Global Carbon Budget 2012

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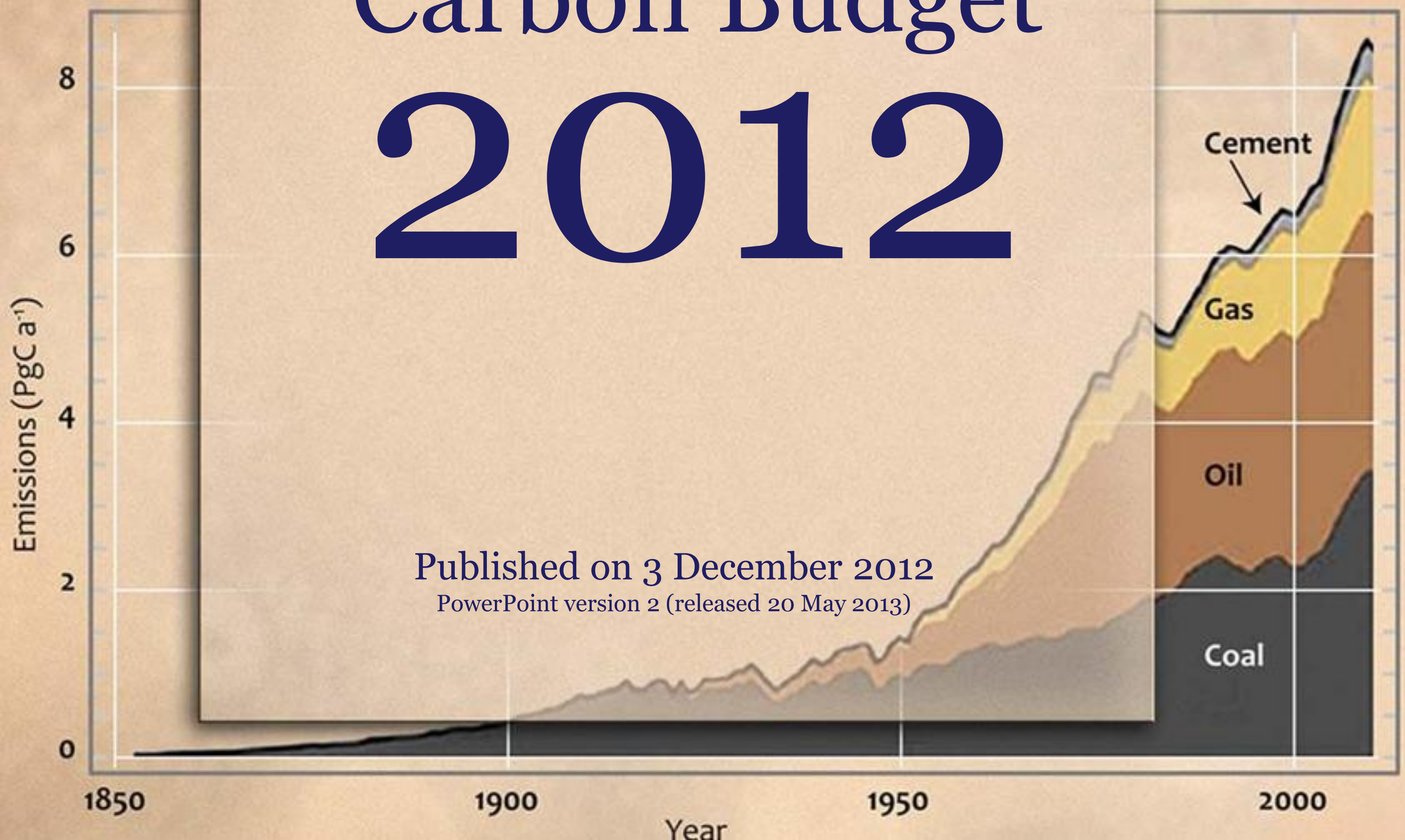

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Publications

opinion & comment

COMMENTARY:

The challenge to keep global warming below 2 °C

Glen P. Peters, Robbie M. Andrew, Tom Boden, Josep G. Canadell, Philippe Ciais, Corinne Le Quéré, Gregg Marland, Michael R. Raupach and Charlie Wilson

The latest carbon dioxide emissions continue to track the high end of emission scenarios, making it even less likely global warming will stay below 2 °C. A shift to a 2 °C pathway requires immediate significant and sustained global mitigation, with a probable reliance on net negative emissions in the longer term.

On-going climate negotiations have recognized a "significant gap" between the current trajectory of global greenhouse-gas emissions and the "likely chance of holding the increase in global average temperature below 2 °C or 1.5 °C above pre-industrial levels"[1]. Here we compare recent trends in carbon dioxide (CO_2) emissions from fossil-fuel combustion, cement production and gas flaring with the primary emission scenarios used by the Intergovernmental Panel on Climate Change (IPCC). Carbon dioxide emissions are the largest contributor to long-term climate change and thus provide a good baseline to assess progress and examine consequences. We find that current emission trends continue to track scenarios that lead to the highest temperature increases. Further delay in global mitigation makes it increasingly difficult to stay below 2 °C.

Long-term emissions scenarios are designed to represent a range of plausible emission trajectories as input for climate change research[2,3]. The IPCC process has resulted in four generations of emissions scenarios[3]: Scientific Assessment 1990 (SA90)[4], IPCC Scenarios 1992 (IS92)[5], Special Report on Emissions Scenarios (SRES)[6], and the evolving Representative Concentration Pathways (RCPs)[7] to be used in the upcoming IPCC Fifth Assessment Report. The RCPs were developed by the research community as a new, parallel process of scenario development, whereby climate models are run using the RCPs while simultaneously socioeconomic and emission scenarios are developed that span the range of the RCPs and beyond[3].

It is important to regularly re-assess the relevance of emissions scenarios in light of changing global circumstances[3,8]. In the past, decadal trends in CO_2 emissions have responded slowly to changes in the underlying emission drivers because of inertia and path dependence in technical, social and political systems[9]. Inertia and path dependence are unlikely to be affected by short-term fluctuations[2,3,9] — such as financial crises[10] — and it is probable that emissions will continue to rise for a period even after global mitigation has started[11]. Thermal inertia and vertical mixing in the ocean, also delay the temperature response to CO_2 emissions[12]. Because of inertia, path dependence and changing global circumstances, there is value in comparing

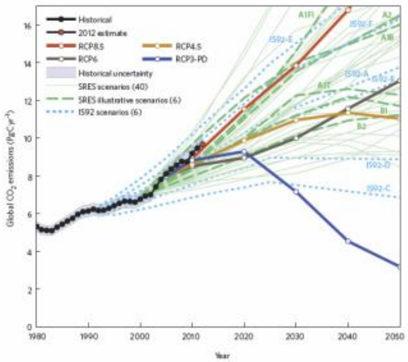

Figure 1 | Estimated CO_2 emissions over the past three decades compared with the IS92, SRES and the RCPs. The SA90 data are not shown, but the most relevant (SA90-A) is similar to IS92-A and IS92-F. The uncertainty in historical emissions is ±5% (one standard deviation). Scenario data is generally reported at decadal intervals and we use linear interpolation for intermediate years.

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Open Access Earth System Science Data Discussions

The global carbon budget 1959–2011

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More information, data sources and data files at

www.globalcarbonproject.org

Unit Conversions

All the data is shown in PgC

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

1 kg carbon (C) = 3.67 kg carbon dioxide (CO_2)

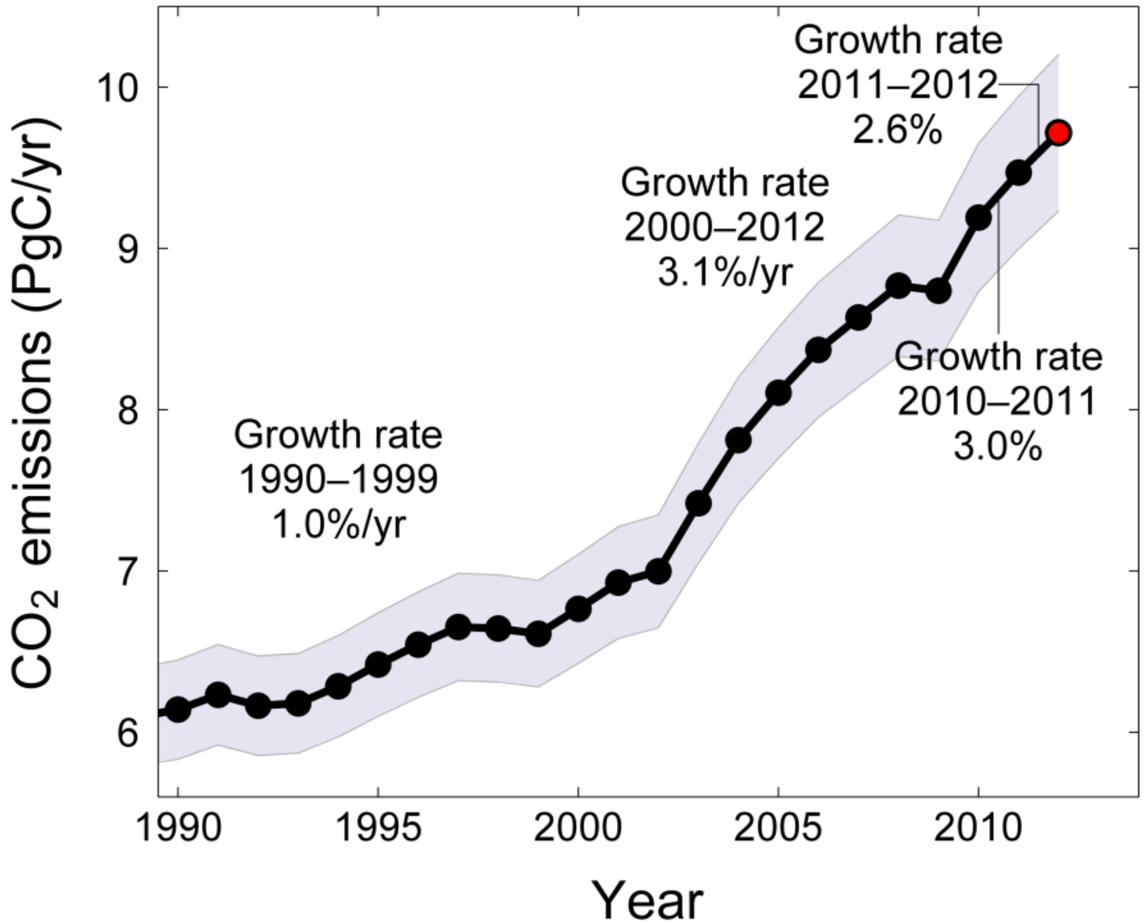
1 PgC = 3.67 billion tonnes CO_2 = 3.67 $GtCO_2$

Observed Emissions versus Emission Scenarios

Fossil and Cement Emissions

Global fossil and cement emissions: 9.5±0.5PgC in 2011, 54% over 1990

Projection for 2012: 9.7±0.5PgC, 58% over 1990



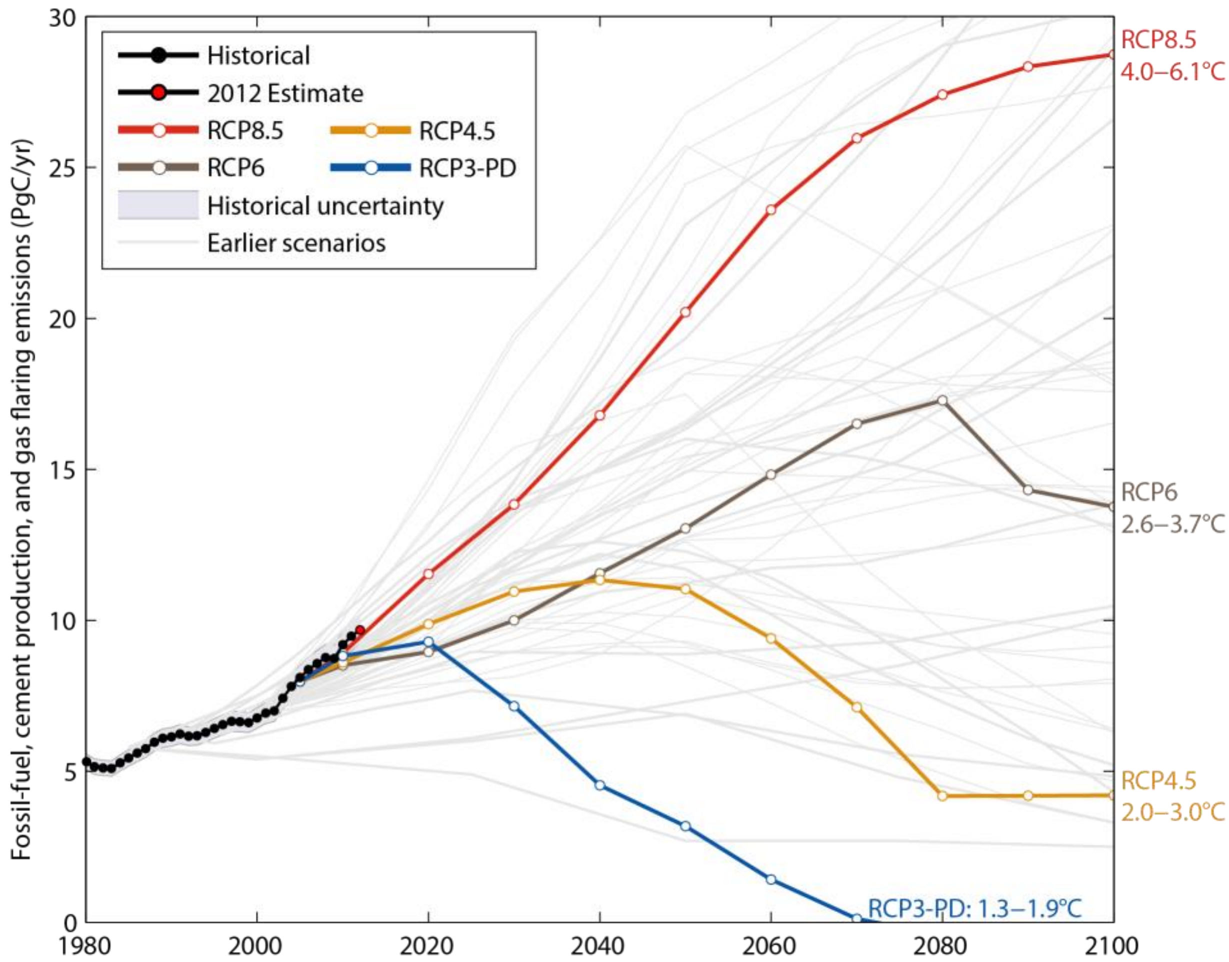
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

