

Global Carbon Budget 2014

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 Earth System
 Science
 Data
 Discussions

This discussion paper is/has been under review for the journal Earth System Science Data (ESSD). Please refer to the corresponding final paper in ESSD if available.

Global carbon budget 2014

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GLOBAL CARBON ATLAS

The Global Carbon Atlas is a platform to explore and visualize the most up-to-date data on carbon fluxes resulting from human activities and natural processes.
 Human impacts on the carbon cycle are the most important cause of climate change.

OUTREACH

Take a journey through the history and future of human development and carbon

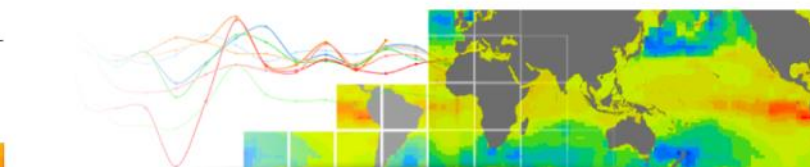


EMISSIONS

Explore and download global and country level carbon emissions from human activity.

RESEARCH

Explore and visualize research carbon data, and get access through data providers



More information, data sources and data files:

www.globalcarbonproject.org

Contact: c.lequere@uea.ac.uk

More information, data sources and data files:

www.globalcarbonatlas.org

Contact: philippe.ciais@lsce.ipsl.fr

All the data is shown in billion tonnes CO₂ (GtCO₂)

1 Gigatonne (Gt) = 1 billion tonnes = 1×10^{15} g = 1 Petagram (Pg)

1 kg carbon (C) = 3.664 kg carbon dioxide (CO₂)

1 GtC = 3.664 billion tonnes CO₂ = 3.664 GtCO₂

Disclaimer

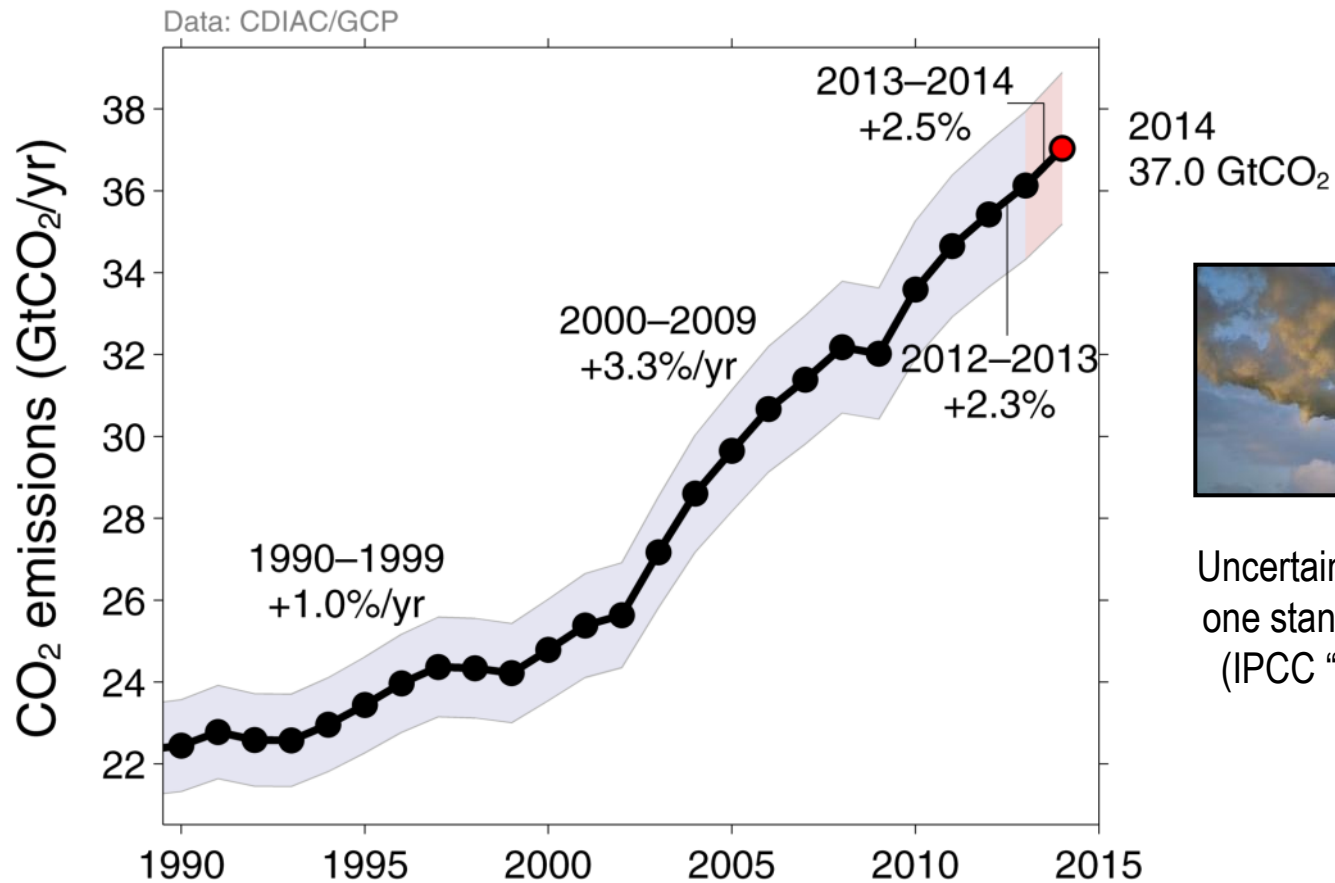
The Global Carbon Budget and the information presented here are intended for those interested in learning about the carbon cycle, and how human activities are changing it. The information contained herein is provided as a public service, with the understanding that the Global Carbon Project team make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

Executive Summary

Fossil Fuel and Cement Emissions

Global fossil fuel and cement emissions: 36.1 ± 1.8 GtCO₂ in 2013, 61% over 1990

● Projection for 2014 : 37.0 ± 1.9 GtCO₂, 65% over 1990



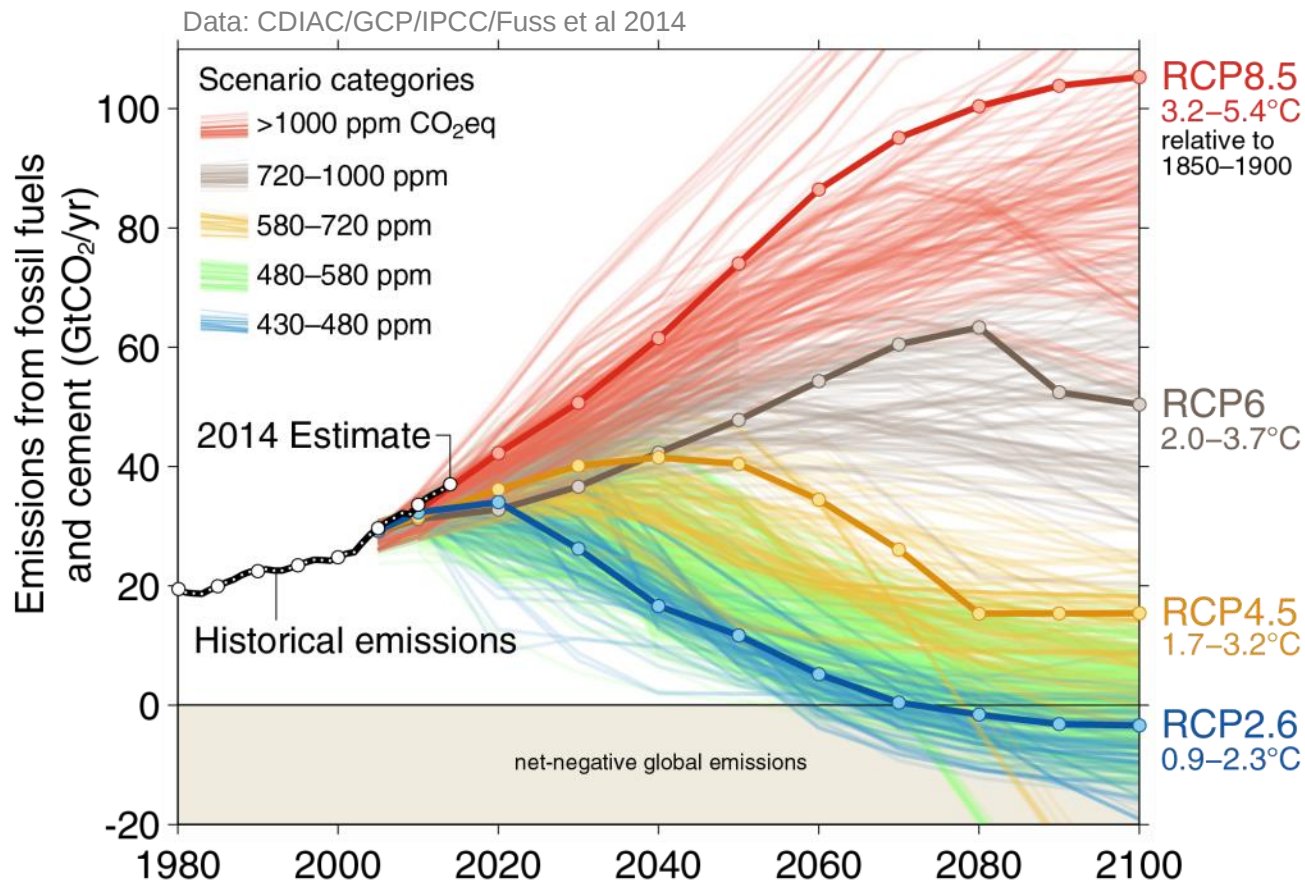
Uncertainty is $\pm 5\%$ for one standard deviation (IPCC “likely” range)

Estimates for 2011, 2012, and 2013 are preliminary

Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Observed Emissions and Emissions Scenarios

Emissions are on track for 3.2–5.4°C “likely” increase in temperature above pre-industrial
Large and sustained mitigation is required to keep below 2°C

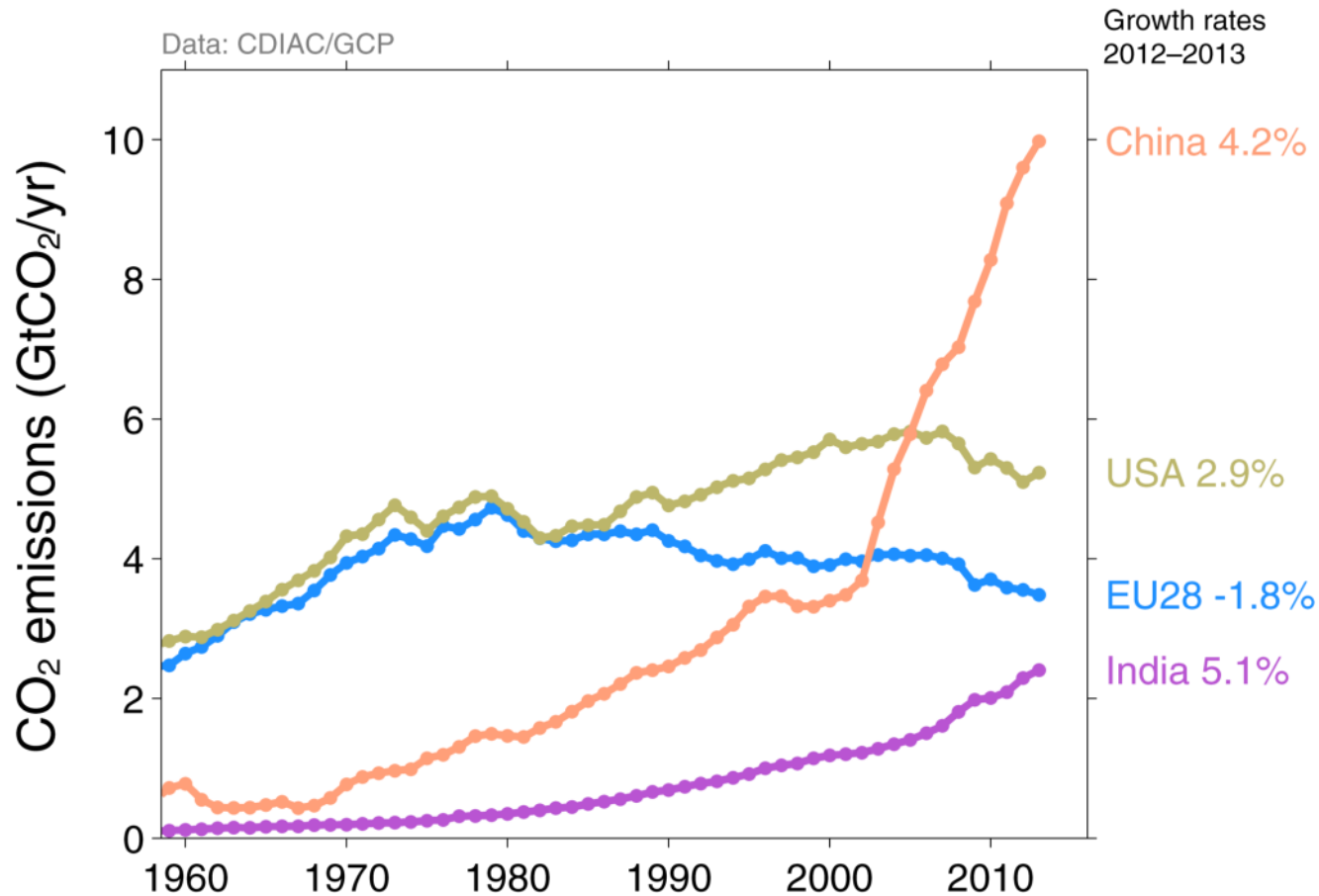


Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

Source: [Fuss et al 2014](#); [CDIAC](#); [Global Carbon Budget 2014](#)

Top Fossil Fuel Emitters (Absolute)

The top four emitters in 2013 covered 58% of global emissions
China (28%), United States (14%), EU28 (10%), India (7%)



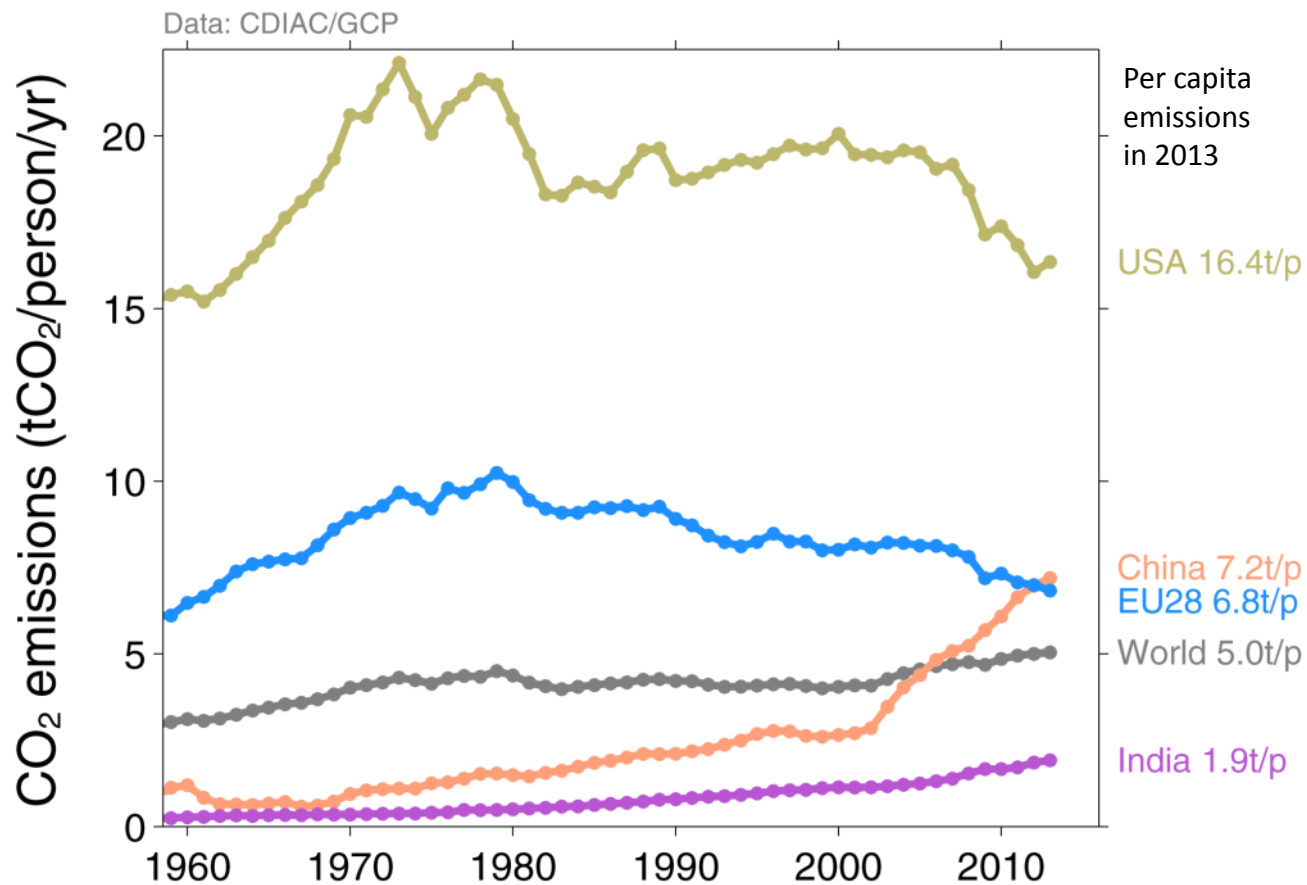
Bunkers fuel used for international transport is 3% of global emissions

Statistical differences between the global estimates and sum of national totals is 3% of global emissions

Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

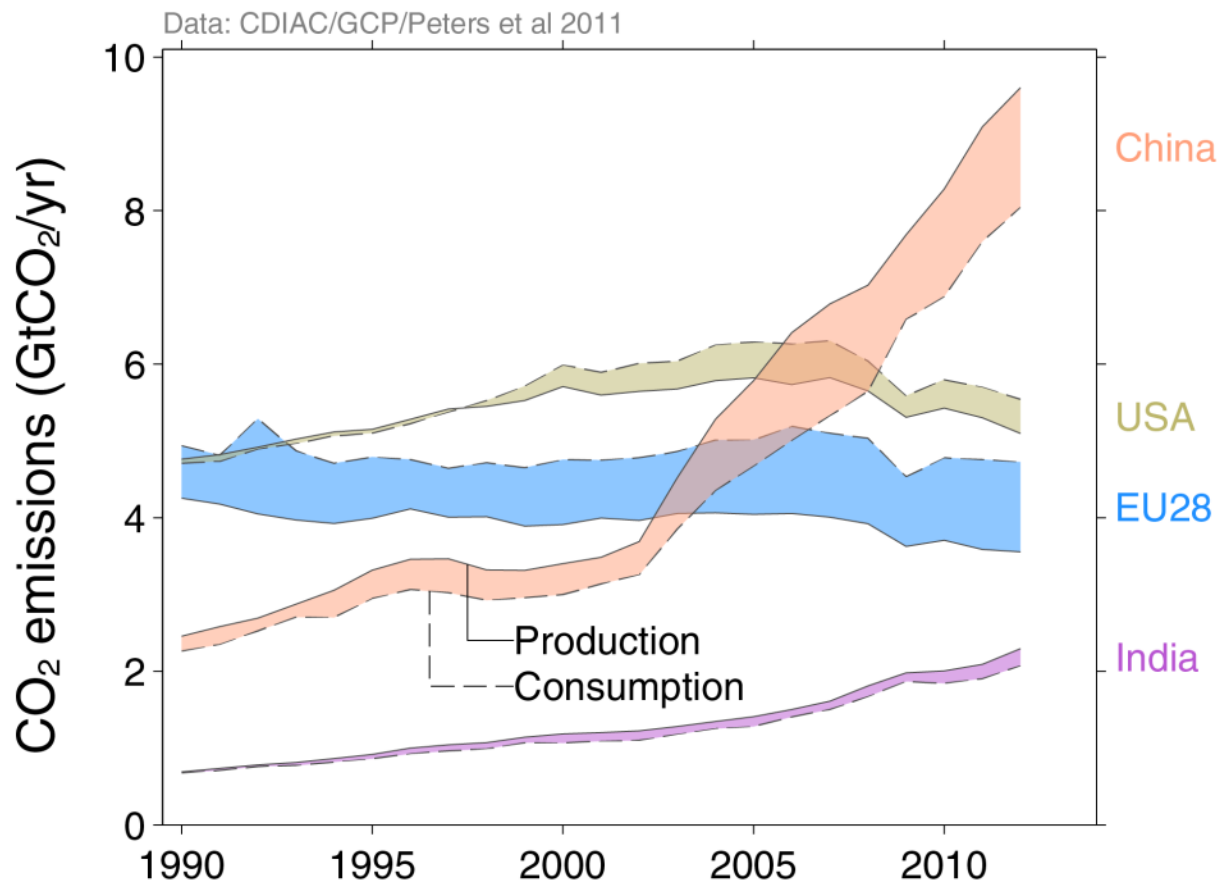
Top Fossil Fuel Emitters (Per Capita)

