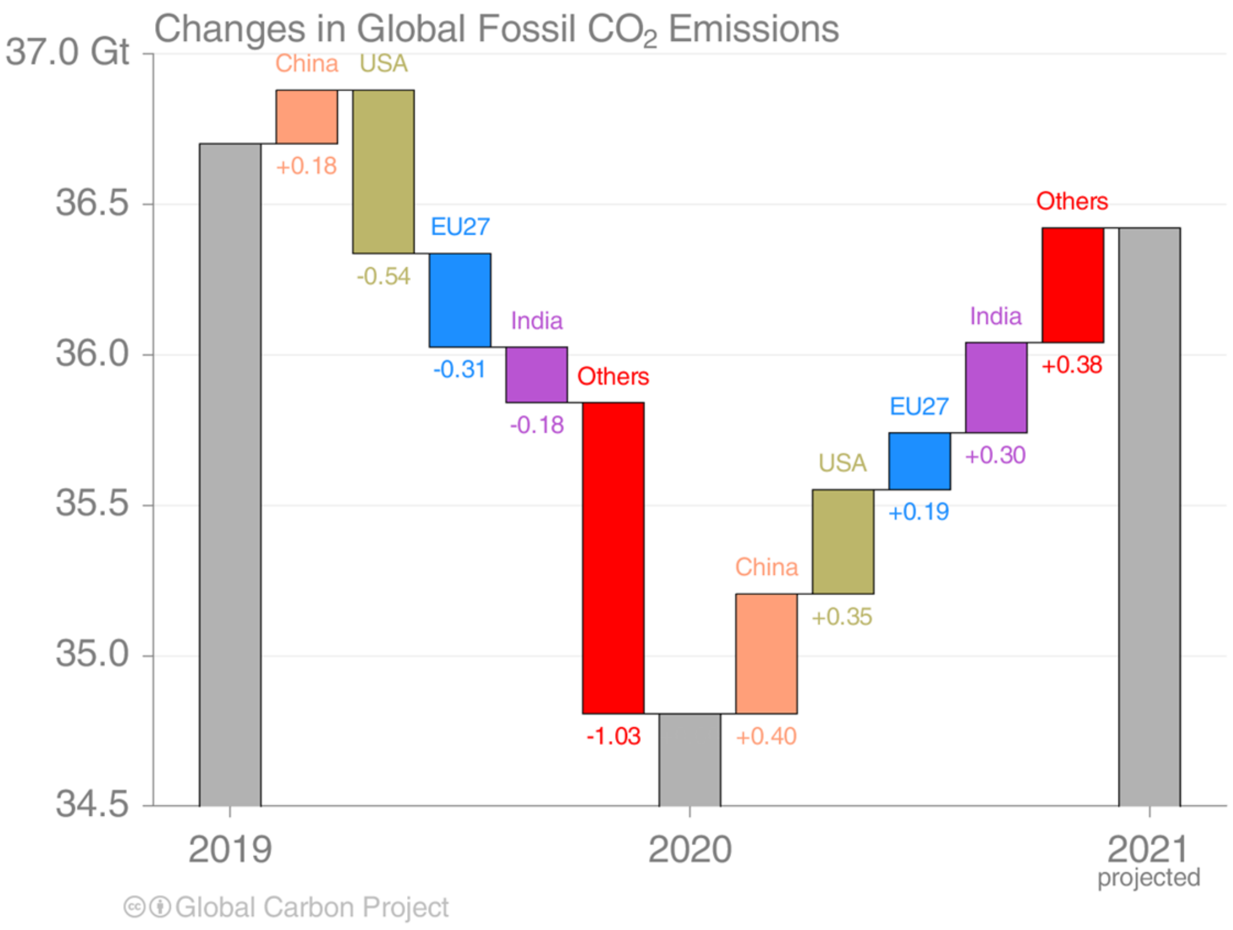
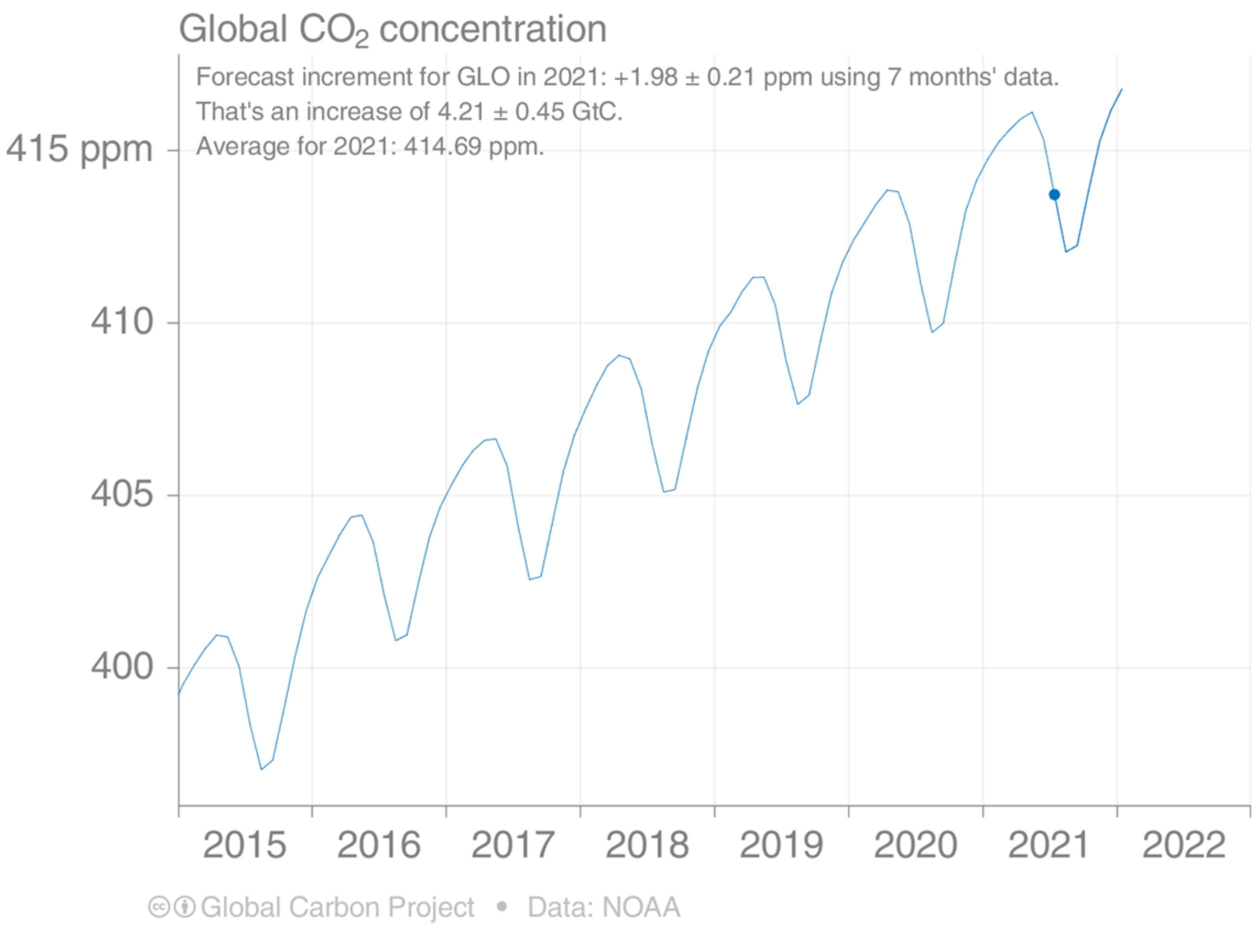


Figure shows the top four countries contributing to emissions changes

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

Forecast of global atmospheric CO_2 concentration

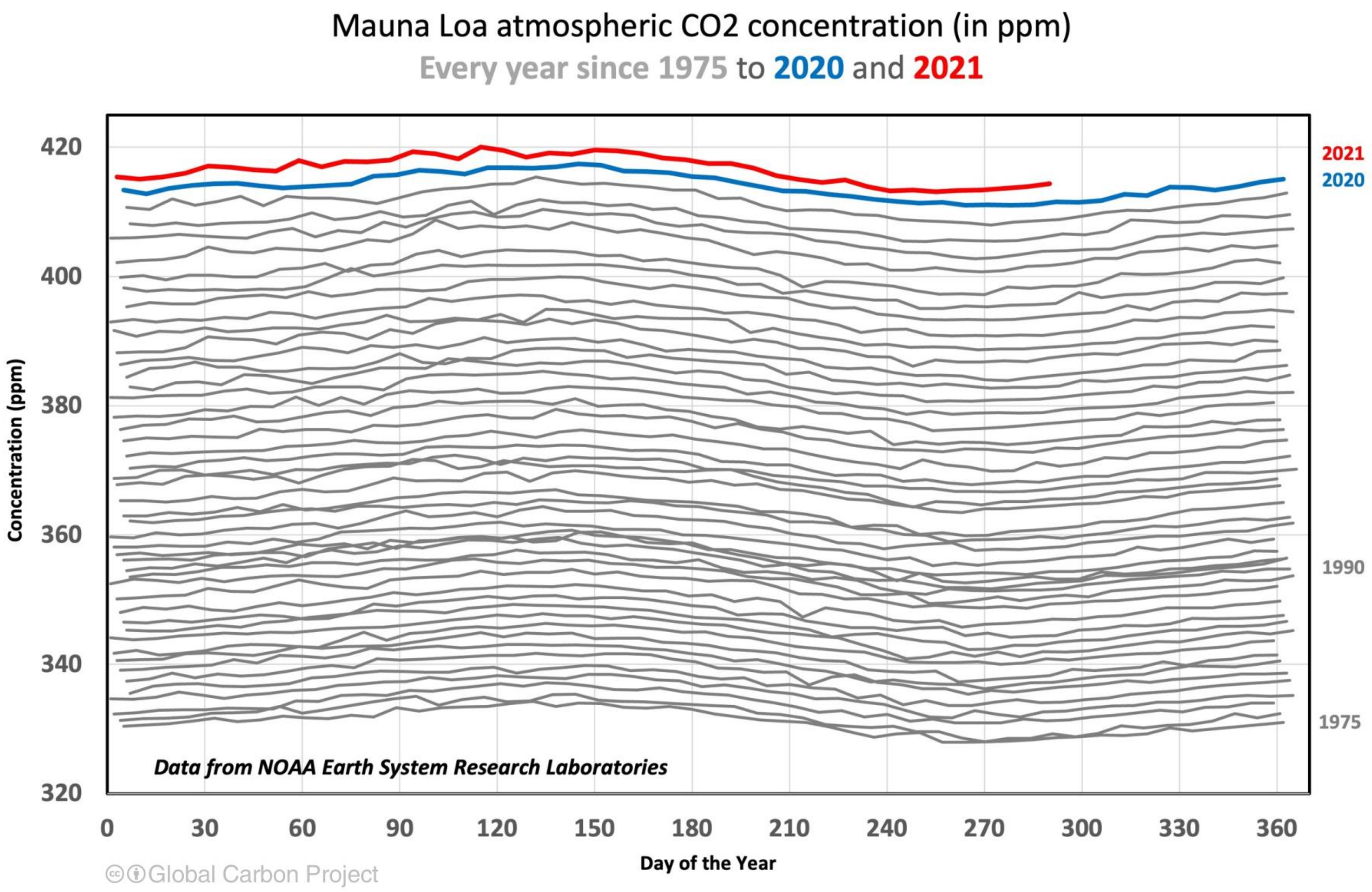
The global atmospheric CO_2 concentration is forecast to average 415 parts per million (ppm) in 2021, increasing by 2.0 ppm



Source: Friedlingstein et al 2021; Global Carbon Budget 2021

Mauna Loa atmospheric CO_2

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

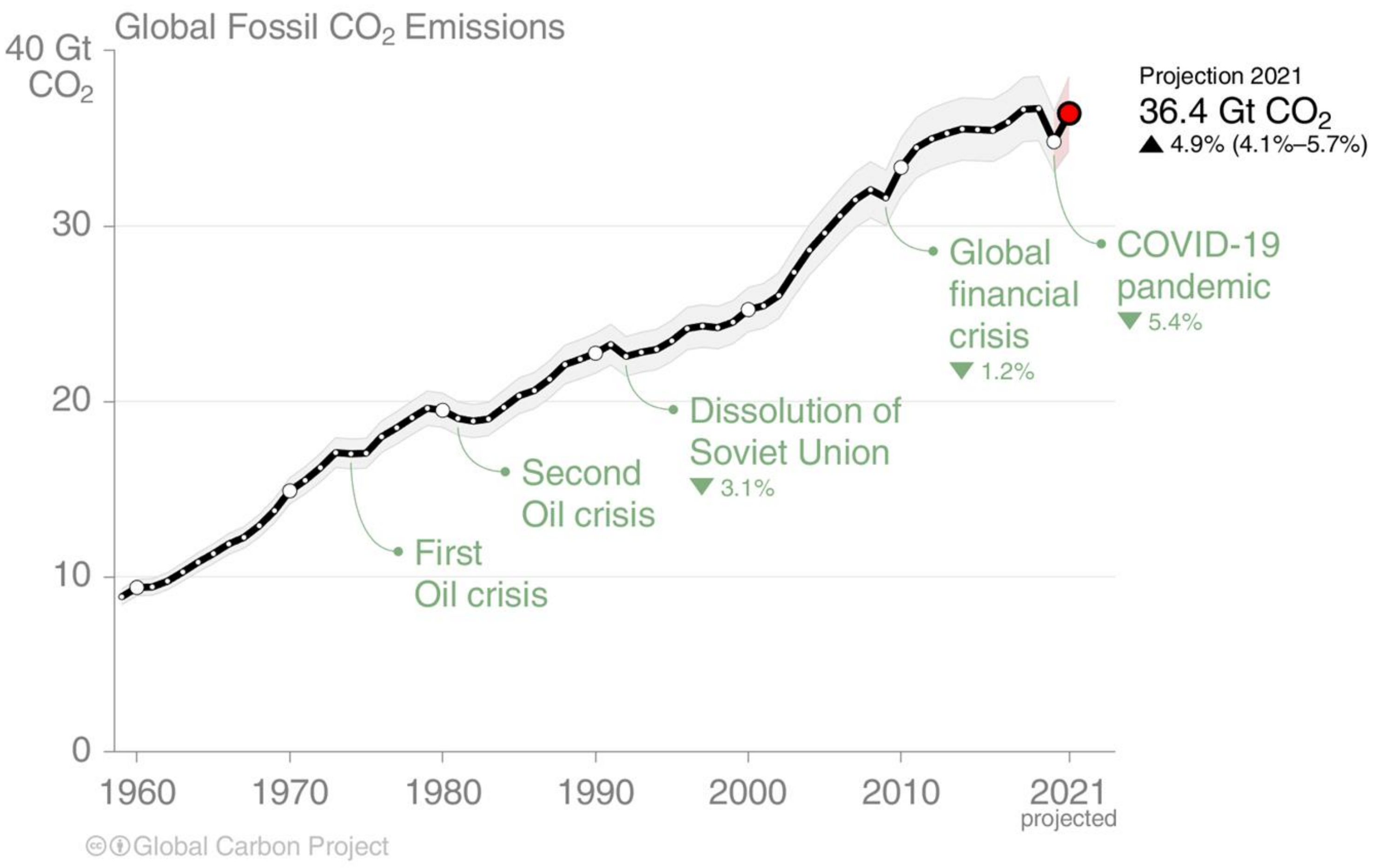


Source: Tans and Keeling (2020); Friedlingstein et al 2021; Global Carbon Budget 2021

Fossil CO_2 Emissions by country

Global Fossil CO_2 Emissions

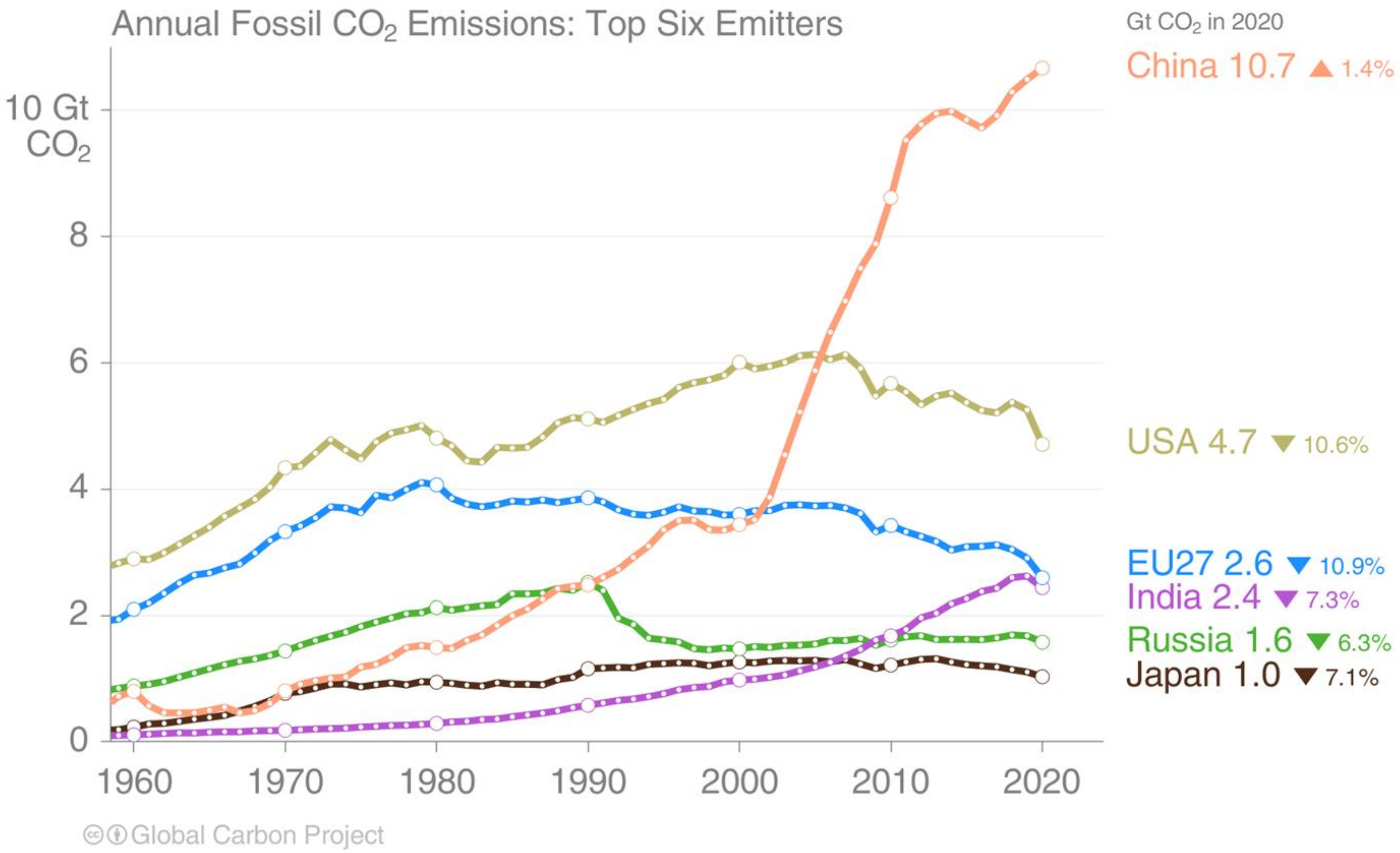
Global fossil CO_2 emissions have risen steadily over the last decades.
Emissions in 2021 are set to rebound towards their pre-COVID-19 levels after an unprecedented drop in 2020.



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

Top emitters: Fossil CO_2 Emissions to 2020

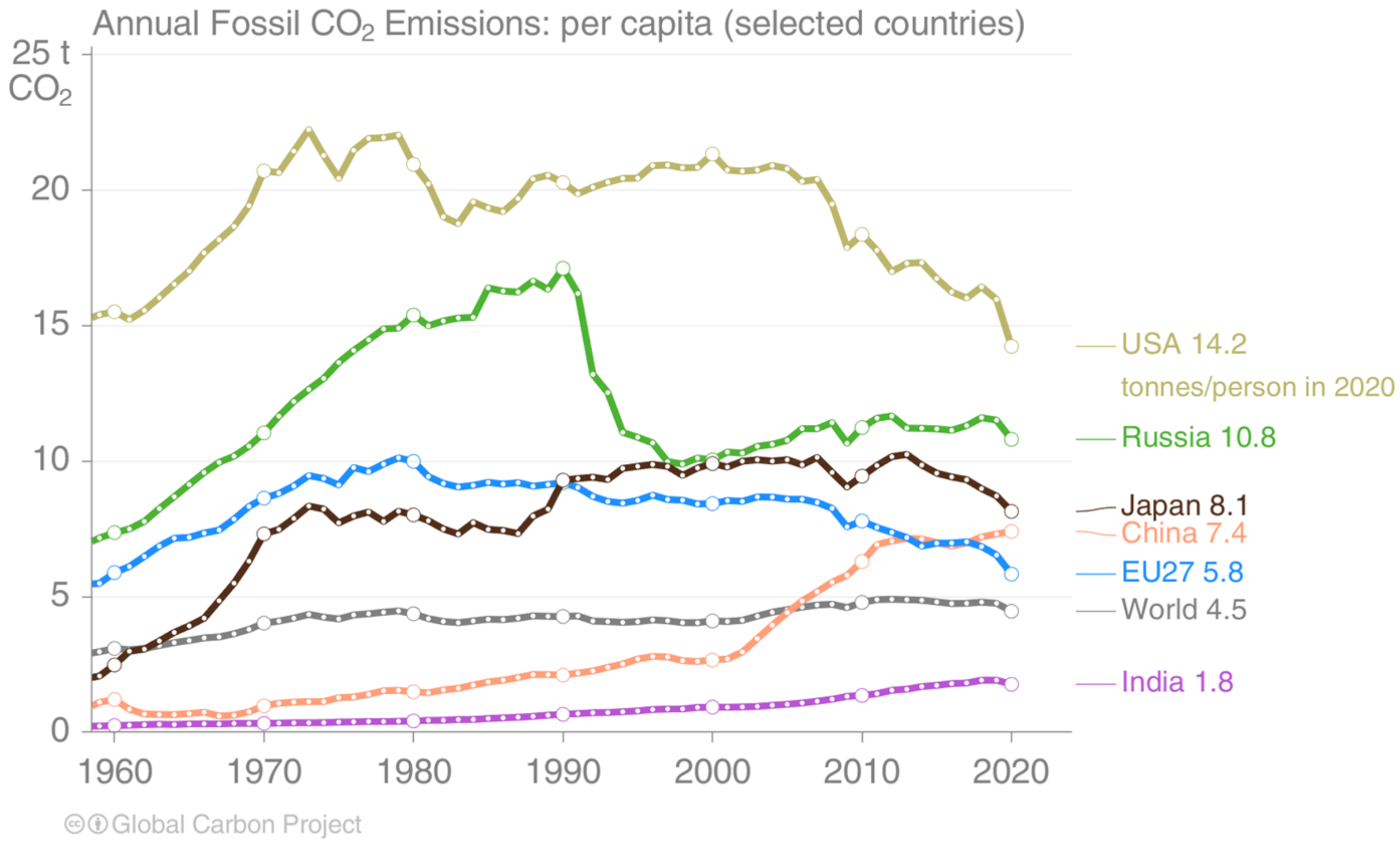
The top six emitters in 2020 covered 66% of global emissions
China 31%, United States 14%, EU27 7%, India 7%, Russia 5%, and Japan 3%



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 CO_2 Emissions per capita to 2020

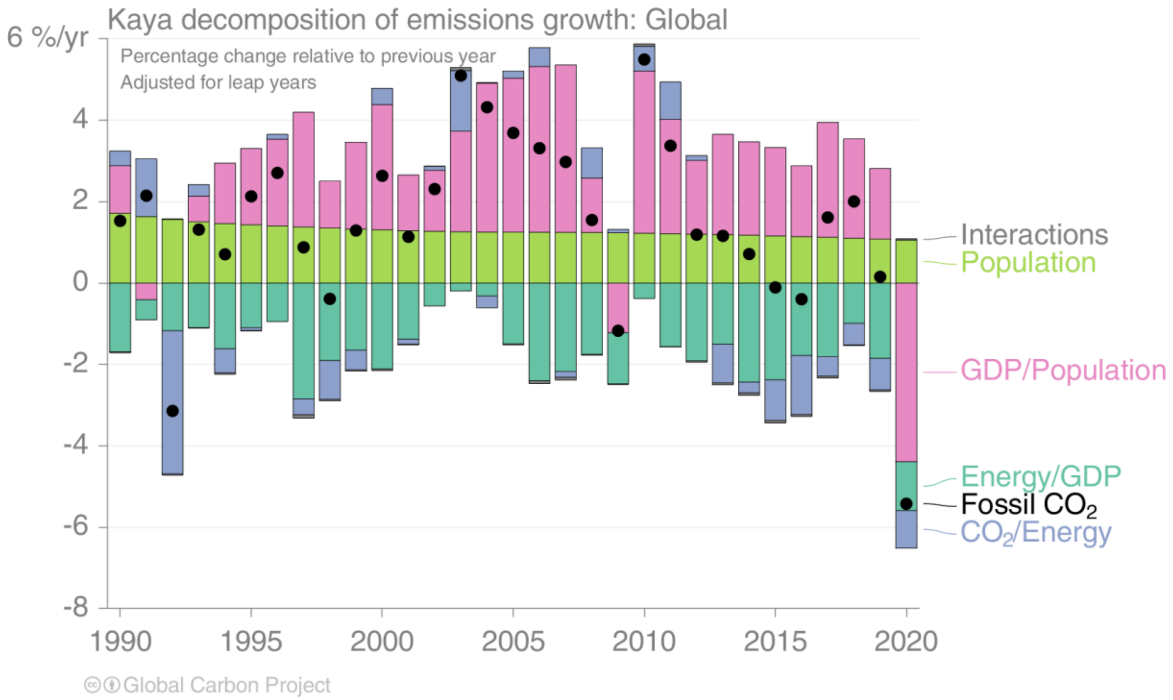
Countries have a broad range of per capita emissions reflecting their national circumstances



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

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.



