GLOBAL CARBON PROJECT

Global Carbon Budget

2020

The GCP is a Global Research Project of futurearth Research. Innovation. Sustainability.

and a Research Partner of WCRP World Climate Research Programme

Published on 11 December 2020

PowerPoint version 1.0 (released 11 December 2020)

GLOBAL CARBON PROJECT

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 2020)
Scripps (Keeling et al. 1976)

Fossil CO_2 emissions
CDIAC (Gilfillan et al. 2019)
Andrew, 2019
UNFCCC, 2020
BP, 2020

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 | MIROC4-ACTM

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
CRU (Harris et al. 2014)
JRA-55 (Kobayashi et al. 2015)

Ocean models
CESM-ETHZ | CSIRO | FESOM-1.4-REcoM2 | MICOM-HAMOCC (NorESM-OCv1.2) | MOM6-COBALT (Princeton) | MPIOM-HAMOCC6 | NEMO3.6-PISCESv2-gas (CNRM) | NEMO-PISCES (IPSL) | NEMO-PlankTOM5

pCO_2-based ocean flux products
Jena-MLS | MPI-SOMFFN | CMEMS
SOCATv2019 | CSIR-ML6 | Watson et al.

Full references provided in Friedlingstein et al 2020

Contributors 86 people | 68 organisations | 16 countries

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

Simone Alin USA | **Luiz E. O. C. Aragão** Brazil | **Almut Arneth** Germany | **Vivek Arora** Canada | **Nicholas R. Bates** Bermuda | **Meike Becker** Norway | **Alice Benoit-Cattin** Iceland | **Henry C. Bittig** Germany | **Laurent Bopp** France | **Selma Bultan** Germany | **Naveen Chandra** Japan | **Frédéric Chevallier** France | **Louise P. Chini** USA | **Wiley Evans** Canada | **Liesbeth Florentie** Netherlands | **Piers M. Forster** UK | **Thomas Gasser** Austria | **Marion Gehlen** France | **Dennis Gilfillan** USA | **Thanos Gkritzalis** Belgium | **Luke Gregor** Switzerland | **Nicolas Gruber** Switzerland | **Ian Harris** UK | **Kerstin Hartung** Germany | **Vanessa Haverd** Australia | **Richard A. Houghton** USA | **Tatiana Ilyina** Germany | **Atul K. Jain** USA | **Emilie Joetzjer** France | **Koji Kadono** Japan | **Etsushi Kato** Japan | **Vassilis Kitidis** UK | **Jan Ivar Korsbakken** Norway | **Peter Landschützer** Germany | **Nathalie Lefèvre** France | **Andrew Lenton** Australia | **Sebastian Lienert** Switzerland | **Zhu Liu** China | **Danica Lombardozzi** USA | **Gregg Marland** USA | **Nicolas Metzl** France | **David R. Munro** USA | **Julia E. M. S. Nabel** Germany | **Shin-ichiro Nakaoka** Japan | **Yosuke Niwa** Japan | **Kevin O'Brien** USA | **Tsueno Ono** Japan | **Paul I. Palmer** UK | **Denis Pierrot** USA | **Benjamin Poulter** USA | **Laure Resplandy** USA | **Eddy Robertson** UK | **Christian Rödenbeck** Germany | **Jörg Schwinger** Norway | **Roland Séférian** France | **Ingunn Skjelvan** Norway | **Adam J. P. Smith** UK | **Adrienne J. Sutton** USA | **Toste Tanhua** Germany | **Pieter P. Tans** USA | **Hanqin Tian** USA | **Bronte Tilbrook** Australia | **Guido R. van der Werf** Netherlands | **Nicolas Vuichard** France | **Anthony P. Walker** USA | **Rik Wanninkhof** USA | **Andrew J. Watson** UK | **David Willis** UK | **Andrew J. Wiltshire** UK | **Wenping Yuan** China | **Xu Yue** China | **Sönke Zaehle** Germany

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

Communications Team
N Hawtin | **K Mansell** | **J Walton** | **E Pihl**

GLOBAL CARBON PROJECT

Data Access and Additional Resources

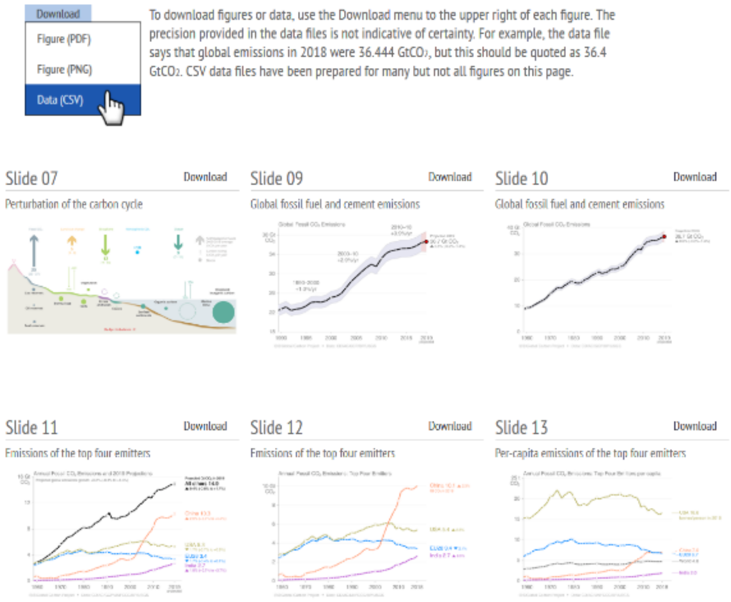
More information, data sources and data files:
http://www.globalcarbonproject.org/carbonbudget
Contact: Pep.Canadell@csiro.au

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

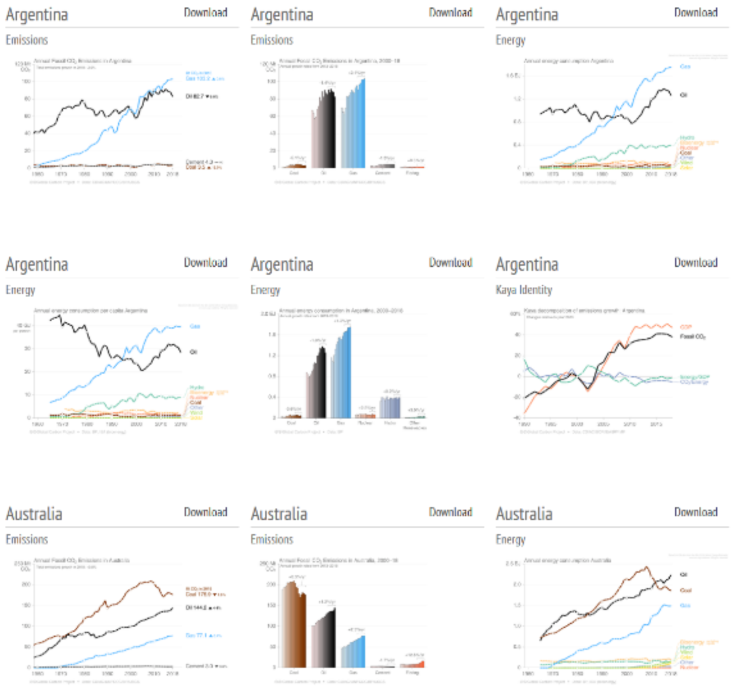
GLOBAL CARBON PROJECT

Download of figures and data

Global Carbon Budget



Additional country figures



Figures and data for most slides available from tinyurl.com/GCB20figs

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/GCB20figs 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

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.

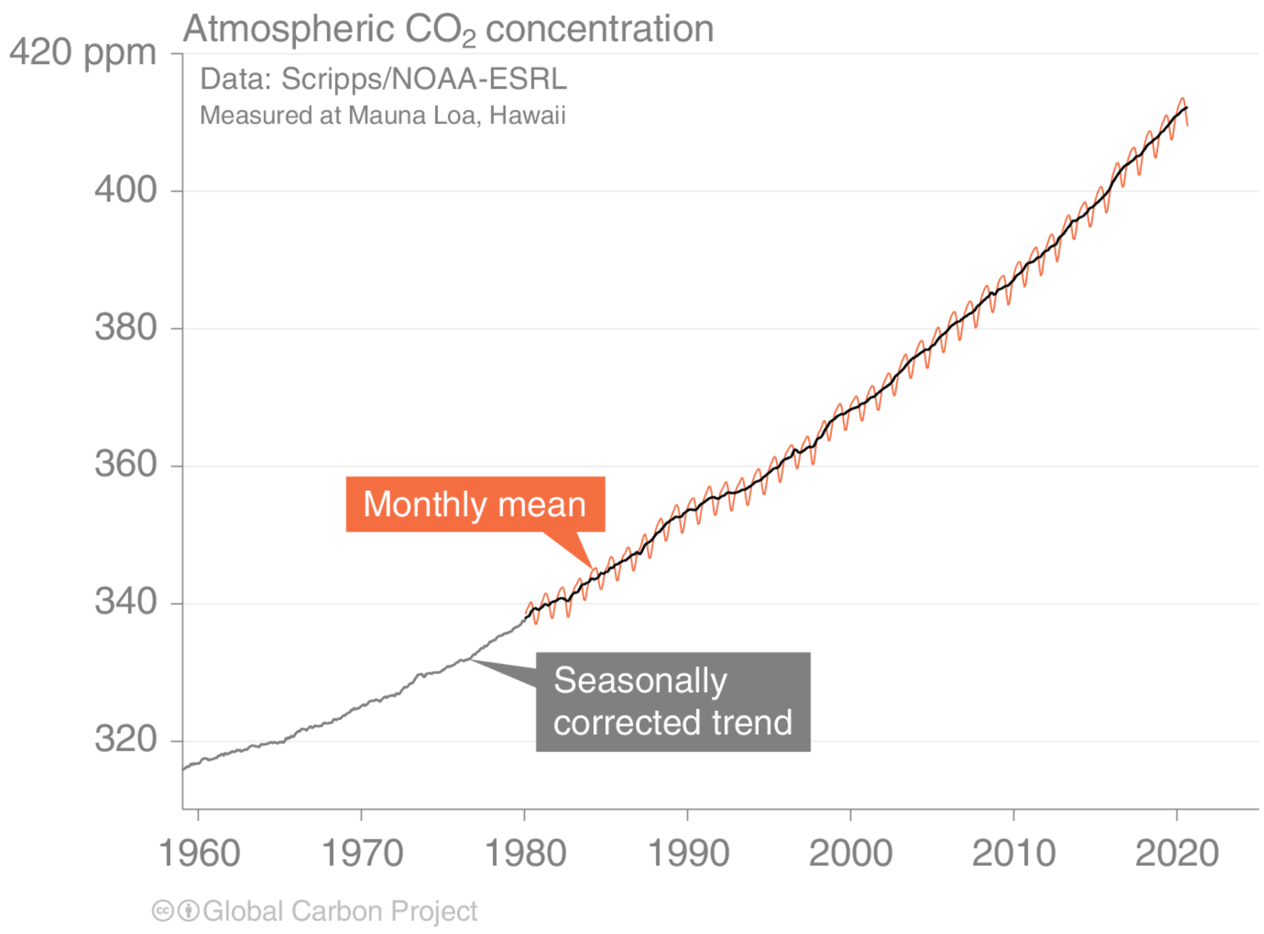
If you're just tweeting a figure or using a figure in a presentation, then it already says at the bottom that it's by the Global Carbon Project, so you're good to go! If you use the data directly or modify the figure then you will need to make sure the attribution is in place.

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 concentration

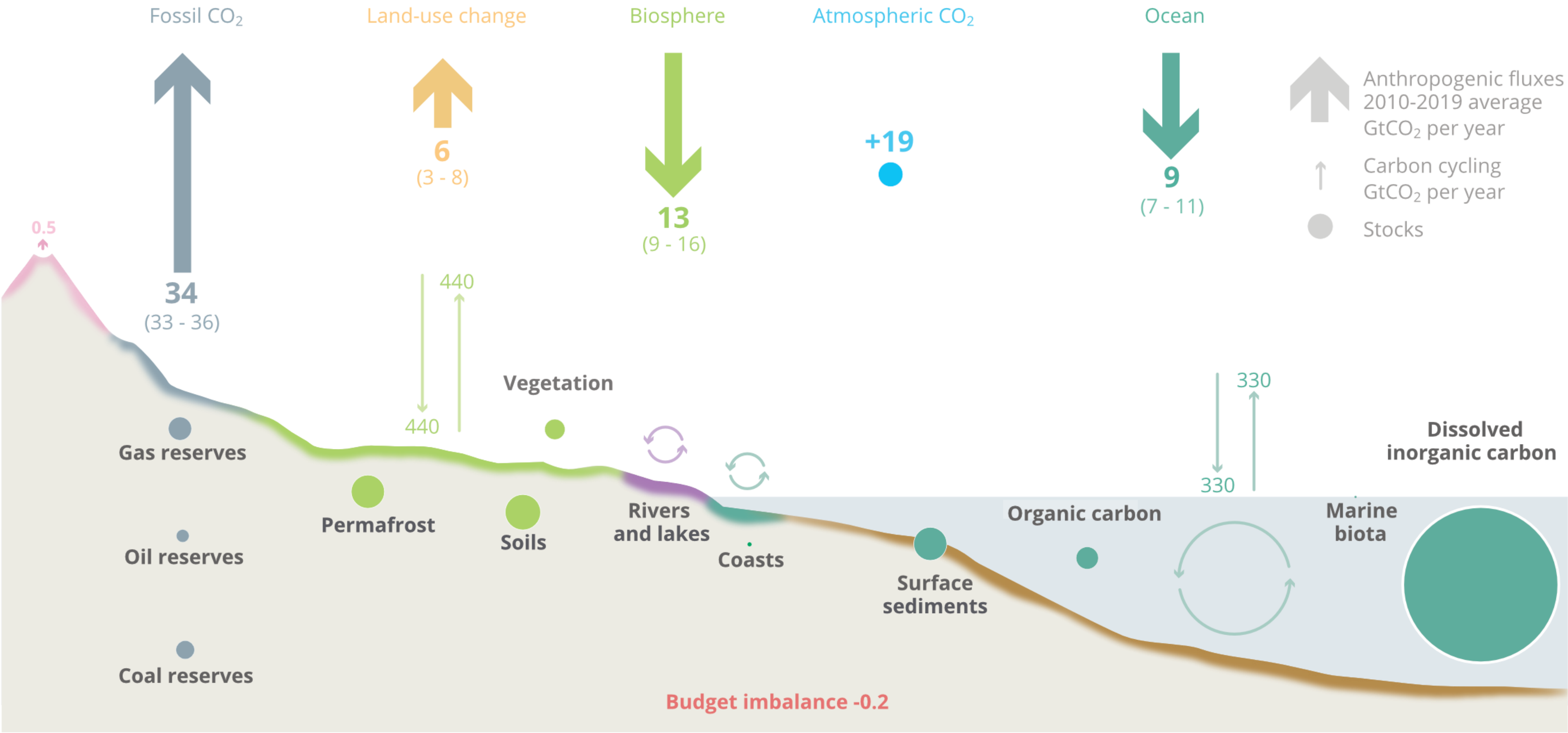
The global CO_2 concentration increased from ~277 ppm in 1750 to 410 ppm in 2019 (up 48%)



Globally averaged surface atmospheric CO_2 concentration. Data from: NOAA-ESRL after 1980;
the Scripps Institution of Oceanography before 1980 (harmonised to recent data by adding 0.542ppm)
Source: NOAA-ESRL; Scripps Institution of Oceanography; Friedlingstein et al 2020; Global Carbon Budget 2020

Anthropogenic perturbation of the global carbon cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2010–2019 ($GtCO_2$/yr)



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

Source: CDIAC; NOAA-ESRL; Friedlingstein et al 2020; Ciais et al. 2013; Global Carbon Budget 2020

Focus on 2020's CO_2 Emissions

Focus on 2020's CO_2 Emissions

We have used four methods to estimate 2020 CO_2 emissions

- **Global Carbon Project (GCP)**: Based on monthly energy data
- **Carbon Monitor (CM)**: Daily absolute difference in emissions between 2019 and 2020
- **University of East Anglia (UEA)**: Daily relative difference in emissions between 2019 and 2020 using confinement levels
- **Priestley Centre**: Daily relative difference in emissions between 2019 and 2020 using Google Mobility data

2020 and COVID-19: Synthesis of four separate studies

University of East Anglia (UEA)

nature climate change
ARTICLES
https://doi.org/10.1038/s41558-020-0797-x

Temporary reduction in daily global CO_2 emissions during the COVID-19 forced confinement

Corinne Le Quéré[1,2], Robert B. Jackson[3,4,5], Matthew W. Jones[1,2], Adam J. P. Smith[1,2], Sam Abernethy[3,6], Robbie M. Andrew[7], Anthony J. De-Gol[1,2], David R. Willis[1,2], Yuli Shan[8], Josep G. Canadell[9], Pierre Friedlingstein[10,11], Felix Creutzig[12,13] and Glen P. Peters[7]

https://doi.org/10.1038/s41558-020-0797-x

Priestley Centre

nature climate change
ARTICLES
https://doi.org/10.1038/s41558-020-0883-0

Current and future global climate impacts resulting from COVID-19

Piers M. Forster[1], Harriet I. Forster[2], Mat J. Evans[3,4], Matthew J. Gidden[5,6], Chris D. Jones[7], Christoph A. Keller[8,9], Robin D. Lamboll[10], Corinne Le Quéré[11,12], Joeri Rogelj[6,10], Deborah Rosen[1], Carl-Friedrich Schleussner[5,13], Thomas B. Richardson[1], Christopher J. Smith[1,6] and Steven T. Turnock[1,7]

https://doi.org/10.1038/s41558-020-0883-0

Carbon Monitor

nature COMMUNICATIONS

ARTICLE
https://doi.org/10.1038/s41467-020-18922-7 OPEN

Near-real-time monitoring of global CO_2 emissions reveals the effects of the COVID-19 pandemic

Zhu Liu et al.[#]

https://doi.org/10.1038/s41467-020-18922-7

Global Carbon Project (GCP)

Earth Syst. Sci. Data, 12, 1–72, 2020
https://doi.org/10.5194/essd-12-1-2020

Open Access Earth System Science Data

Global Carbon Budget 2020

Pierre Friedlingstein[1,2], Michael O'Sullivan[2], Matthew W. Jones[3], Robbie M. Andrew[4], Judith Hauck[5], Are Olsen[6,7], Glen P. Peters[4], Wouter Peters[8,9], Julia Pongratz[10,11], Stephen Sitch[12], Corinne Le Quéré[3], Josep G. Canadell[13], Philippe Ciais[14], Robert B. Jackson[15], Simone Alin[16], Luiz E. O. C. Aragão[17,12], Almut Arneth[18], Vivek Arora[19], Nicholas R. Bates[20,21], Meike Becker[6,7], Alice Benoit-Cattin[22], Henry C. Bittig[23], Laurent Bopp[24], Selma Bultan[10], Naveen Chandra[25,26], Frédéric Chevallier[14], Louise P. Chini[27], Wiley Evans[28], Liesbeth Florentie[8], Piers M. Forster[29], Thomas Gasser[30], Marion Gehlen[14], Dennis Gilfillan[31], Thanos Gkritzalis[32], Luke Gregor[33], Nicolas Gruber[33],

https://doi.org/10.5194/essd-12-3269-2020

2020 Results Summary

Region / Country	2019 emissions (billion tonnes/yr)	2019 growth (percent)	2020 projected growth** (percent)	2020 projected emissions** (billion tonnes/yr)
China	10.2	2.2%	-1.7%	10.0
USA	5.3	-2.6%	-12.2%	4.7
EU27	2.9	-4.5%	-11.3%	2.6
India	2.6	1.0%	-9.1%	2.4
World (incl. bunkers*)	36.4	0.1%	-6.7%	34.1

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

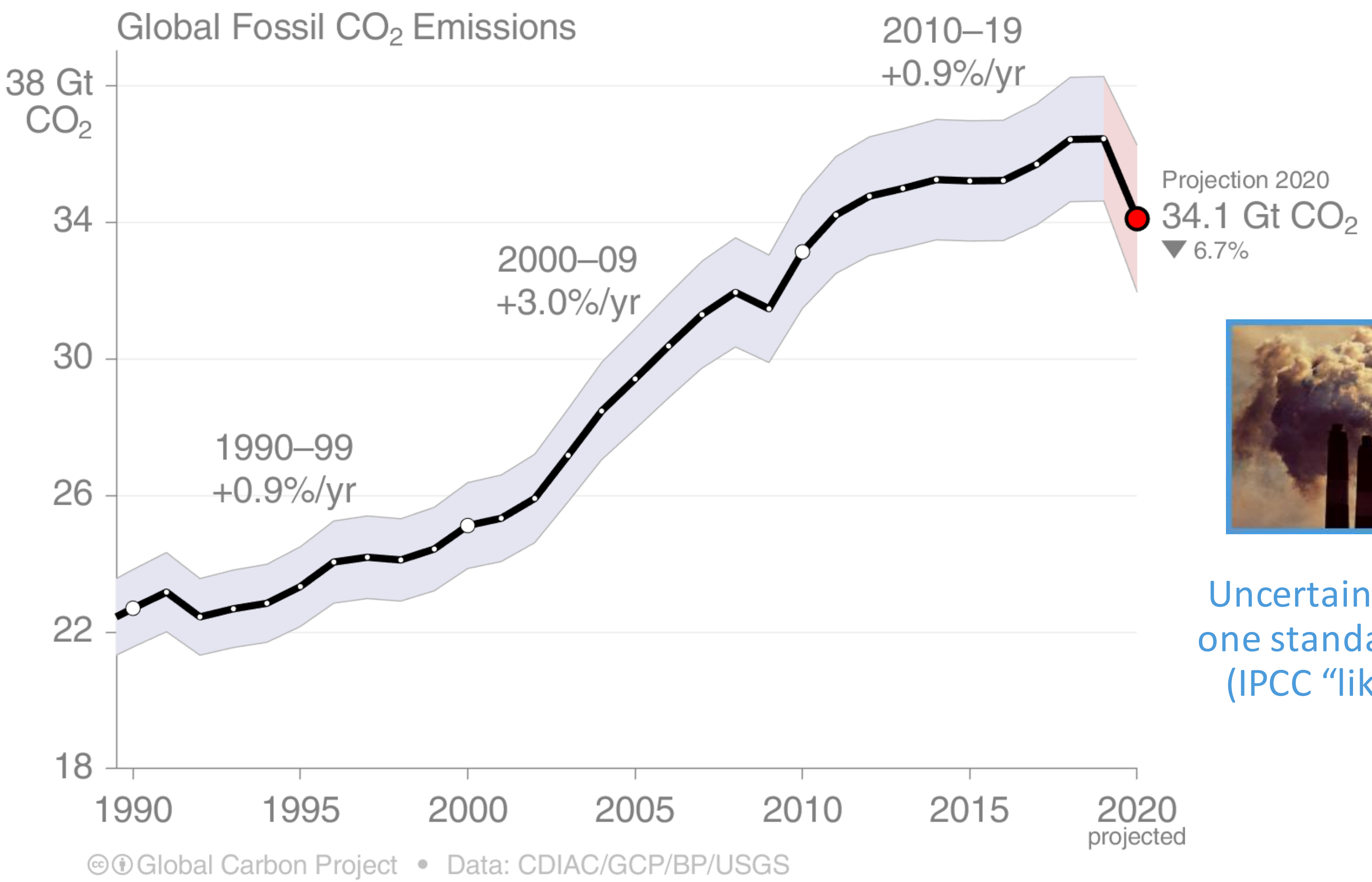
**Median of the four studies

Source: Friedlingstein et al 2020; Global Carbon Budget 2020

Global Fossil CO_2 Emissions

Global fossil CO_2 emissions: 36.4 ± 2 $GtCO_2$ in 2019, 61% over 1990

● Projection for 2020: 34.1 ± 2 GtCO2, about 7% lower than 2019



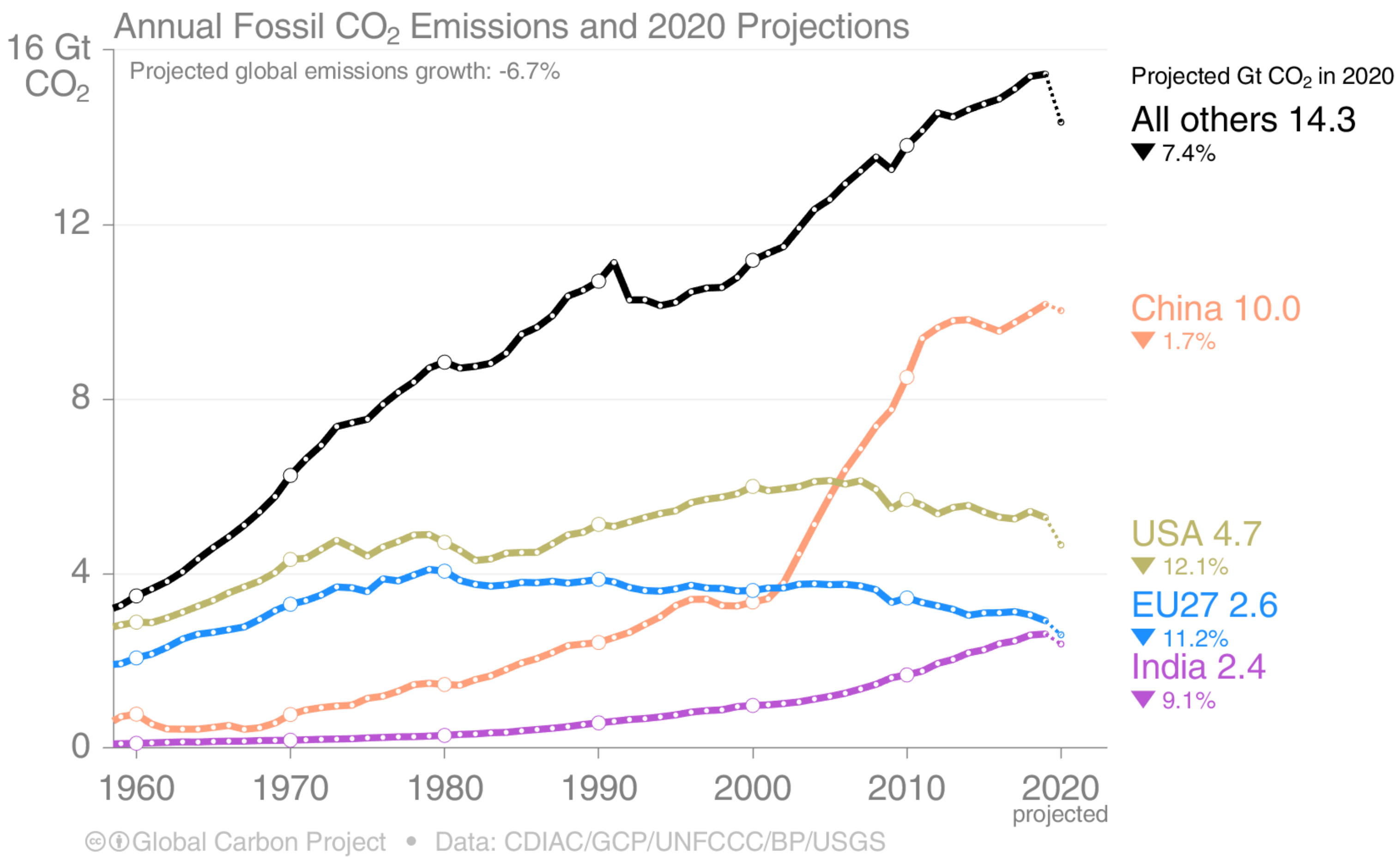
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

The 2020 projection is based on preliminary data and modelling, and is the median of the four studies.

Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

Emissions Projections for 2020

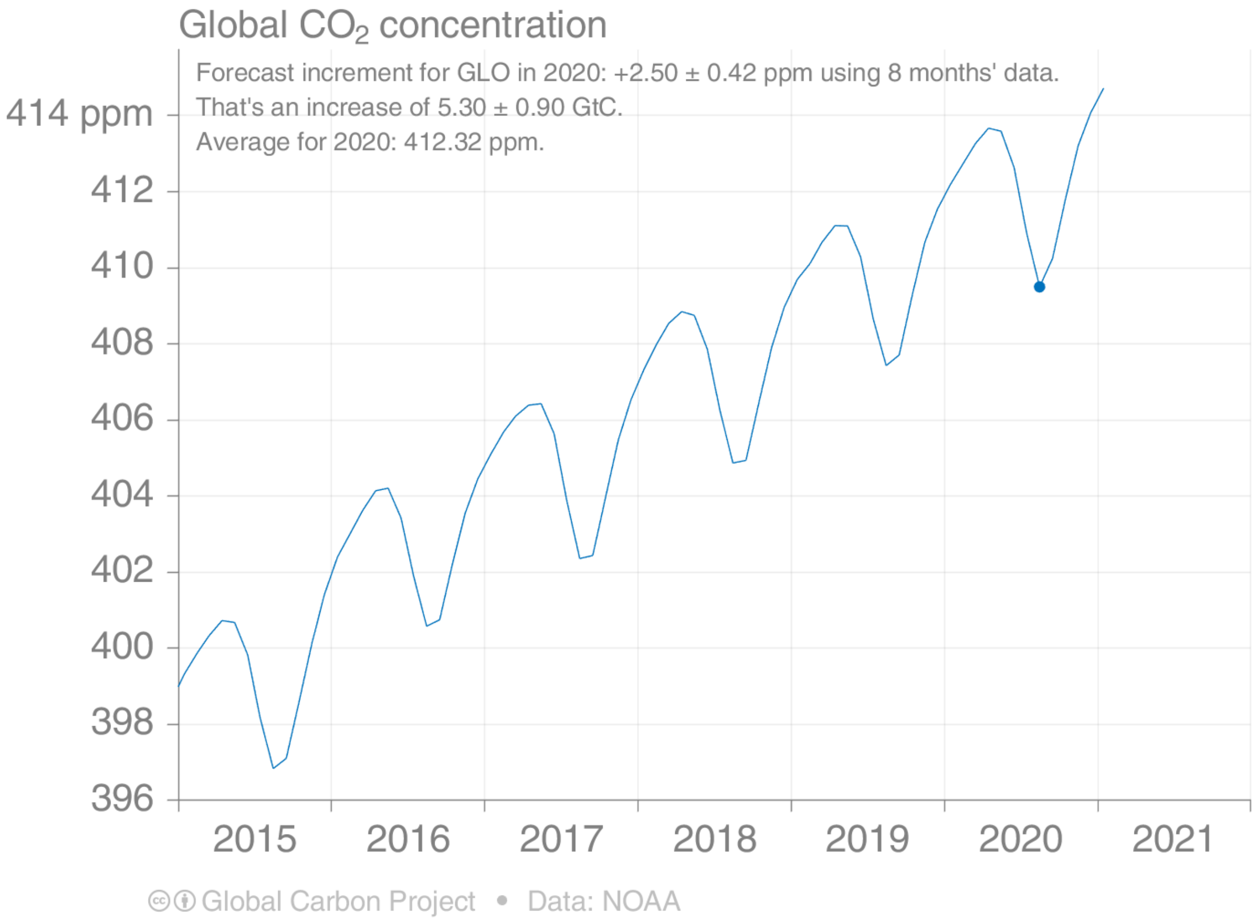
Global fossil CO_2 emissions are projected to decline by about 7% in 2020
Based on the median of four different estimates



The 2020 projections are based on preliminary data and modelling, and is the median of the four studies.
Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

Forecast of global atmospheric CO_2 concentration

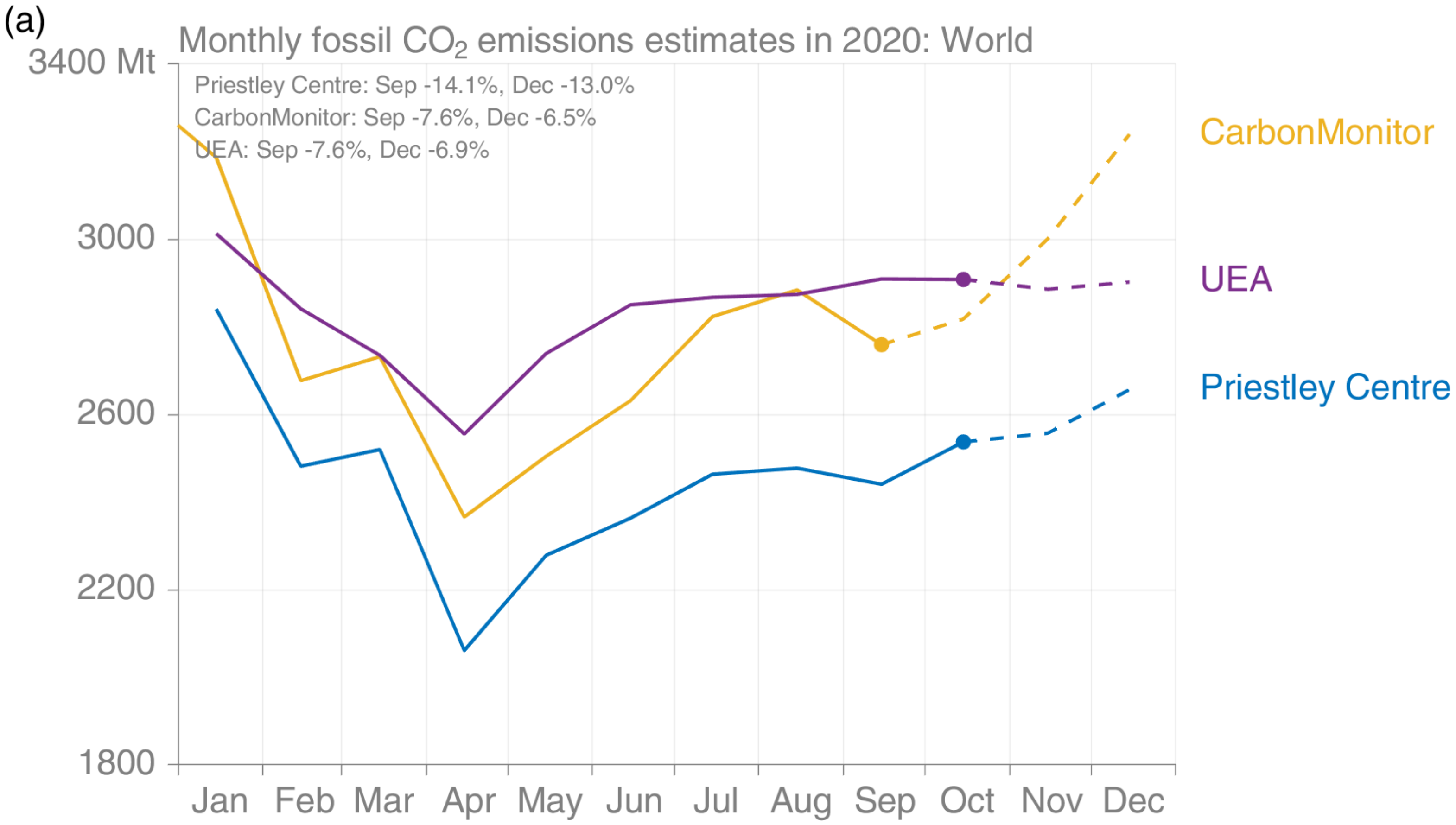
The global atmospheric CO_2 concentration is forecast to average 412 ppm in 2020, increasing 2.5 ppm in 2020
Lower emissions in 2020 due to the COVID-19 pandemic have had little effect on the atmospheric CO_2 concentration



ppm: parts per million
Data source: Tans and Keeling (2020), NOAA-ESRL

Global emissions through 2020

Monthly emissions from three of the real-time fossil CO_2 emissions datasets included in the 2020 Budget
Daily datasets: Carbon Monitor, University of East Anglia (UEA), Priestley Centre

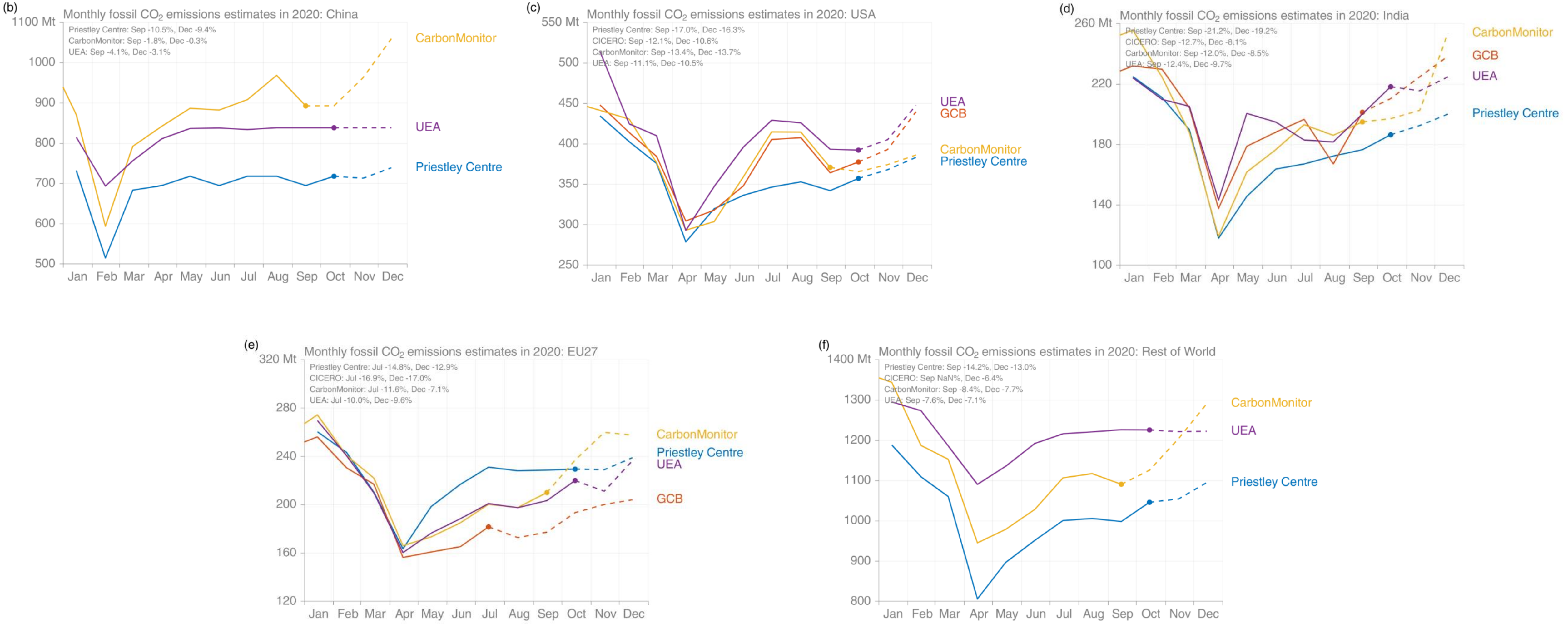


The GCP only estimates full year emissions: -5.6%
Source: [Friedlingstein et al 2020](); [Global Carbon Budget 2020]()

GLOBAL CARBON PROJECT

Regional emissions through 2020

Monthly emissions from the real-time fossil CO_2 emissions datasets included in the 2020 Budget



The GCP only estimates full-year emissions for China (+0.5%) and Rest of World (-6.4%)

Source: [Friedlingstein et al 2020](); [Global Carbon Budget 2020]()

Fossil CO_2 emissions growth: 2018–2020

Emissions are likely to decline in most countries in 2020, with the largest drops in USA, EU, and India
China's emissions have dropped less because of early recovery and significant economic stimulus

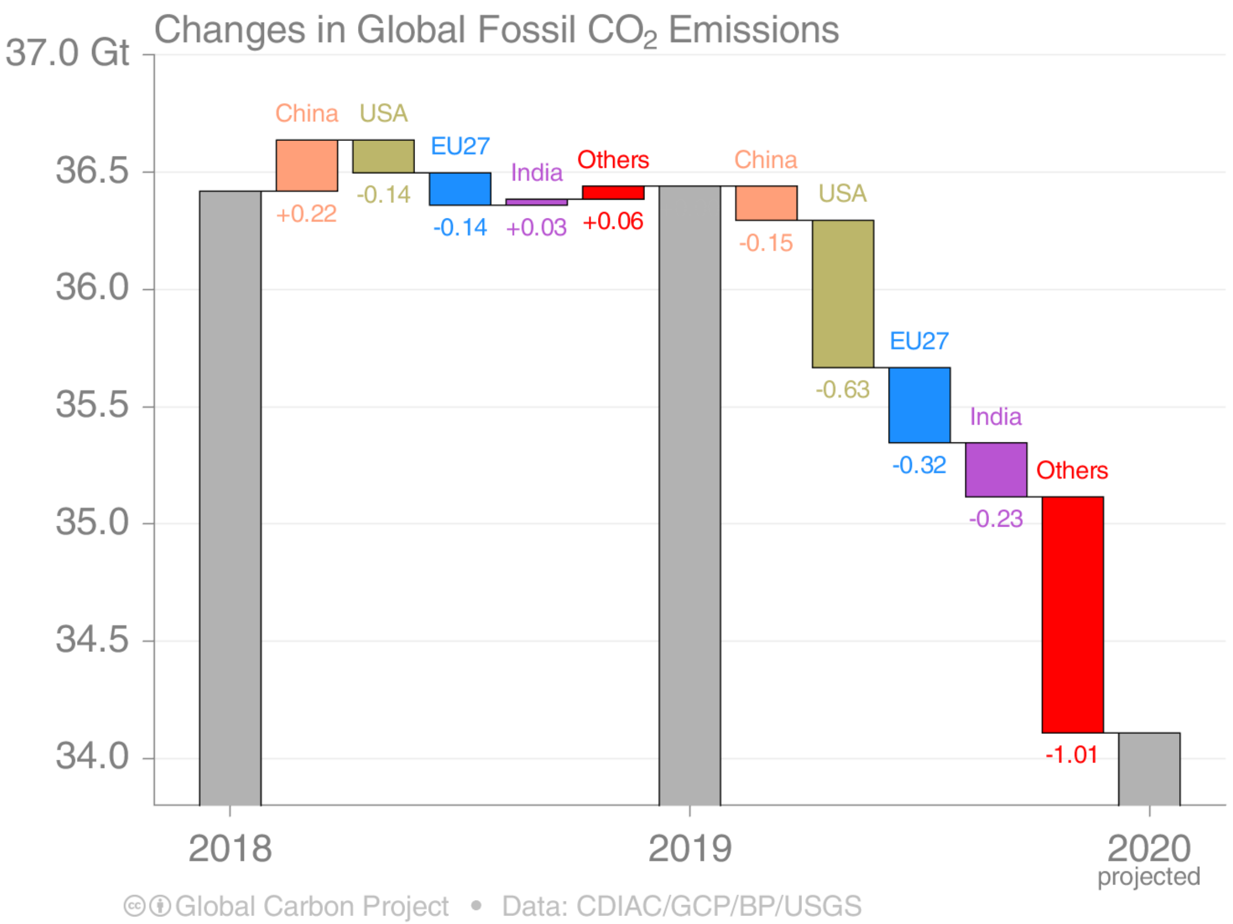
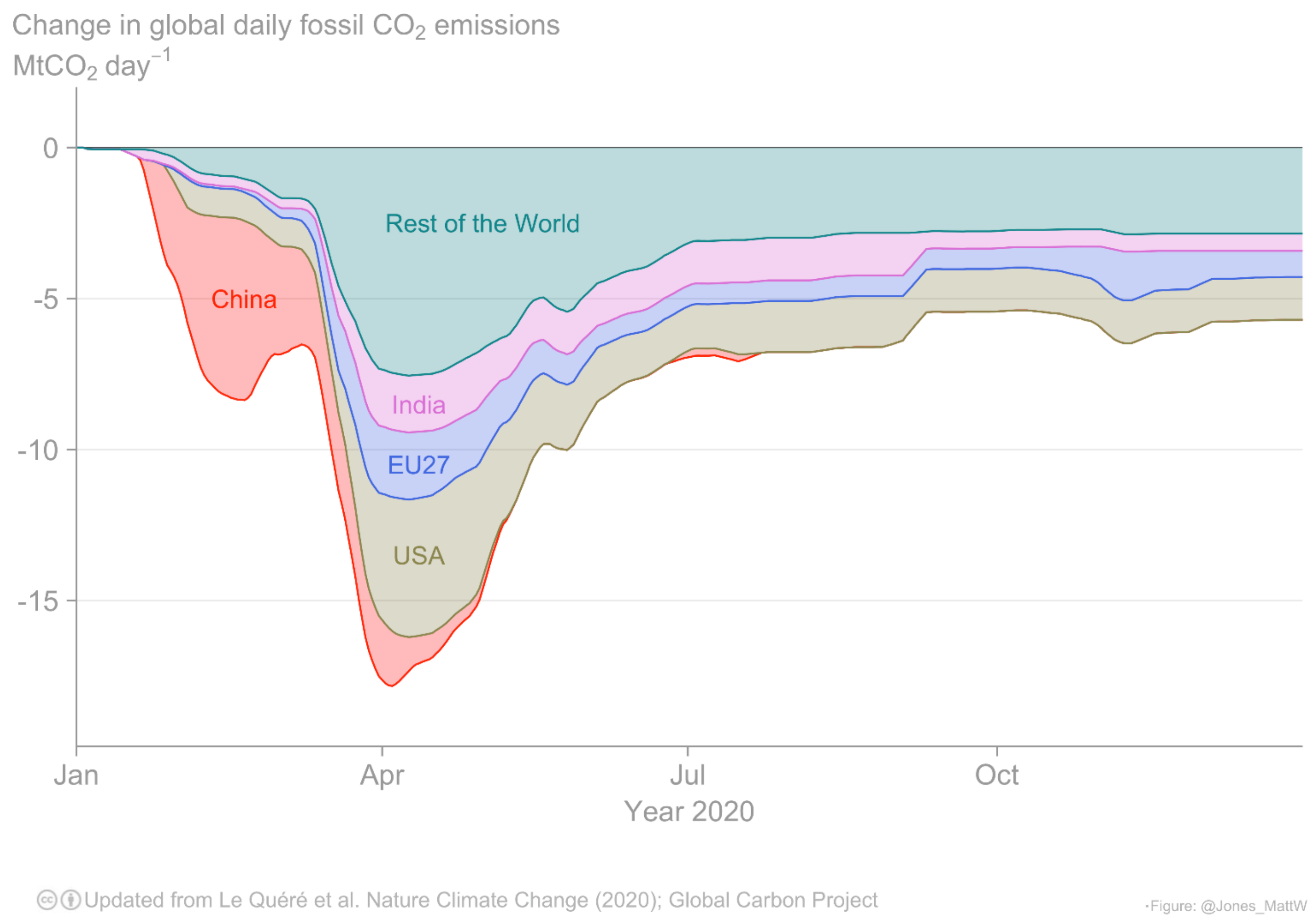


Figure shows the top four countries contributing to emissions changes
Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

UEA Projection: Overall impact of COVID-19 on regional emissions

While China's emissions declined strongly during February,
emissions declines in the rest of the world reached their peaks in April.



Source: [Le Quéré et al 2020](); https://www.icos-cp.eu/gcp-covid19

UEA Projection: Overall impact of COVID-19 on emissions by sector

Global emissions from surface transport, especially road transport, have been affected the most by the restrictions aimed at reducing infection rates.

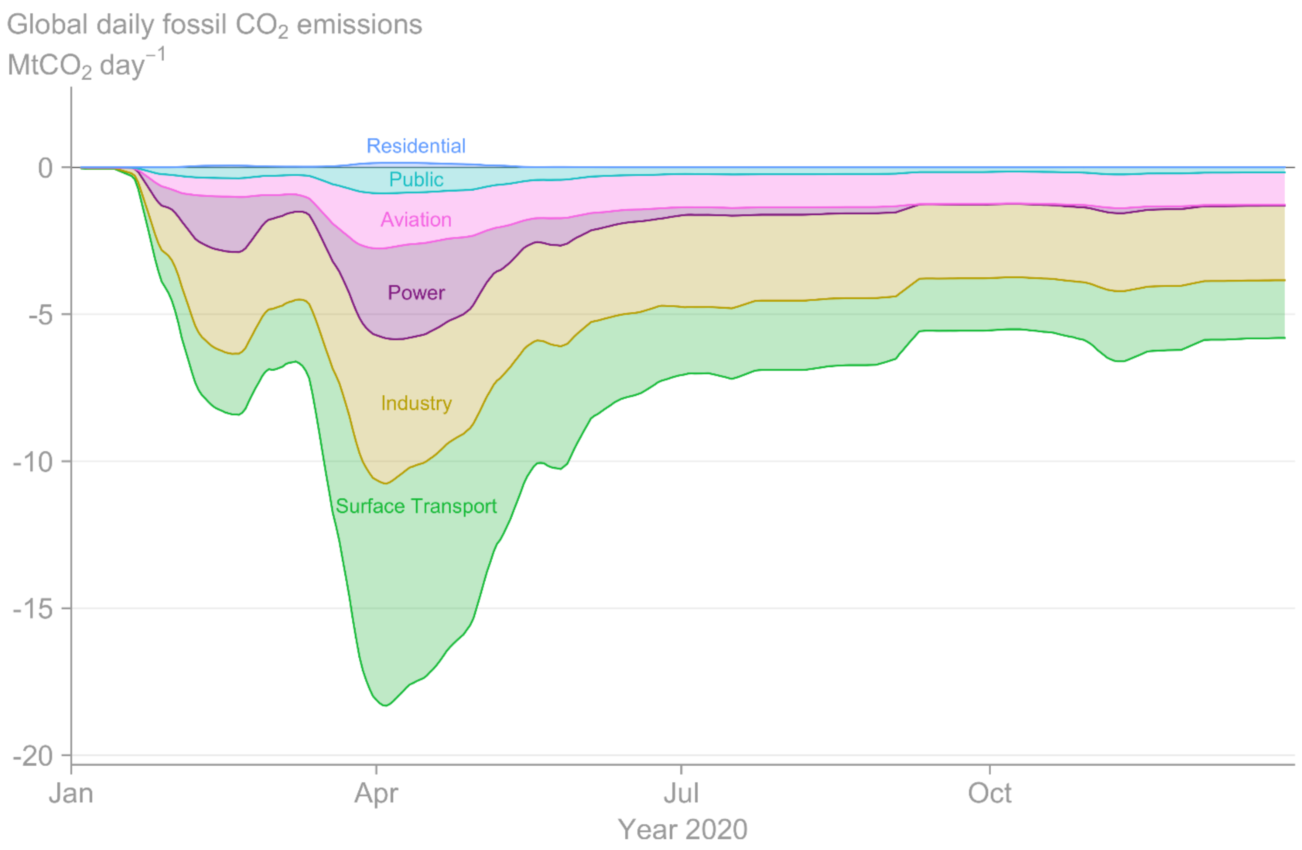
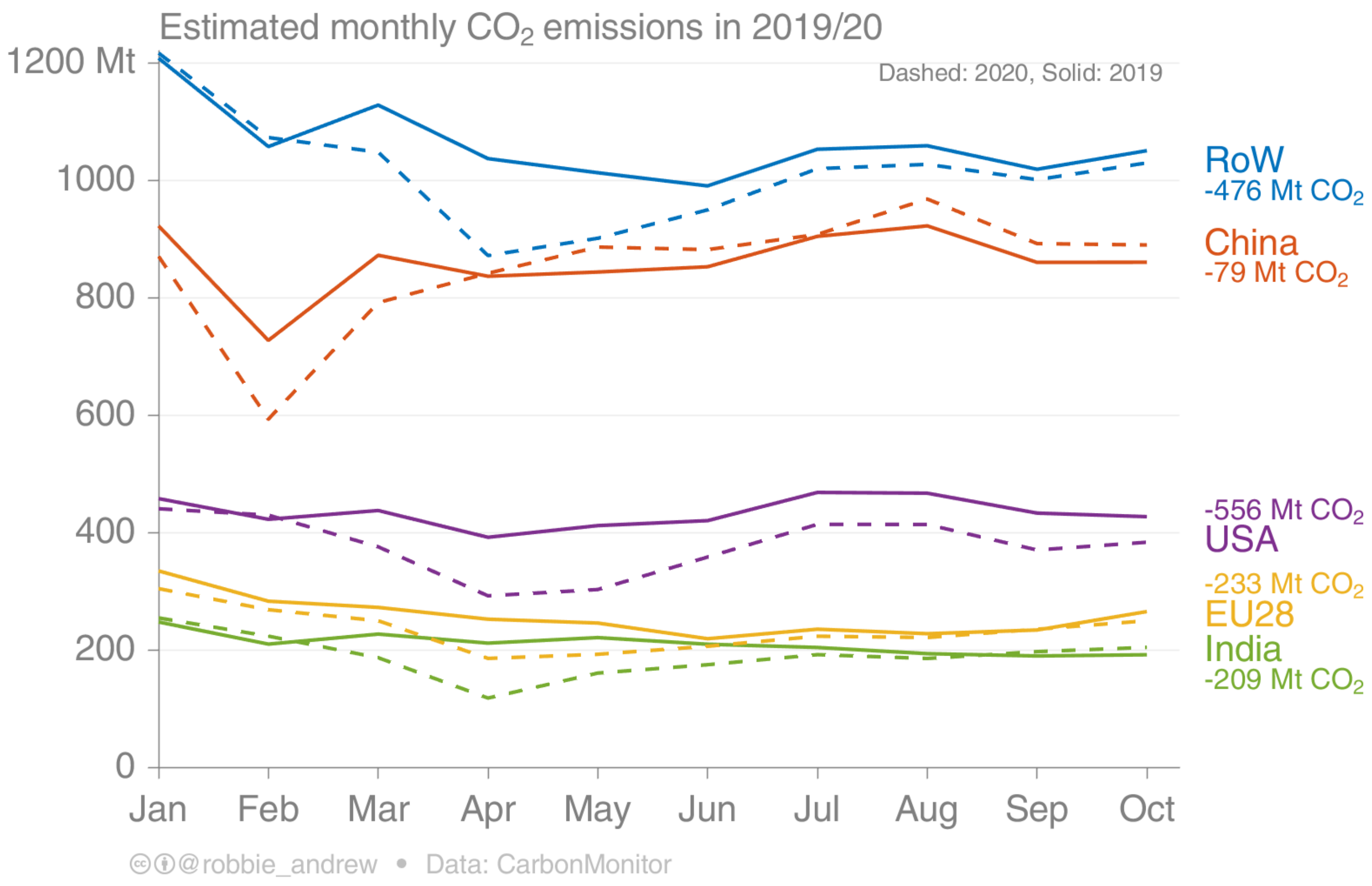


Figure: @Jones_MattW

Source: Le Quéré et al 2020; https://www.icos-cp.eu/gcp-covid19

Carbon Monitor: Overall impact of COVID-19 on regional emissions

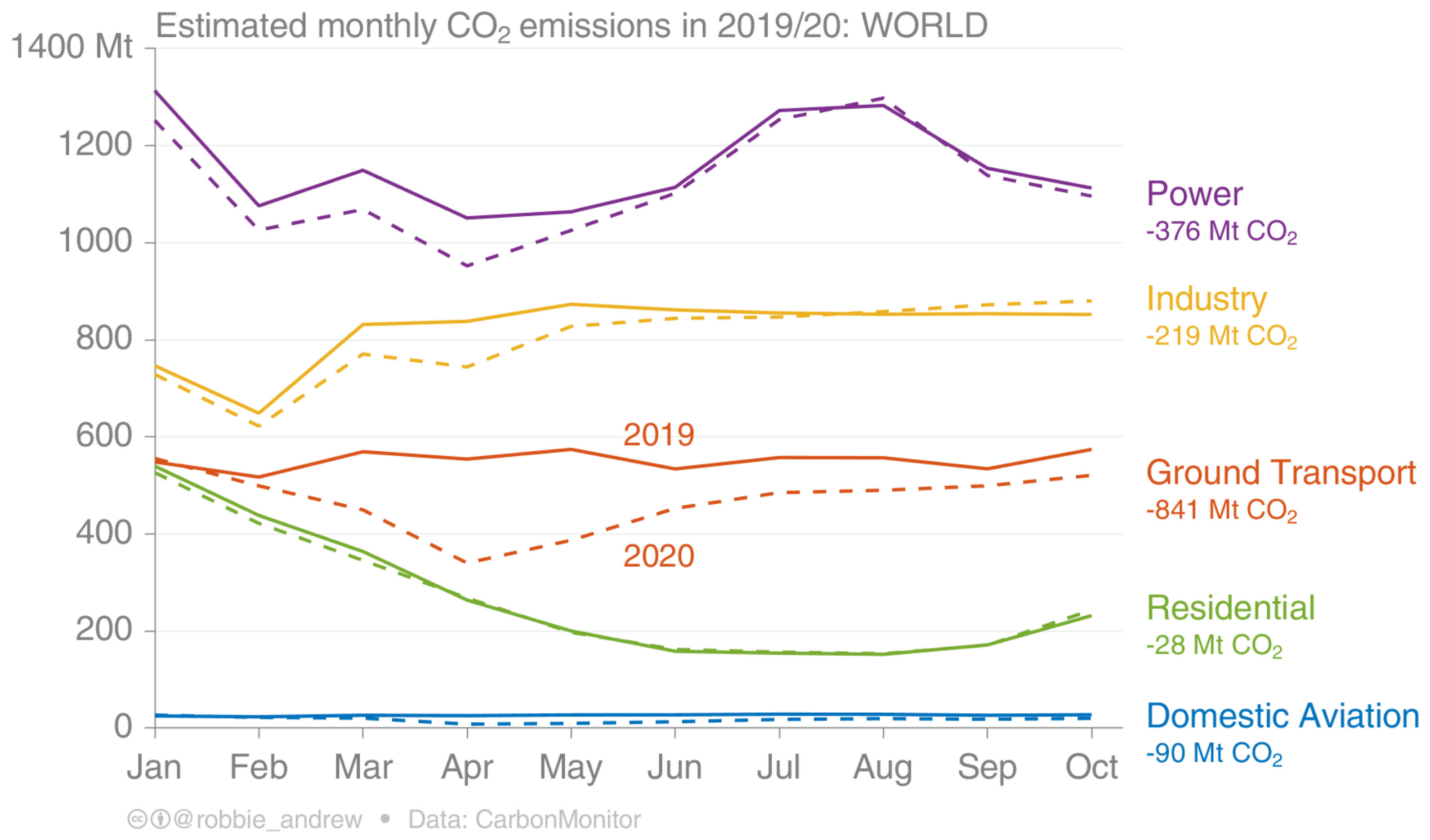
Carbon Monitor estimates absolute daily emissions in 2019 and 2020 and compares the two years
China's emissions are already above levels of 2019, while the USA's are still well below



Source: Liu et al 2020; https://carbonmonitor.org/

Carbon Monitor: Overall impact of COVID-19 on emissions by sector

Carbon Monitor estimates absolute daily emissions in 2019 and 2020 and compares the two years
Many sectors are already back to their pre-COVID levels, except transport where declines remain

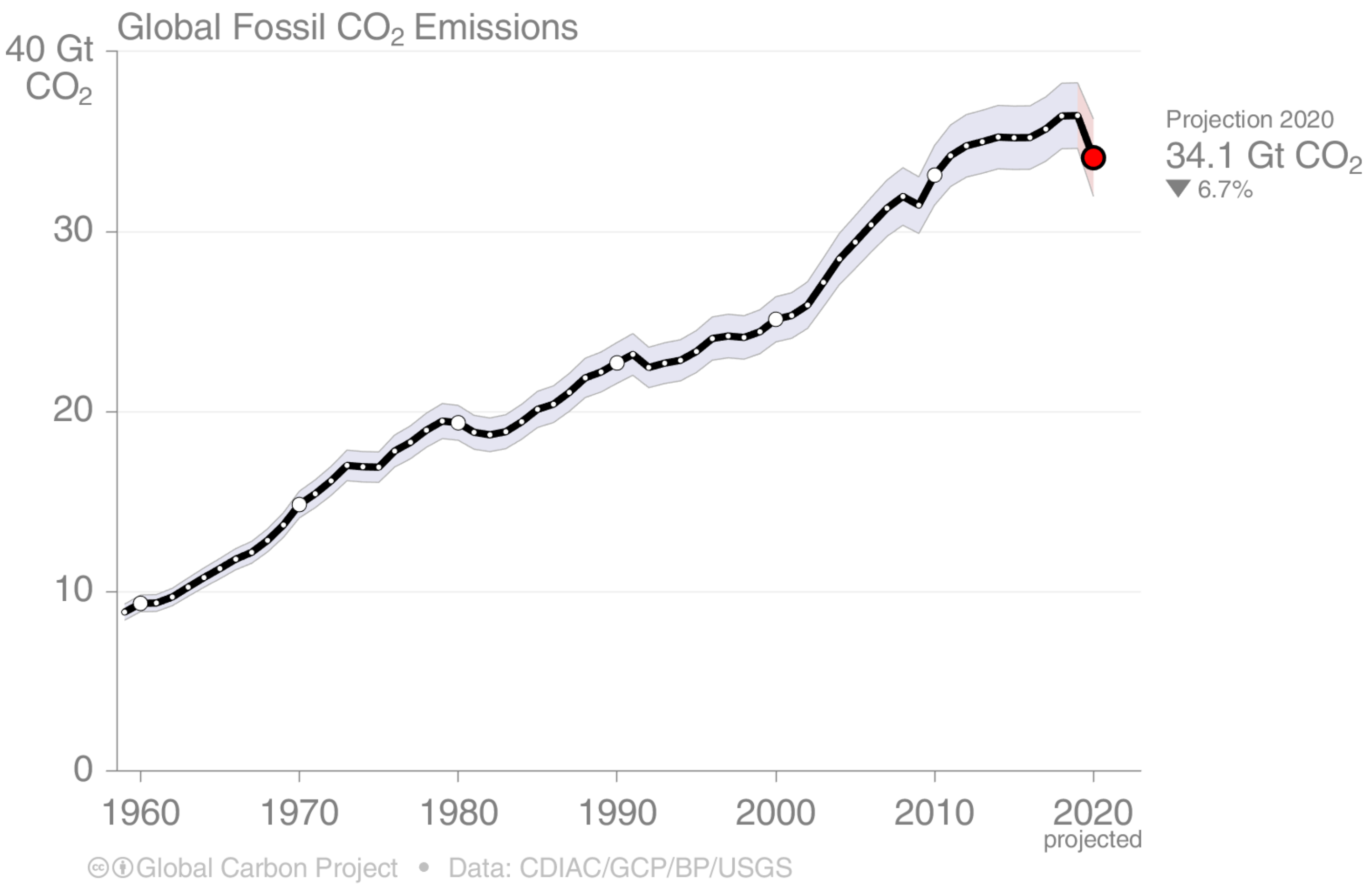


Source: Liu et al 2020; https://carbonmonitor.org/

Fossil CO_2 Emissions

Global Fossil CO_2 Emissions

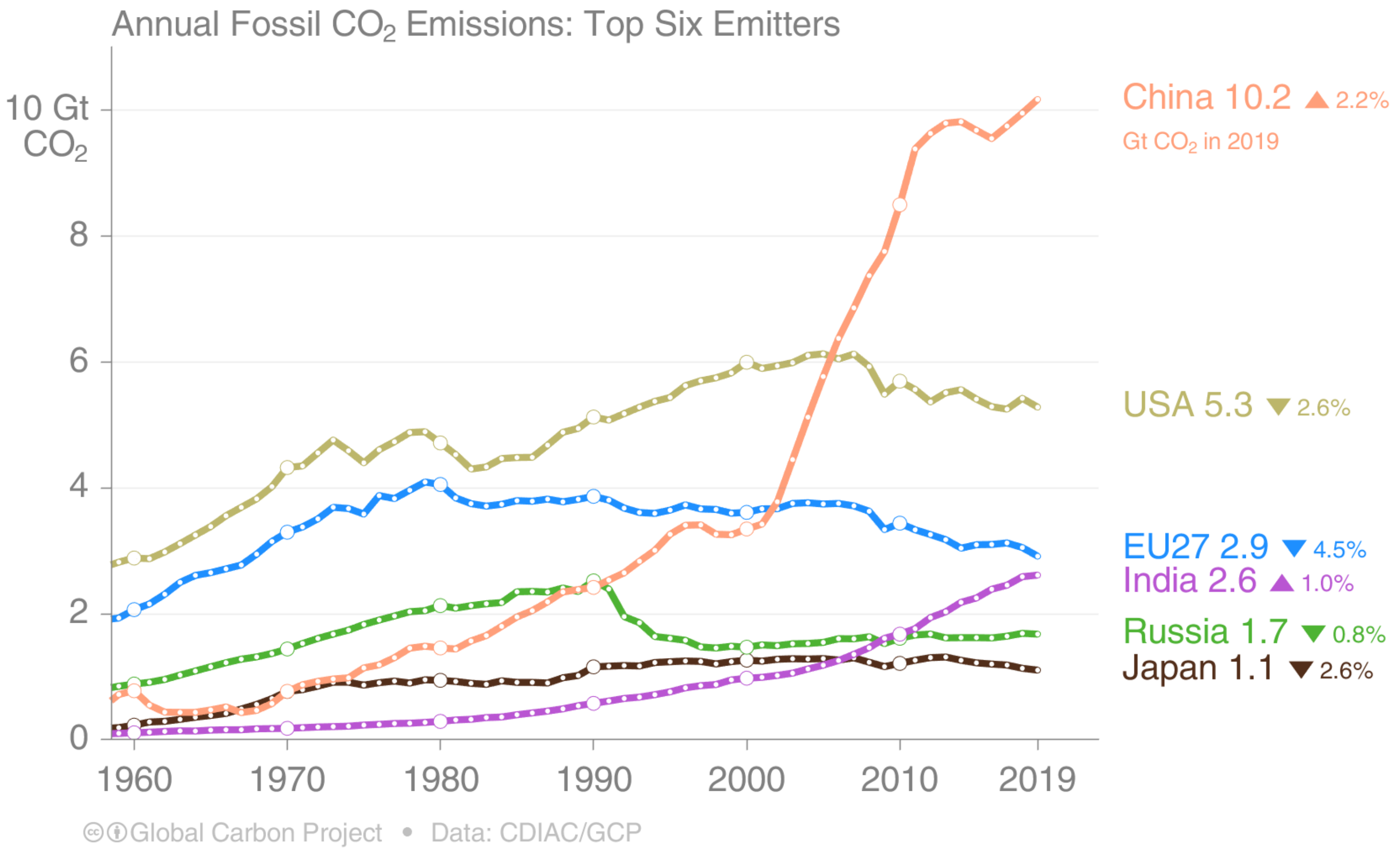
Global fossil CO_2 emissions have risen steadily over the last decades
While 2020 has witnessed an unprecedented drop, emissions will likely rebound in 2021



