Global Carbon Budget

2019

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GLOBAL CARBON PROJECT

Acknowledgements

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Atmospheric CO_2 datasets
NOAA/ESRL (Dlugokencky and Tans 2019)
Scripps (Keeling et al. 1976)

Fossil Fuels and Industry
CDIAC (Gilfillan et al. 2019)
Andrew, 2019
UNFCCC, 2019
BP, 2019

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

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

Atmospheric inversions
CarbonTracker Europe (van der Laan-Luijkx et al. 2017)
Jena CarboScope (Rödenbeck et al. 2003)
CAMS (Chevallier et al. 2005)

Land models
CABLE-POP | CLASS-CTEM | CLM5.0 | DLEM | ISAM | ISBA-CTRIP | JSBACH | JULES-ES | LPJ-GUESS | LPJ | LPX-Bern | OCN | ORCHIDEE-Trunk | ORCHIDEE-CNP | SDGVM | VISIT
CRU (Harris et al. 2014) JRA-55

Ocean models
CESM-ETHZ | CSIRO | MICOM-HAMOCC (NorESM-OC) | MITgem-REcoM2 | 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

Full references provided in Friedlingstein et al 2019

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Publications

Global Carbon Budget 2019

Earth System Science Data (Open Access)

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comment

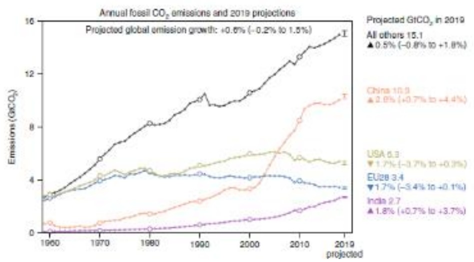
Carbon dioxide emissions continue to grow amidst slowly emerging climate policies

A failure to recognize the factors behind continued emissions growth could limit the world's ability to shift to a pathway consistent with 1.5 °C or 2 °C of global warming. Continued support for low-carbon technologies needs to be combined with policies directed at phasing out the use of fossil fuels.

G. P. Peters, R. M. Andrew, J. G. Canadell, P. Friedlingstein, R. B. Jackson, J. I. Korsbakken, C. Le Quéré and A. Peregon

Global fossil CO_2 emissions grew at 0.9% per year in the 1990s and accelerated to 3.0% per year in the 2000s, but have returned to a slower growth rate of 0.9% per year since 2010, with a more pronounced slowdown from 2014 to 2016. Despite modest declines in emissions in the United States and the European Union (EU) over the past decade, the growth in emissions in China, India and most developing countries has dominated global emission trends over the past 20 years. The Global Carbon Budget projection[1] suggests that global fossil CO_2 emissions will grow by 0.6% (range -0.2% to 1.5%) in 2019, with emissions projected to decline in the United States and the EU28, but projected to increase in China, India and the rest of the world (Fig. 1a).

a



https://doi.org/10.1038/s41558-019-0659-6

PERSPECTIVE

OPEN ACCESS

Persistent fossil fuel growth threatens the Paris Agreement and planetary health

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Keywords: CO_2 emissions, coal, oil and natural gas, fossil fuels, climate change, global warming, energy

Abstract

Amidst declarations of planetary emergency and reports that the window for limiting climate change to 1.5 °C is rapidly closing, global average temperatures and fossil fuel emissions continue to rise. Global fossil CO_2 emissions have grown three years consecutively: +1.5% in 2017, +2.1% in 2018, and our slower central projection of +0.6% in 2019 (range of -0.32% to 1.5%) to 37 ± 2 GtCO_2 (Friedlingstein *et al* 2019 *Earth Syst. Sci. Data* accepted), after a temporary growth hiatus from 2014 to 2016. Economic indicators and trends in global natural gas and oil use suggest a further rise in emissions in 2020 is likely. CO_2 emissions are decreasing slowly in many industrialized regions, including the European Union (preliminary estimate of −1.7% [−3.4% to +0.1%] for 2019, −0.8%/yr for 2003–2018) and United States (−1.7% [−3.7% to +0.3%] in 2019, −0.8%/yr for 2003–2018), while emissions continue growing in India (+1.8% [+0.7% to 3.7%] in 2019, +5.1%/yr for 2003–2018), China (+2.6% [+0.7% to 4.4%] in 2019, +0.4%/yr for 2003–2018), and rest of the world ((+0.5% [−0.8% to 1.8%] in 2019, +1.4%/yr for 2003–2018). Two under-appreciated trends suggest continued long-term growth in both oil and natural gas use is likely. Because per capita oil consumption in the US and Europe remains 5- to 20-fold higher than in China and India, increasing vehicle ownership and air travel in Asia are poised to increase global CO_2 emissions from oil over the next decade or more. Liquified natural gas exports from Australia and the United States are surging, lowering natural gas prices in Asia and increasing global access to this fossil resource. To counterbalance increasing emissions, we need accelerated energy efficiency improvements and reduced consumption, rapid deployment of electric vehicles, carbon capture and storage technologies, and a decarbonized electricity grid, with new renewable capacities replacing fossil fuels, not supplementing them. Stronger global commitments and carbon pricing would help implement such policies at scale and in time.

https://doi.org/10.1088/1748-9326/ab57b3

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Data Access and Additional Resources

Global Carbon Budget

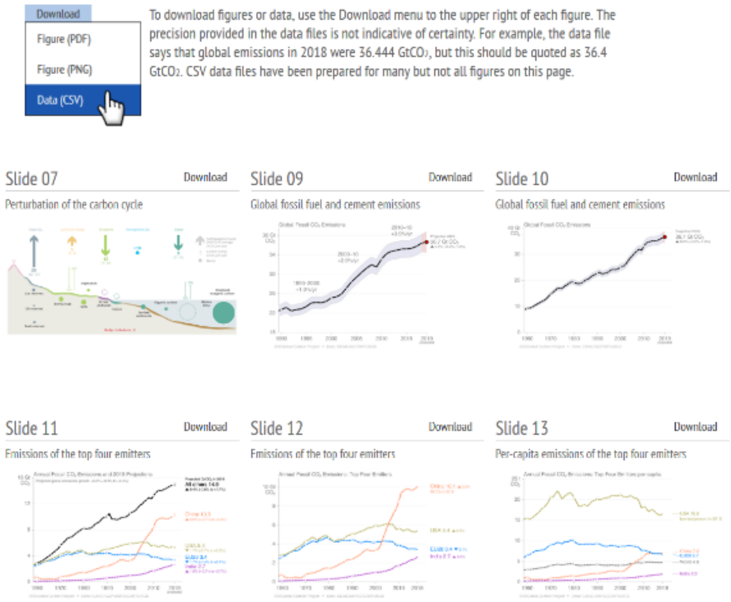
More information, data sources and data files:
http://www.globalcarbonproject.org/carbonbudget
Contact: Pep.Canadell@csiro.au

Global Carbon Atlas

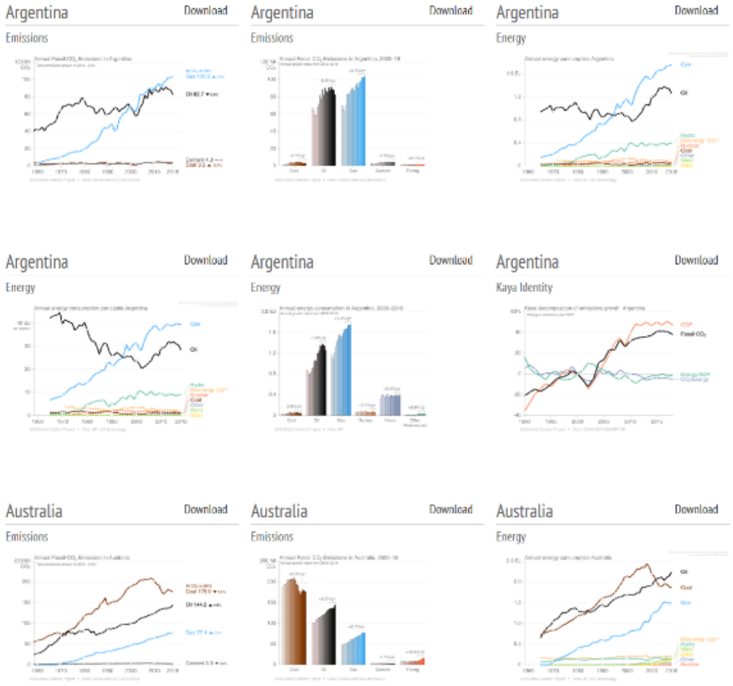
More information, data sources and data files:
www.globalcarbonatlas.org
(co-funded in part by BNP Paribas Foundation)
Contact: philippe.ciais@lsce.ipsl.fr

Download of figures and data

Global Carbon Budget



Additional country figures



Figures and data for most slides available from tinyurl.com/GCB19figs

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)

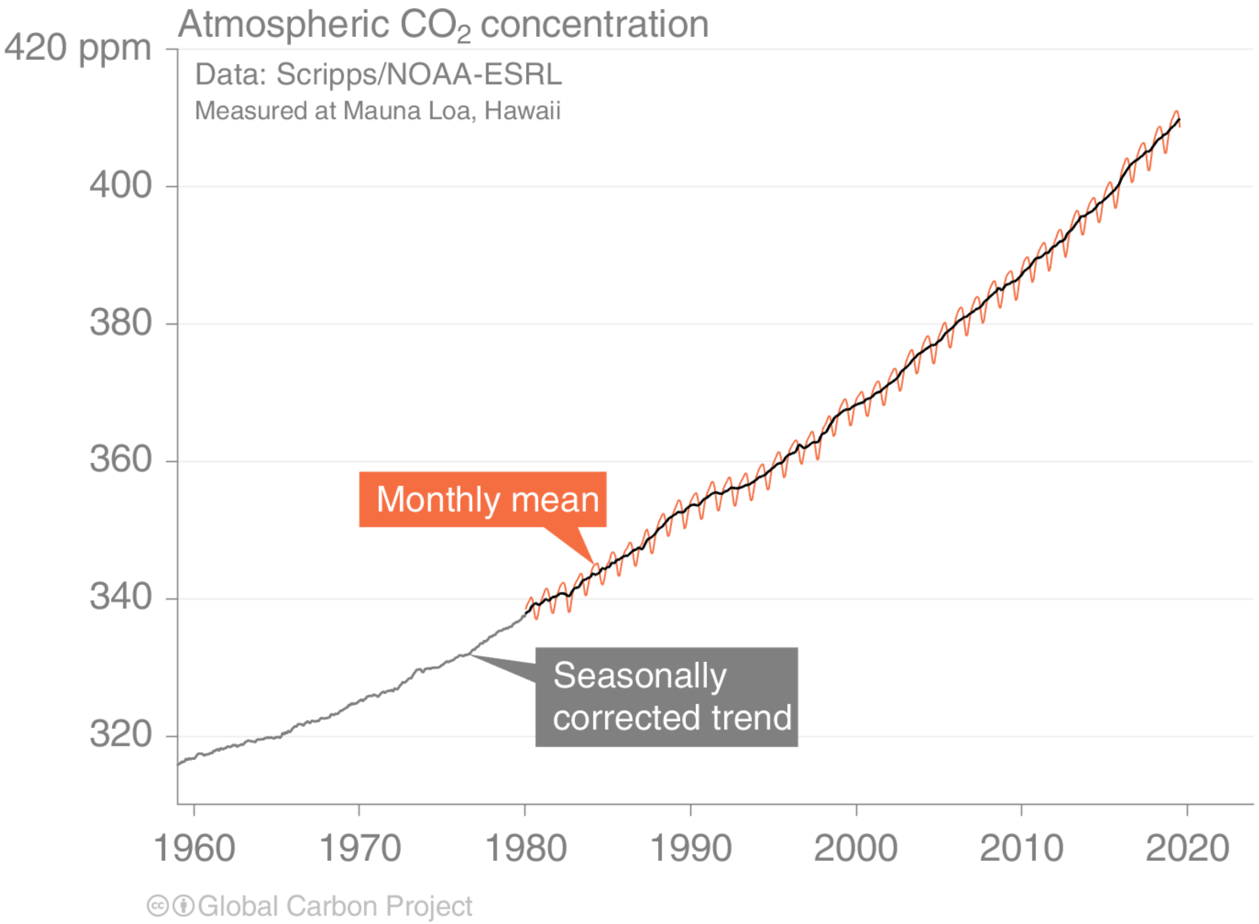
Most figures in this presentation are available for download as PNG files from tinyurl.com/GCB19figs along with the data required to produce them.

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.

Atmospheric concentration

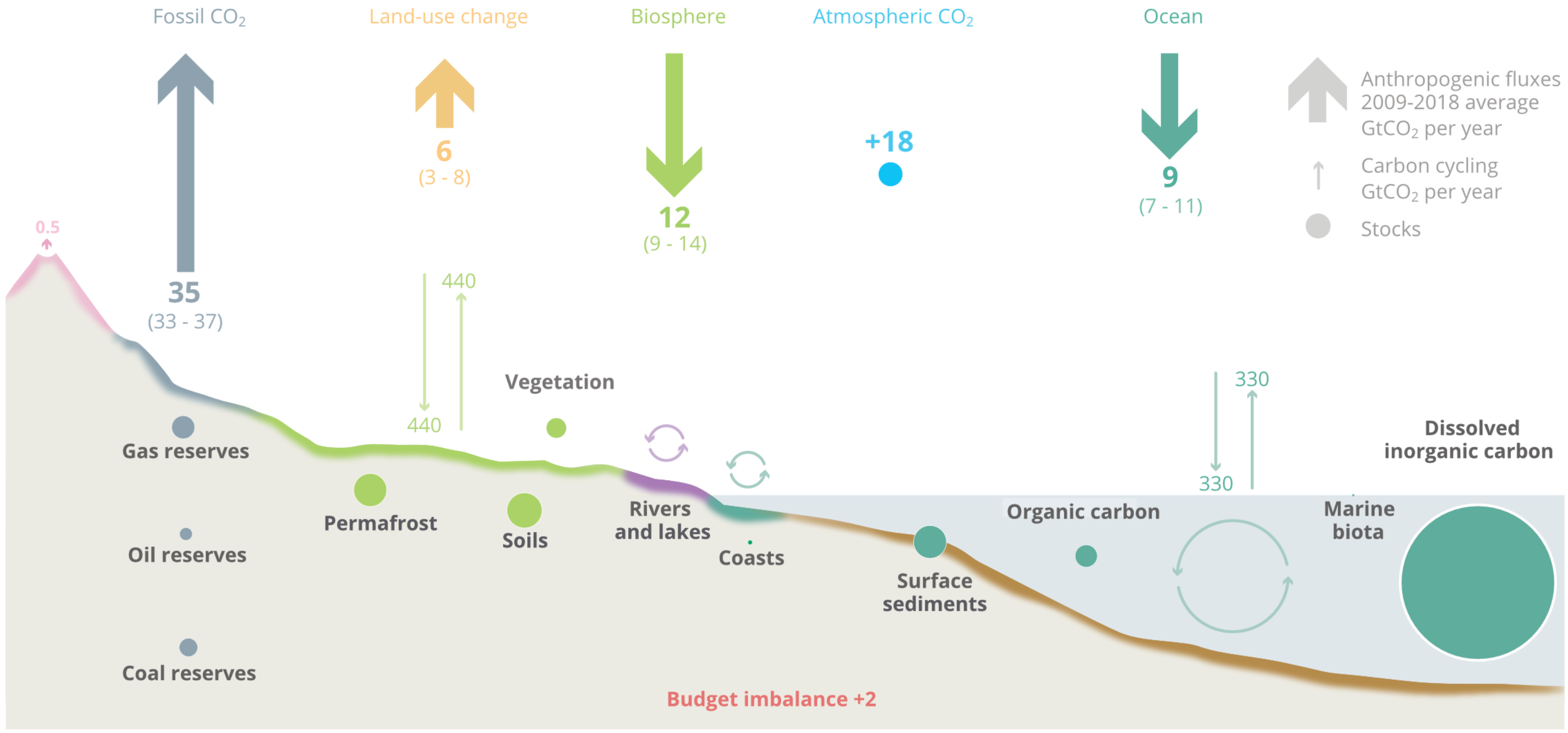
The global CO_2 concentration increased from ~277ppm in 1750 to 407ppm in 2018 (up 46%)
2016 was the first full year with concentration above 400ppm



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 2019; Global Carbon Budget 2019

Anthropogenic perturbation of the global carbon cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2009–2018 ($GtCO_2$/yr)



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

Source: CDIAC; NOAA-ESRL; Friedlingstein et al 2019; Ciais et al. 2013; Global Carbon Budget 2019

Fossil CO_2 Emissions

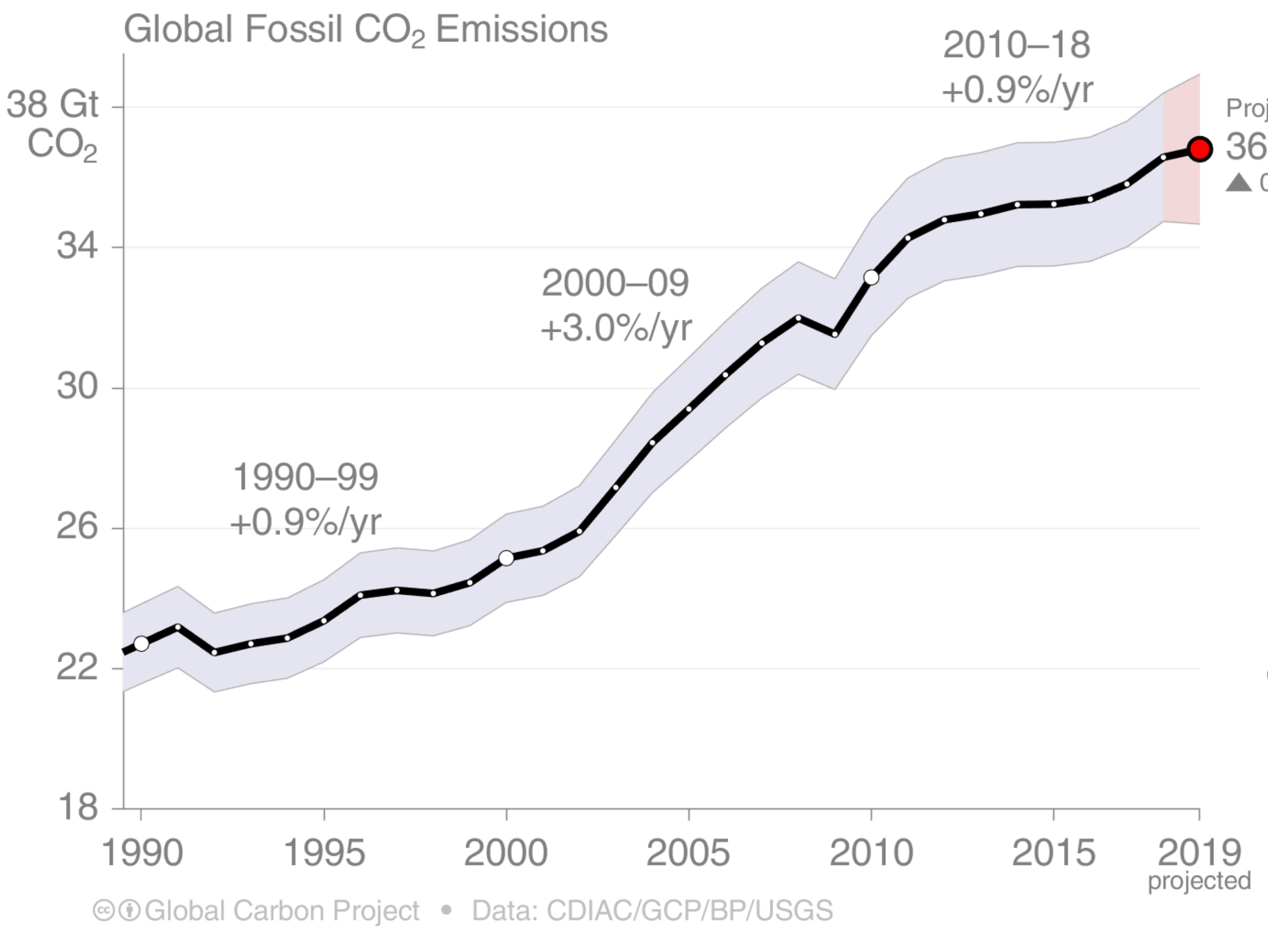
from fossil fuel use and industry

Global Fossil CO_2 Emissions

Global fossil CO_2 emissions: 36.6 ± 2 $GtCO_2$ in 2018, 61% over 1990

● Projection for 2019: 36.8 ± 2 $GtCO_2$, 0.6% higher than 2018 (range -0.2% to 1.5%)

Fossil CO_2 emissions will likely be more than 4% higher in 2019 than the year of the Paris Agreement in 2015



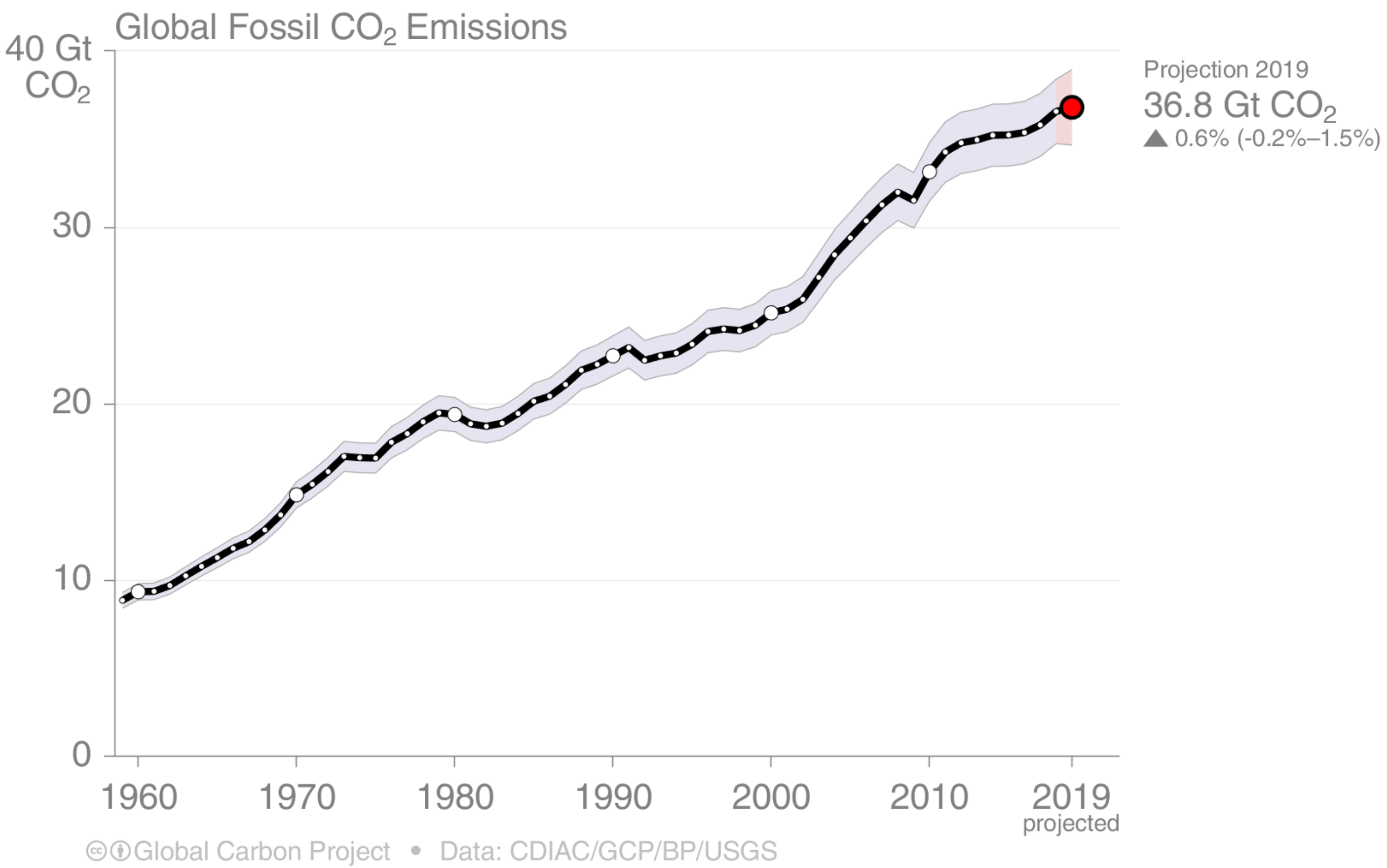
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

The 2019 projection is based on preliminary data and modelling.

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

Global Fossil CO_2 Emissions

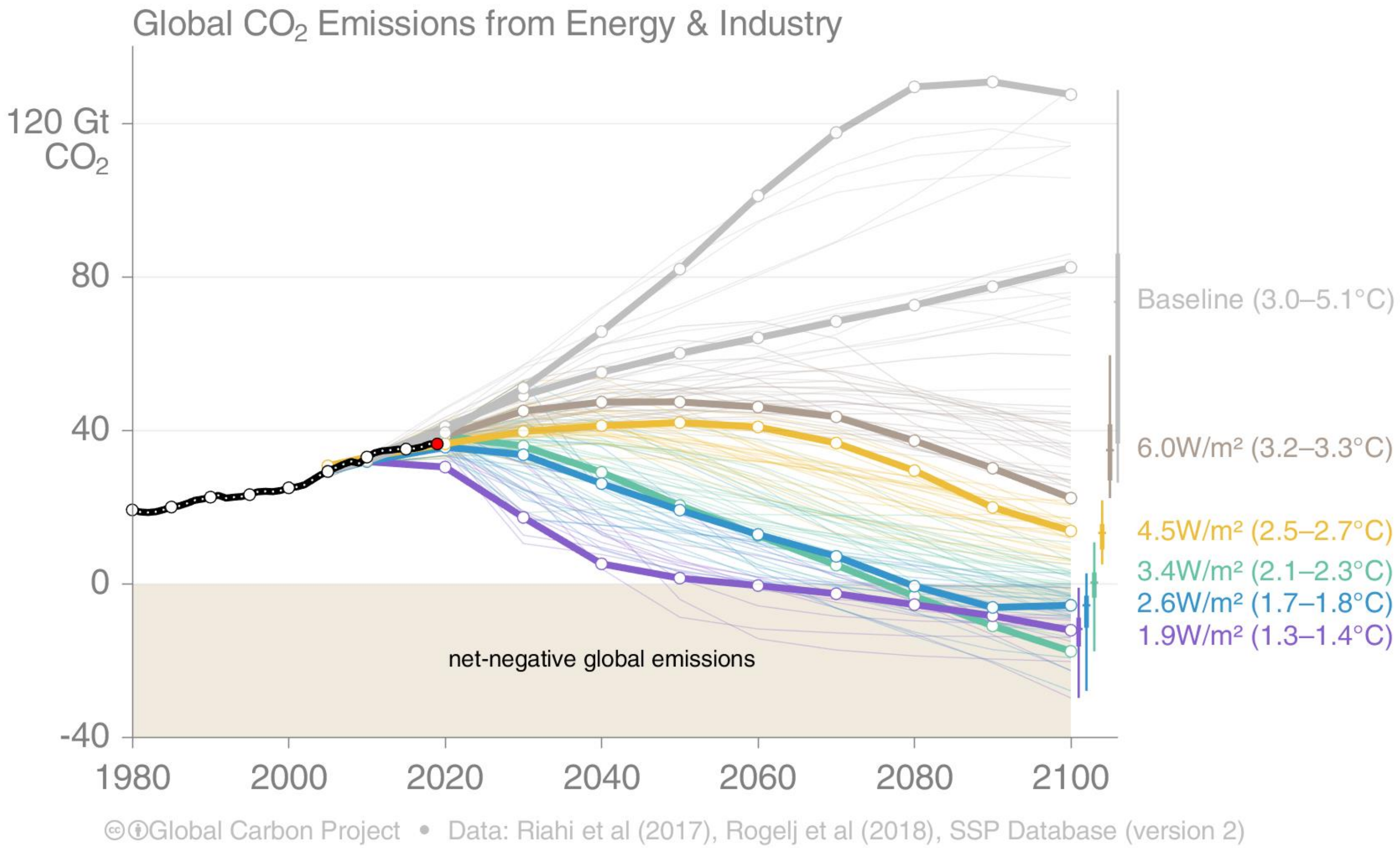
Global fossil CO_2 emissions have risen steadily over the last decades & show no sign of peaking
Fossil CO_2 emissions will likely be 62% higher in 2019 than the year of the 1st IPCC report in 1990



The 2019 projection is based on preliminary data and modelling.
Source: CDIAC; Friedlingstein et al 2019; Global Carbon Budget 2019

Shared Socioeconomic Pathways (SSPs)

The SSPs lead to a broad range in baselines (grey), with more aggressive mitigation leading to lower temperature outcomes. The bold lines are scenarios that will be analysed in CMIP6 and the results assessed in the IPCC AR6 process.

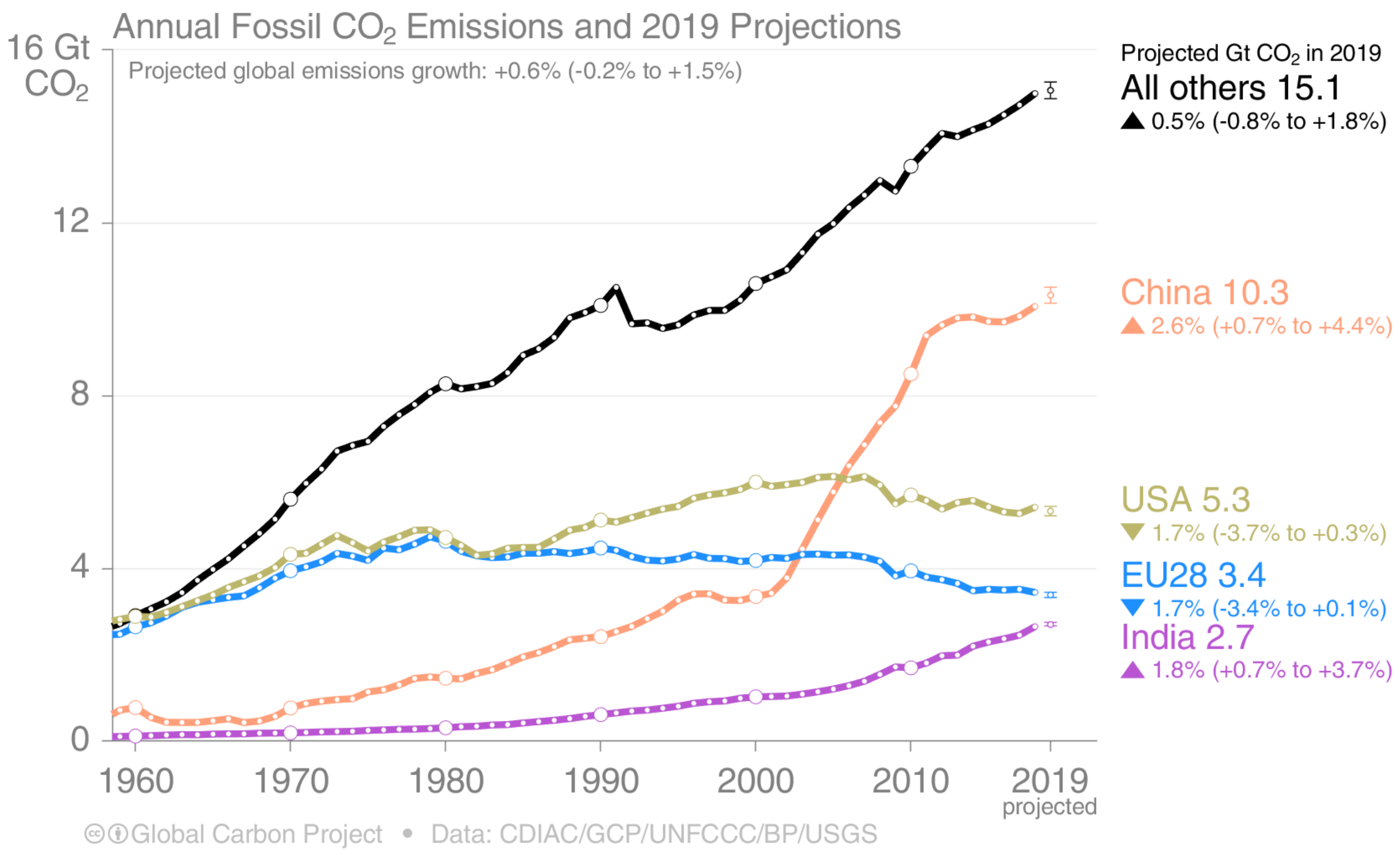


This set of quantified SSPs are based on the output of six Integrated Assessment Models (AIM/CGE, GCAM, IMAGE, MESSAGE, REMIND, WITCH). Net emissions include those from land-use change and bioenergy with CCS.

