Global Carbon Budget

2017

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Acknowledgements

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

Atmospheric CO_2 datasets
NOAA/ESRL (Dlugokencky and Tans 2017)
Scripps (Keeling et al. 1976)

Fossil Fuels and Industry
CDIAC (Boden et al. 2017)
USGS, 2017
UNFCCC, 2017
BP, 2017

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

Land-Use Change
Houghton and Nassikas 2017
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. 2011)

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 | CLASS-CTEM | CLM4.5(BGC) | DLEM | ISAM | JSBACH | JULES | LPJ-GUESS | LPJ | LPX-Bern | OCN | ORCHIDEE | ORCHIDEE-MICT | SDGVM | VISIT
CRU (Harris et al. 2014)

Ocean models
CCSM-BEC | CSIRO | MITgem-REcoM2 | MPIOM-HAMOCC | MICOM-HAMOCC | NEMO-PISCES (CNRM) | NEMO-PISCES(IPSL)| NEMO-PlankTOM5 | NorESM-OC

pCO_2-based ocean flux products
Jena CarboScope (Rödenbeck et al. 2014)
Landschützer et al. 2016
SOCATv5 (Bakker et al. 2016)

Full references provided in Le Quéré et al 2017

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Publications

Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-123
Manuscript under review for journal Earth Syst. Sci. Data
This is just a preview and not the published paper.

Open Access Earth System Science Data Discussions

Global Carbon Budget 2017

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comment

Towards real-time verification of CO_2 emissions

The Paris Agreement has increased the incentive to verify reported anthropogenic carbon dioxide emissions with independent Earth system observations. Reliable verification requires a step change in our understanding of carbon cycle variability.

Glen P. Peters, Corinne Le Quéré, Robbie M. Andrew, Josep G. Canadell, Pierre Friedlingstein, Tatiana Ilyina, Robert B. Jackson, Fortunat Joos, Jan Ivar Korsbakken, Galen A. McKinley, Stephen Sitch and Pieter Tans

Emissions of CO_2 from fossil fuels and industry did not change from 2014 to 2016, yet there was a record increase in CO_2 concentration in the atmosphere[1]. This apparent inconsistency is explained by the response of the natural carbon cycle to the 2015–2016 El Niño event[2], but it raises important questions about our ability to detect a sustained change in emissions from the atmospheric record. High-accuracy calibrated atmospheric measurements, diverse satellite data, and integrative modelling approaches could, and ultimately must, provide independent evidence of the effectiveness of collective action to address climate change. This verification will only be possible if we can fully filter out the background variability in atmospheric CO_2 concentrations driven by natural processes, a challenge that still escapes us

(0.2–3.8%) and in the rest of the world of 1.9% (0.3%–3.4%) (ref. [3]). The increased fossil fuel and industry emissions technically bring an end to the three years of approximately constant emissions that persisted from 2014 to 2016. Land-use change emissions in 2017 should be similar to their 2016 level[5], based on fire observations using satellite data. When combining CO_2 emissions from fossil fuels, industry, and land-use change, we project 2017 global emissions to be 41.5 ± 4.4 billion tonnes of CO_2, similar to 2015 levels. Even though the projected 2017 emissions match those of the record year in 2015, they are not expected to increase atmospheric CO_2 concentration as much as in 2015 because of reinvigorated carbon uptake in natural reservoirs after the 2015–2016 El Niño event (Fig. 1).

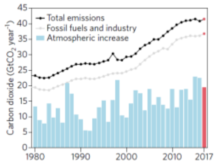

Fig. 1 | Trends in CO_2 emissions and atmospheric CO_2 concentrations. Even though CO_2 emissions from fossil fuel and industry, and total emissions including land-use change, have been relatively flat from 2014 to 2016, atmospheric concentrations saw a record increase in 2015 and 2016 (bars) due to El Niño conditions. We expect

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EDITORIAL

Warning signs for stabilizing global CO_2 emissions

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Abstract

Carbon dioxide (CO_2) emissions from fossil fuels and industry comprise ~90% of all CO_2 emissions from human activities. For the last three years, such emissions were stable, despite continuing growth in the global economy, Many positive trends contributed to this unique hiatus, including reduced coal use in China and elsewhere, continuing gains in energy efficiency, and a boom in low-carbon renewables such as wind and solar. However, the temporary hiatus appears to have ended in 2017. For 2017, we project emissions growth of 2.0% (range: 0.8%–2.9%) from 2016 levels (leap-year adjusted), reaching a record 36.8 ± 1.8 Gt CO_2. Economic projections suggest further emissions growth in 2018 is likely. Time is running out on our ability to keep global average temperature increases below 2 °C and, even more immediately, anything close to 1.5 °C.

https://doi.org/10.1088/1748-9326/aa9662

Data Access and Additional Resources

GCP Website

More information, data sources and data files:
http://www.globalcarbonproject.org/carbonbudget
Contact: c.lequere@uea.ac.uk

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

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 $GtCO_2$

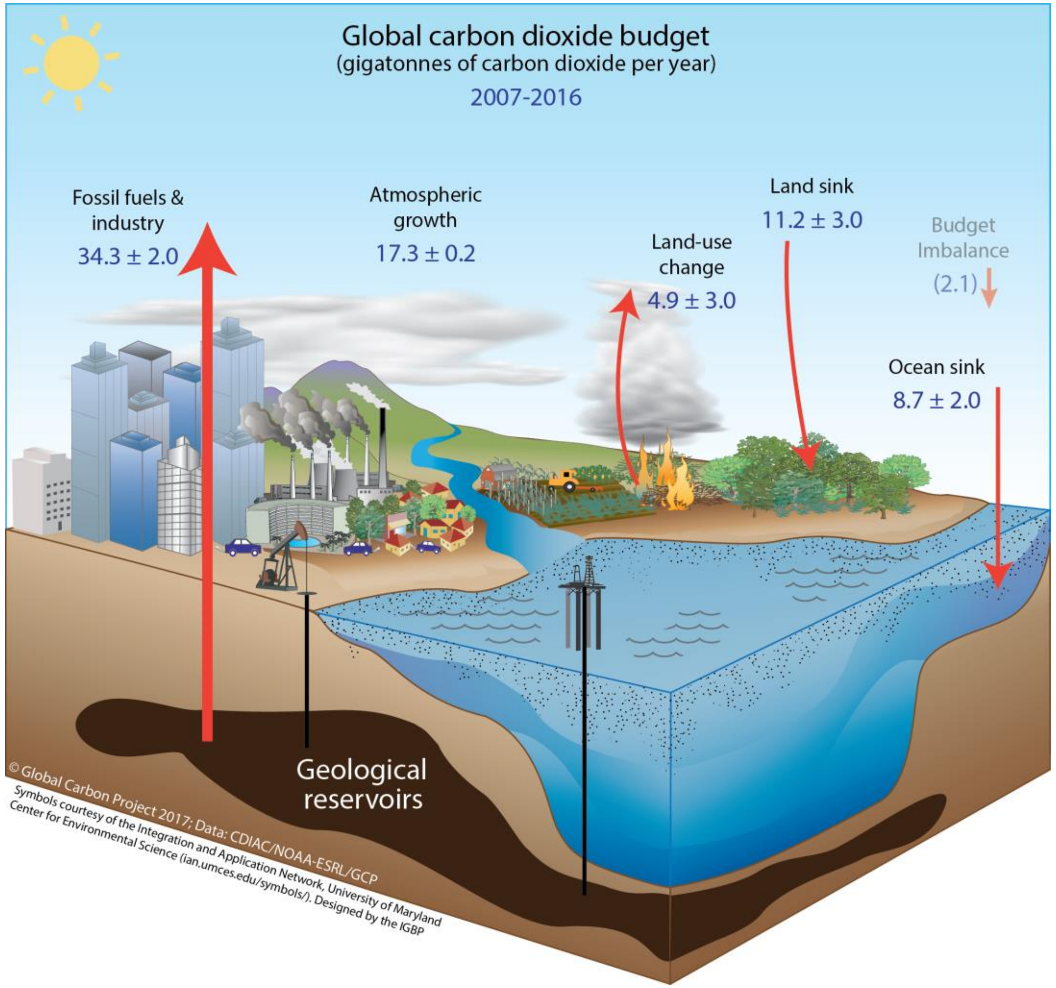
(Figures in units of GtC and $GtCO_2$ are available from http://globalcarbonbudget.org/carbonbudget)

Most figures in this presentation are available for download as PDF or PNG from tinyurl.com/GCB17figs along with the data required to produce them.

Disclaimer

Anthropogenic perturbation of the global carbon cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2007–2016 ($GtCO_2$/yr)



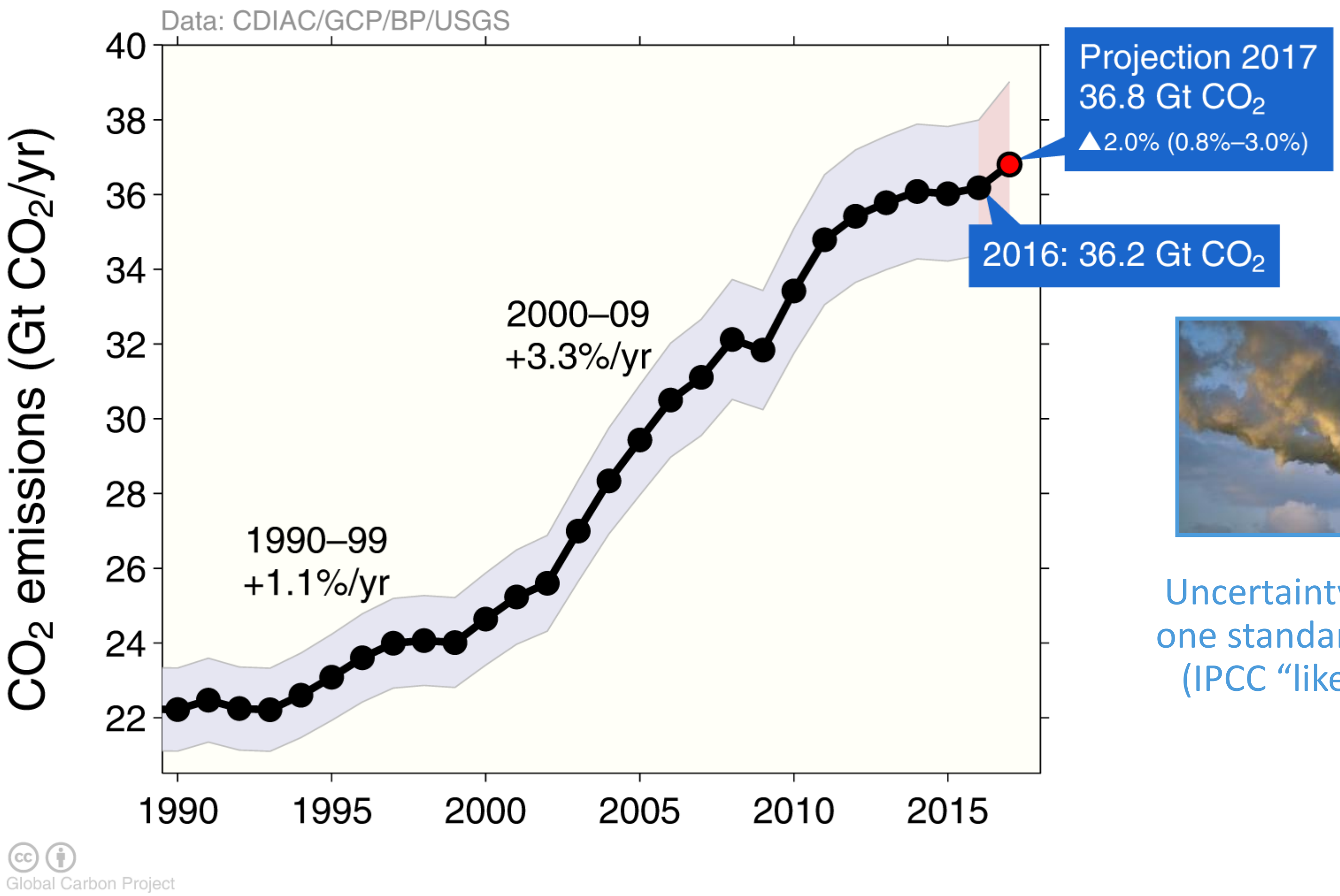
The budget imbalance is the difference between the estimated emissions and sinks.
Source: CDIAC; NOAA-ESRL; Le Quéré et al 2017; Global Carbon Budget 2017

Fossil Fuel and Industry Emissions

Emissions from fossil fuel use and industry

Global emissions from fossil fuel and industry: 36.2 ± 2 $GtCO_2$ in 2016, 62% over 1990

● Projection for 2017: 36.8 ± 2 $GtCO_2$, 2.0% higher than 2016



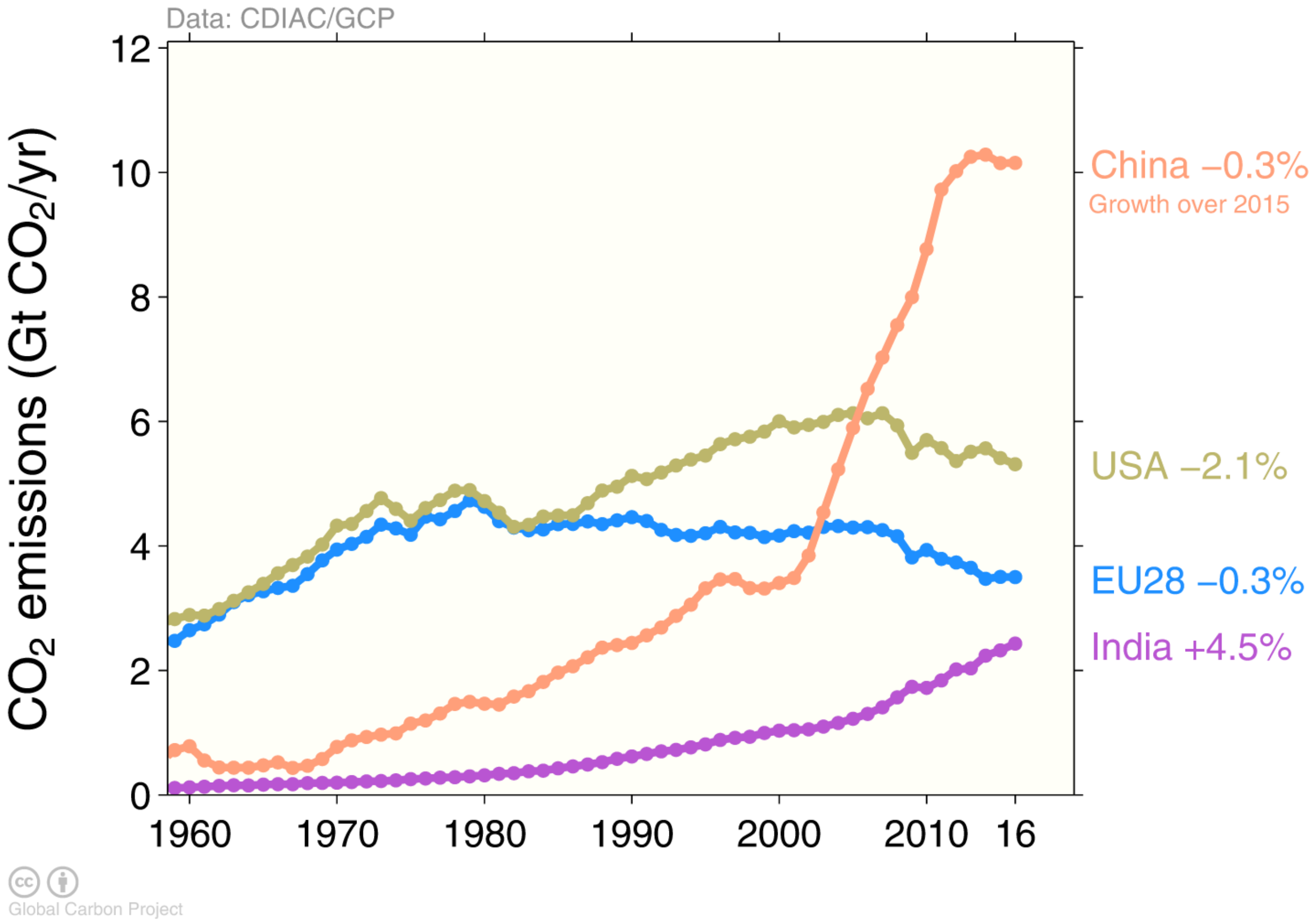
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

Estimates for 2015 and 2016 are preliminary. Growth rate is adjusted for the leap year in 2016.

Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

Top emitters: fossil fuels and industry (absolute)

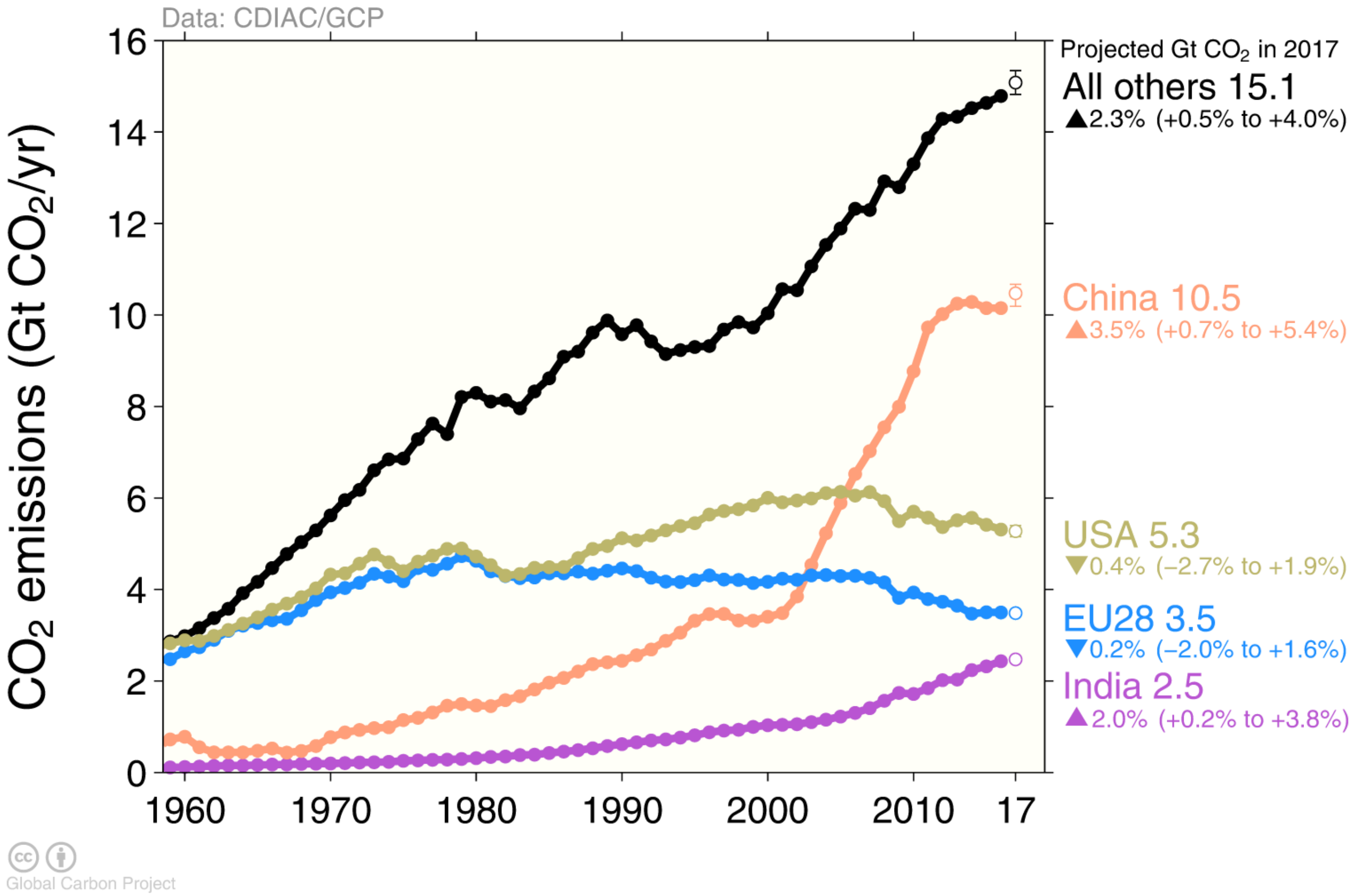
The top four emitters in 2016 covered 59% of global emissions
China (28%), United States (15%), EU28 (10%), India (7%)



Bunker fuels are used for international transport is 3.1% of global emissions.
Statistical differences between the global estimates and sum of national totals are 0.6% of global emissions.
Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

Emissions Projections for 2017

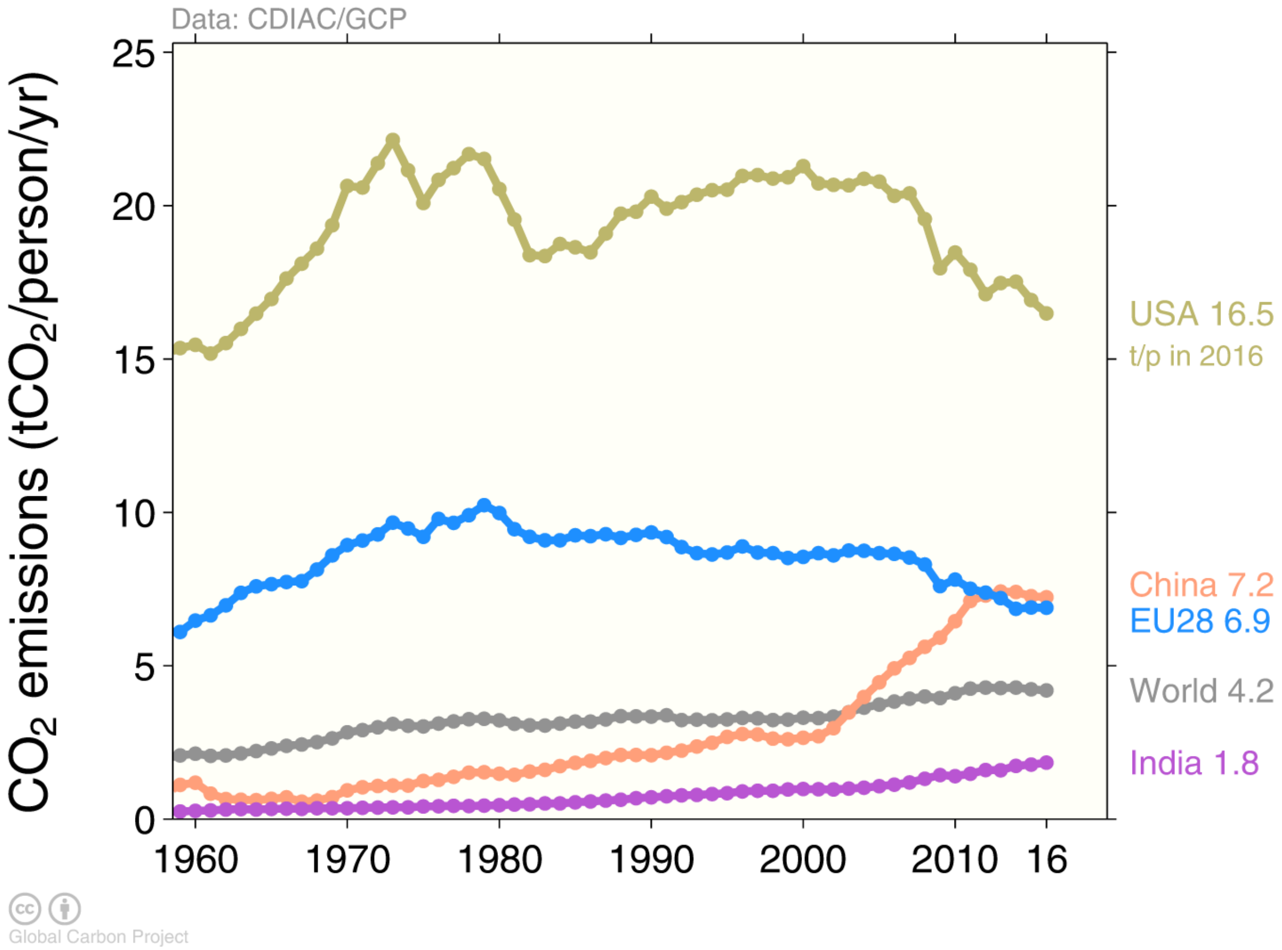
Global emissions from fossil fuels and industry are projected to rise by 2.0% in 2017
The global projection has a large uncertainty, ranging from +0.8% to +3.0%



