GLOBAL CARBON PROJECT

Global Carbon Budget

2015

futureearth research for global sustainability

GLOBAL IGBP International Geosphere-Biosphere Programme CHANGE

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Acknowledgements

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Atmospheric CO_2 datasets
NOAA/ESRL (Dlugokencky et al. 2015)
Scripps (Keeling et al. 1976)

Fossil Fuels and Industry
CDIAC (Boden et al. 2015)
USGS, 2015
UNFCCC, 2015
BP, 2015

Consumption Emission
Peters et al. 2011

Land-Use Change
Houghton et al. 2012
van der Werf et al. 2010

Atmospheric inversions
CarbonTracker (Peters et al. 2010)
Jena CarboScope (Rödenbeck et al. 2003)
MACC (Chevallier et al. 2005)

Land models
CLM4-5BGC | ISAM | JSBACH | JULES | LPJ-GUESS | LPJ | LPJmL | OCNv1.r240 | ORCHIDEE | VEGAS | VISIT

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

SOCAT
SOCATv3 (Bakker et al. 2014, 2015)

Ocean Data products
Jena CarboScope (Rödenbeck et al. 2014)
Landschützer et al. 2015

Full references provided in Le Quéré et al 2015

GLOBAL CARBON PROJECT

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Data access

Earth Syst. Sci. Data, 7, 349–396, 2015
www.earth-syst-sci-data.net/7/349/2015/
doi:10.5194/essd-7-349-2015

Open Access Earth System Science Data

Global Carbon Budget 2015

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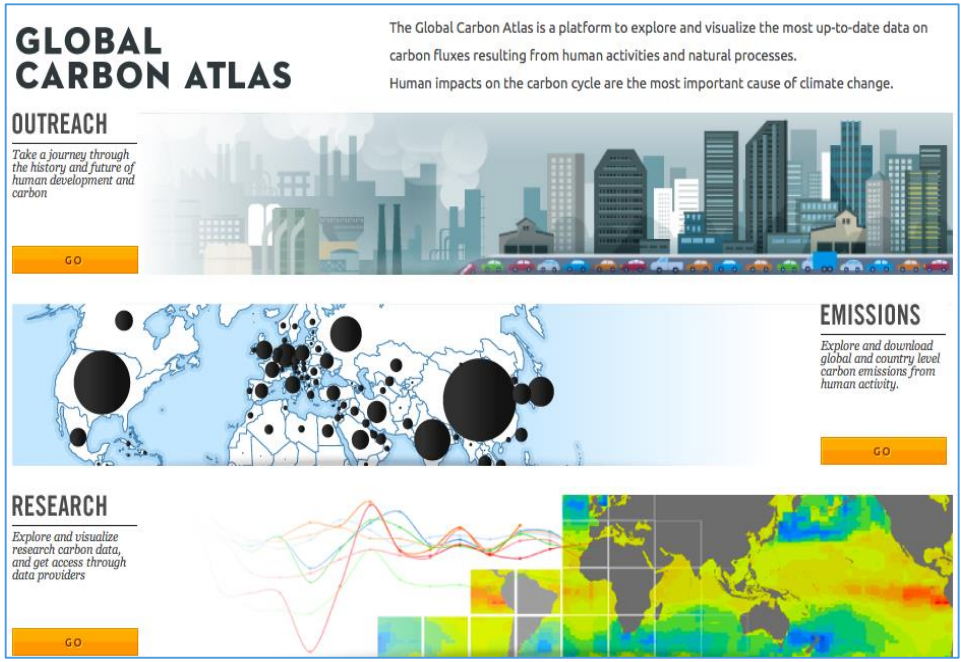

More information, data sources and data files:
www.globalcarbonproject.org
Contact: c.lequere@uea.ac.uk

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www.globalcarbonatlas.org
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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 $GtCO_2$

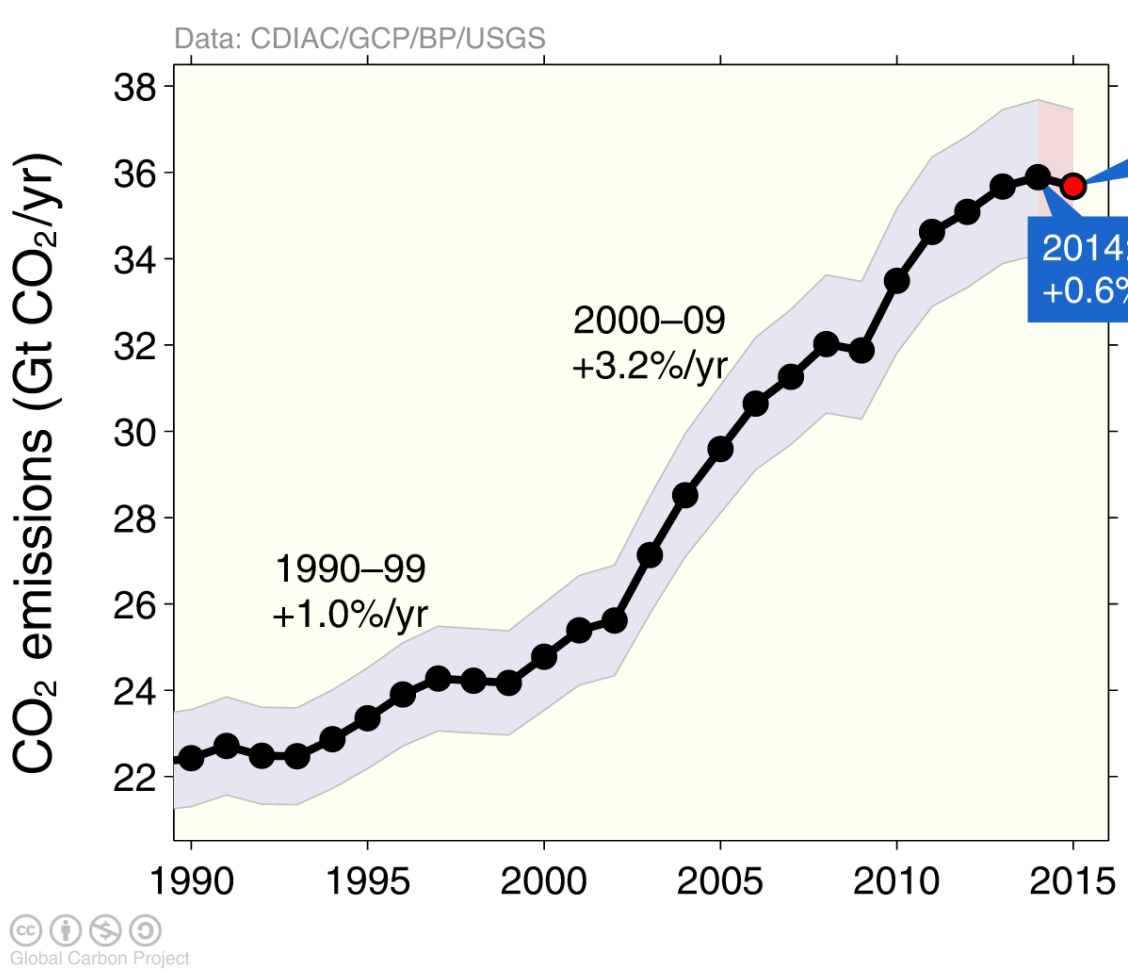
Disclaimer

Executive Summary

Emissions from fossil fuel use and industry

Global emissions from fossil fuel and industry: 35.9 ± 1.8 $GtCO_2$ in 2014, 60% over 1990

Projection for 2015: 35.7 ± 1.8 $GtCO_2$, 59% over 1990



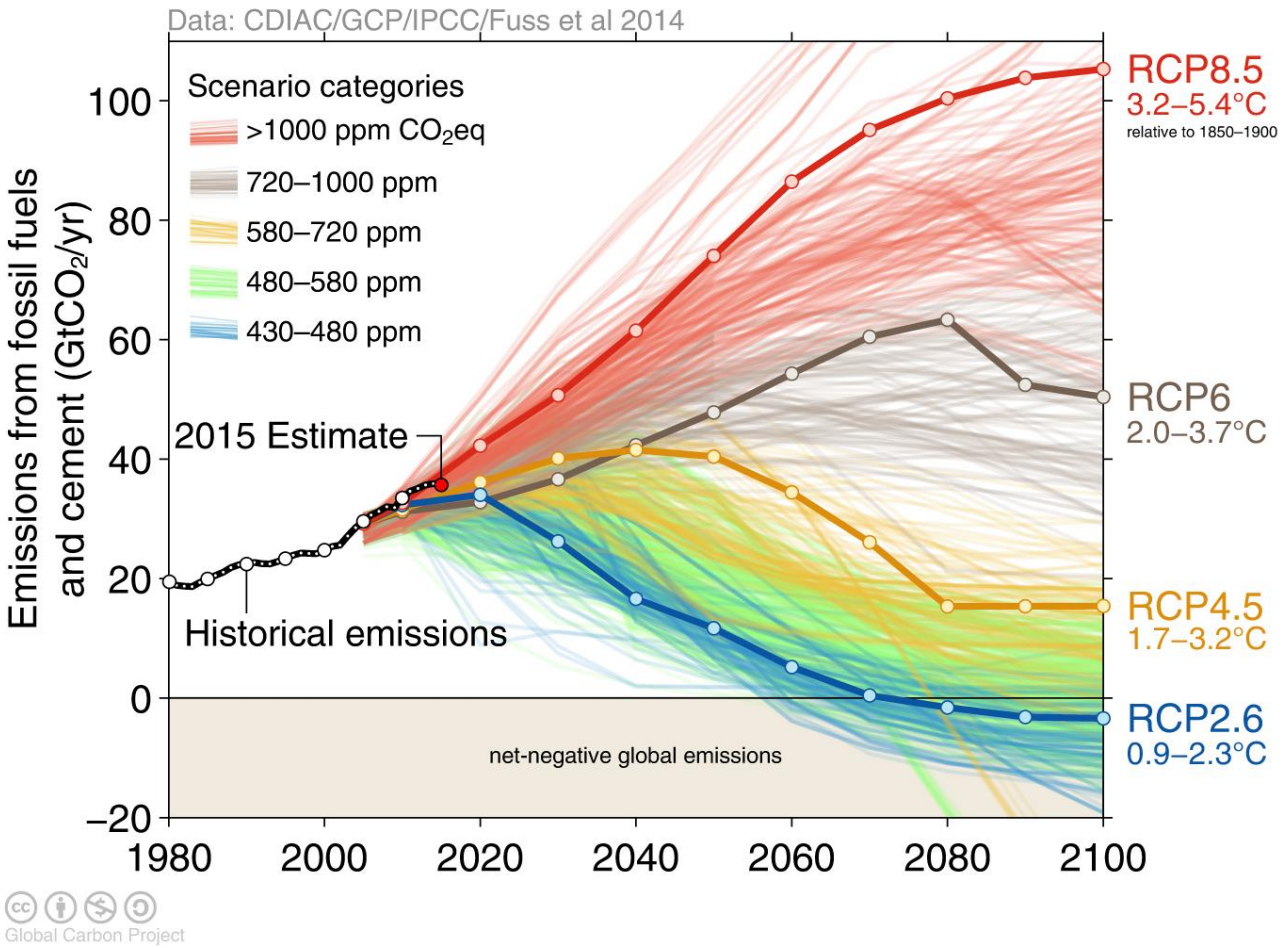
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

Estimates for 2012, 2013, 2014, and 2015 are preliminary

Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Observed emissions and emissions scenarios

The emission pledges submitted to the Paris climate summit avoid the worst effects of climate change (red), most studies suggest a likely temperature increase of about 3°C (brown)

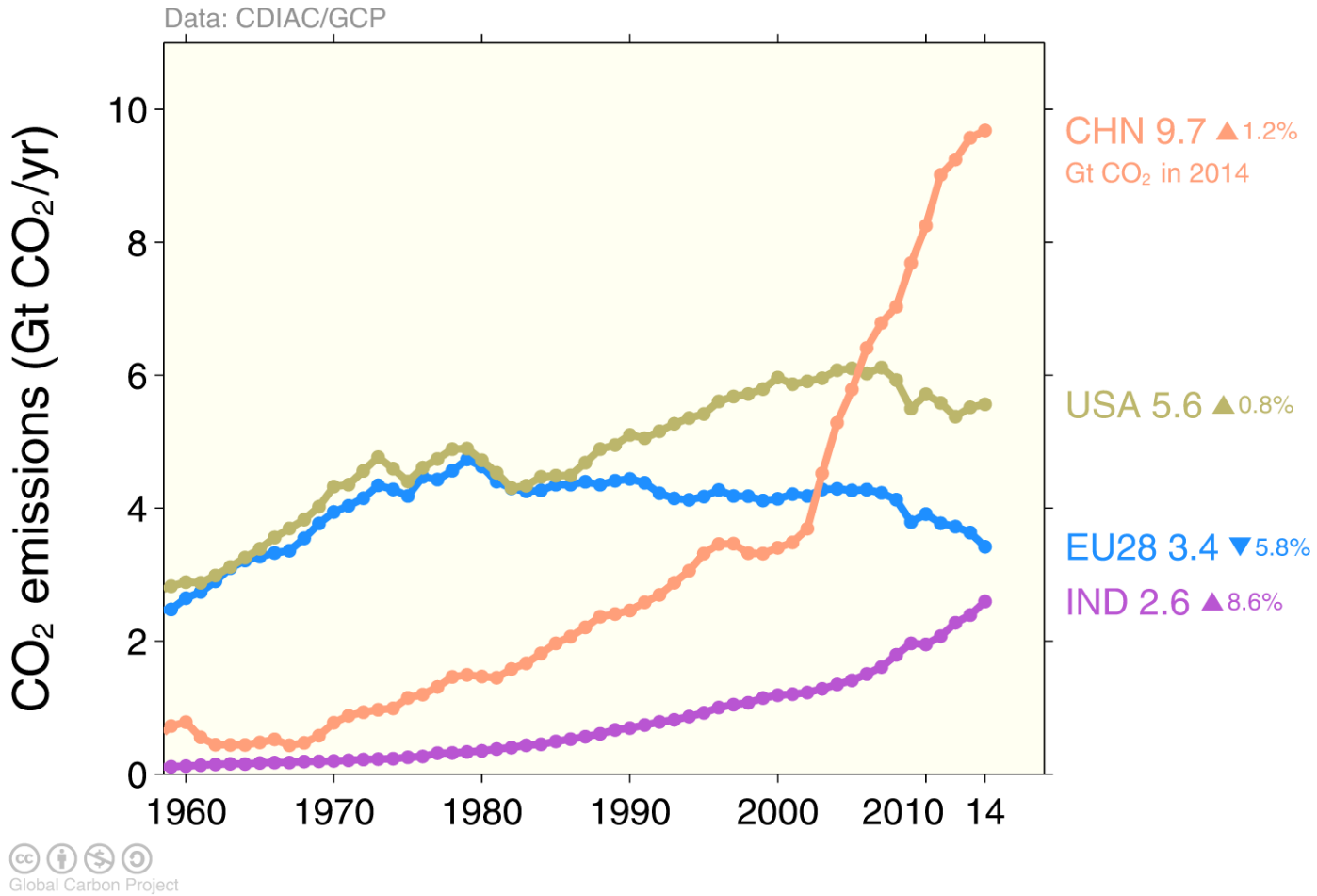


Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2015

Top fossil fuel emitters

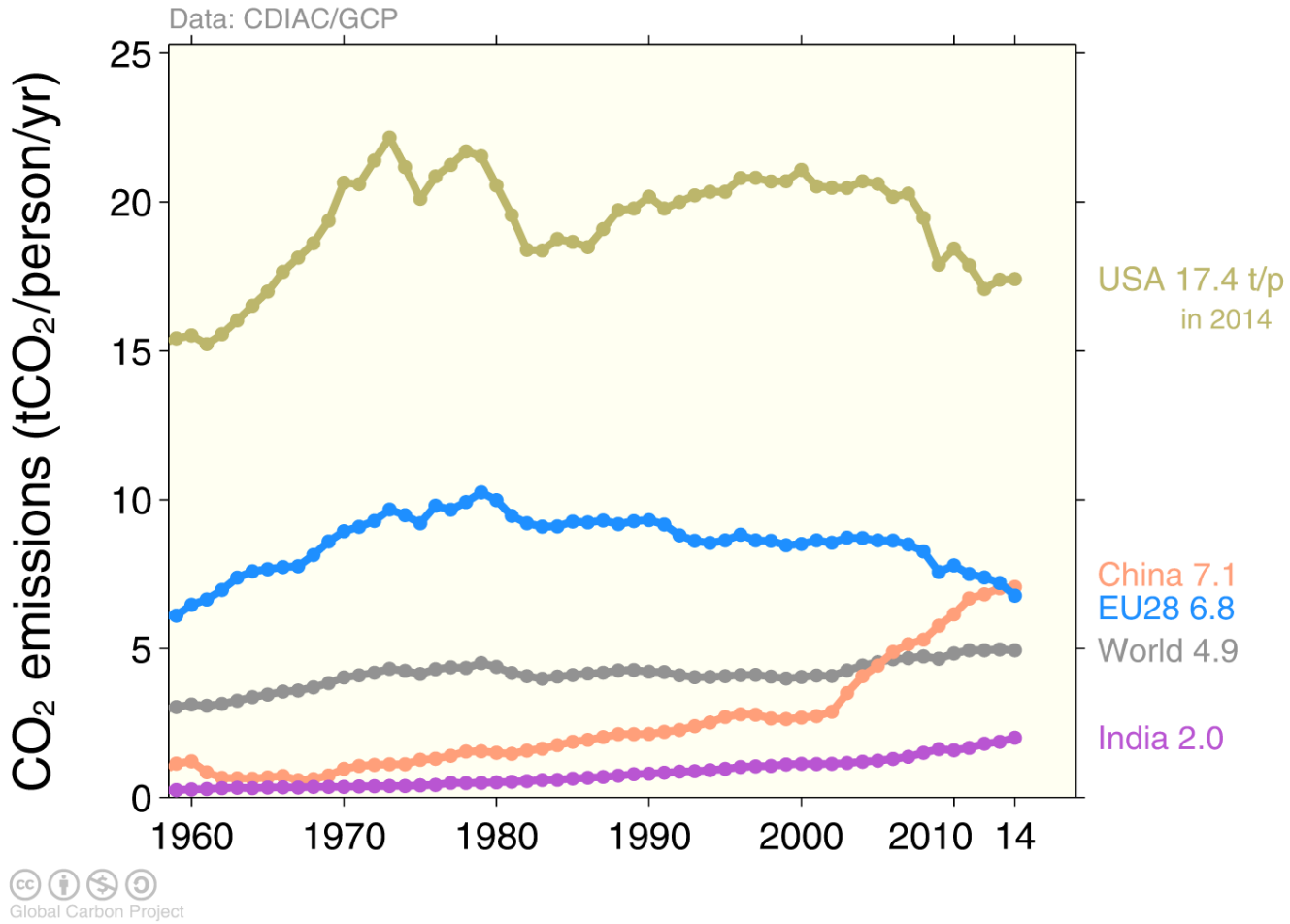
The top four emitters in 2014 covered 59% of global emissions
China (27%), United States (15%), EU28 (10%), India (7%)



Bunker fuels are used for international transport is 3.0% of global emissions
Statistical differences are between the global estimates and sum of national totals is 1.1% of global emissions
Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Top fossil fuel emitters (per capita)

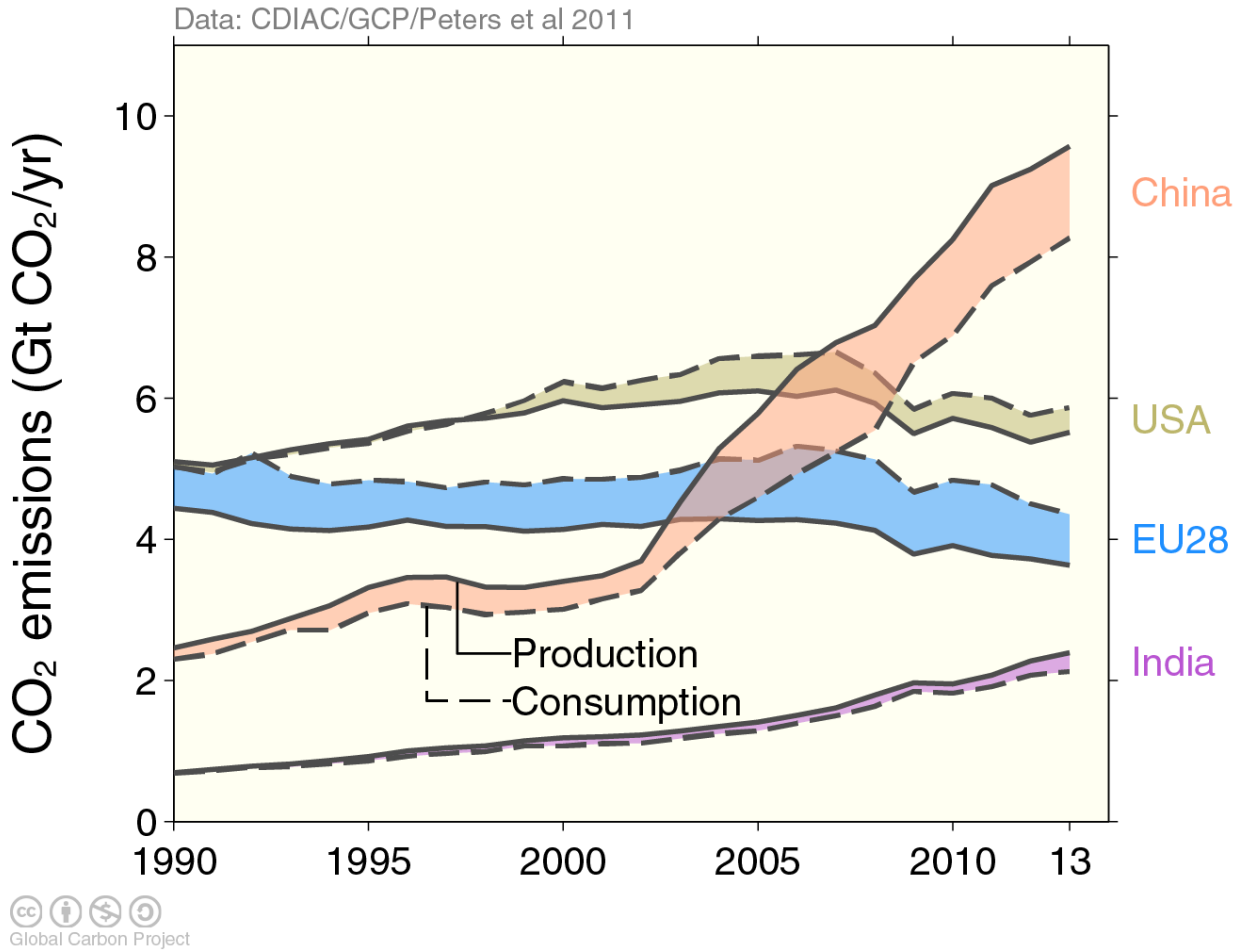
Countries have a broad range of per capita emissions reflecting their national circumstances
China's per capita emissions have passed the EU28 and are 43% above the global average



Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Consumption-based emissions (carbon footprint)

Allocating emissions to the consumption of goods and services provides an alternative perspective on emission drivers