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

Key statistics for emissions in 2020

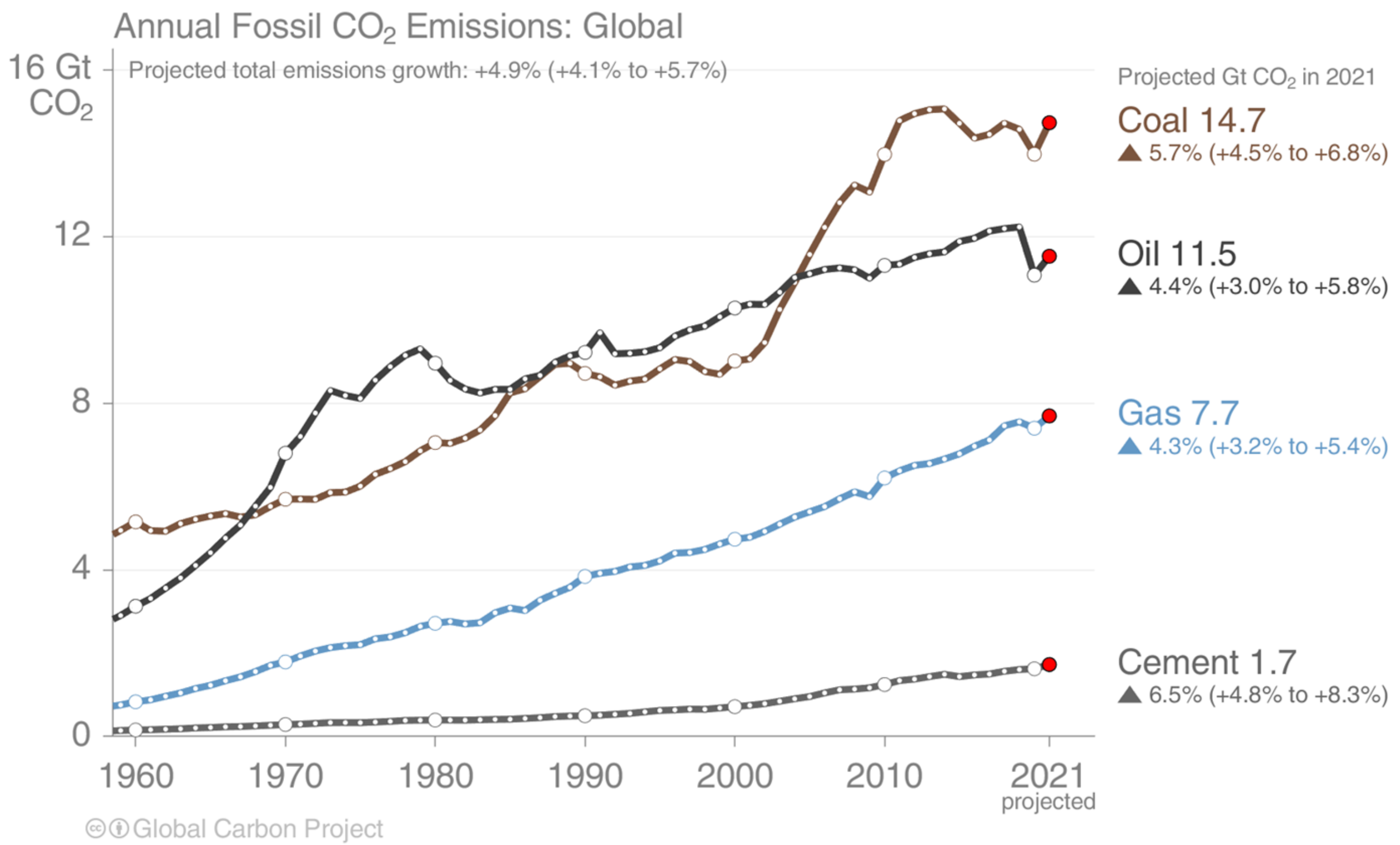
Region/Country	Emissions 2020: Per capita	Total		Growth 2019–20	
	tCO_2 per person	$GtCO_2$	%	$GtCO_2$	%
Global (including bunkers)	4.5	34.81	100	-1.895	-5.4
OECD Countries					
OECD	8.4	11.05	31.7	-1.185	-9.9
USA	14.2	4.71	13.5	-0.543	-10.6
OECD Europe	5.8	2.86	8.2	-0.347	-11.1
Japan	8.1	1.03	3.0	-0.075	-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

Source: Friedlingstein et al 2021; Global Carbon Project 2021

Fossil CO_2 Emissions by source

Fossil CO_2 Emissions by source

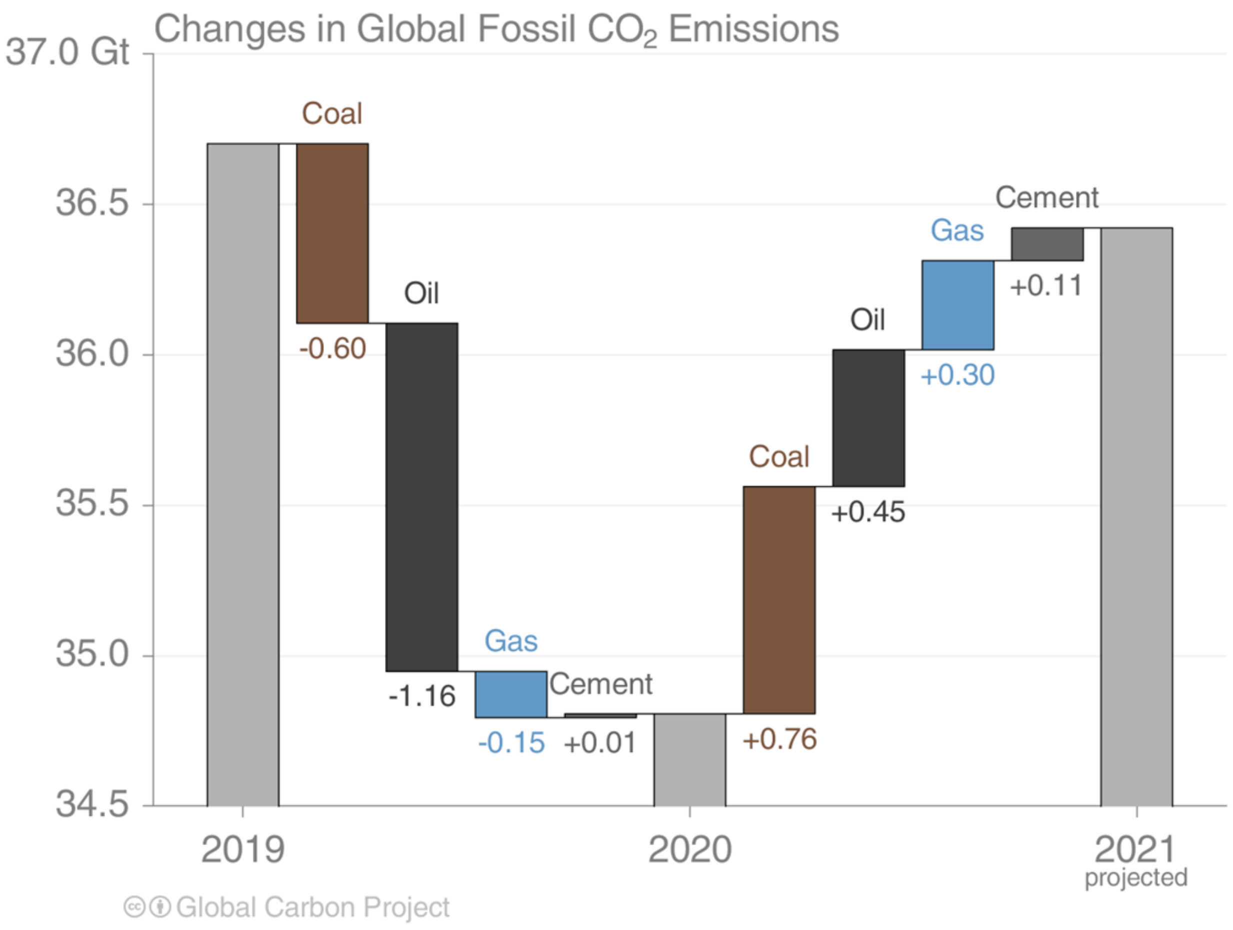
Share of global fossil CO2 emissions in 2020: coal (40%), oil (32%), gas (21%), cement (5%), flaring and others (2%, not shown)
Projection by fuel type is based on monthly data (GCP analysis)



Source: Friedlingstein et al 2021; Global Carbon Project 2021

Fossil CO_2 emissions growth: 2019–2021

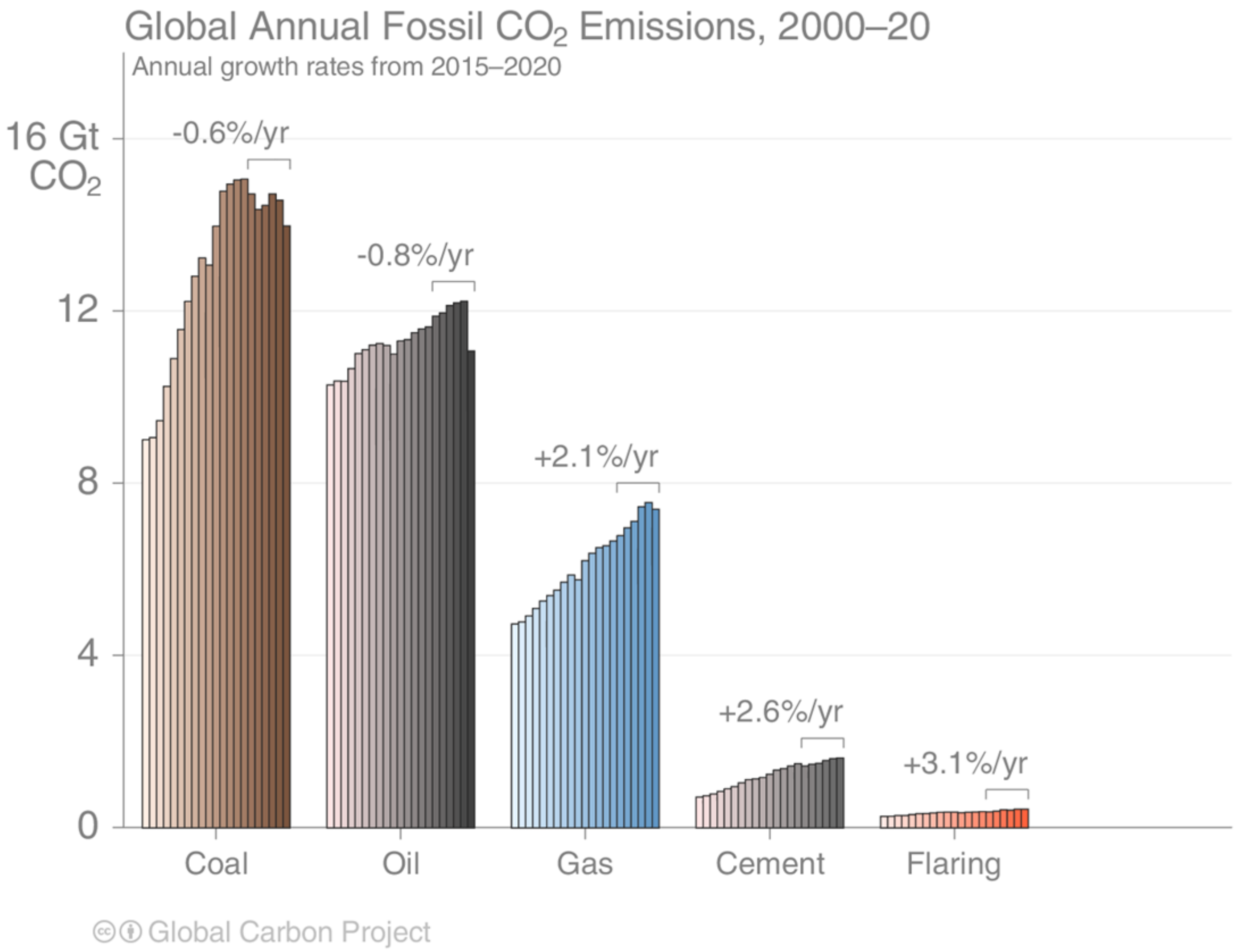
Global emissions in 2020 dropped across all categories.
In 2021 coal and natural gas have more than recovered this loss, while oil still lags with from subdued transportation.



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

Fossil CO_2 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

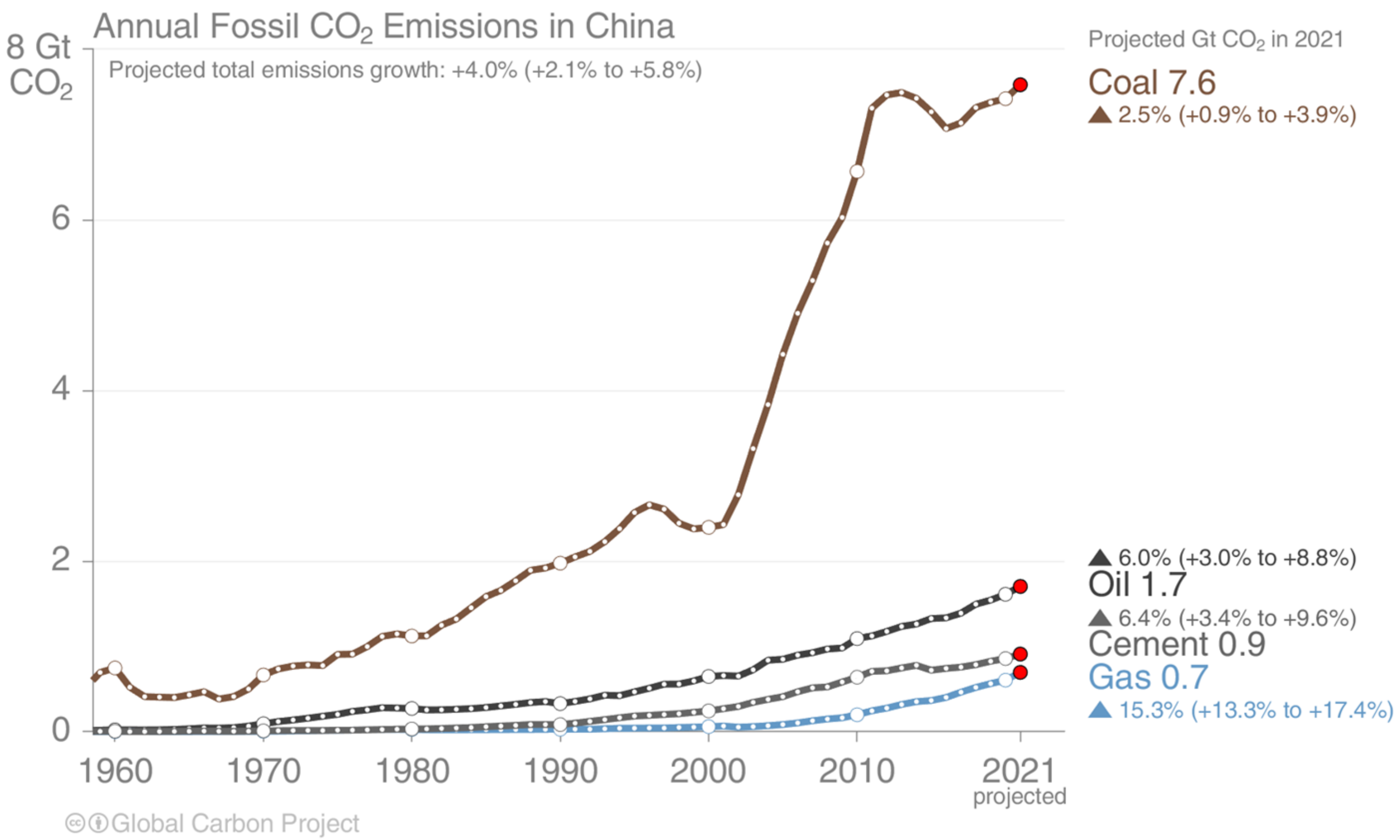


Source: CDIAC; Global Carbon Project 2021

Fossil CO_2 Emission by source for top emitters

Fossil CO_2 Emissions in China

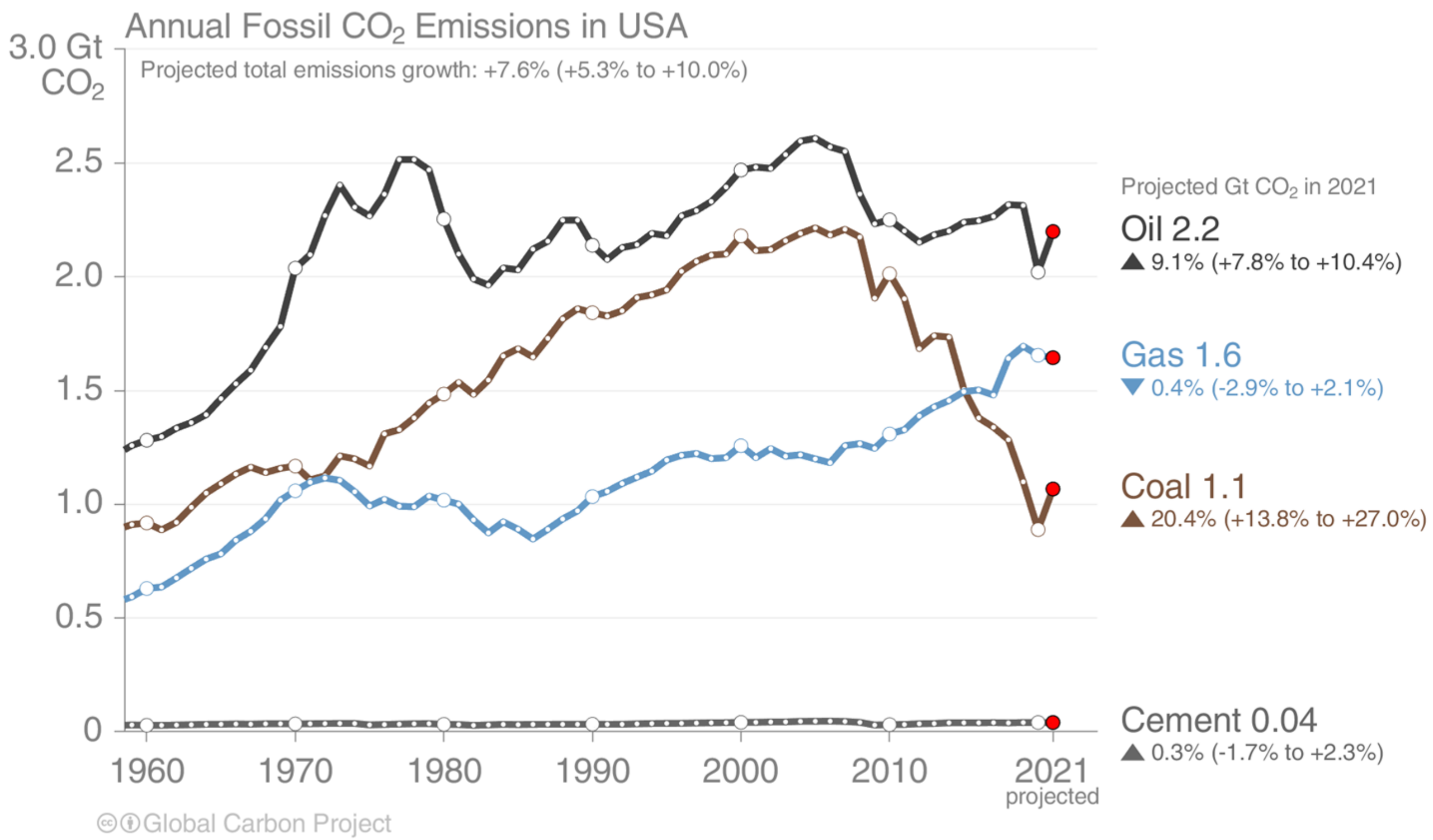
Annual emissions in China are expected to reach another record high in 2021, with substantial industrial growth



Source: Friedlingstein et al 2021; Global Carbon Project 2021

Fossil CO_2 Emissions in USA

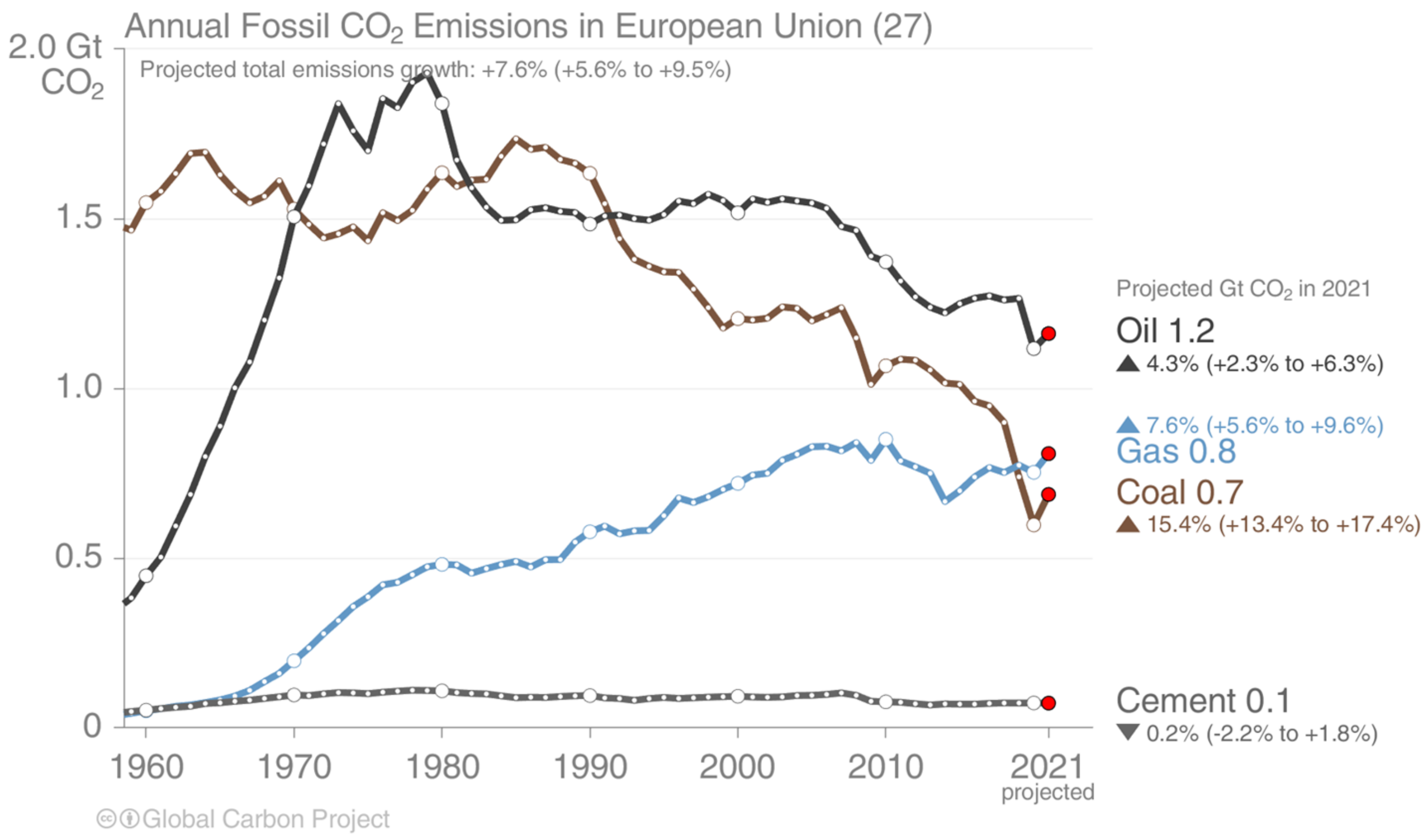
The USA's emissions from coal are expected to bounce back in 2021, partly as a result of supply constraints on natural gas. Emissions from oil do not return to 2019's level.



Source: EIA 2020; Friedlingstein et al 2021; Global Carbon Project 2021

Fossil CO_2 Emissions in the European Union

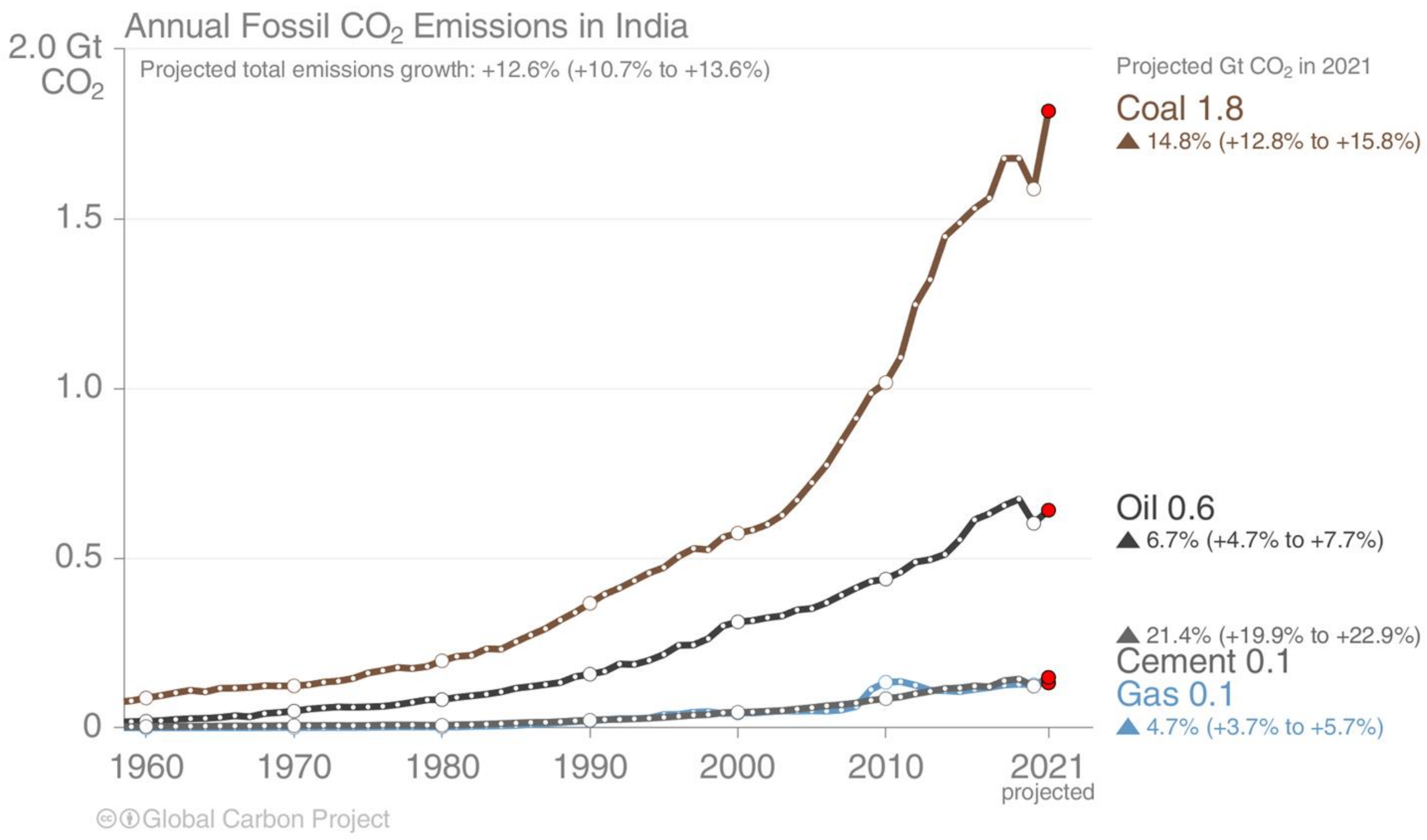
In the first half of 2021 EU coal power generation was strong due partly to very low generation from wind power, but the 2021 total is expected to remain below 2019's level and continue to decline.



Source: Friedlingstein et al 2021; Global Carbon Project 2021

Fossil CO_2 Emissions in India

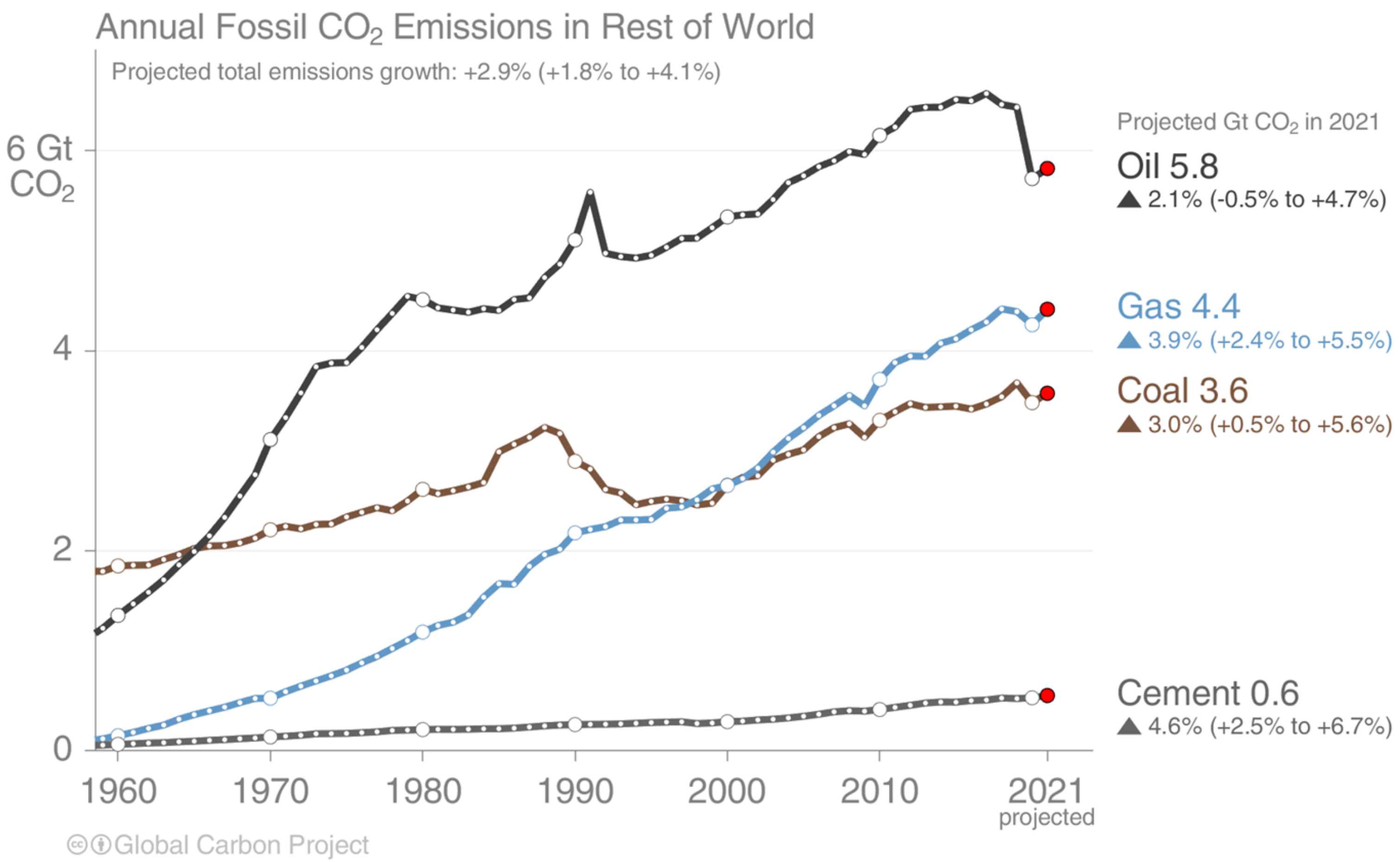
India’s emissions are expected to jump sharply in 2021, returning to a strongly growing trend driven largely by use of coal in power generation.



