GLOBAL CARBON PROJECT

GlobalCarbonProject.org

# Global carbon project
## (some activities in 2015/2016)

futureearth
research for global sustainability

# The Global Carbon Project

- The Global Carbon Project (GCP) was established in 2001 in recognition of the large scientific challenges and critical nature of the carbon cycle for Earth's sustainability.
- GCP forms a part of the international research programmes becoming part of Future Earth
- The scientific goal of the project is to develop a complete picture of the global carbon cycle, including both its biophysical and human dimensions together with the interactions and feedbacks between them.

# The Global Carbon Project

GCP

**Patterns and Variability:** What are the current geographical and temporal distributions of the major pools and fluxes in the global carbon cycle?

**Processes and Interactions:** What are the control and feedback mechanisms - both anthropogenic and non-anthropogenic - that determine the dynamics of the carbon cycle?

**Carbon Management:** What are the dynamics of the carbon-climate-human system into the future, and what points of intervention and windows of opportunity exist for human societies to manage this system?

Integrated assessment world

# The global carbon project


Zhu Z, et al (2016) Greening the Earth and its Drivers. **Nature Climate Change**, online publication 25 April 2016. DOI:10.1038/nclimate3004

Tian H, et al.(2016) The terrestrial biosphere as a net source of greenhouse gases to the atmosphere. **Nature** 531: 525-228. DOI:10.1038/nature16946.

Thompson RL, et al. (2016) Top–down assessment of the Asian carbon budget since the mid 1990s. **Nature Communications** 7:10724. DOI:10.1038/ncomms10724.

Jackson RB, (2016). Reaching peak emissions. **Nature Climate Change** 6: 7-10. Published online 07 December 2015. DOI: 10.1038/NCLIMATE2892.

Smith P,. (2016) Biophysical and economic limits to negative $CO_2$ emissions. **Nature Climate Change** 6: 42–50. Published online 07 December 2015. DOI: 10.1038/NCLIMATE2870

Le Quéré C, (2015) Global Carbon Budget 2015. **Earth System Science Data** 7: 349-396. DOI:10.5194/essd-7-349-2015

Sitch S (2015) Recent trends and drivers of regional sources and sinks of carbon Dioxide. **Biogeosciences** 12: 653–679. DOI:10.5194/bg-12-653-2015

Le Quéré C, (2015) Global Carbon Budget 2014. **Earth System Science Data**, DOI:10.5194/essd–7–47–2015.

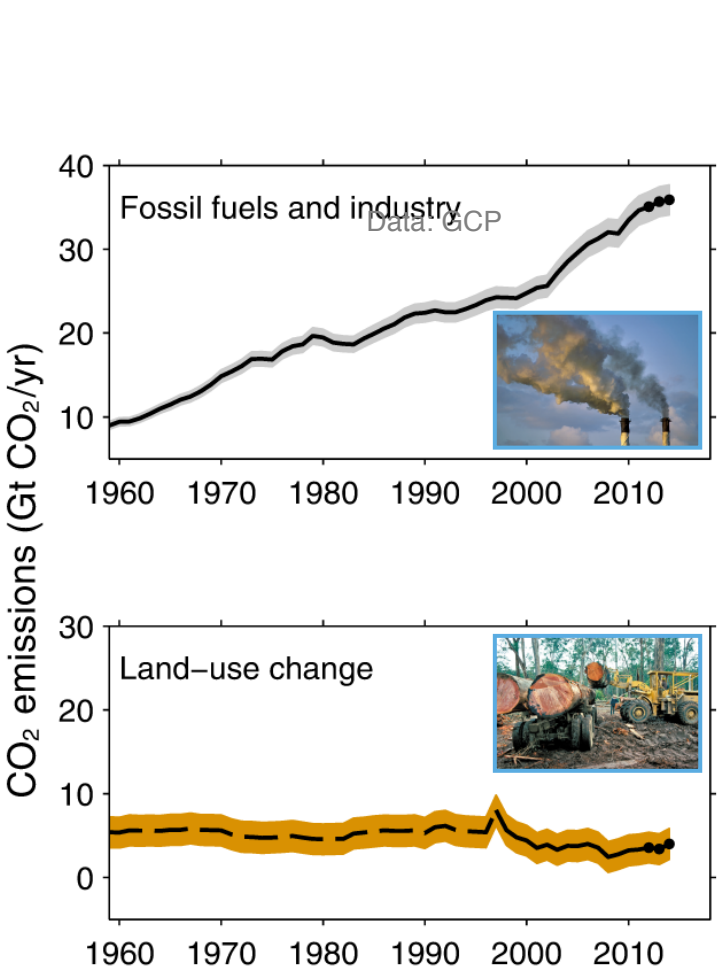
Raupach MR, (2014) Sharing a quota on cumulative carbon emissions. **Nature Climate Change** 4: 873–879. DOI: 10.1038/NCLIMATE2384.

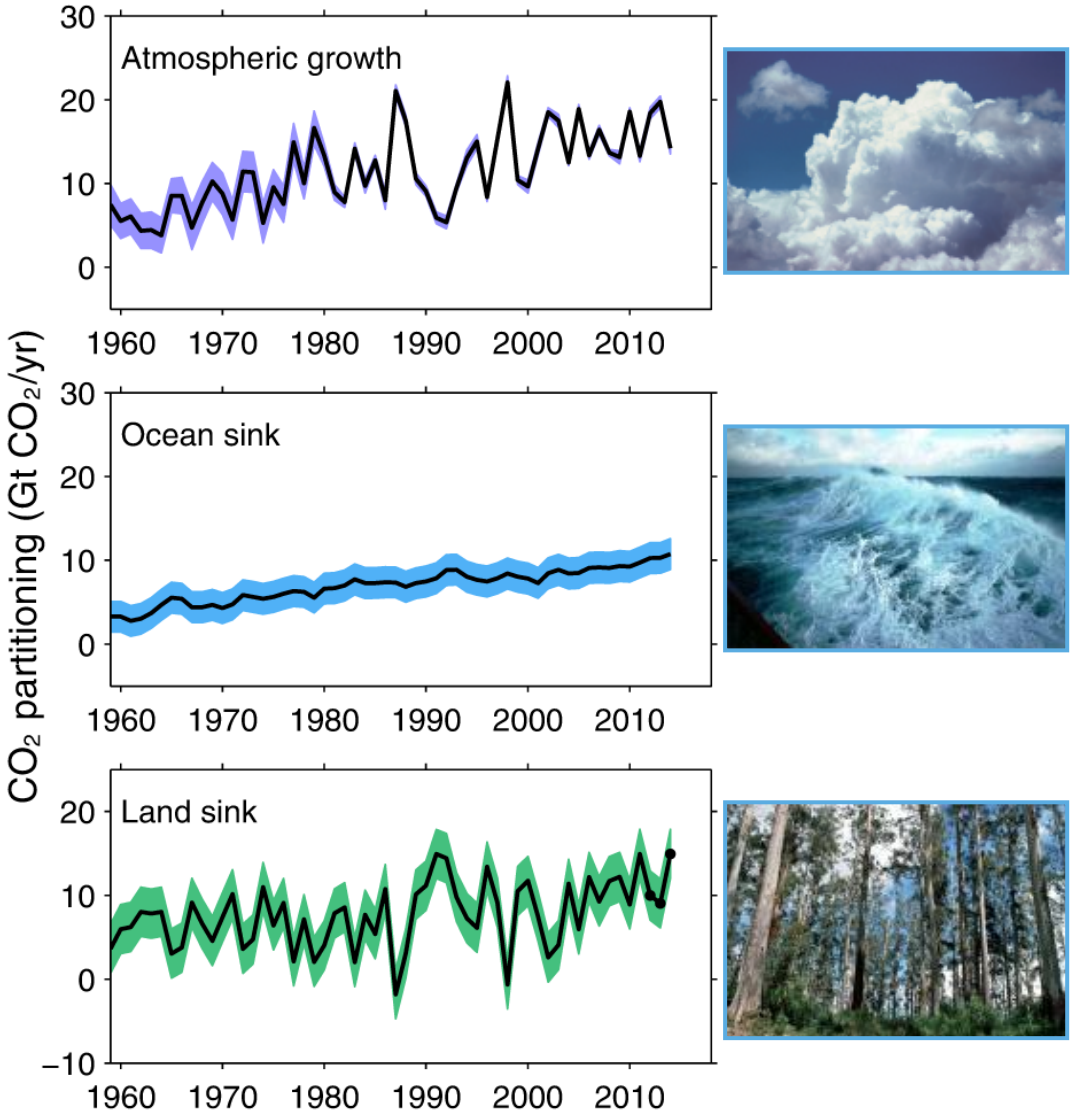
Fuss S, (2014) Betting on Negative Emissions. **Nature Climate Change** 4: 850–853.

Friedlingstein P, et al (2014)
Persistent growth of CO2 emissions and implications for reaching climate targets. **Nature GeoScience** 7: 709–715.

Ciais P, A. J. et al.. (2014)
Current systematic carbon-climate observations and the need for implementing a policy-relevant carbon observing system. **Biogeosciences** 11: 3547–602.

