Global Carbon Budget

2014

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Freidlingstein et al. 2014, Raupach et al. 2014 & Fuss et al. 2014 (not already mentioned above)

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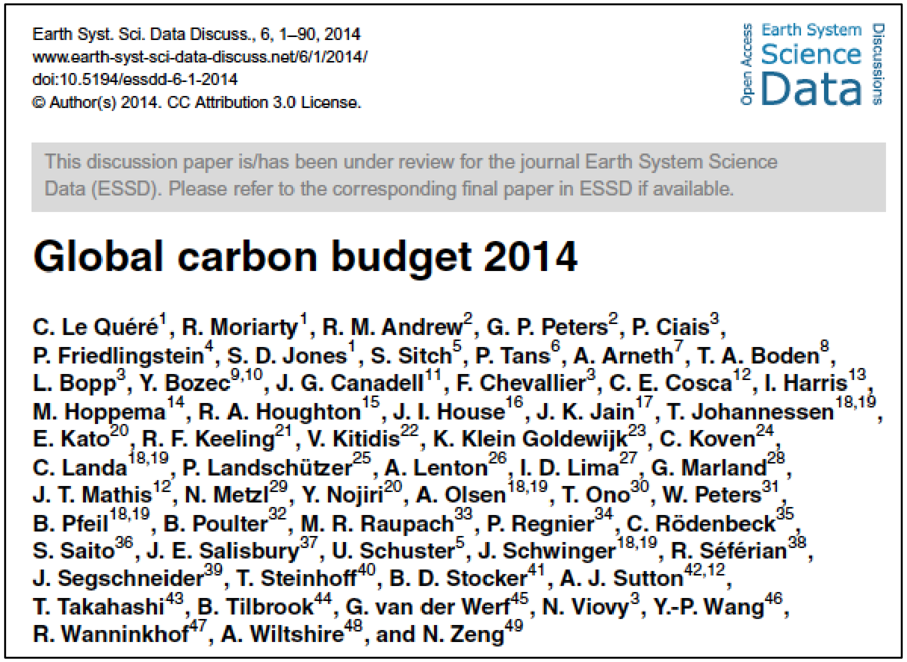
Data Access



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Open Access 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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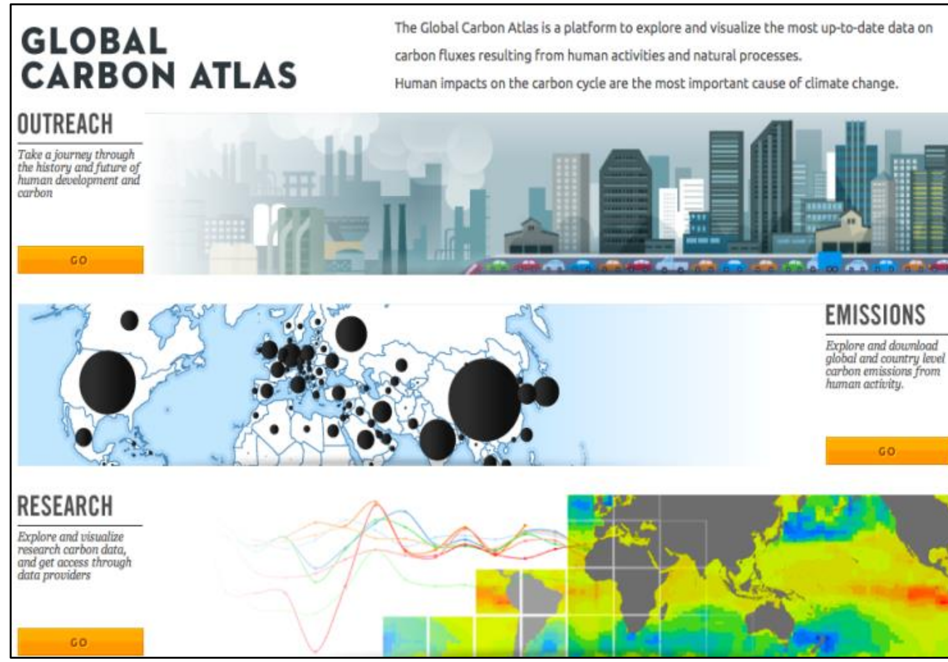


More information, data sources and data files:
www.globalcarbonproject.org
Contact: c.lequere@uea.ac.uk

More information, data sources and data files:
www.globalcarbonatlas.org
Contact: philippe.ciais@lsce.ipsl.fr

All the data is shown in billion tonnes 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 $GtCO_2$

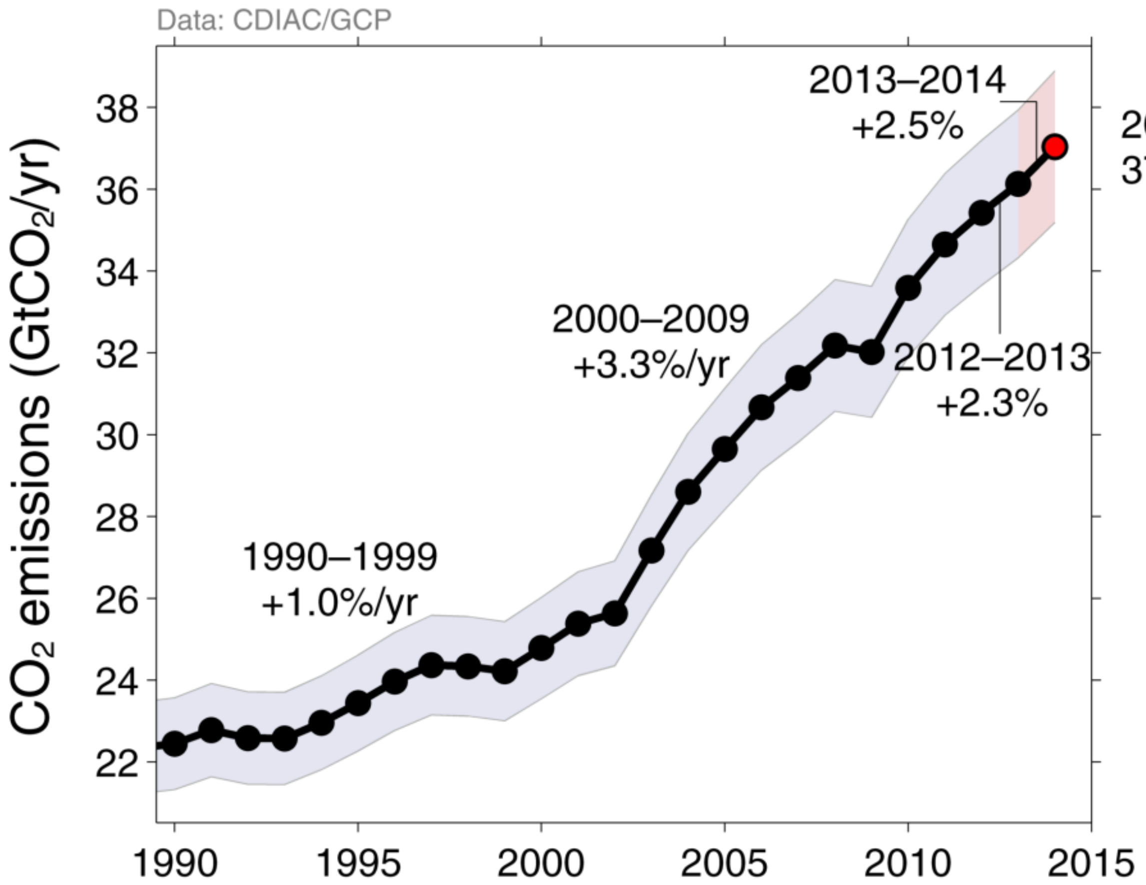
Disclaimer

Executive Summary

Fossil Fuel and Cement Emissions

Global fossil fuel and cement emissions: 36.1 ± 1.8 GtCO_2 in 2013, 61% over 1990

● Projection for 2014 : 37.0 ± 1.9 GtCO_2, 65% over 1990



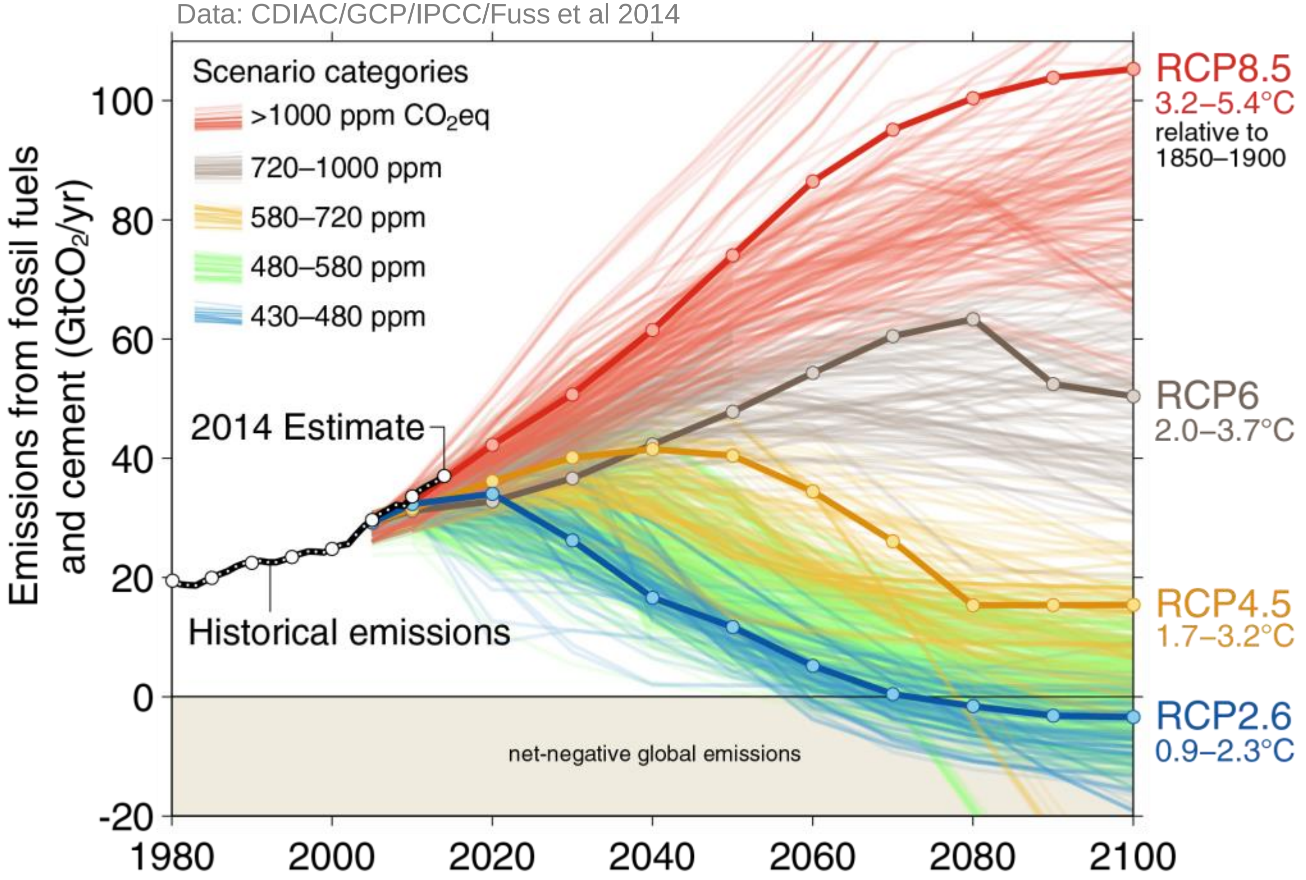
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

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 3.2–5.4ºC "likely" increase in temperature above pre-industrial
Large and sustained mitigation is required to keep below 2ºC

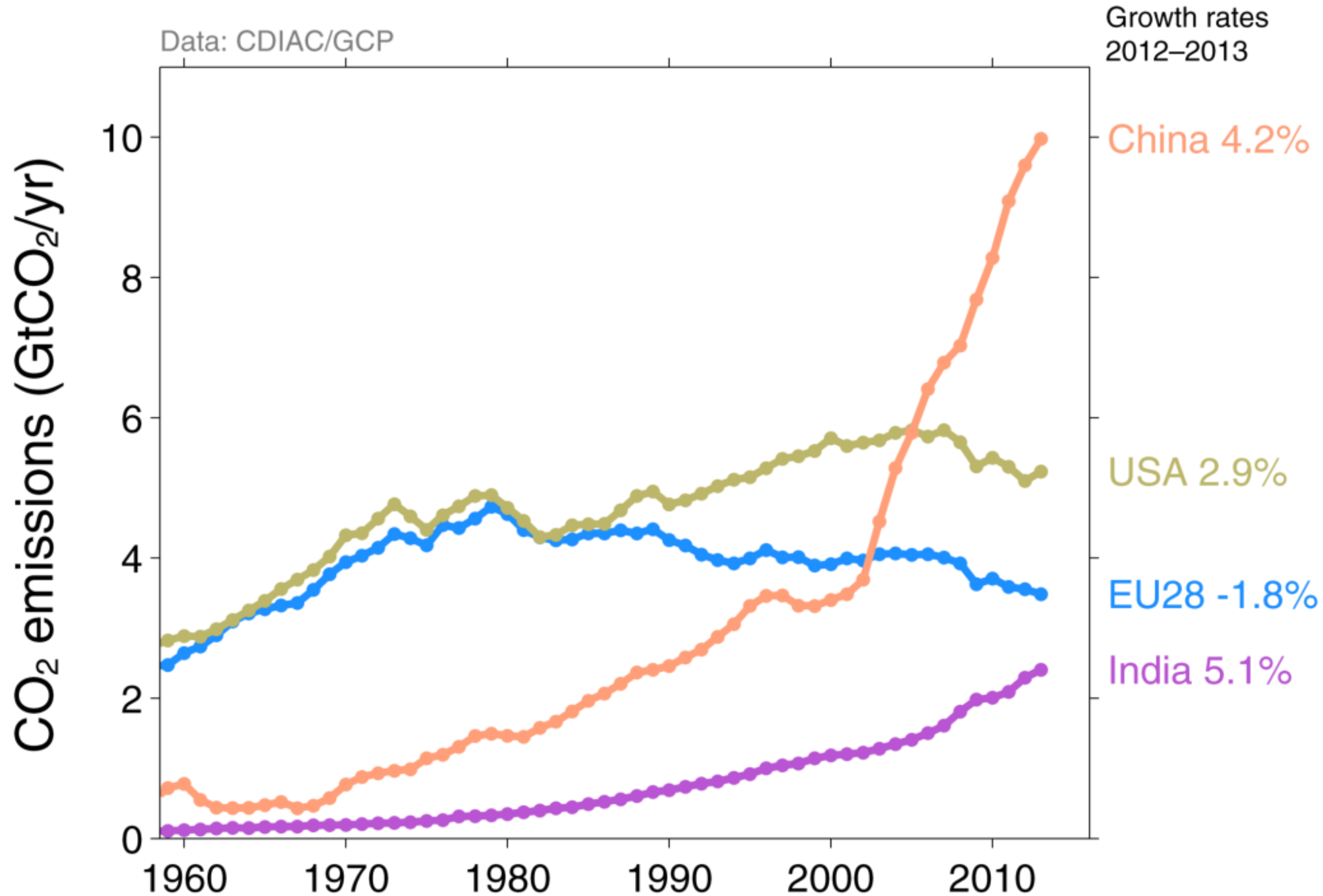


Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

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

Top Fossil Fuel Emitters (Absolute)

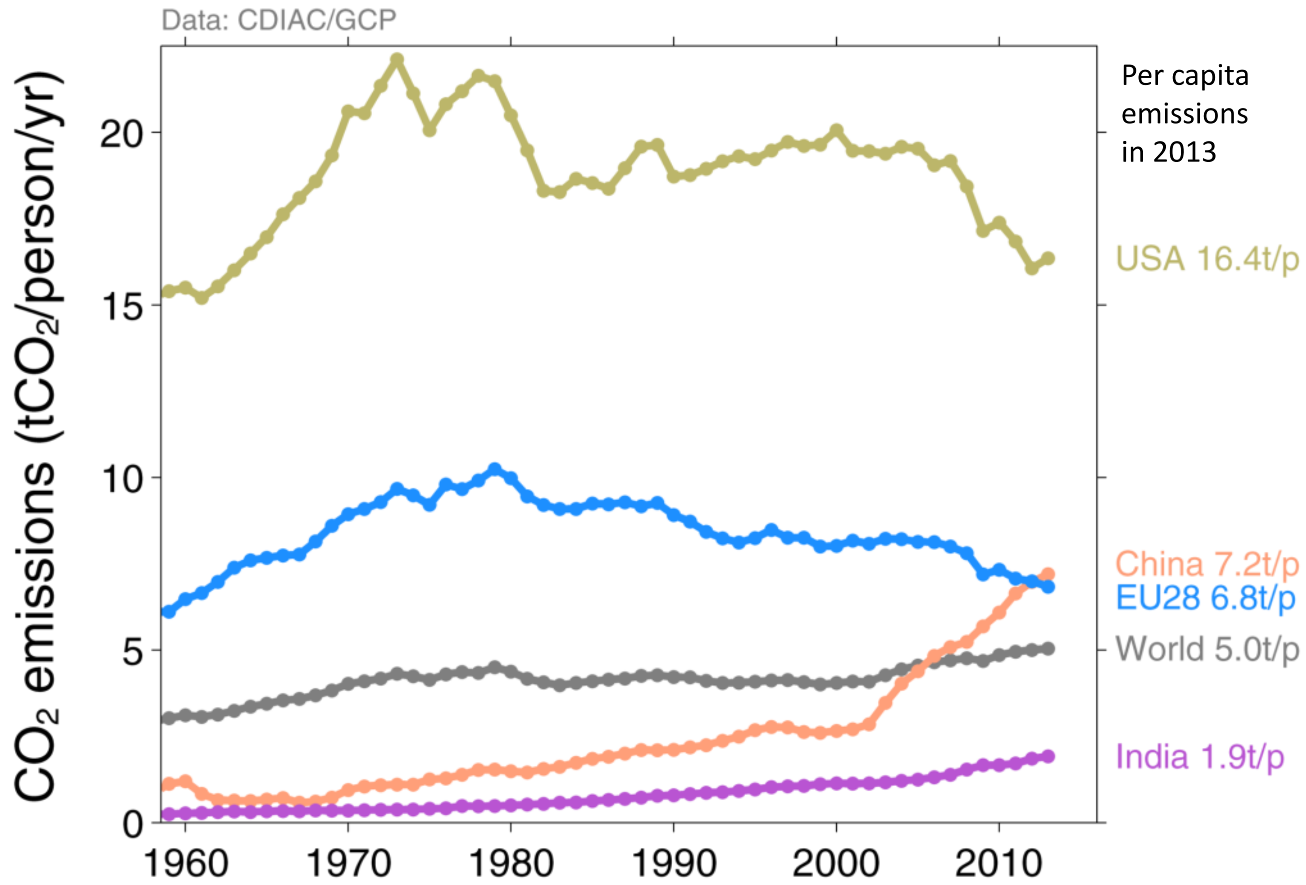
The top four emitters in 2013 covered 58% of global emissions
China (28%), United States (14%), EU28 (10%), India (7%)



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)