Source: Peters et al. 2012a; Le Quéré et al. 2012; CDIAC Data; Global Carbon Project 2012

Observed Emissions and Emission Scenarios

Emissions are heading to a 4.0-6.1ºC "likely" increase in temperature

Large and sustained mitigation is required to keep below 2ºC

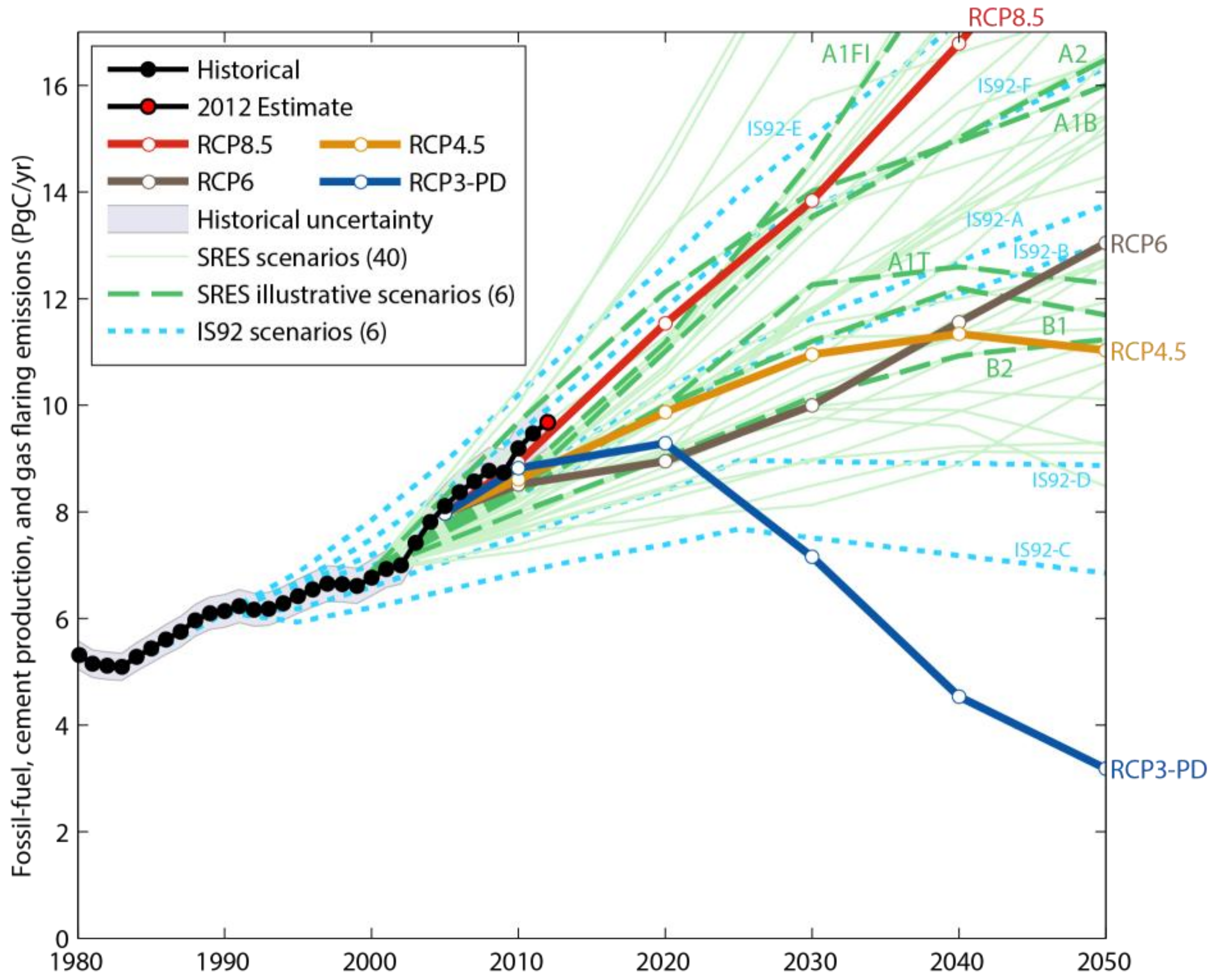


Linear interpolation is used between individual datapoints

Source: Peters et al. 2012a; Global Carbon Project 2012;

Observed Emissions and Emission Scenarios

The IPCC has been associated with four generations of emission scenarios

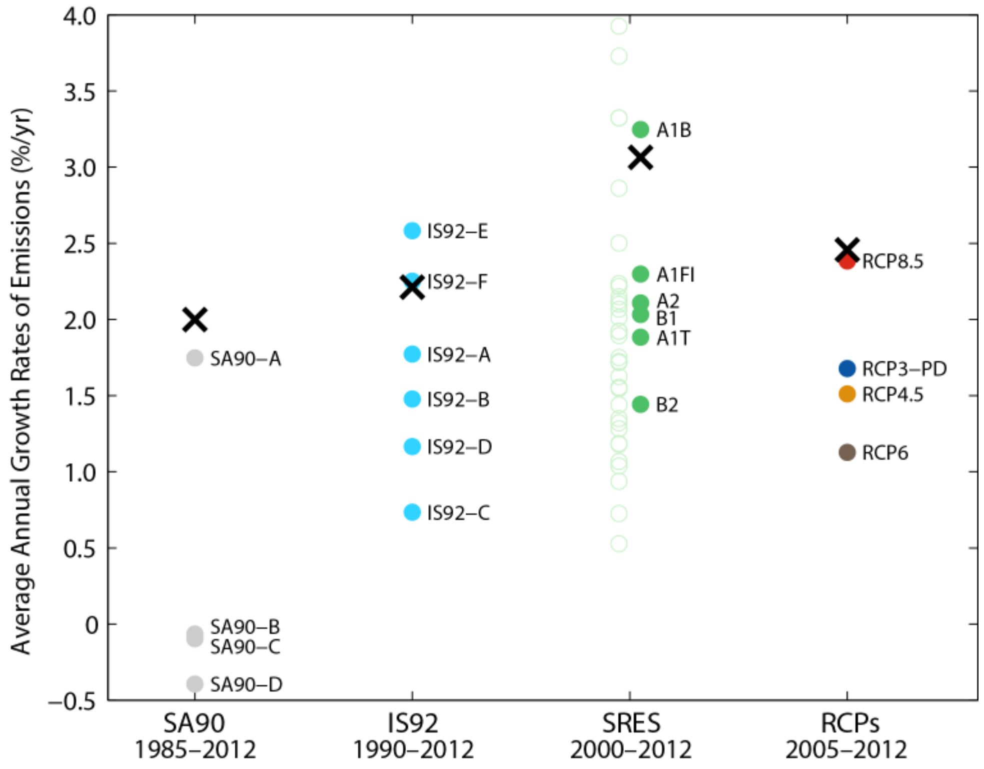


Main periods of use: SA90 (1990-1992, not shown), IS92 (1992-2000), SRES (2000-2012), RCPs (2012+)

Source: Peters et al. 2012a; Global Carbon Project 2012

Observed Emissions and Emission Scenarios

Observed emissions (**X**) continue to track the top-end of all scenarios (●)



Crosses (**X**) : Historical emissions growth over the period in horizontal axis

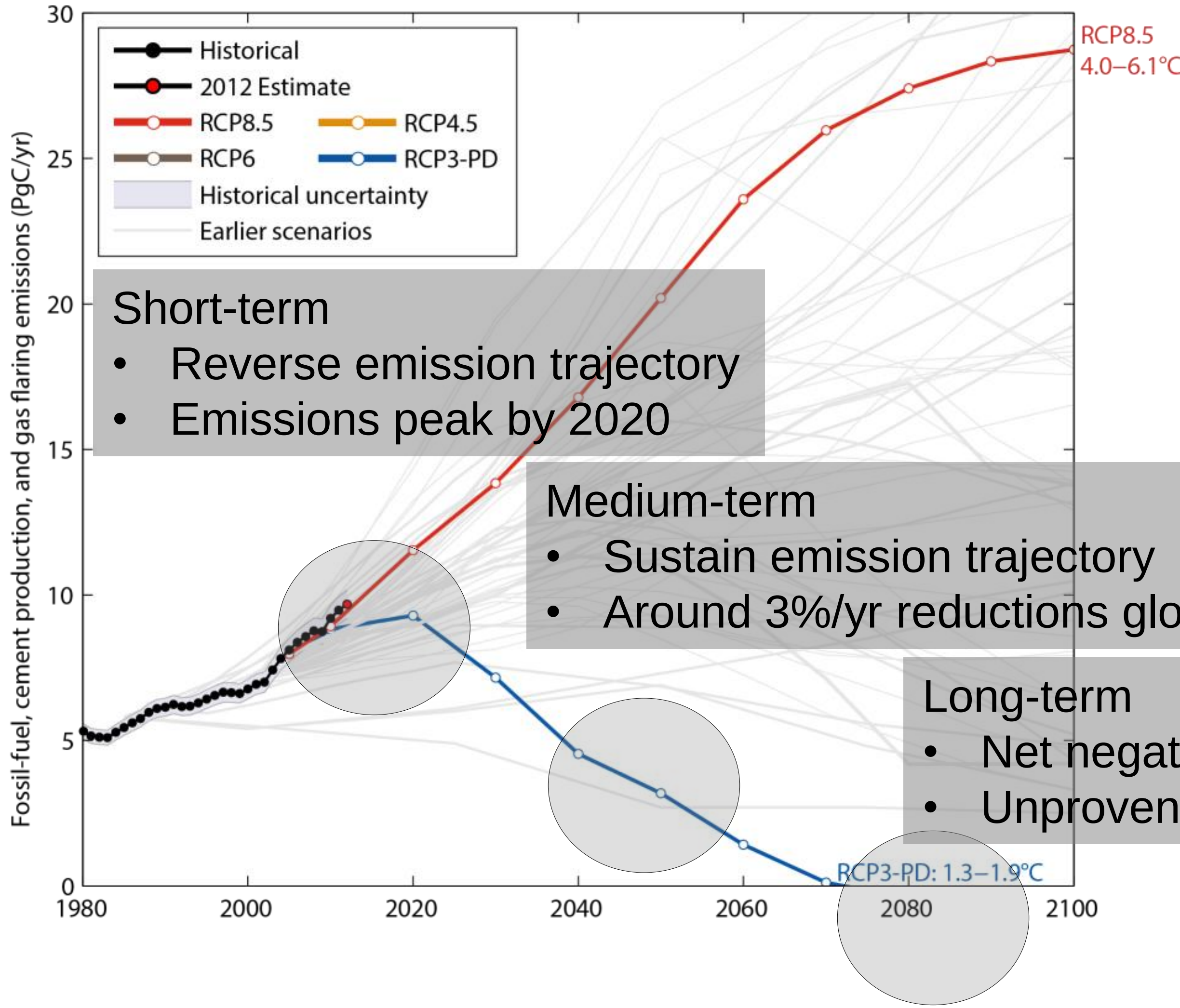
Circles (●) : Scenario emissions growth over the period in horizontal axis

Source: Peters et al. 2012a; Global Carbon Project 2012

Keeping below 2ºC

Challenges to keep below 2ºC

An emission pathway with a “likely chance” to keep the temperature increase below 2ºC has significant challenges



Short-term
- Reverse emission trajectory
- Emissions peak by 2020

Medium-term
- Sustain emission trajectory
- Around 3%/yr reductions globally

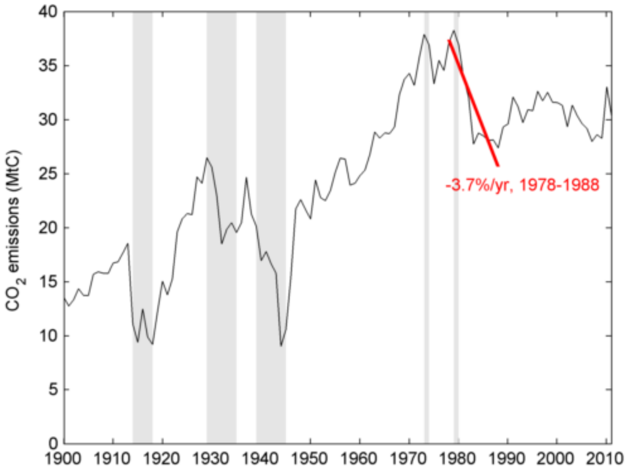
Long-term
- Net negative emissions
- Unproven technologies