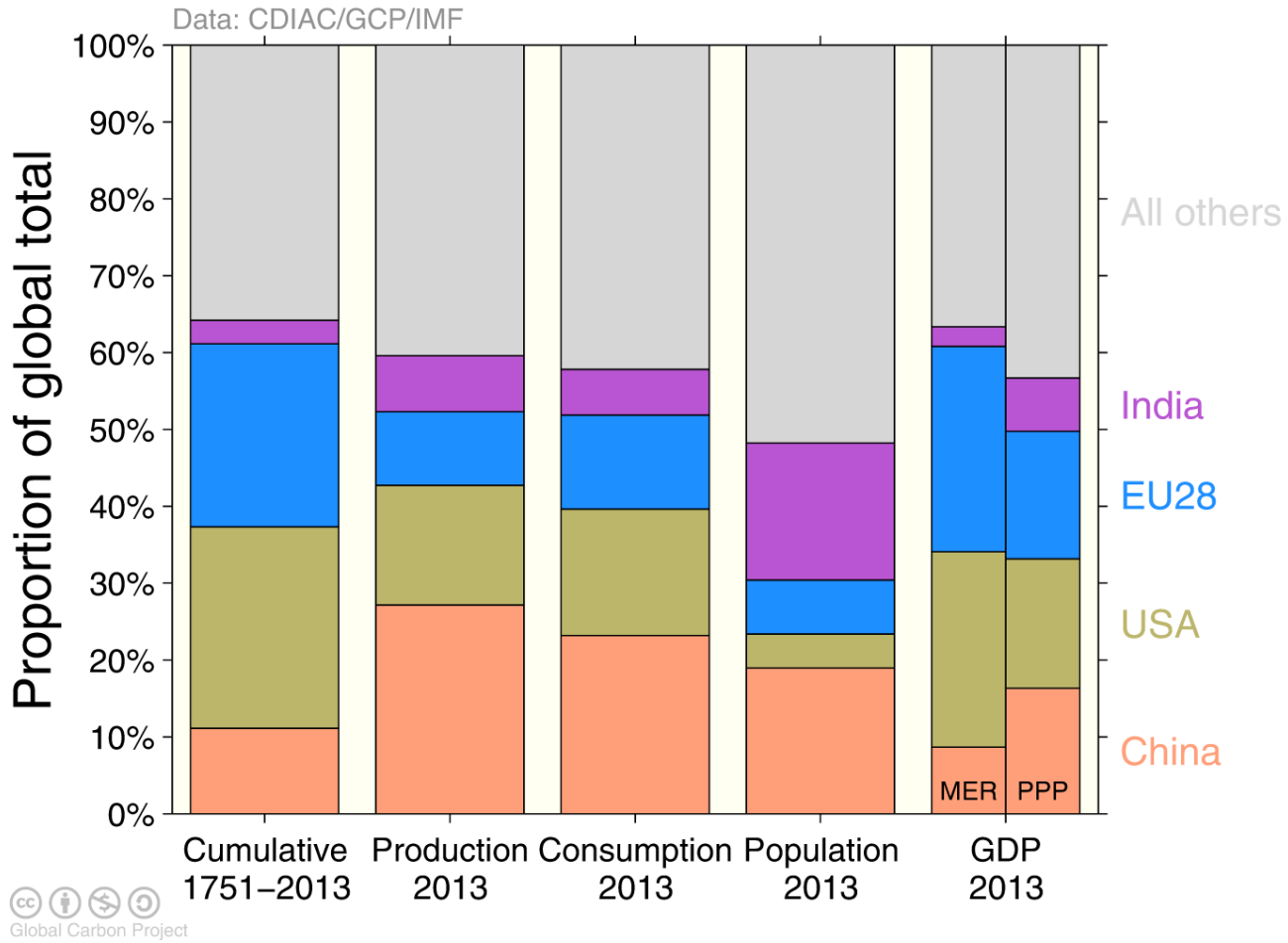


Consumption-based emissions are calculated by adjusting the standard production-based emissions to account for international trade

Source: Le Quéré et al 2015; Peters et al 2011; Global Carbon Project 2015

Alternative rankings of countries

Depending on perspective, the significance of individual countries changes

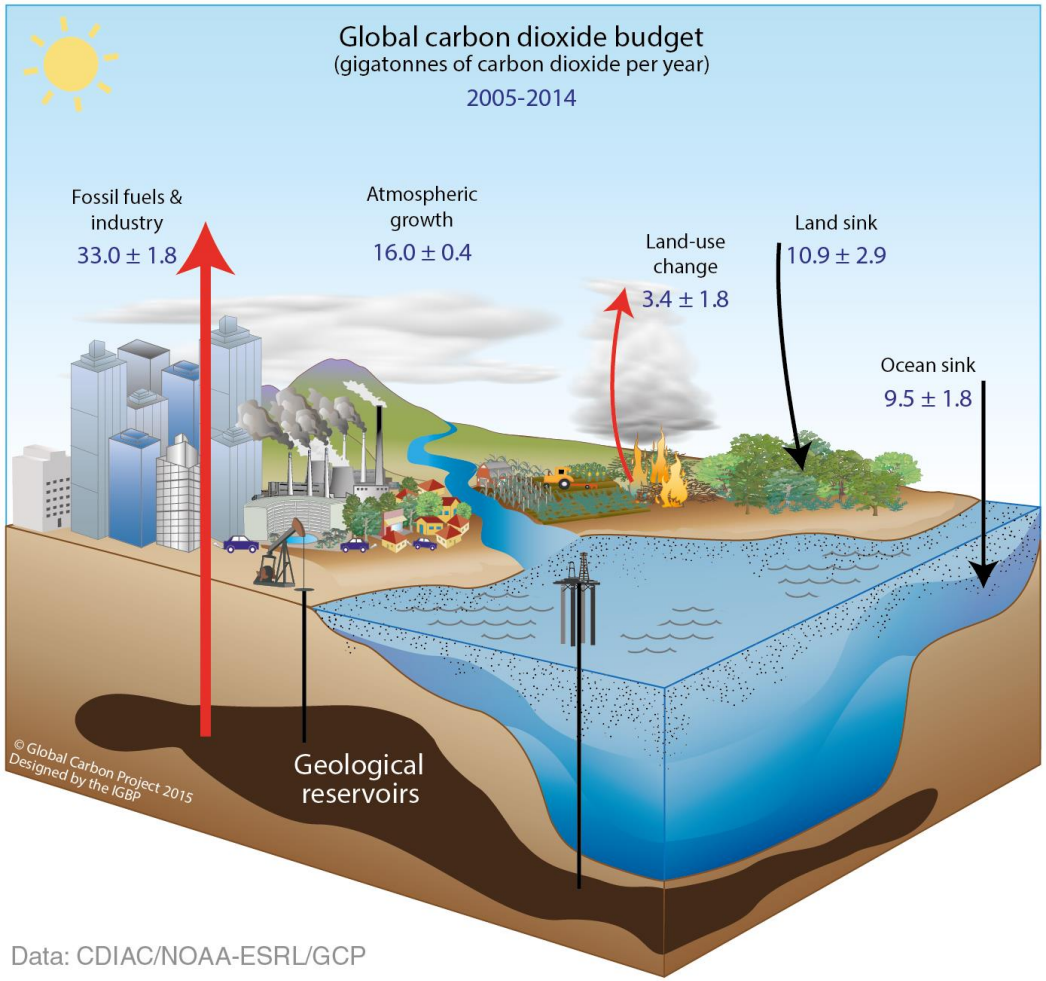


GDP: Gross Domestic Product in Market Exchange Rates (MER) and Purchasing Power Parity (PPP)

Source: CDIAC; United Nations; Le Quéré et al 2015; Global Carbon Budget 2015

Anthropogenic perturbation of the global carbon cycle

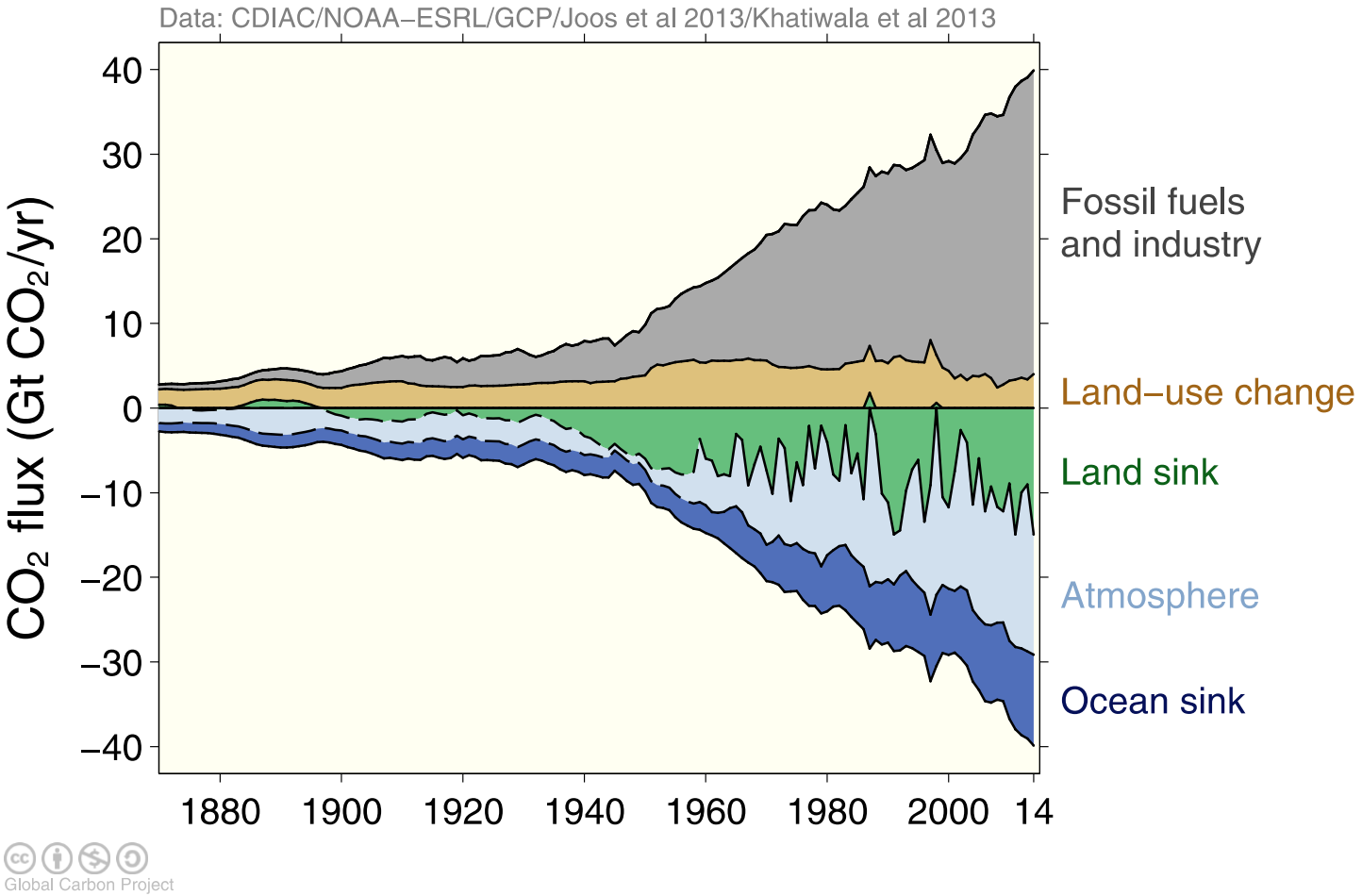
Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2005–2014 ($GtCO_2$/yr)



Source: CDIAC; NOAA-ESRL; Le Quéré et al 2015; Global Carbon Budget 2015

Global carbon budget

The carbon sources from fossil fuels, industry, and land use change emissions are balanced by the atmosphere and carbon sinks on land and in the ocean



Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Joos et al 2013; Khatiwala et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

Global carbon budget

The cumulative contributions to the global carbon budget from 1870

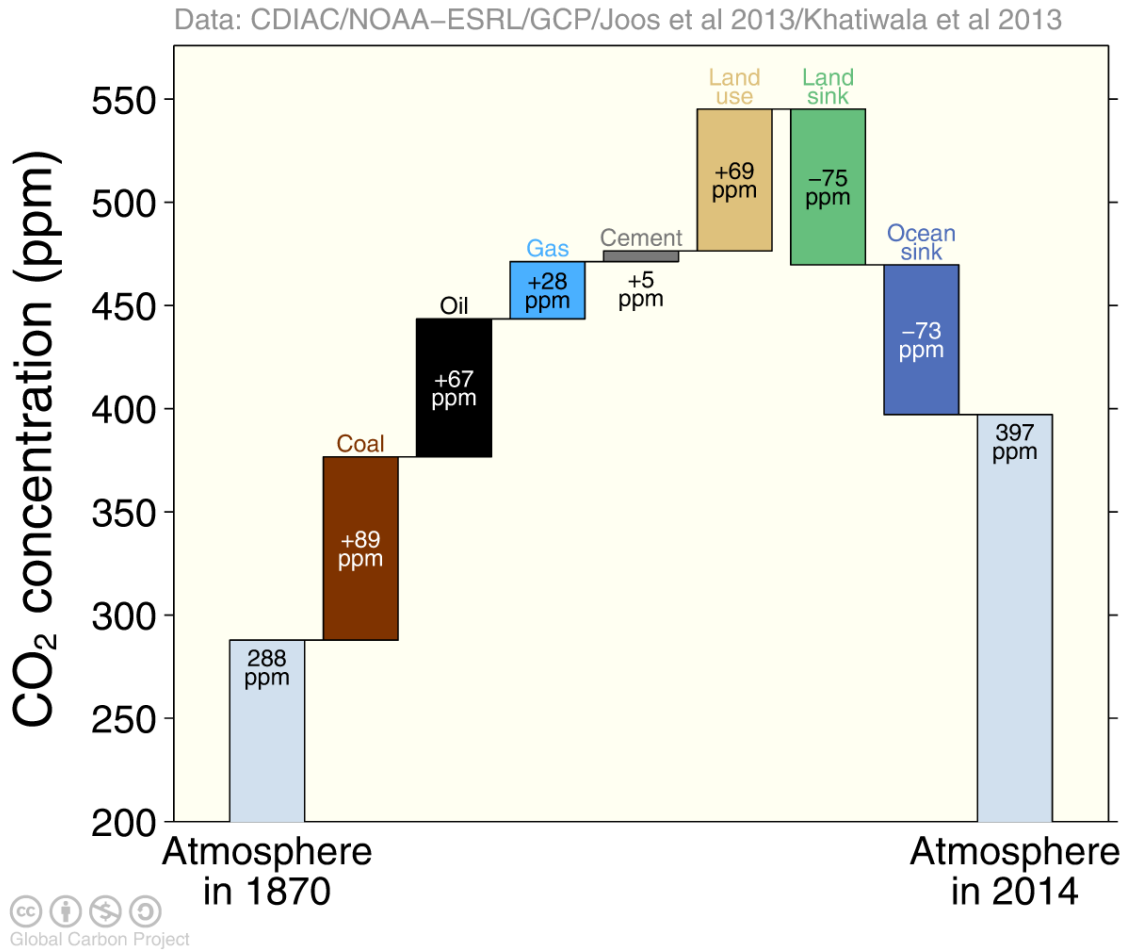


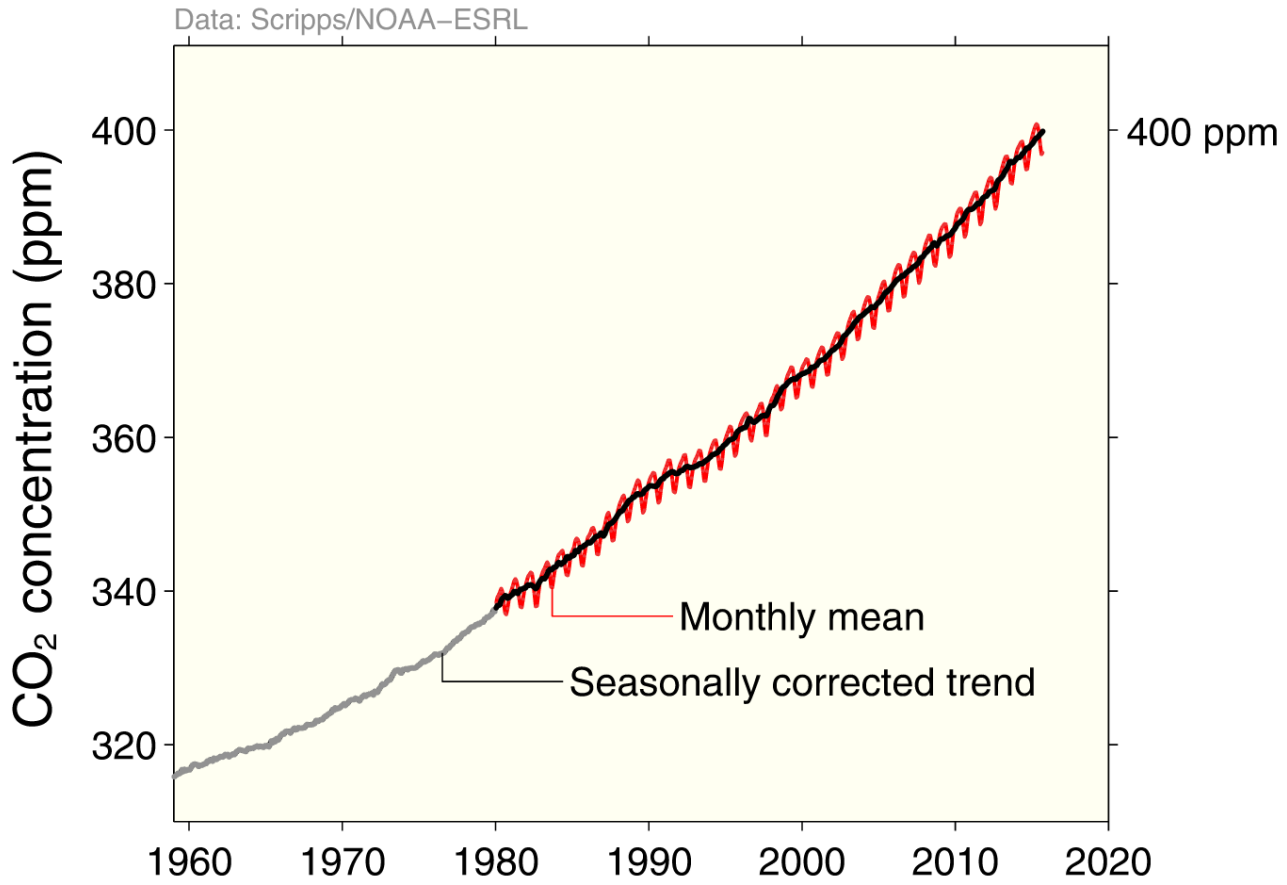
Figure concept from Shrink That Footprint

Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Joos et al 2013; Khatiwala et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

Atmospheric concentration

The global CO_2 concentration increased from ~277ppm in 1750 to 397ppm in 2014 (up 43%)

Mauna Loa registered the first seasonally-corrected monthly mean over 400ppm in March 2015



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; Global Carbon Budget 2015

GLOBAL CARBON PROJECT

nature climate change

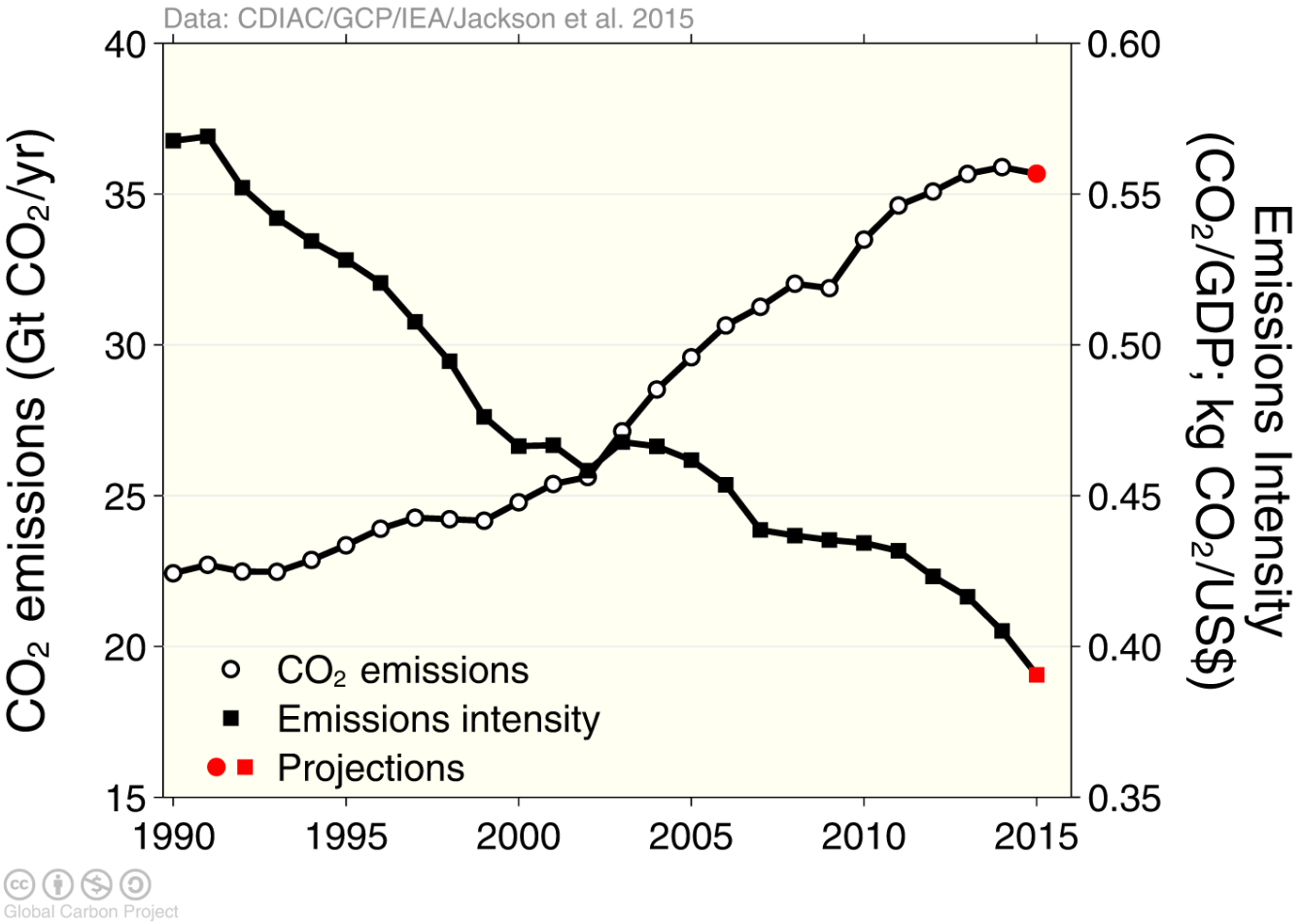
COMMENTARY:

Reaching peak emissions

Robert B. Jackson, Josep G. Canadell, Corinne Le Quéré, Robbie M. Andrew, Jan Ivar Korsbakken, Glen P. Peters and Nebojsa Nakicenovic

Emissions from fossil fuel use and industry

Global CO_2 emissions from fossil fuel use and industry (left axis) and emissions per unit economic activity (right axis). Red symbols are projections for 2015