The 2020 projection is based on preliminary data and modelling.
Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

Top emitters: Fossil CO_2 Emissions to 2019

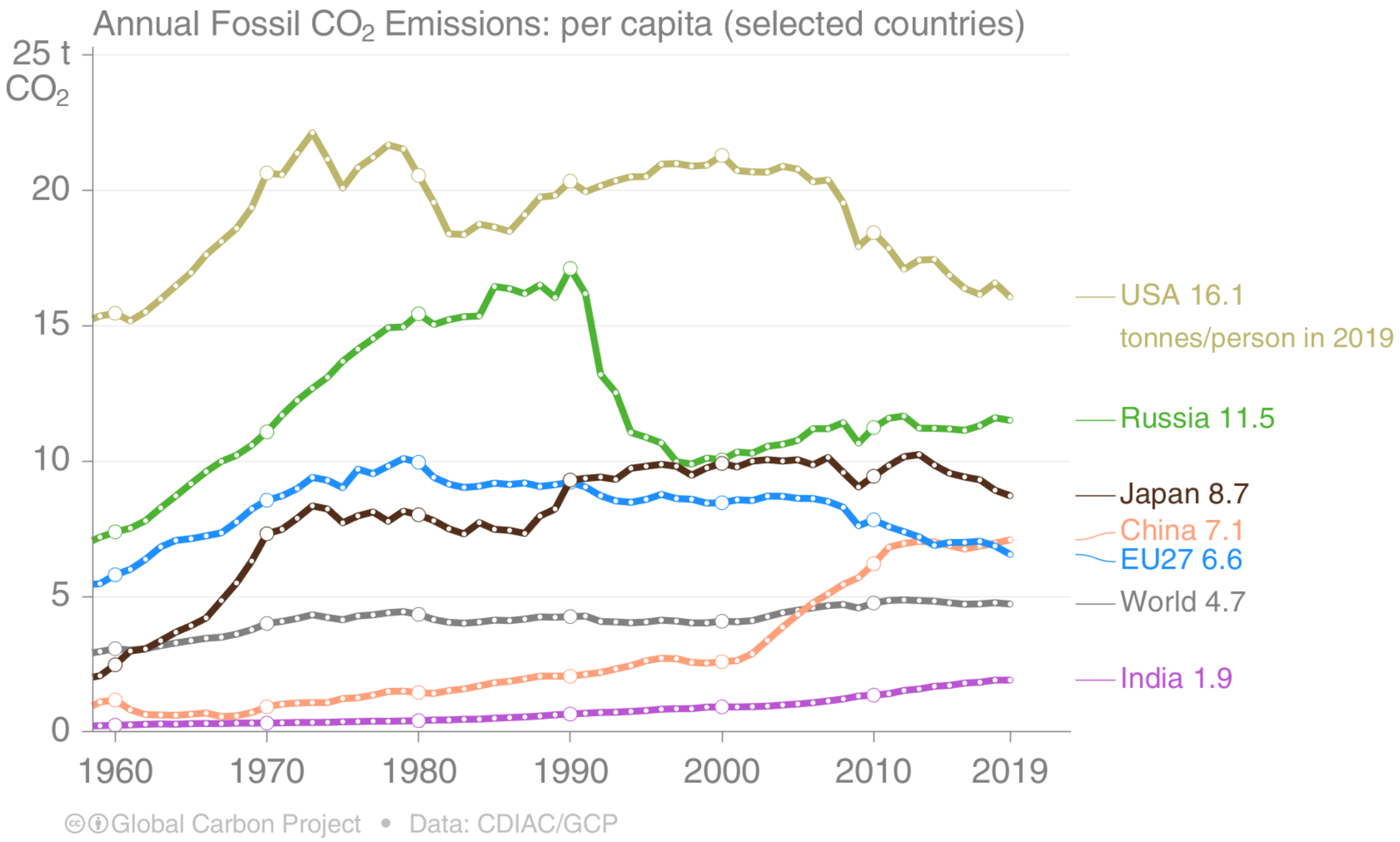
The top six emitters in 2019 covered 65% of global emissions
China 28%, United States 15%, EU27 8%, India 7%, Russia 5%, and Japan 3%



Bunker fuels, used for international transport, are 3.5% of global emissions.
Source: CDIAC; Peters et al 2019; Friedlingstein et al 2020; Global Carbon Budget 2020

Top emitters: Fossil CO_2 Emissions per capita to 2019

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



Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

GLOBAL CARBON PROJECT

Key statistics for emisions in 2019

Region/Country	Per capita	Total		Growth 2018–19	
	tCO_2 per person	$GtCO_2$	%	$GtCO_2$	%
Global (including bunkers)	4.7	36.44	100	0.022	0.1
OECD Countries					
OECD	9.4	12.23	33.6	-0.378	-3.0
USA	16.1	5.28	14.5	-0.140	-2.6
OECD Europe	6.5	3.21	8.8	-0.145	-4.3
Japan	8.7	1.11	3.0	-0.029	-2.6
South Korea	11.9	0.61	1.7	-0.024	-3.7
Canada	15.4	0.58	1.6	-0.010	-1.7
Non-OECD Countries					
Non-OECD	3.6	22.94	63.0	0.400	1.8
China	7.1	10.17	27.9	0.218	2.2
India	1.9	2.62	7.2	0.025	1.0
Russia	11.5	1.68	4.6	-0.013	-0.8
Iran	9.4	0.78	2.1	0.024	3.2
Indonesia	2.3	0.62	1.7	0.041	7.1
International Bunkers					
Bunkers	-	1.27	3.5	0.000	0.0

Emissions 2019

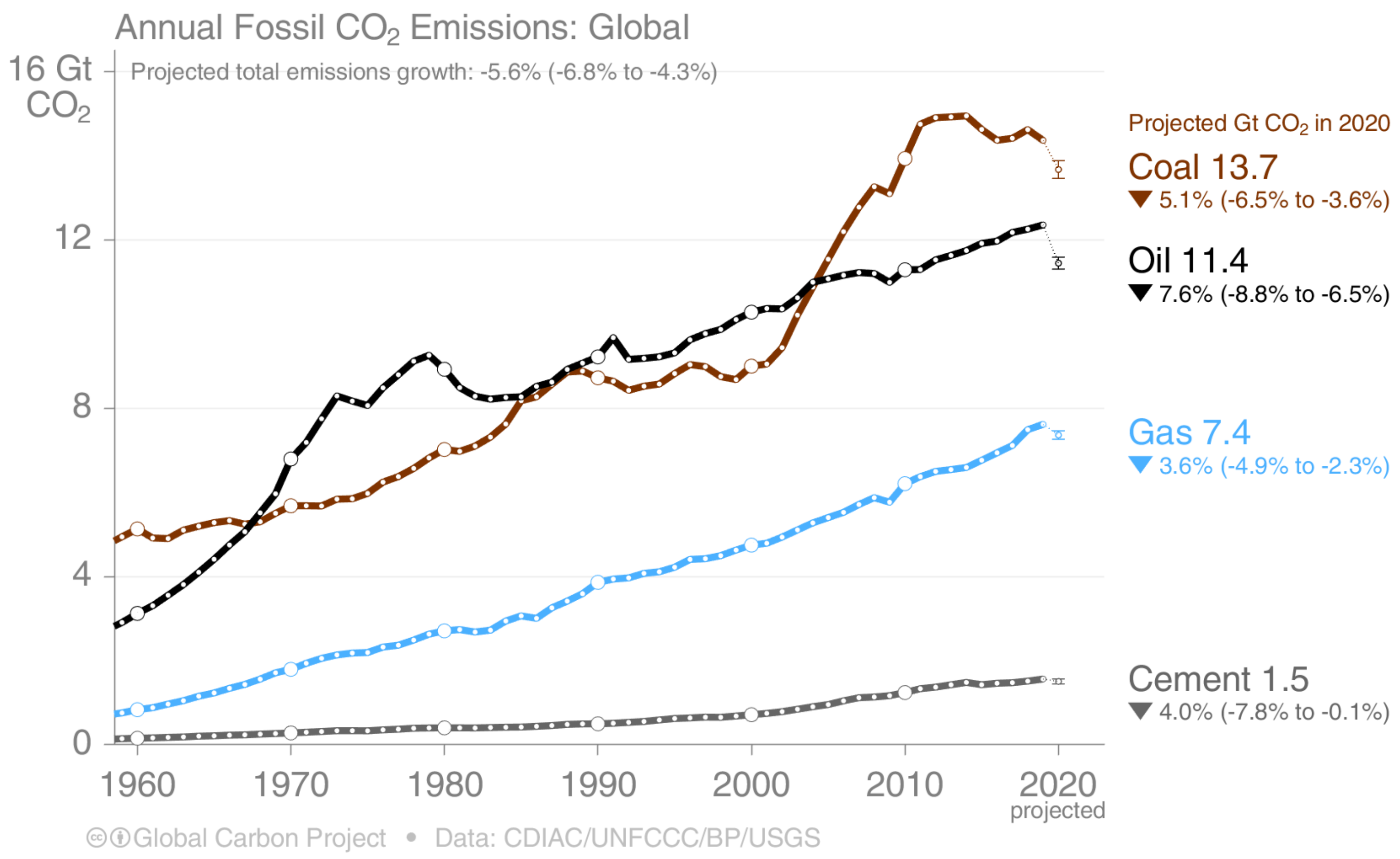
Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

Fossil CO_2 Emissions by source

from fossil fuel use and industry

Fossil CO_2 Emissions by source

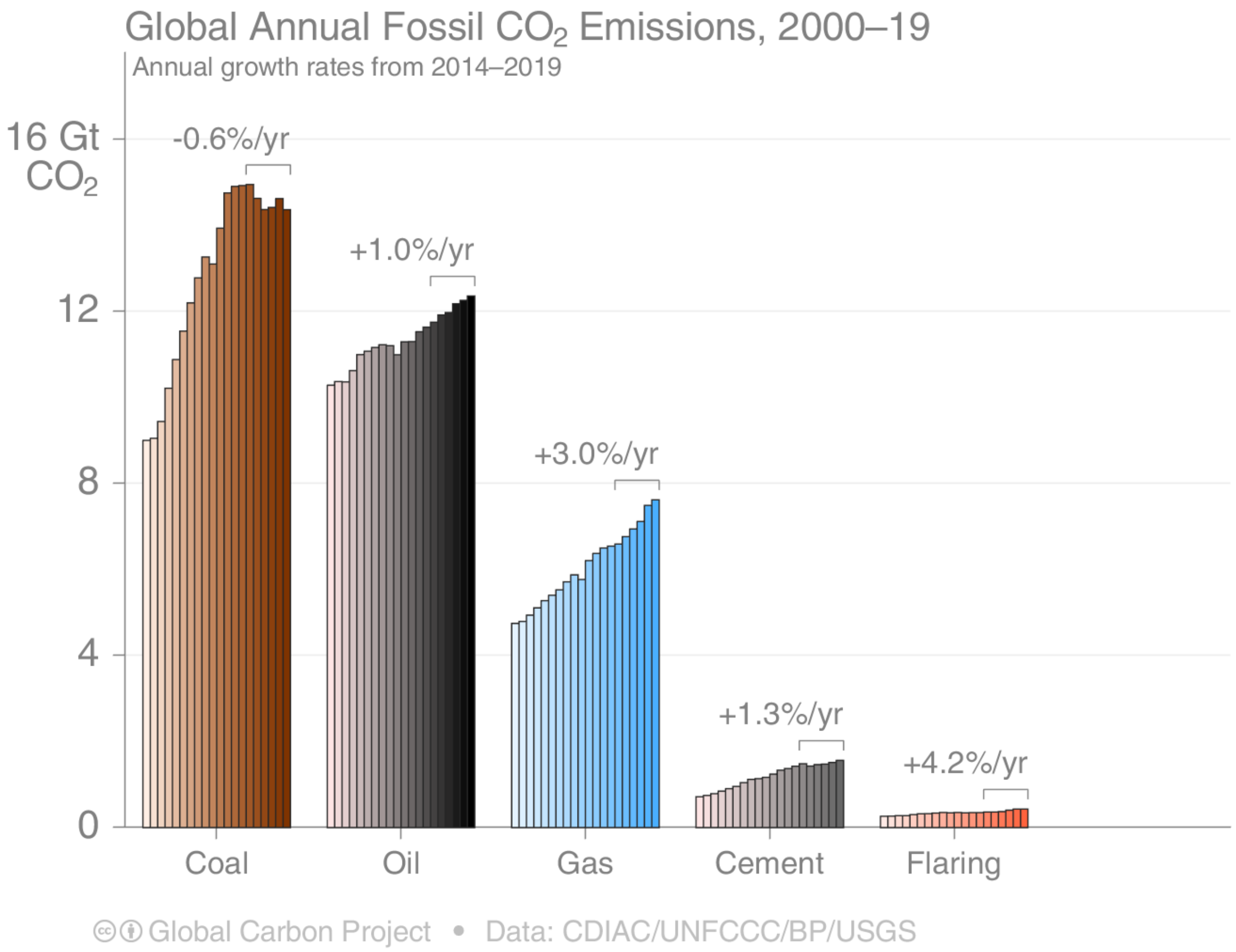
Share of global fossil CO_2 emissions in 2019: coal (39%), oil (33%), gas (21%), cement (4%), flaring (1%, not shown)
Projection by fuel type is based on monthly data (GCP analysis)



Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

Fossil CO_2 Emissions by source

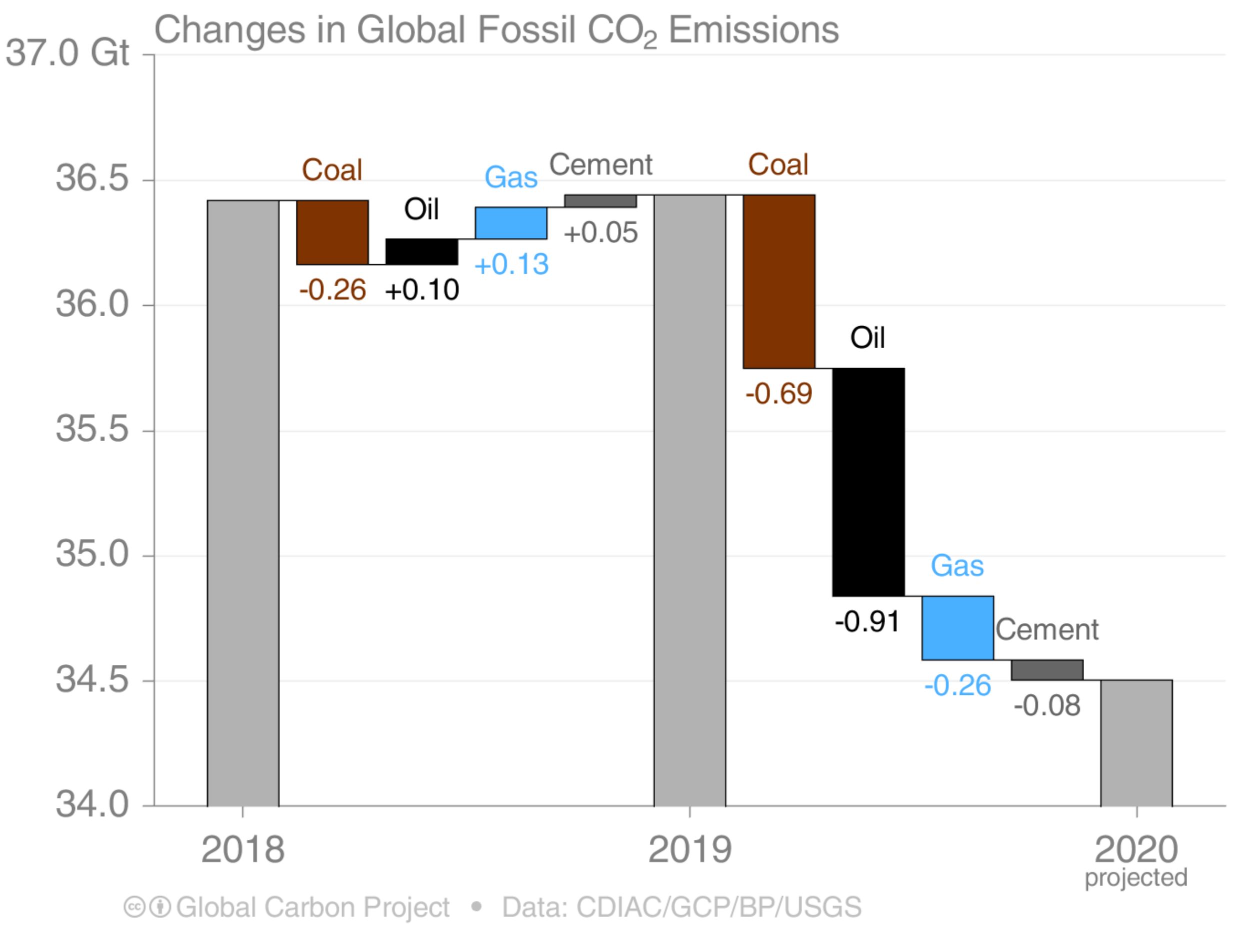
Emissions by category from 2000 to 2019, with growth rates indicated for the more recent period of 2014 to 2019
Coal use has declined since 2014, while other fossil fuels continue to grow close to historical rates



Source: CDIAC; Global Carbon Budget 2020

Fossil CO_2 emissions growth: 2018–2020

Global emissions in 2020 have dropped across all categories, but particularly in coal from reduced electricity demand, and in oil from reduced transportation



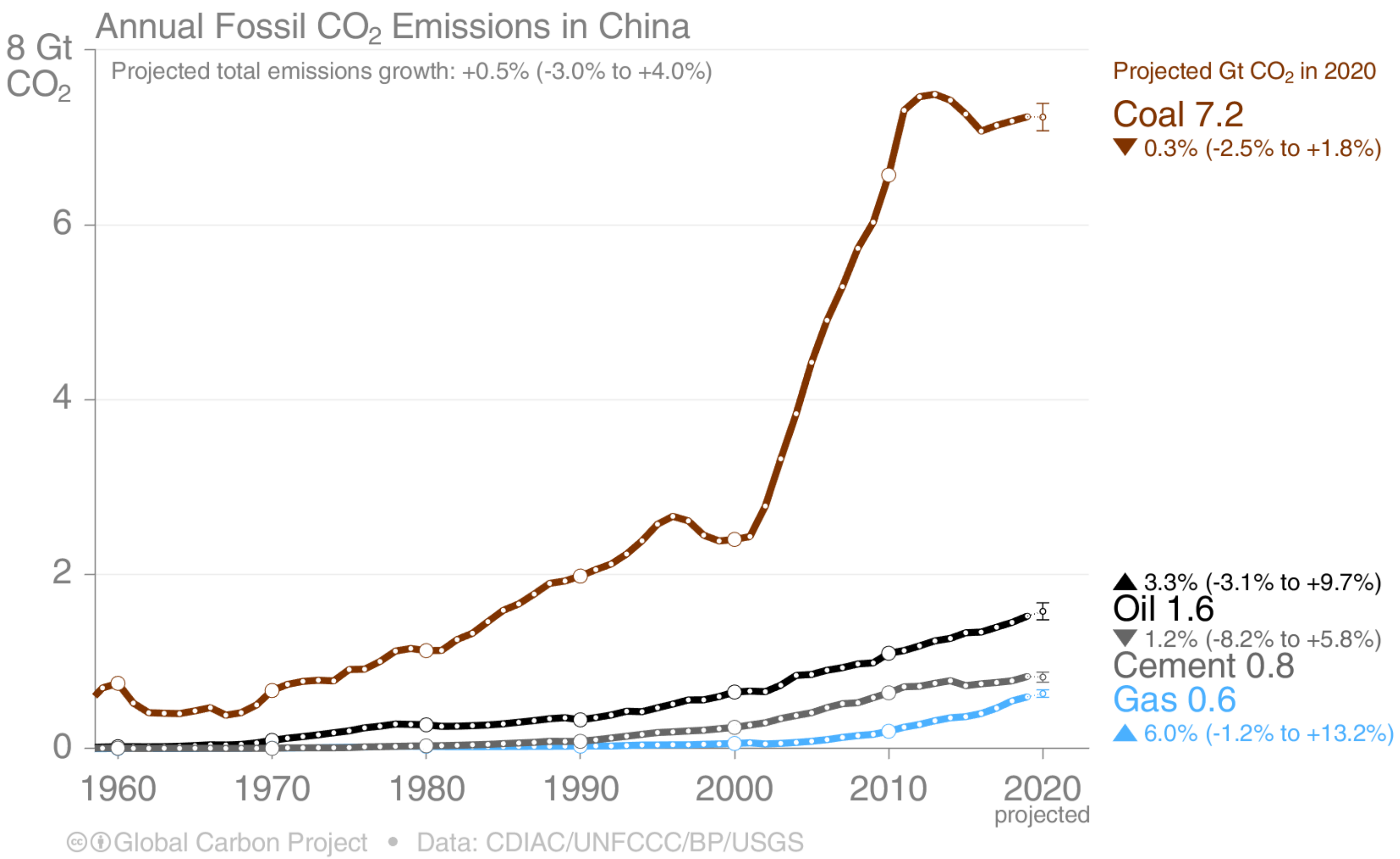
Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

Fossil CO_2 Emission by source for top emitters

from fossil fuel use and industry
results from GCP's analysis of monthly data

Fossil CO_2 Emissions in China

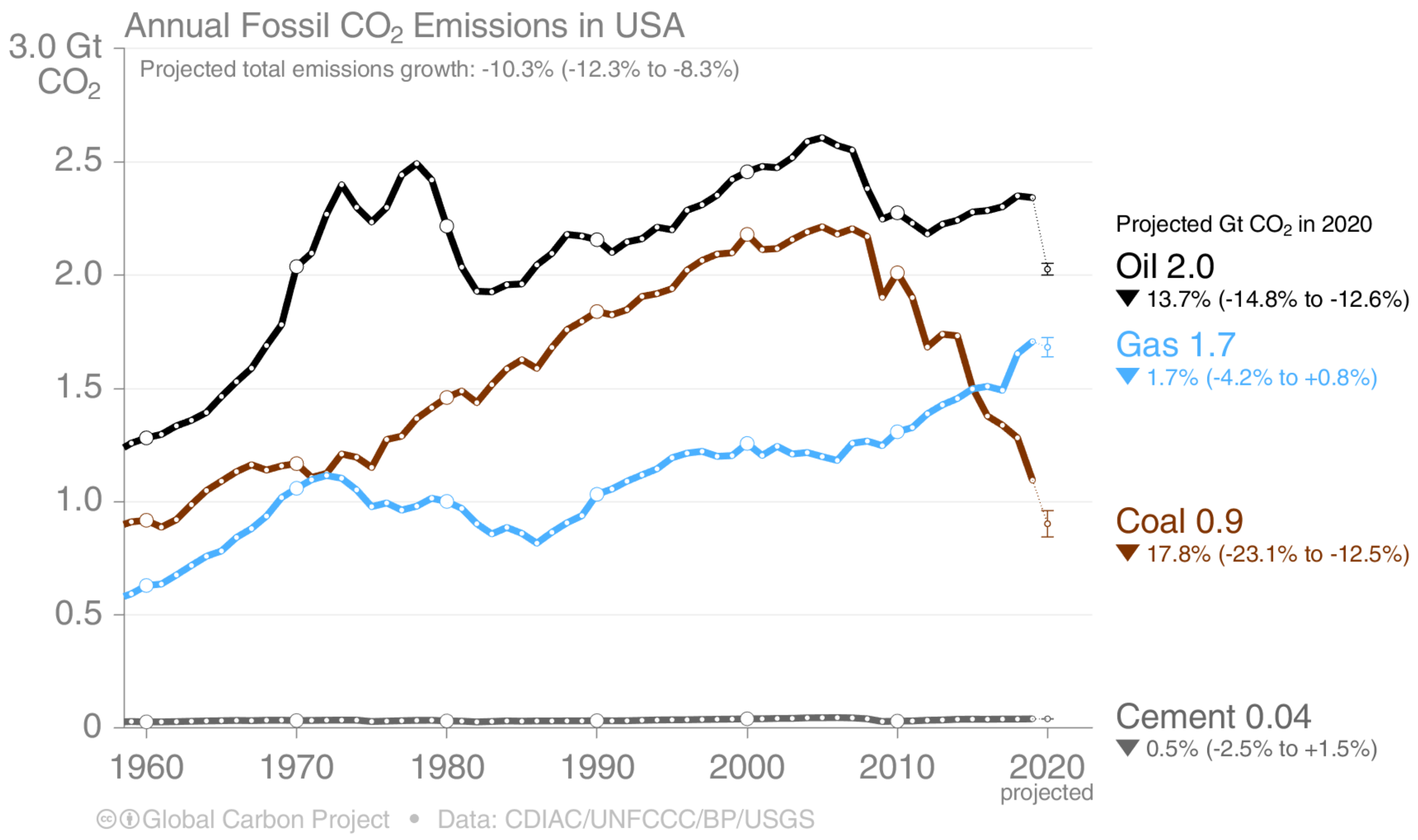
Annual emissions for China hide the story of 2020, suggesting no impact from the global pandemic
Emissions from oil and natural gas continue to grow strongly



Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

Fossil CO_2 Emissions in USA

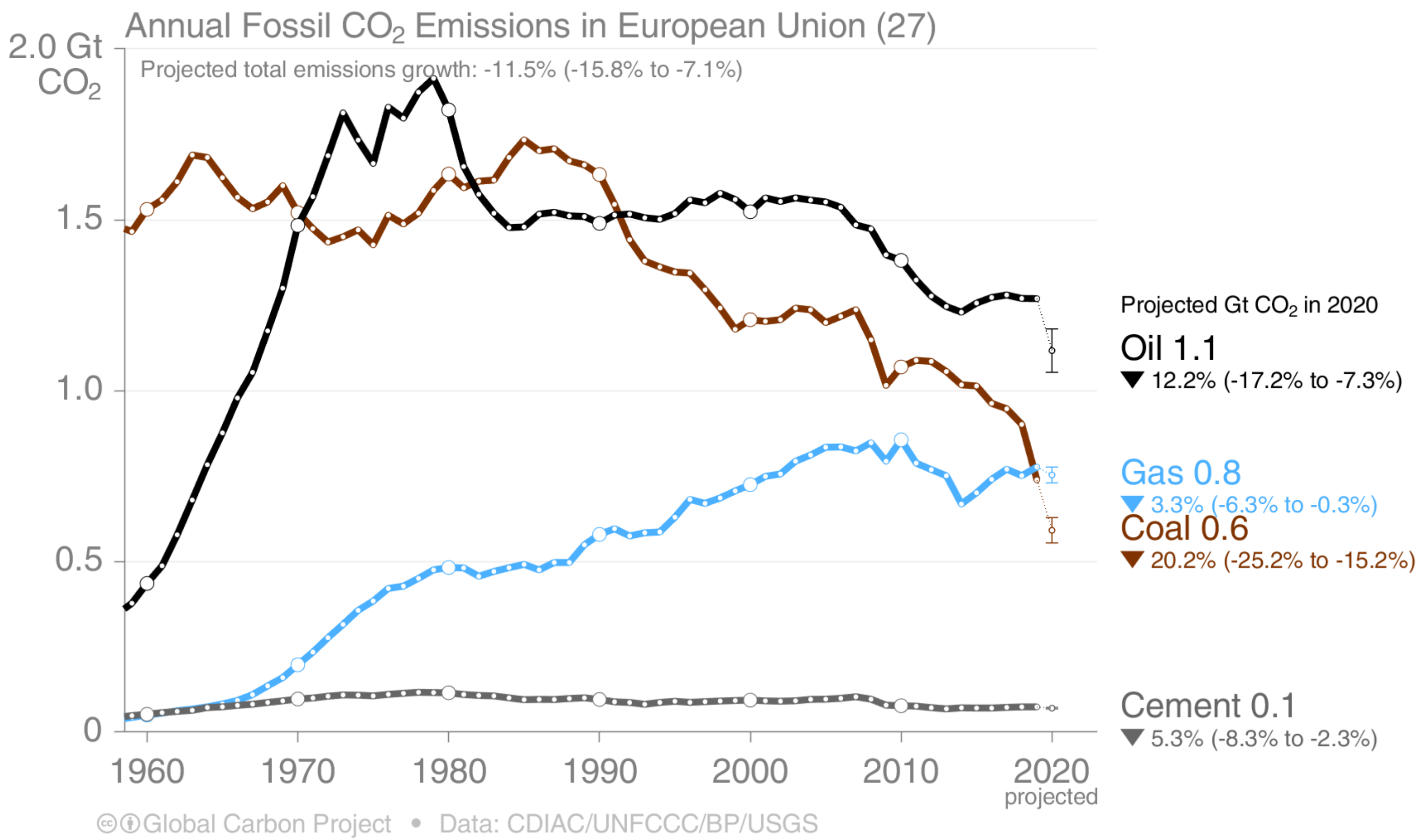
The USA's emissions from oil are expected to decline sharply in 2020 as a result of restrictions on transportation
Coal emissions also decline, while the recent strong growth in natural gas falters.