Source: Riahi et al. 2016; Rogelj et al. 2018; IIASA SSP Database; IAMC; Global Carbon Budget 2019

Emissions Projections for 2019

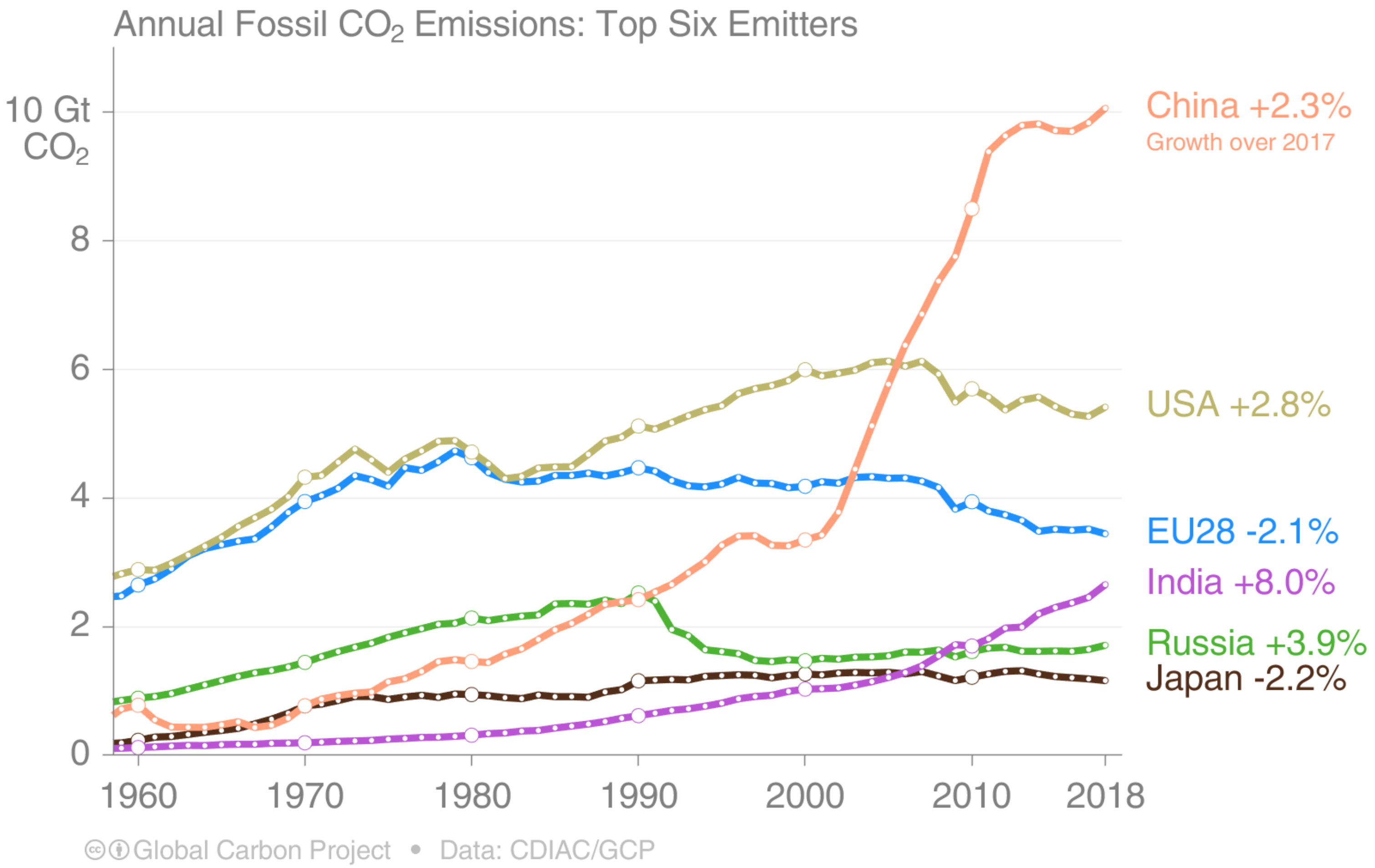
Global fossil CO_2 emissions are projected to rise by 0.6% in 2019 [range: -0.2% to +1.5%]
The global growth is driven by the underlying changes at the country level.



Source: CDIAC; Peters et al 2019; Friedlingstein et al 2019; Global Carbon Budget 2019

Top emitters: Fossil CO_2 Emissions

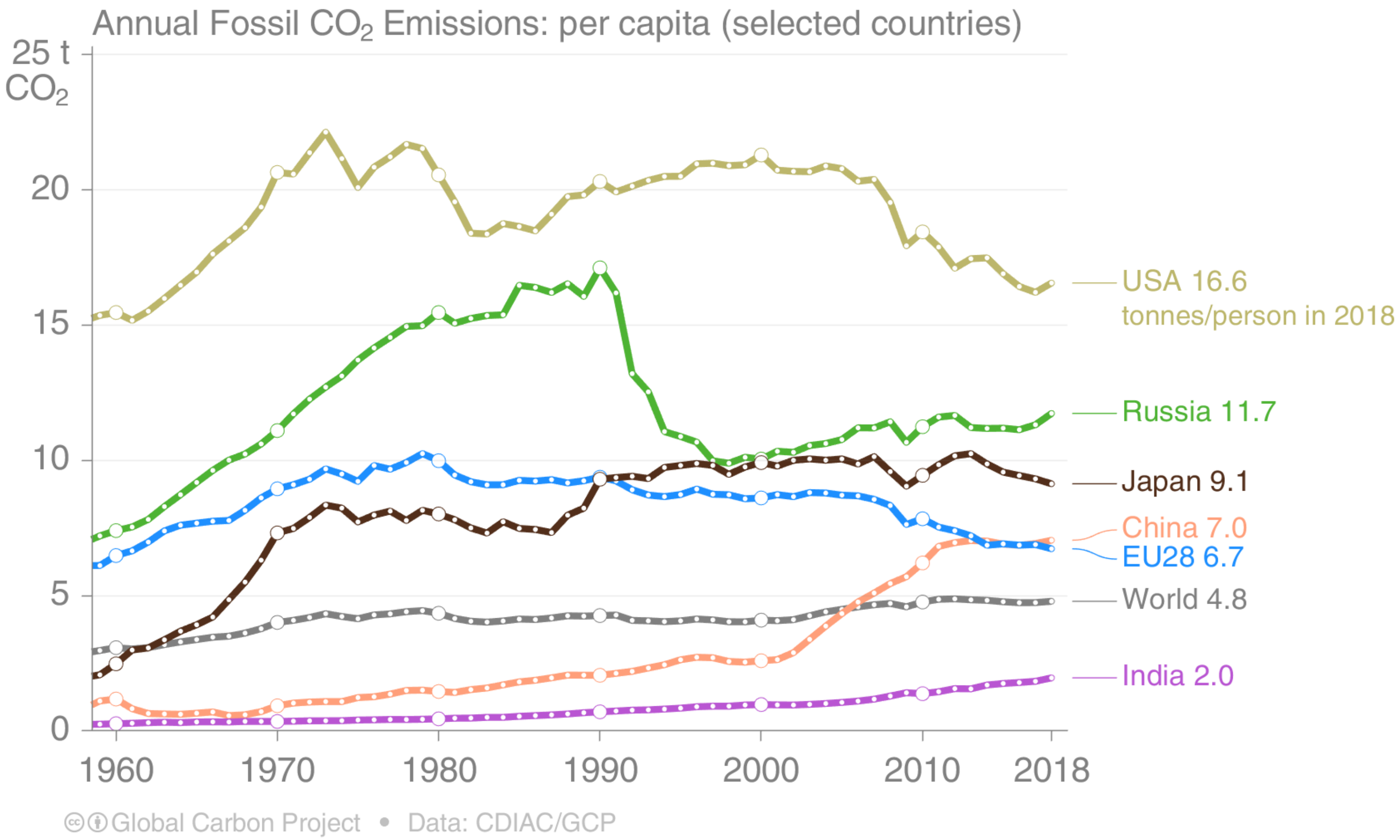
The top six emitters in 2018 covered 67% of global emissions
China 28%, United States 15%, EU28 9%, India 7%, Russia 5%, and Japan 3%



Bunker fuels, used for international transport, are 3.4% of global emissions.
Source: CDIAC; Peters et al 2019; Friedlingstein et al 2019; Global Carbon Budget 2019

Top emitters: Fossil CO_2 Emissions per capita

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



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

GLOBAL CARBON PROJECT

Key statistics

Region/Country	Emissions 2018				
	Per capita	Total		Growth 2017–18	
	tCO_2 per person	$GtCO_2$	%	$GtCO_2$	%
Global (with bunkers)	4.8	36.57	100	0.762	2.1
OECD Countries					
OECD	9.8	12.69	34.7	0.056	0.4
USA	16.6	5.42	14.8	0.146	2.8
OECD Europe	6.9	3.37	9.2	-0.070	-2.0
Japan	9.1	1.16	3.2	-0.026	-2.2
South Korea	12.9	0.66	1.8	0.018	2.8
Canada	15.3	0.57	1.6	-0.003	-0.5
Non-OECD Countries					
Non-OECD	3.6	22.65	61.9	0.692	3.2
China	7.0	10.06	27.5	0.226	2.3
India	2.0	2.65	7.3	0.197	8.0
Russia	11.7	1.71	4.7	0.064	3.9
Iran	8.8	0.72	2.0	0.034	5.0
Saudi Arabia	18.4	0.62	1.7	-0.012	-1.9
International Bunkers					
Bunkers	-	1.24	3.4	0.014	1.2

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

Fossil CO_2 emissions growth: 2017–2019

Emissions in the China, India, and USA increased most in 2018.
In 2019 China continues to grow but India's growth slows, while USA's emissions are down.

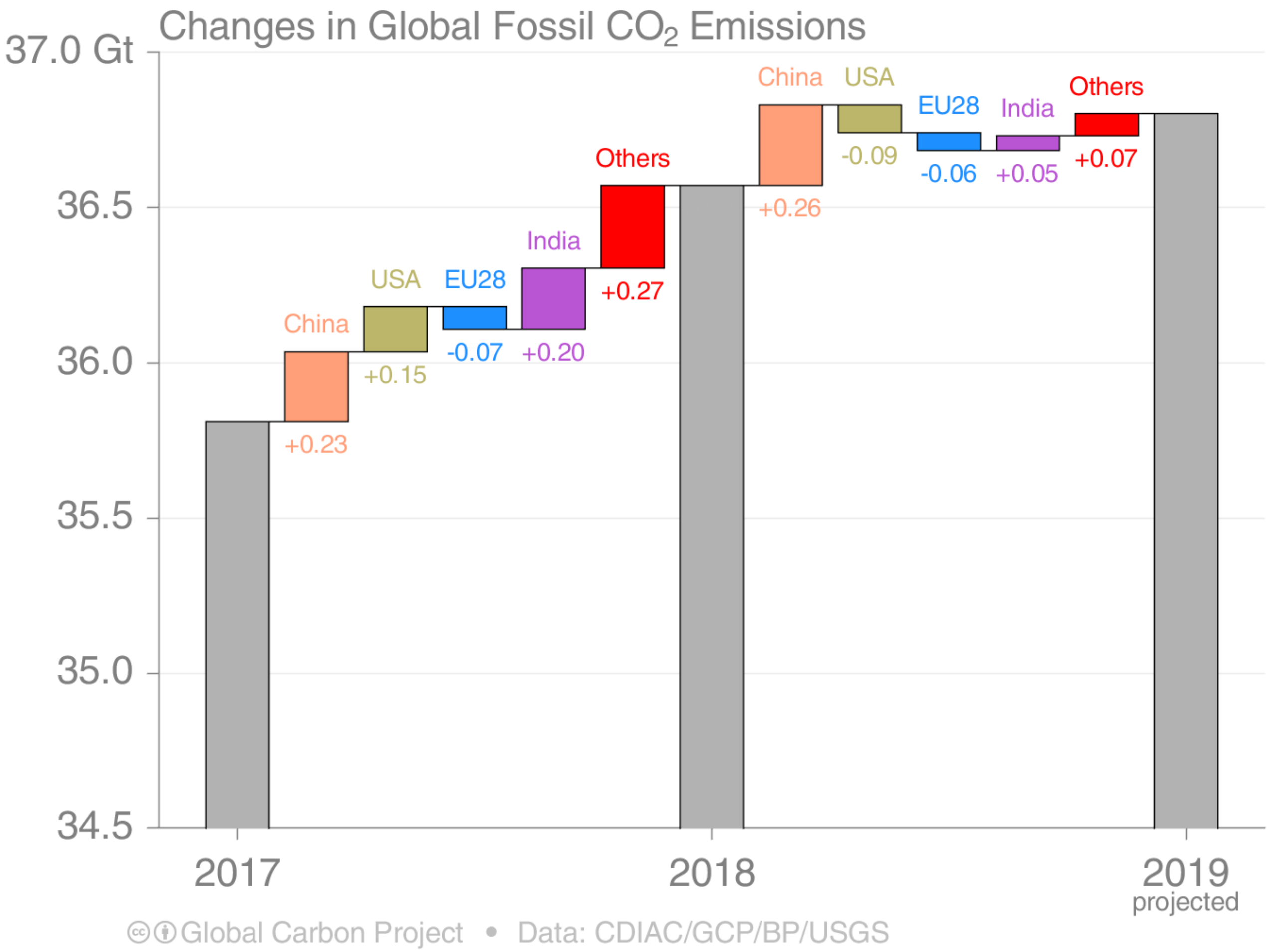


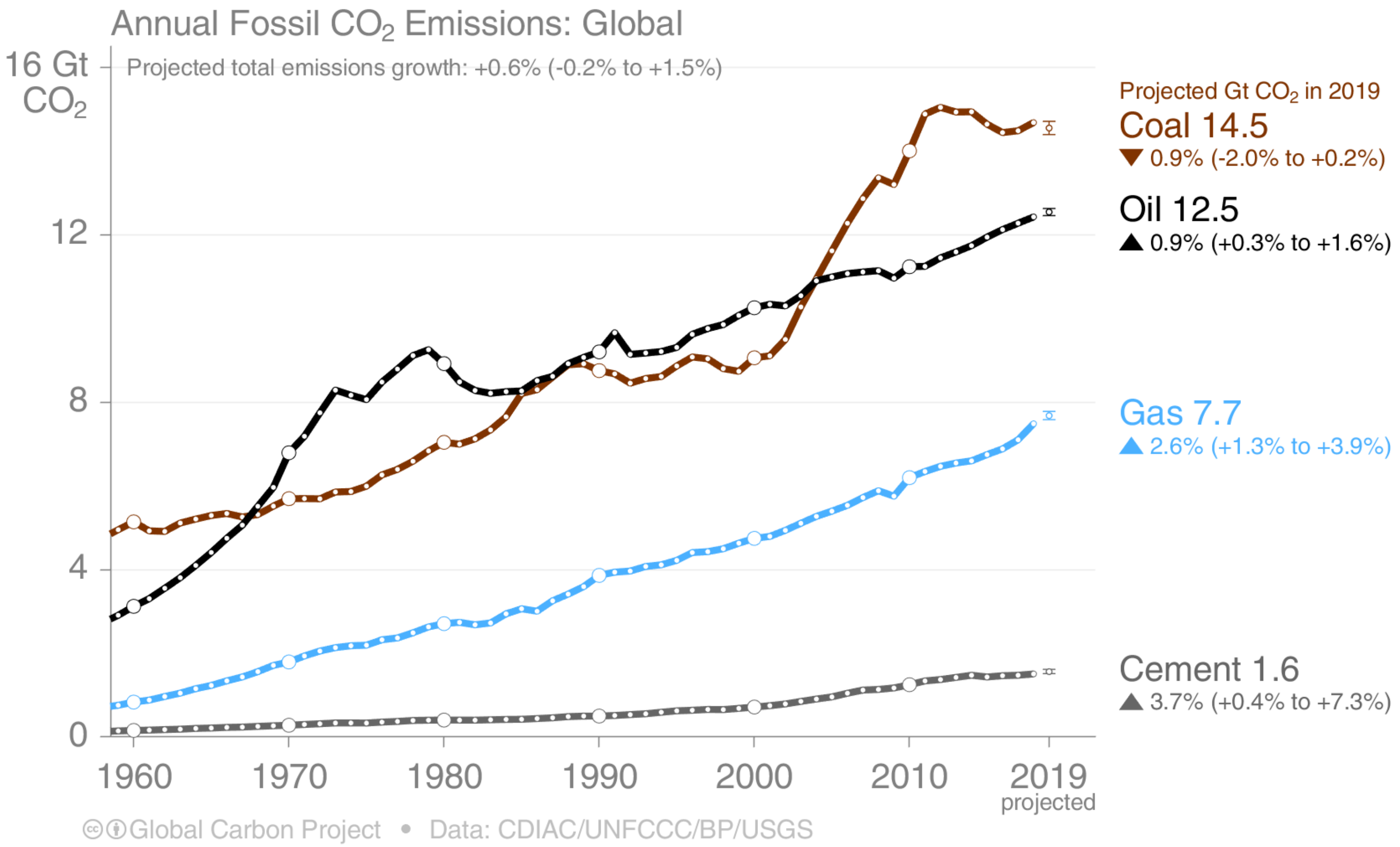
Figure shows the top four countries contributing to emissions changes in 2018
Source: CDIAC; Friedlingstein et al 2019; Global Carbon Budget 2019

Fossil CO_2 Emissions by source

from fossil fuel use and industry

Fossil CO_2 Emissions by source

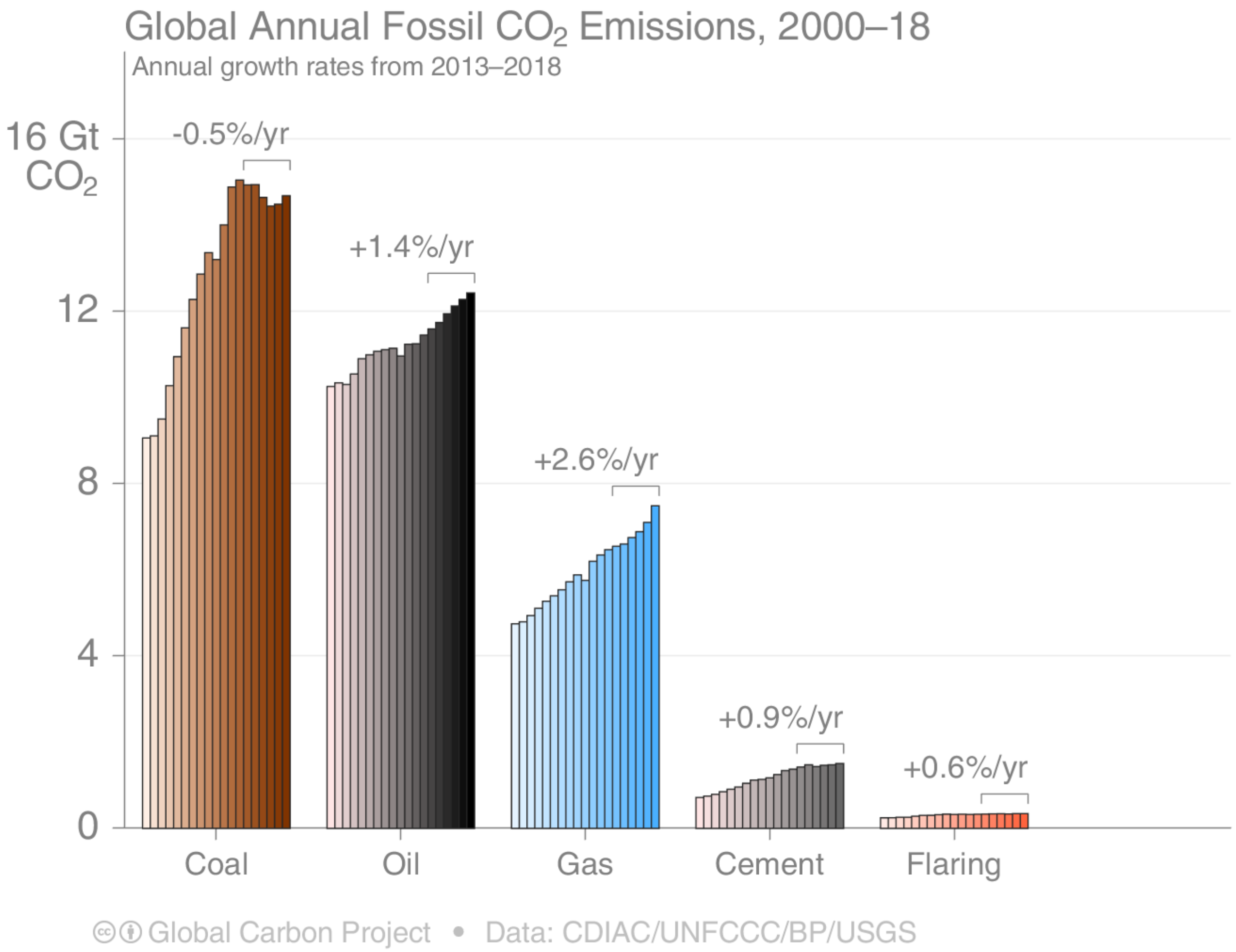
Share of global fossil CO_2 emissions in 2018:
coal (40%), oil (34%), gas (20%), cement (4%), flaring (1%, not shown)



Source: CDIAC; Peters et al 2019; Friedlingstein et al 2019; Global Carbon Budget 2019

Fossil CO_2 Emissions by source

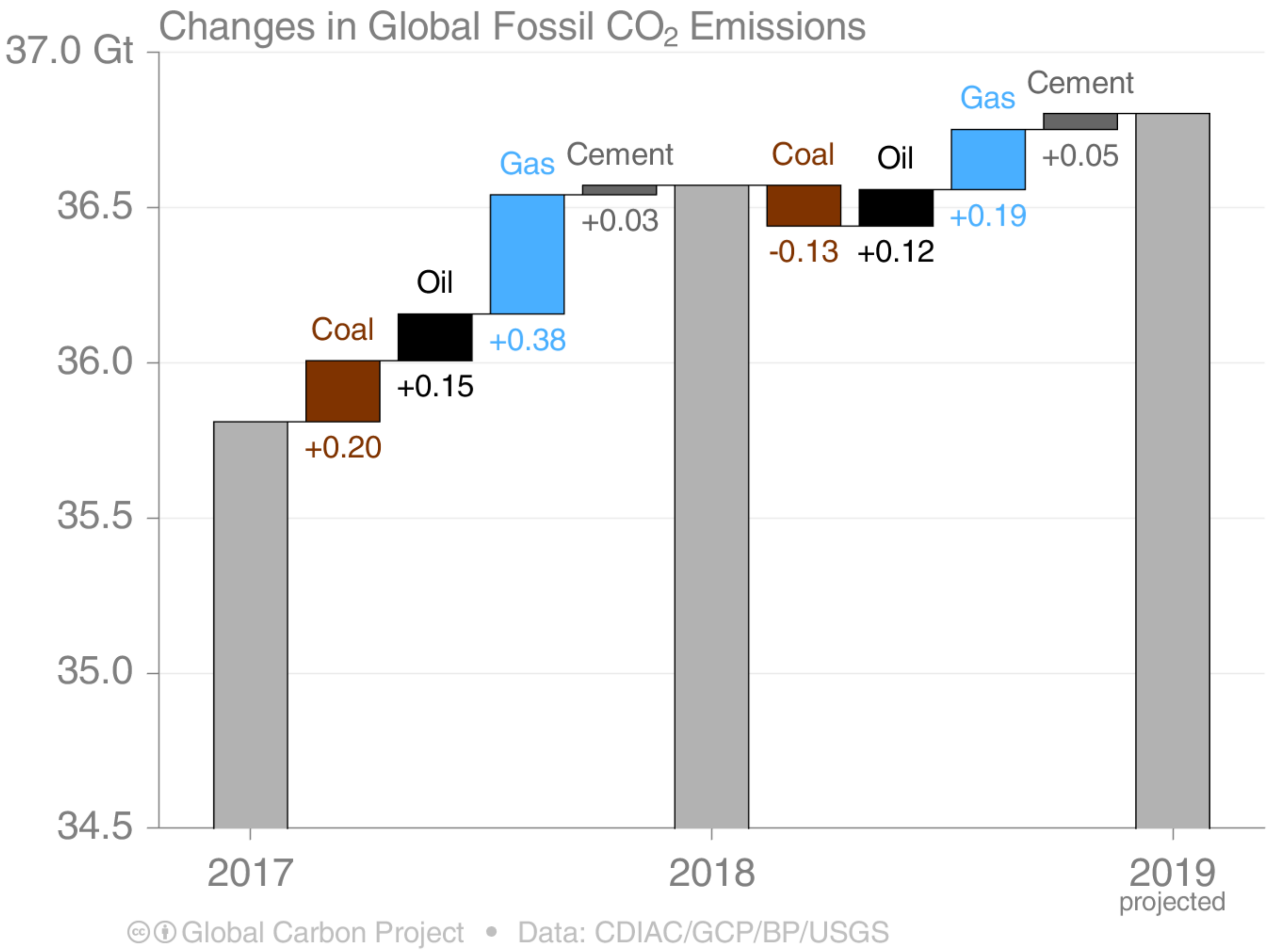
Emissions by category from 2000 to 2018, with growth rates indicated for the more recent period of 2013 to 2018



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

Fossil CO_2 emissions growth: 2017–2019

Natural gas is contributing the most to global emissions growth, followed by oil, while coal emissions are more variable
Since the potential peak in coal emissions in 2012, natural gas is responsible for more than half global emissions growth



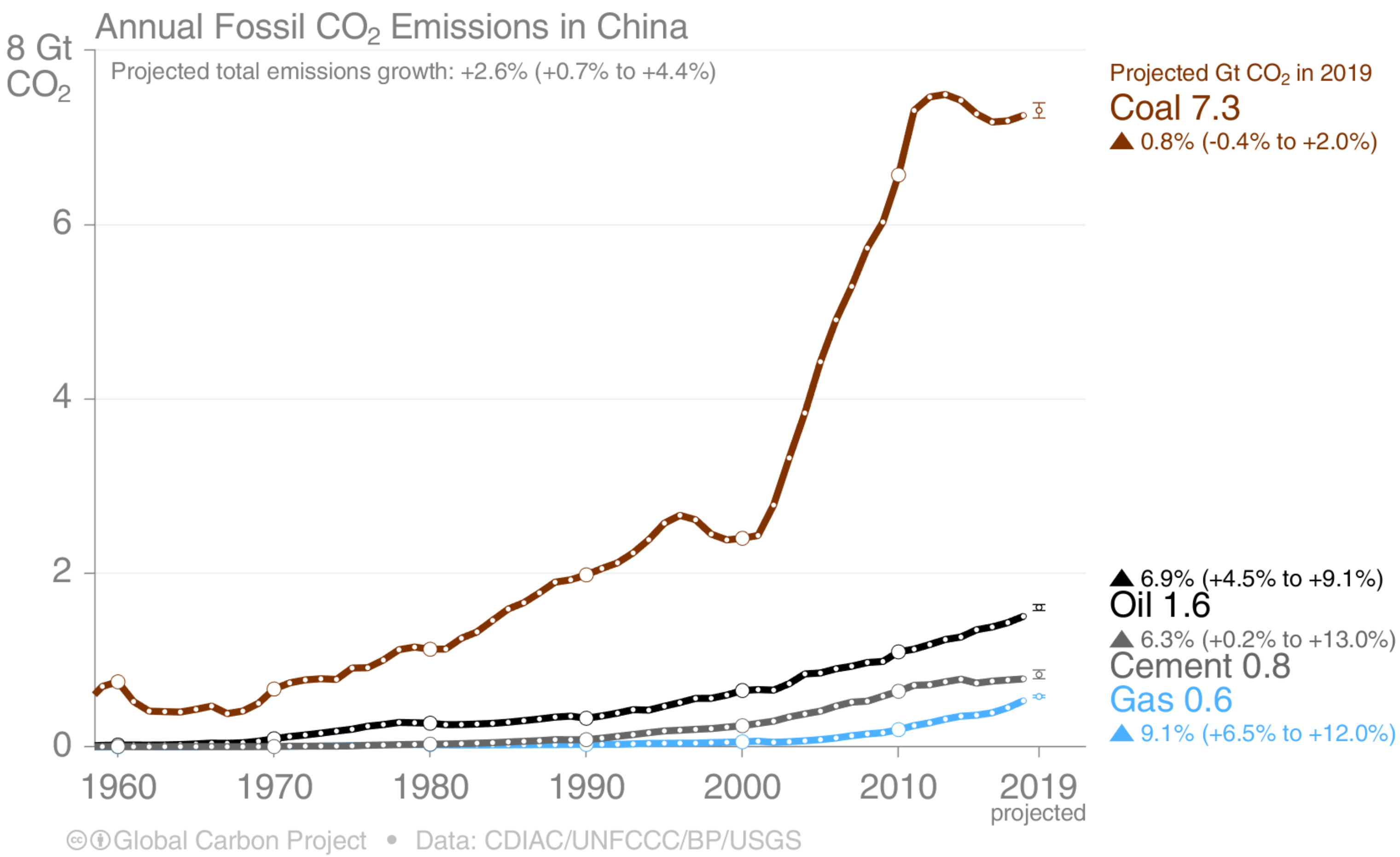
Source: CDIAC; Friedlingstein et al 2019; Global Carbon Budget 2019

Fossil CO_2 Emission by source for top emitters

from fossil fuel use and industry

Fossil CO_2 Emissions in China

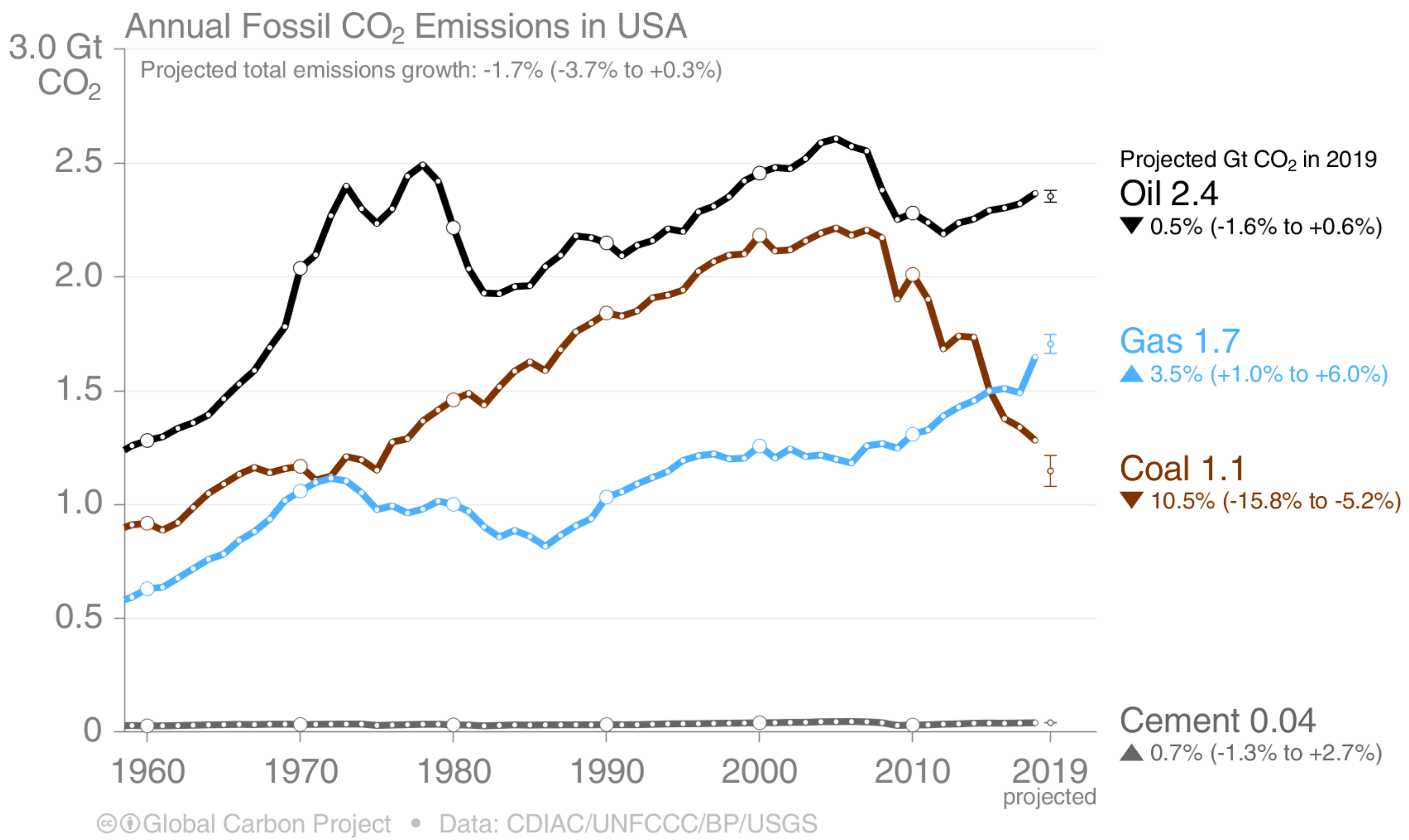
China's emissions are dominated by coal use, with strong and sustained growth in oil & gas
The recent declines in coal emissions may soon be undone if the return to growth persists



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

Fossil CO_2 Emissions in USA

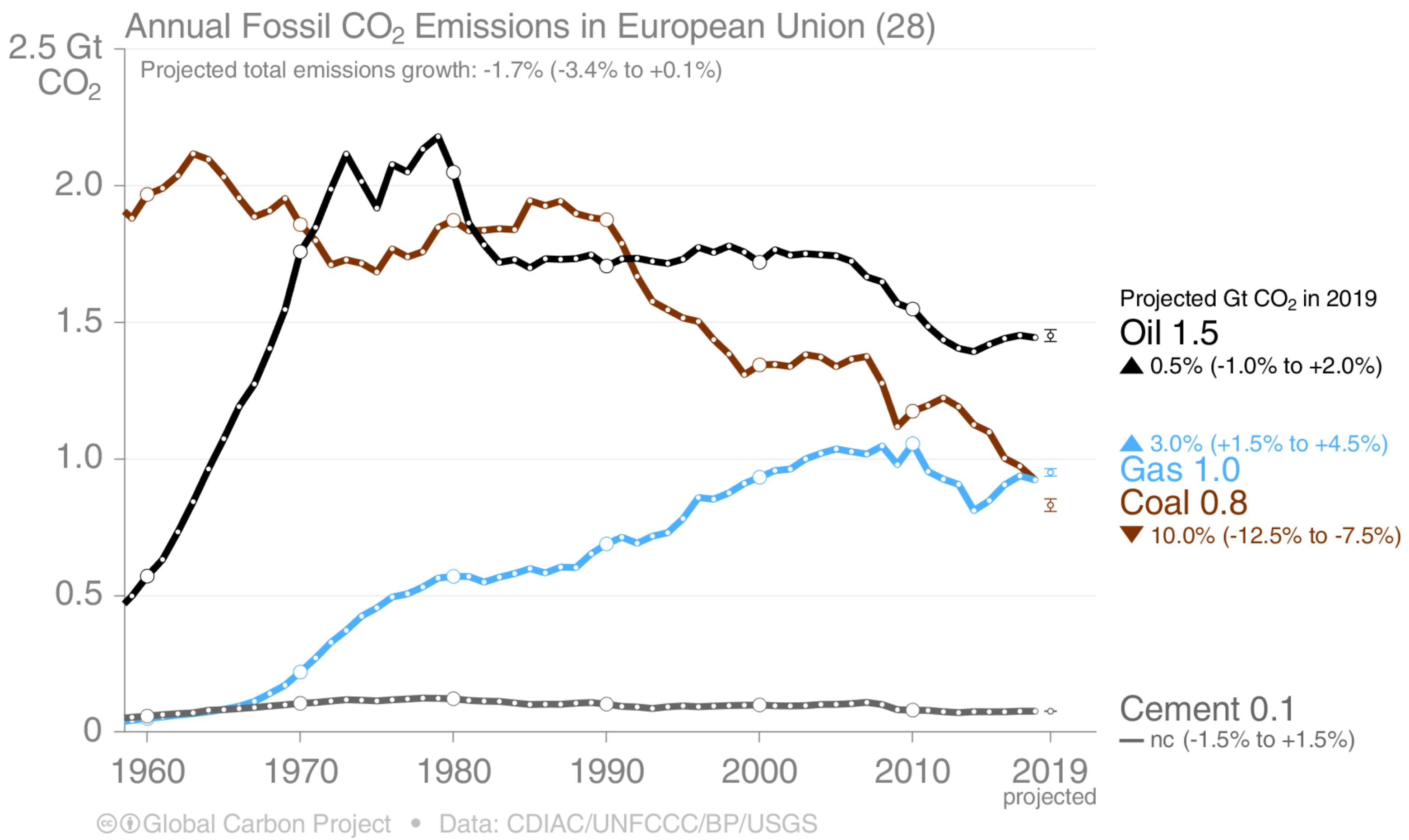
USA's CO_2 emissions have declined since 2007, driven by coal being displaced by gas, solar, & wind.
Oil use has returned to growth. Emissions growth in 2018 was driven partly by weather.