China's per capita emissions have passed the EU28 and are 45% above the global average



Consumption-based emissions (carbon footprint)

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

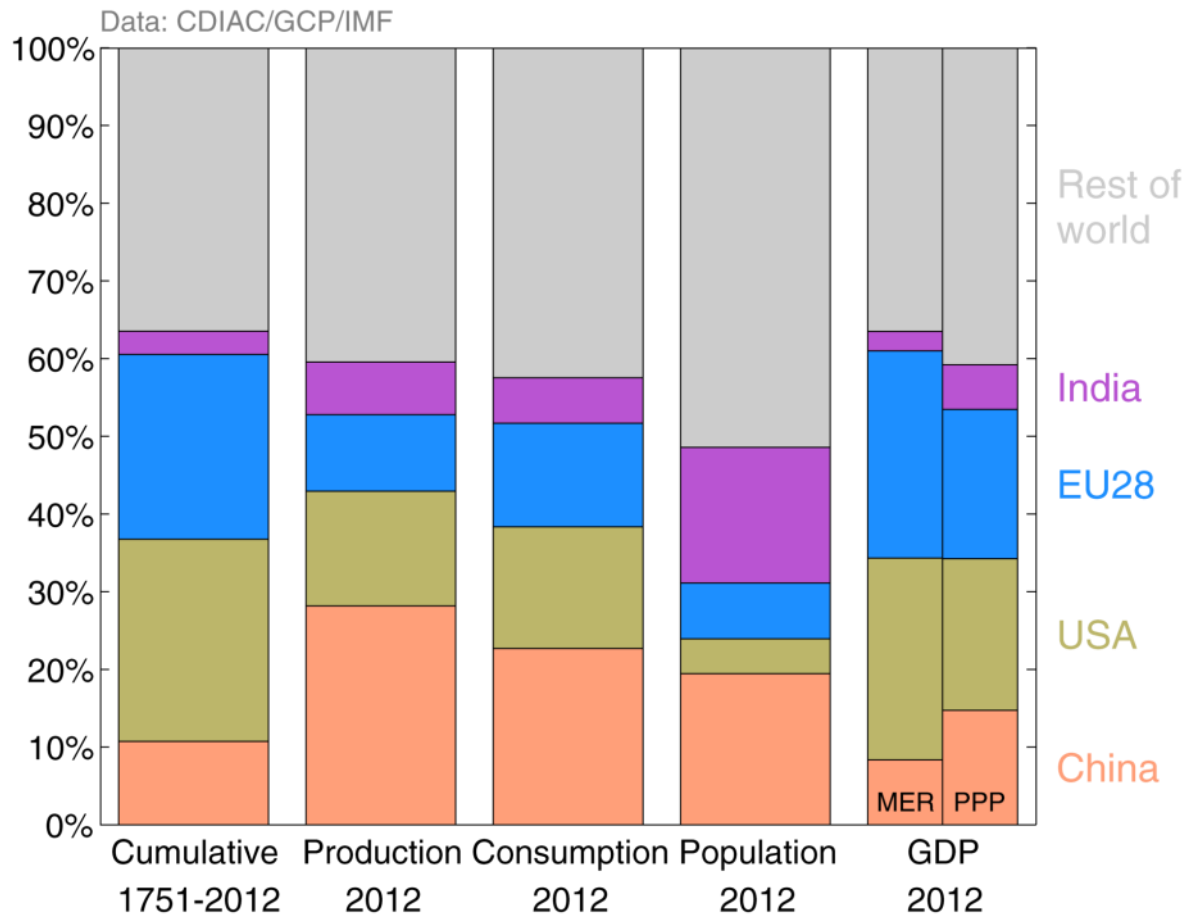


Consumption-based emissions are calculated by adjusting the standard production-based emissions to account for international trade

Source: [Le Quéré et al 2014](#); [Peters et al 2011](#); [Global Carbon Project 2014](#)

Alternative Ranking of Countries

Depending on perspective, the significance of individual countries changes



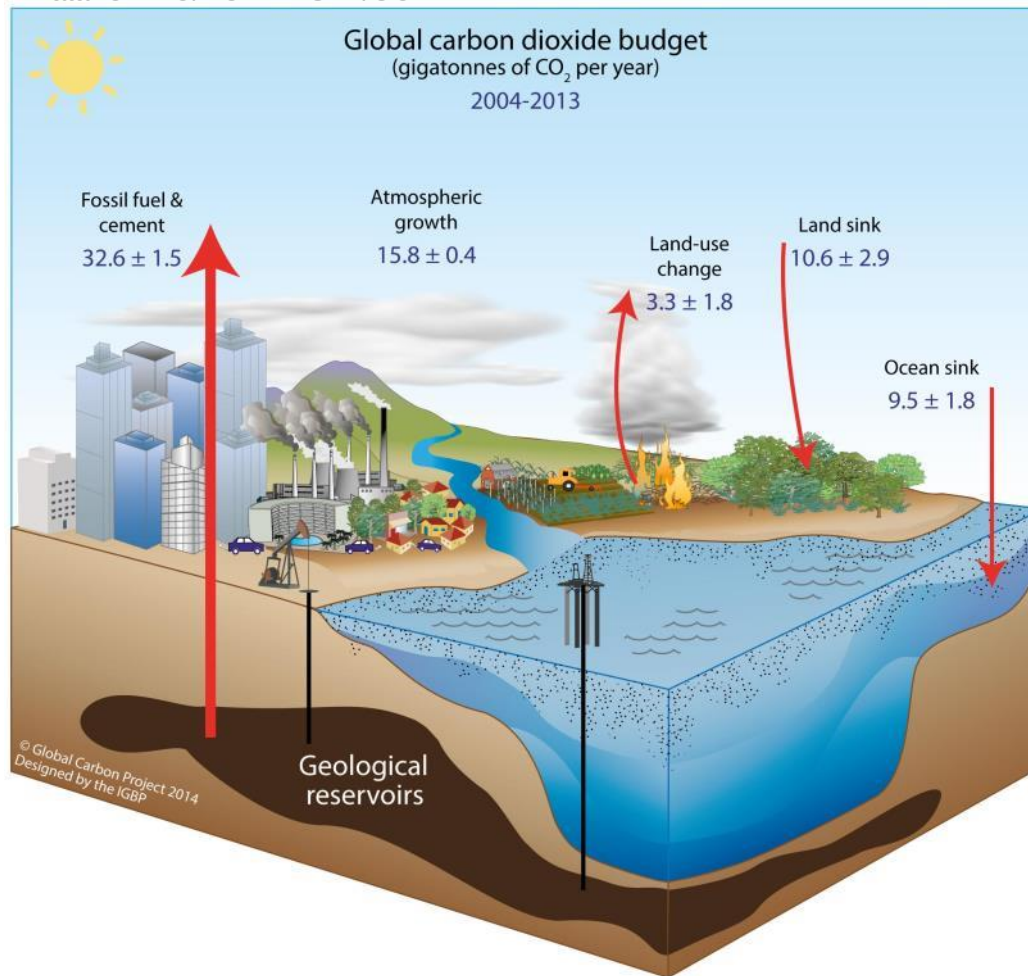
GDP: Gross Domestic Product in Market Exchange Rates (MER) and Purchasing Power Parity (PPP)

Source: [CDIAC](#); [United Nations](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Anthropogenic Perturbation of the Global Carbon Cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2004–2013 (GtCO₂/yr)

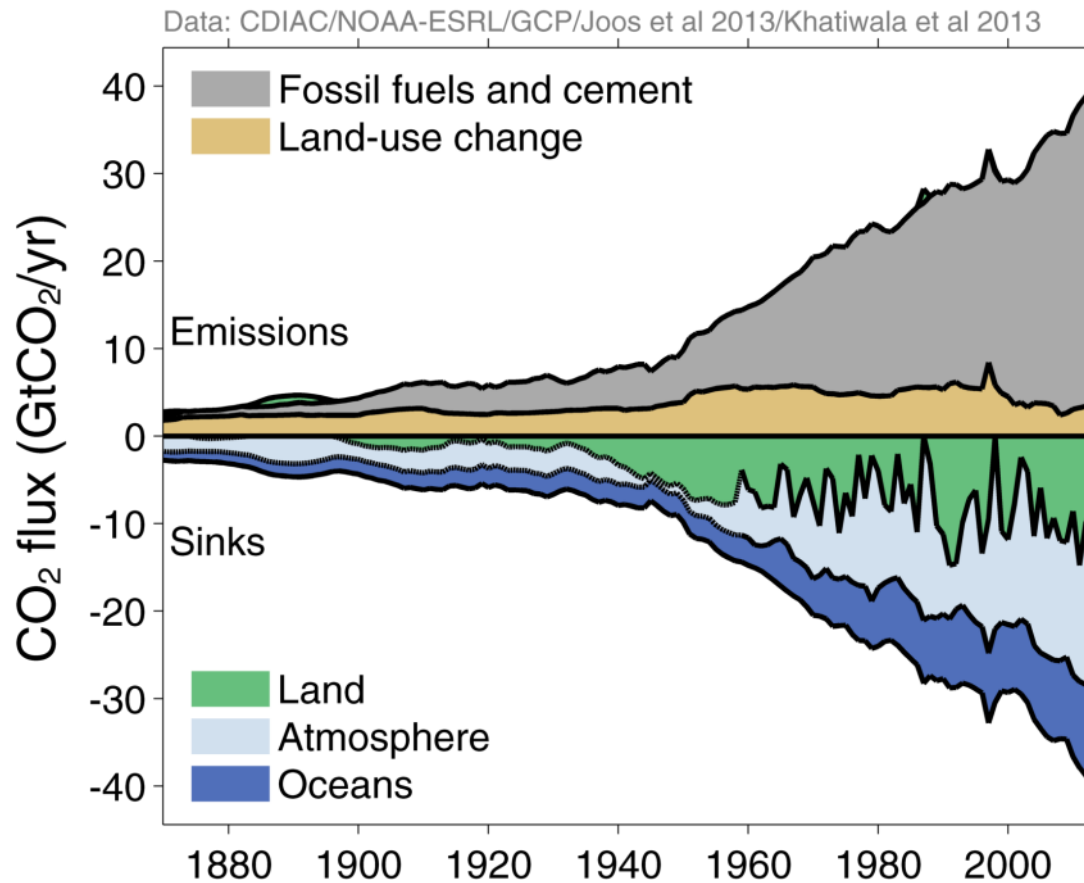
Data: CDIAC/NOAA-ESRL/GCP



Source: [CDIAC](#); [NOAA-ESRL](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Global Carbon Budget

Emissions are partitioned between the atmosphere, land, and 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 2014](#); [Global Carbon Budget 2014](#)

Global Carbon Budget

The cumulative contributions to the Global Carbon Budget from 1870
Contributions are shown in parts per million (ppm)

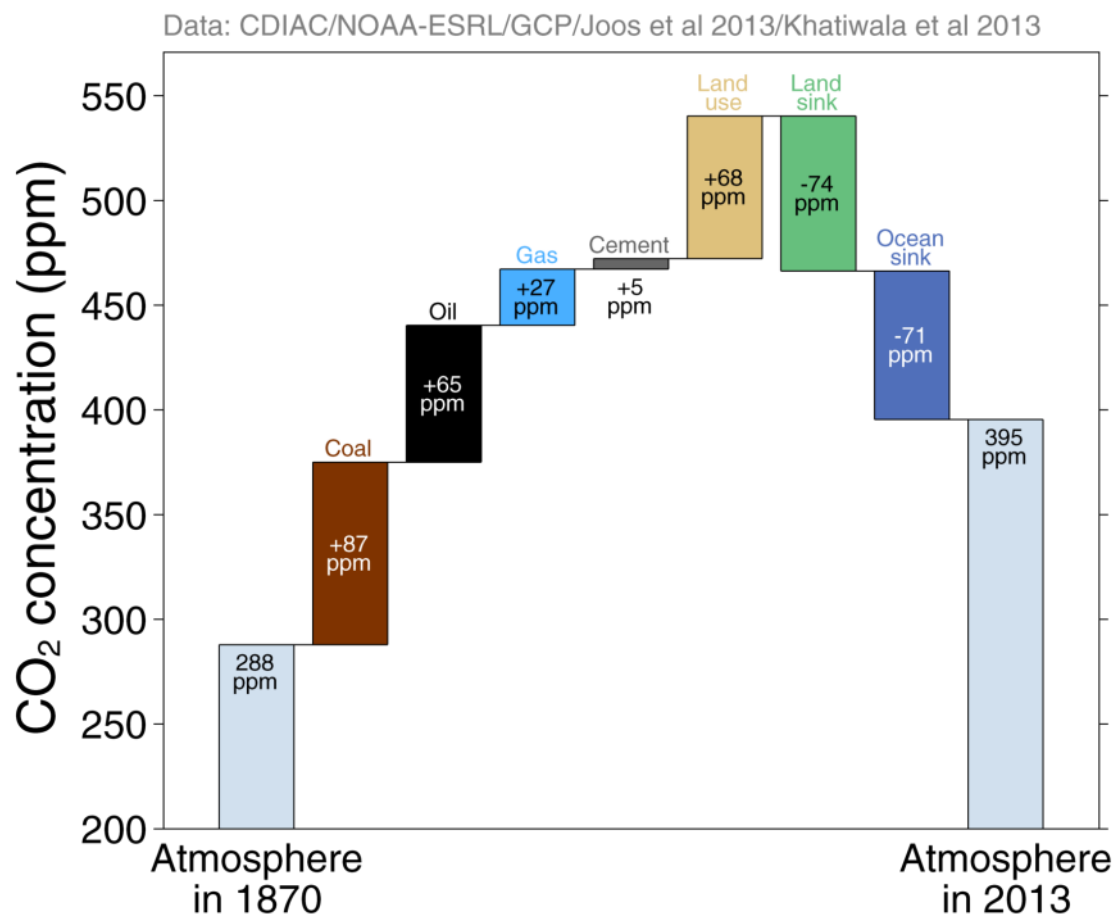
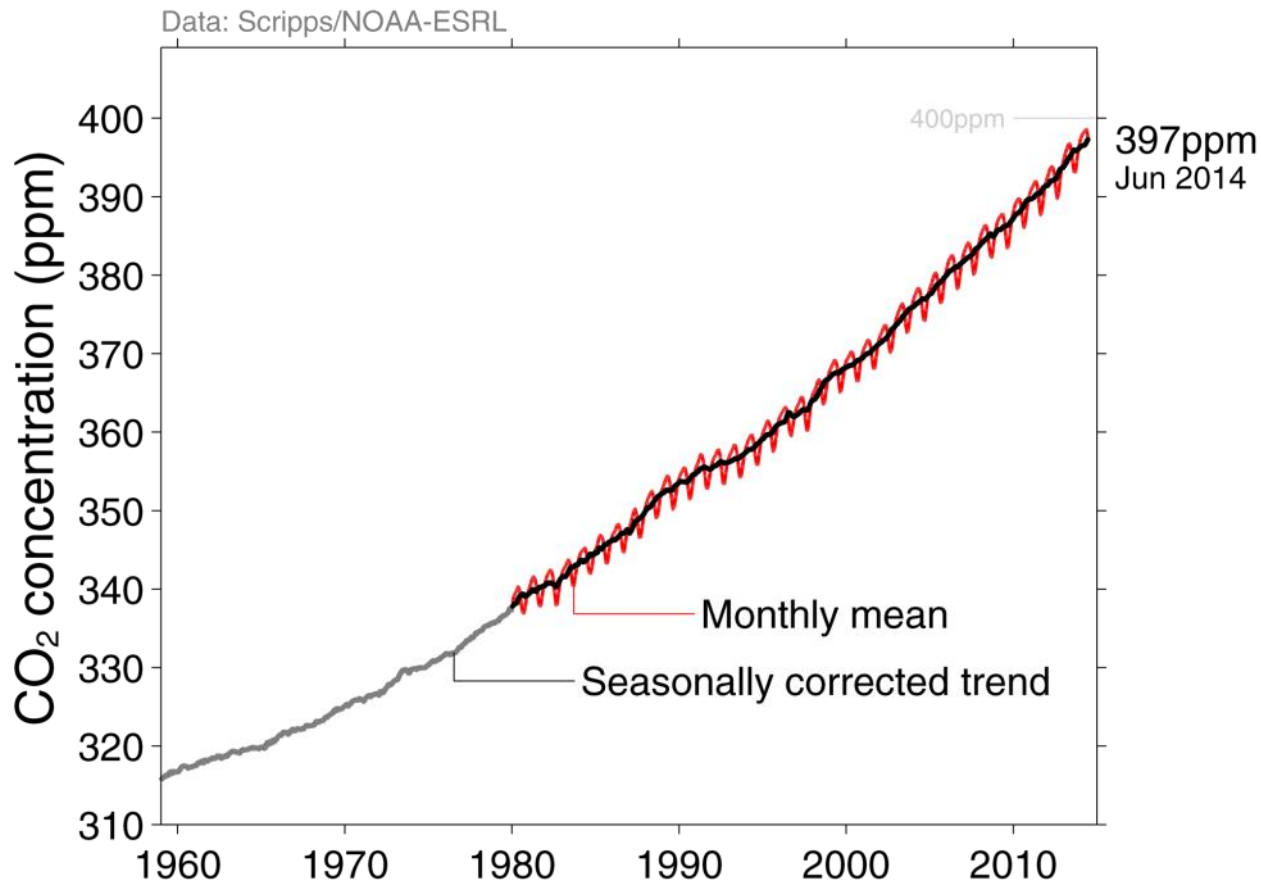


Figure concept from [Shrink That Footprint](#)

Source: [CDIAC](#); [NOAA-ESRL](#); [Houghton et al 2012](#); [Giglio et al 2013](#); [Joos et al 2013](#); [Khatiwala et al 2013](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Atmospheric Concentration

The global CO₂ concentration increased from ~277ppm in 1750 to 395ppm in 2013 (up 43%)
 Mauna Loa registered the first daily measurements above 400ppm in May 2013



Globally averaged surface atmospheric CO₂ 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 2014](#)

