Societal aspects of climate change

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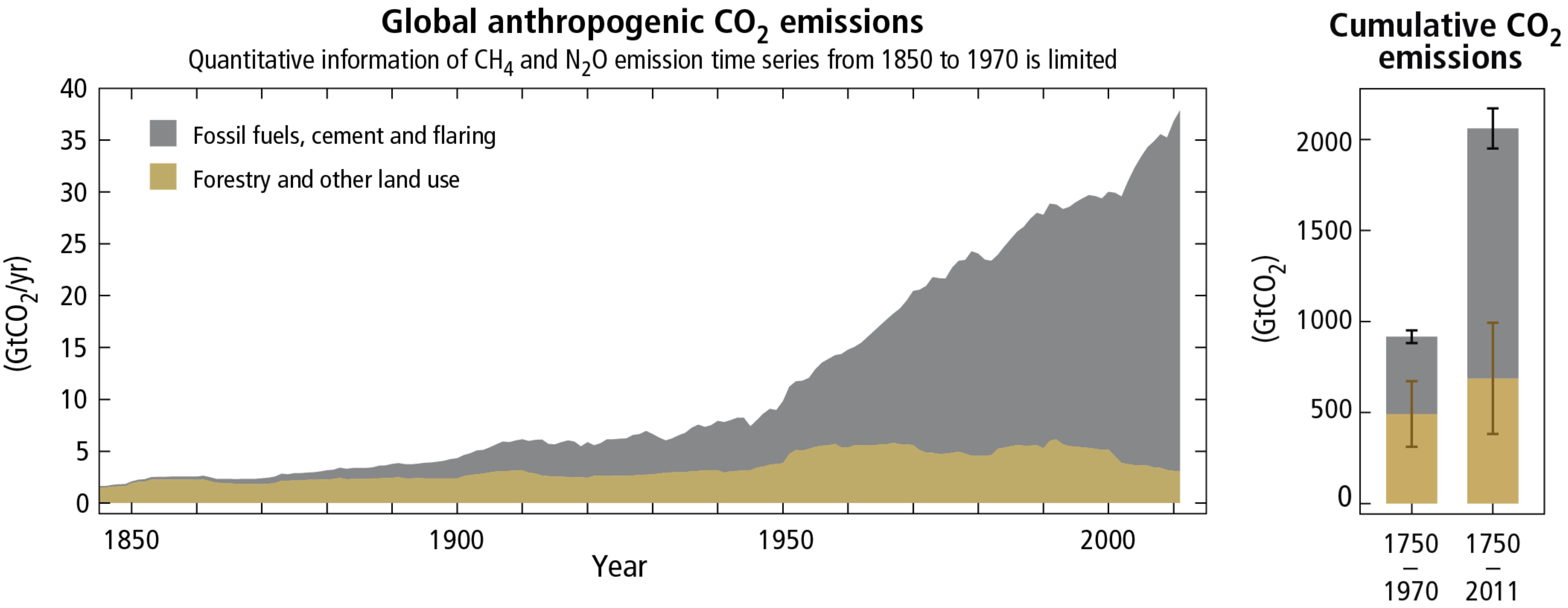
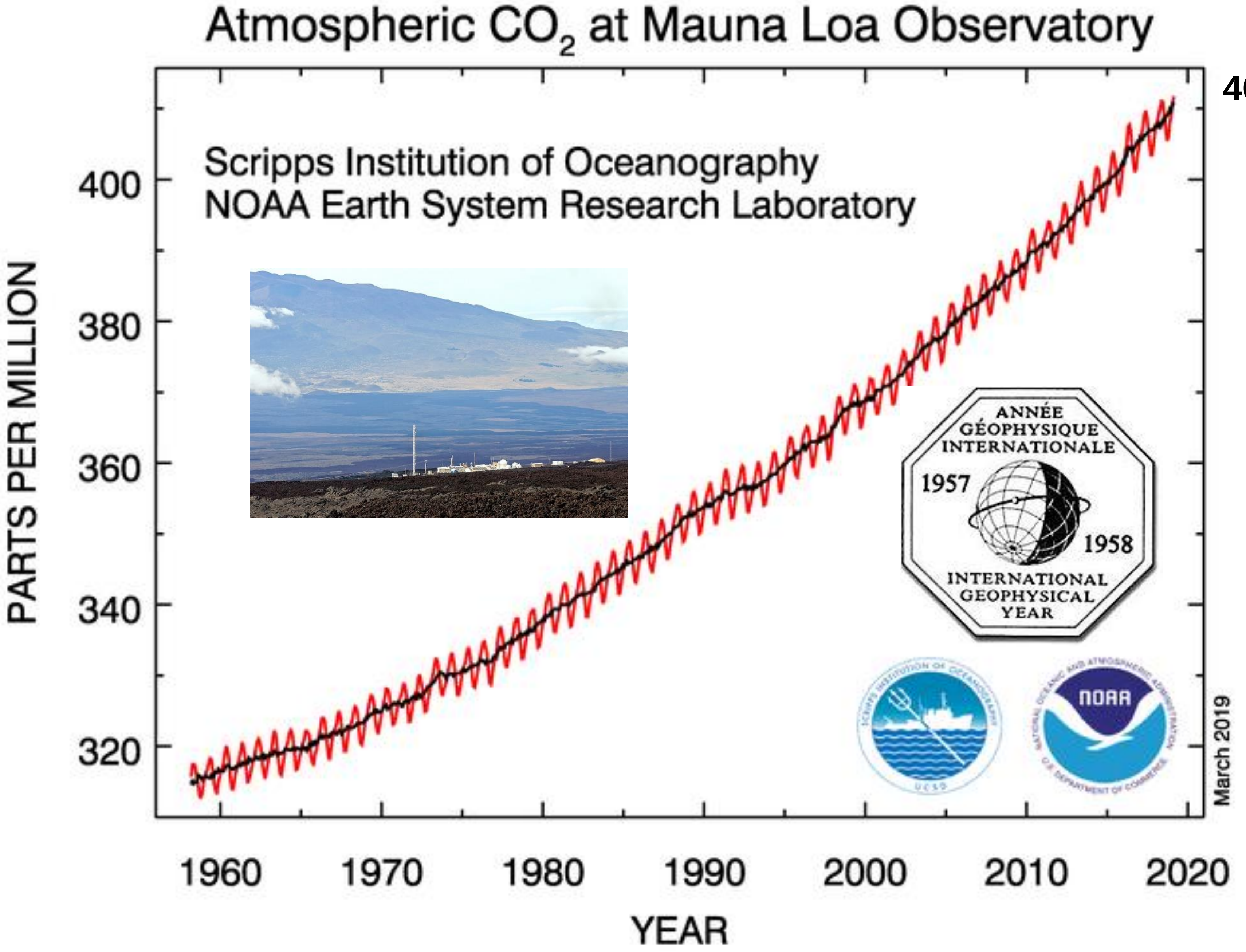
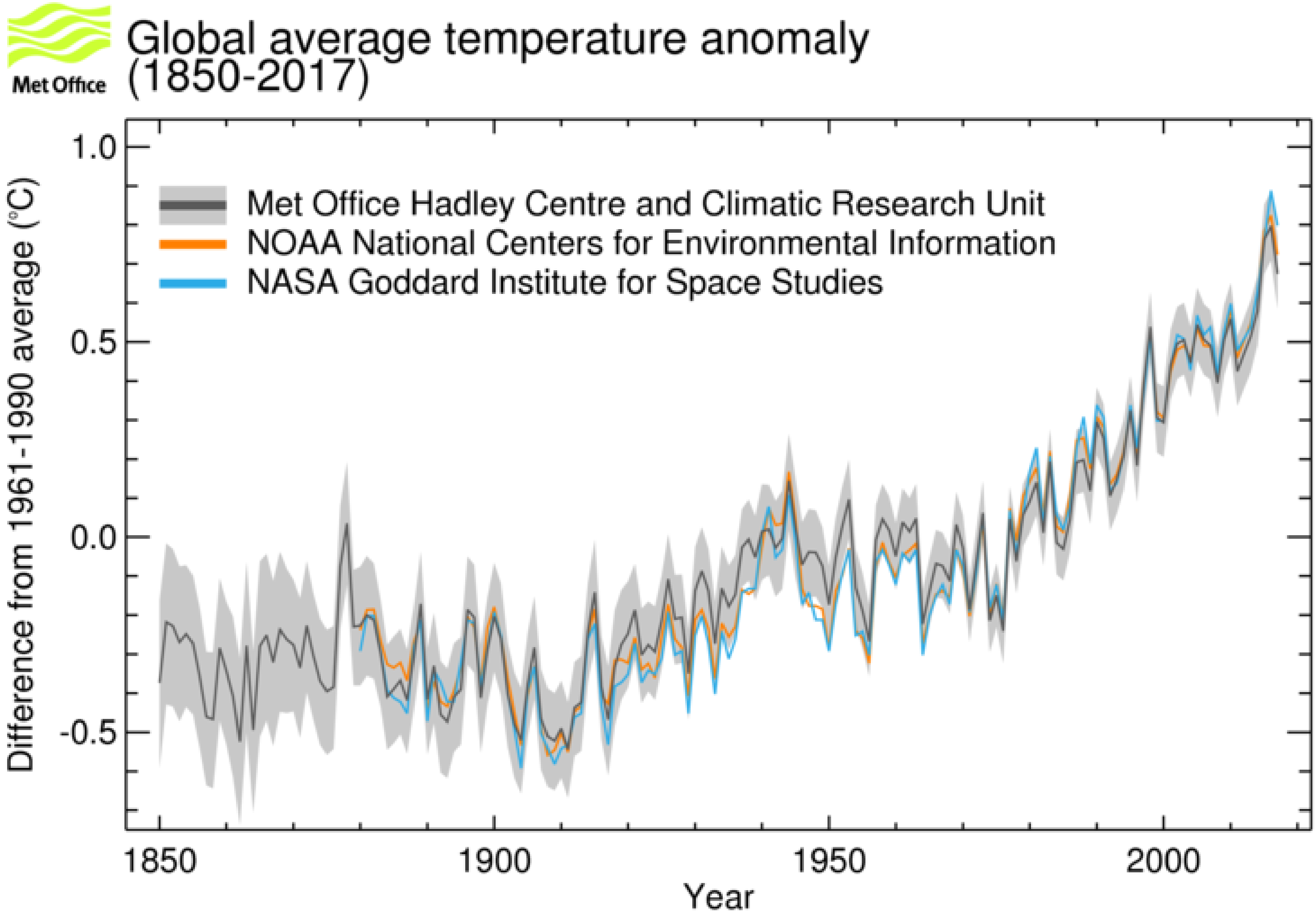
Konverentsi
”Kliimaneutraalsus”
Tallin, Radisson Blu Sky
Hotel 13.9.2019