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

Fossil CO_2 Emissions in the European Union (EU28)

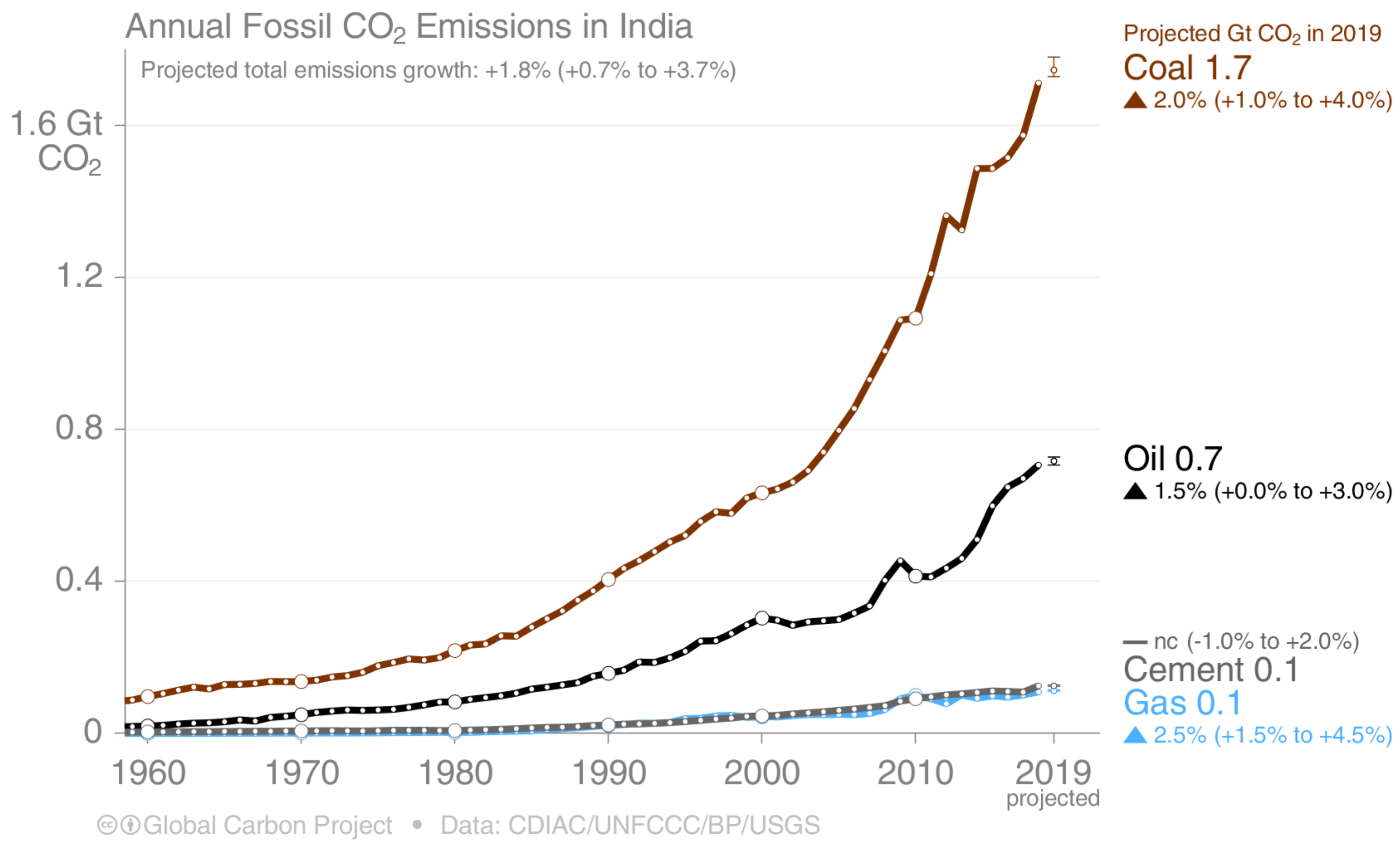
Emissions in the EU28 declined steadily from 2008 (the Global Financial Crisis) to 2014, but oil and gas emissions are growing again. A small decline is expected in 2019.



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

Fossil CO_2 Emissions in India

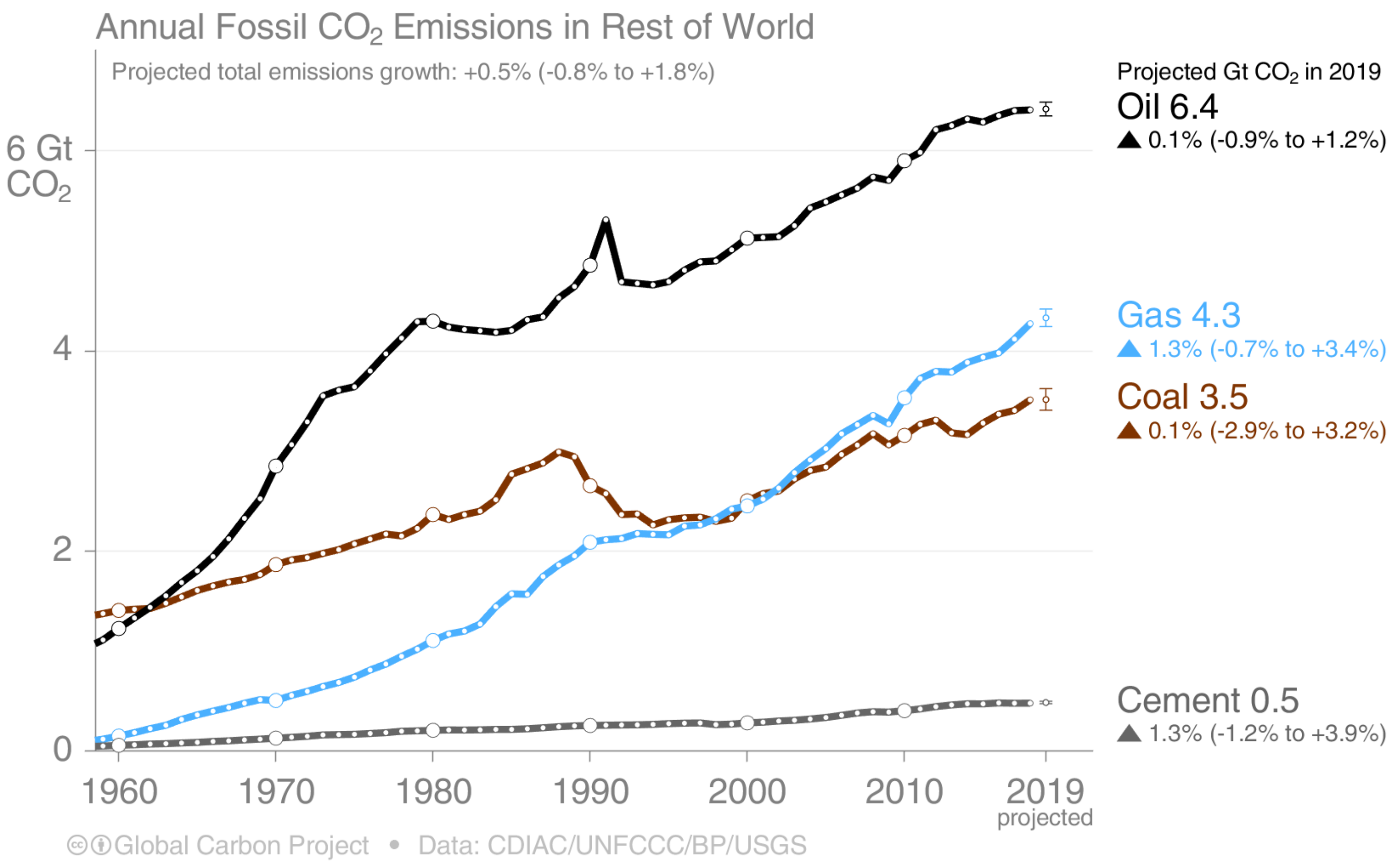
India's emissions are growing strongly along with rapid growth in economic activity.
Although India is rapidly deploying solar & wind power, coal continues to grow.



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

Fossil CO_2 Emissions in Rest of World

Emissions in the Rest of the World are expected to grow weakly in 2019, on the back of weaker economic growth.
Growth is estimated based on efficiency improvements of the last 10 years combined with projected economic growth.



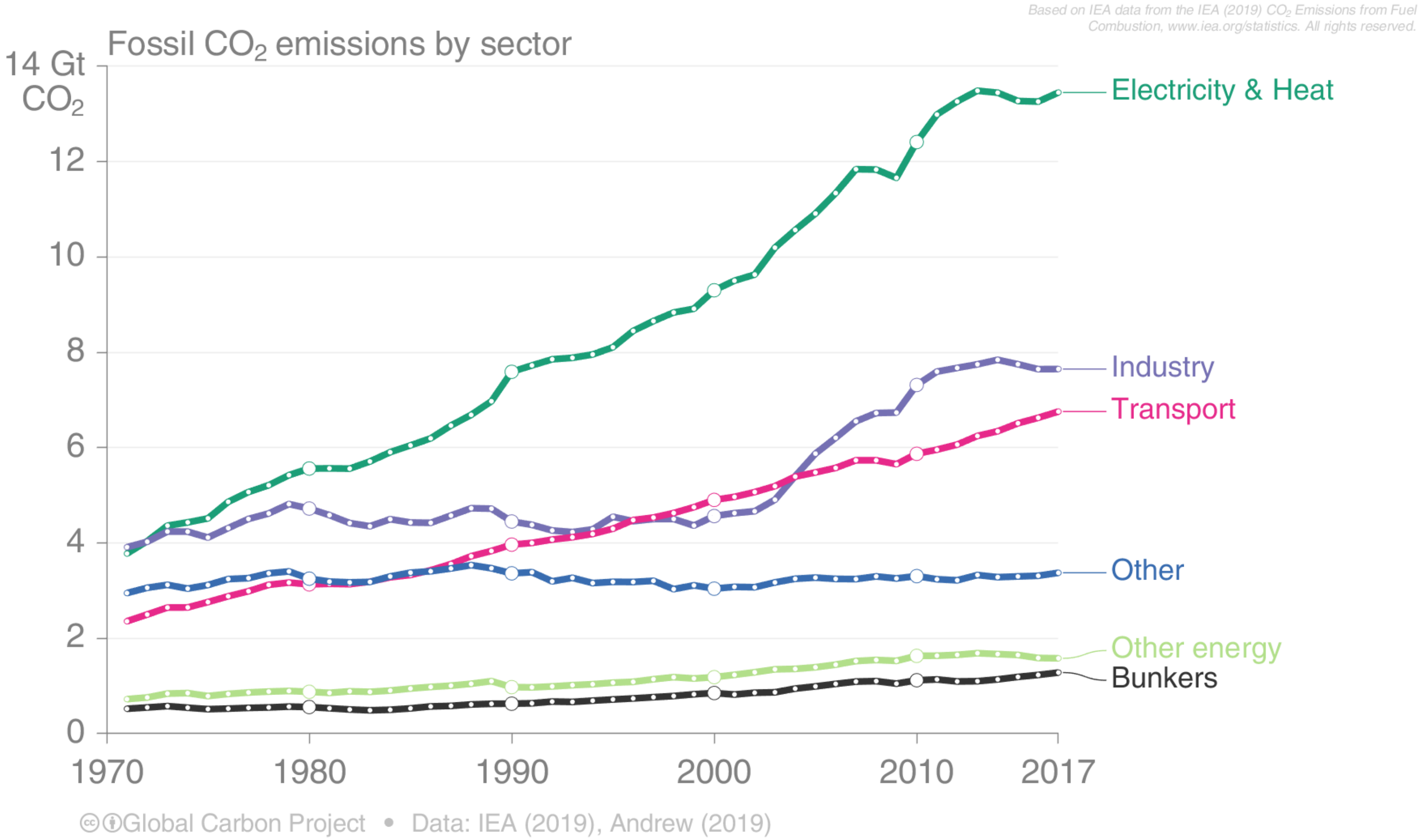
The Rest of the World is the global total less China, US, EU, and India. It also includes international aviation and marine bunkers.
Source: CDIAC; Friedlingstein et al 2019; Global Carbon Budget 2019

Fossil CO_2 Emissions by sectors

from fossil fuel use and industry

Fossil CO_2 Emissions by Sector

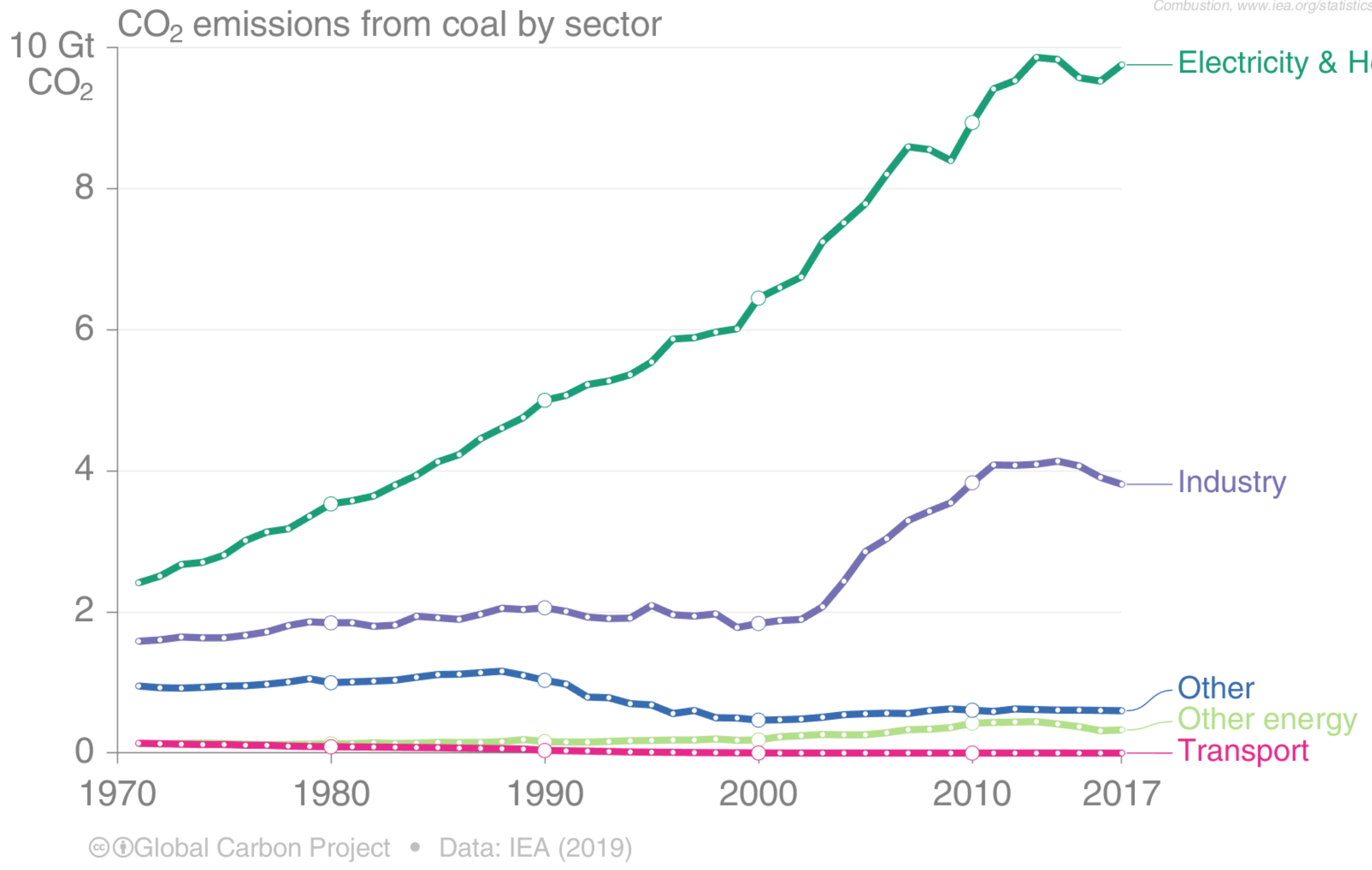
Global fossil CO_2 emissions are dominated by electricity, heat, & energy (45%), industry (23%), & national transport (19%). International aviation and marine bunkers are 3.5% & remaining sectors 10%.



Source: IEA 2019; Peters et al 2019; Global Carbon Budget 2019

Coal CO_2 Emissions by Sector

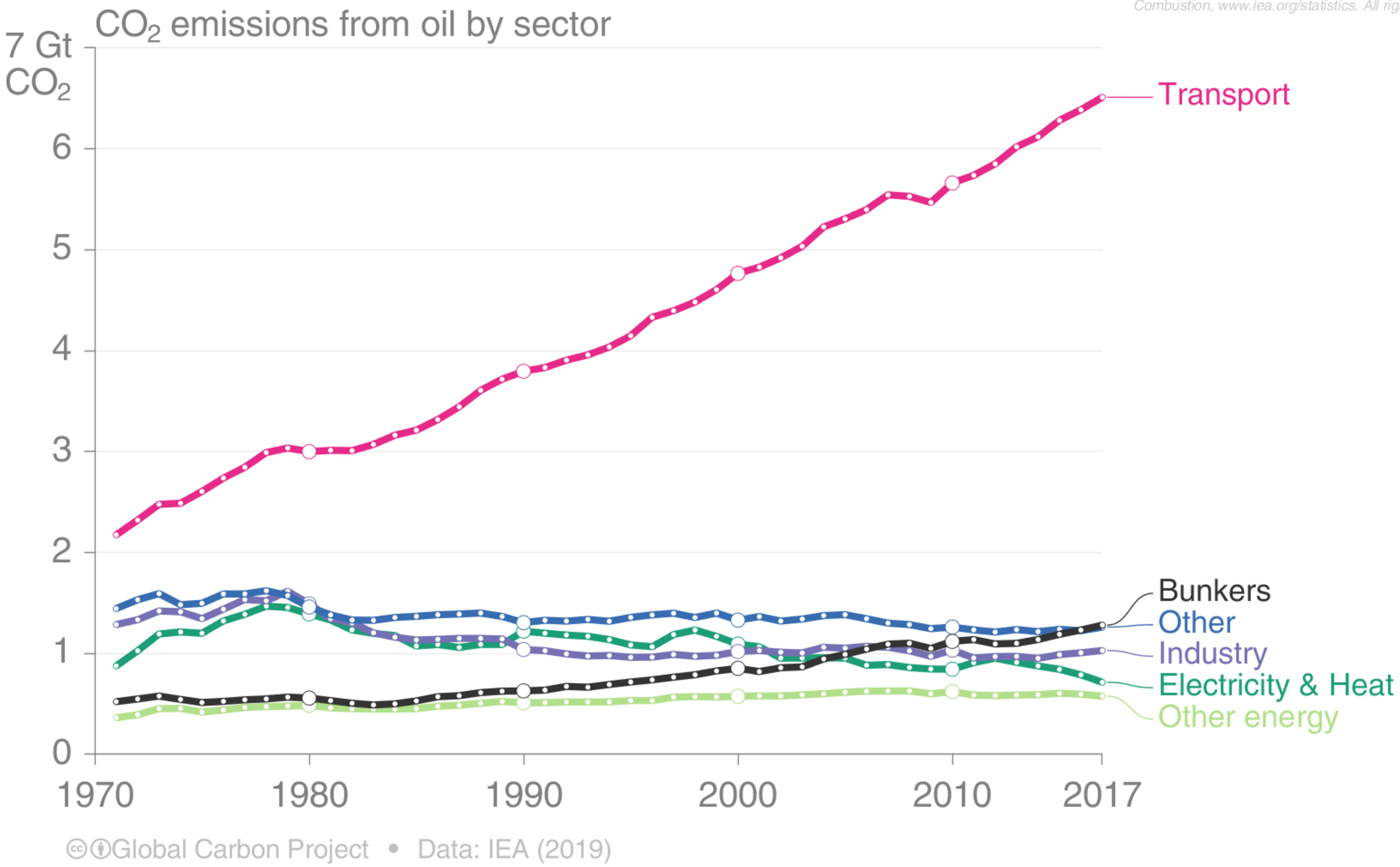
Coal CO_2 emissions are dominated by electricity, heat, and industry,
with both showing significantly lower growth & even declines in the last few years



Source: IEA 2019; Peters et al 2019; Global Carbon Budget 2019

Oil CO_2 Emissions by Sector

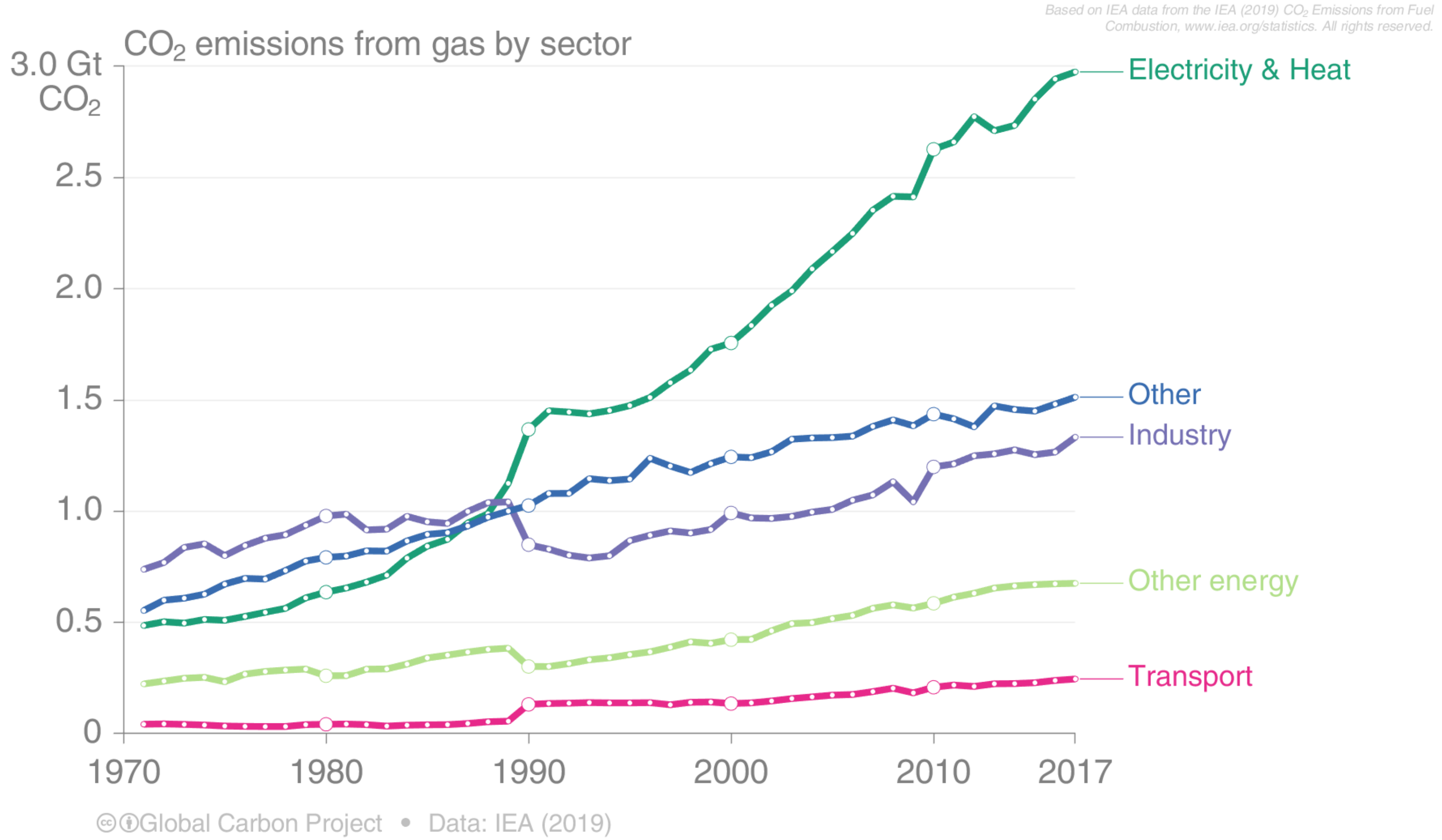
Oil CO_2 emissions are dominated by national transport with almost linear growth over five decades
Road transport is half the total growing at 1.9% while national & international aviation is 8% growing at 3% per year



Source: IEA 2019; Peters et al 2019; Global Carbon Budget 2019

Gas CO_2 Emissions by Sector

Gas CO_2 emissions are dominated by electricity & heat, industry, and other commercial & residential sectors
Gas CO_2 emissions are growing rapidly in most countries and sectors, dominating growth in CO_2 emissions in recent years.



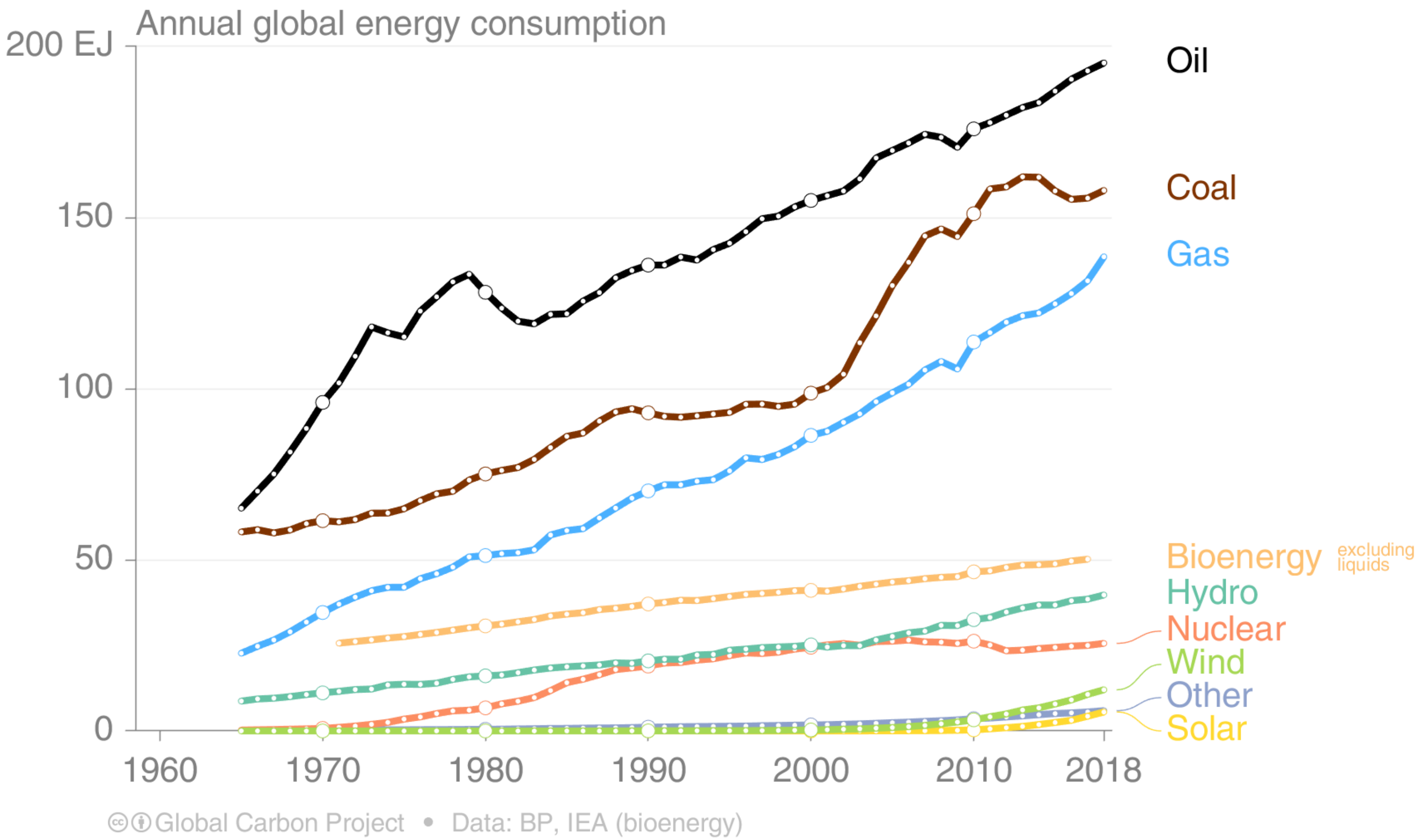
Source: IEA 2019; Peters et al 2019; Global Carbon Budget 2019

Energy use by source

from fossil fuel use and industry

Energy use by source

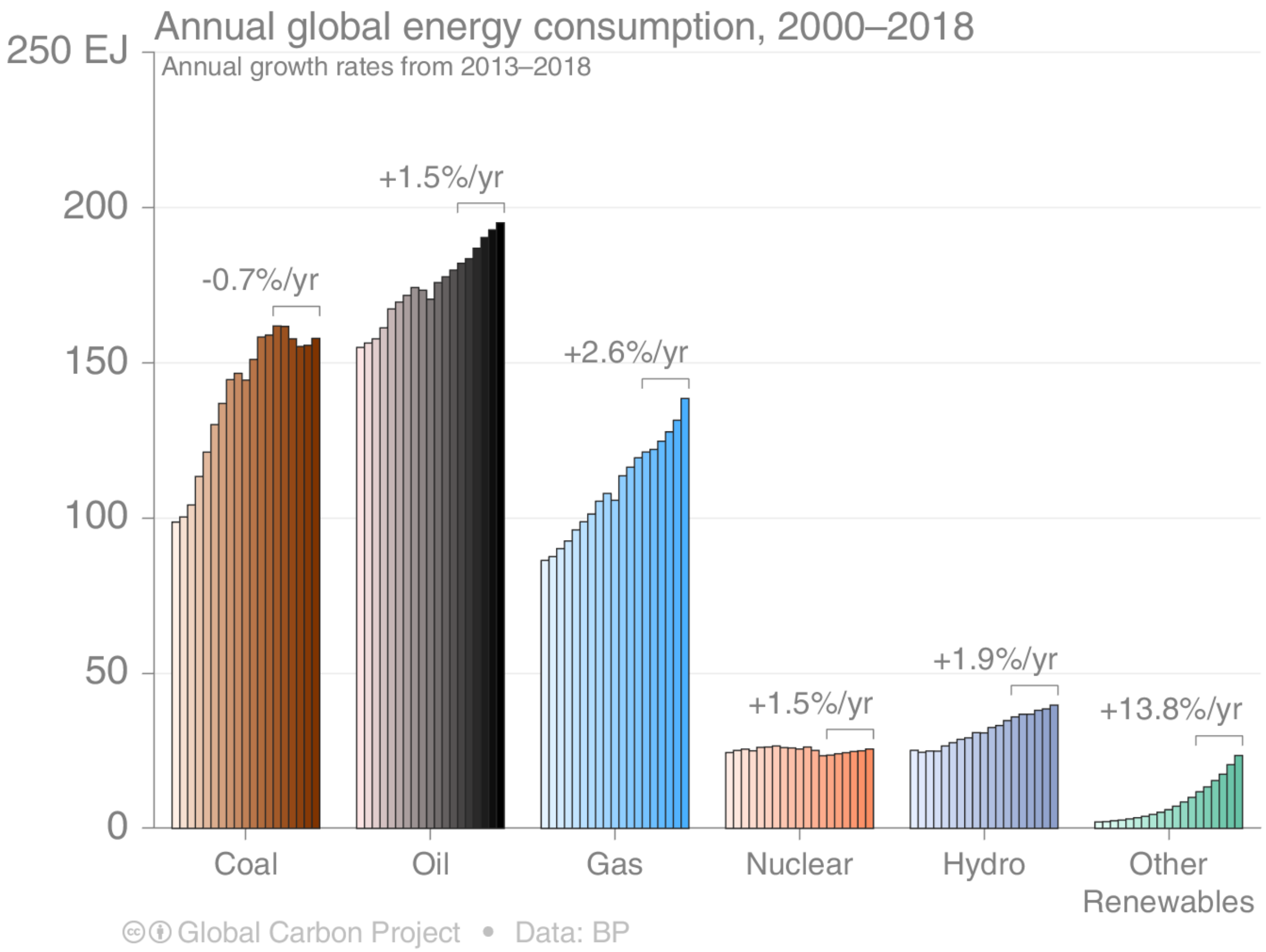
Renewable energy is growing exponentially, but this growth has so far been too low to offset the growth in fossil energy consumption.