Source: Peters et al. 2012a; Global Carbon Project 2012

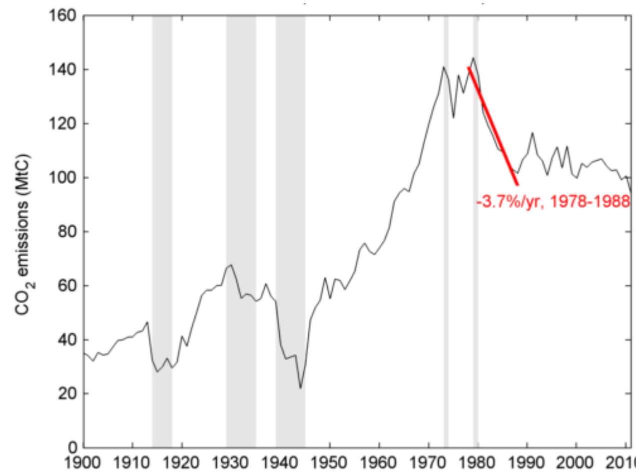
Previous CO_2 emission reductions

Without climate policies, some countries have reduced emissions at 1-5%/yr

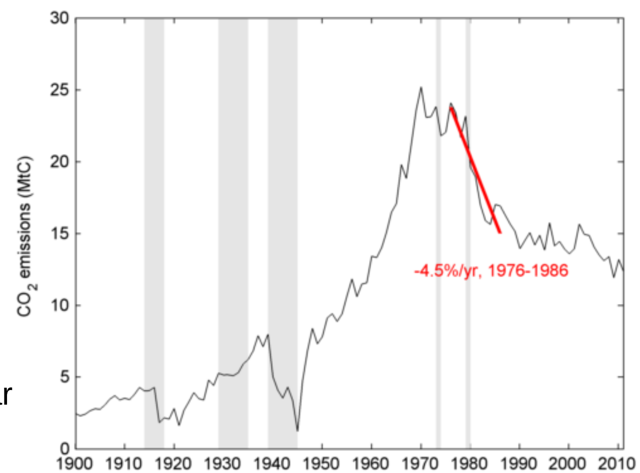
Repeating with modern low-carbon technologies can "kick-start" mitigation



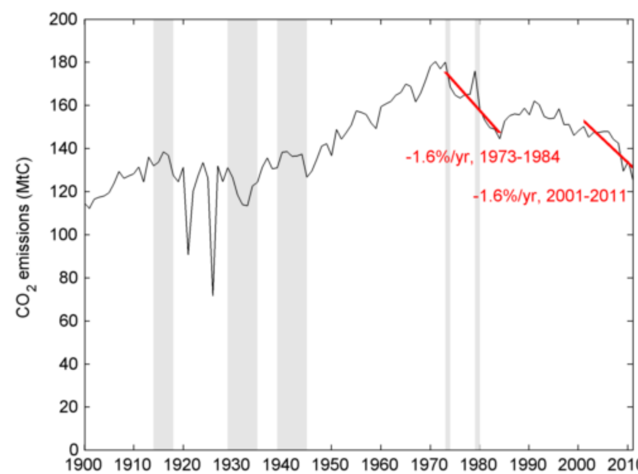
Belgium
Increased Nuclear
Reduced Oil



France
Increased Nuclear
Reduced Oil & Coal



Sweden
Increased Nuclear
Reduced Oil



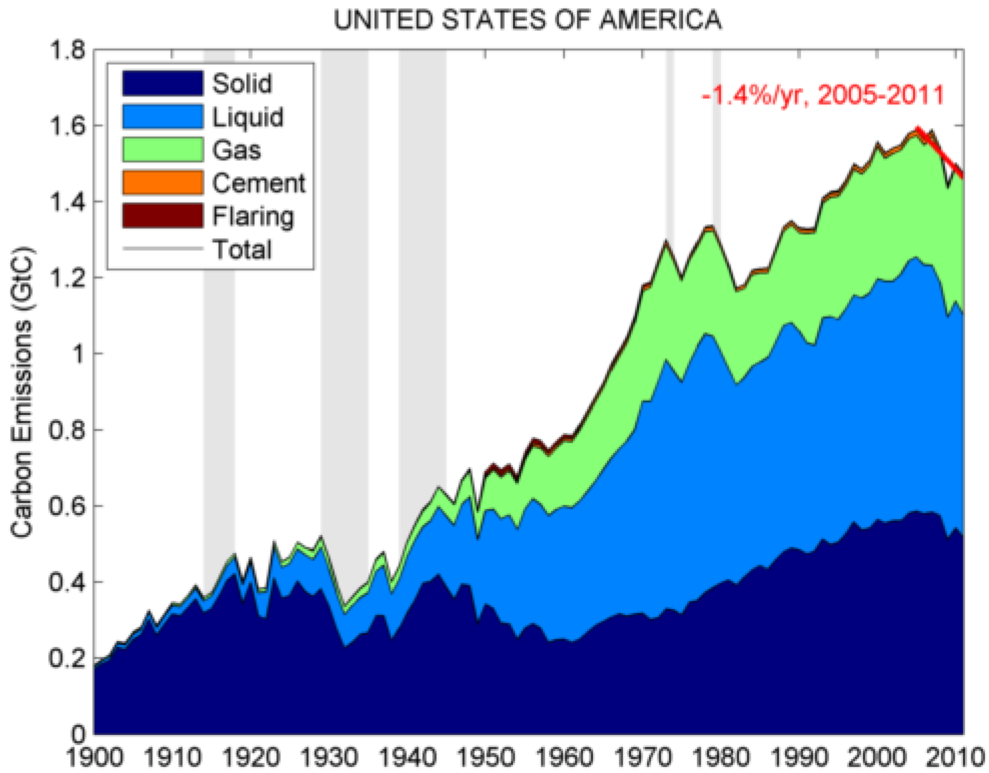
United Kingdom
Coal to gas
Reduced Oil
Increased Nuclear

Grey areas are: World War I, Great Depression, World War II, oil shocks

Source: Peters et al. 2012a; CDIAC Data; Global Carbon Project 2012

The recent shift from coal to gas in the USA

The recent shift from coal to gas in the US could "kick start" mitigation
To keep below 2ºC requires a shift to technologies with lower emissions



Grey areas are: World War I, Great Depression, World War II, oil shocks

Source: Peters et al. 2012a; CDIAC Data; Global Carbon Project 2012

Fossil and Cement Emissions

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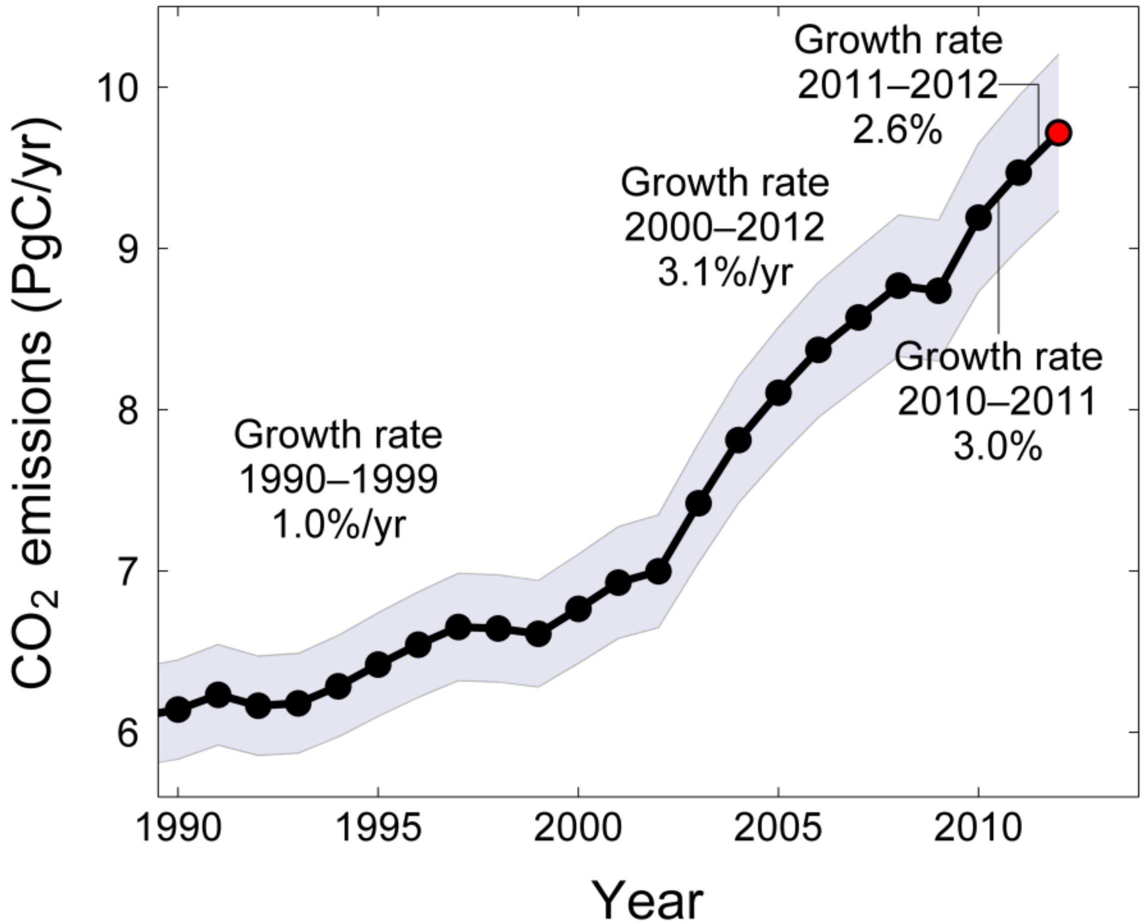


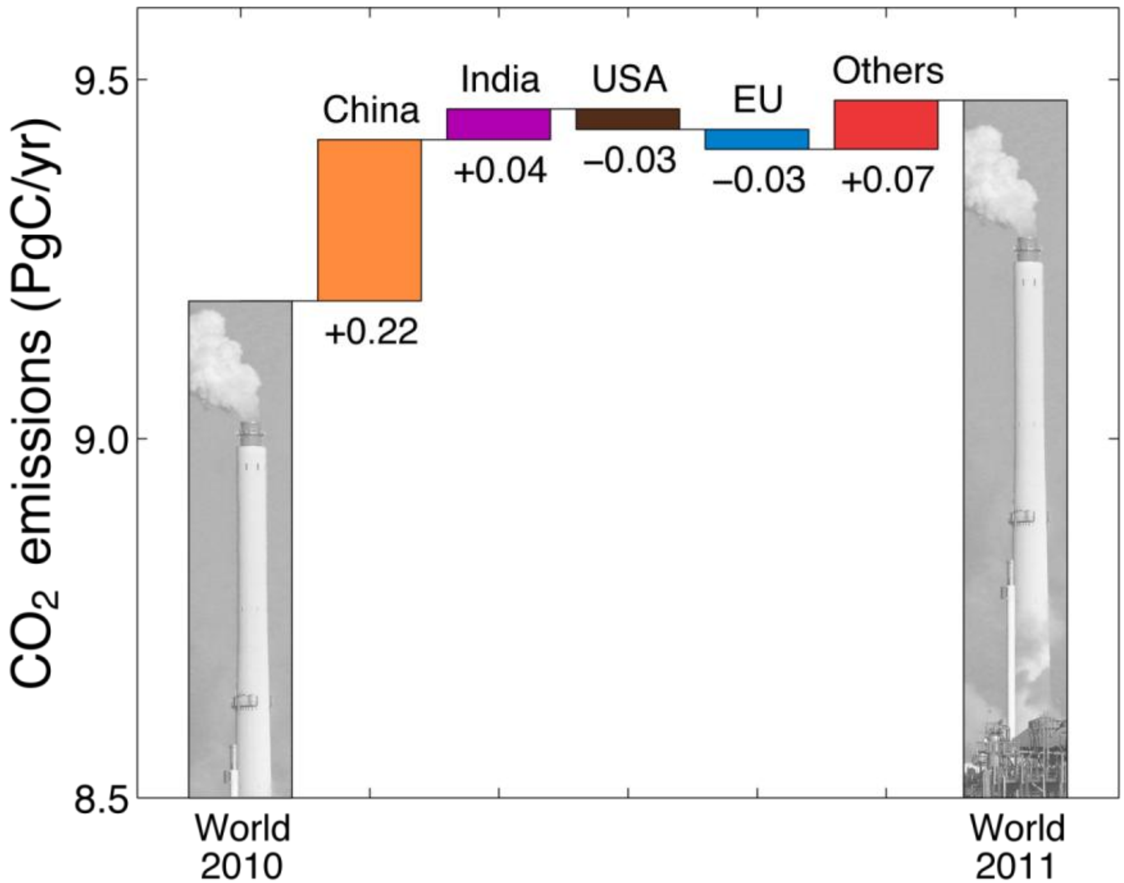
Uncertainty is ±5% for one standard deviation (IPCC “likely” range)

Source: Peters et al. 2012a; Le Quéré et al. 2012; CDIAC Data; Global Carbon Project 2012

Fossil and Cement Emissions Growth 2011

Emissions growth in 2011 was dominated by China

China was responsible for 80% of the global emissions growth in 2011



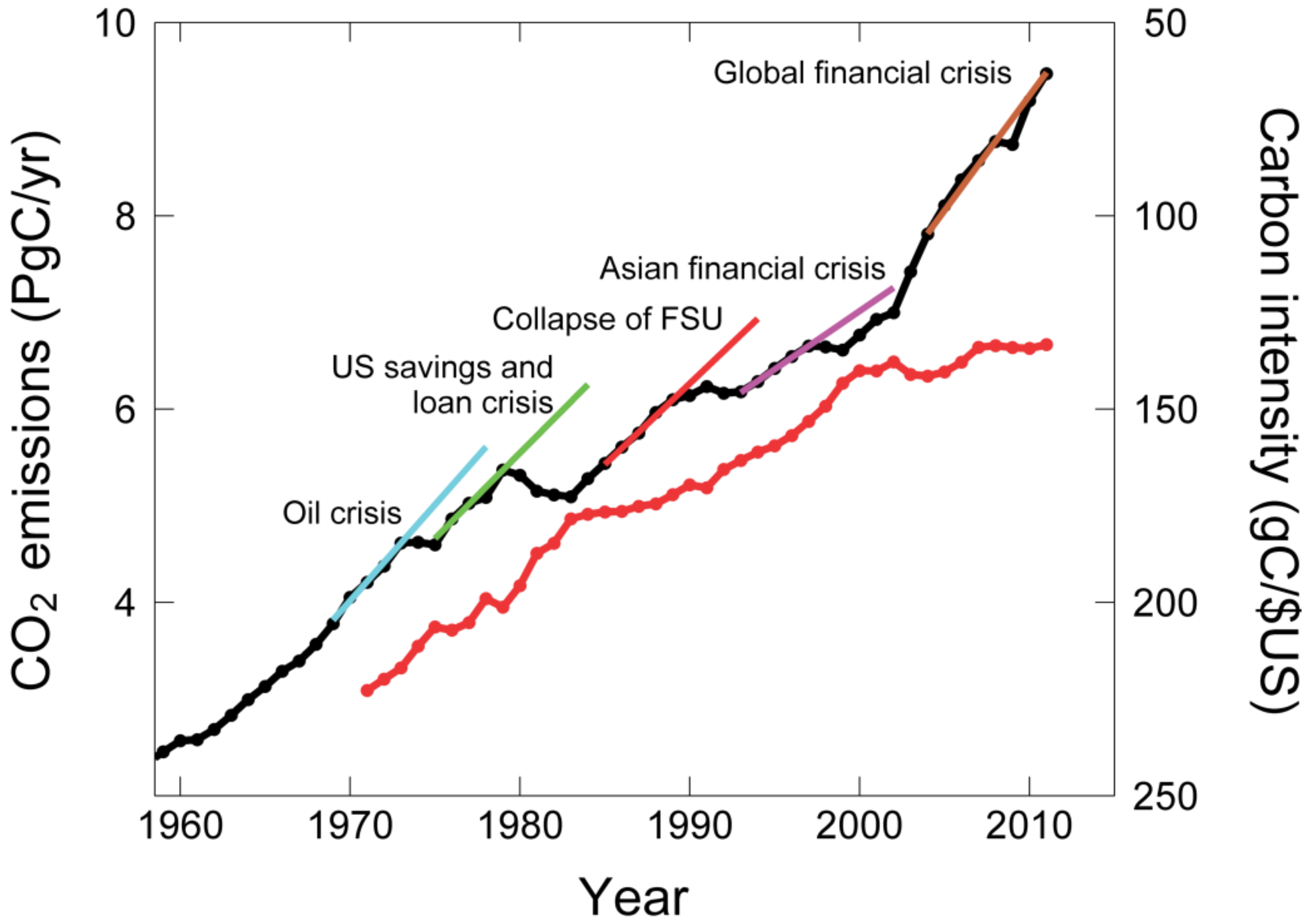
For comparison, Germany emitted a total of 0.2PgC in 2011