Source: CDIAC; Jackson et al 2017; Le Quéré et al 2017; Global Carbon Budget 2017

Top emitters: fossil fuels and industry (per capita)

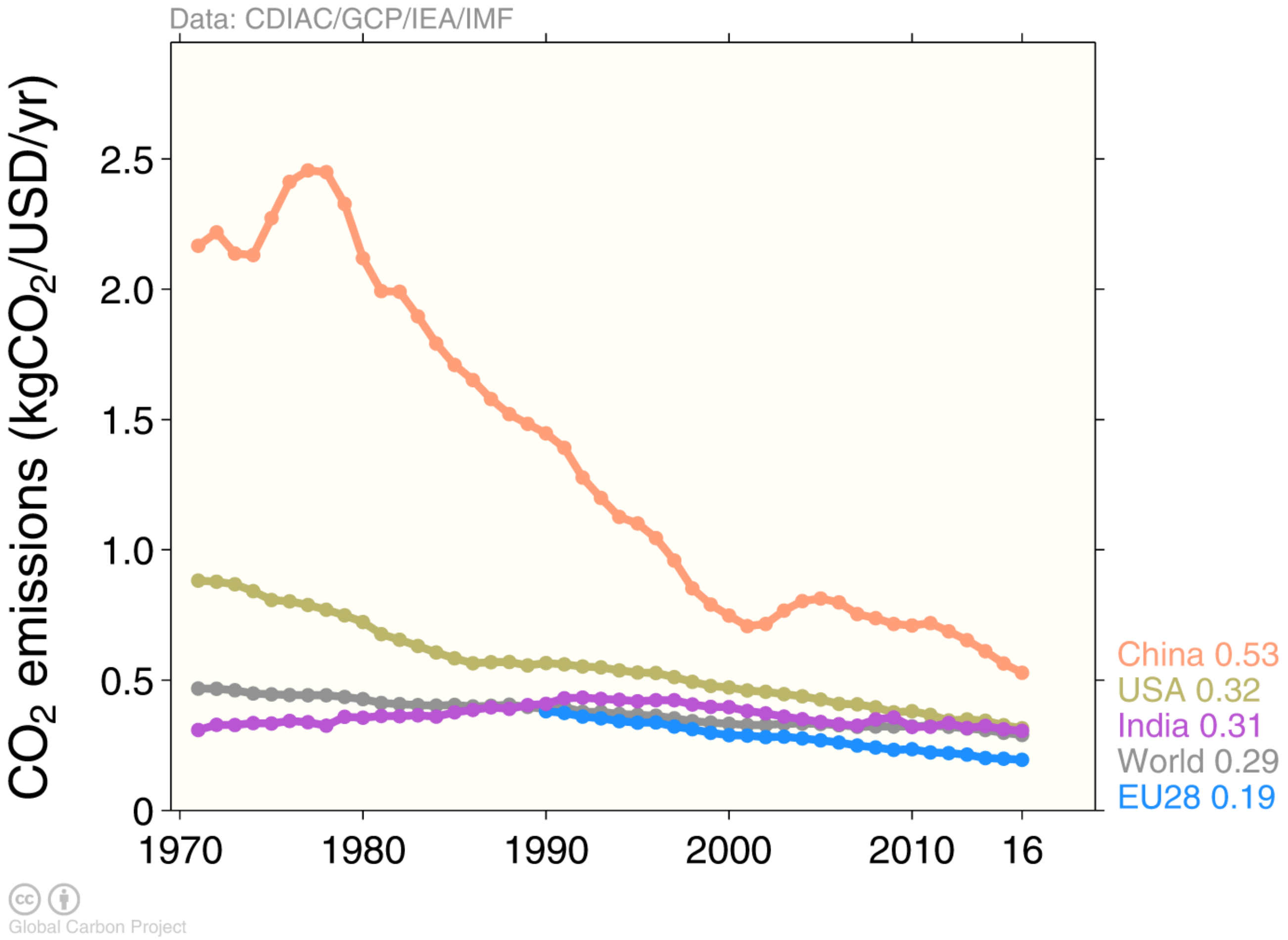
Countries have a broad range of per capita emissions reflecting their national circumstances



Source: [CDIAC](); [Le Quéré et al 2017](); [Global Carbon Budget 2017]()

Top emitters: fossil fuels and industry (per dollar)

Emissions per unit economic output (emissions intensities) generally decline over time
China's intensity is declining rapidly, but is still much higher than the world average

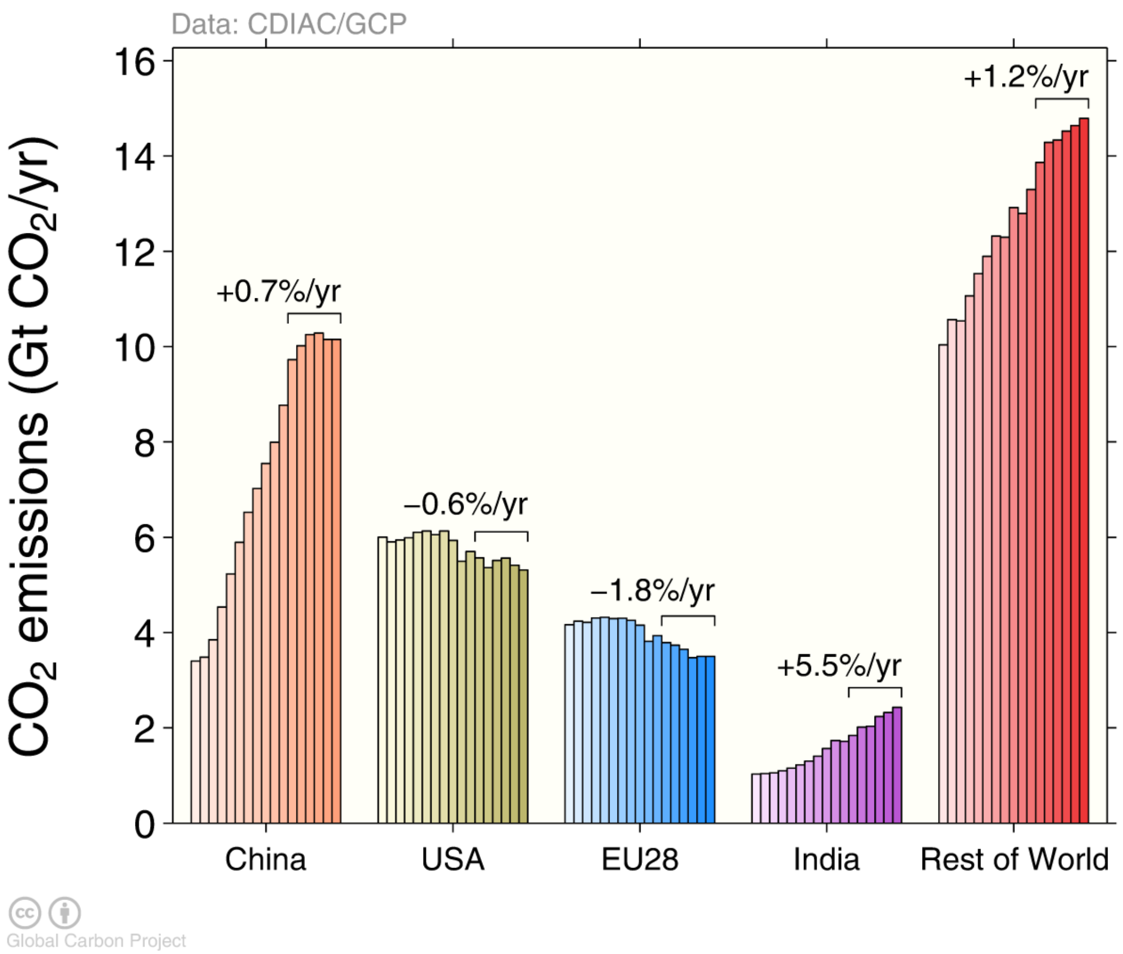


GDP is measured in purchasing power parity (PPP) terms in 2010 US dollars.

Source: CDIAC; IEA 2016 GDP to 2014, IMF 2017 growth rates to 2016; Le Quéré et al 2017; Global Carbon Budget 2017

Top emitters: fossil fuels and industry (bar chart)

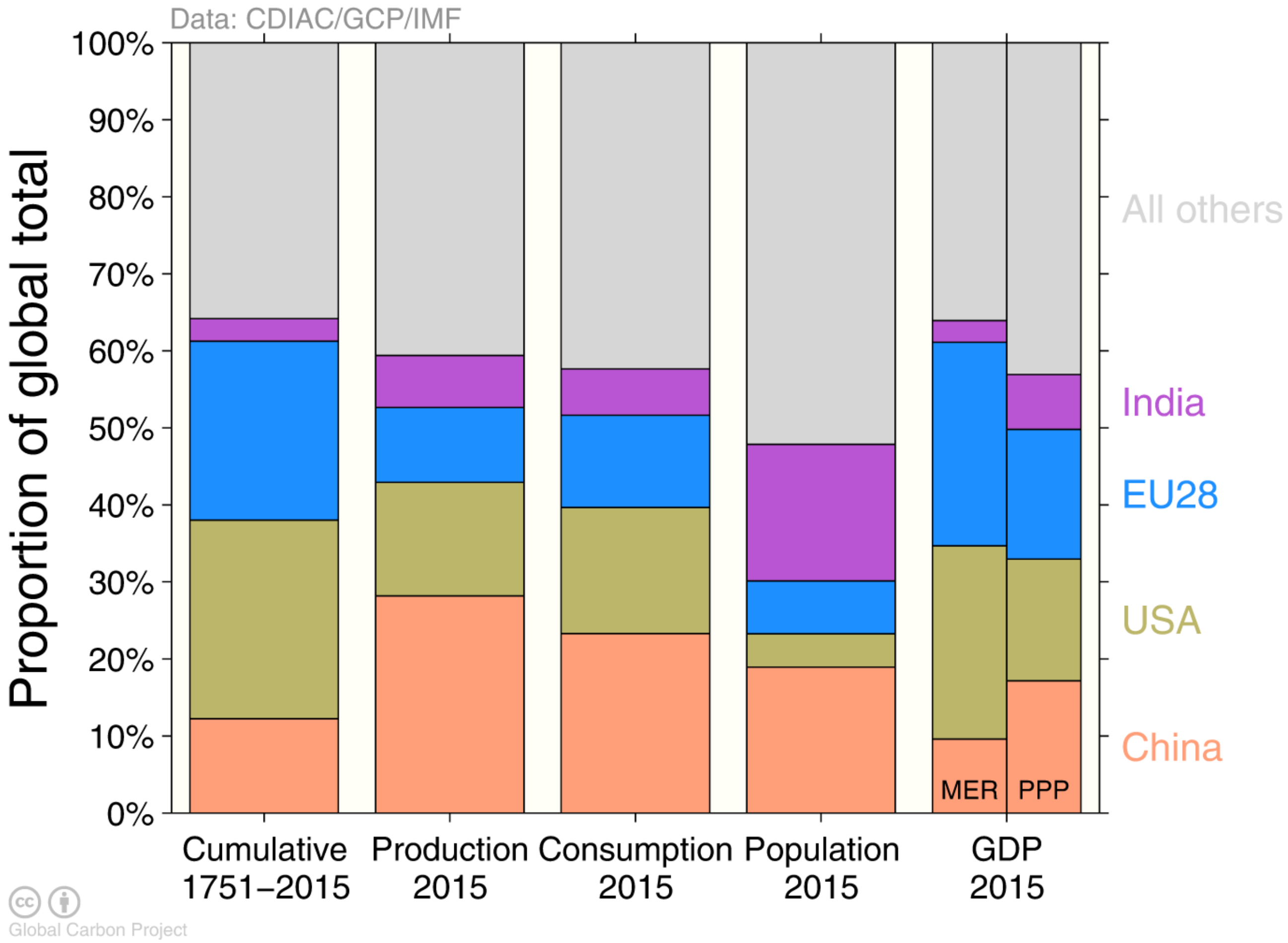
Emissions by country from 2000 to 2016, with growth rates indicated for the more recent period of 2011 to 2016



Source: [CDIAC](); [Le Quéré et al 2017](); [Global Carbon Budget 2017]()

Alternative rankings of countries

Depending on perspective, the significance of individual countries changes.
Emissions from fossil fuels and industry.



GDP: Gross Domestic Product in Market Exchange Rates (MER) and Purchasing Power Parity (PPP)
Source: CDIAC; United Nations; Le Quéré et al 2017; Global Carbon Budget 2017

Fossil fuel and industry emissions growth

Emissions in the US, Russia and Brazil declined in 2016
Emissions in India and all other countries combined increased

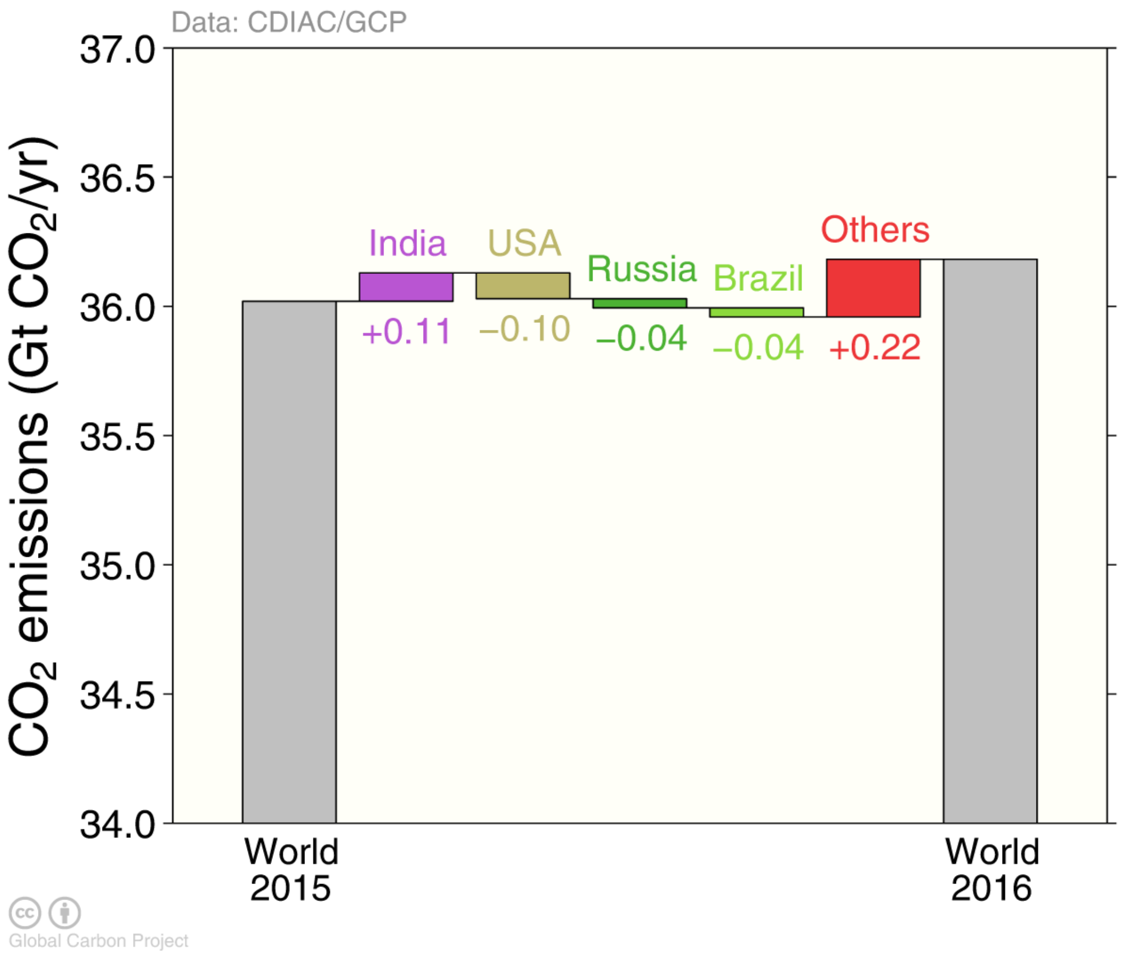
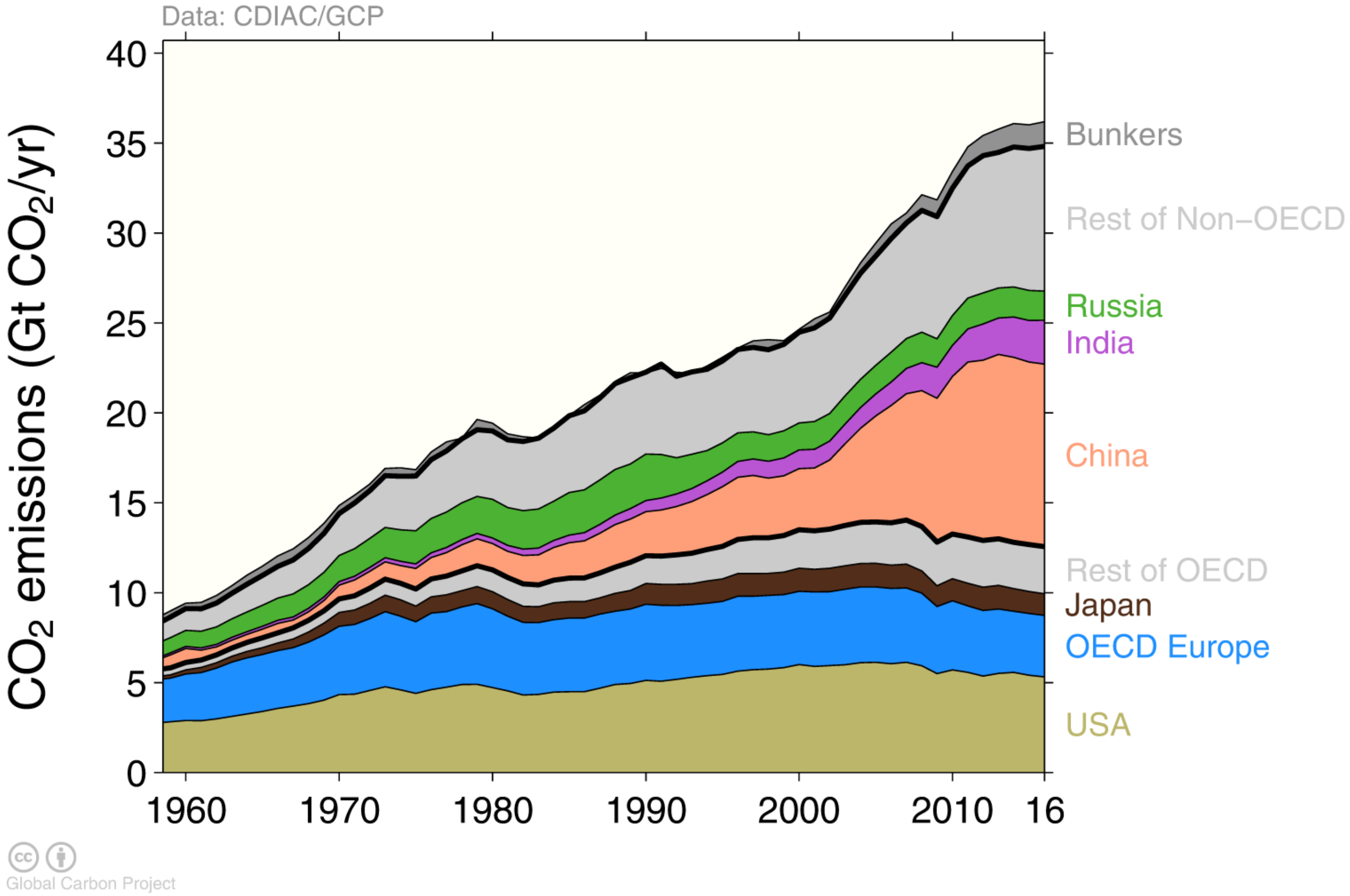


Figure shows the top four countries contributing to emissions changes in 2016
Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