Source: CDIAC; EIA 2020; Friedlingstein et al 2020; Global Carbon Budget 2020

Fossil CO_2 Emissions in the European Union (EU27)

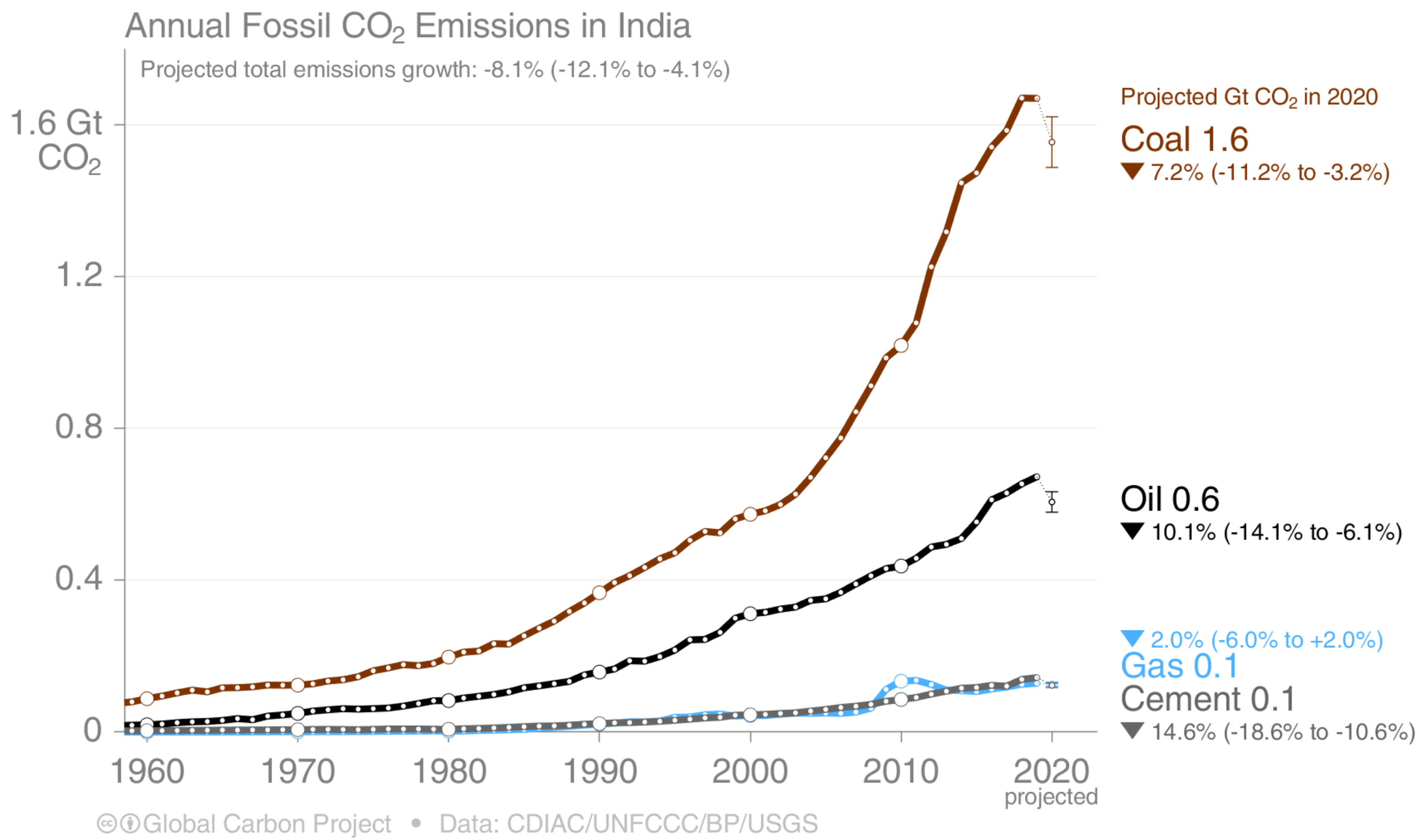
Emissions in the EU see sharp declines in both oil and coal due to the pandemic, with less effect seen for natural gas



Source: [CDIAC]; [Friedlingstein et al 2020]; [Global Carbon Budget 2020]

Fossil CO_2 Emissions in India

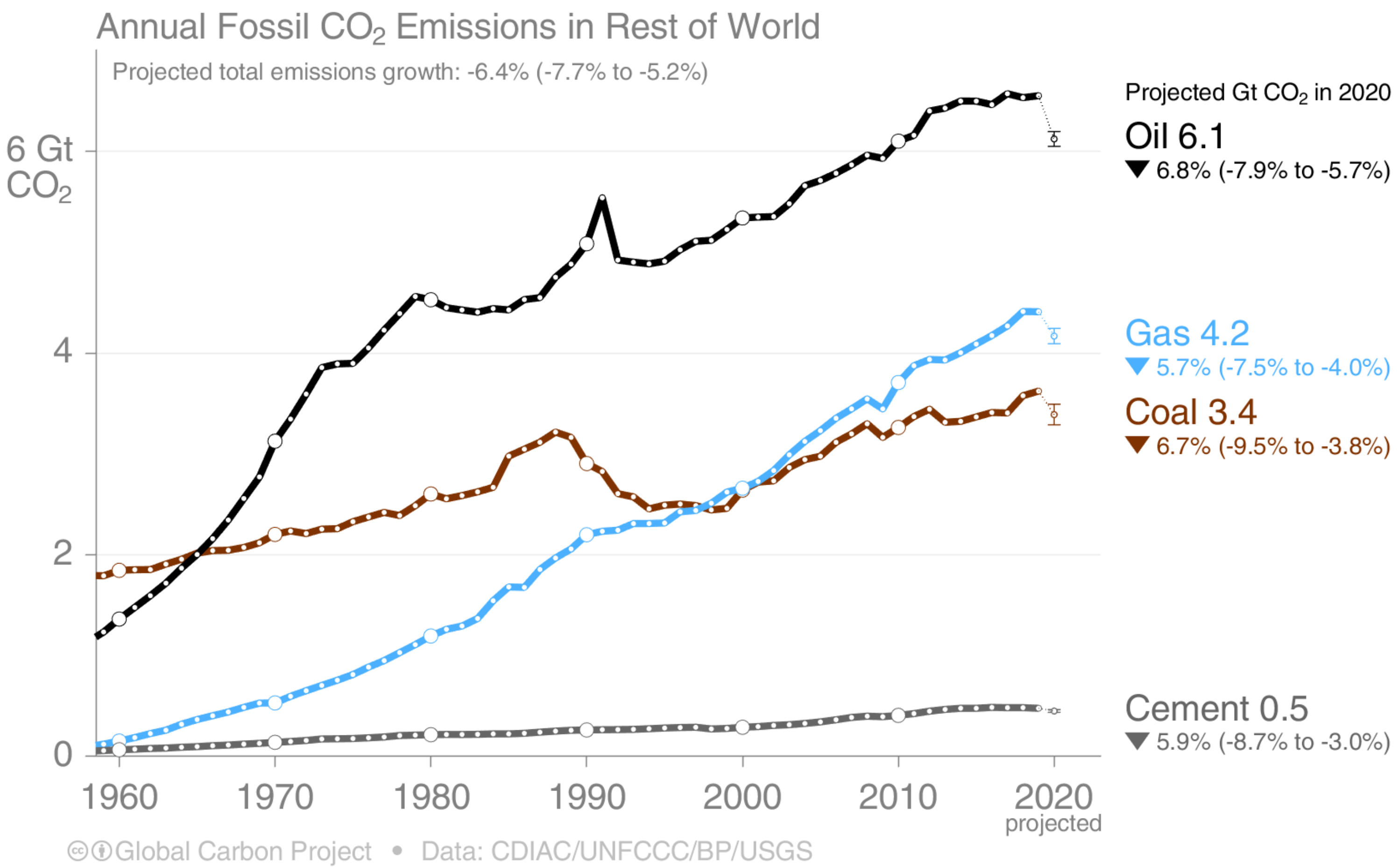
India's emissions are likely to drop about 8% in 2020, following substantial contractions in economic activity because of strict lockdowns in response to the pandemic



Source: [CDIAC]; [Friedlingstein et al 2020]; [Global Carbon Budget 2020]

Fossil CO_2 Emissions in Rest of World

Emissions in the Rest of the World are expected to drop sharply in 2020, on the back of weaker economic activity. Growth is estimated based on efficiency improvements of the last 10 years combined with projected economic growth.

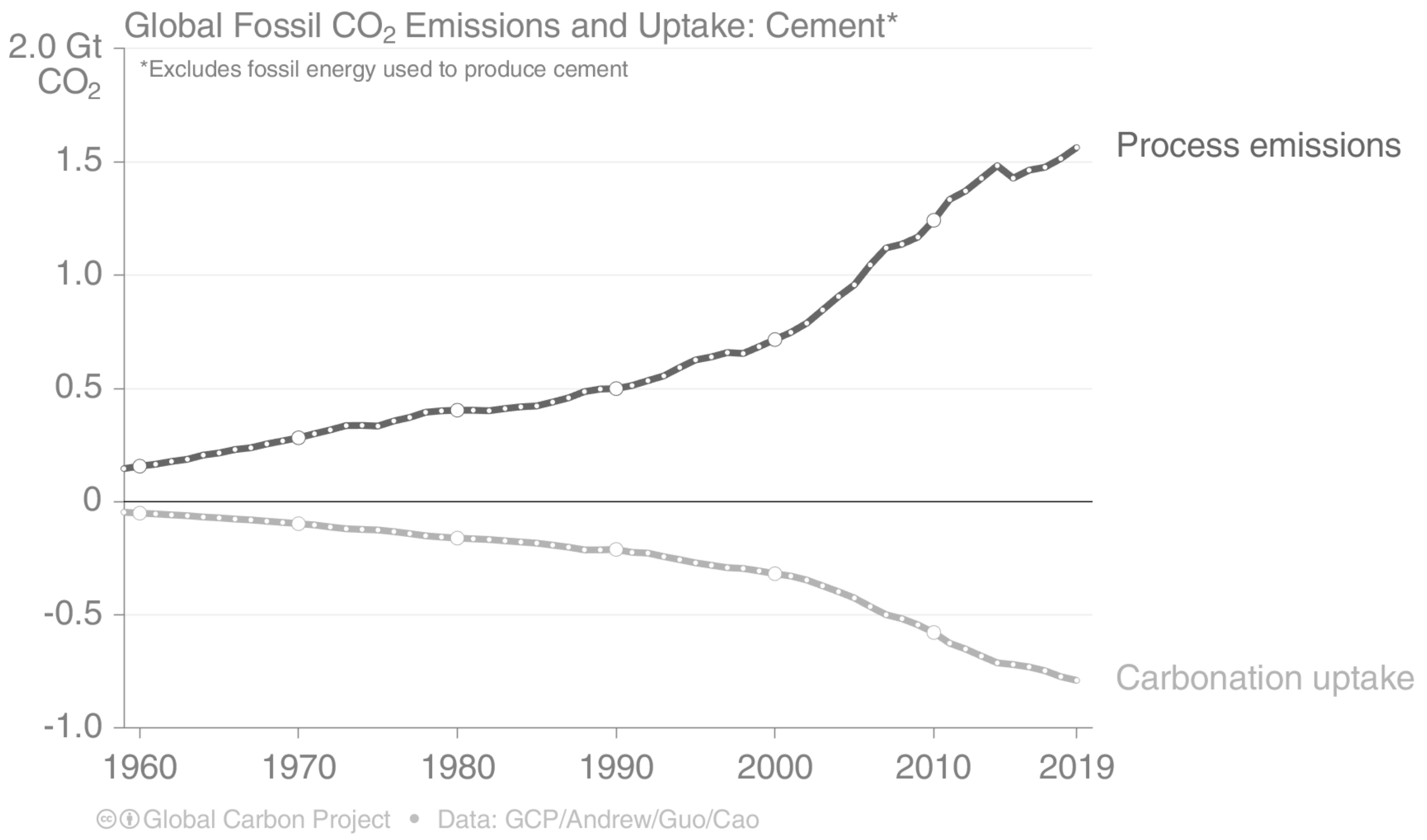


The Rest of the World is the global total less China, US, EU, and India. It also includes international aviation and marine bunkers.

Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

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



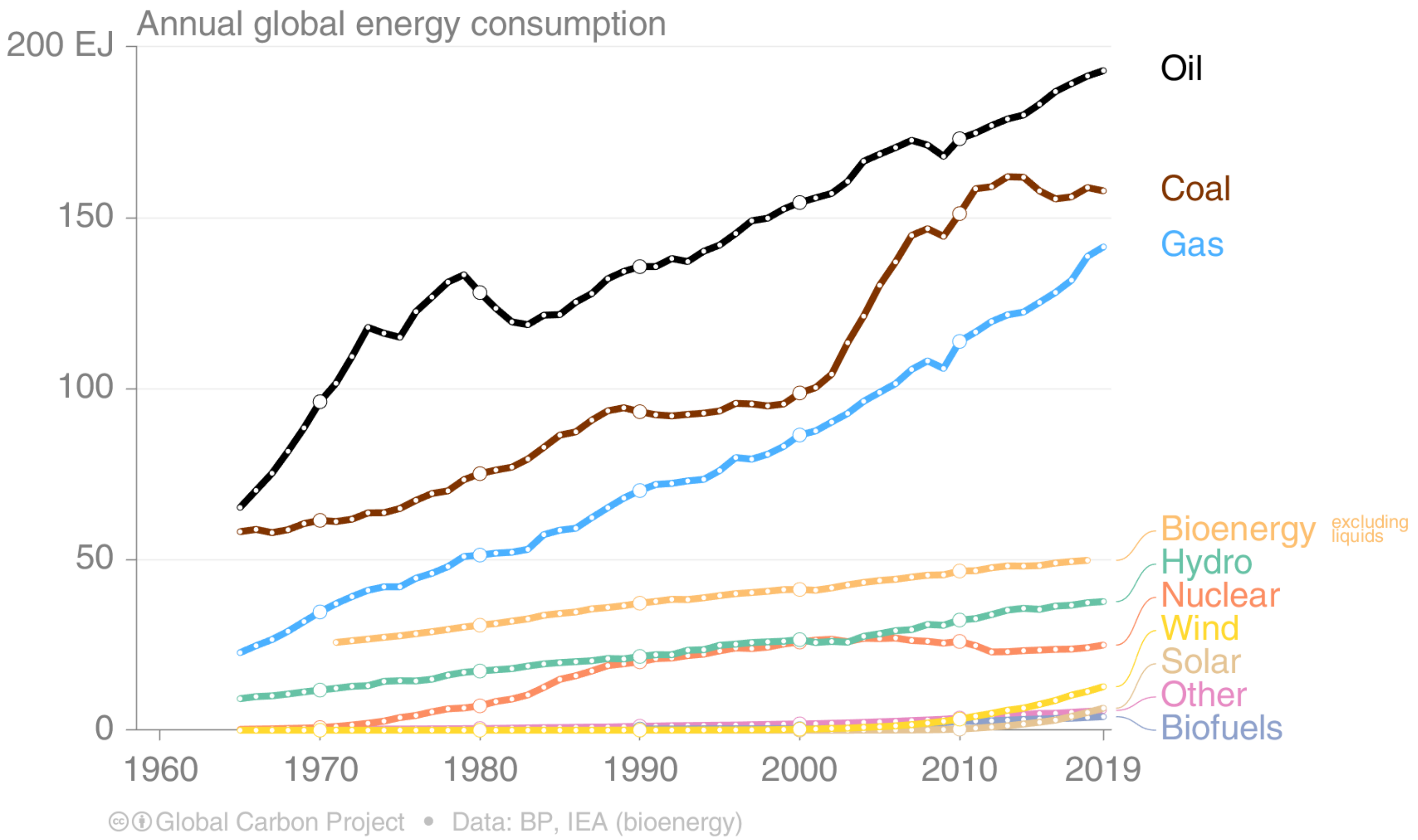
Source: Andrew, 2019; Guo et al 2020; Cao et al 2020; Friedlingstein et al 2020; Global Carbon Budget 2020

Energy use by source

from fossil fuel use and industry

Energy use by source

Renewable energy is growing exponentially, but this growth has so far been too low to offset the growth in fossil energy consumption.

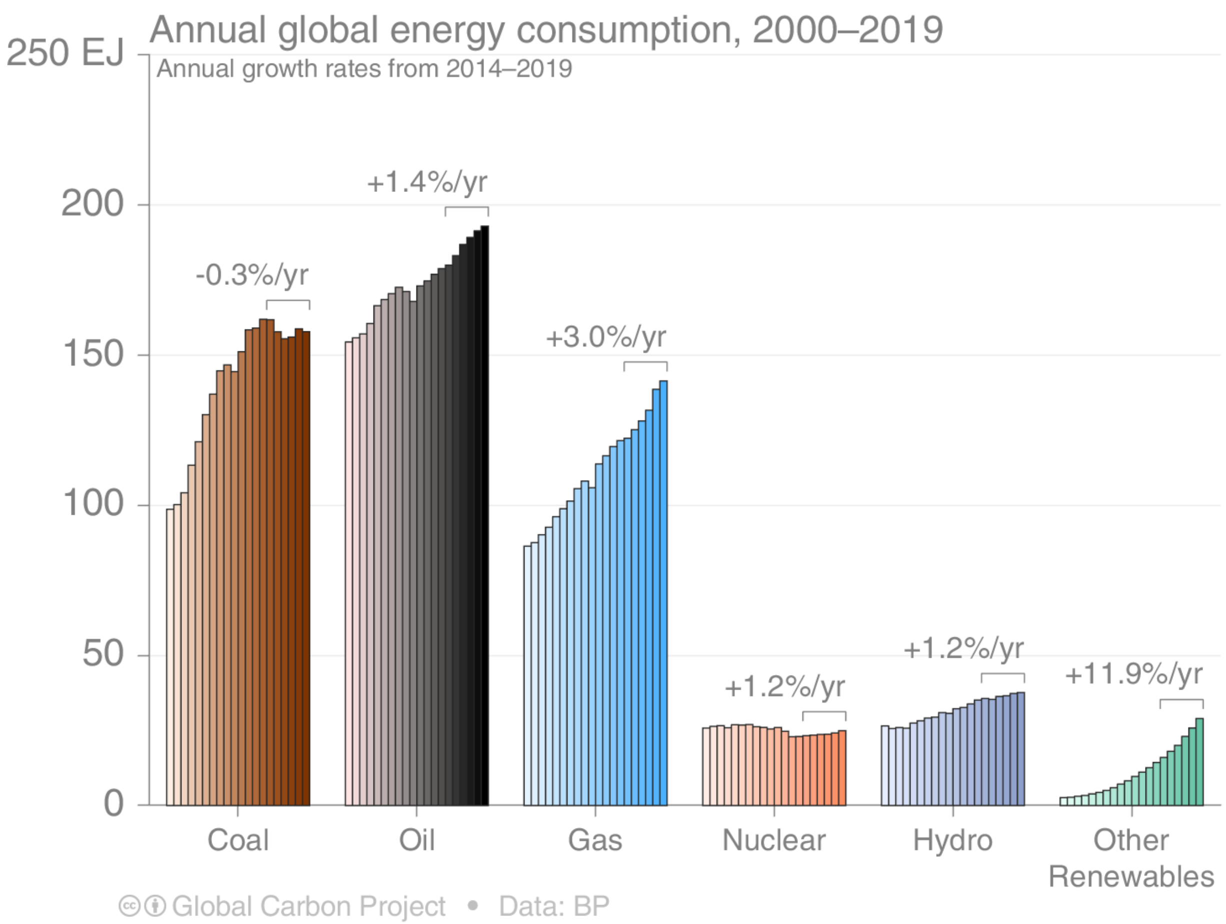


This figure shows "primary energy" using the BP substitution method (non-fossil sources are scaled up by an assumed fossil efficiency of 0.38)

Source: [BP 2020]; [Global Carbon Budget 2020]

Energy use by source

Energy consumption by fuel source from 2000 to 2019, with growth rates indicated for the more recent period of 2014 to 2019

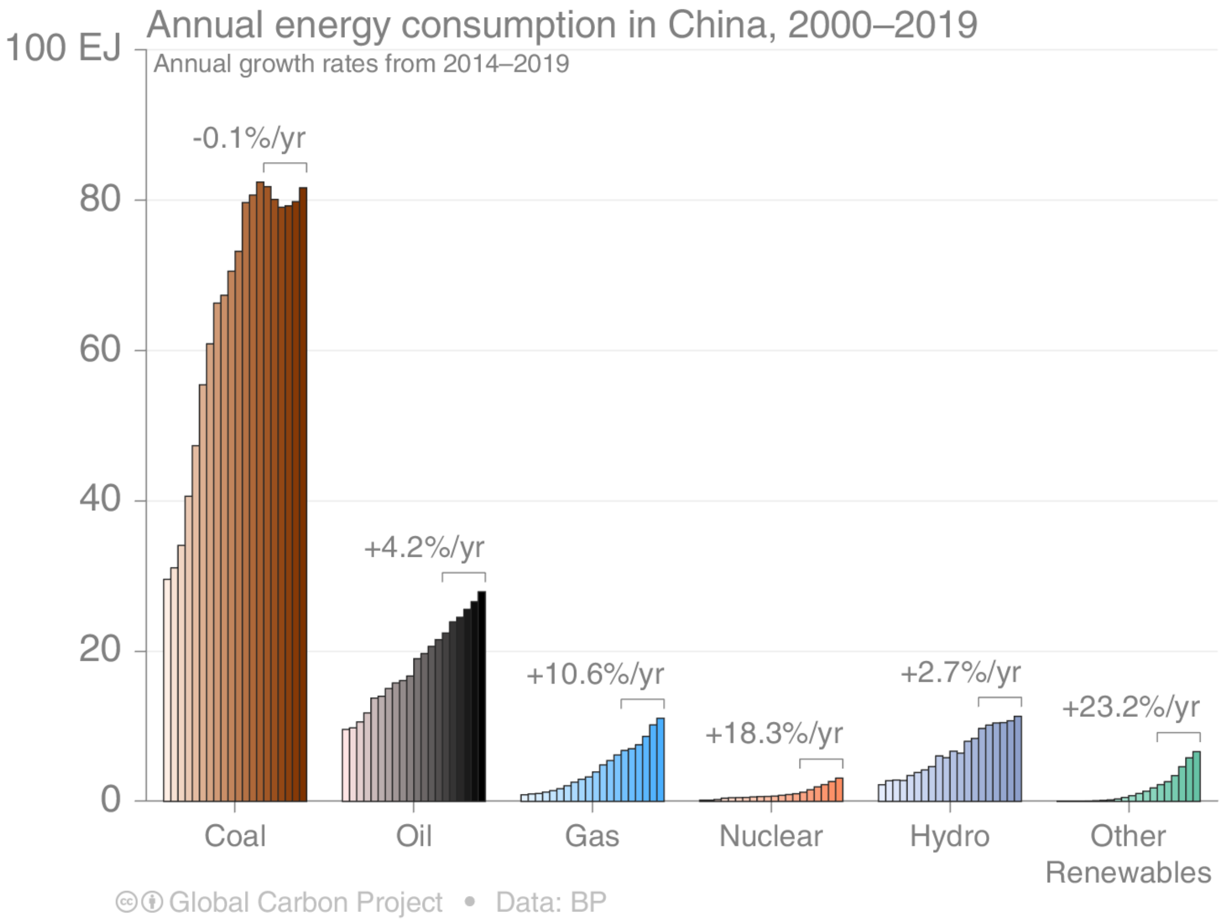


This figure shows "primary energy" using the BP substitution method (non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)

Source: BP 2020; Jackson et al 2019; Global Carbon Budget 2020

Energy use in China

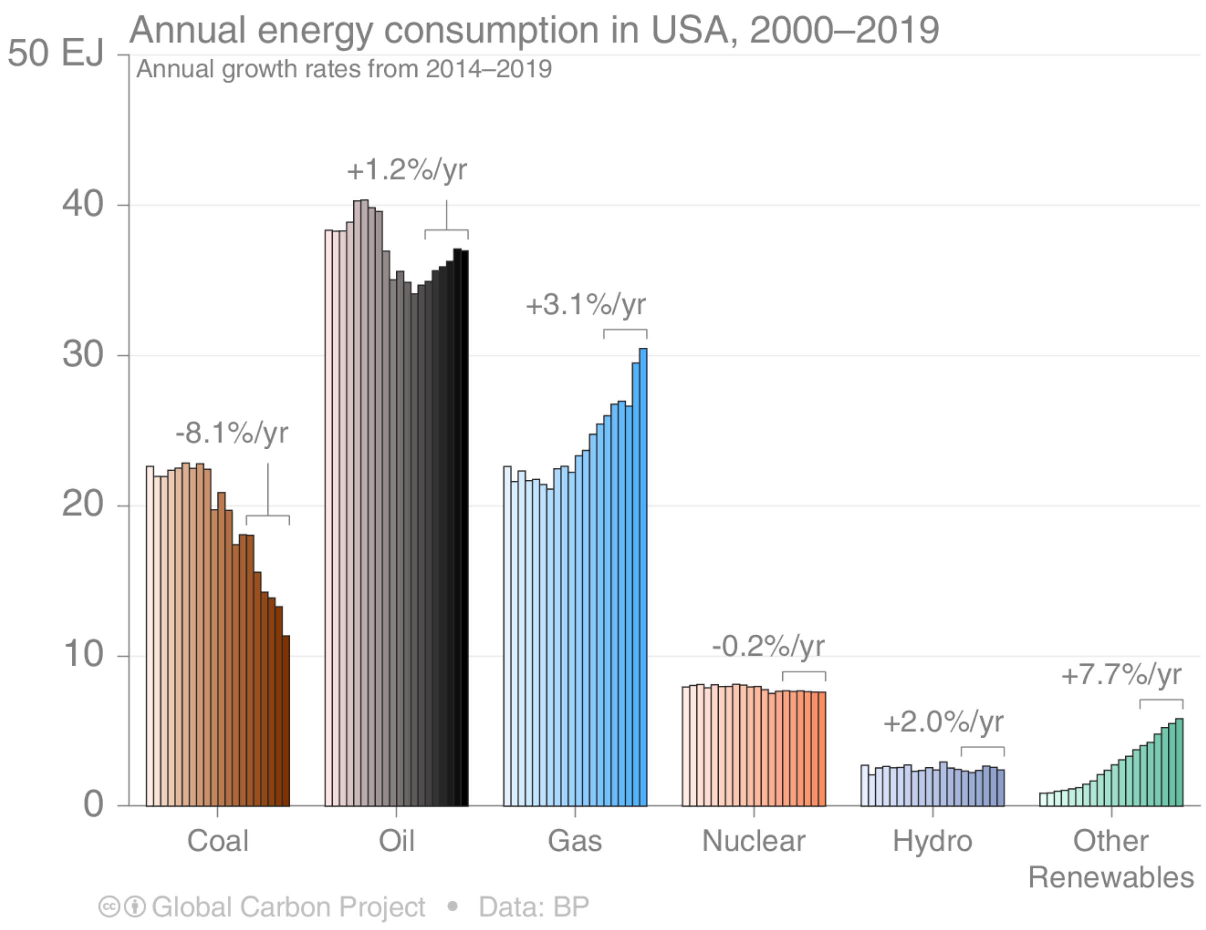
Coal consumption in energy units may have already peaked in China, while consumption of all other energy sources is growing strongly



Source: [BP 2020](); [Jackson et al 2019](); [Global Carbon Budget 2020]()

Energy use in USA

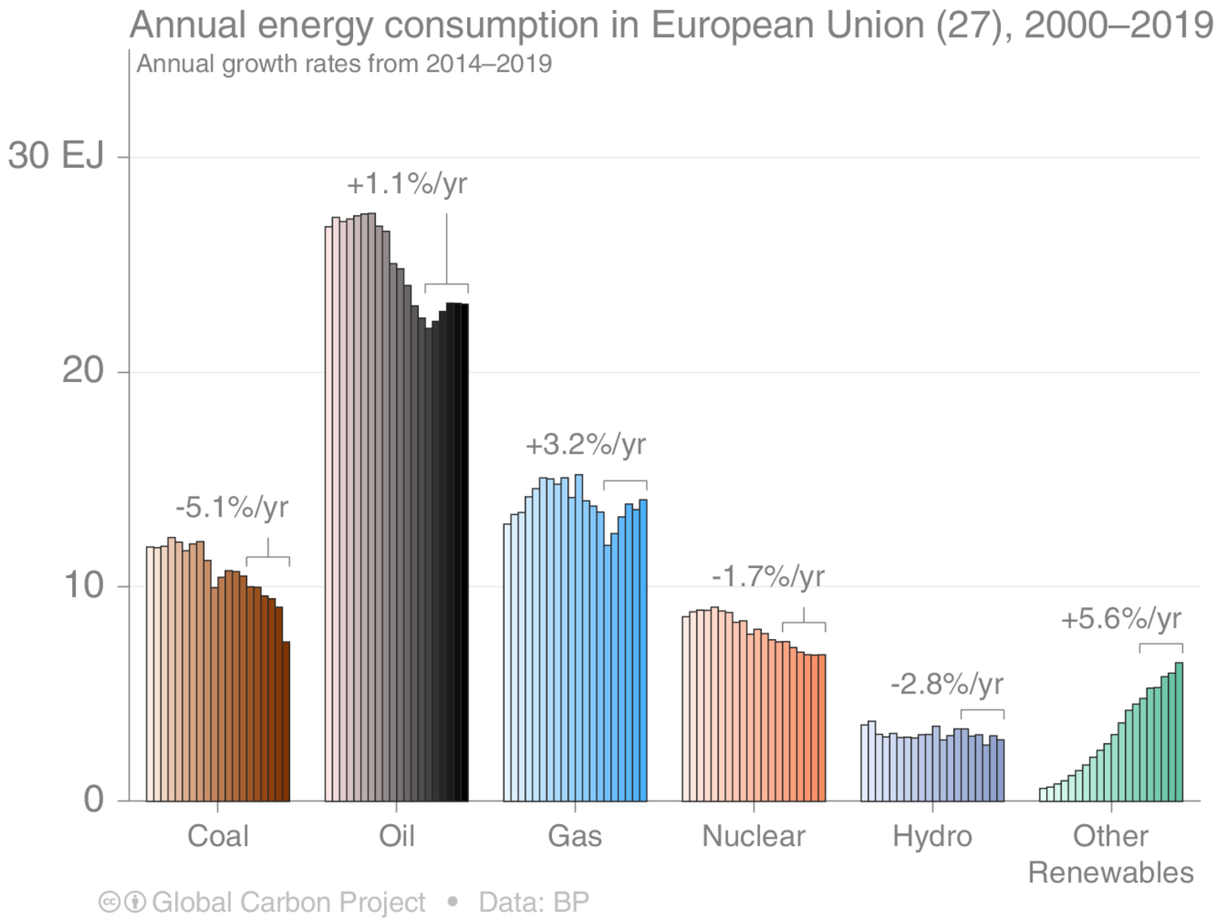
Coal consumption has declined sharply in recent years with the shale gas boom and strong renewables growth. Growth in oil consumption has resumed.



Source: [BP 2020](); [Jackson et al 2019](); [Global Carbon Budget 2020]()

Energy use in the European Union

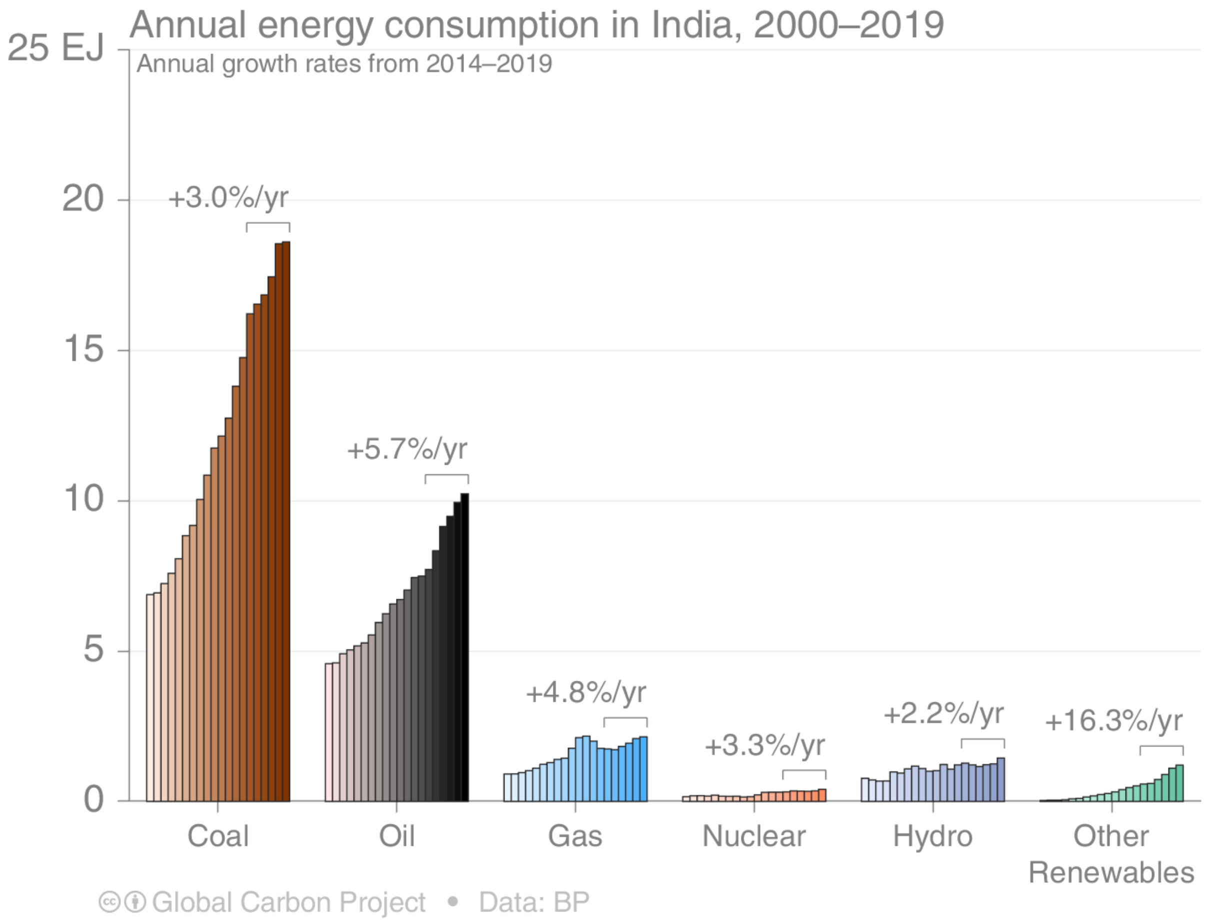
Consumption of both oil and gas has rebounded in recent years, while coal continues to decline.
Renewables are growing strongly.