Remaining CO₂ emission quota

nature
geoscience

REVIEW ARTICLE

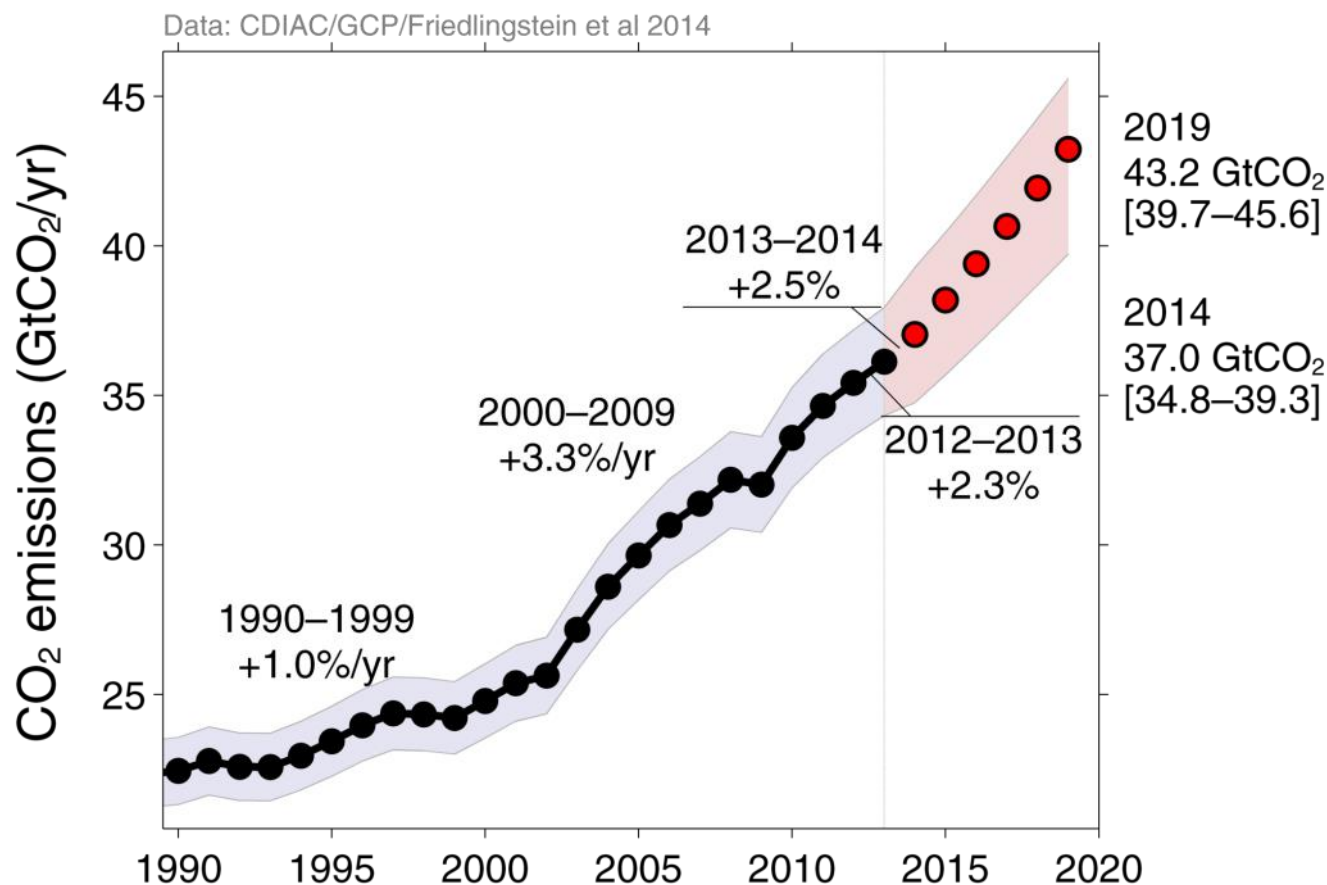
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Persistent growth of CO₂ emissions and implications for reaching climate targets

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Persistent Growth – Global

Assuming emissions follow projected GDP growth and accounting for improvement in carbon intensity, we project fossil fuel and cement emissions to grow 3.1%/yr to reach 43.2 GtCO₂/yr by 2019

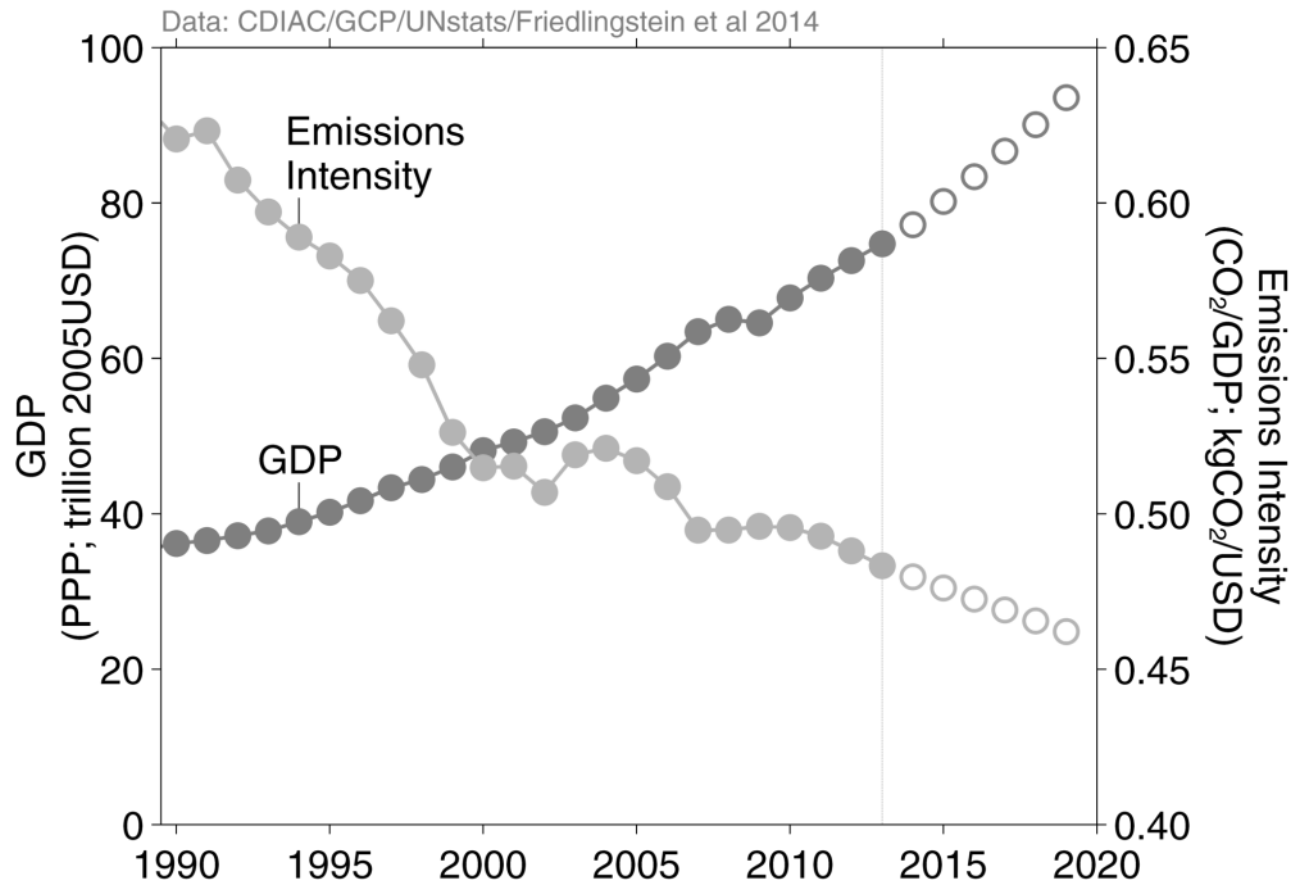


Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend

Source: [CDIAC](#); [Friedlingstein et al 2014](#)

Carbon Intensity of Economic Activity – Global

GDP and carbon intensity trends are relatively stable over time, leading to stable emission growth
 Step changes in emission intensity are required for emission trends to change for a given GDP

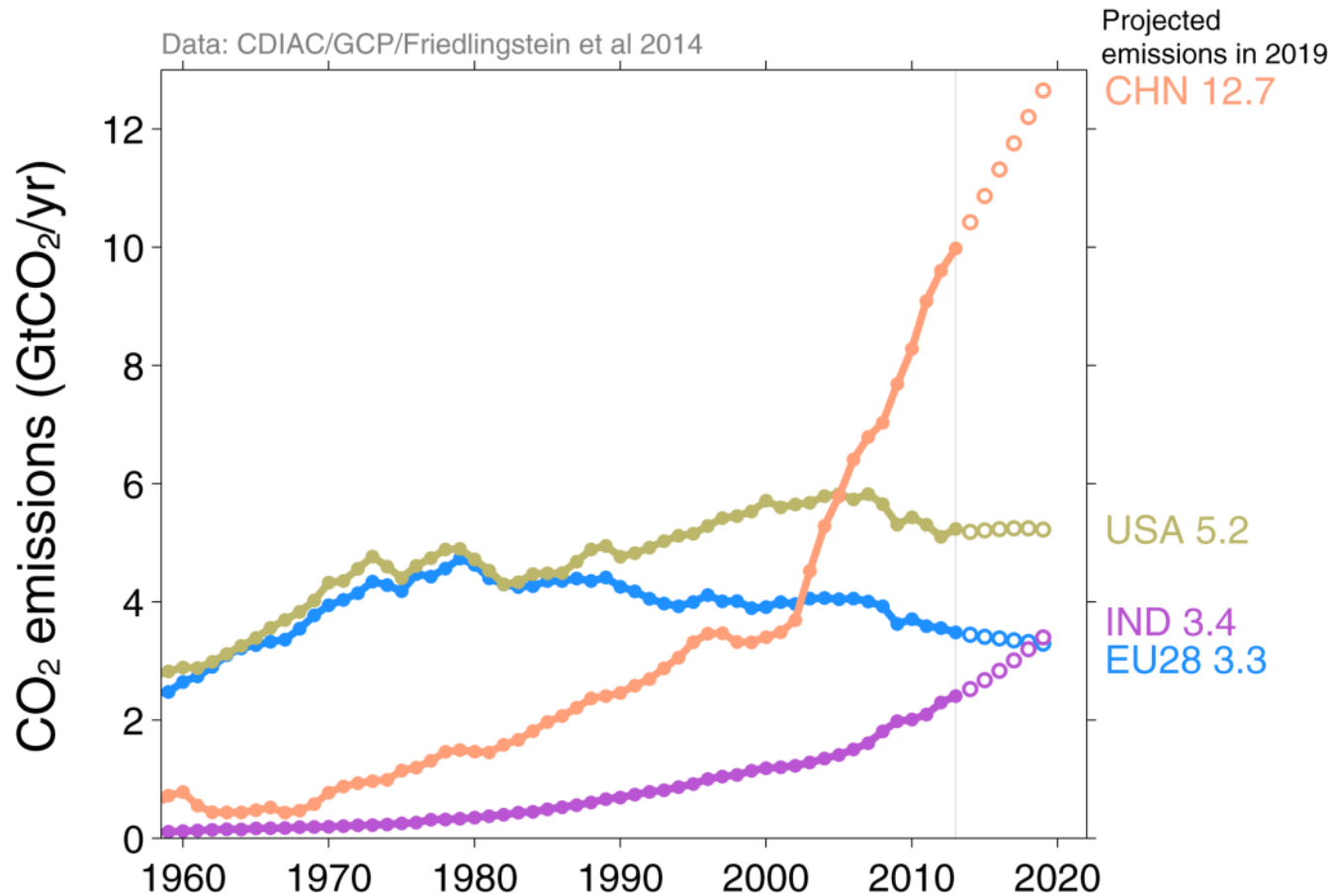


Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend

Source: [CDIAC](#); [Friedlingstein et al 2014](#)

Persistent Growth – Regional

Continued trends suggest that by 2019 China's emissions could exceed the USA, EU28 and India combined, and India could emit more than the EU28

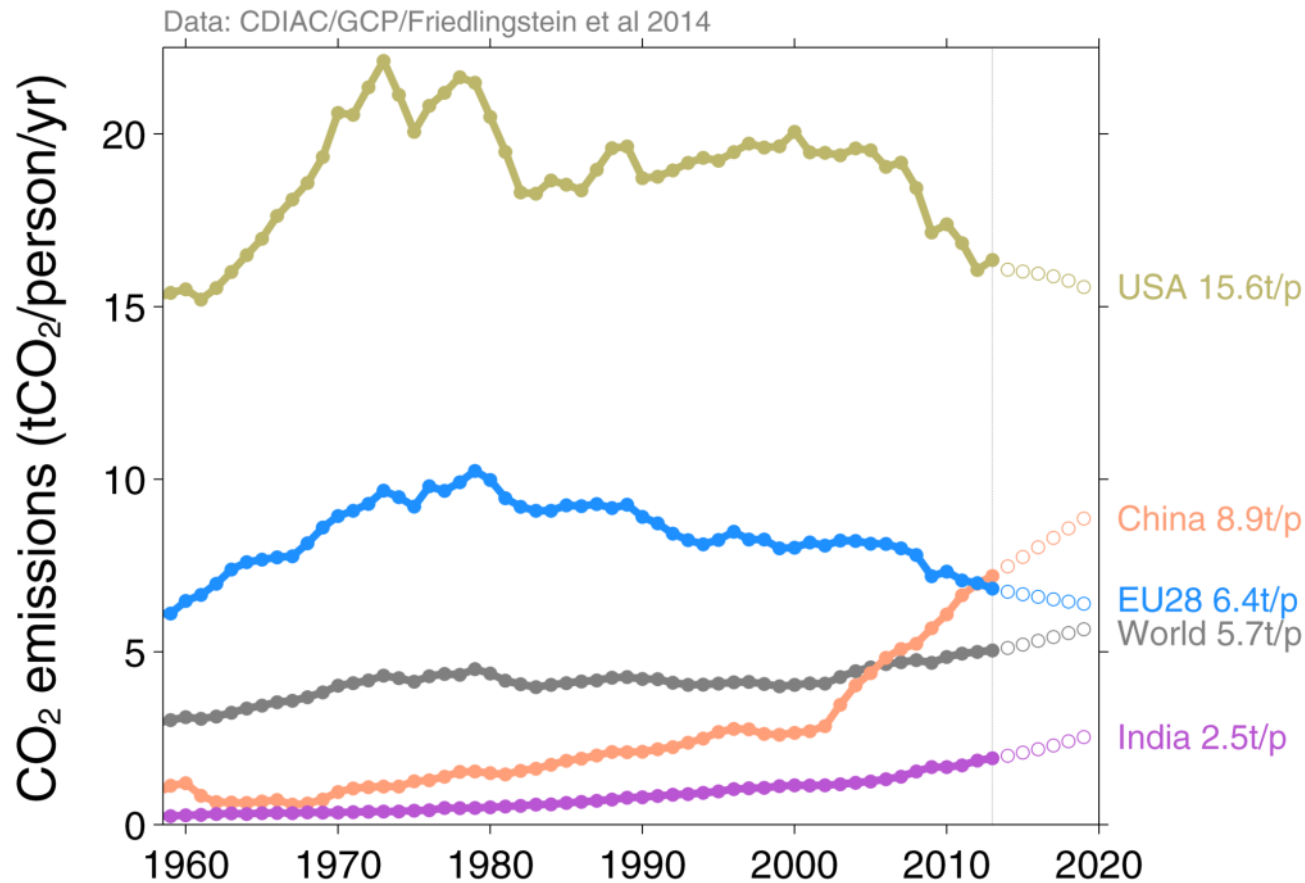


Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend

Source: [CDIAC](#); [Friedlingstein et al 2014](#)

Top Fossil Fuel Emitters (Per Capita)

The divergence between EU28 and Chinese per capita emissions is likely to continue
USA continues with high and India with low per capita emissions

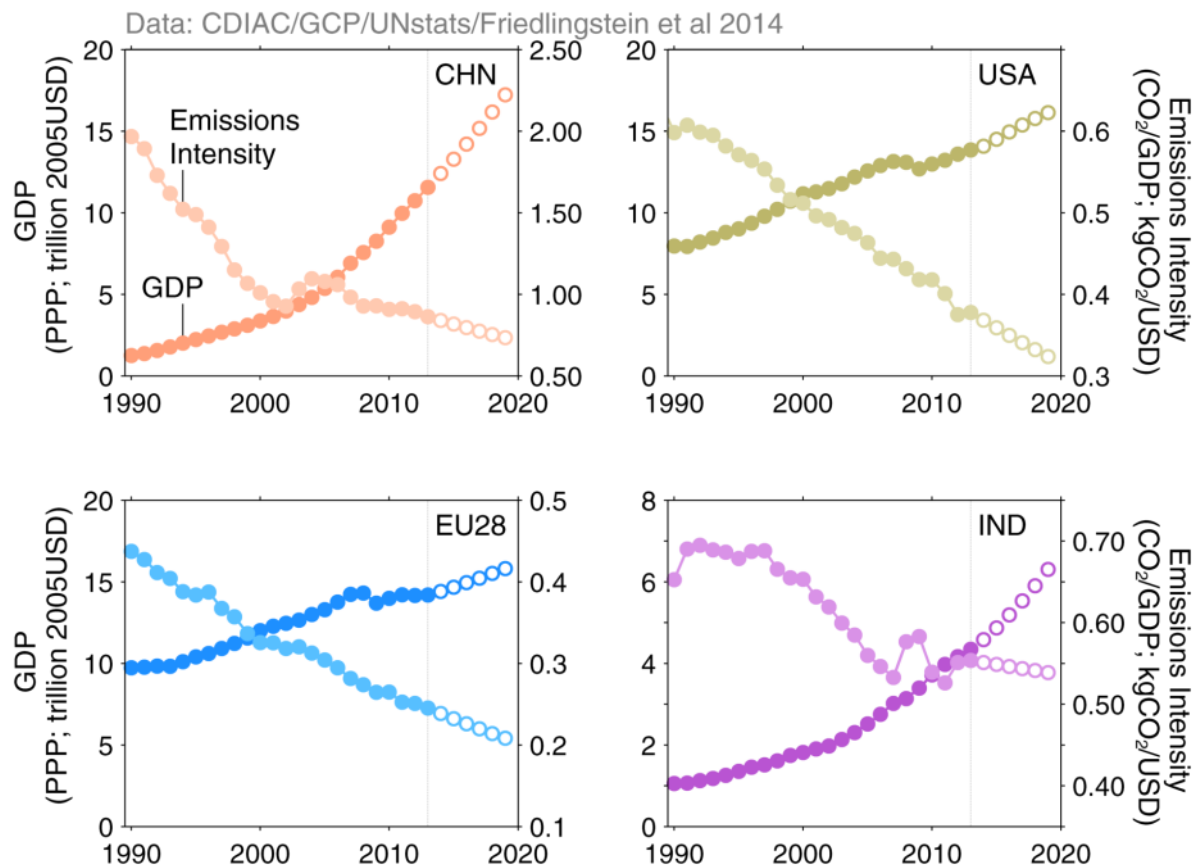


Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend

Source: [CDIAC](#); [Friedlingstein et al 2014](#)

Carbon Intensity of Economic Activity – Regional

GDP in China and India is growing faster than improvements in carbon intensity of GDP, with the opposite in the USA and EU