Breakdown of global emissions by country

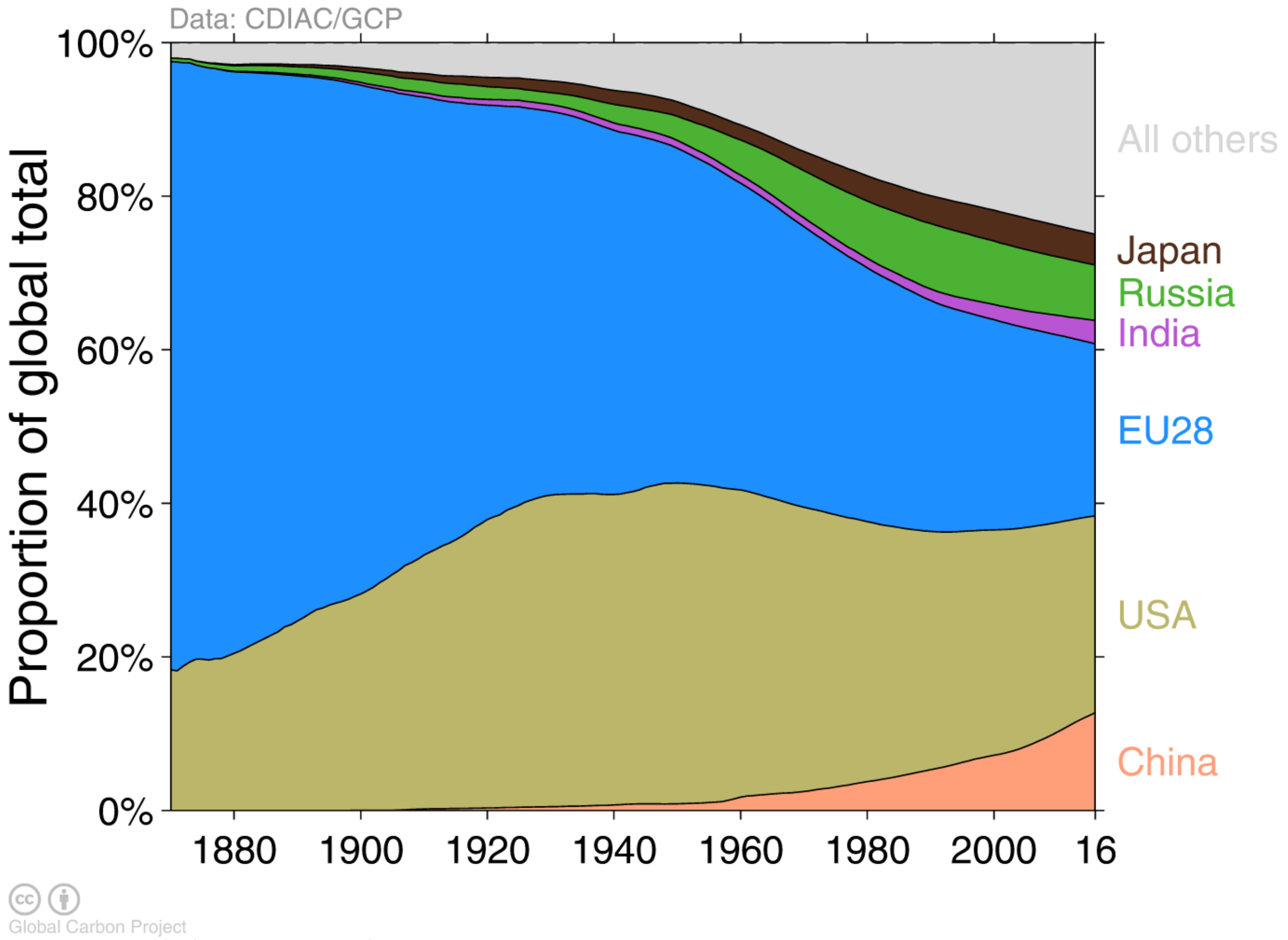
Emissions from OECD countries are about the same as in 1990
Emissions from non-OECD countries have increased rapidly in the last decade



Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

Historical cumulative emissions by country

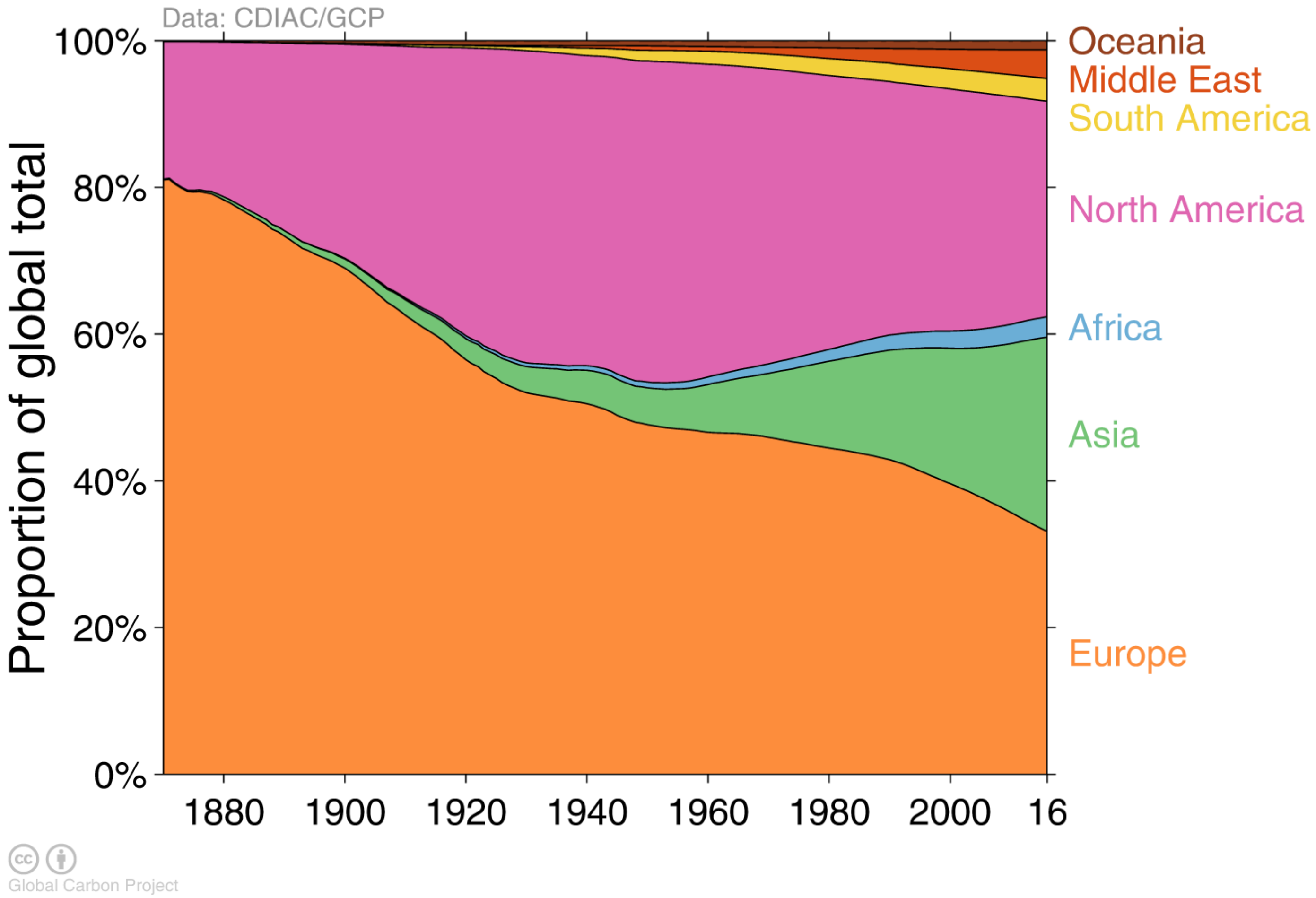
Cumulative emissions from fossil-fuel and industry were distributed (1870–2016):
USA 26%, EU28 22%, China 13%, Russia 7%, Japan 4% and India 3%



Cumulative emissions (1990–2016) were distributed China 20%, USA 20%, EU28 14%, Russia 6%, India 5%, Japan 4%
'All others' includes all other countries along with bunker fuels and statistical differences
Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

Historical cumulative emissions by continent

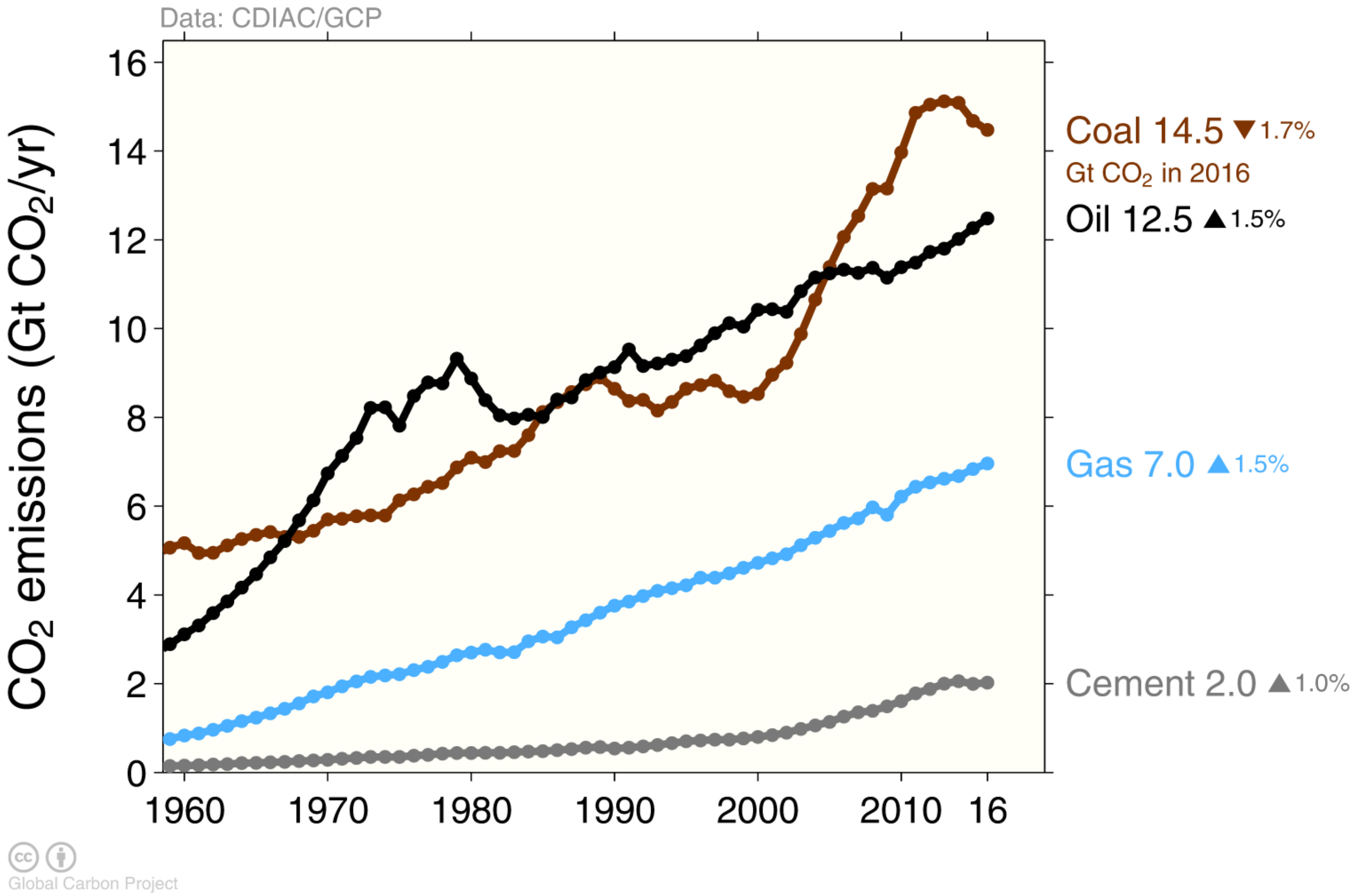
Cumulative emissions from fossil-fuel and industry (1870–2016)
North America and Europe responsible for most cumulative emissions, but Asia growing fast



The figure excludes bunker fuels and statistical differences
Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

Emissions from coal, oil, gas, cement

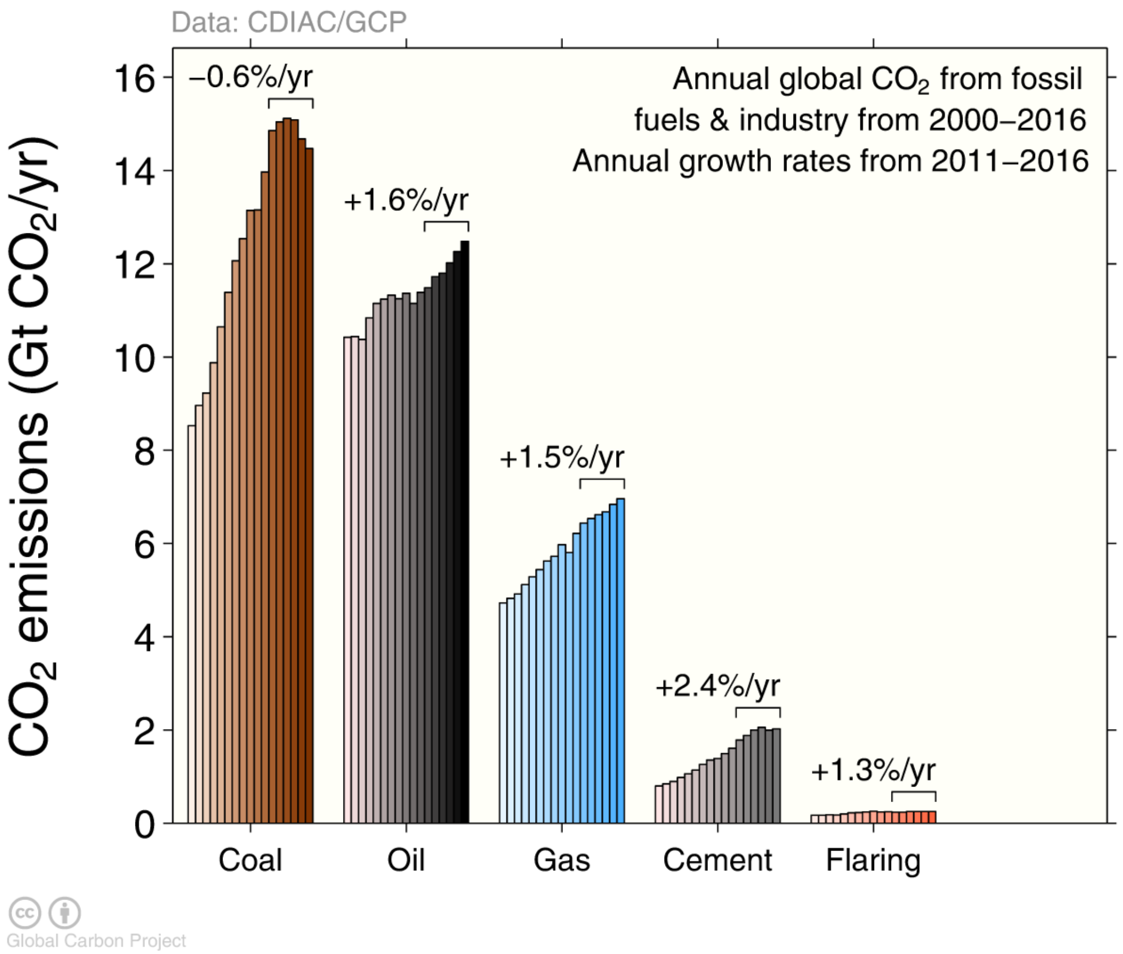
Share of global emissions in 2016:
coal (40%), oil (34%), gas (19%), cement (6%), flaring (1%, not shown)



Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

Emissions by category

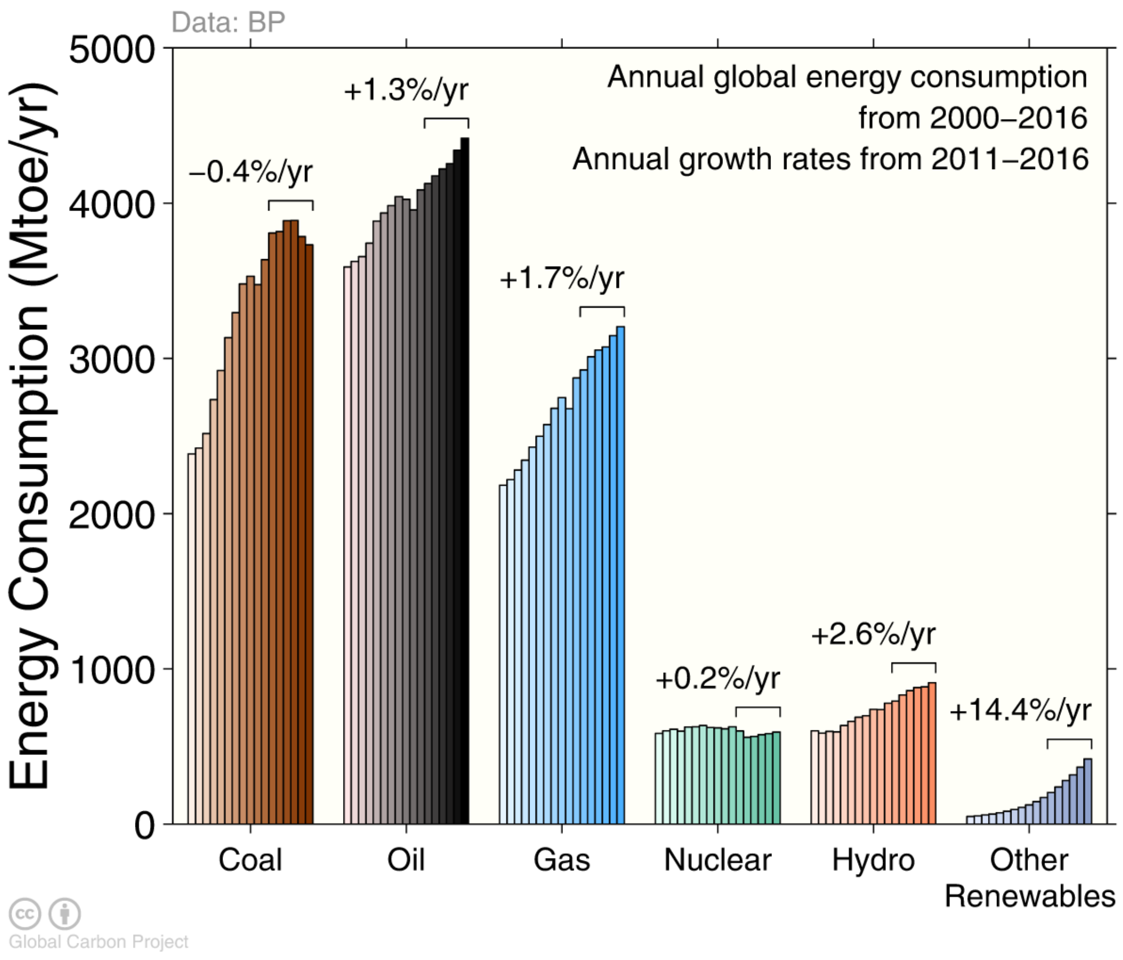
Emissions by category from 2000 to 2016, with growth rates indicated for the more recent period of 2011 to 2016



Source: [CDIAC](); [Jackson et al 2017](); [Global Carbon Budget 2017]()

Energy consumption by energy type

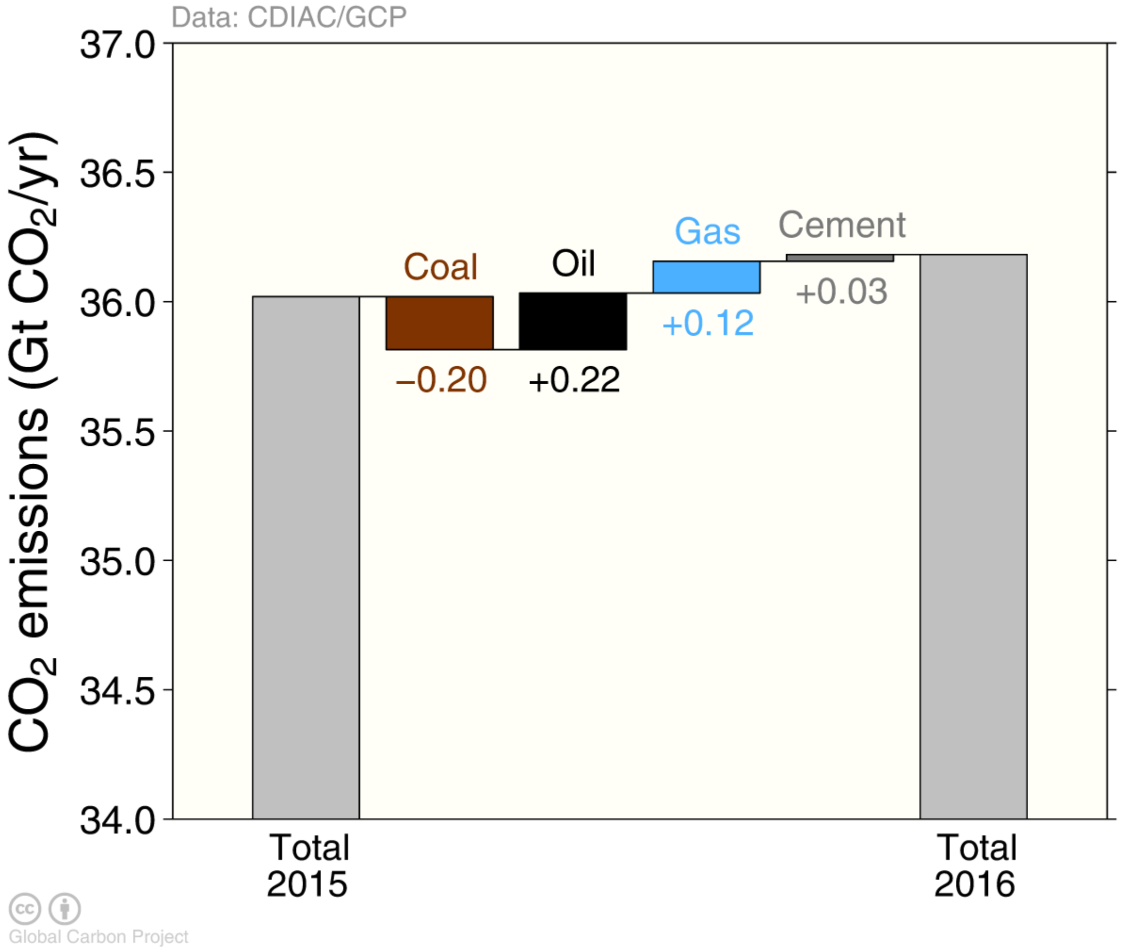
Energy consumption by fuel source from 2000 to 2016, with growth rates indicated for the more recent period of 2011 to 2016



Source: [BP 2017](); [Jackson et al 2017](); [Global Carbon Budget 2017]()