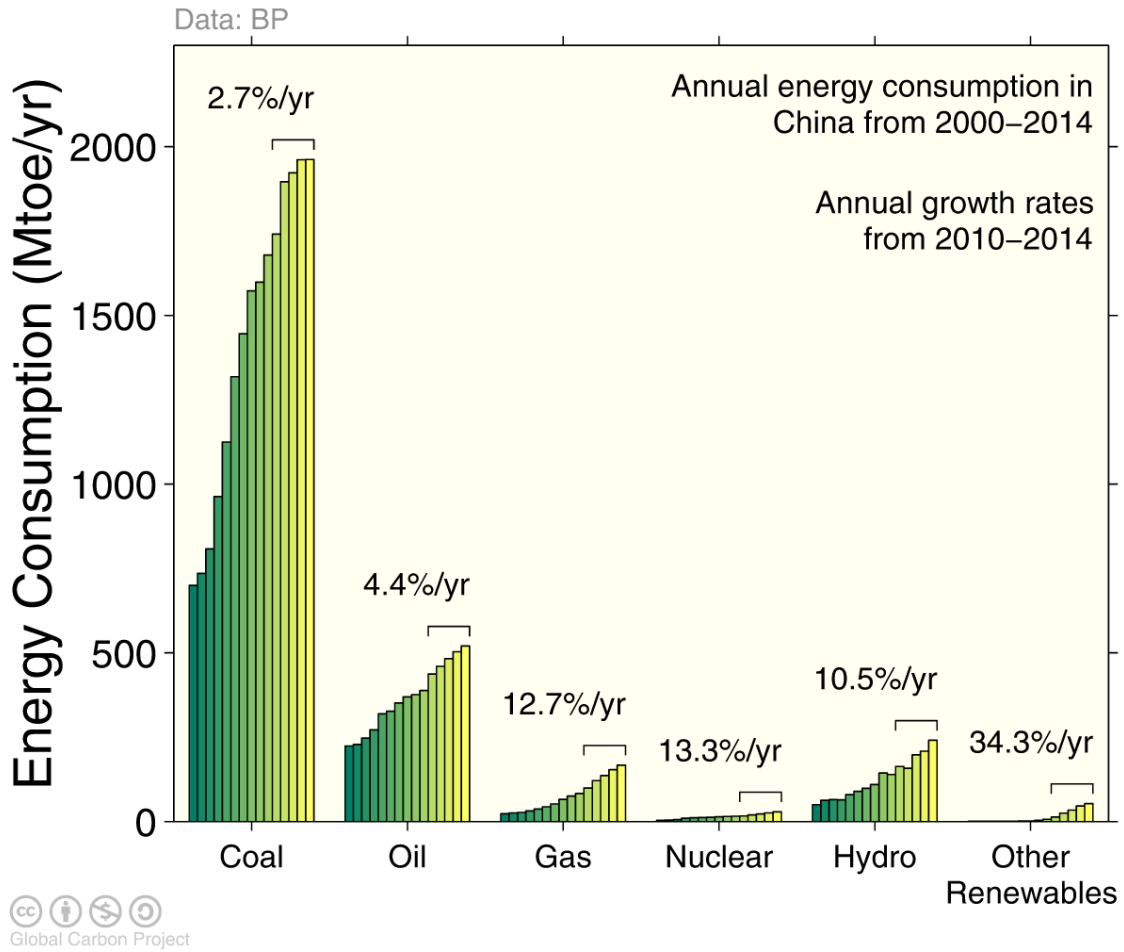


GDP: Gross Domestic Product using Purchasing Power Parity

Source: Jackson et al 2015a; Global Carbon Budget 2015

Energy consumption by energy type - China

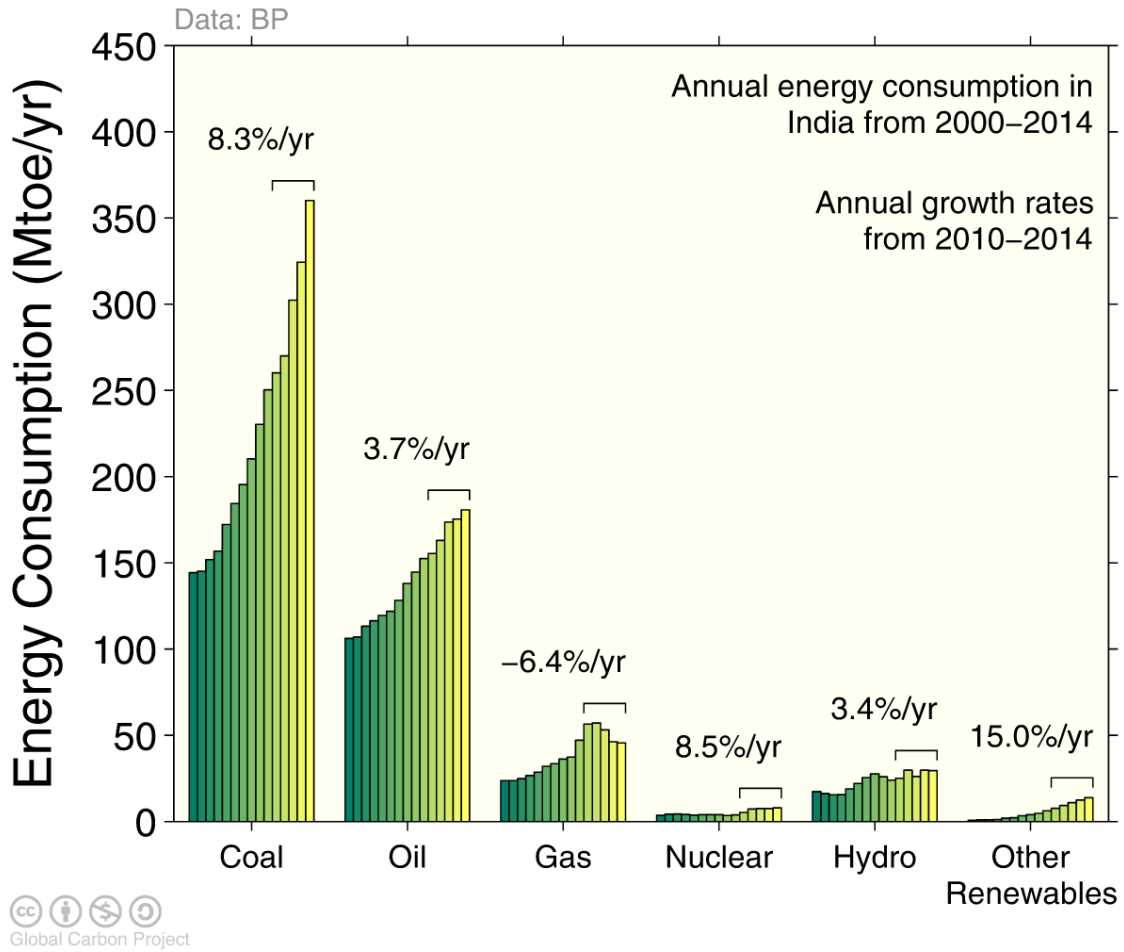
Energy consumption by fuel source from 2000 to 2014, with growth rates indicated for the more recent period of 2010 to 2014 for China



Source: BP 2015; Jackson et al 2015; Global Carbon Budget 2015

Energy consumption by energy type - India

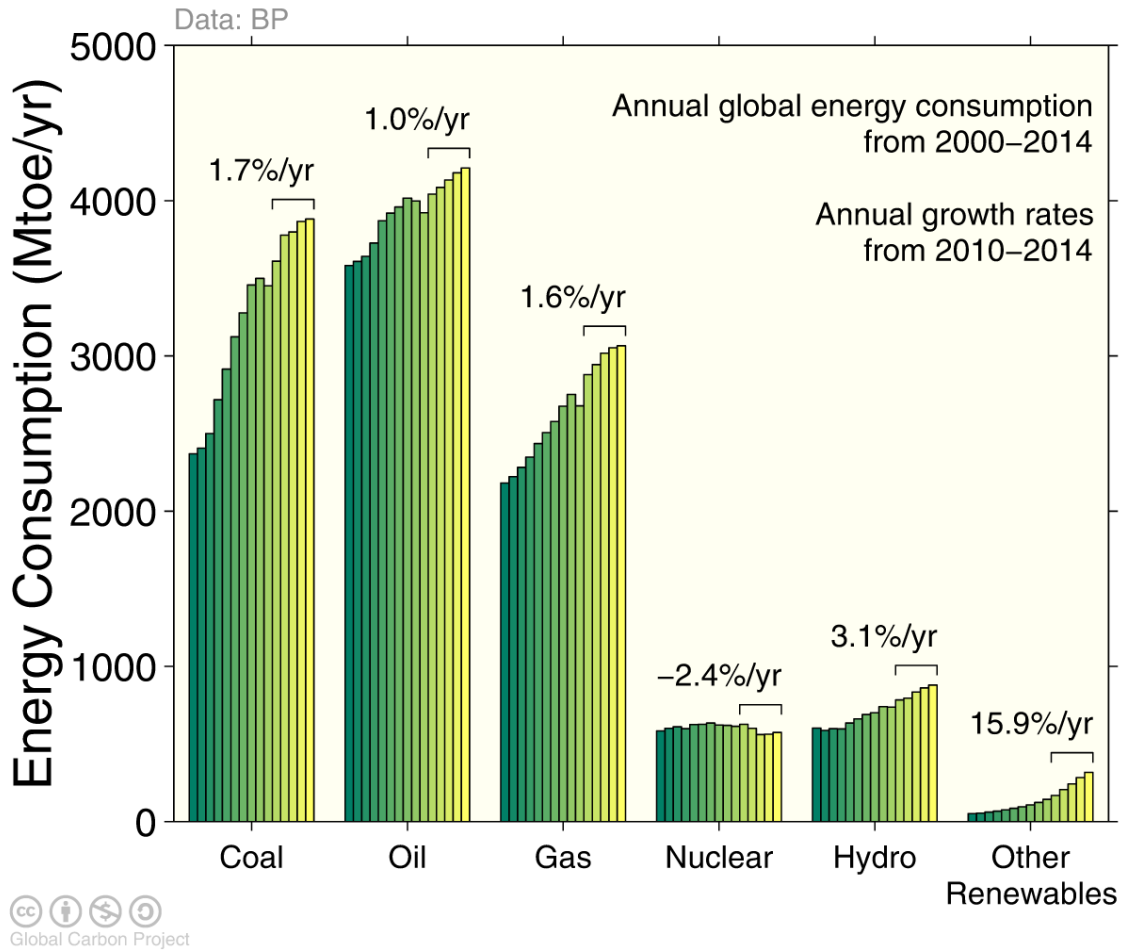
Energy consumption by fuel source from 2000 to 2014, with growth rates indicated for the more recent period of 2010 to 2014 for India



Source: BP 2015; Jackson et al 2015; Global Carbon Budget 2015

Energy consumption by energy type - global

Energy consumption by fuel source from 2000 to 2014, with growth rates indicated for the more recent period of 2010 to 2014 for the globe

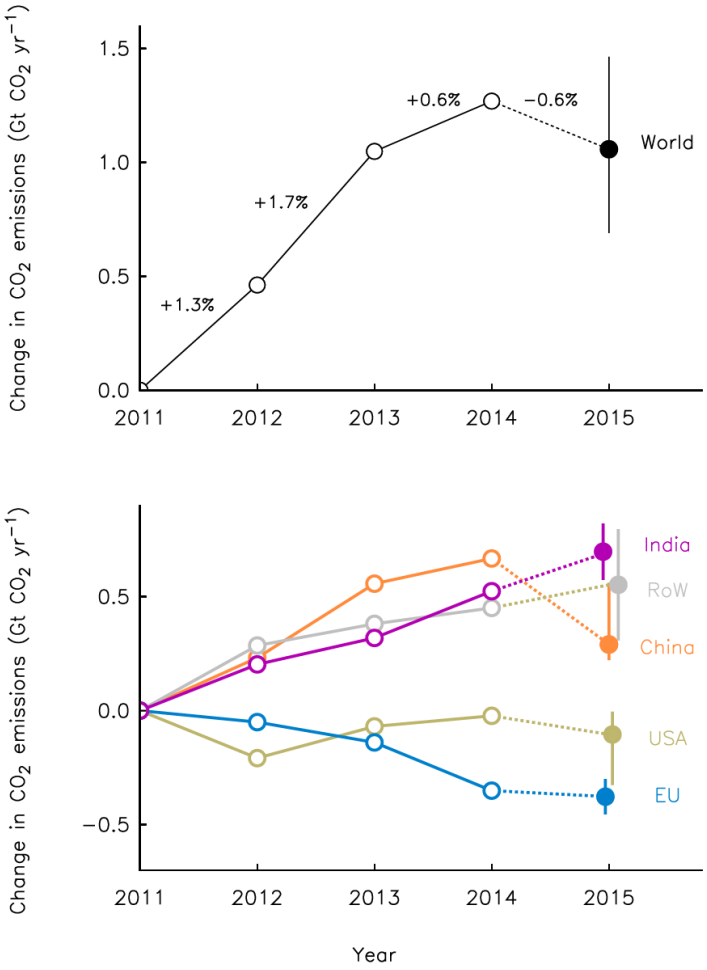


Source: BP 2015; Jackson et al 2015; Global Carbon Budget 2015

Change in CO_2 emissions from fossil-fuel use and industry

Top: Annual change in global CO_2 emissions relative to 2011

Bottom: Annual for the EU, US, China, India, and the rest of the world



The most recent projected change in emissions is from ~35.9 CO2 (9.8 Gt C) in 2014 to ~35.7 Gt CO2 (9.7 Gt C) in 2015. The filled symbols for 2015 denote projections.

Source: Jackson et al 2015; Global Carbon Budget 2015

The BRIDGE

NATIONAL ACADEMY OF ENGINEERING

Summer 2015

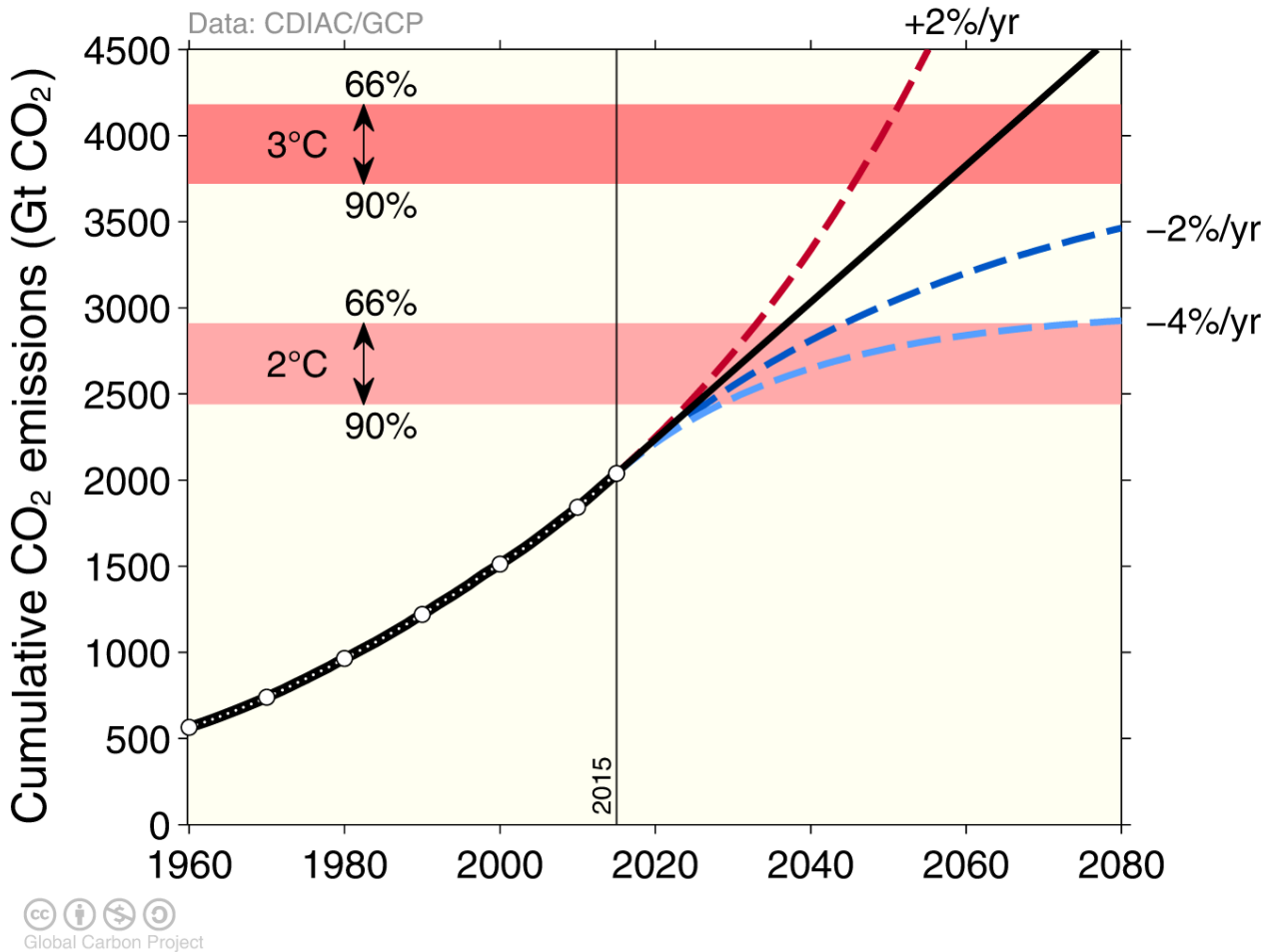
Two or Three Degrees

CO_2 Emissions and Global Temperature Impacts

Robert B. Jackson, Pierre Friedlingstein,
Josep G. Canadell, and Robbie M. Andrew

Cumulative global CO_2 emissions and temperature

Cumulative global CO_2 emissions from fossil fuels, industry, and land use change and four simplified future pathways compared to probability of exceeding different temperatures (red)



The red shaded areas are the chance of exceeding different temperatures above pre-industrial levels using the cumulative emissions concept

Source: Jackson et al 2015b; Global Carbon Budget 2015

GLOBAL CARBON PROJECT

nature climate change

REVIEW ARTICLE

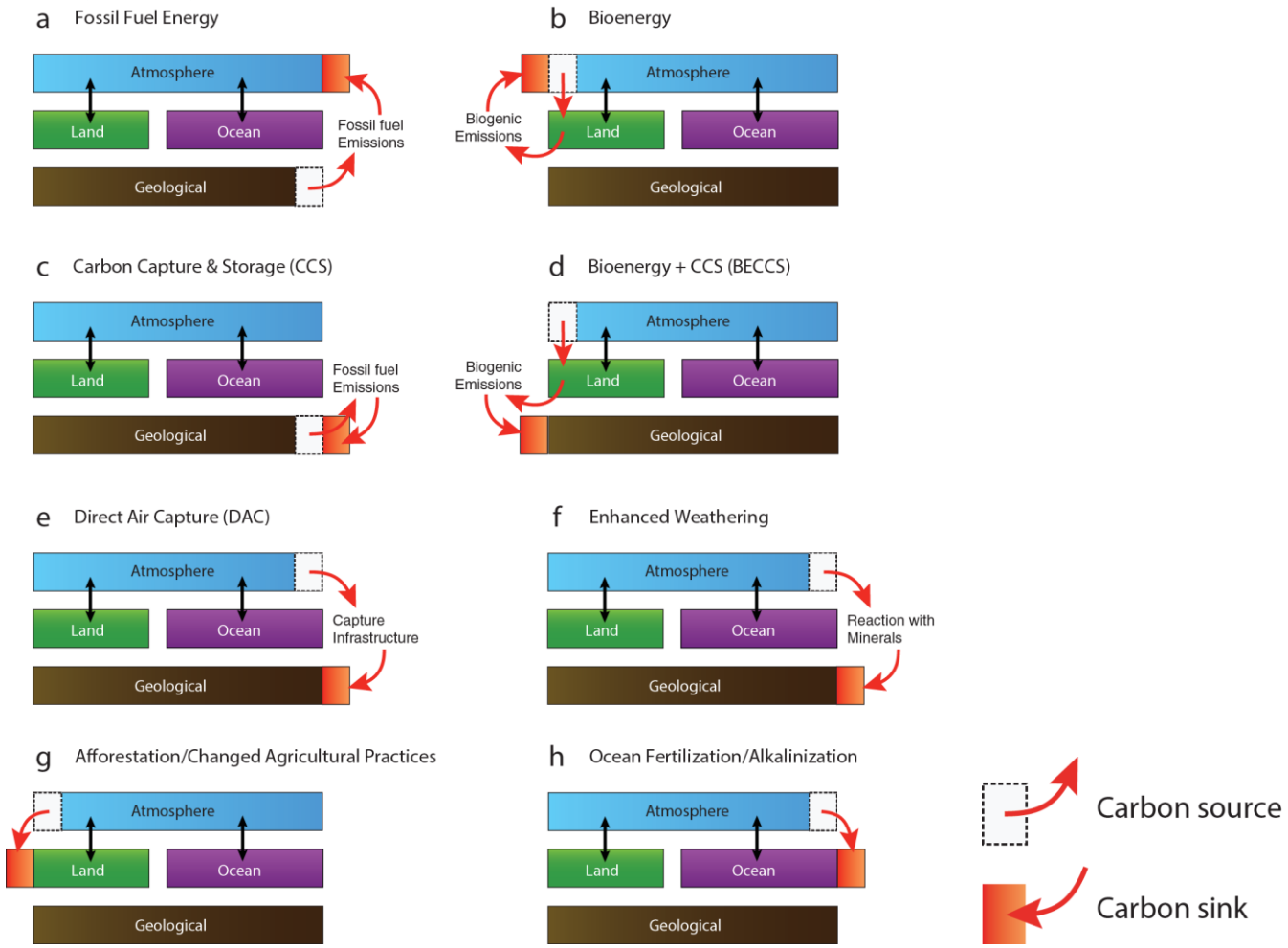
PUBLISHED ONLINE: 7 DECEMBER 2015 | DOI: 10.1038/NCLIMATE2870

Biophysical and economic limits to negative CO_2 emissions

Pete Smith[1*], Steven J. Davis[2], Felix Creutzig[3,4], Sabine Fuss[3], Jan Minx[3,5,6], Benoit Gabrielle[7,8], Etsushi Kato[9], Robert B. Jackson[10], Annette Cowie[11], Elmar Kriegler[5], Detlef P. van Vuuren[12,13], Joeri Rogelj[14,15], Philippe Ciais[16], Jennifer Milne[17], Josep G. Canadell[18], David McCollum[15], Glen Peters[19], Robbie Andrew[19], Volker Krey[15], Gyami Shrestha[20], Pierre Friedlingstein[21], Thomas Gasser[16,22], Arnulf Grübler[15], Wolfgang K. Heidug[23], Matthias Jonas[15], Chris D. Jones[24], Florian Kraxner[15], Emma Littleton[25], Jason Lowe[24], José Roberto Moreira[26], Nebojsa Nakicenovic[15], Michael Obersteiner[15], Anand Patwardhan[27], Mathis Rogner[15], Ed Rubin[28], Ayyoob Sharifi[29], Asbjørn Torvanger[19], Yoshiki Yamagata[30], Jae Edmonds[31] and Cho Yongsung[32]