Current rate 42 Gt/yr

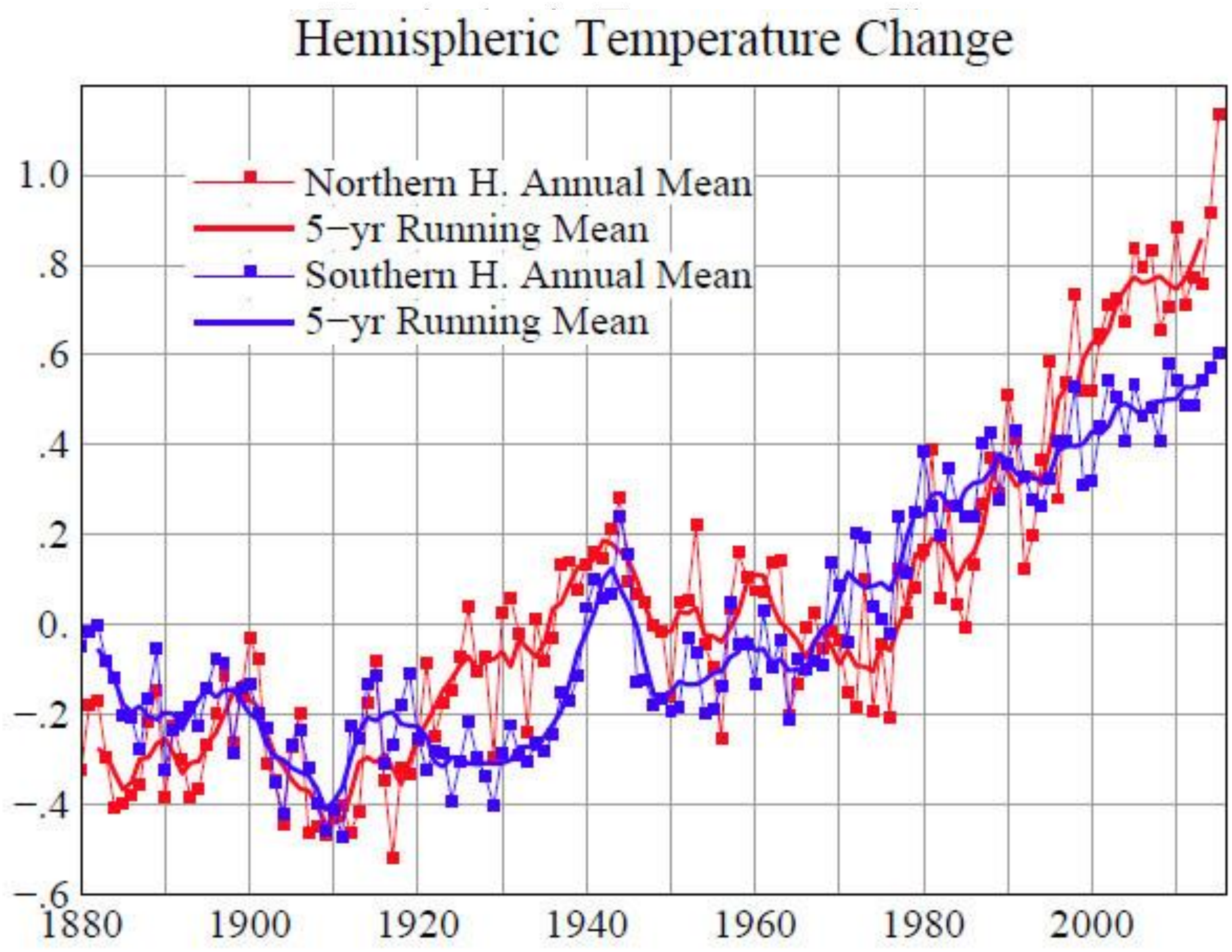



Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
YEAR
ANNÉE GÉOPHYSIQUE INTERNATIONALE
1957
1958
INTERNATIONAL GEOPHYSICAL YEAR
NOAA
March 2019

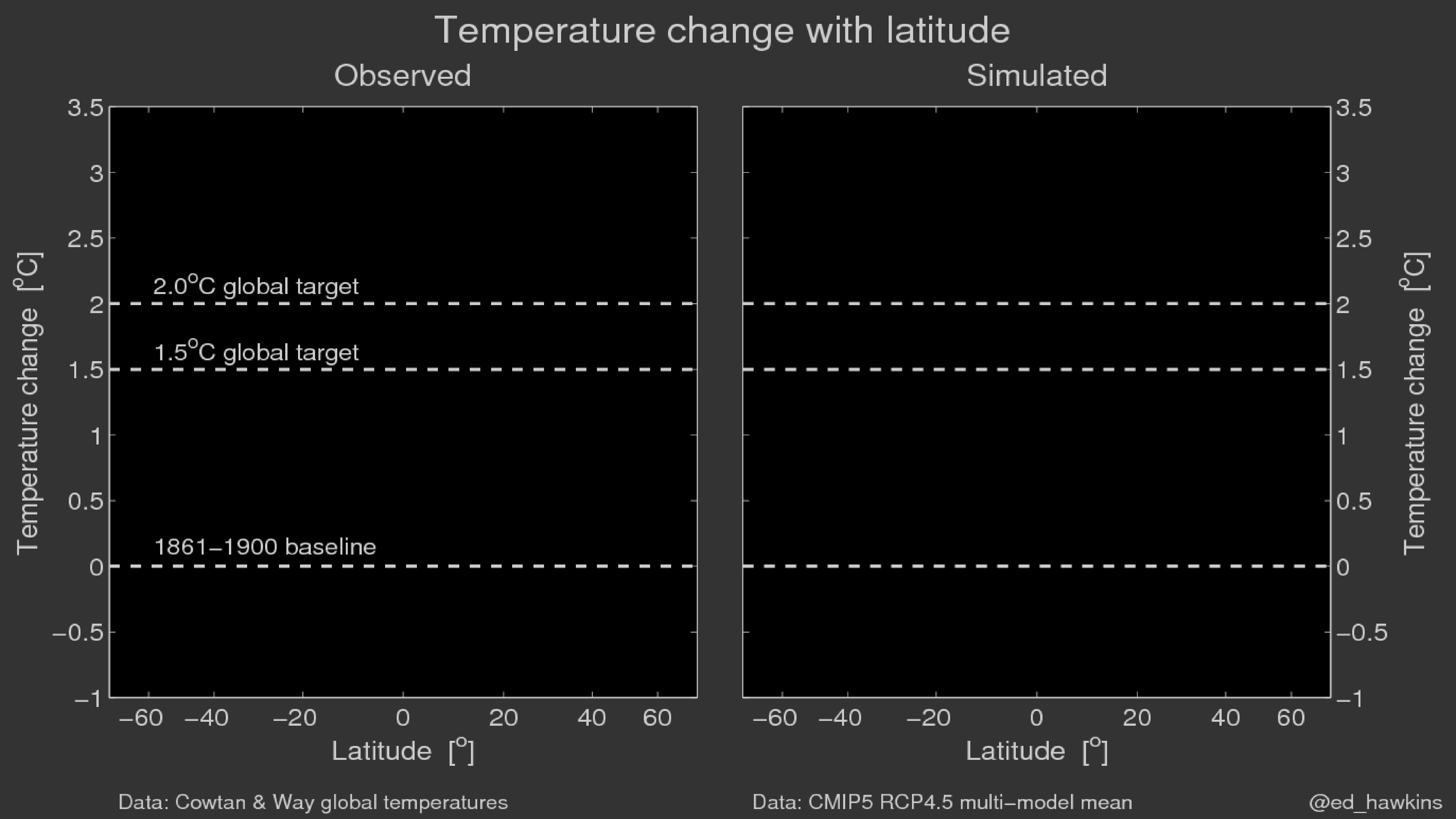
409,95 ppm



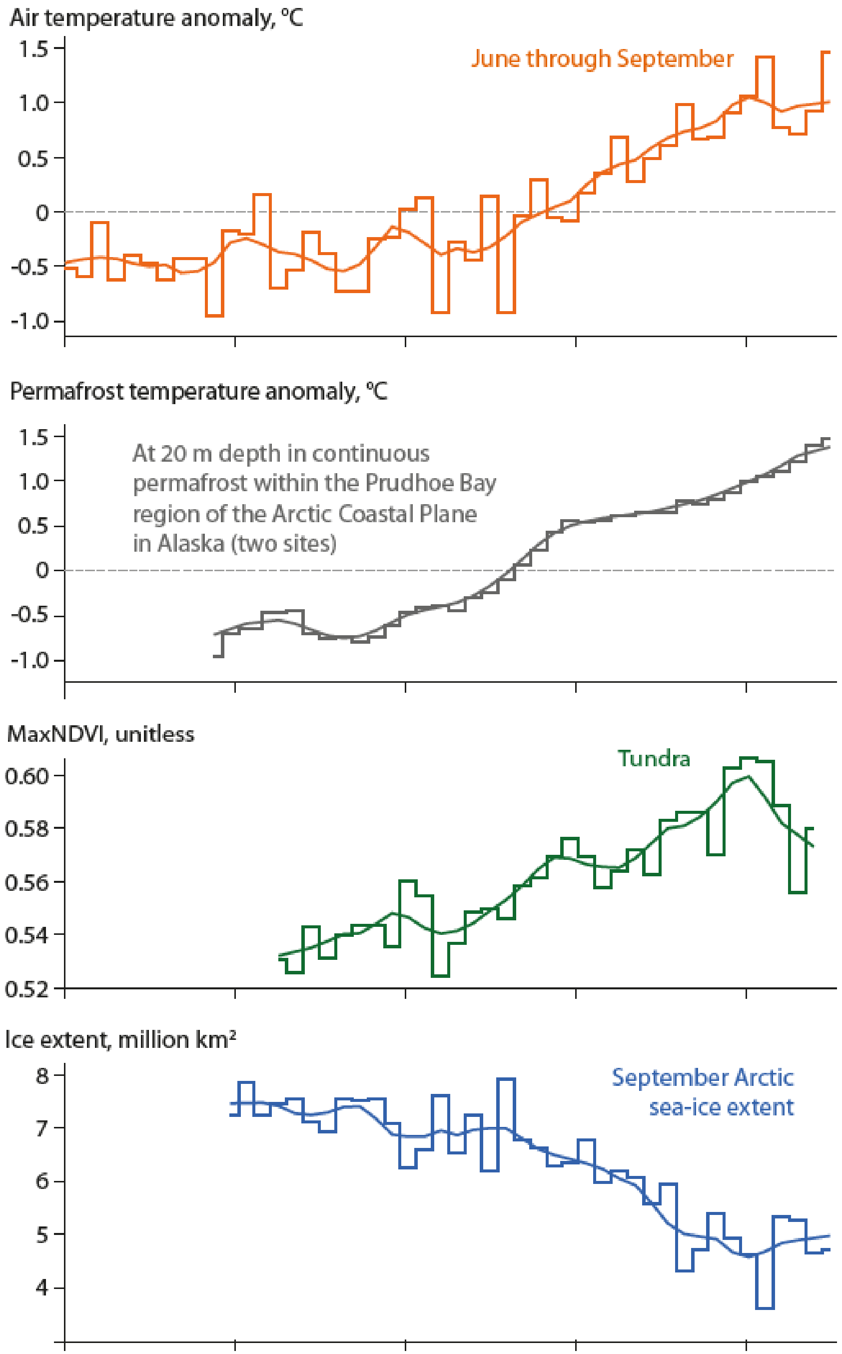
Met Office
Global average temperature anomaly
(1850-2017)
Met Office Hadley Centre and Climatic Research Unit
NOAA National Centers for Environmental Information
NASA Goddard Institute for Space Studies
Difference from 1961-1990 average (°C)
1.0
0.5
0.0
-0.5
1850
1900
1950
2000
Year