Source: Friedlingstein et al 2021; Global Carbon Project 2021

Fossil CO_2 Emissions in Rest of World

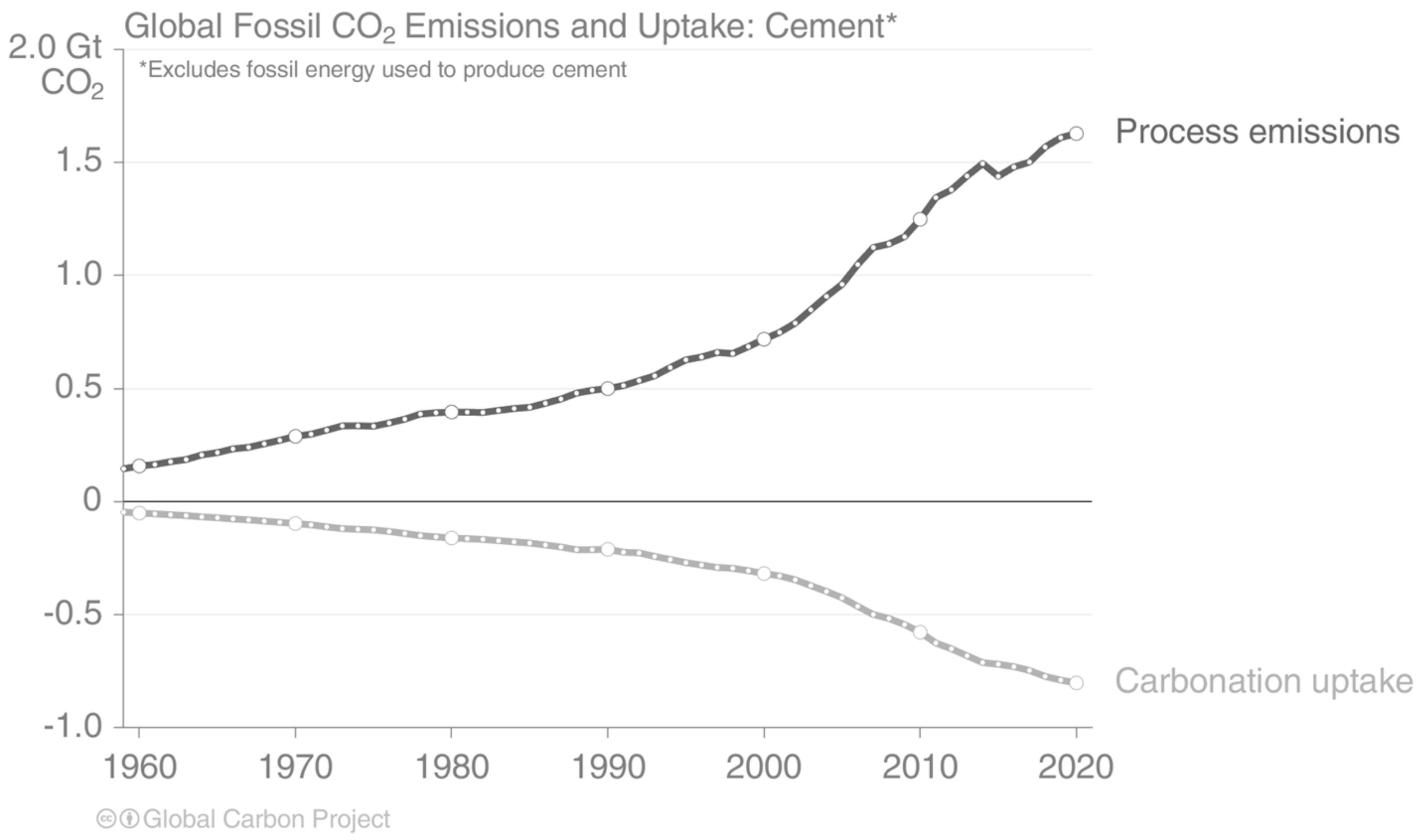
In the Rest of the World, emissions from coal and natural gas are expected to recover most of their losses in 2020.
Oil, which here includes internationship transport, remains subdued.



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 CO_2 from the chemical reaction
During its lifetime, cement slowly absorbs CO_2 from the atmosphere

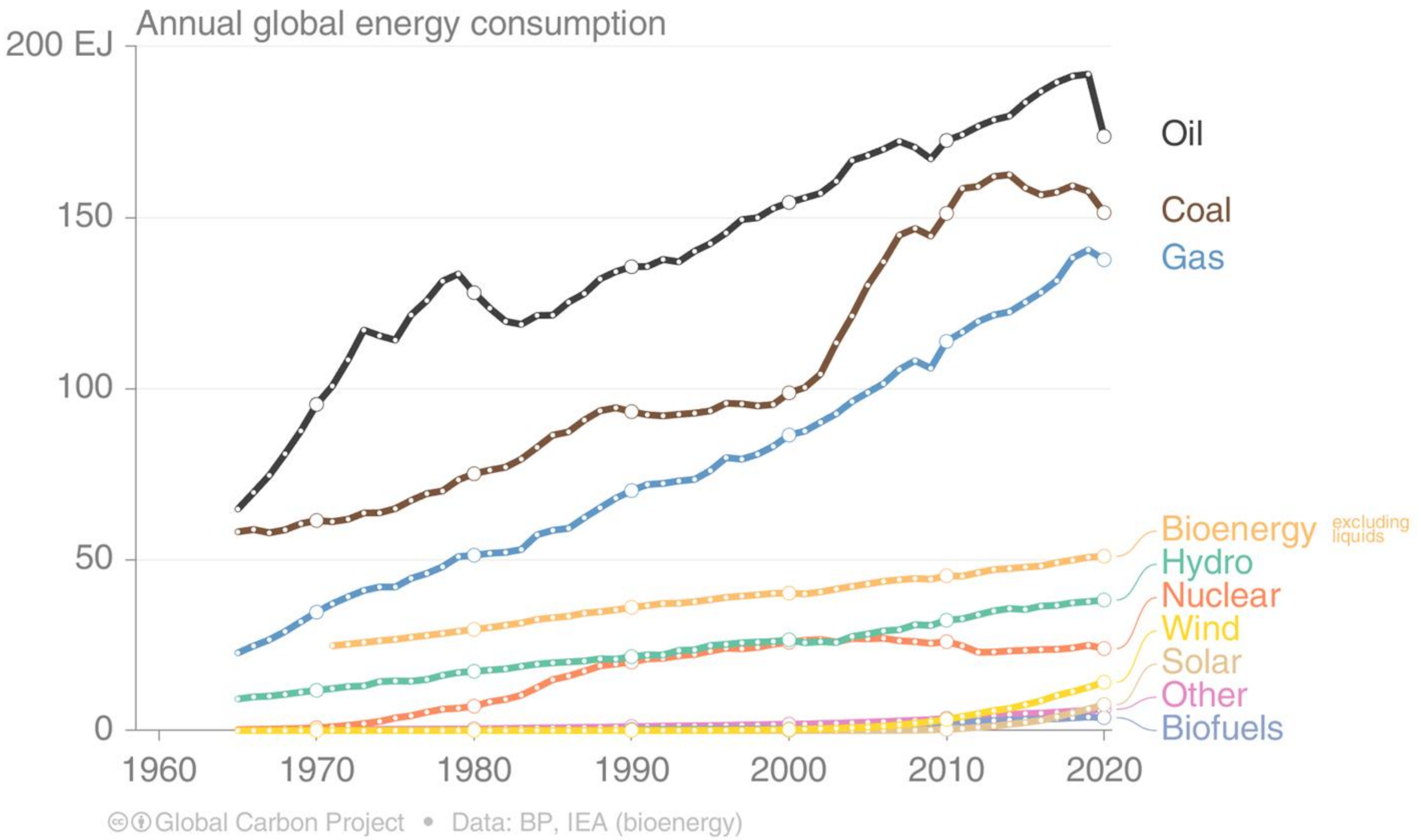


Source: [Friedlingstein et al 2021](); [Global Carbon Project 2021]()

Energy use by source

Energy use by source

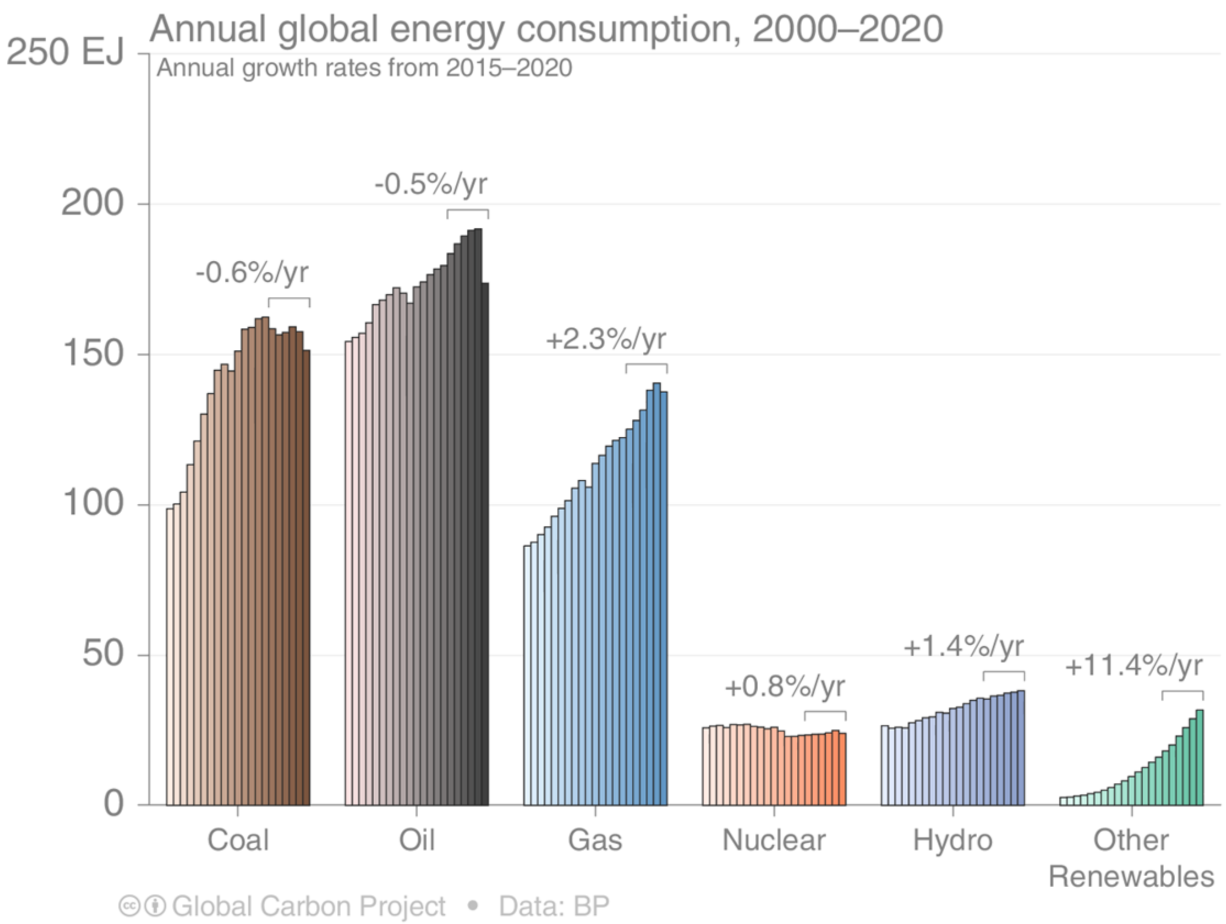
Consumption of energy from fossil sources declined in 2020.
Renewable energy continued to grow, but needs to grow even faster to replace fossil energy consumption.



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

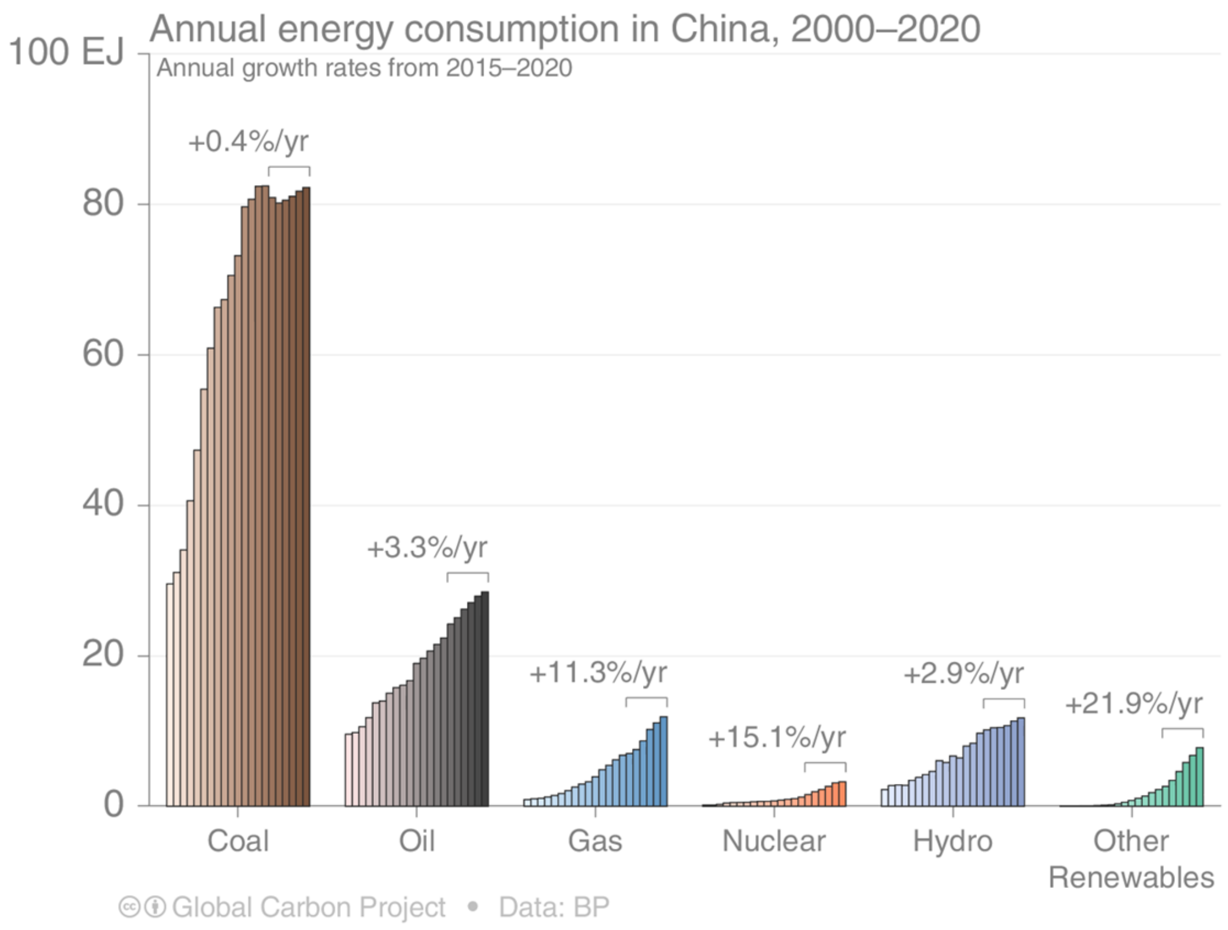
Energy consumption by fuel source from 2000 to 2020, with growth rates indicated for the more recent period of 2015 to 2020



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

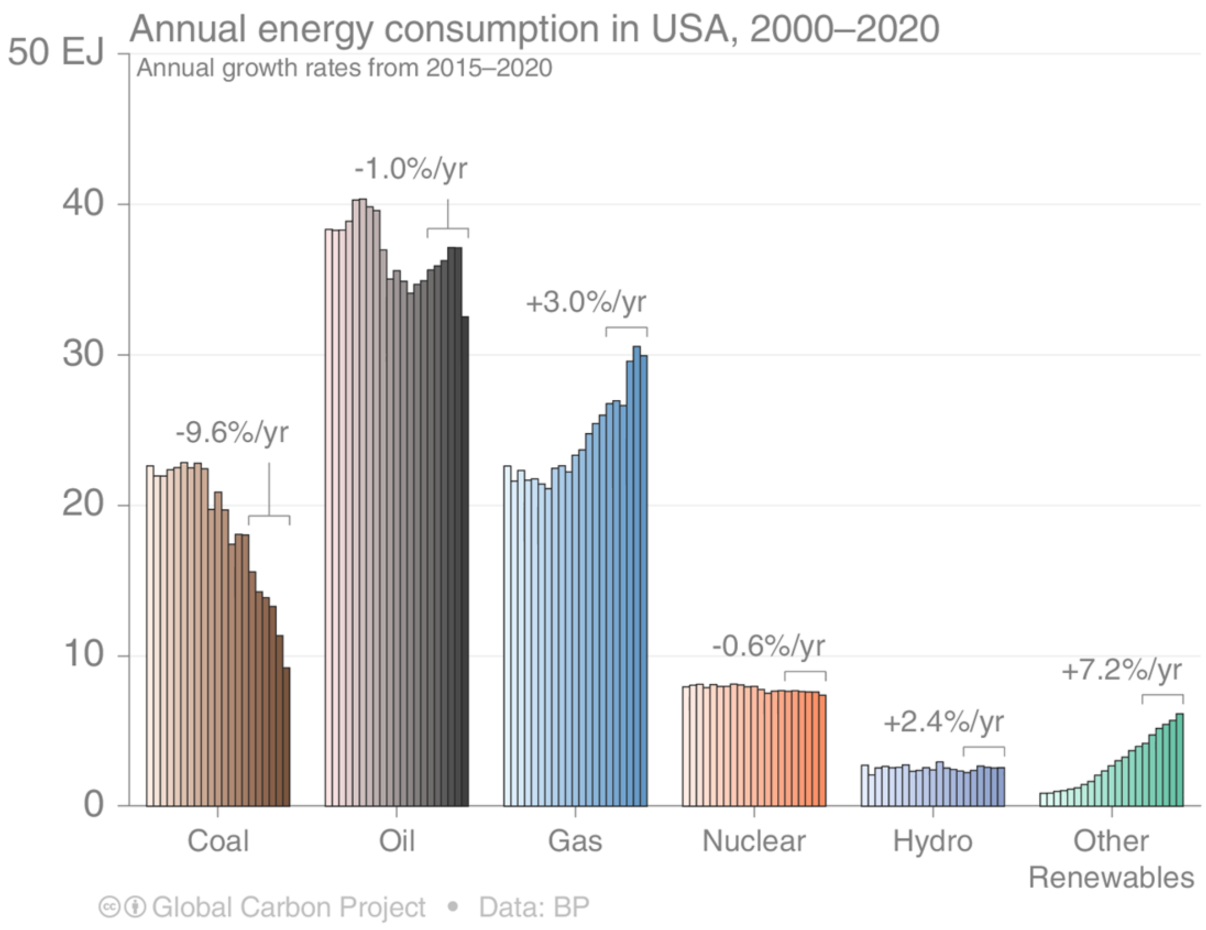
Coal consumption in energy units has returned to peak levels,
while consumption of all other energy sources is growing strongly



Source: BP 2020; Global Carbon Project 2021

Energy use in USA

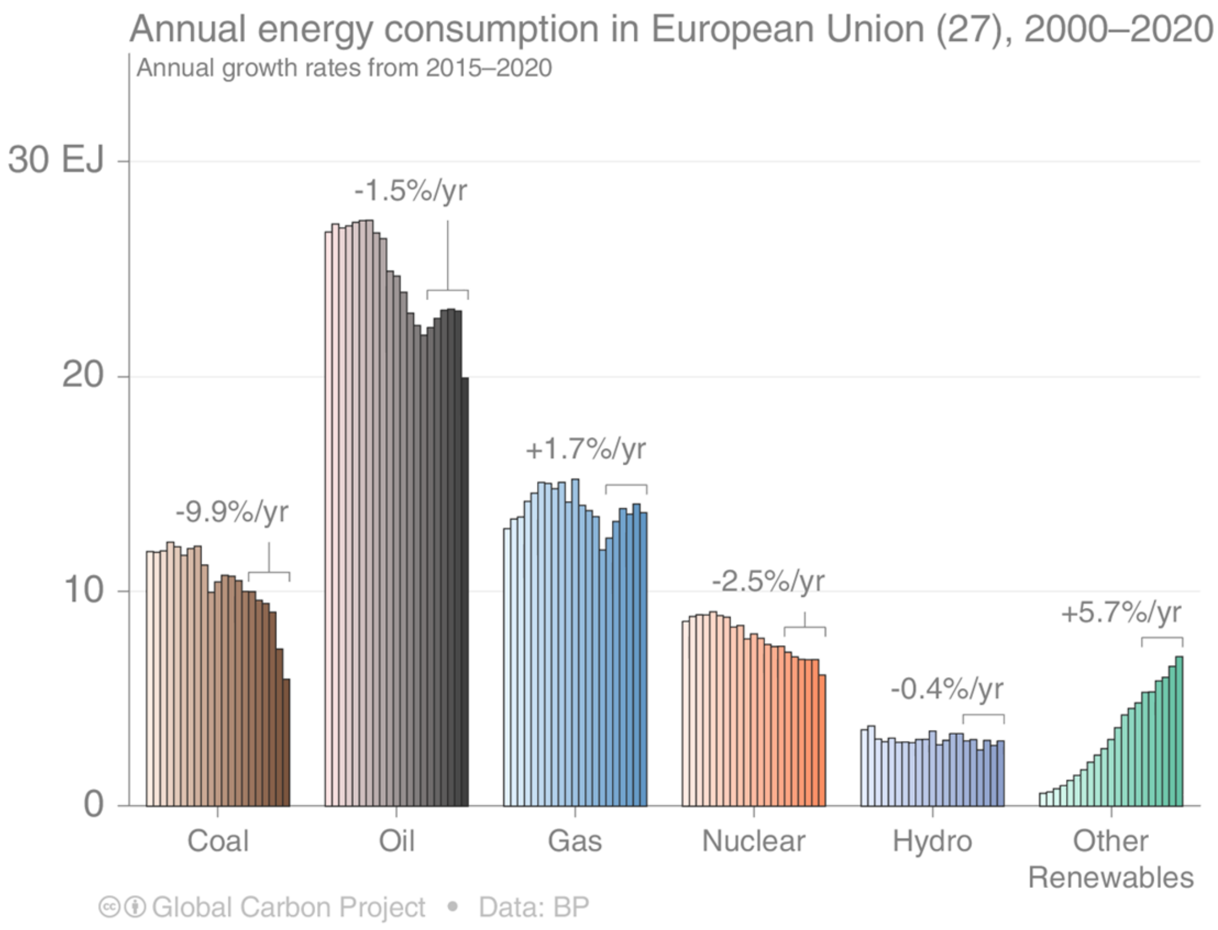
Coal consumption has declined sharply in recent years with the shale gas boom and strong renewables growth. Output from nuclear power is slowly declining as stations are retired.



Source: BP 2020; Global Carbon Project 2021

Energy use in the European Union

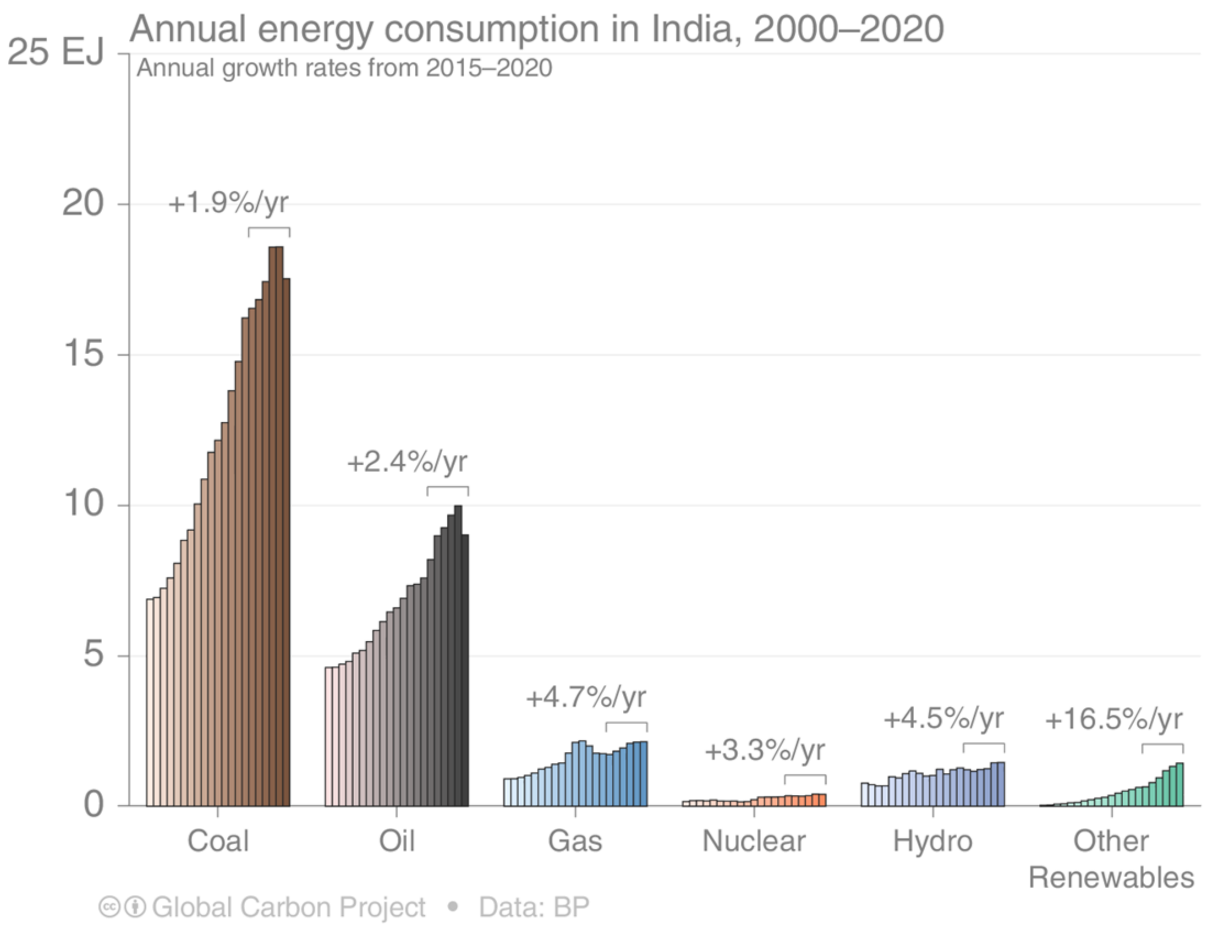
Consumption of both oil and gas has rebounded in recent years, while coal continues to decline.
Renewables are growing strongly, now providing more energy than nuclear power.