Source: BP 2020; Jackson et al 2019; Global Carbon Budget 2020

Energy use in India

Consumption of coal and oil in India is growing very strongly,
as are renewables, albeit from a lower base.



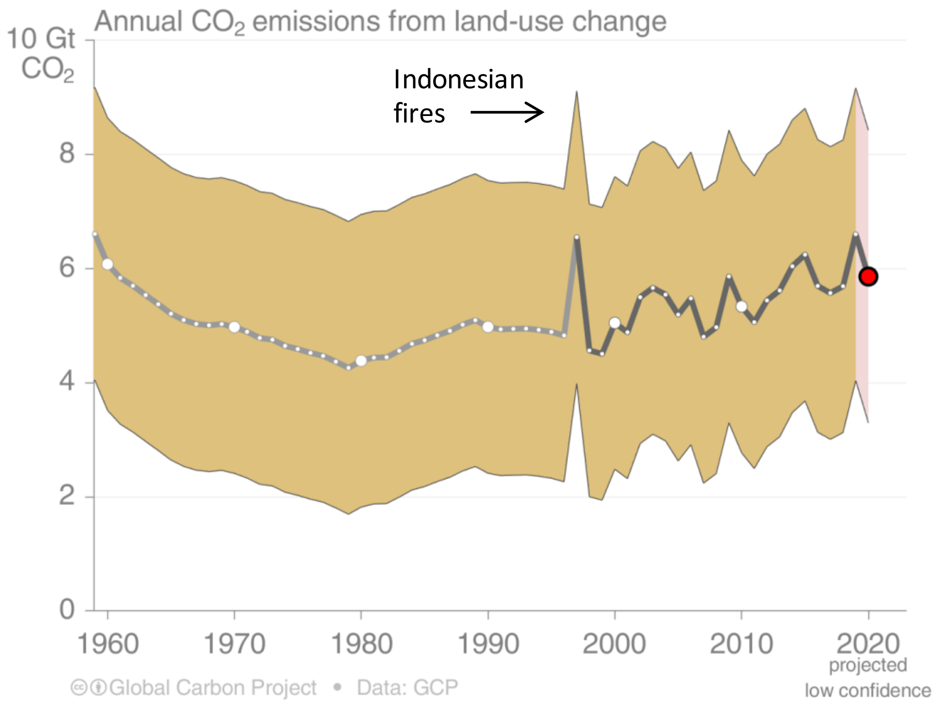
Source: BP 2020; Jackson et al 2019; Global Carbon Budget 2020

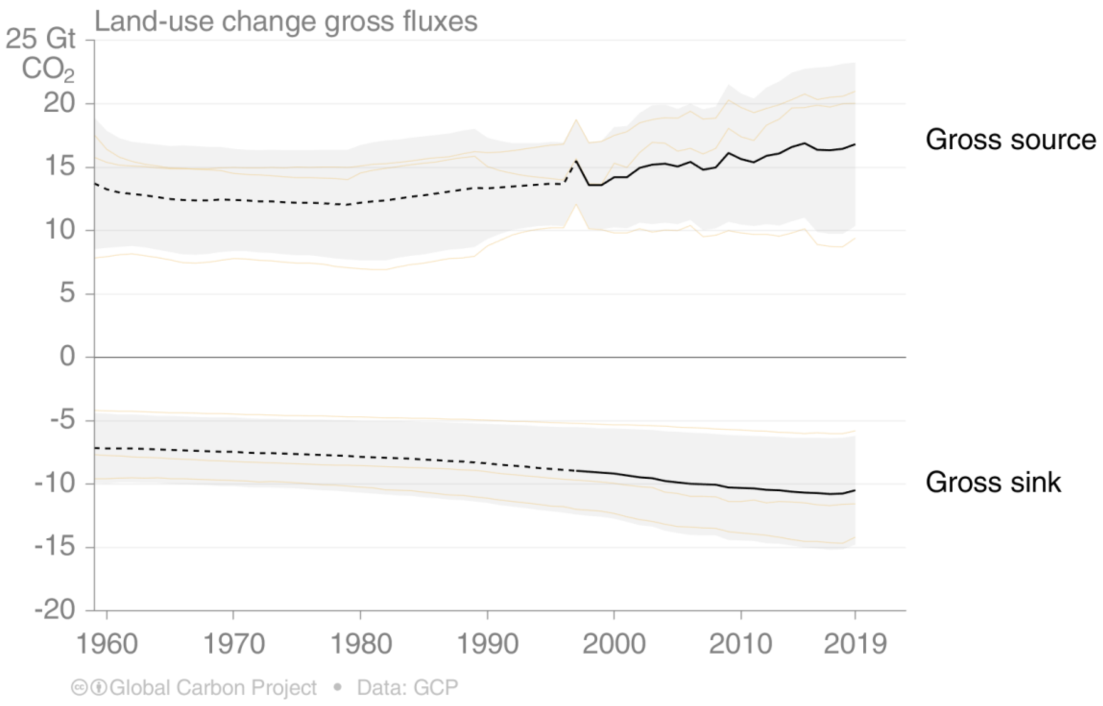
Land-use Change Emissions

Land-use change emissions

Land-use change emissions are highly uncertain, with no clear trend in the last decade.

Net land-use emissions are the difference between CO_2 source, primarily from deforestation, and CO_2 sink, primarily from abandonment of agricultural land



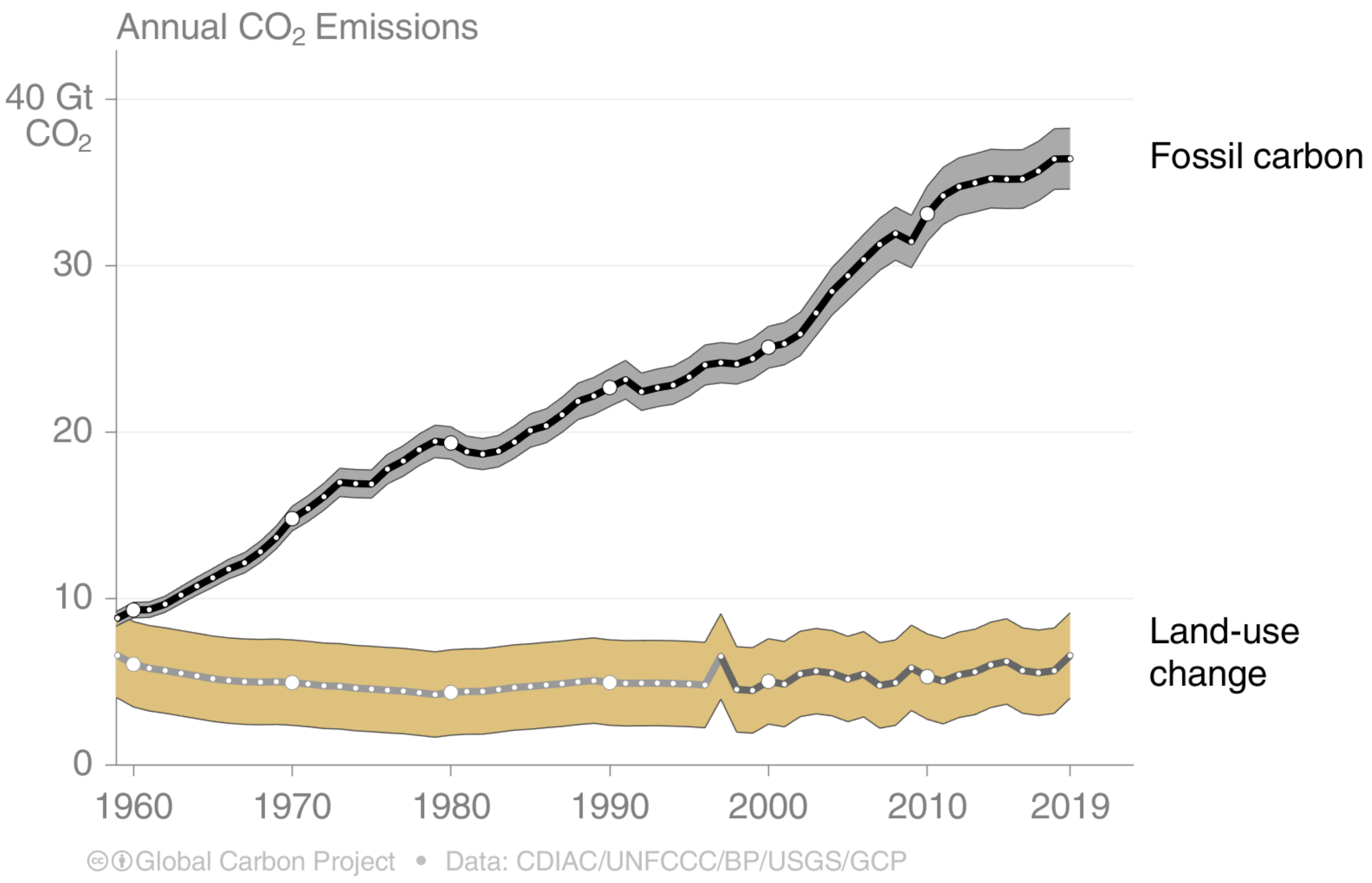


Estimates from three bookkeeping models, using fire-based variability from 1997

Source: Houghton and Nassikas 2017; Hansis et al 2015; Gasser et al 2020; van der Werf et al. 2017; Friedlingstein et al 2020; Global Carbon Budget 2020

Total global emissions

Total global emissions: 43.0 ± 3.3 $GtCO_2$ in 2019, 56% over 1990
Percentage land-use change: 39% in 1960, 14% averaged 2010–2019



Land-use change estimates from three bookkeeping models, using fire-based variability from 1997
Source: CDIAC; Houghton and Nassikas 2017; Hansis et al 2015; Gasser et al 2020; van der Werf et al. 2017; Friedlingstein et al 2020; Global Carbon Budget 2020

Closing the Global Carbon Budget

GLOBAL CARBON PROJECT

Fate of anthropogenic CO_2 emissions (2010–2019)

Sources = Sinks

34.4 $GtCO_2$/yr

86%

14%

5.7 $GtCO_2$/yr

18.6 $GtCO_2$/yr

46%

31%

12.5 $GtCO_2$/yr

23%

9.2 $GtCO_2$/yr

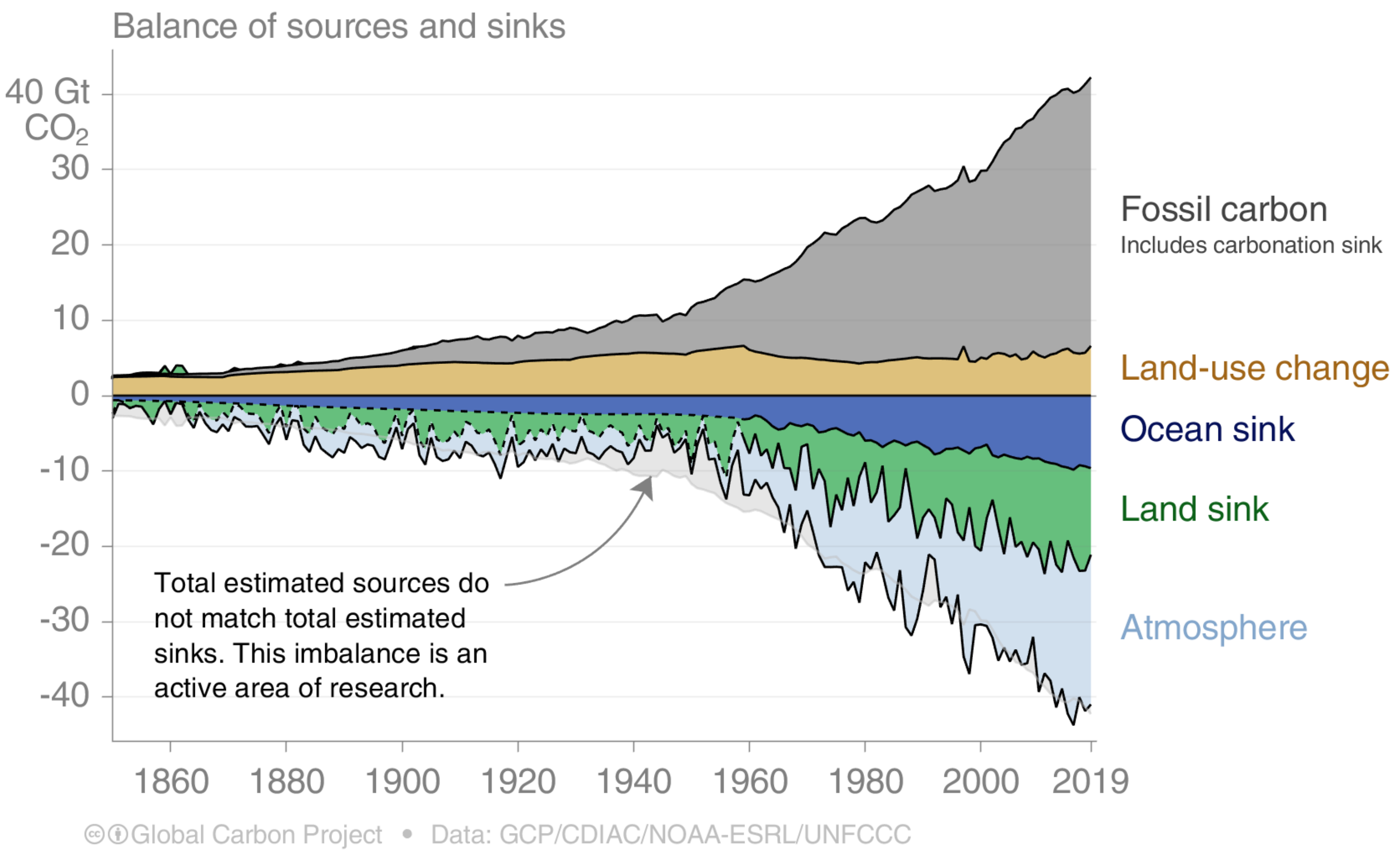
Budget Imbalance:
(the difference between estimated sources & sinks)

0.4%
0.2 $GtCO_2$/yr

Source: Friedlingstein et al 2020; Global Carbon Budget 2020

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

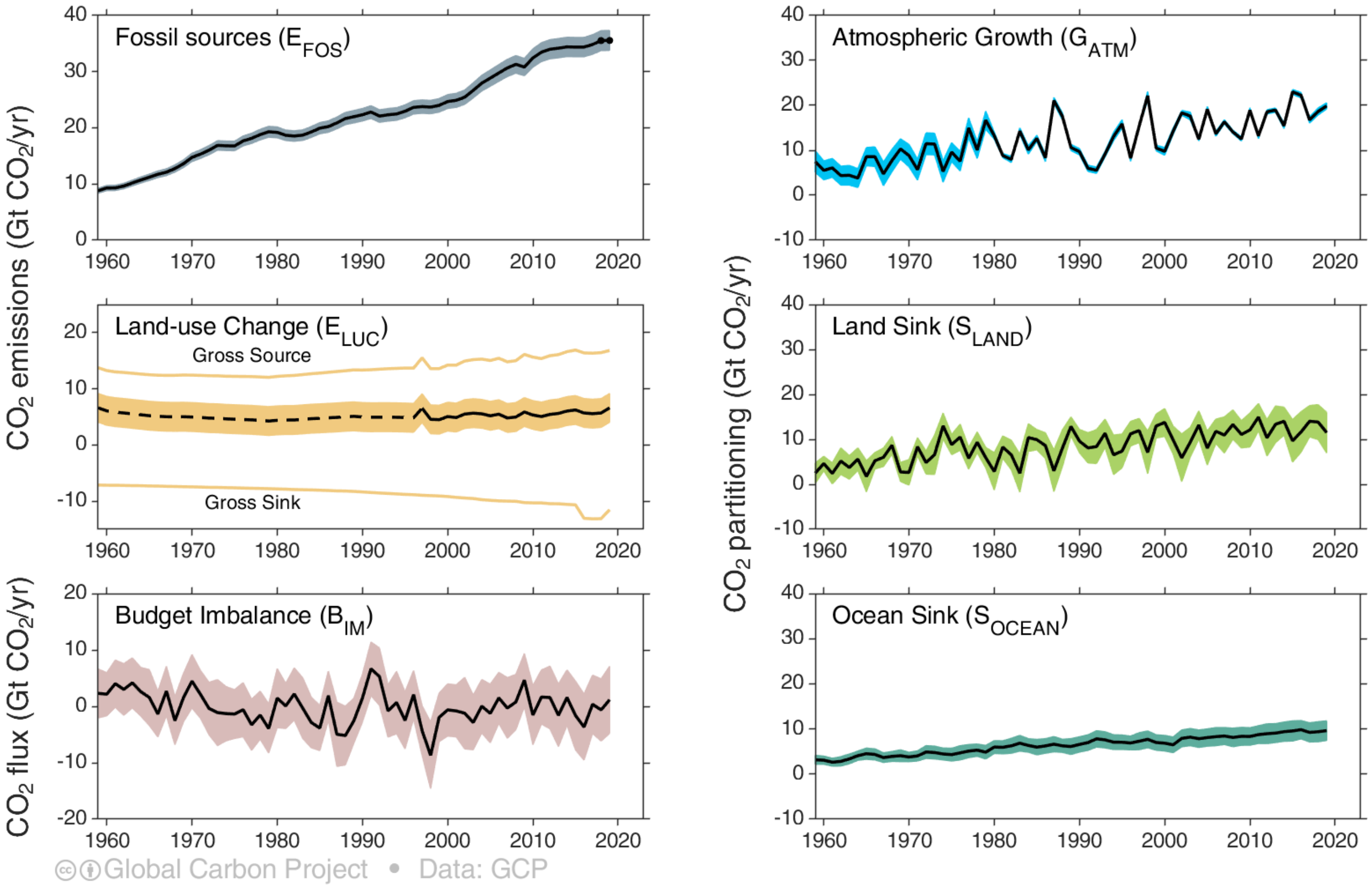


Source: Friedlingstein et al 2020; Global Carbon Budget 2020

GLOBAL CARBON PROJECT

Changes in the budget over time

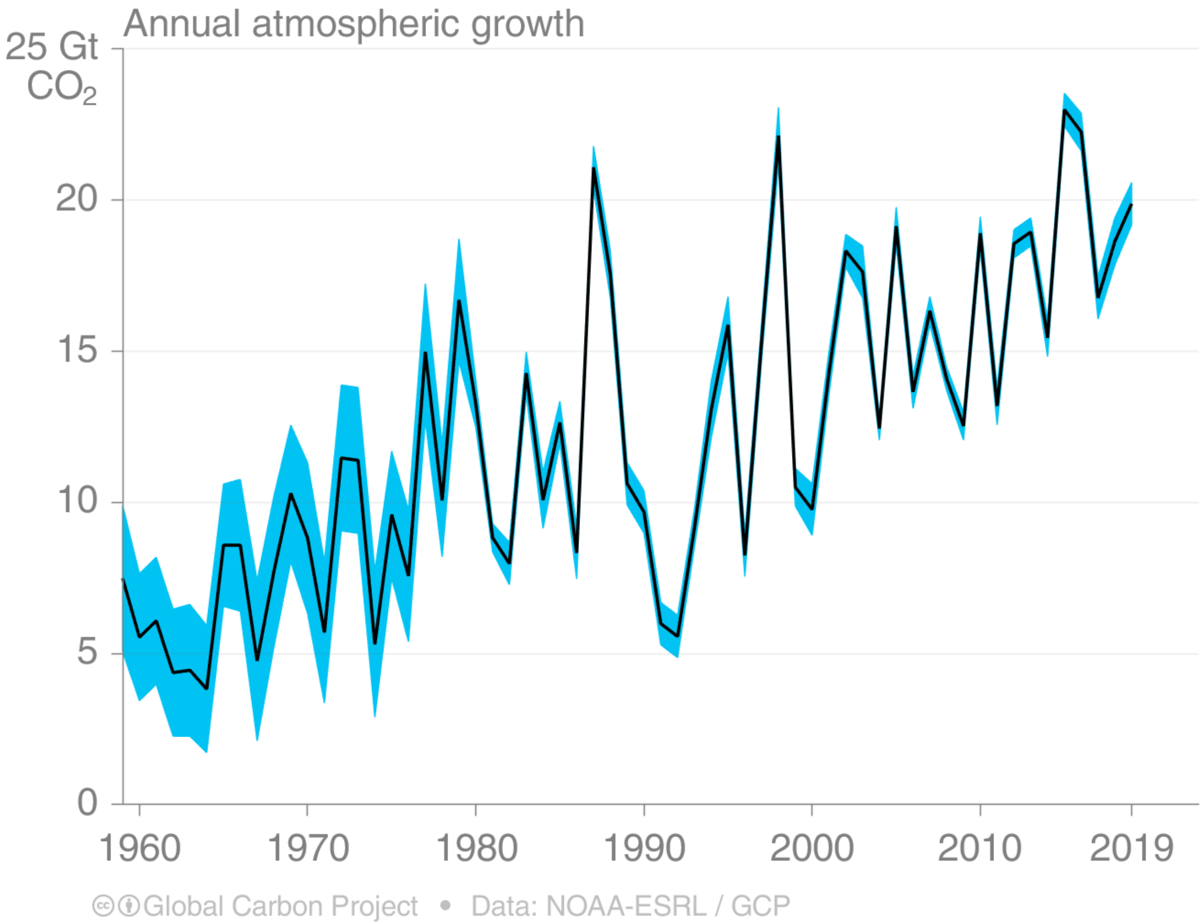
The sinks have continued to grow with increasing emissions, but climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere



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 2020](); [Global Carbon Budget 2020]()

Atmospheric concentration

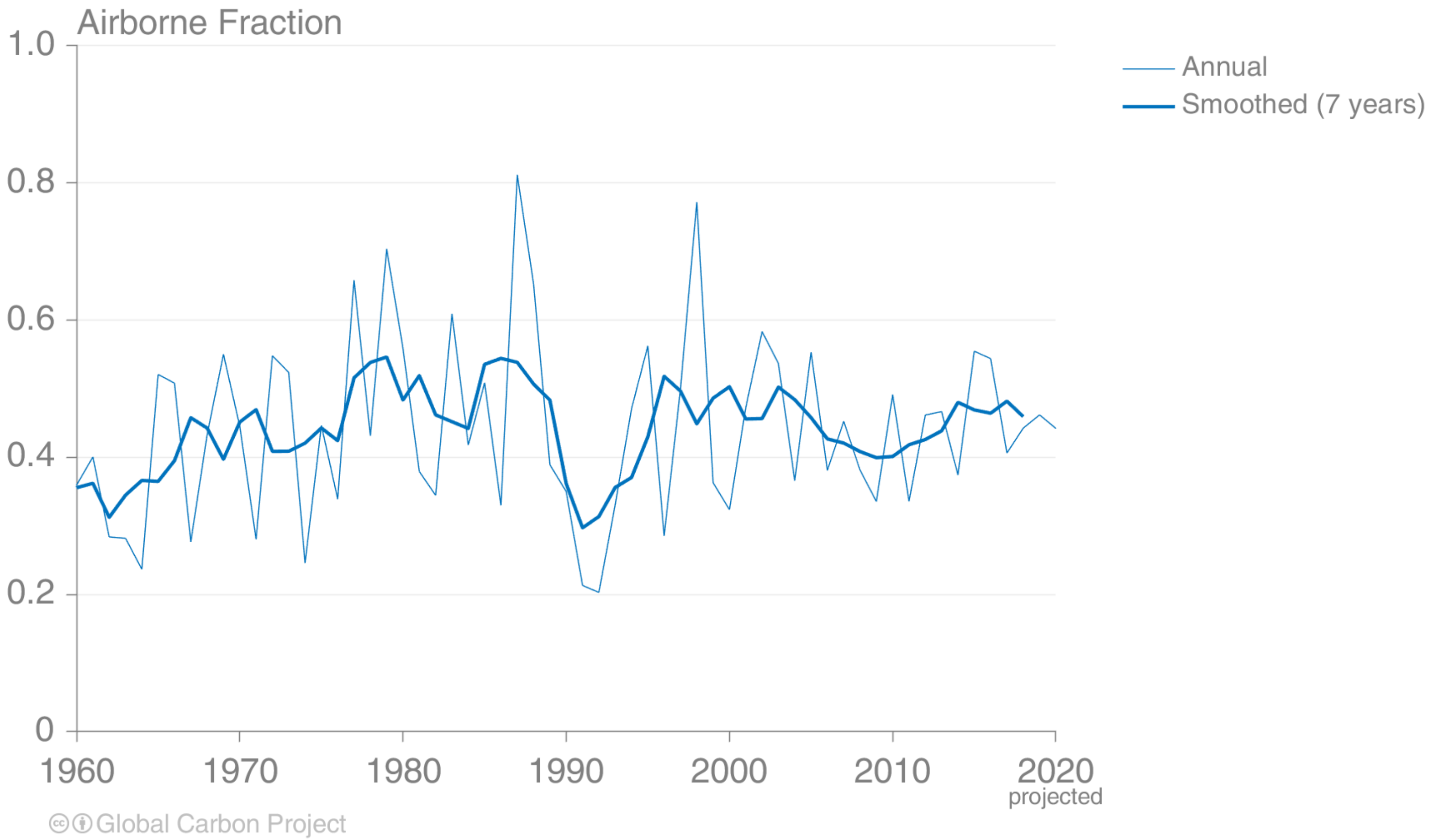
The atmospheric concentration growth rate has shown a steady increase
The high growth in 1987, 1998, & 2015–16 reflect a strong El Niño, which weakens the land sink



Source: NOAA-ESRL; Friedlingstein et al 2020; Global Carbon Budget 2020

Airborne Fraction

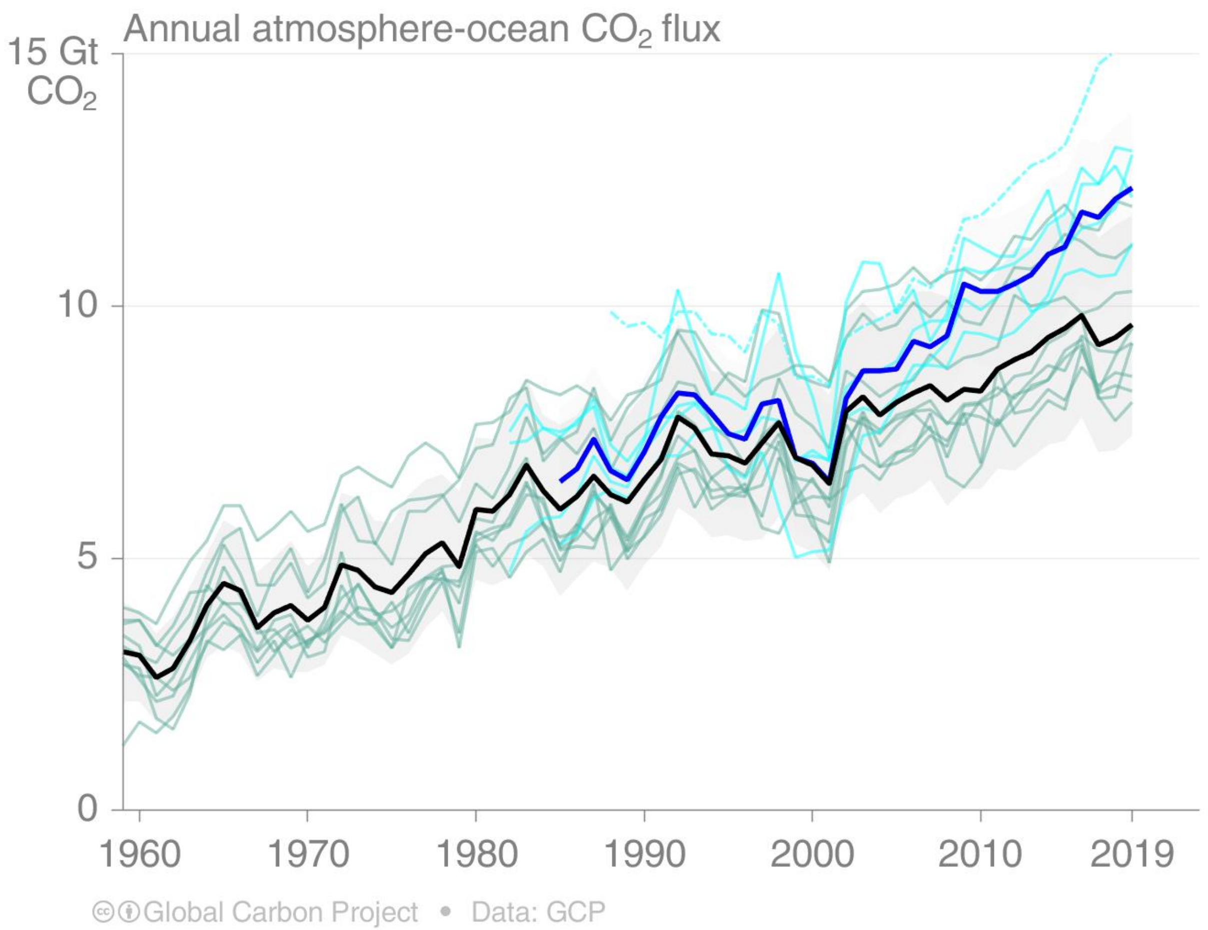
The airborne fraction is the ratio of the growth in atmospheric concentration and total annual CO_2 emissions.
Around 45% of CO_2 emissions remain in the atmosphere despite sustained growth in CO_2 emissions.