Hemispheric Temperature Change
Northern H. Annual Mean
5−yr Running Mean
Southern H. Annual Mean
5−yr Running Mean
1.0
.8
.6
.4
.2
0.
−.2
−.4
−.6
1880
1900
1920
1940
1960
1980
2000


Temperature change with latitude
Observed
Simulated
2.0°C global target
1.5°C global target
1861–1900 baseline
Temperature change [°C]
Latitude [°]
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−60 −40 −20 0 20 40 60
Data: Cowtan & Way global temperatures
Data: CMIP5 RCP4.5 multi–model mean
@ed_hawkins

11.2.1 Climate trends



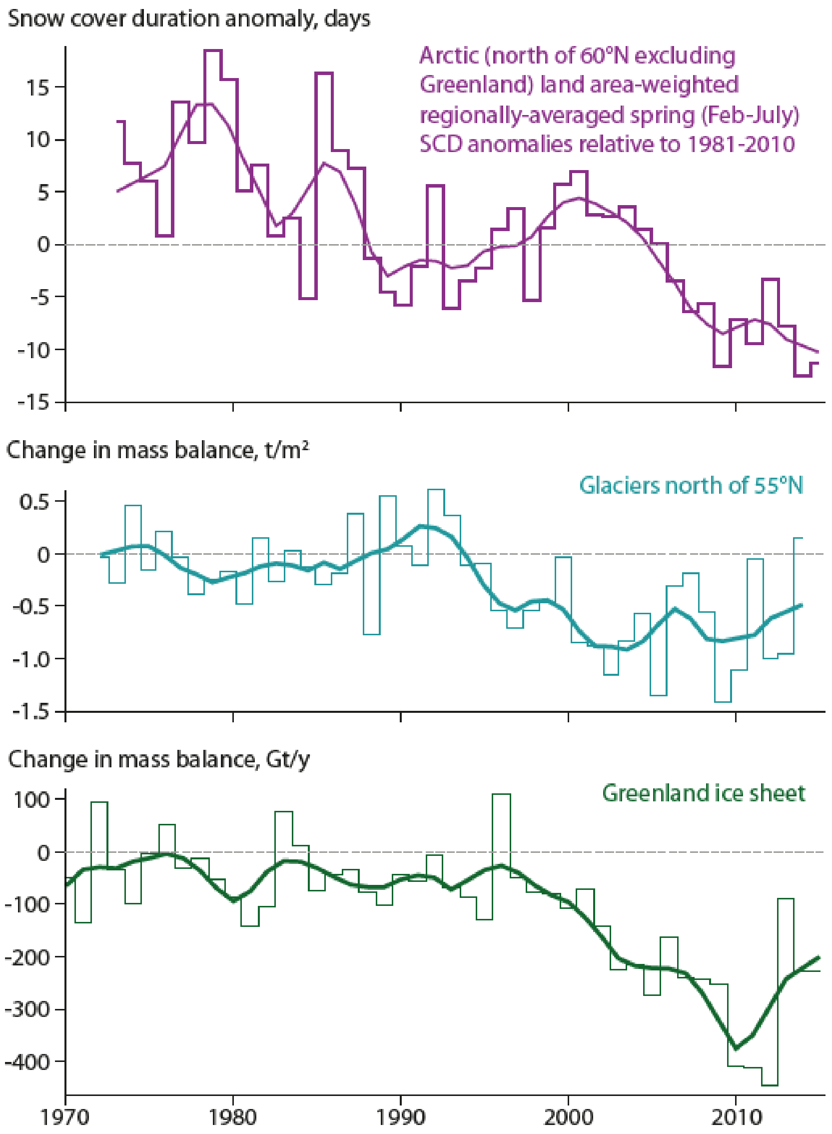
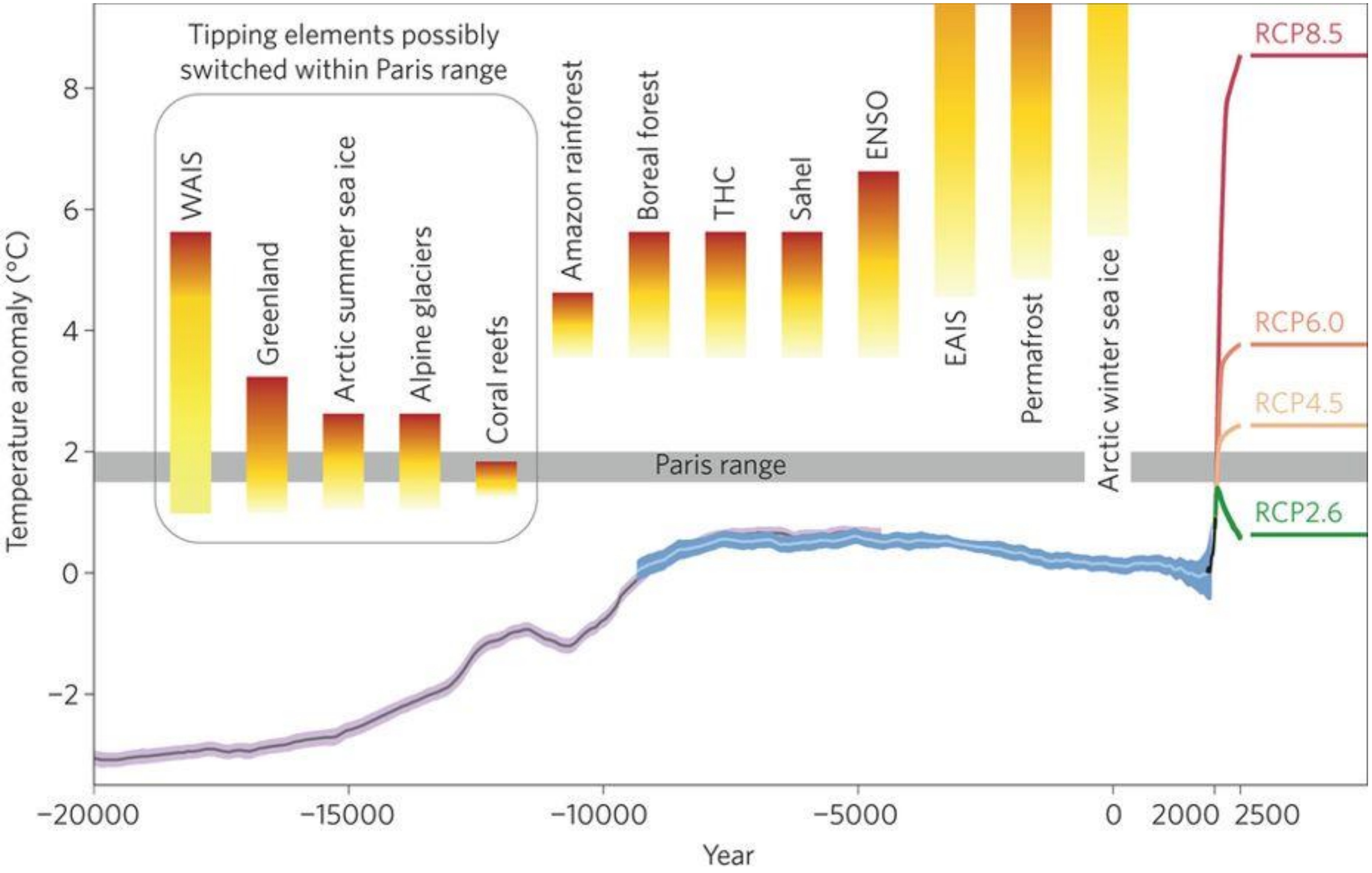


Figure 11.2 Relative change in multiple Arctic cryospheric indicators since 1970.