Source: BP 2020; Global Carbon Project 2021

Energy use in India

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



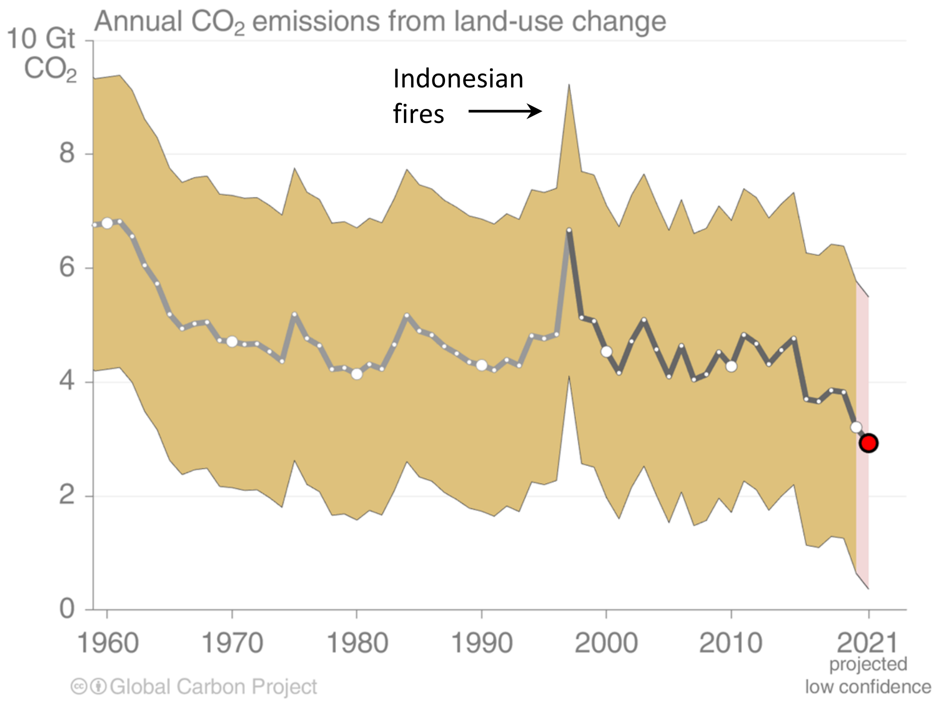
Source: BP 2020; Global Carbon Project 2021

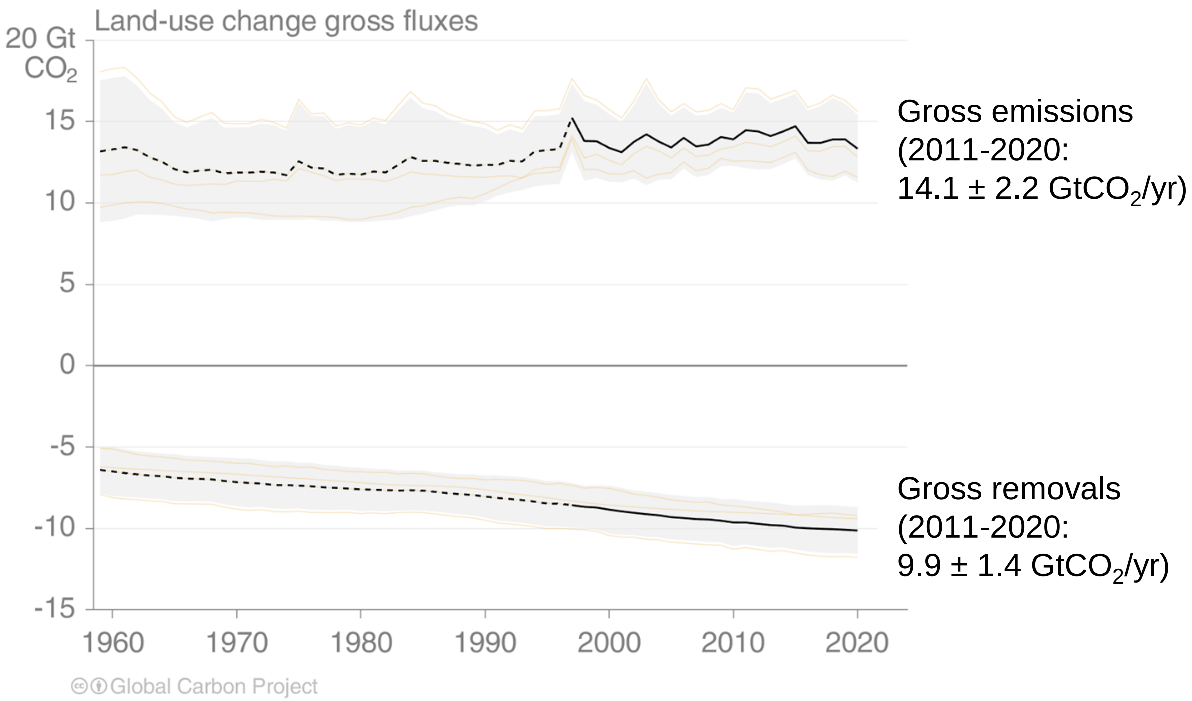
Land-use Change Emissions

Land-use change emissions

Land-use change emissions are 4.1 ± 2.6 $GtCO_2$ 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 CO_2 emissions, primarily from deforestation, and CO_2 removals, primarily from abandonment of agricultural land

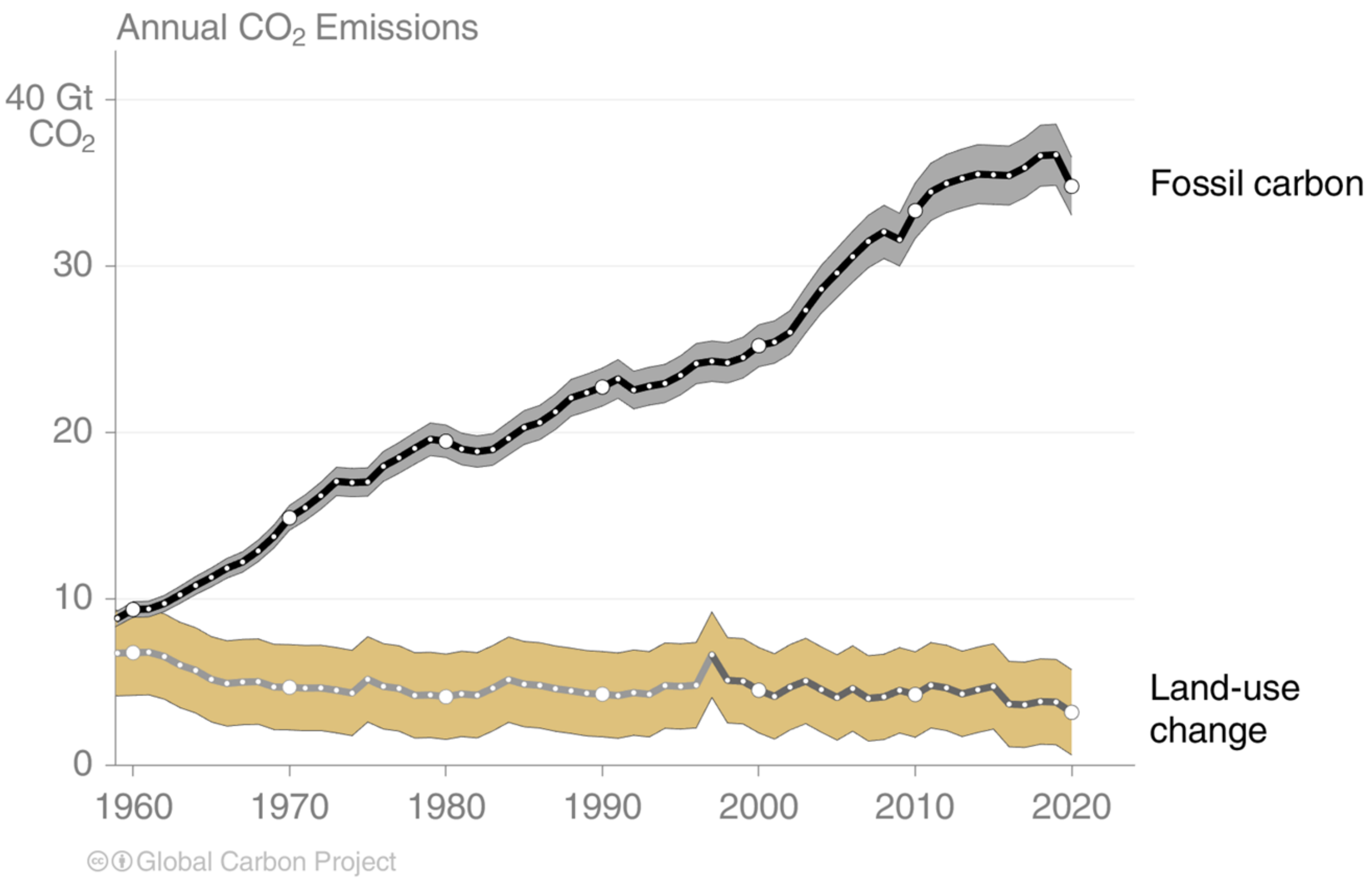




Estimates from three bookkeeping models
Source: Friedlingstein et al 2021; Global Carbon Project 2021

Total global emissions

Total global emissions: 38.0 ± 3.1 $GtCO_2$ 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

GLOBAL CARBON PROJECT

Fate of anthropogenic CO_2 emissions (2011–2020)

Sources = Sinks

34.8 $GtCO_2$/yr

89%

11%

4.1 $GtCO_2$/yr

18.6 $GtCO_2$/yr

48%

29%

11.2 $GtCO_2$/yr

26%

10.2 $GtCO_2$/yr

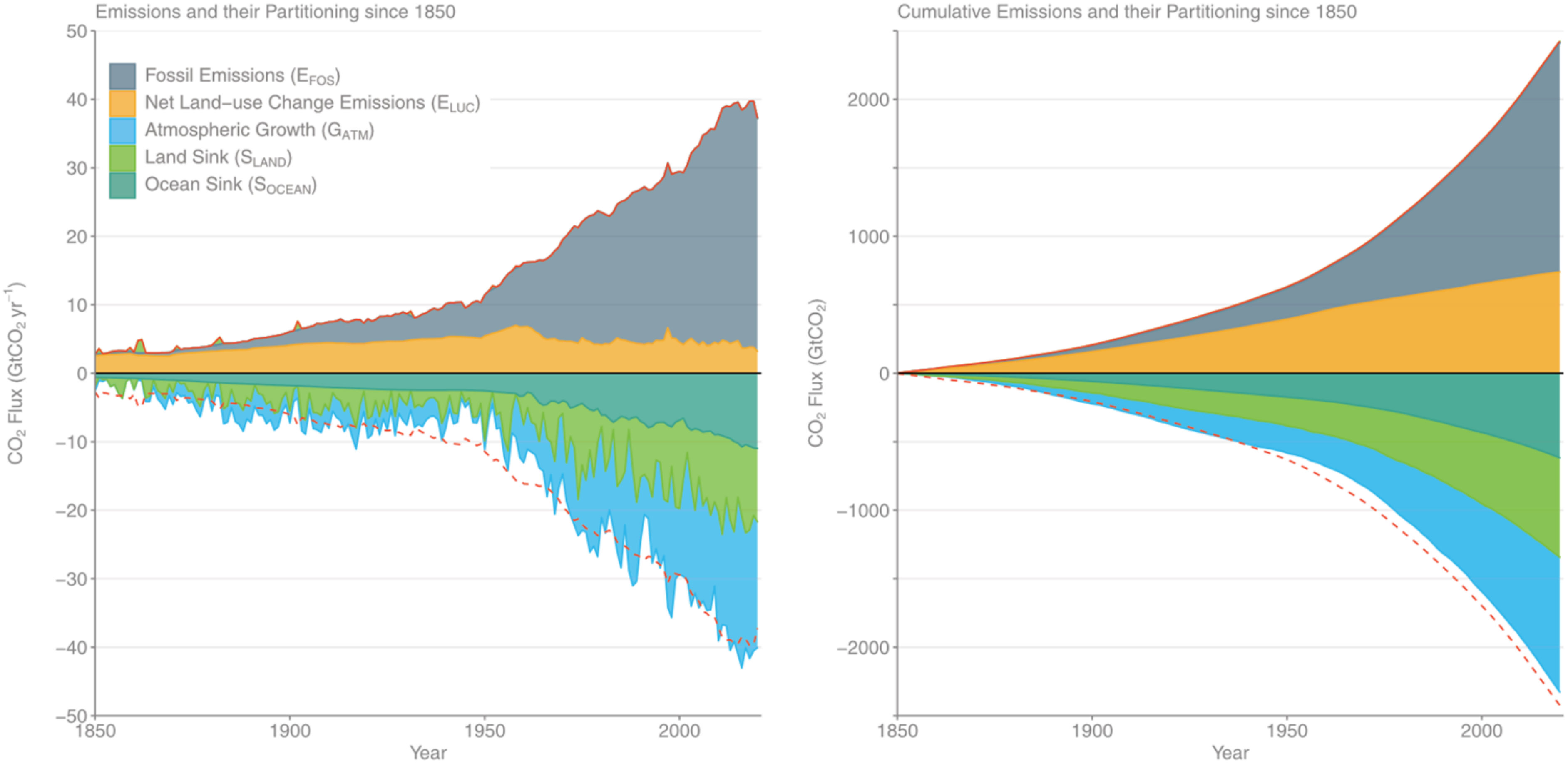
Budget Imbalance:
(the difference between estimated sources & sinks)

3%
-1.0 $GtCO_2$/yr

Source: Friedlingstein et al 2021; Global Carbon Project 2021

Global carbon budget

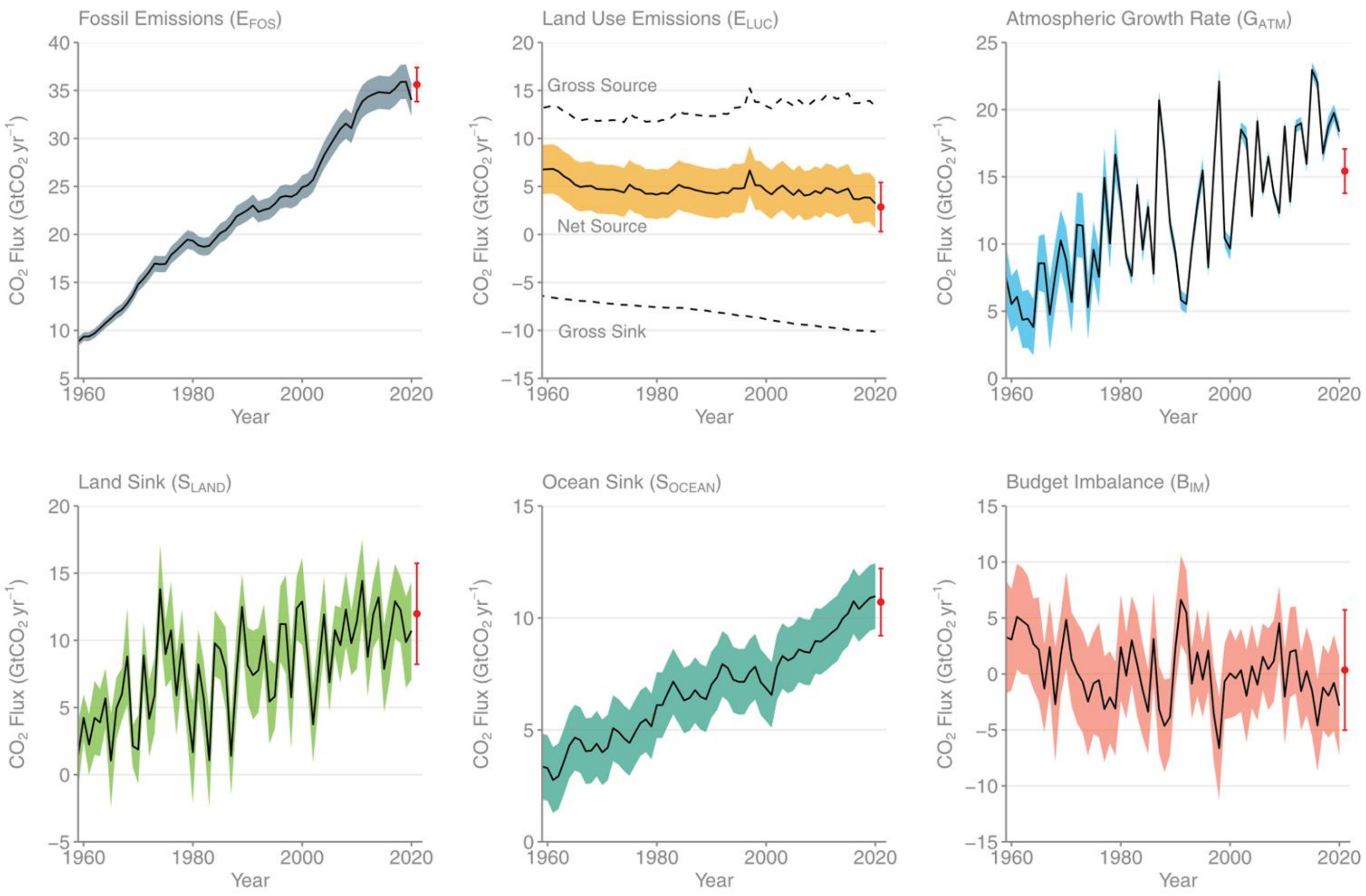
Carbon emissions are partitioned among the atmosphere and carbon sinks on land and in the ocean
The “imbalance” between total emissions and total sinks is an active area of research



Source: Friedlingstein et al 2021; Global Carbon Project 2021

Changes in the budget over time

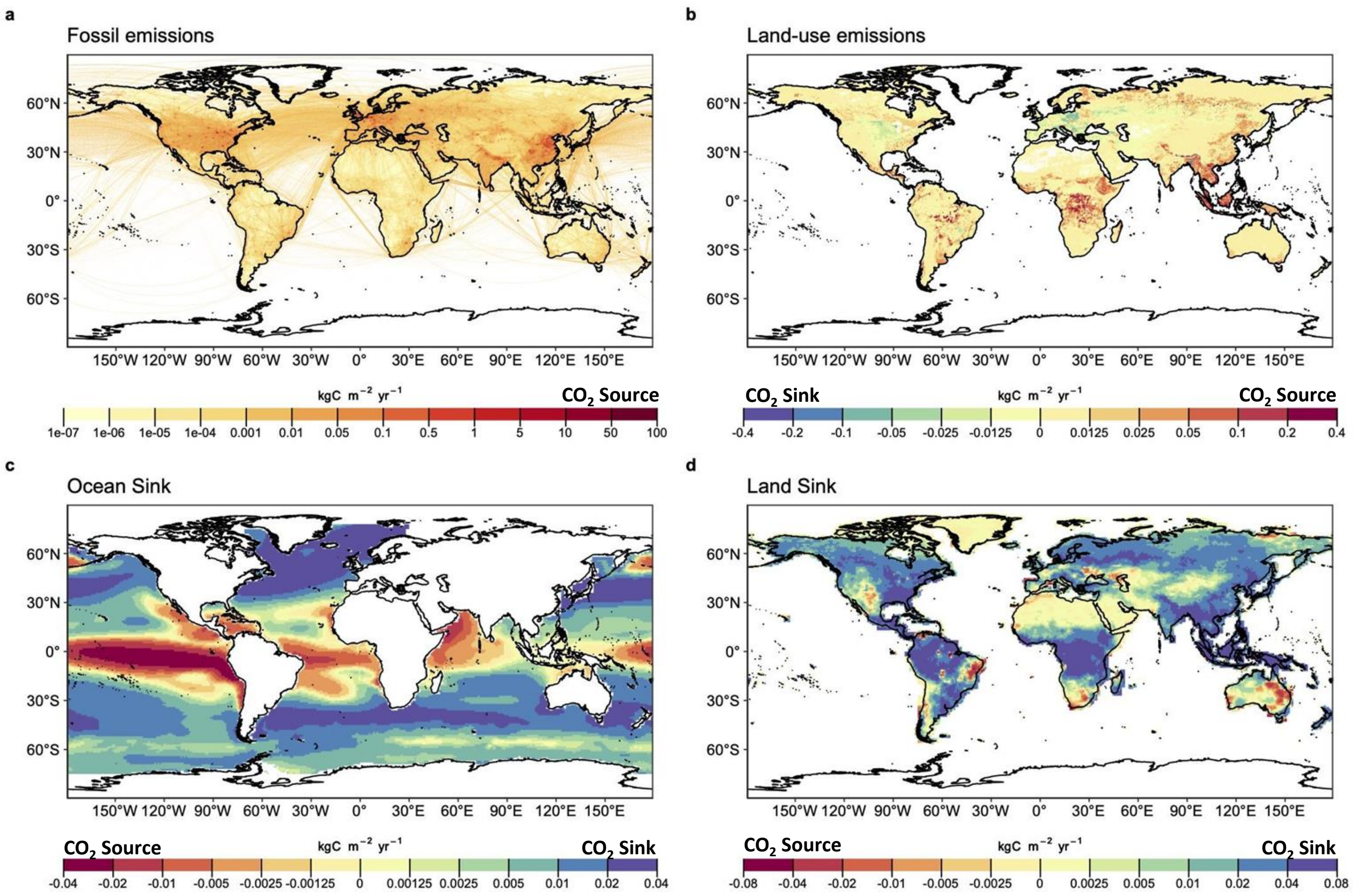
The sinks have continued to grow with increasing emissions, but climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere



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 2021; Global Carbon Project 2021

Global carbon budget

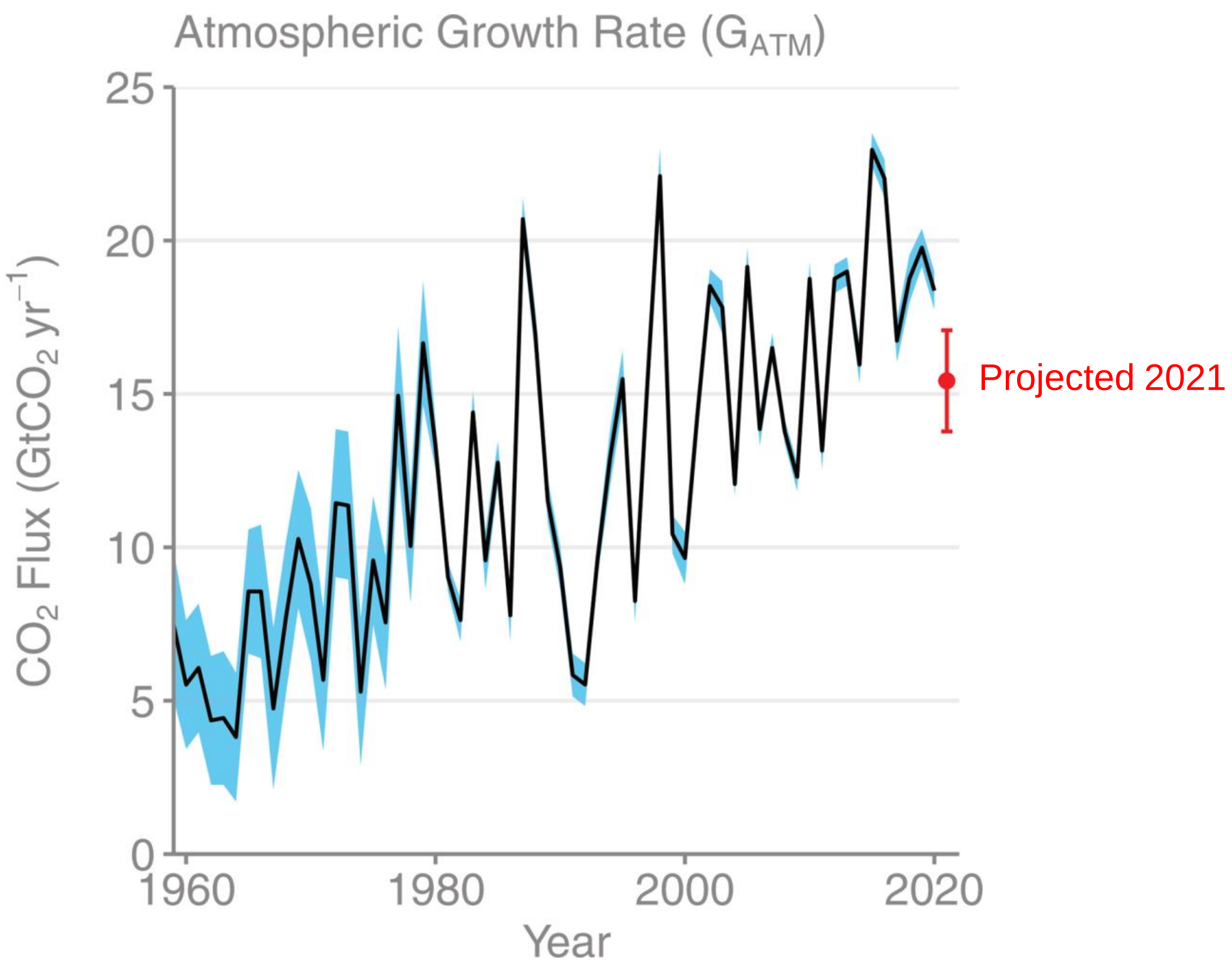
Fossil emissions dominate in the Northern Hemisphere, while land-use emissions are important in the tropics.
The North Atlantic and Southern Ocean are carbon sinks while the tropical ocean is a source of CO_2.
Tropical, temperate and boreal forest are the main terrestrial carbon sinks



Source: Friedlingstein et al 2021; Global Carbon Budget 2021

Atmospheric concentration

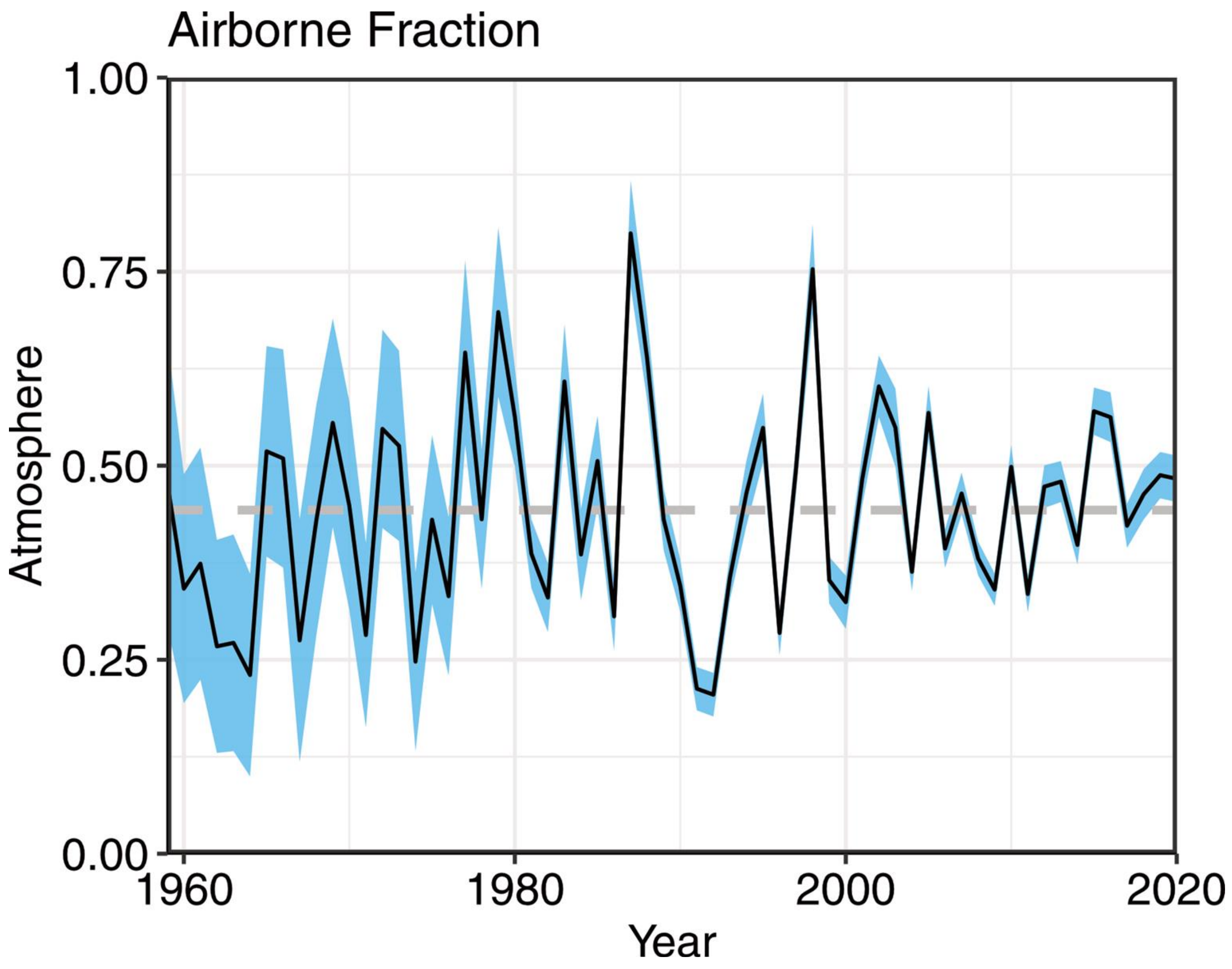
The atmospheric concentration growth rate has increased steadily.
The high growth in 1987, 1998, & 2015–16 reflect a strong El Niño, which weakens the land sink.