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 2019; Jackson et al 2019; Global Carbon Budget 2019

Energy use by source

Energy consumption by fuel source from 2000 to 2018, with growth rates indicated for the more recent period of 2013 to 2018

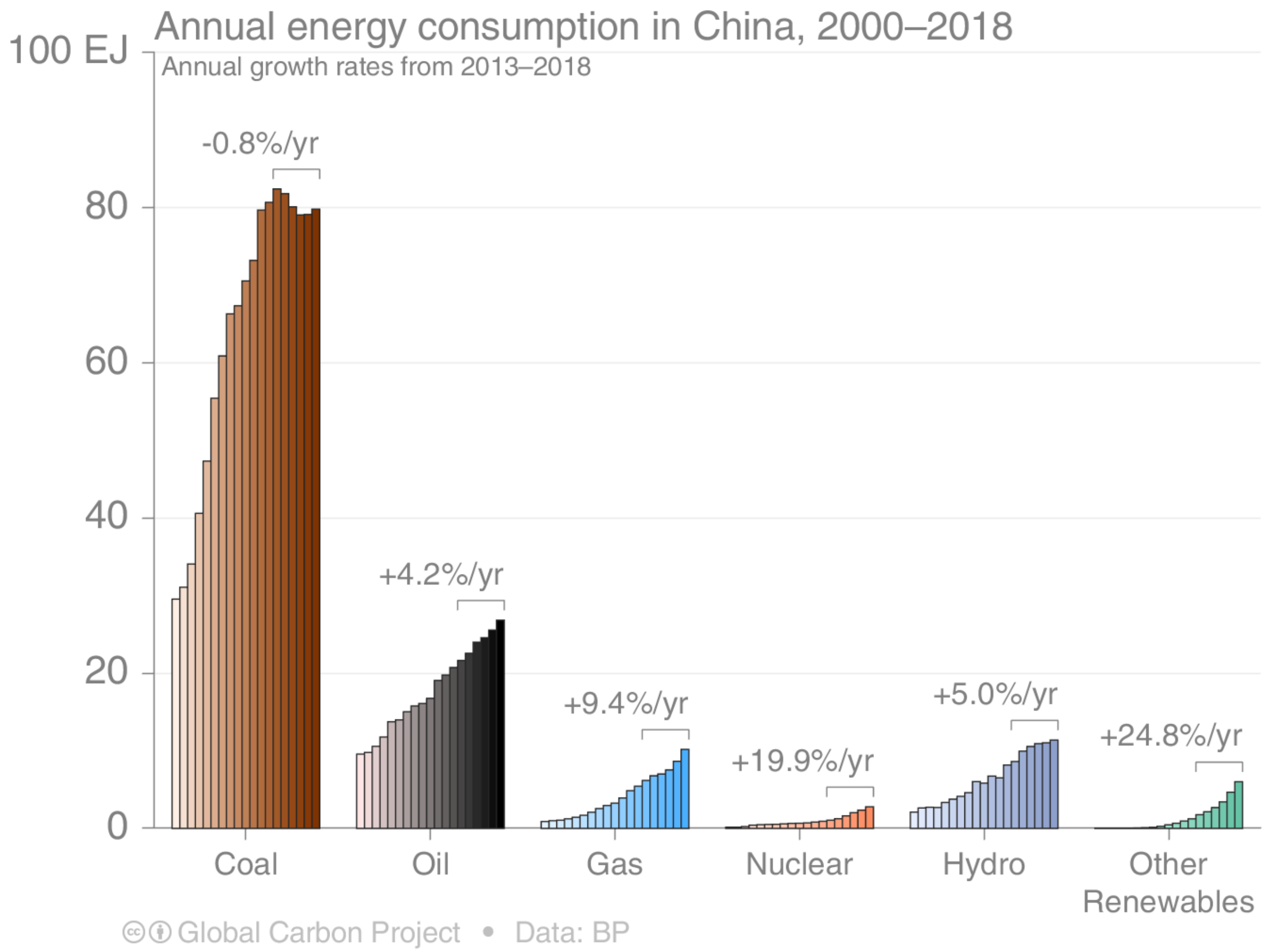


This figure shows "primary energy" using the BP substitution method (non-fossil sources are scaled up by an assumed fossil efficiency of 0.38)

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

Energy use in China

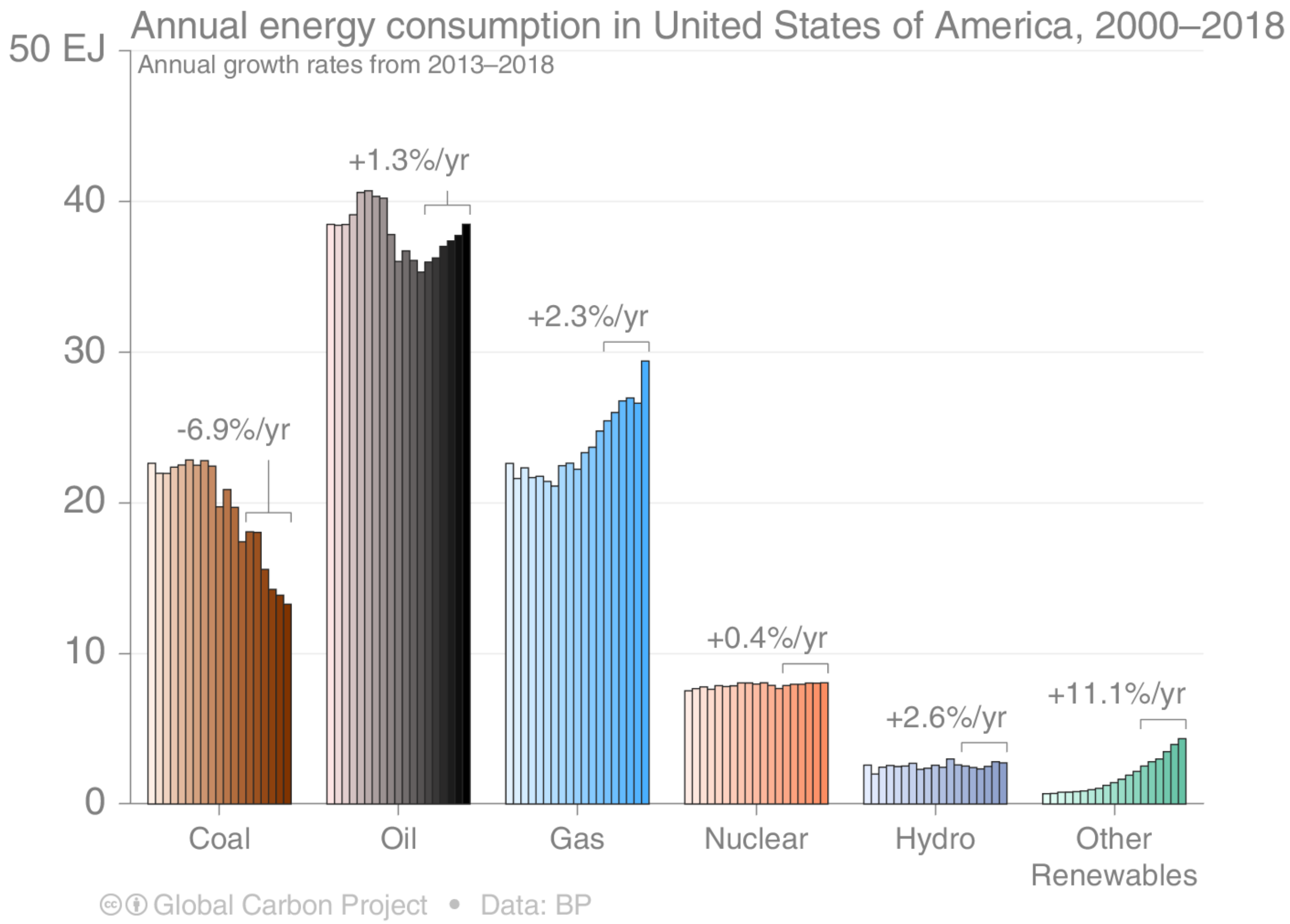
Coal consumption in energy units may have already peaked in China,
while consumption of all other energy sources is growing strongly



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

Energy use in USA

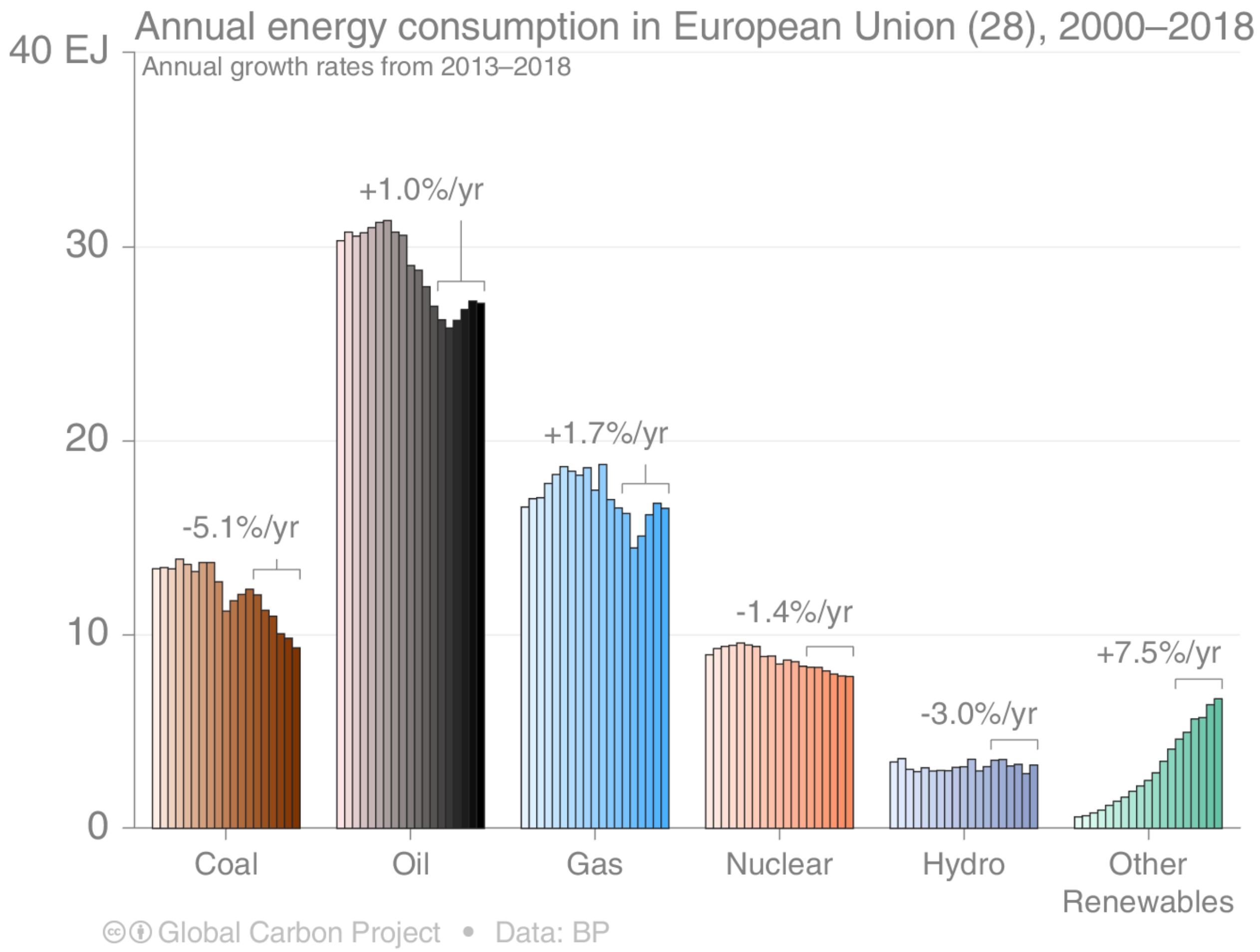
Coal consumption has declined sharply in recent years with the shale gas boom and strong renewables growth. Growth in oil consumption has resumed.



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

Energy use in the European Union

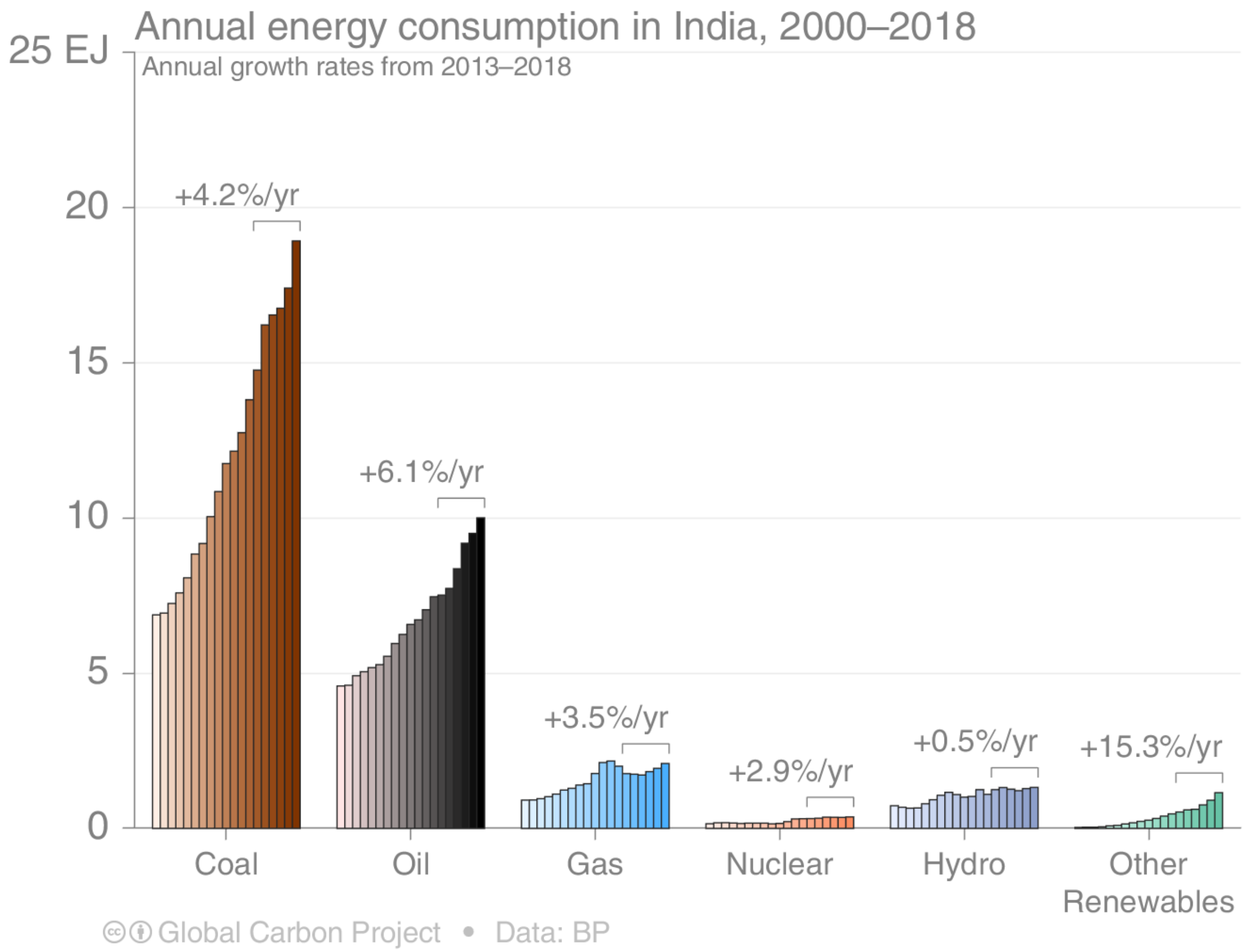
Consumption of both oil and gas has rebounded in recent years, while coal continues to decline. Renewables are growing strongly.



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

Energy use in India

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

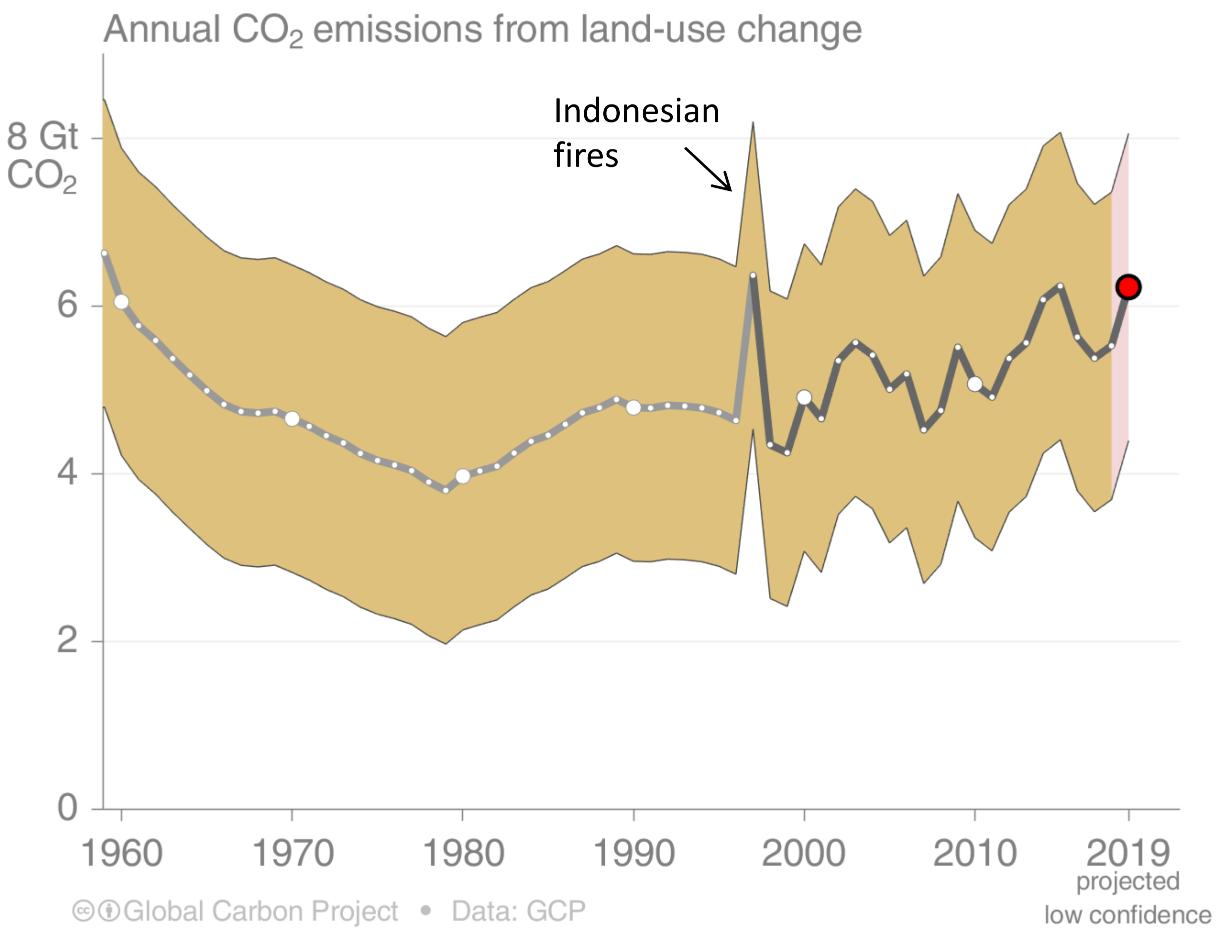


Source: [BP 2019](); [Jackson et al 2019](); [Global Carbon Budget 2019]()

Land-use Change Emissions

Land-use change emissions

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

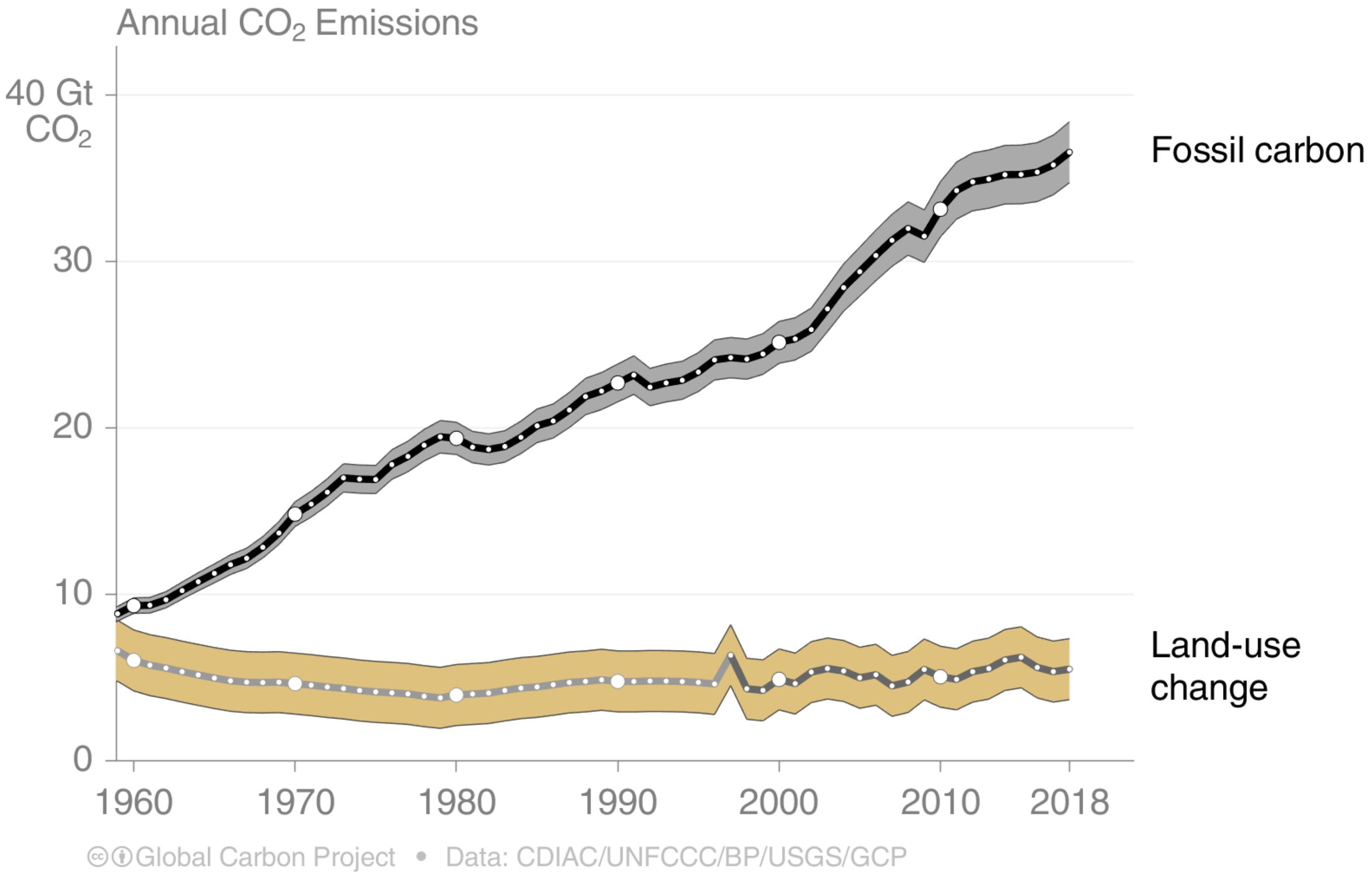


Estimates from two bookkeeping models, using fire-based variability from 1997

Source: Houghton and Nassikas 2017; Hansis et al 2015; van der Werf et al. 2017; Friedlingstein et al 2019; Global Carbon Budget 2019

Total global emissions

Total global emissions: 42.1 ± 2.8 GtCO_2 in 2018, 55% over 1990
Percentage land-use change: 39% in 1960, 14% averaged 2009–2018



Land-use change estimates from two bookkeeping models, using fire-based variability from 1997
Source: CDIAC; Houghton and Nassikas 2017; Hansis et al 2015; van der Werf et al. 2017; Friedlingstein et al 2019; Global Carbon Budget 2019

Closing the Global Carbon Budget

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Fate of anthropogenic CO_2 emissions (2009–2018)

Sources = Sinks

Sources

34.7 $GtCO_2$/yr

86%

14%

5.5 $GtCO_2$/yr

Sinks

17.9 $GtCO_2$/yr

44%

29%

11.5 $GtCO_2$/yr

23%

9.2 $GtCO_2$/yr

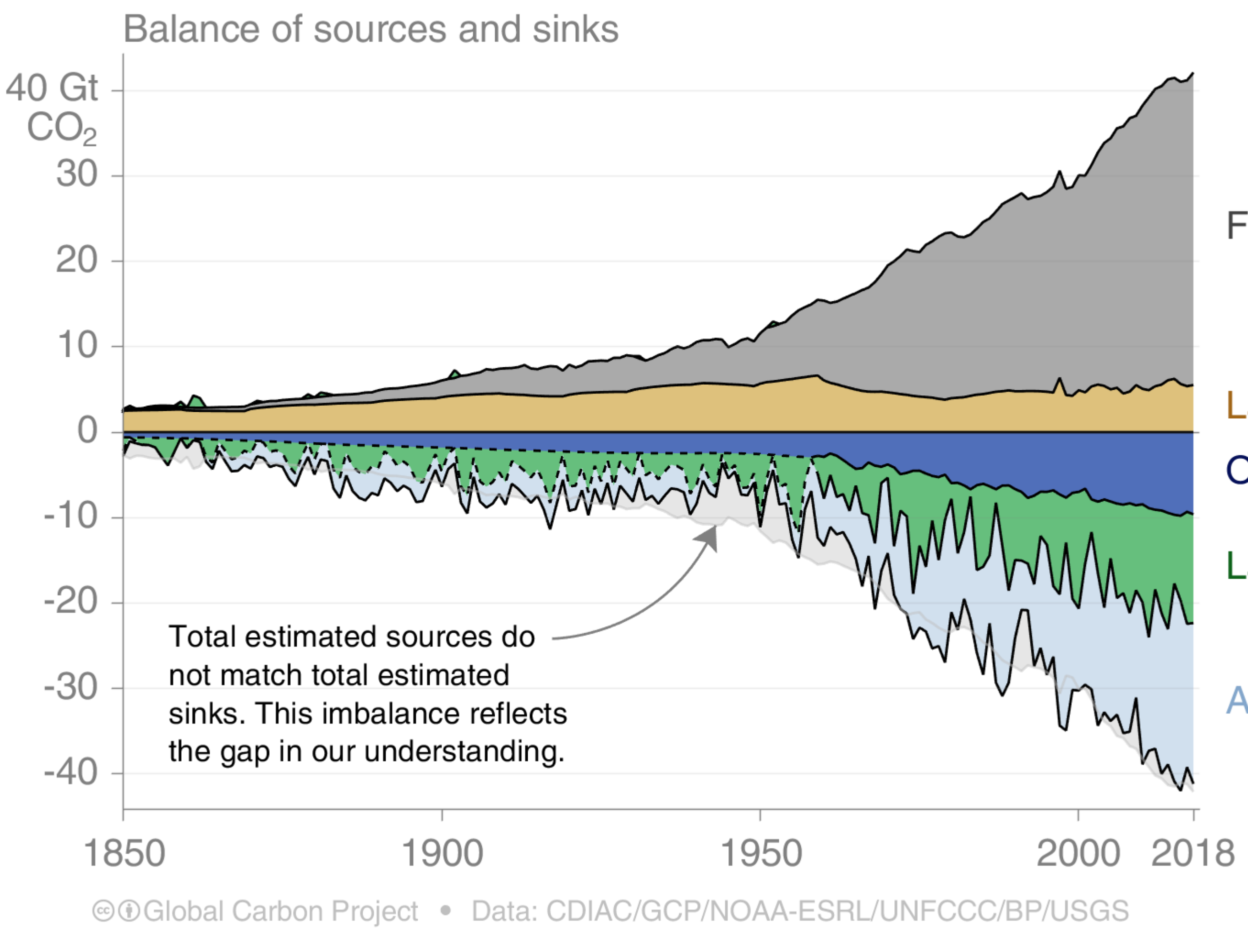
Budget Imbalance:
(the difference between estimated sources & sinks)

4%
1.6 $GtCO_2$/yr

Source: CDIAC; NOAA-ESRL; Houghton and Nassikas 2017; Hansis et al 2015; Friedlingstein et al 2019; Global Carbon Budget 2019