# Carbon Budget: Trends in Emissions and Sinks



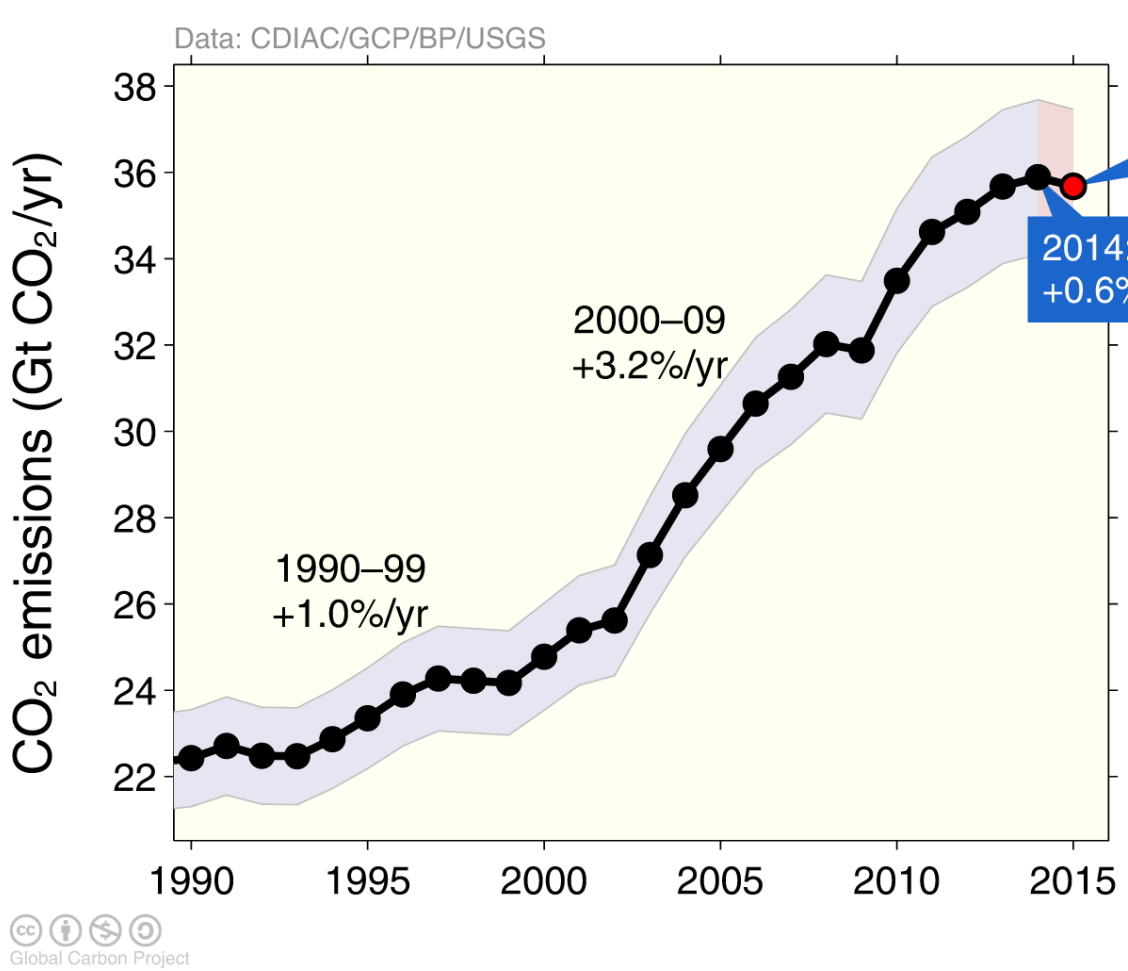




GCP 2015; Le Quere et al. 2015, ESDD

# 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)

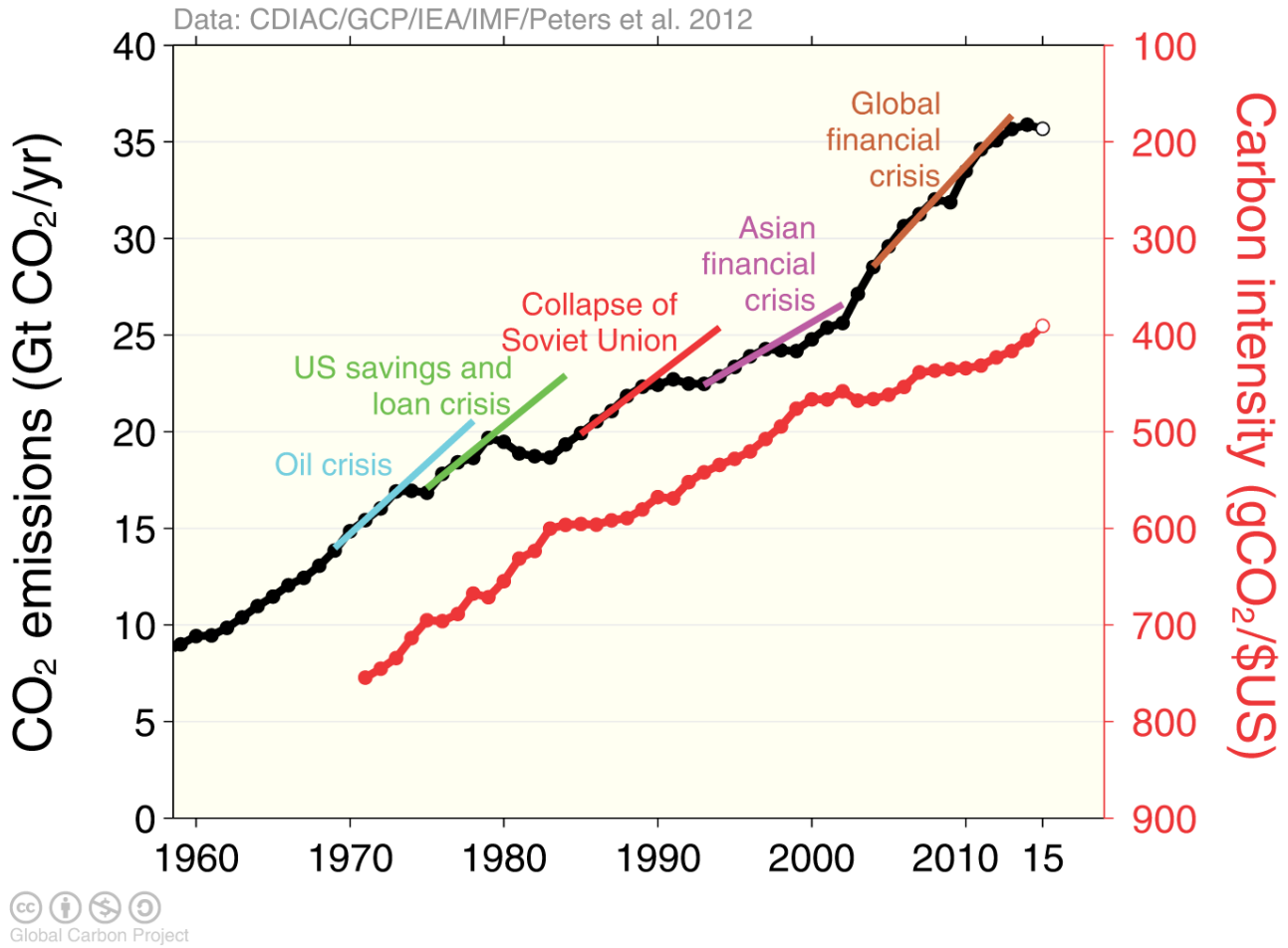
Estimates for 2012, 2013, 2014, and 2015 are preliminary