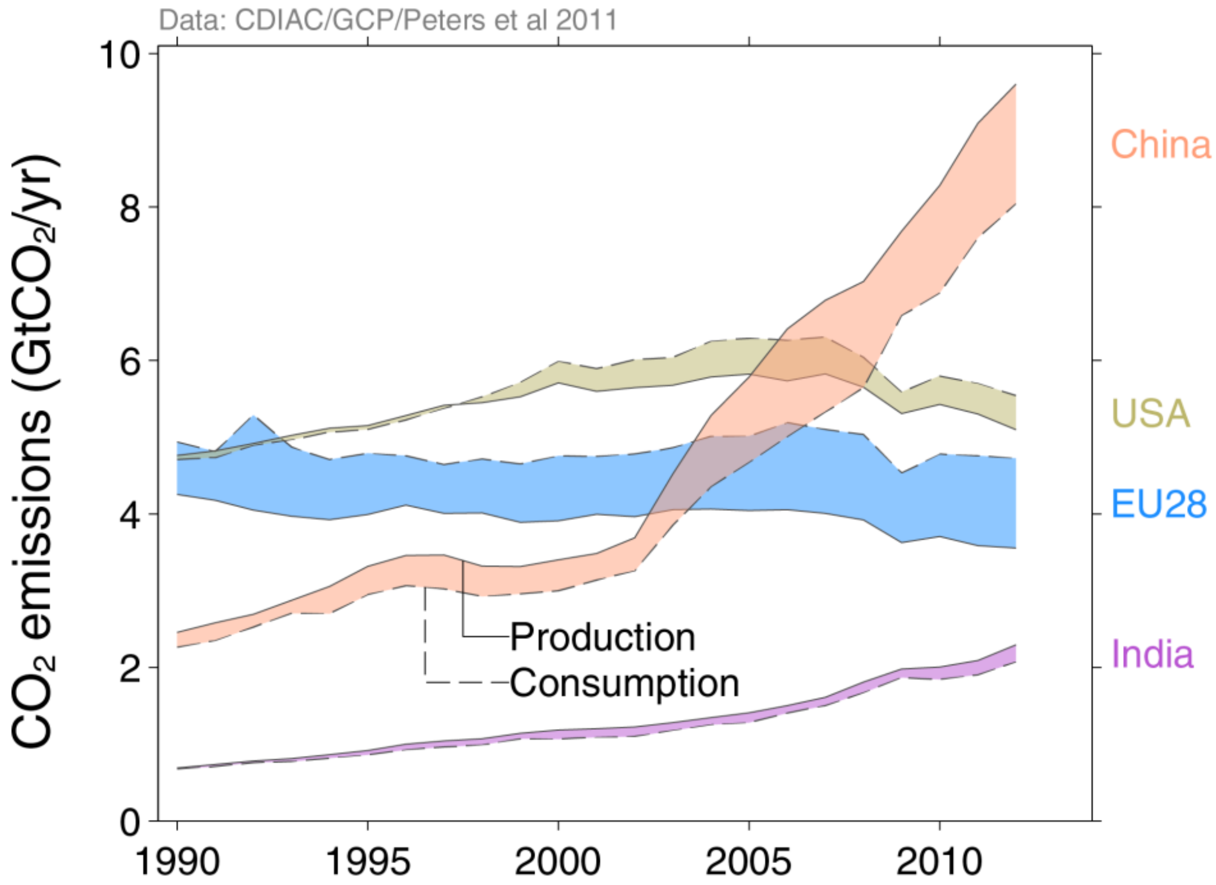
China's per capita emissions have passed the EU28 and are 45% above the global average



Source: CDIAC; Le Quéré et al 2014; Global Carbon Budget 2014

Consumption-based emissions (carbon footprint)

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

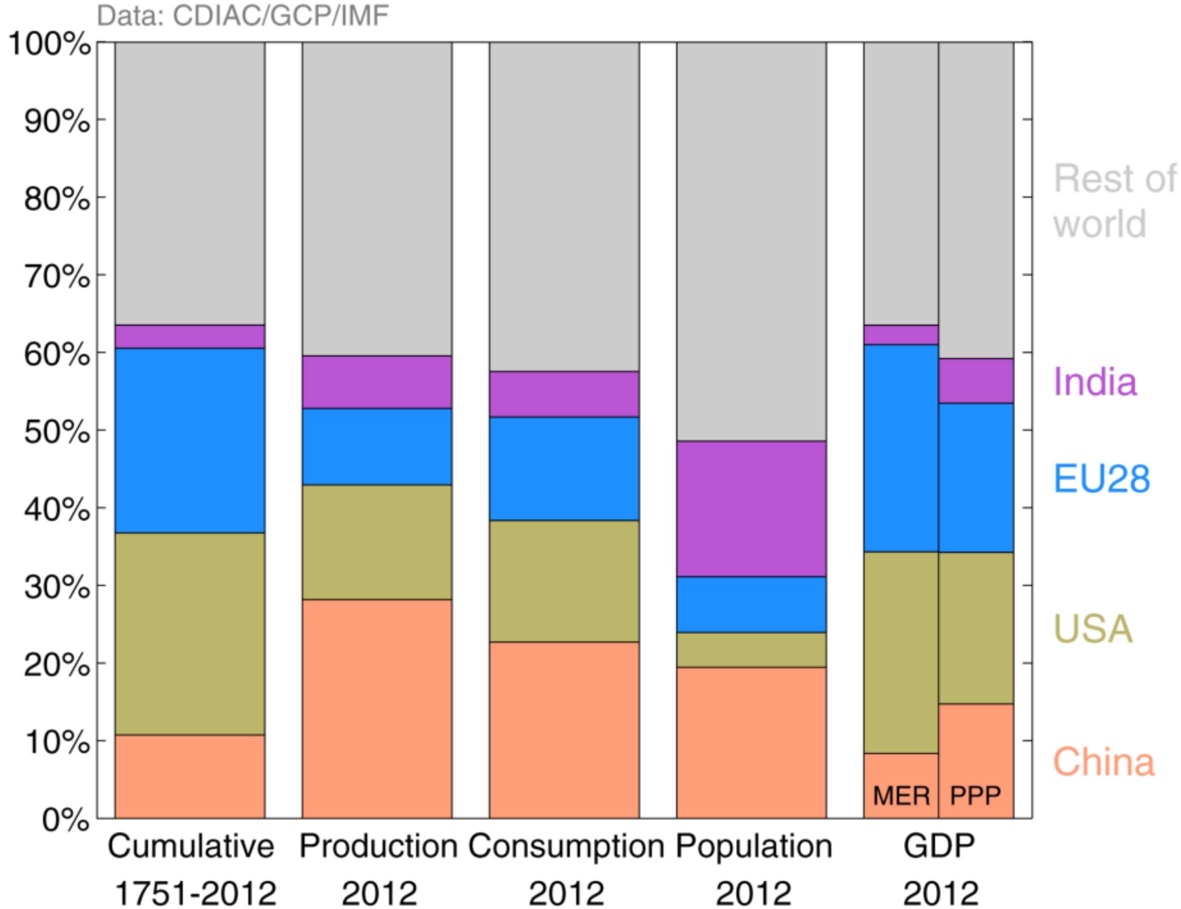


Consumption-based emissions are calculated by adjusting the standard production-based emissions to account for international trade

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



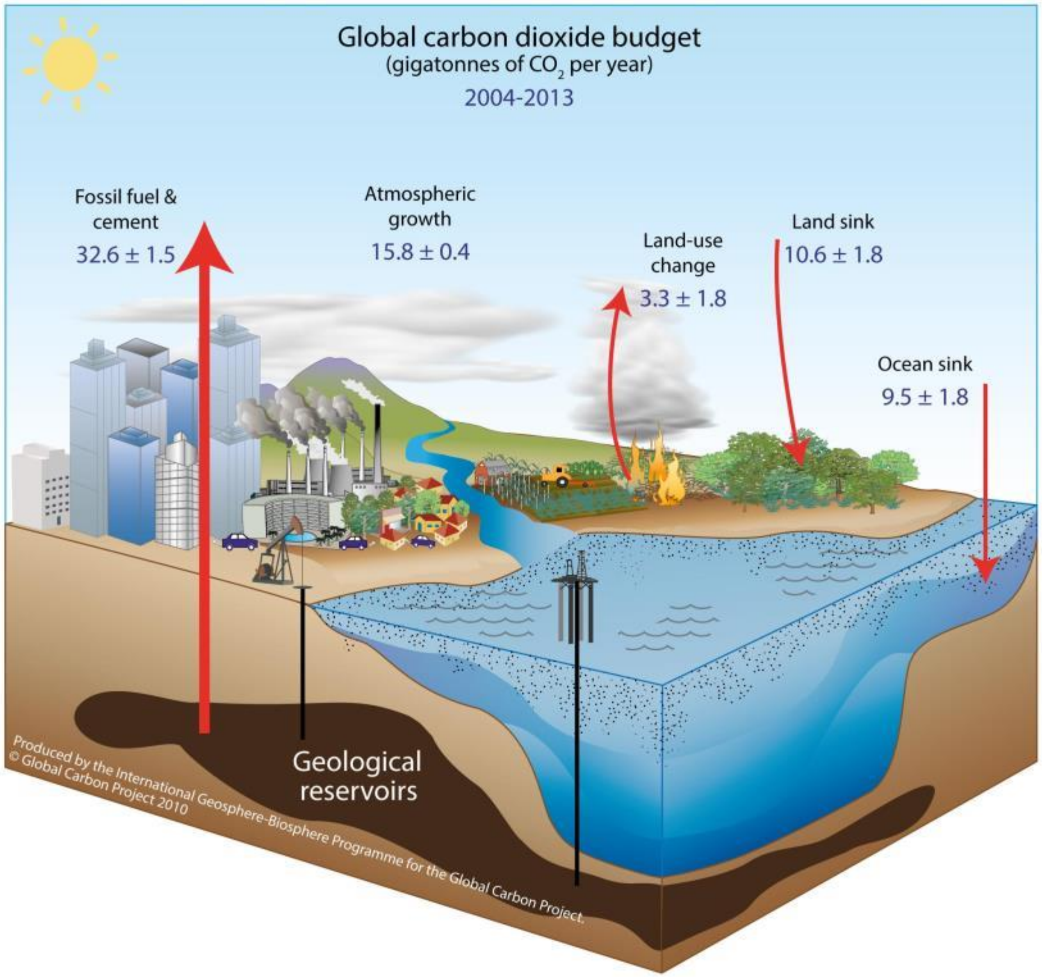
GDP: Gross Domestic Product in Market Exchange Rates (MER) and Purchasing Power Parity (PPP)

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 ($GtCO_2$/yr)

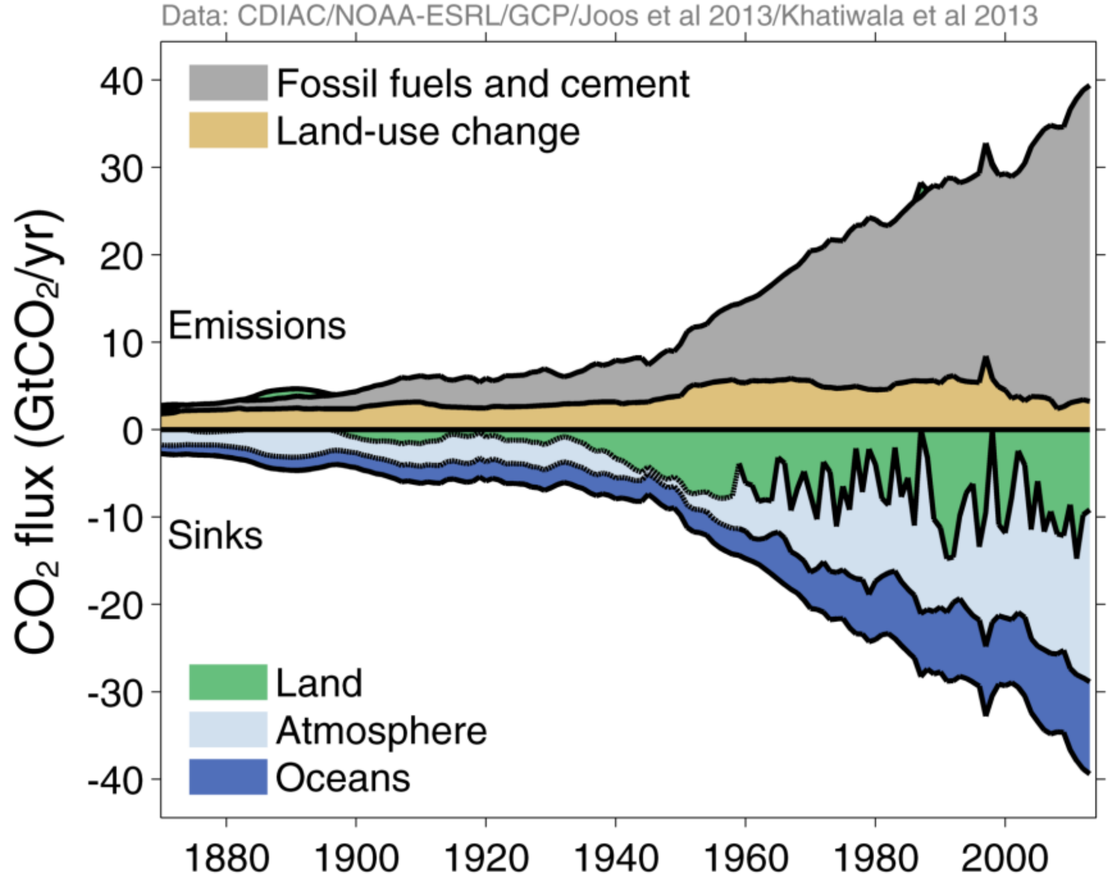
Data: CDIAC/NOAA-ESRL/GCP



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)

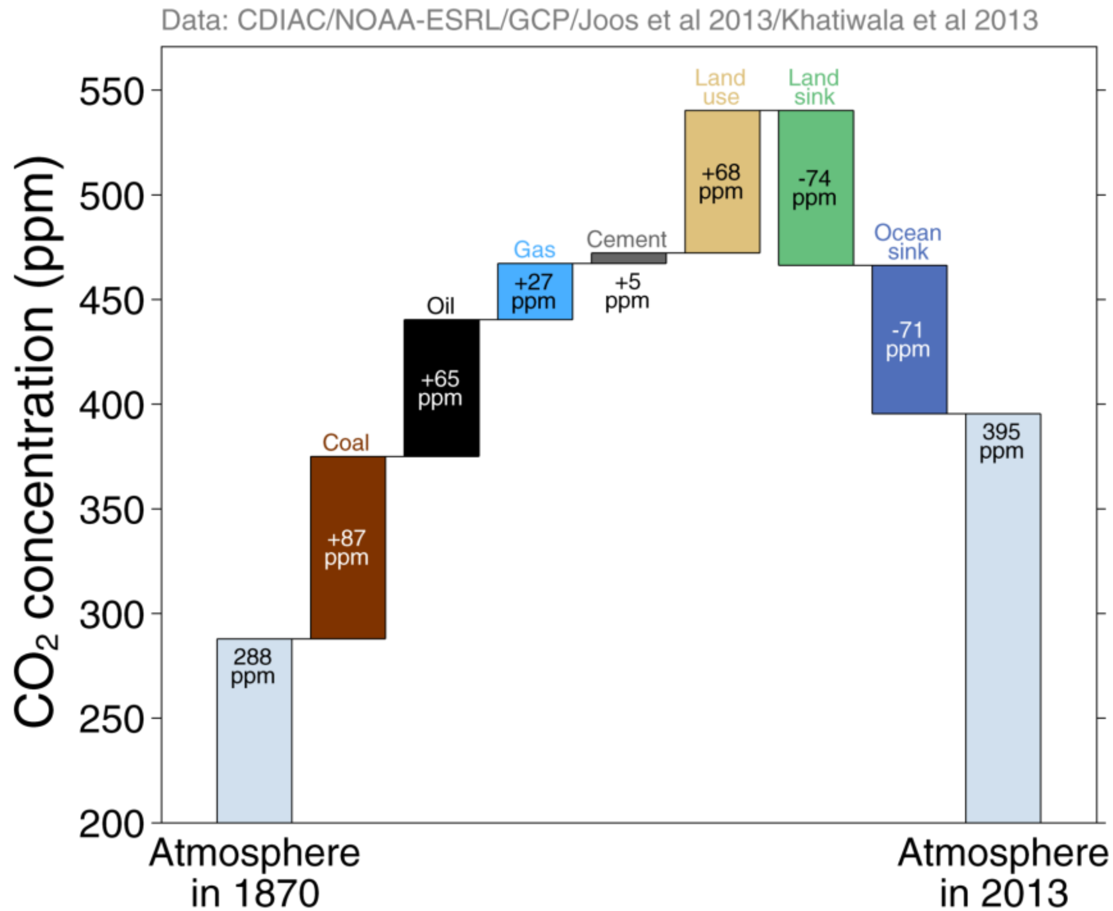
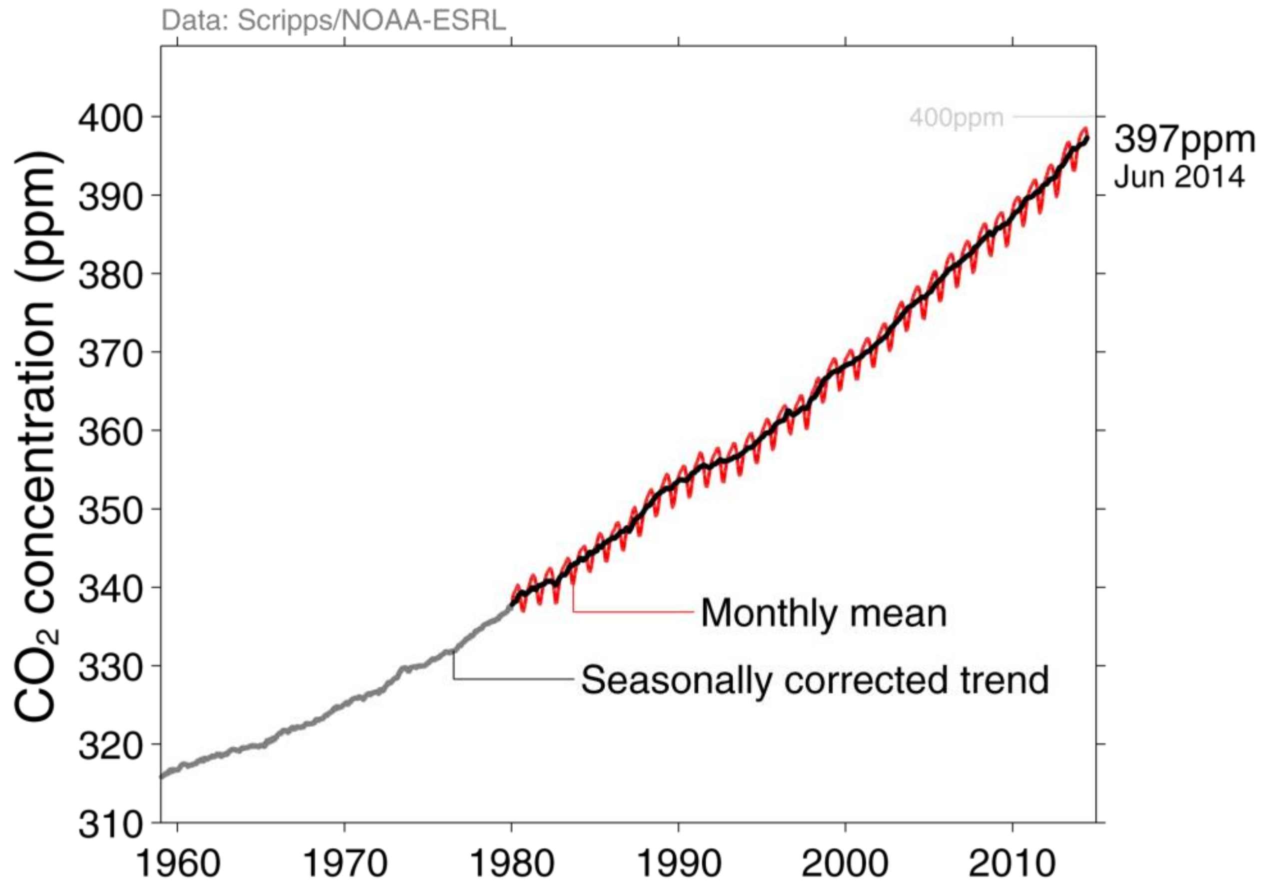


Figure concept from [Shrink That Footprint]
Source: [CDIAC]; [NOAA-ESRL]; [Houghton et al 2012]; [Giglio et al 2013]; [Joos et al 2013]; [Khatiwala et al 2013]; [Le Quéré et al 2014]; [Global Carbon Budget 2014]

Atmospheric Concentration

The global CO_2 concentration increased from ~277ppm in 1750 to 395ppm in 2013 (up 43%)
Mauna Loa registered the first daily measurements above 400pm in May 2013