Fossil fuel and cement emissions growth

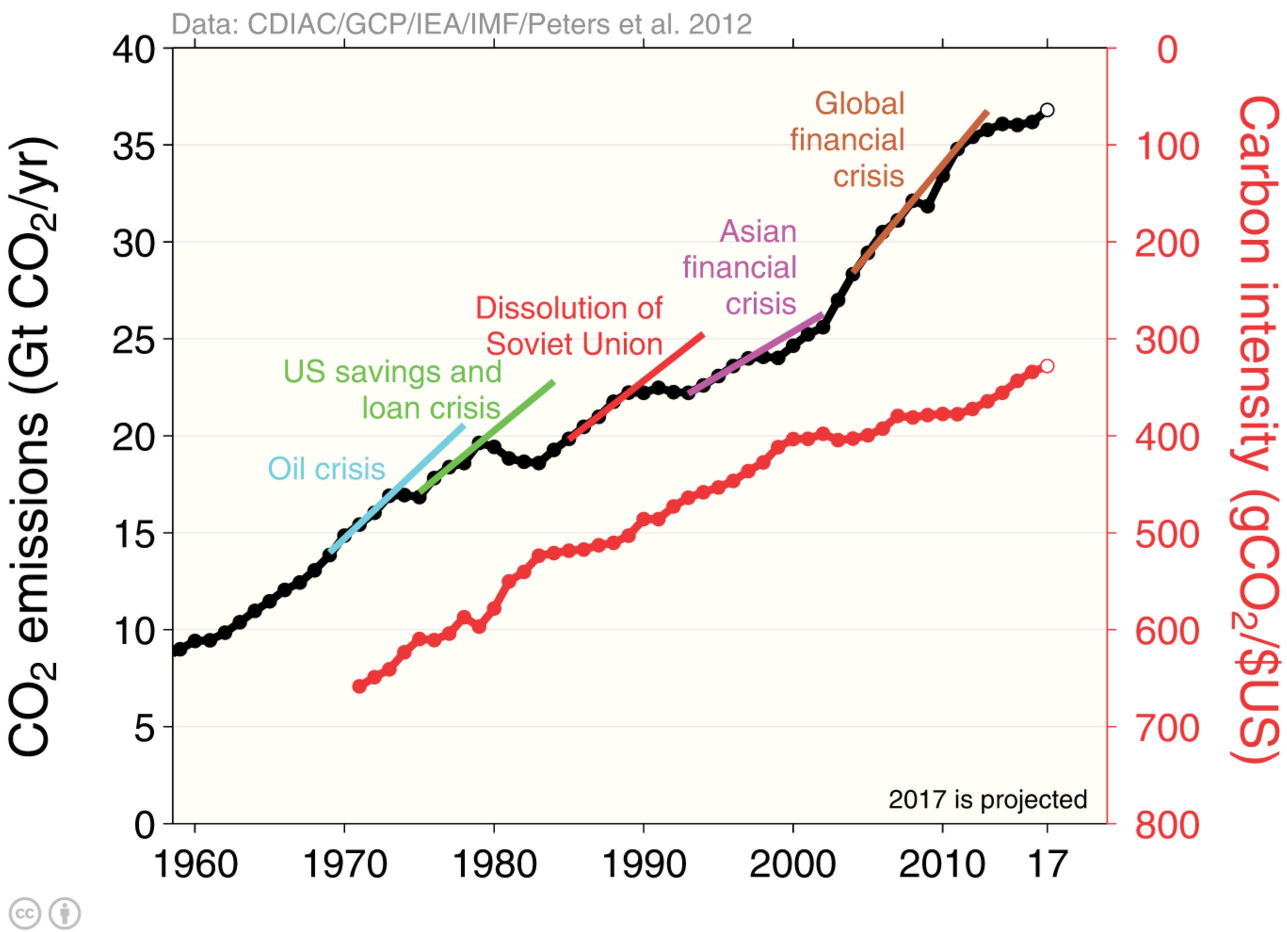
The biggest changes in emissions were from a decline in coal and an increase in oil



Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

Carbon intensity of economic activity

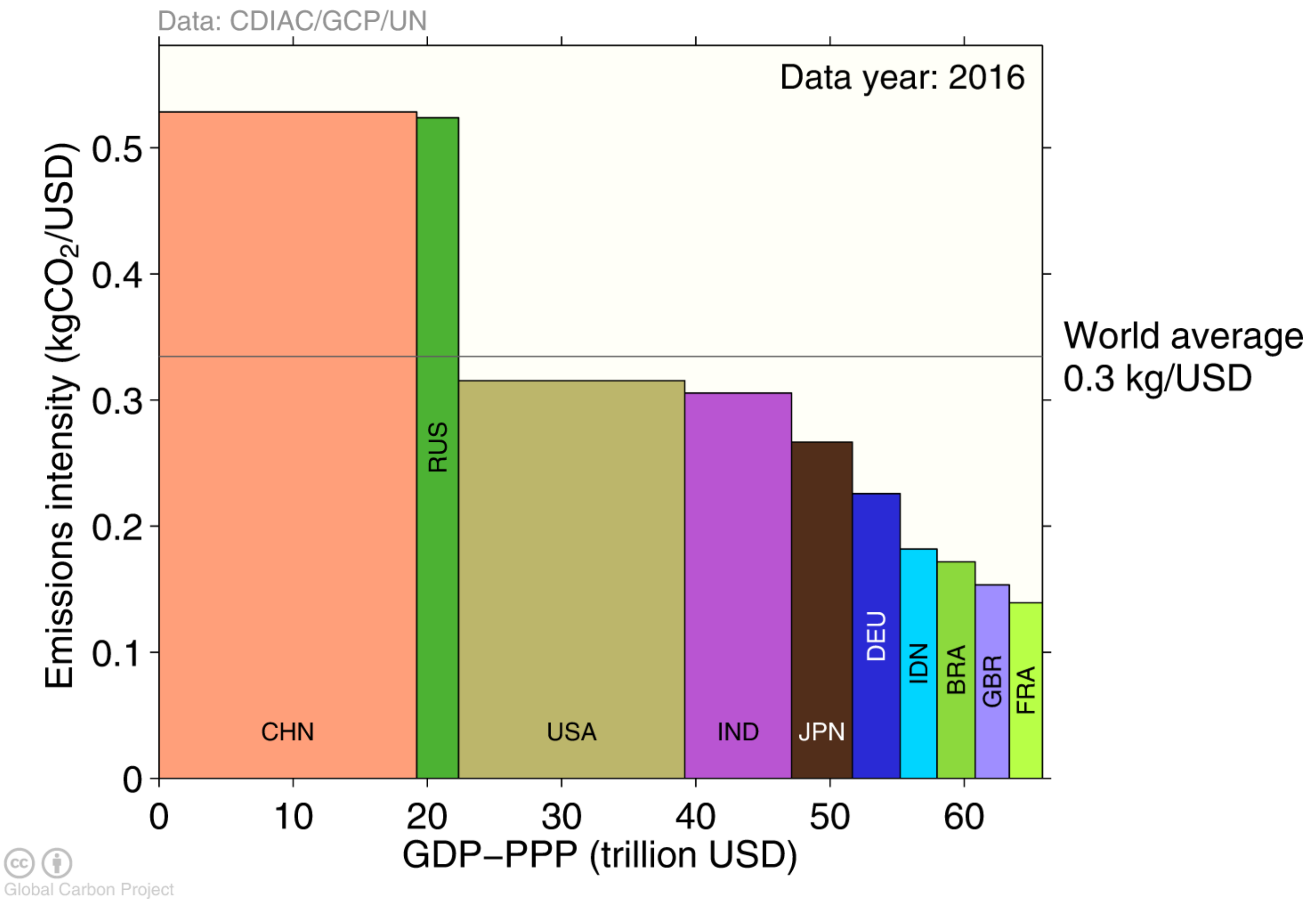
Global emissions growth has generally recovered quickly from previous financial crises
It is unclear if the recent slowdown in global emissions is related to the Global Financial Crisis



Economic activity is measured in purchasing power parity (PPP) terms in 2010 US dollars.
Source: CDIAC; Peters et al 2012; Le Quéré et al 2017; Global Carbon Budget 2017

Emissions intensity per unit economic activity

The 10 largest economies have a wide range of emissions intensity of economic production

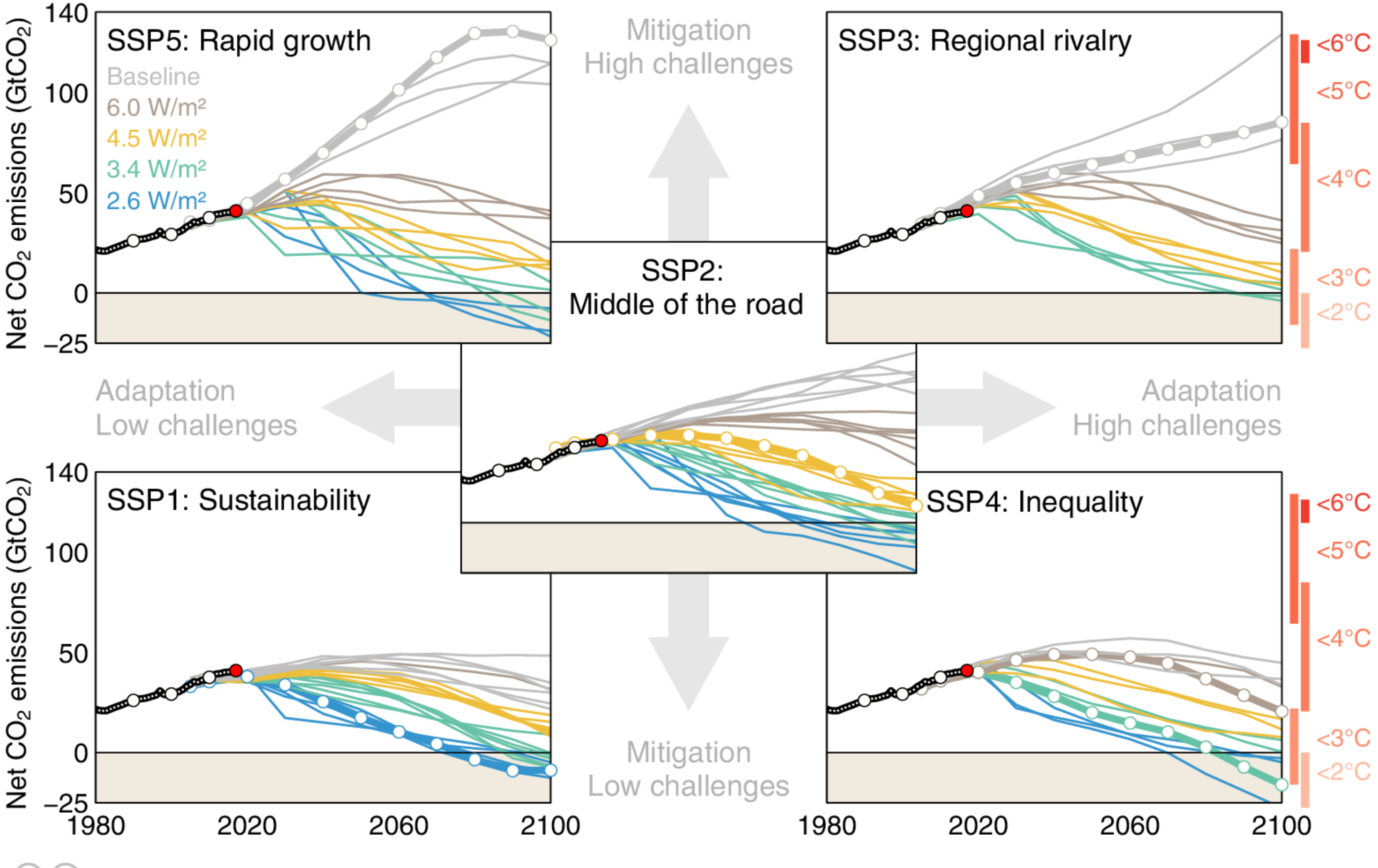


Emission intensity: CO_2 emissions from fossil fuel and industry divided by Gross Domestic Product

Source: Global Carbon Budget 2017

New generation of emissions scenarios

In the lead up to the IPCC's Sixth Assessment Report new scenarios have been developed to more systematically explore key uncertainties in future socioeconomic developments



Five Shared Socioeconomic Pathways (SSPs) have been developed to explore challenges to adaptation and mitigation.
Shared Policy Assumptions (SPAs) are used to achieve target forcing levels (W/m²). Marker Scenarios are indicated.
Source: Riahi et al. 2016; IIASA SSP Database; Global Carbon Budget 2017

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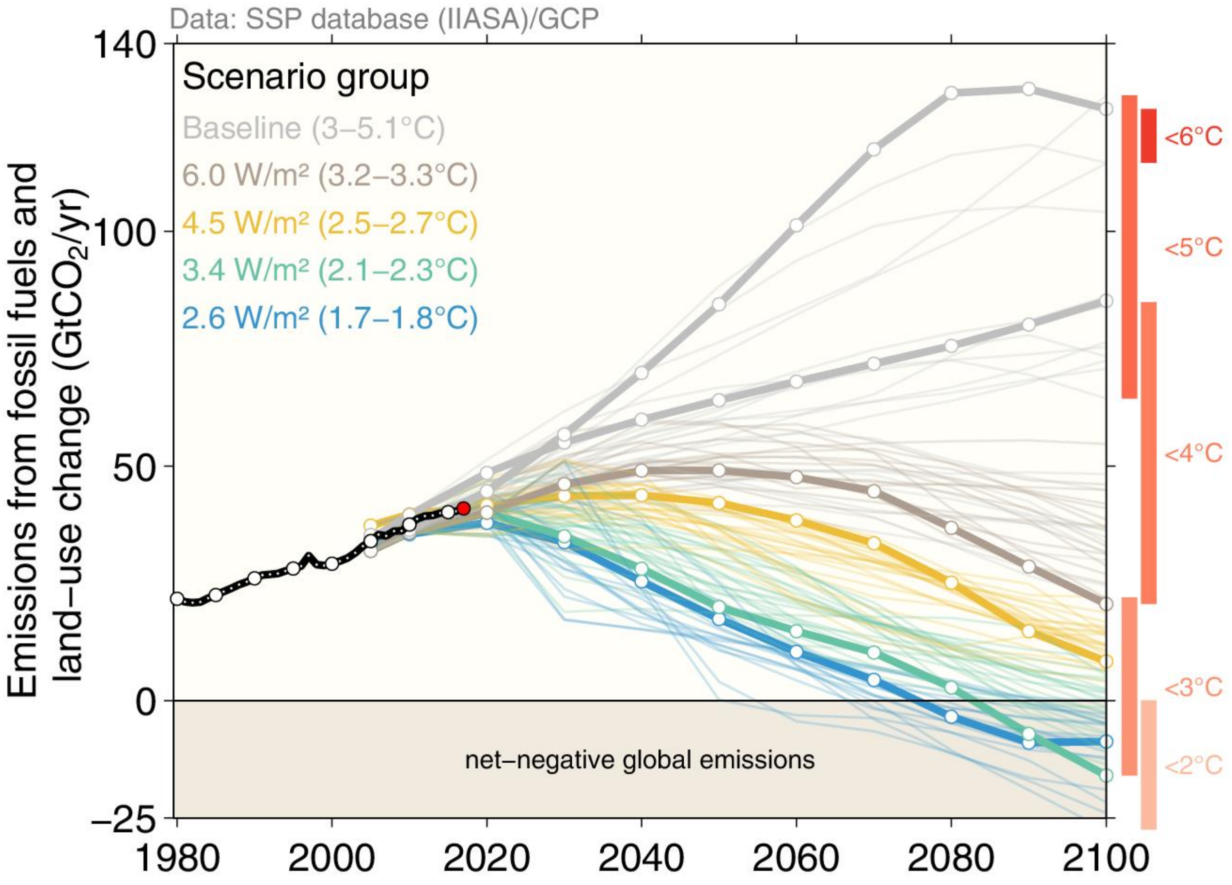

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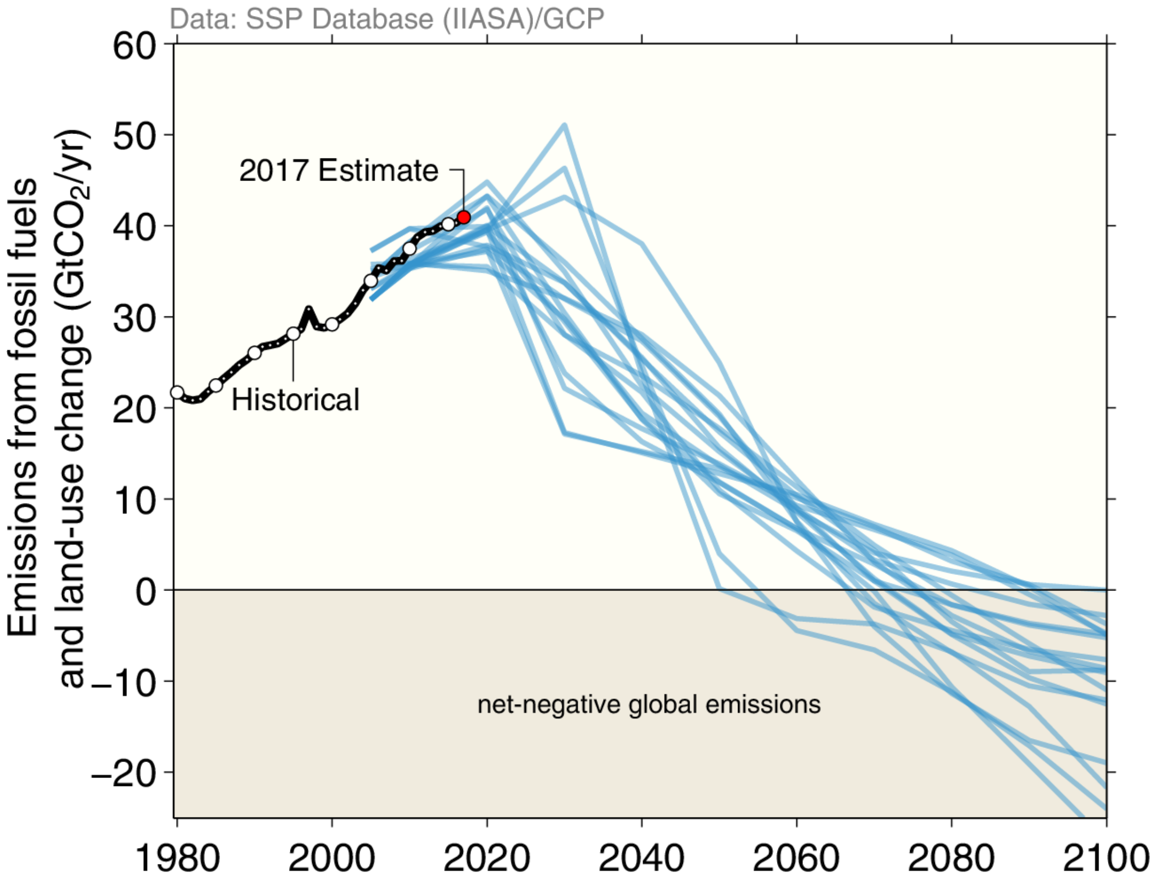
Shared Policy Assumptions (SPAs) are used to achieve target forcing levels (W/m²). Marker Scenarios are indicated.
Source: Riahi et al. 2016; IIASA SSP Database; Global Carbon Budget 2017

Pathways that avoid 2°C of warming

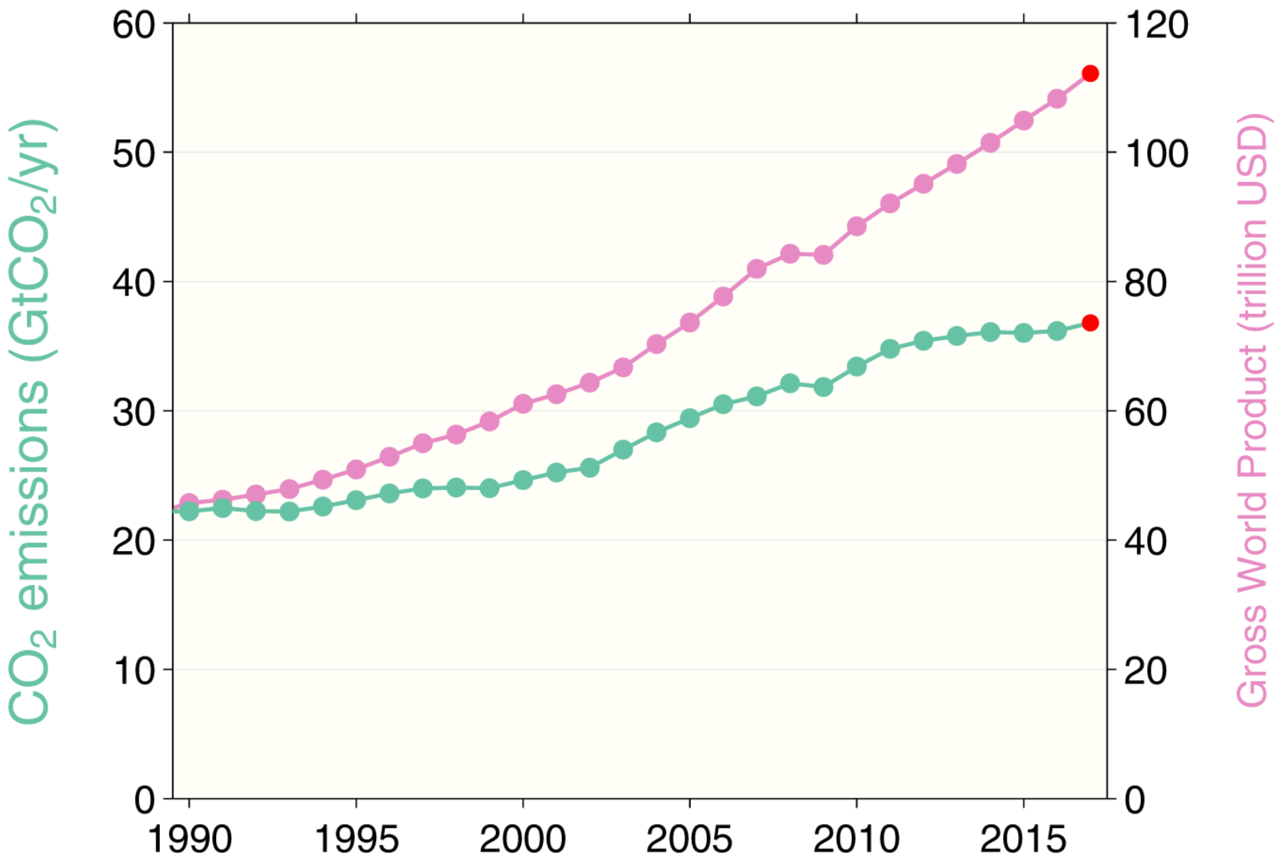
According to the Shared Socioeconomic Pathways (SSP) that avoid 2°C of warming, global CO_2 emissions need to decline rapidly and cross zero emissions after 2050