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

# 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

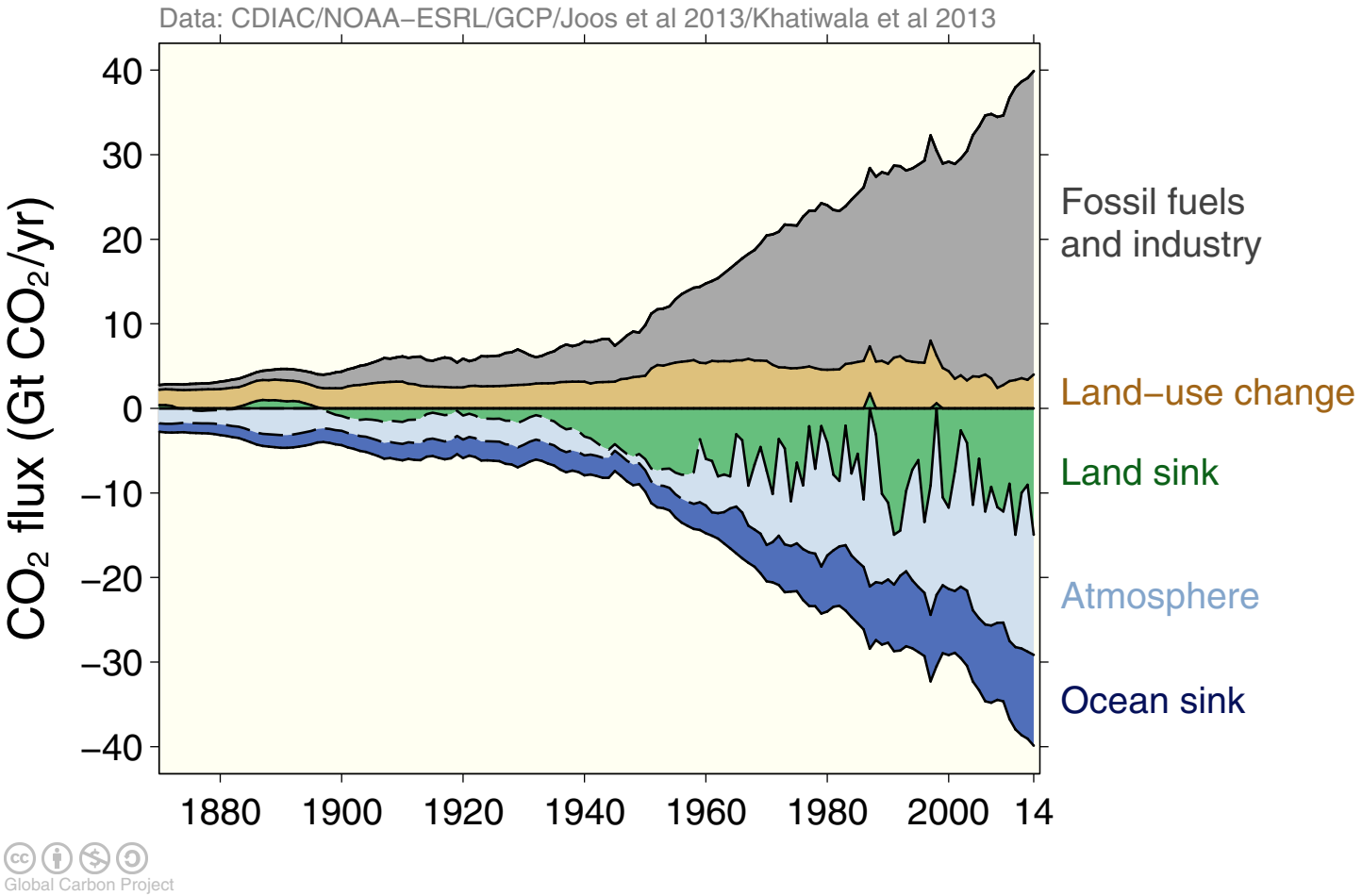



Economic activity is measured in Purchasing Power Parity

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

# Global carbon budget

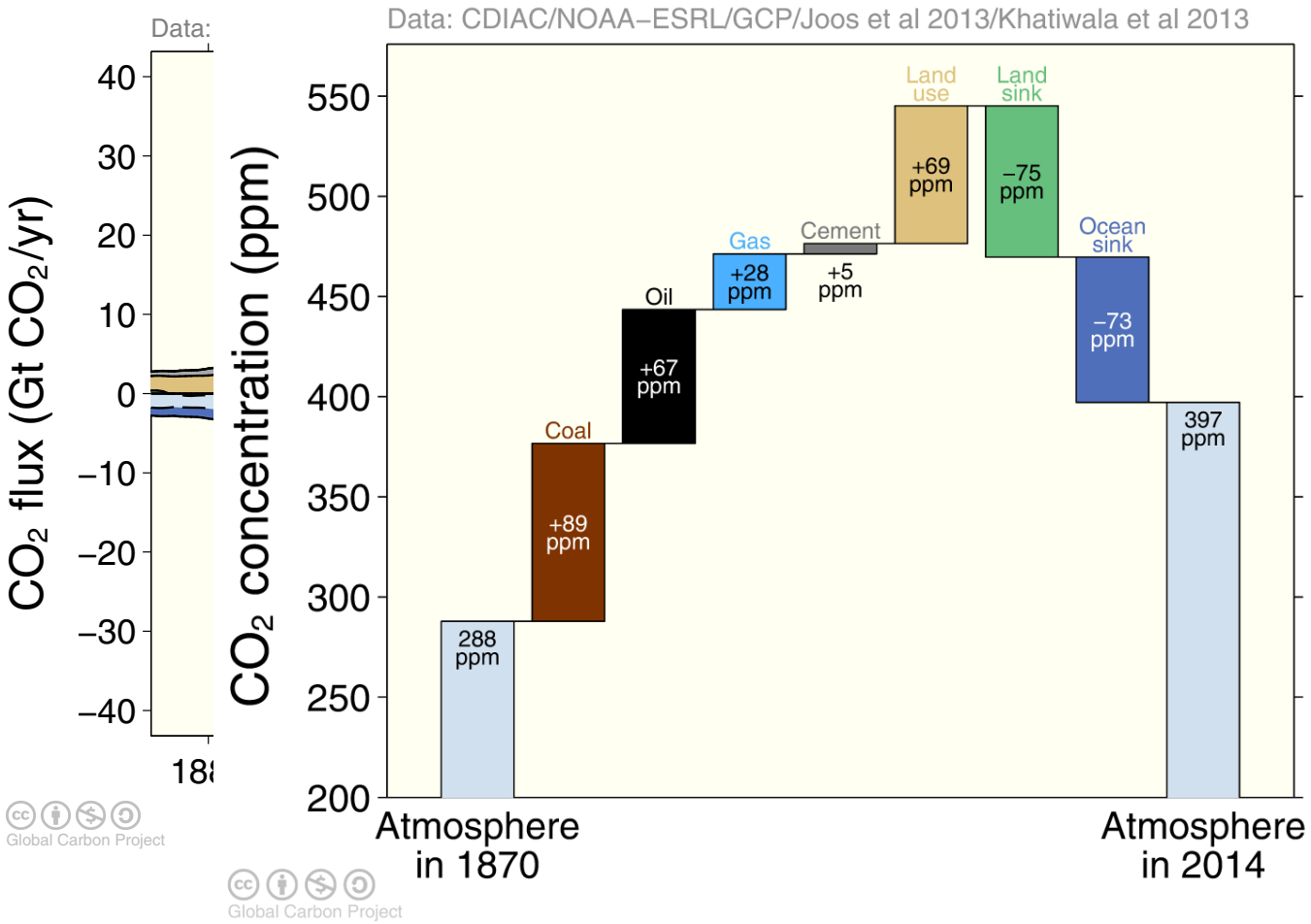
The carbon sources from fossil fuels, industry, and land use change emissions are balanced by the atmosphere and carbon sinks on land and in the ocean




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

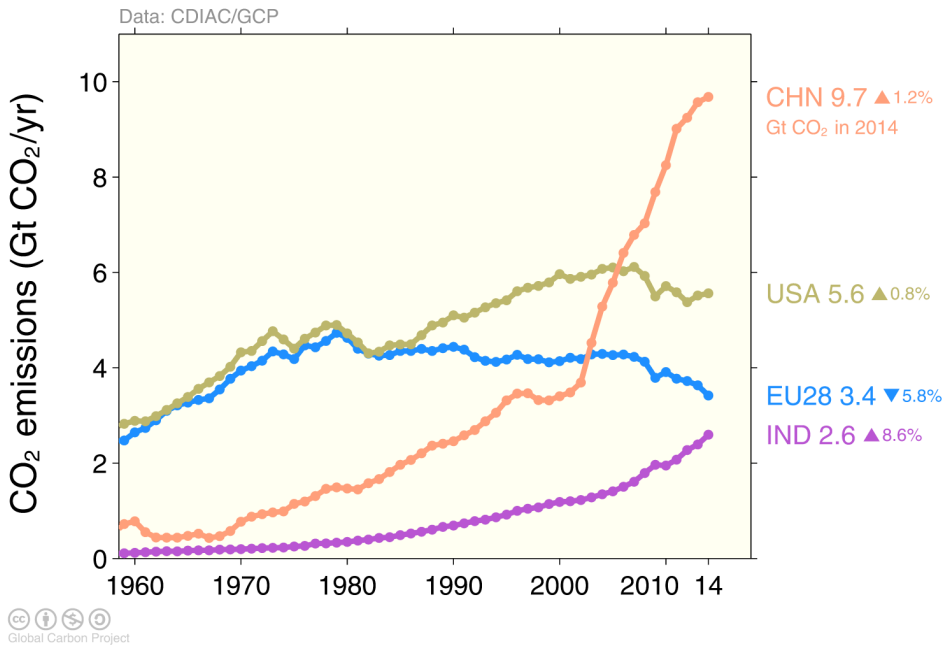
The carbon sources from fossil fuels, industry, and land use change emissions are balanced by the atmosphere and carbon sinks on land and in the ocean

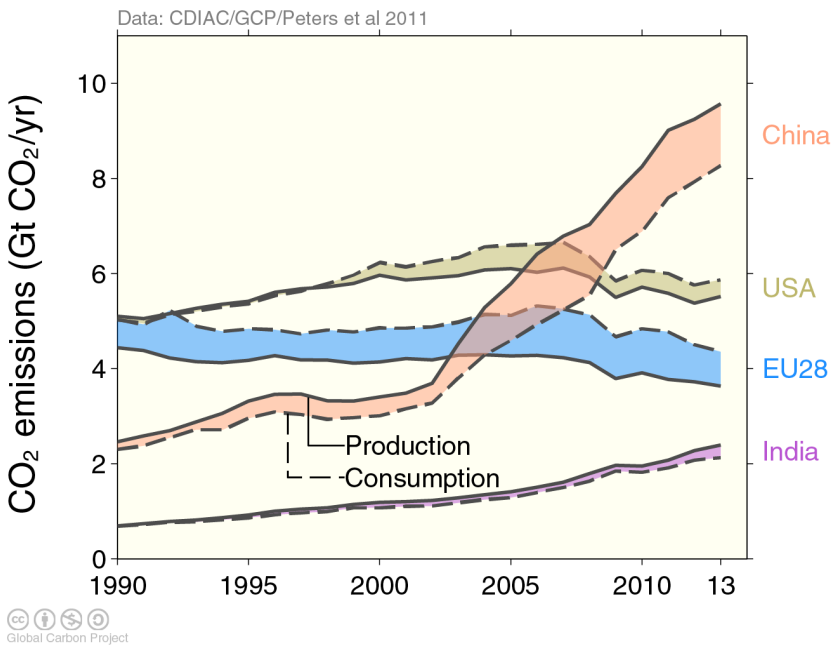



Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Joos et al 2013; Khatiwala et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

# Top fossil fuel emitters

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




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

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

New release 2015

# 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 history and future of human development and carbon*

Go


## Emissions

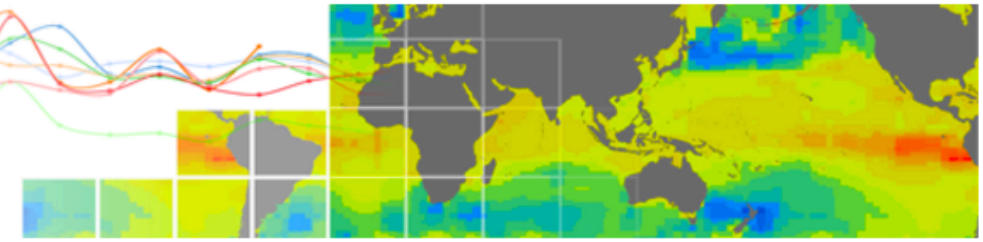
*Explore and download global and country level carbon emissions from human activity*