Source: CDIAC Data; Le Quéré et al. 2012; Global Carbon Project 2012

Carbon Intensity of Economic Activity

The global financial crisis of 2008/2009 had no lasting effect on emissions

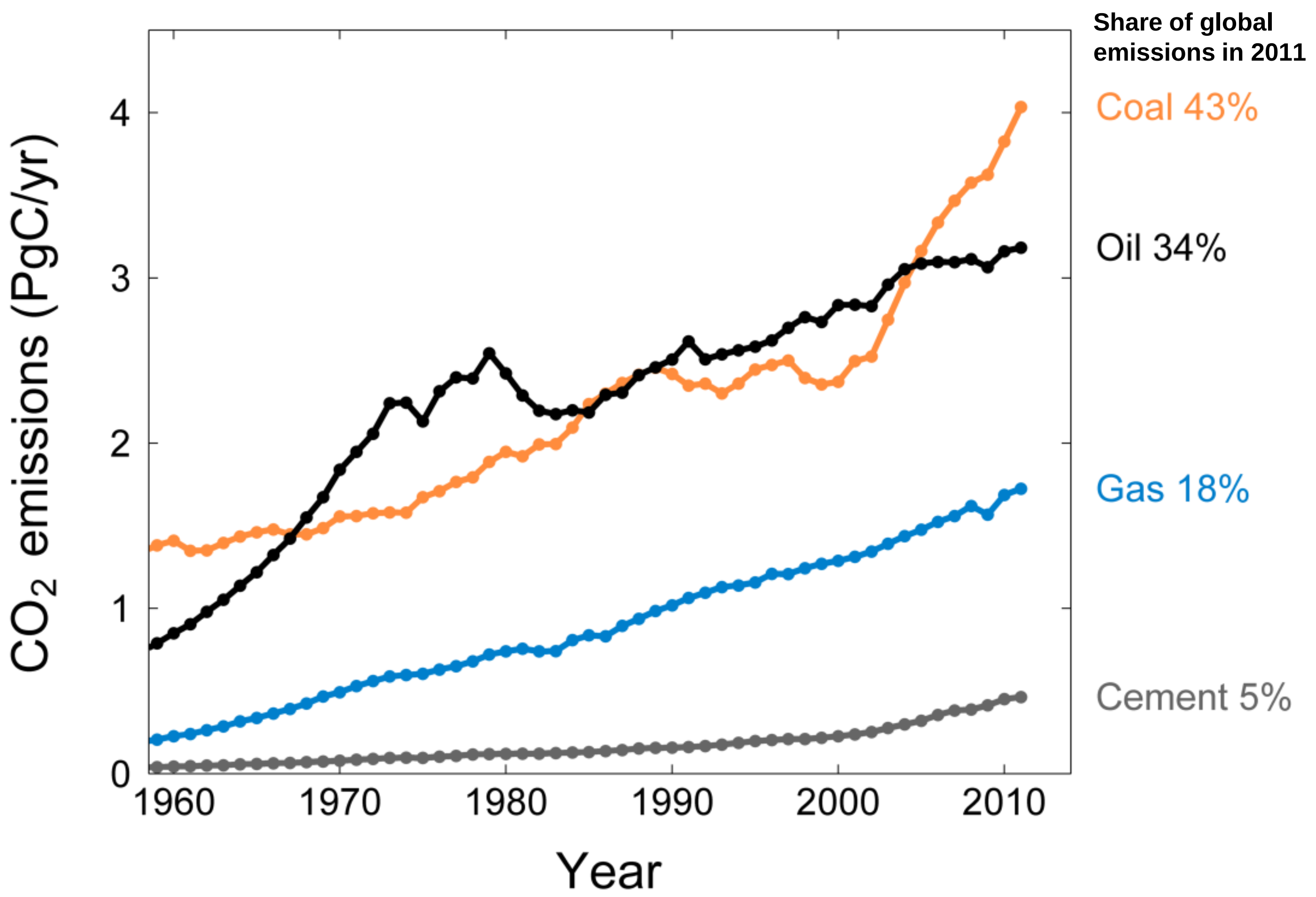
Carbon intensity has not improved with increased economic activity since 2005



Source: Peters et al. 2012a; Le Quéré et al. 2012; CDIAC Data; Global Carbon Project 2012

Emissions from coal, oil, gas, cement

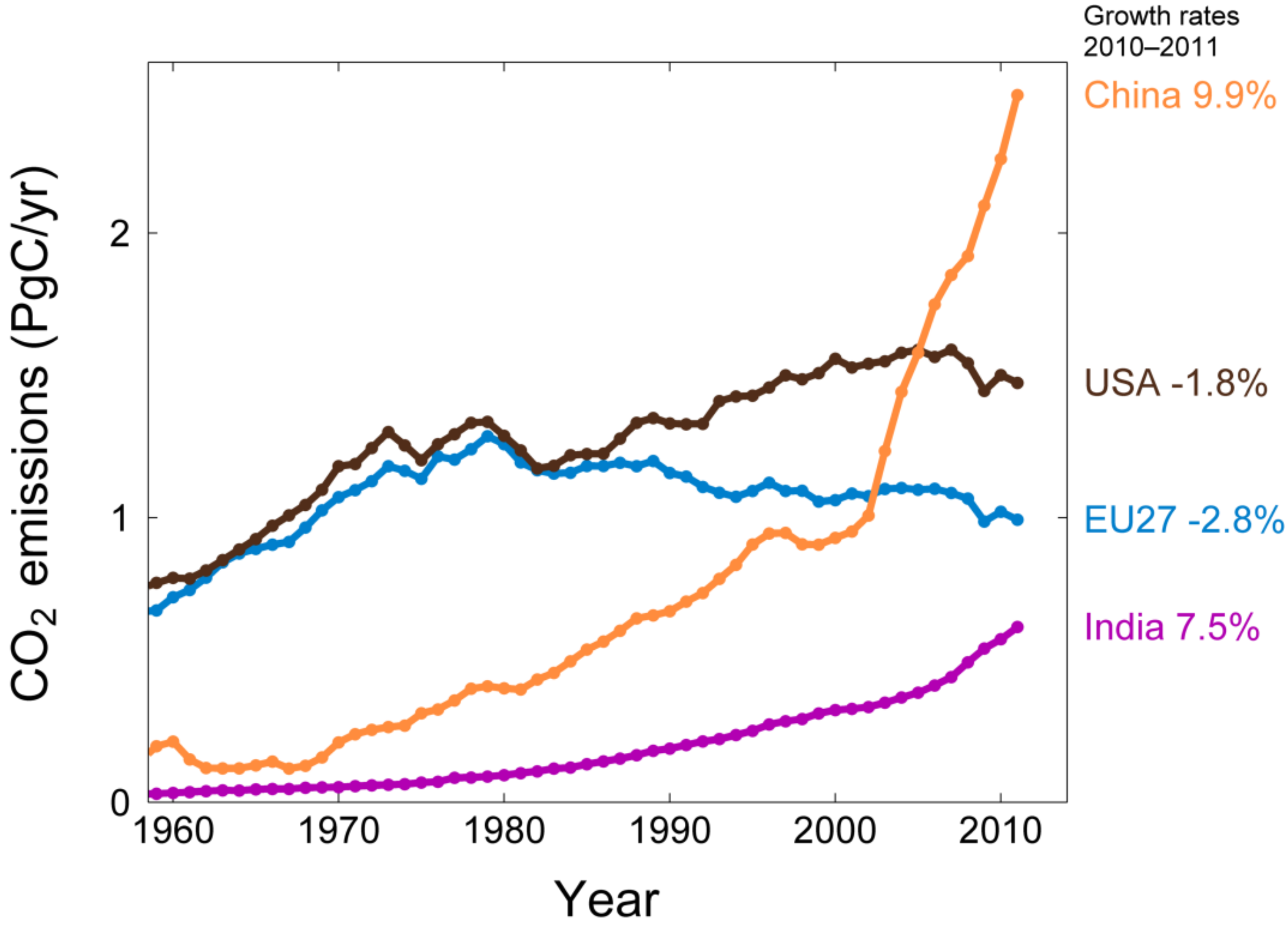
Emissions growth 2000-2011: coal (4.9%/yr), oil (1.1%/yr), gas (2.7%/yr), cement (6.9%/yr), flaring (4.3%/yr, not shown)



Source: CDIAC Data; Le Quéré et al. 2012; Global Carbon Project 2012

Top Fossil Fuel Emitters (Absolute)

Top four emitters in 2011 covered 62% of global emissions
China (28%), United States (16%), EU27 (11%), India (7%)

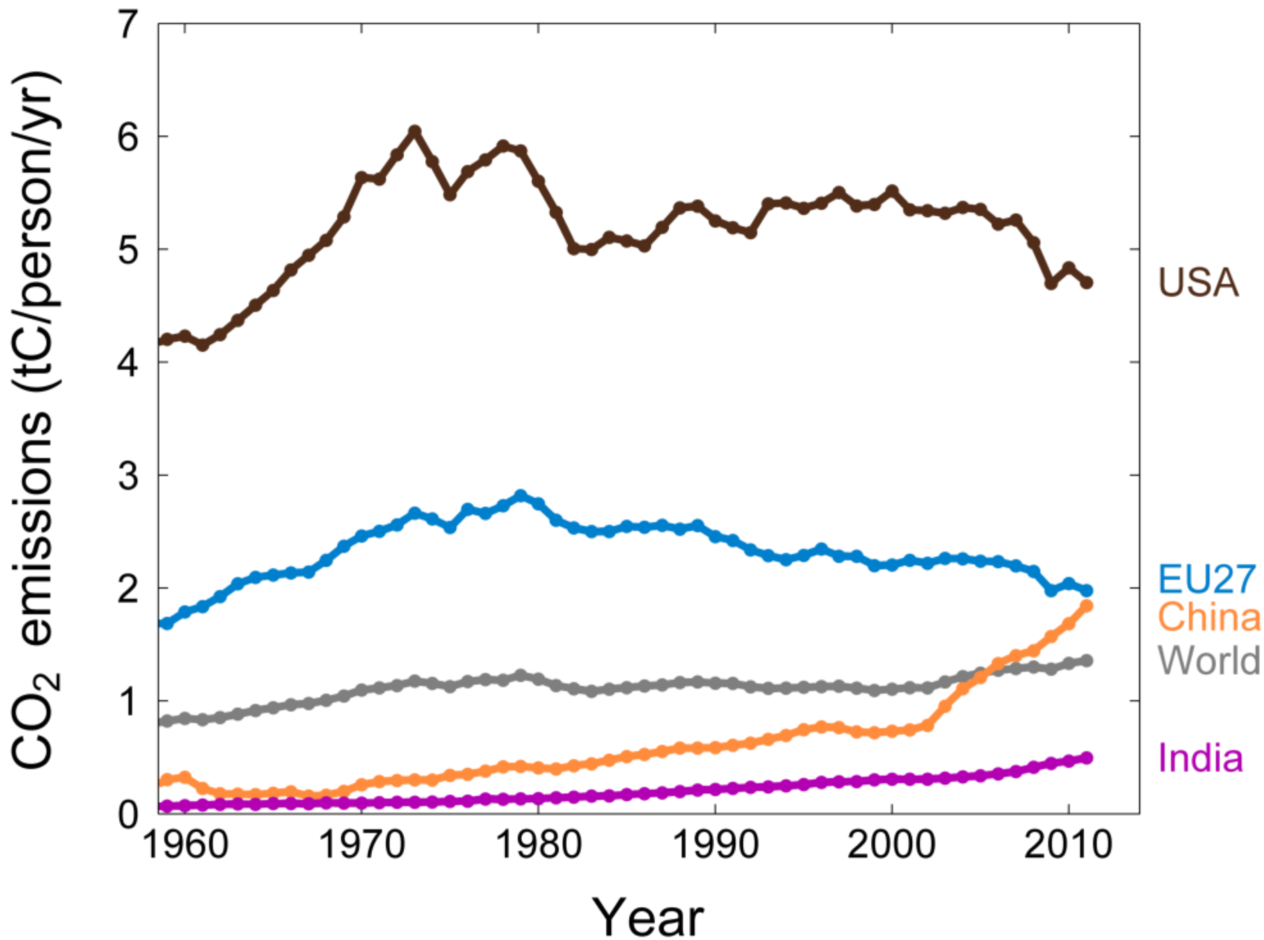


The growing gap between EU27 and USA is due to emission decreases in Germany (45% of the 1990-2011 cumulative difference), UK (19%), Romania (13%), Czech Republic (8%), and Poland (5%)