Different Negative Emission Technologies

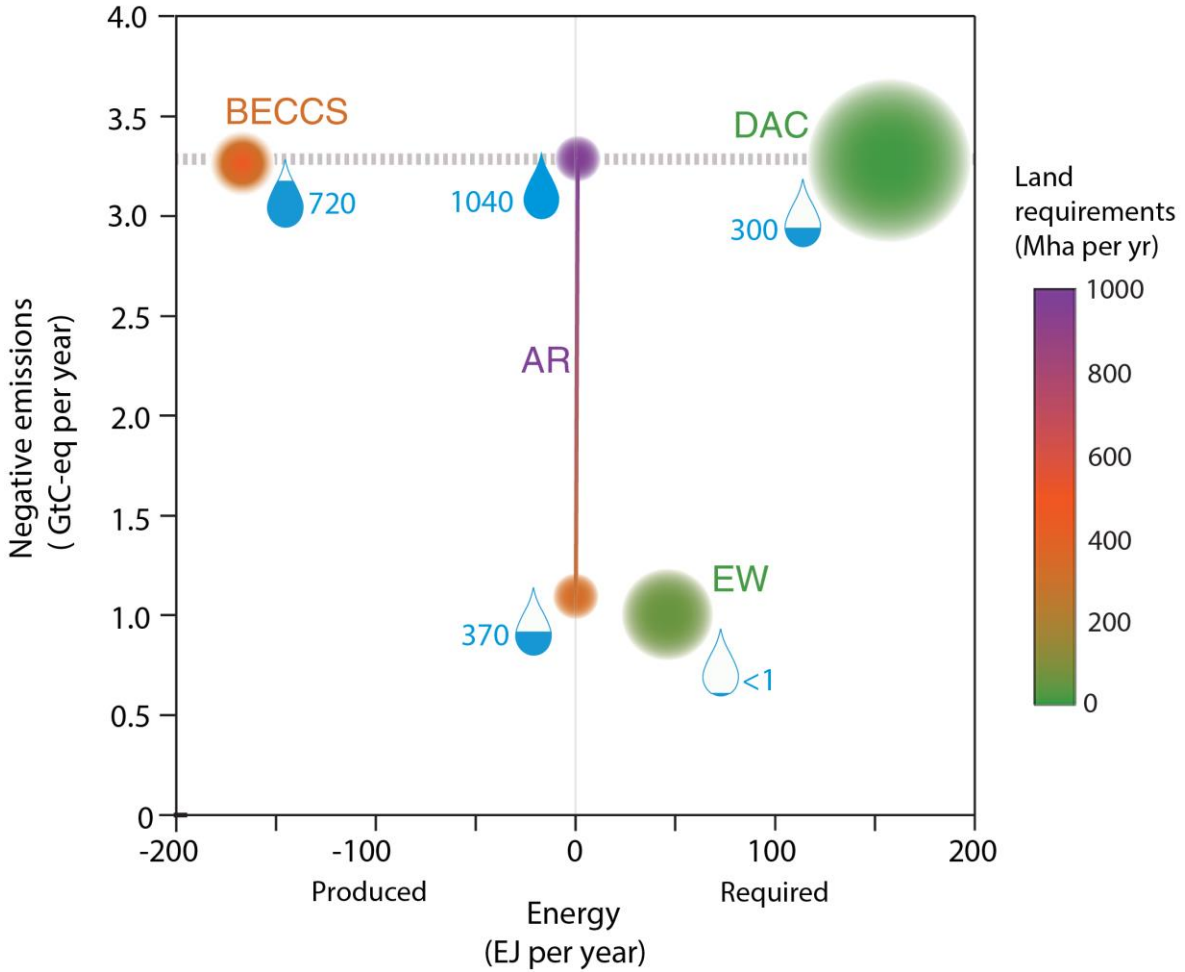
Schematic representation of carbon flows among atmospheric, land, ocean and geological reservoirs for different technologies



Source: Smith et al 2015; Global Carbon Budget 2015

Impact/limit summary for Negative Emission Technologies

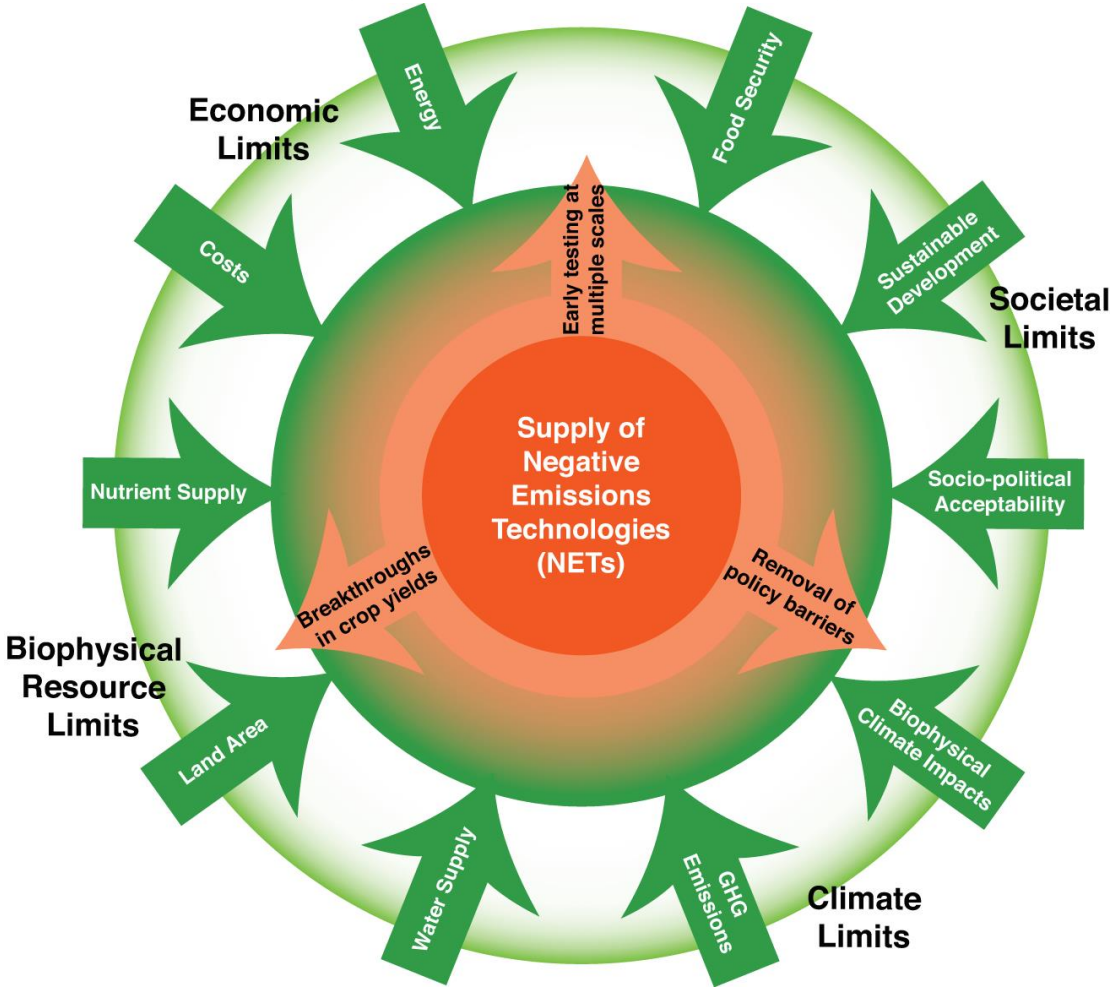
The impacts and investment requirements of Negative Emissions Technologies to limit warming to 2°C



Water requirement is shown as water droplets, with quantities in km^3 per year.
All values are for the year 2100 except relative costs, which are for 2050
Source: Smith et al 2015; Global Carbon Budget 2015

Global Negative Emission Technologies capacity

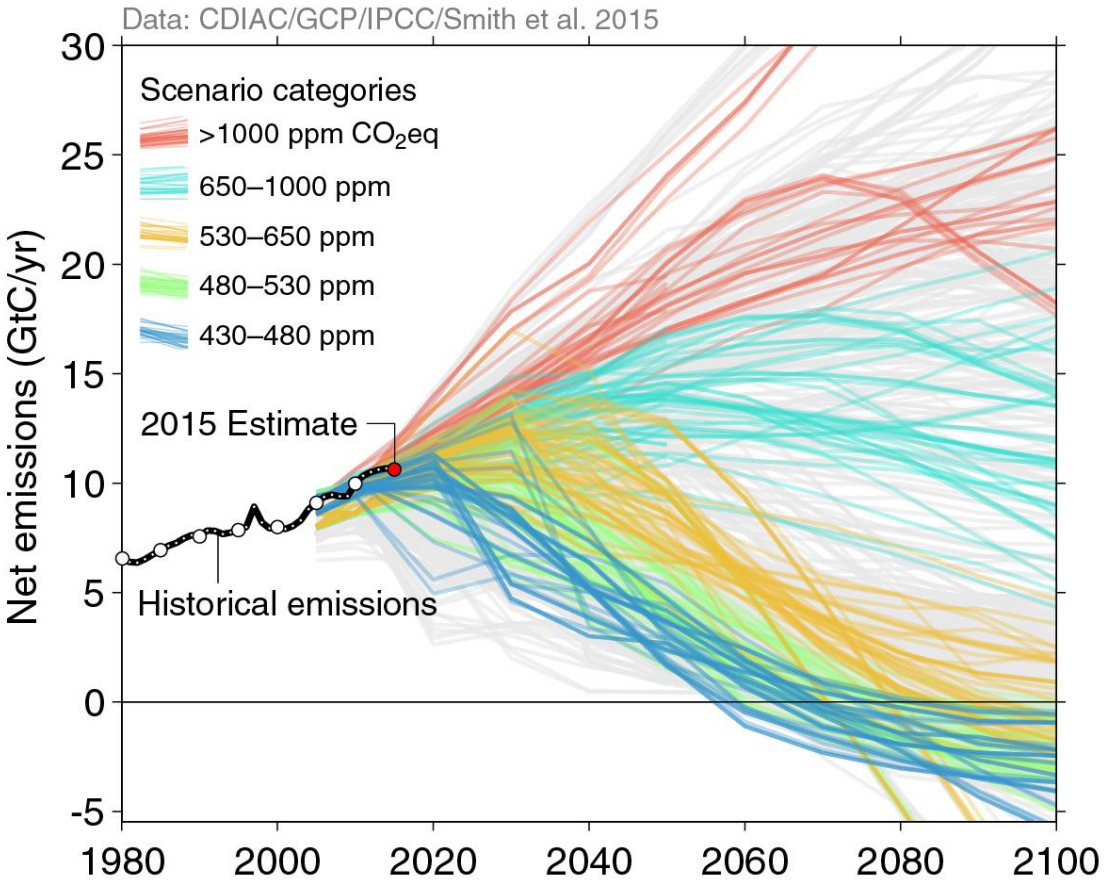
Factors potentially enhancing or limiting the global capacity for Negative Emission Technologies



Source: Smith et al 2015; Global Carbon Budget 2015

Scenarios including Negative Emission Technologies

Scenarios including Negative Emission Technologies for each scenario category (colours), net land use change fluxes are included



Scenarios with Negative Emissions Technologies from the AMPERE and LIMITS modelling comparison exercises (colours), with all other scenarios from the IPCC AR5 database shown in grey

Source: Smith et al 2015; Global Carbon Budget 2015

Environmental Research Letters

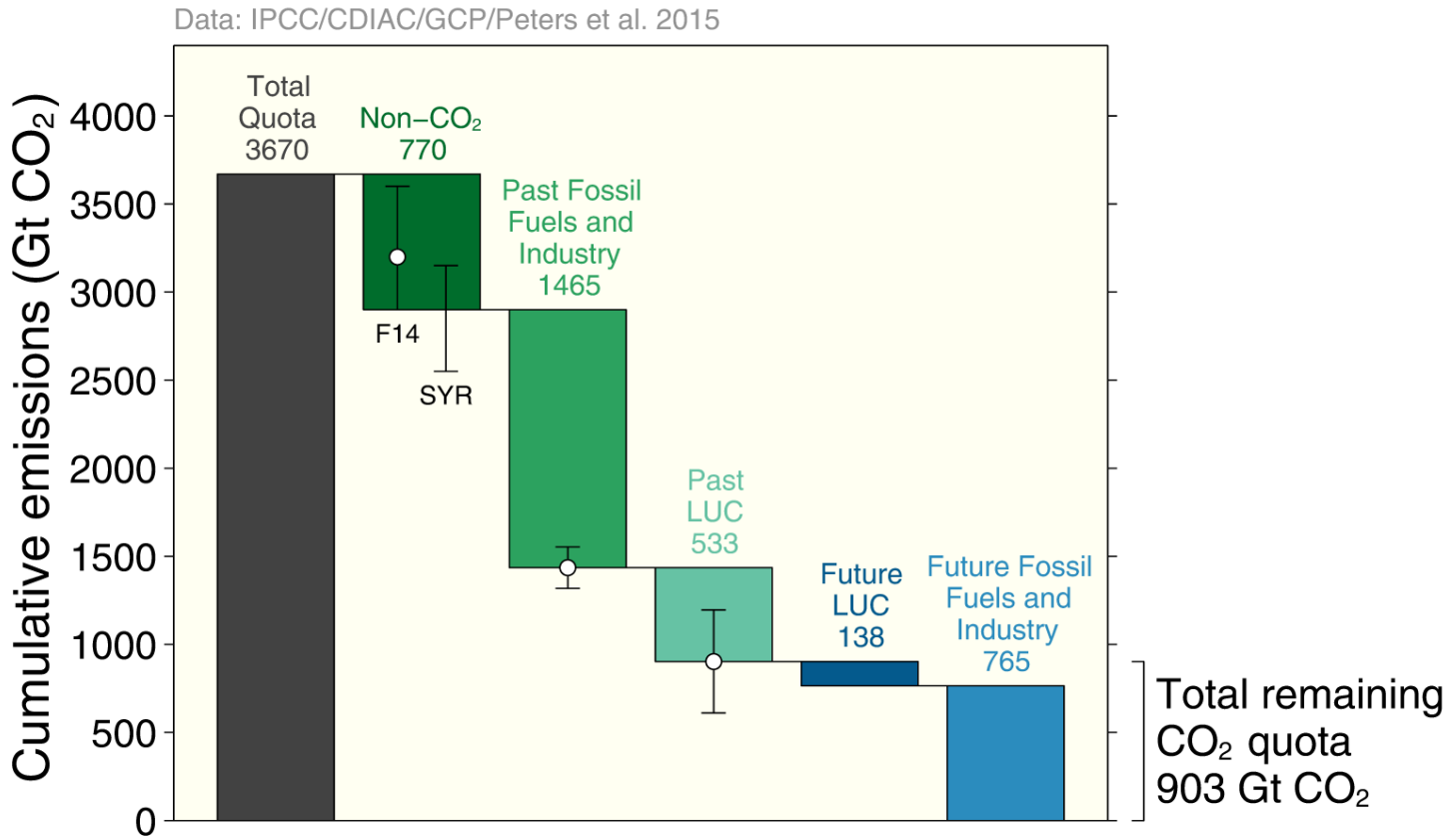
Measuring a fair and ambitious climate agreement using cumulative emissions

Glen P Peters[1], **Robbie M Andrew**[1], **Susan Solomon**[2] **and Pierre Friedlingstein**[3]

[1] Center for International Climate and Environmental Research—Oslo (CICERO), PB 1129 Blindern, 0318 Oslo, Norway
[2] Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA
[3] College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter EX4 4QF, UK

The remaining carbon quota for 66% chance <2°C

The total remaining emissions from 2014 to keep global average temperature below 2°C ($900GtCO_2$) will be used in around 20 years at current emission rates

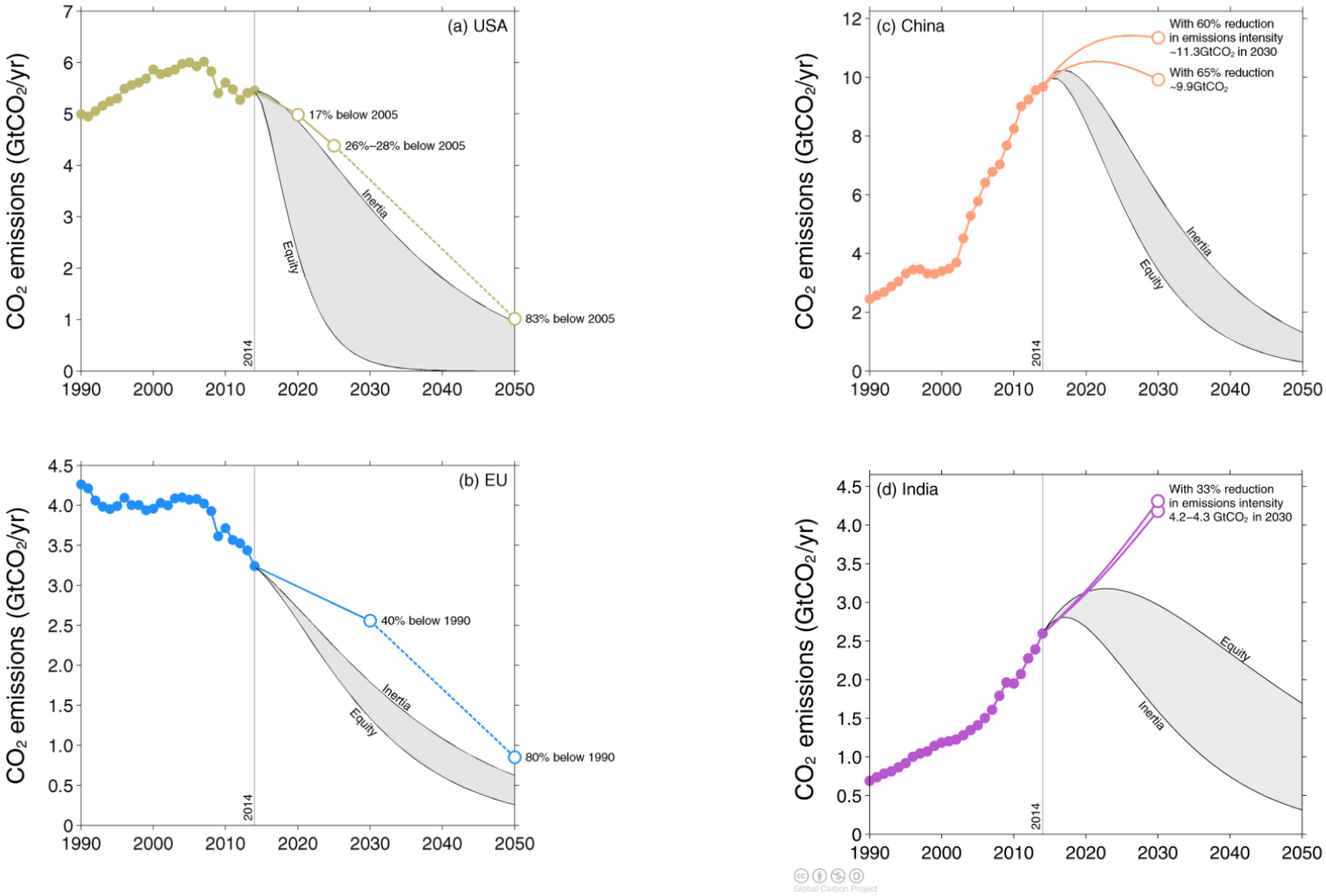


Grey: Total quota for 2°C. Green: Removed from quota. Blue: remaining quota.
With projected 2015 emissions, this remaining quota drops to 865 Gt CO_2

Source: Peters et al 2015; Global Carbon Budget 2015

The emission pledges (INDCs) of the top-4 emitters

The emission pledges compared to different ways of sharing the remaining 2°C quota

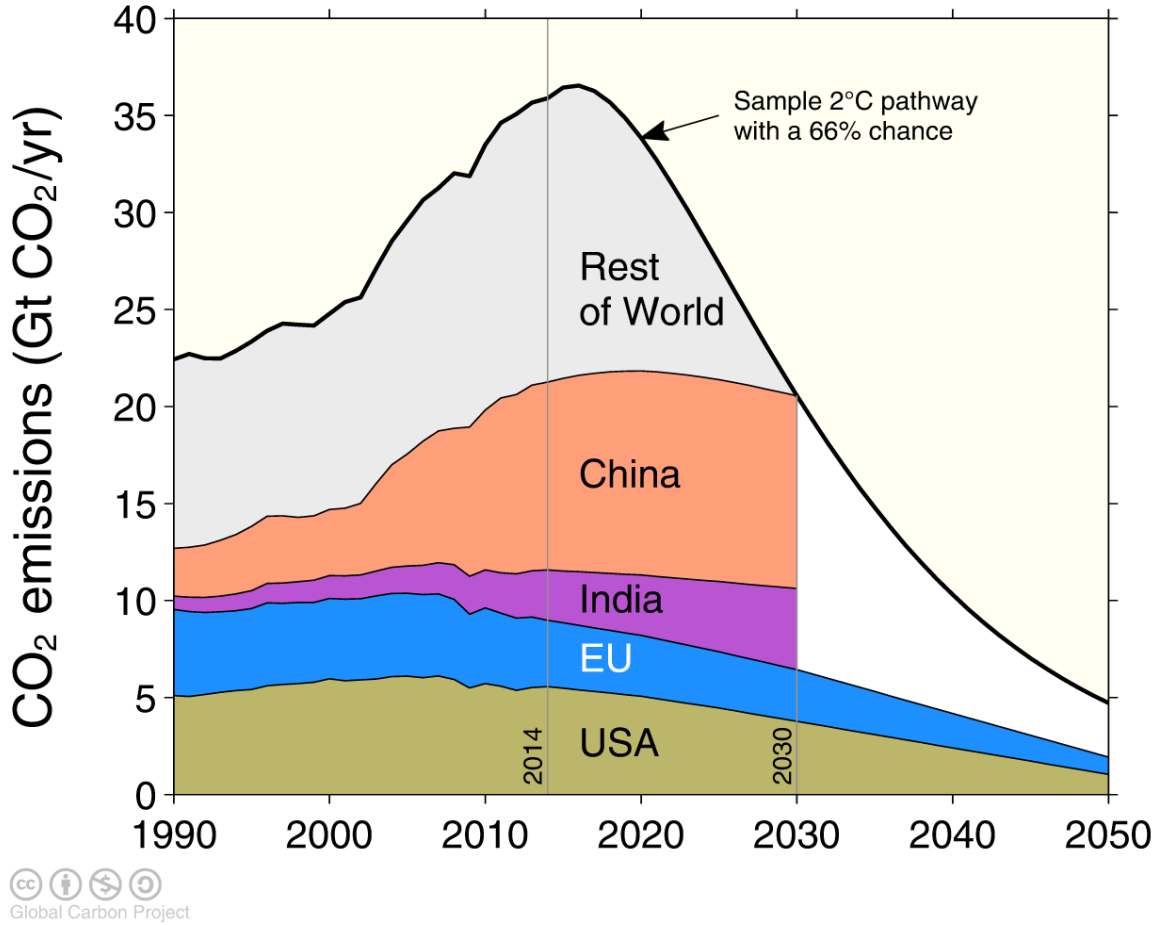


Equity: Remaining quota shared by current population. Inertia: The remaining quota shared by current emissions.