SWIPA Report 2018

IPCC Special Report on Global Warming of 1.5°C

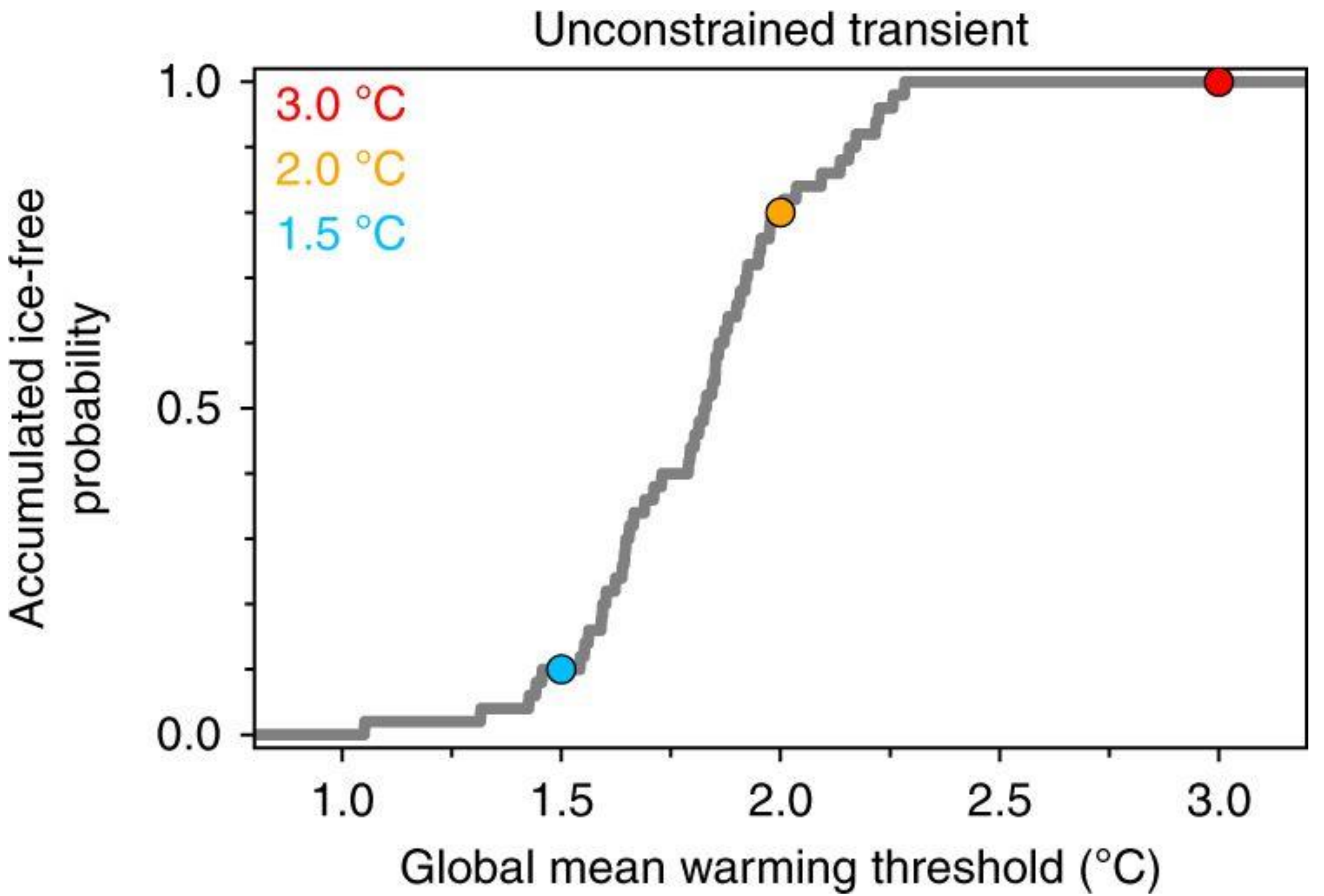
- Limiting global warming to 1.5°C would require "rapid and far-reaching" transitions in land, energy, industry, buildings, transport, and cities.
- Global net human-caused emissions of carbon dioxide (CO2) would need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050.
- This means that any remaining emissions would need to be balanced by removing CO2 from the air.



WAIS = West Antarctic Ice Sheet
THC = thermohaline circulation
ENSO = El Niño–Southern Oscillation
EAIS = East Antarctic Ice Sheet

Schellnhuber et al. 2016, NCC

The accumulated ice-free probability. The coloured circles indicate the accumulated ice-free probability at 1.5 °C (blue), 2.0 °C (orange) and 3.0 °C (red) global mean warming.



Sigmond et al. 2018. Nature Climate Change

A climate change experiment study (Webb et al. 2016) in Alaska shows that carbon loss from soils during the **snow covered period** offsets carbon uptake by plants during the growing season. This results in a shift in the subarctic tundra ecosystem from a carbon sink to a carbon **source**.

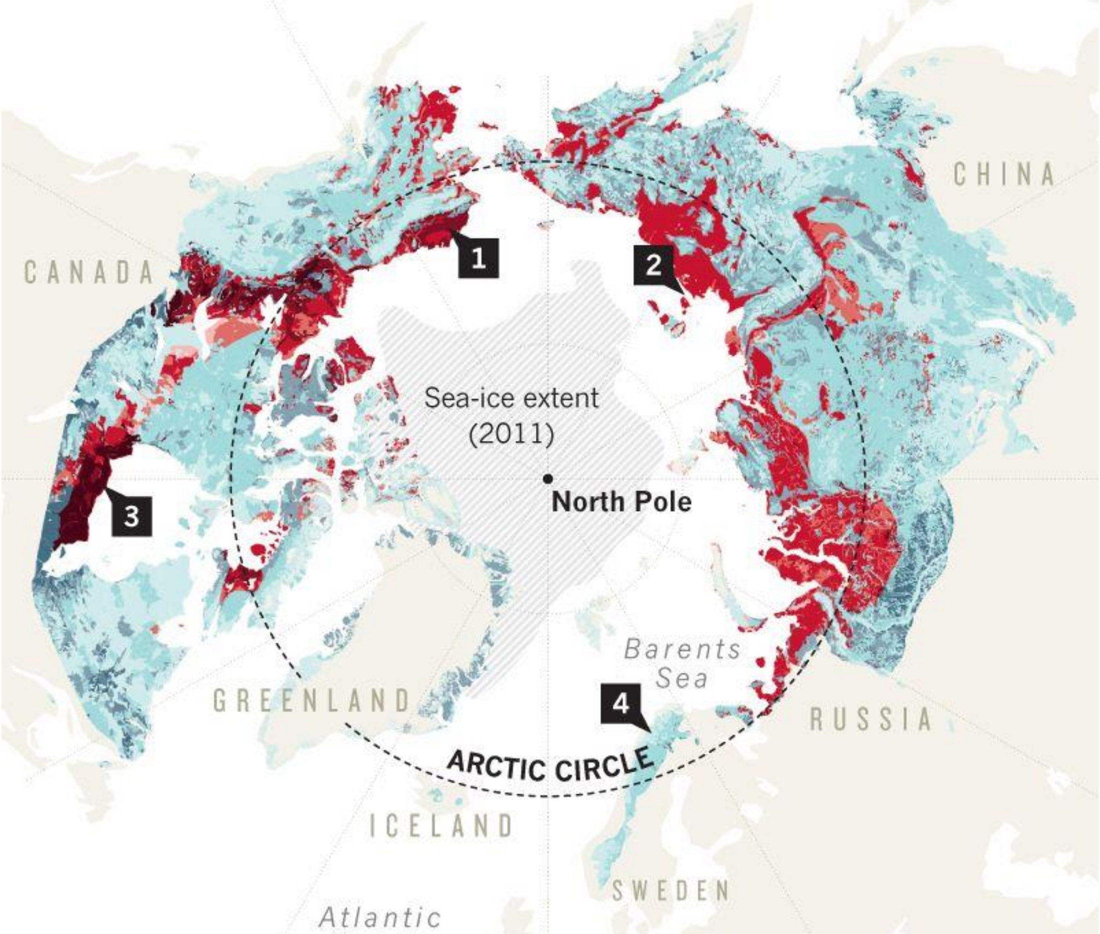
ARCTIC PERMAFROST

One-fifth of frozen soils at high latitudes are thawing rapidly and becoming unstable, leading to landslides and floods that release carbon into the atmosphere.

CARBON-RICH SOIL LEVELS
kilograms of carbon per square metre
(% of region vulnerable to type of thawing)

Rapid thawing
>139 (8%) · 139–105 (10%) · 104–70 (60%) · 69–36 (19%) · 35–0 (3%)

Gradual thawing
>139 (4%) · 139–105 (3%) · 104–70 (26%) · 69–36 (39%) · 35–0 (28%)



1 NORTH SLOPE, ALASKA, USA
Abrupt thawing is triggering landslides and eroding mountains.

2 DMITRI LAPTEV STRAIT, NORTHEAST SIBERIA
Permafrost containing thick layers of ground ice collapses suddenly when the ice melts.

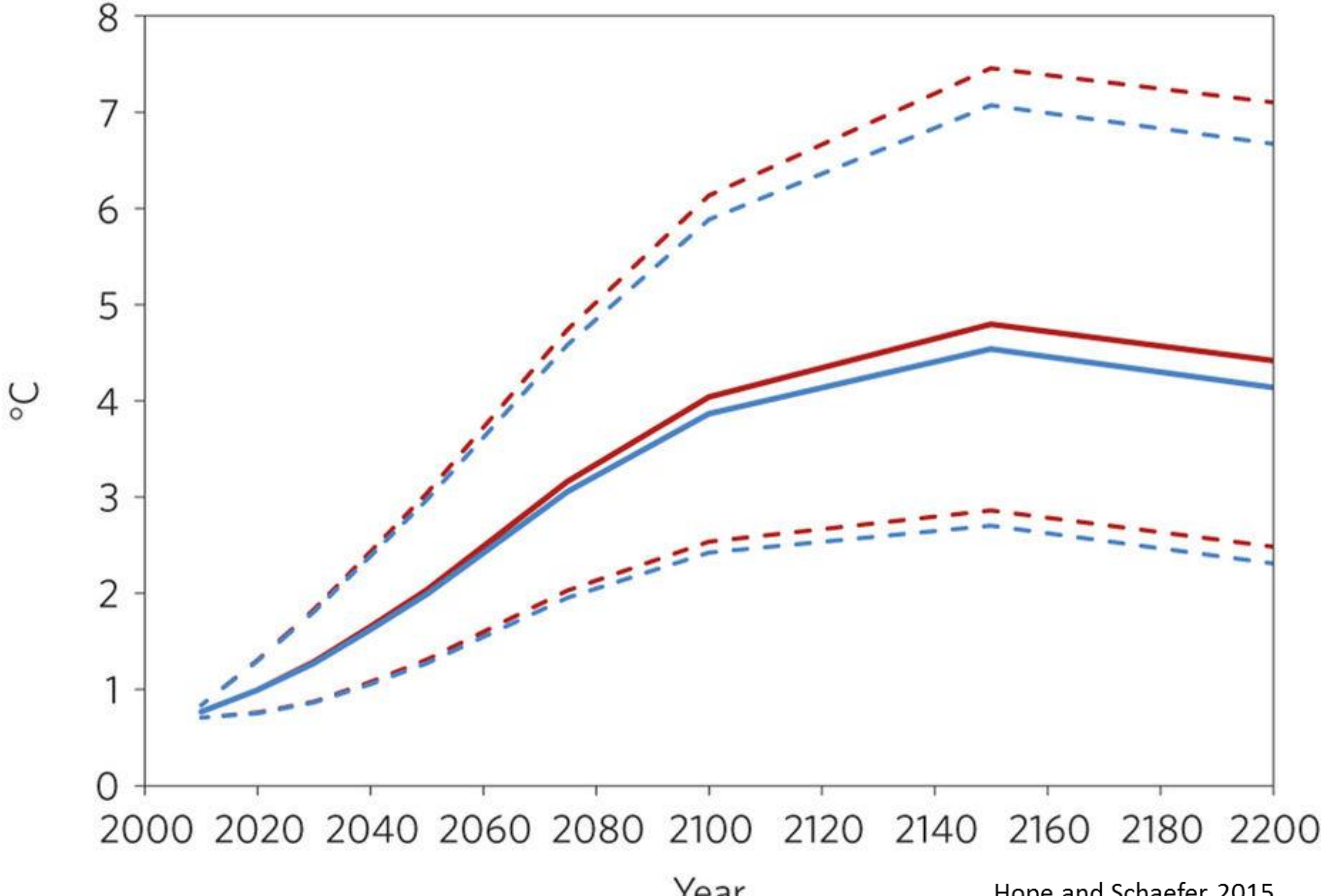
3 HUDSON BAY LOWLANDS, CANADA
Thawing peatlands could release a lot of carbon.