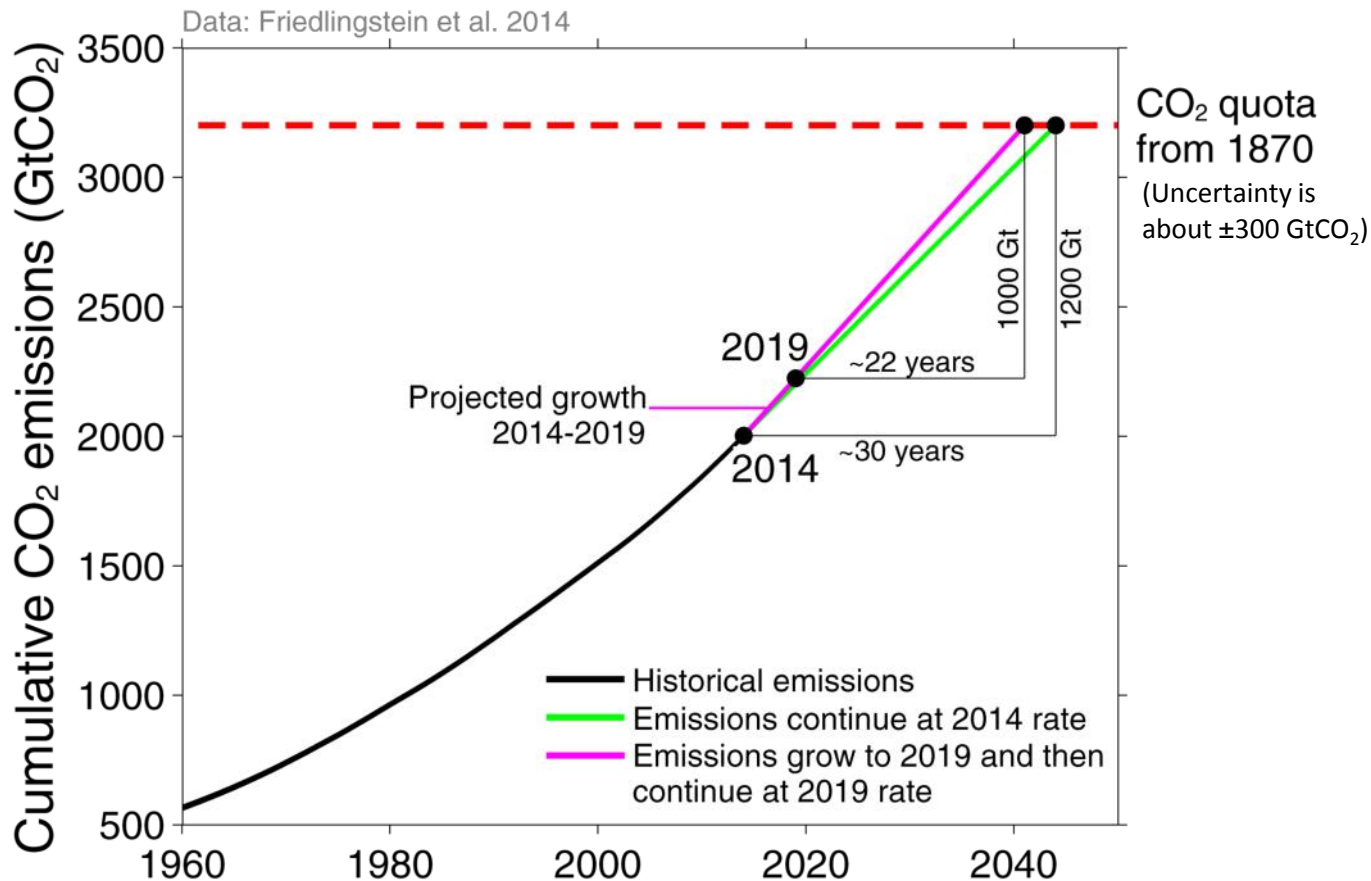


Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend

Source: [CDIAC](#); [Friedlingstein et al 2014](#)

Remaining emissions quota

Cumulative CO₂ emissions should remain below about 3200 Gt for a 66% chance of staying below 2°C
At present emissions rates the remaining budget would be used up in about 30 years



If emissions continue to grow as projected to 2019 and then continue at the 2019 rate, the remaining budget would be used up about 22 years from 2019

Source: [Friedlingstein et al 2014](#)

Sharing the CO₂ emission quota

nature
climate change

PERSPECTIVE

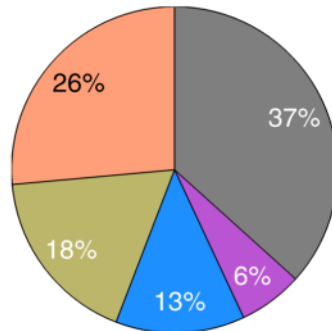
PUBLISHED ONLINE: 21 SEPTEMBER 2014 | DOI: 10.1038/NCLIMATE2384

Sharing a quota on cumulative carbon emissions

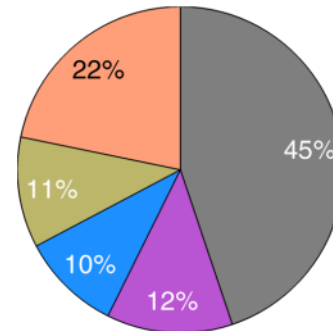
Michael R. Raupach^{1*}, Steven J. Davis², Glen P. Peters³, Robbie M. Andrew³, Josep G. Canadell⁴, Philippe Ciais⁵, Pierre Friedlingstein⁶, Frank Jotzo⁷, Detlef P. van Vuuren^{8,9} and Corinne Le Quéré¹⁰

Sharing the CO₂ emission quota

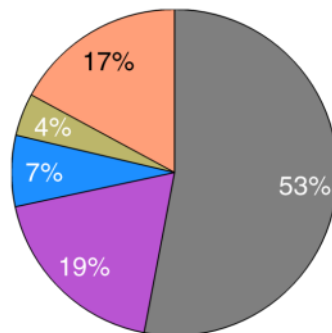
The share of an available CO₂ emission quota allocated to countries
A 'blended' option gives more feasible mitigation rates, without penalising developing regions



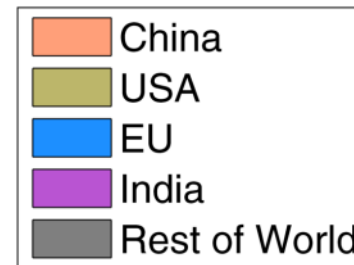
Inertia



Blended



Equity



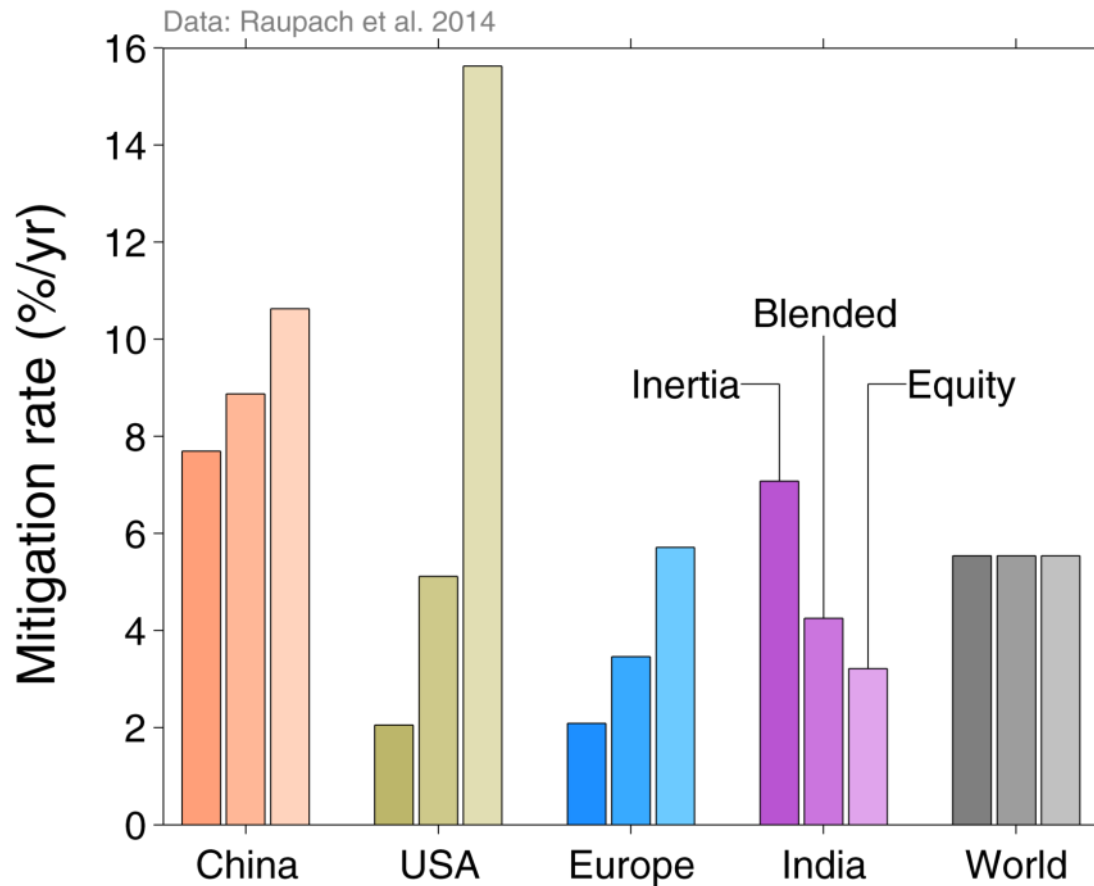
Data: Raupach et al. 2014

Inertia (current emissions), equity (population), blended (50-50 split)
Emissions trading would allow additional sharing of the quota, together with financial transfers

Source: [Raupach et al 2014](#)

Mitigation rates become infeasible under some schemes

The necessary mitigation rates can change significantly for some countries
 'Blended' effort sharing can strike a balance between fairness and feasibility

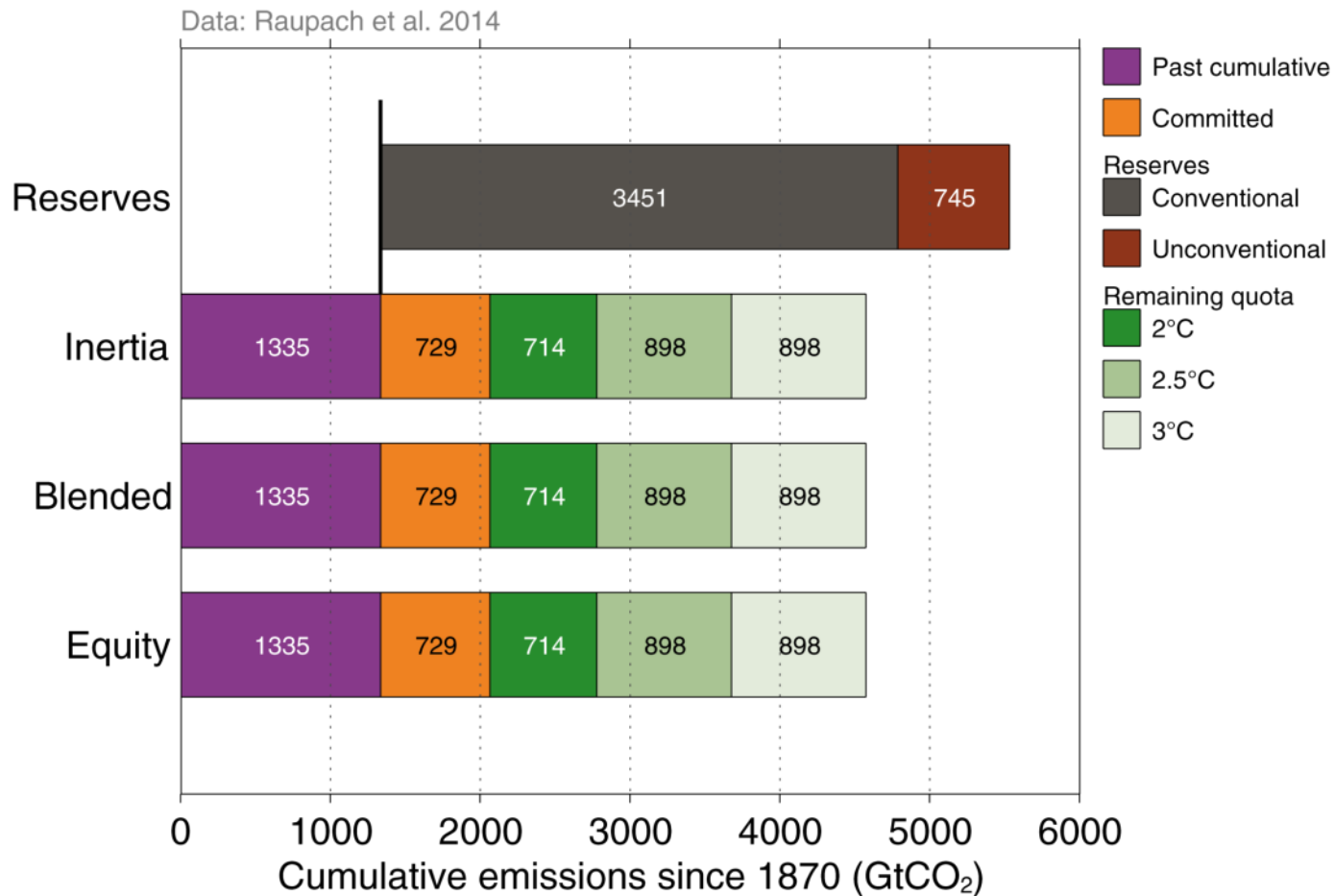


For comparison, the nuclear transitions in some European countries
 led to ~4%/yr reductions for 10-year periods

Source: [Raupach et al 2014](#)

Global Quotas, Committed Emissions, Fossil-Fuel Reserves

To keep temperatures below 2°C requires two-thirds of fossil fuels to remain in the ground*
Committed emissions in existing infrastructure represents 50% of the remaining quota*



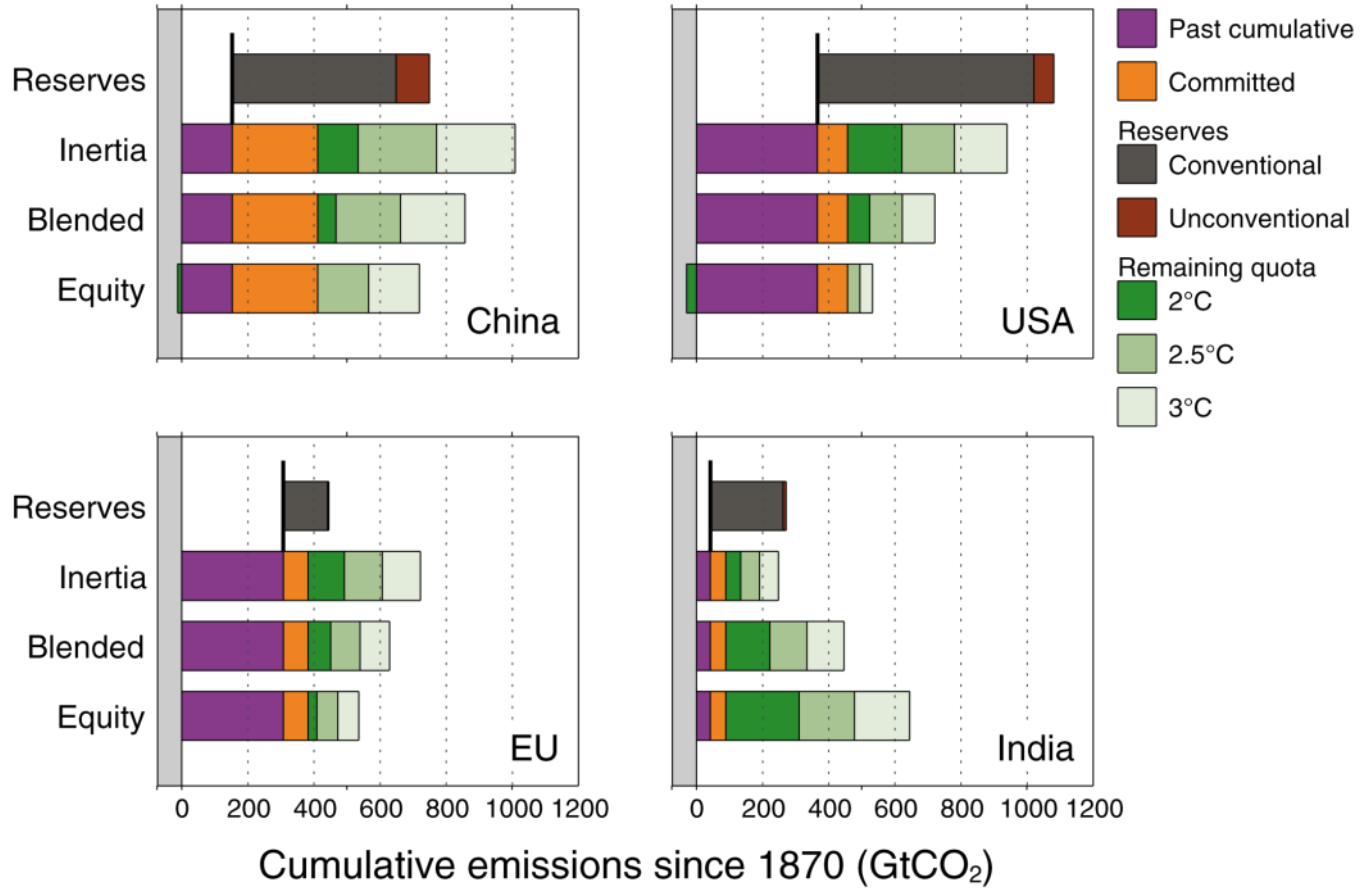
*Assuming a 50% chance to stay below 2°C and no carbon-capture and storage

Source: [Raupach et al 2014](#)

Regional Quotas, Committed Emissions, Fossil-Fuel Reserves

With population-based (equity) sharing & committed emissions, the USA and China have already exceeded their 2°C quotas

Data: Raupach et al. 2014



Trade in fossil fuels redistributes the emissions from fossil-fuel reserves amongst nations

Source: [Raupach et al 2014](#)

Betting on Negative Emissions

opinion & comment

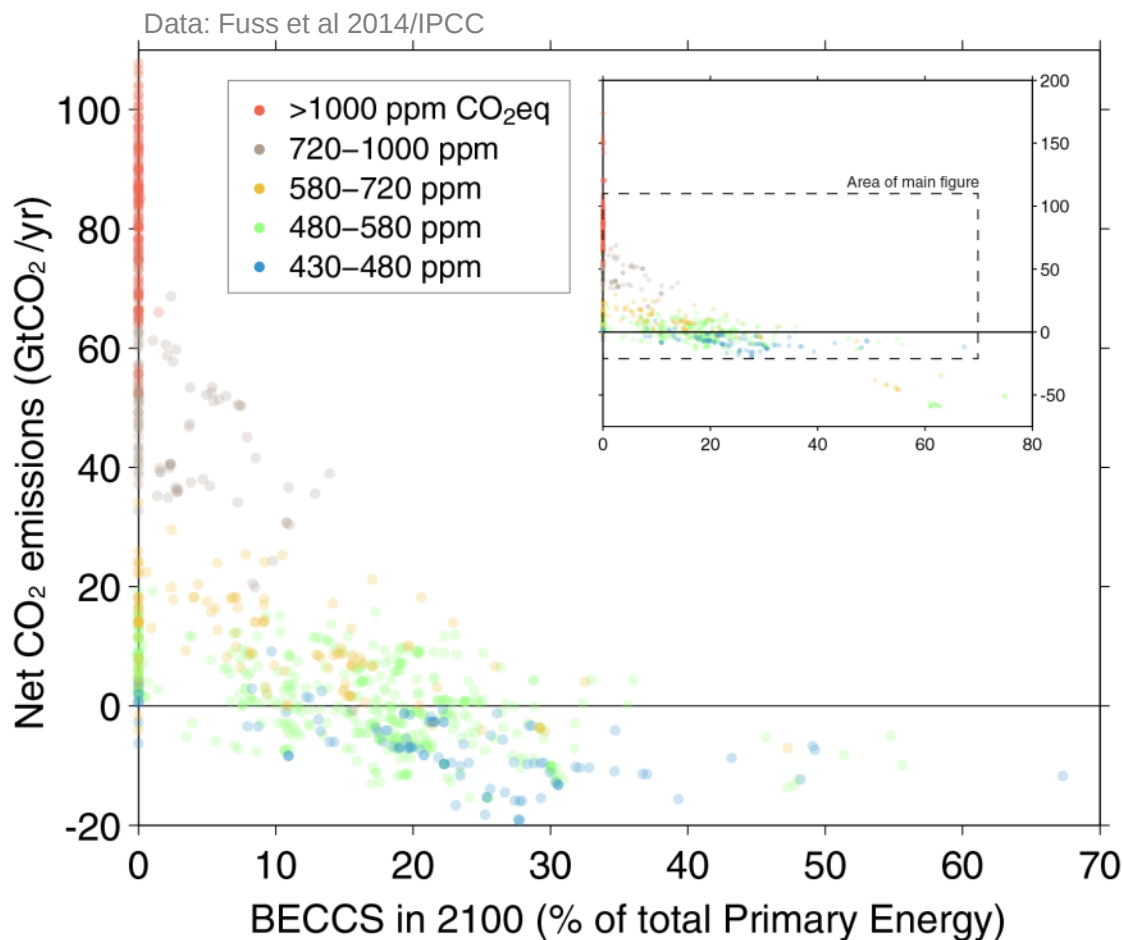
COMMENTARY:

Betting on negative emissions

Sabine Fuss, Josep G. Canadell, Glen P. Peters, Massimo Tavoni, Robbie M. Andrew, Philippe Ciais, Robert B. Jackson, Chris D. Jones, Florian Kraxner, Nebosja Nakicenovic, Corinne Le Quéré, Michael R. Raupach, Ayyoob Sharifi, Pete Smith and Yoshiki Yamagata

BECCS is necessary, but not sufficient for 2°C

BECCS is used in over half of scenarios, but ~40% have net positive emissions in 2100
 ~90% of 2°C and ~35% of other mitigation scenarios have net negative emissions in 2100

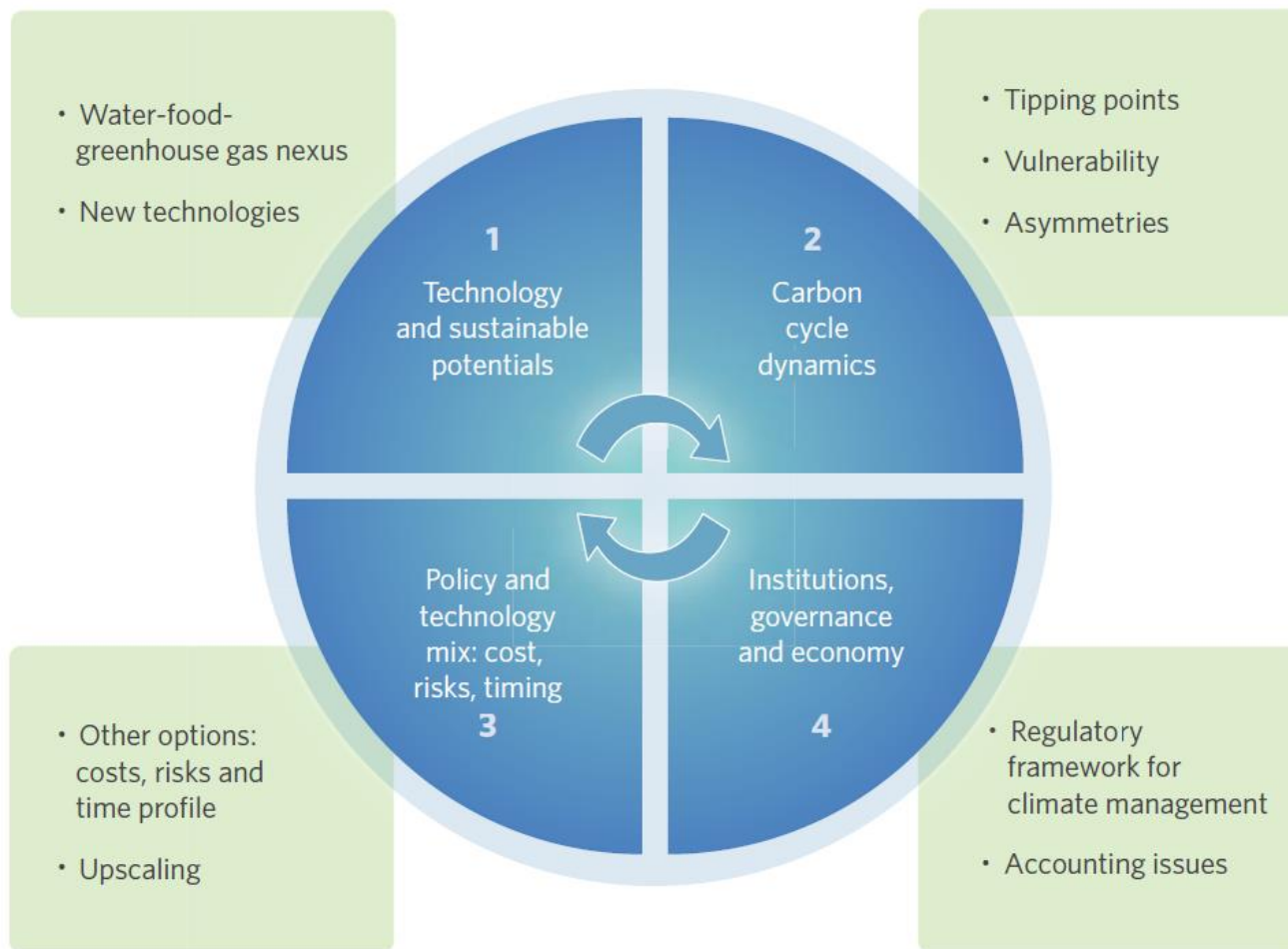


BECCS = Bioenergy with Carbon Capture and Storage; Scenarios from IPCC Fifth Assessment Report

Source: [Fuss et al 2014](#)

Four components of consistent negative emissions narratives

The viability of BECCS as a climate change mitigation option is unproven and its widespread use in climate stabilization scenarios might become a dangerous distraction

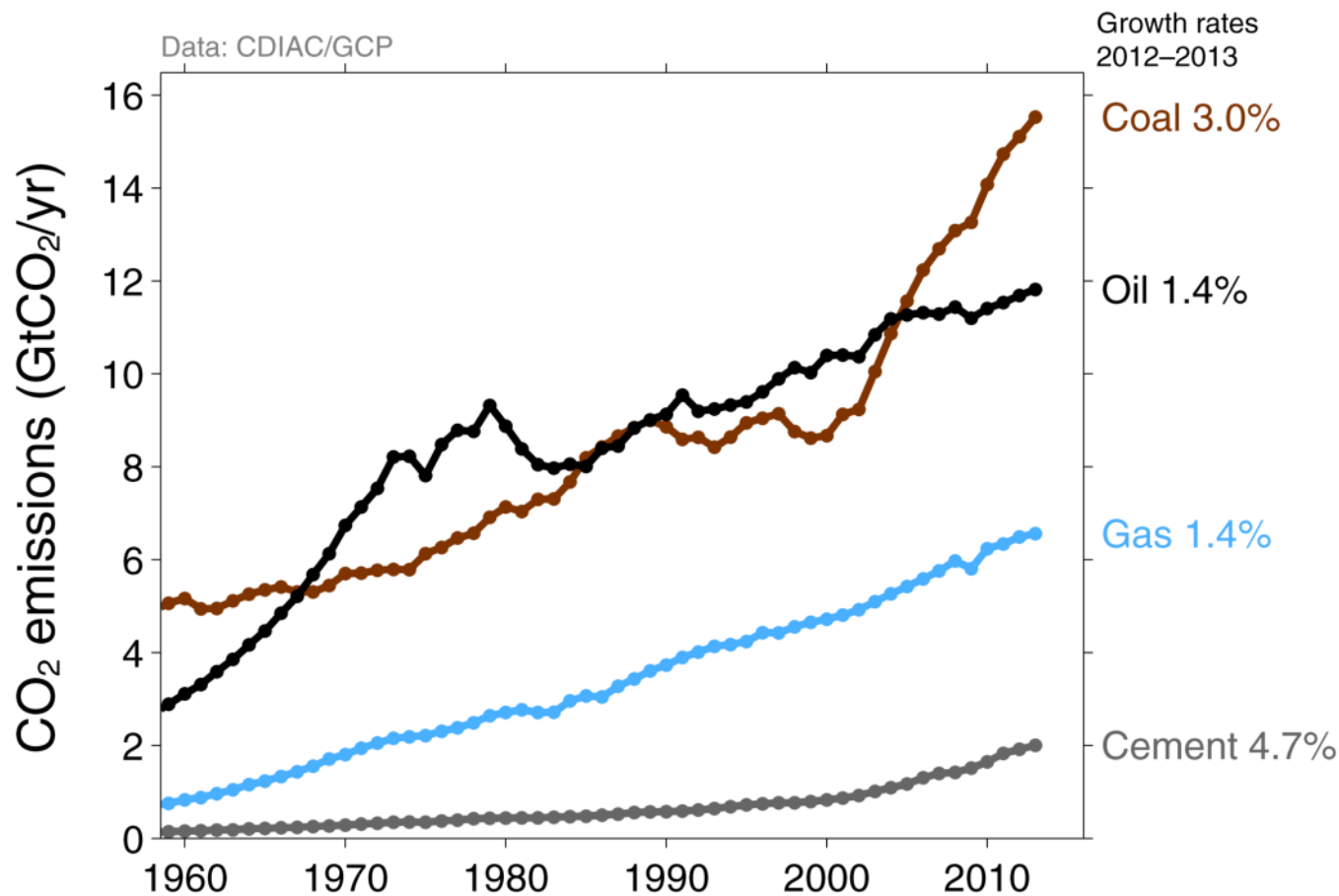


Supplementary Budget Slides

Fossil Fuel and Cement Emissions

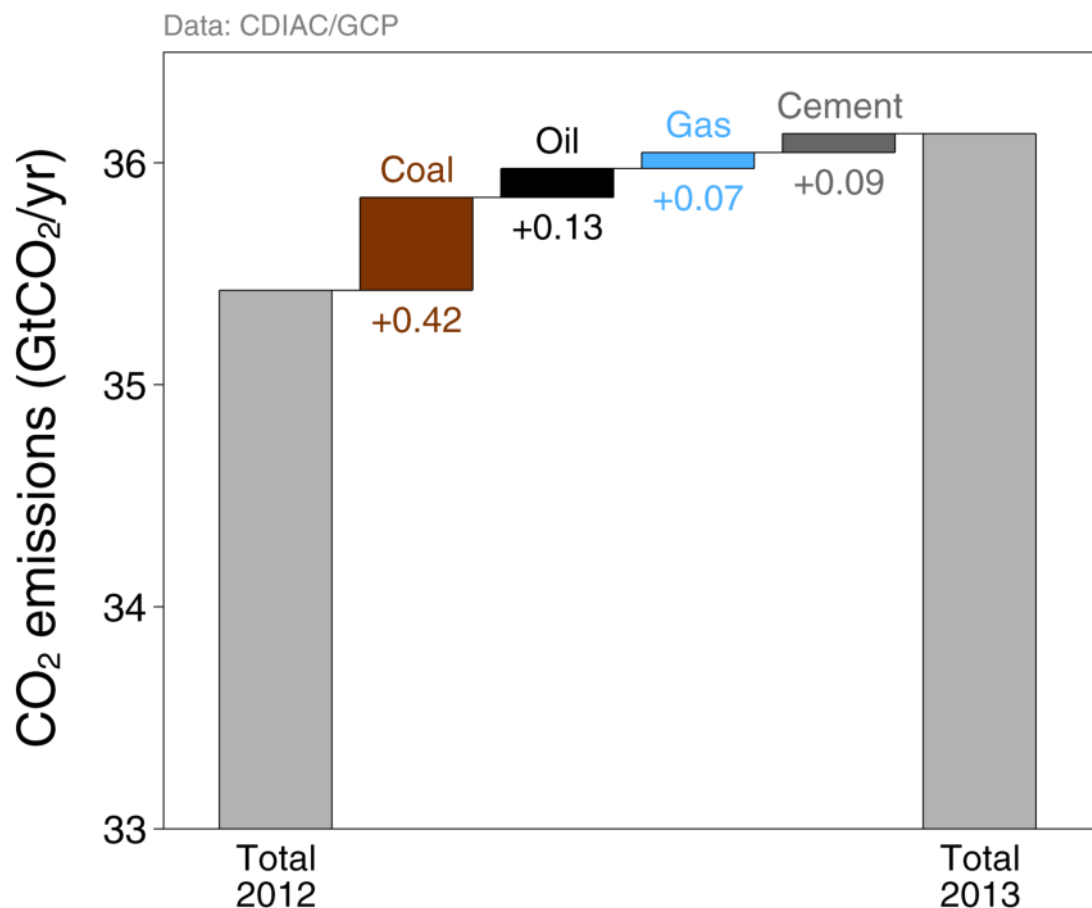
Emissions from Coal, Oil, Gas, Cement

Share of global emissions in 2013:
coal (43%), oil (33%), gas (18%), cement (6%), flaring (1%, not shown)



Fossil Fuel and Cement Emissions Growth

Coal accounted for 59% of the growth in global emissions in 2013, oil 18%, gas 10%, and cement 12%.



Fossil Fuel and Cement Emissions Growth

Much of the growth in emissions in 2013 was in China, the USA, and India, while Europe's emissions declined

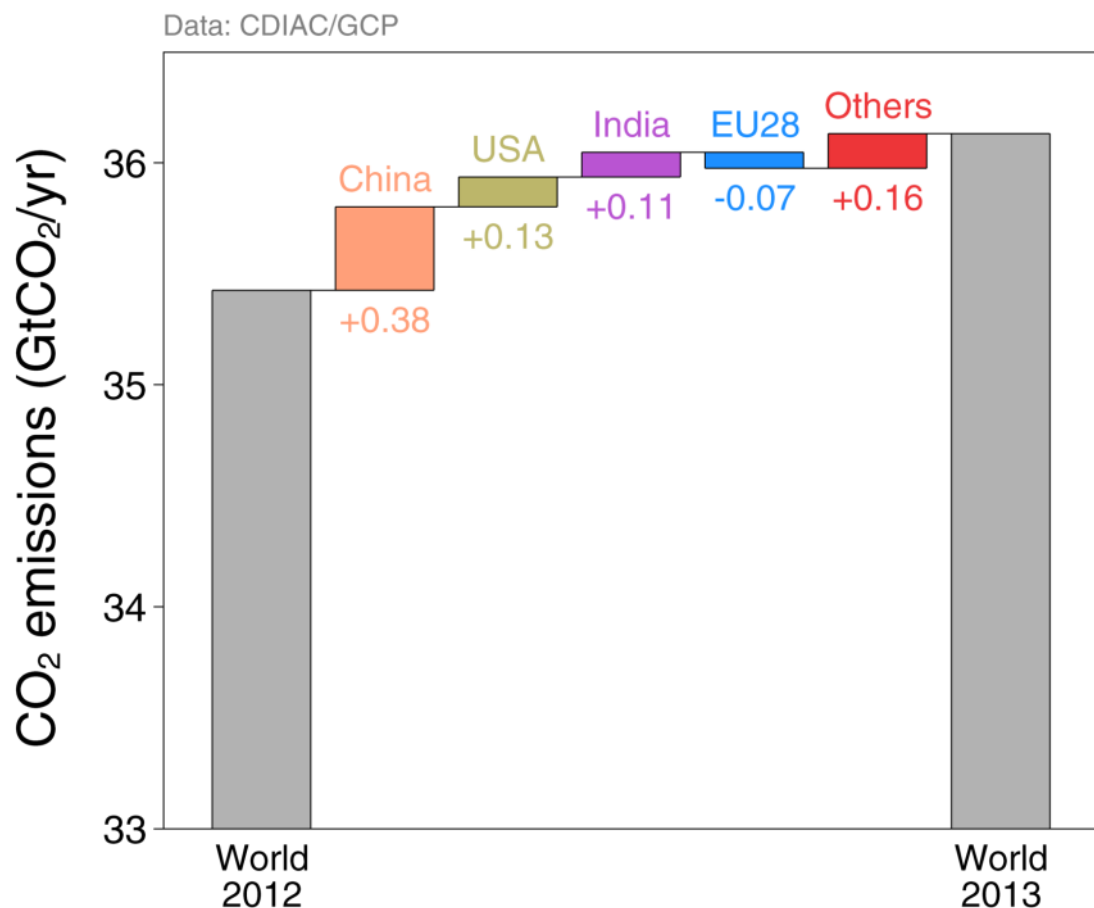
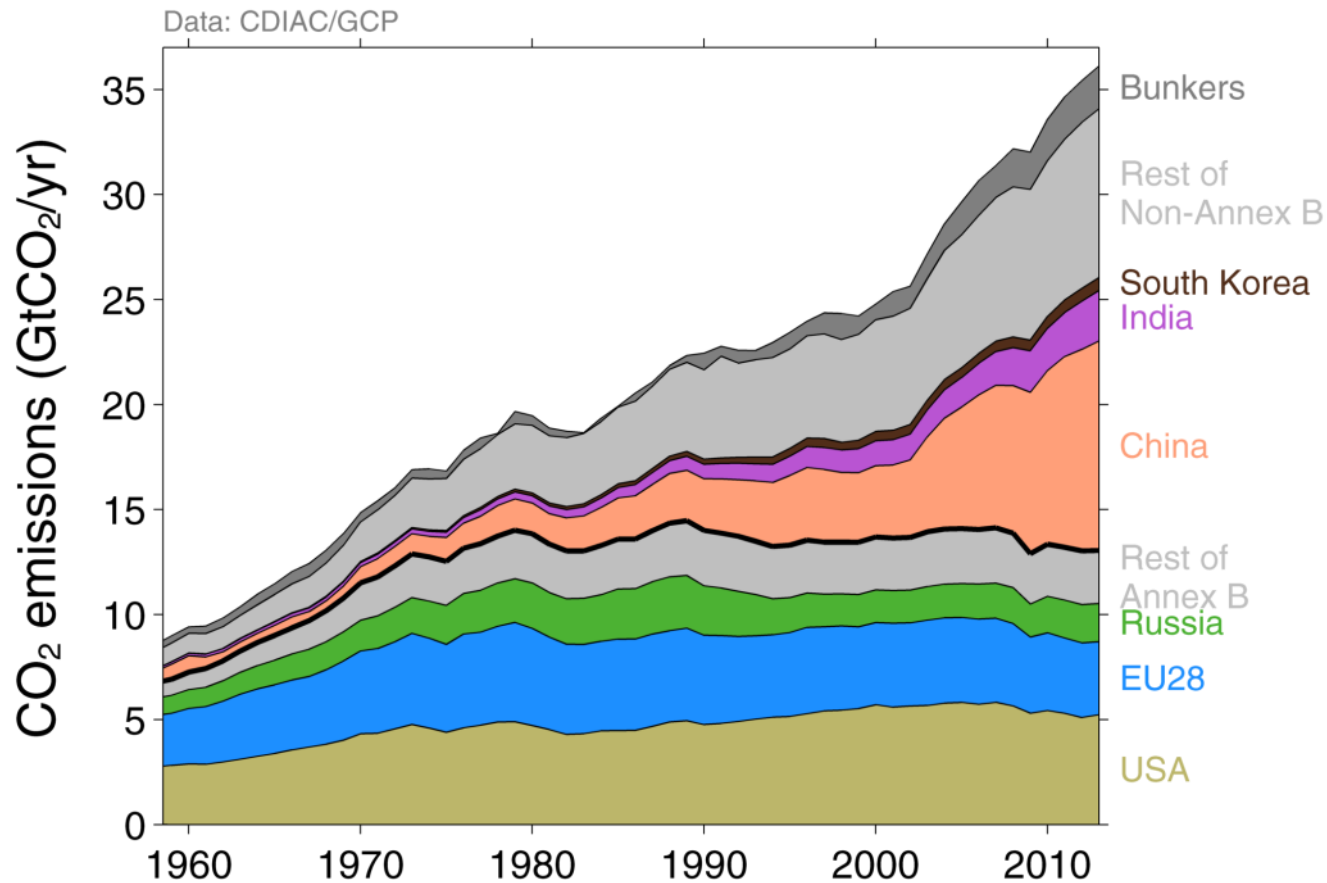