Source: Peters et al 2015; Global Carbon Budget 2015

The emission pledges (INDCs) of the top-4 emitters

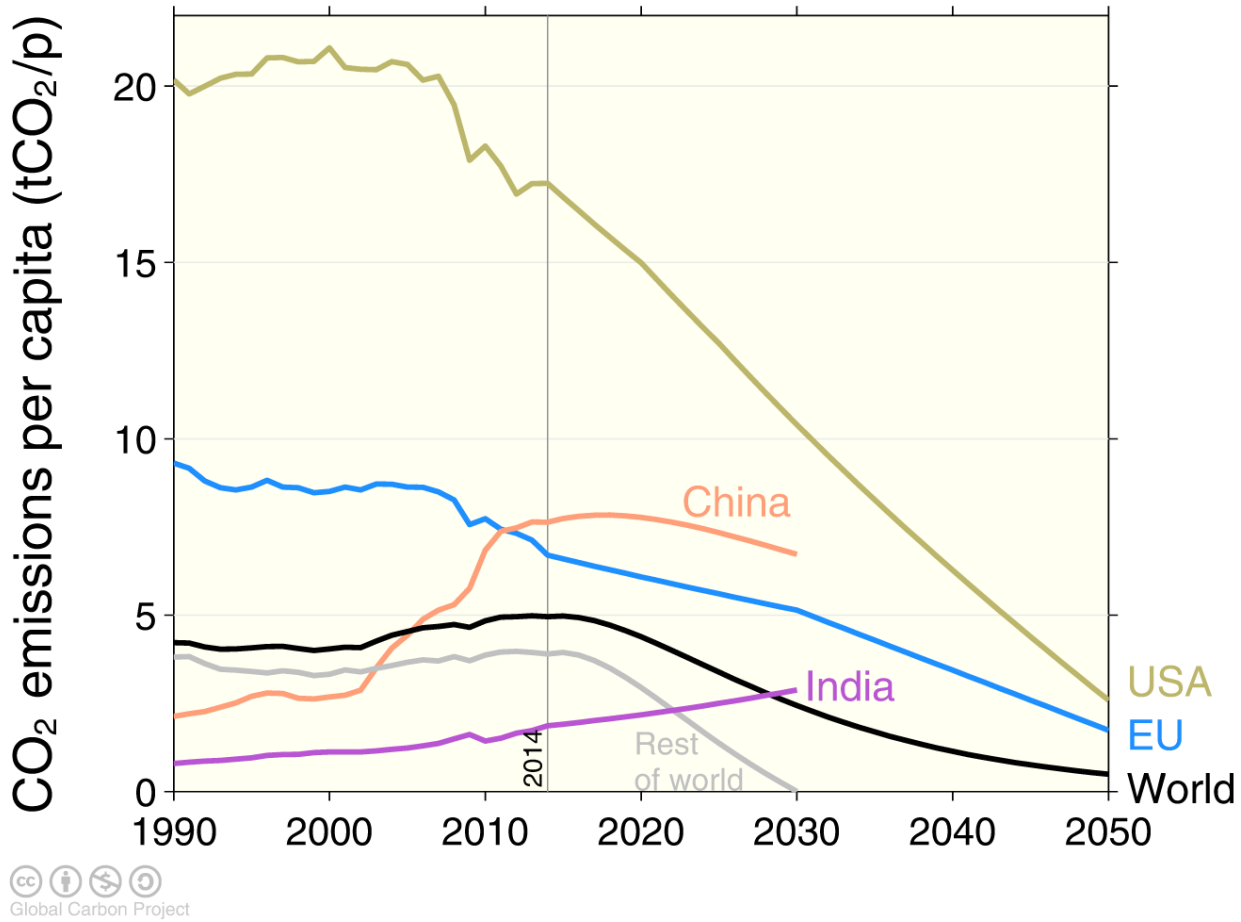
The emission pledges from the US, EU, China, and India leave little room for other countries to emit in a 2°C emission budget (66% chance)



Source: Peters et al 2015; Global Carbon Budget 2015

The emission pledges (INDCs) of the top-4 emitters

To remain consistent with 2°C and given the emission pledges from the US, EU, China, and India, the 'Rest of the World' would need zero per-capita emissions by 2030



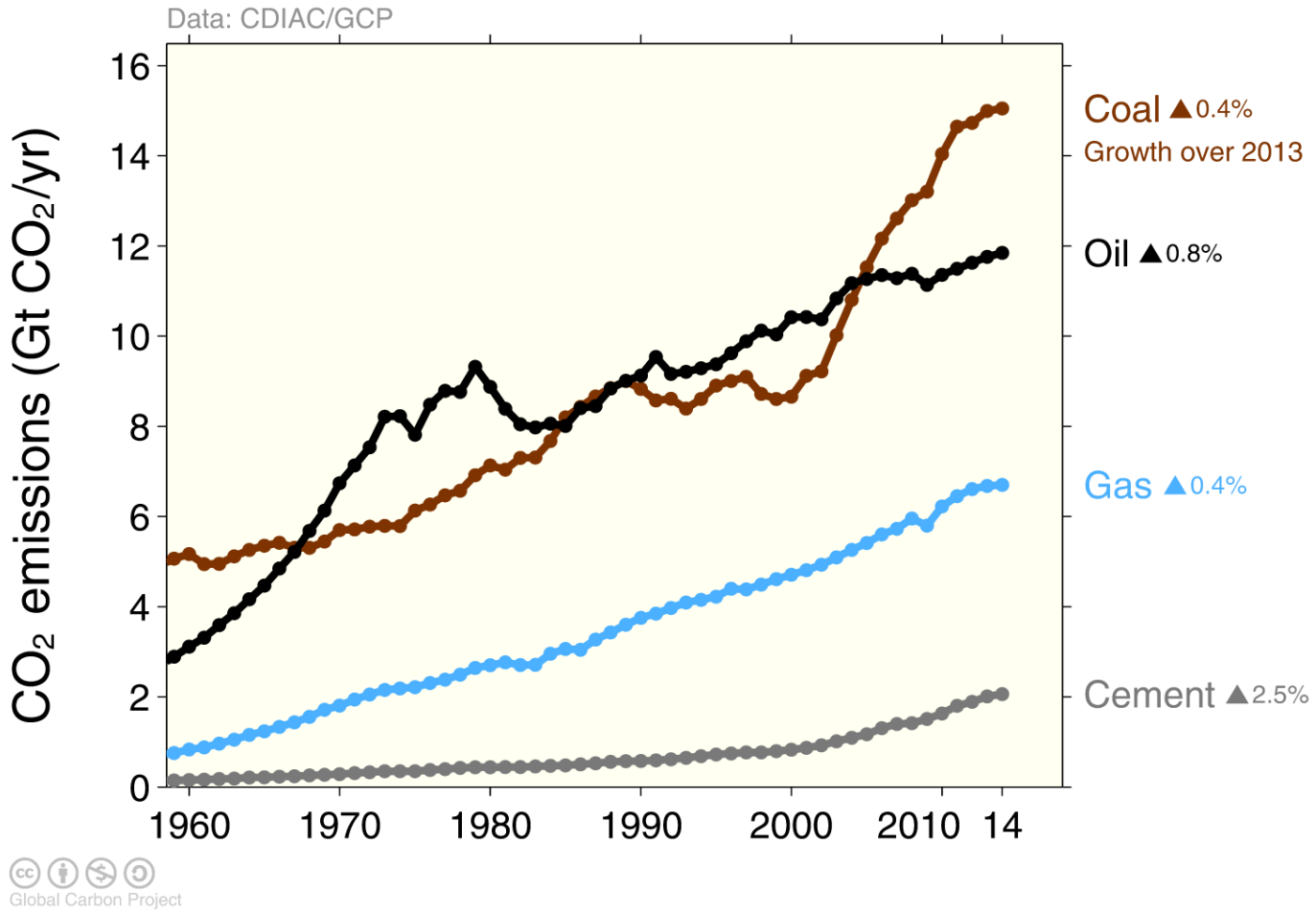
Source: Peters et al 2015; Global Carbon Budget 2015

Supplementary Budget Slides

Fossil fuel and industry emissions

Emissions from coal, oil, gas, cement

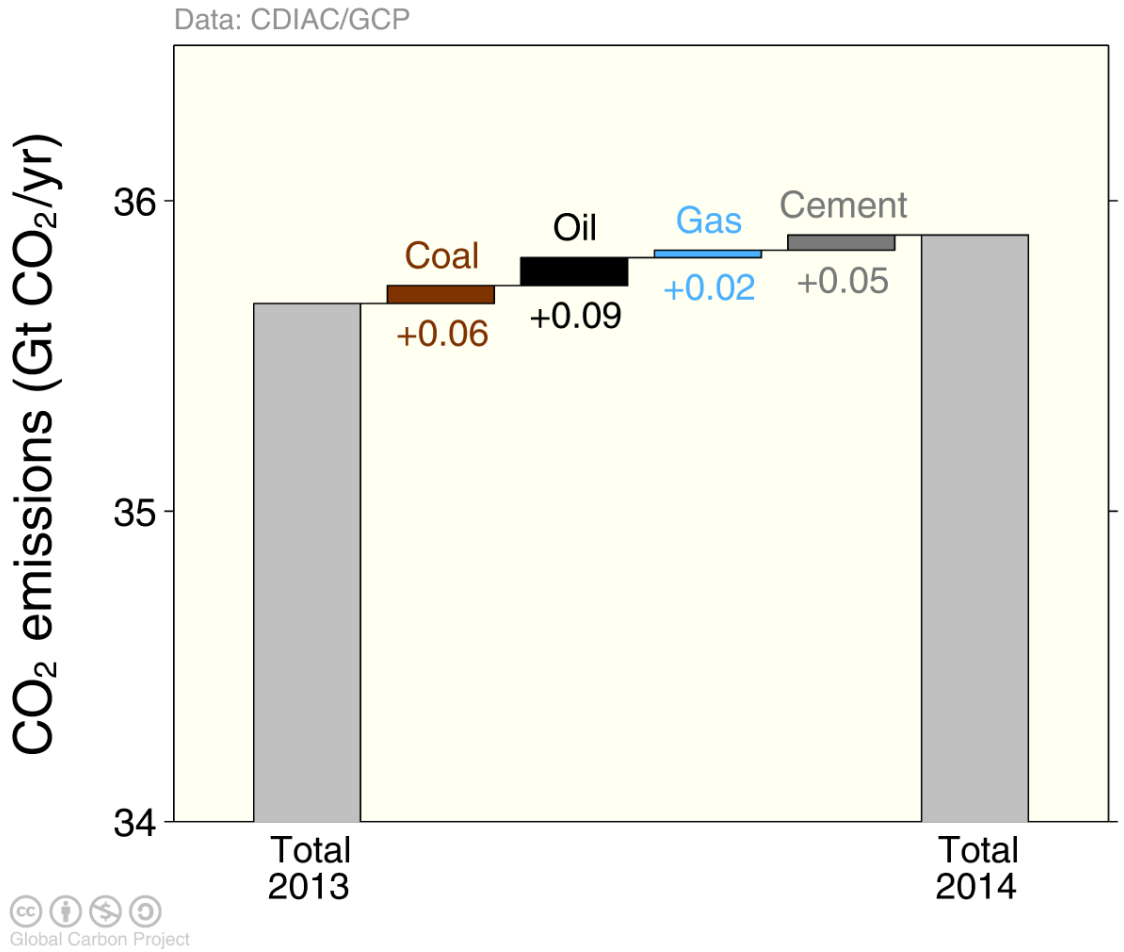
Share of global emissions in 2014:
coal (42%), oil (33%), gas (19%), cement (6%), flaring (1%, not shown)



Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Fossil fuel and industry emissions growth

Coal accounted for 26% of the growth in global emissions in 2014, oil 41%, gas 11%, and cement 22%.



Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Fossil fuel and cement emissions growth

Much of the growth in emissions in 2014 was in India and China, while Europe's emissions declined

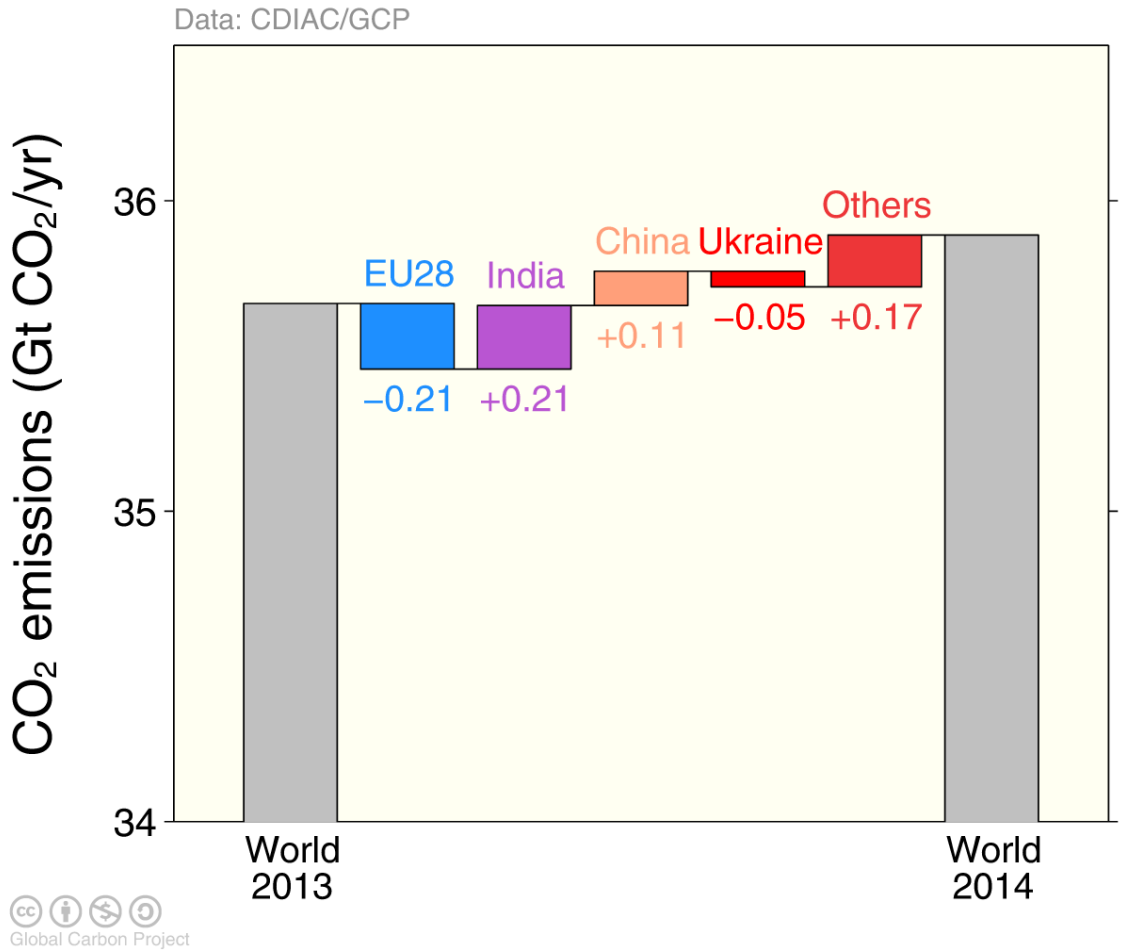
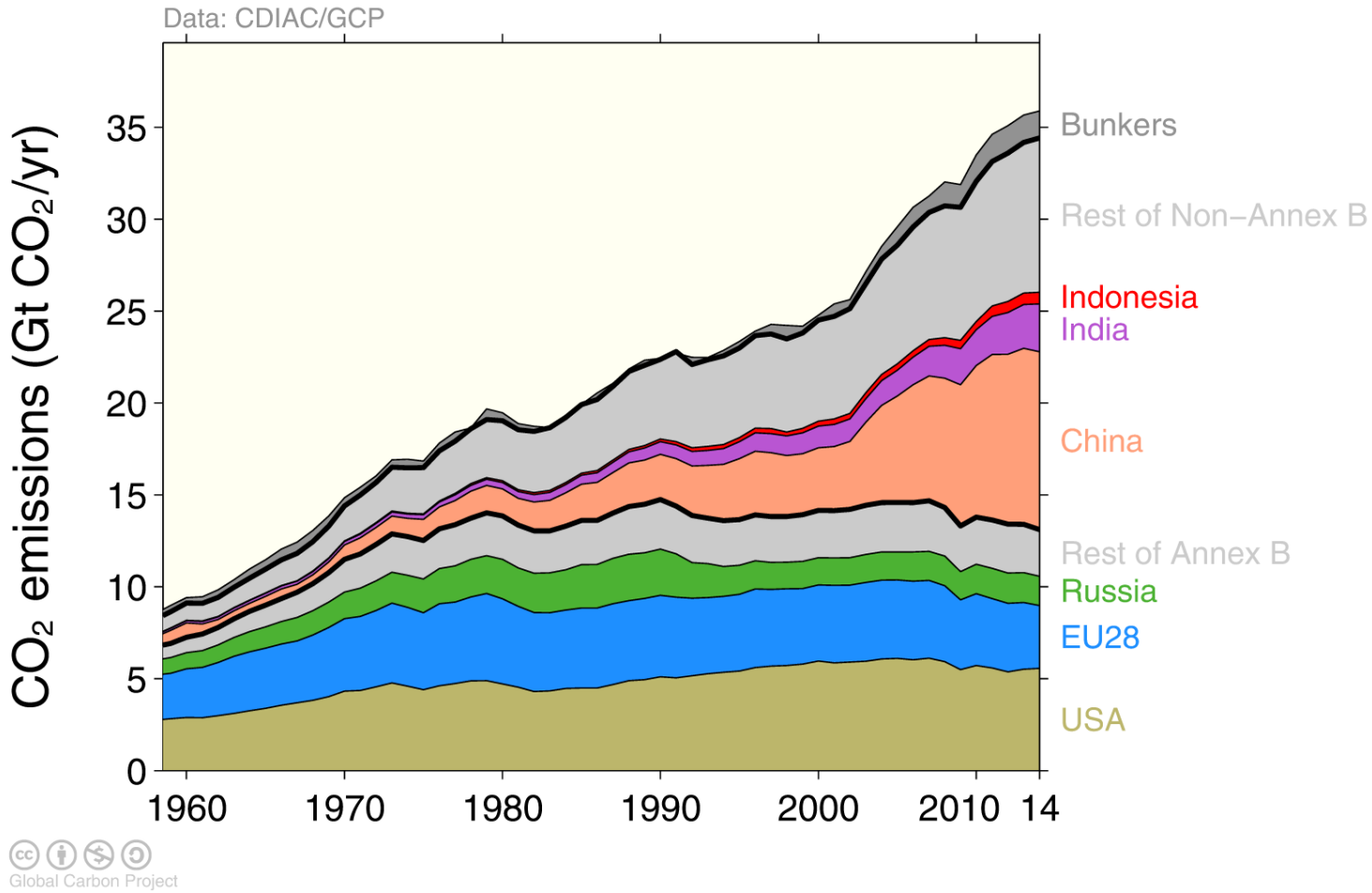


Figure shows the top four countries contributing to emissions changes in 2014

Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Breakdown of global emissions by country

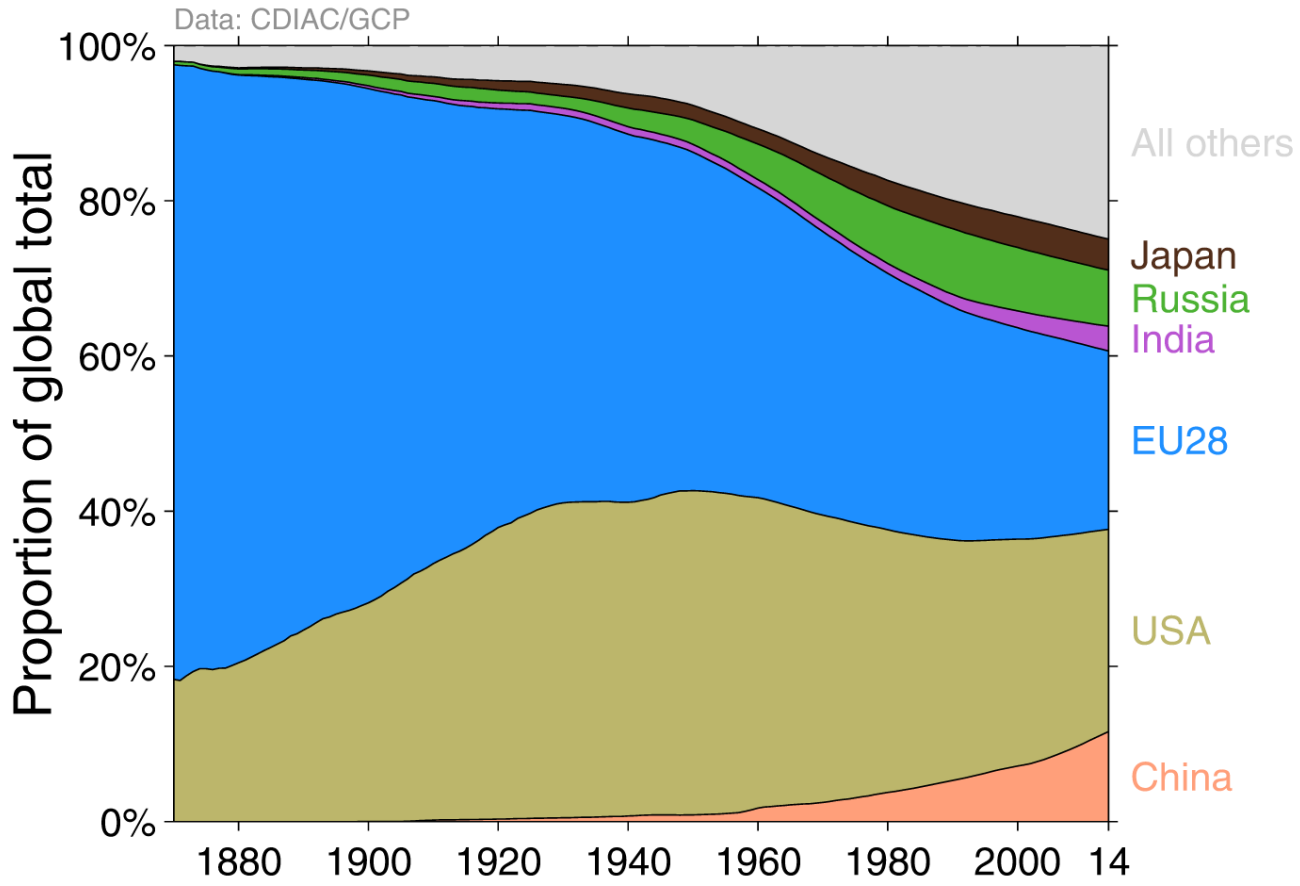
Emissions from Annex B countries have slightly declined since 1990
Emissions from non-Annex B countries have increased rapidly in the last decade



Annex B countries had emission commitments in the Kyoto Protocol (excluding Canada and USA)
Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Historical cumulative emissions by country

Cumulative emissions from fossil-fuel and cement were distributed (1870–2014): USA (26%), EU28 (23%), China (12%), and India (3%) covering 64% of the total share



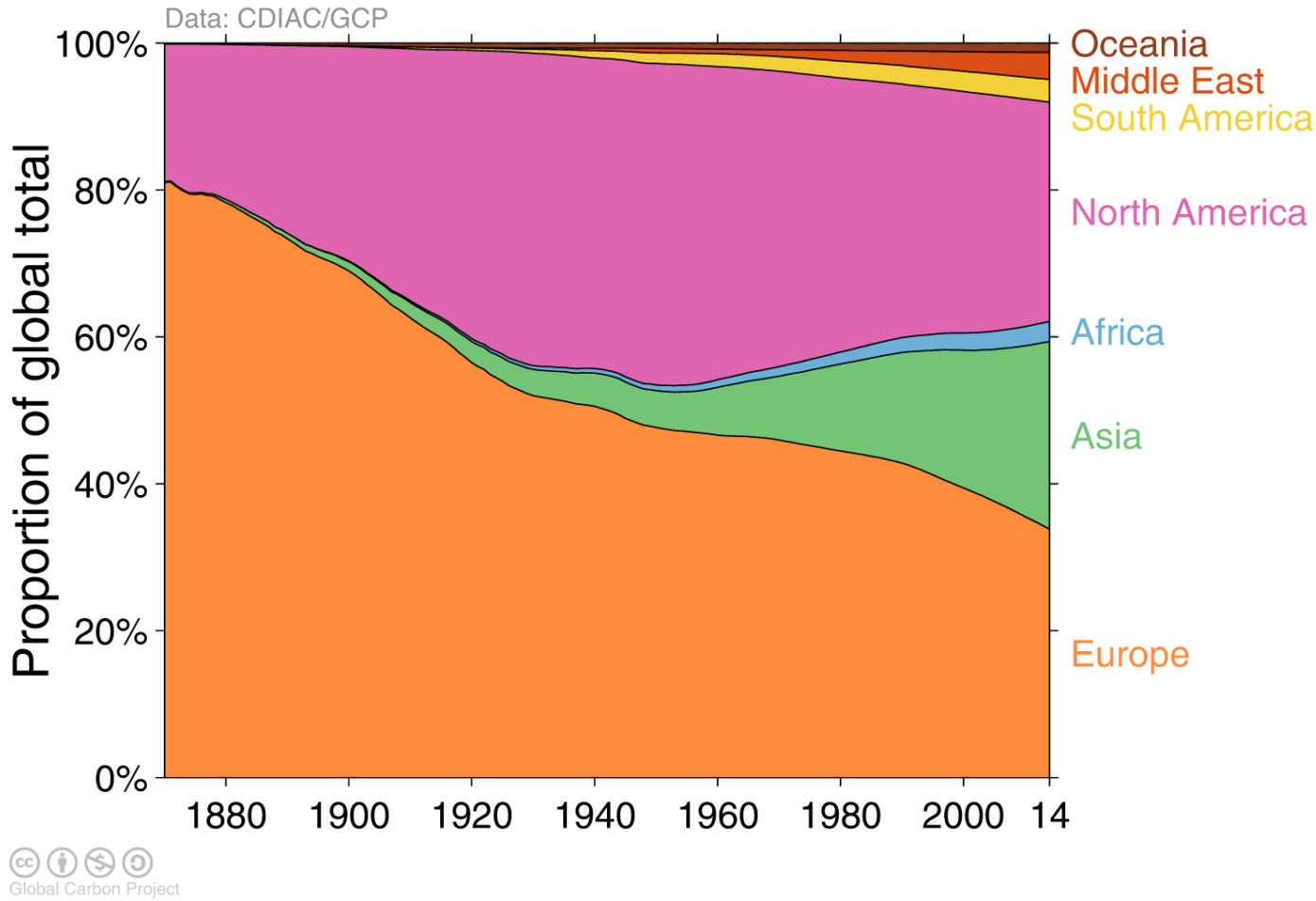
Cumulative emissions (1990–2014) were distributed USA (20%), China (19%), EU28 (15%), India (5%)