4 TAVVAVUOMA, NORTHERN SWEDEN
Growing thaw lakes are major sources of methane.

Turetsky et al. 2019

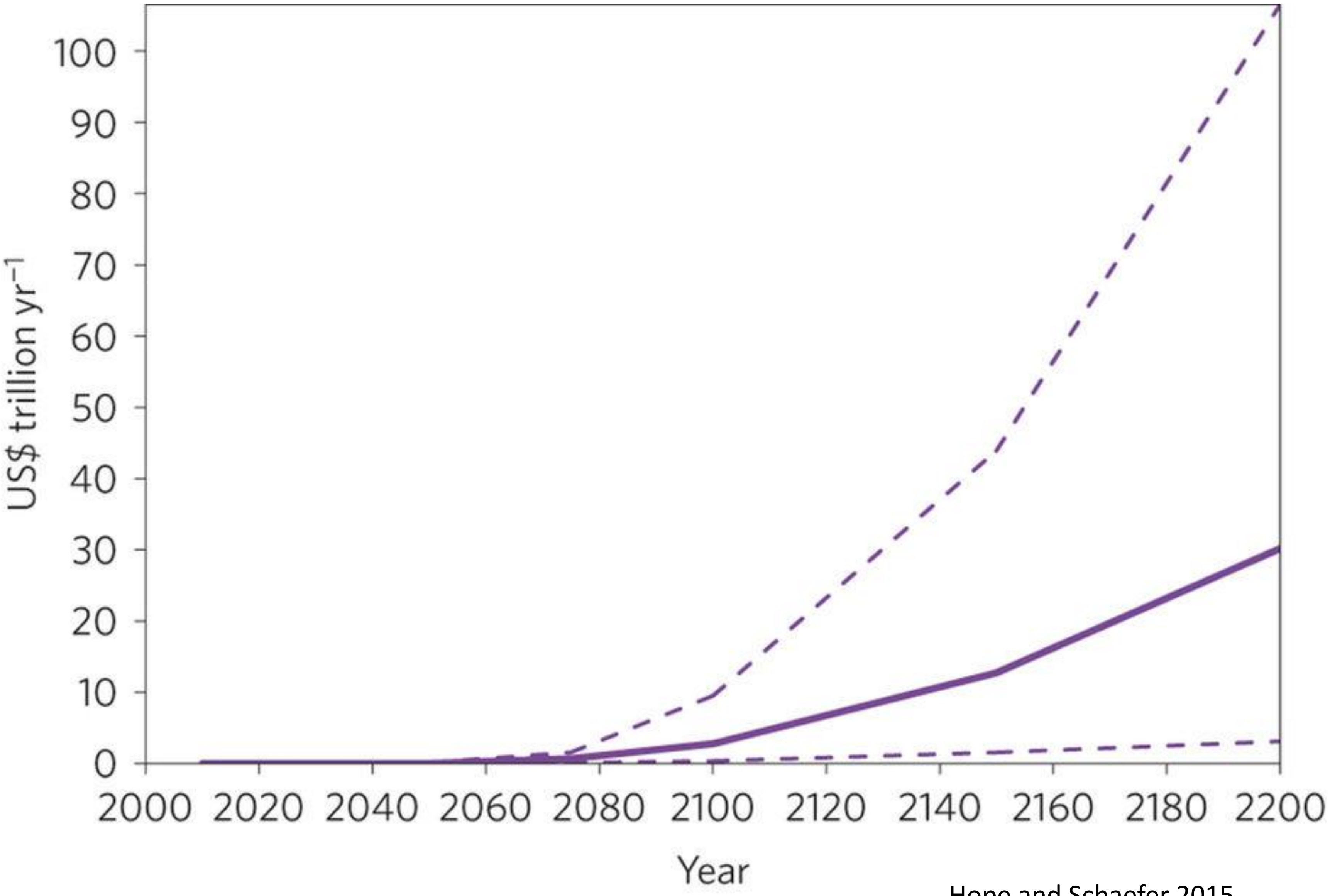
©nature

Global mean temperature rise relative to pre-industrial conditions by date, with and without permafrost CO_2 and CH_4 emissions for the IPCC AR4 A1B scenario

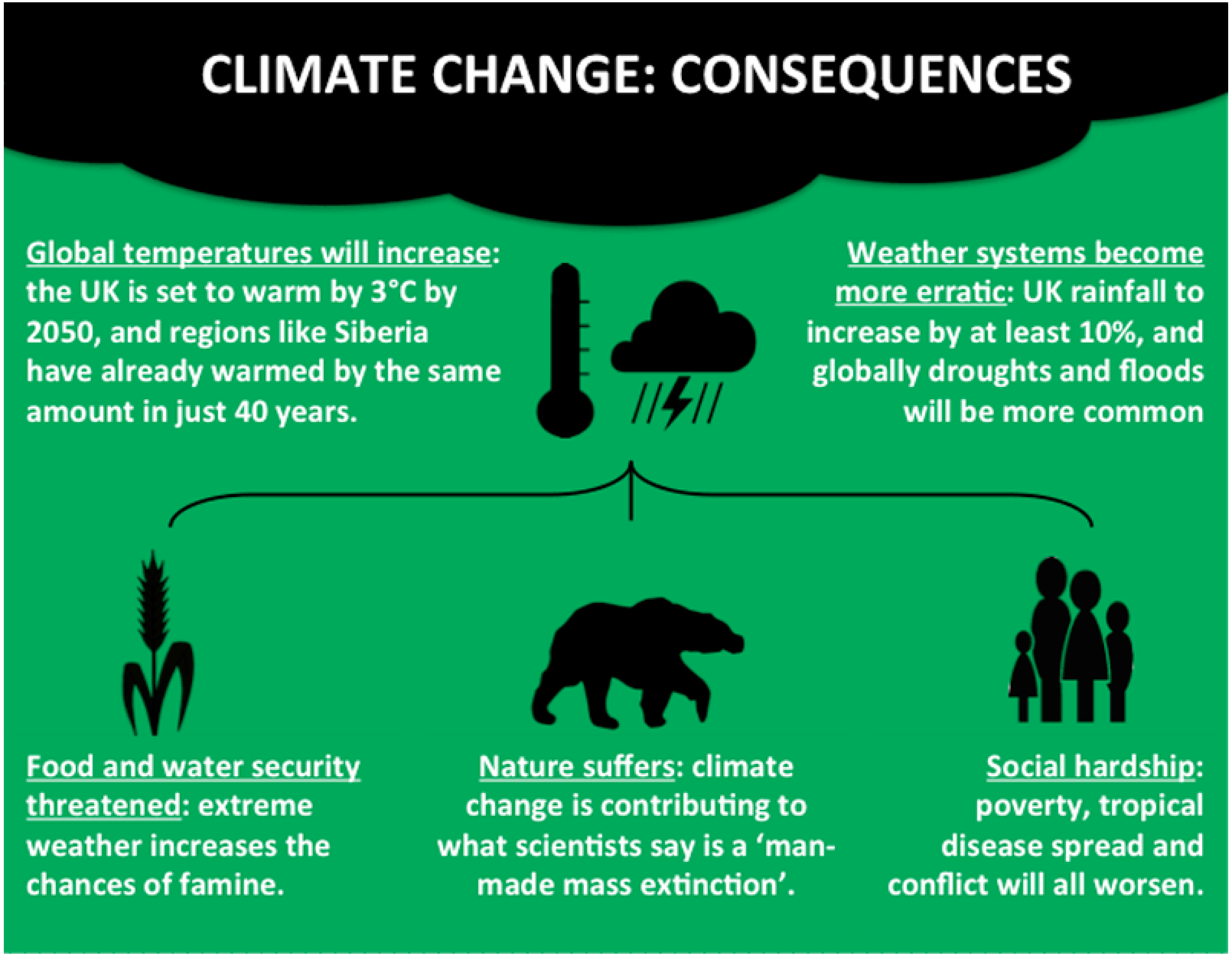


Hope and Schaefer 2015

Extra annual economic impacts from permafrost CO_2 and CH_4 emissions, by date, for the IPCC AR4 A1B scenario estimated using the default PAGE09 model.