Global carbon budget

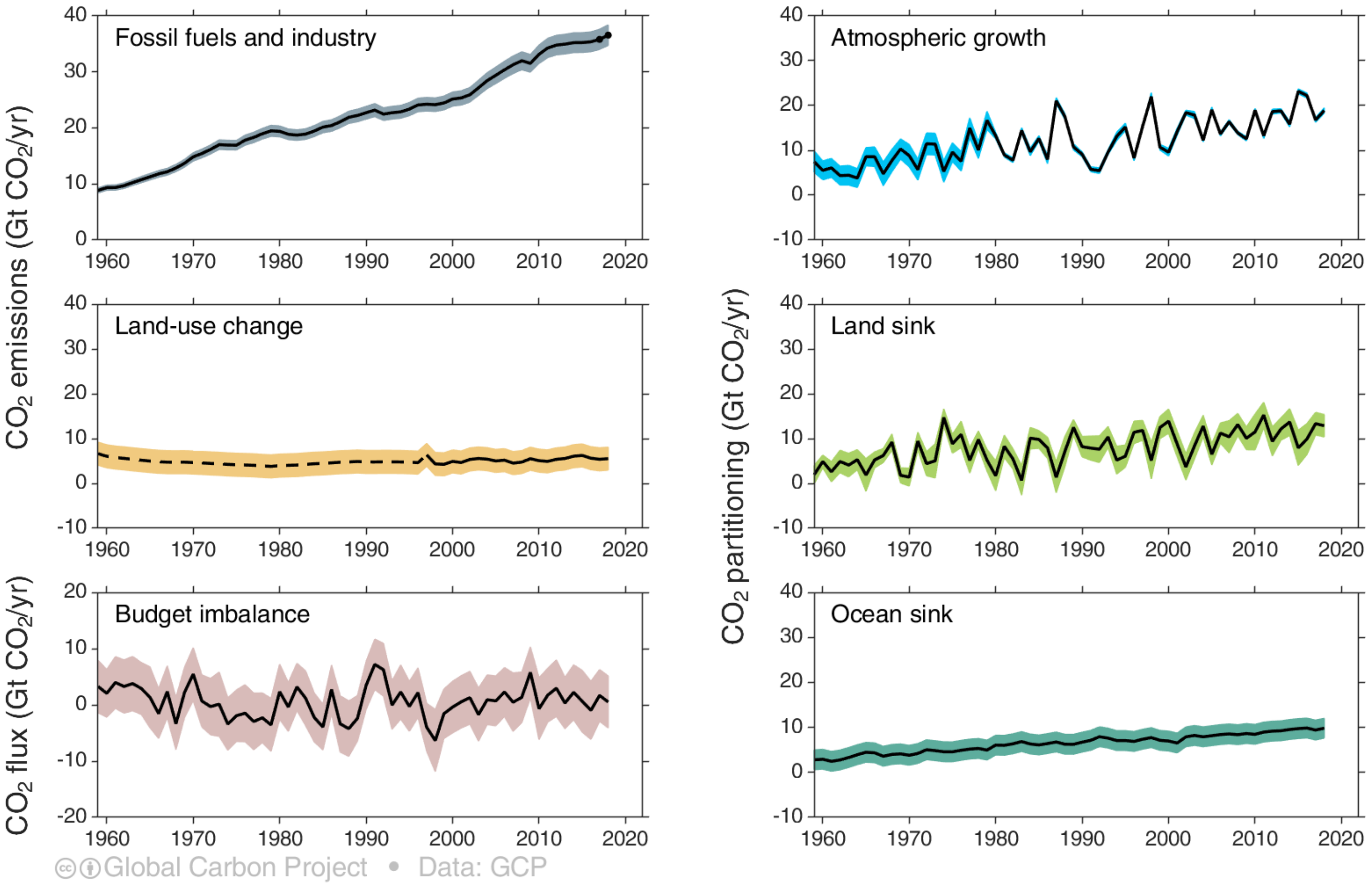
Carbon emissions are partitioned among the atmosphere and carbon sinks on land and in the ocean
The “imbalance” between total emissions and total sinks reflects the gap in our understanding



Source: CDIAC; NOAA-ESRL; Houghton and Nassikas 2017; Hansis et al 2015; Joos et al 2013; Khatiwala et al. 2013; DeVries 2014; Friedlingstein et al 2019; Global Carbon Budget 2019

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

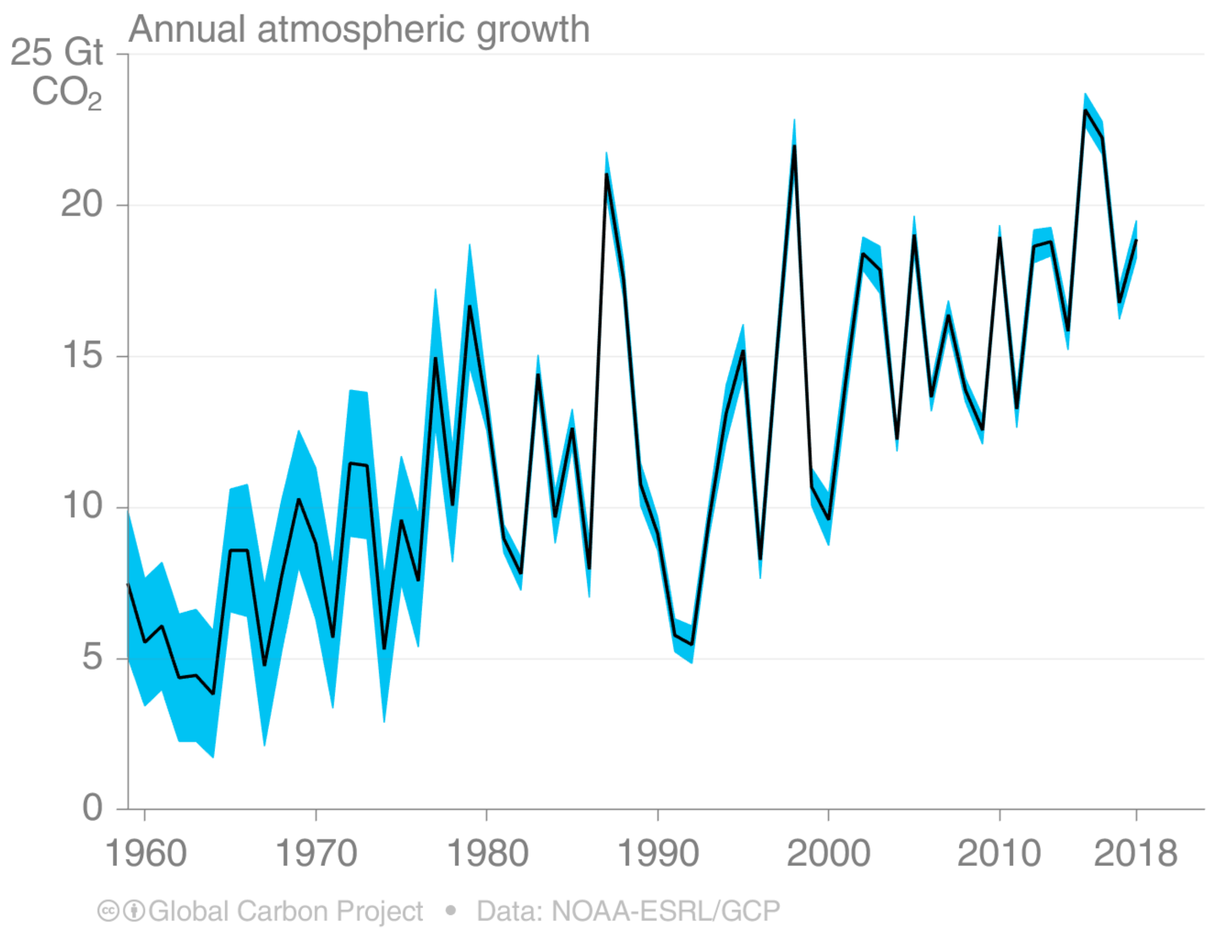


The budget imbalance is the total emissions minus the estimated growth in the atmosphere, land and ocean.
It reflects the limits of our understanding of the carbon cycle.

Source: CDIAC; NOAA-ESRL; Houghton and Nassikas 2017; Hansis et al 2015; Friedlingstein et al 2019; Global Carbon Budget 2019

Atmospheric concentration

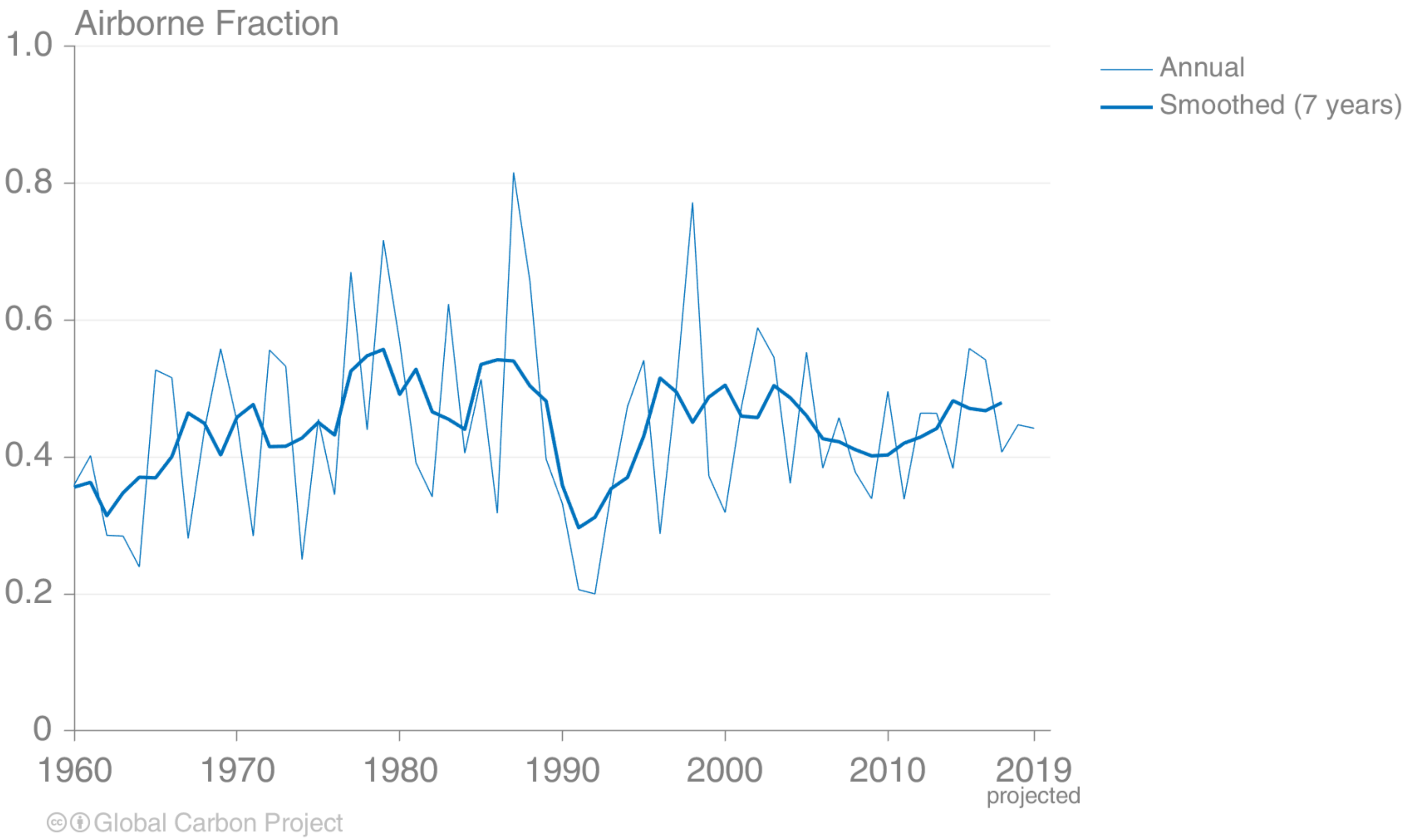
The atmospheric concentration growth rate has shown a steady increase
The high growth in 1987, 1998, & 2015–16 reflect a strong El Niño, which weakens the land sink



Source: NOAA-ESRL; Friedlingstein et al 2019; Global Carbon Budget 2019

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.

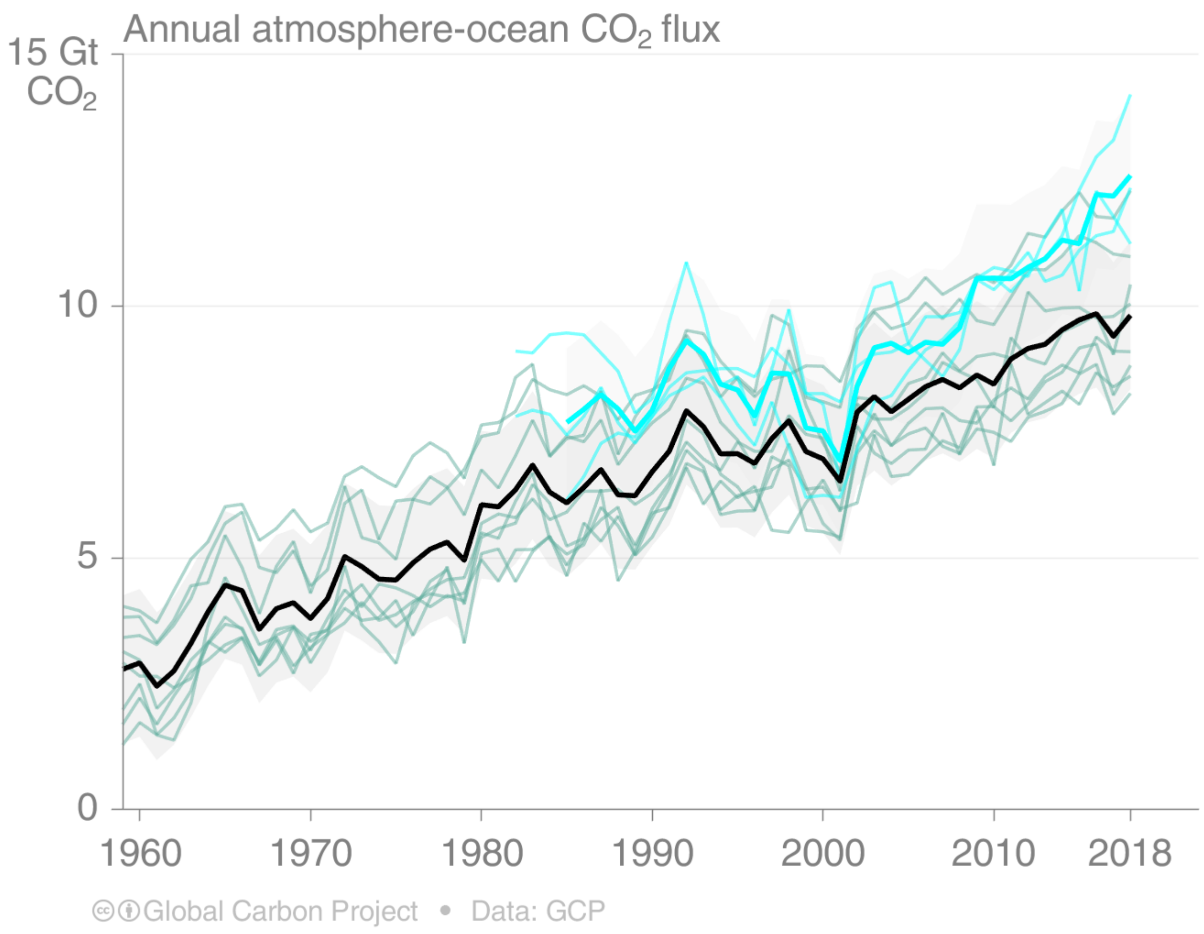


Source: NOAA-ESRL; Global Carbon Budget 2019

Ocean sink

The ocean carbon sink continues to increase

9.2±2.2 $GtCO_2$/yr for 2009–2018 and 9.6±2.2 $GtCO_2$/yr in 2018

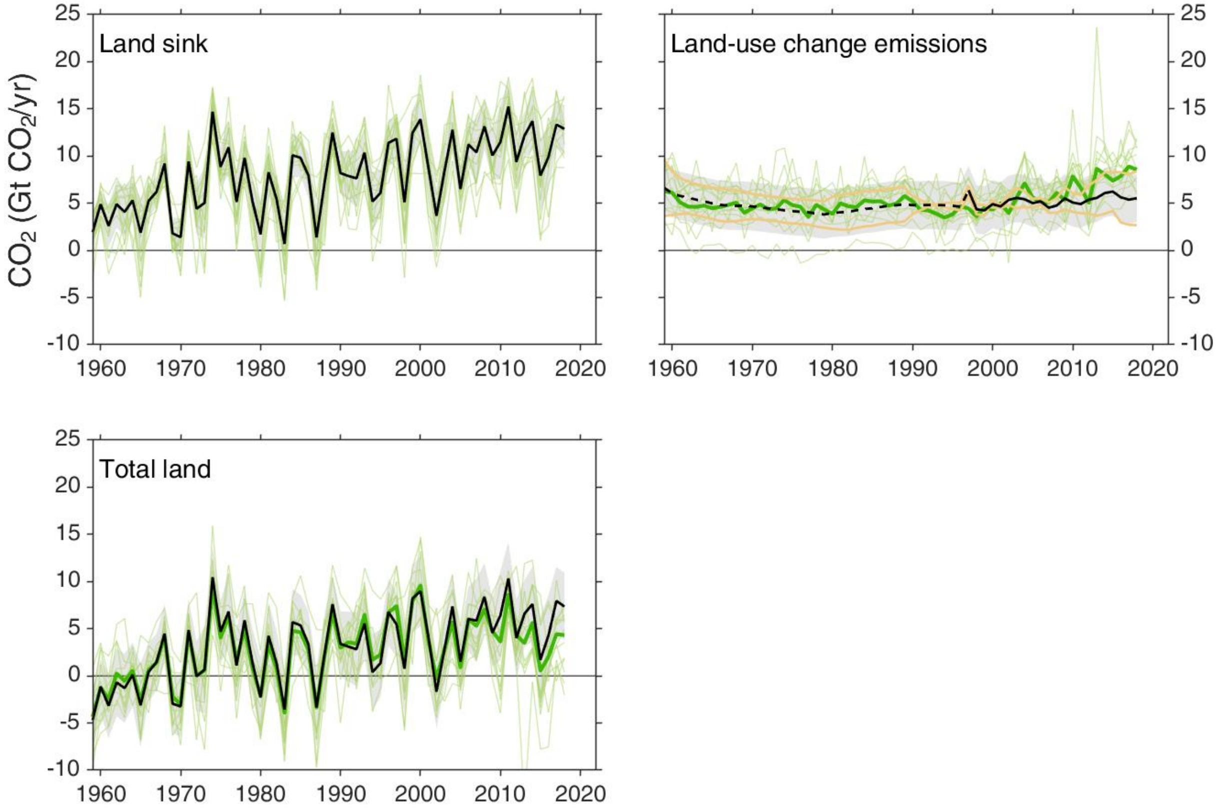


Source: SOCATv6; Bakker et al 2016; Friedlingstein et al 2019; Global Carbon Budget 2019

(see Table 4 for detailed references)

Terrestrial sink

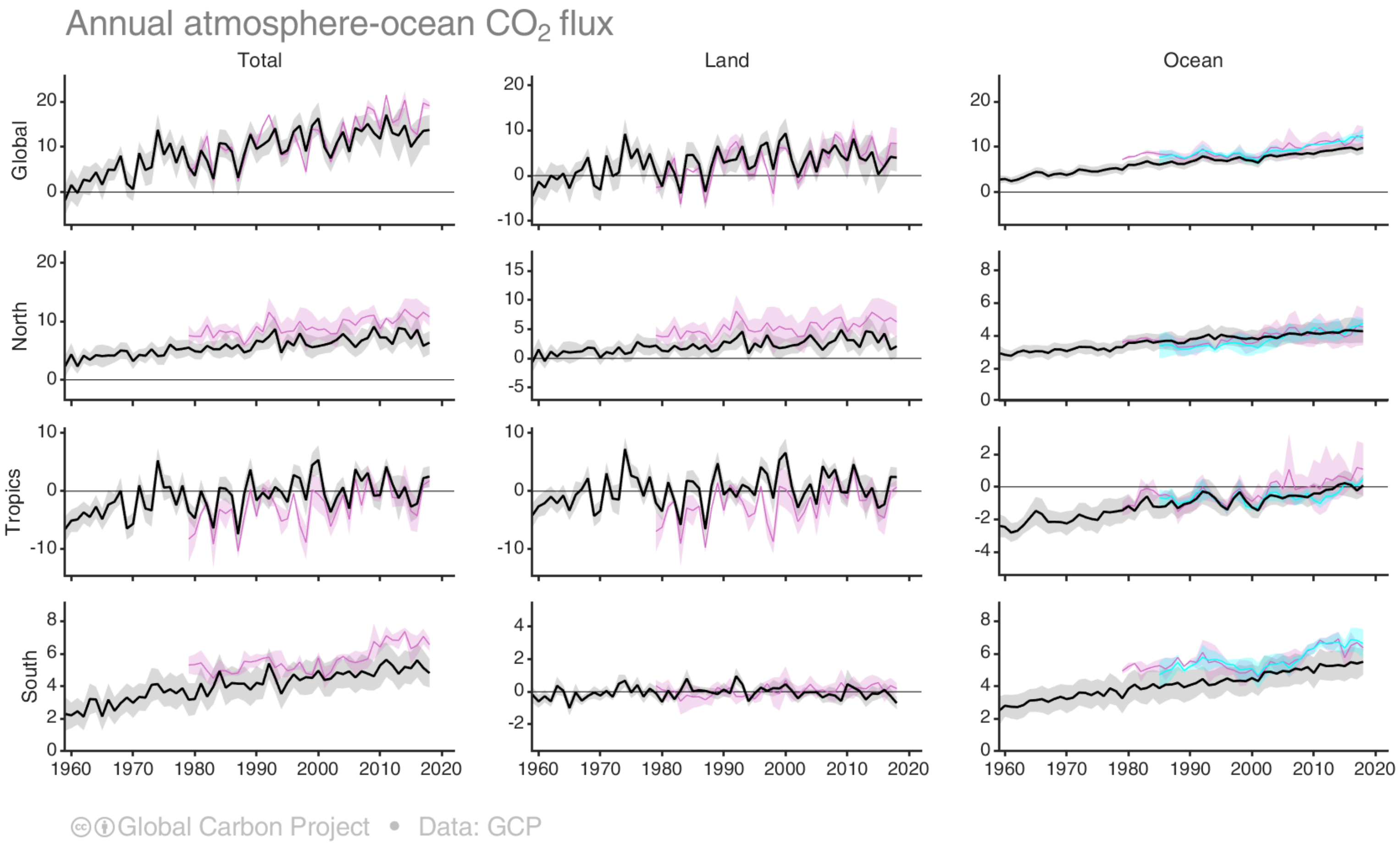
The land sink was 11.5±2.2 $GtCO_2$/yr during 2009–2018 and 12.7±2.5 $GtCO_2$/yr in 2018
Total CO_2 fluxes on land (including land-use change) are constrained by atmospheric inversions



Source: [Friedlingstein et al 2019](#) (see Table 4 for detailed references)

Total land and ocean fluxes

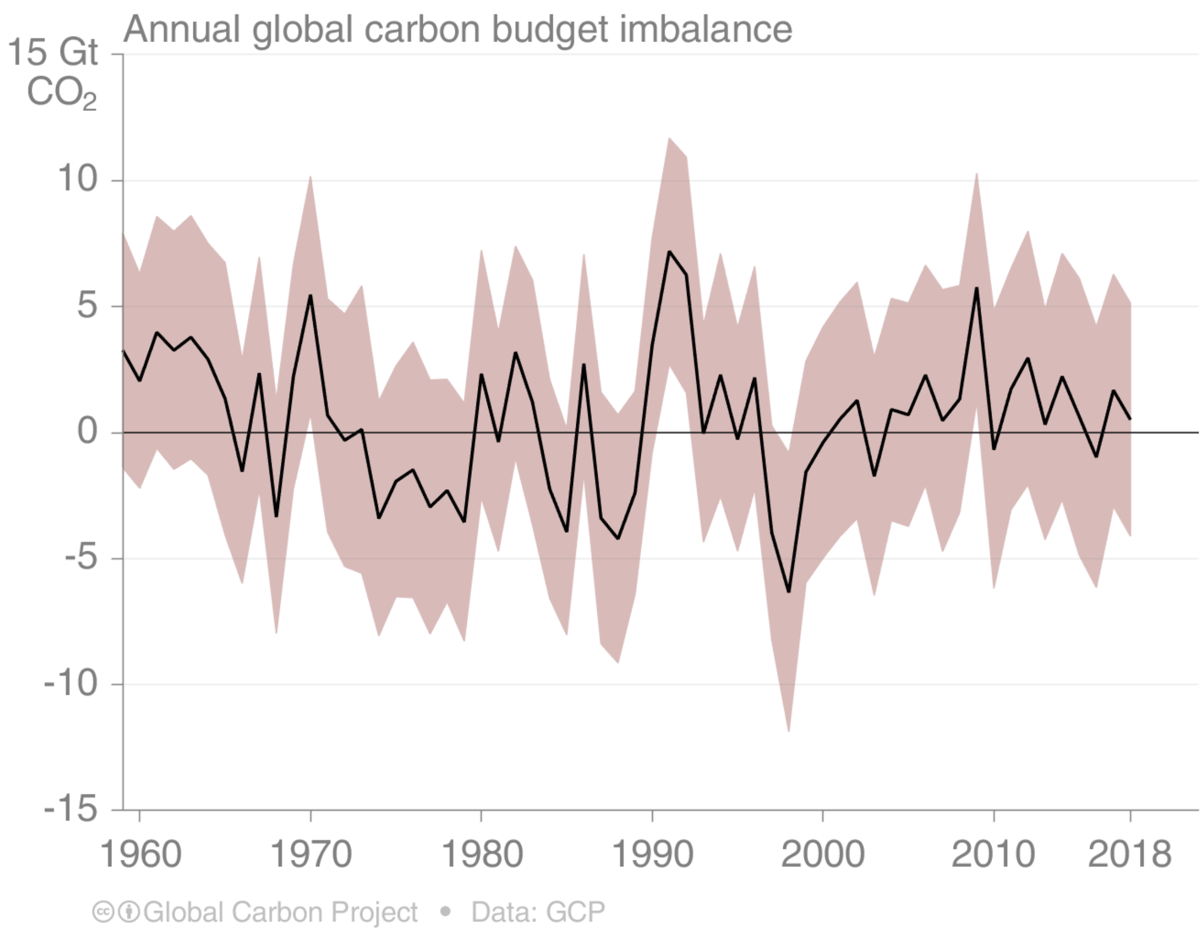
Total land and ocean fluxes show more interannual variability in the tropics



Source: [Friedlingstein et al 2019](#) (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



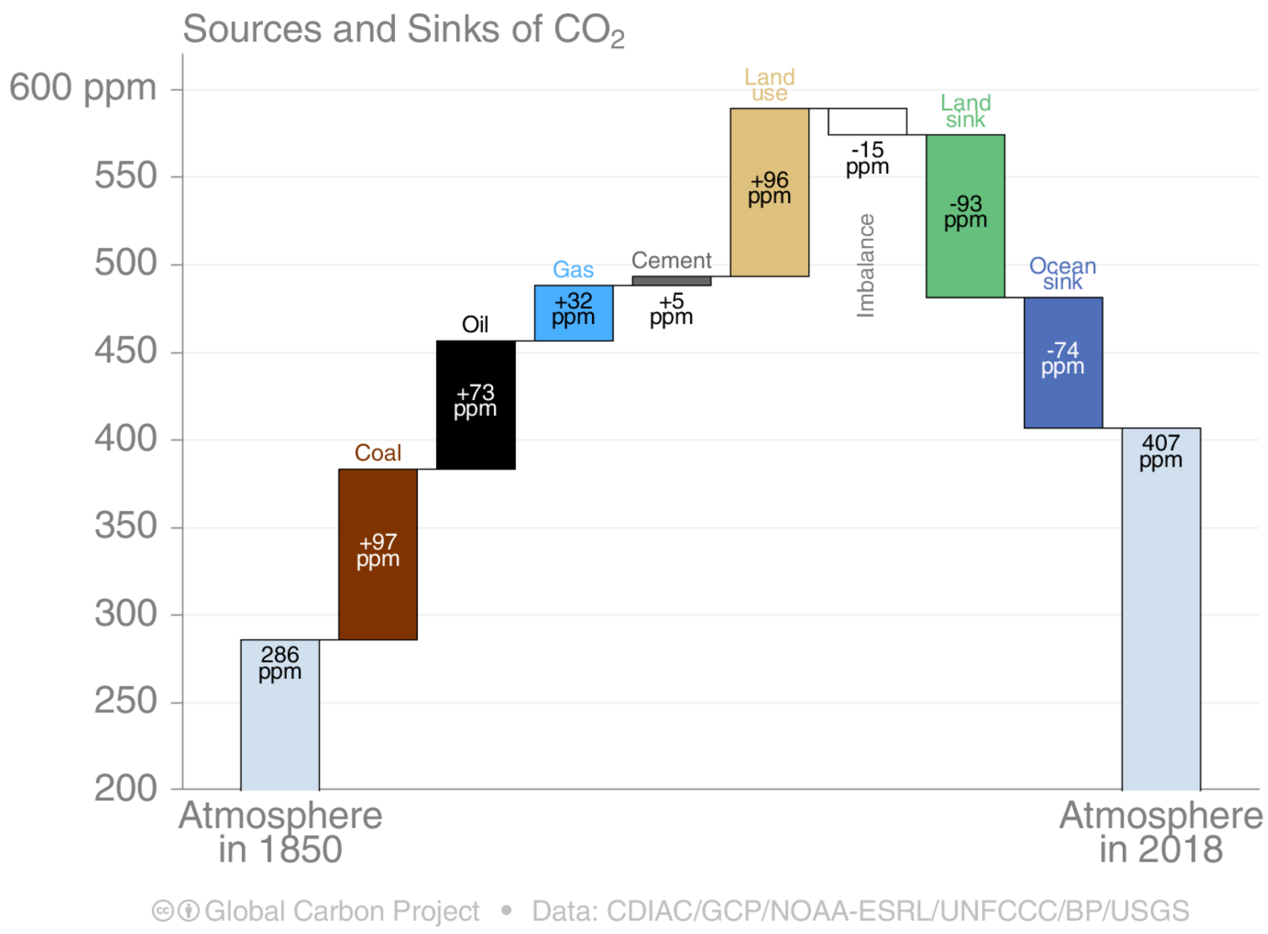
positive values mean overestimated emissions and/or underestimated sinks

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 2019; Global Carbon Budget 2019

Global carbon budget

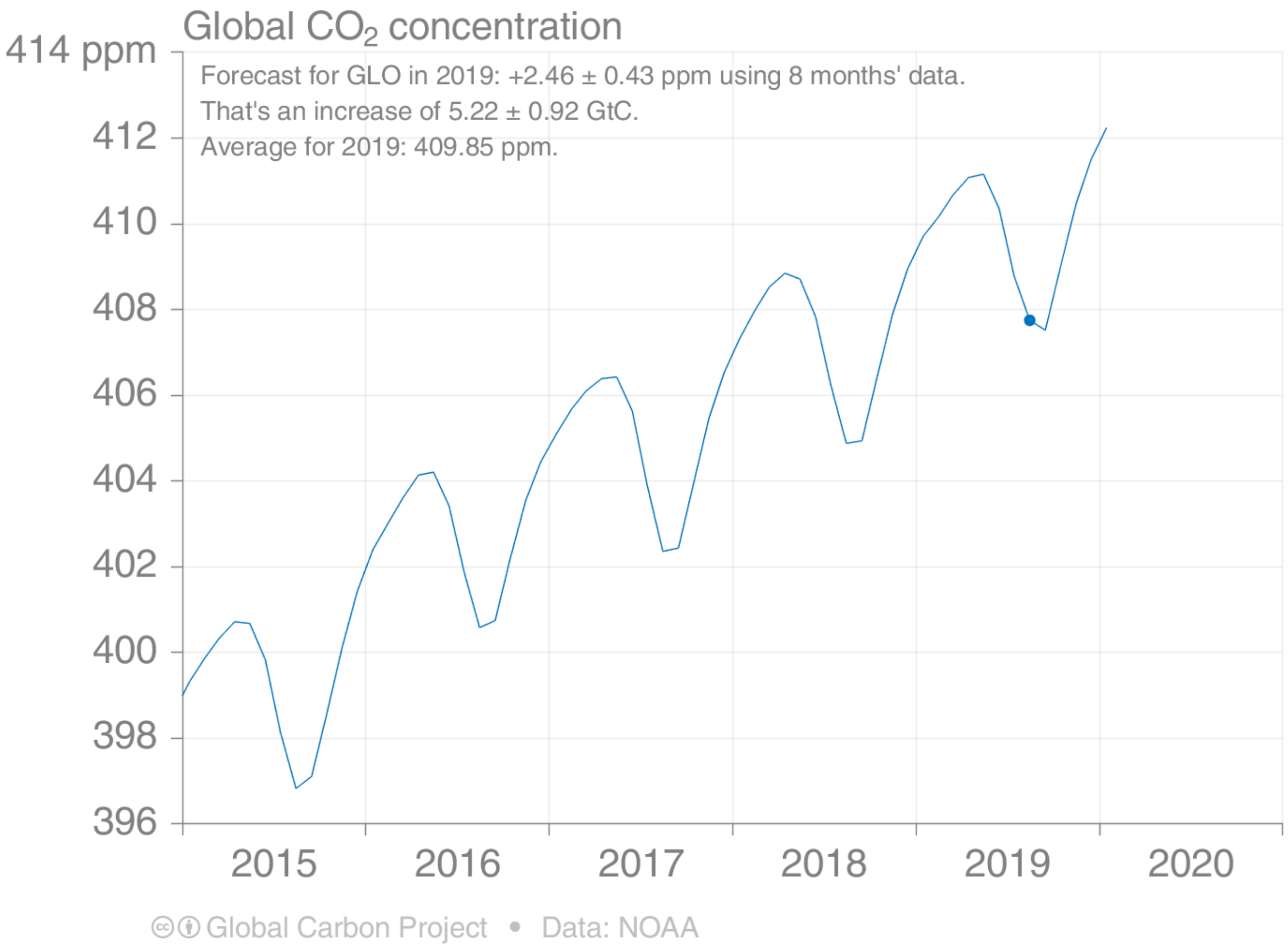
The cumulative contributions to the global carbon budget from 1850
The carbon imbalance represents the gap in our current understanding of sources & sinks



Source: CDIAC; NOAA-ESRL; Houghton and Nassikas 2017; Hansis et al 2015; Joos et al 2013; Khatiwala et al. 2013; DeVries 2014; Friedlingstein et al 2019; Global Carbon Budget 2019

Forecast of global atmospheric CO_2 concentration

The global concentration of atmospheric CO_2 is forecast to average 410 ppm in 2019



Data source: Tans and Keeling (2019), NOAA-ESRL

Infographics

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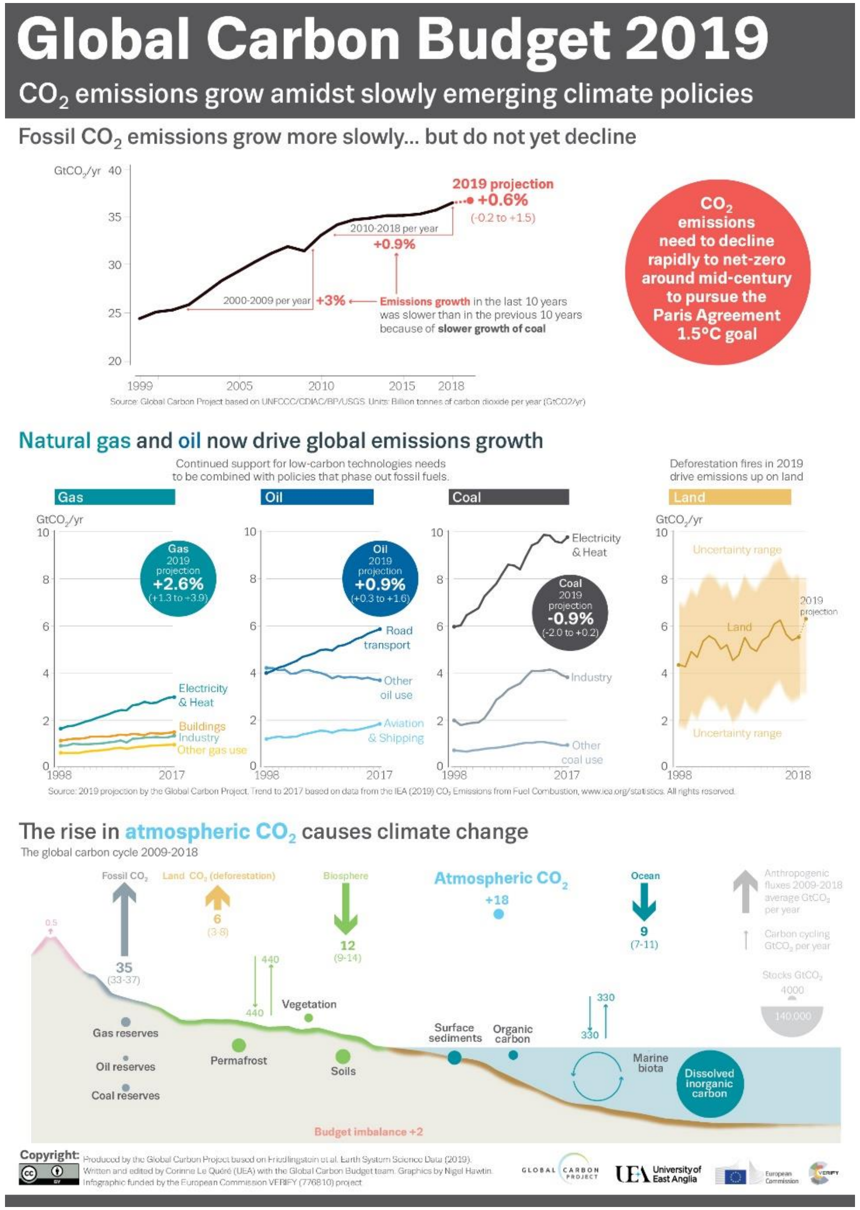
Infographic

futurearth
Research. Innovation. Sustainability.