Source: Riahi et al. 2016; IIASA SSP Database; Global Carbon Budget 2017

CO_2 emissions and economic activity

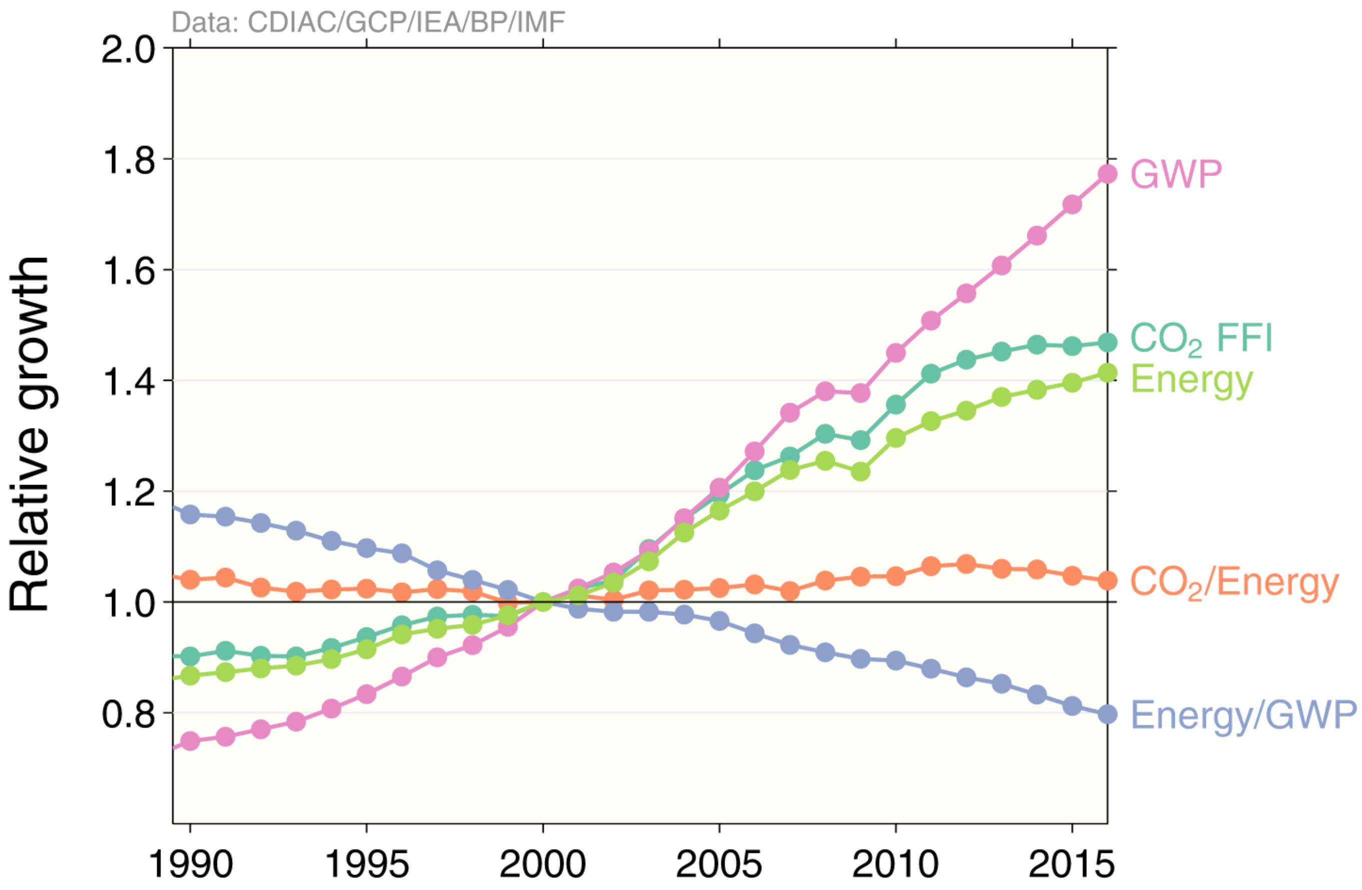
In recent years, CO_2 emissions have been almost flat despite continued economic growth



Source: [Jackson et al 2017](); [Global Carbon Budget 2017]()

Kaya decomposition

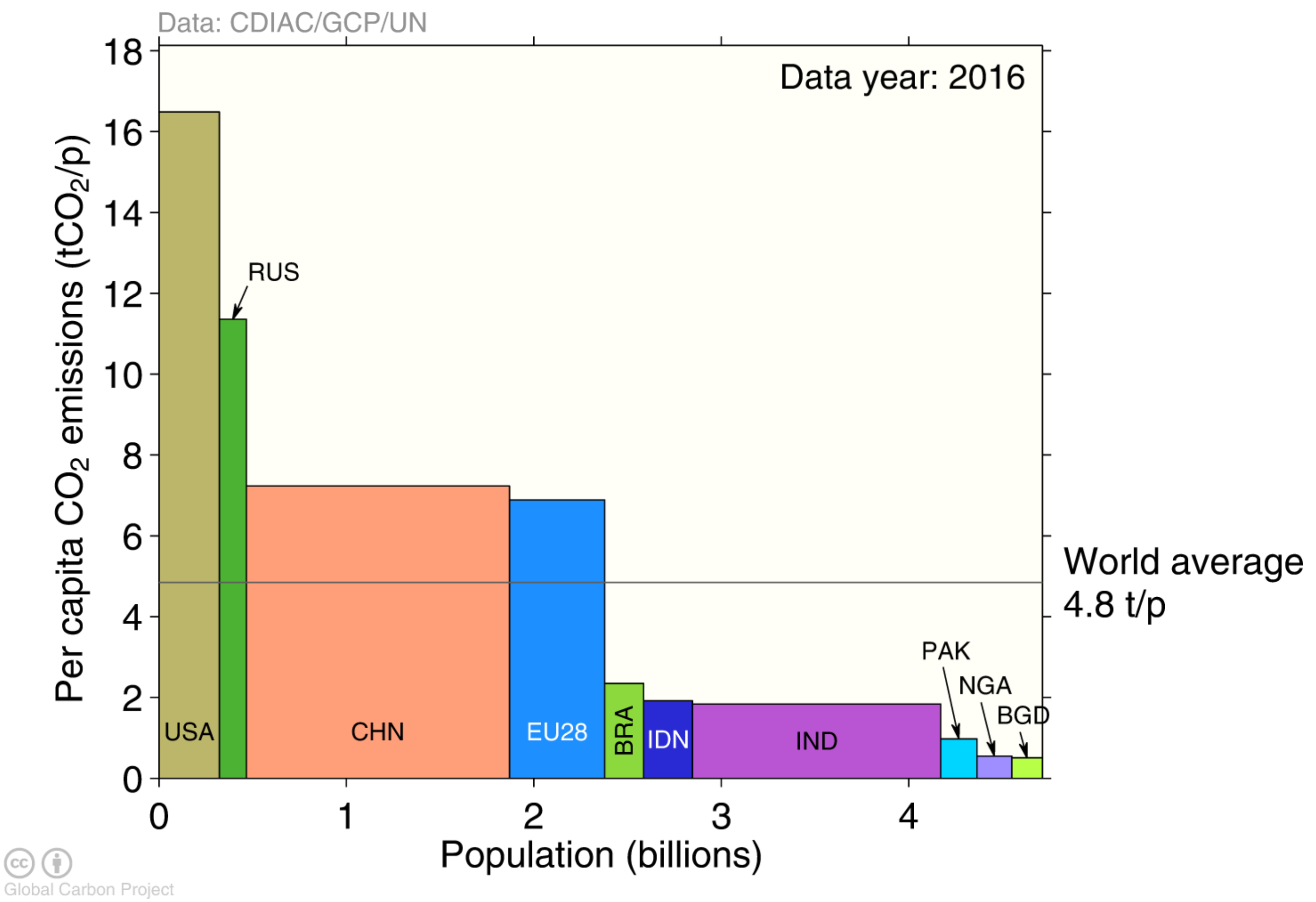
The Kaya decomposition demonstrates the recent relative decoupling of economic growth from CO_2 emissions, driven by improved energy intensity



GWP: Gross World Product (economic activity), FFI: Fossil Fuel and Industry,
Energy is Primary Energy from BP statistics using the substitution accounting method
Source: Jackson et al 2017; Global Carbon Budget 2017

Emissions per capita

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



Emission per capita: CO_2 emissions from fossil fuel and industry divided by population

Source: Global Carbon Budget 2017

GLOBAL CARBON PROJECT

Key statistics

Region/Country	Emissions 2016				
	Per capita	Total		Growth 2015-16	
	tCO_2 per person	$GtCO_2$	%	$GtCO_2$	%
Global (with bunkers)	4.8	36.18	100	0.163	0.0
OECD Countries					
OECD	9.8	12.56	34.7	-0.110	-1.1
USA	16.5	5.31	14.7	-0.100	-2.1
OECD Europe	7.0	3.42	9.5	0.000	-0.3
Japan	9.5	1.21	3.3	-0.016	-1.6
South Korea	11.7	0.60	1.6	0.003	0.3
Canada	15.5	0.56	1.6	-0.005	-1.2
Non-OECD Countries					
Non-OECD	3.6	22.25	61.5	0.220	0.7
China	7.2	10.15	28.1	0.000	-0.3
India	1.8	2.43	6.7	0.110	4.5
Russia	11.4	1.63	4.5	-0.036	-2.4
Iran	8.2	0.66	1.8	0.014	1.9
Saudi Arabia	19.7	0.63	1.8	0.011	1.4
International Bunkers					
Aviation and Shipping	-	1.37	3.8	0.053	4.0

Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

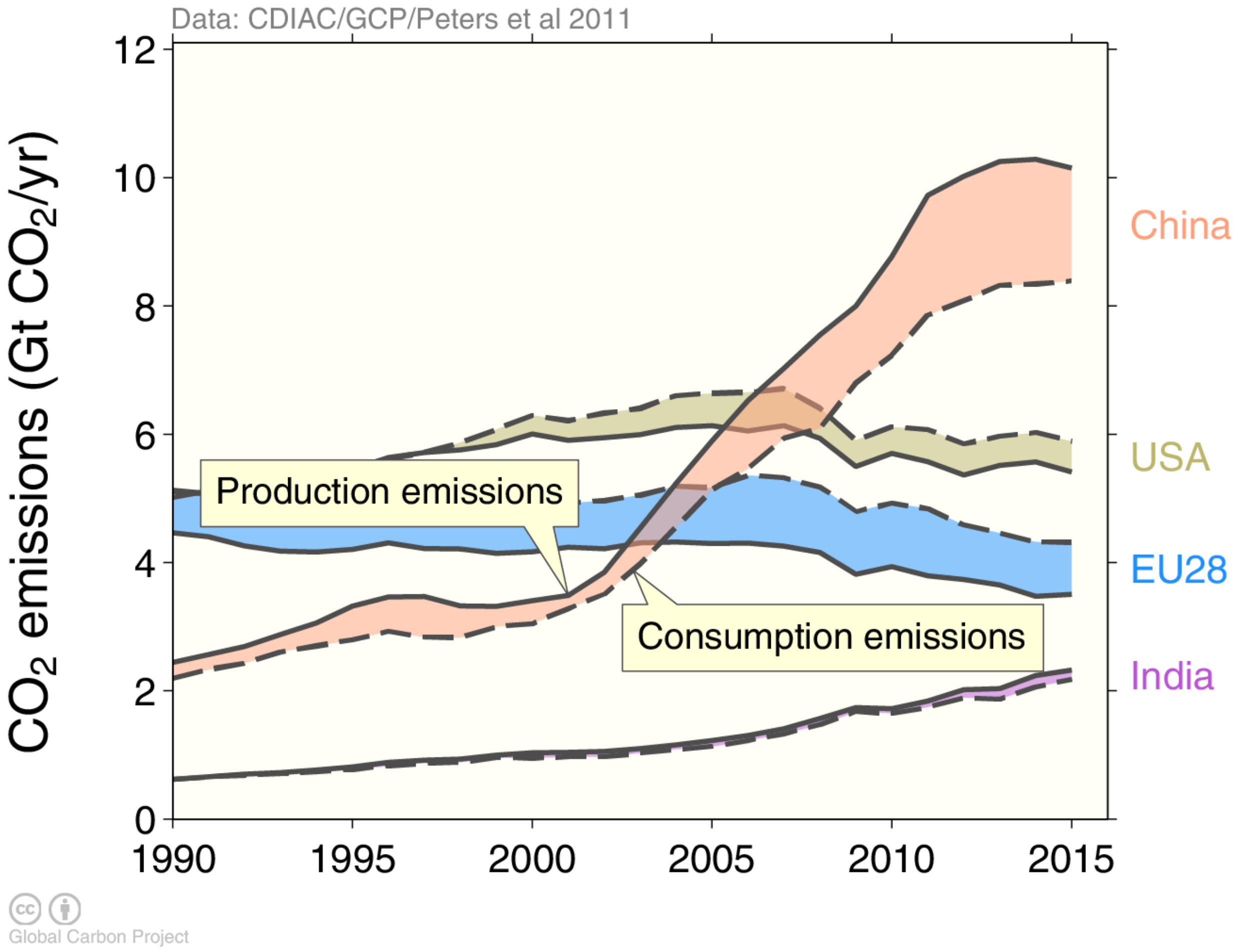
Consumption-based Emissions

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)

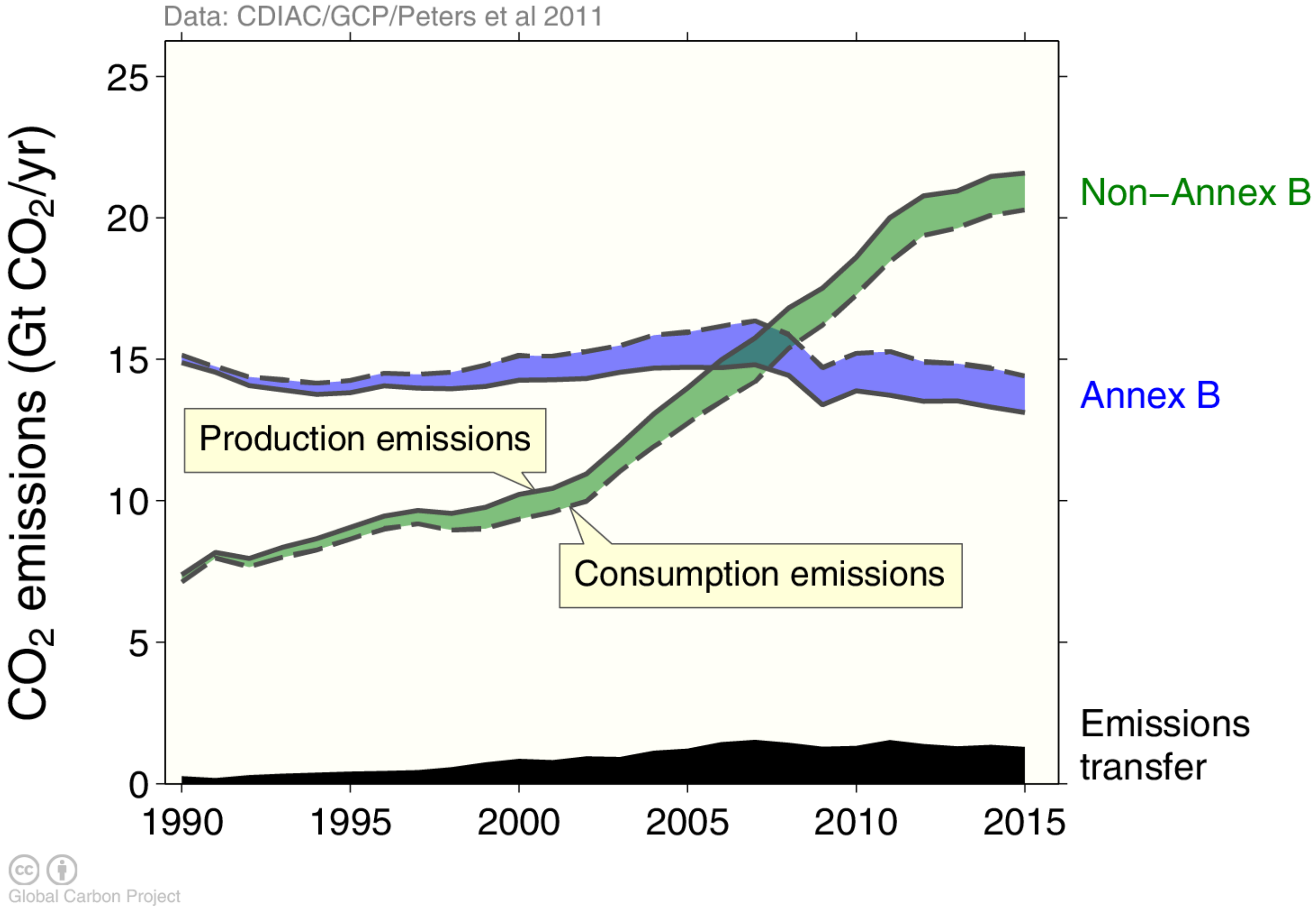
Allocating fossil and industry emissions to the consumption of products provides an alternative perspective.
USA and EU28 are net importers of embodied emissions, China and India are net exporters.



Consumption-based emissions are calculated by adjusting the
standard production-based emissions to account for international trade
Source: Peters et al 2011; Le Quéré et al 2017; Global Carbon Project 2017

Consumption-based emissions (carbon footprint)

Transfers of emissions embodied in trade from non-Annex B countries to Annex B countries grew at over 11% per year between 1990 and 2007, but have since declined at over 1% per year.

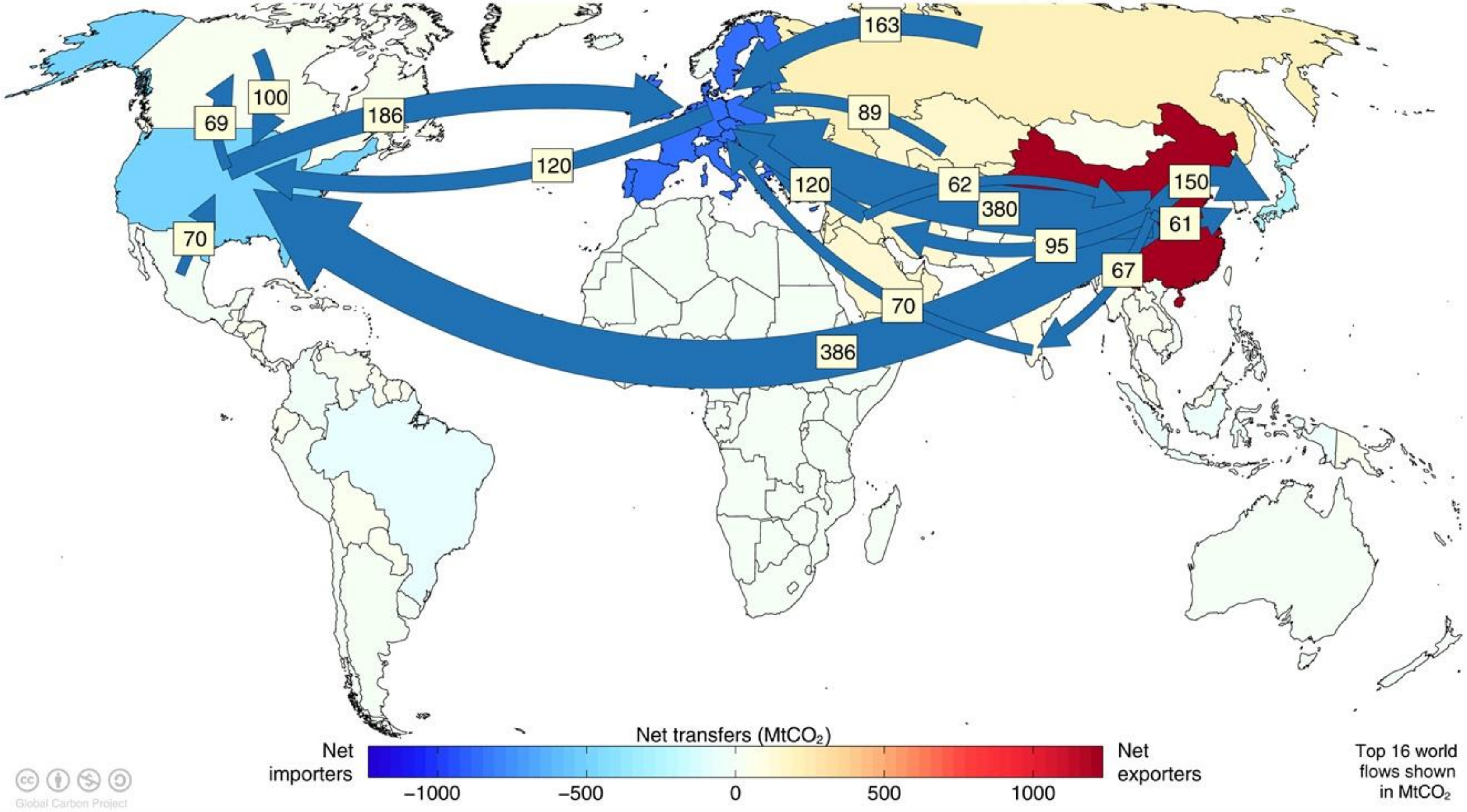


Annex B countries were used in the Kyoto Protocol, but this distinction is less relevant in the Paris Agreement