Go

## Research

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

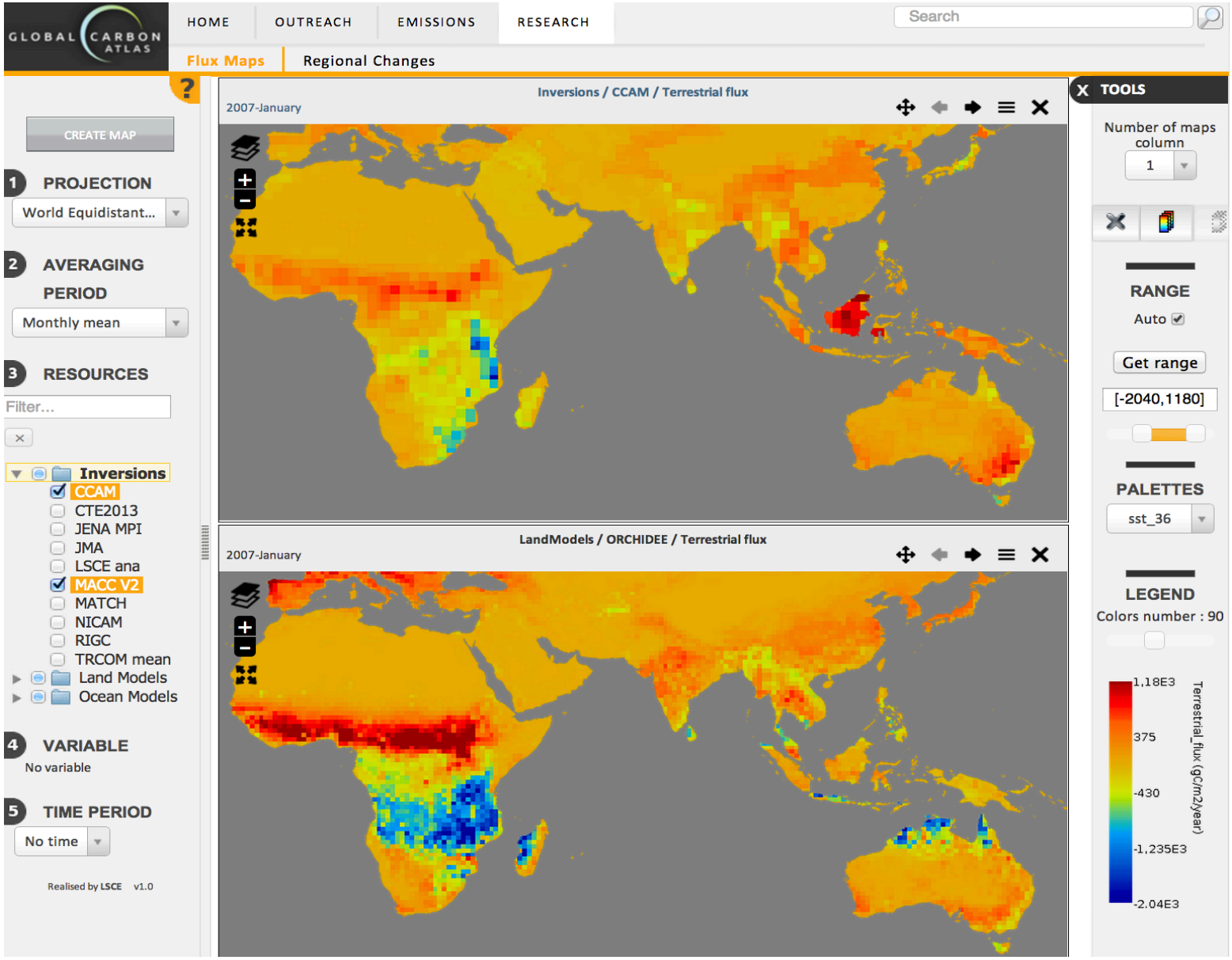
Go



# Atlas 1: Engagement with General Public

# Atlas 2: Engagement with Policy Actors (Data Access, Plotting)

# Atlas 3: Engagement with Research Community



GLOBAL CARBON PROJECT

nature climate change

COMMENTARY:

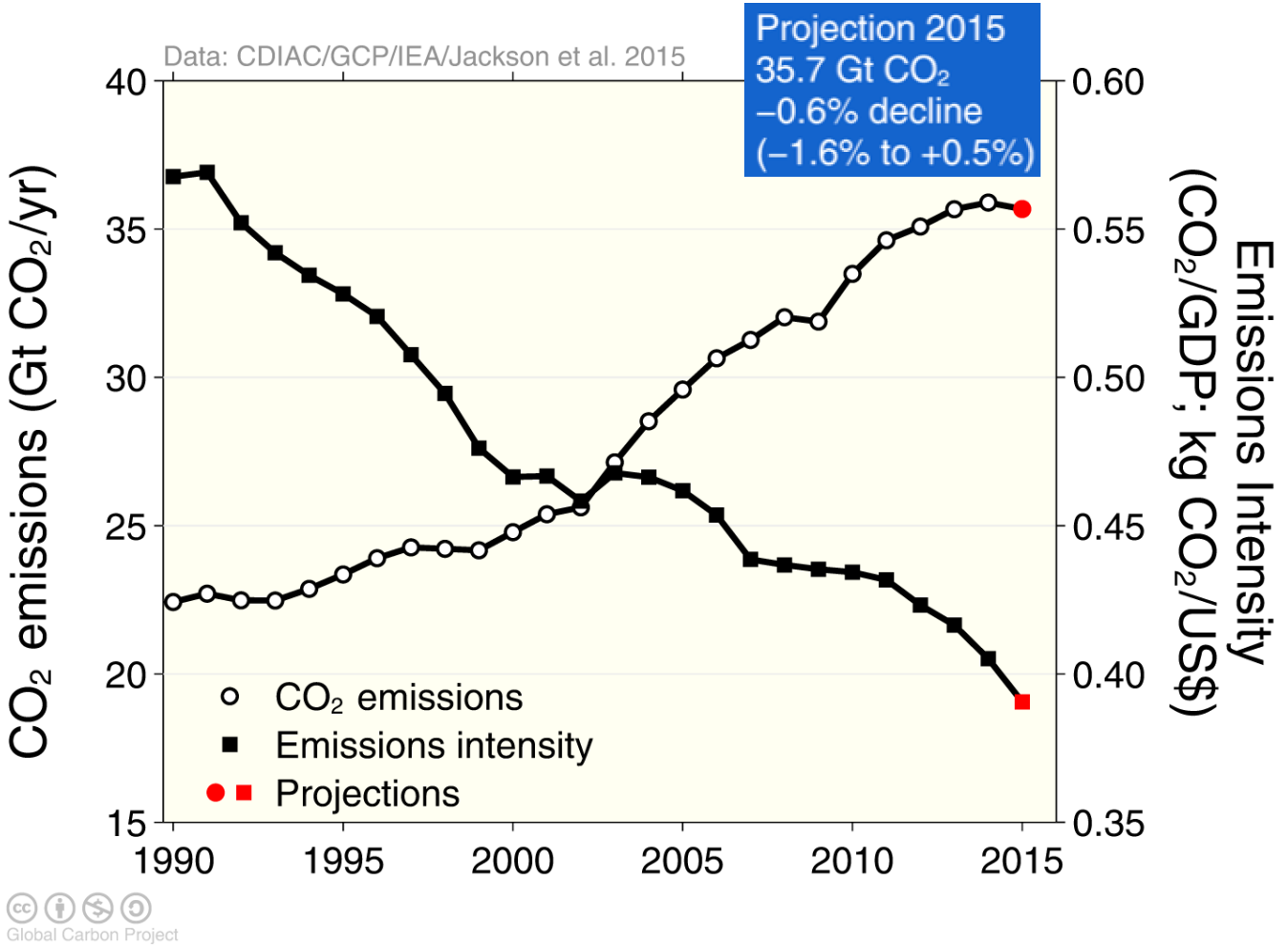
# Reaching peak emissions

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

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

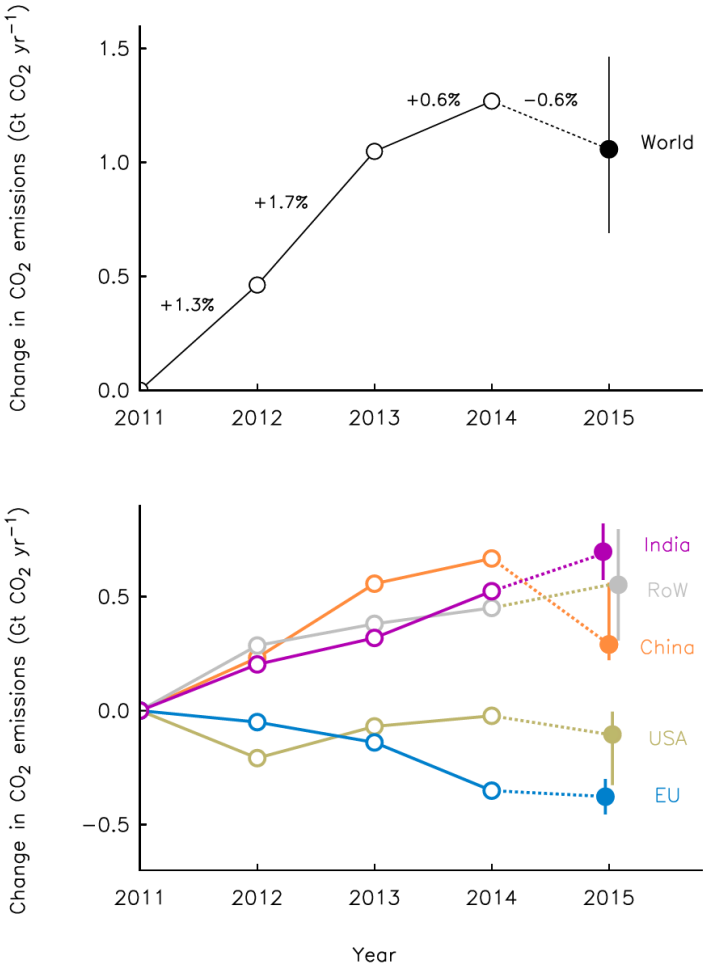



GDP: Gross Domestic Product using Purchasing Power Parity

Source: Jackson et al 2015a; 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