'All others' includes all other countries along with bunker fuels and statistical differences

Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Historical cumulative emissions by continent

Cumulative emissions from fossil-fuel and cement (1870–2014)
North America and Europe responsible for most cumulative emissions, but Asia growing fast

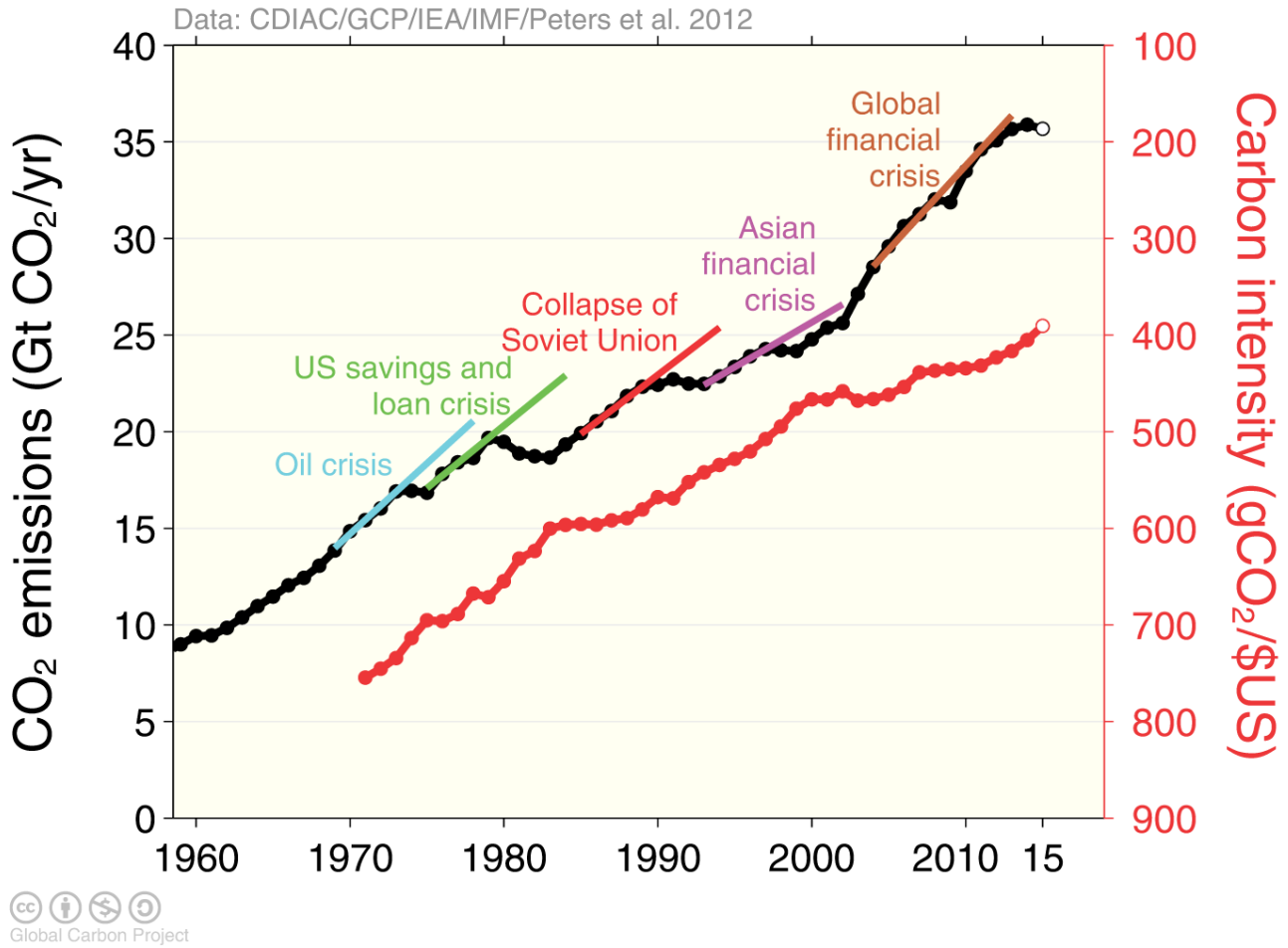


The figure excludes bunker fuels and statistical differences
Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Carbon intensity of economic activity - global

Financial crises have had little lasting effect on emissions growth

Global carbon intensity has returned to a phase of improvement after stalling for some years

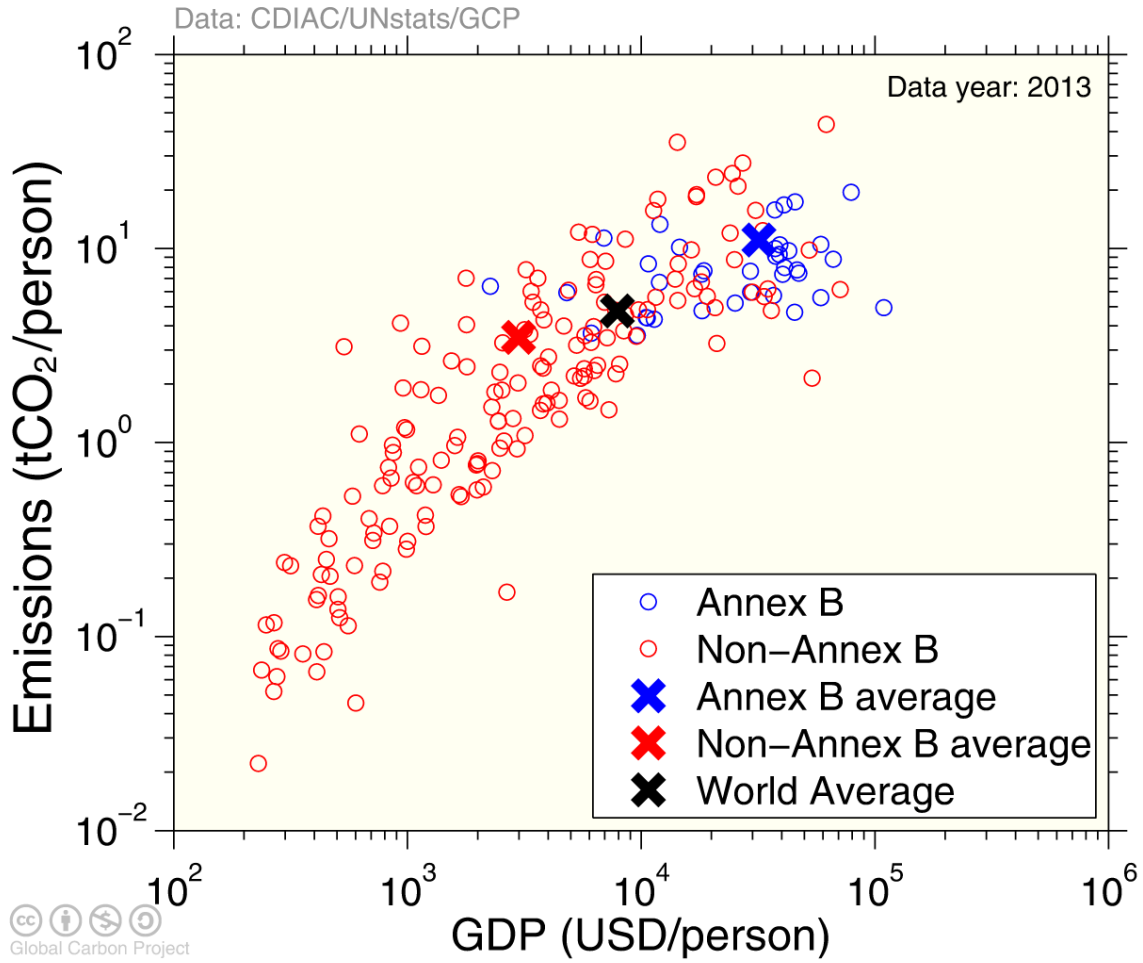


Economic activity is measured in Purchasing Power Parity

Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Annex B versus non-Annex B countries

There is not a clear distinction between Annex B and non-Annex B countries based on economic activity per capita or emissions per capita

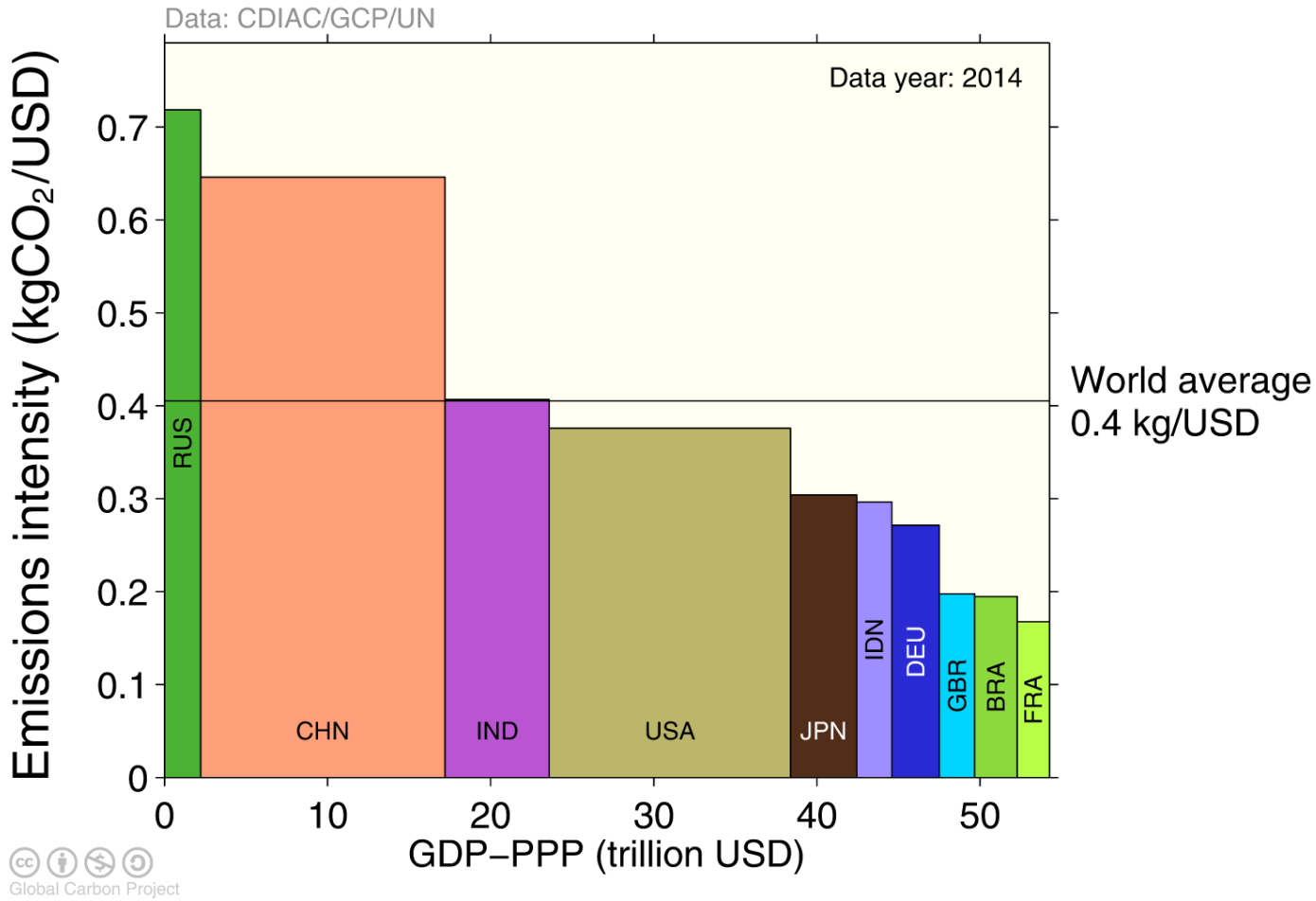


GDP is measured here in Market Exchange Rates

Source: United Nations; CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Emissions intensity of GDP

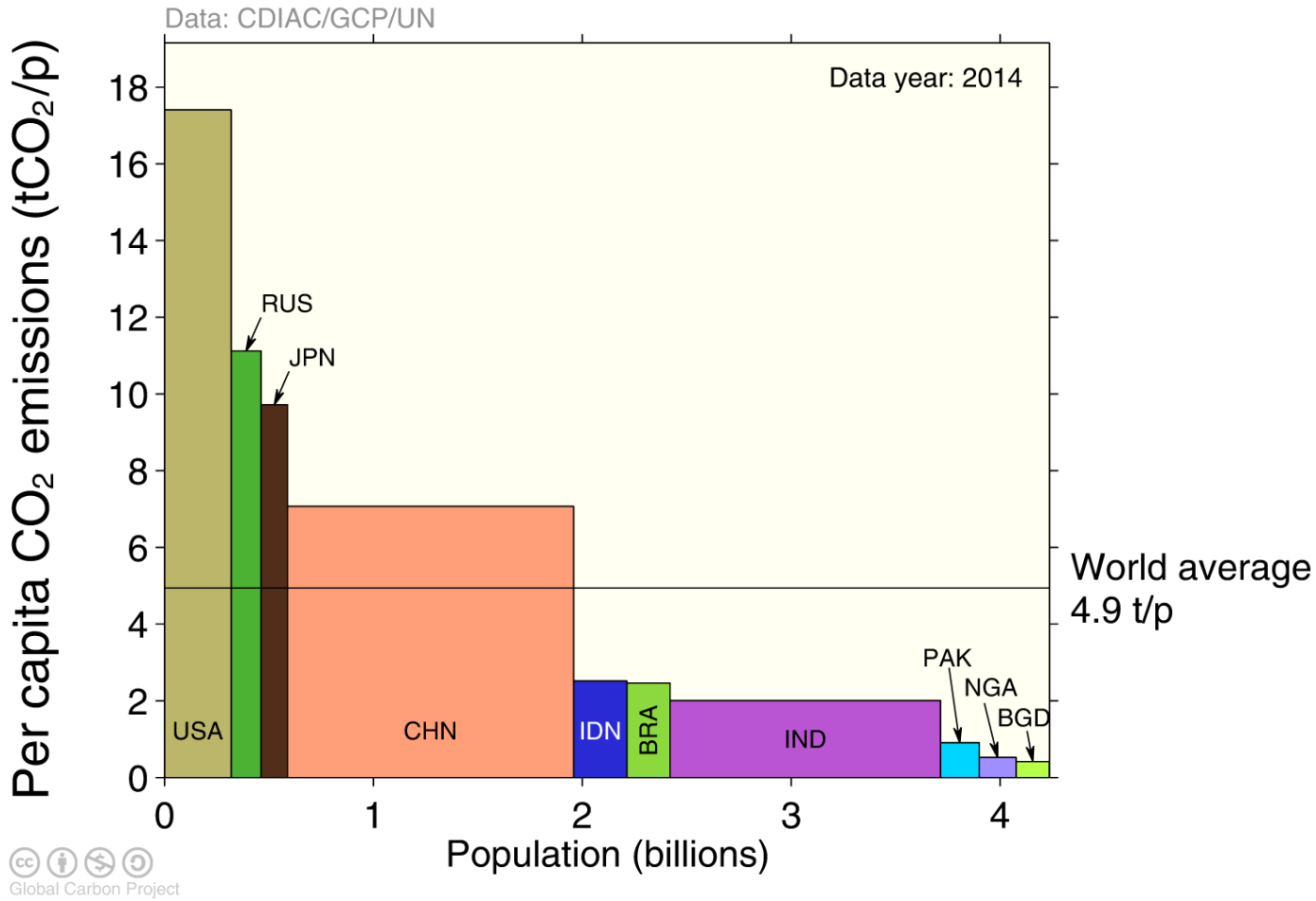
The 10 largest economies have a wide range of emissions intensity of economic production



Source: Global Carbon Budget 2015

Emissions intensity per capita

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



Source: Global Carbon Budget 2015

Key statistics

Region/Country	Emissions 2014				
	Per capita	Total		Growth 2013-14	
	tCO_2 per person	$GtCO_2$	%	$GtCO_2$	%
Global (with bunkers)	4.9	35.89	100	0.220	0.0
Developed Countries (Annex B)					
Annex B	10.7	13.03	36.3	-0.288	-2.2
USA	17.4	5.56	15.5	0.047	0.8
EU28	6.6	3.34	9.3	-0.209	-5.9
Russia	11.1	1.59	4.4	-0.027	-1.7
Japan	9.7	1.23	3.4	-0.036	-2.9
Canada	15.7	0.56	1.6	-0.001	0.2
Developing Countries (Non-Annex B)					
Non-Annex B	3.4	20.20	56.3	0.533	2.7
China	7.1	9.68	27.0	0.111	1.2
India	2.0	2.60	7.23	0.205	8.6
Indonesia	2.5	0.64	1.78	0.024	3.9
Iran	7.9	0.62	1.72	0.016	2.7
Saudi Arabia	19.5	0.60	1.68	0.043	7.7
International Bunkers					
Aviation and Shipping	-	2.66	7.4	-0.024	-0.879

Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

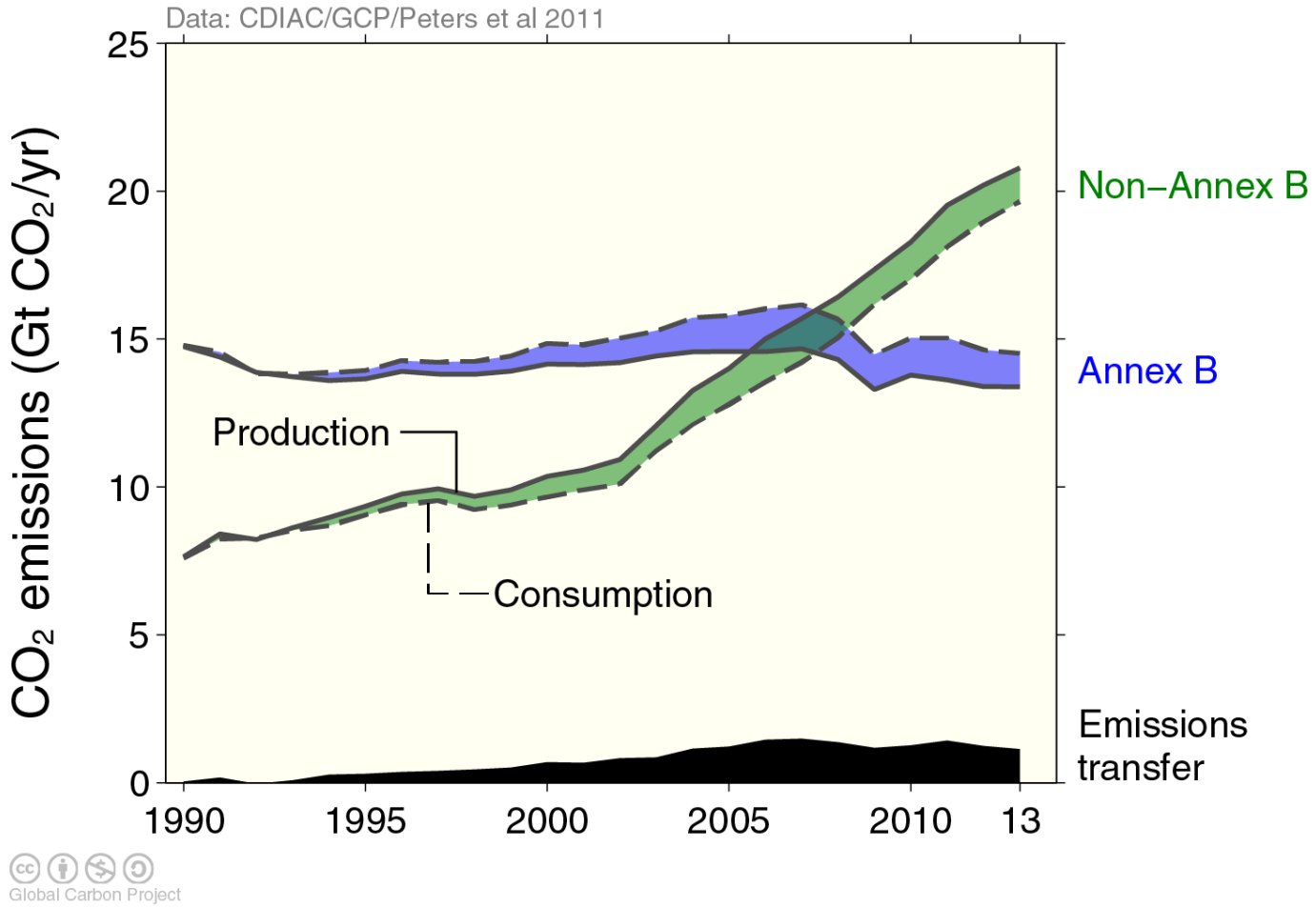
Consumption-based emissions

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 emissions per the Kyoto Protocol

The net emissions transfers into Annex B countries more than offsets the Annex B emission reductions achieved within the Kyoto Protocol

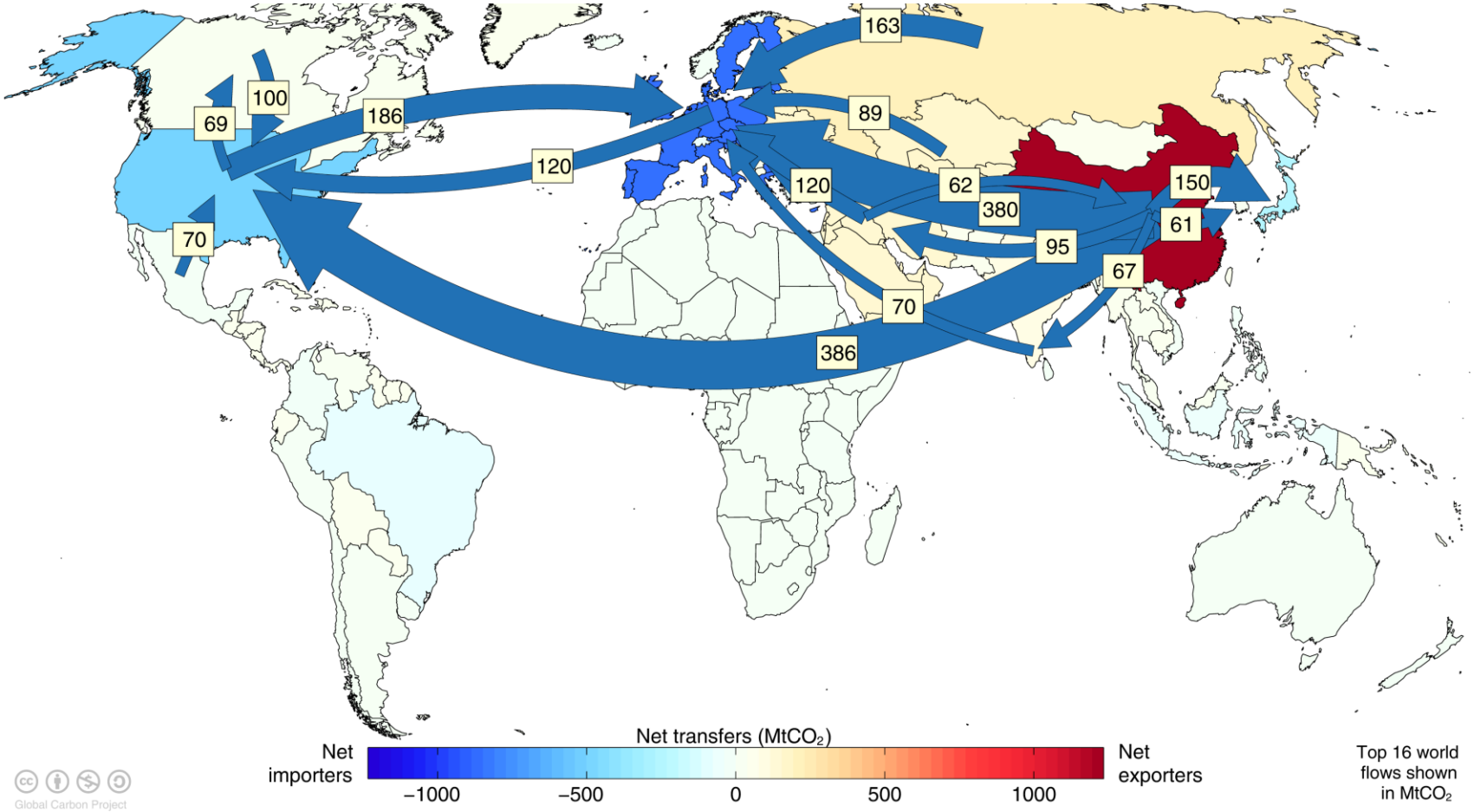


Transfers of emissions embodied in trade from non-Annex B countries to Annex B countries grew at about 20% per year between 1990 and 2007, but have since declined at about 3% per year.