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 2014

Remaining CO_2 emission quota

nature geoscience

REVIEW ARTICLE

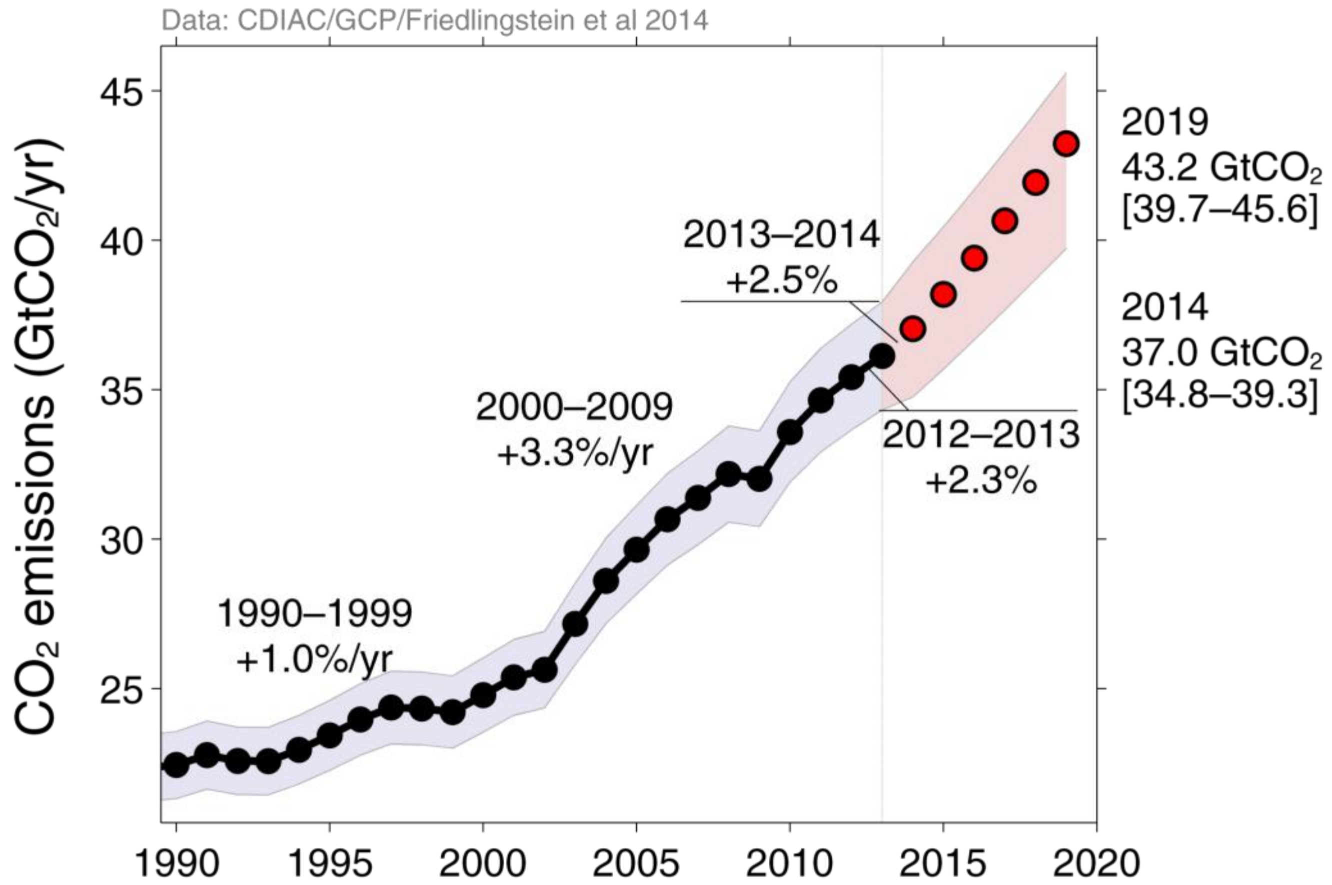
PUBLISHED ONLINE: 21 SEPTEMBER 2014 | DOI: 10.1038/NGEO2248

Persistent growth of CO_2 emissions and implications for reaching climate targets

P. Friedlingstein[1*], R. M. Andrew[2], J. Rogelj[3,4], G. P. Peters[2], J. G. Canadell[5], R. Knutti[3], G. Luderer[6], M. R. Raupach[7], M. Schaeffer[8,9], D. P. van Vuuren[10,11] and C. Le Quéré[12]

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 $GtCO_2$/yr by 2019

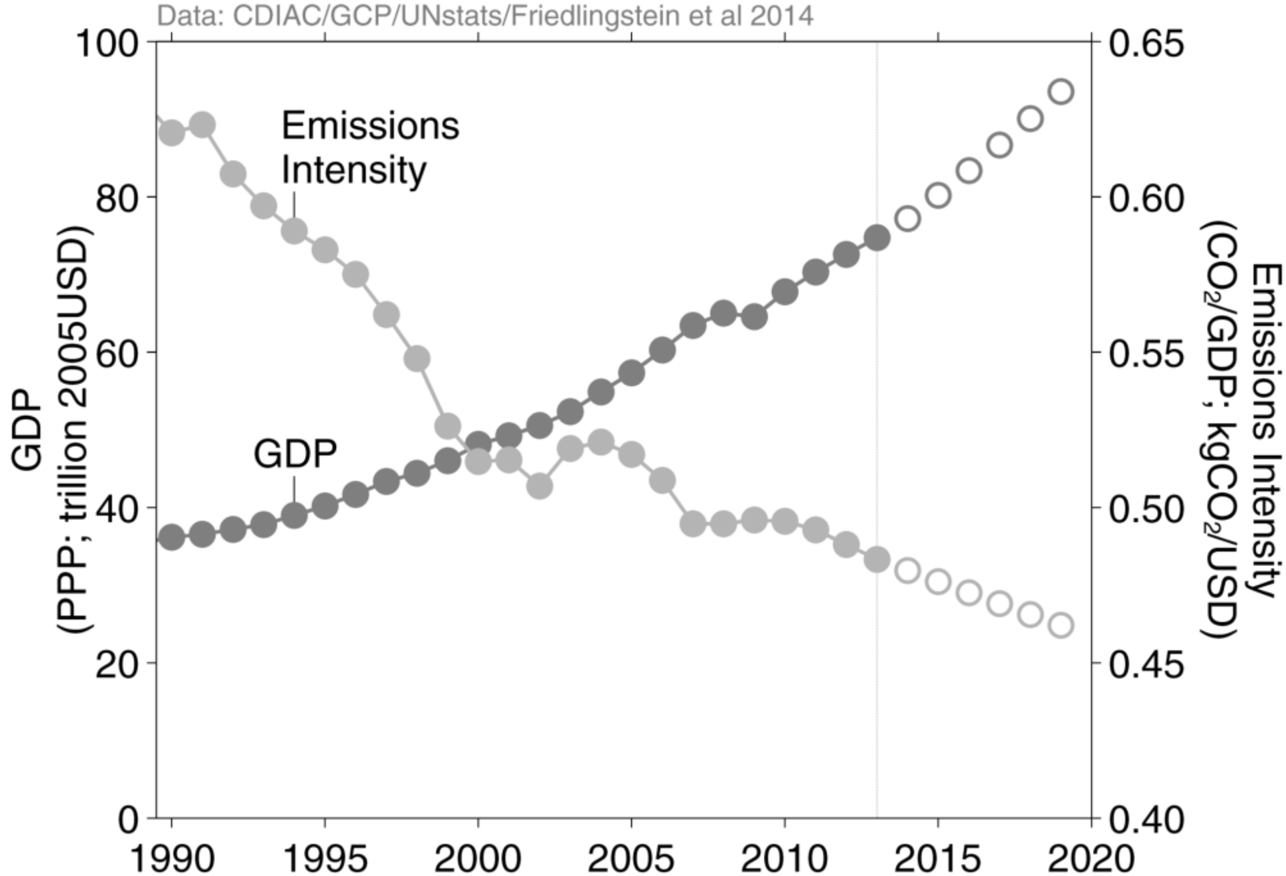


Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend

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

Carbon Intensity of Economic Activity – Global

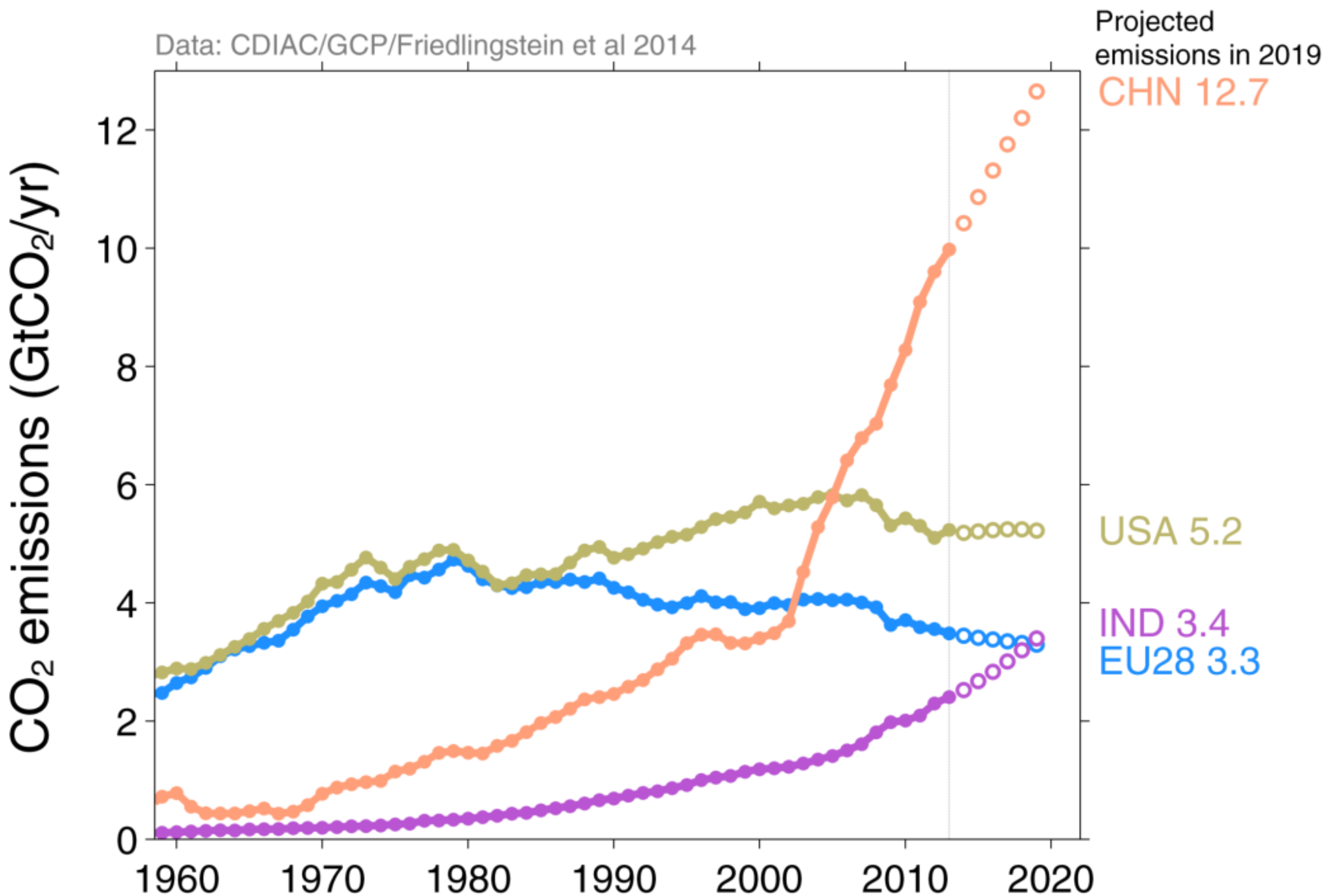
GDP and carbon intensity trends are relatively stable over time, leading to stable emission growth
Step changes in emission intensity are required for emission trends to change for a given GDP



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

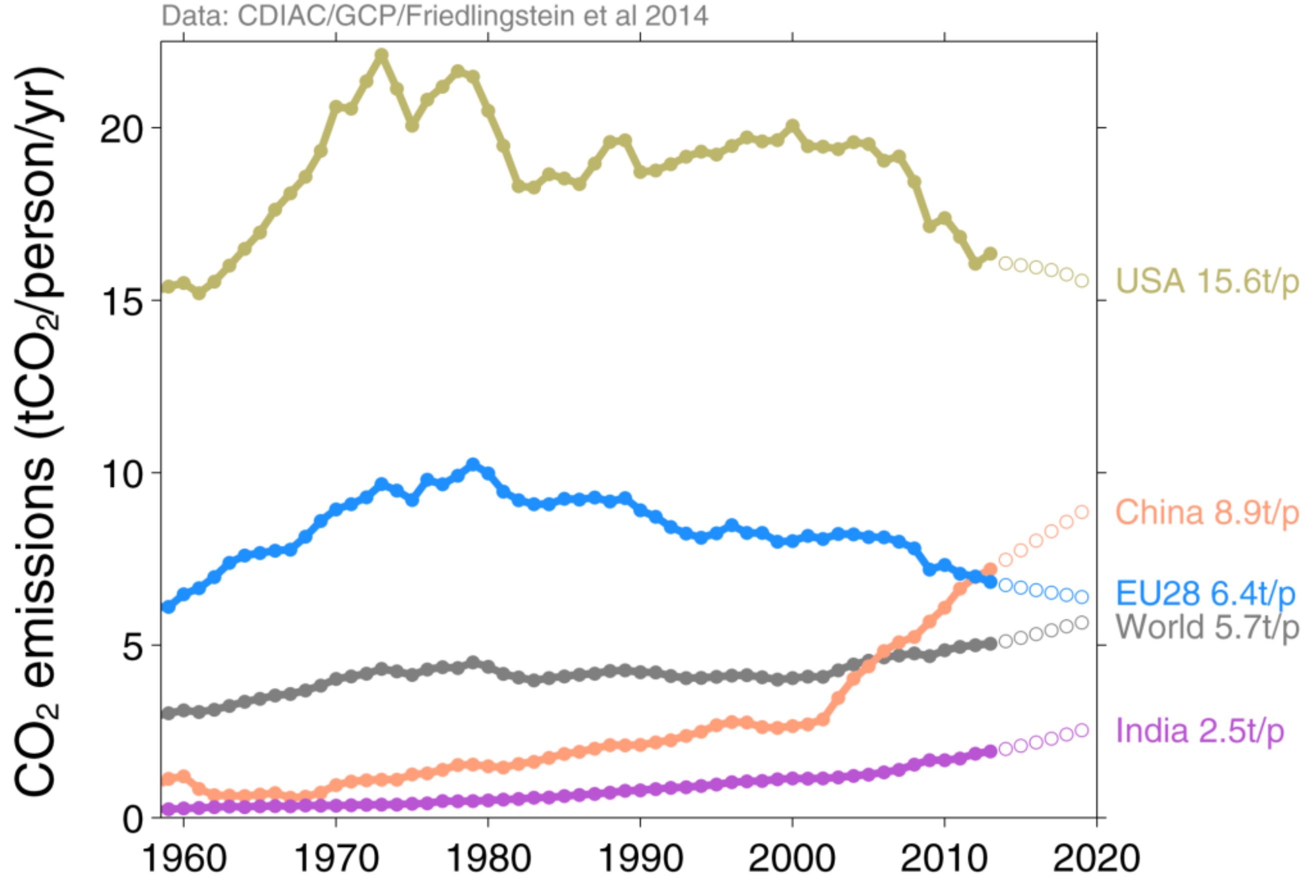


Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend

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

Top Fossil Fuel Emitters (Per Capita)

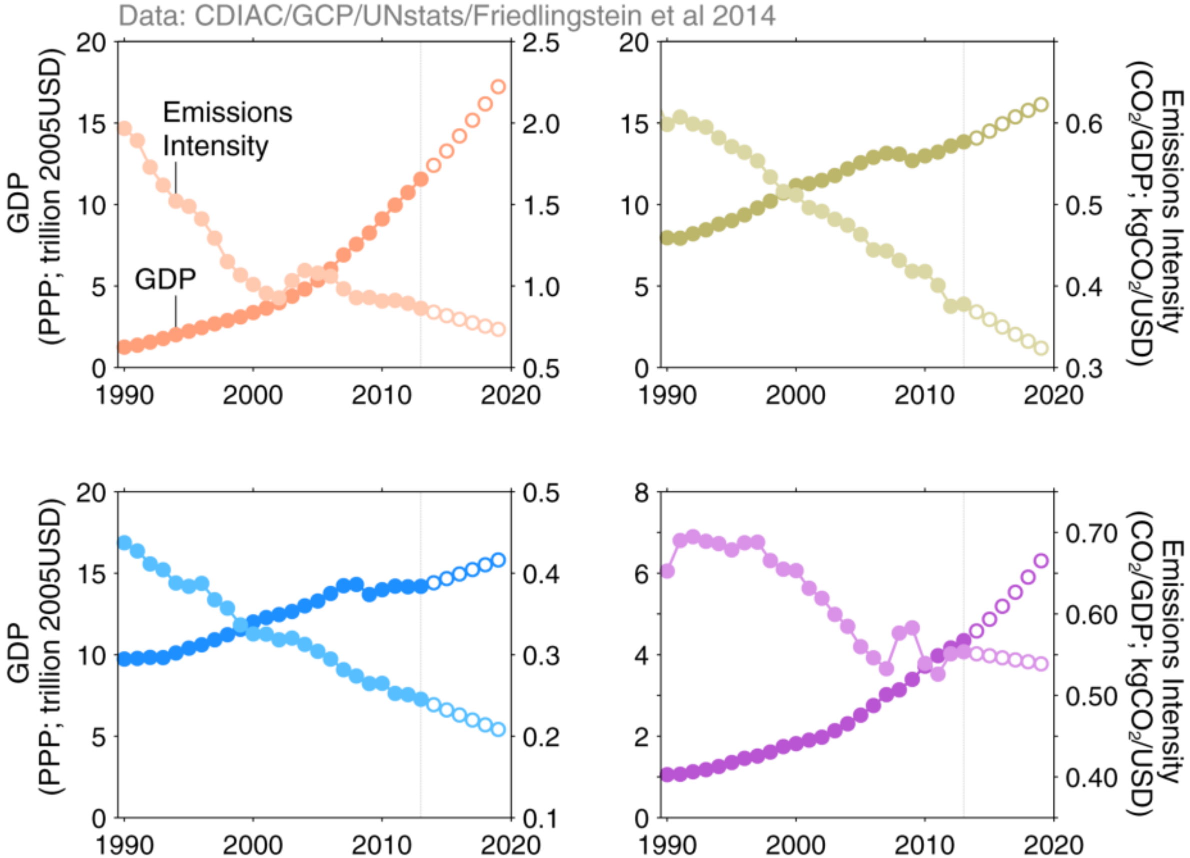
The divergence between EU28 and Chinese per capita emissions is likely to continue
USA continues with high and India with low per capita emissions