Source: CDIAC Data; Le Quéré et al. 2012; Global Carbon Project 2012

Top Fossil Fuel Emitters (Per Capita)

World average per capita emissions in 2011 were 1.4tC/p
China (1.8tC/p), United States (4.7tC/p), EU27 (2.0tC/p), India (0.5tC/p)



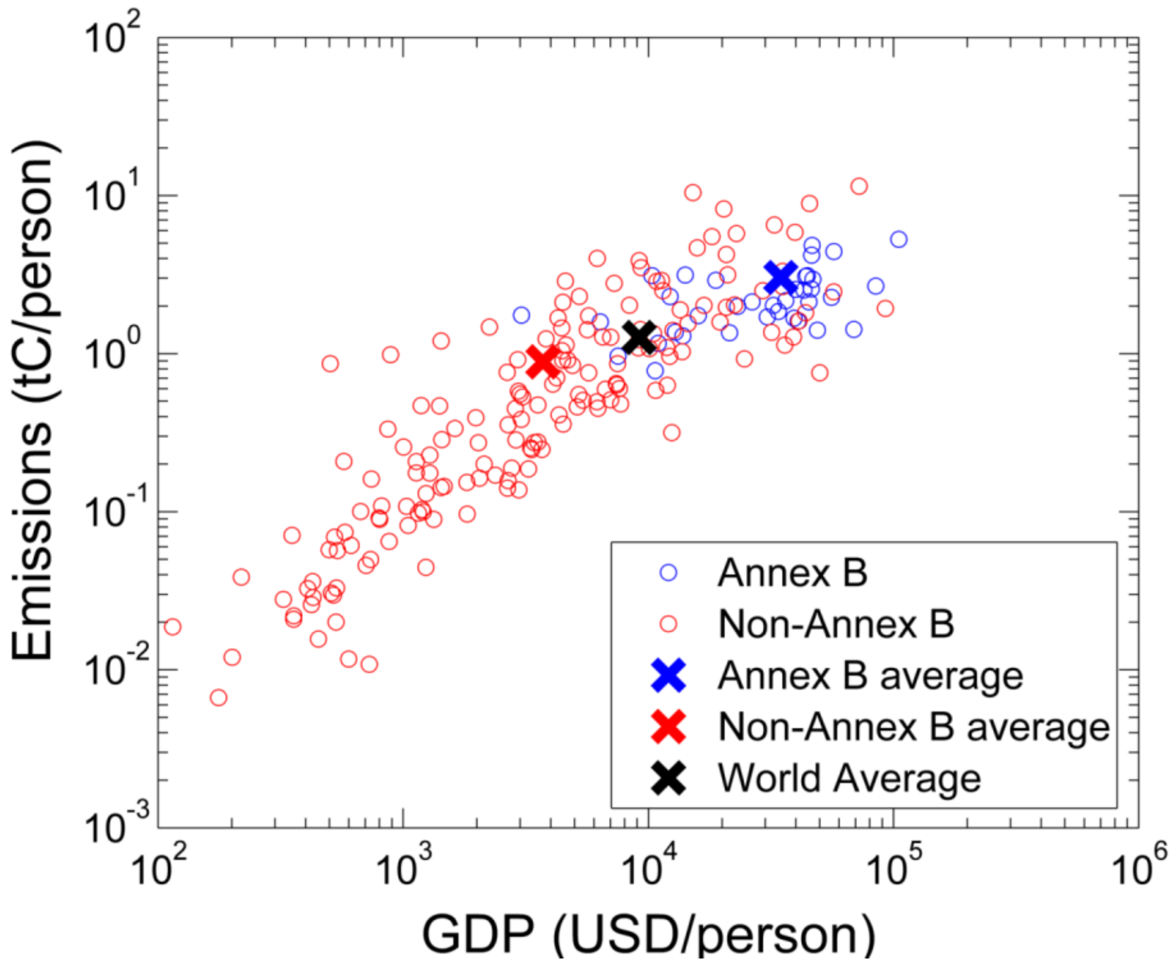
Chinese per capita emissions are almost equal to the EU27, and 36% higher than the global average

Source: CDIAC Data; Le Quéré et al. 2012; Global Carbon Project 2012

Annex B versus non-Annex B Countries

Annex B countries have emission reduction commitments in the Kyoto Protocol

Annex B countries do not necessarily have highest economic activity per capita



Source: CDIAC Data; Unstats; Global Carbon Project 2012

Key Statistics

Region/Country	Per capita emissions 2011	Total emissions 2011	Emissions growth 2011
	(tonnes C/p)	(PgC, % of global)	(PgC/yr, %/yr)
Global (with bunkers)	1.4	9.5	0.28 (3.0%)
Global (no bunkers)	1.3	9.1	0.30 (3.5%)
	Developed Countries (Annex B)		
Annex B	3.0	3.6 (40%)	-0.026 (-0.7%)
United States of America	4.7	1.5 (16%)	-0.028 (-1.8%)
EU27	2.0	1.0 (11%)	-0.029 (-2.8%)
Russian Federation	3.2	0.46 (5.1%)	0.013 (2.9%)
Japan	2.6	0.32 (3.6%)	0.001 (0.4%)
Germany	2.5	0.20 (2.2%)	-0.008 (-3.6%)
	Developing Countries (non-Annex B)		
Non-Annex B	0.9	5.4 (60%)	0.329 (6.5%)
China	1.8	2.5 (28%)	0.226 (9.9%)
India	0.5	0.62 (6.8%)	0.043 (7.5%)
Iran	2.3	0.17 (1.9%)	0.003 (1.9%)
South Korea	3.3	0.16 (1.7%)	0.006 (3.7%)
South Africa	2.8	0.14 (1.6%)	0.002 (1.5%)

Source: CDIAC Data; Le Quéré et al. 2012; Global Carbon Project 2012

Consumption-based Emissions

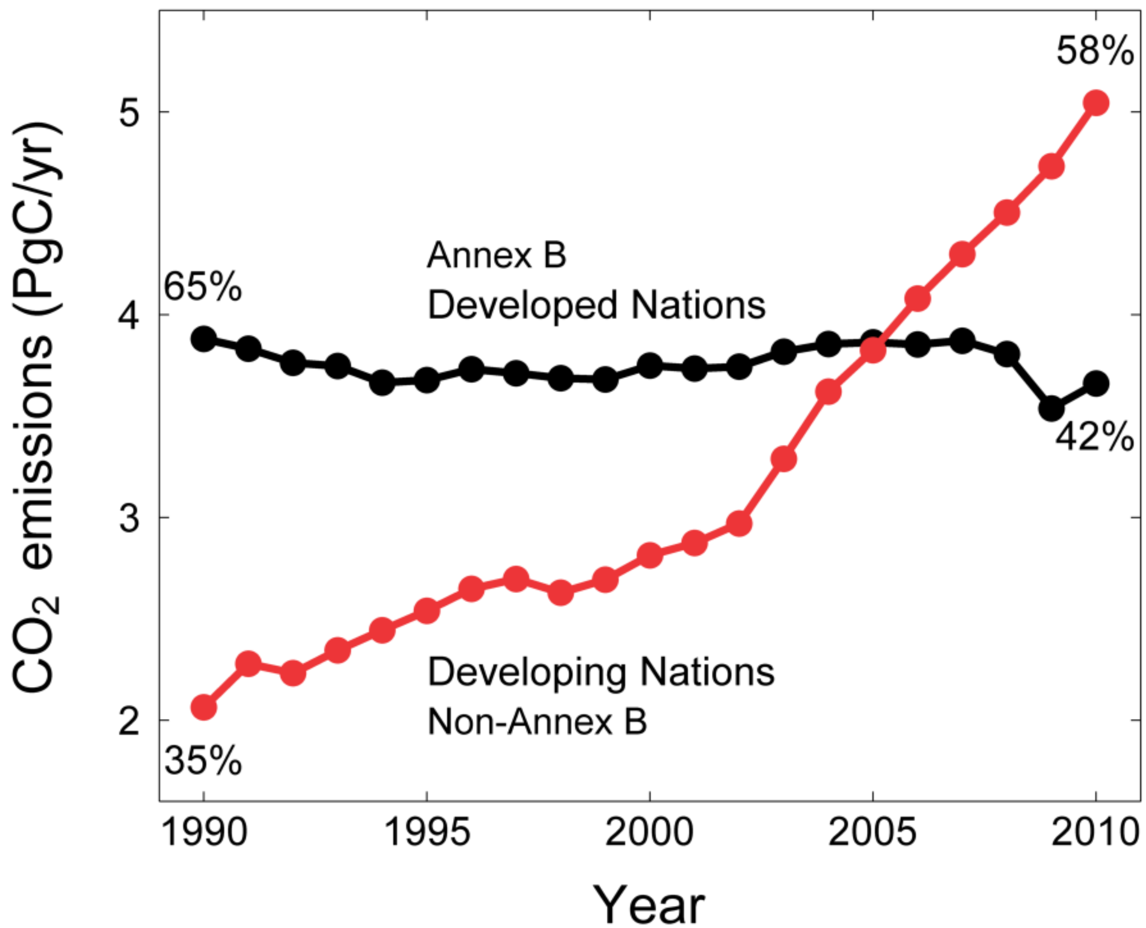
Consumption-based emissions allocate emissions to the location that goods and services are consumed

Consumption-based emissions = Production/Territorial-based emissions minus emission embodied in exports plus the emissions embodied in imports

Territorial emissions as per the Kyoto Protocol

The Kyoto Protocol is based on the global distribution of emissions in 1990

The global distribution of emissions is now starkly different



Share of global emissions in 2010

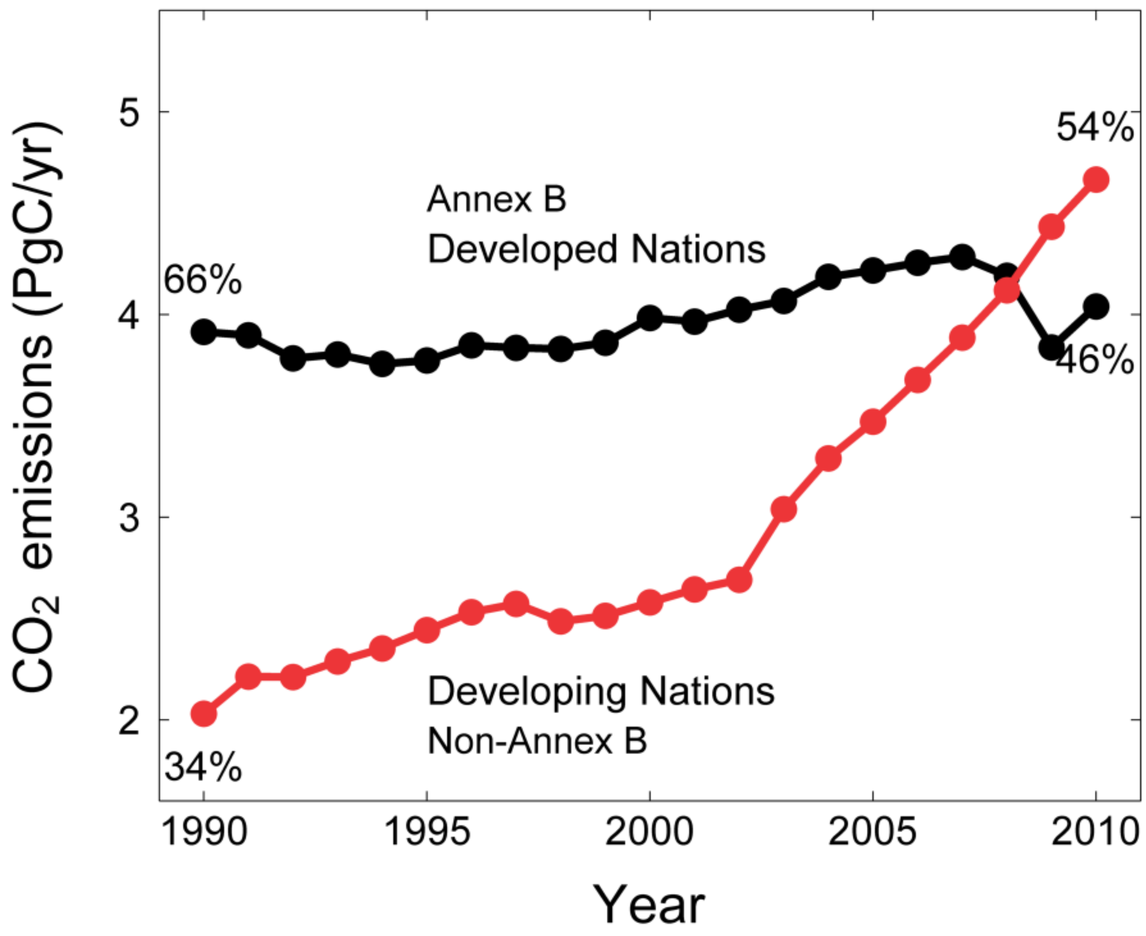
In 2011:

- Annex B 40%
- Non-Annex B 60%

Source: CDIAC Data; Le Quéré et al. 2012; Global Carbon Project 2012

Consumption emissions as per the Kyoto Protocol

Consumption-based emissions =
Territorial emissions plus imported emissions minus exported emissions