Source: NOAA-ESRL; Friedlingstein et al 2021; Global Carbon Project 2021

Airborne Fraction

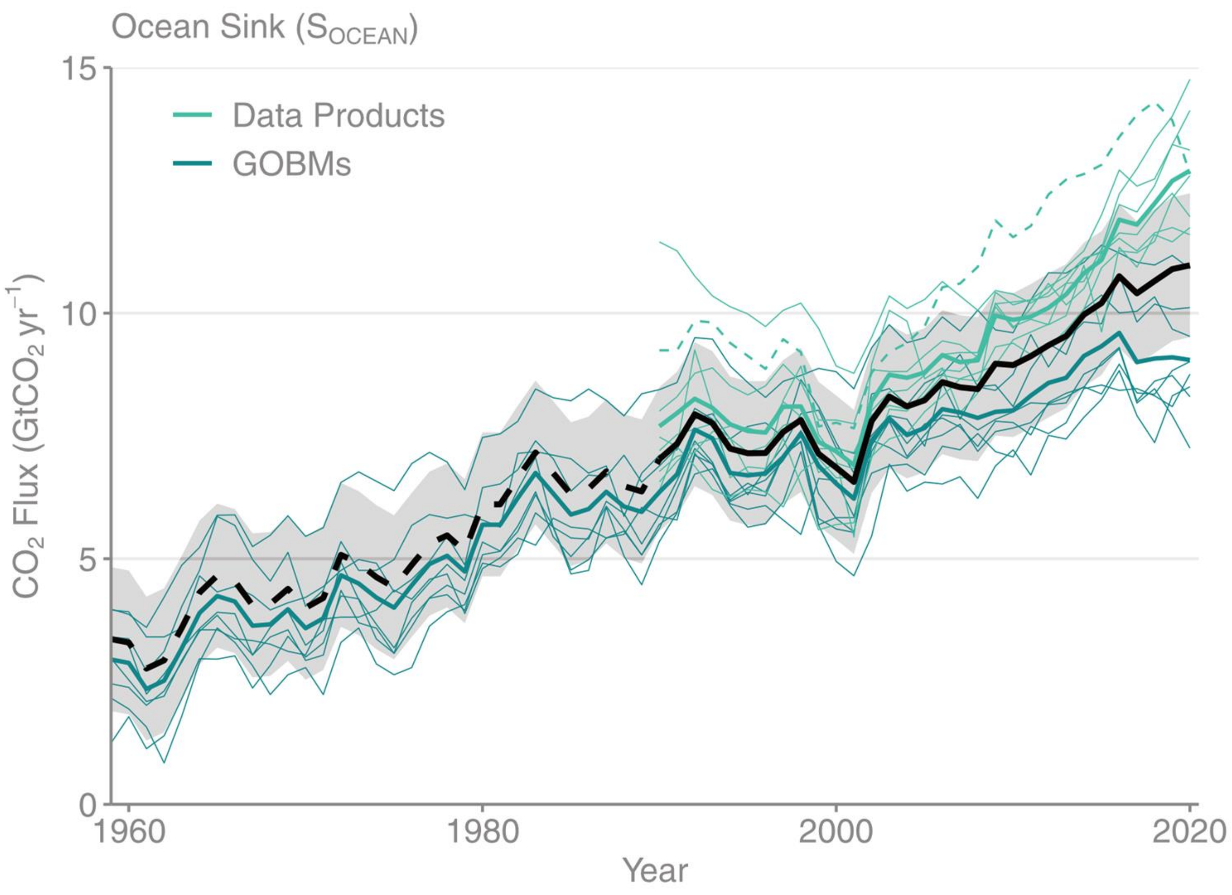
The airborne fraction is the proportion of the total annual CO_2 emissions that remains in the atmosphere.
The rest of CO_2 emissions are removed by the land and ocean sinks.
Around 45% of CO_2 emissions remain in the atmosphere despite sustained growth in CO_2 emissions.



Source: NOAA-ESRL; Global Carbon Project 2021

Ocean sink

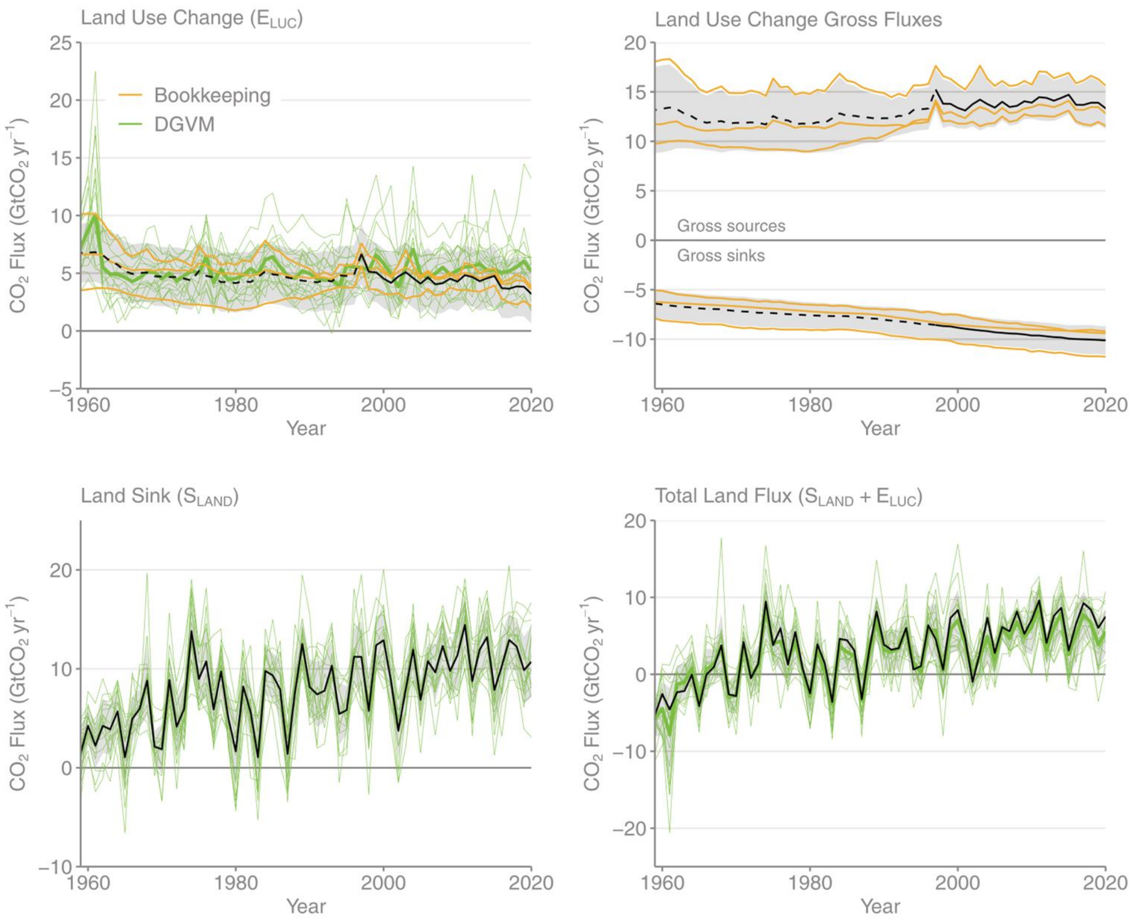
The ocean carbon sink, estimated by Global Ocean Biogeochemical Models and observation-based data products, continues to increase 10.2 ± 1.5 GtCO2/yr for 2011–2020 and 11.0 ± 1.5 GtCO2/yr in 2020



Source: SOCATv7; Bakker et al 2016; Friedlingstein et al 2021; Global Carbon Project 2021

Terrestrial sink

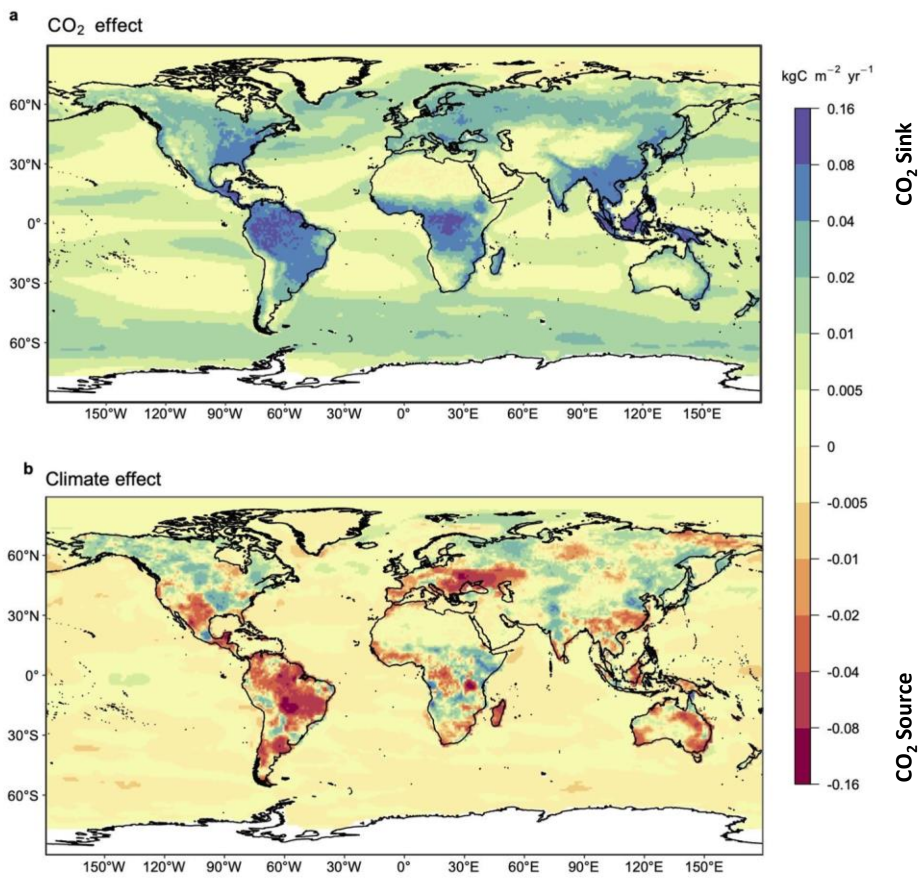
The land carbon sink, estimated by Dynamic Global Vegetation Models, was 11.2 ± 2.2 GtCO2/yr during 2011–2020 and 10.7 ± 3.6 GtCO2/yr in 2020.
Total CO_2 fluxes on land (including land-use change) are also constrained by atmospheric inversions.



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

Land and ocean sinks — Effects of CO_2 vs climate change

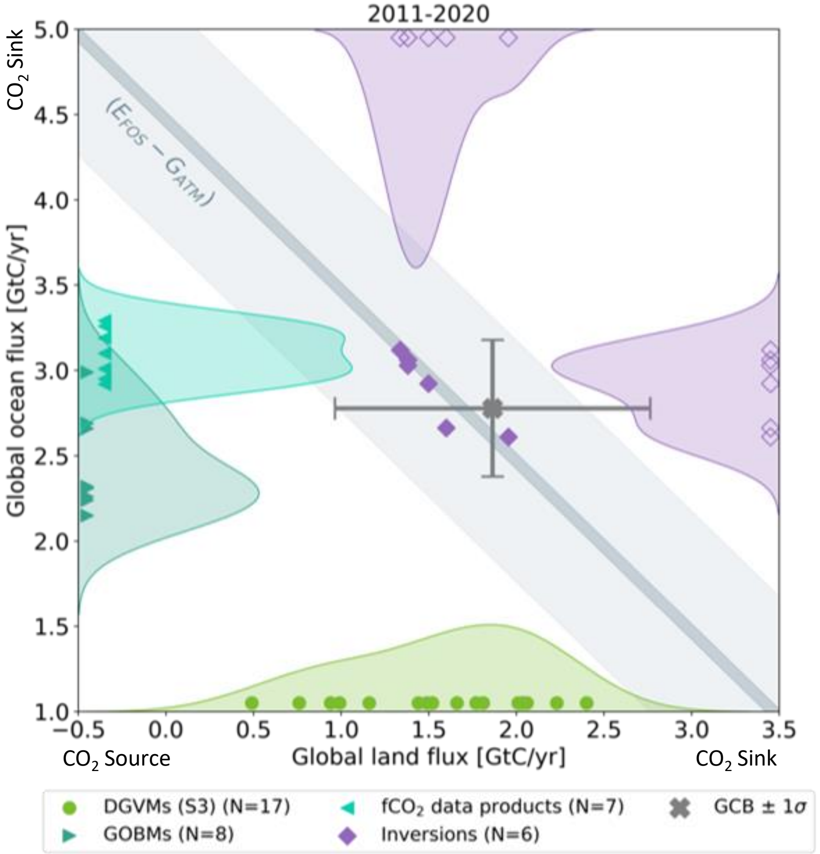
Process models suggest that increasing atmospheric CO_2 drives the land and ocean sinks while climate change reduces the carbon sinks; the climate effect is largest in tropical and semi-arid land ecosystems.
Globally during the 2011-2020 decade, climate change reduced the land sink by ~15% and the ocean sink by ~5%



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

Land and ocean sinks — Estimates from atmospheric inversions

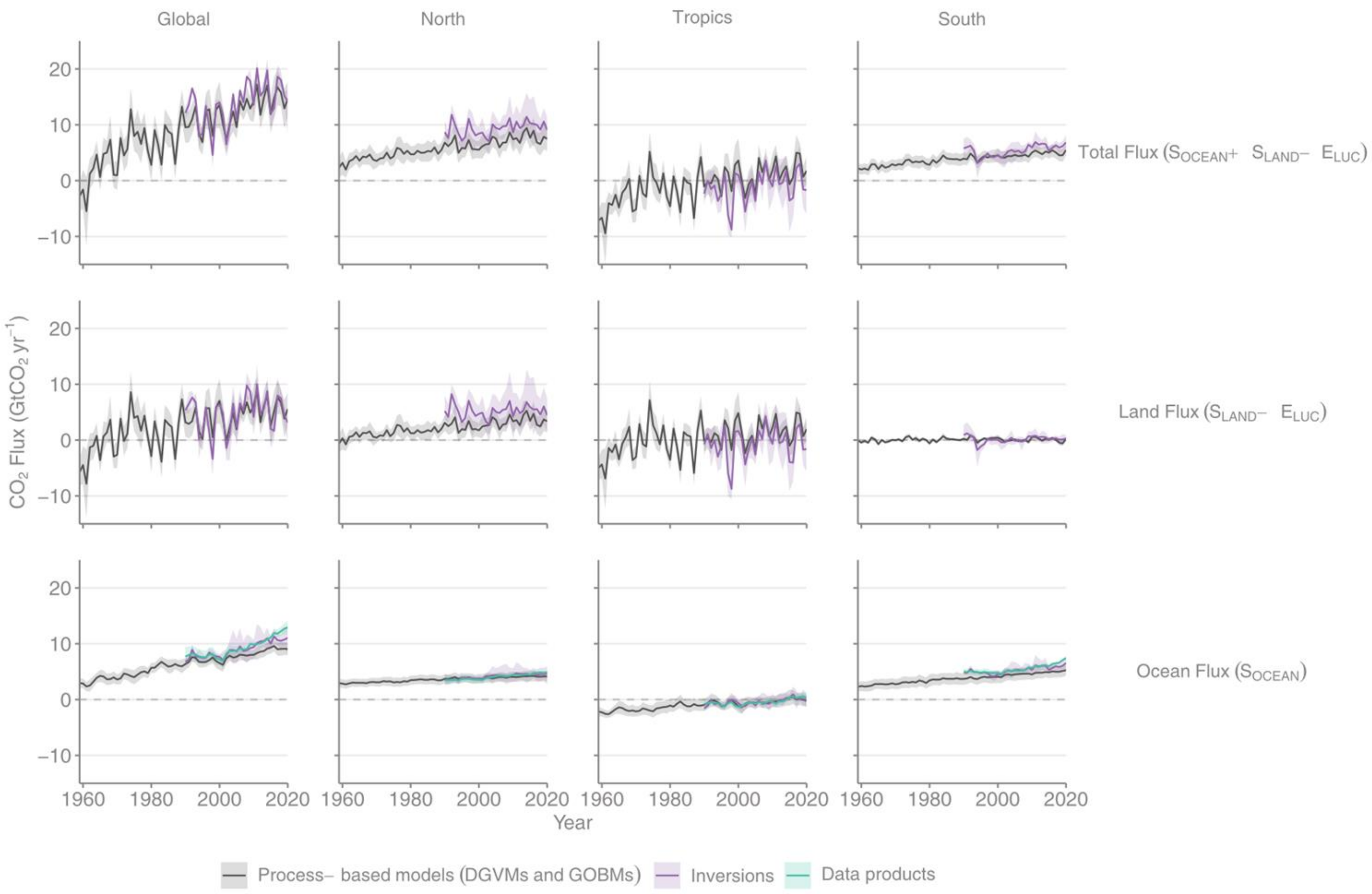
Atmospheric CO_2 inversions allow to estimate the land and ocean carbon fluxes, independently from the land and ocean process-based models estimates, confirming the global carbon budget estimates of the land and ocean partitioning of anthropogenic CO_2



Source: Friedlingstein et al 2021; Global Carbon Budget 2021

Total land and ocean fluxes

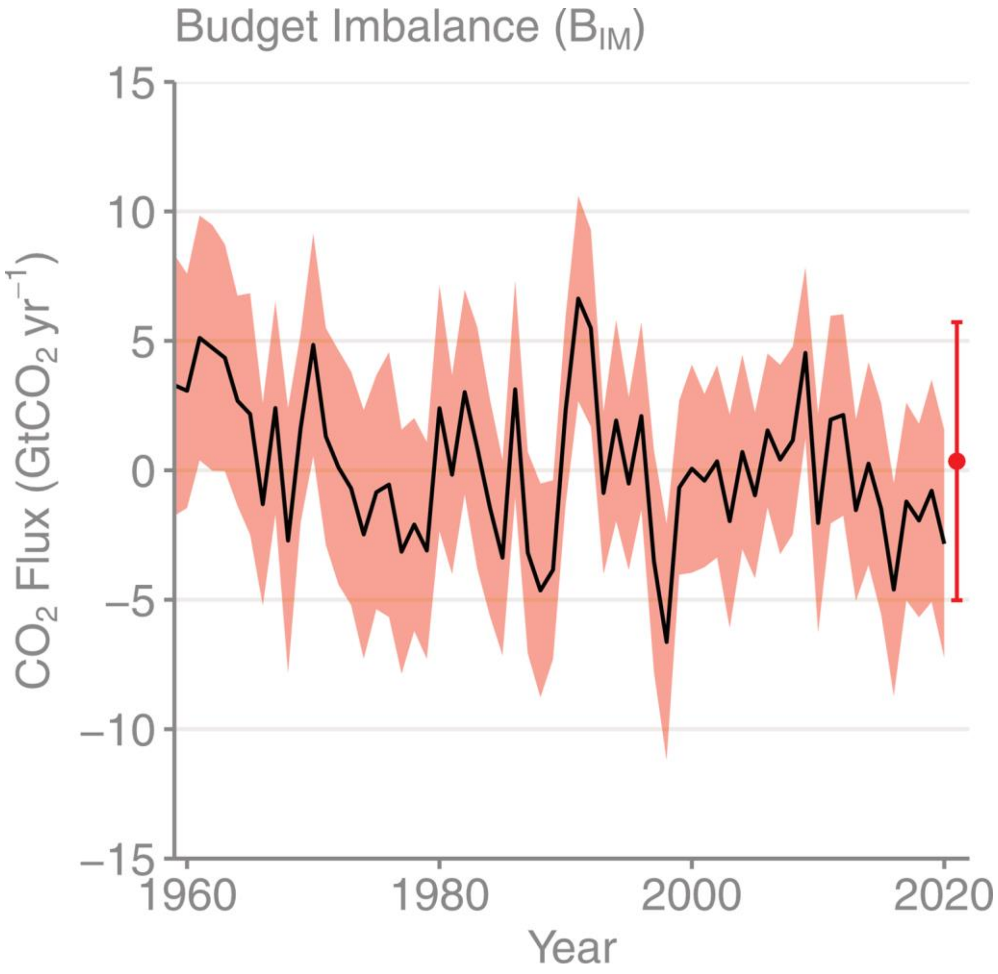
Total land and ocean fluxes show more interannual variability in the tropics



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

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



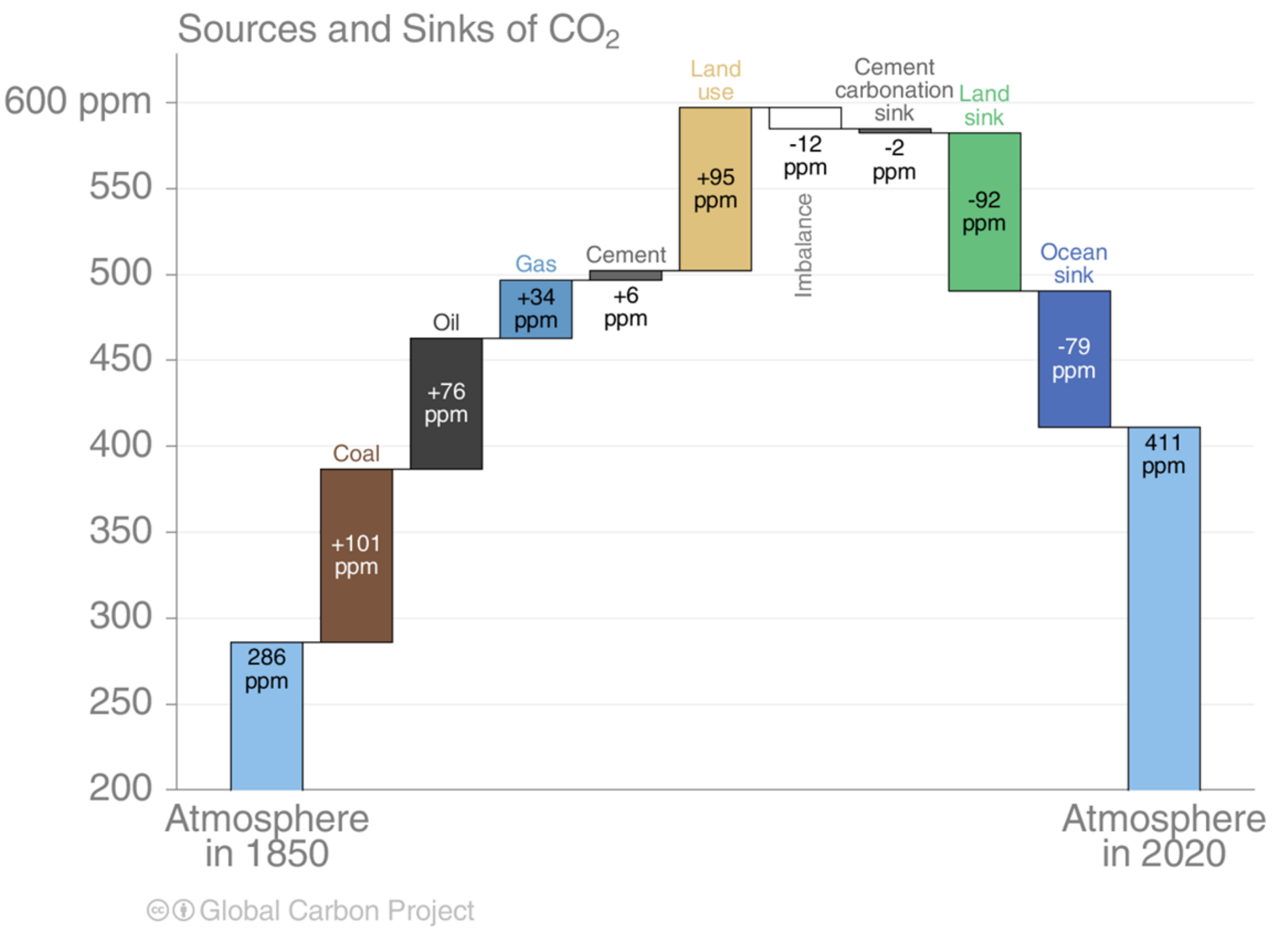
positive values mean overestimated emissions and/or underestimated sinks

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 2021; Global Carbon Project 2021