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

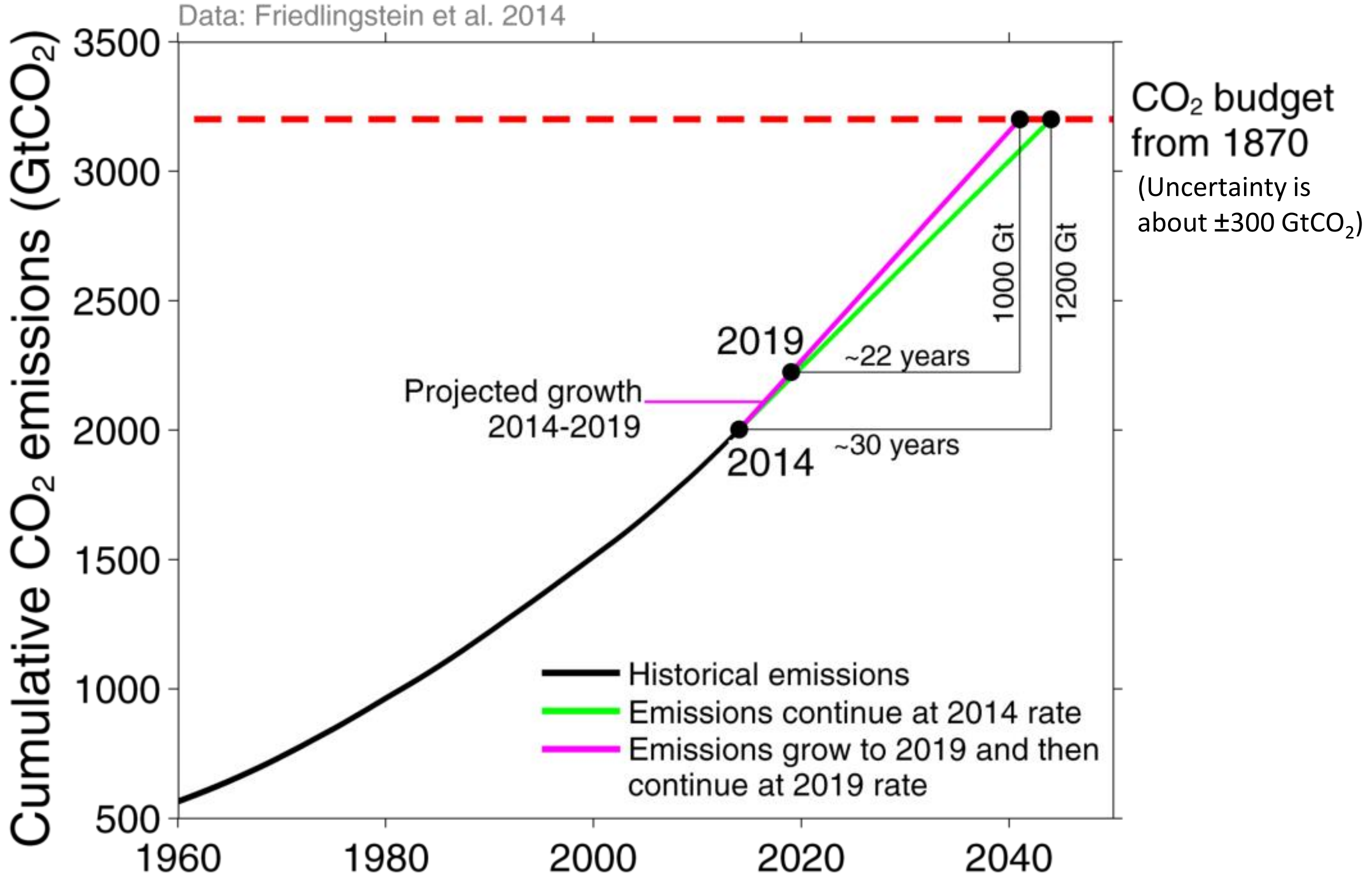


Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend

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

Remaining emissions budget

Cumulative CO_2 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

GLOBAL CARBON PROJECT

Sharing the CO_2 emission quota

nature climate change

PERSPECTIVE

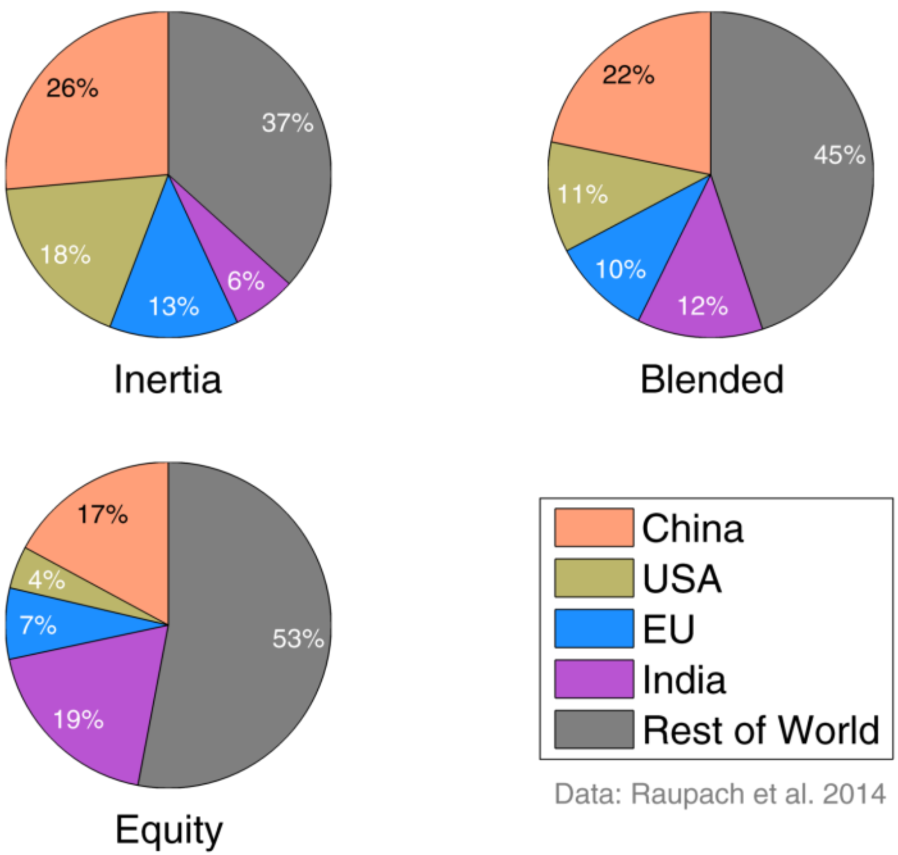
PUBLISHED ONLINE: 21 SEPTEMBER 2014 | DOI: 10.1038/NCLIMATE2384

Sharing a quota on cumulative carbon emissions

Michael R. Raupach[1*], Steven J. Davis[2], Glen P. Peters[3], Robbie M. Andrew[3], Josep G. Canadell[4], Philippe Ciais[5], Pierre Friedlingstein[6], Frank Jotzo[7], Detlef P. van Vuuren[8,9] and Corinne Le Quéré[10]

Sharing the CO_2 emission quota

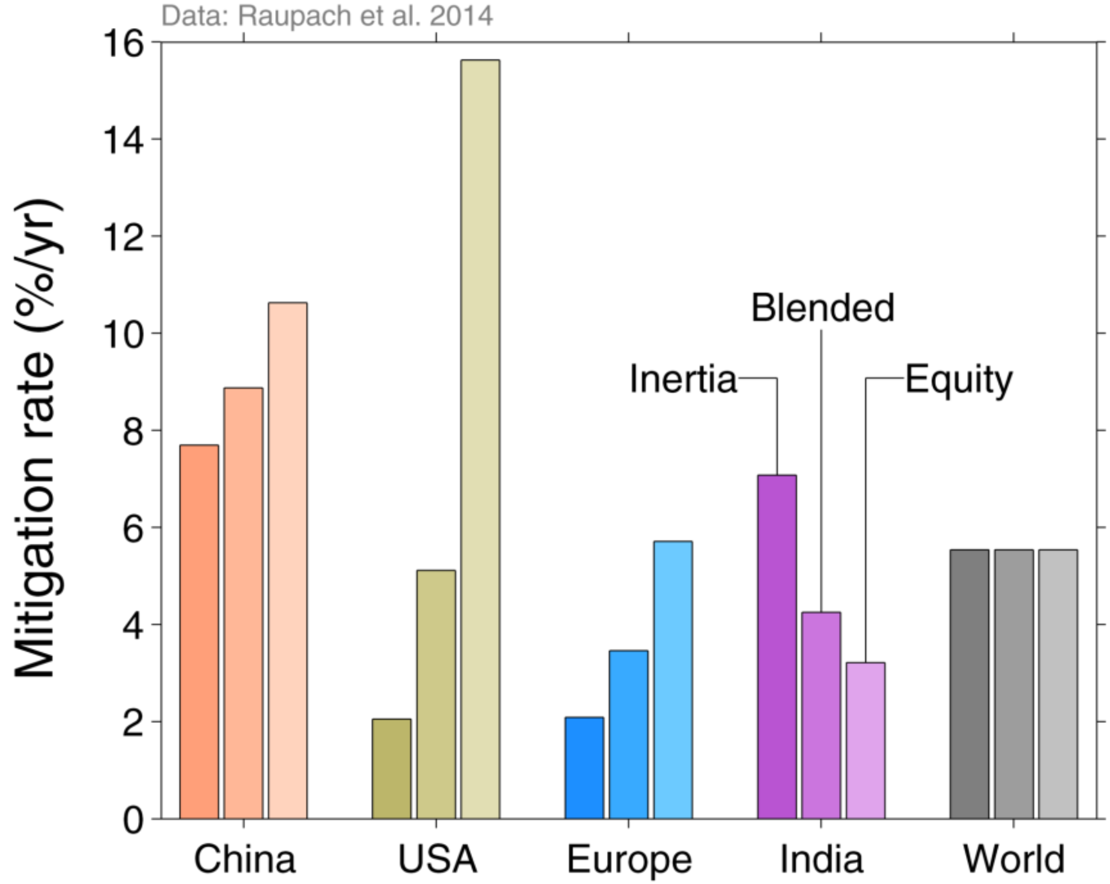
The share of an available CO_2 emission quota allocated to countries
A 'blended' option gives more feasible mitigation rates, without penalising developing regions



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

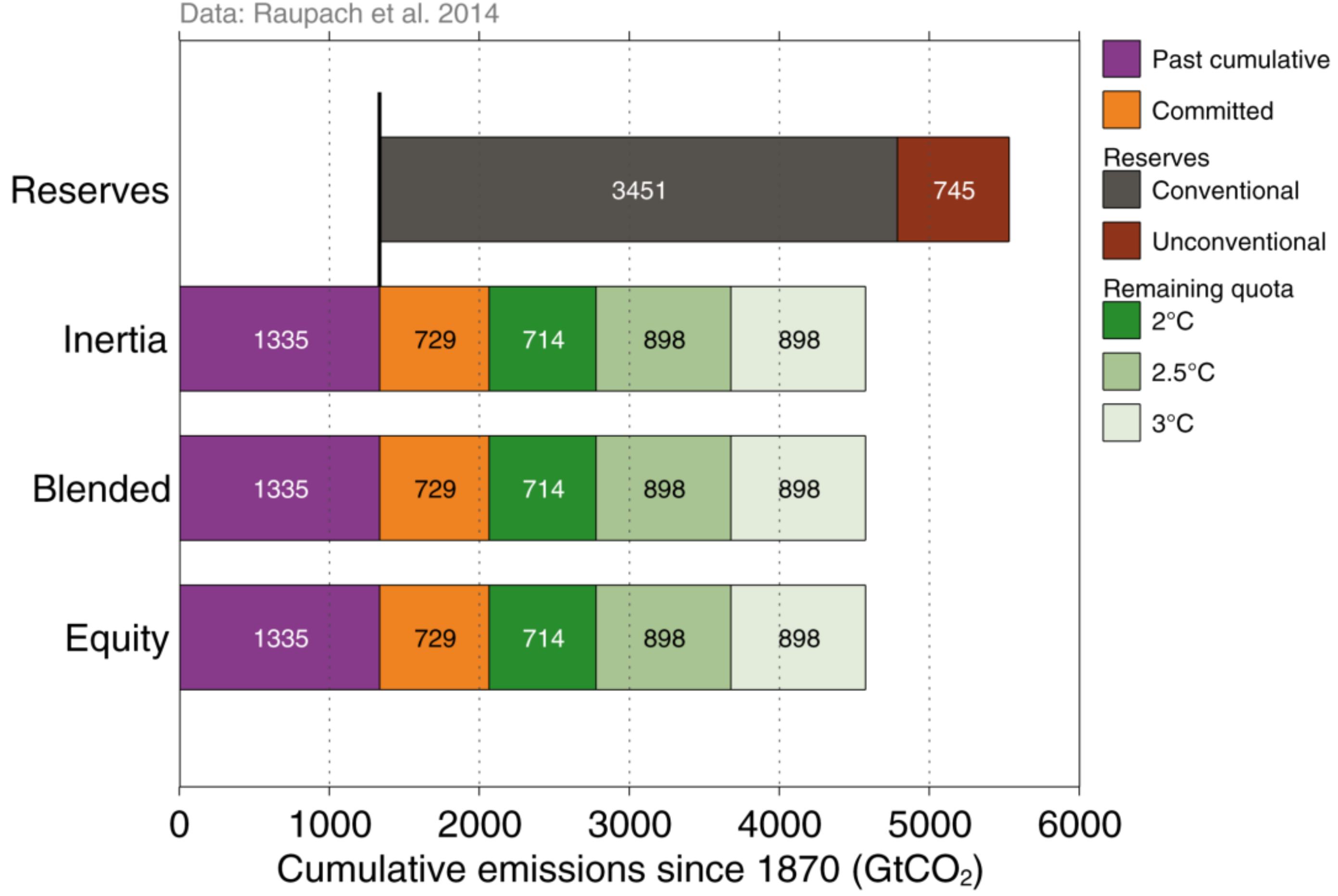


For comparison, the nuclear transitions in some European countries
led to ~4%/yr reductions for 10-year periods

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*

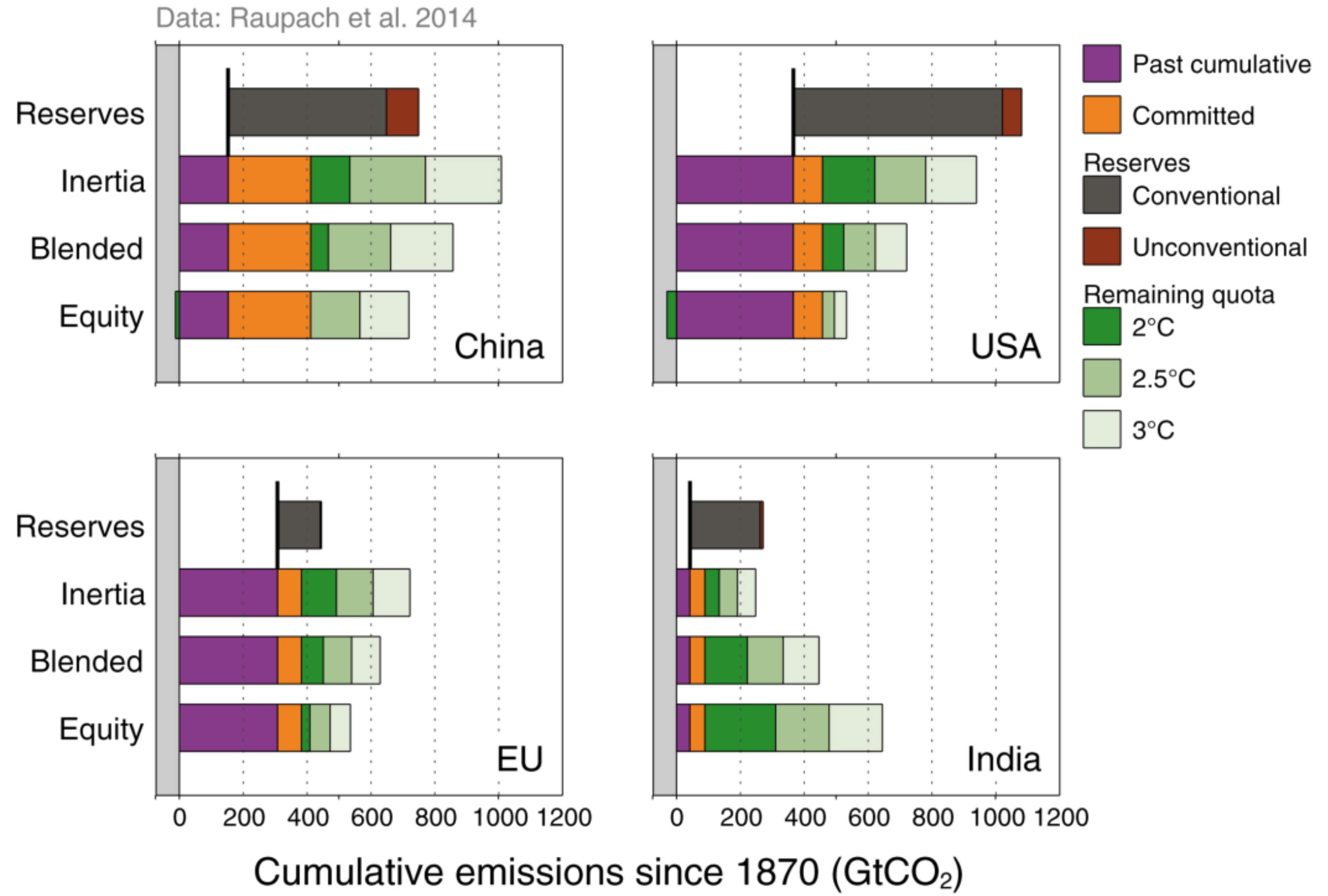


*Assuming a 50% chance to stay below 2°C and no carbon-capture and storage

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



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

Source: [Raupach et al 2014]

Betting on Negative Emissions

opinion & comment

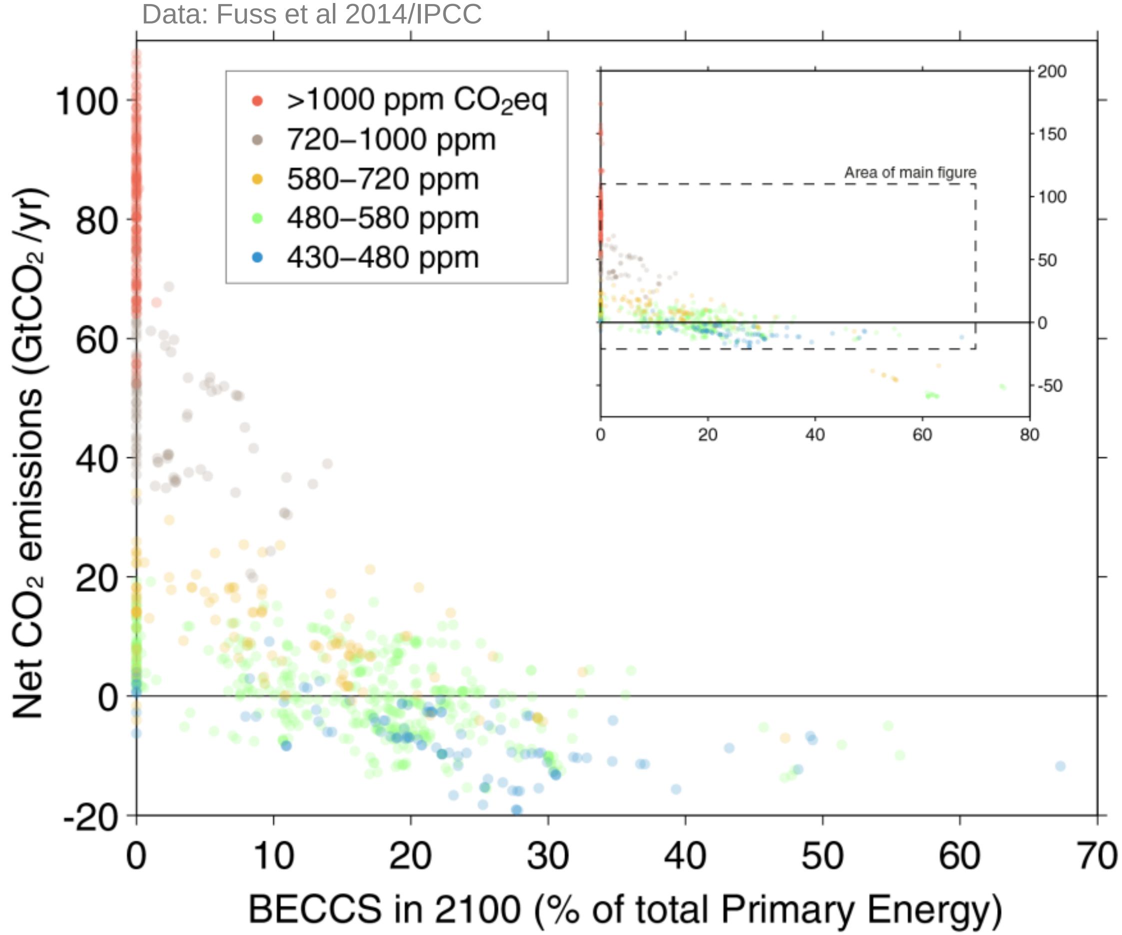
COMMENTARY:

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 2ºC

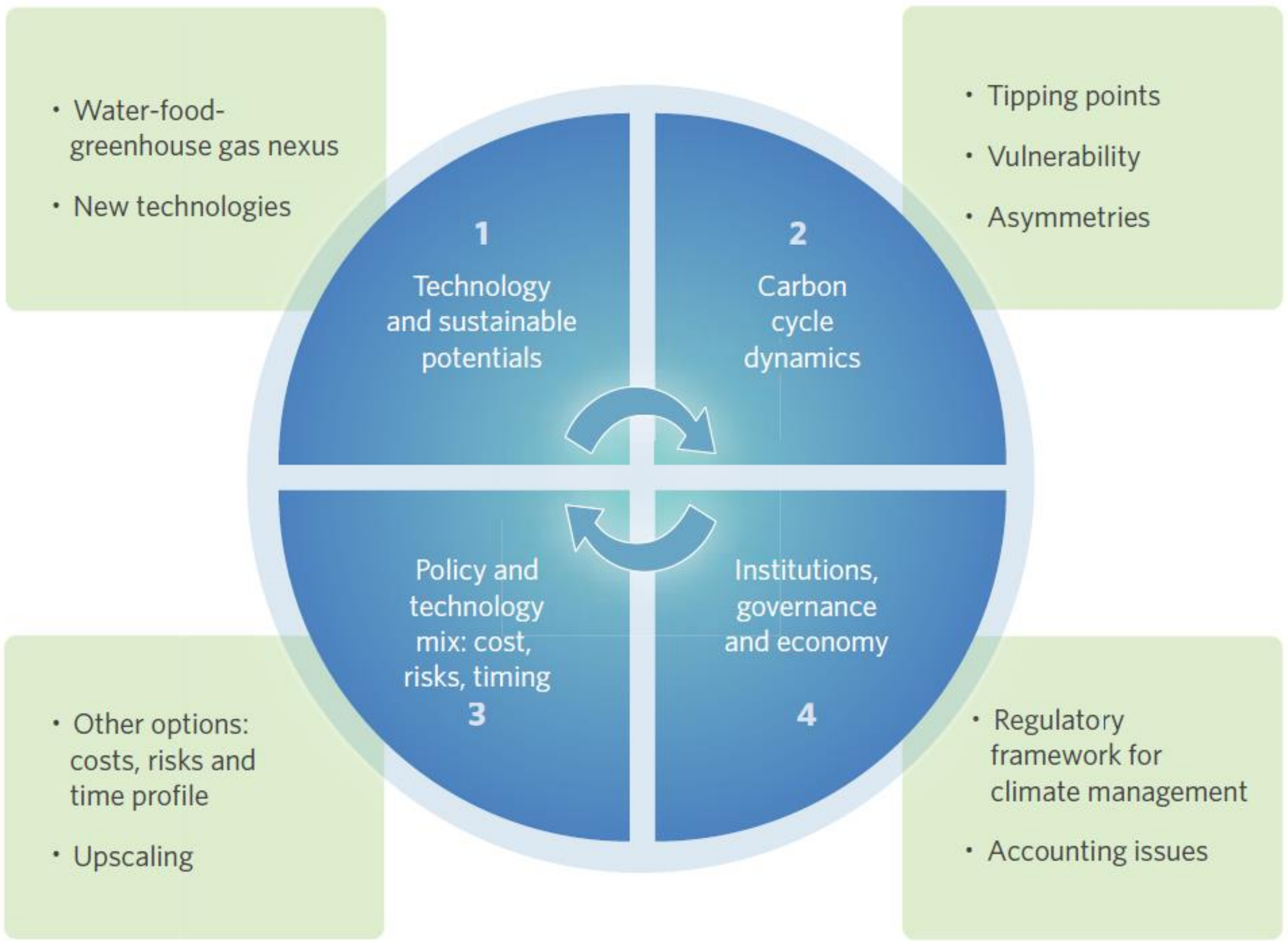
BECCS is used in over half of scenarios, but ~40% have net positive emissions in 2100
~90% of 2ºC and ~35% of other mitigation scenarios have net negative emissions in 2100



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



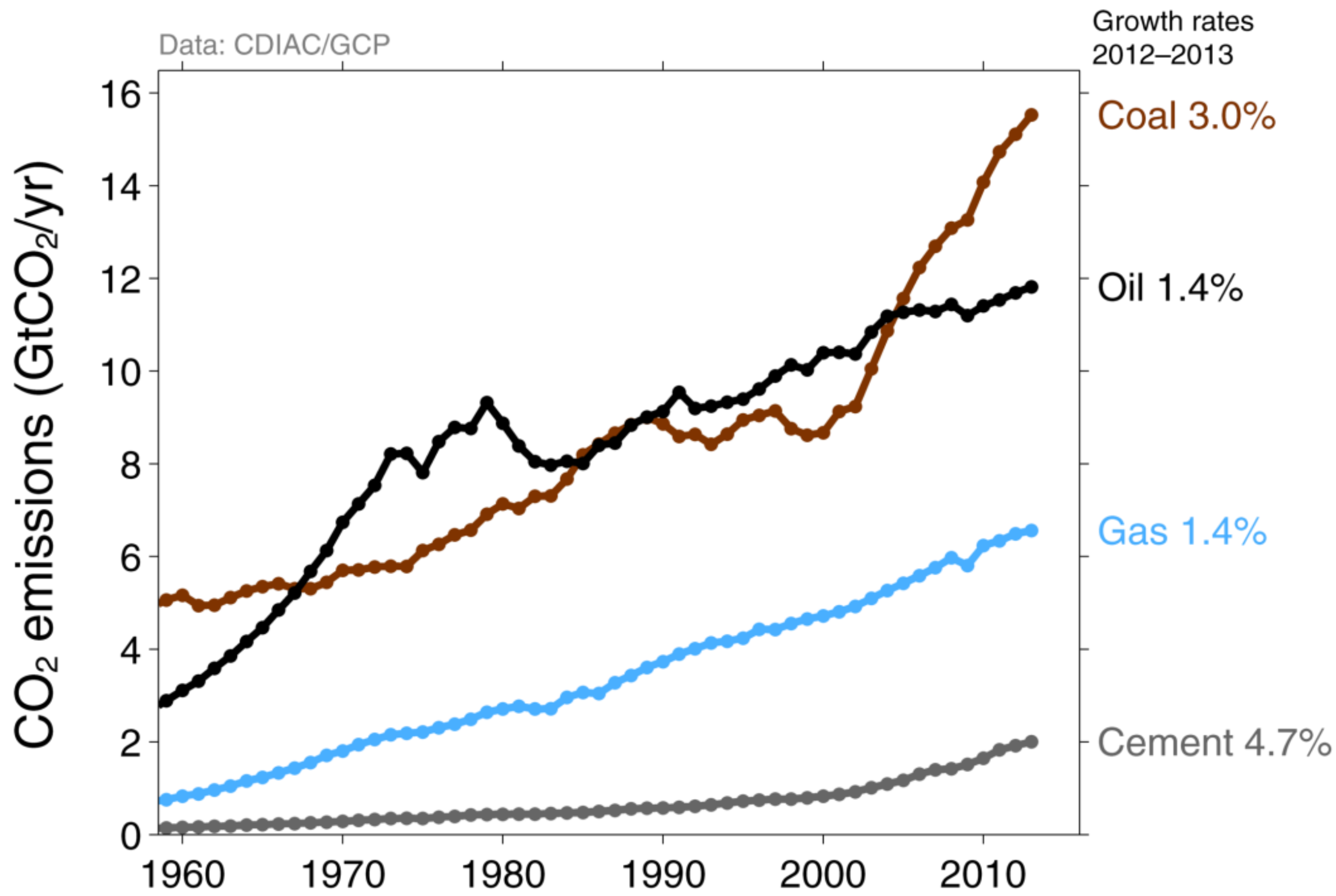
Source: Fuss et al 2014

Supplementary Budget Slides

Fossil Fuel and Cement Emissions

Emissions from Coal, Oil, Gas, Cement

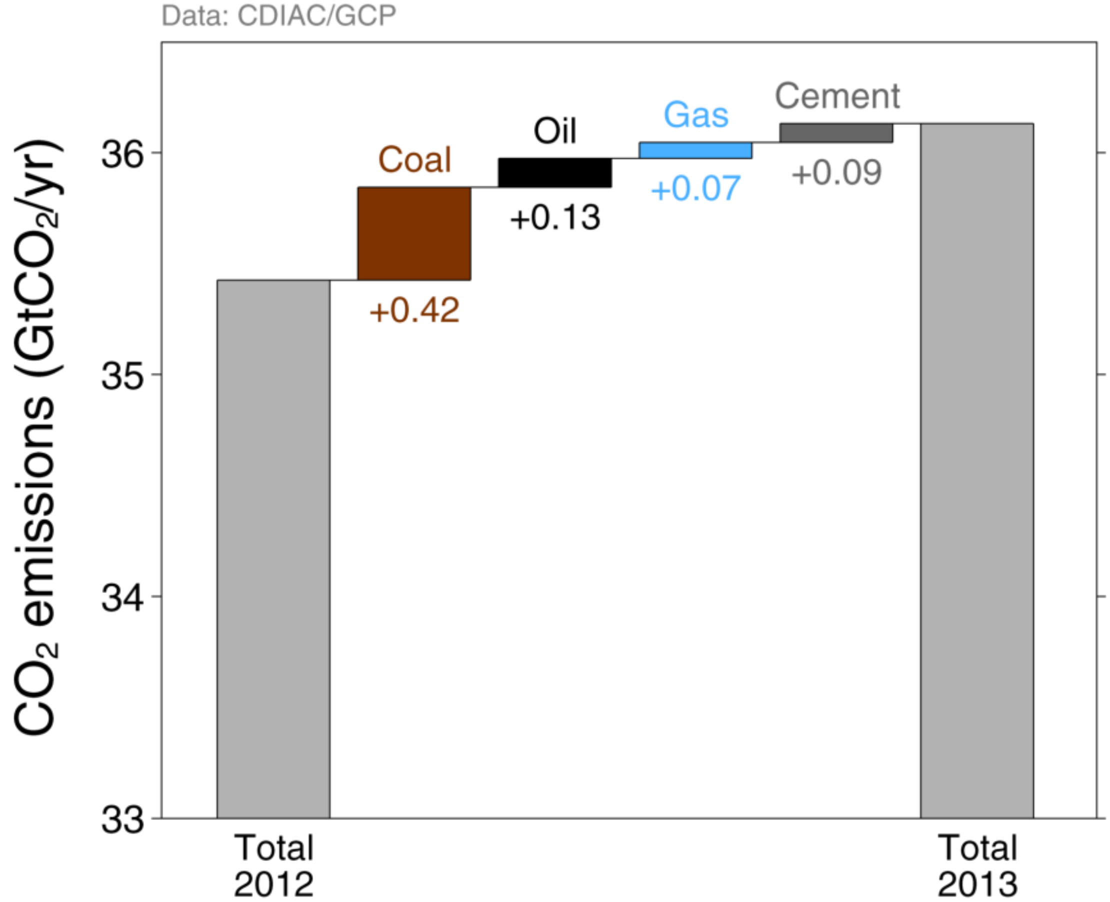
Share of global emissions in 2013:
coal (43%), oil (33%), gas (18%), cement (6%), flaring (1%, not shown)



Source: CDIAC; Le Quéré et al 2014; Global Carbon Budget 2014

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%.



Source: CDIAC; Le Quéré et al 2014; Global Carbon Budget 2014

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

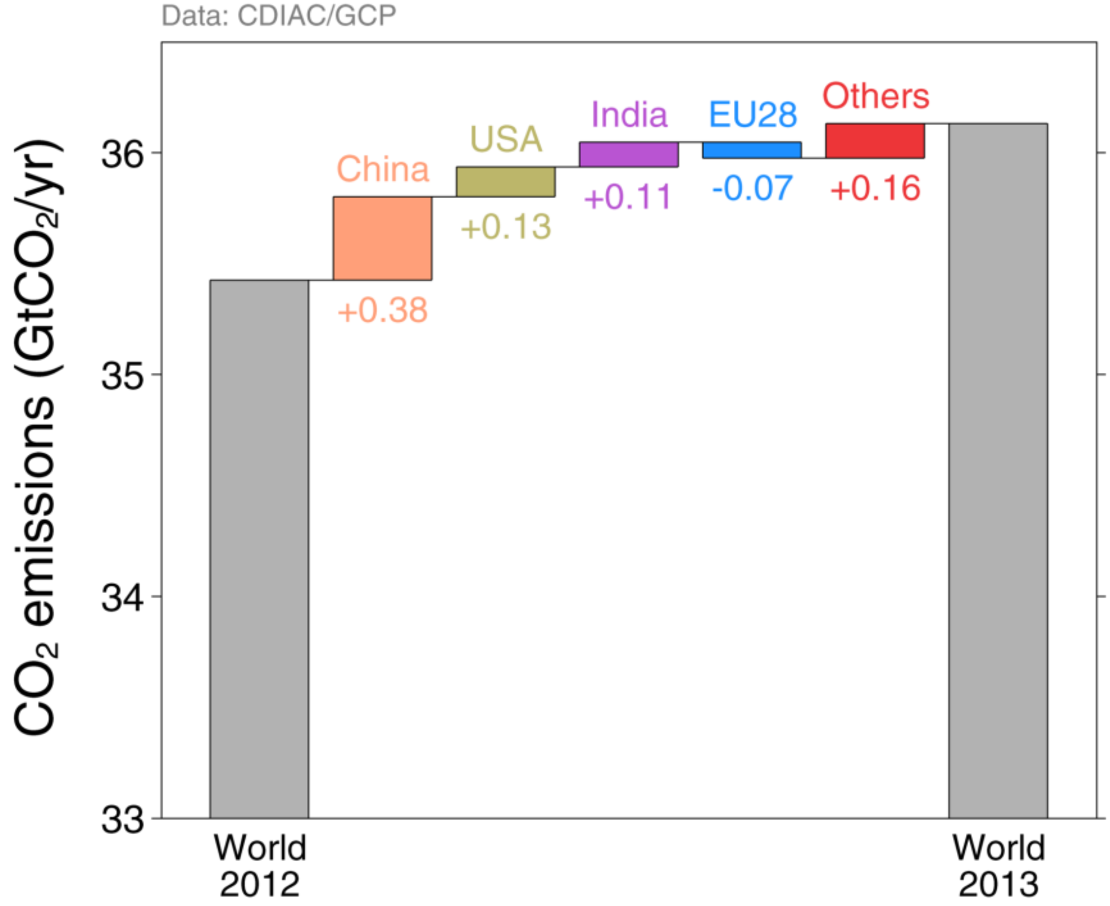
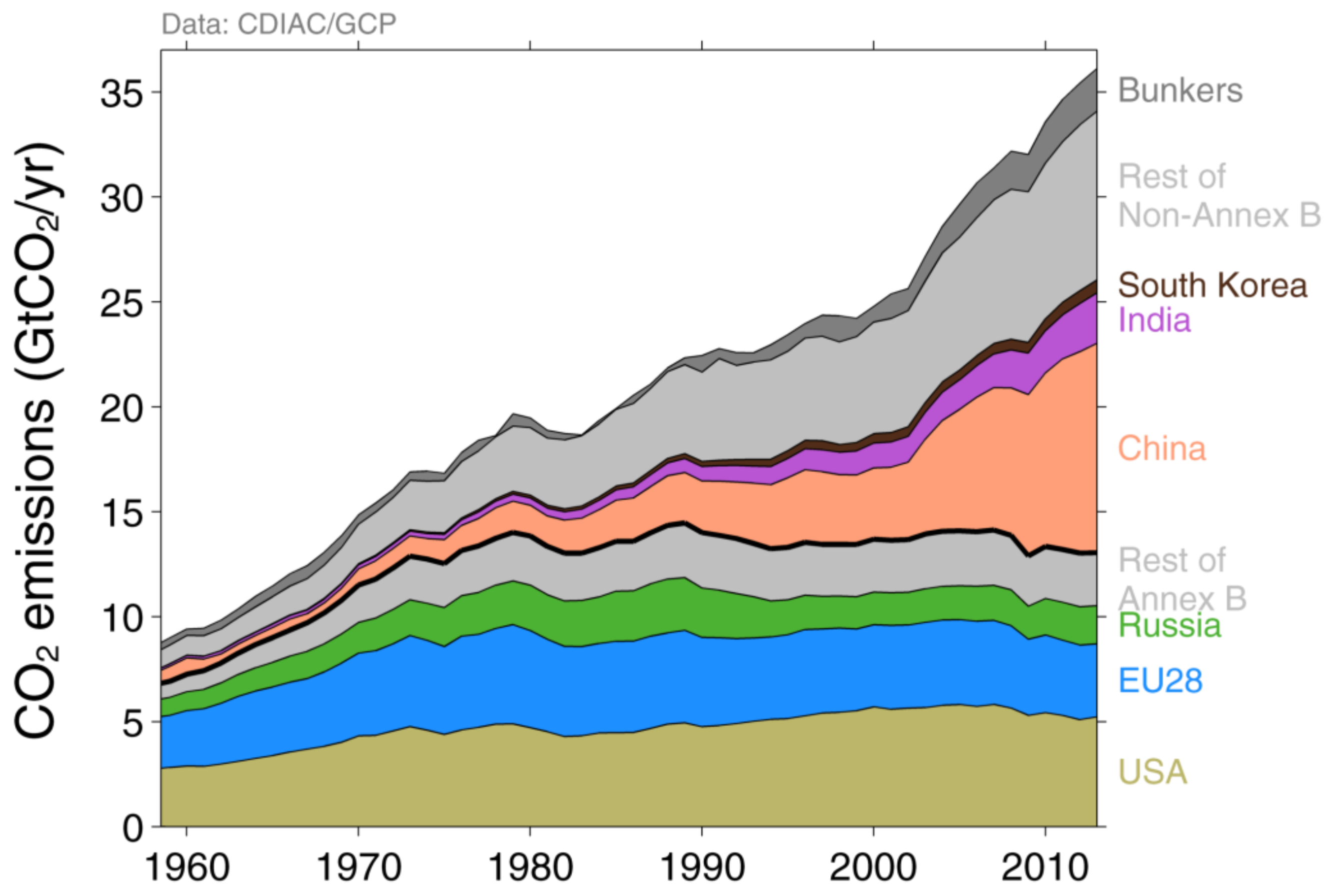


Figure shows the top four countries contributing to emissions changes in 2013

Source: CDIAC; Le Quéré et al 2014; Global Carbon Budget 2014

Breakdown of Global Emissions by Country

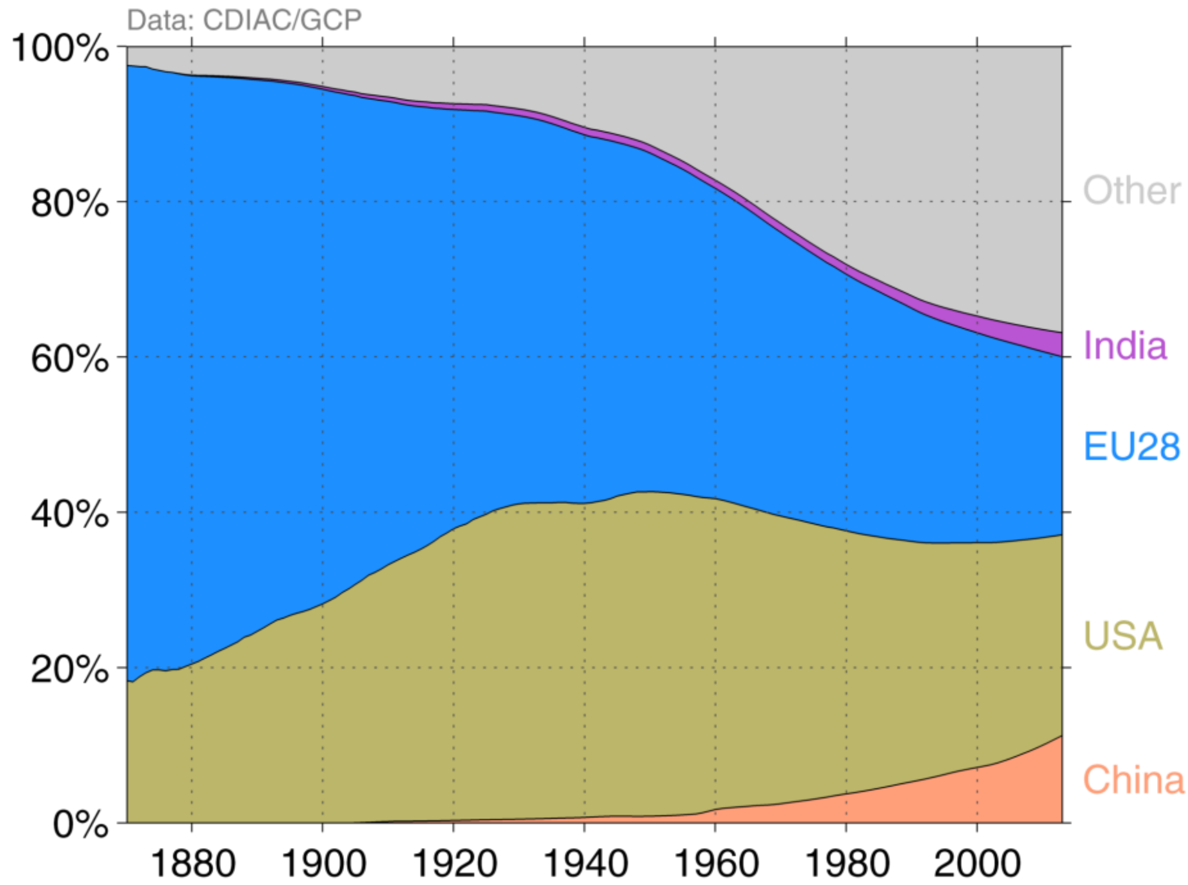
Emissions from Annex B countries have slightly declined since 1990
Emissions from non-Annex B countries have increased rapidly in the last decade