Hope and Schaefer 2015

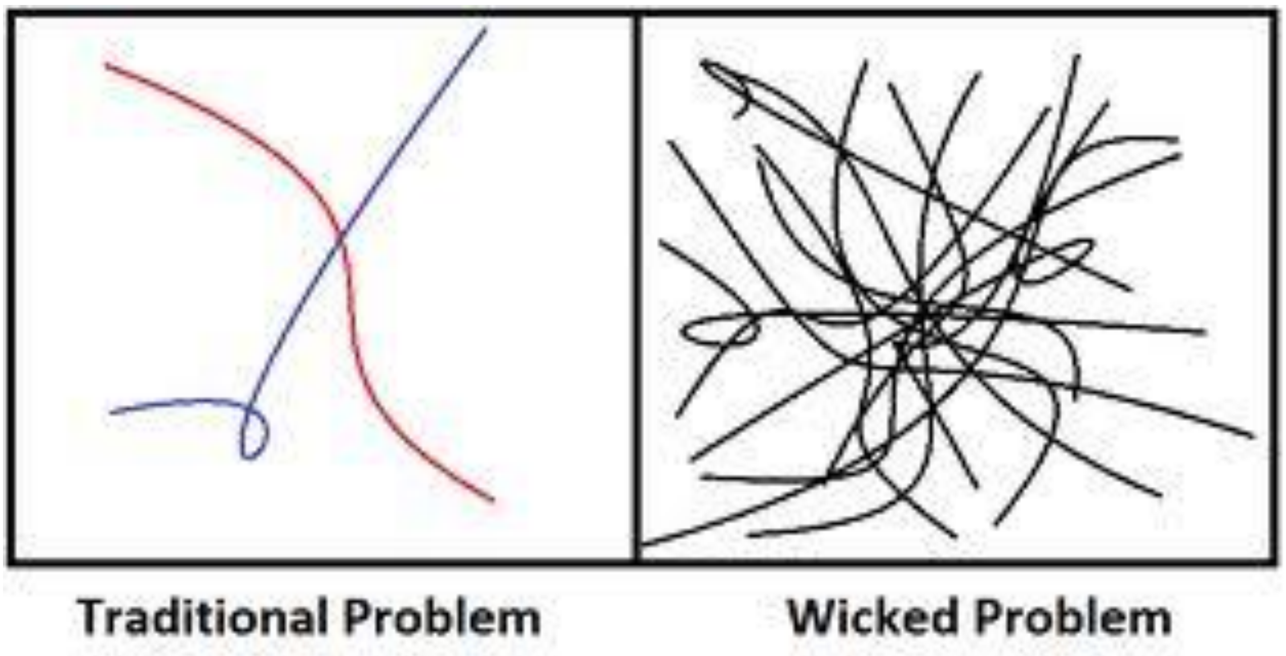


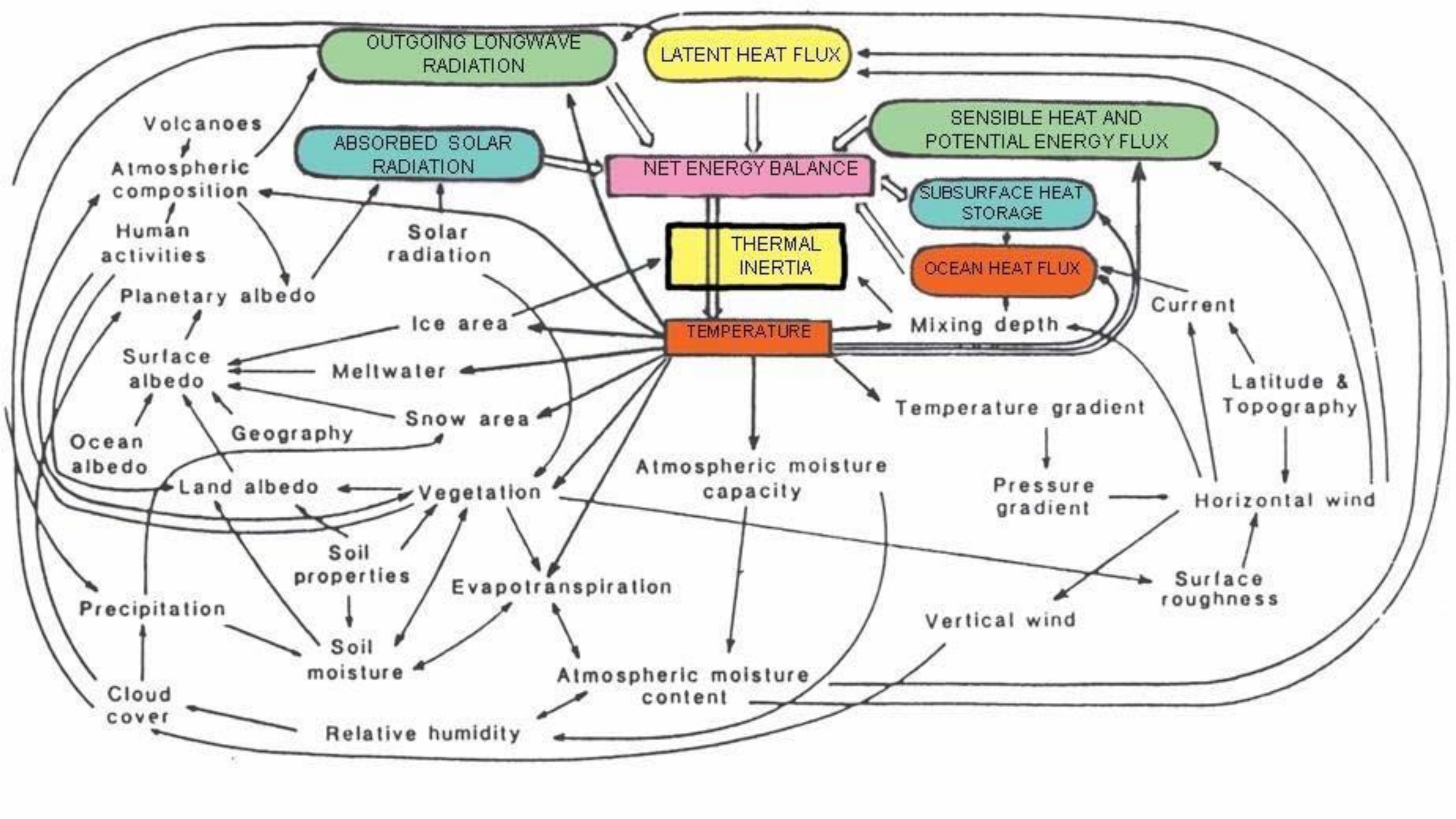
https://www.barnsleyhospital.nhs.uk/about/sustainability/attachment/climate-change-consequences-2/

Why haven’t the climate problem been solved yet?


WICKED
THE UNTOLD STORY OF THE WITCHES OF OZ

Wicked Problem





Flow diagram for climate modeling, showing feedback loops. From Robock (1985).

Wicked problem

Rittel and Webber (1973)

- There is **no definitive formulation** of a wicked problem
  (defining wicked problems is itself a wicked problem).
- Wicked problems have **no stopping rule**
- Solutions to wicked problems are not true-or-false, but **better or worse**.
- There is no immediate and **no** ultimate **test** of a solution to a wicked problem.
- Every solution to a wicked problem is a "**one-shot operation**"; because there is no opportunity to learn by trial and error, every attempt counts significantly.
- Wicked problems **do not have an enumerable** (or an exhaustively describable) **set of potential solutions**, nor is there a well-described set of permissible operations that may be incorporated into the plan.
- Every wicked problem can be considered to be a **symptom of another deeper problem**.

Super wicked problems

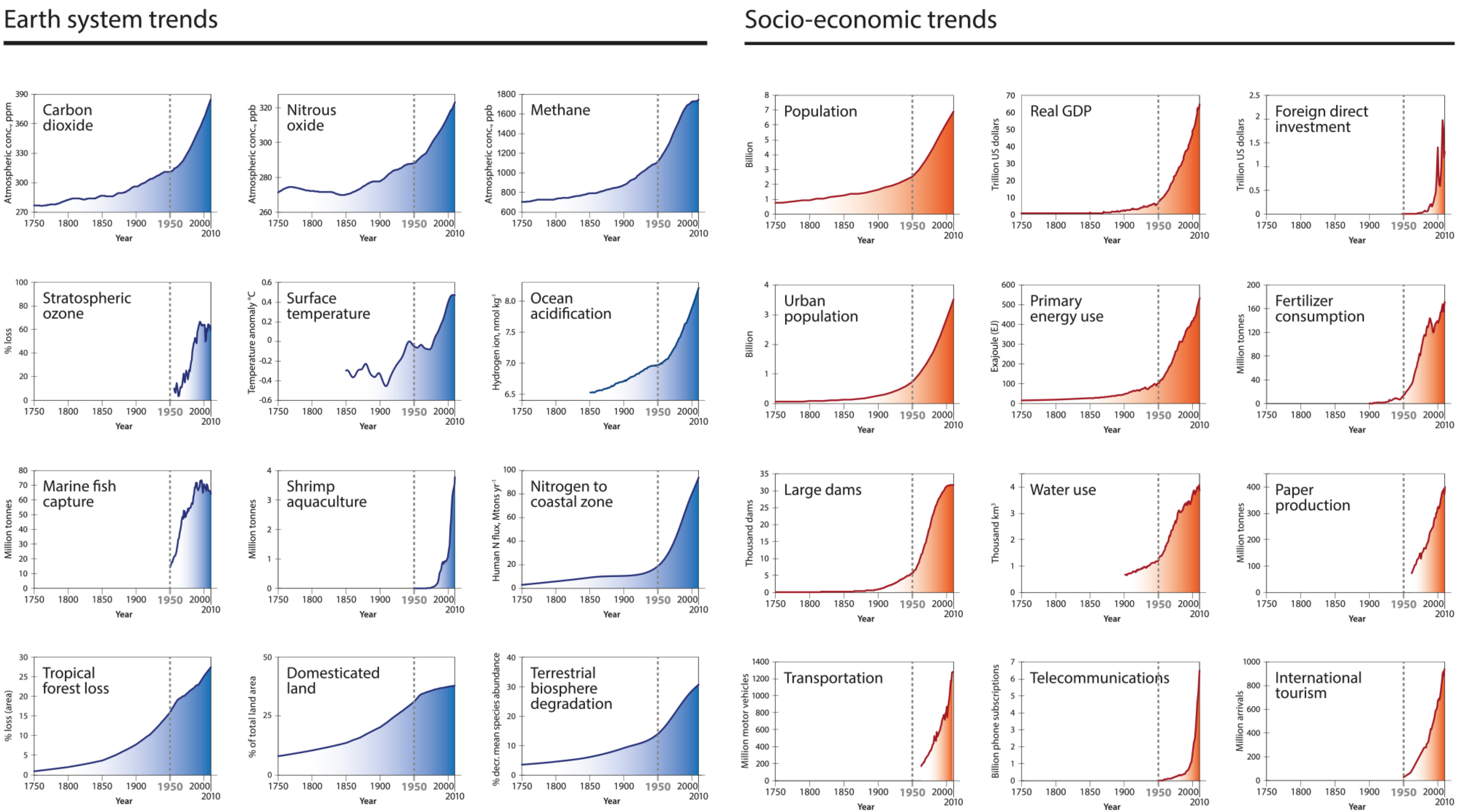
(Levin et al. 2007)

- Time is running out.
- No central authority.
- Those seeking to solve the problem are also causing it.
- Hyperbolic discounting occurs (tendency for people to increasingly choose a smaller-sooner reward over a larger-later reward)

Climate change: What sort of problem?