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Acknowledgements

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The work presented in the **Global Carbon Budget 2019** 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.

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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.

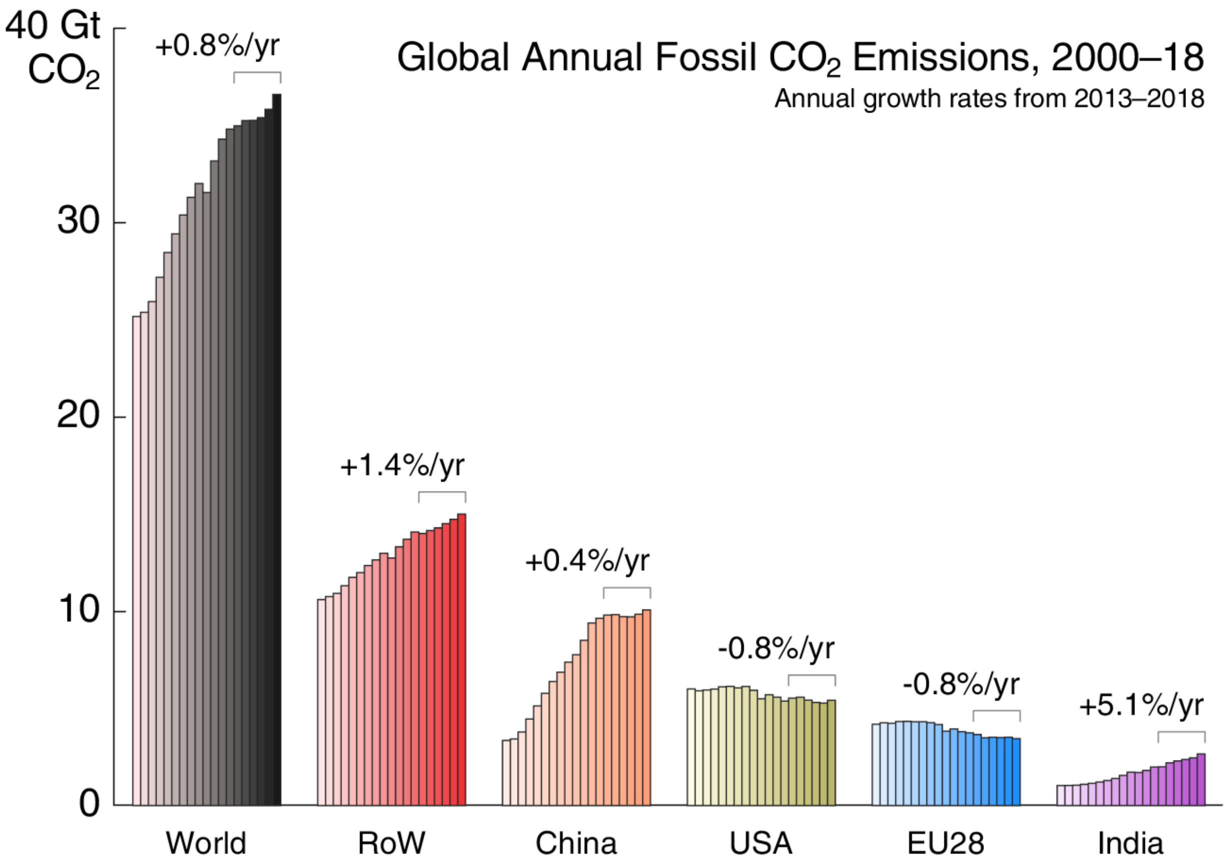
License

Additional Figures

Additional Figures
Fossil CO_2

Top emitters: Fossil CO_2 Emissions

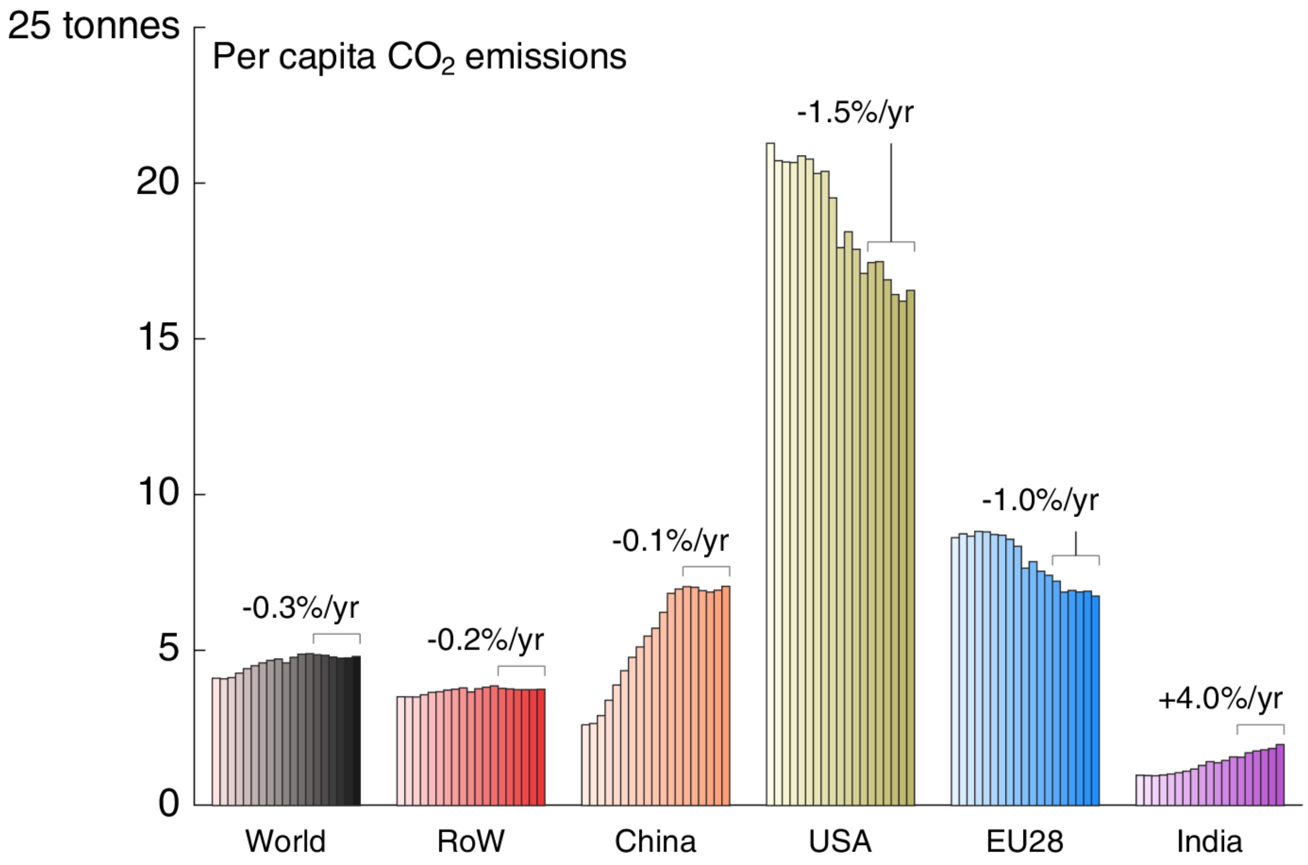
Emissions by country from 2000 to 2018, with the growth rates indicated for the more recent period of 2013 to 2018



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

Per capita CO_2 emissions

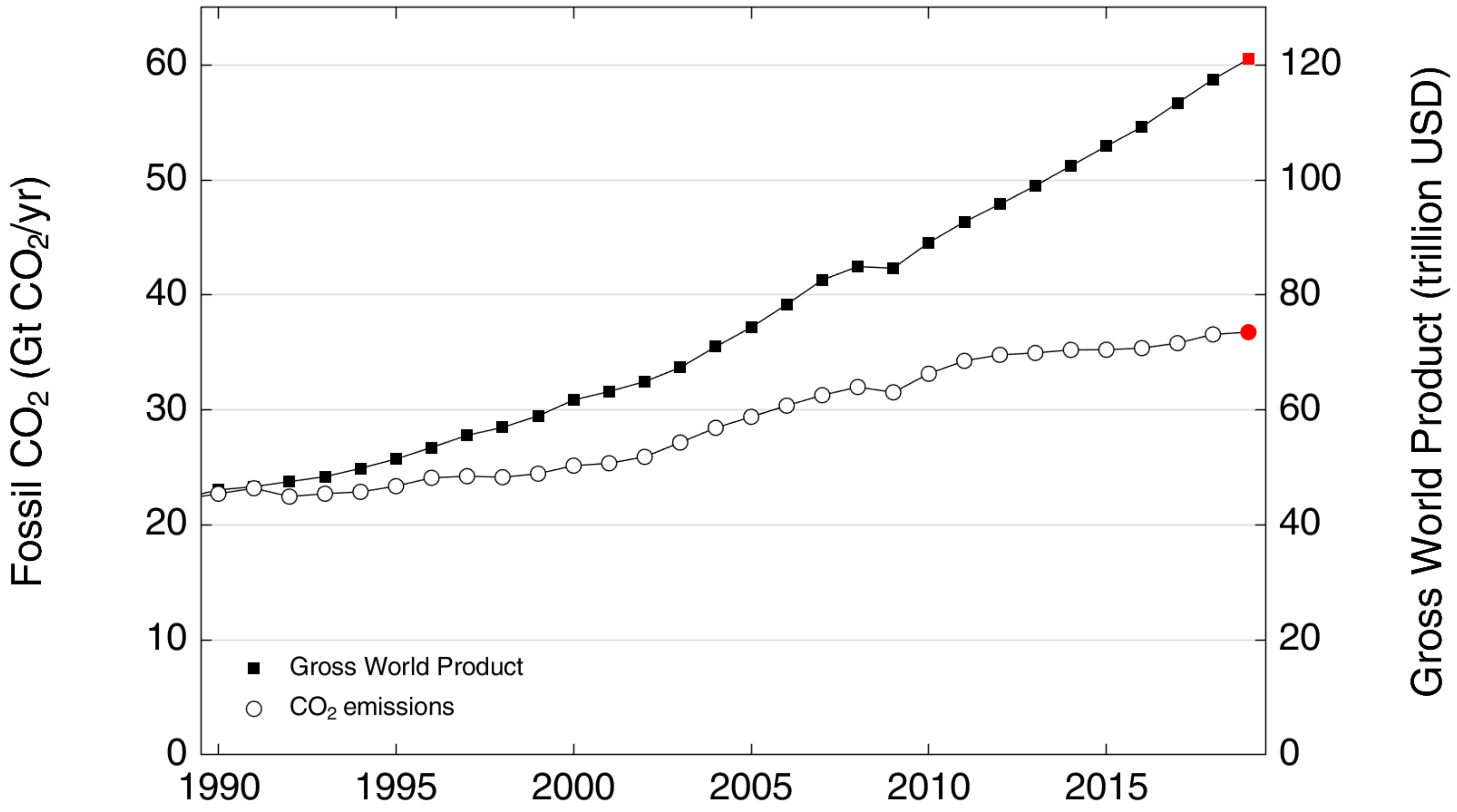
The US has high per capita emissions, but this has been declining steadily. China's per capita emissions have levelled out and is now the same as the EU. India's emissions are low per capita.



Source: Jackson et al 2019; Global Carbon Budget 2019

CO_2 emissions and economic activity

The global economy continues to grow faster than emissions.
A step change is needed in emission intensity improvements to drive emissions down.

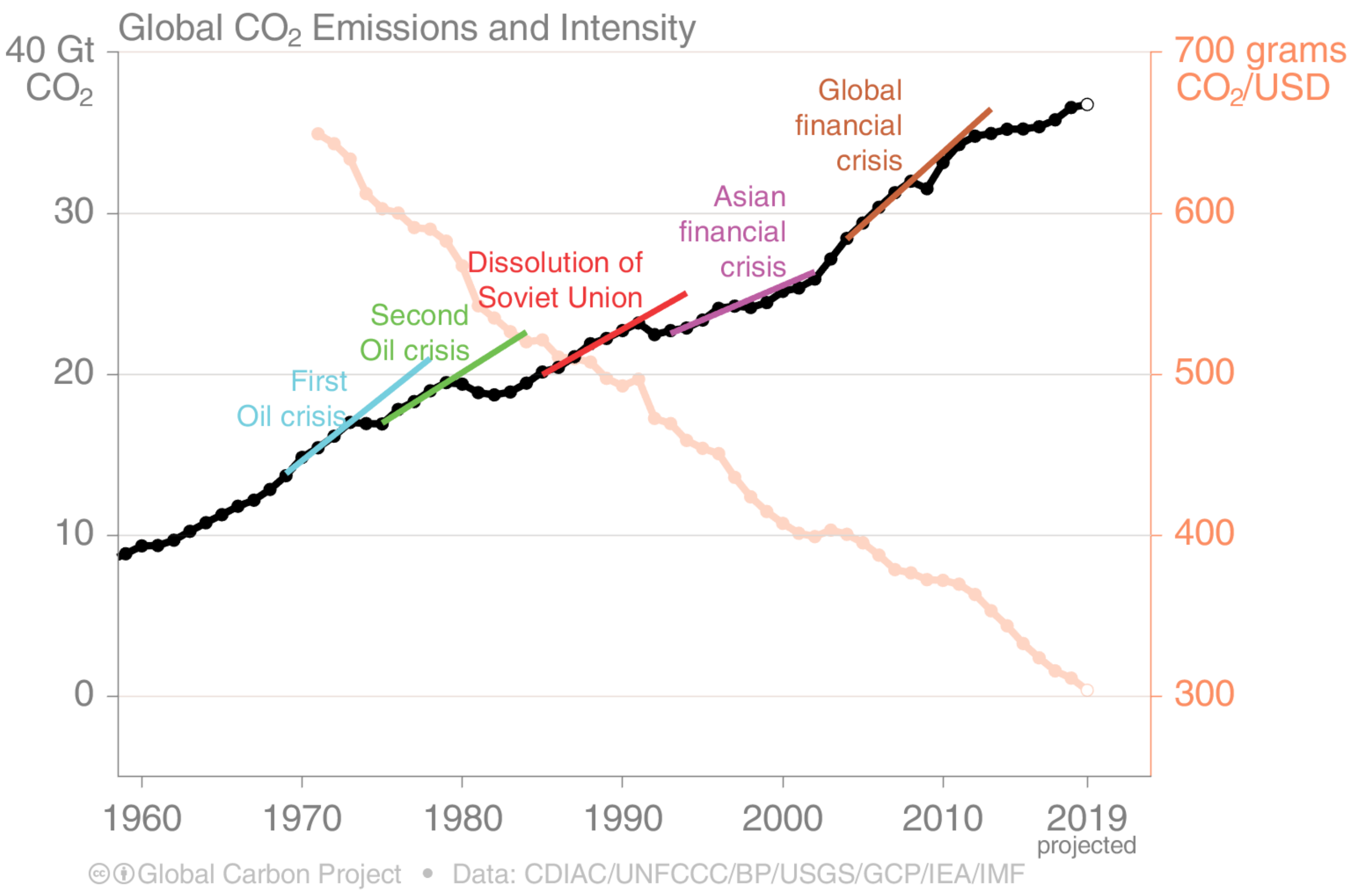


CO_2 = CO_2 intensity × GDP

Source: Jackson et al 2019; Global Carbon Budget 2019

Fossil CO_2 emission intensity

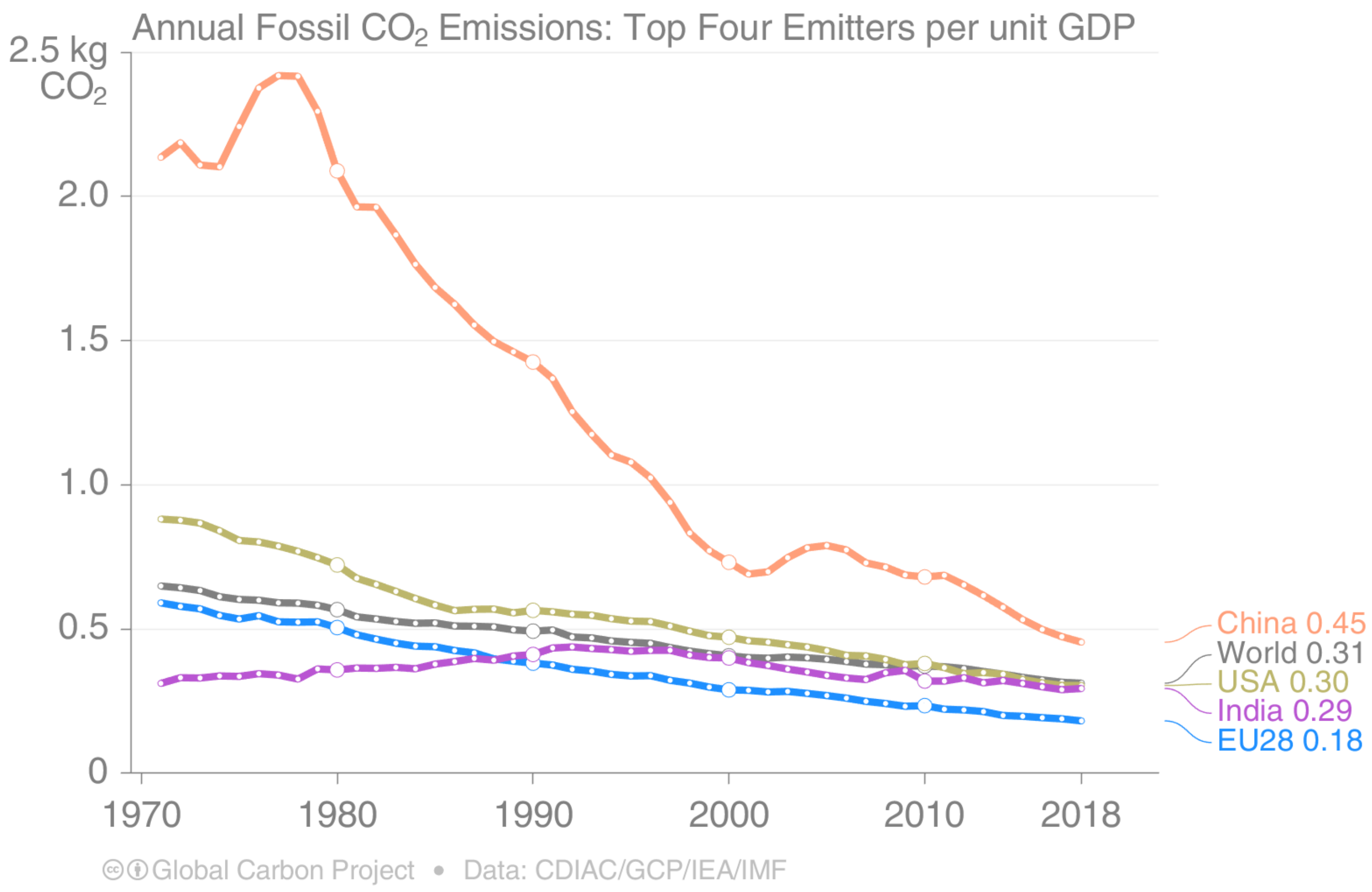
Global CO_2 emissions growth has generally resumed quickly from financial crises.
Emission intensity has steadily declined but not sufficiently to offset economic growth.



Economic activity is measured in purchasing power parity (PPP) terms in 2010 US dollars.
Source: CDIAC; Peters et al 2012; Friedlingstein et al 2019; Global Carbon Budget 2019

Top emitters: Fossil CO_2 Emission Intensity

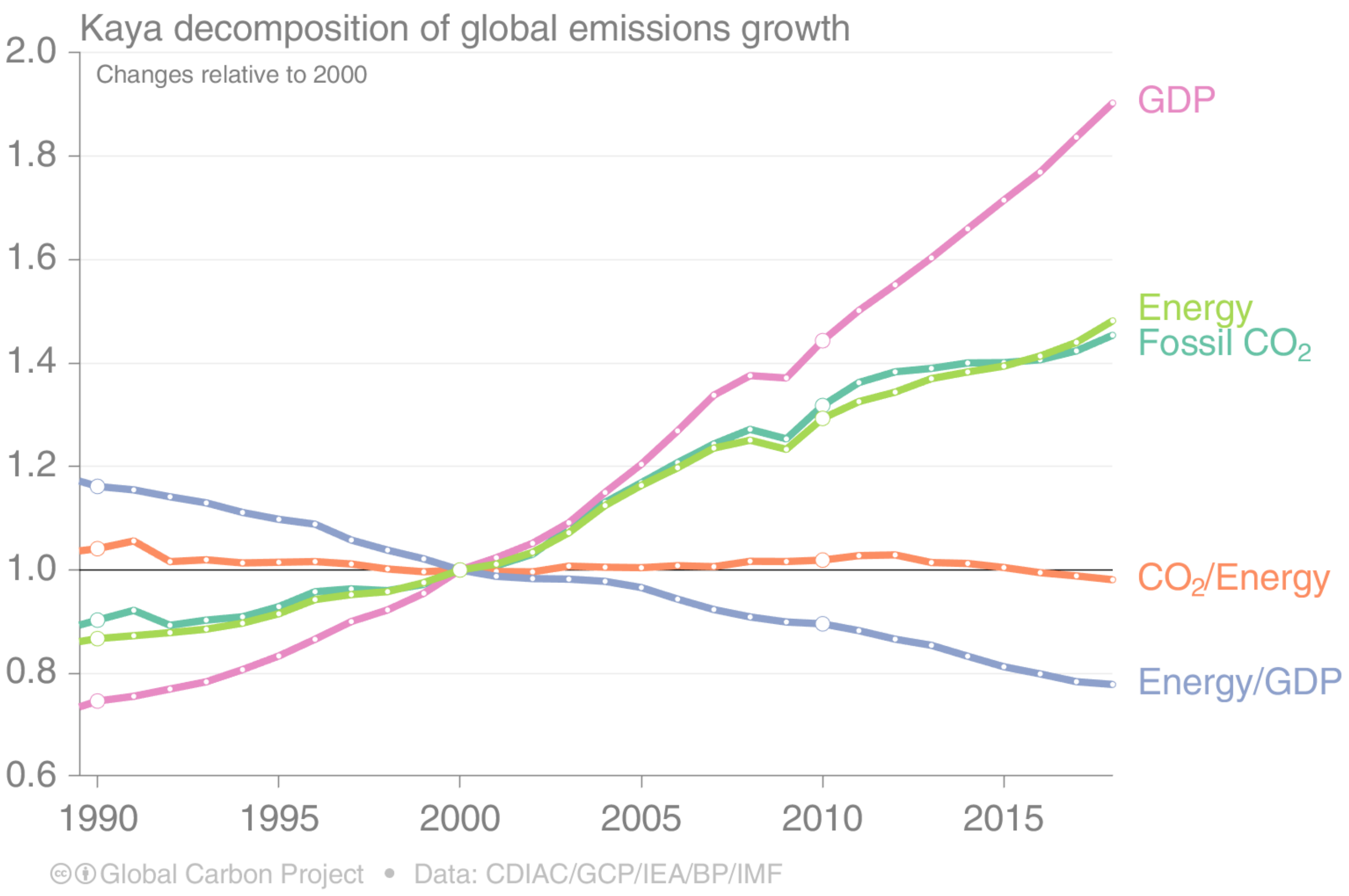
Emission intensity (emission per unit economic output) generally declines over time.
In many countries, these declines are insufficient to overcome economic growth.



GDP is measured in purchasing power parity (PPP) terms in 2010 US dollars.
Source: CDIAC; IEA 2018 GDP to 2016, IMF 2019 growth rates to 2018; Friedlingstein et al 2019; Global Carbon Budget 2019

Kaya decomposition

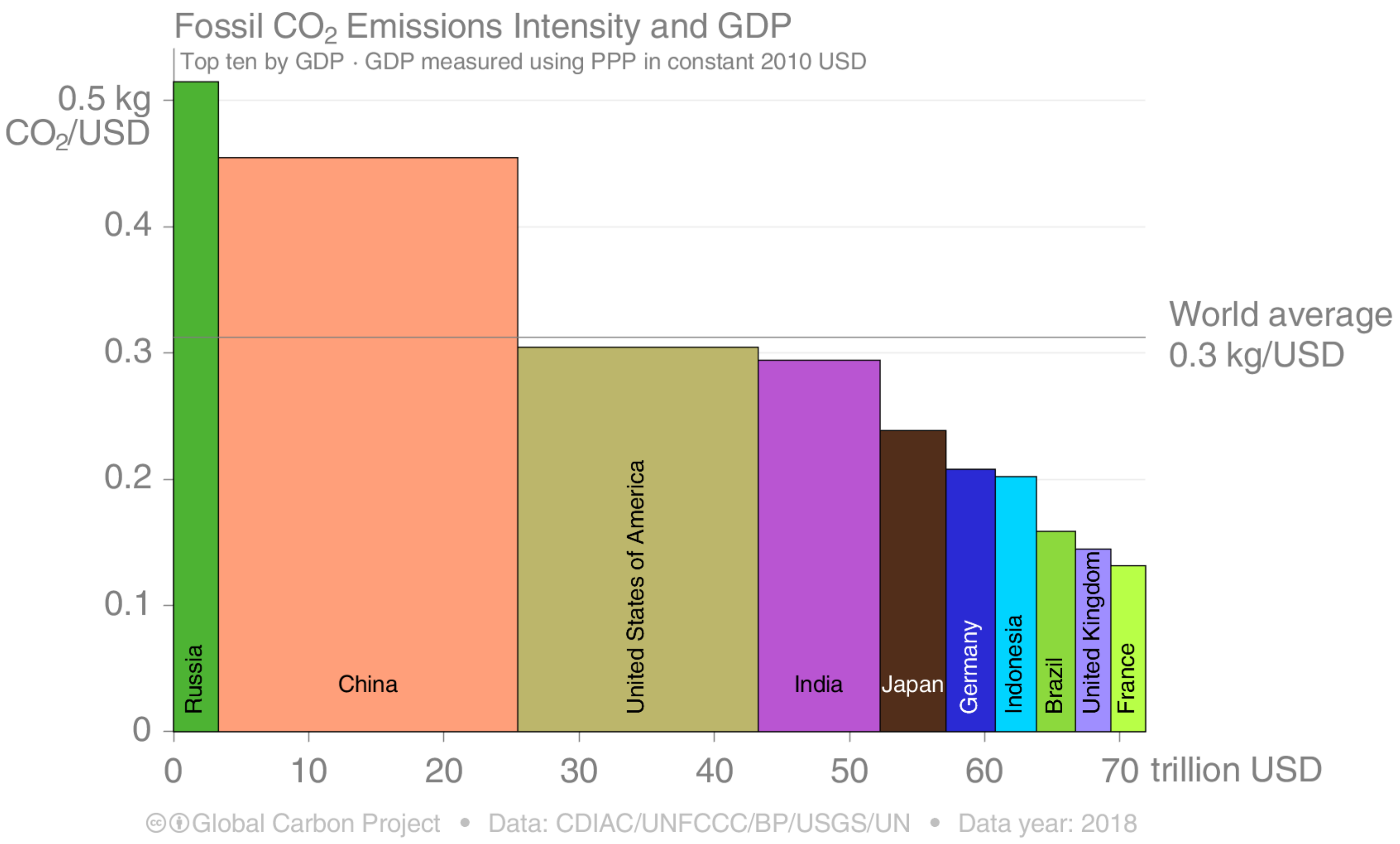
The Kaya decomposition illustrates that relative decoupling of economic growth from CO_2 emissions is driven by improved energy intensity (Energy/GDP)