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

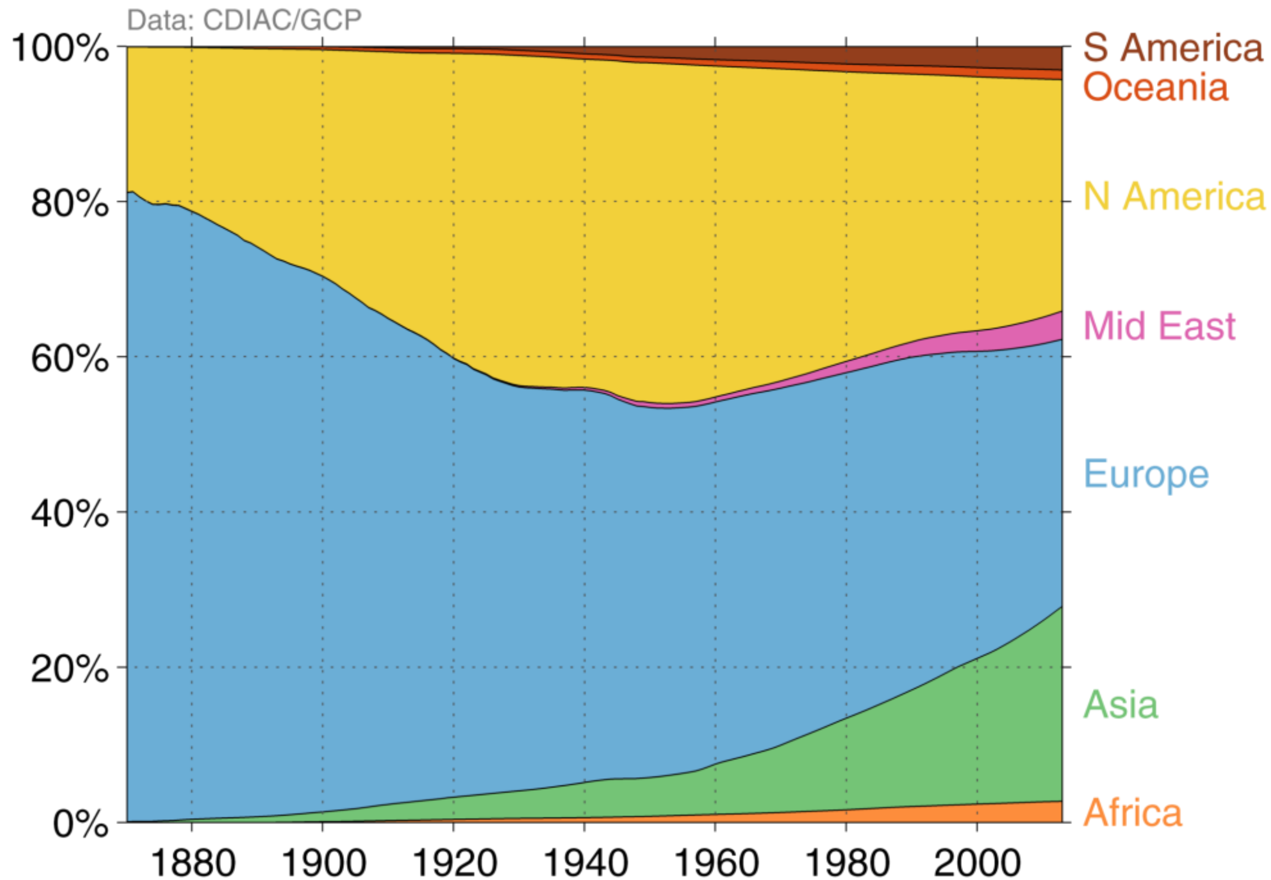
Cumulative emissions from fossil-fuel and cement were distributed (1870–2013):
USA (26%), EU28 (23%), China (11%), and India (3%) covering 63% of the total share



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

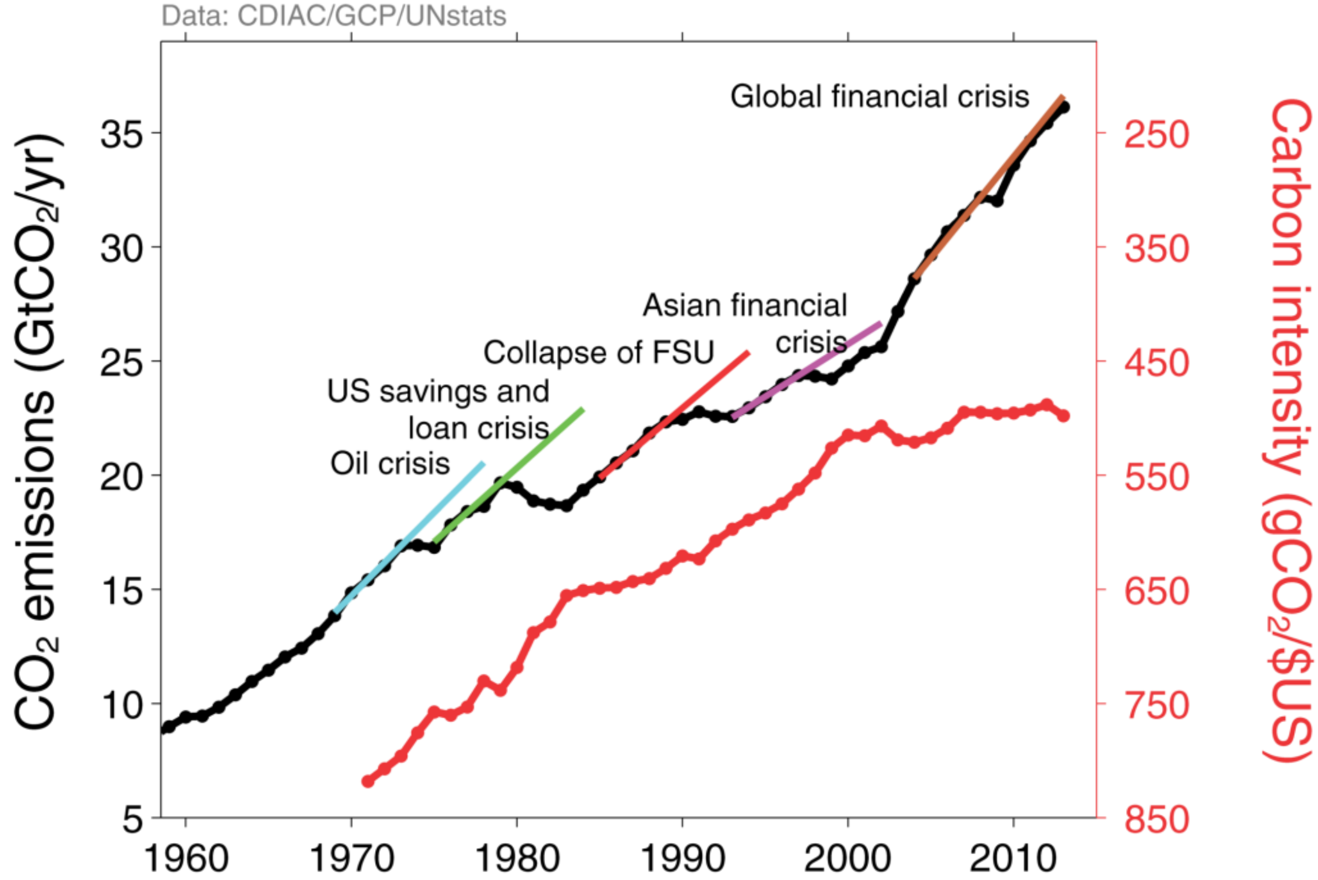
Cumulative emissions from fossil-fuel and cement (1870–2013)
North America and Europe responsible for most cumulative emissions, but Asia growing fast



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

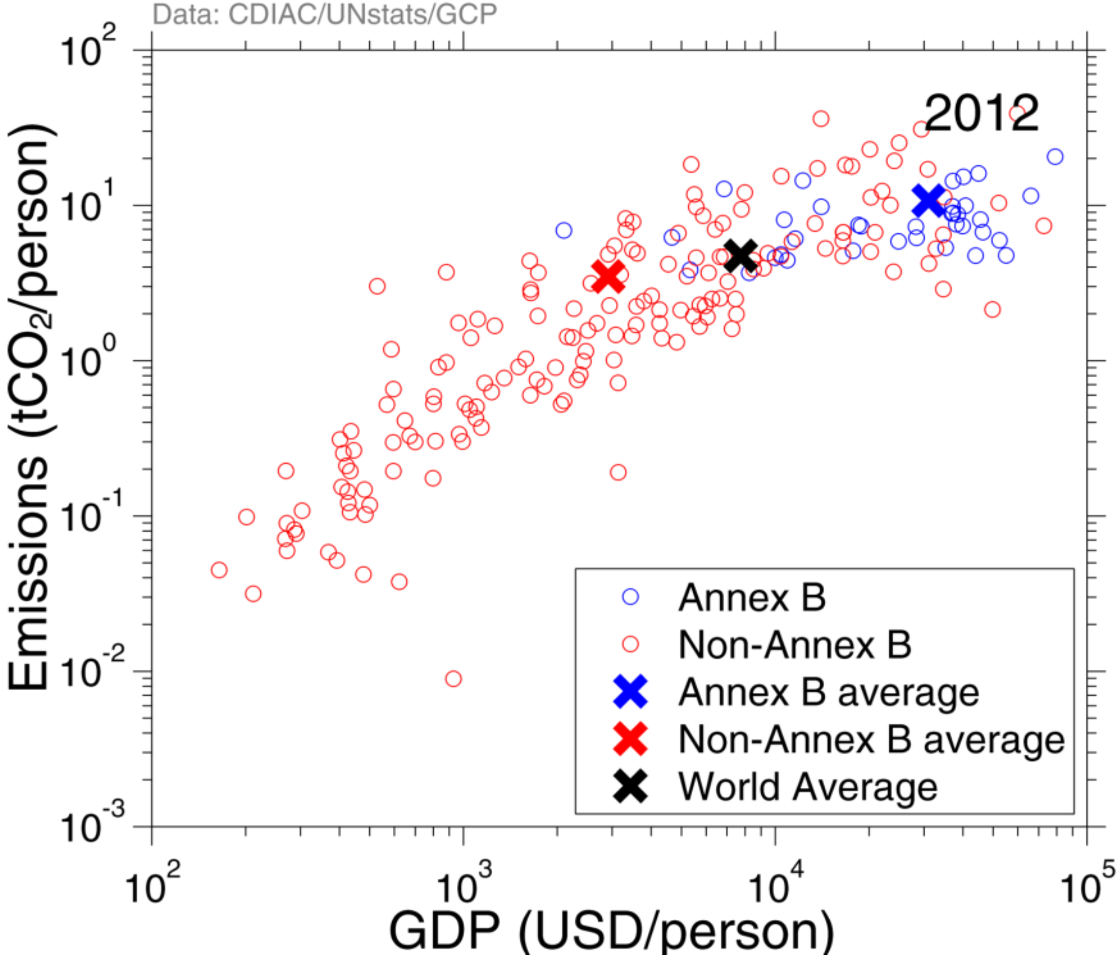
Financial crises have little lasting effect on emissions
Carbon intensity has had minimal improvements since 2000



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

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

Region/Country	Emissions 2013				
	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

Source: CDIAC Data; Le Quéré et al 2014; Global Carbon Project 2014

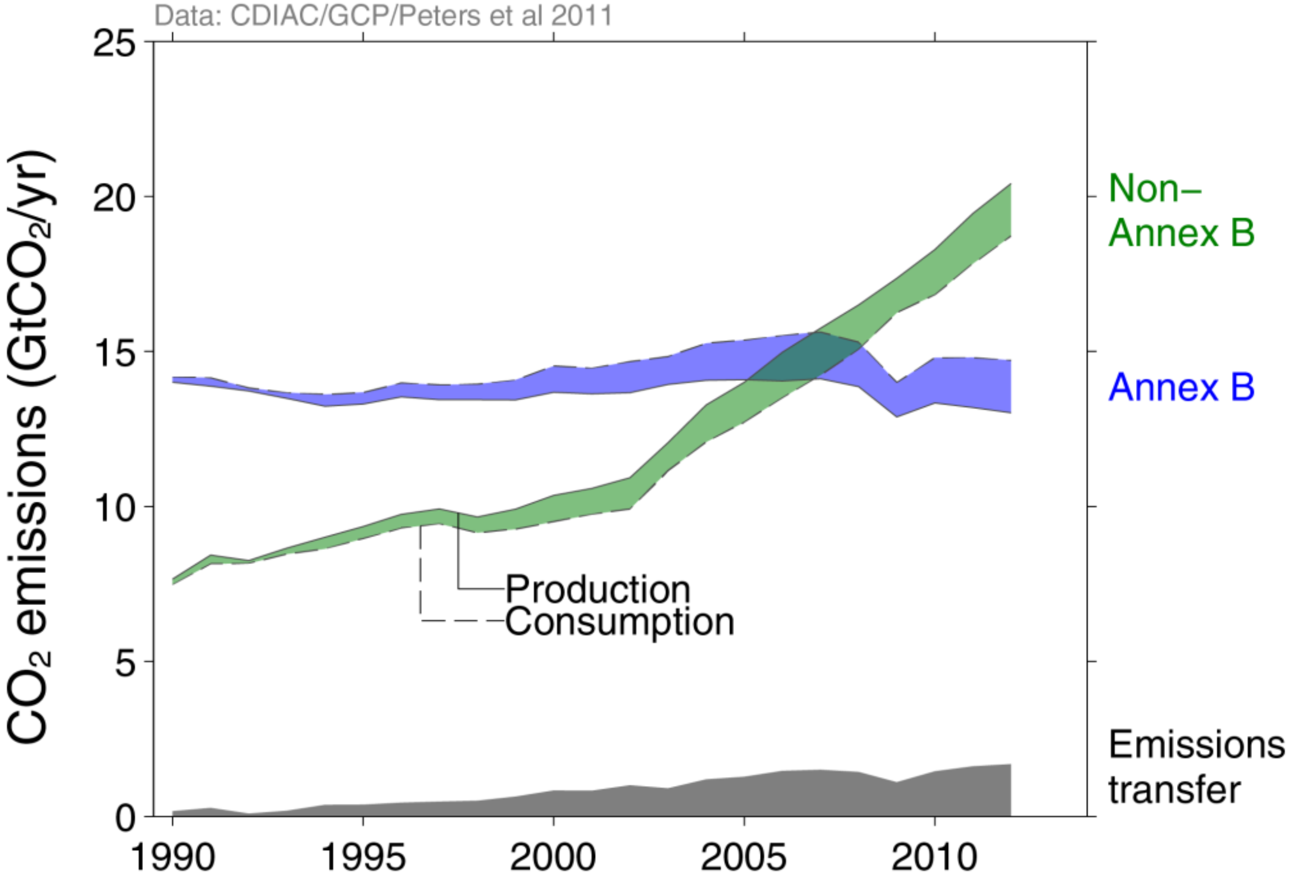
Consumption-based Emissions

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

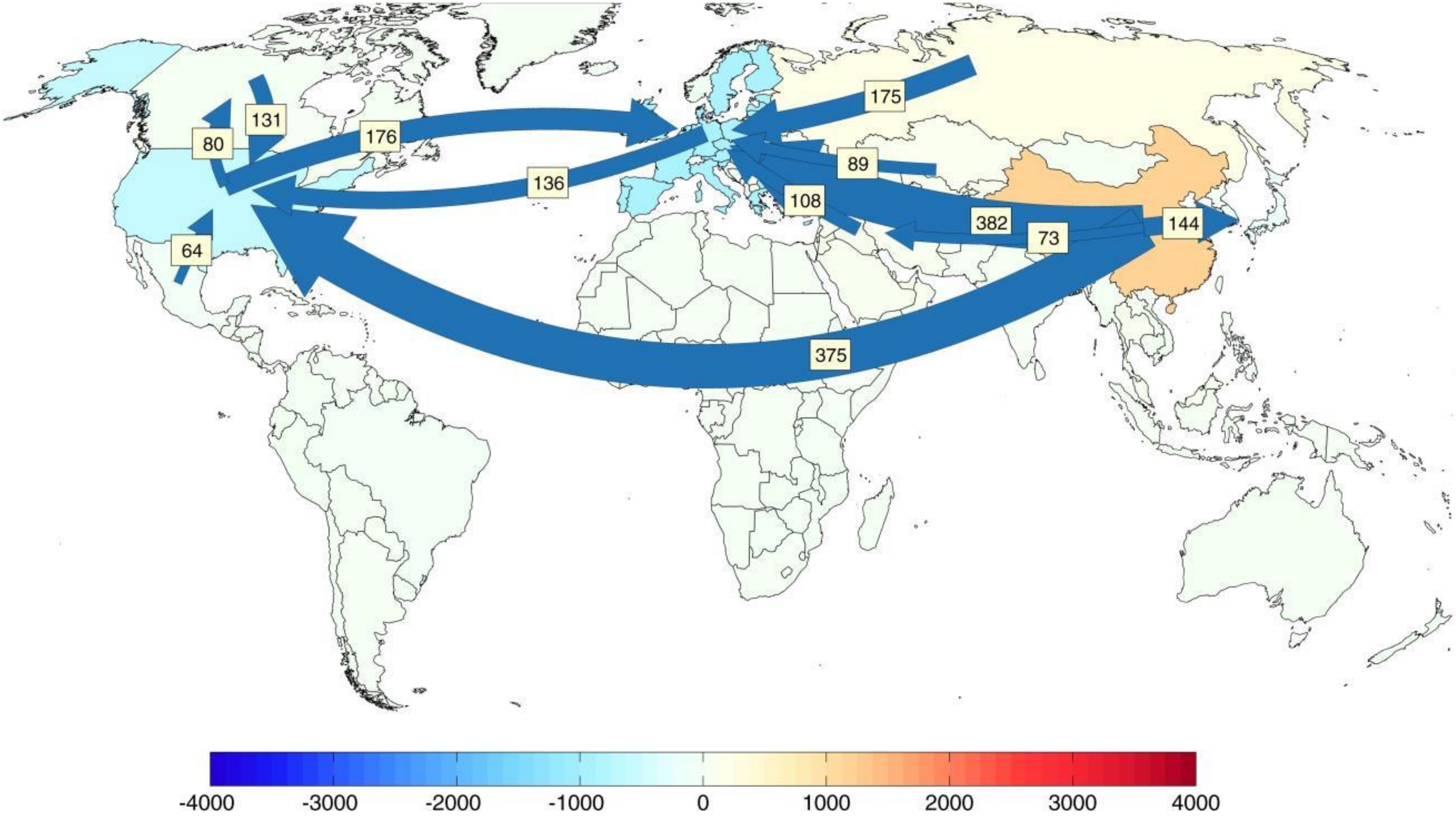


In Annex B, production-based emissions have had a slight decrease while consumption-based emissions have grown at 0.5% per year, and emission transfers have grown at 11% per year