Source: CDIAC; Peters et al 2011; Le Quéré et al 2017; Global Carbon Budget 2017

Major flows from production to consumption

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

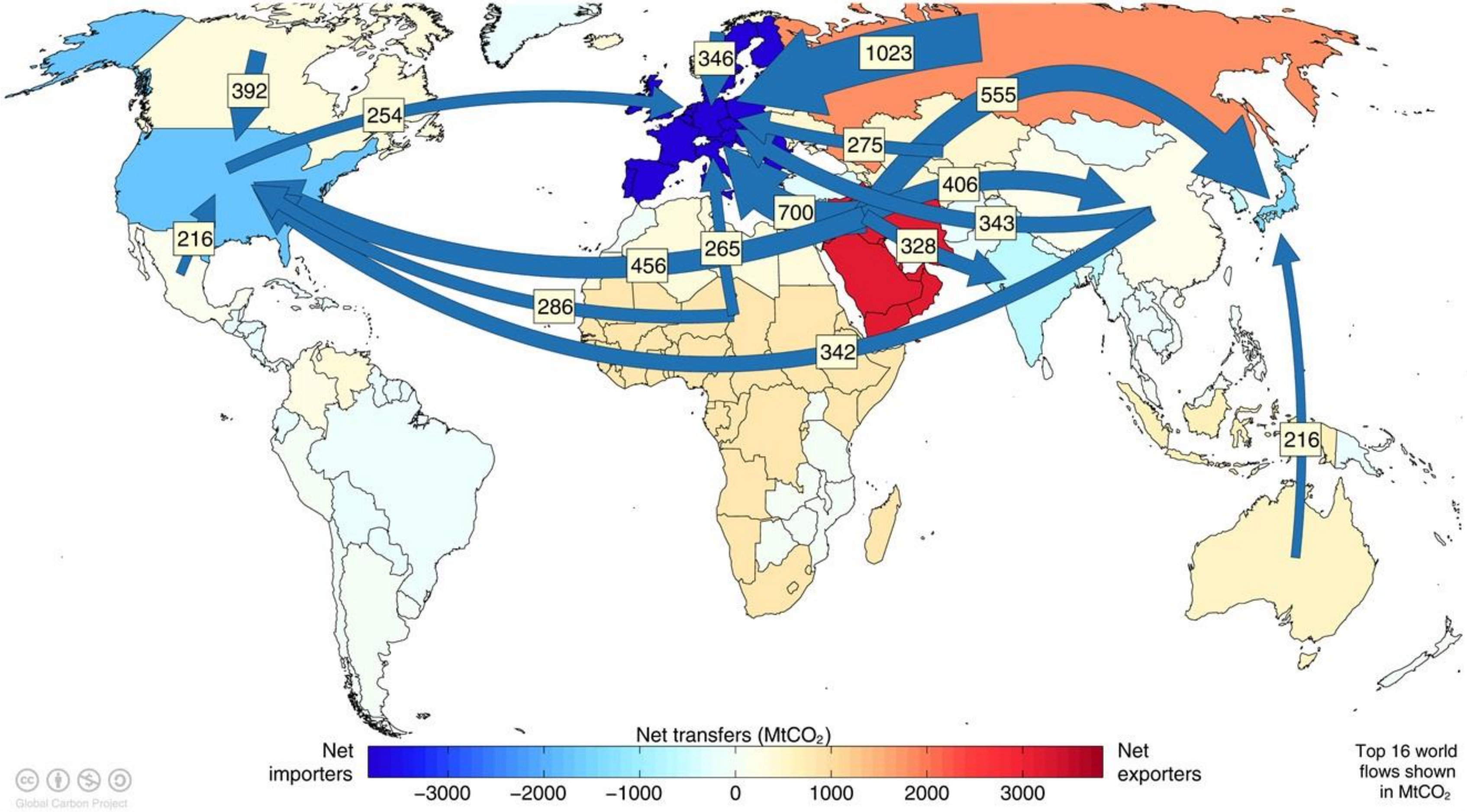


Values for 2011. EU is treated as one region. Units: $MtCO_2$

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



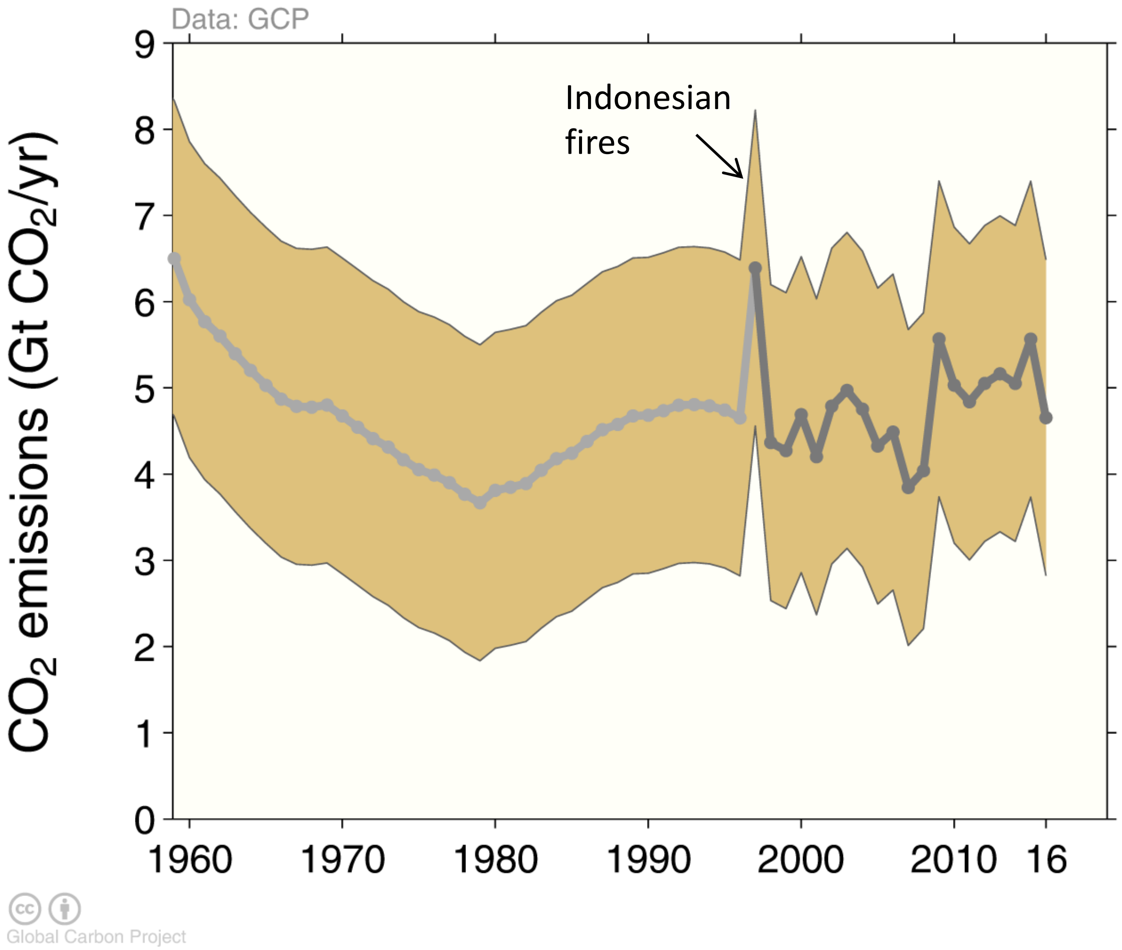
Values for 2011. EU is treated as one region. Units: $MtCO_2$

Source: Andrew et al 2013

Land-use Change Emissions

Land-use change emissions

Land-use change emissions are highly uncertain. Higher emissions in 2016 are linked to increased fires during dry El Niño conditions in tropical Asia

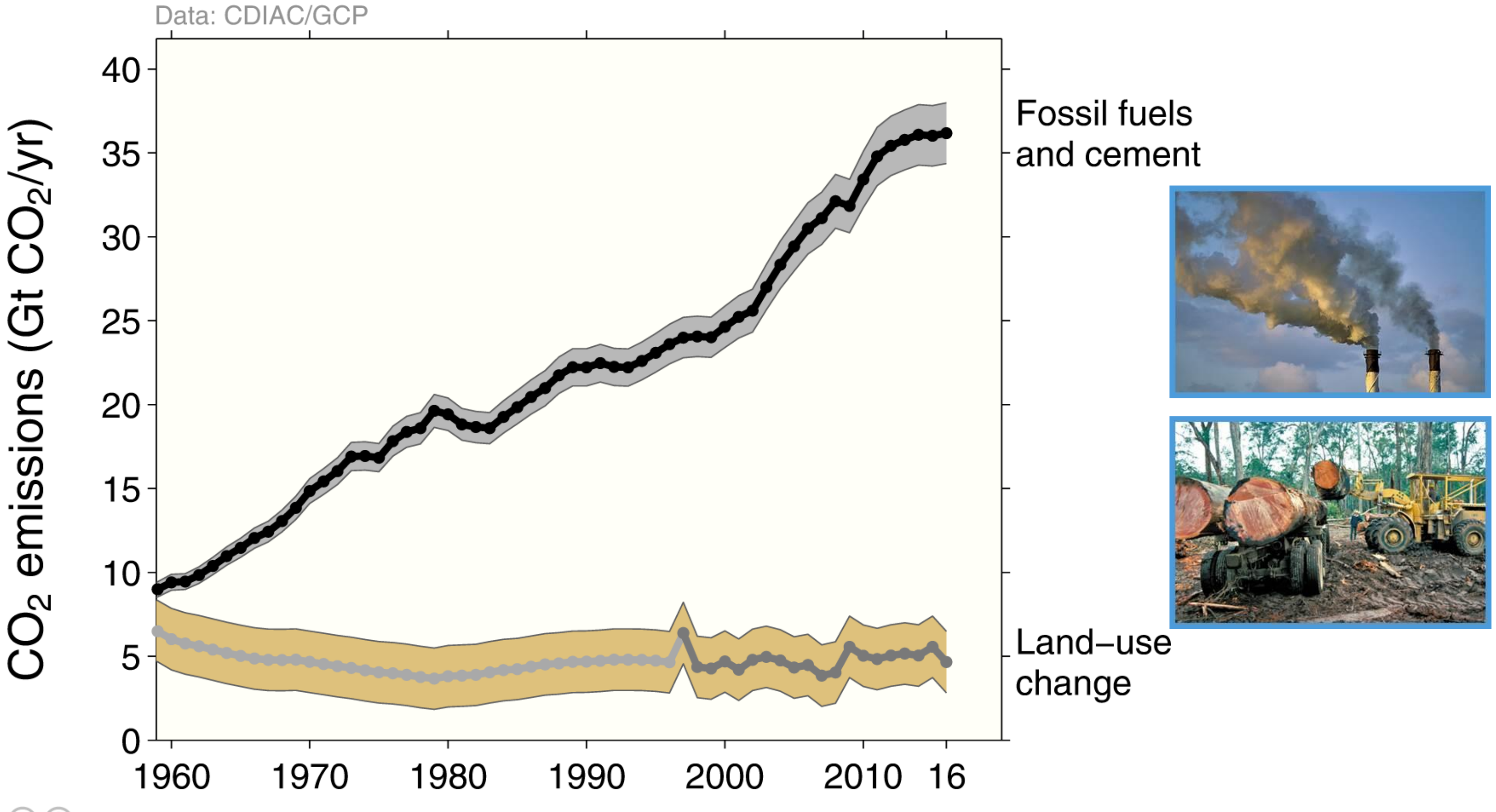


Estimates from two bookkeeping models, using fire-based variability from 1997

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

Total global emissions

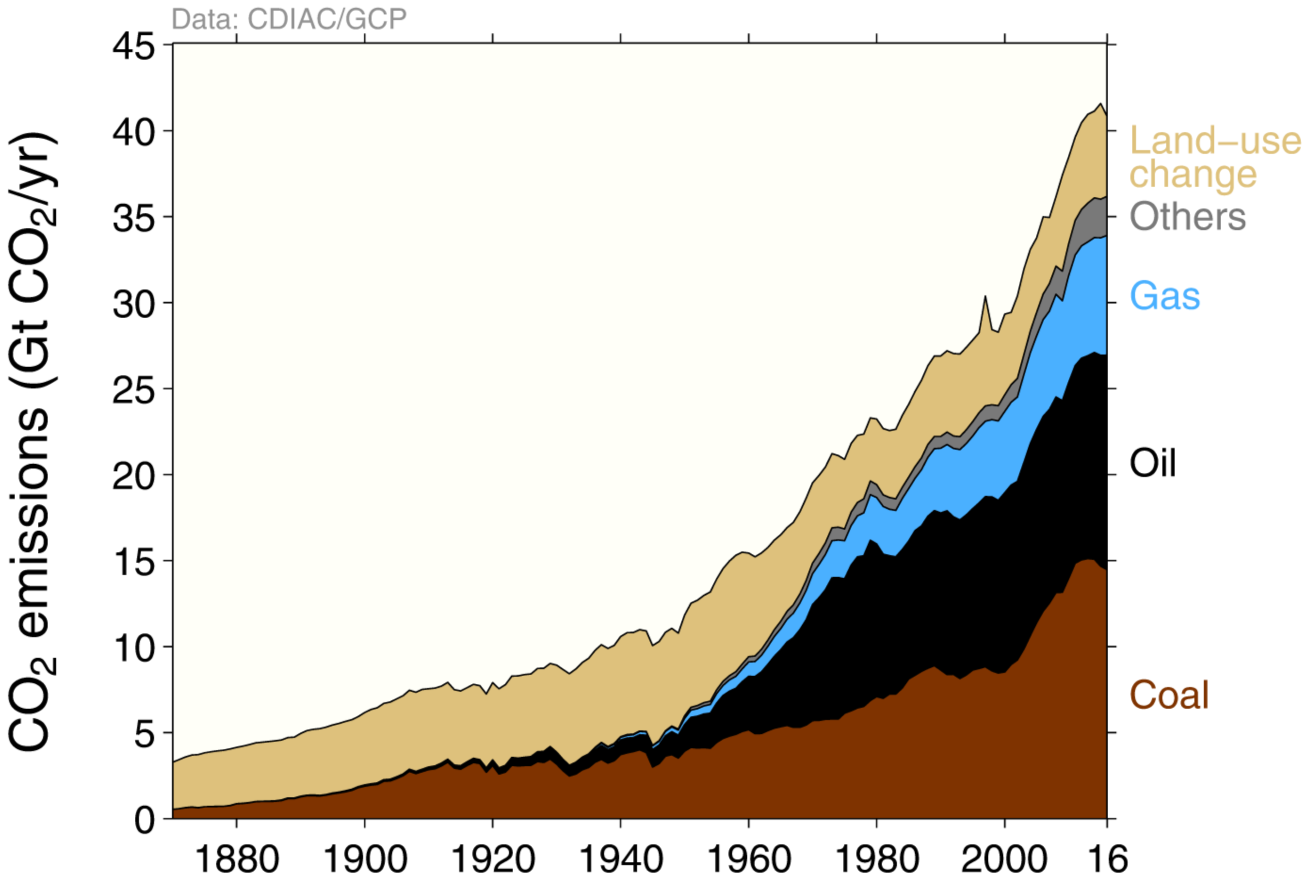
Total global emissions: 40.8 ± 2.7 $GtCO_2$ in 2016, 52% over 1990
Percentage land-use change: 42% in 1960, 12% averaged 2007-2016



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; Le Quéré et al 2017; Global Carbon Budget 2017

Total global emissions by source

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

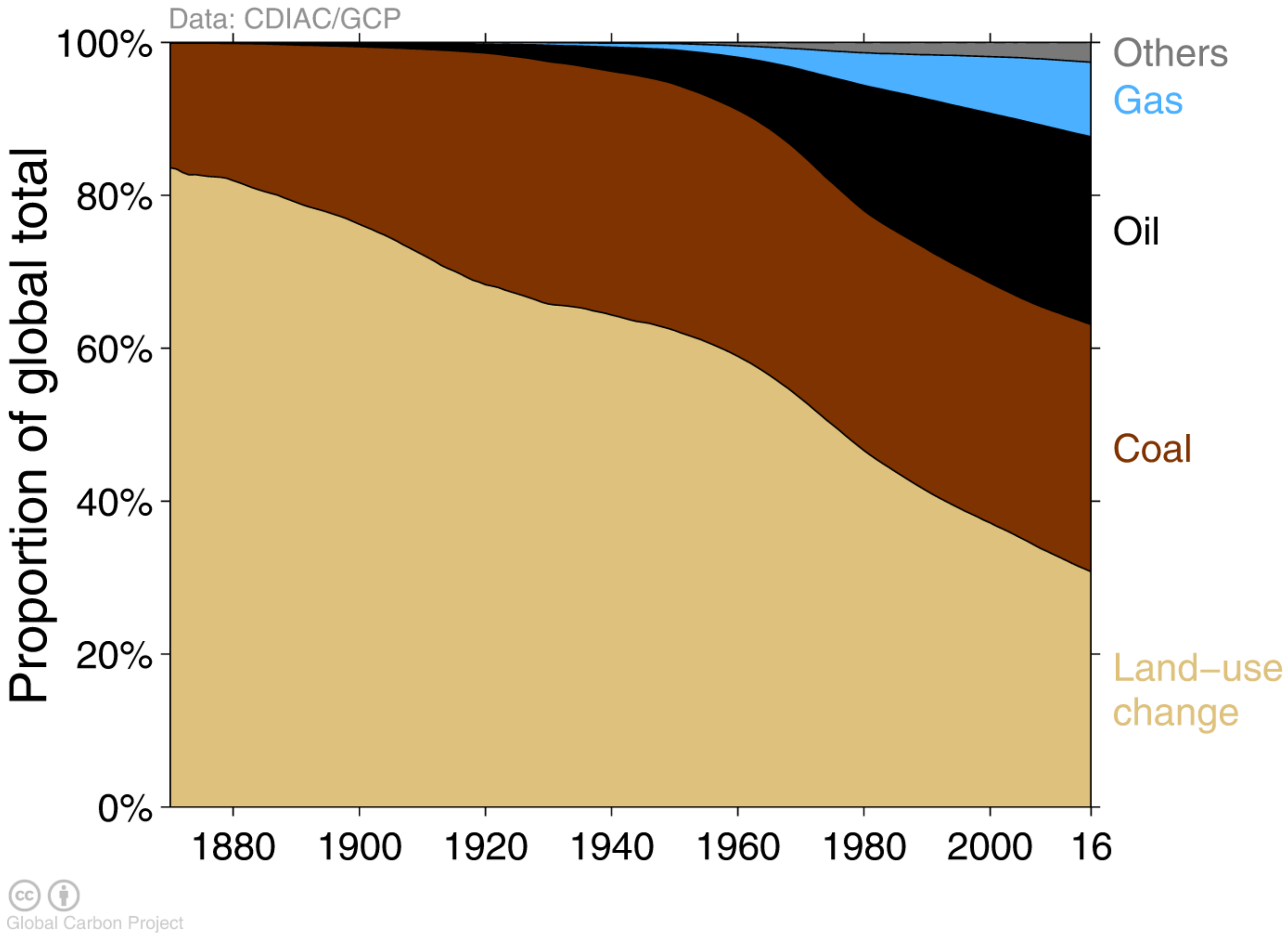


Others: Emissions from cement production and gas flaring

Source: CDIAC; Houghton and Nassikas 2017; Hansis et al 2015; Le Quéré et al 2017; Global Carbon Budget 2017

Historical cumulative emissions by source

Land-use change represents about 31% of cumulative emissions over 1870–2016,
coal 32%, oil 25%, gas 10%, and others 3%



Others: Emissions from cement production and gas flaring

Source: CDIAC; Houghton and Nassikas 2017; Hansis et al 2015; Le Quéré et al 2017; Global Carbon Budget 2017

Closing the Global Carbon Budget

Fate of anthropogenic CO_2 emissions (2007–2016)

Sources = Sinks

34.3 $GtCO_2$/yr
88%

12%
4.9 $GtCO_2$/yr

17.3 $GtCO_2$/yr
47%

30%
11.2 $GtCO_2$/yr

23%
8.7 $GtCO_2$/yr

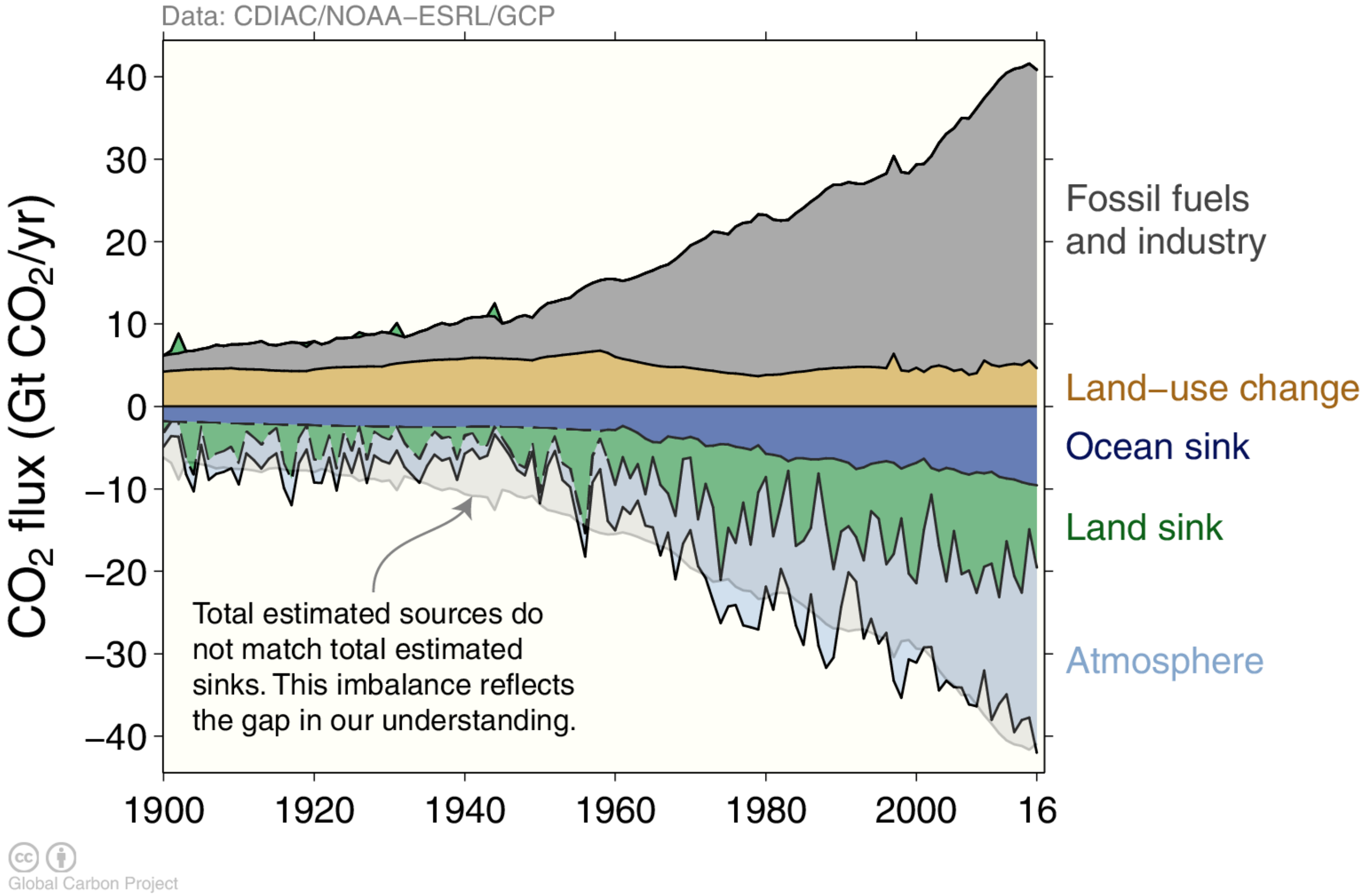
Budget Imbalance:
(the difference between estimated sources & sinks)