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 2019

Fossil CO_2 emission intensity

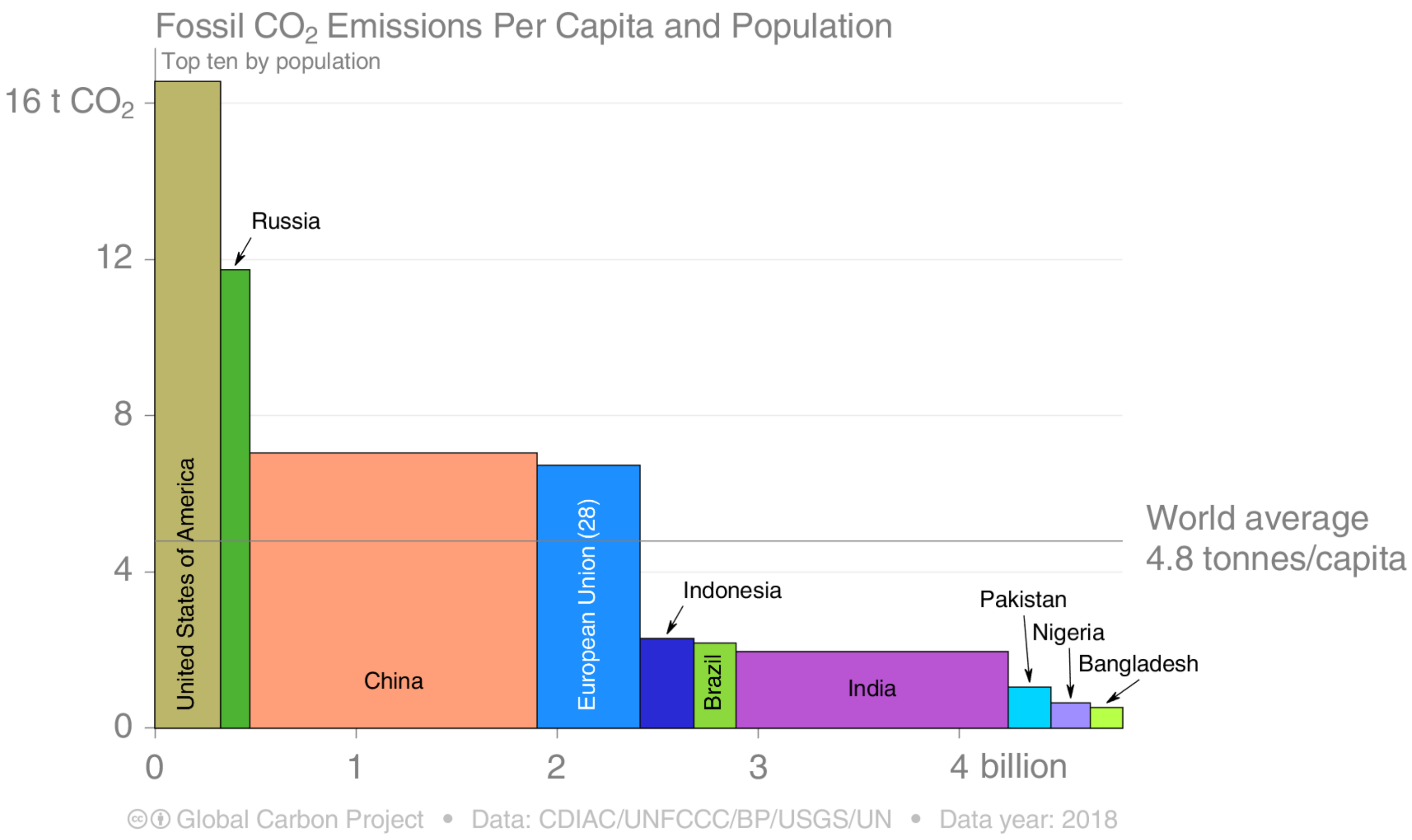
The 10 largest economies have a wide range of emission intensity of economic activity



Emission intensity: Fossil CO_2 emissions divided by Gross Domestic Product (GDP)
Source: Global Carbon Budget 2019

Fossil CO_2 Emissions per capita

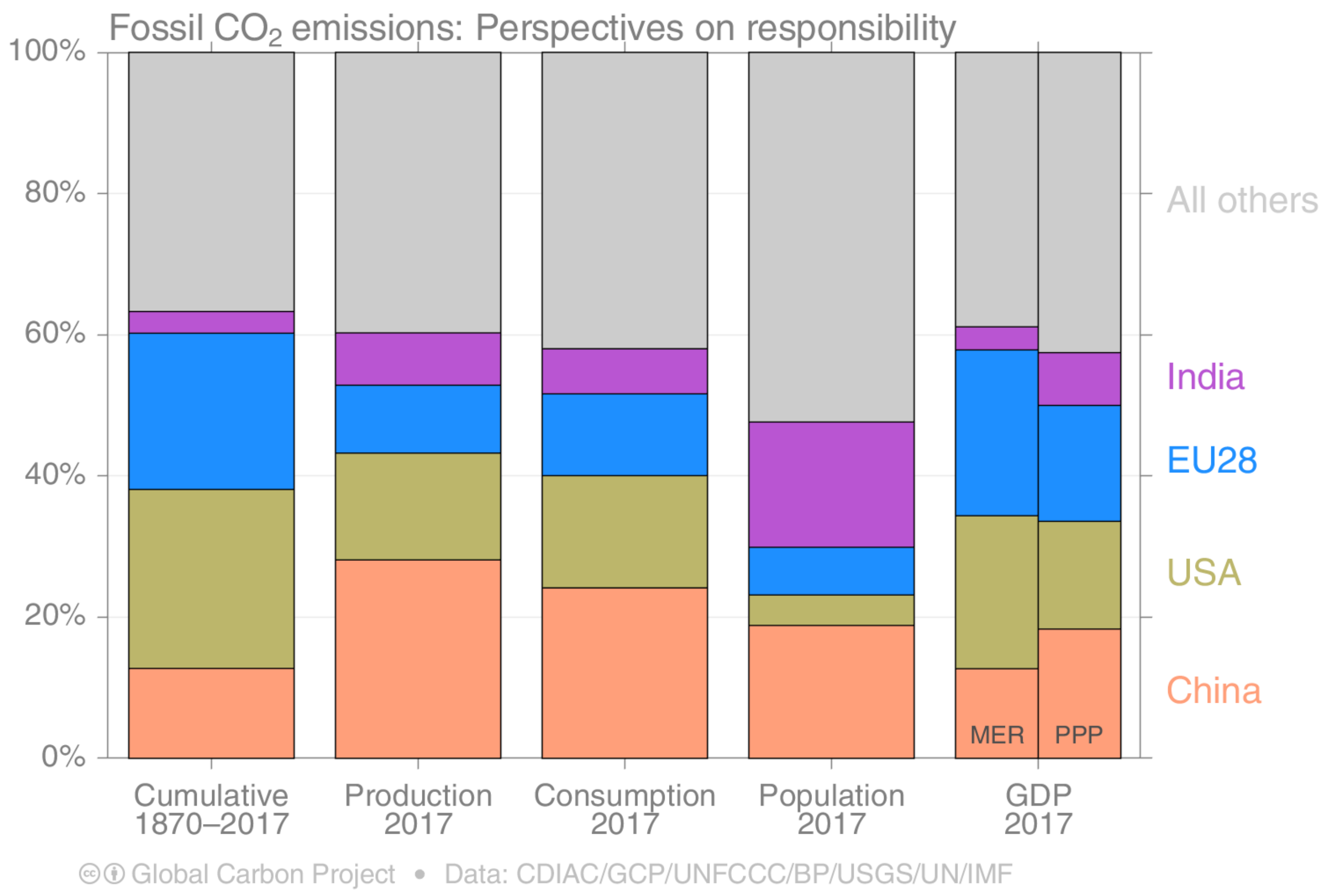
The 10 most populous countries span a wide range of development and emissions per capita



Emission per capita: Fossil CO_2 emissions divided by population
Source: Global Carbon Budget 2019

Alternative rankings of countries

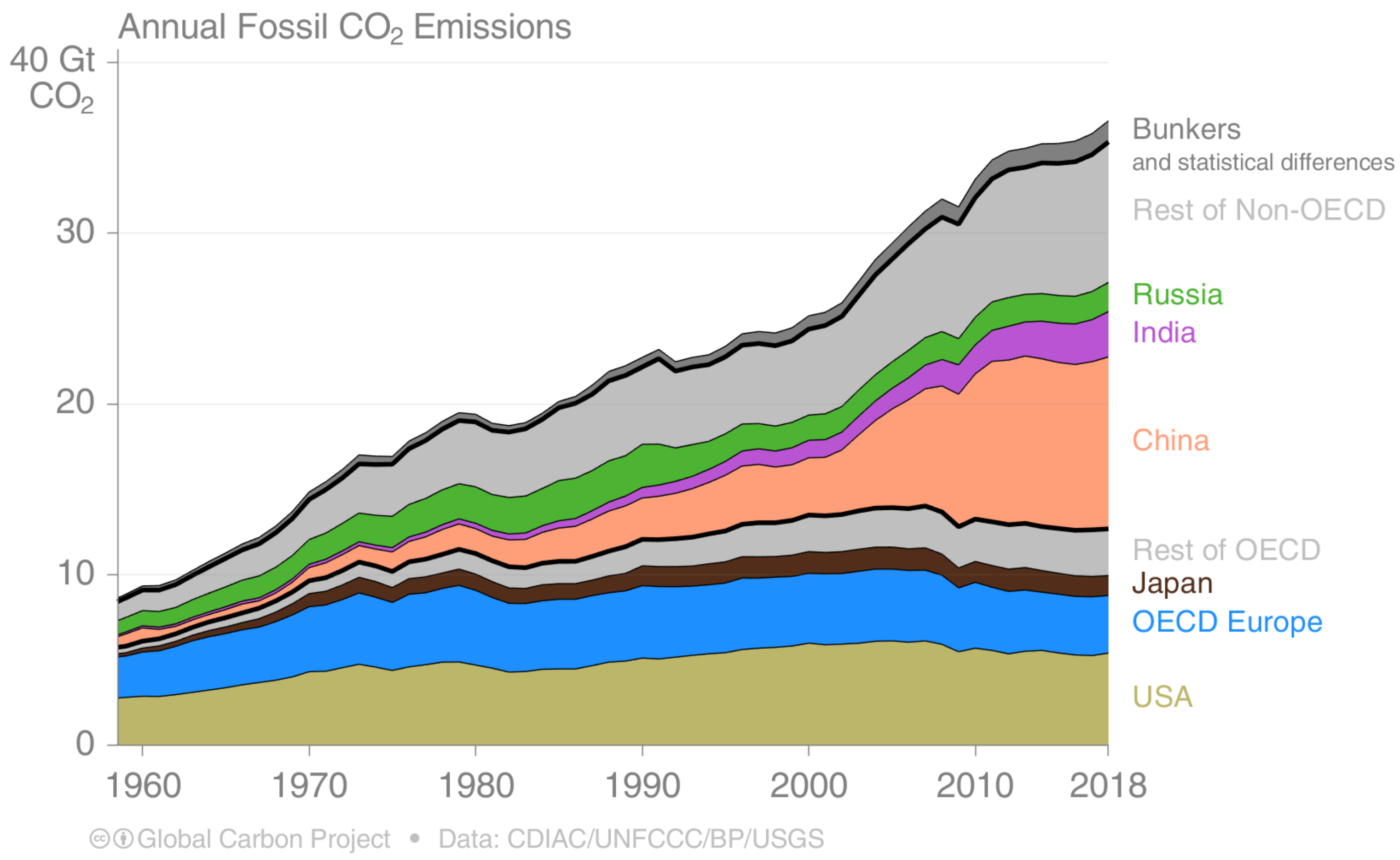
The responsibility of individual countries depends on perspective.
Bars indicate fossil CO_2 emissions, population, and GDP.



GDP: Gross Domestic Product in Market Exchange Rates (MER) and Purchasing Power Parity (PPP)
Source: CDIAC; United Nations; Friedlingstein et al 2019; Global Carbon Budget 2019

Breakdown of global fossil CO_2 emissions by country

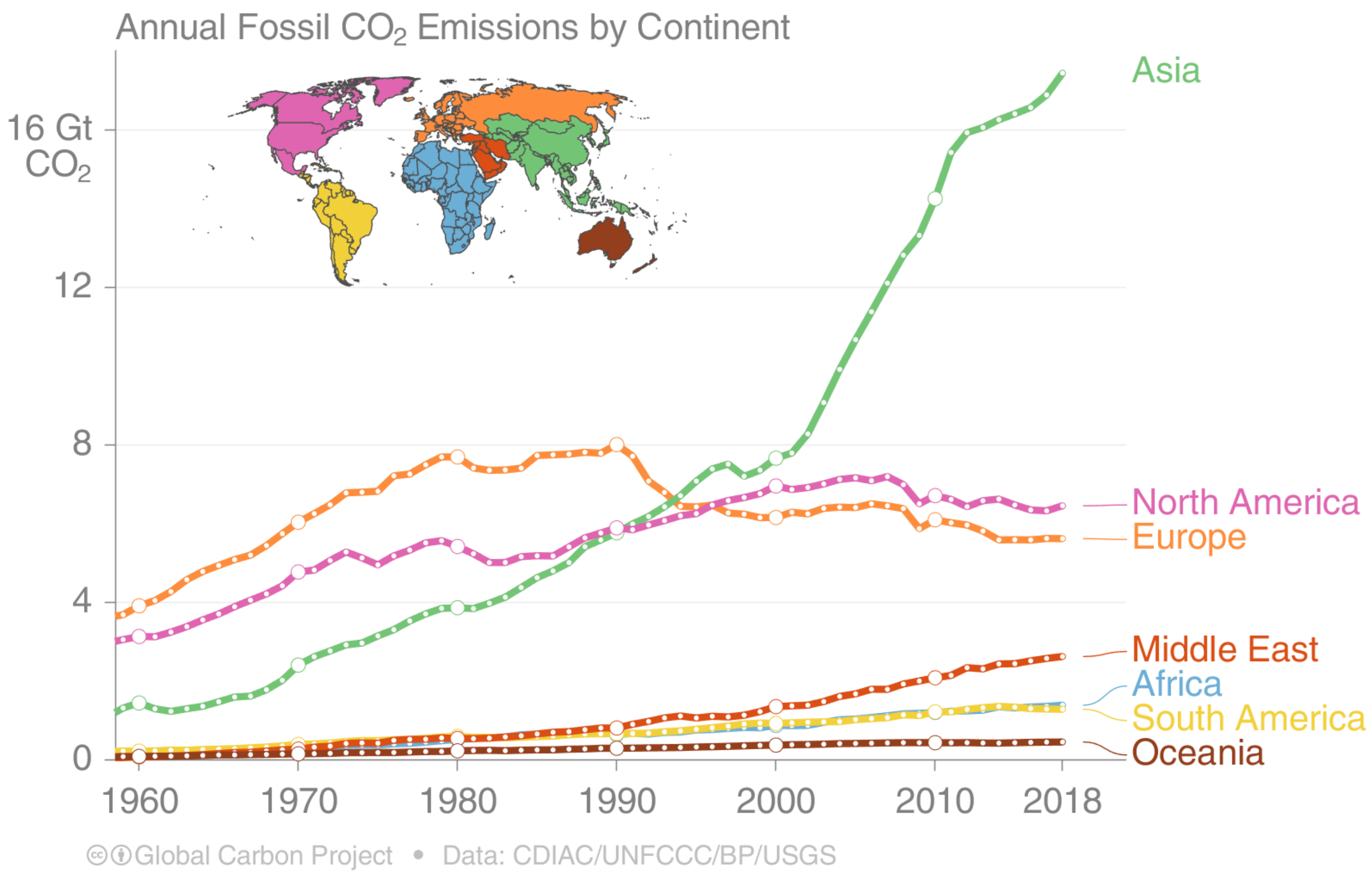
Emissions in OECD countries have increased by 5% since 1990, despite declining 10% from their maximum in 2007
Emissions in non-OECD countries & from international shipping and aviation (bunkers) have more than doubled since 1990



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

Fossil CO_2 emissions by continent

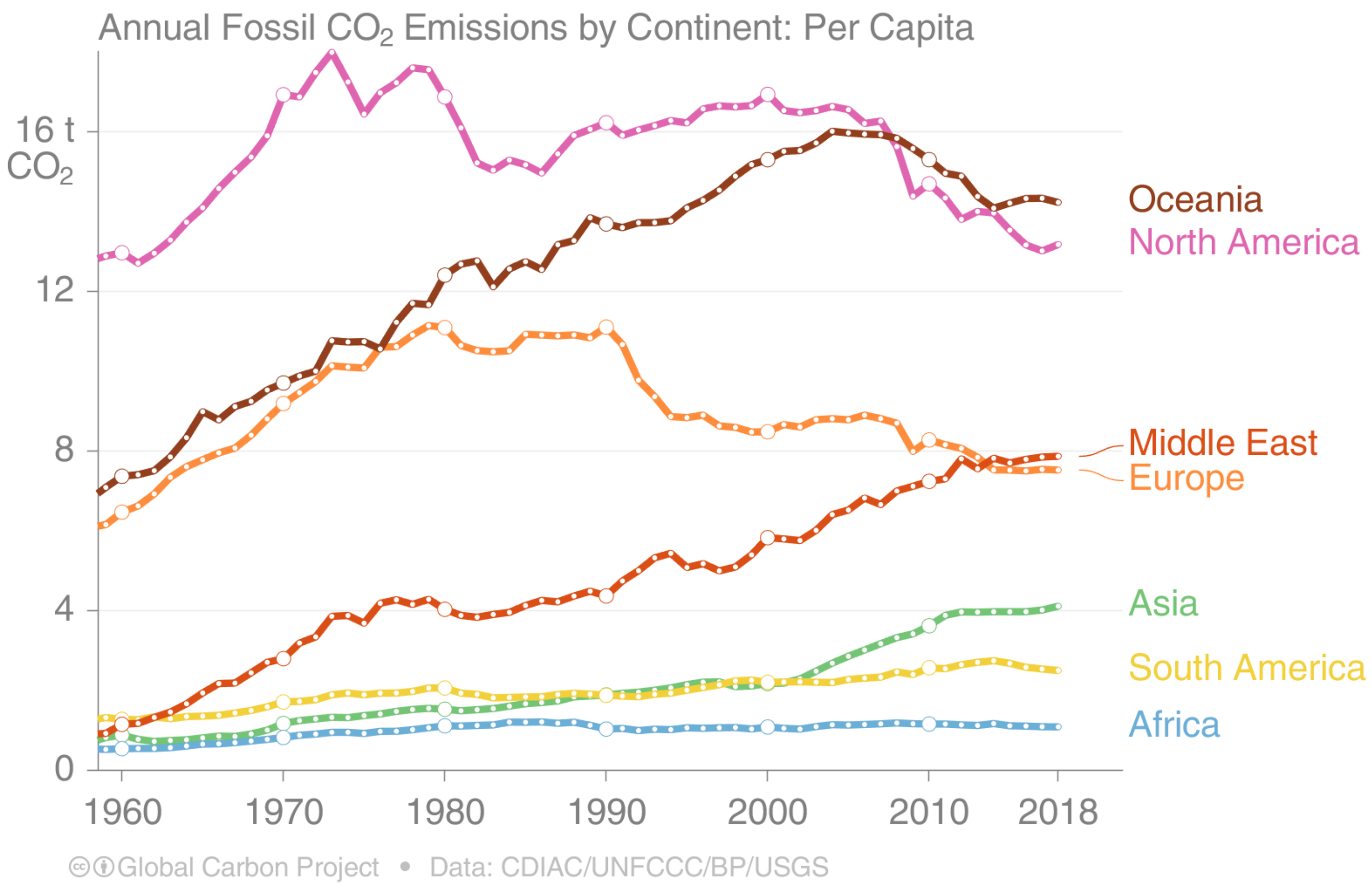
Asia dominates global fossil CO_2 emissions, while emissions in North America are of similar size to those in Europe, and the Middle East is growing rapidly.



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

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.



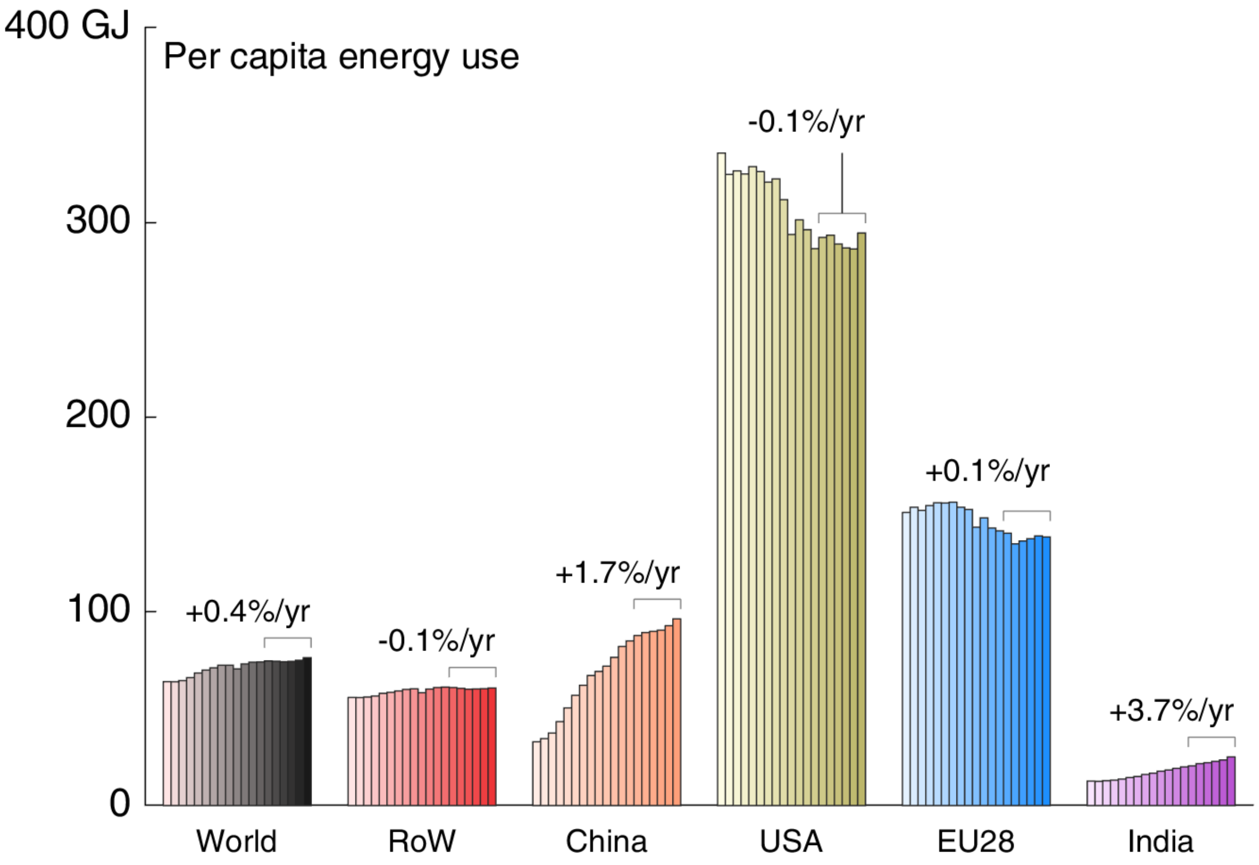
The global average was 4.8 tonnes per capita in 2018.

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

Additional Figures
Energy use

Per capita energy use

There are large differences in energy use per capita between countries, with some differences to emissions per capita due to differences in the country-level energy mix



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

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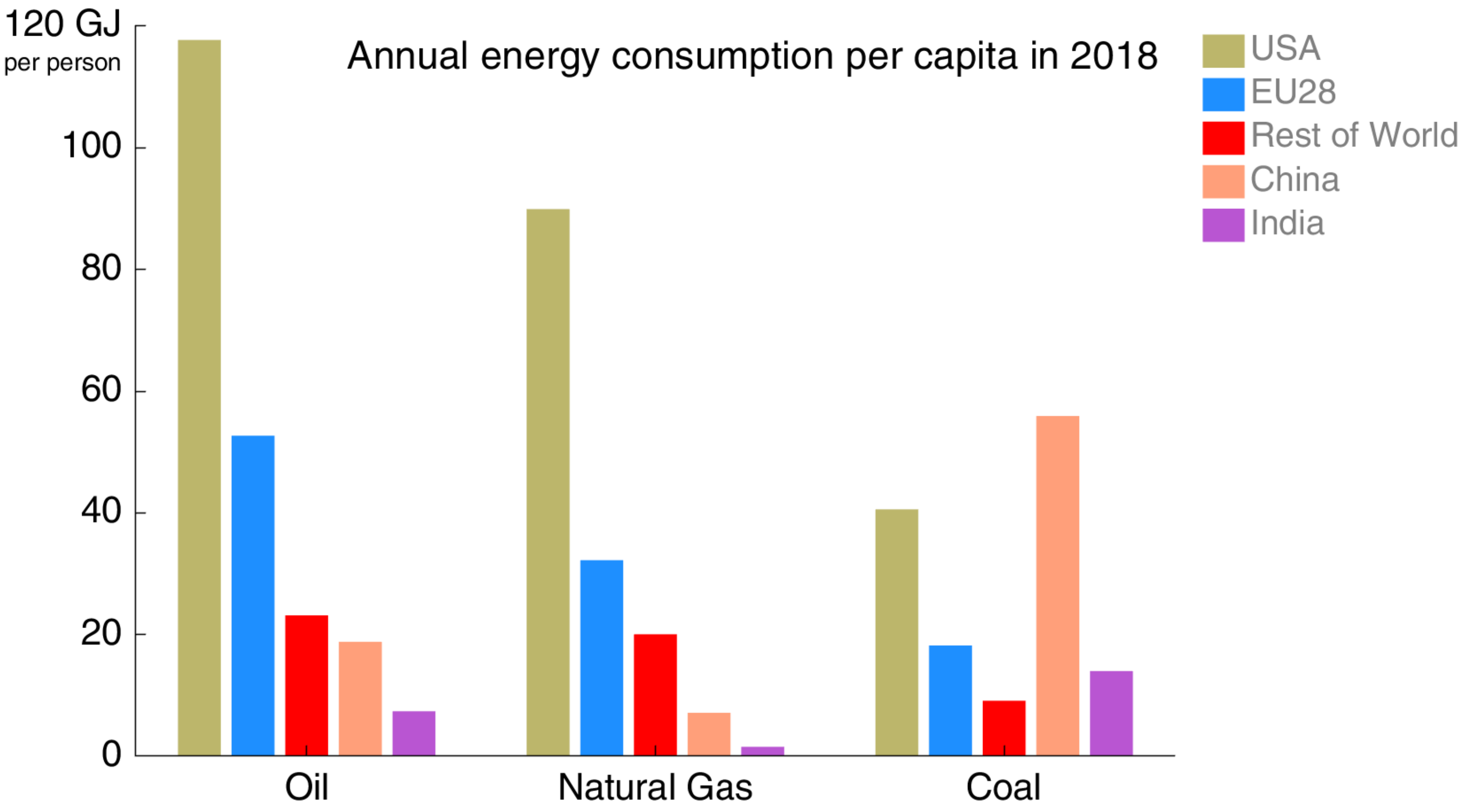
Per capita energy use

There are large differences in energy use per capita between countries, with some differences to emissions per capita due to differences in the country-level energy mix



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

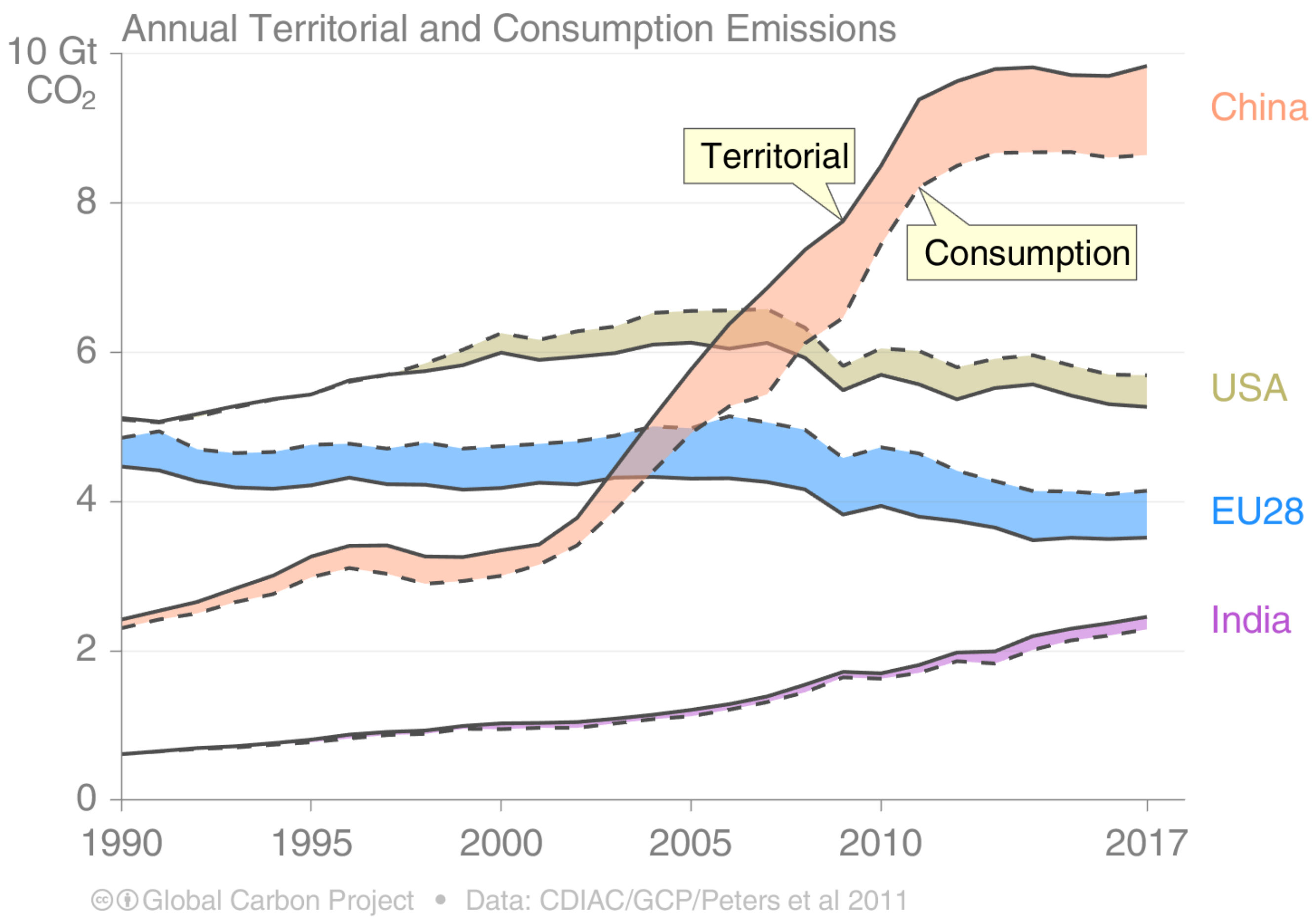
Additional Figures
Consumption-based Emissions

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.

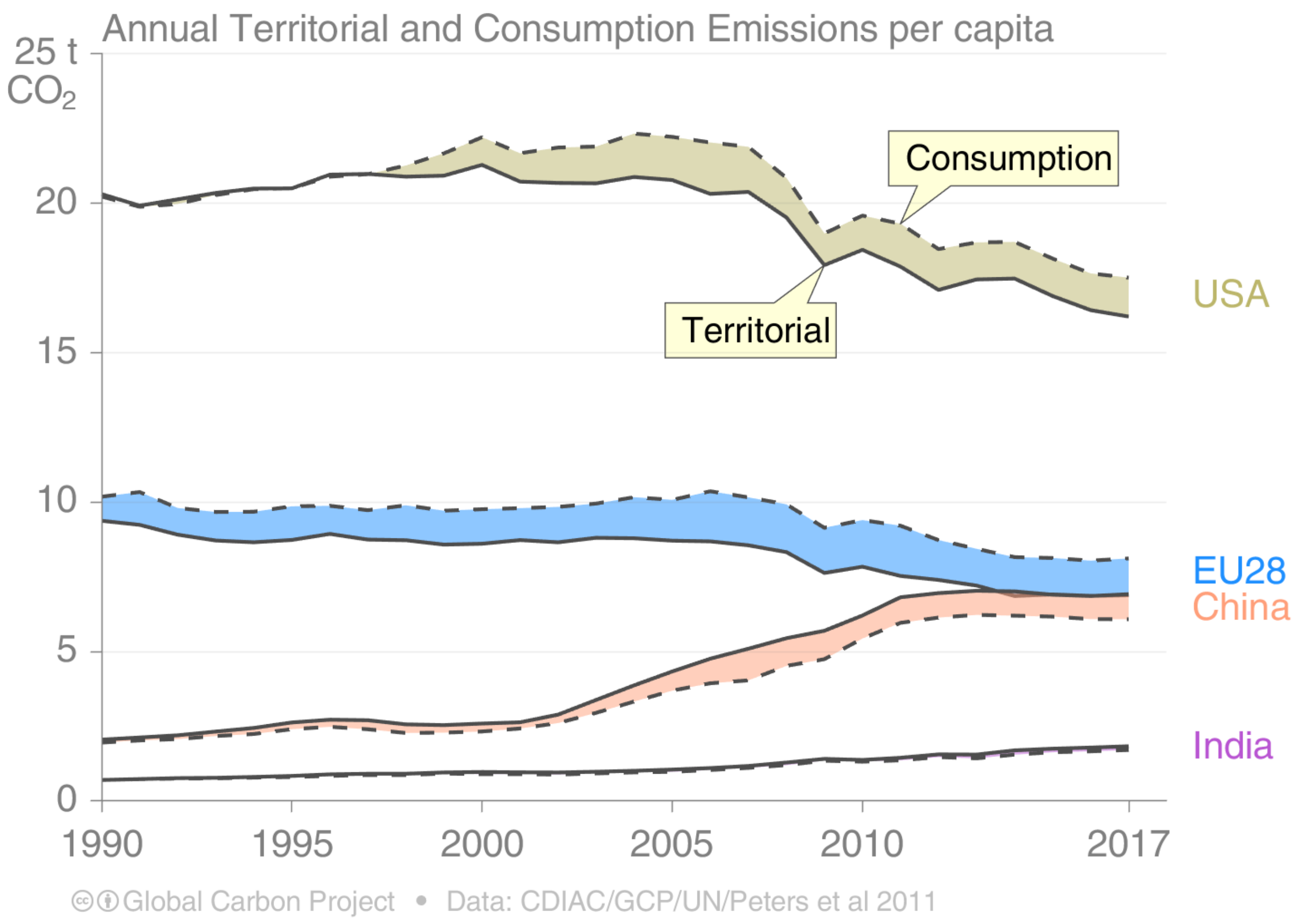


Consumption-based emissions are calculated by adjusting the standard production-based emissions to account for international trade

Source: Peters et al 2011; Friedlingstein et al 2019; 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.