Figure shows the top four countries contributing to emissions changes in 2013

Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

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

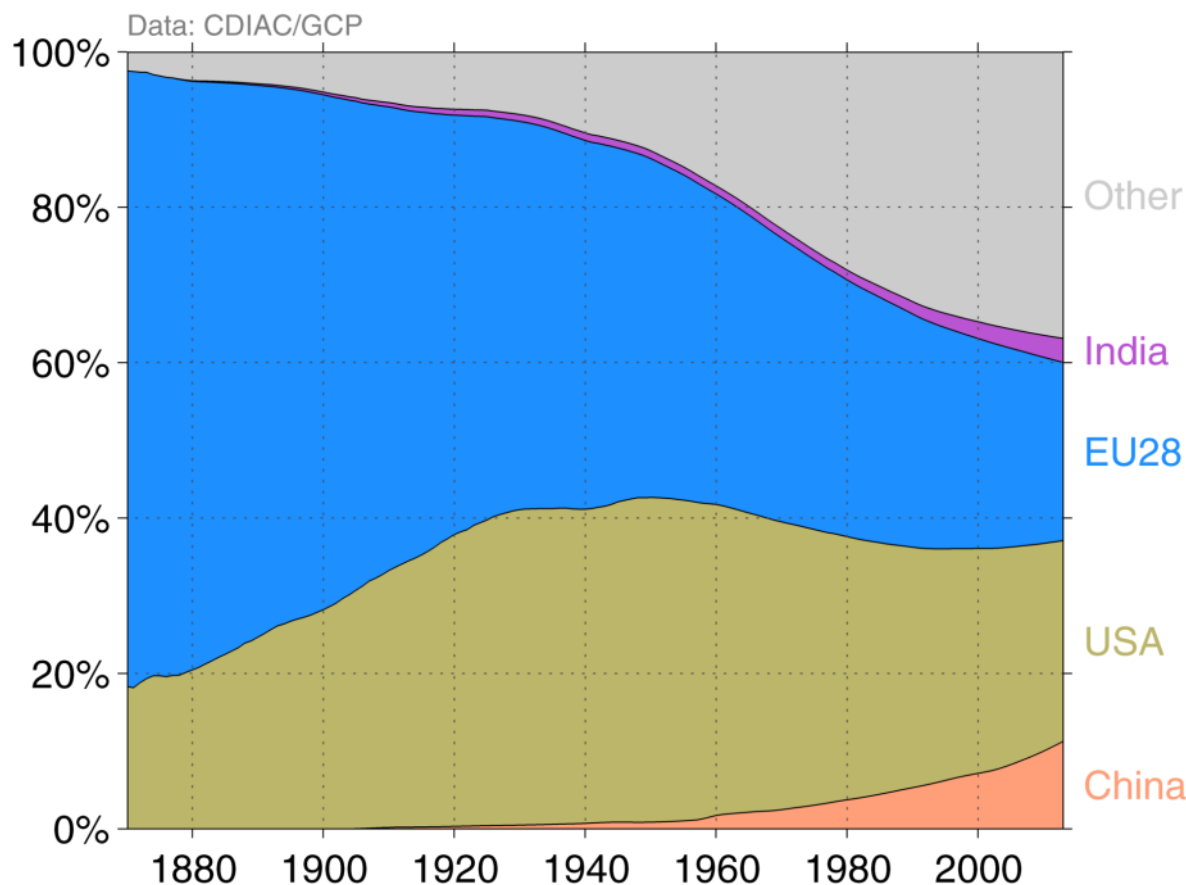


Annex B countries have emission commitments in the Kyoto Protocol (excluding Canada and USA)

Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Historical Cumulative Emissions by Country

Cumulative emissions from fossil-fuel and cement were distributed (1870–2013):
USA (26%), EU28 (23%), China (11%), and India (3%) covering 63% of the total share



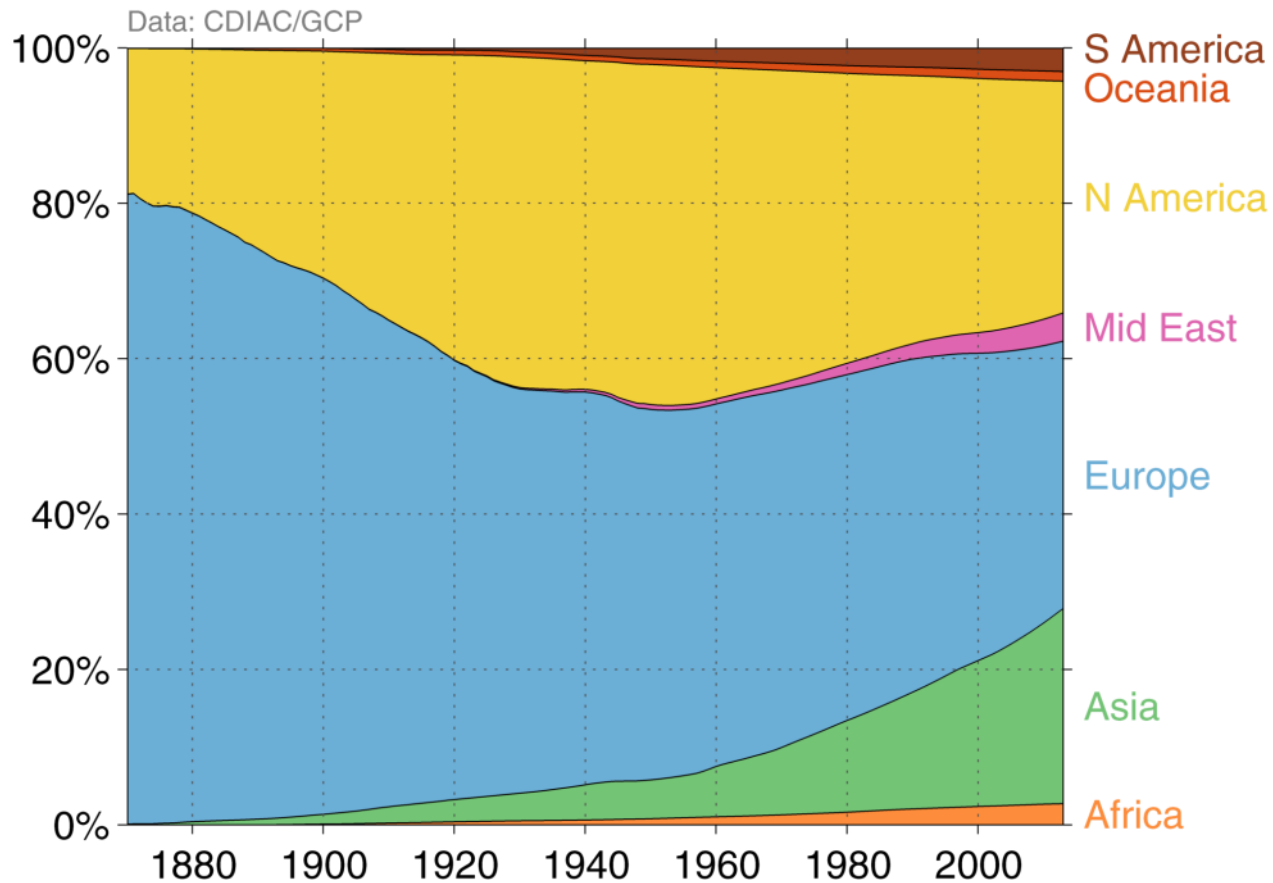
Cumulative emissions (1990–2013) were distributed USA (20%), China (20%), EU28 (14%), India (5%)
'Other' includes all other countries along with bunker fuels and statistical differences

Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Historical Cumulative Emissions by Region

Cumulative emissions from fossil-fuel and cement (1870–2013)

North America and Europe responsible for most cumulative emissions, but Asia growing fast

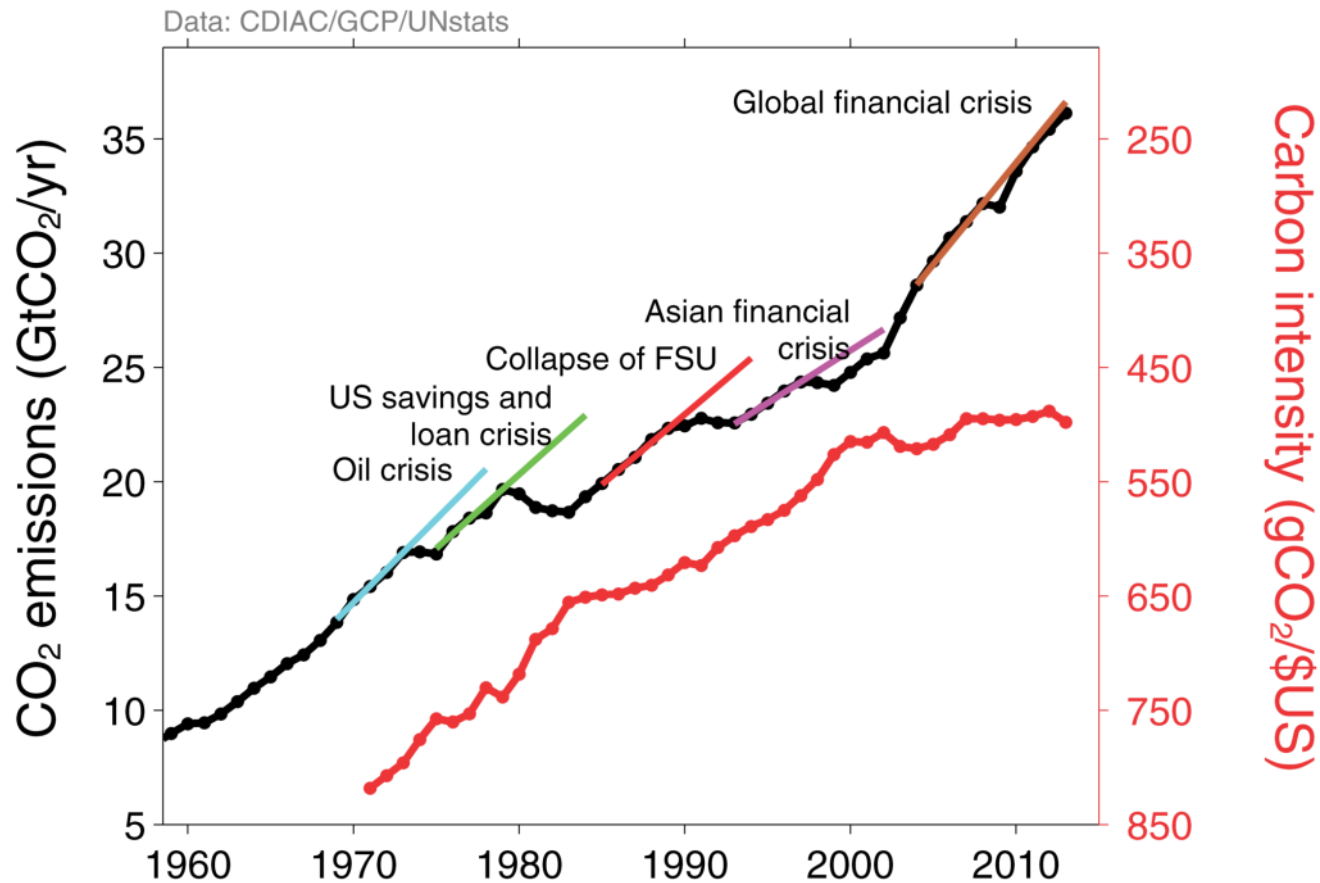


The figure excludes bunker fuels and statistical differences

Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

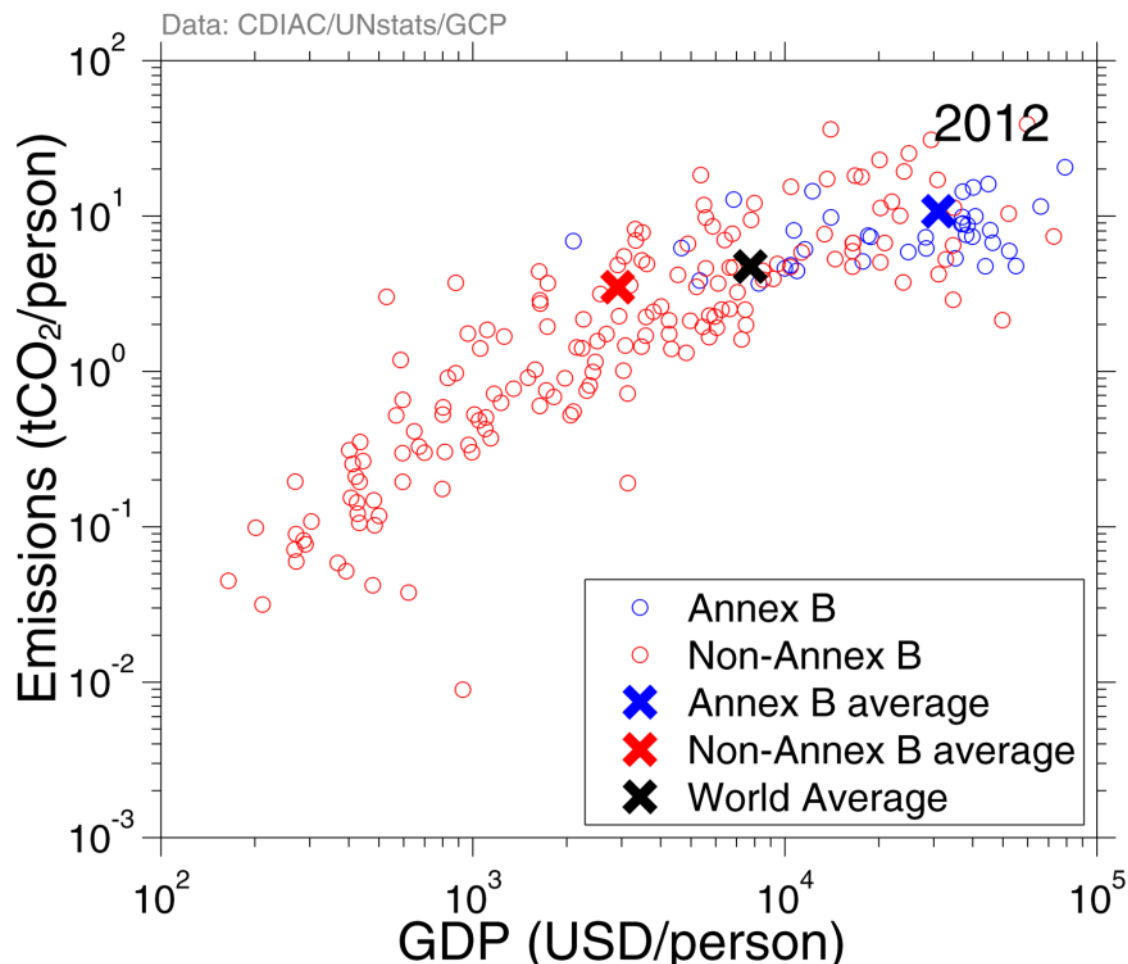
Carbon Intensity of Economic Activity – Global

Financial crises have little lasting effect on emissions
Carbon intensity has had minimal improvements since 2000



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 in Market Exchange Rates

Source: [United Nations](#); [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Key Statistics

Emissions 2013

Region/Country	Per capita	Total		Growth 2012-13	
	tCO ₂ per person	GtCO ₂	%	GtCO ₂	%
Global (with bunkers)	5.0	36.13	100	0.706	0.0
Developed Countries (Annex B)					
Annex B	7.5	13.05	36.1	0.019	0.4
USA	16.4	5.23	14.5	0.134	2.9
EU28	6.8	3.48	9.6	-0.073	-1.8
Russia	12.7	1.81	5.0	-0.016	-0.6
Japan	9.8	1.25	3.4	-0.009	-0.4
Canada	14.3	0.50	1.4	0.003	1.0
Developing Countries (Non-Annex B)					
Non-Annex B	3.5	21.04	58.2	0.637	3.4
China	7.2	9.98	27.6	0.376	4.2
India	1.9	2.41	6.7	0.111	5.1
South Korea	12.5	0.62	1.7	0.009	1.7
Iran	7.9	0.61	1.7	0.013	2.4
Saudi Arabia	18.0	0.52	1.4	0.014	3.0
International Bunkers					
Aviation and Shipping	-	2.04	5.6	0.050	2.5