Source: NOAA-ESRL; Global Carbon Budget 2020

Ocean sink

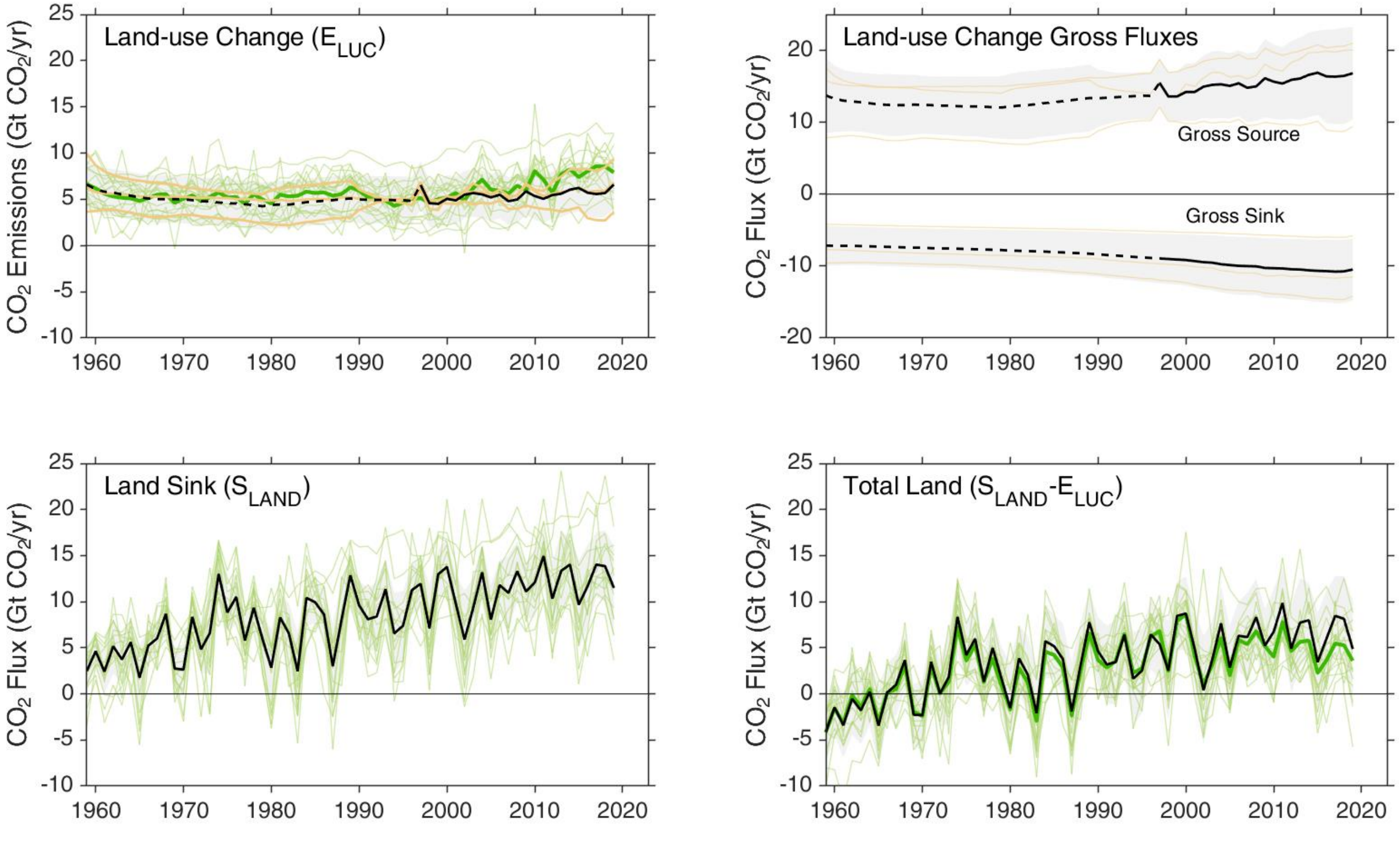
The ocean carbon sink continues to increase
9.2±2.1 $GtCO_2$/yr for 2010–2019 and 9.6±2.1 $GtCO_2$/yr in 2019



Source: SOCATv6; Bakker et al 2016; Friedlingstein et al 2020; Global Carbon Budget 2020
(see Table 4 for detailed references)

Terrestrial sink

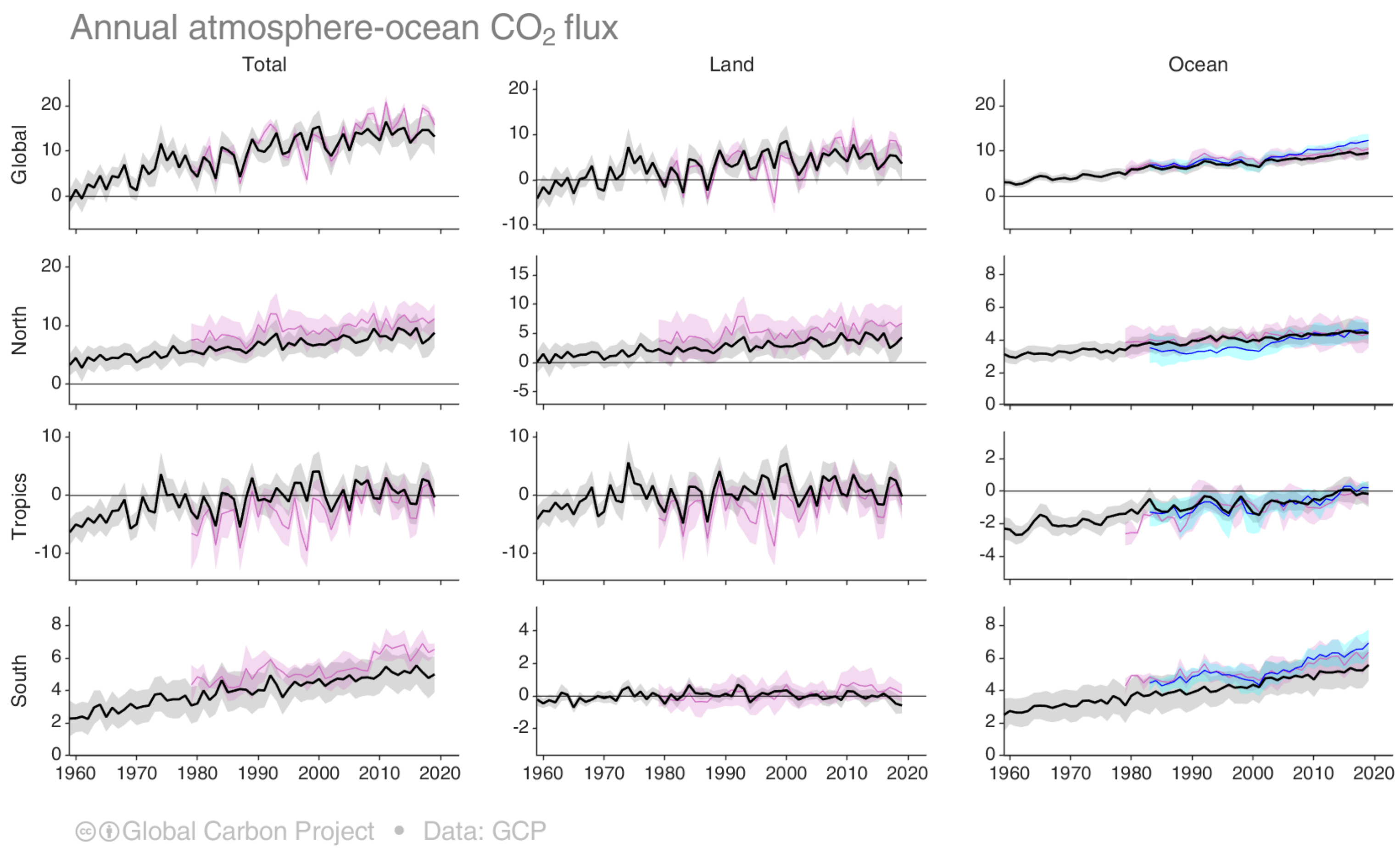
The land sink was 12.6±3.3 GtCO_2/yr during 2010–2019 and 11.5±4.5 GtCO_2/yr in 2019
Total CO_2 fluxes on land (including land-use change) are constrained by atmospheric inversions



Source: [Friedlingstein et al 2020](#) (see Table 4 for detailed references)

Total land and ocean fluxes

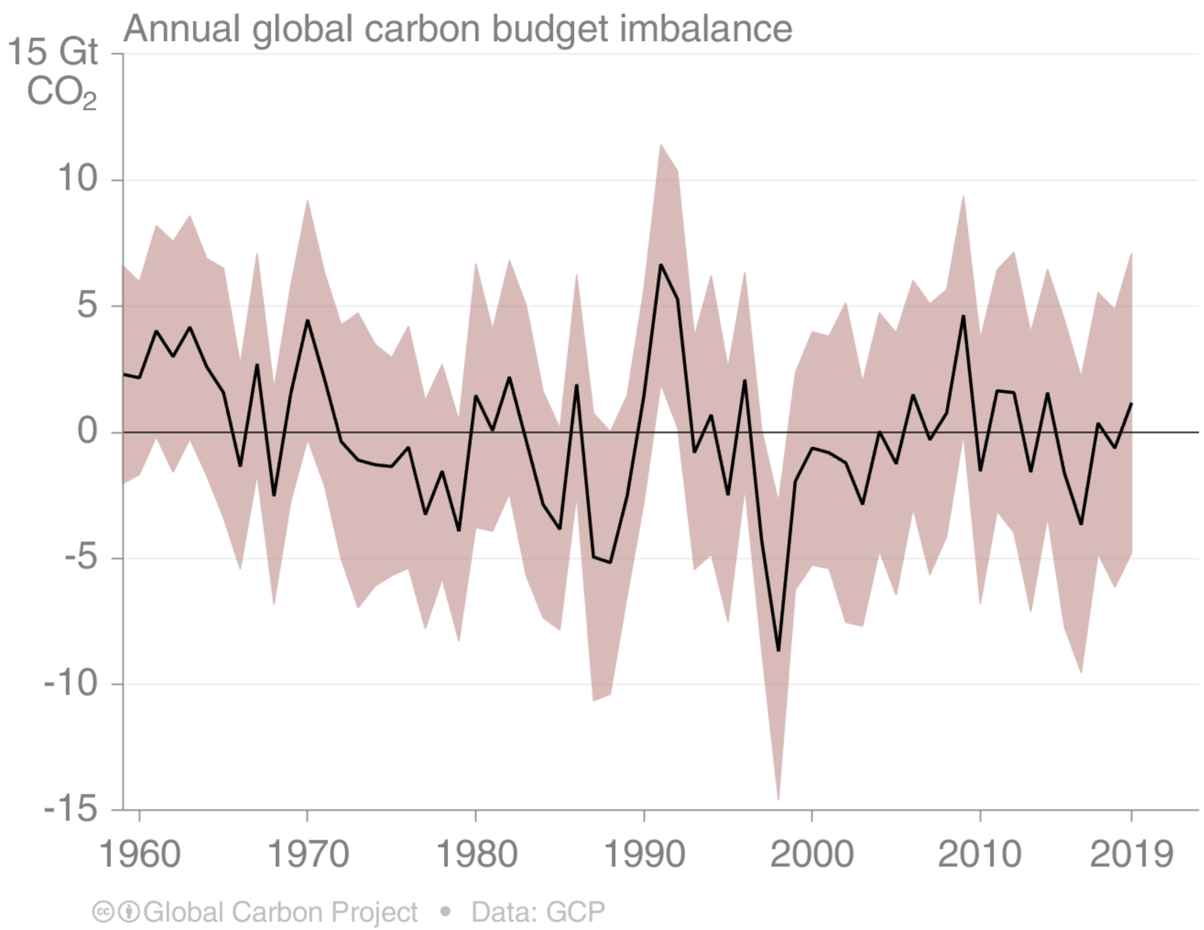
Total land and ocean fluxes show more interannual variability in the tropics



Source: Friedlingstein et al 2020 (see Table 4 for detailed references)

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



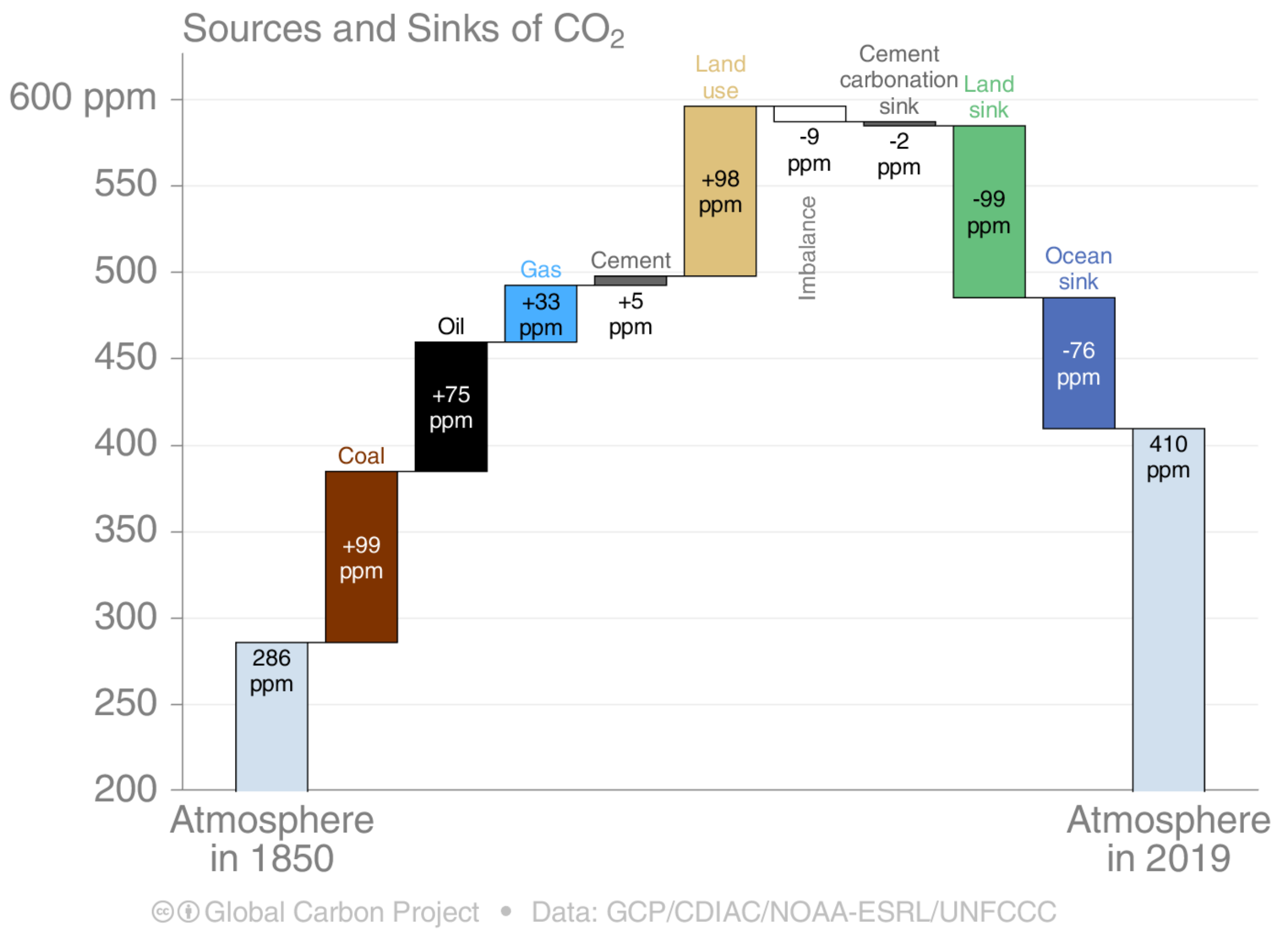
positive values mean overestimated emissions and/or underestimated sinks

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 2020; Global Carbon Budget 2020

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

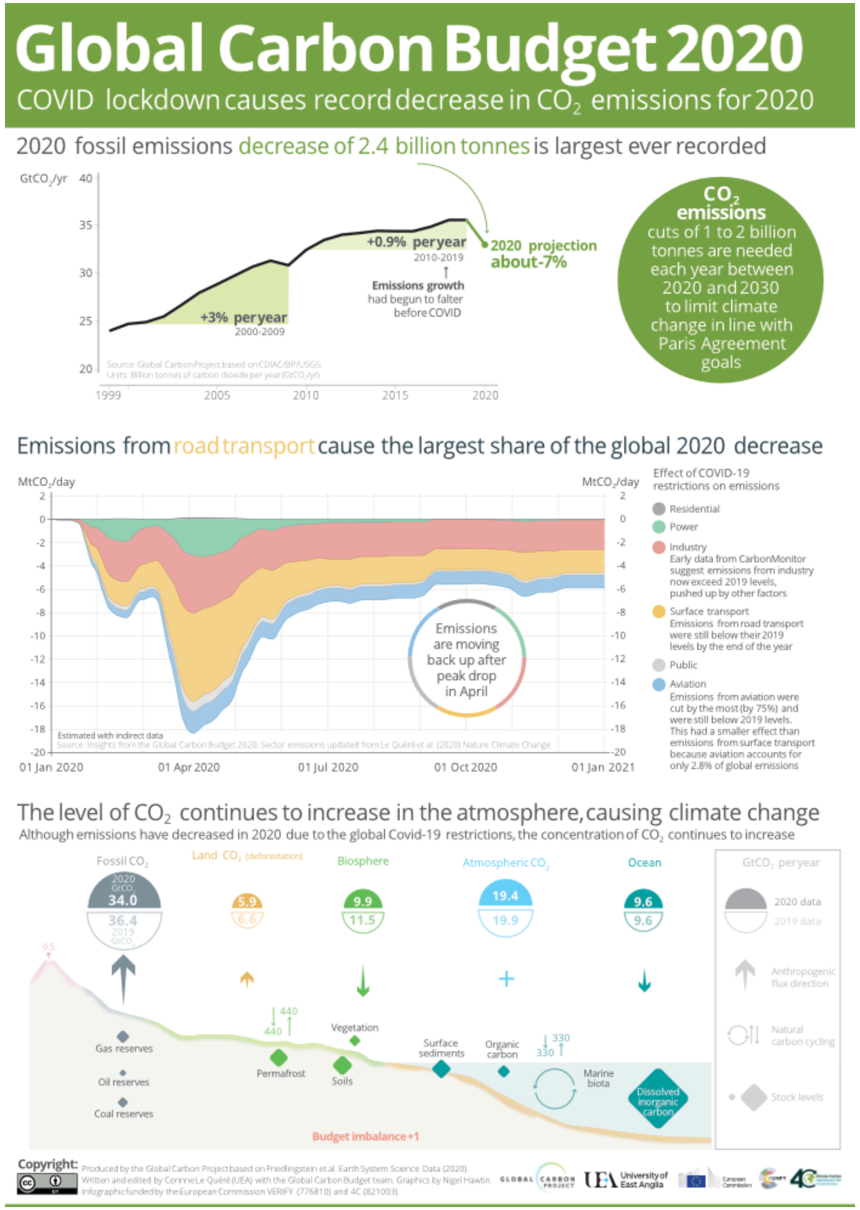


Source: Friedlingstein et al 2020; Global Carbon Budget 2020

GLOBAL CARBON PROJECT

Infographics

Infographic



[Download in full resolution]

Acknowledgements

Acknowledgements

The work presented in the **Global Carbon Budget 2020** 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 VERIFY (776810) and 4C (821003) 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. 2020. https://doi.org/10.5194/essd-12-3269-2020

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

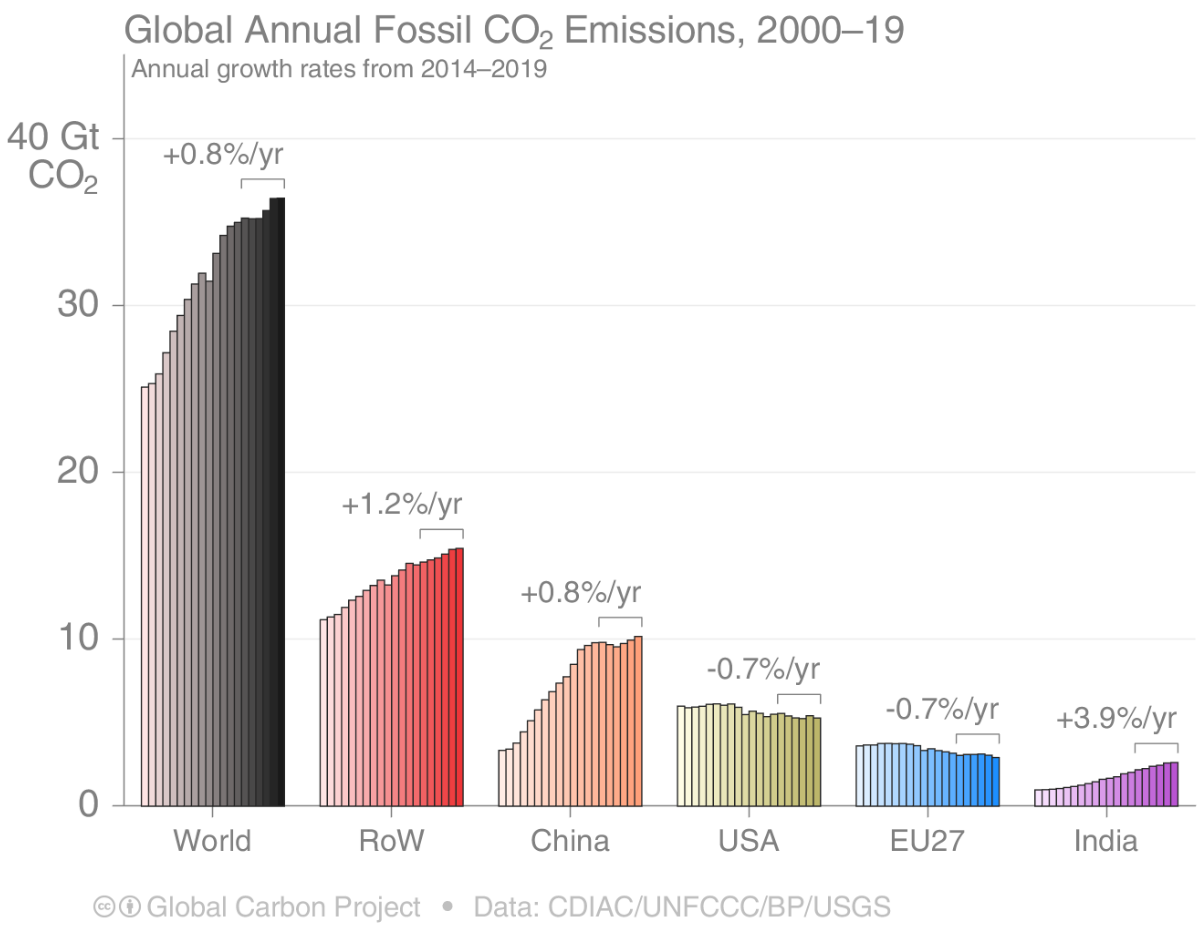
This presentation was created by Robbie Andrew with Pep Canadell, Glen Peters, Corinne Le Quéré and Pierre Friedlingstein in support of the international carbon research community.

Additional Figures

Additional Figures
Fossil CO_2

Top emitters: Fossil CO_2 Emissions

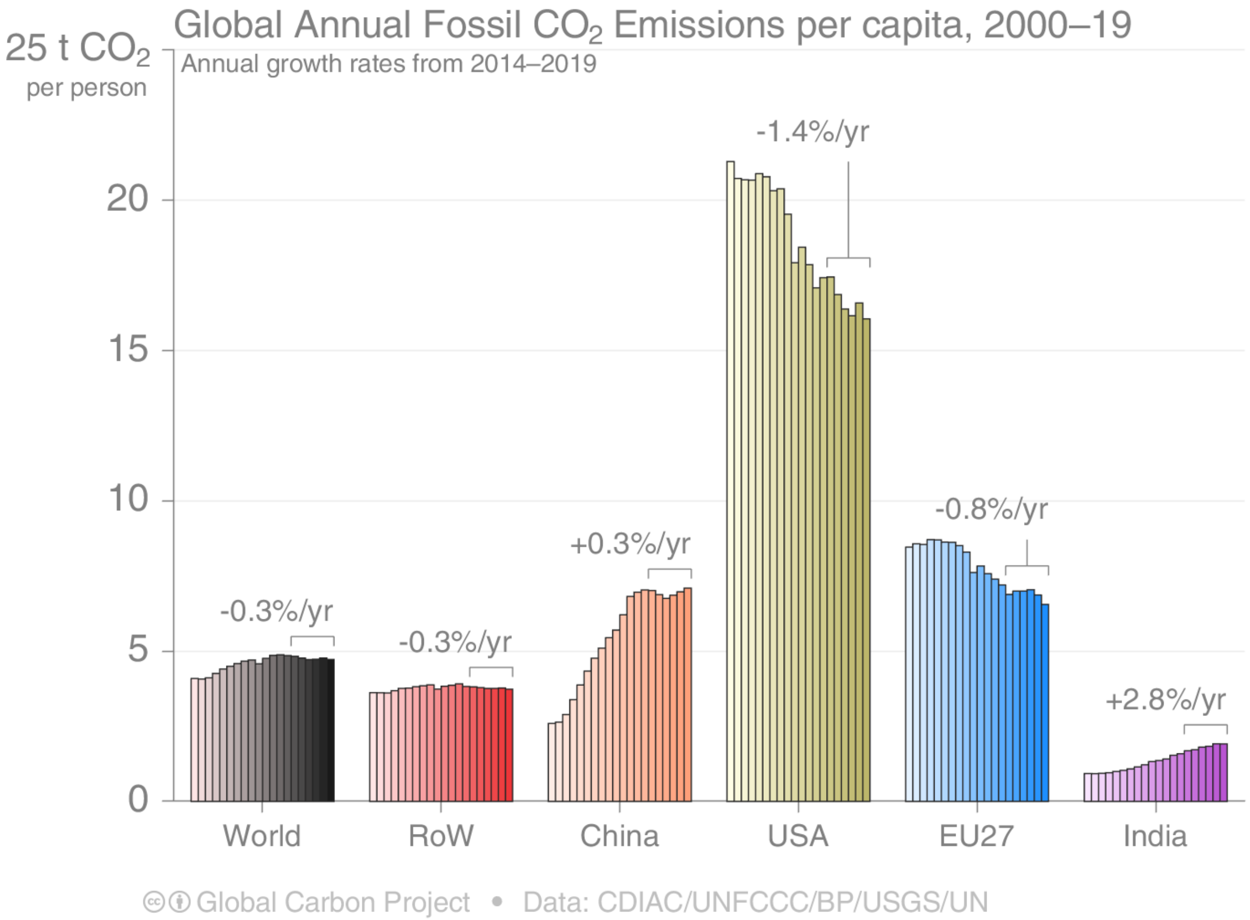
Emissions by country from 2000 to 2019, with the growth rates indicated for the more recent period of 2014 to 2019



Source: CDIAC; Jackson et al 2019; Friedlingstein et al 2020; Global Carbon Budget 2020

Per capita CO_2 emissions

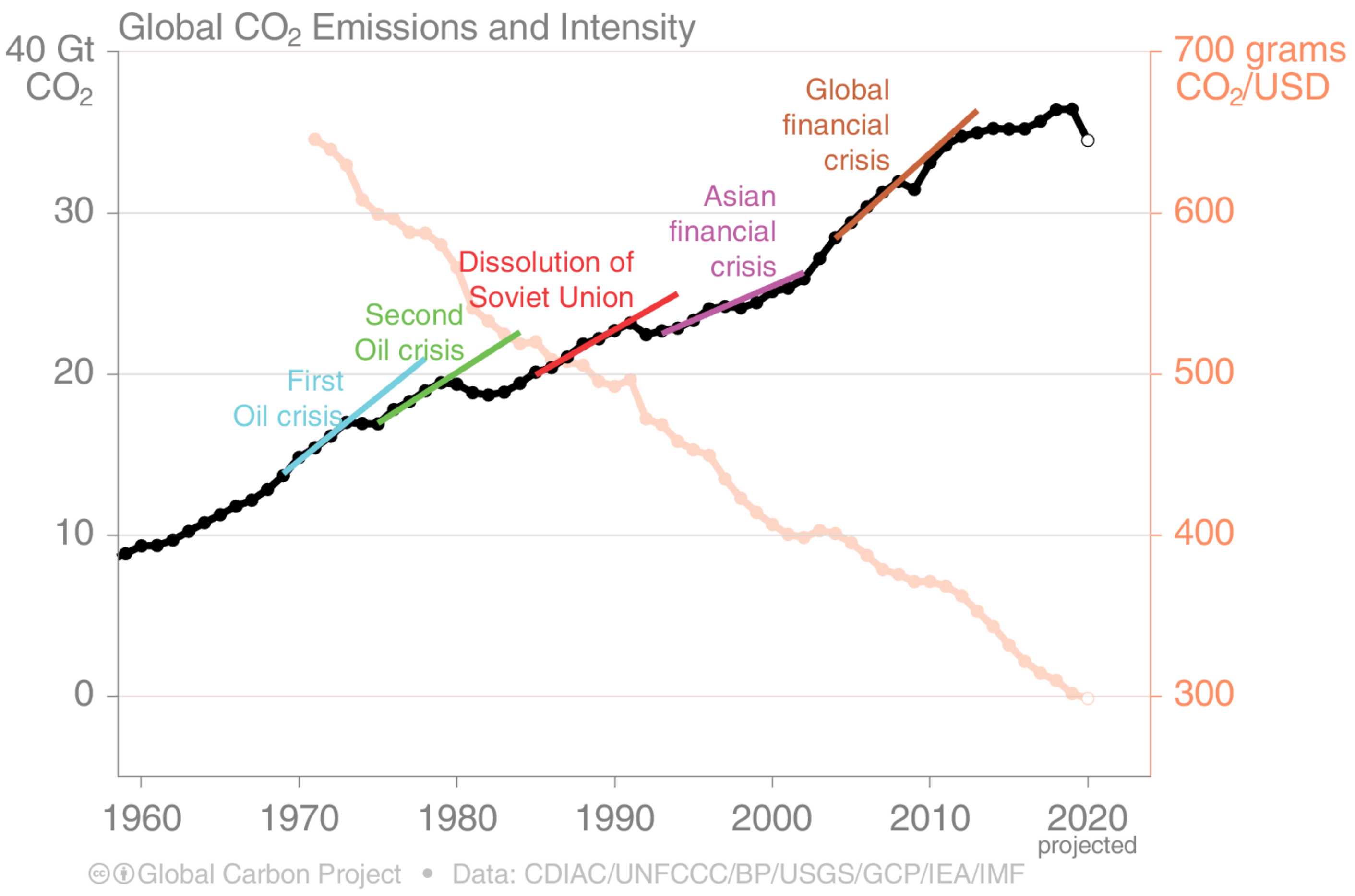
The US has high per capita emissions, but this has been declining steadily. China's per capita emissions have levelled out and are now the same as the EU. India's emissions are low per capita.



Source: Jackson et al 2019; Global Carbon Budget 2020

Fossil CO_2 emission intensity

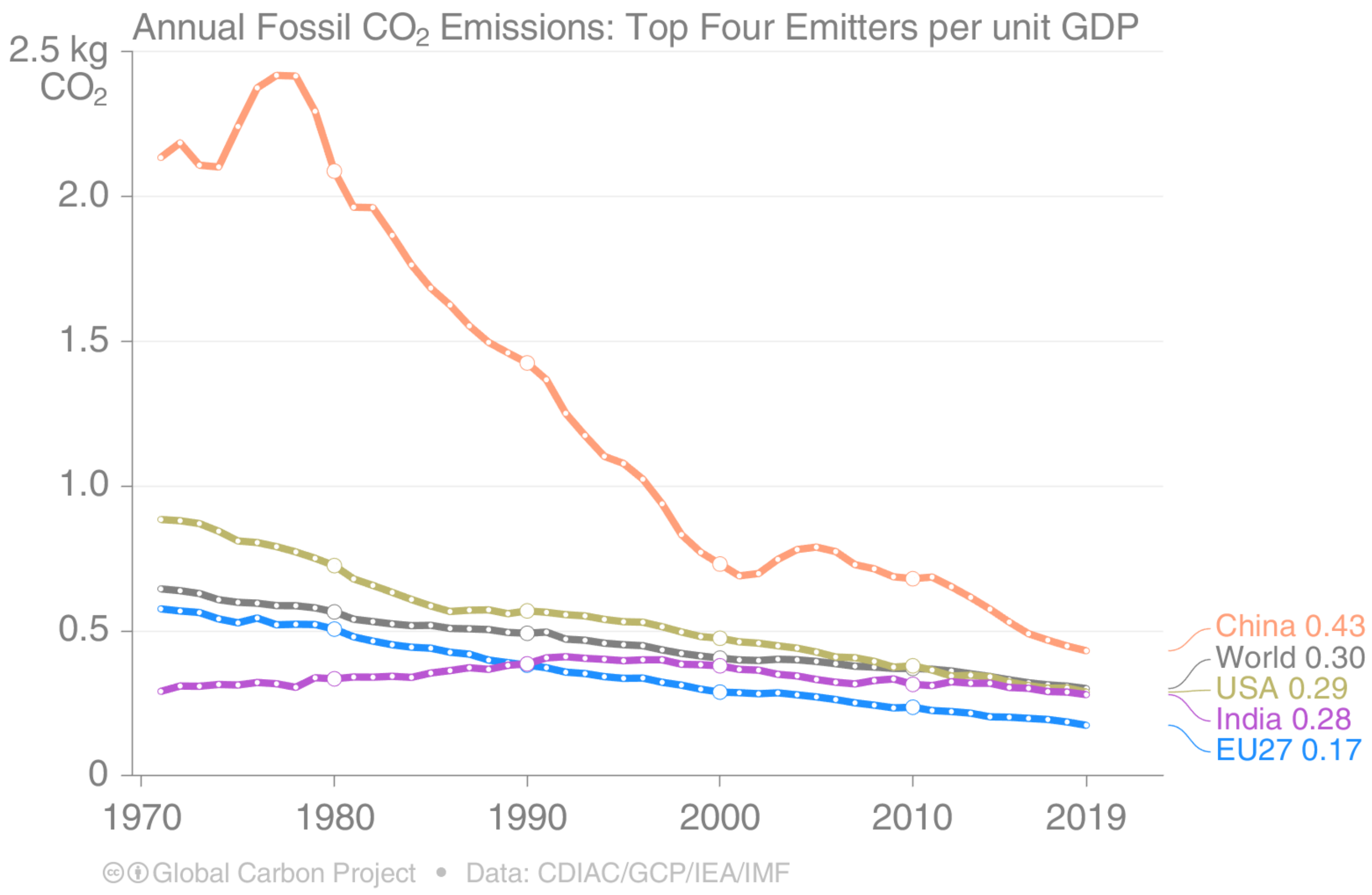
Global CO_2 emissions growth has generally resumed quickly from financial crises.
Emission intensity has steadily declined but not sufficiently to offset economic growth.