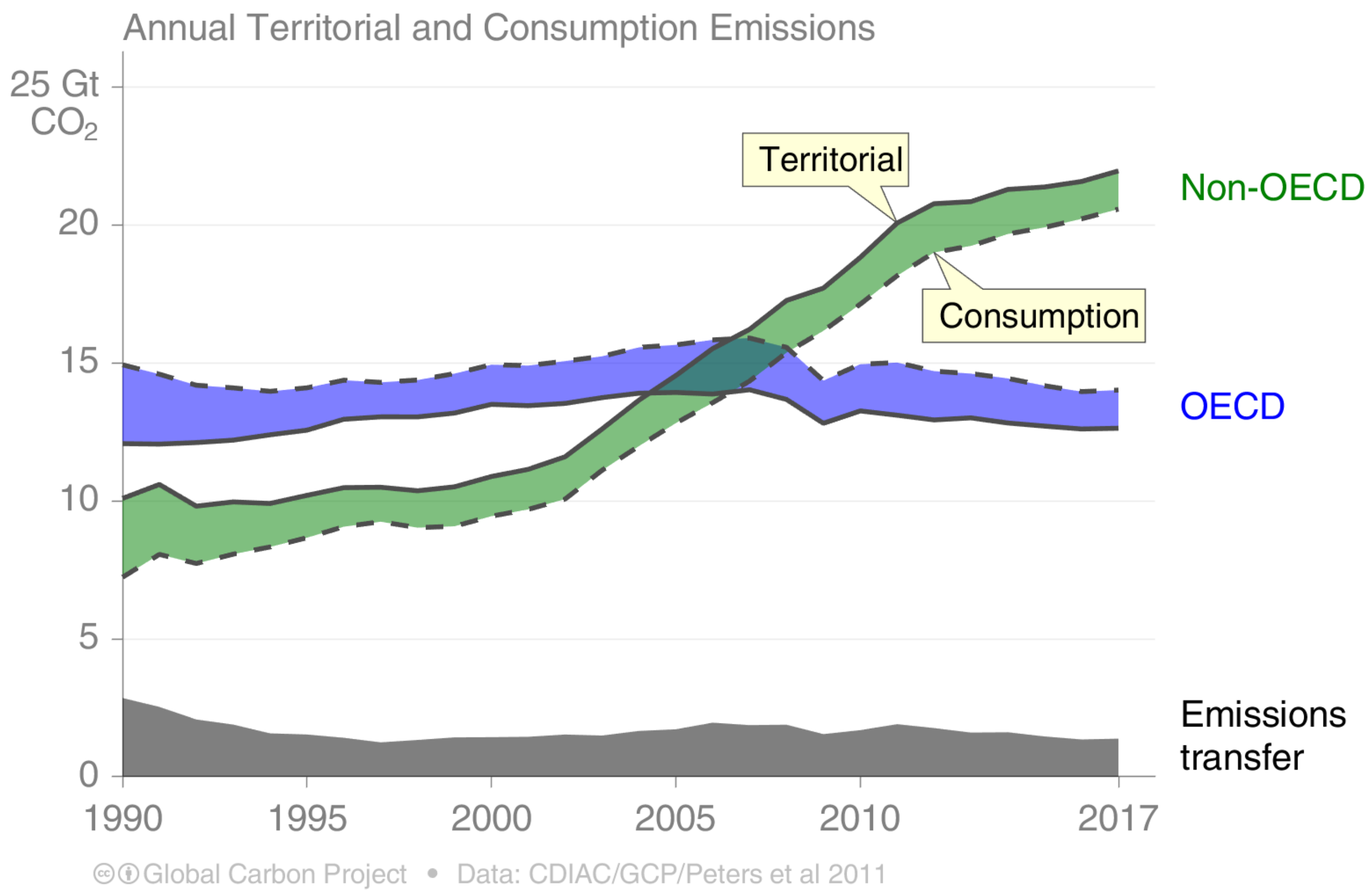


Consumption-based emissions are calculated by adjusting the standard production-based emissions to account for international trade

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

Consumption-based emissions (carbon footprint)

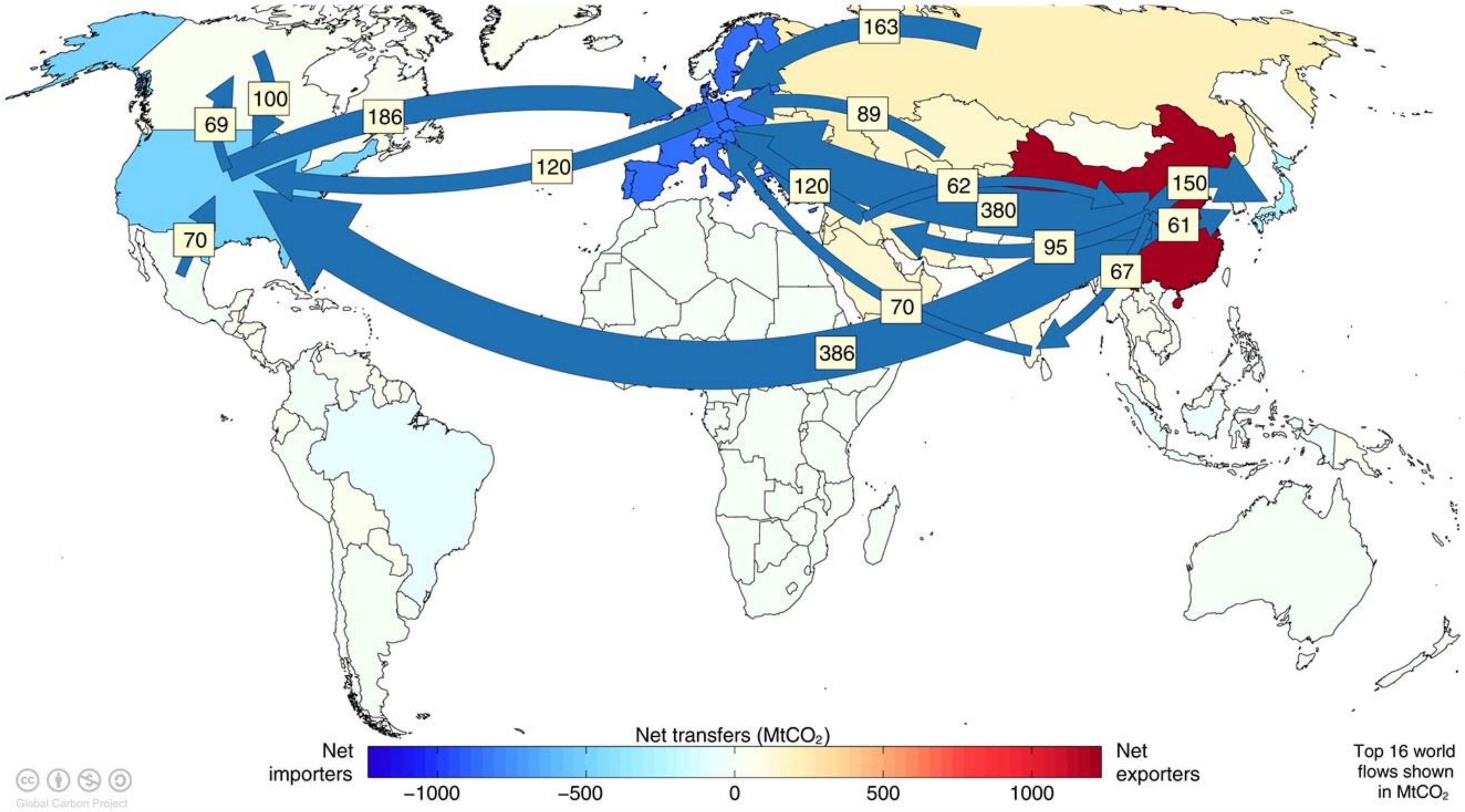
Transfers of emissions embodied in trade between OECD and non-OECD countries grew slowly during the 2000's, but has since slowly declined.



Source: CDIAC; Peters et al 2011; Friedlingstein et al 2019; Global Carbon Budget 2019

Major flows from production to consumption

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

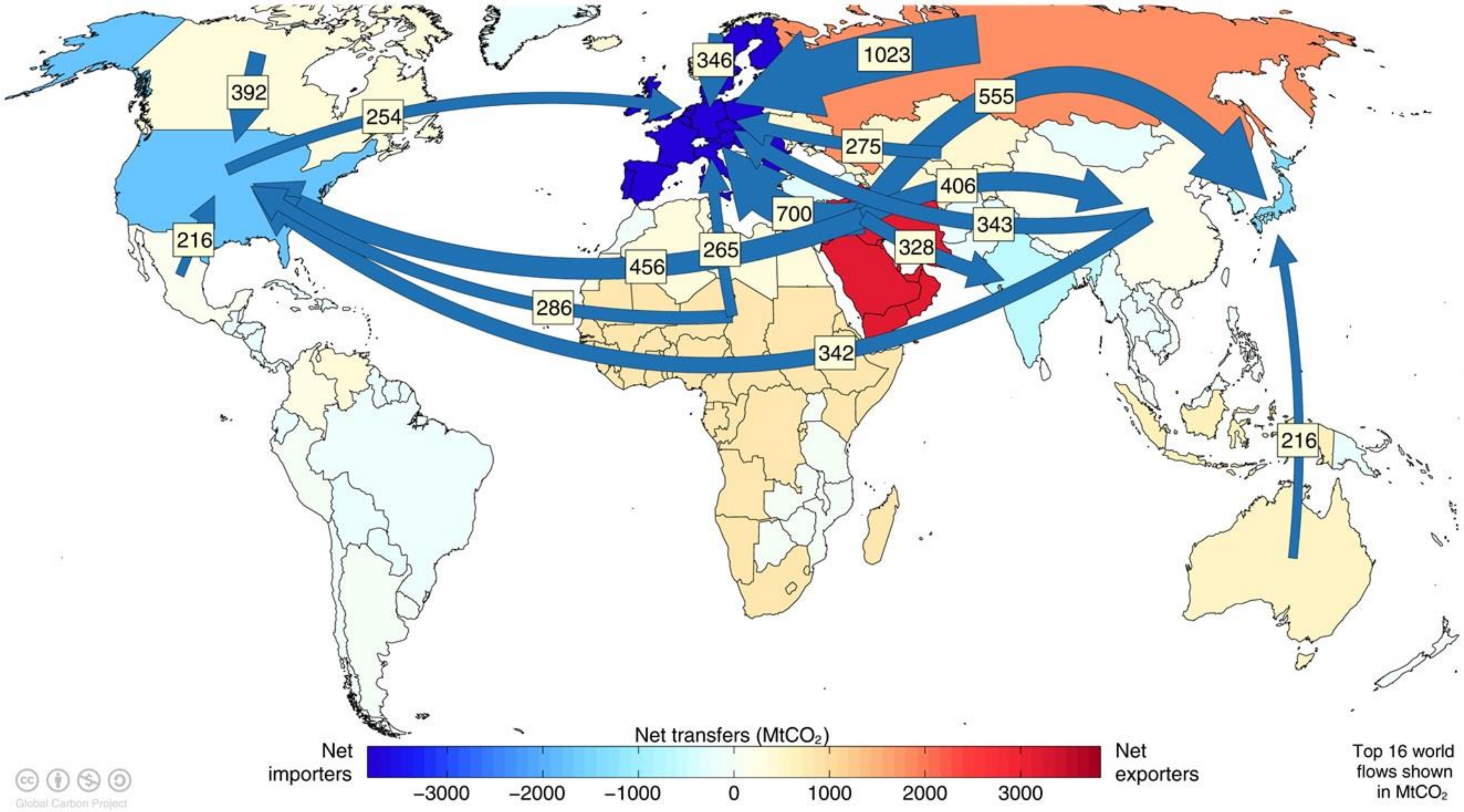


Values for 2011. EU is treated as one region. Units: $MtCO_2$

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



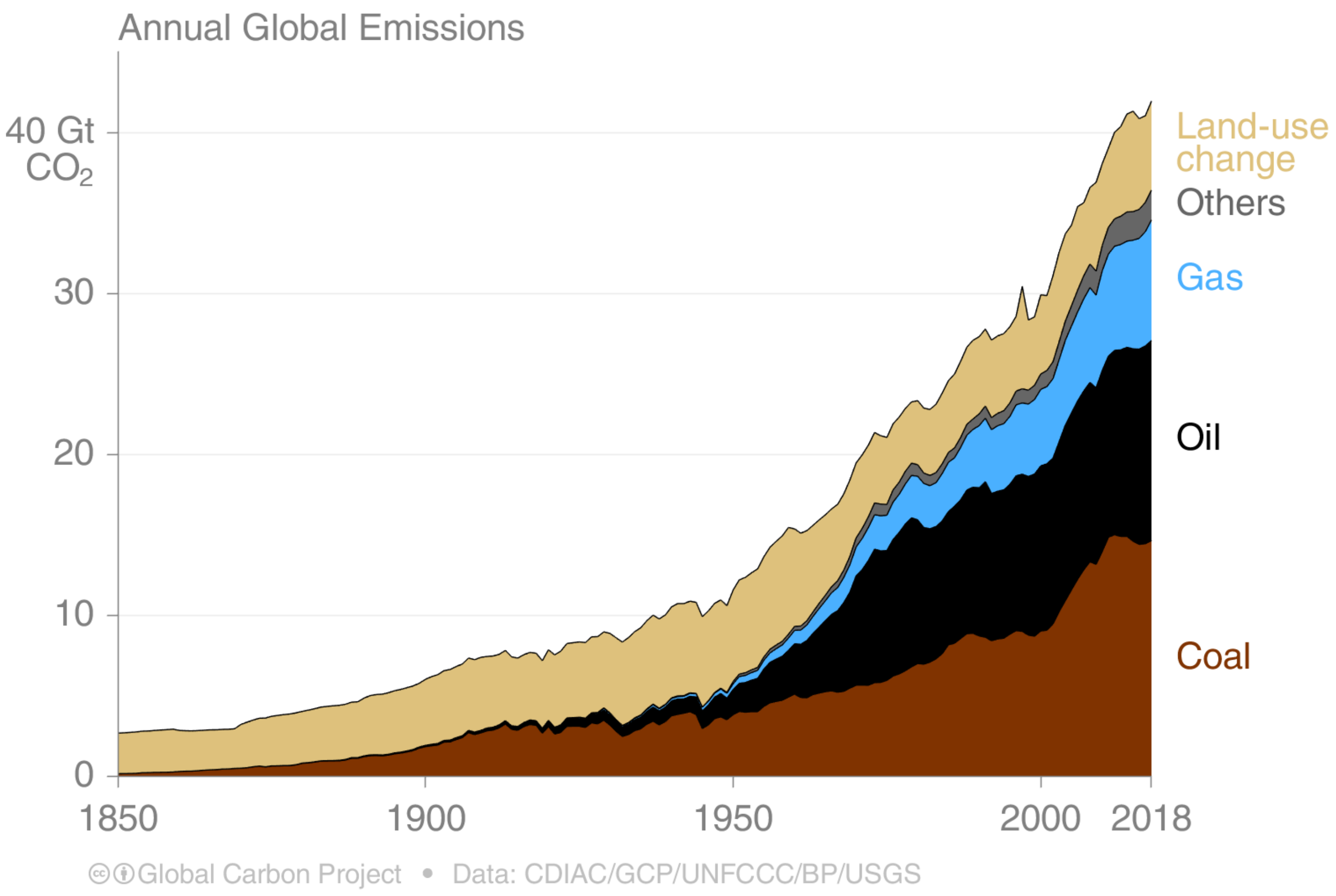
Values for 2011. EU is treated as one region. Units: $MtCO_2$

Source: Andrew et al 2013

Additional Figures
Historical Emissions

Total global emissions by source

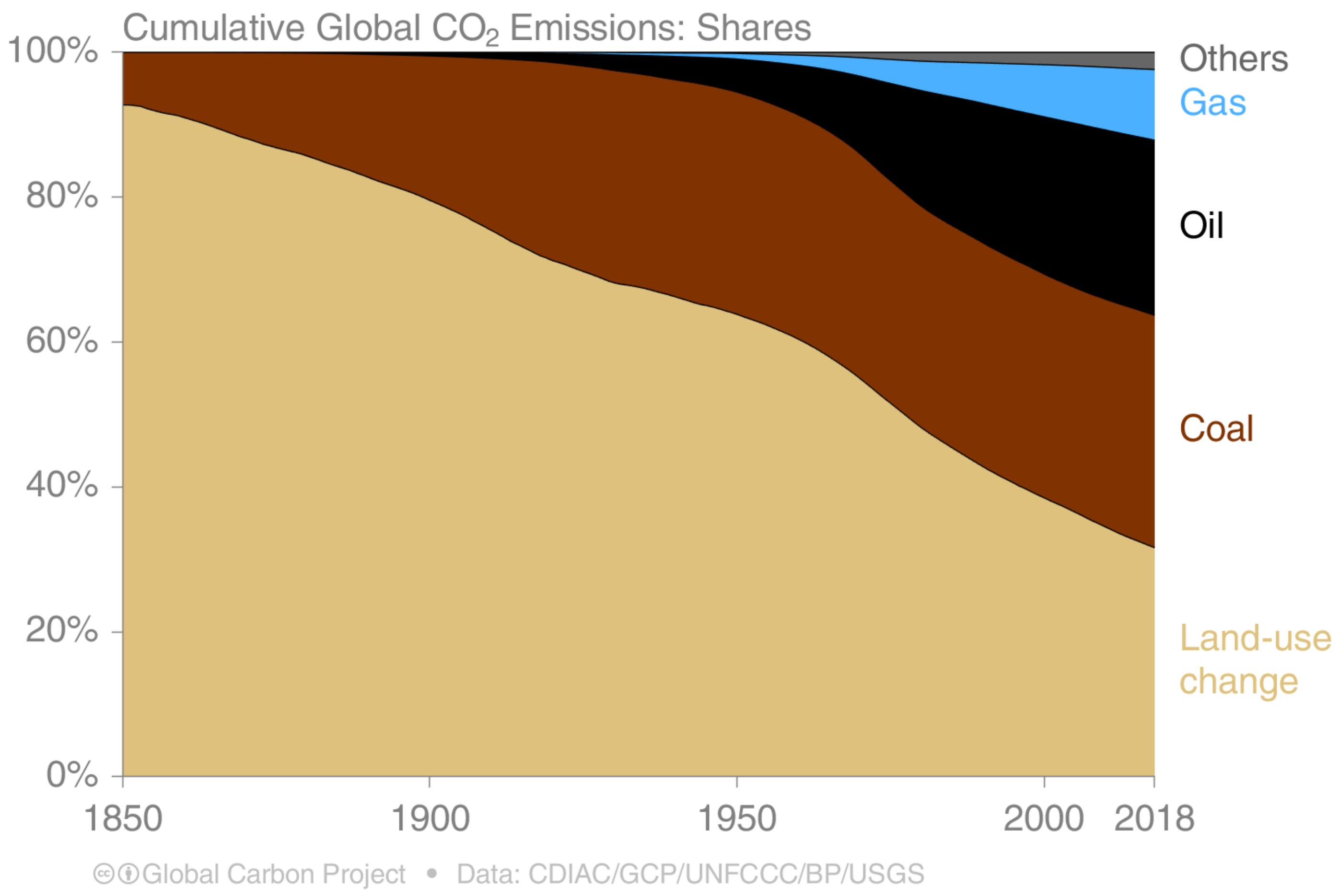
Land-use change was the dominant source of annual CO_2 emissions until around 1950.
Fossil CO_2 emissions now dominate global changes.



Others: Emissions from cement production and gas flaring
Source: CDIAC; Houghton and Nassikas 2017; Hansis et al 2015; Friedlingstein et al 2019; Global Carbon Budget 2019

Historical cumulative emissions by source

Land-use change represents about 30% of cumulative emissions over 1870–2018, coal 33%, oil 25%, gas 10%, and others 2%

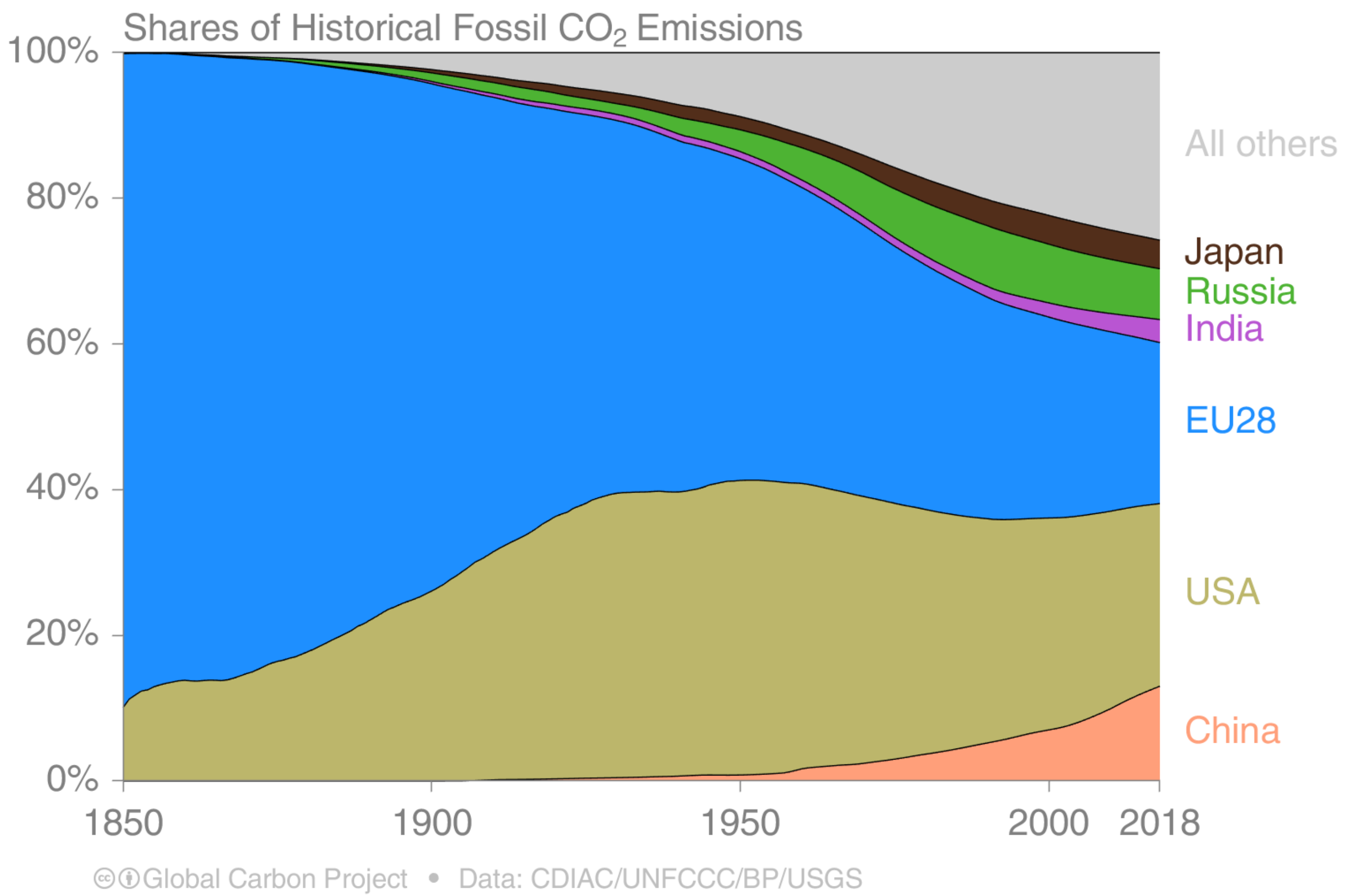


Others: Emissions from cement production and gas flaring

Source: CDIAC; Houghton and Nassikas 2017; Hansis et al 2015; Friedlingstein et al 2019; Global Carbon Budget 2019

Historical cumulative fossil CO_2 emissions by country

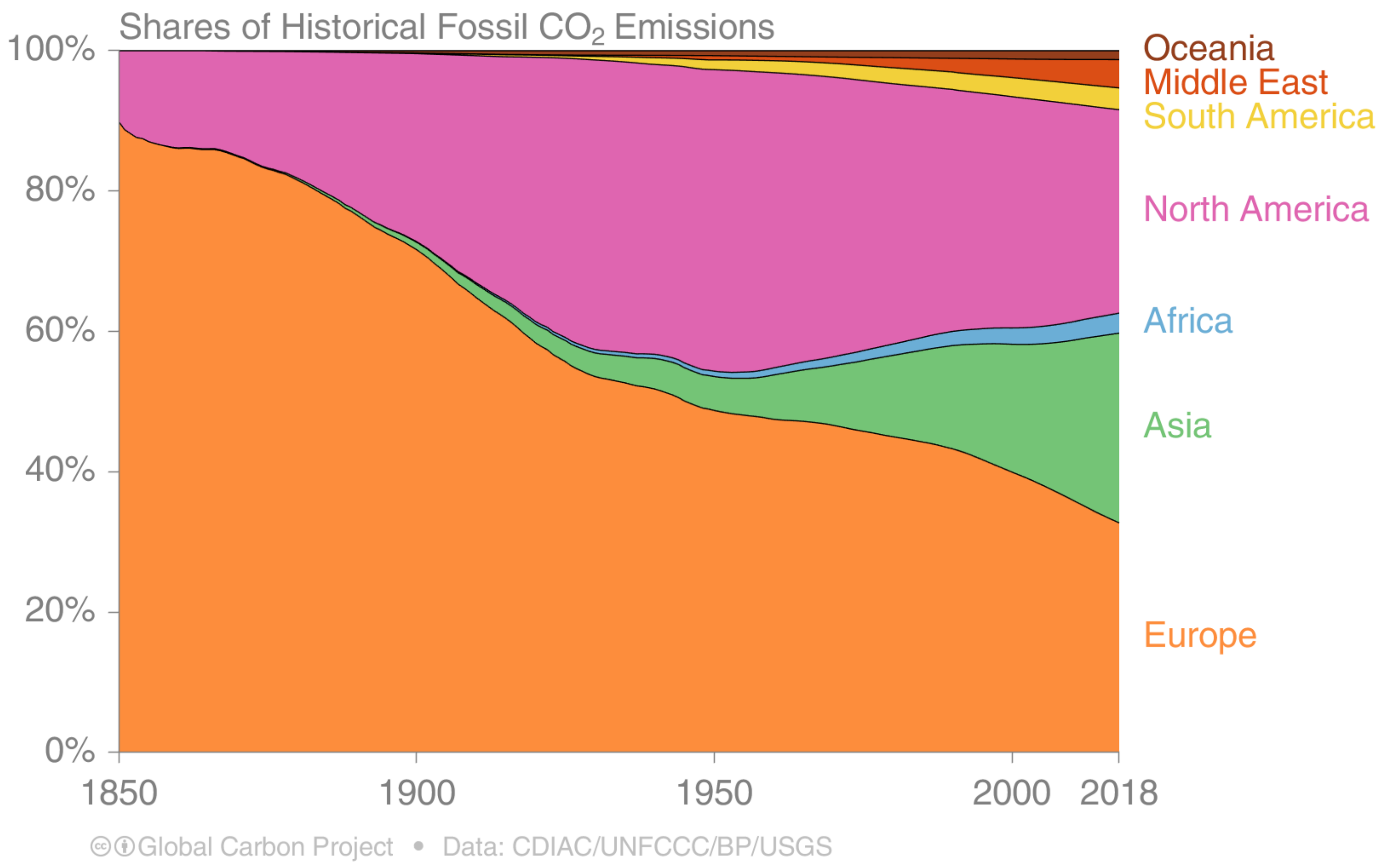
Cumulative fossil CO_2 emissions were distributed (1870–2018):
USA 25%, EU28 22%, China 13%, Russia 7%, Japan 4% and India 3%



Cumulative emissions (1990–2018) were distributed China 20%, USA 20%, EU28 14%, Russia 6%, India 5%, Japan 4%
'All others' includes all other countries along with international bunker fuels
Source: CDIAC; Friedlingstein et al 2019; Global Carbon Budget 2019

Historical cumulative emissions by continent

Cumulative fossil CO_2 emissions (1870–2018). North America and Europe have contributed the most cumulative emissions, but Asia is growing fast



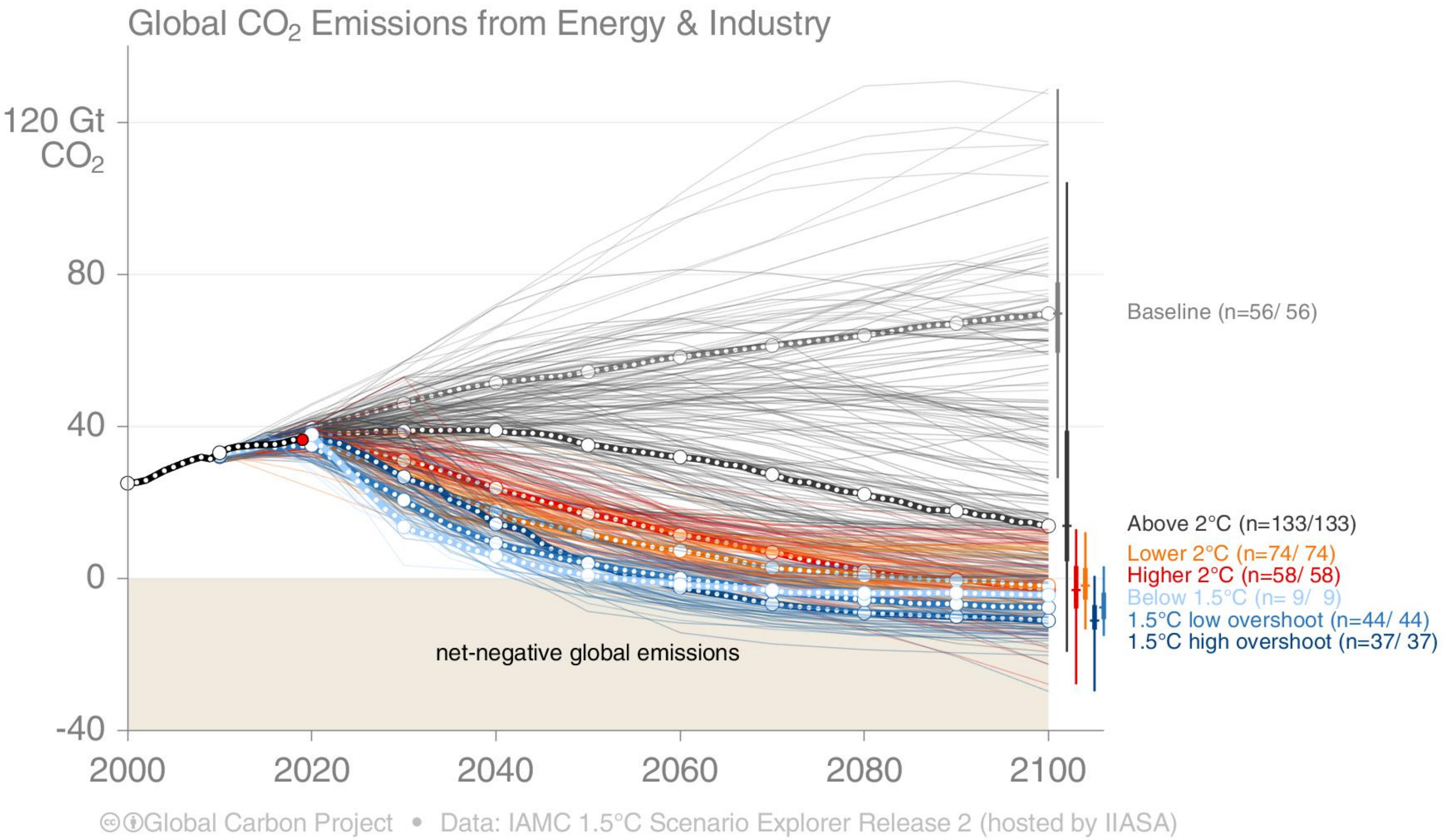
The figure excludes bunker fuels

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

Additional Figures
Emission scenarios

The IPCC Special Report on "Global Warming of 1.5°C"

The IPCC Special Report on "Global Warming of 1.5°C" presented new scenarios: 1.5°C scenarios generally require halving emissions by ~2030, net-zero by ~2050, and negative thereafter



Net emissions include those from bioenergy with carbon capture and storage (BECCS).

Source: Huppmann et al 2018; IAMC 1.5C Scenario Database; IPCC SR15; Global Carbon Budget 2019