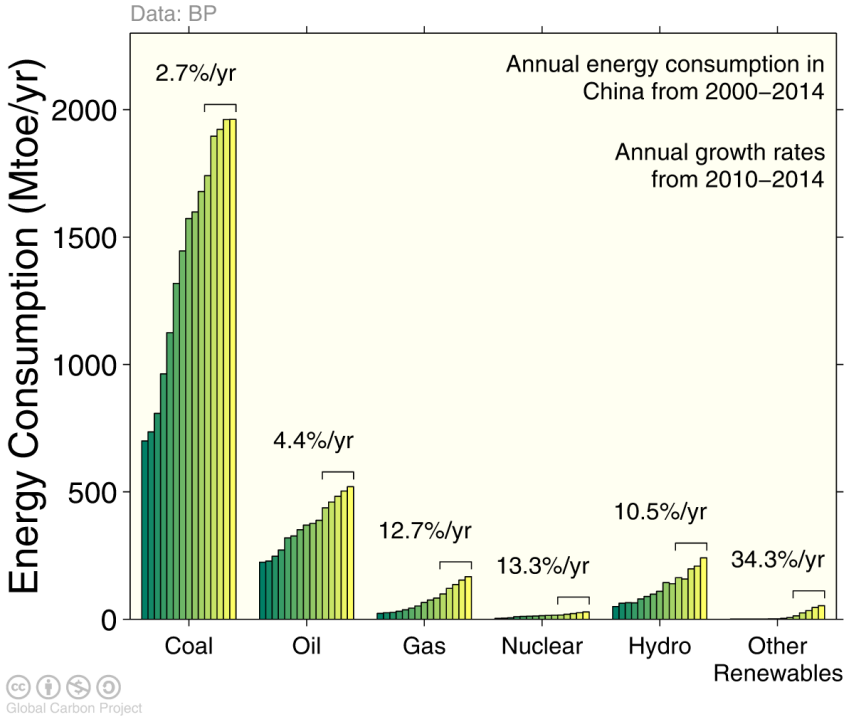



The most recent projected change in emissions is from ~35.9 CO2 (9.8 Gt C) in 2014 to ~35.7 Gt CO2 (9.7 Gt C) in 2015.
The filled symbols for 2015 denote projections.
Source: Jackson et al 2015; Global Carbon Budget 2015

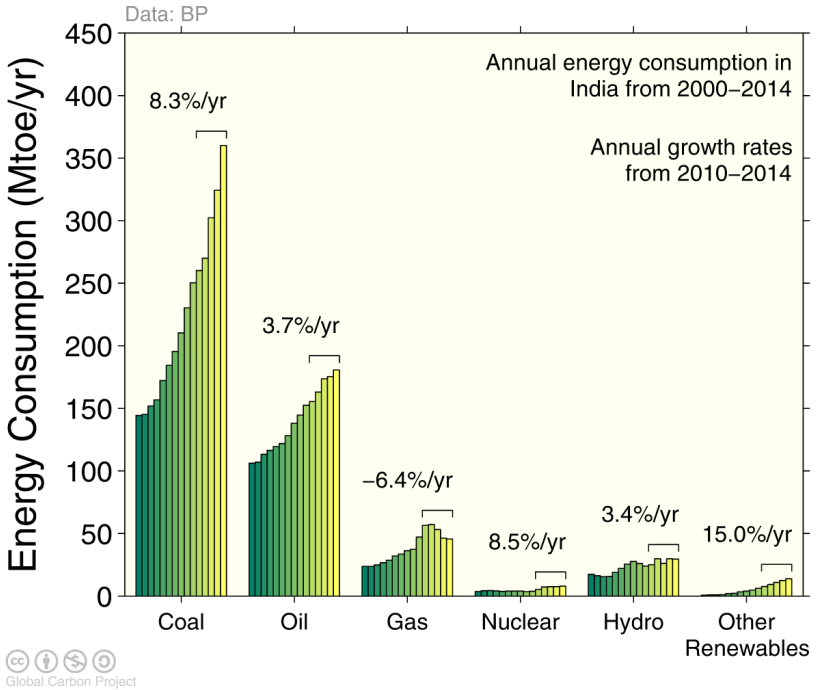
# Energy consumption by energy type - China