Share of global territorial emissions

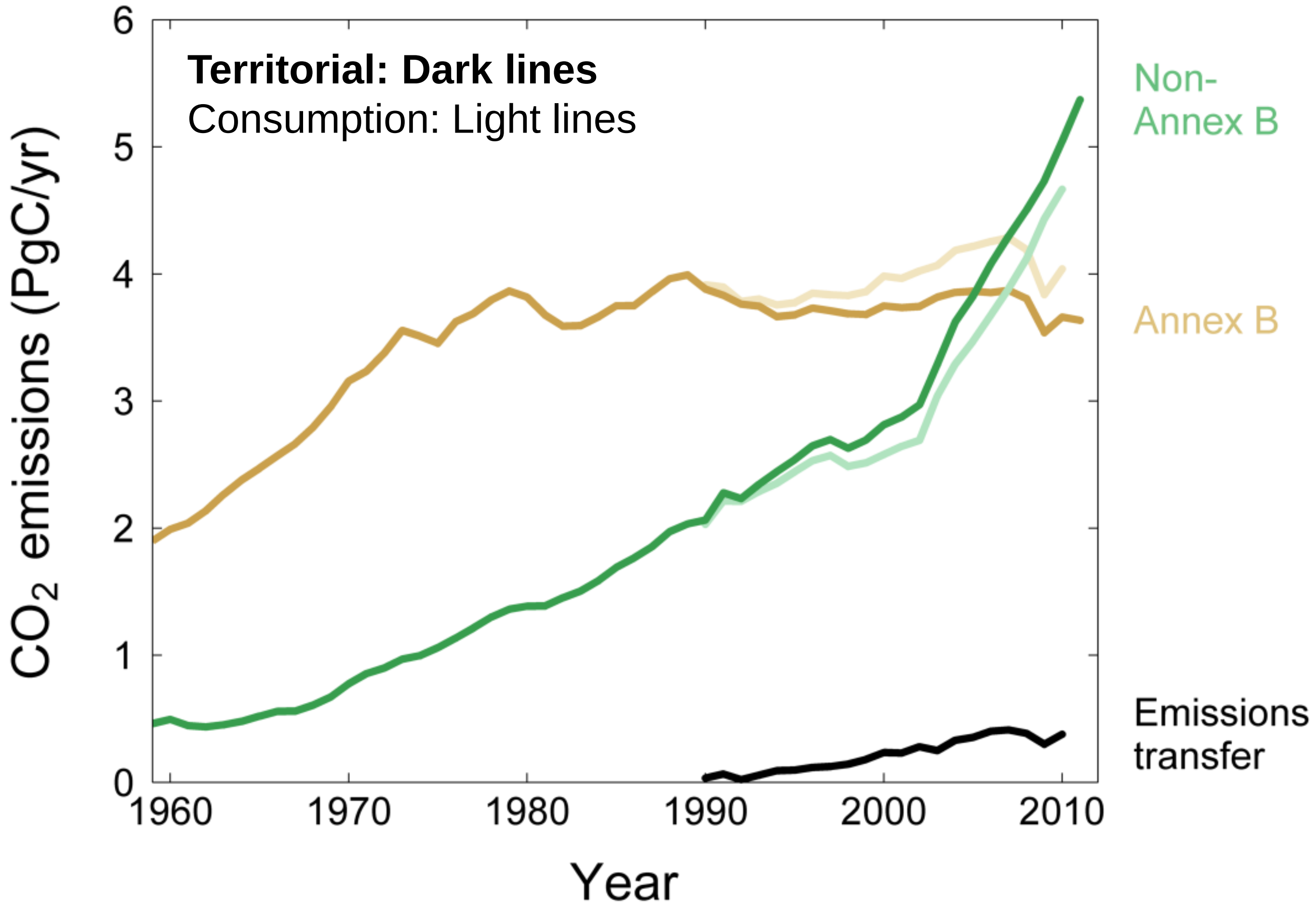
Annex B 58%

Non-Annex B 42%

Source: Le Quéré et al. 2012; Peters et al 2011; Global Carbon Project 2012

Consumption emissions as per the Kyoto Protocol

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



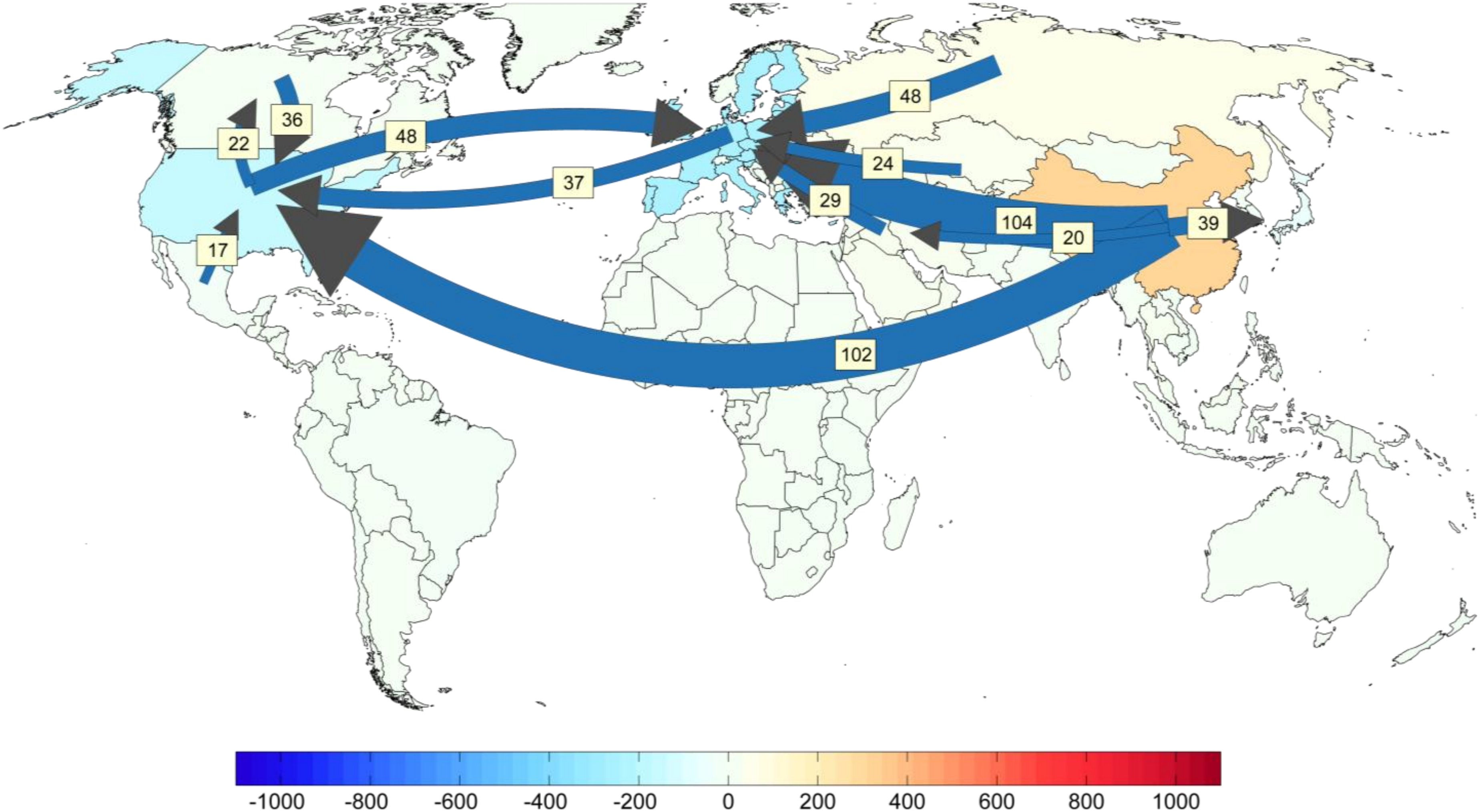
In Annex B, production/territorial-based emissions have had a slight decrease, consumption-based emissions have grown at 0.5%/yr, and emission transfers have grown at 10%/yr

Source: Le Quéré et al. 2012; Peters et al 2011; Global Carbon Project 2012

Major flows from Production to Consumption

Start of Arrow: fossil-fuel consumption (production)

End of arrow: goods and services consumption



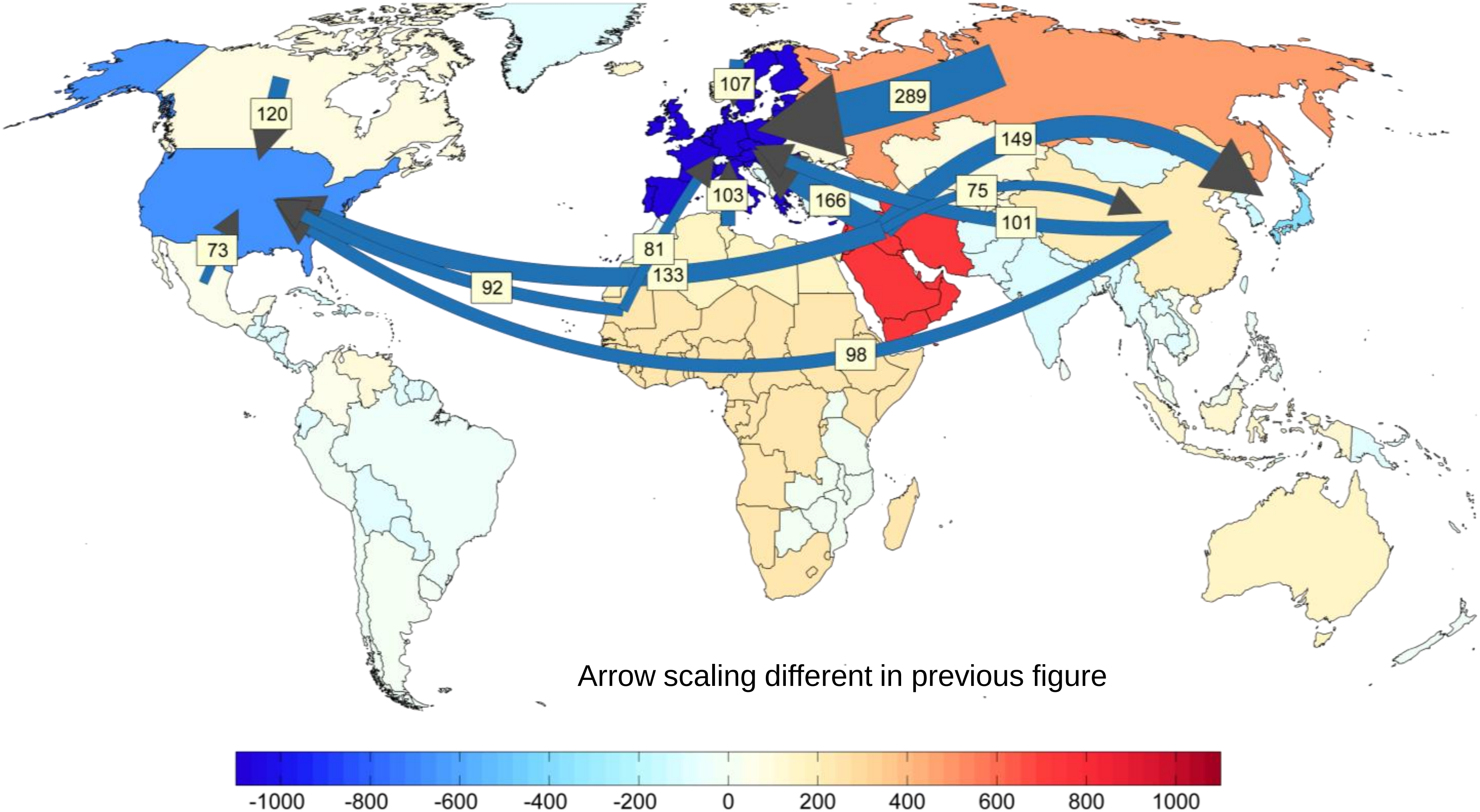
Values for 2007. EU27 is treated as one region. Units: TgC=PgC/1000

Source: Peters et al 2012b

Major flows from Extraction to Consumption

Start of Arrow: fossil-fuel extraction

End of arrow: goods and services consumption

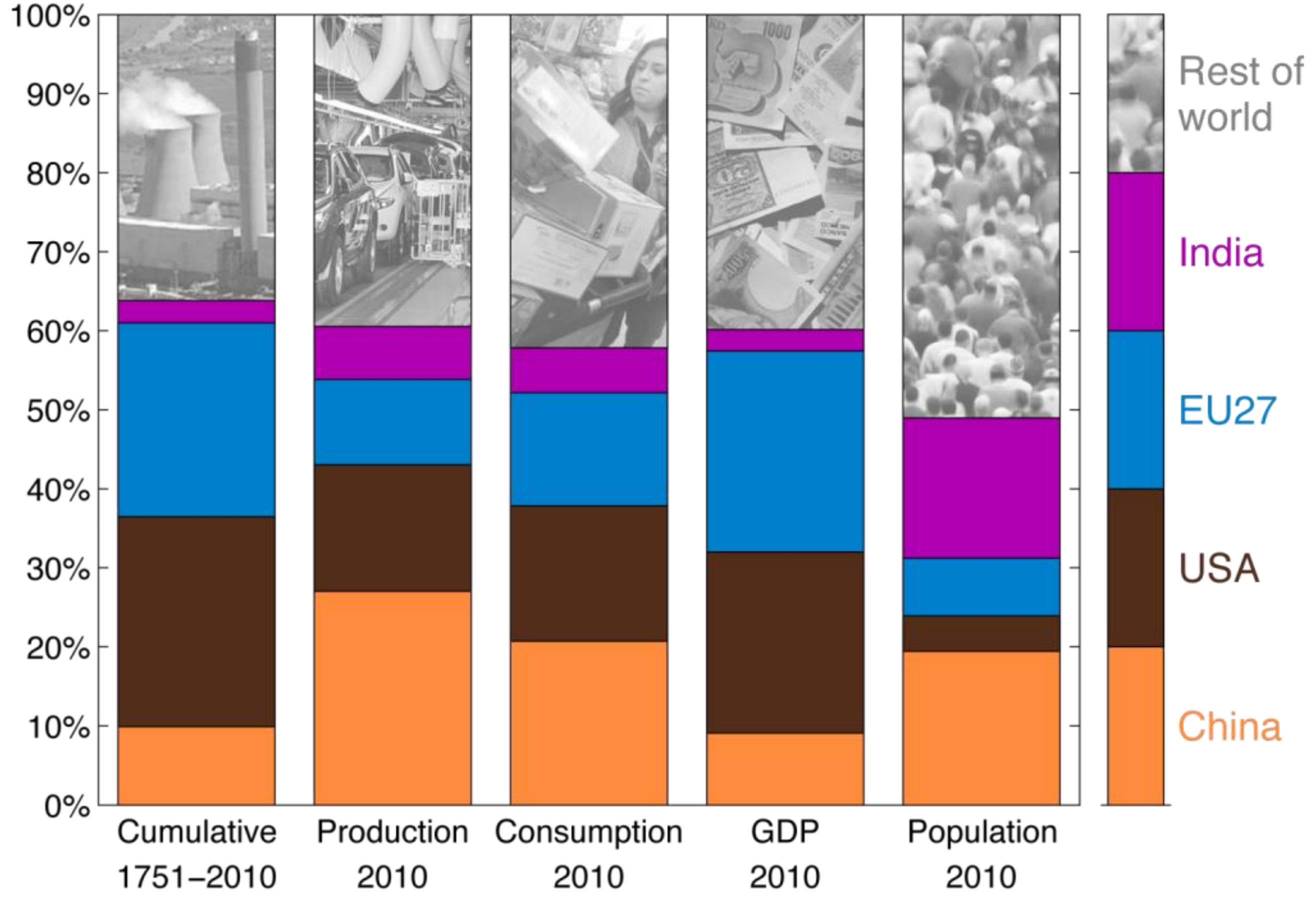


Values for 2007. EU27 is treated as one region. Units: TgC=PgC/1000

Source: Peters et al 2012b

Alternative measures of “Responsibility”