Source: CDIAC; Peters et al 2011; Le Quéré et al 2015; Global Carbon Budget 2015

Major flows from production to consumption

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

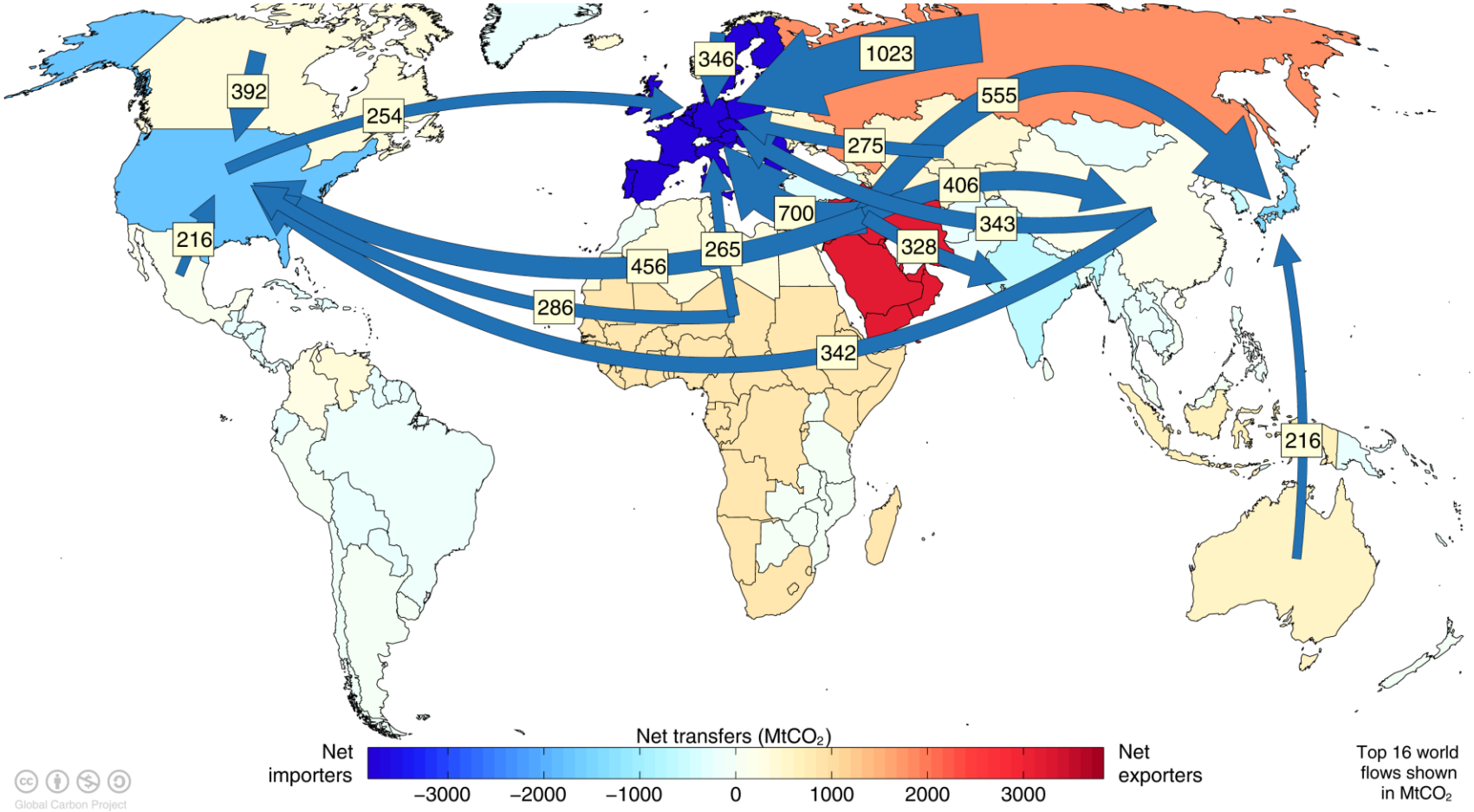


Values for 2011. EU is treated as one region. Units: $MtCO_2$

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



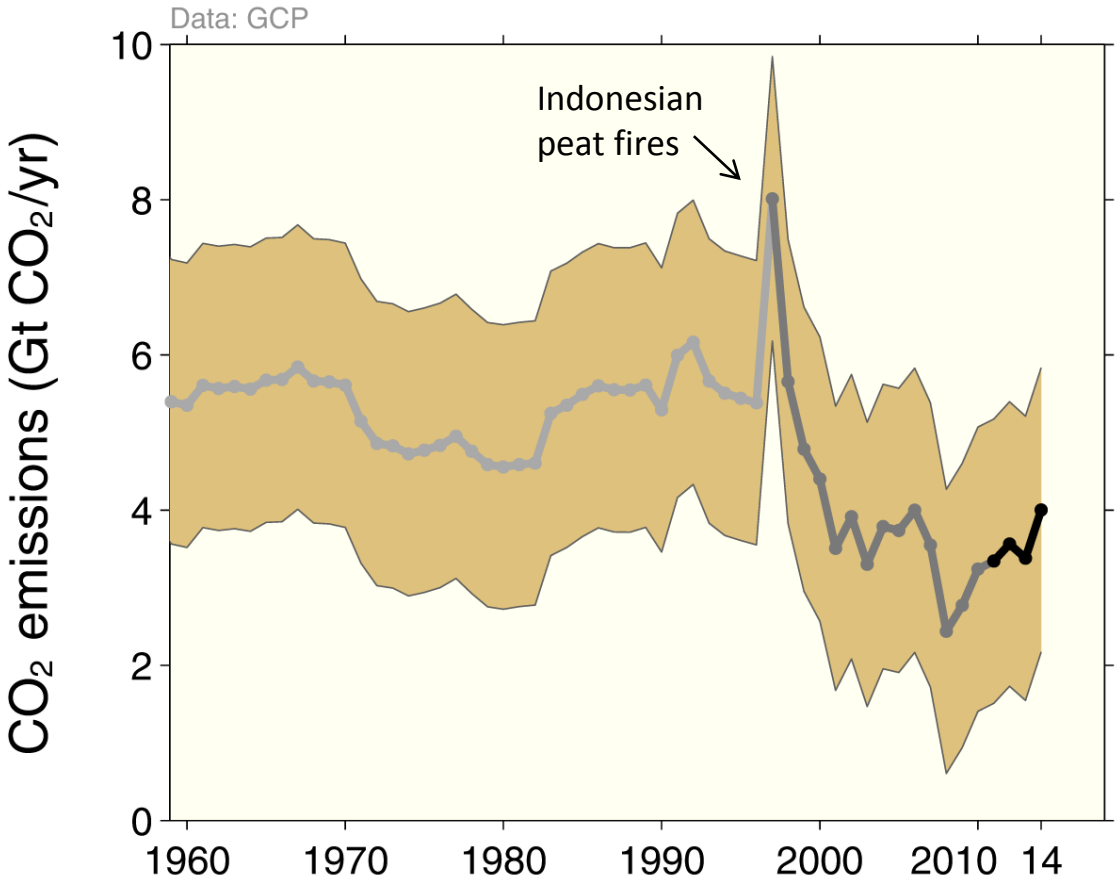
Values for 2011. EU is treated as one region. Units: $MtCO_2$

Source: Andrew et al 2013

Land-use change emissions

Land-use change emissions

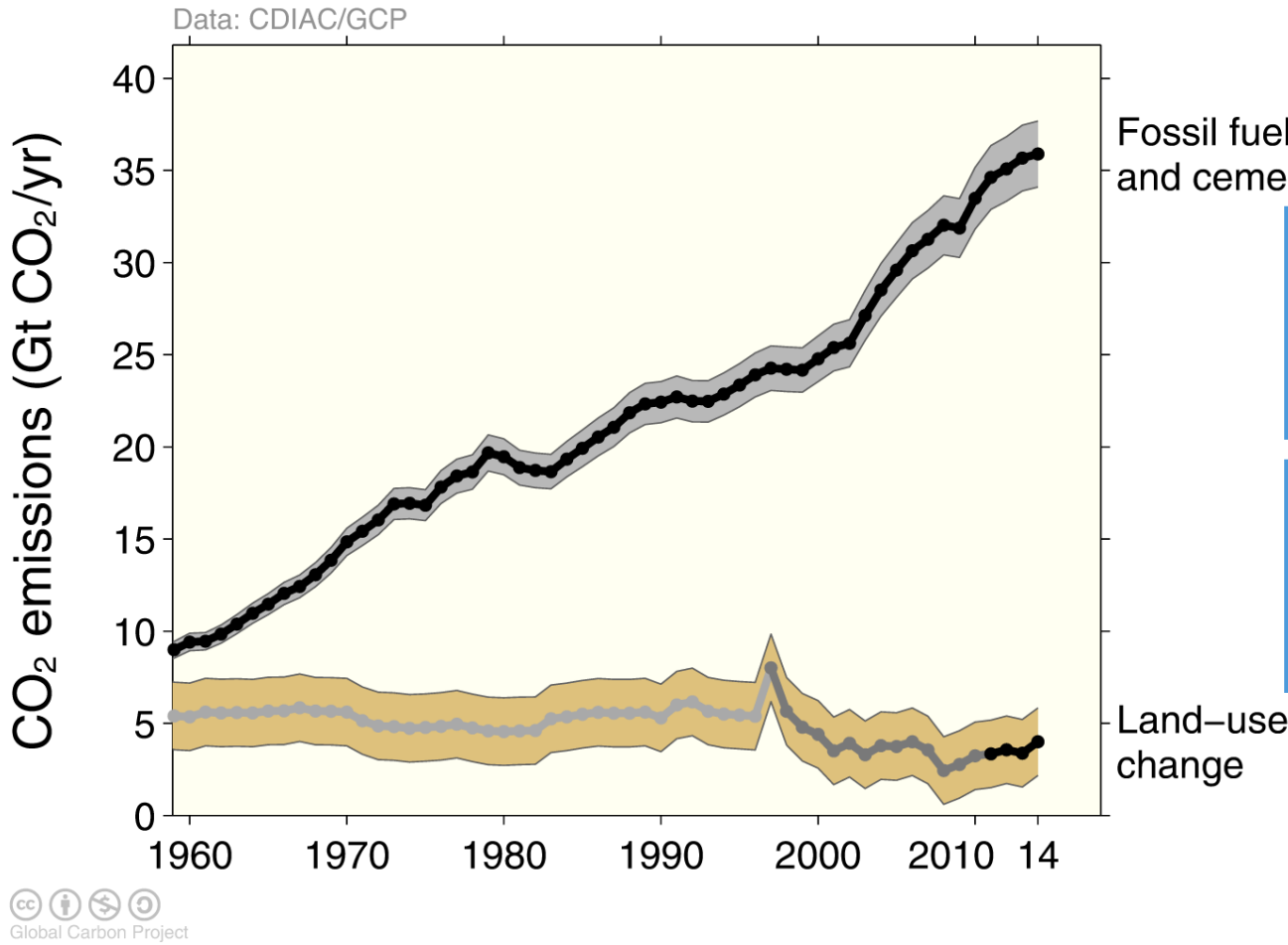
Global land-use change emissions are estimated as 3.3 ± 1.8 $GtCO_2$ during 2005–2014
The data suggests a general decrease in emissions since 1990, with large uncertainties



Three different estimation methods have been used, indicated here by different shades of grey
Land-use change also emits CH_4 and N_2O which are not shown here
Source: Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2015; Global Carbon Budget 2014

Total global emissions

Total global emissions: 39.9 ± 3.8 $GtCO_2$ in 2014, 44% over 1990
Percentage land-use change: 36% in 1960, 19% in 1990, 10% in 2014

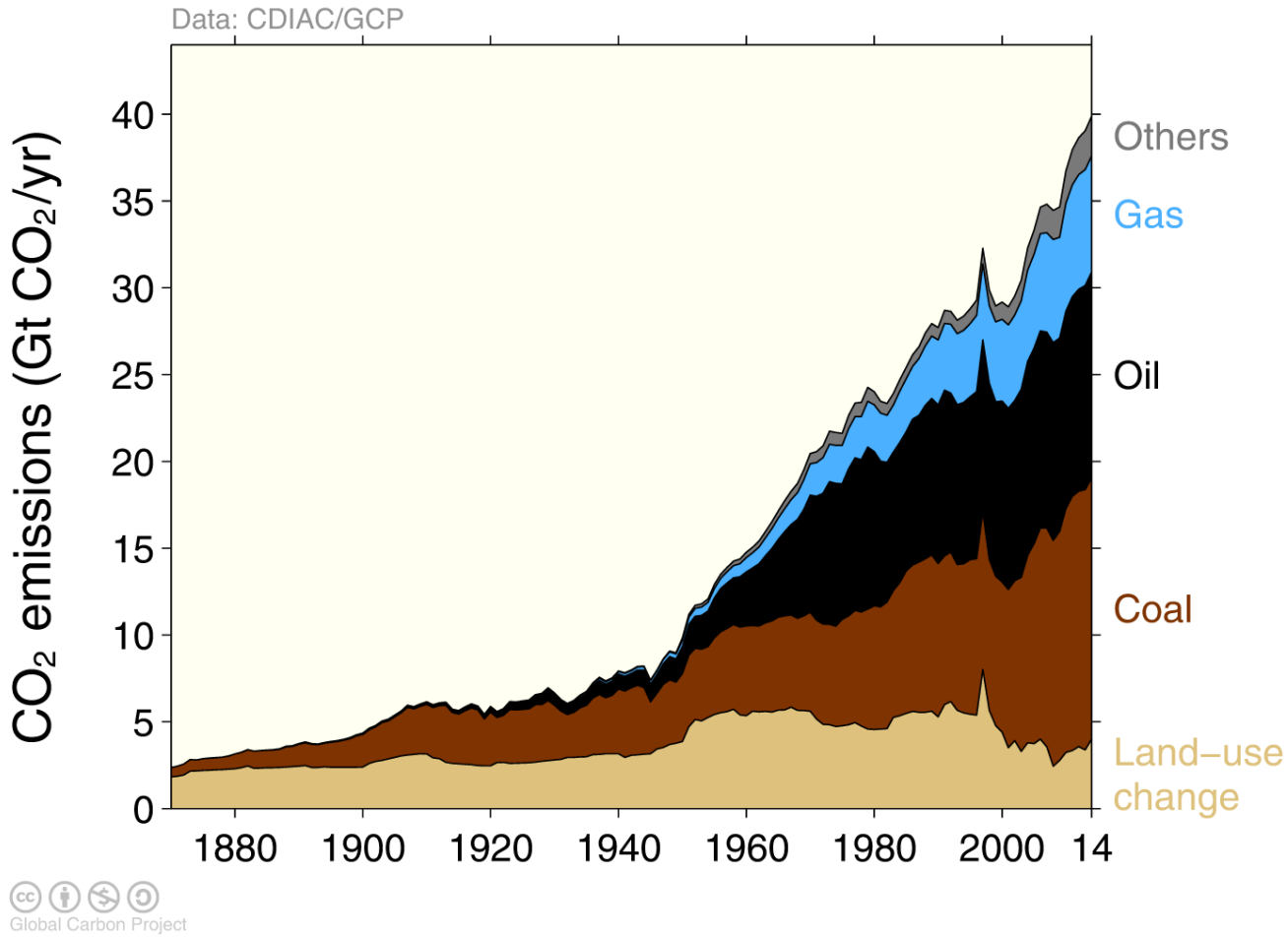


Three different methods have been used to estimate land-use change emissions, indicated here by different shades of grey

Source: CDIAC; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

Total global emissions by source

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

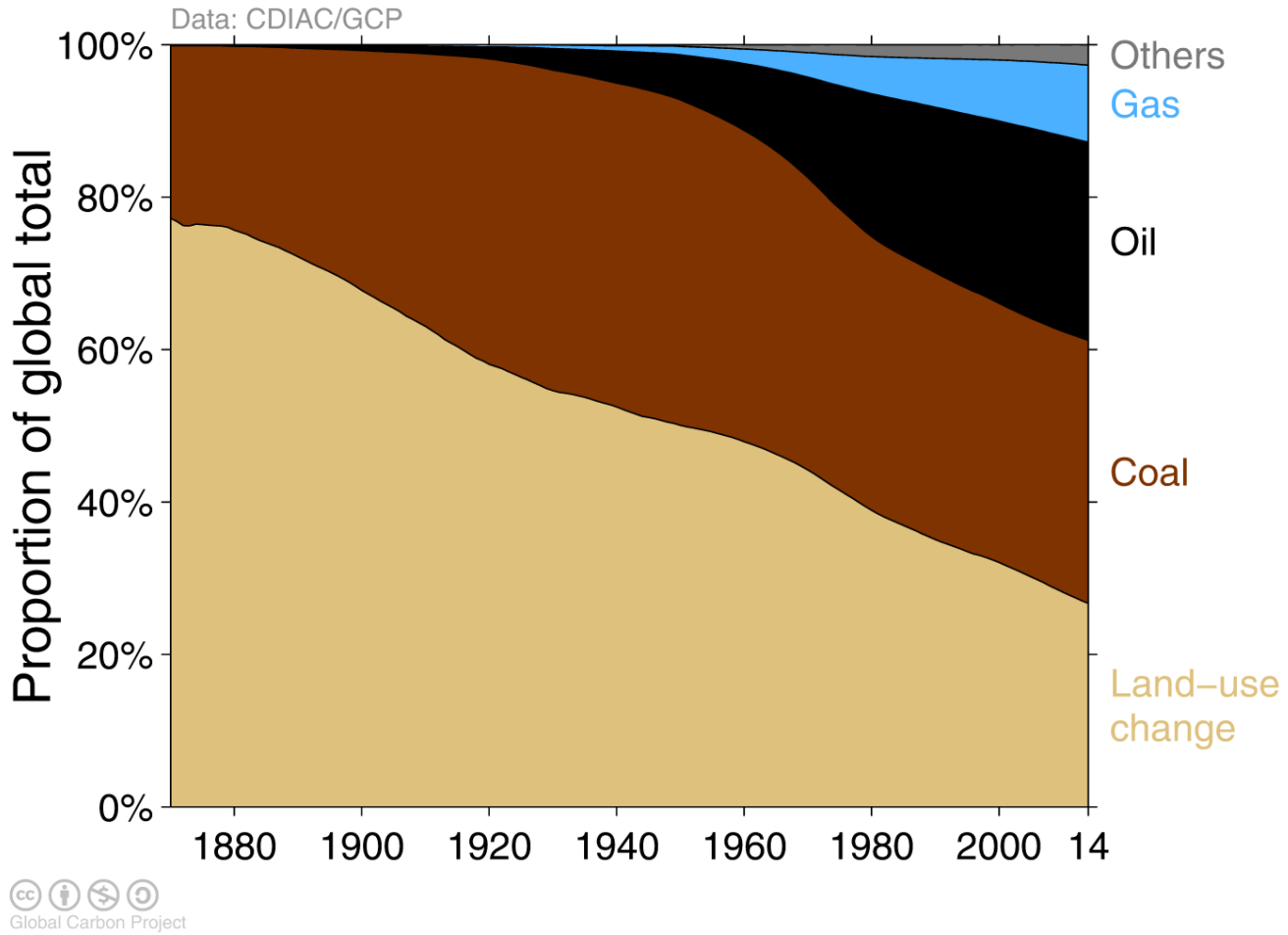


Others: Emissions from cement production and gas flaring

Source: CDIAC; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

Historical cumulative emissions by source

Land-use change represents about 27% of cumulative emissions in 2014, coal 35%, oil 26%, gas 10%, and others 3%



Others: Emissions from cement production and gas flaring

Source: CDIAC; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

Closing the carbon budget

Fate of anthropogenic CO_2 emissions (2005-2014 average)

33.0±1.8 $GtCO_2$/yr 91%

Sources

3.4±1.8 $GtCO_2$/yr 9%

16.0±0.4 $GtCO_2$/yr
44%

Partitioning

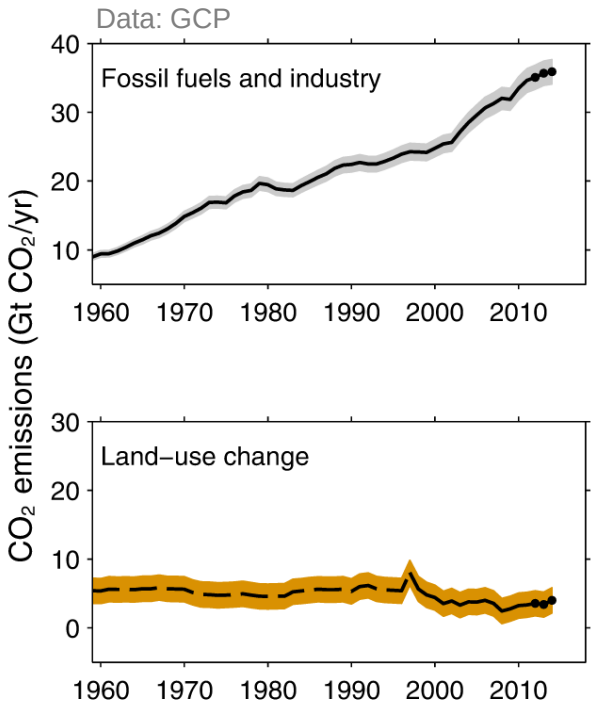
10.9±2.9 $GtCO_2$/yr
30%
Calculated as the residual
of all other flux components