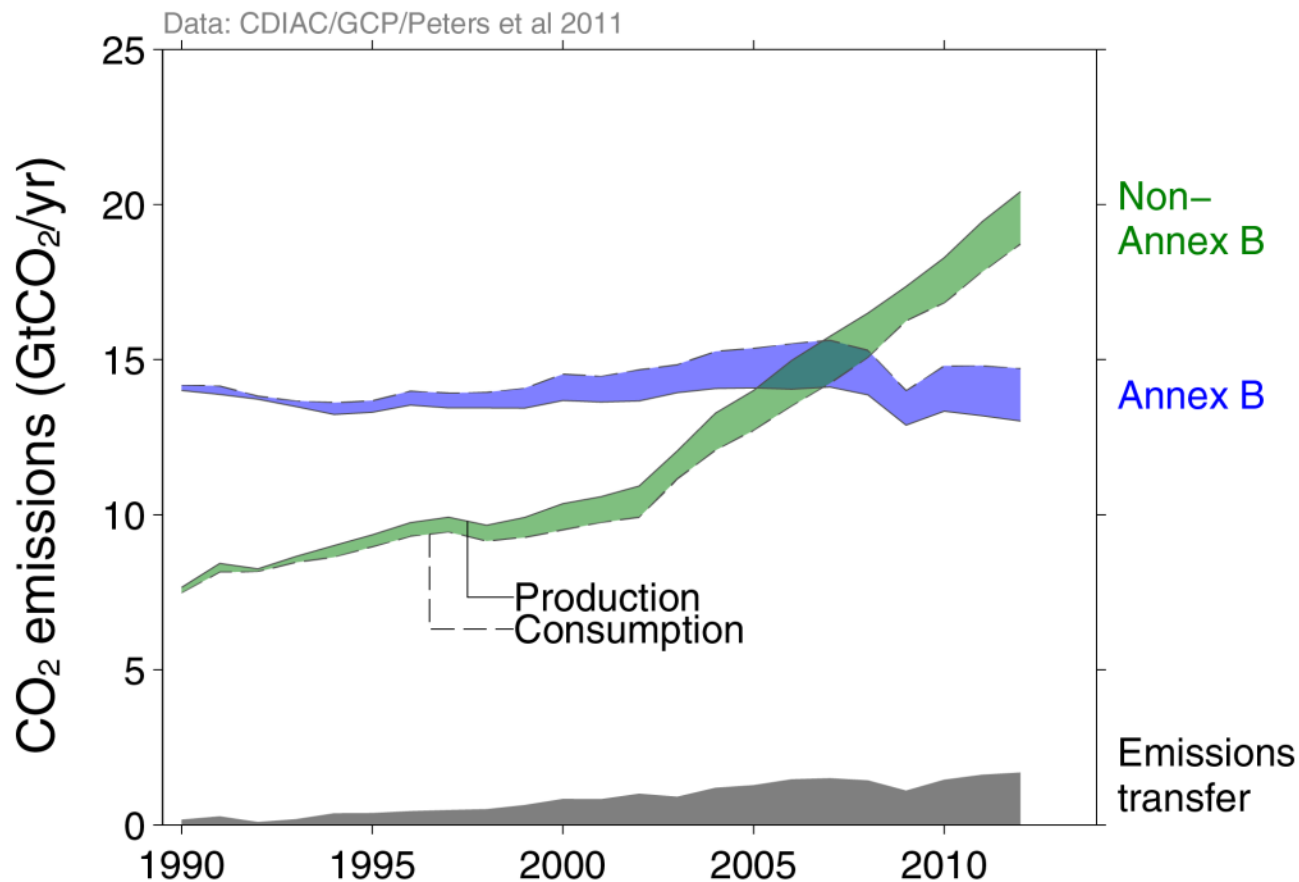
Consumption-based Emissions

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

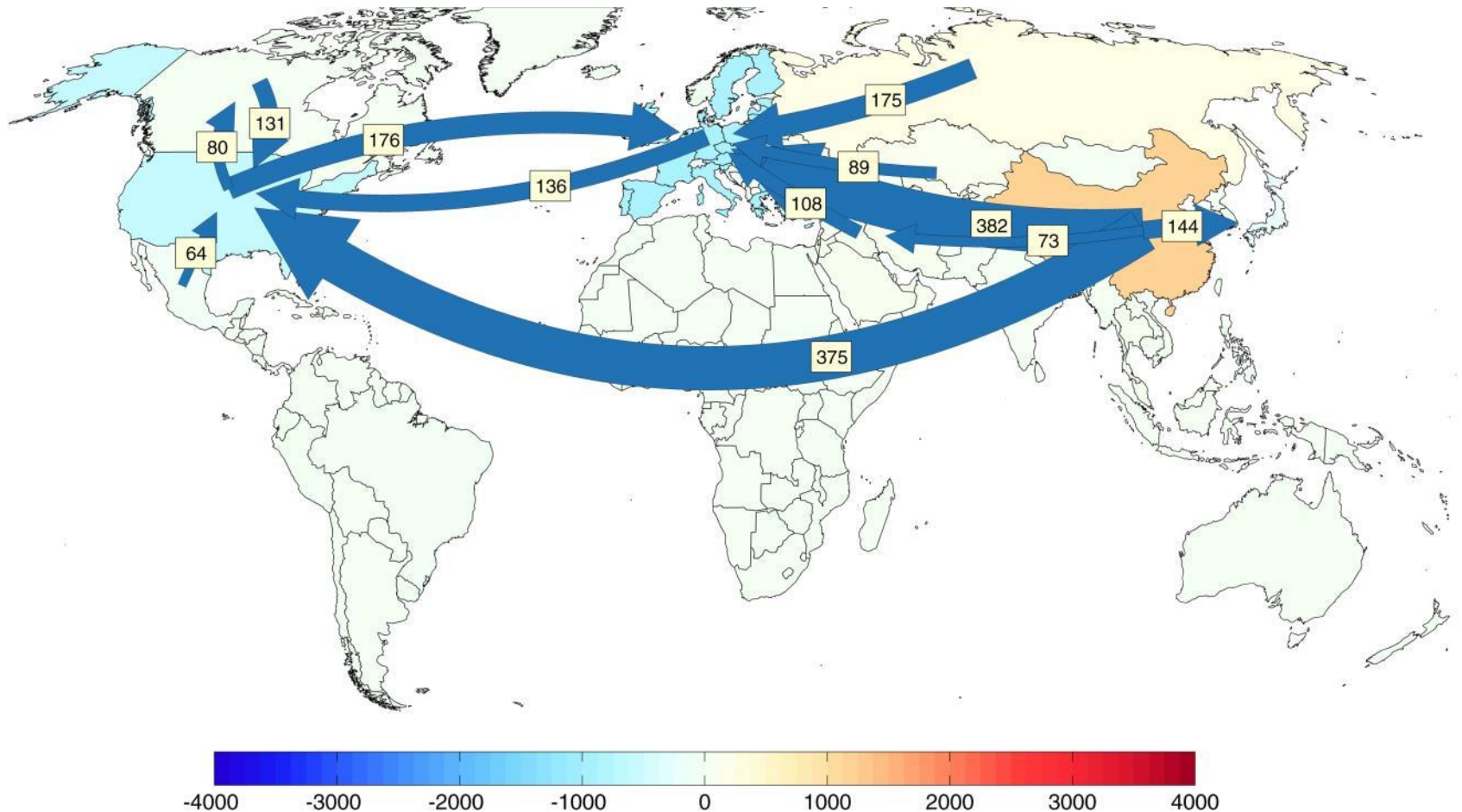


In Annex B, production-based emissions have had a slight decrease while consumption-based emissions have grown at 0.5% per year, and emission transfers have grown at 11% per year

Source: [CDIAC](#); [Peters et al 2011](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Major Flows from Production to Consumption

Start of Arrow: fossil-fuel combustion
End of arrow: goods and services consumption

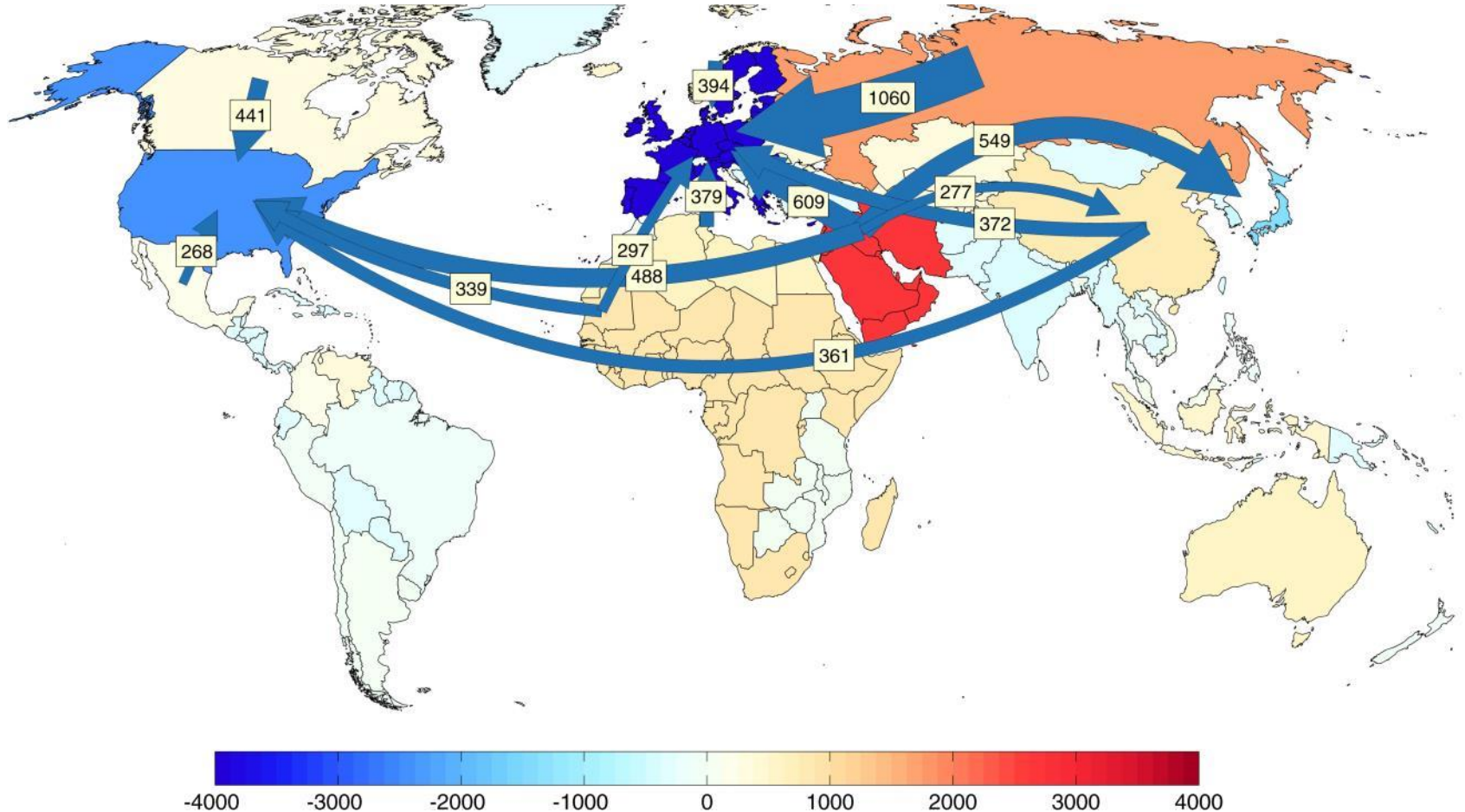


Values for 2007. EU is treated as one region. Units: MtCO₂

Source: [Peters et al 2012](#)

Major Flows from Extraction to Consumption

Start of Arrow: fossil-fuel extraction
End of arrow: goods and services consumption



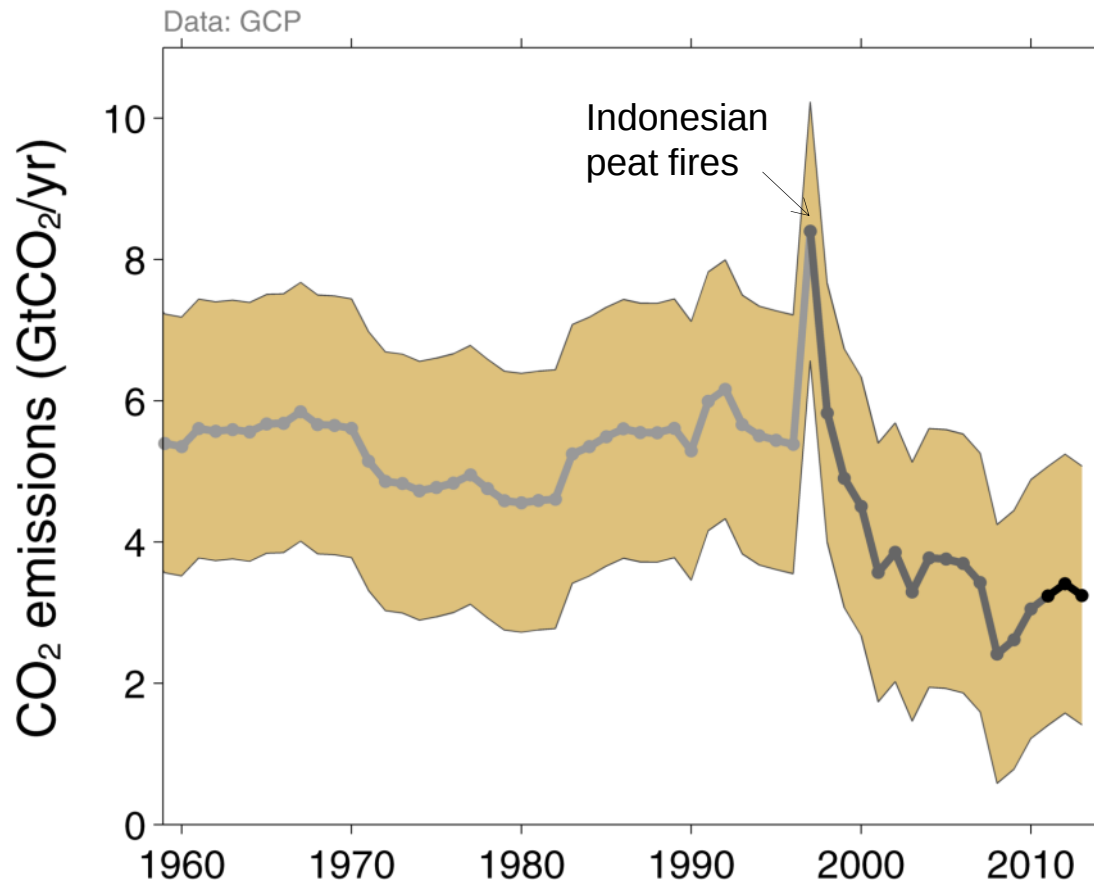
Values for 2007. EU is treated as one region. Units: MtCO₂

Source: [Andrew et al 2013](#)

Land-Use Change Emissions

Land-Use Change Emissions

Global land-use change emissions are estimated 3.3 ± 1.8 GtCO₂/yr during 2004–2013
The data suggests a general decrease in emissions since 1990

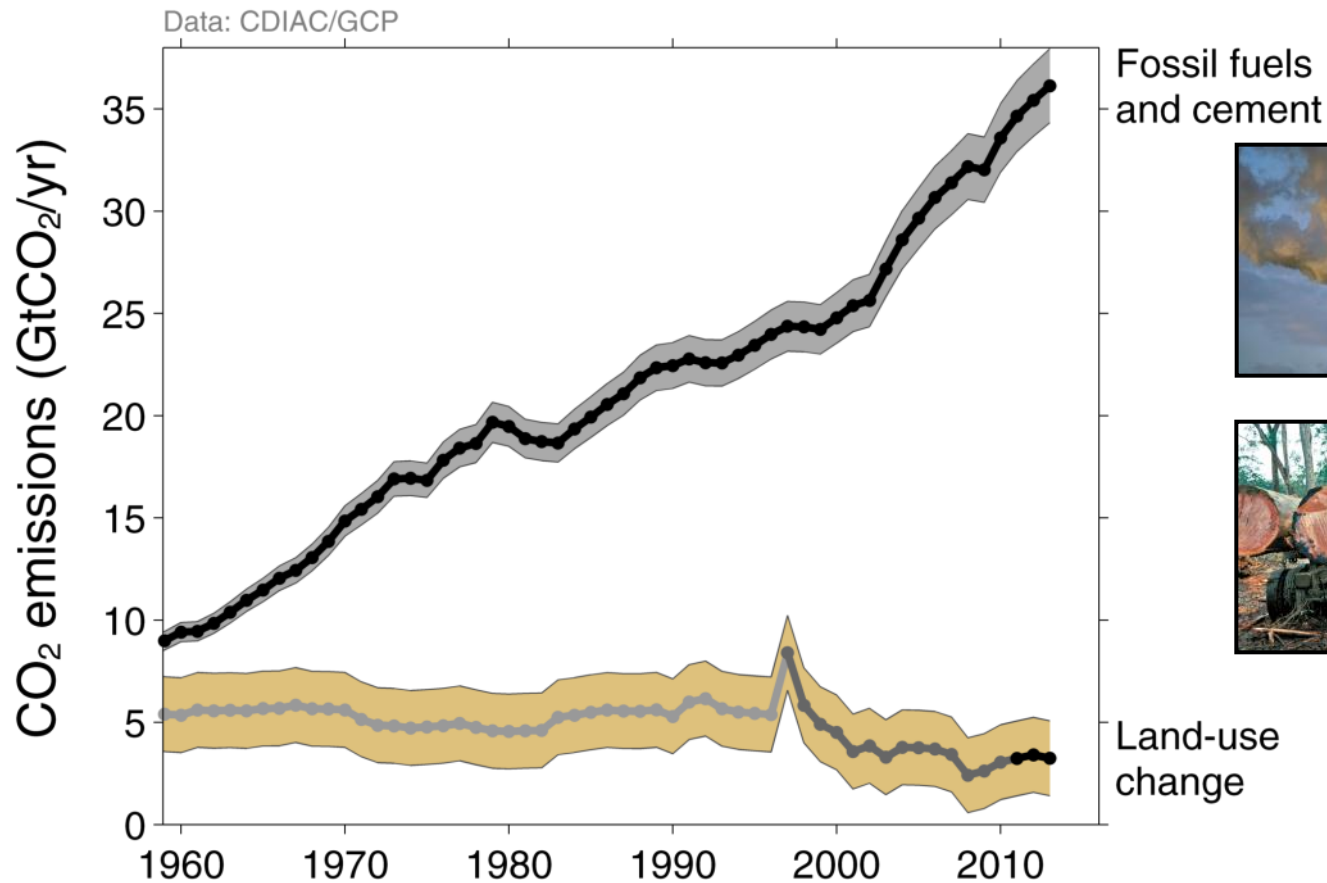


Three different estimation methods have been used, indicated here by different shades of grey
Land-use change also emits CH₄ and N₂O which are not shown here

Source: [Houghton et al 2012](#); [Giglio et al 2013](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Total Global Emissions

Total global emissions: 39.4 ± 3.4 GtCO₂ in 2013, 42% over 1990
 Percentage land-use change: 36% in 1960, 19% in 1990, 8% in 2013

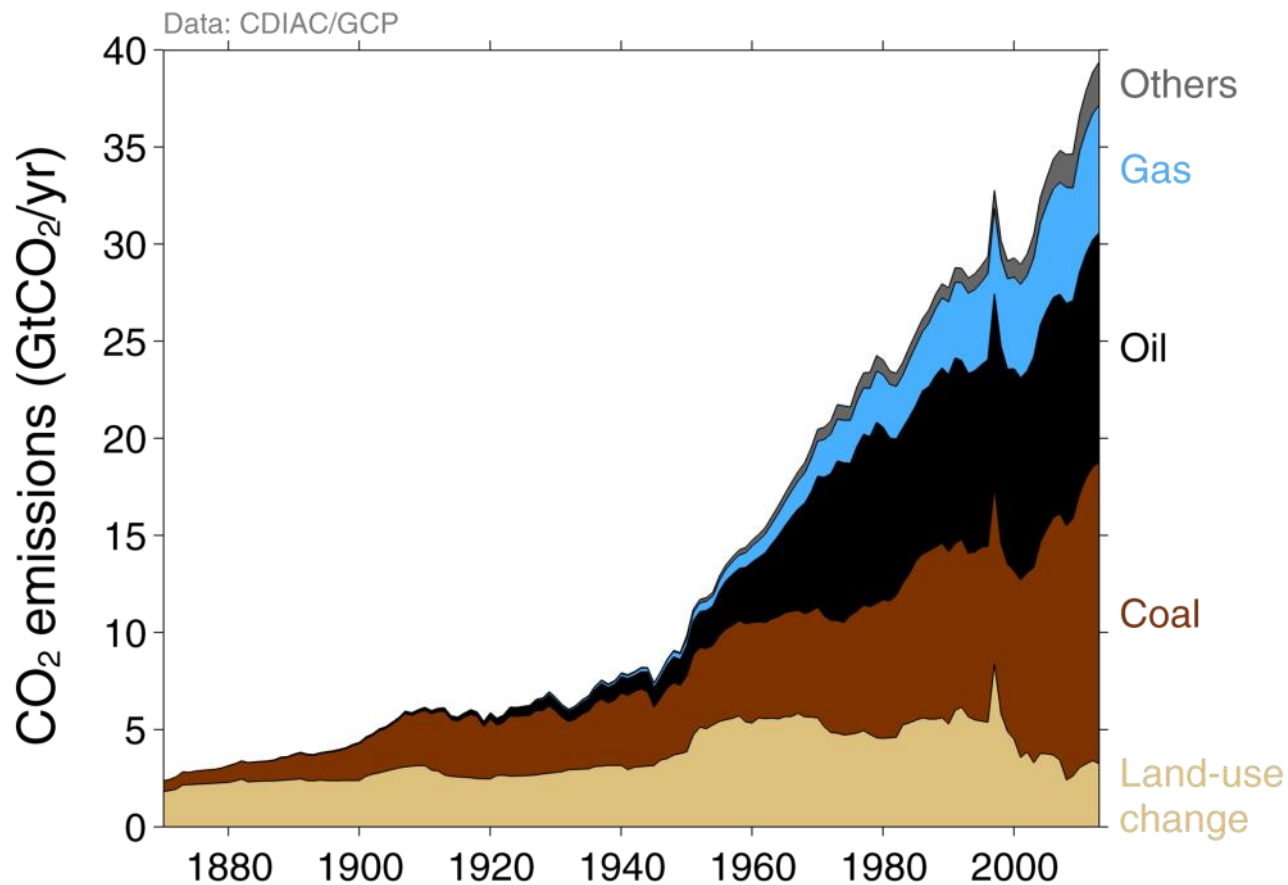


Three different methods have been used to estimate land-use change emissions, indicated here by different shades of grey

Source: [CDIAC](#); [Houghton et al 2012](#); [Giglio et al 2013](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Total Global Emissions by Source

Land-use change was the dominant source of annual CO₂ emissions until around 1950
Coal consumption continues to grow strongly