Depending on perspective, the importance of individual countries changes



Cumulative emissions from 1751; Production is also called Territorial; GDP: Gross Domestic Product

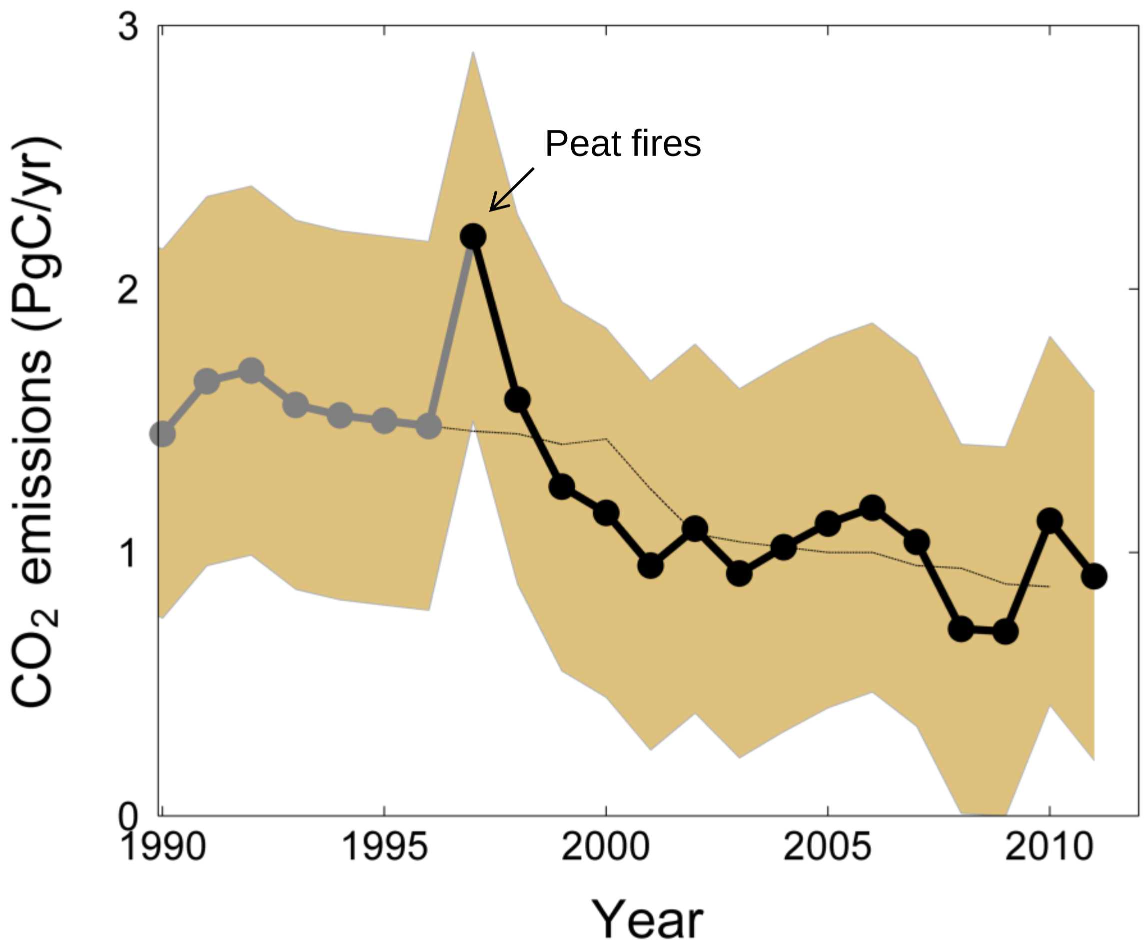
Source: CDIAC Data; Unstats; Le Quéré et al. 2012; Global Carbon Project 2012

Land-Use Change Emissions

Land-Use Change Emissions

Global land-use change emissions: 0.9±0.5PgC in 2011

The data suggests a general decrease in emissions since 1990



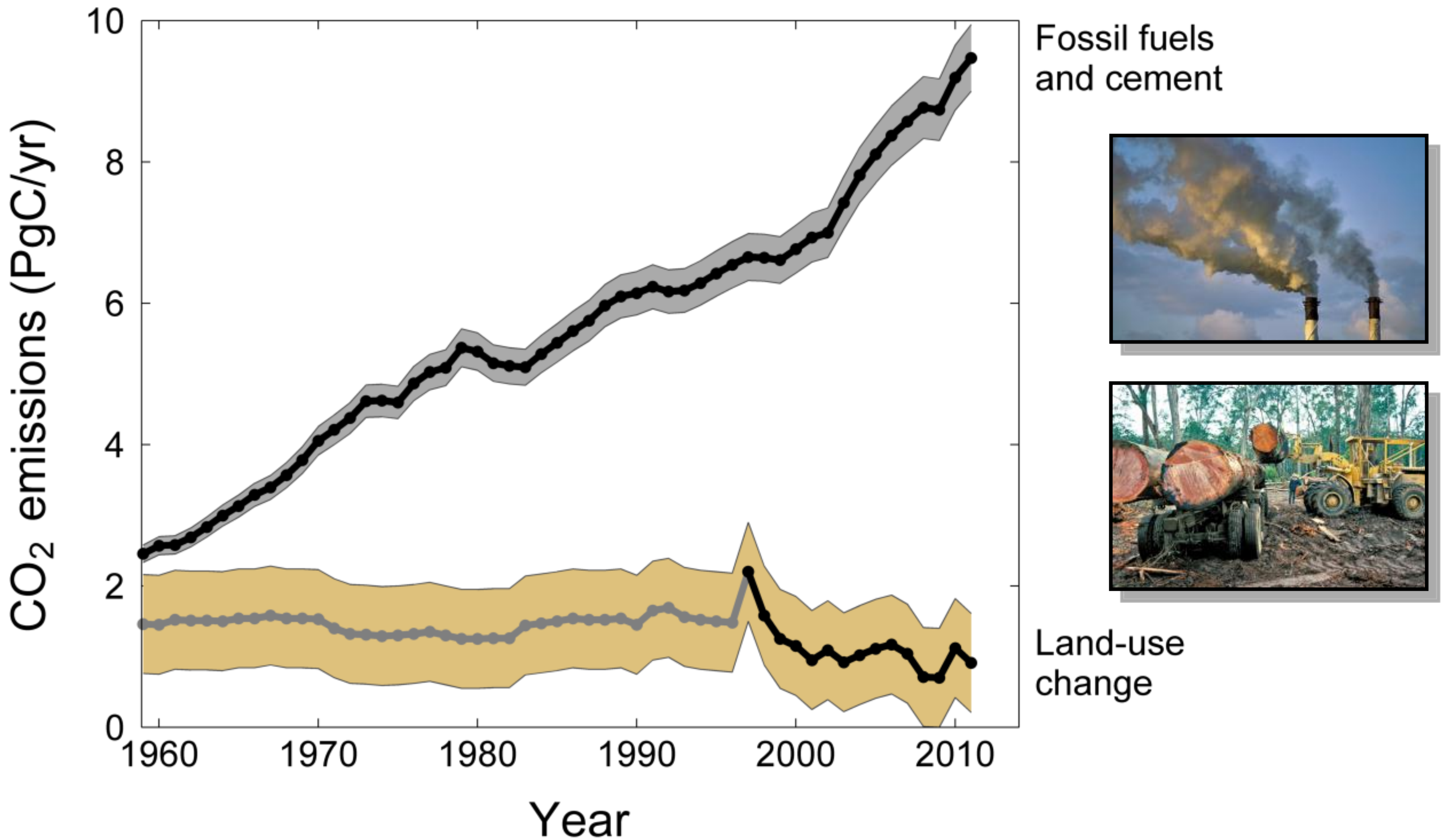
Black line: Includes management-climate interactions; Thin line: Previous estimate

Source: Le Quéré et al. 2012; Global Carbon Project 2012

Total Global Emissions

Total global emissions: 10.4±0.7PgC in 2011, 37% over 1990

Percentage land-use change: 36% in 1960, 18% in 1990, 9% in 2011



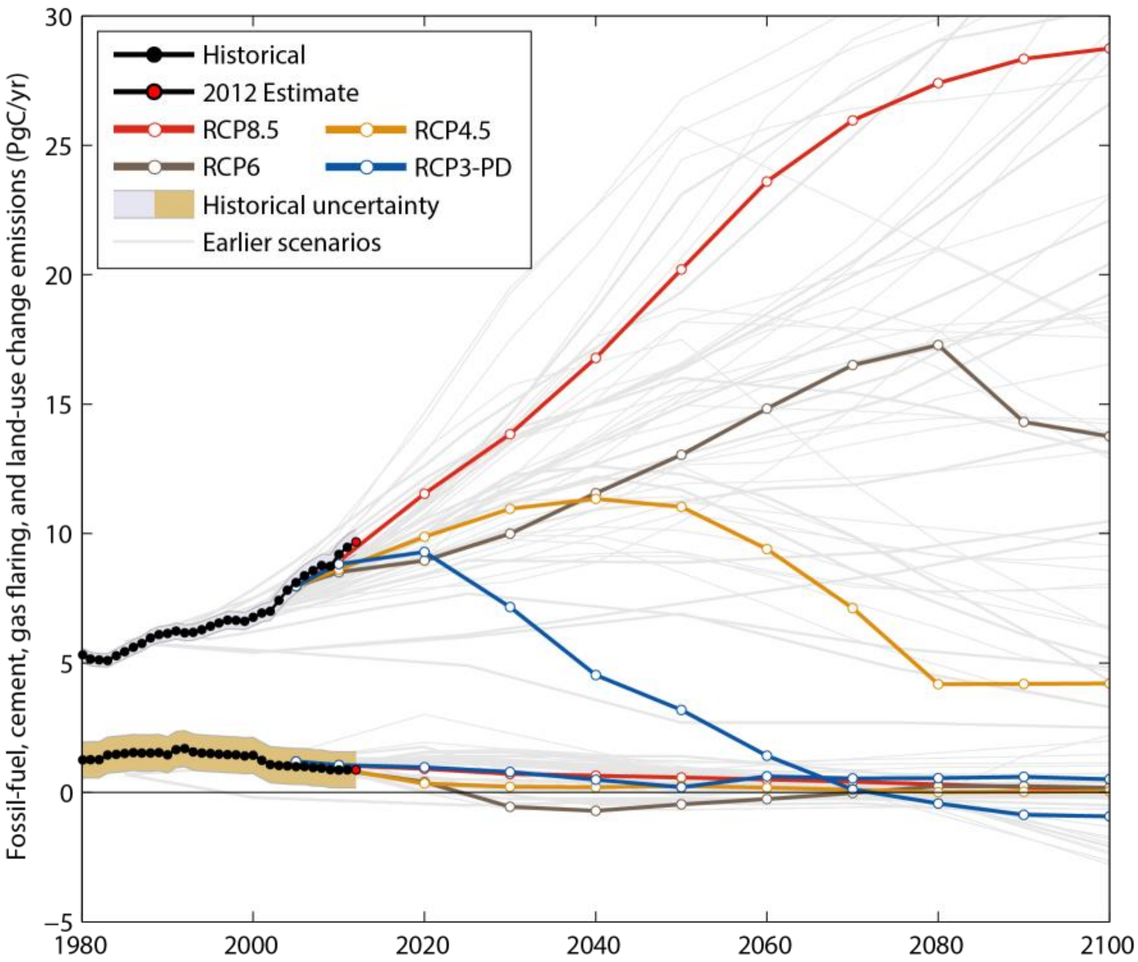
Land-use change black line: Includes management-climate interactions