Global carbon budget

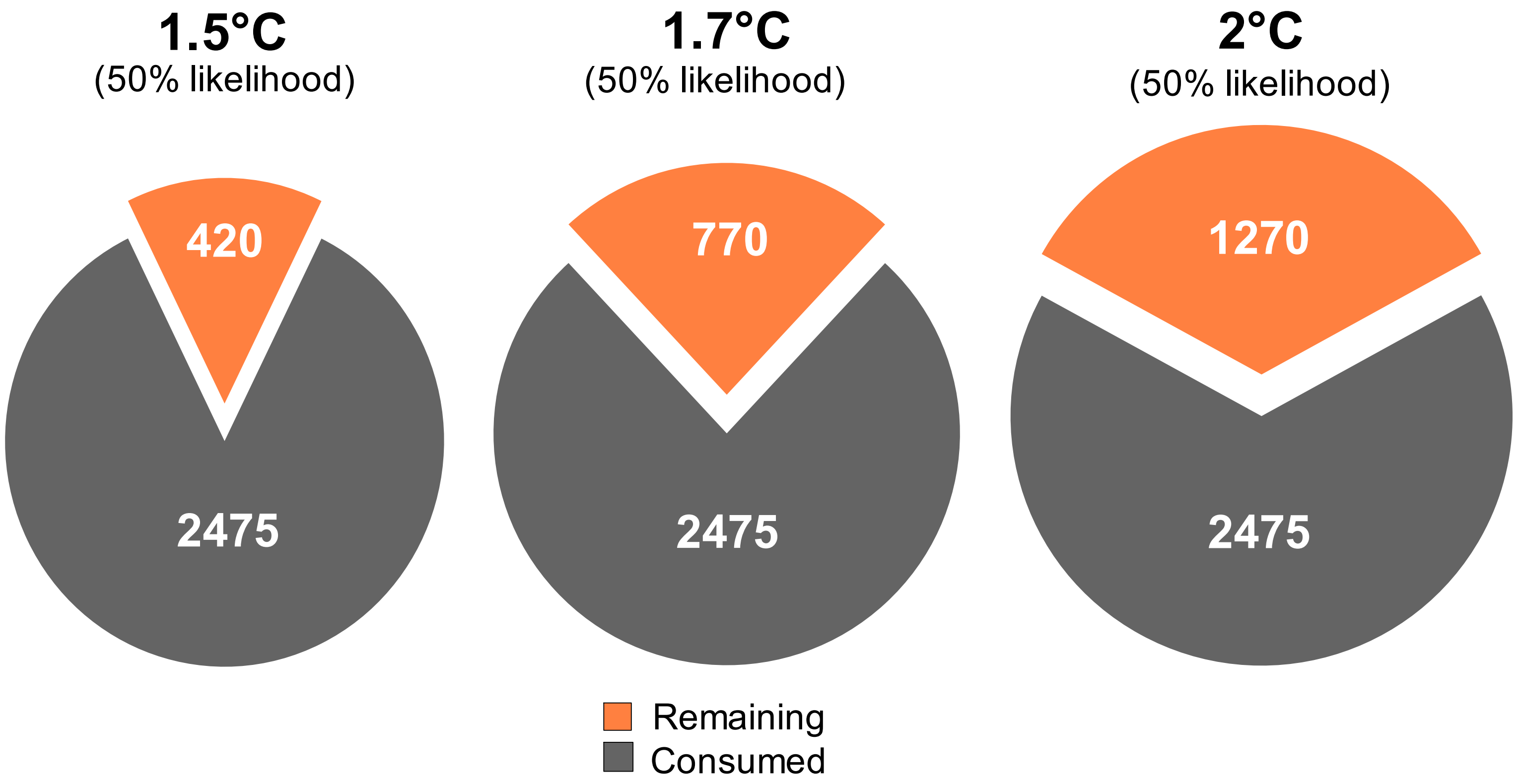
The cumulative contributions to the global carbon budget from 1850
The carbon imbalance represents the gap in our current understanding of sources & sinks



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 $GtCO_2$, 770 $GtCO_2$, and 1270 $GtCO_2$ respectively, equivalent to 11, 20 and 32 years from 2022.
2475 $GtCO_2$ have been emitted since 1750



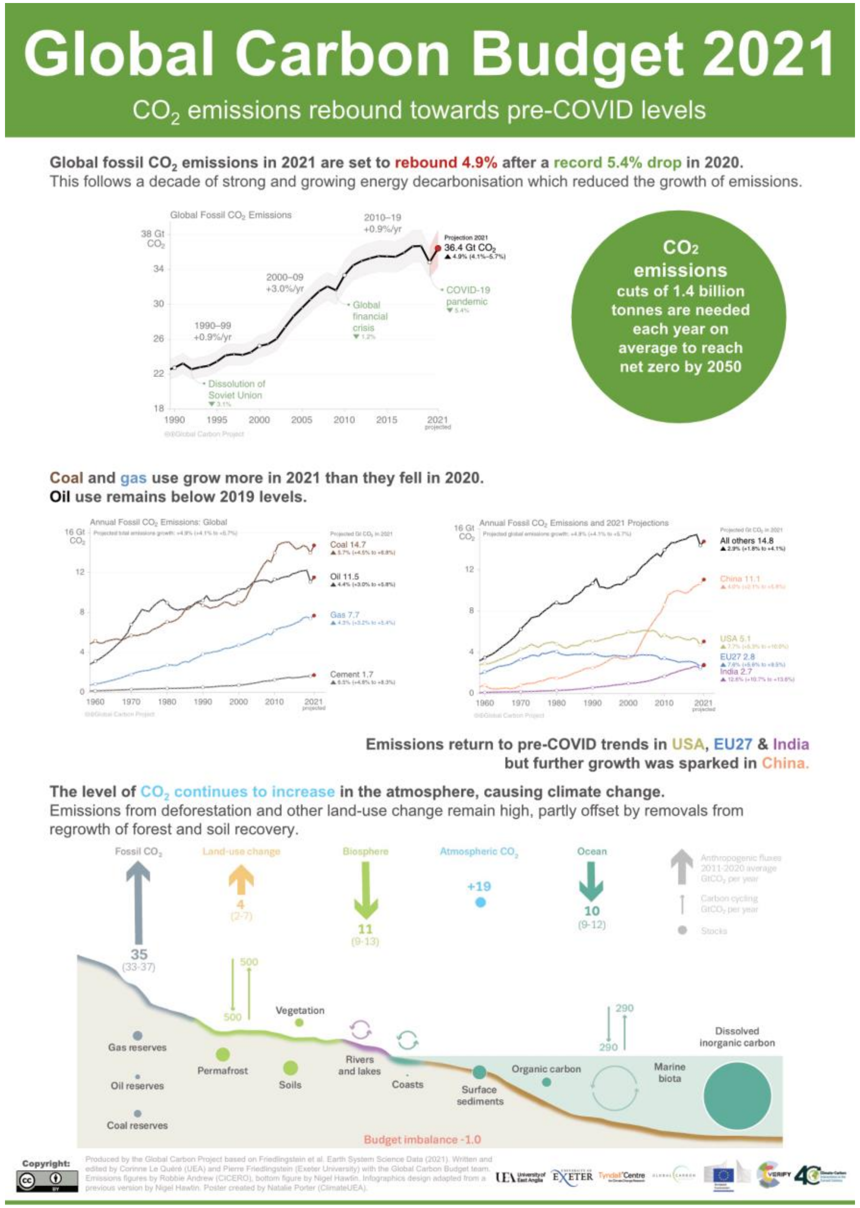
Quantities are subject to [additional] uncertainties e.g., future mitigation choices of non-CO_2 emissions
Source: IPCC AR6 WG1; Friedlingstein et al 2021; Global Carbon Budget 2021

Infographics

GLOBAL CARBON PROJECT

Infographic

futurearth
Research. Innovation. Sustainability.



Download in full resolution

GLOBAL CARBON PROJECT

Acknowledgements

GLOBAL CARBON PROJECT

Acknowledgements

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.

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

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

We also want 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. 2021.

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

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

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

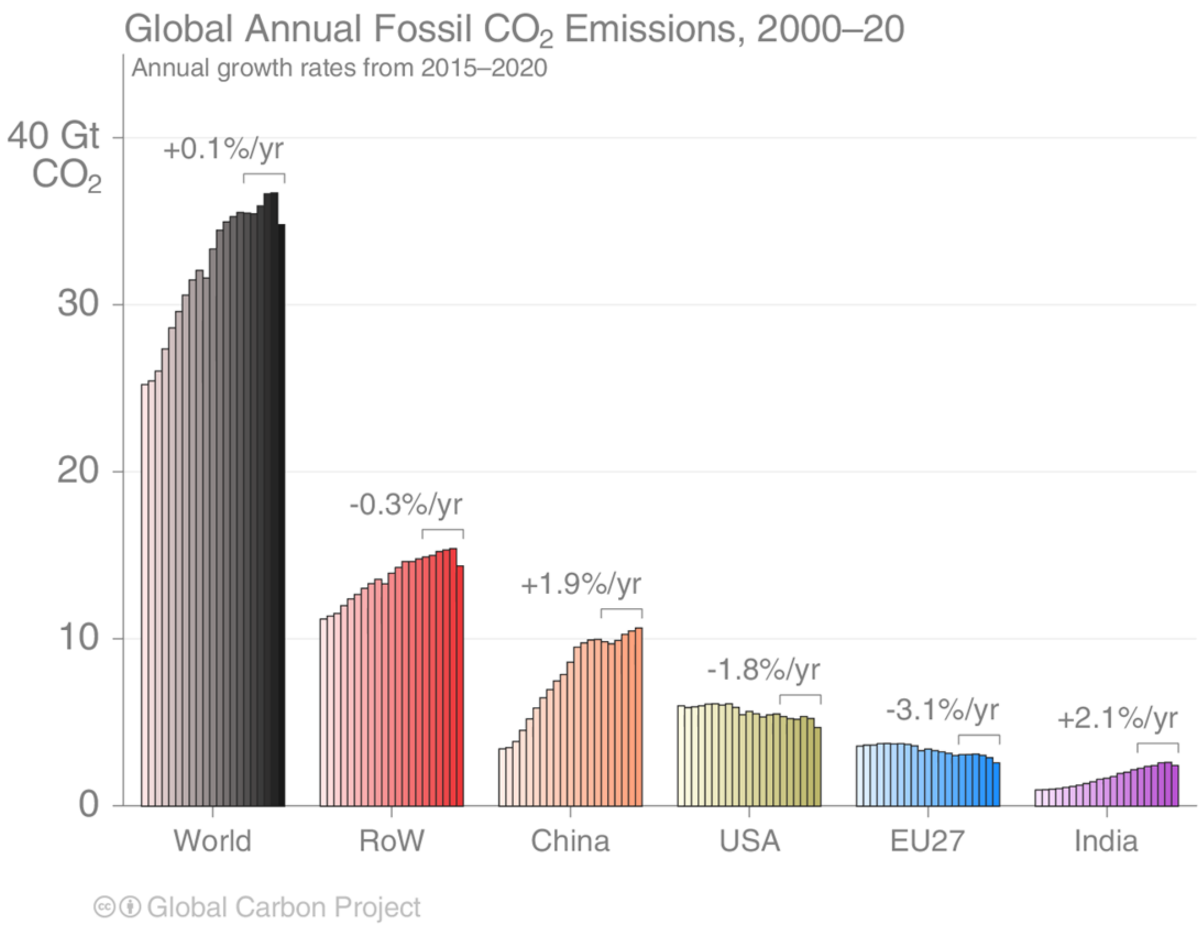
Additional Figures

Additional Figures

Fossil CO_2

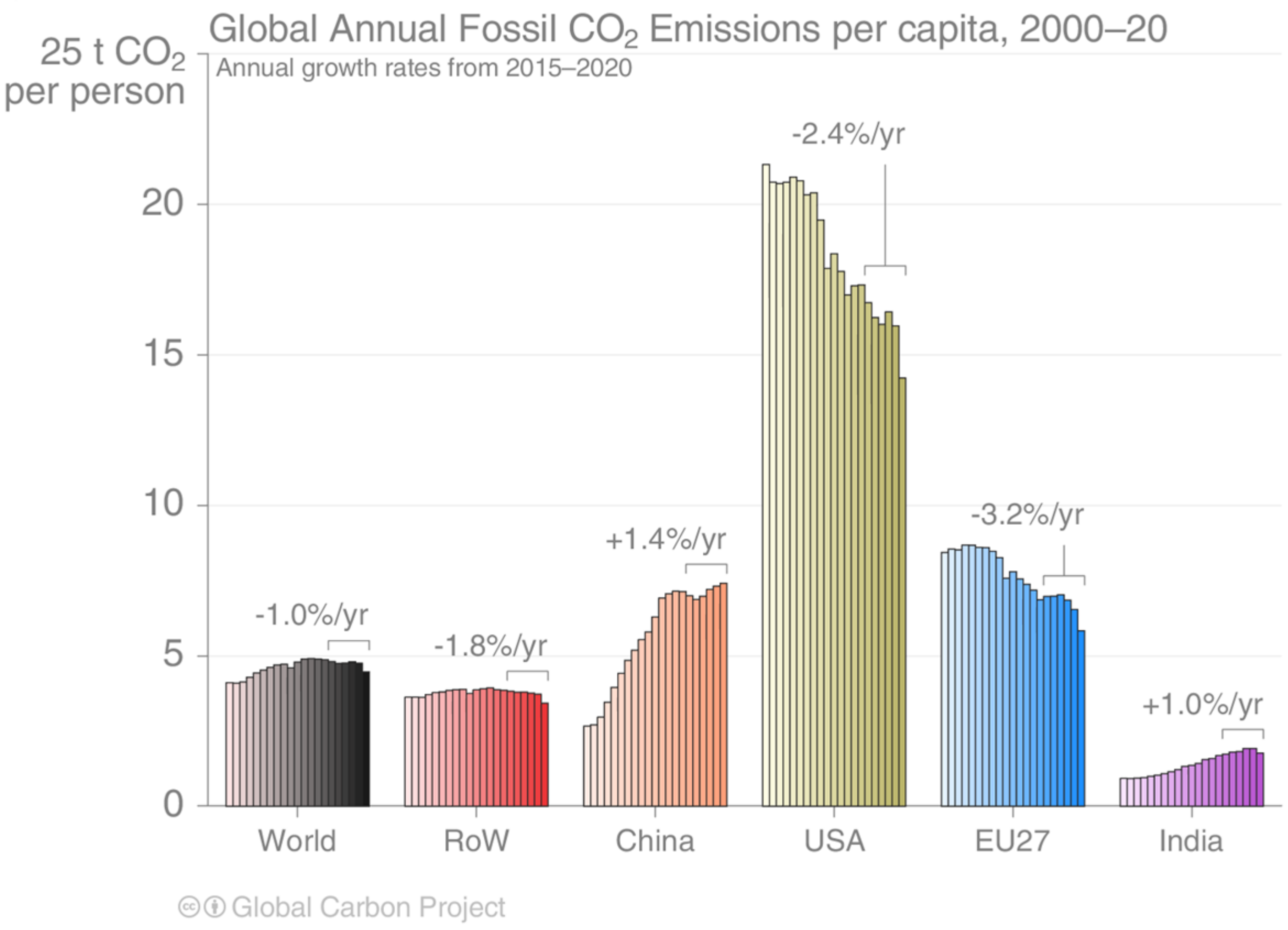
Top emitters: Fossil CO_2 Emissions

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



Source: Friedlingstein et al 2021; Global Carbon Project 2021

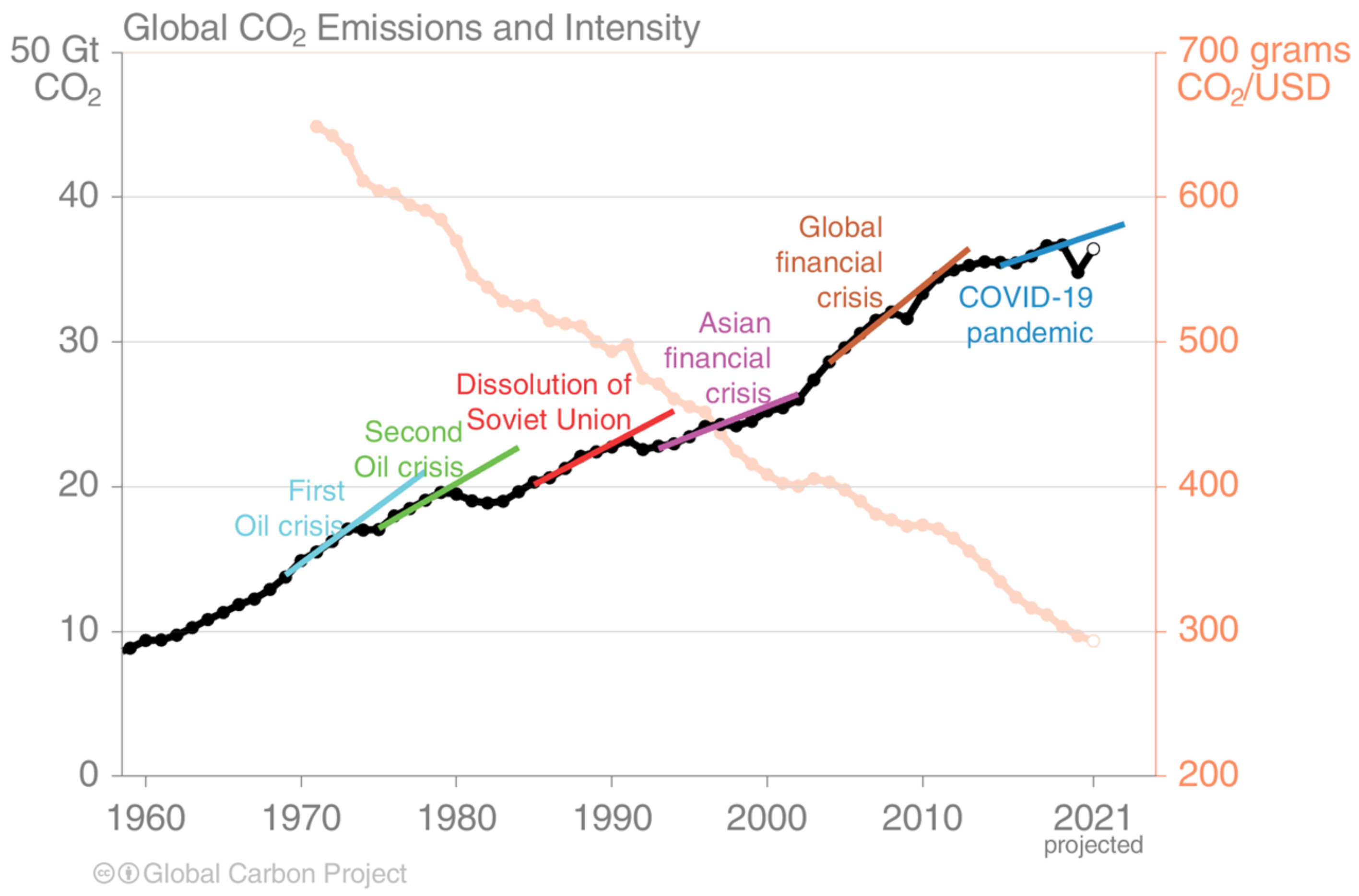
Per capita CO_2 emissions



Source: Friedlingstein et al 2021; Global Carbon Project 2021

Fossil CO_2 emission intensity

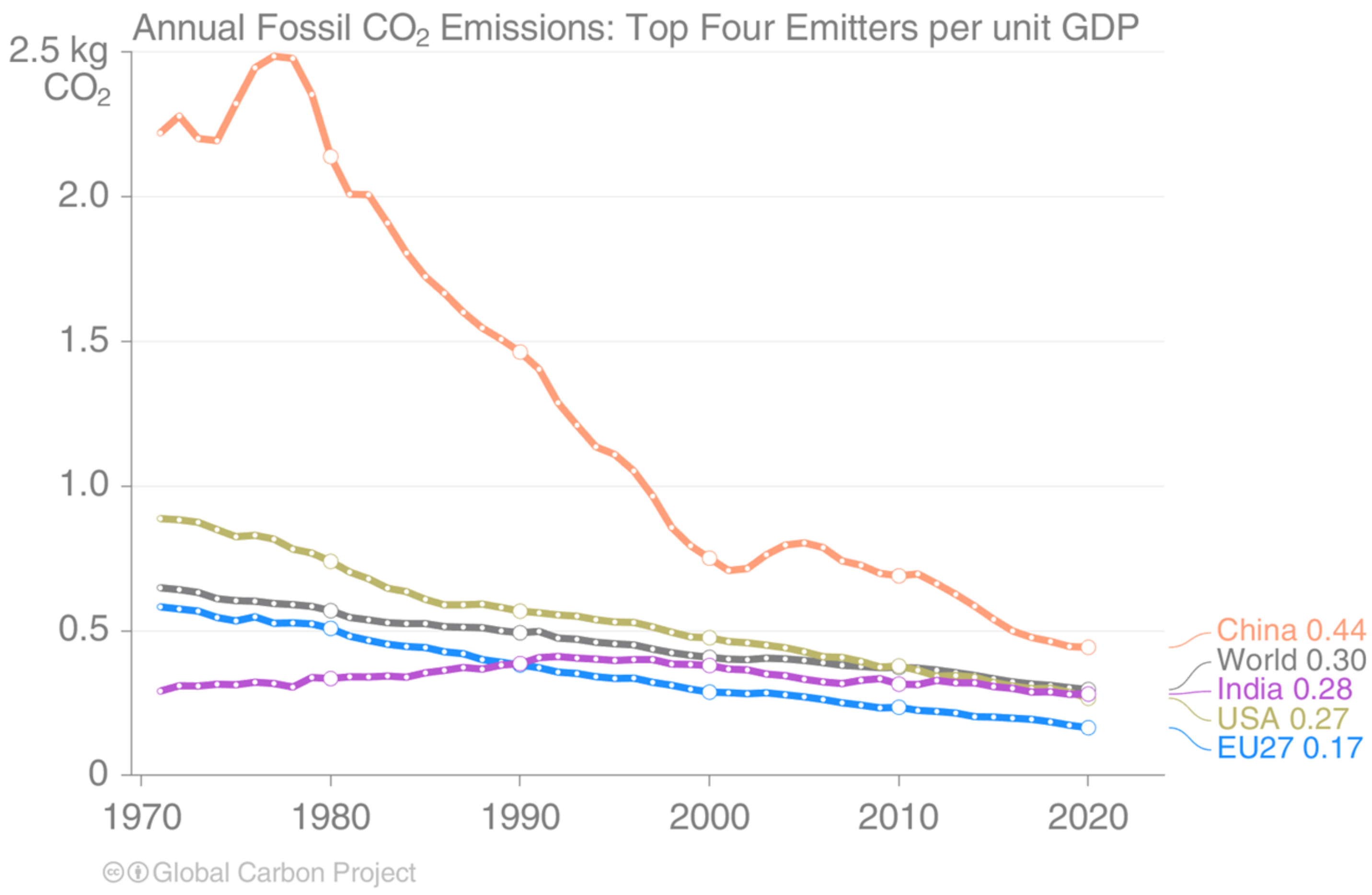
Global CO_2 emissions growth has generally resumed quickly from global crises.
Emission intensity has steadily declined but not sufficiently to offset economic growth.



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 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.

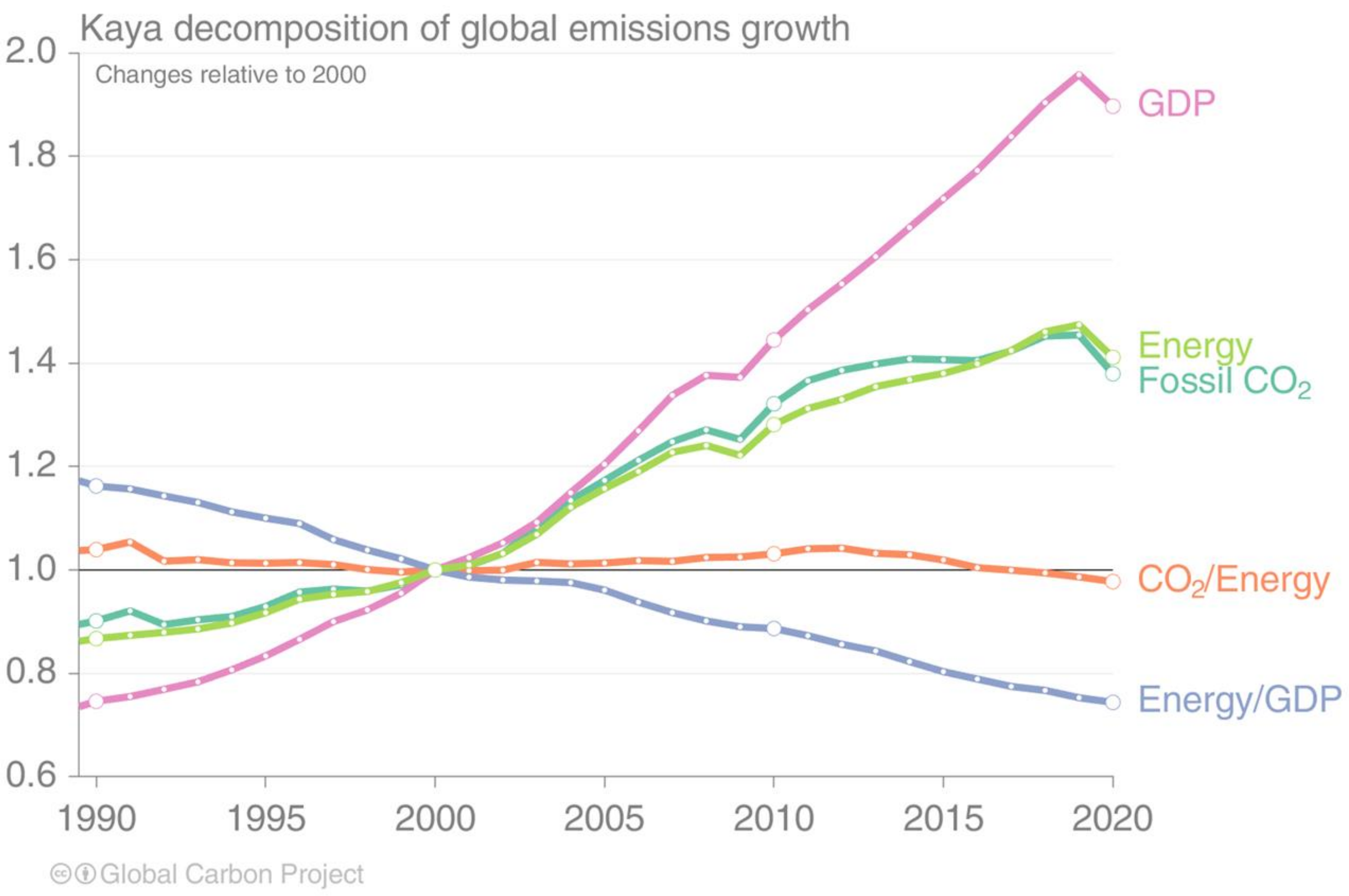


GDP is measured in purchasing power parity (PPP) terms in 2010 US dollars.