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

China

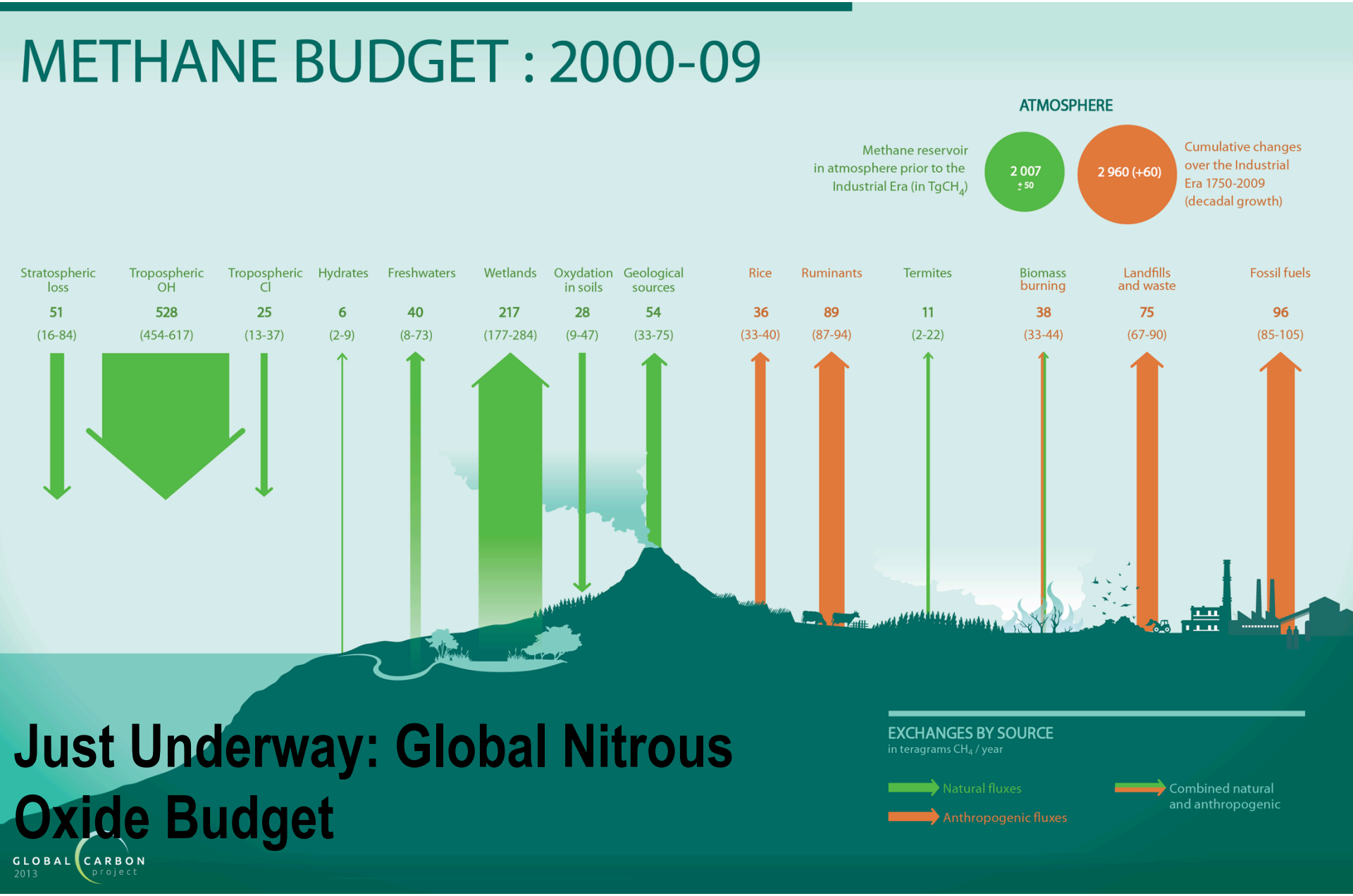



India




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

# Global Methane Budget (2nd budget is nearing completion)




**Just Underway: Global Nitrous Oxide Budget**

Based on Kirschke et al. 2013, Nature Geoscience

GLOBAL CARBON PROJECT

nature climate change

REVIEW ARTICLE

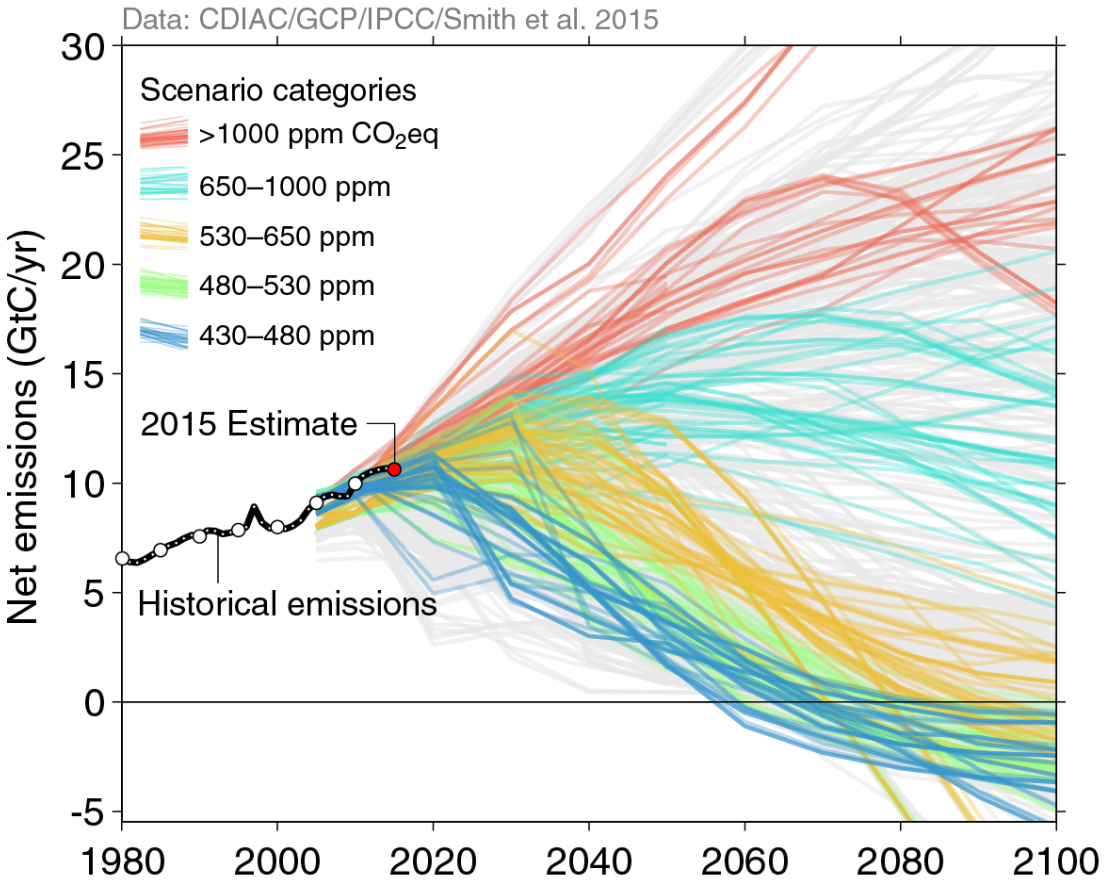
PUBLISHED ONLINE: 7 DECEMBER 2015 | DOI: 10.1038/NCLIMATE2870

# 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]

# Scenarios including Negative Emission Technologies

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



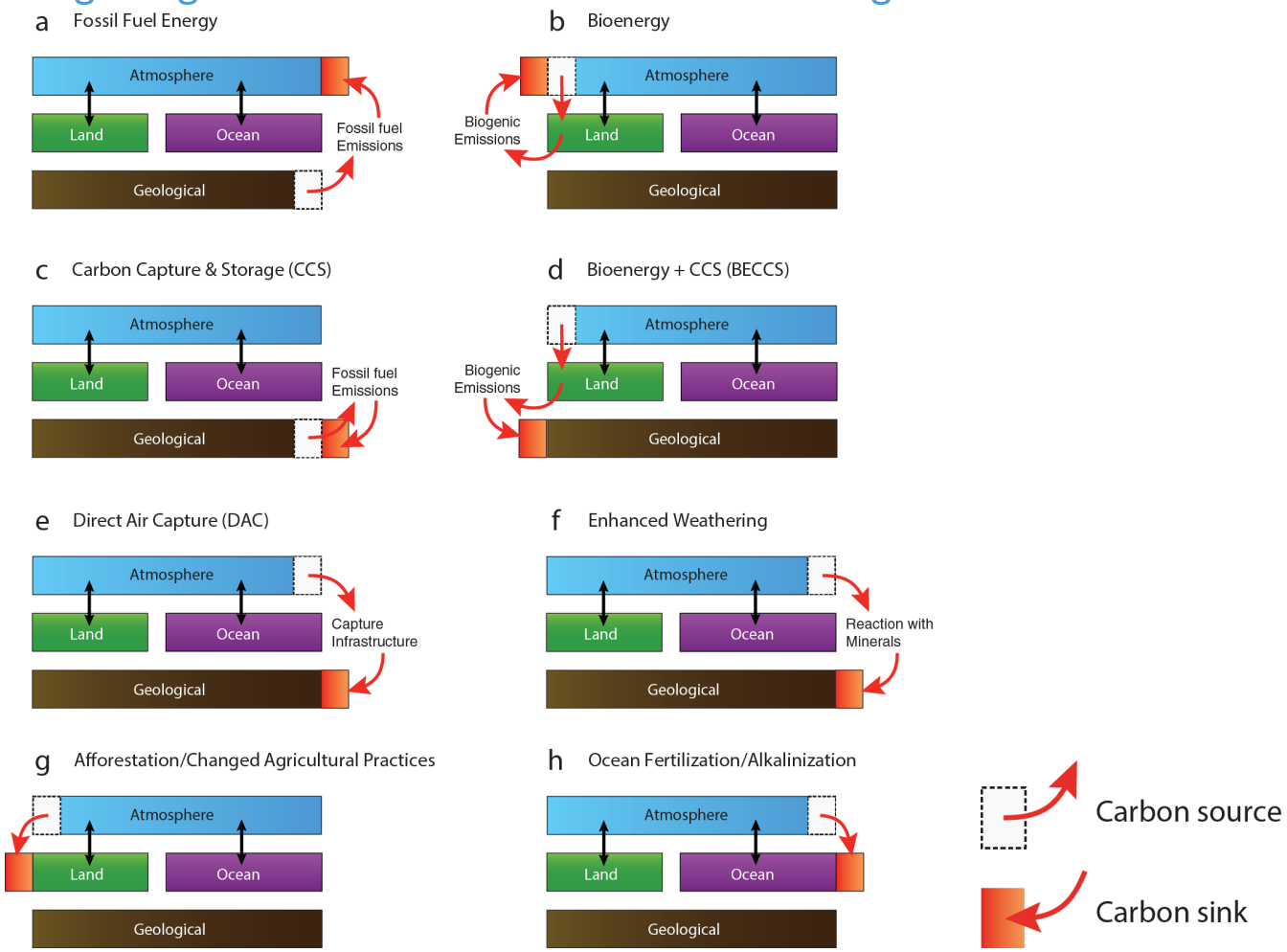



Scenarios with Negative Emissions Technologies from the AMPERE and LIMITS modelling comparison exercises (colours), with all other scenarios from the IPCC AR5 database shown in grey

Source: Smith et al 2015; Global Carbon Budget 2015

# 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

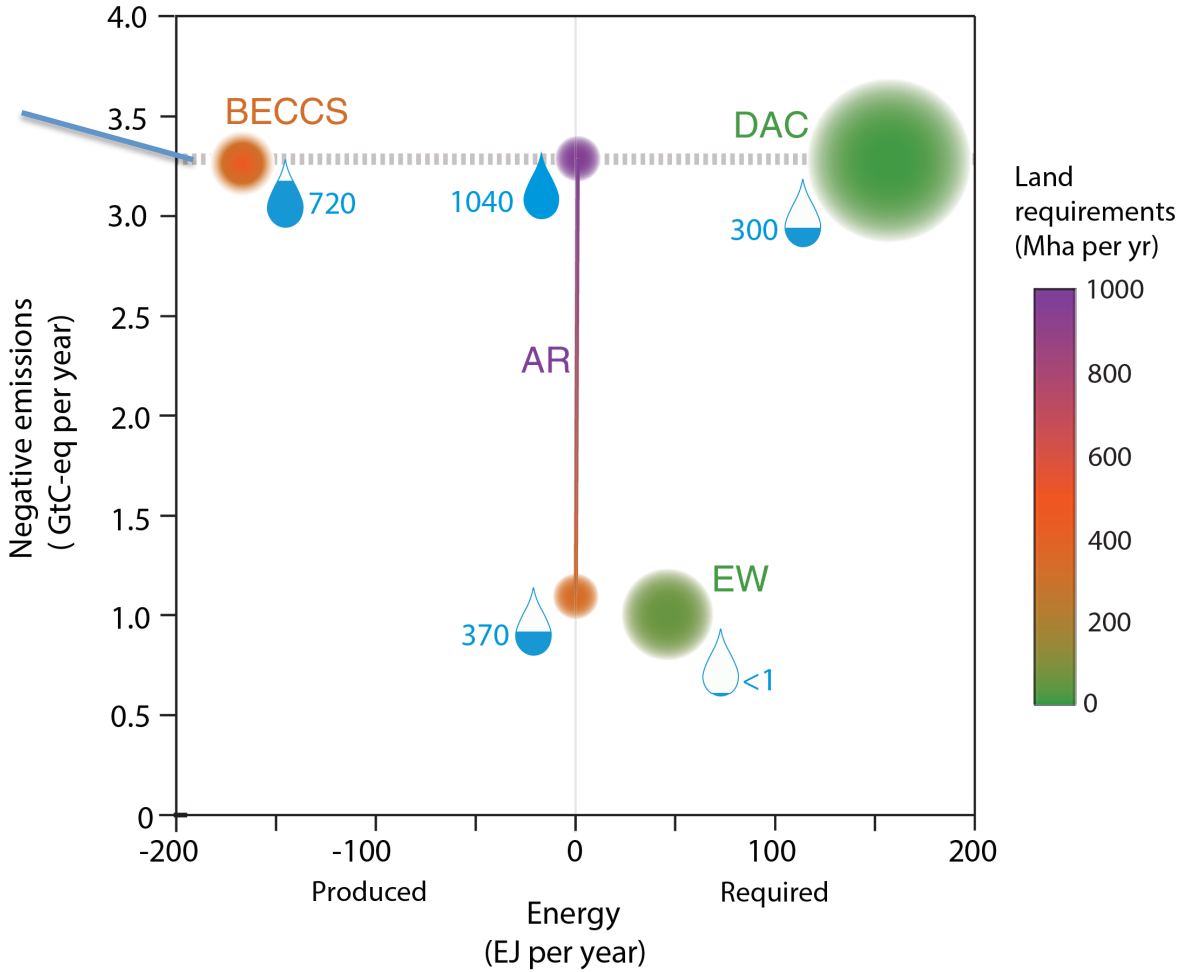
# Impact/limit summary for Negative Emission Technologies