Source: Le Quéré et al. 2012; Global Carbon Project 2012

Total Global Emissions and Scenarios

Fossil and cement emissions dominate in most scenarios

RCP-3PD (blue) has net negative emissions

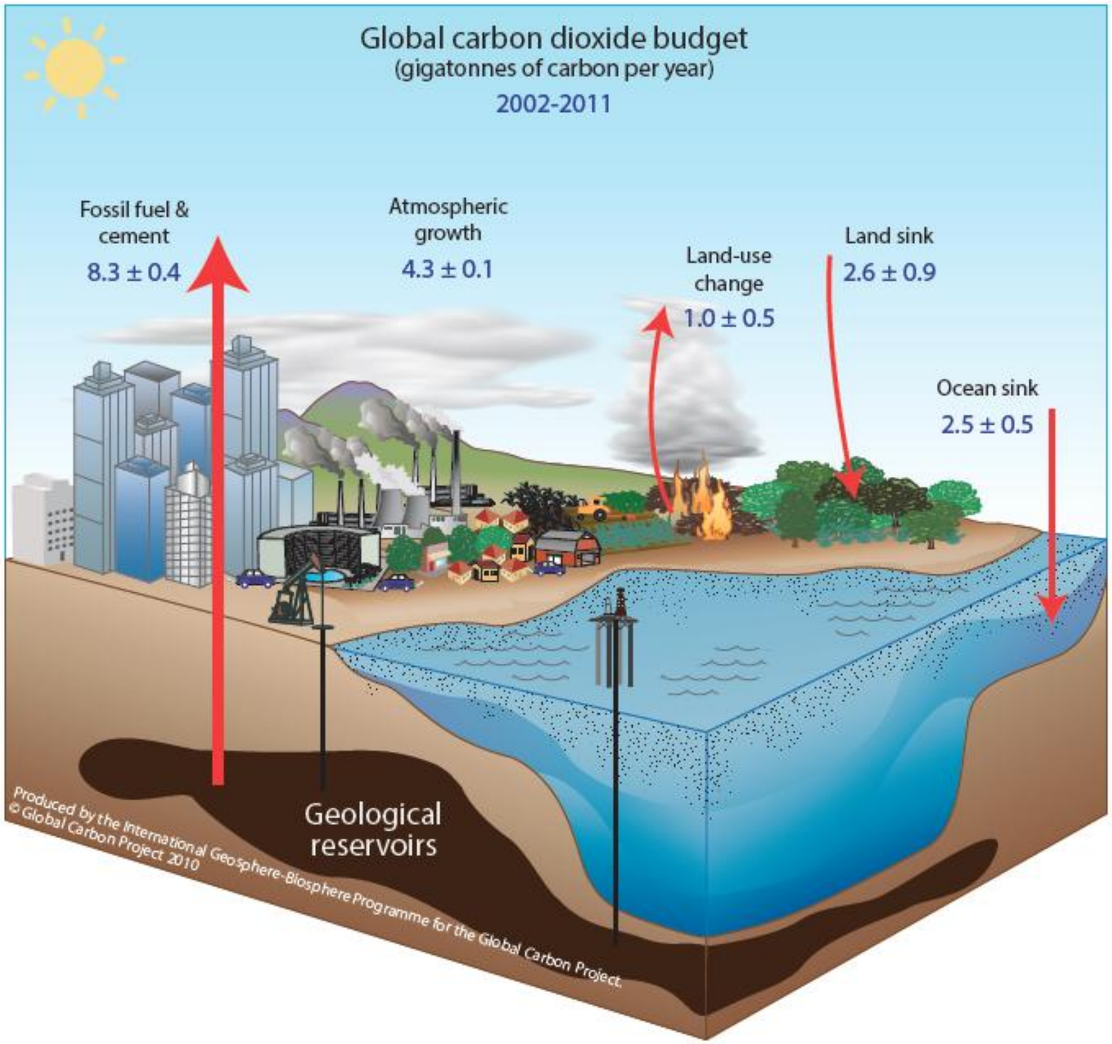


Source: Peters et al. 2012a; Le Quéré et al. 2012; Global Carbon Project 2012

Closing the Carbon Budget

Anthropogenic Perturbation of the Global Carbon Cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2002–2011 (PgC/yr)

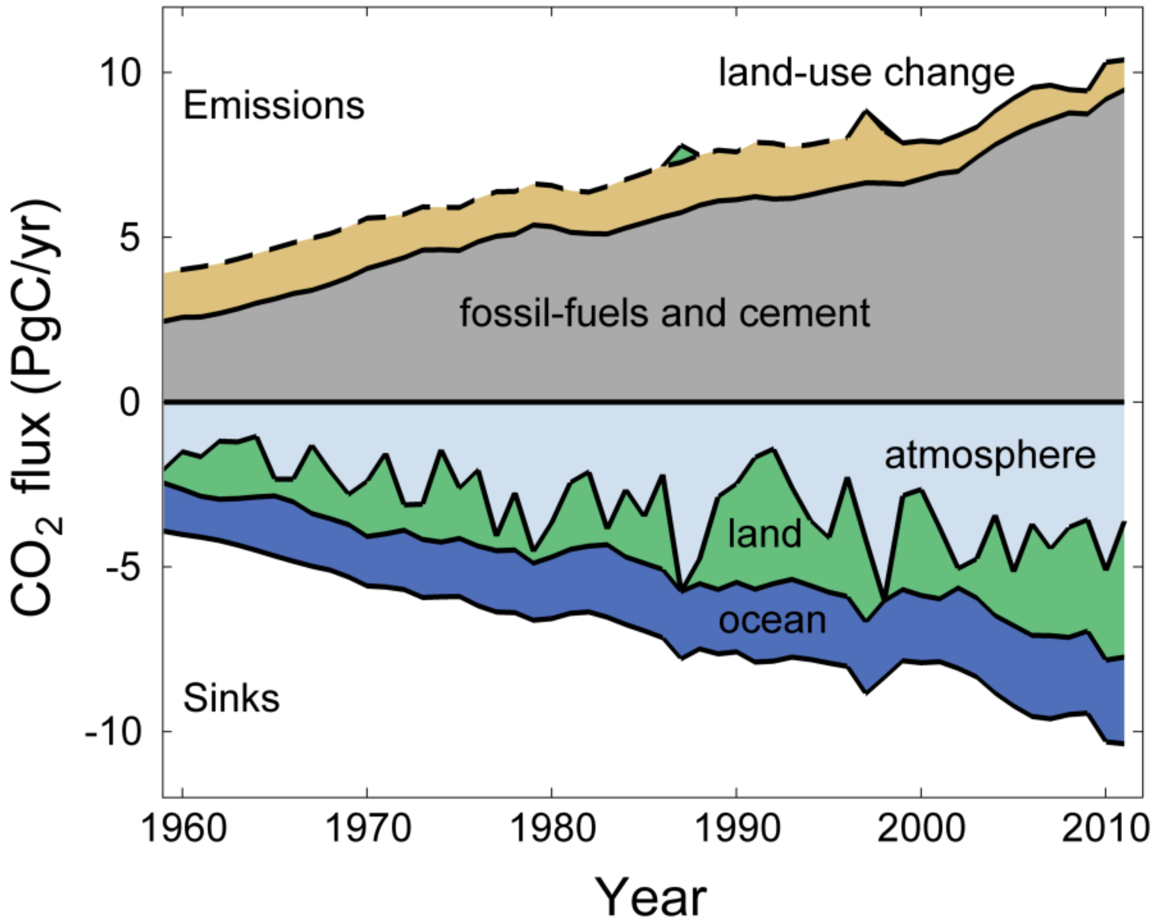


Source: Le Quéré et al. 2012; Global Carbon Project 2012

Global Carbon Budget

Emissions to the atmosphere are balanced by the sinks

Averaged sinks since 1959: 44% atmosphere, 28% land, 28% ocean



The dashed land-use change line does not include management-climate interactions

The land sink was a source in 1987 and 1998 (1997 visible as an emission)

Source: Le Quéré et al. 2012; Global Carbon Project 2012

Fate of Anthropogenic CO_2 Emissions (2002-2011 average)

8.3±0.4 PgC/yr 90%

1.0±0.5 PgC/yr 10%

+

4.3±0.1 PgC/yr
46%

2.6±0.8 PgC/yr
28%

Calculated as the residual
of all other flux components

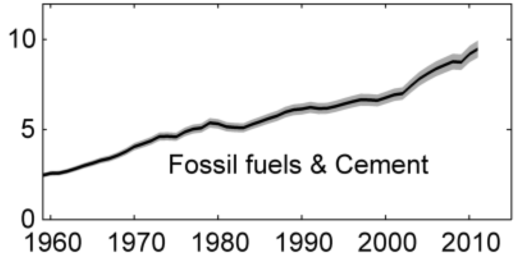
26%
2.5±0.5 PgC/yr

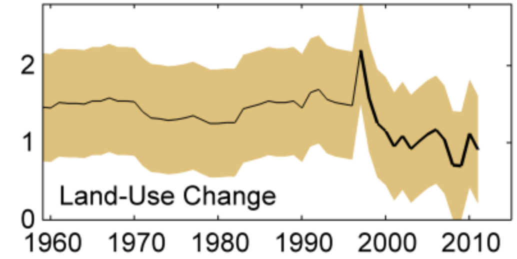
Source: Le Quéré et al. 2012; Global Carbon Project 2012

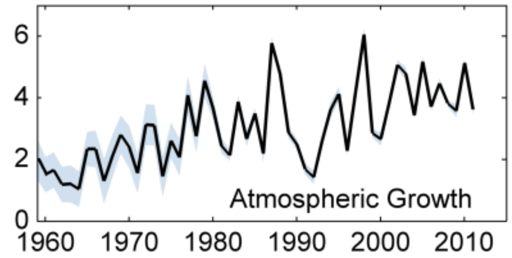
Changes in the Global Carbon Budget over Time

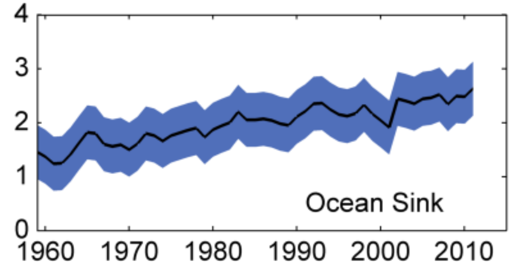
The sinks have continued to grow with increasing emissions

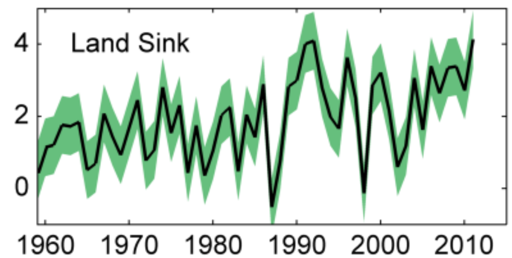
It is uncertain how efficient the sinks will be in the future









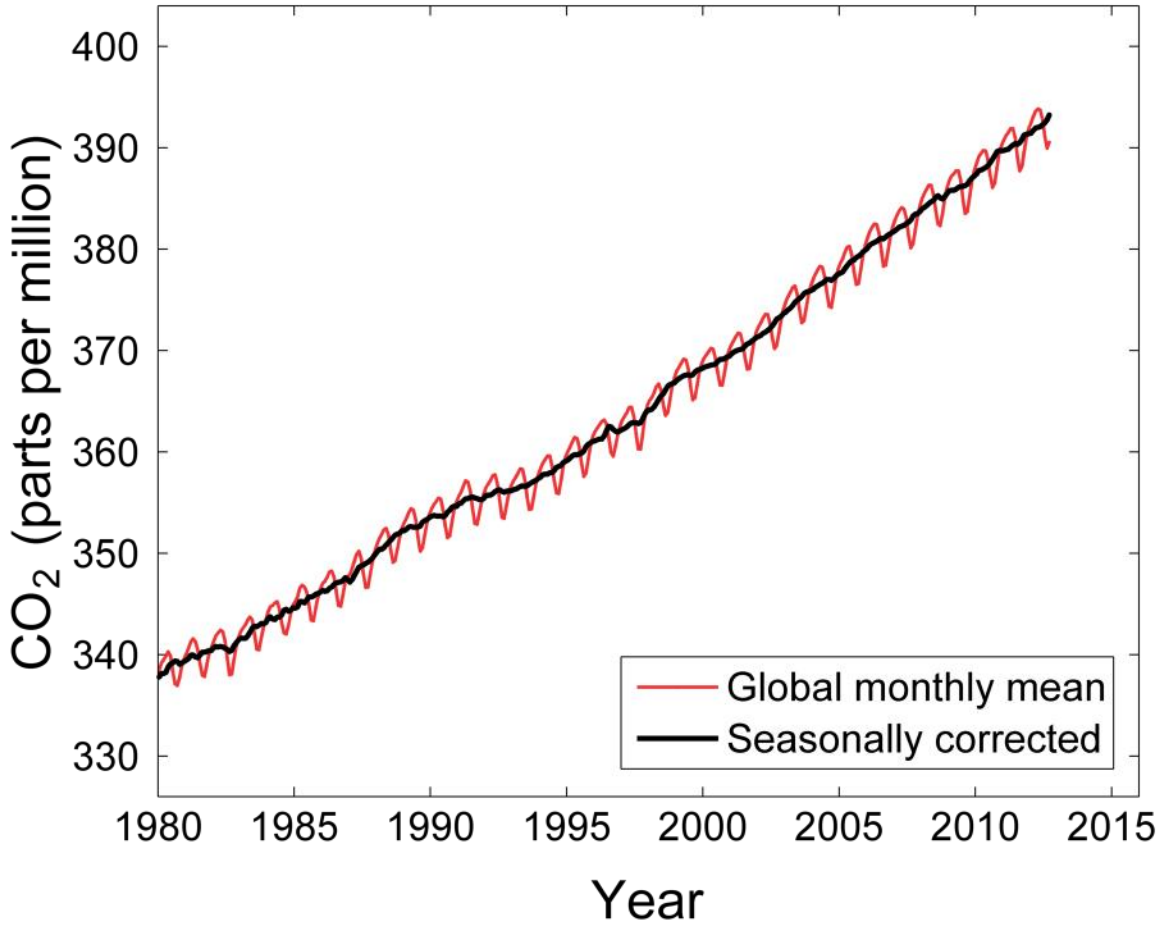


Source: Le Quéré et al. 2012; Global Carbon Project 2012

Atmospheric Concentration

The pre-industrial (1750) atmospheric concentration was 278ppm

This has increased to 390ppm in 2011, a 40% increase



"Seasonally corrected" is a moving average of seven adjacent seasonal cycles

Source: NOAA/ESRL; Global Carbon Project 2012

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Global Carbon Project (2012) More information, data sources and data files at www.globalcarbonproject.org

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GLOBAL IGBP CHANGE International Geosphere-Biosphere Programme
IHDP International Human Dimensions Programme on Global Environmental Change
WCRP World Climate Research Programme
DIVERSITAS an international programme of biodiversity science
CSIRO
Australian Government Department of Climate Change and Energy Efficiency
NIES
環境省 Ministry of the Environment
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LSCE
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