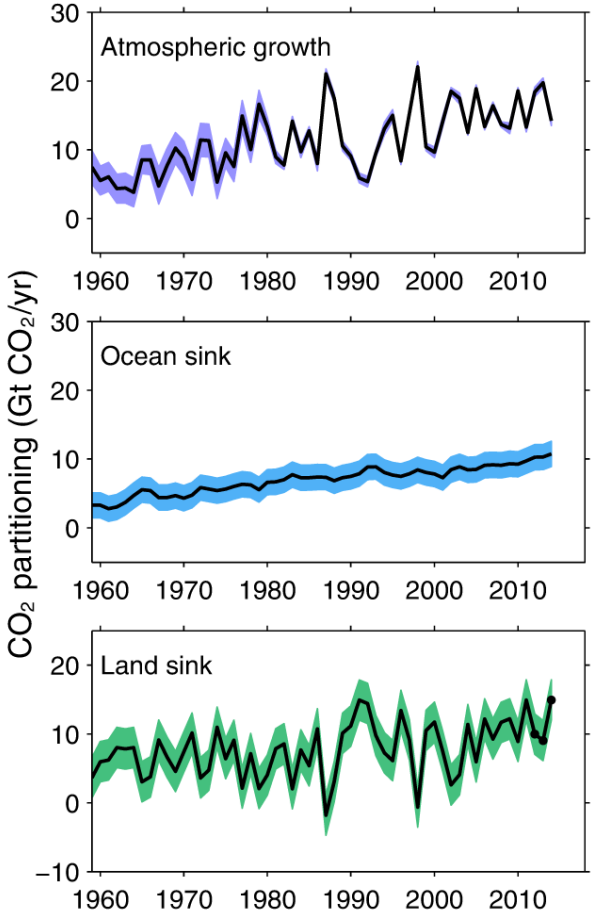
26%
9.5±1.8 $GtCO_2$/yr

Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

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

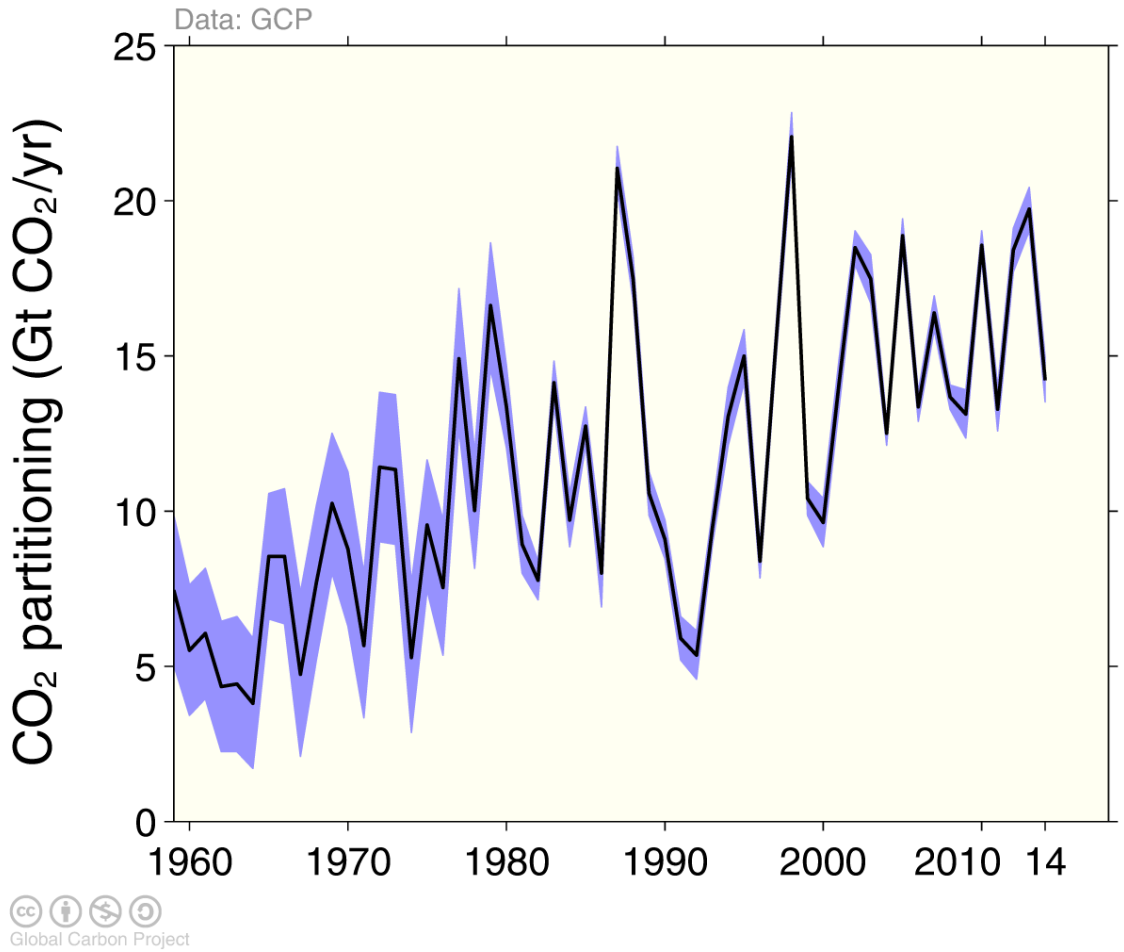




Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

Atmospheric concentration

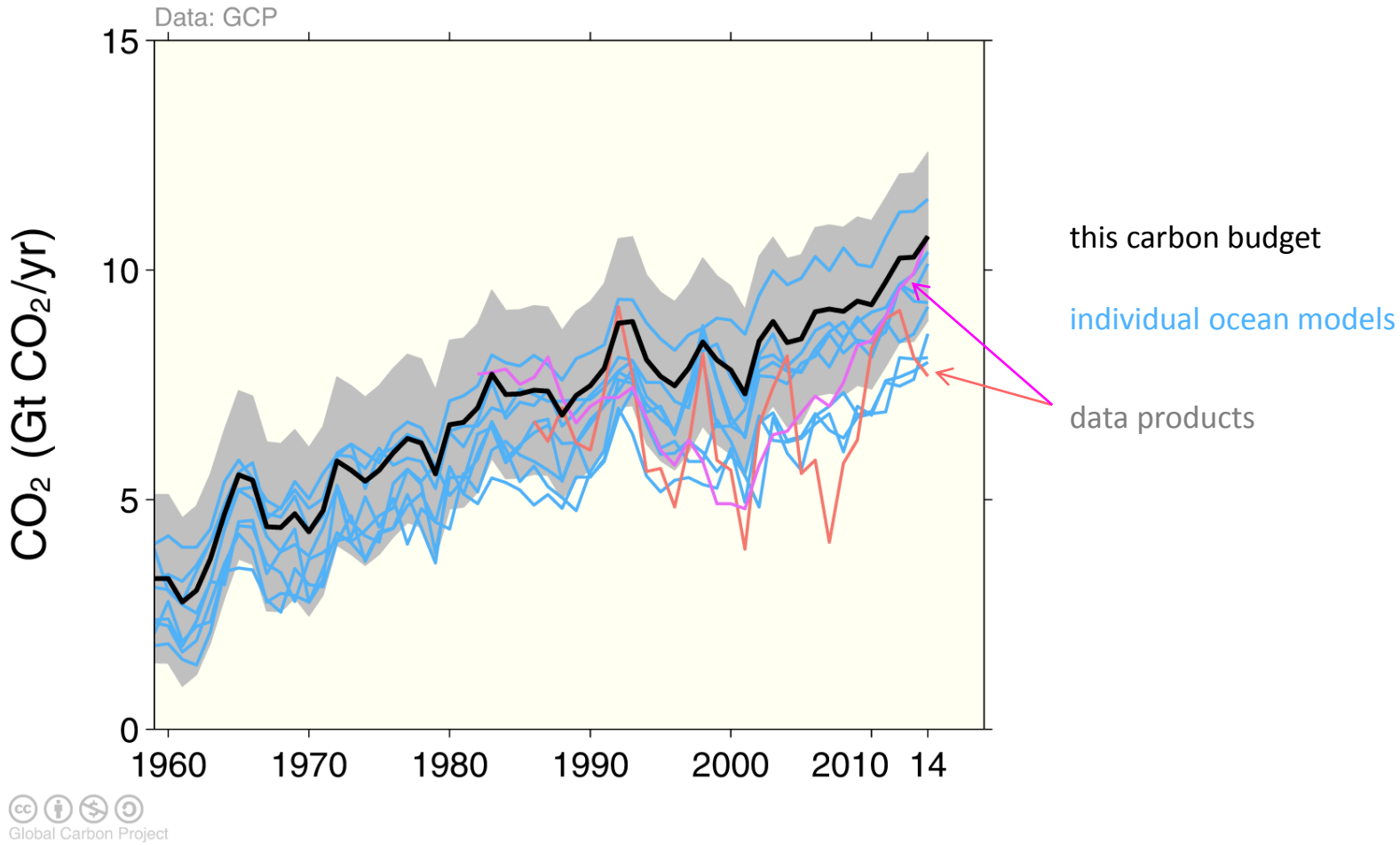
The atmospheric concentration growth rate has shown a steady increase
The growth in 2014 reflects the growth in fossil emissions, with small changes in the sinks



Source: NOAA-ESRL; Global Carbon Budget 2015

Ocean sink

Ocean carbon sink continues to increase
9.5±1.8 $GtCO_2$/yr for 2005-2015 and 10.7±1.8 $GtCO_2$/yr in 2014

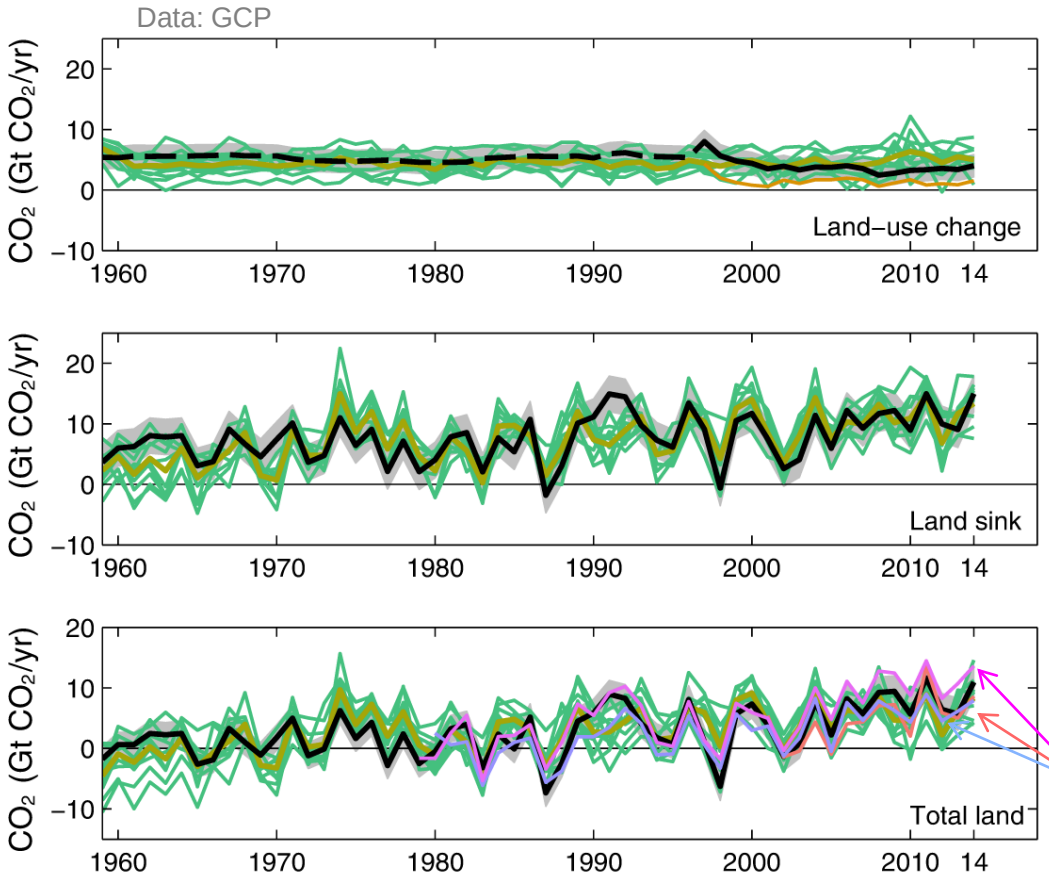


Source: Le Quéré et al 2015; Global Carbon Budget 2015

Individual estimates from Buitenhuis et al. (2010); Aumont and Bopp (2006); Doney et al. (2009); Assmann et al. (2010); Ilyiana et al. (2013); Sérérian et al. (2013); Oke et al. (2013); Landschützer et al. (2014); Park et al. (2010); Rödenbeck et al. (2014). References provided in Le Quéré et al. (2015).

Terrestrial sink

The residual land sink is increasing with time to 15.0±2.9 $GtCO_2$/yr in 2014, with large variability Total CO_2 fluxes on land (including land-use change) are constrained by atmospheric inversions



Source: Le Quéré et al 2015; Global Carbon Budget 2015

Individual estimates from Zhang et al. (2013); Oleson et al. (2013); Jain et al. (2013); Clarke et al. (2011); Smith et al. (2001); Sitch et al. (2003); Stocker et al. (2013); Krinner et al. (2005); Zeng et al. (2005); Kato et al. (2013); Peters et al. (2010); Rodenbeck et al. (2003); Chevallier et al. (2005). References provided in Le Quéré et al. (2014).

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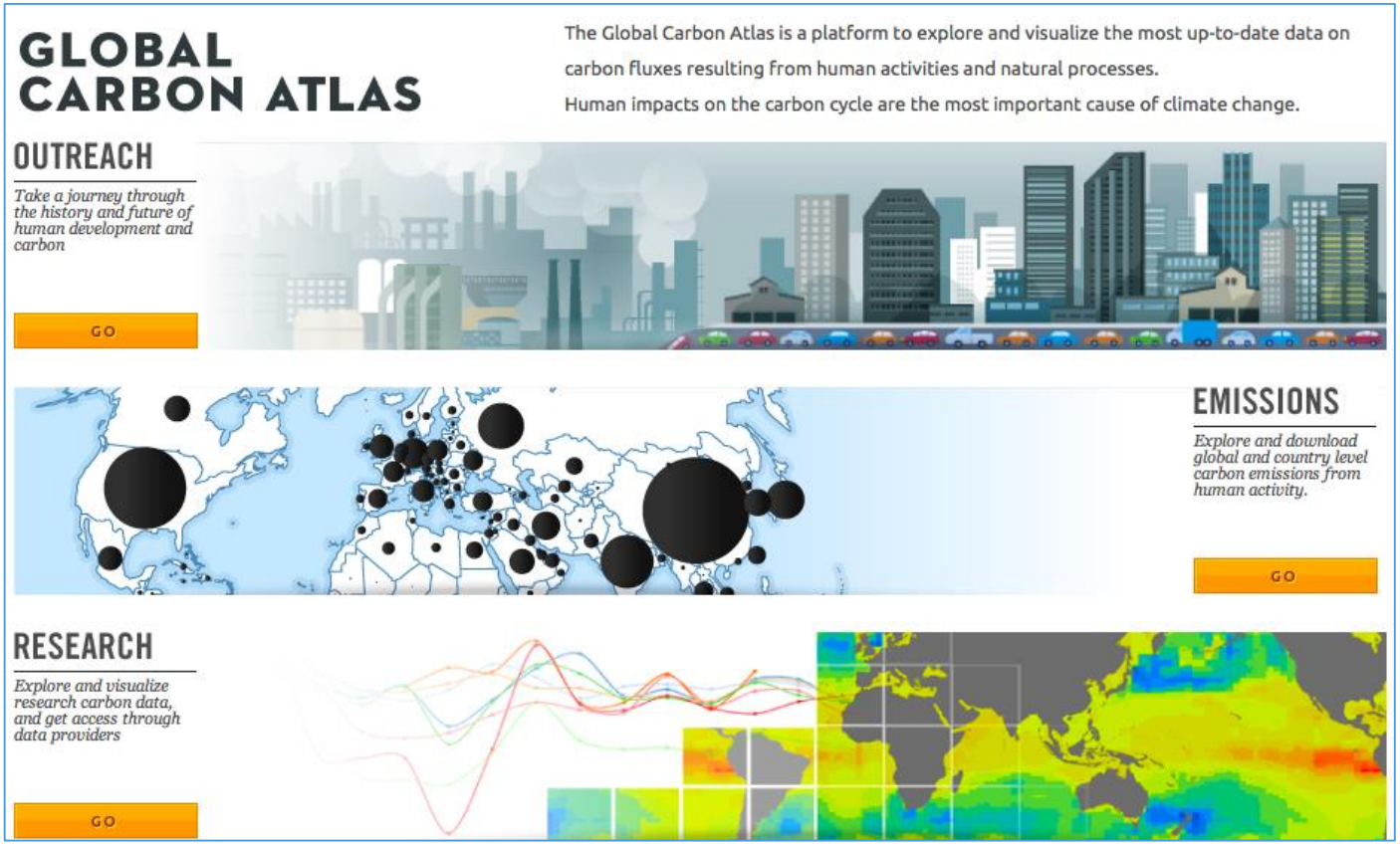
Global Carbon Atlas

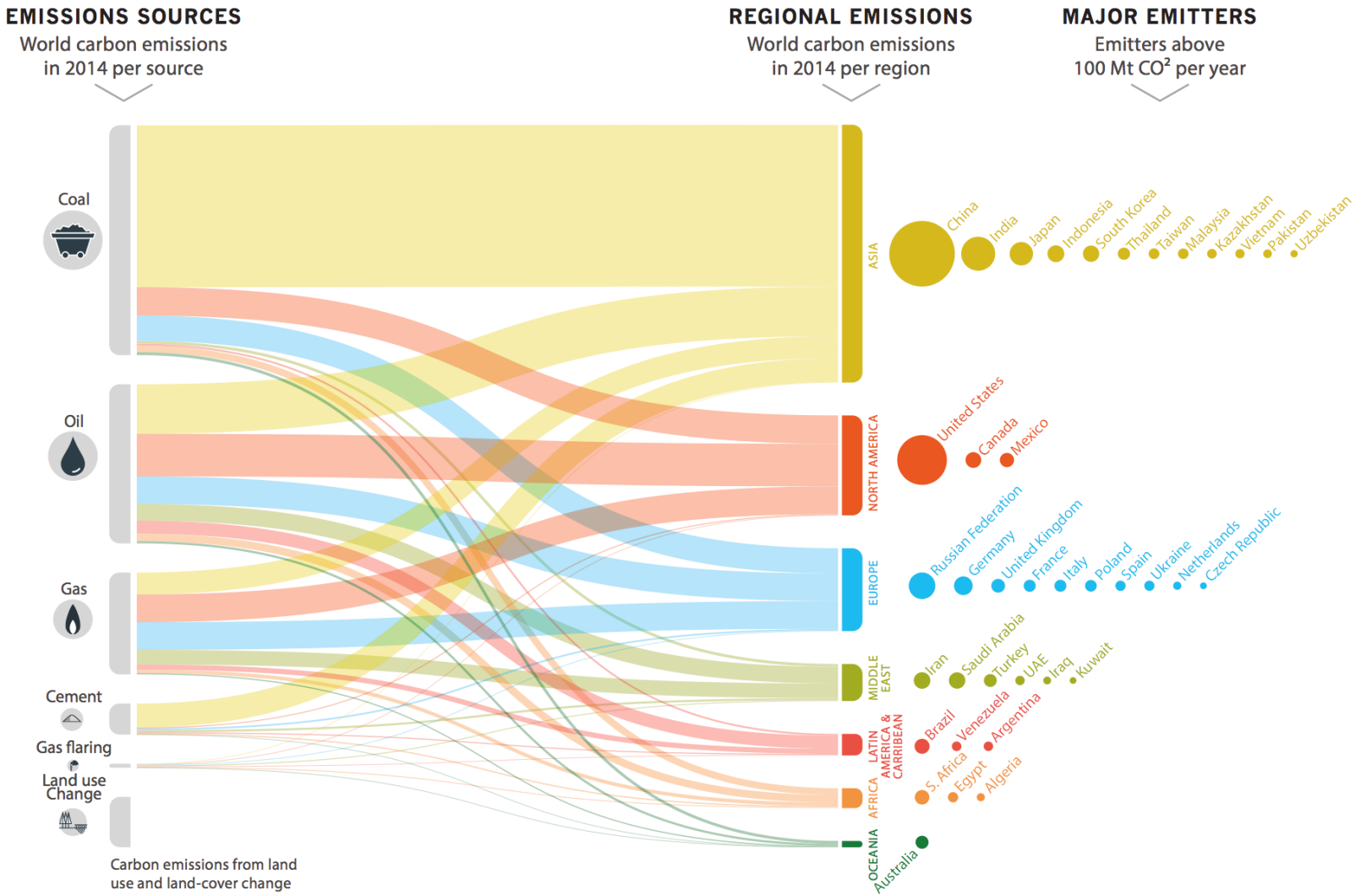
Explore CO_2 emissions at the global and country levels, compare among countries, visualize, and download data and illustrations ('Emissions' application). Also explore 'Outreach' and 'Research'.



www.globalcarbonatlas.org

GLOBAL CARBON PROJECT

Where do carbon emissions come from?



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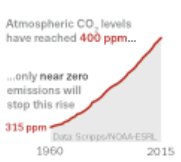
Global Carbon Budget 2015

Emissions from fossil fuels and industry **grew +0.6% in 2014**, and are projected to **decline by −0.6% (−1.6 to +0.5) in 2015**. This marks a break in the rapid emissions growth of 2.4% of the previous decade



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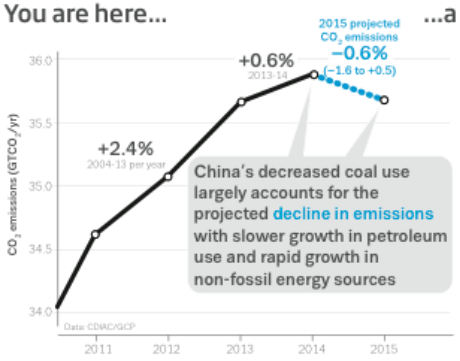
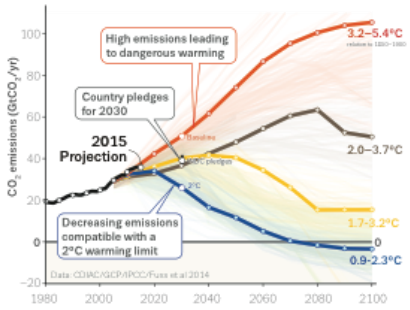
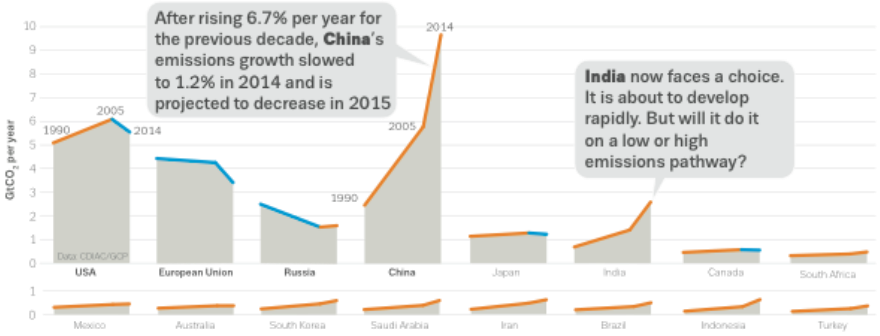


...a long way from near zero emissions...

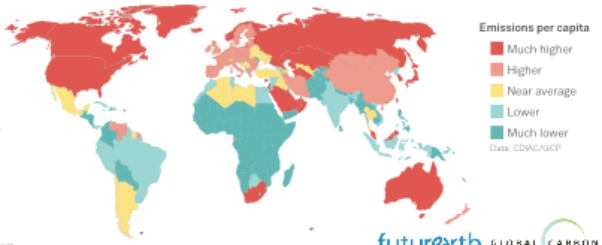


...though emissions are beginning to decline in many countries



Global emissions must quickly drop to zero to hold to 2°C

Our average per capita emissions are **4.9 tCO_2** each year



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