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

~3% of the freshwater currently appropriated for human use

380–700 Mha

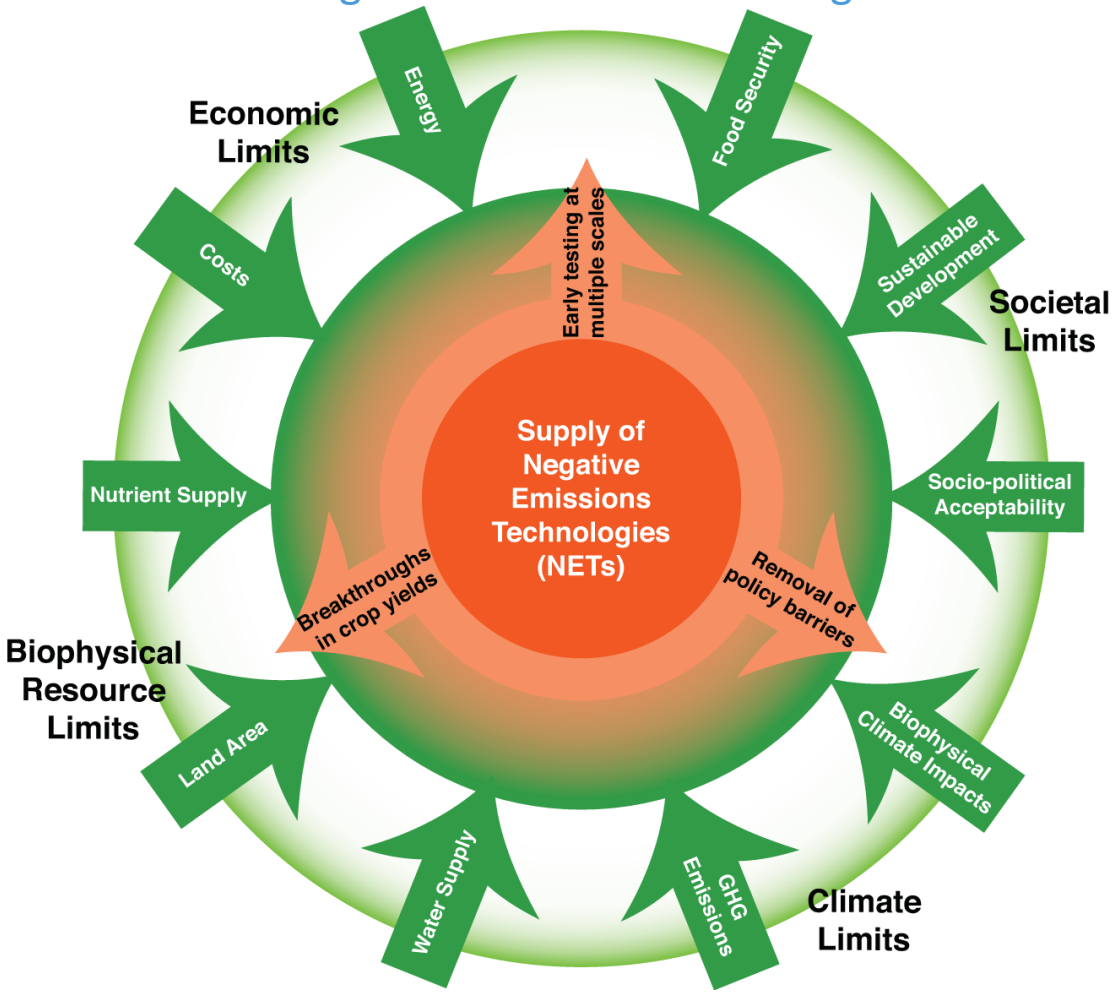
138 billion




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

Environmental Research Letters

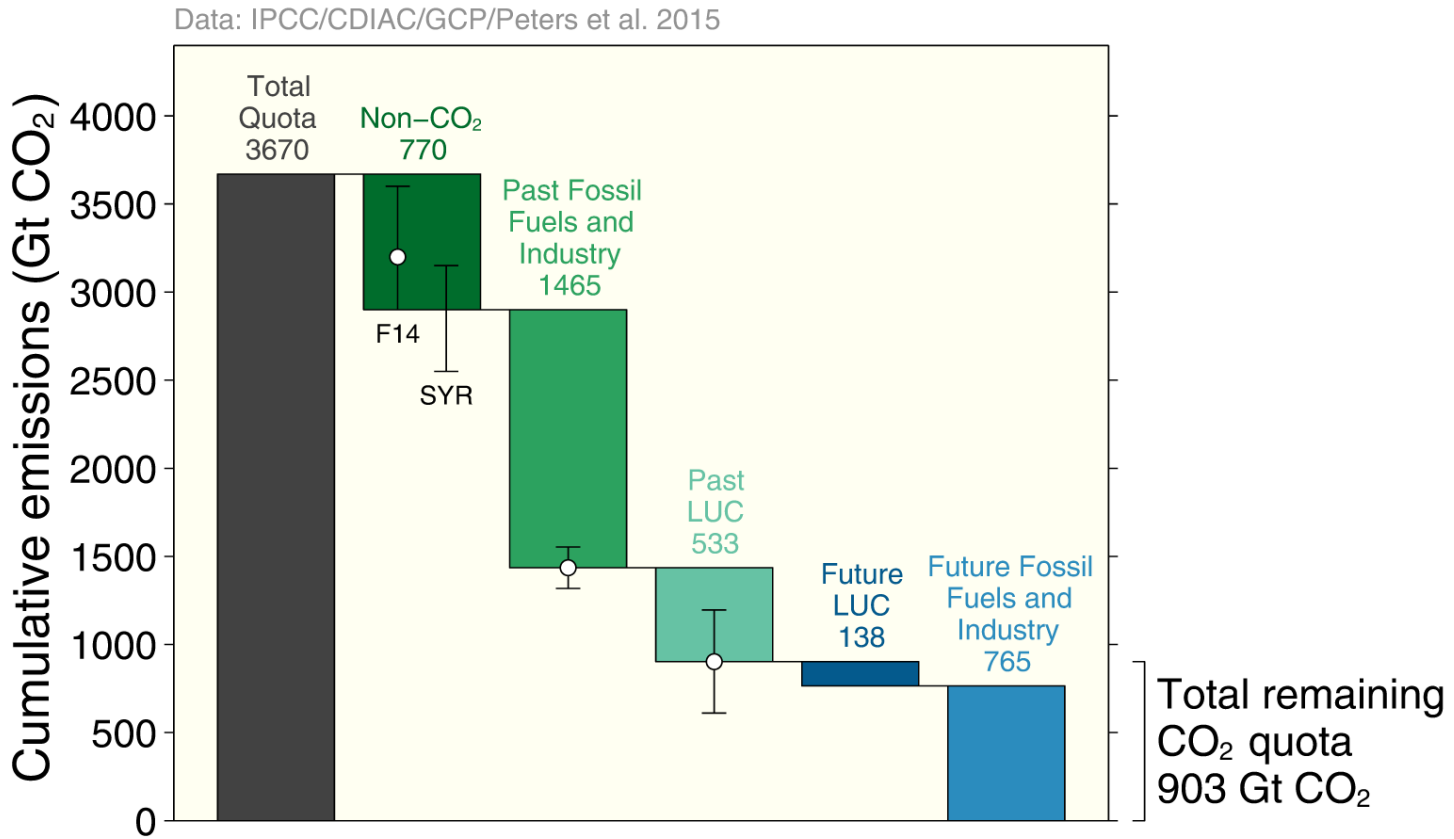
# Measuring a fair and ambitious climate agreement using cumulative emissions