Source: CDIAC; Peters et al 2011; Le Quéré et al 2014; Global Carbon Budget 2014

Major Flows from Production to Consumption

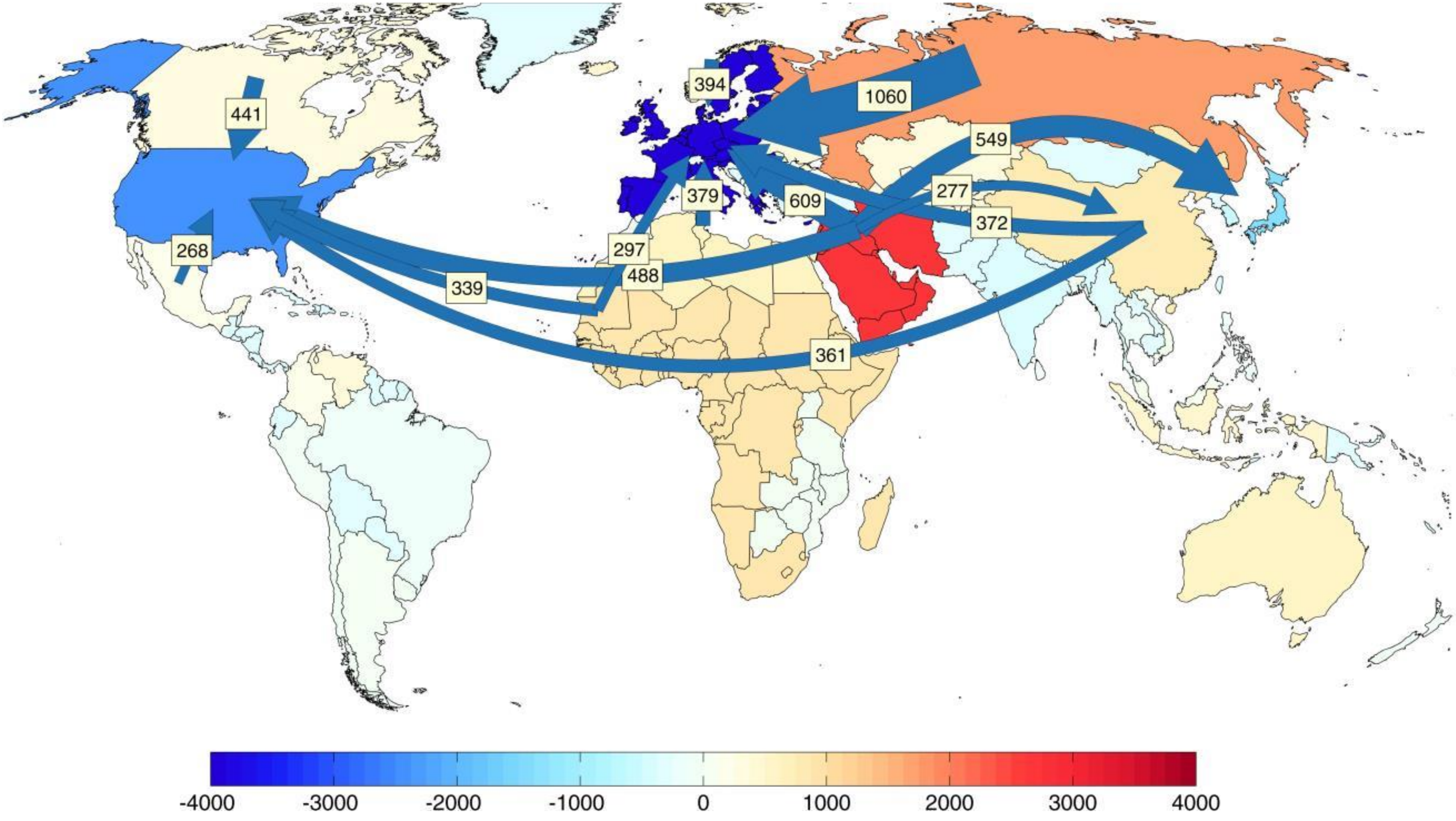
Start of Arrow: fossil-fuel combustion
End of arrow: goods and services consumption



Values for 2007. EU is treated as one region. Units: $MtCO_2$
Source: Peters et al 2012

Major Flows from Extraction to Consumption

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



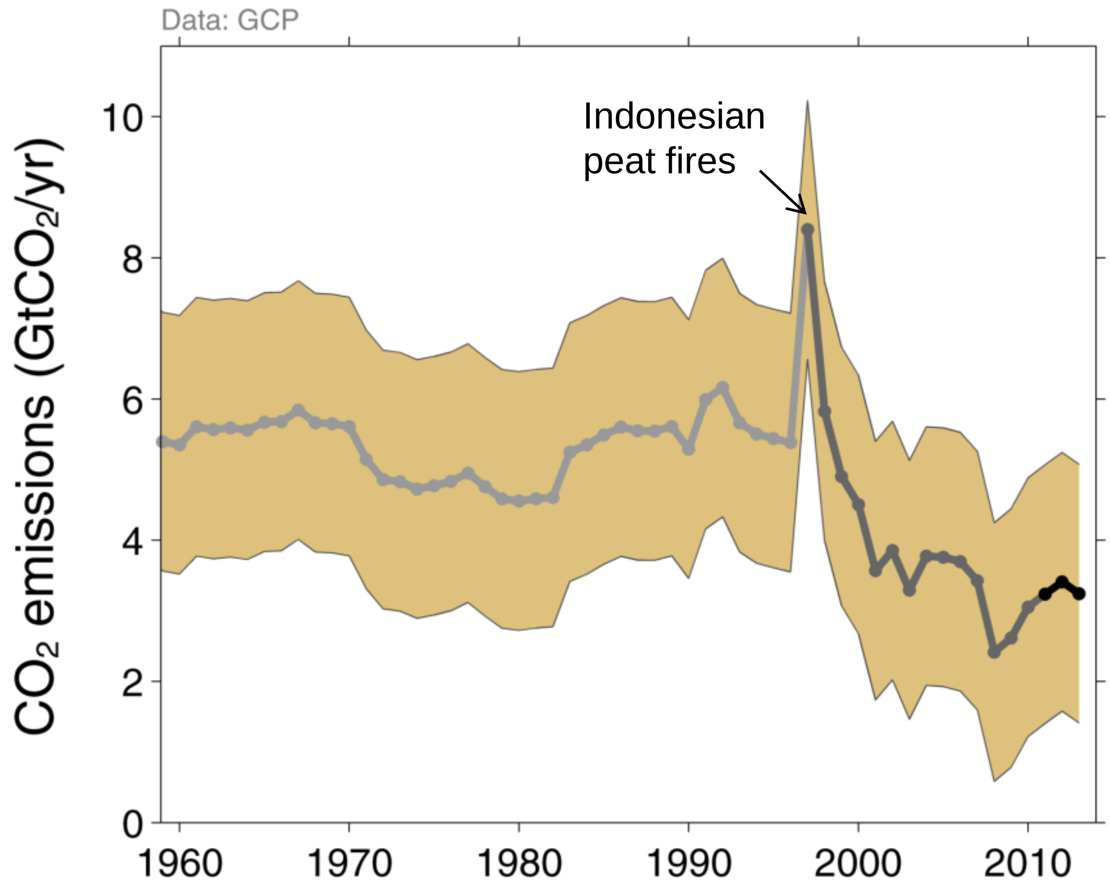
Values for 2007. EU is treated as one region. Units: $MtCO_2$
Source: Andrew et al 2013

GLOBAL CARBON PROJECT

Land-Use Change Emissions

Land-Use Change Emissions

Global land-use change emissions are estimated 3.3 ± 1.8 $GtCO_2$ during 2004–2013
The data suggests a general decrease in emissions since 1990

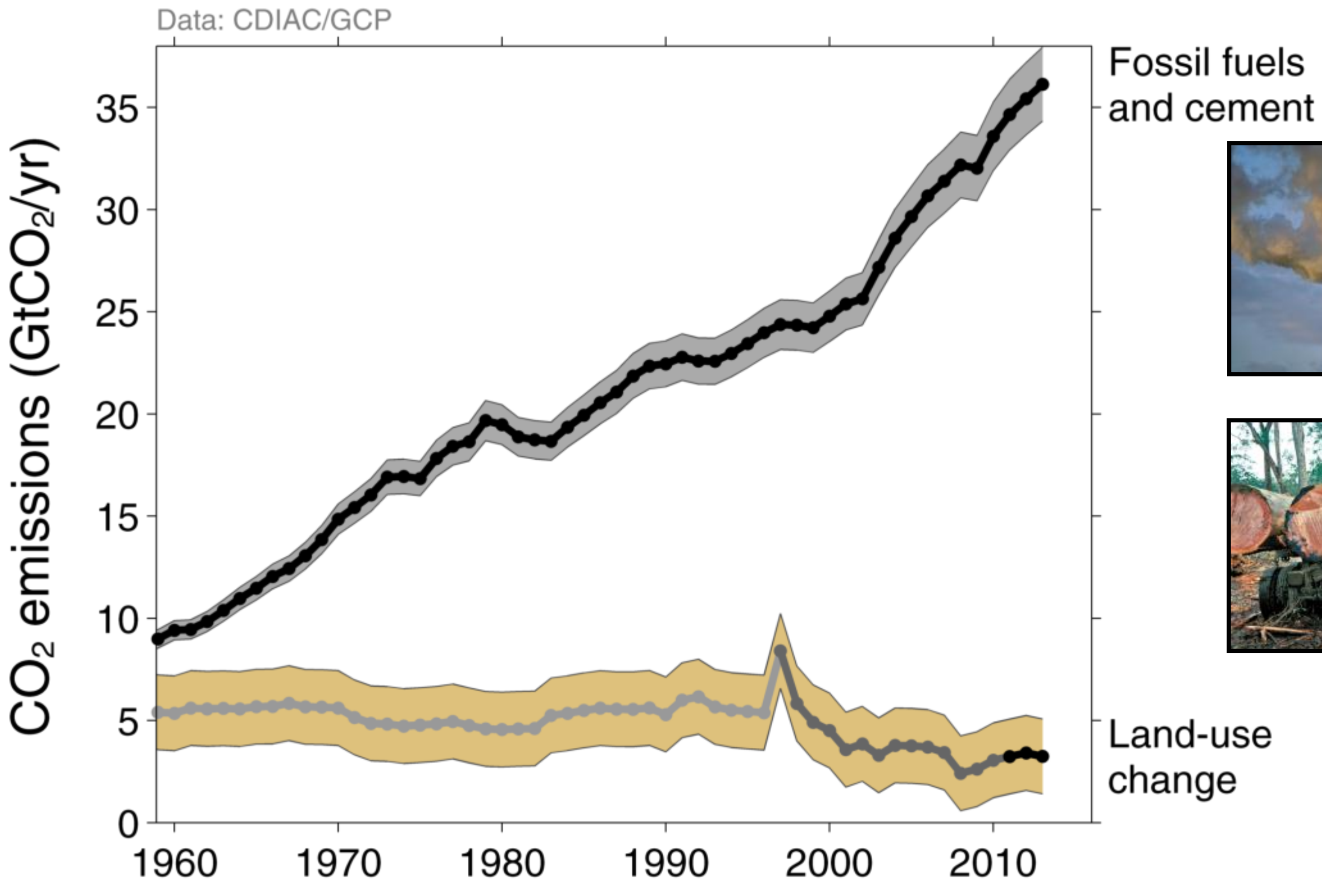


Three different estimation methods have been used, indicated here by different shades of grey
Land-use change also emits CH_4 and N_2O which are not shown here
Source: Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2014; Global Carbon Budget 2014

GLOBAL CARBON PROJECT

Total Global Emissions

Total global emissions: 39.4 ± 3.4 $GtCO_2$ in 2013, 42% over 1990
Percentage land-use change: 36% in 1960, 19% in 1990, 8% in 2013

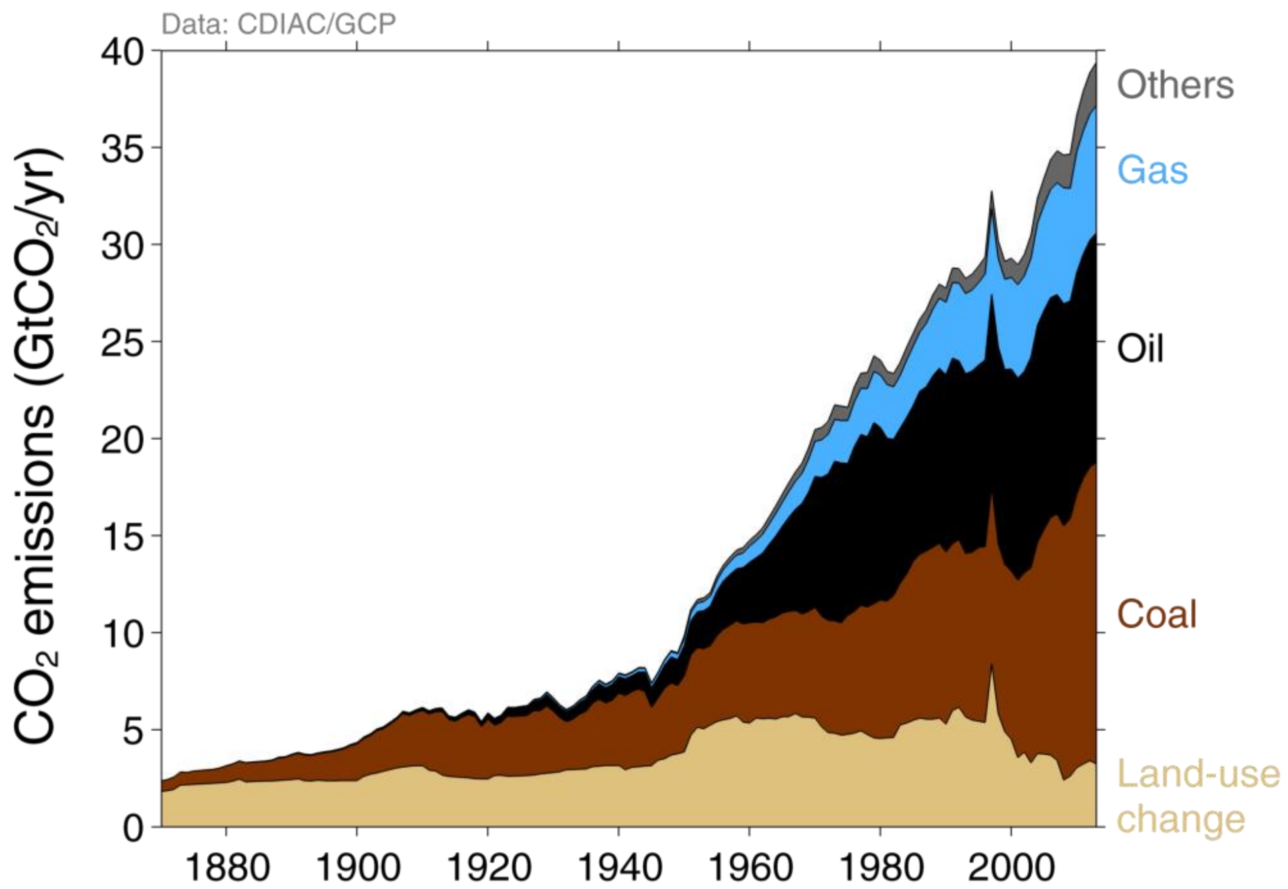


Three different methods have been used to estimate land-use change emissions, indicated here by different shades of grey

Source: CDIAC; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2014; Global Carbon Budget 2014

Total Global Emissions by Source

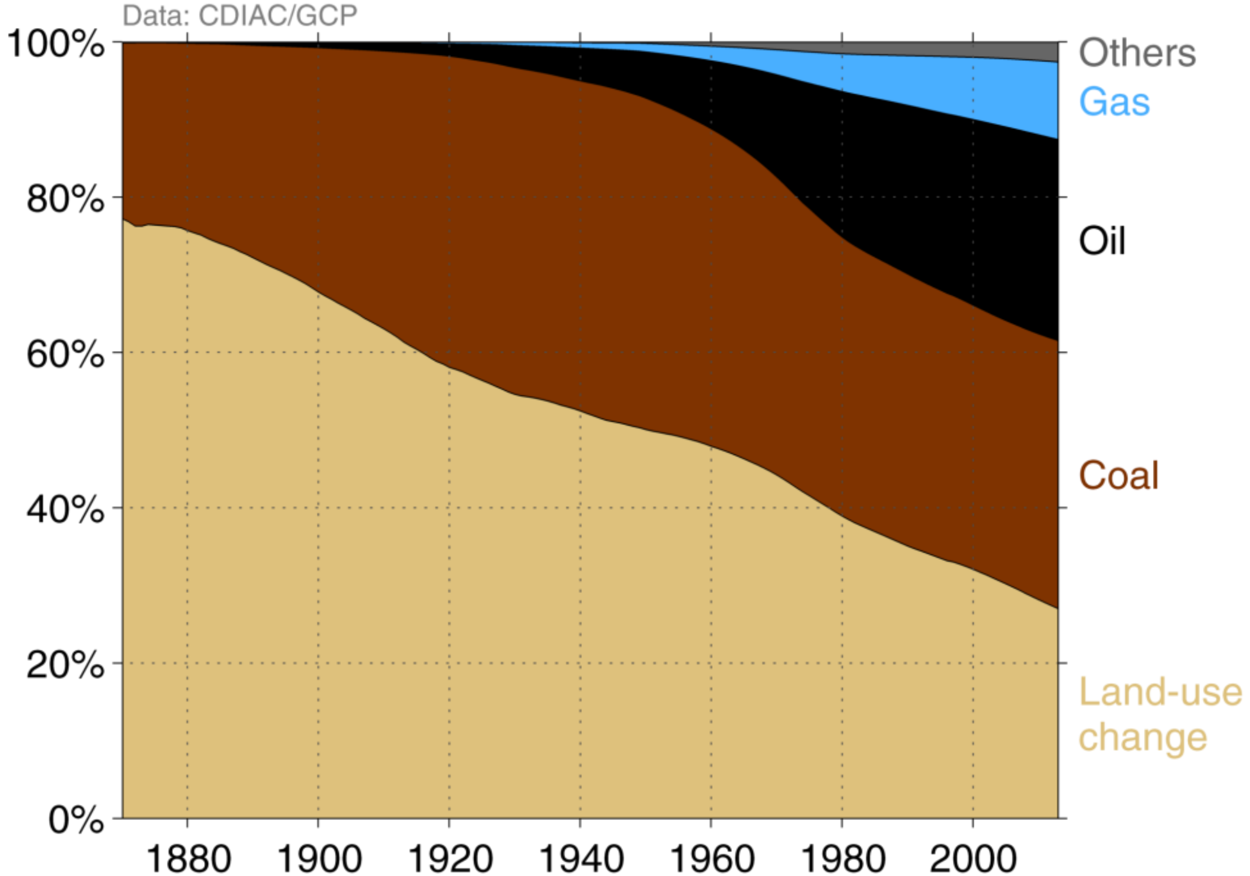
Land-use change was the dominant source of annual CO_2 emissions until around 1950
Coal consumption continues to grow strongly



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 CO_2 Emissions (2004-2013 average)

32.4±1.6 $GtCO_2$/yr 91%

3.3±1.8 $GtCO_2$/yr 9%

+

15.8±0.4 $GtCO_2$/yr
44%

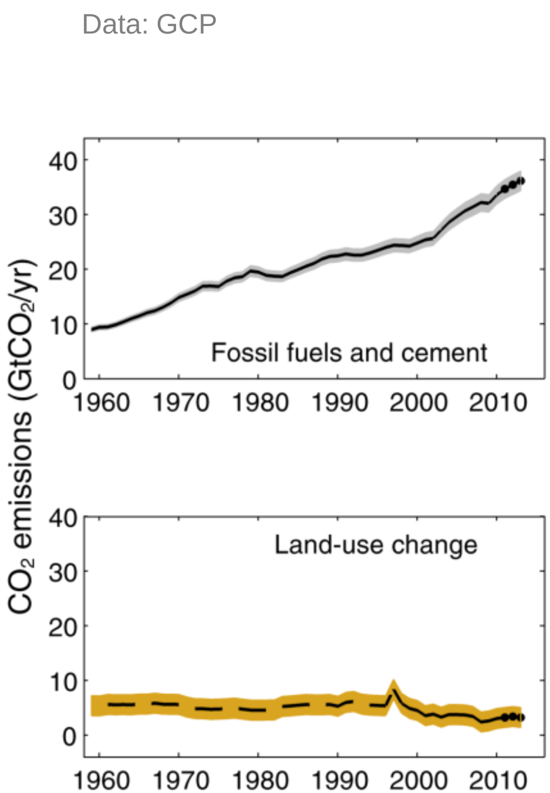
10.5±1.8 $GtCO_2$/yr
29%
Calculated as the residual
of all other flux components

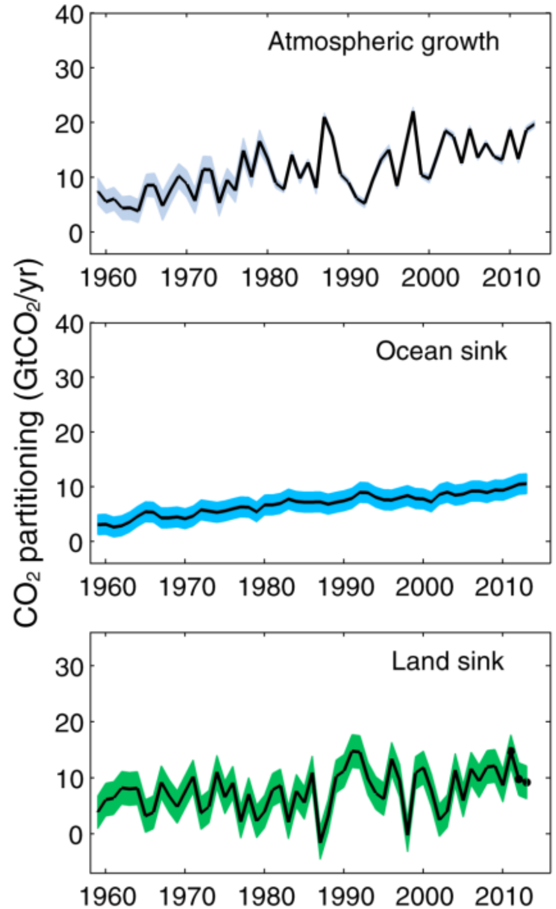
26%
9.4±1.8 $GtCO_2$/yr

Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2014; Global Carbon Budget 2014