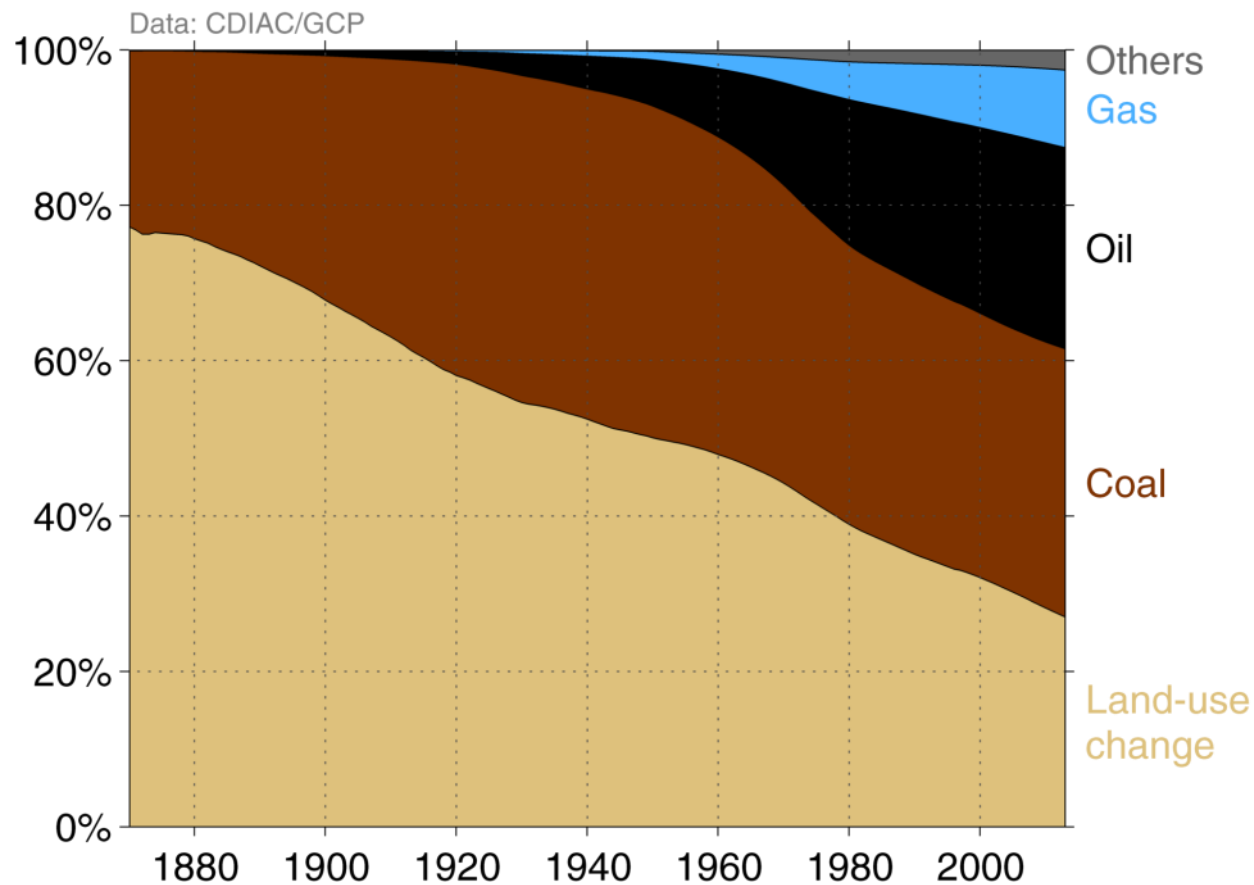


Others: Emissions from cement production and gas flaring

Source: [CDIAC](#); [Houghton et al 2012](#); [Giglio et al 2013](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Historical Cumulative Emissions by Source

Despite reductions in land-use change, it represents about 27% of cumulative emissions in 2013
Coal represents about 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 2014](#); [Global Carbon Budget 2014](#)

Closing the Carbon Budget

Fate of Anthropogenic CO₂ Emissions (2004-2013 average)

32.4 ± 1.6 GtCO₂/yr 91%



3.3 ± 1.8 GtCO₂/yr 9%



15.8 ± 0.4 GtCO₂/yr 44%



10.6 ± 2.9 GtCO₂/yr 29%



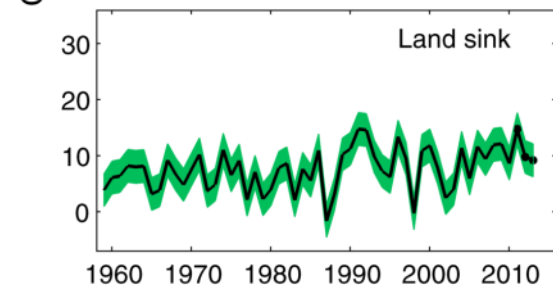
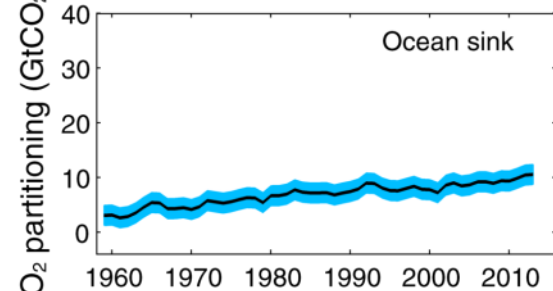
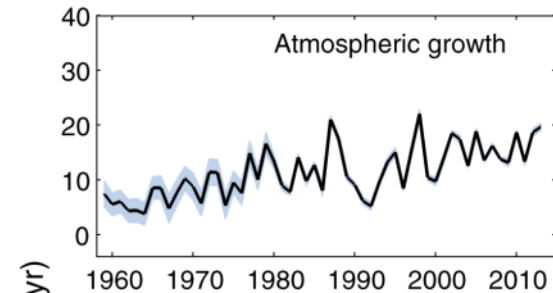
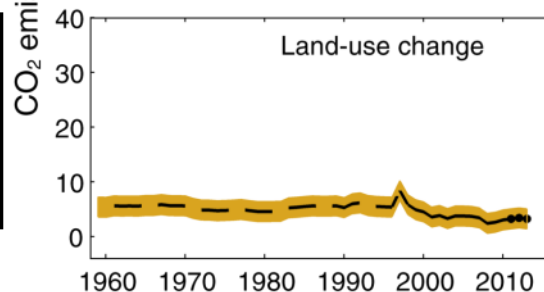
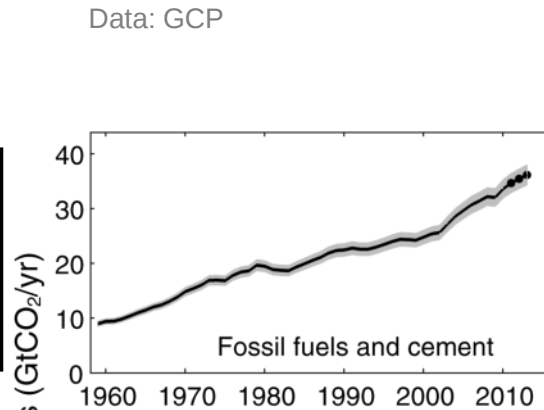
Calculated as the residual
of all other flux components

9.4 ± 1.8 GtCO₂/yr 26%



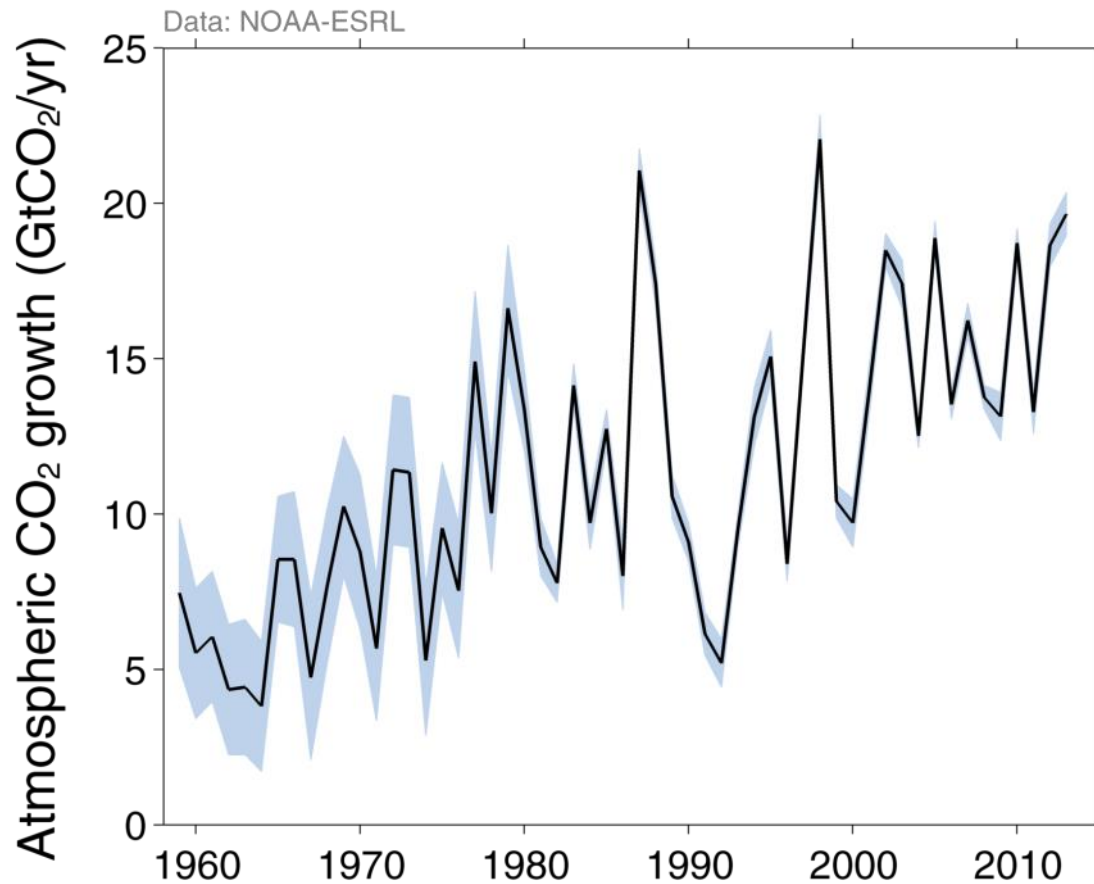
Changes in the Budget over Time

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 CO₂ in the atmosphere



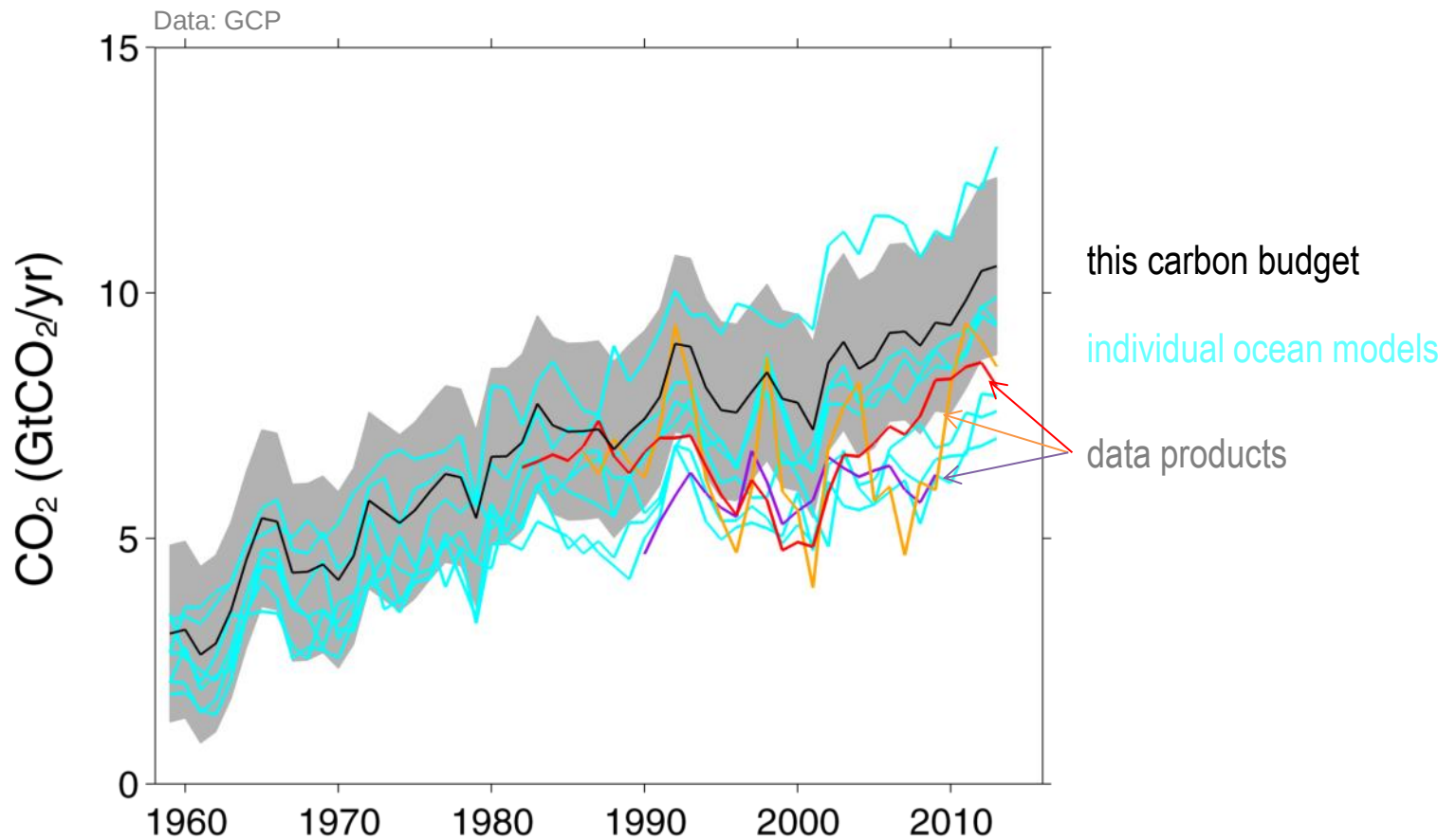
Atmospheric Concentration

The atmospheric concentration growth rate has shown a steady increase
The growth in 2013 reflects the growth in fossil emissions, with small changes in the sinks



Ocean Sink

Ocean carbon sink continues to increase
 $9.4 \pm 1.8 \text{ GtCO}_2/\text{yr}$ for 2004–2013 and $10.5 \pm 1.8 \text{ GtCO}_2/\text{yr}$ in 2013

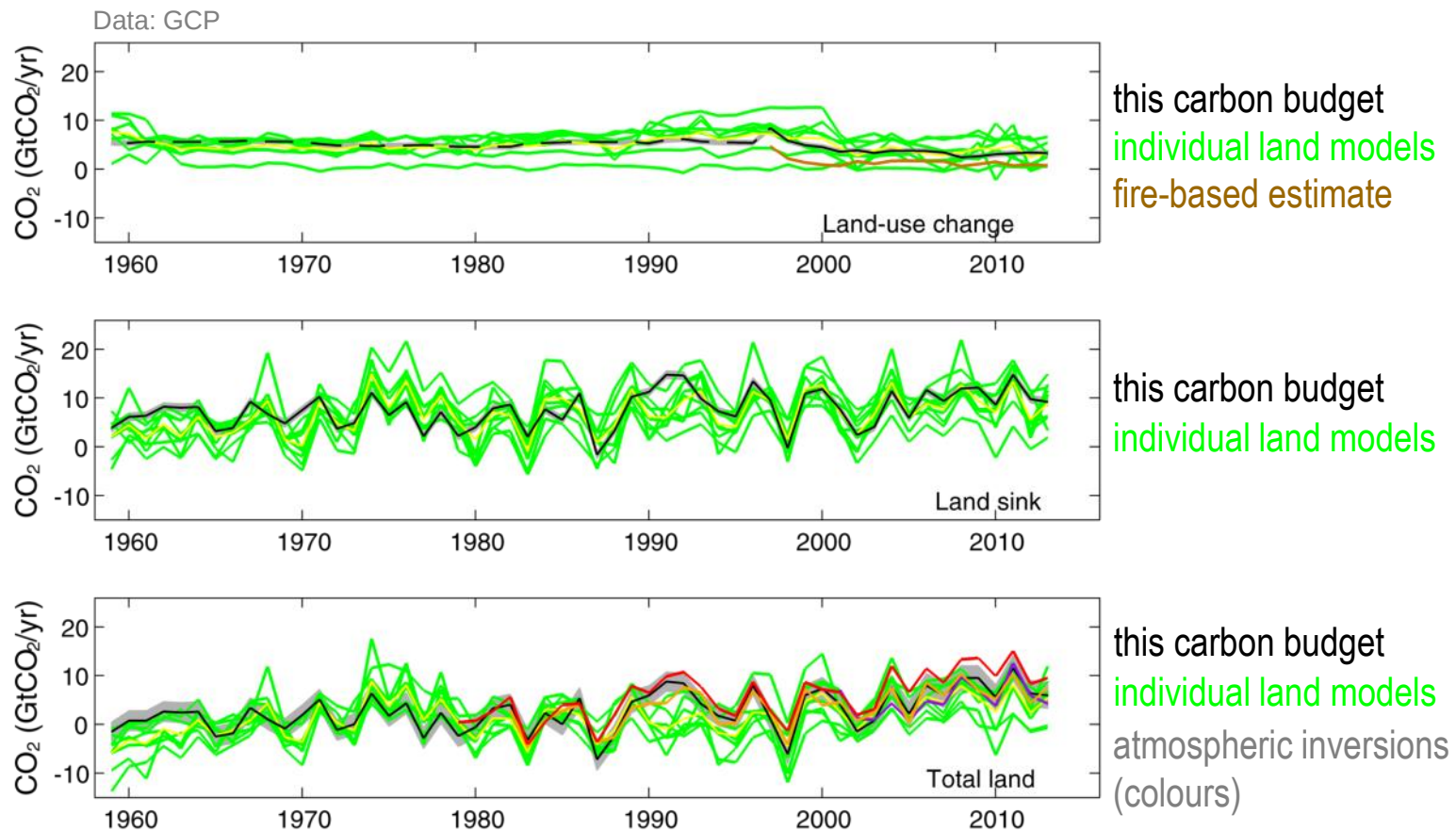


Source: [Le Quéré et al 2014](#); [Global Carbon Project 2014](#)

Individual estimates from Buitenhuis et al. (2010); Aumont and Bopp (2006); Doney et al. (2009); Assmann et al. (2010); Ilyiana et al. (2013); Sérénian 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. (2014).

Terrestrial Sink

The residual land sink is increasing with time to 9.2 ± 1.8 GtCO₂/yr in 2013, with large variability
Total CO₂ fluxes on land (including land-use change) are constrained by atmospheric inversions



Source: [Le Quéré et al 2014](#); [Global Carbon Project 2014](#)

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 CO₂ emissions at the global and country levels, compare among countries, visualize, and download data and illustrations (“Emissions” application). Also explore “Outreach” and “Research”.

GLOBAL CARBON ATLAS

The Global Carbon Atlas is a platform to explore and visualize the most up-to-date data on carbon fluxes resulting from human activities and natural processes.

Human impacts on the carbon cycle are the most important cause of climate change.

OUTREACH

Take a journey through the history and future of human development and carbon

GO





EMISSIONS

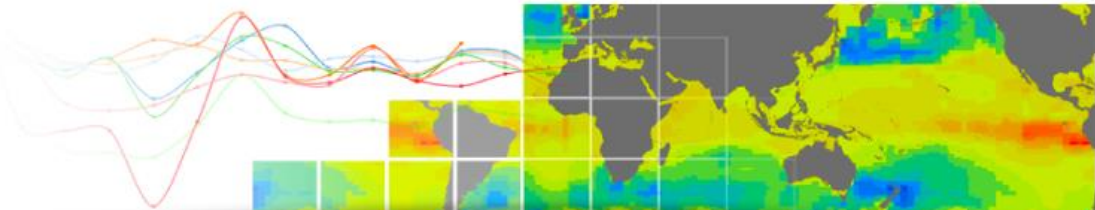
Explore and download global and country level carbon emissions from human activity.

GO

RESEARCH

Explore and visualize research carbon data, and get access through data providers

GO



www.globalcarbonatlas.org

Acknowledgements

The work presented in the Global Carbon Budget 2014 has been possible thanks to the contributions of hundreds of people involved in observational networks, modeling, and synthesis efforts. Not all of them are individually acknowledged in this presentation for reasons of space (see slide 2 for those individuals directly involved).

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