**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



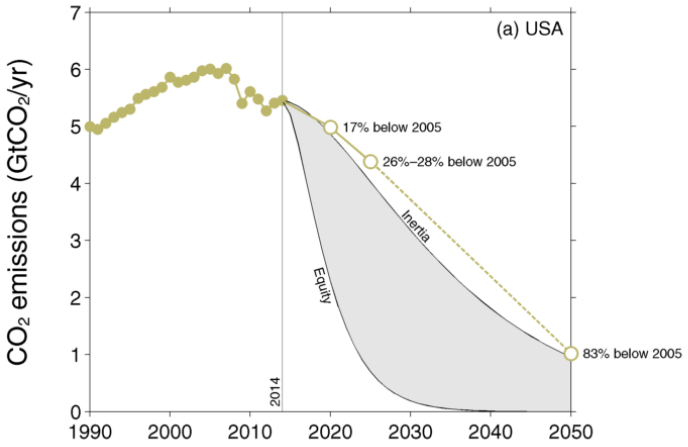


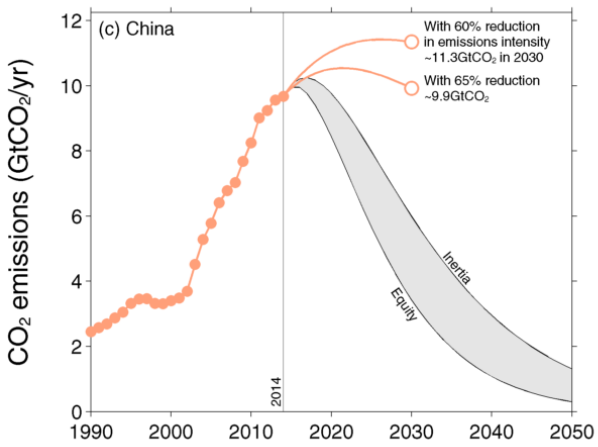

Grey: Total quota for 2°C. Green: Removed from quota. Blue: remaining quota.
With projected 2015 emissions, this remaining quota drops to 865 Gt $CO_2$

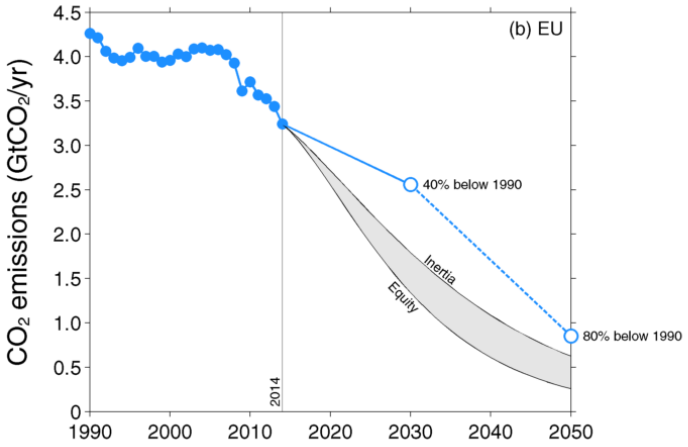
Source: Peters et al 2015; Global Carbon Budget 2015

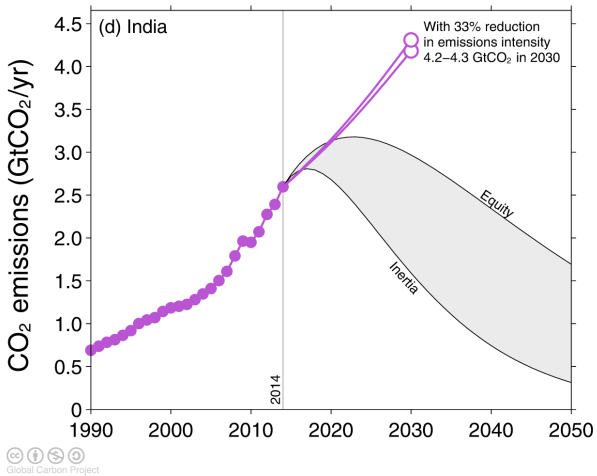
# The emission pledges (INDCs) of the top-4 emitters

## 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

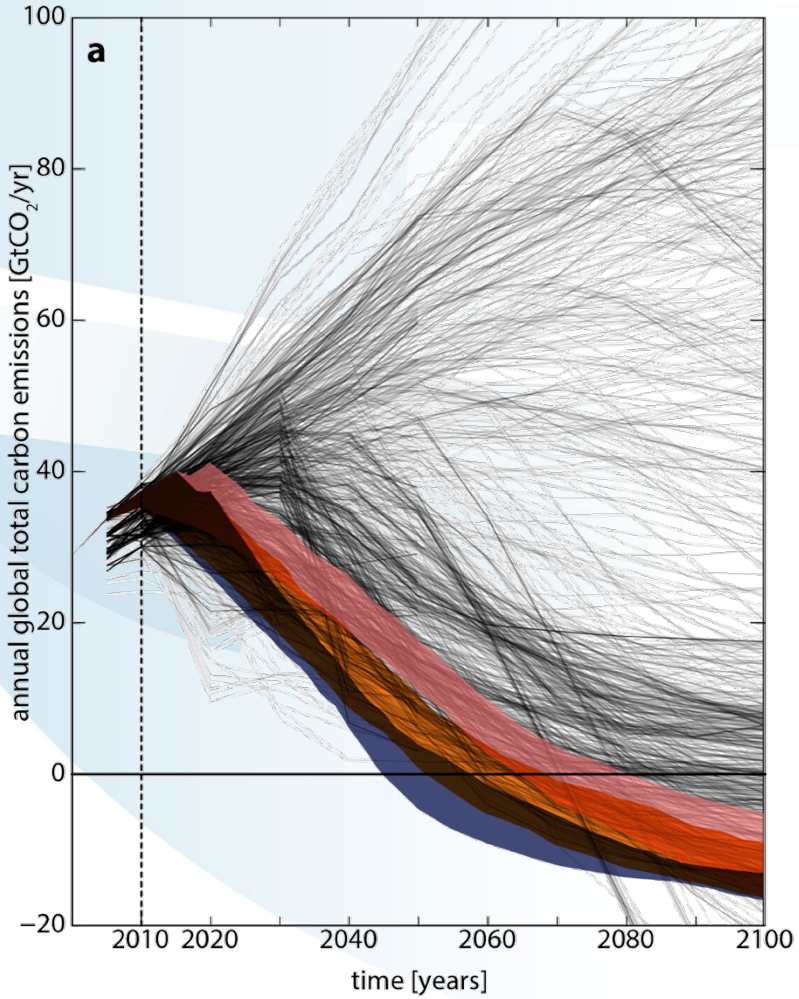
GLOBAL CARBON PROJECT

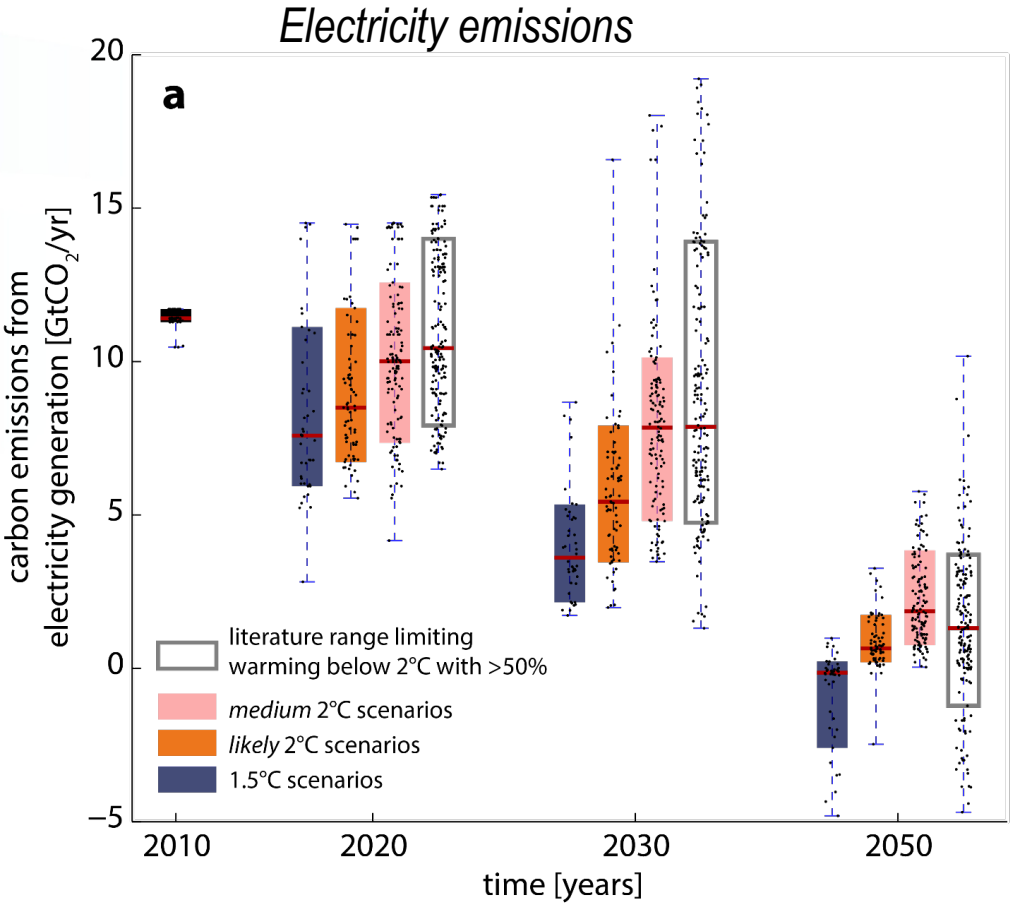
# Meeting Stanford 2016

Specific attention to negative emissions and 1.5 deg C scenarios

# What do 1.5°C scenarios look like?

*(How do they differ from 2°C?)*




this study's scenarios
- *medium* 2°C
- *likely* 2°C
- below 1.5°C

Rogelj et al (2015) NCC

# Future

- Maintain and grow data-driven work on:
  - Contemporary multi-GHG Budgets
  - Peak emissions and permissible budgets to climate stabilization.
  - Sustainable deployment of carbon-mitigation options, including negative emission technologies.

- Development of Knowledge Action Networks of Future Earth:
  - Primarily, provide leadership for the “Decarbonization” KAN.
  - Secondarily, contribute to other KANs: nexus water-food-energy, urbanization, oceans, others.

# Acknowledgements

The work presented here has been possible thanks to the enormous observational and modeling efforts of many institutions and networks, some of which are listed below:

**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; Jackson et al. 2015