Source: Friedlingstein et al 2021; Global Carbon Project 2021

Kaya decomposition

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

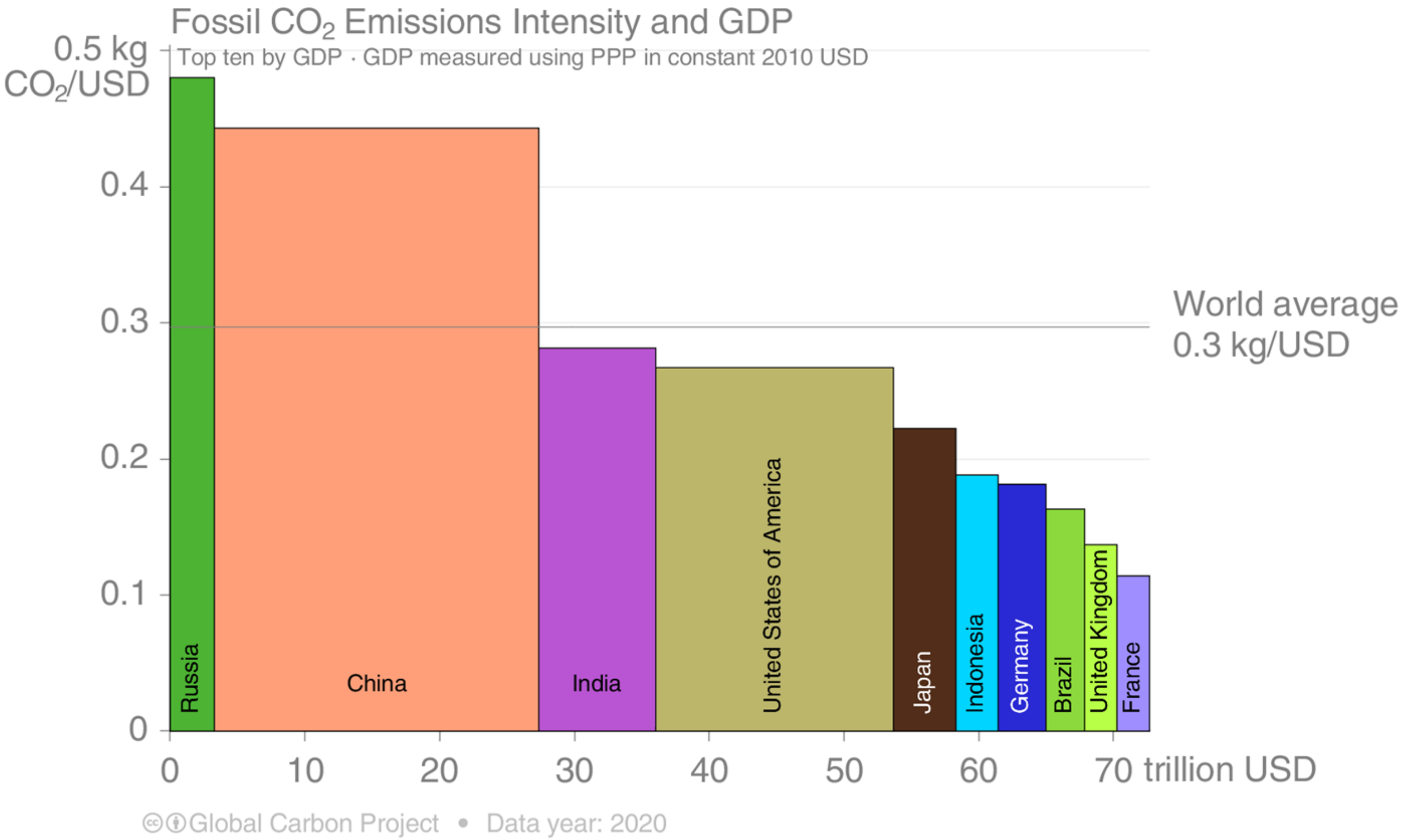


GDP: Gross Domestic Product (economic activity)

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

Fossil CO_2 emission intensity

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

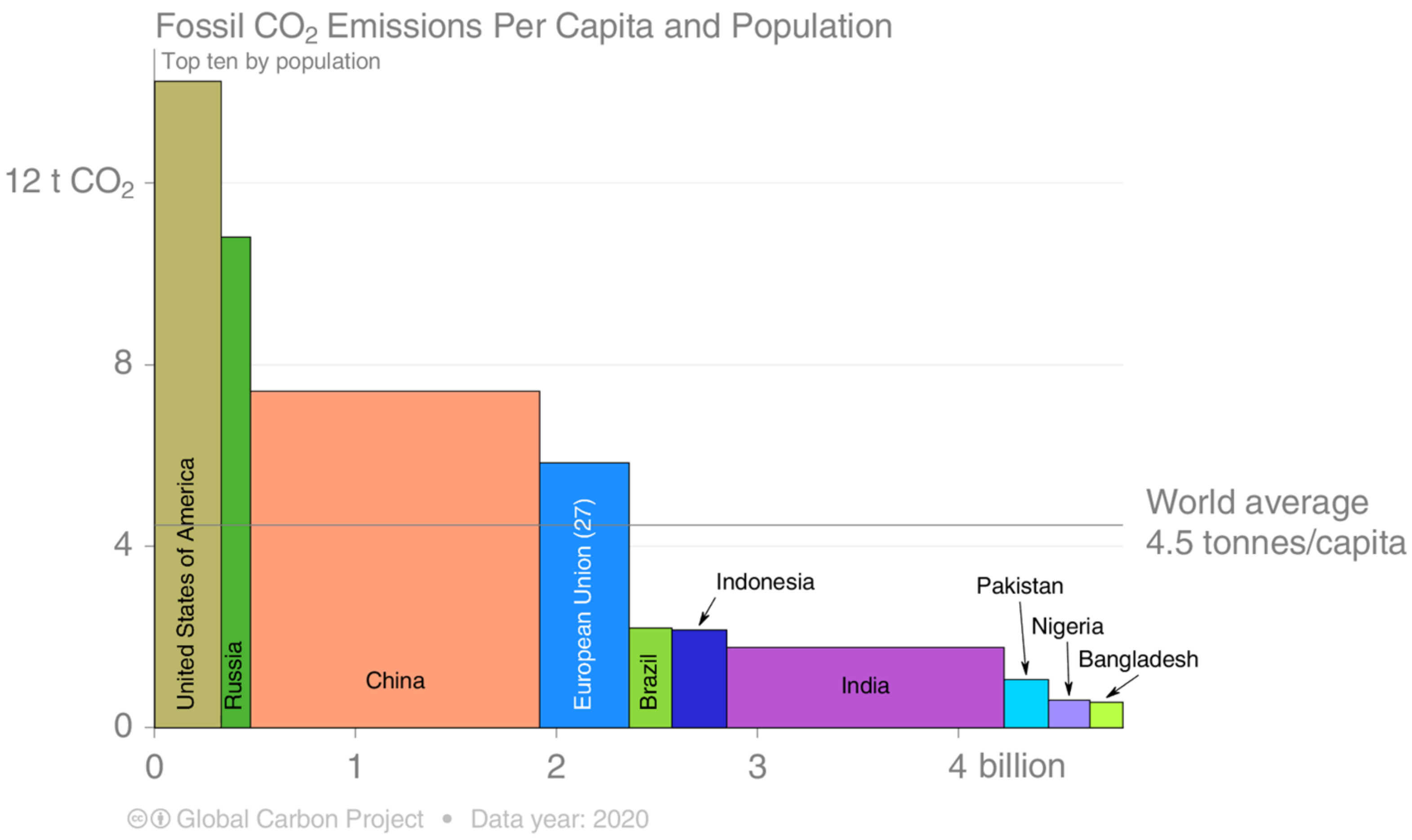


Emission intensity: Fossil CO_2 emissions divided by Gross Domestic Product (GDP)

Source: Friedlingstein et al 2021; Global Carbon Project 2021

Fossil CO_2 Emissions per capita

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

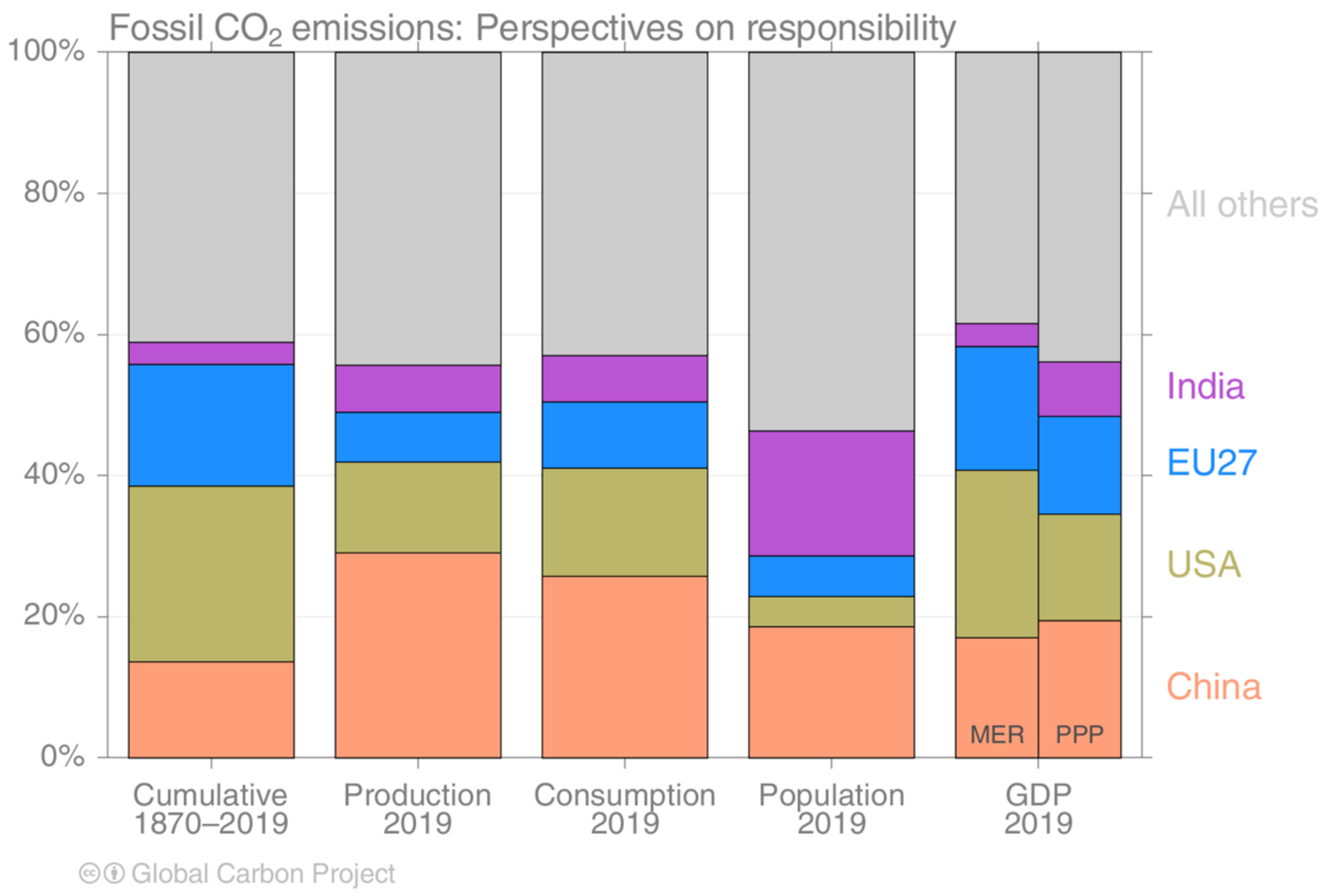


Emission per capita: Fossil CO_2 emissions divided by population

Source: Friedlingstein et al 2021; Global Carbon Project 2021

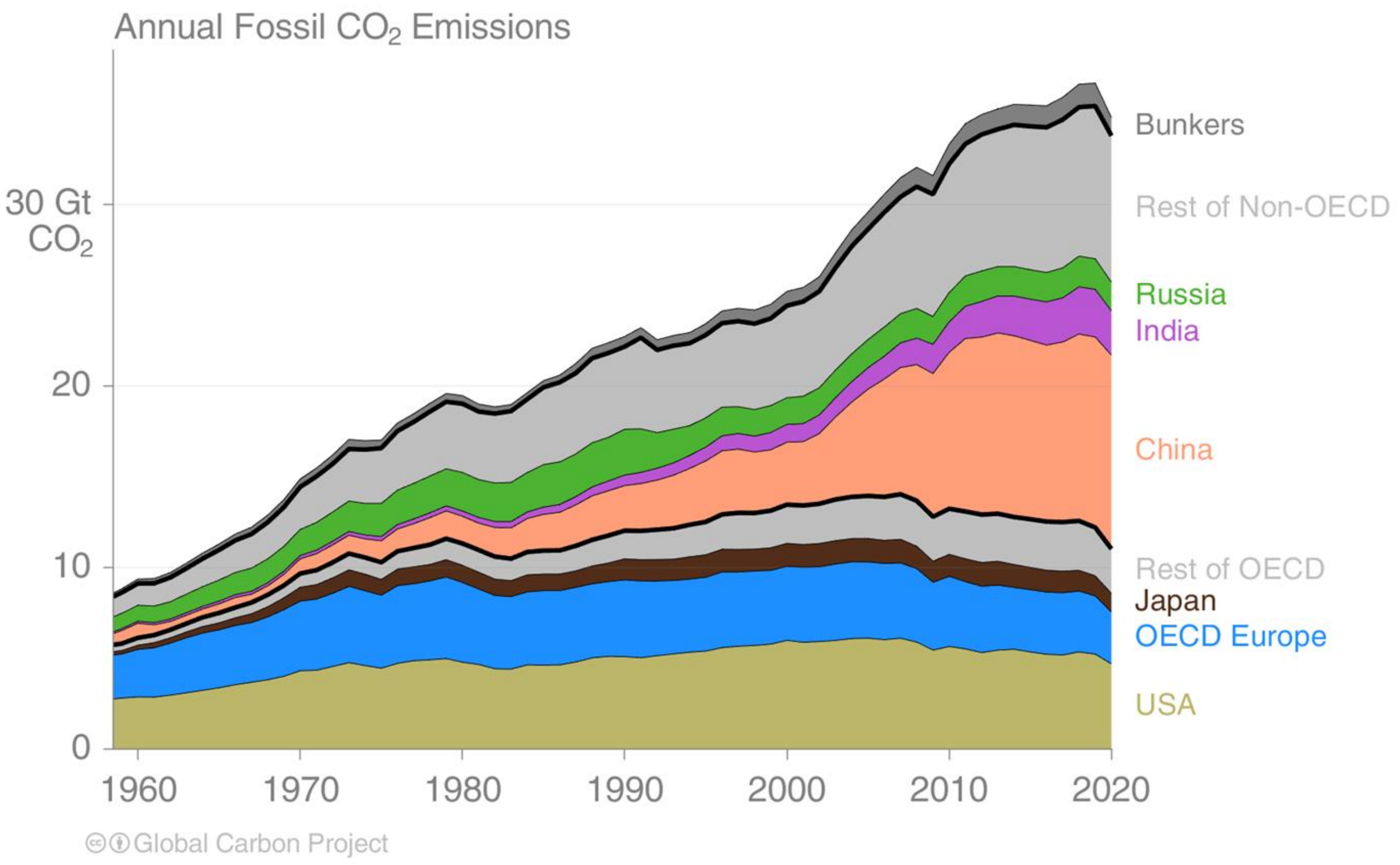
Alternative rankings of countries

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 2021; Global Carbon Project 2021

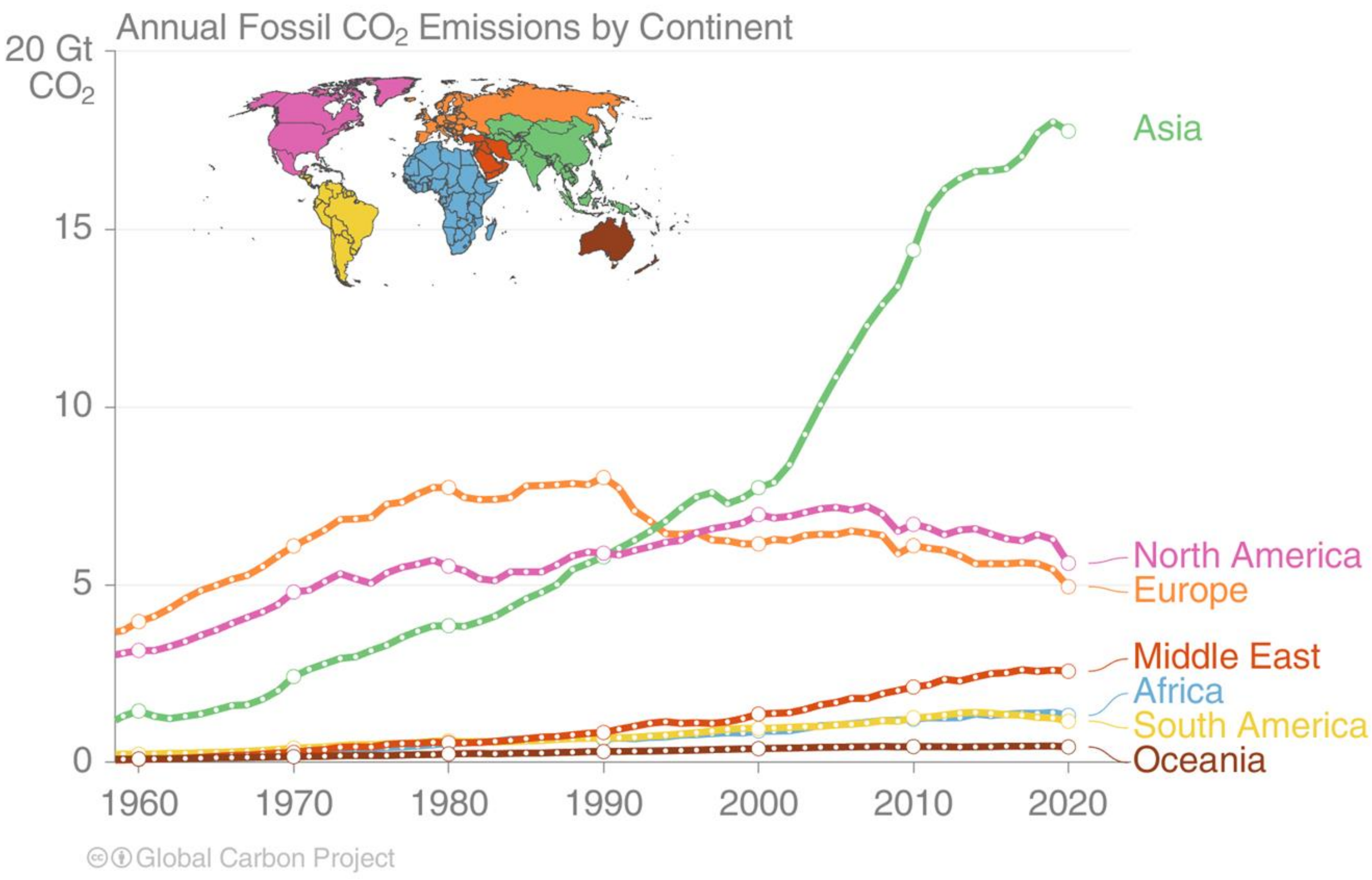
Breakdown of global fossil CO_2 emissions by country



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

Fossil CO_2 emissions by continent

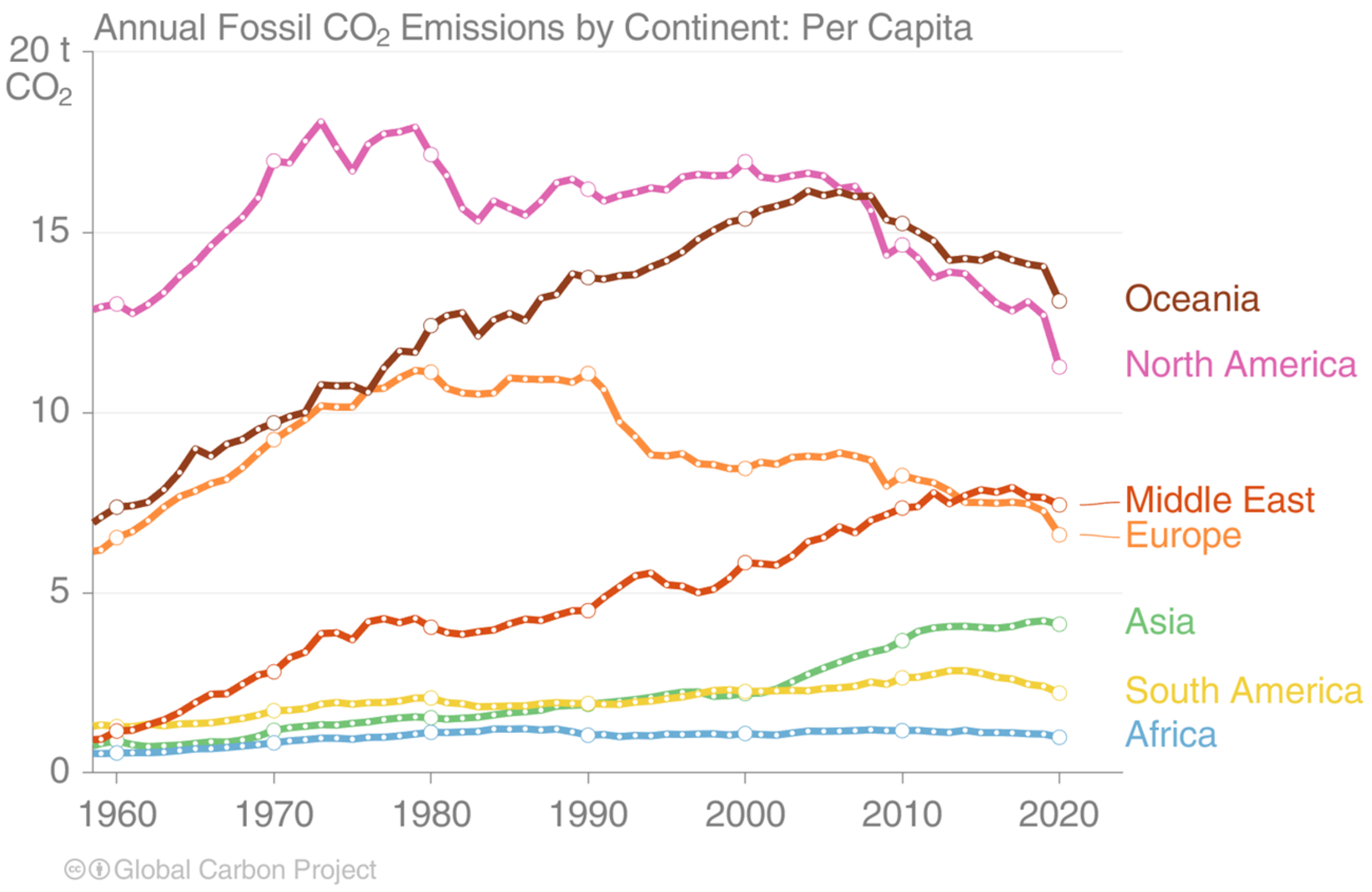
Asia dominates global fossil CO_2 emissions, while emissions in North America are of similar size to those in Europe, and the Middle East is growing rapidly.



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

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 2021; Global Carbon Project 2021

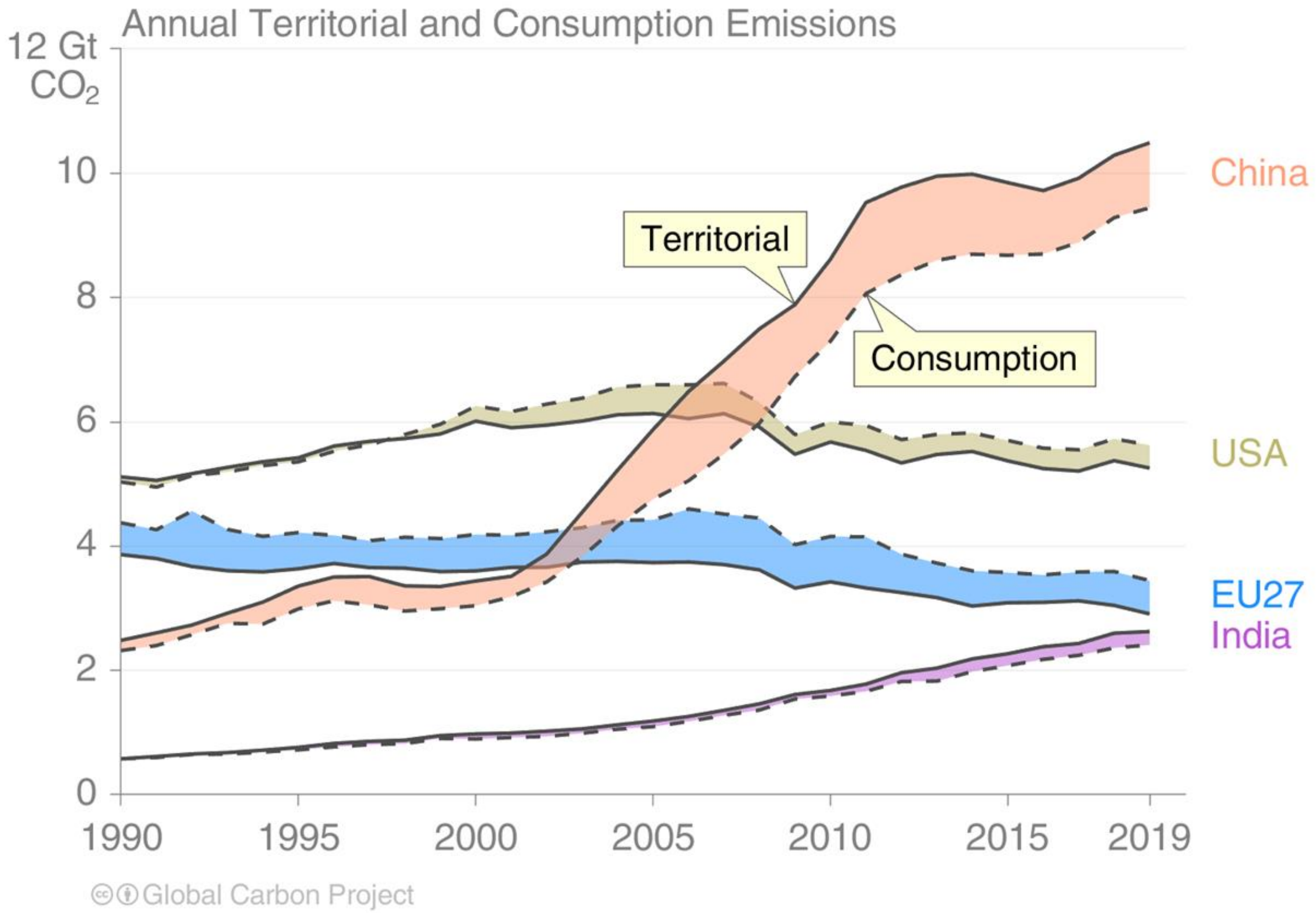
Additional Figures
Consumption-based Emissions

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)

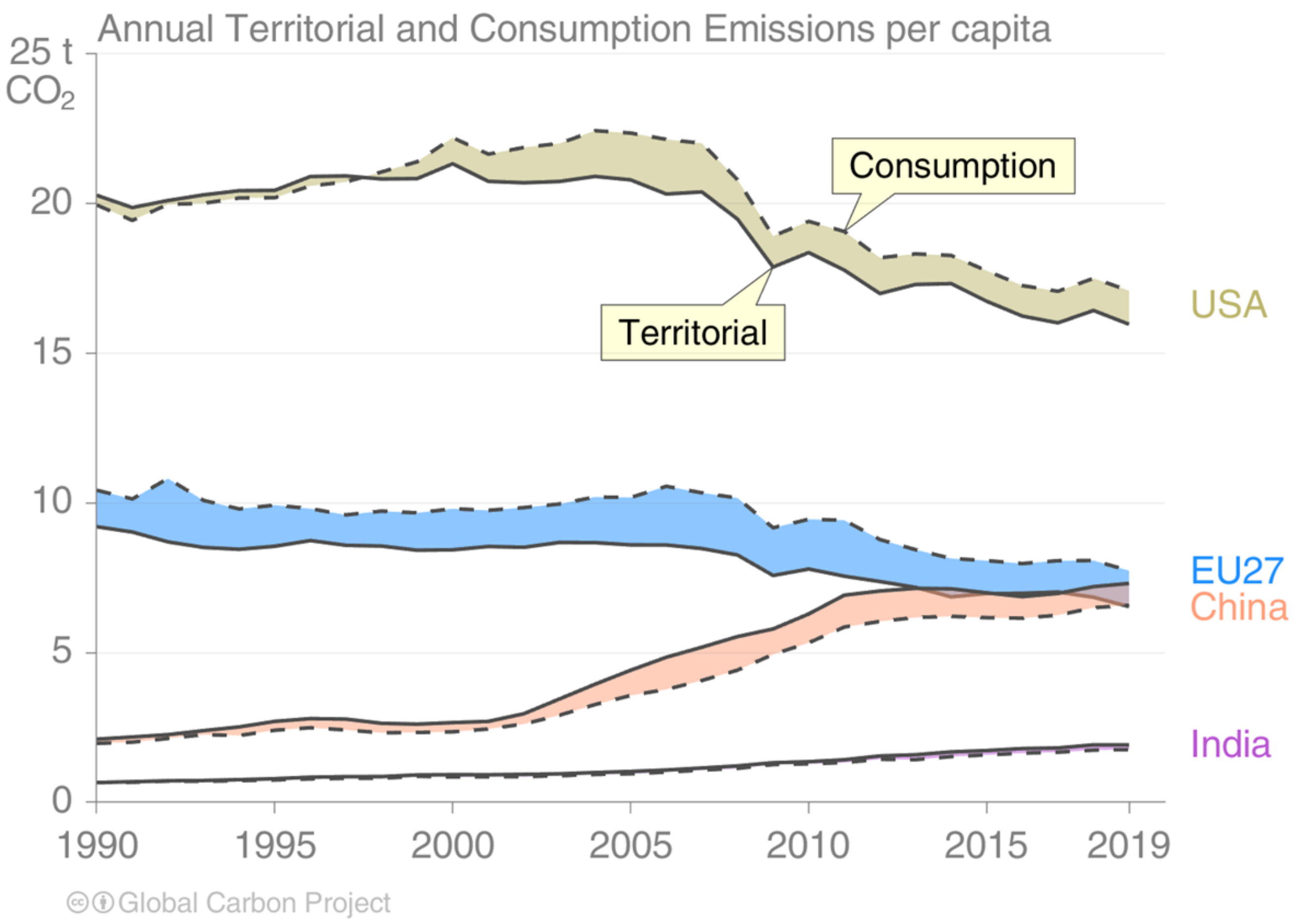
Allocating fossil CO_2 emissions to consumption provides an alternative perspective.
USA and EU28 are net importers of embodied emissions, China and India are net exporters.