Economic activity is measured in purchasing power parity (PPP) terms in 2010 US dollars.
Source: CDIAC; Peters et al 2012; Friedlingstein et al 2020; Global Carbon Budget 2020

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.

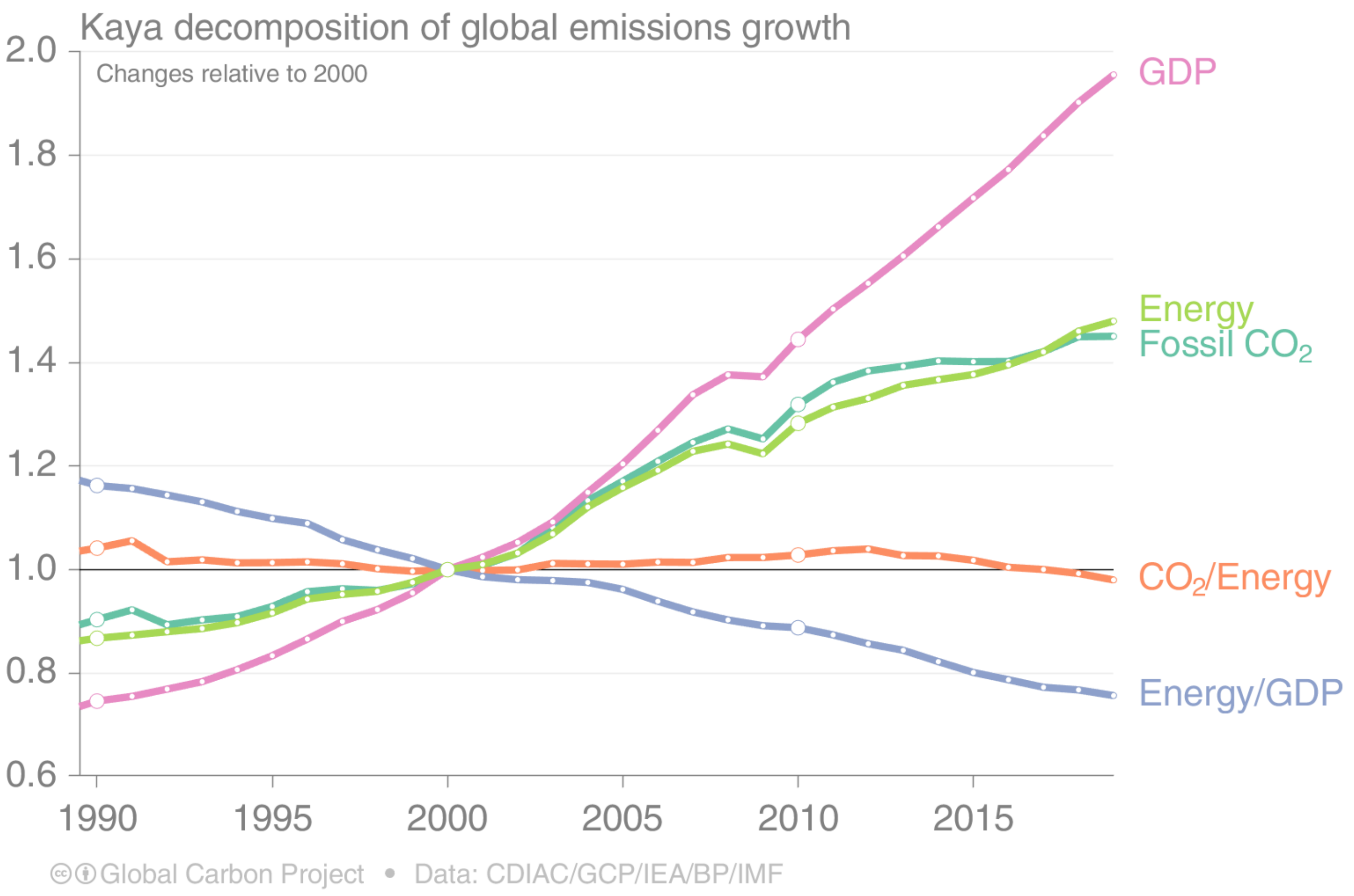


GDP is measured in purchasing power parity (PPP) terms in 2010 US dollars.

Source: CDIAC; IEA 2019 GDP to 2016, IMF 2020 growth rates to 2019; Friedlingstein et al 2020; Global Carbon Budget 2020

Kaya decomposition

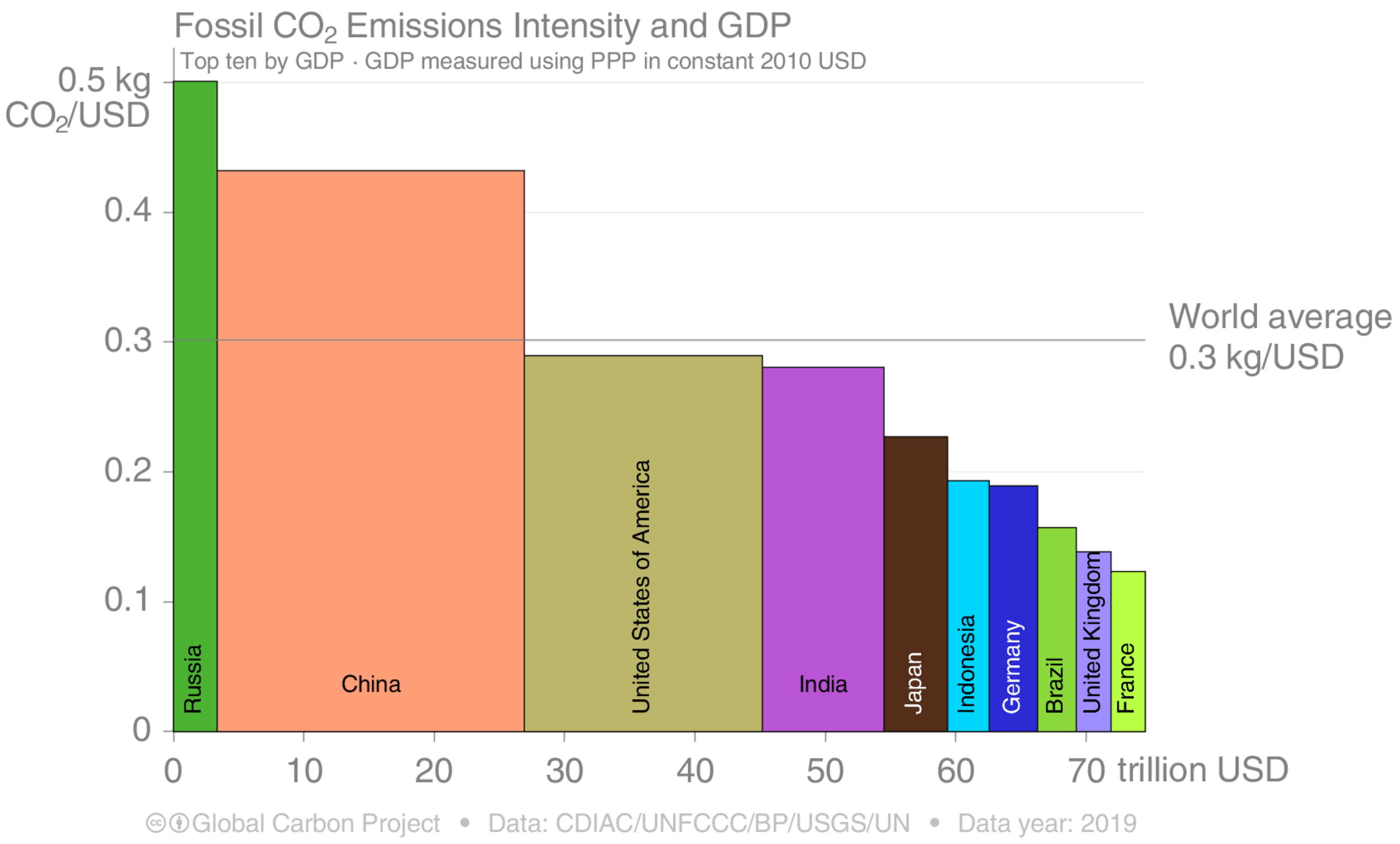
The Kaya decomposition illustrates that relative decoupling of economic growth from CO_2 emissions is driven by improved energy intensity (Energy/GDP)



GDP: Gross Domestic Product (economic activity)
Energy is Primary Energy from BP statistics using the substitution accounting method
Source: Jackson et al 2019; Global Carbon Budget 2020

Fossil CO_2 emission intensity

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

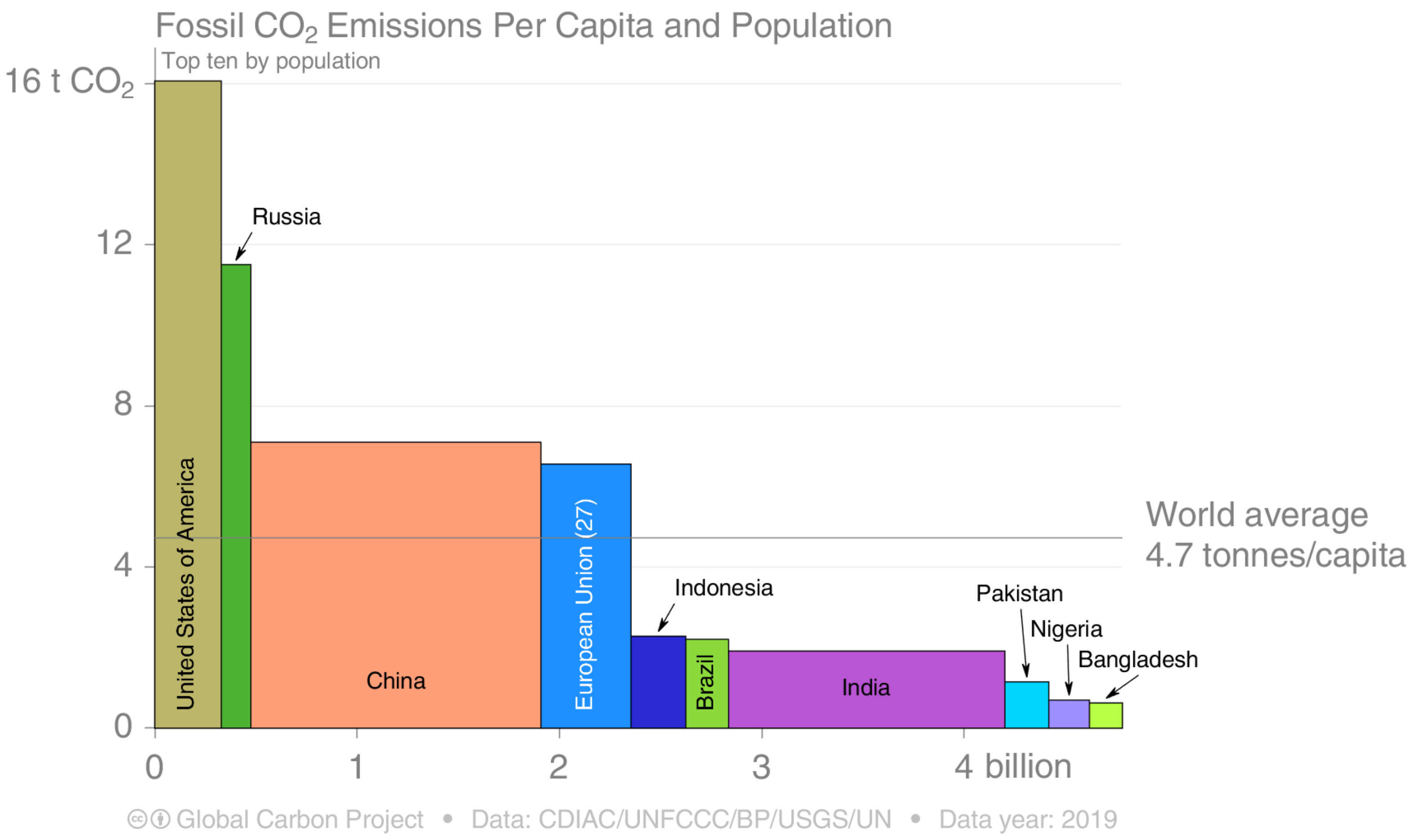


Emission intensity: Fossil CO_2 emissions divided by Gross Domestic Product (GDP)

Source: Global Carbon Budget 2020

Fossil CO_2 Emissions per capita

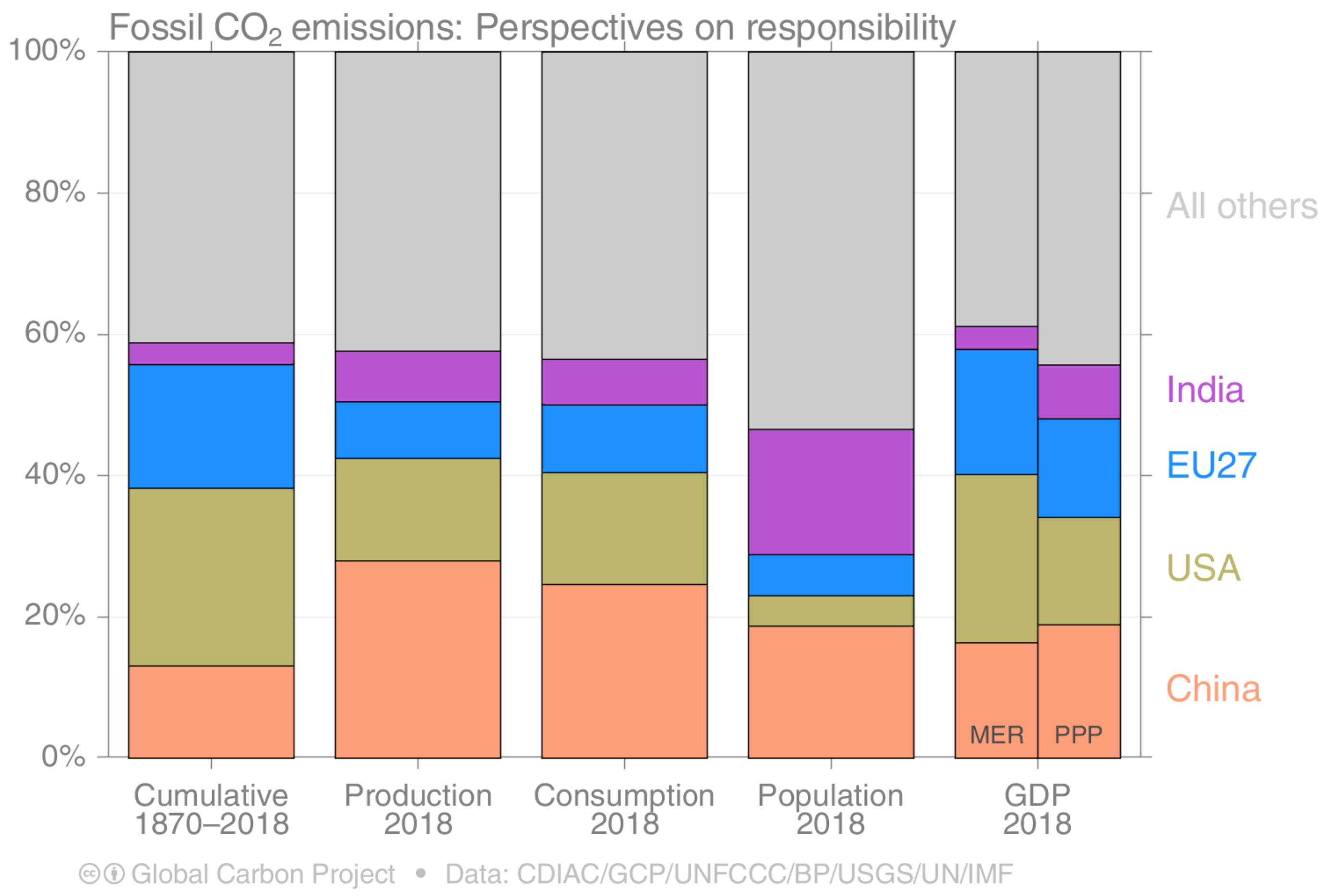
The 10 most populous countries span a wide range of development and emissions per capita



Emission per capita: Fossil CO_2 emissions divided by population
Source: Global Carbon Budget 2020

Alternative rankings of countries

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

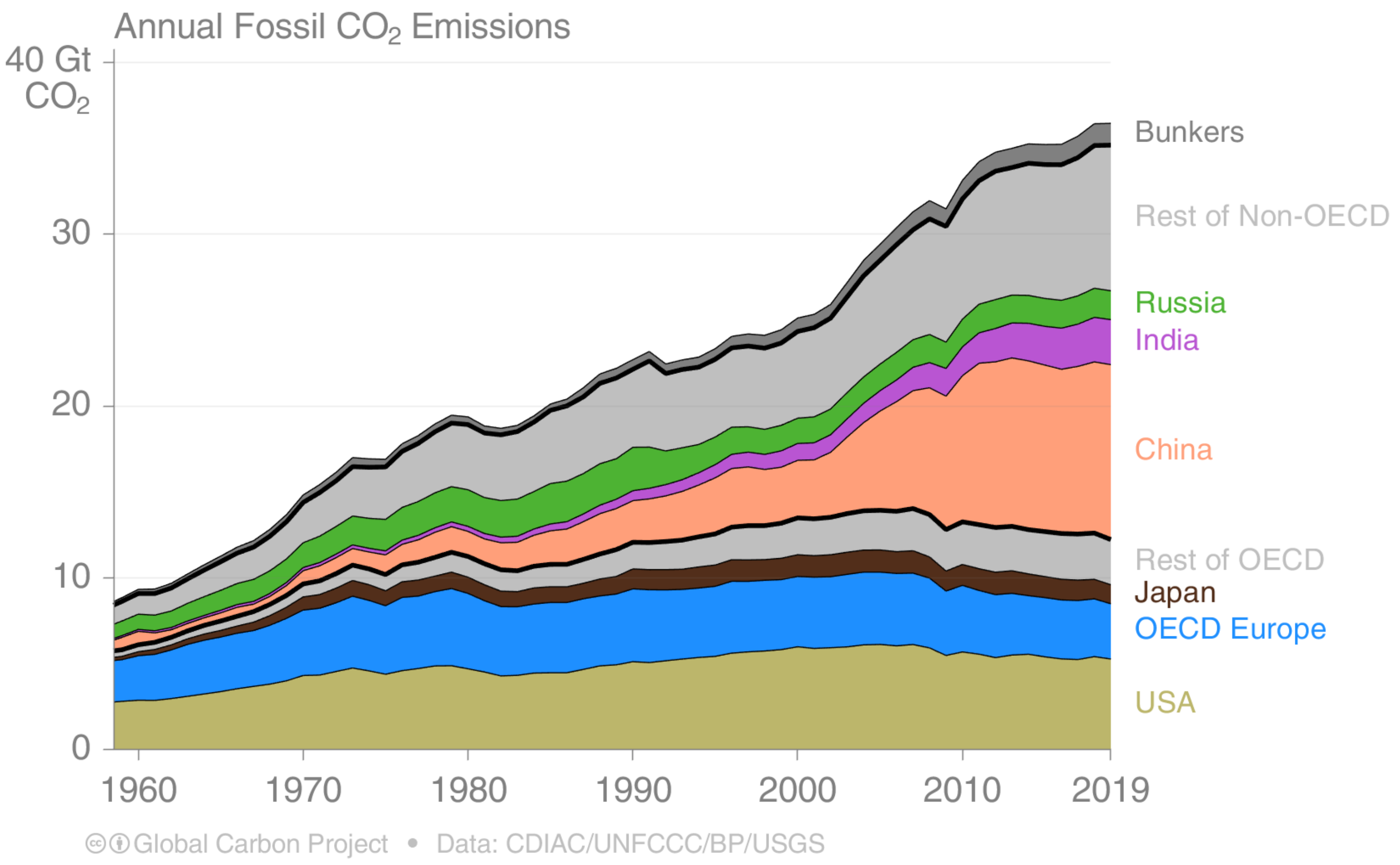


GDP: Gross Domestic Product in Market Exchange Rates (MER) and Purchasing Power Parity (PPP)
Source: CDIAC; United Nations; Friedlingstein et al 2020; Global Carbon Budget 2020

Breakdown of global fossil CO_2 emissions by country

Emissions in OECD countries have increased by 1% since 1990, despite declining 13% from their maximum in 2007

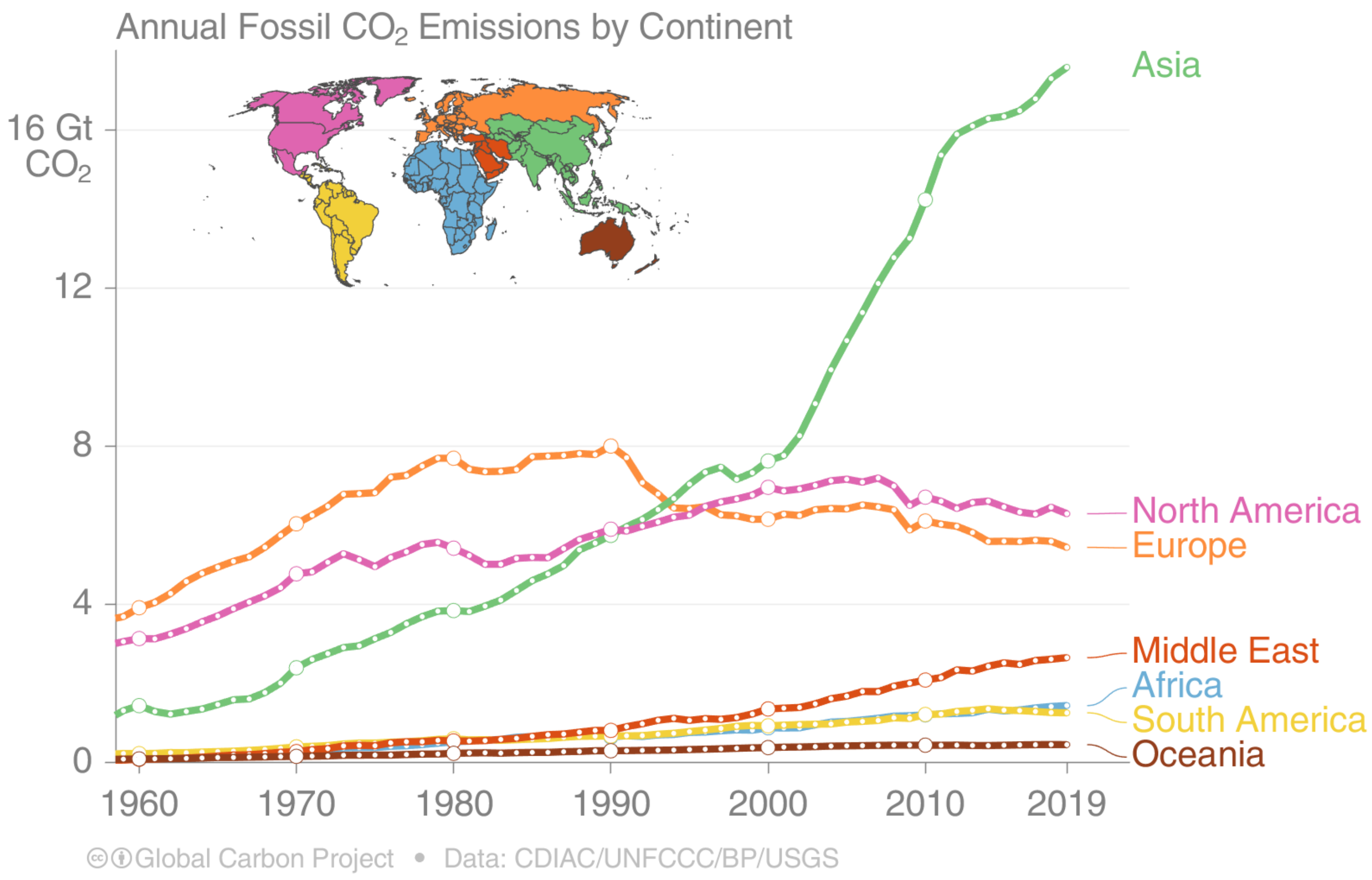
Emissions in non-OECD countries have more than doubled since 1990



Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

Fossil CO_2 emissions by continent

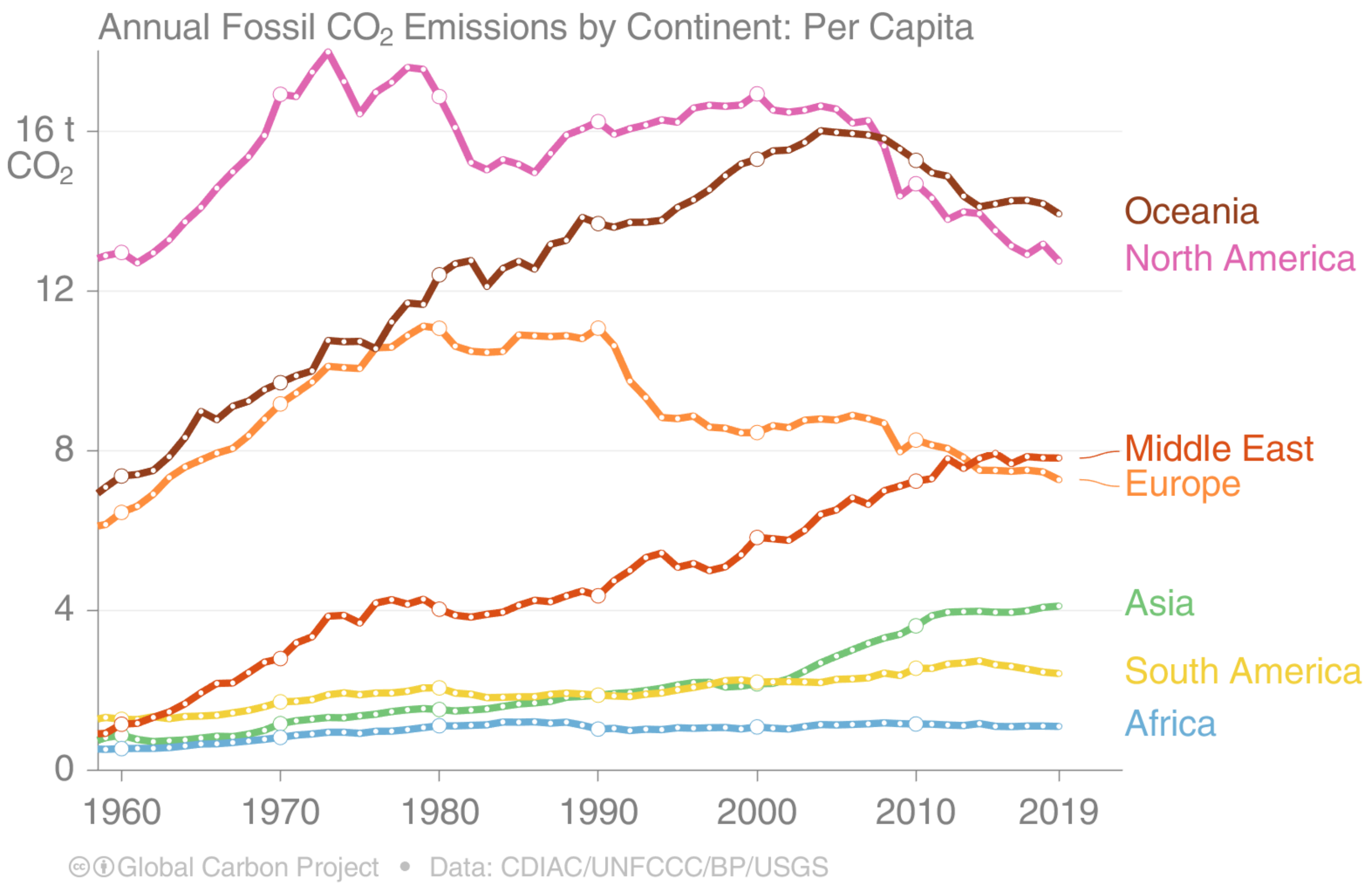
Asia dominates global fossil CO_2 emissions, while emissions in North America are of similar size to those in Europe, and the Middle East is growing rapidly.



Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

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.



The global average was 4.8 tonnes per capita in 2018.

Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

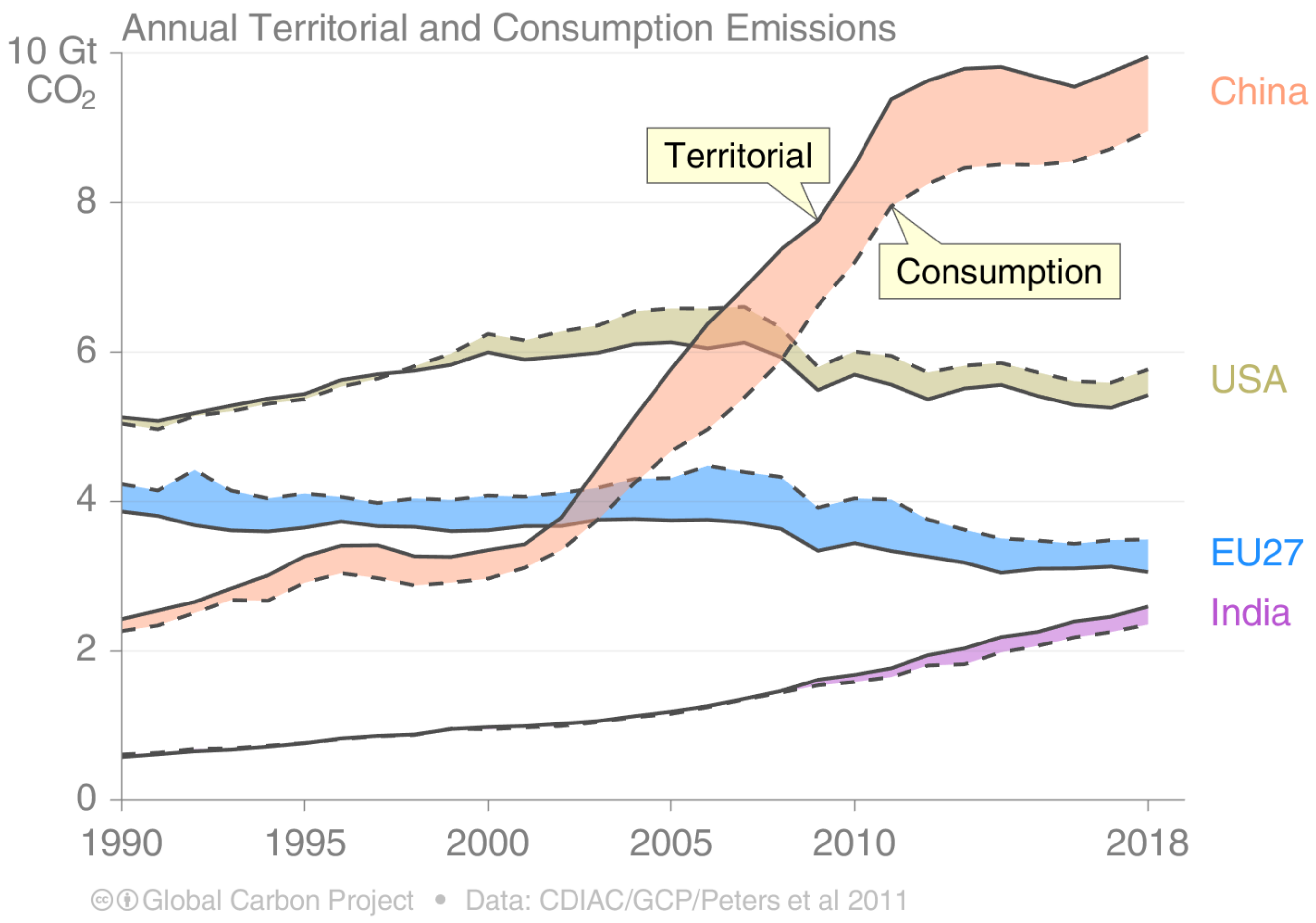
Additional Figures
Consumption-based Emissions

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.