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

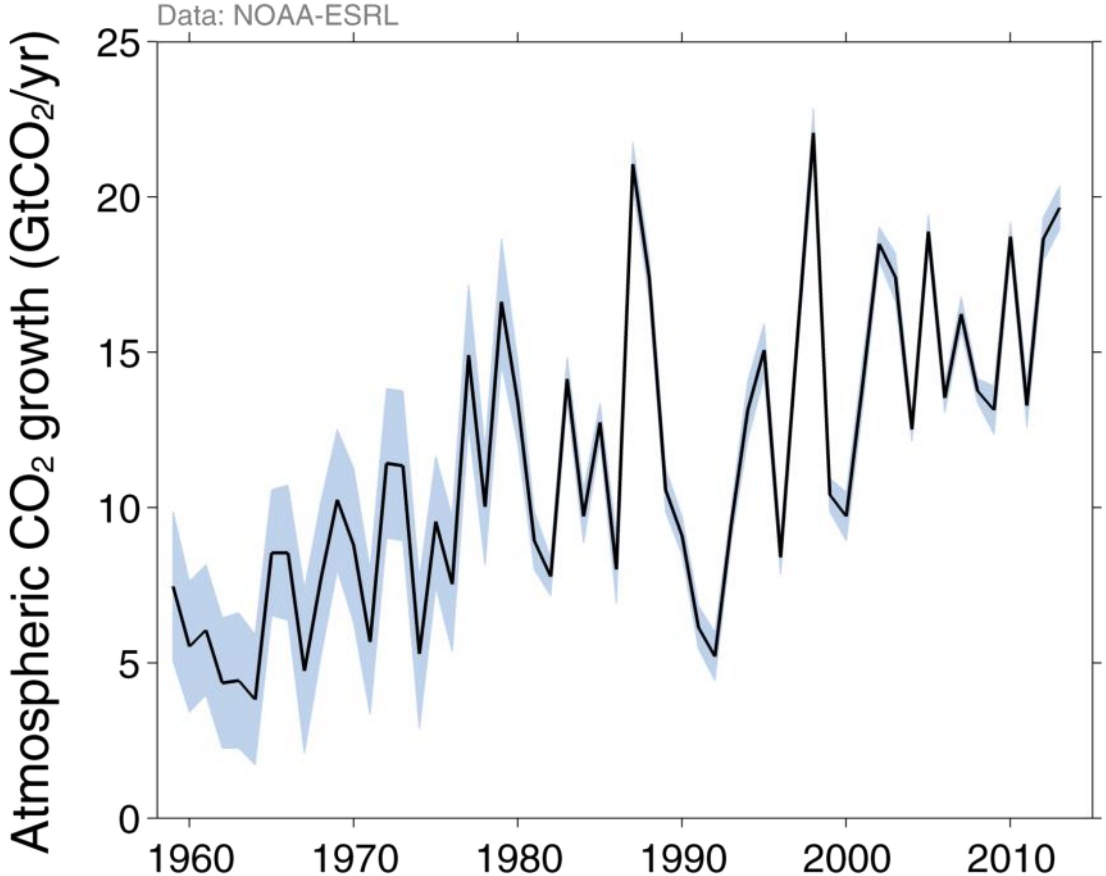




Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2014; Global Carbon Budget 2014

Atmospheric Concentration

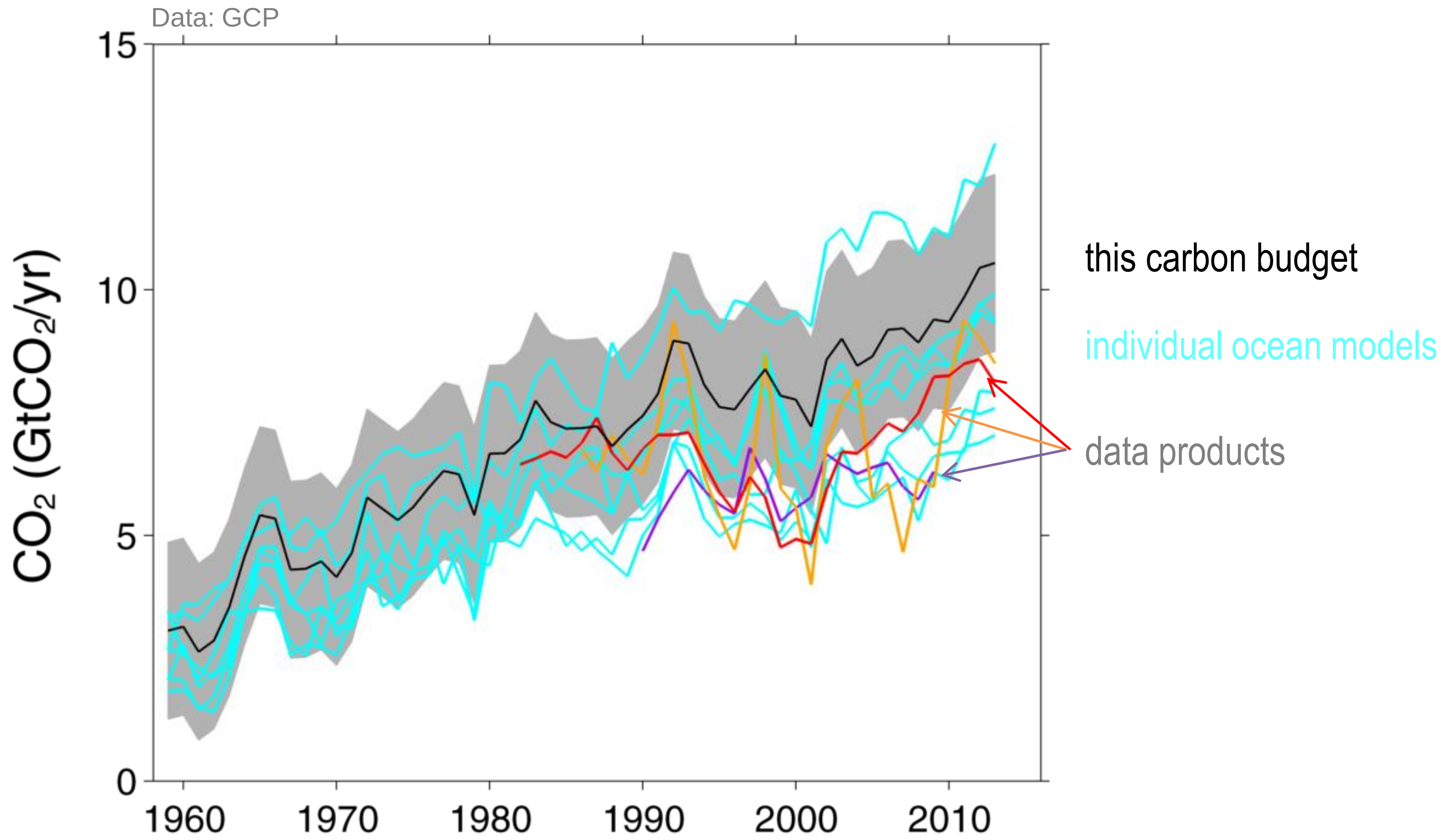
The atmospheric concentration growth rate has shown a steady increase
The growth in 2013 reflects the growth in fossil emissions, with small changes in the sinks



Source: NOAA-ESRL; Global Carbon Budget 2014

Ocean Sink

Ocean carbon sink continues to increase
9.4±1.8 $GtCO_2$/yr for 2004–2013 and 10.5±1.8 $GtCO_2$/yr in 2013

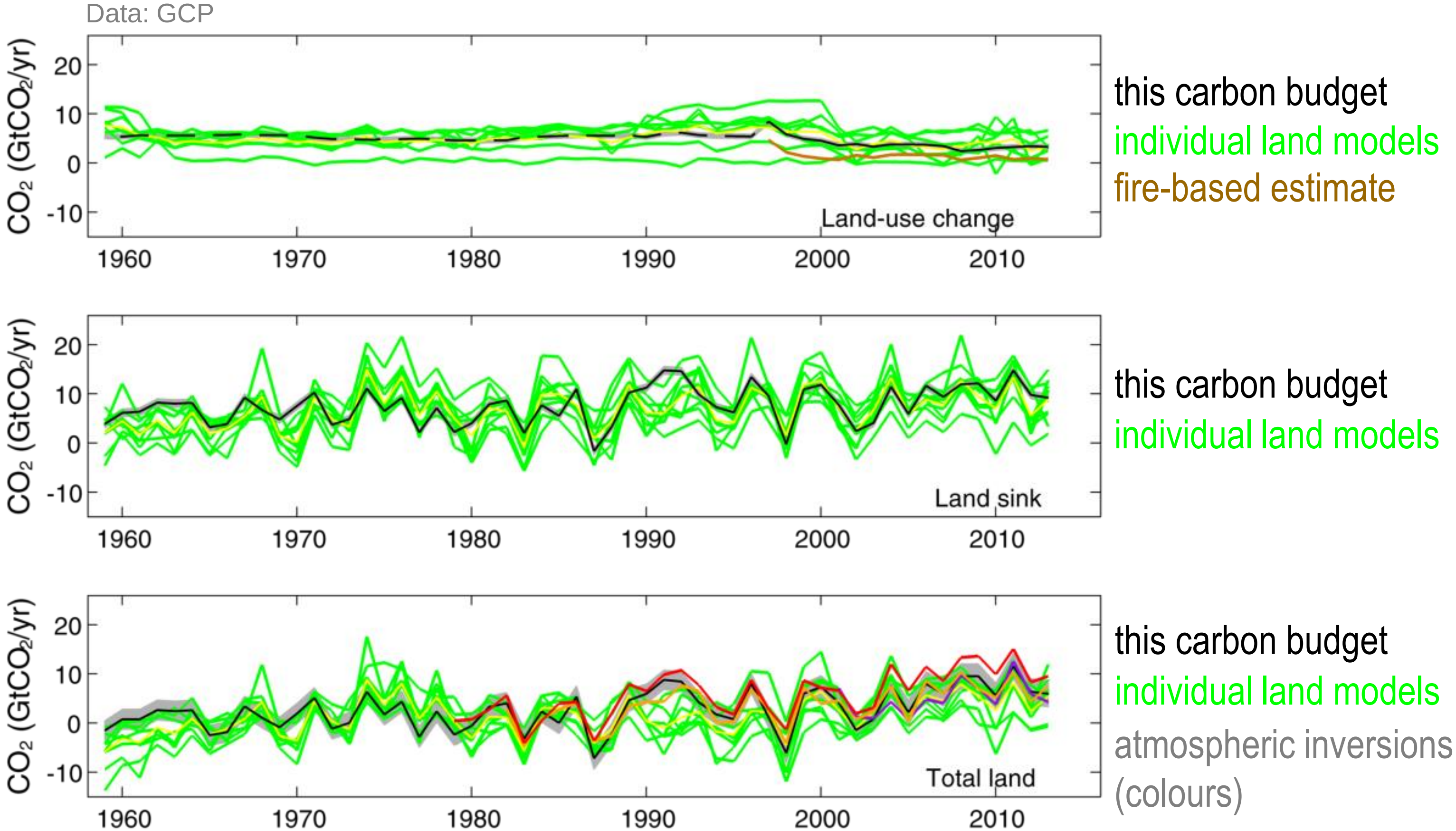


Source: Le Quéré et al 2014; Global Carbon Project 2014

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

Terrestrial Sink

The residual land sink is increasing with time to 9.2±1.8 $GtCO_2$/yr in 2013, with large variability
Total CO_2 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).

References Used in this Presentation

Global Carbon Budget (2014) More information, data sources and data files at http://www.globalcarbonproject.org/carbonbudget/

C. Le Quéré, R. Moriarty, R.M. Andrew, G.P.Peters, P. Ciais, P. Friedlingstein, S.D. Jones, S. Sitch, P.Tans, A. Arneth, T.A. Boden, L. Bopp, Y. Bozec, J.G. Canadell, F. Chevallier, C.E. Cosca, I. Harris, M. Hoppema, R.A. Houghton, J.I. House, J.K Jain, T. Johannessen, E. Kato, R.F. Keeling, V. Kitidis, K. Klein Goldewijk, C. Koven, C. Landa, P. Landschützer, A. Lenton, I.D. Lima, G. Marland, J.T. Mathis, N. Metzl, Y. Nojiri, A. Olsen, T. Ono, W. Peters, B. Pfeil, B. Poulter, M.R. Raupach, P. Regnier, C. Rödenbeck, S. Saito, J.E. Salisbury, U. Schuster, J. Schwinger, R. Séférian, J. Segschneider, T. Steinhoff, B.D. Stocker, A.J. Sutton, T. Takahashi, B. Tilbrook, G.van der Werf, N. Viovy, Y.P. Wang, R. Wanninkhof, A. Wiltshire, N. Zeng (2014) "Global Carbon Budget 2014", *Earth System Science Data Discussions* (in review), http://dx.doi.org/10.5194/essdd-7-521-2014

R. Andrew, G.P. Peters, S. Davis (2013) "Climate Policy and Dependence on Traded Carbon" *Environmental Research Letters*, http://dx.doi.org/10.1088/1748-9326/8/3/034011, DOI:10.1088/1748-9326/8/3/034011

T. Boden, G. Marland, R. Andres (2013) "Global, Regional, and National Fossil-Fuel CO_2 Emissions in Trends", Carbon Dioxide Information Analysis Center **(CDIAC)**, http://cdiac.ornl.gov/trends/emis/meth_reg.html

E. Dlugokencky and P. Tans (2013) "Trends in Atmospheric Carbon Dioxide", National Oceanic & Atmosphere Administration, Earth System Research Laboratory **(NOAA-ESRL)**, http://www.esrl.noaa.gov/gmd/ccgg/trends/

L. Giglio, J.T. Randerson, G.R. van der Werf (2014) "Analysis of daily, monthly, and annual burned area using the fourth-generation global fire emissions database (GFED4)", Journal Geophysical Research Biogeosciences, 118, TS10, 2013, http://onlinelibrary.wiley.com/doi/10.1002/jgrg.20042/abstract, DOI:10.1002/jgrg.20042

R.A. Houghton, J.I. House, J. Pongratz, G.R. van der Werf, R.S. DeFries, M.C. Hansen, C. Le Quéré, N. Ramankutty (2012), "Carbon emissions from land use and land-cover change", http://www.biogeosciences.net/9/5125/2012/bg-9-5125-2012.html, DOI:10.5194/bg-9-5125-2012

F. Joos, R. Roth, J.Fuglestvedt, G. Peters, I. Enting, W. von Bloh, V. Brovkin, E. Burke, M. Eby, N. Edwards, T. Friedrich, T. Frölicher, P. Halloran, P. Holden, C. Jones, T. Kleinen, F. Mackenzie, K. Matsumoto, M. Meinshausen, G.-K. Plattner, A. Reisinger, J. Segschneider, G. Shaffer, M. Steinacher, K. Strassmann, K. Tanaka, A. Timmermann, and A. Weaver (2013) "Carbon dioxide and climate impulse response functions for the computation of greenhouse gas metrics: a multi-model analysis", *Atmospheric Chemistry and Physics*, http://www.atmos-chem-phys.net/13/2793/2013/acp-13-2793-2013.html, DOI: 0.5194/acp-13-2793-2013

S. Khatiwala, T. Tanhua, S. Mikaloff Fletcher, M. Gerber, S. Doney, H. Graven, N. Gruber, G. McKinley, A. Murata, A. Rios, C. Sabine (2013), "Global ocean storage of anthropogenic carbon", *Biogeosciences*, http://www.biogeosciences.net/10/2169/2013/bg-10-2169-2013.html, doi:10.5194/bg-10-2169-2013

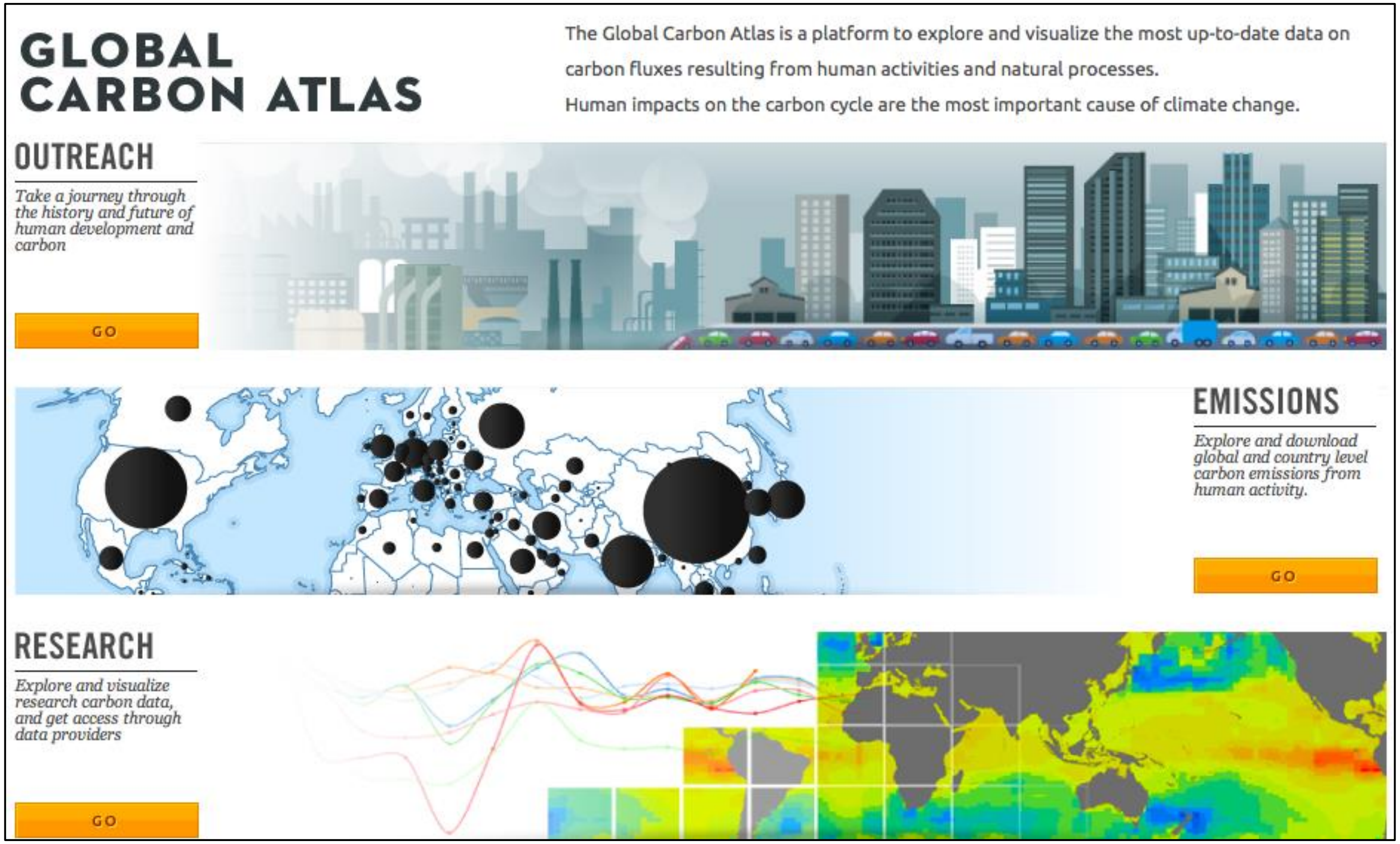
G.P. Peters, J. Minx, C. Weber, O. Edenhofer (2011) "Growth in emission transfers via international trade from 1990 to 2008", *Proceedings of the National Academy of Sciences*, www.pnas.org/content/108/21/8903 DOI:10.1073/pnas.1006388108

G.P. Peters, S. Davis, R. Andrew (2012) "A synthesis of carbon in international trade", *Biogeosciences*, http://www.biogeosciences.net/9/3247/2012/bg-9-3247-2012.html, DOI:10.5194/bg-9-3247-2012

UN (2014) United Nations Statistics Division http://unstats.un.org/unsd/default.htm

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

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