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 2021; 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.

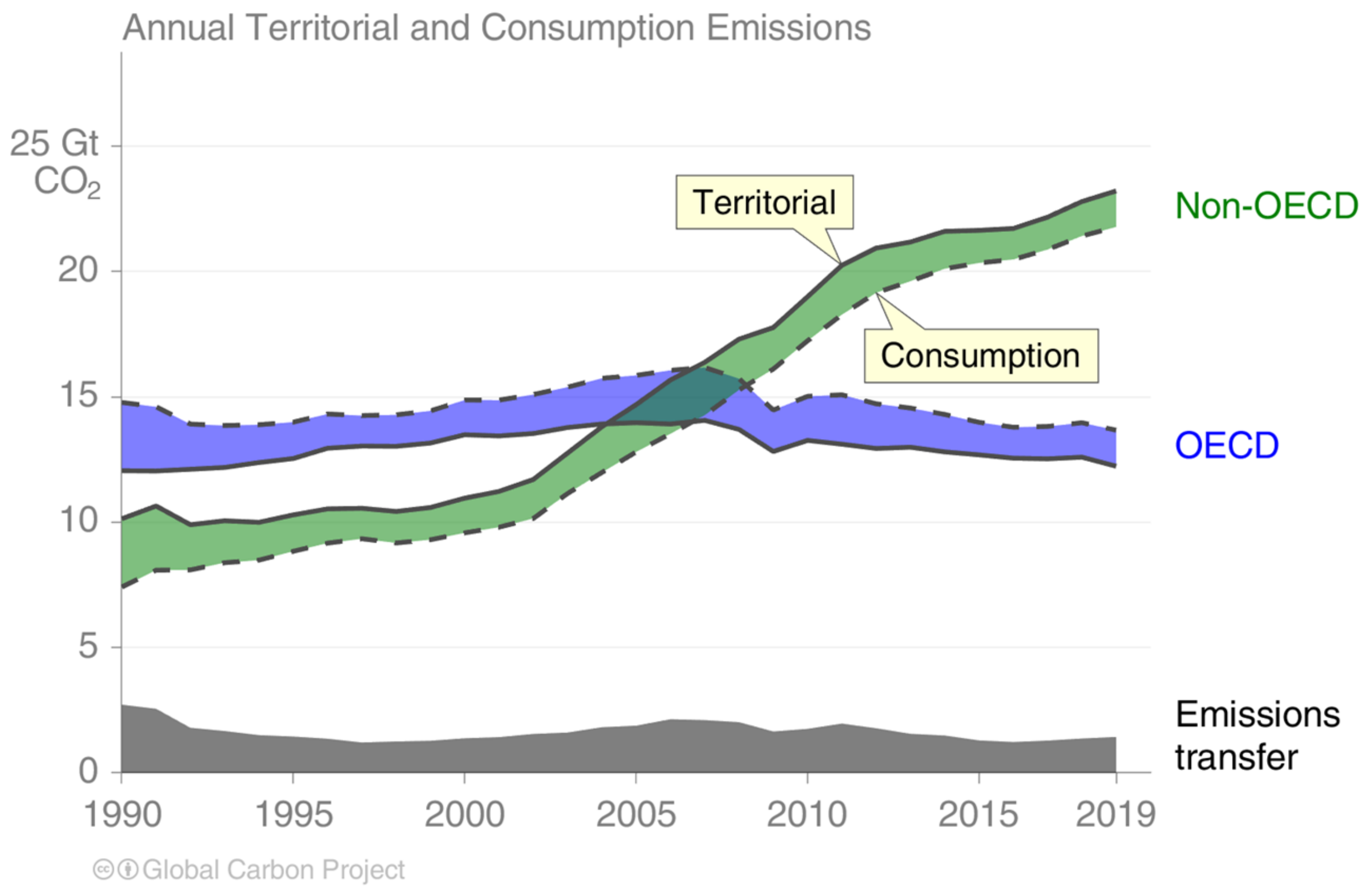


Consumption-based emissions are calculated by adjusting the standard production-based emissions to account for international trade

Source: Peters et al 2011; Friedlingstein et al 2021; Global Carbon Project 2019

Consumption-based emissions (carbon footprint)

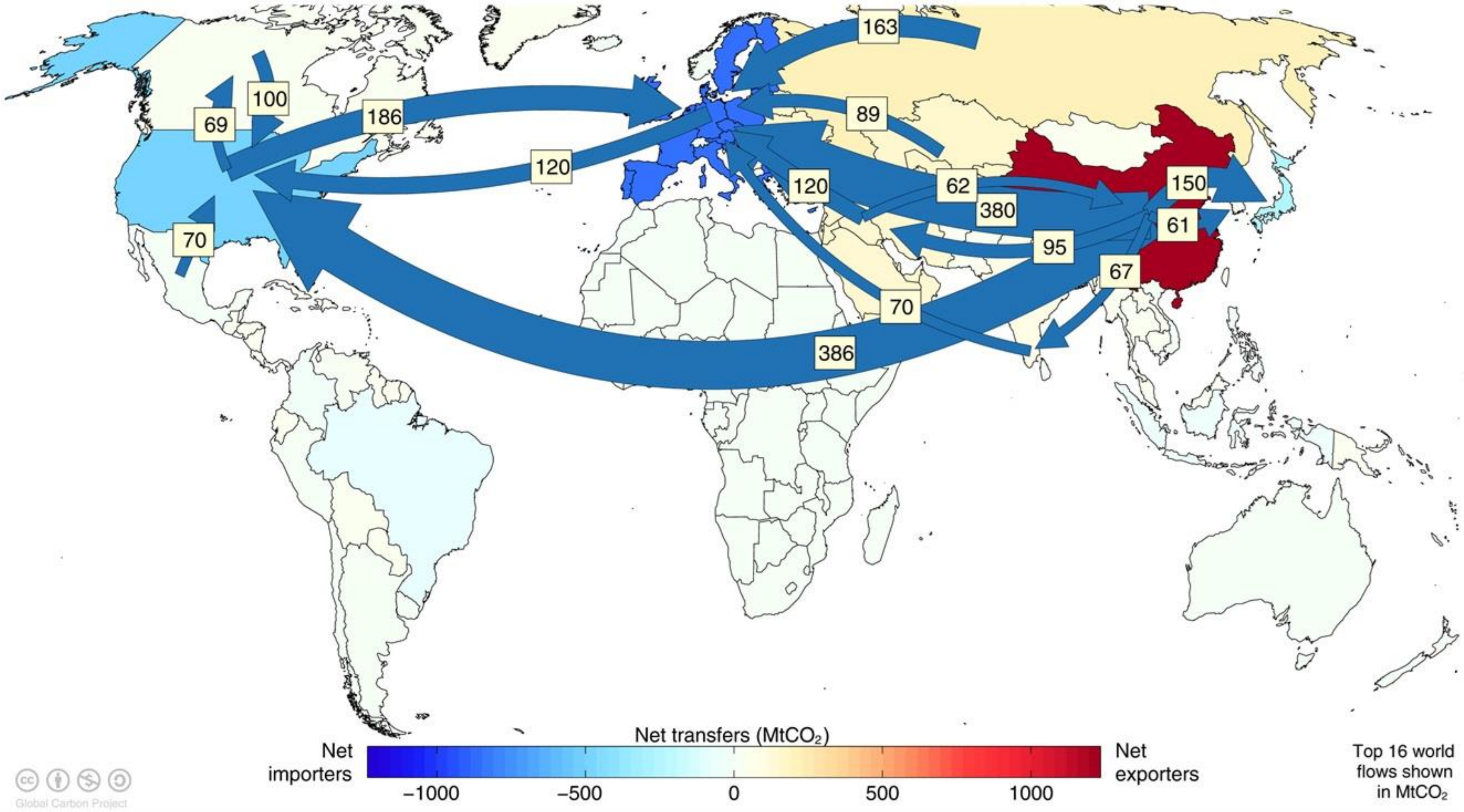
Transfers of emissions embodied in trade between OECD and non-OECD countries grew slowly during the 2000's, but has since slowly declined.



Source: Peters et al 2011; Friedlingstein et al 2021; Global Carbon Project 2021

Major flows from production to consumption

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

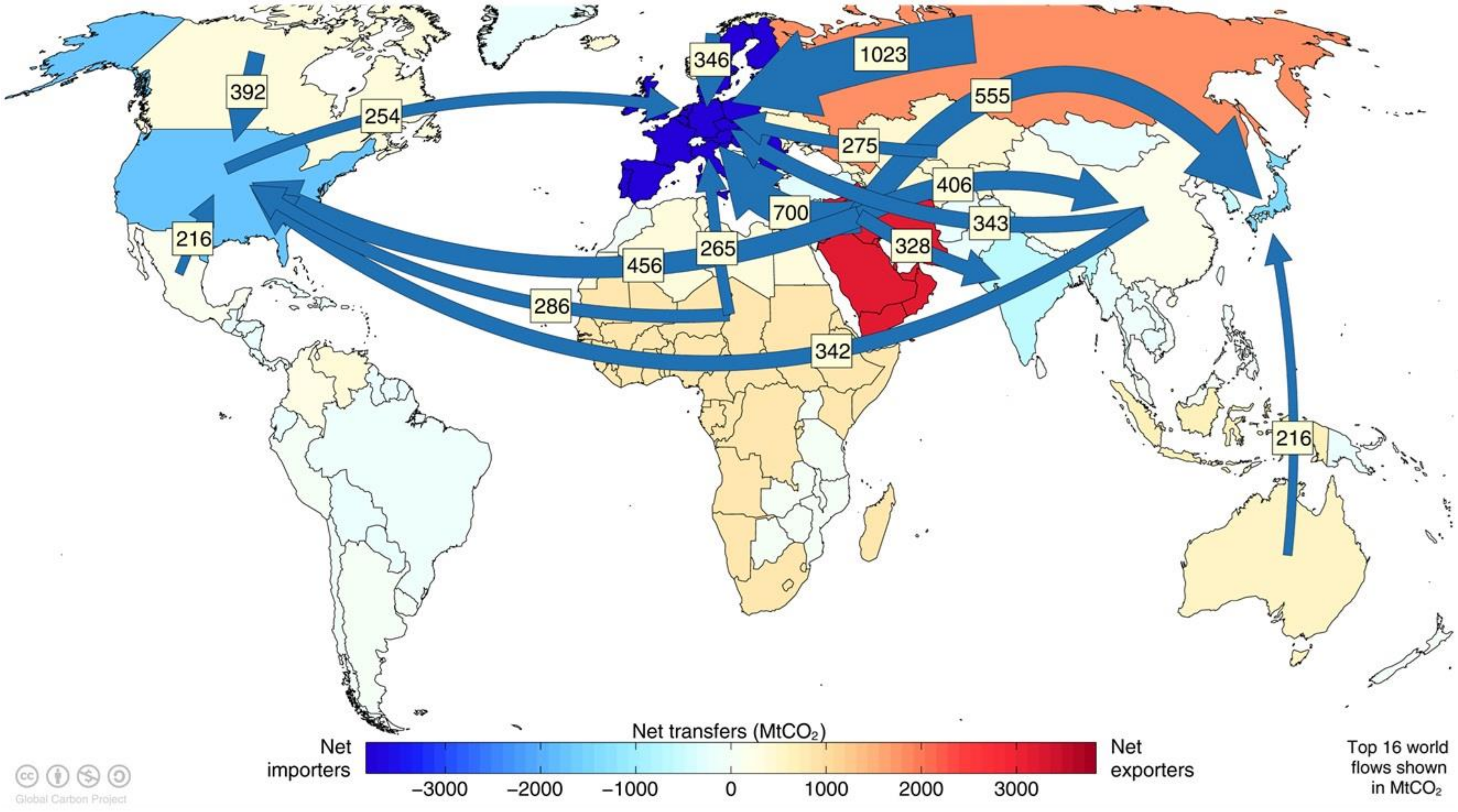


Values for 2011. EU is treated as one region. Units: $MtCO_2$

Source: [Peters et al 2012]

Major flows from extraction to consumption

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



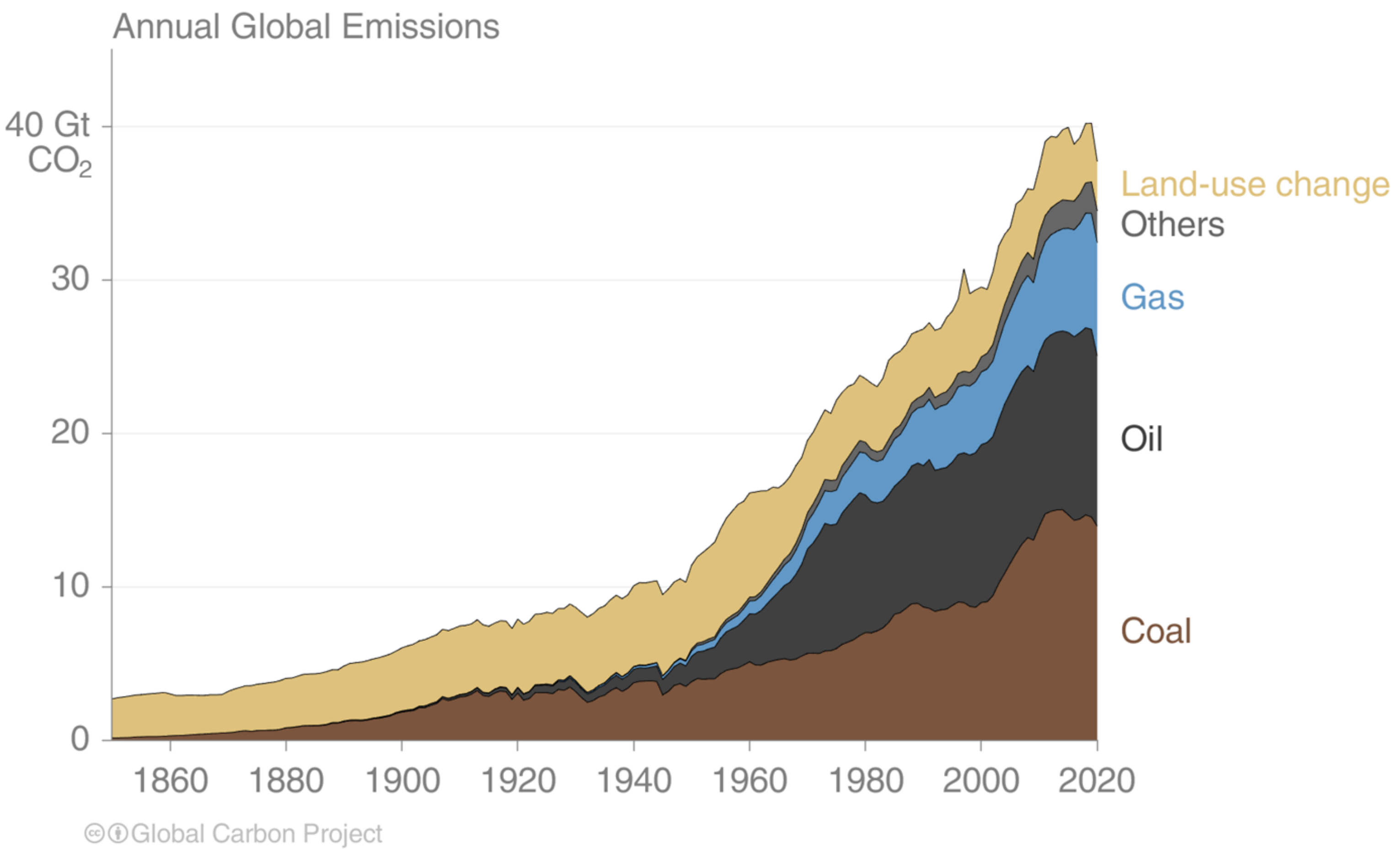
Values for 2011. EU is treated as one region. Units: $MtCO_2$

Source: Andrew et al 2013

Additional Figures
Historical Emissions

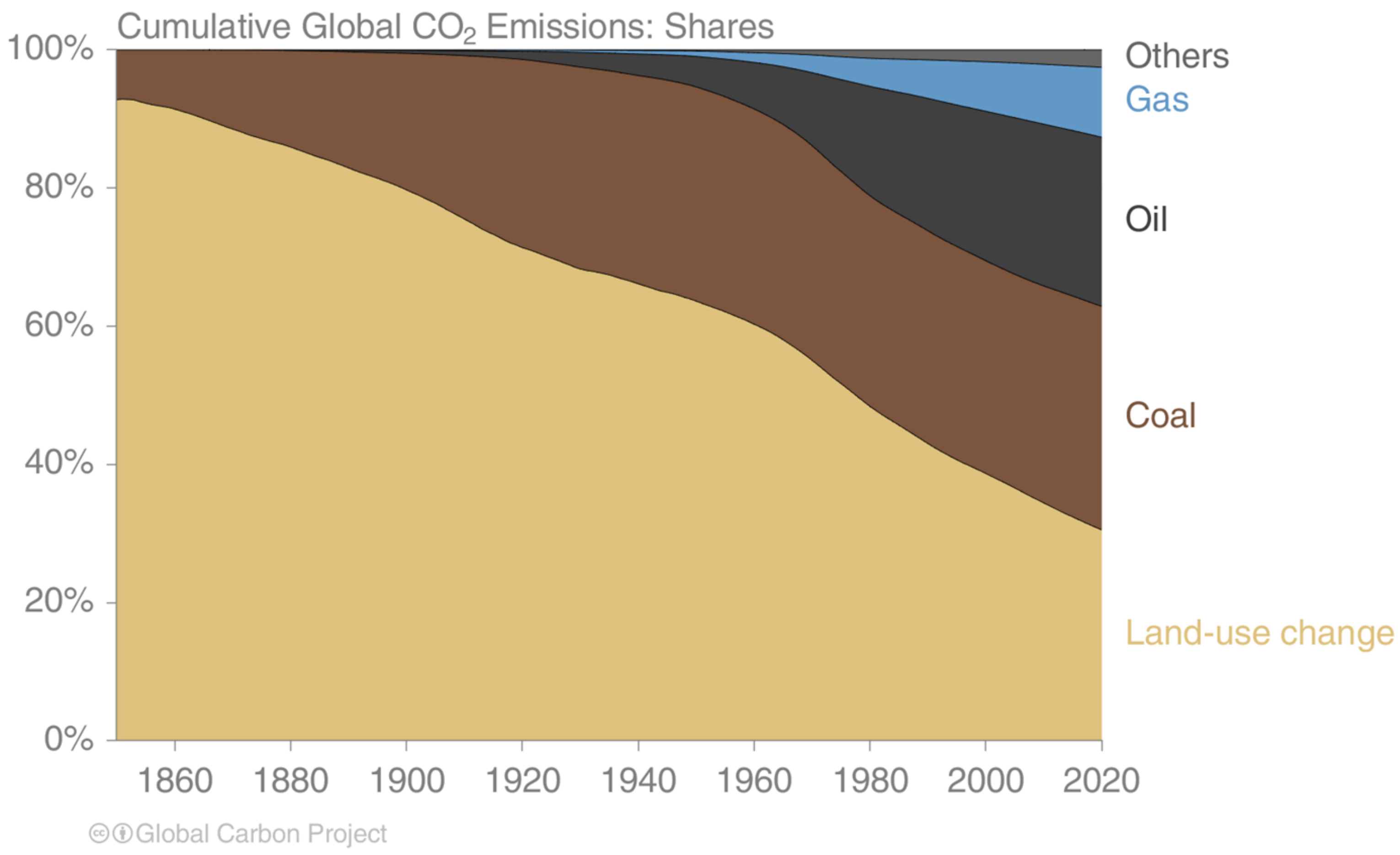
Total global emissions by source

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

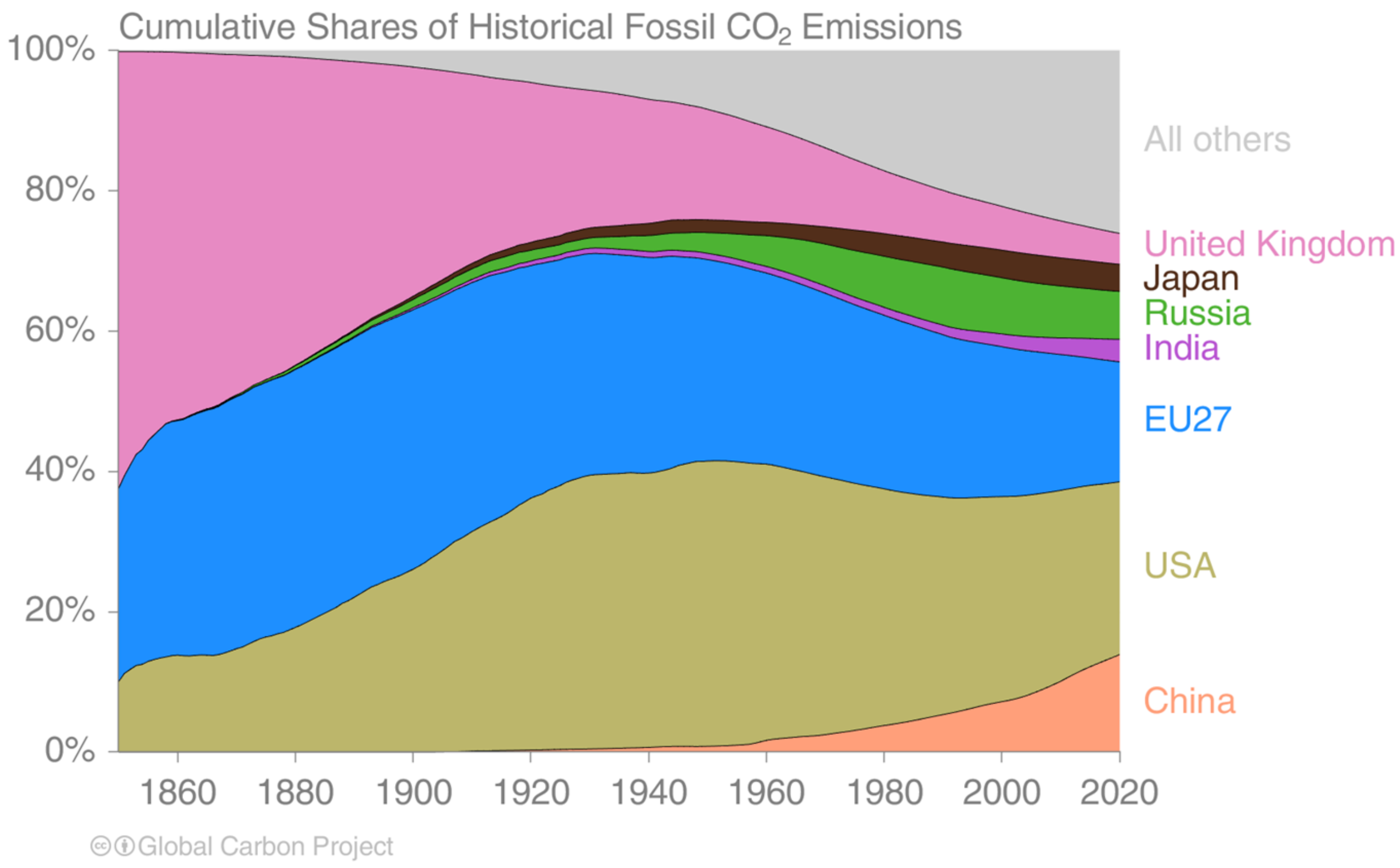


Others: Emissions from gas flaring and carbonate decomposition

Source: Friedlingstein et al 2021; Global Carbon Project 2021

GLOBAL CARBON PROJECT

Historical cumulative fossil CO_2 emissions by country

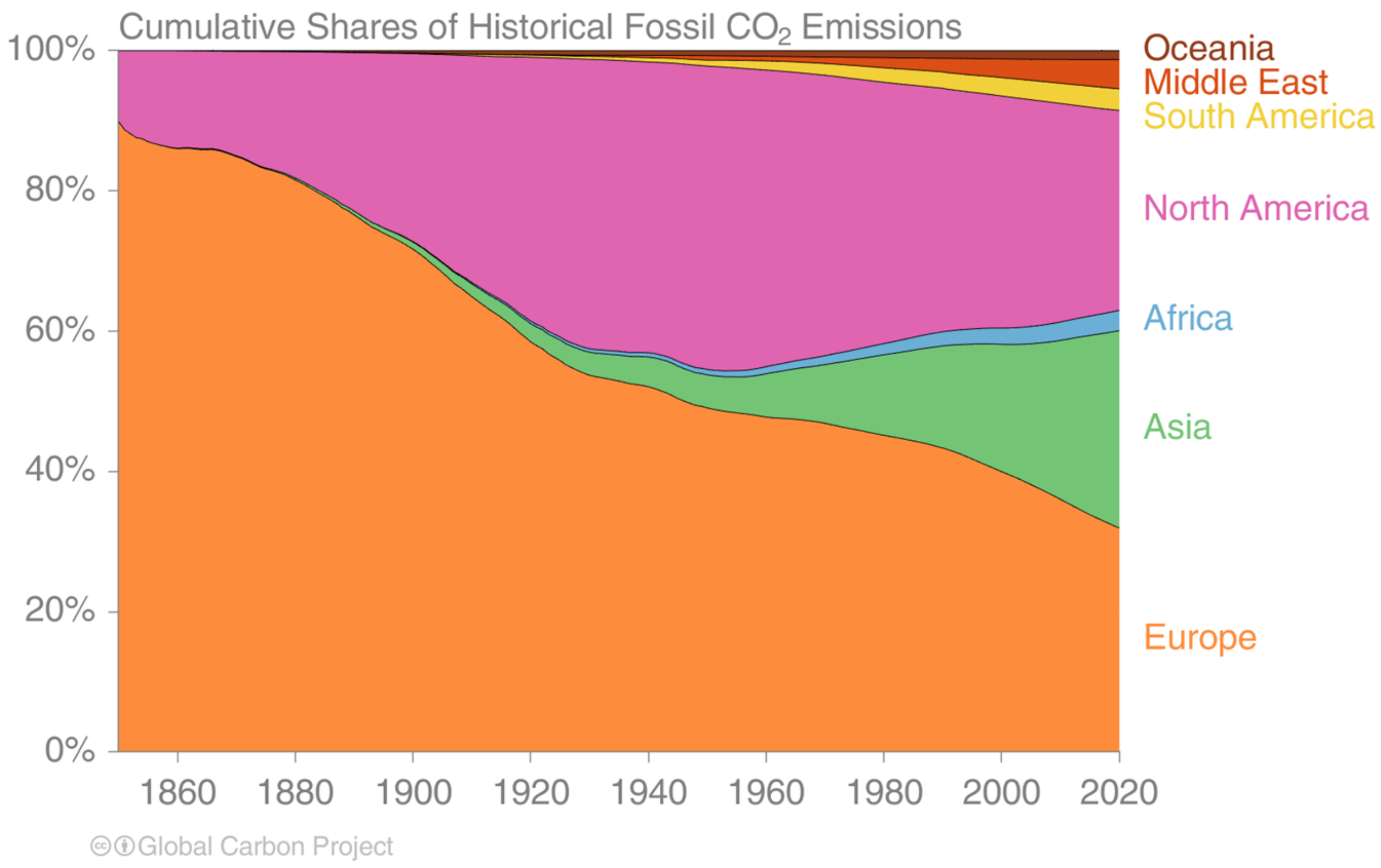


‘All others’ includes all other countries along with emissions from international aviation and maritime shipping

Source: Friedlingstein et al 2021; Global Carbon Project 2021

Historical cumulative emissions by continent

Cumulative fossil CO_2 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