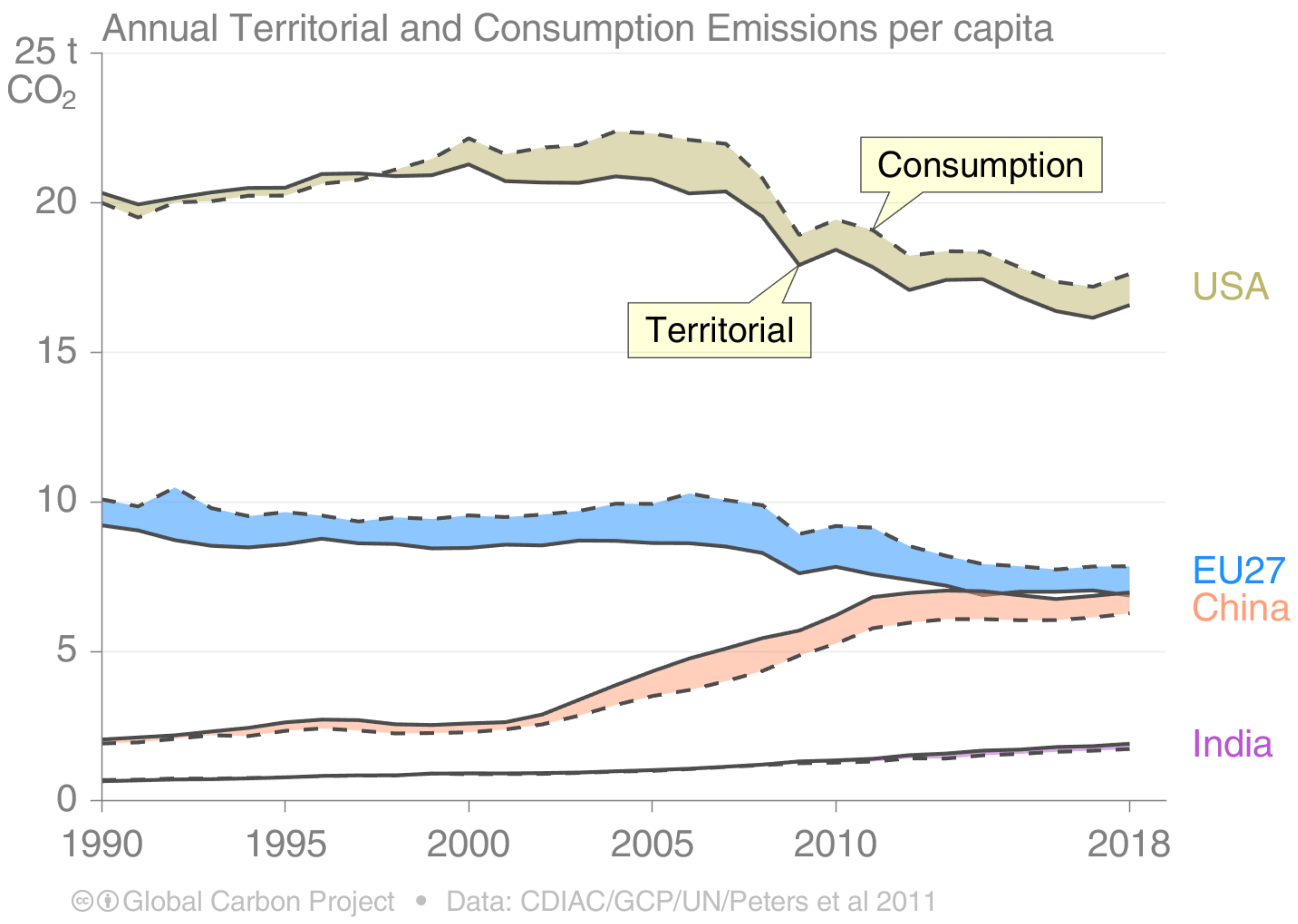


Consumption-based emissions are calculated by adjusting the standard production-based emissions to account for international trade

Source: [Peters et al 2011](); [Friedlingstein et al 2020](); [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.

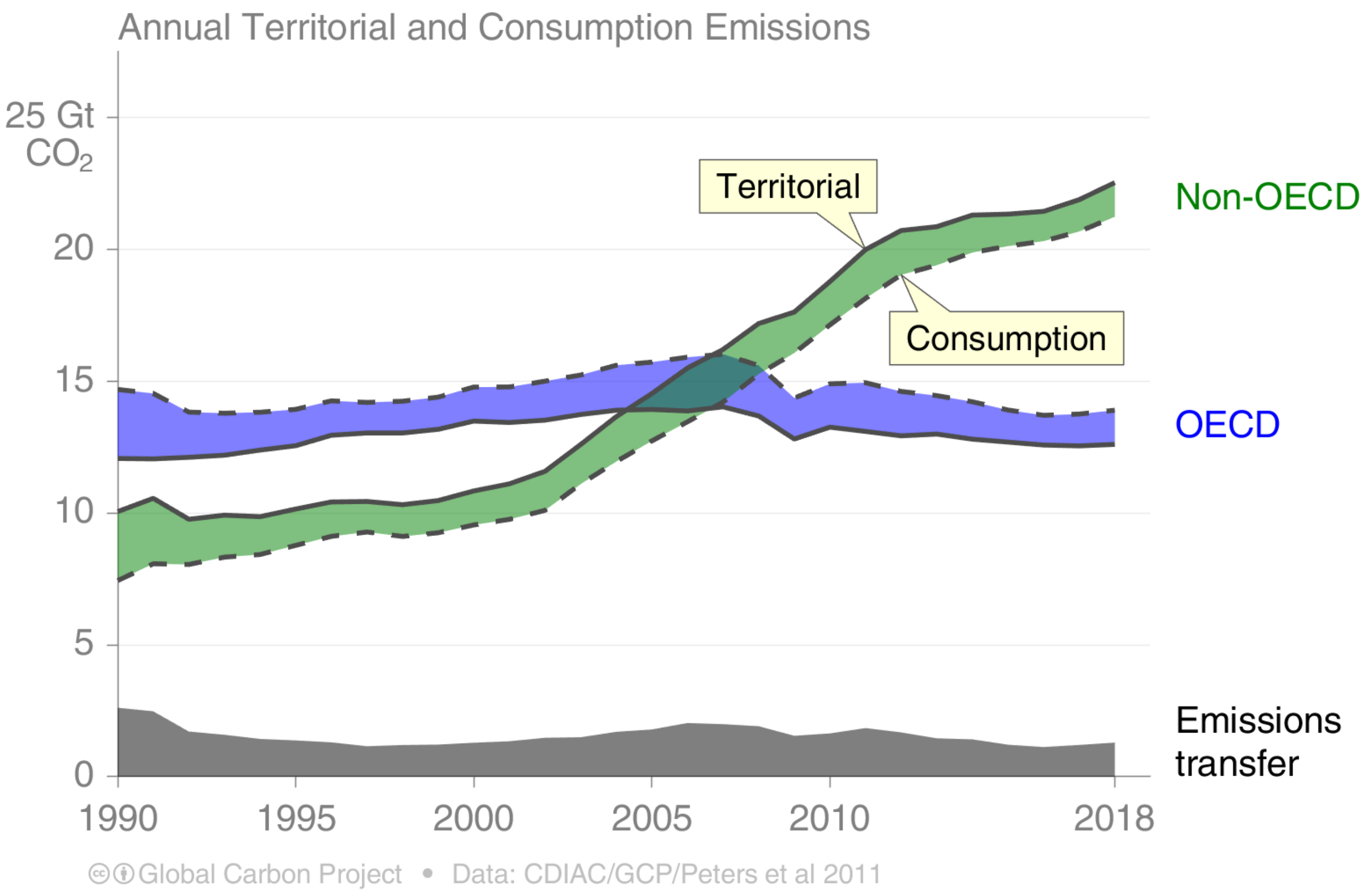


Consumption-based emissions are calculated by adjusting the standard production-based emissions to account for international trade

Source: Peters et al 2011; Friedlingstein et al 2020; Global Carbon Project 2019

Consumption-based emissions (carbon footprint)

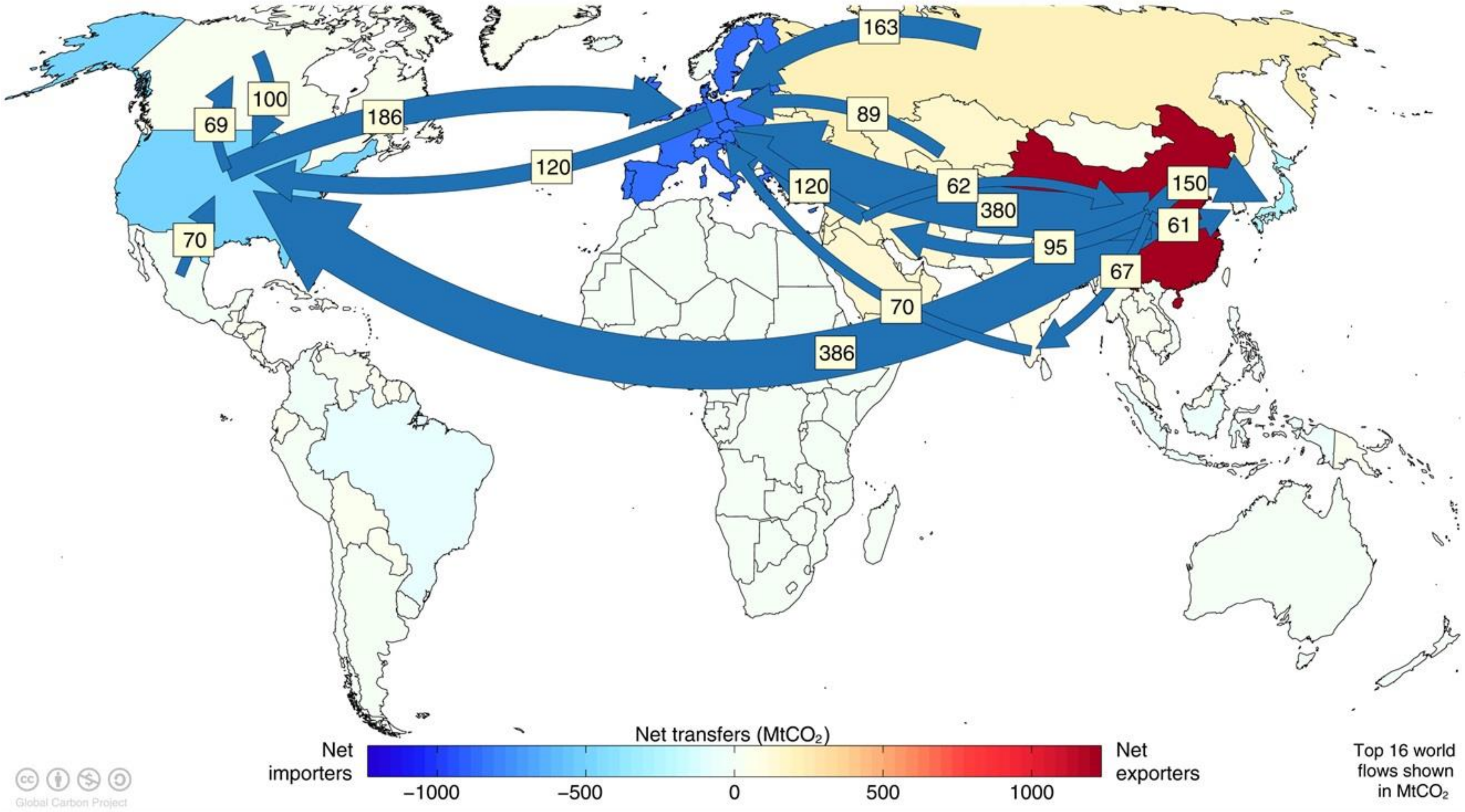
Transfers of emissions embodied in trade between OECD and non-OECD countries grew slowly during the 2000’s, but has since slowly declined.



Source: [CDIAC]; [Peters et al 2011]; [Friedlingstein et al 2020]; [Global Carbon Budget 2020]

Major flows from production to consumption

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

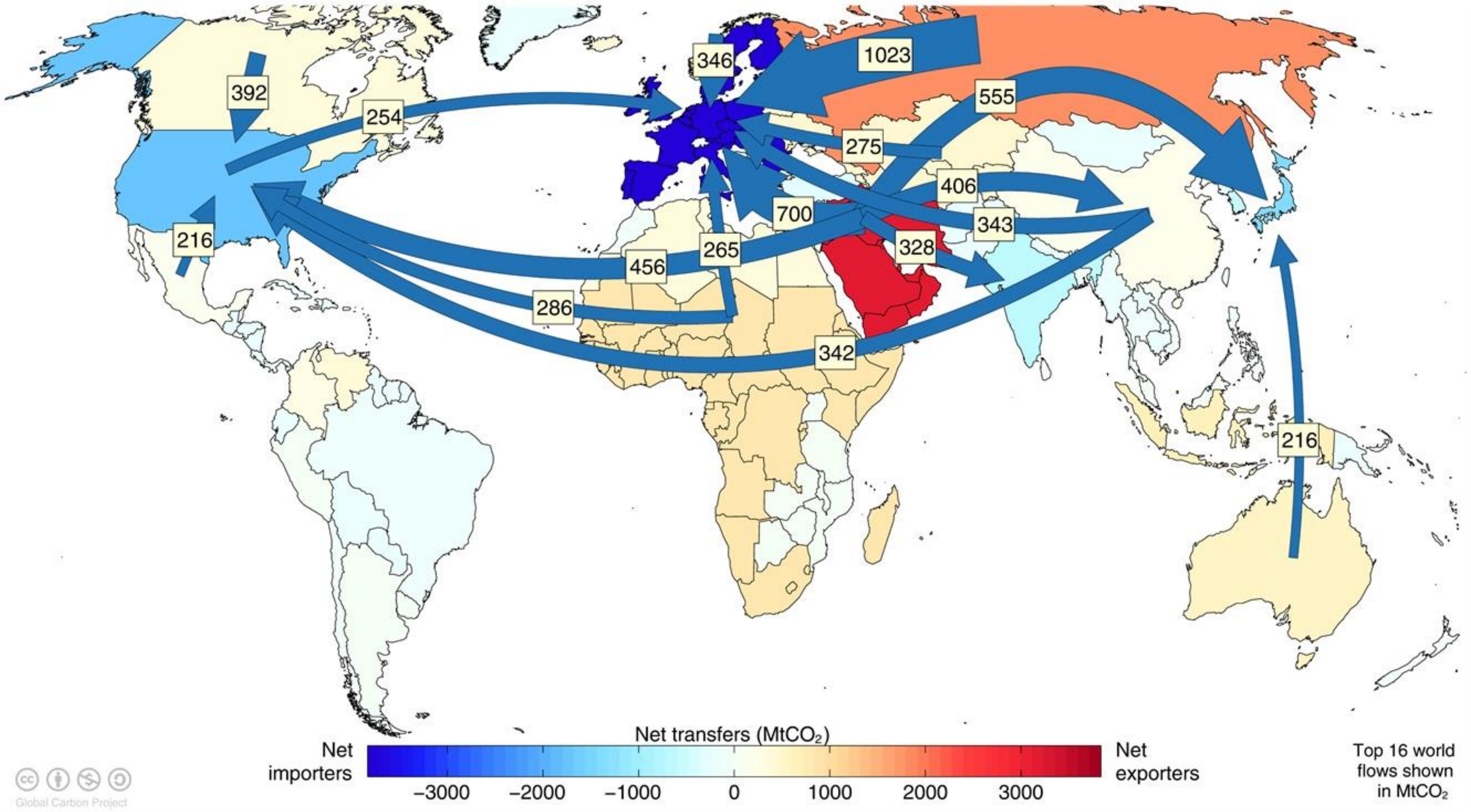


Values for 2011. EU is treated as one region. Units: $MtCO_2$
Source: Peters et al 2012

GLOBAL CARBON PROJECT

Major flows from extraction to consumption

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



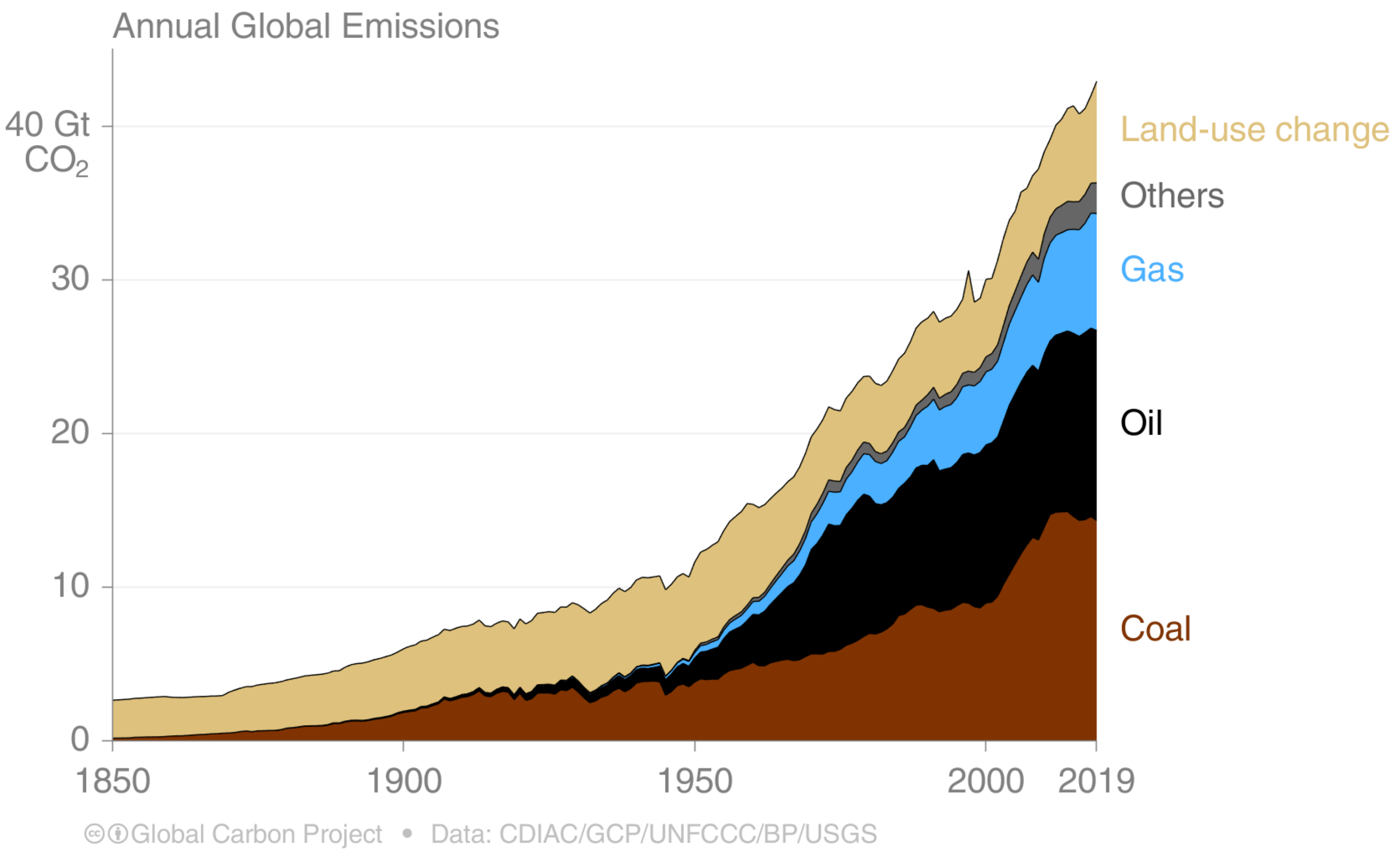
Values for 2011. EU is treated as one region. Units: $MtCO_2$

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.

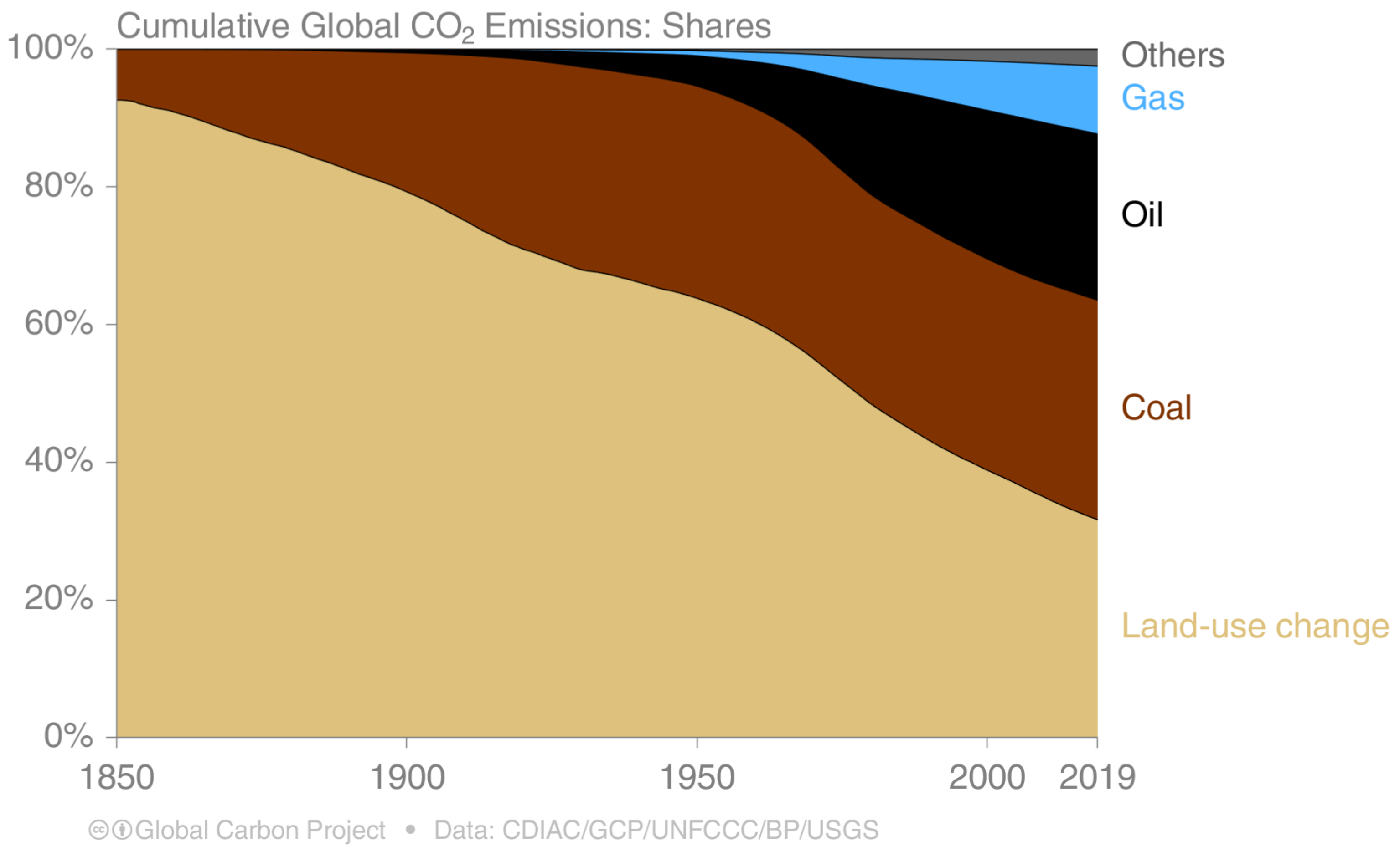


Others: Emissions from cement production and gas flaring

Source: CDIAC; Houghton and Nassikas 2017; Hansis et al 2015; Gasser et al 2020; Friedlingstein et al 2020; Global Carbon Budget 2020

Historical cumulative emissions by source

Land-use change represents about 32% of cumulative emissions over 1850–2019,
coal 32%, oil 24%, gas 10%, and others 2%

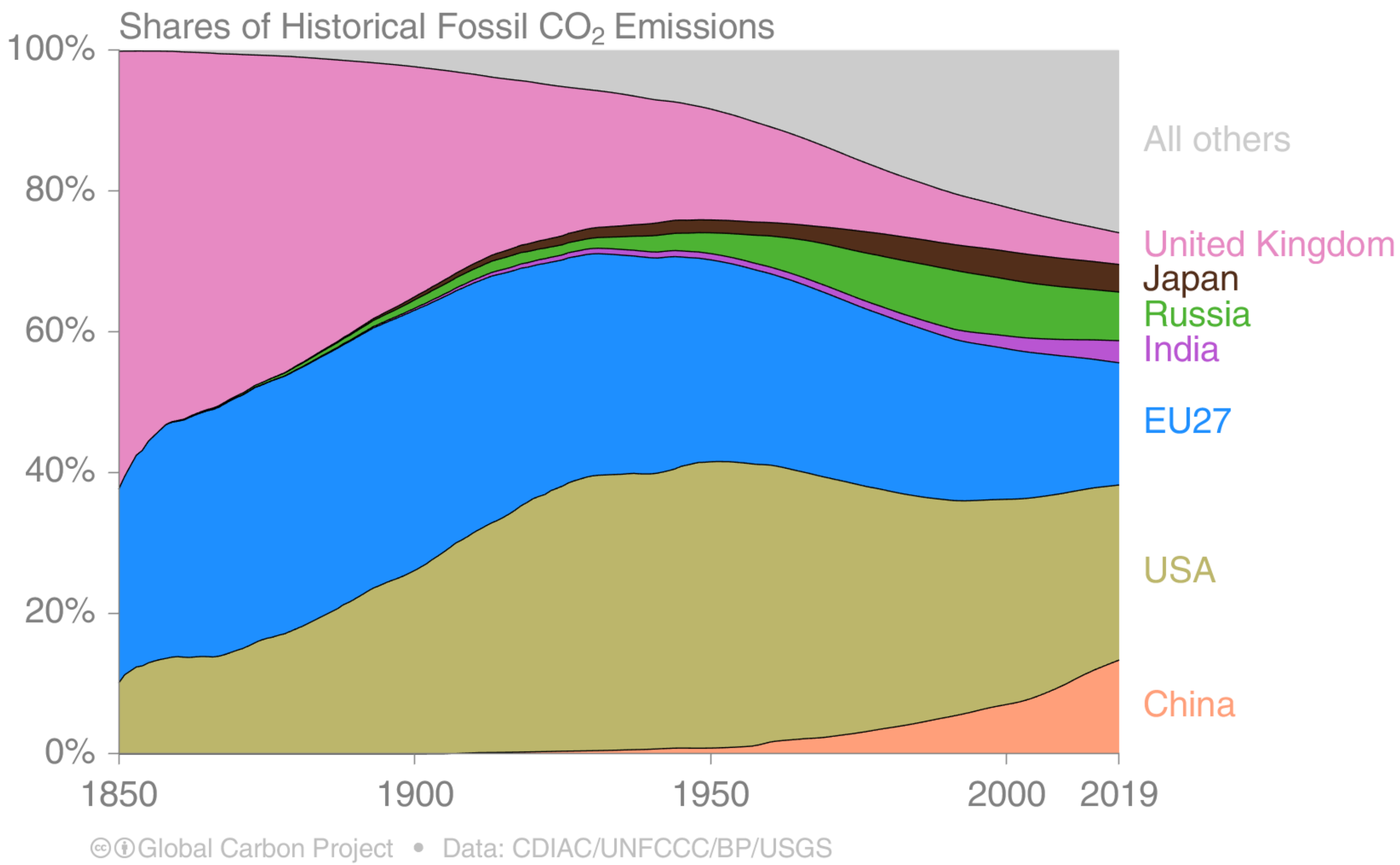


Others: Emissions from cement production and gas flaring

Source: CDIAC; Houghton and Nassikas 2017; Hansis et al 2015; Gasser et al 2020; Friedlingstein et al 2020; Global Carbon Budget 2020

Historical cumulative fossil CO_2 emissions by country

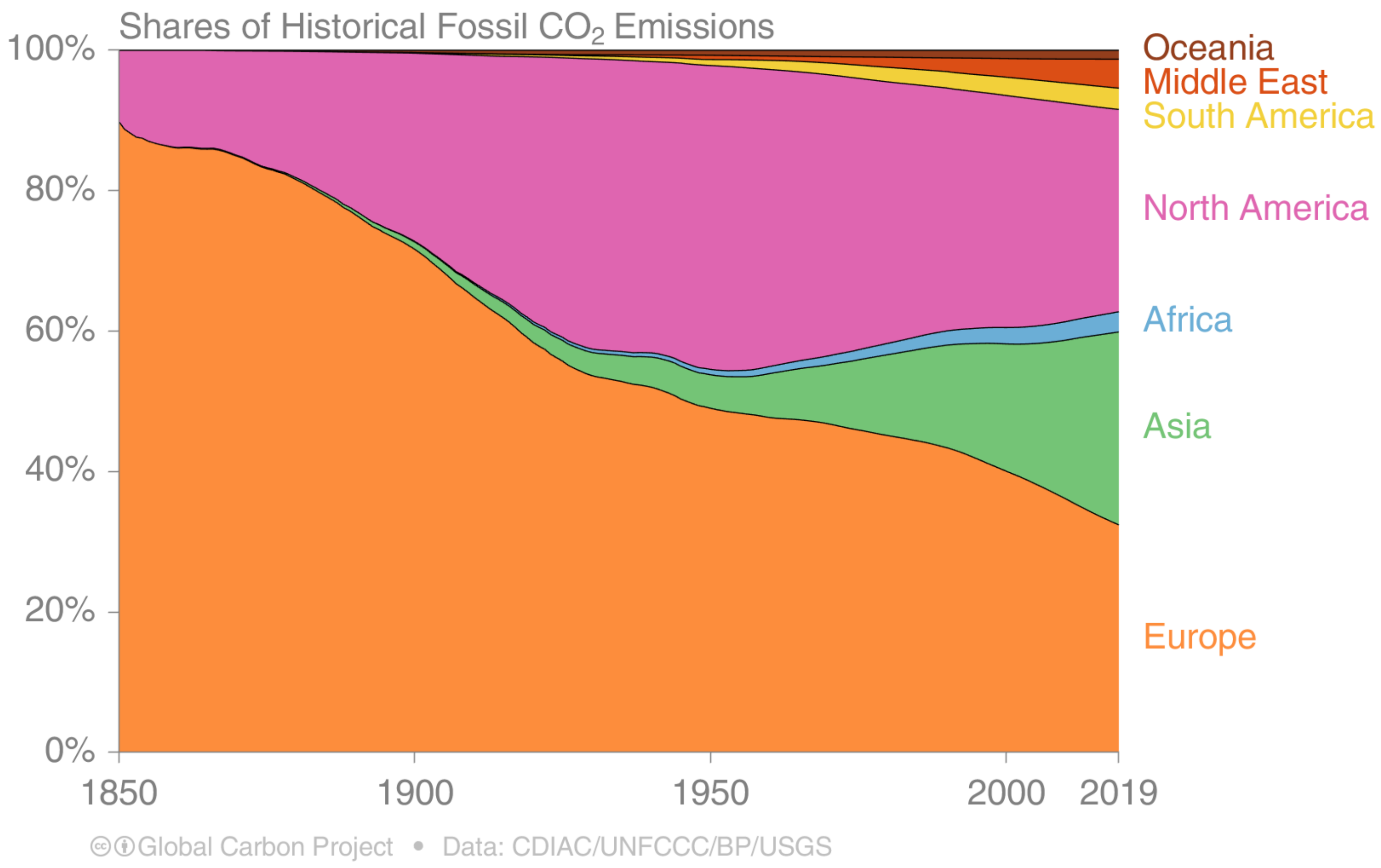
Cumulative fossil CO_2 emissions were distributed (1850–2019):
USA 25%, EU27 17%, China 13%, Russia 7%, UK 5%, Japan 4% and India 3%



Cumulative emissions (1990–2019) were distributed China 21%, USA 19%, EU27 12%, Russia 6%, India 5%, Japan 4%, UK 2%
'All others' includes all other countries along with international bunker fuels
Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020

Historical cumulative emissions by continent

Cumulative fossil CO_2 emissions (1850–2019). North America and Europe have contributed the most cumulative emissions, but Asia is growing fast



The figure excludes bunker fuels

Source: CDIAC; Friedlingstein et al 2020; Global Carbon Budget 2020