6%
2.1 $GtCO_2$/yr

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

Global carbon budget

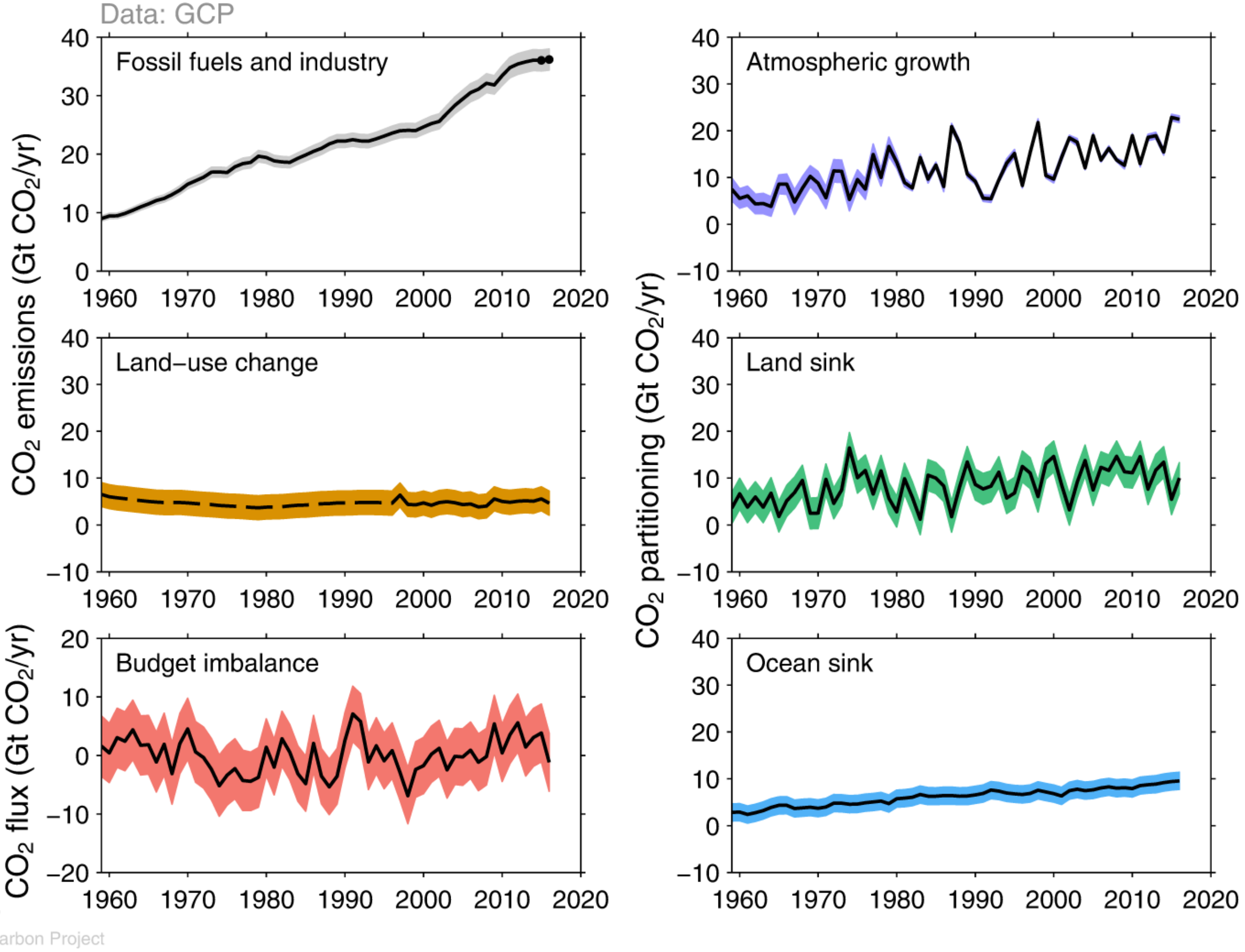
Carbon emissions are partitioned among the atmosphere and carbon sinks on land and in the ocean
The "imbalance" between total emissions and total sinks reflects the gap in our understanding



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

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

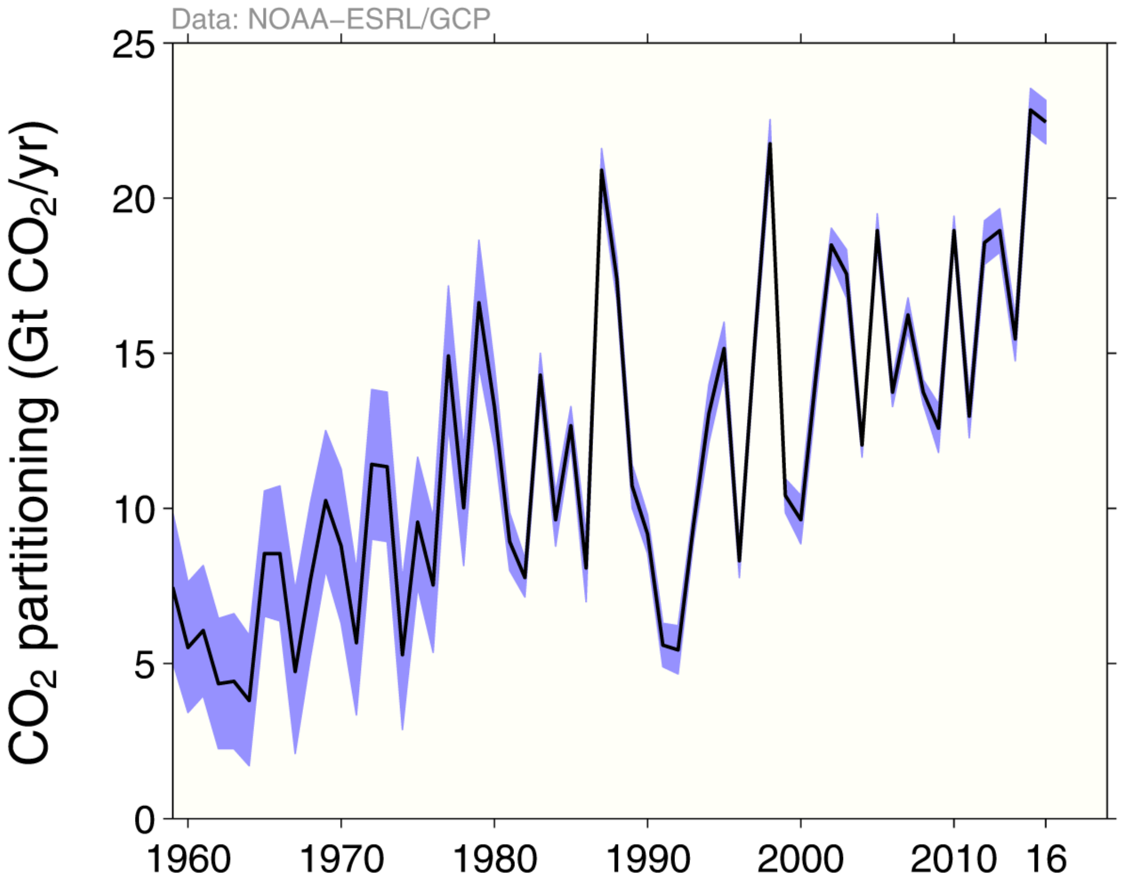


The budget imbalance is the total emissions minus the estimated growth in the atmosphere, land and ocean.
It reflects the limits of our understanding of the carbon cycle.

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

Atmospheric concentration

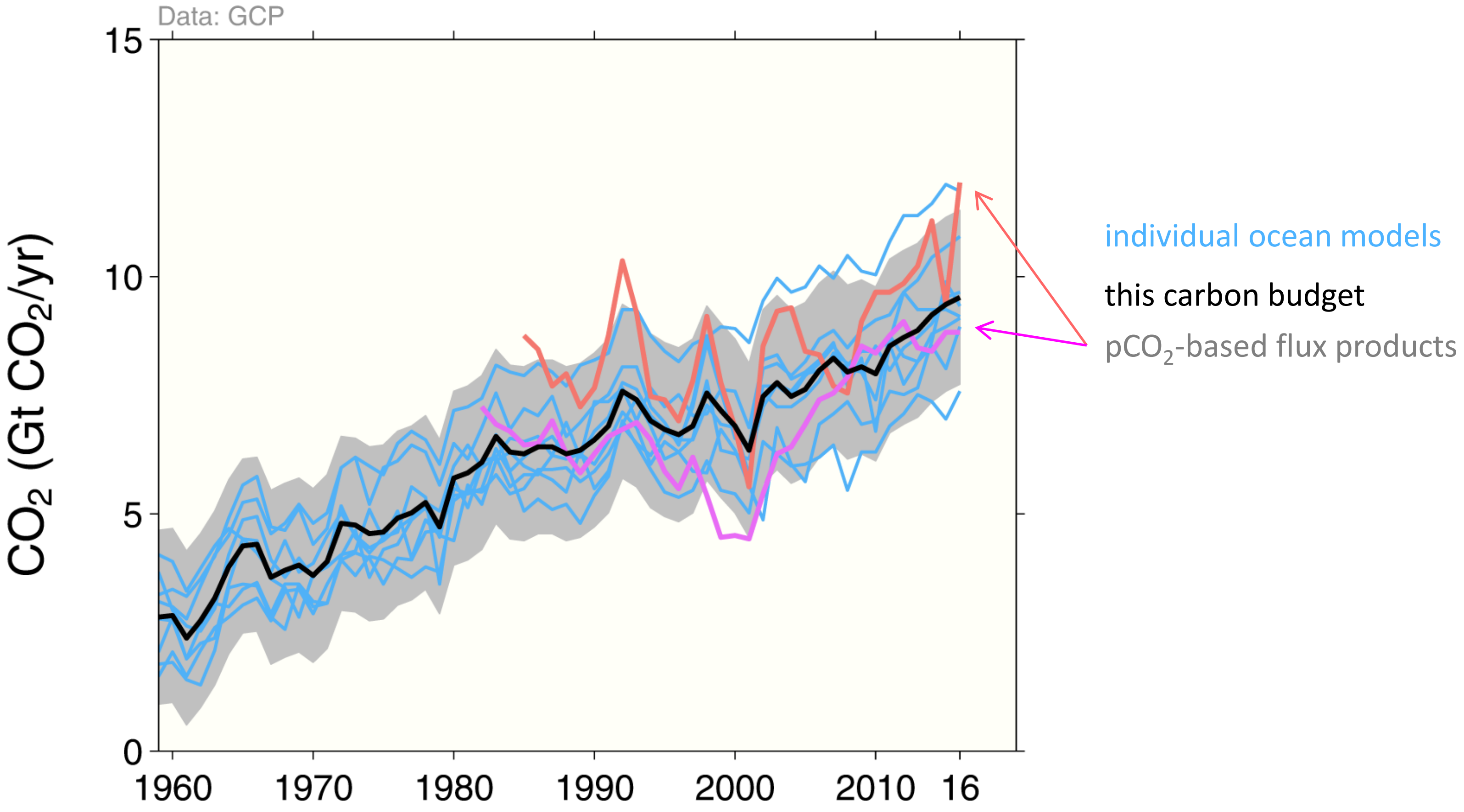
The atmospheric concentration growth rate has shown a steady increase
The high growth in 1987, 1998, & 2015-16 reflect a strong El Niño, which weakens the land sink



Source: [NOAA-ESRL](); [Global Carbon Budget 2017]()

Ocean sink

The ocean carbon sink continues to increase
8.7±2 $GtCO_2$/yr for 2007–2016 and 9.6±2 $GtCO_2$/yr in 2016

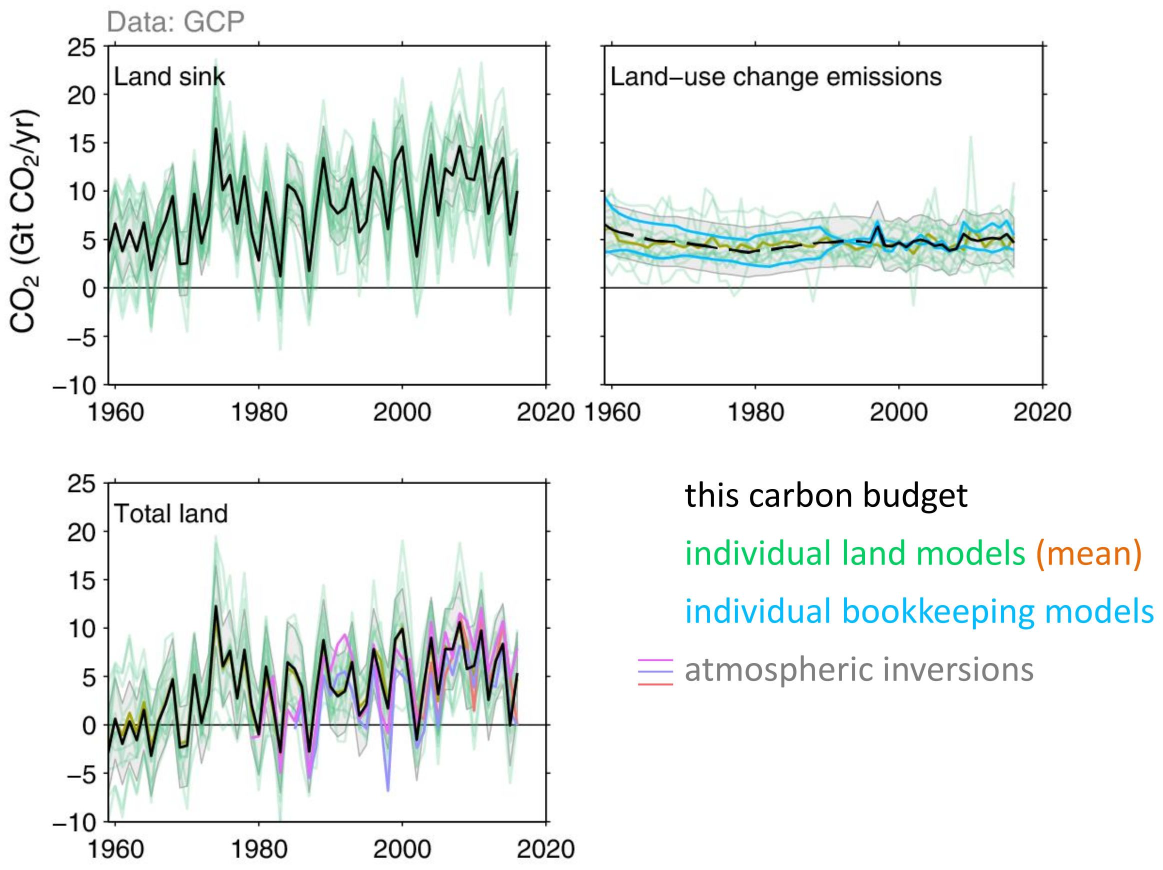


Source: SOCATv5; Bakker et al 2016; Le Quéré et al 2017; Global Carbon Budget 2017

Individual estimates from: Aumont and Bopp (2006); Buitenhuis et al. (2010); Doney et al. (2009); Hauck et al. (2016); Ilyina et al. (2013); Landschützer et al. (2016); Law et al. (2017); ; Rödenbeck et al. (2014). Séférian et al. (2013); Schwinger et al. (2016). Full references provided in Le Quéré et al. (2017).

Terrestrial sink

The land sink was 11.2±3 GtCO2/yr during 2007-2016 and 10±3 $GtCO_2$/yr in 2016
Total CO_2 fluxes on land (including land-use change) are constrained by atmospheric inversions

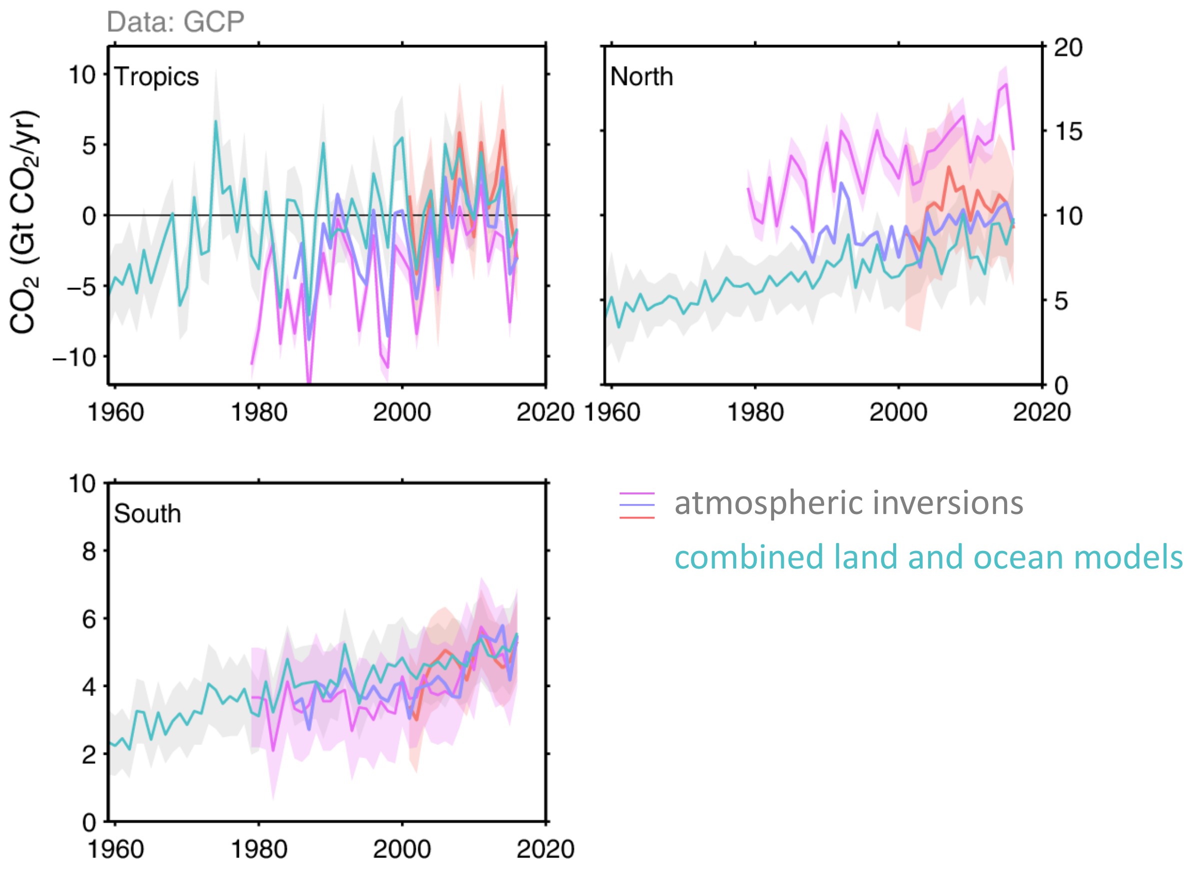


Source: Le Quéré et al 2017; Global Carbon Budget 2017

Individual estimates from: Chevallier et al. (2005); Clarke et al. (2011); Guimberteau et al. (2017); Hansis et al. (2015); Haverd et al. (2017); Houghton and Nassikas (2017); Jain et al. (2013); Kato et al. (2013); Keller et al. (2017); Krinner et al. (2005); Melton and Arora (2016); Oleson et al. (2013); Reick et al. (2013); Rodenbeck et al. (2003); Sitch et al. (2003); Smith et al. (2014); Tian et al. (2015); van der Laan-Luijkx et al. (2017); Woodward et al. (1995); Zaehle and Friend (2010). Full references provided in Le Quéré et al. (2017).

Total land and ocean fluxes

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

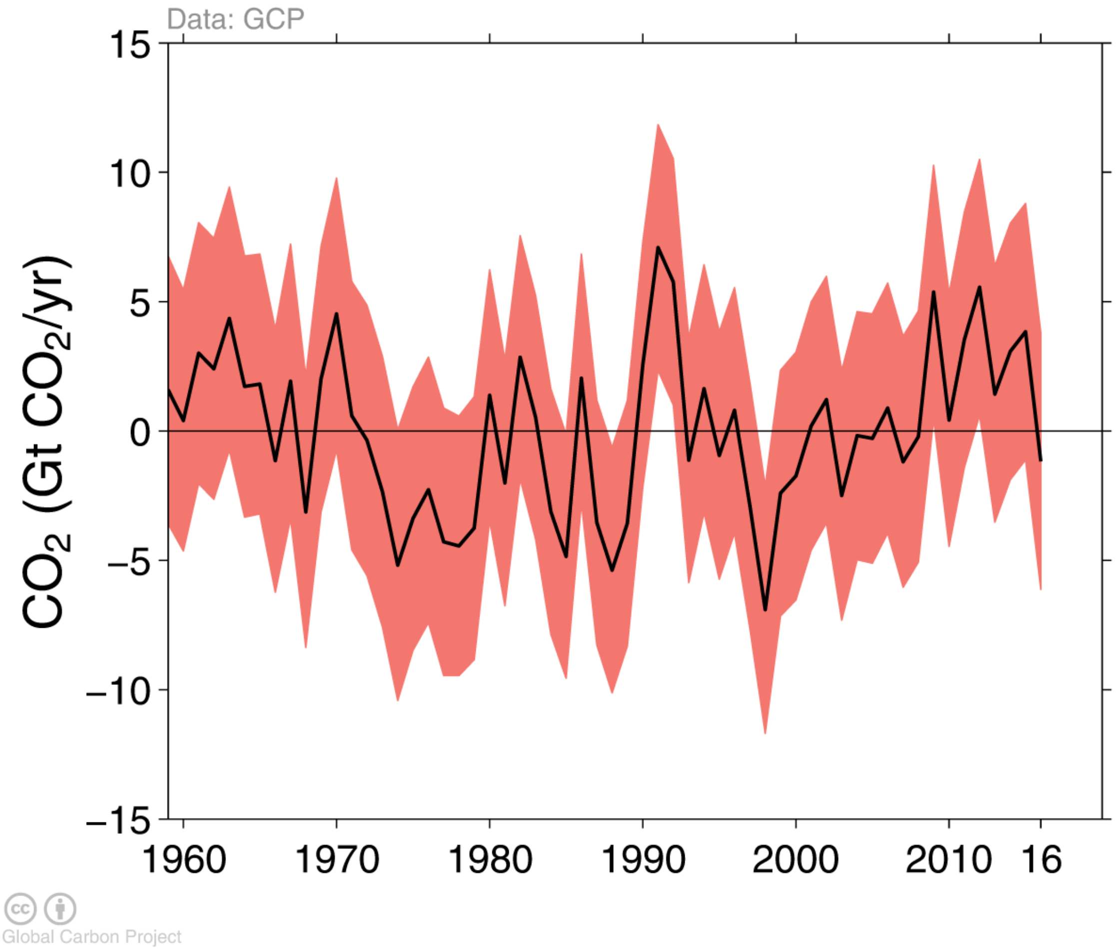


Source: Le Quéré et al 2017; Global Carbon Budget 2017

Individual estimates from: Aumont and Bopp (2006); Buitenhuis et al. (2010); Chevallier et al. (2005); Clarke et al. (2011); ; Doney et al. (2009); Guimberteau et al. (2017); Hauck et al. (2016); Haverd et al. (2017); Ilyina et al. (2013); Jain et al. (2013); Kato et al. (2013); Keller et al. (2017); Krinner et al. (2005); Landschützer et al. (2016); Law et al. (2017); Melton and Arora (2016); Oleson et al. (2013); Reick et al. (2013); Rödenbeck et al. (2003); Rödenbeck et al. (2014); Séférian et al. (2013); Schwinger et al. (2016); Sitch et al. (2003); Smith et al. (2014); Tian et al. (2015); van der Laan-Luijkx et al. (2017); Woodward et al. (1995); Zaehle and Friend (2010). Full references provided in Le Quéré et al. (2017).