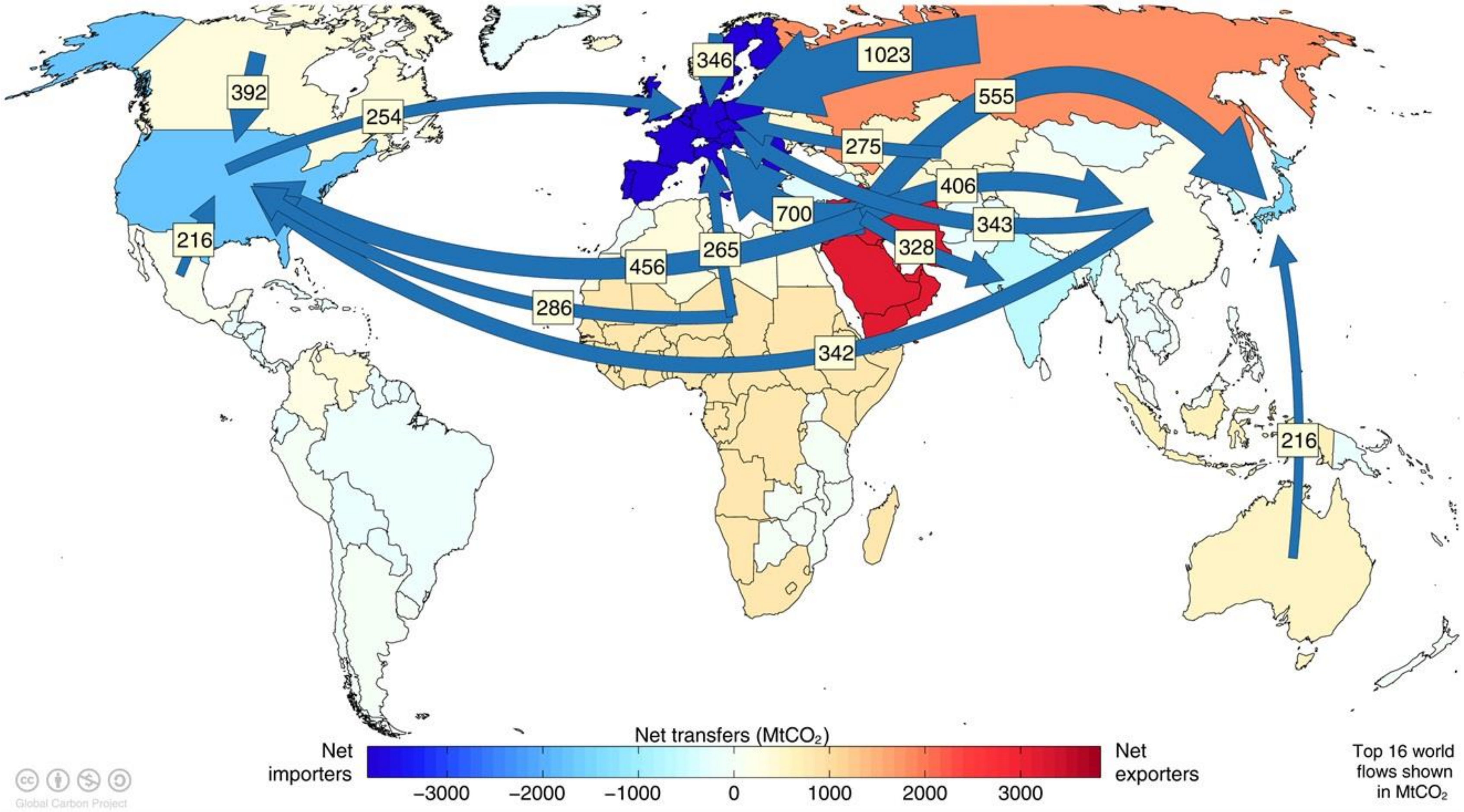
- Atmospheric problem?
- Population growth problem?
- Economic problem (economic growth, structure)?
- Energy problem?
- Consumption problem?
- Technological problem?
- Natural resources problem (development, potentials)?
- Equality problem?
- Political problem?
- Scientific problem?
- Pollution problem?
- Social problem?
- Communication problem?

The trajectory of the Anthropocene: The Great Acceleration (Anthropocene Review) 15 January 2015.



Major flows from extraction to consumption

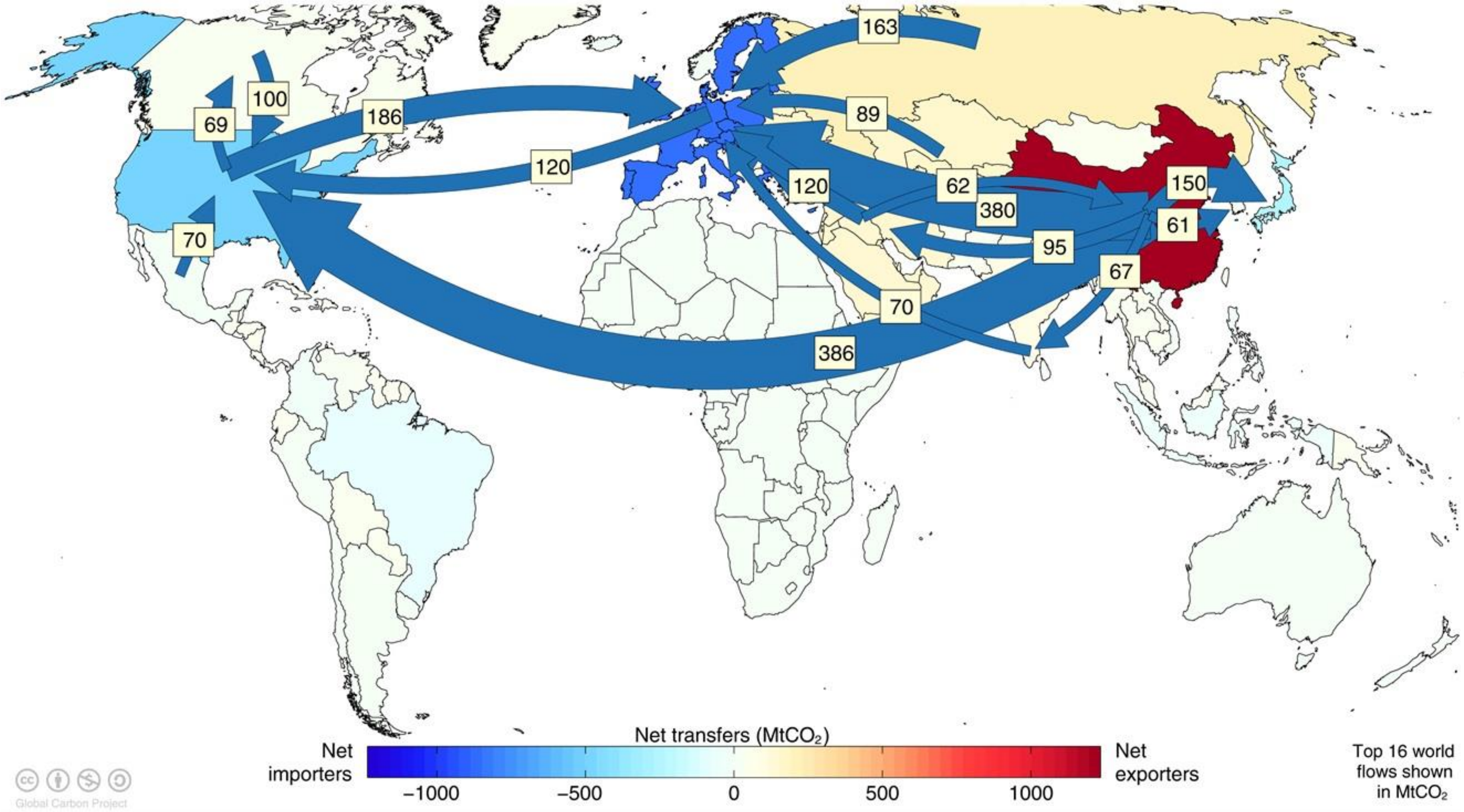
Flows from location of fossil fuel extraction to location of consumption of goods and services



Values for 2011. EU is treated as one region. Units: $MtCO_2$
Source: Andrew et al 2013