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: [Le Quéré et al 2017](); [Global Carbon Budget 2017]()

Global carbon budget

The cumulative contributions to the global carbon budget from 1870
The carbon imbalance represents the gap in our current understanding of sources and sinks

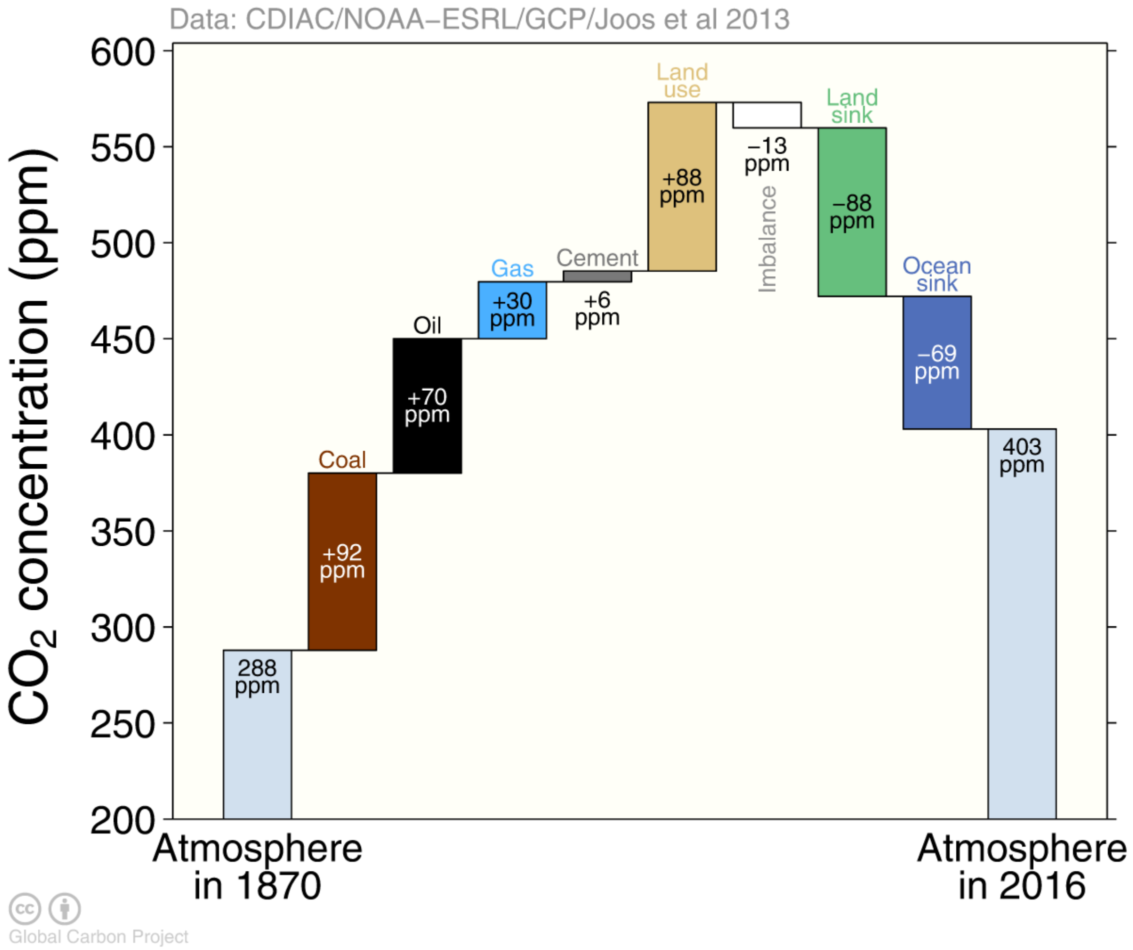
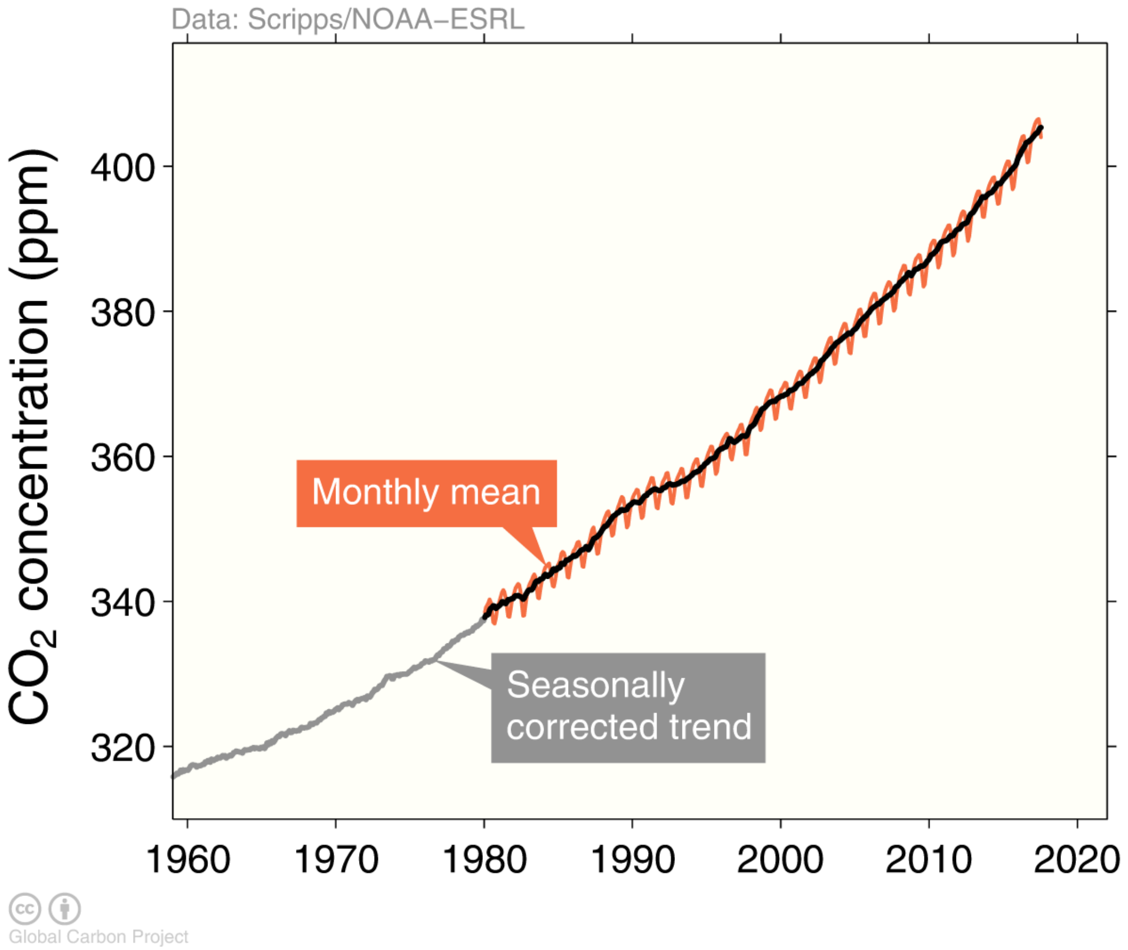


Figure concept from Shrink That Footprint
Source: CDIAC; NOAA-ESRL; Houghton and Nassikas 2017; Hansis et al 2015; Joos et al 2013; Khatiwala et al. 2013; DeVries 2014; Le Quéré et al 2017; Global Carbon Budget 2016

Atmospheric concentration

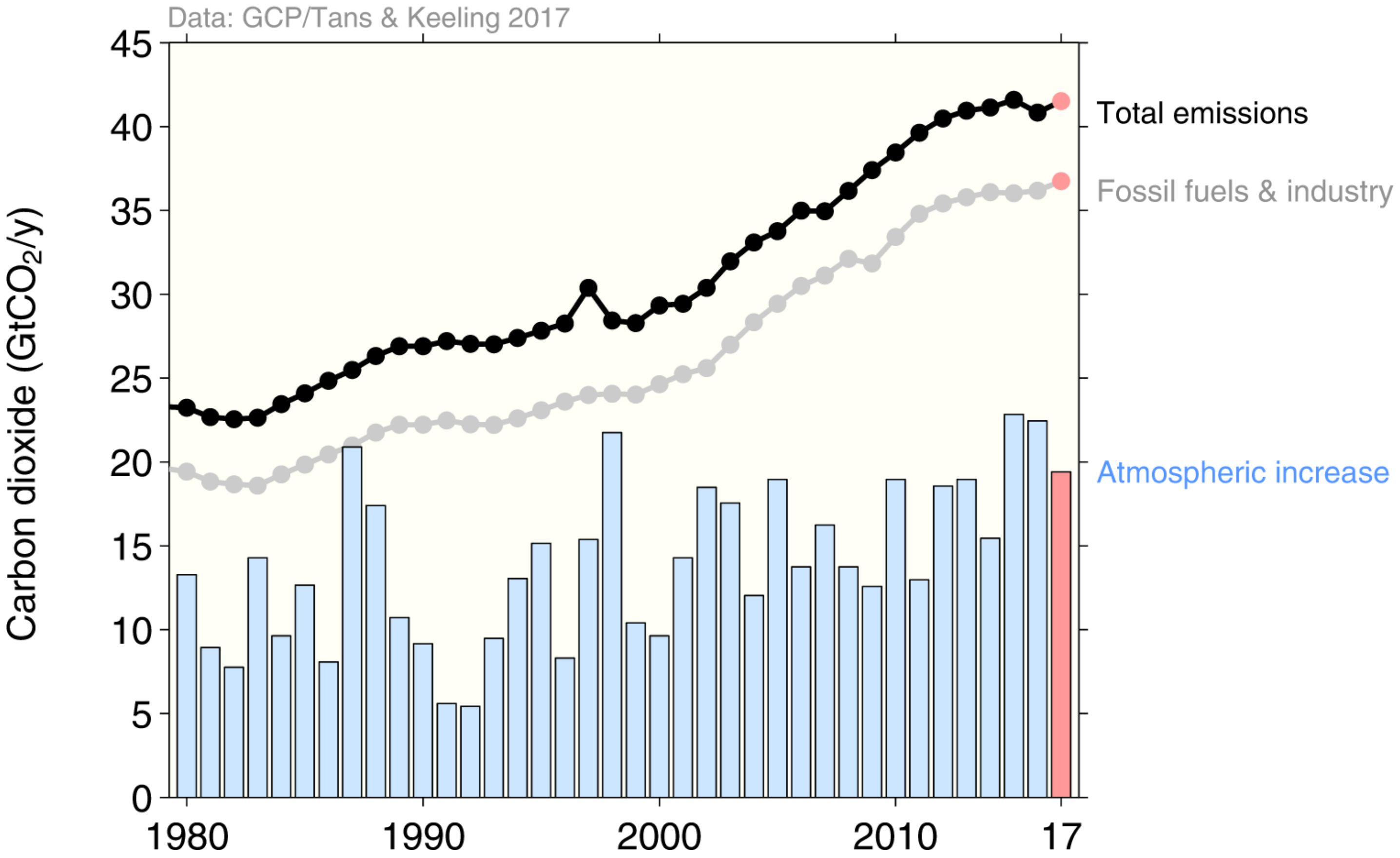
The global CO_2 concentration increased from ~277ppm in 1750 to 403ppm in 2016 (up 45%)
2016 was the first full year with concentration above 400ppm



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; Le Quéré et al 2017; Global Carbon Budget 2017

Trends in CO_2 emissions and concentrations

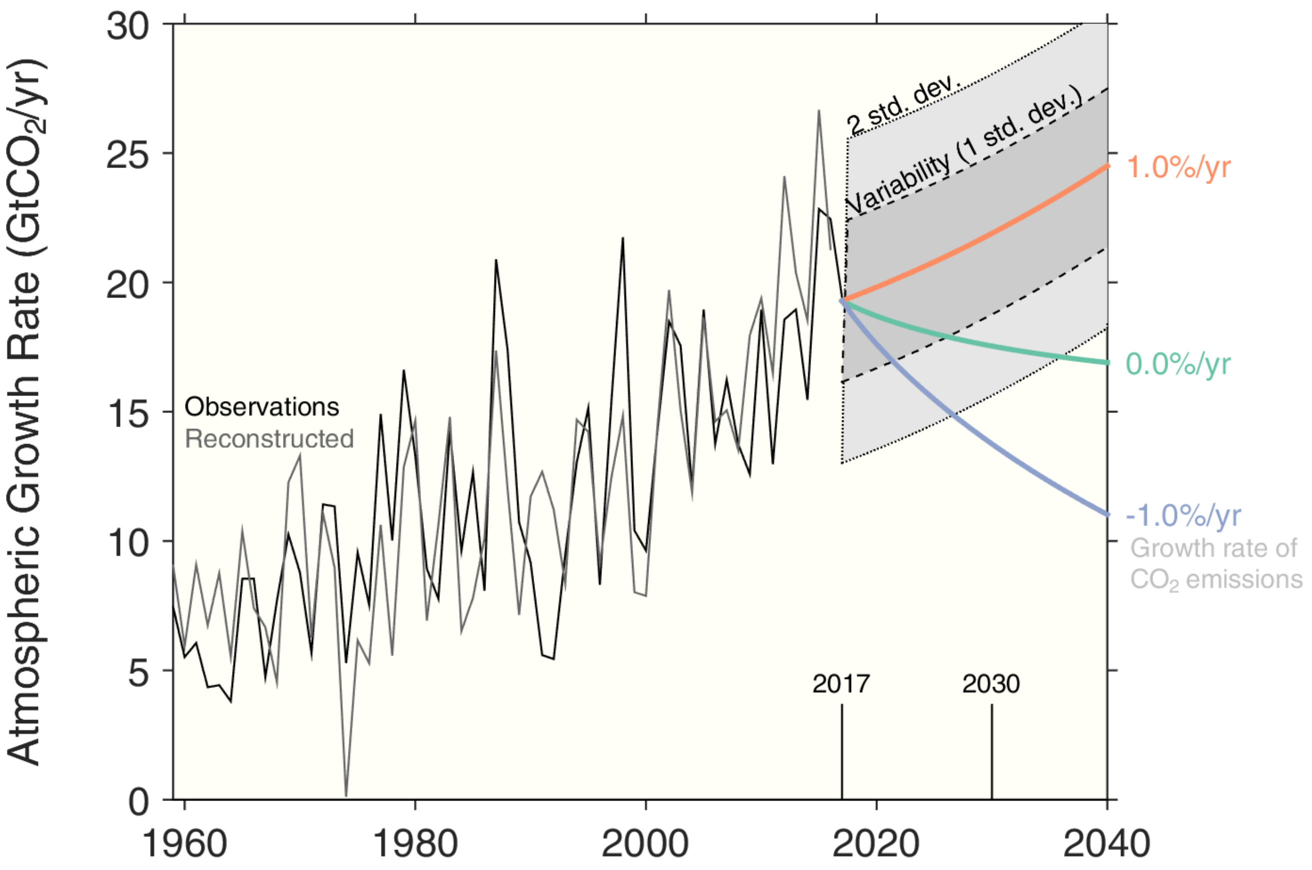
Atmospheric CO_2 concentration had record growth in 2015 & 2016 due to record high emissions and El Niño conditions, but growth is expected to reduce due to the end of El Niño



Source: Peters et al 2017; Global Carbon Budget 2017

Verification of a sustained change in CO_2 emissions

Our ability to detect changes in CO_2 emissions based on atmospheric observations is limited by our understanding of carbon cycle variability

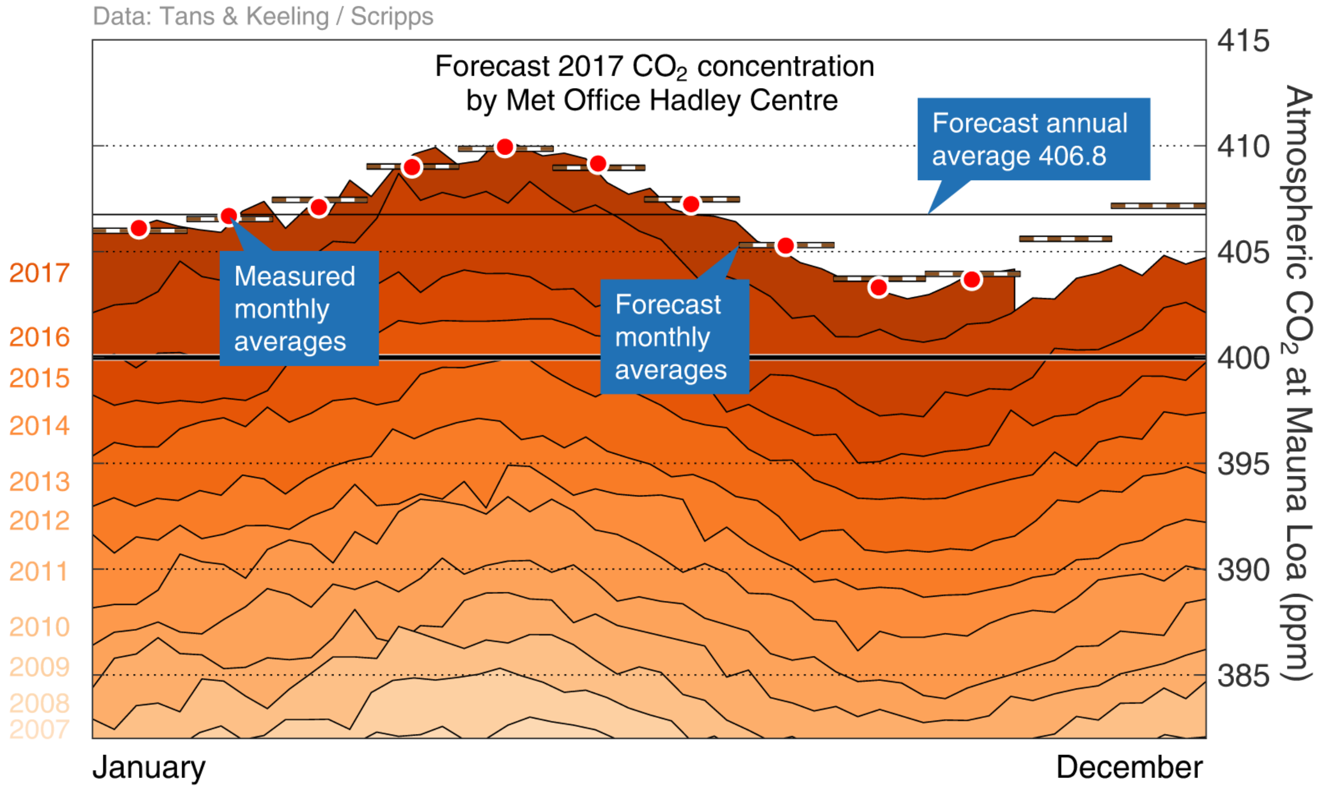


Observations show a large-interannual to decadal variability, which can only be partially *reconstructed* through the global carbon budget. The difference between observations and reconstructed is the “budget imbalance”.

Source: Peters et al 2017; Global Carbon Budget 2017

Seasonal variation of atmospheric CO_2 concentration

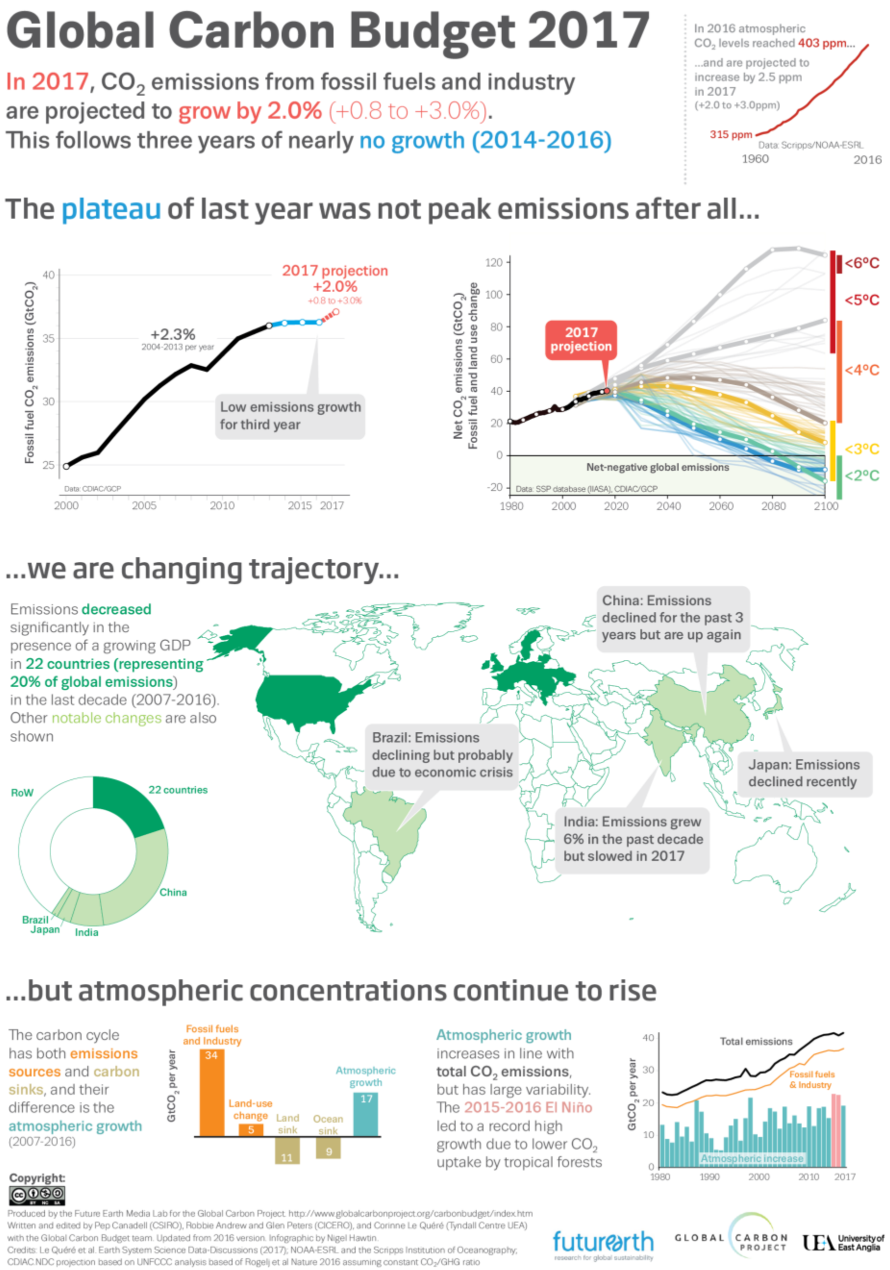
Weekly CO_2 concentration measured at Mauna Loa stayed above 400ppm throughout 2016
and is forecast to average 406.8 in 2017



Forecasts are an update of Betts et al 2016. The deviation from monthly observations is 0.24 ppm (RMSE).
Updates of this figure are available, and another on the drivers of the atmospheric growth
Source: Tans and Keeling (2017), NOAA-ESRL, Scripps Institution of Oceanography

End notes

Infographic



Acknowledgements

The work presented in the **Global Carbon Budget 2017** 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.

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https://doi.org/10.5194/essdd-2017-123

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

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