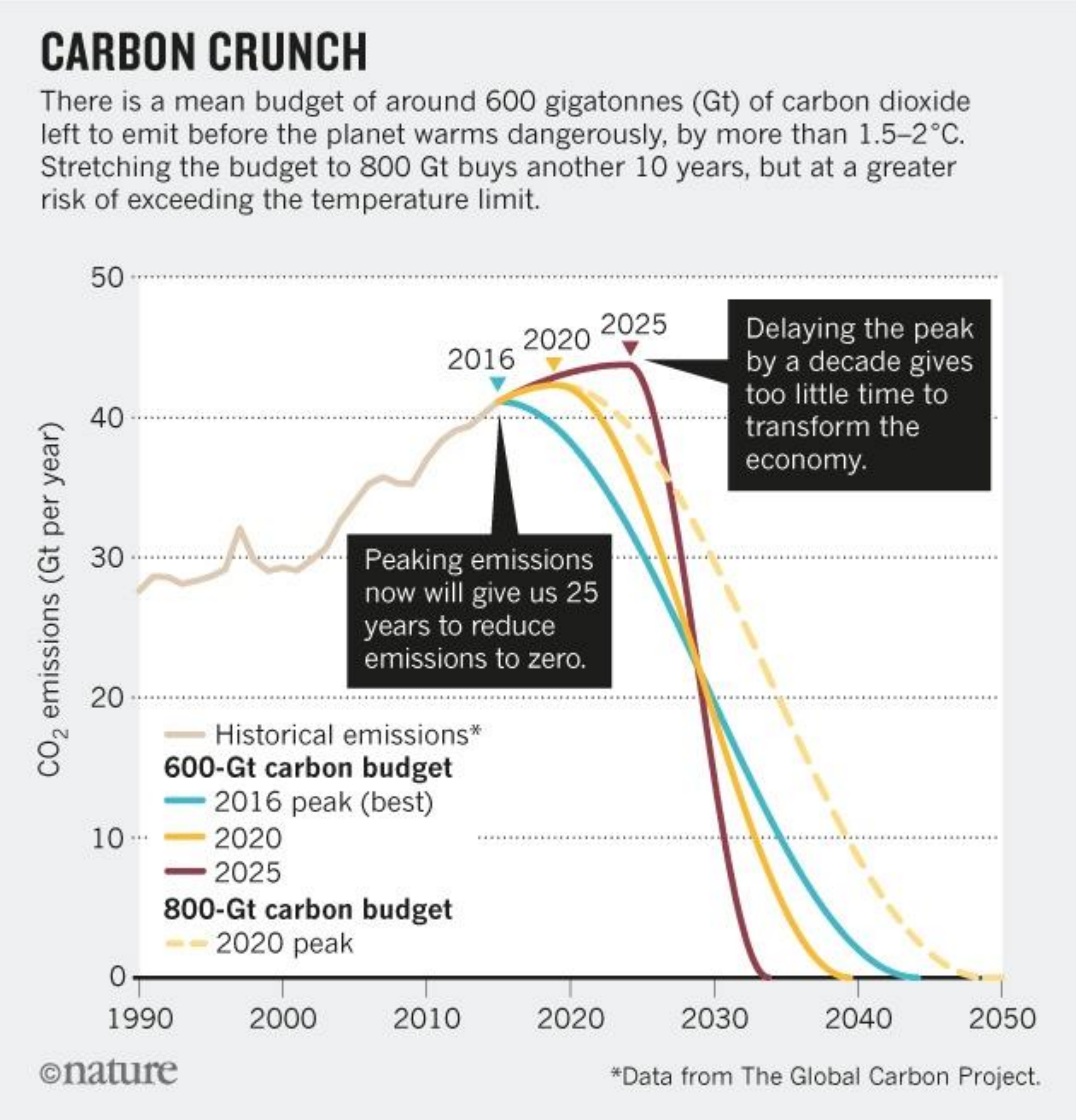
Major flows from production to consumption

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



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

Source: Peters et al 2012



1.5 degree target

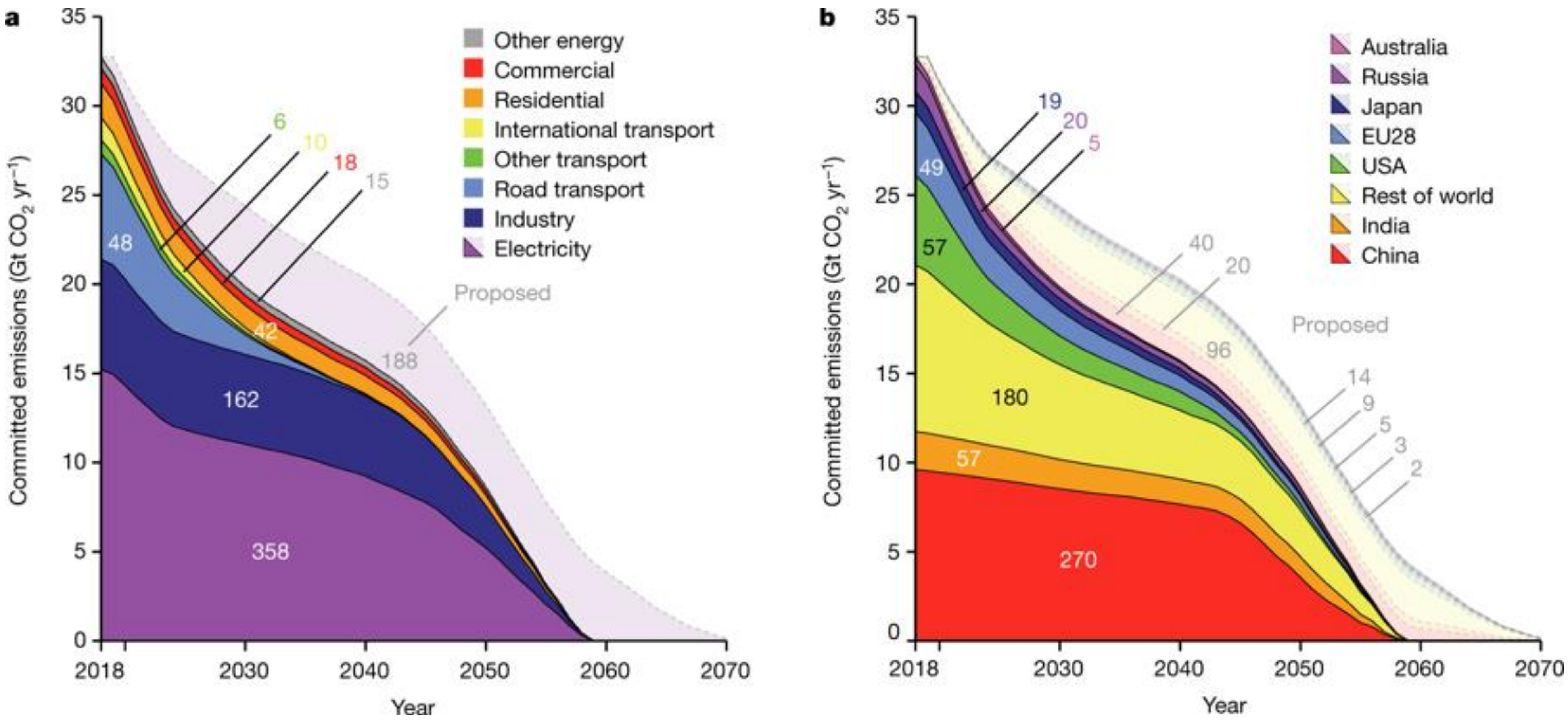
Carbon budget: ≈ 600 Gt
Current emissions: ≈ 42 Gt/yr

≈ 14 years left

Figueres et al. 2017

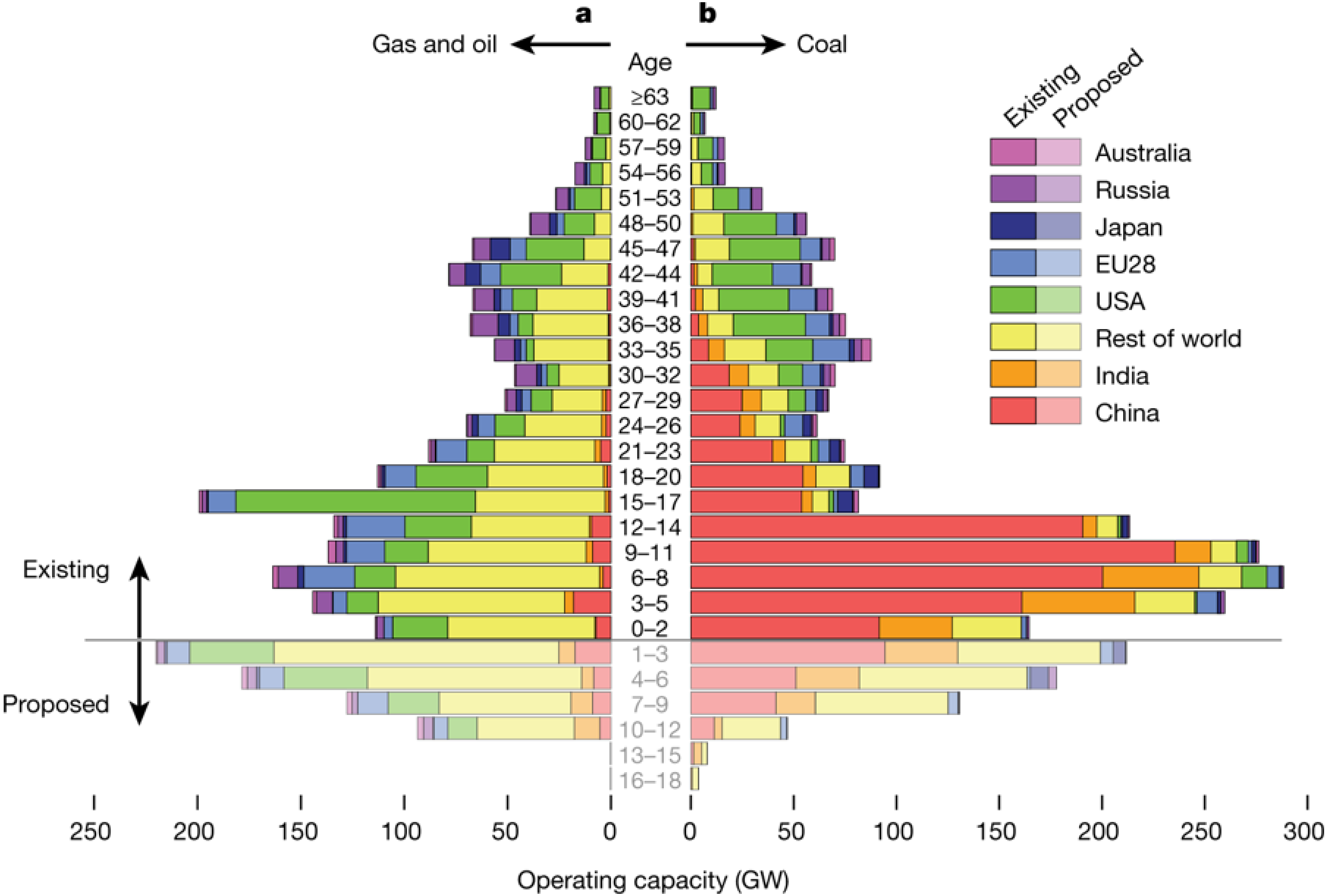
Committed annual CO2 emissions from existing and proposed energy infrastructure

Estimates of future CO_2 emissions by industry sector (**a**) and country/region (**b**), assuming historical lifetimes and utilization rates. Emissions from existing infrastructure are shown with darker shading, and emissions from proposed power plants (that is, electricity) are more lightly shaded. Numbers within graphs show total amounts of emissions over the period shown.



Tong et al. N*ature* **572**: 373–377 (2019)

Age structure of global electricity-generating capacity



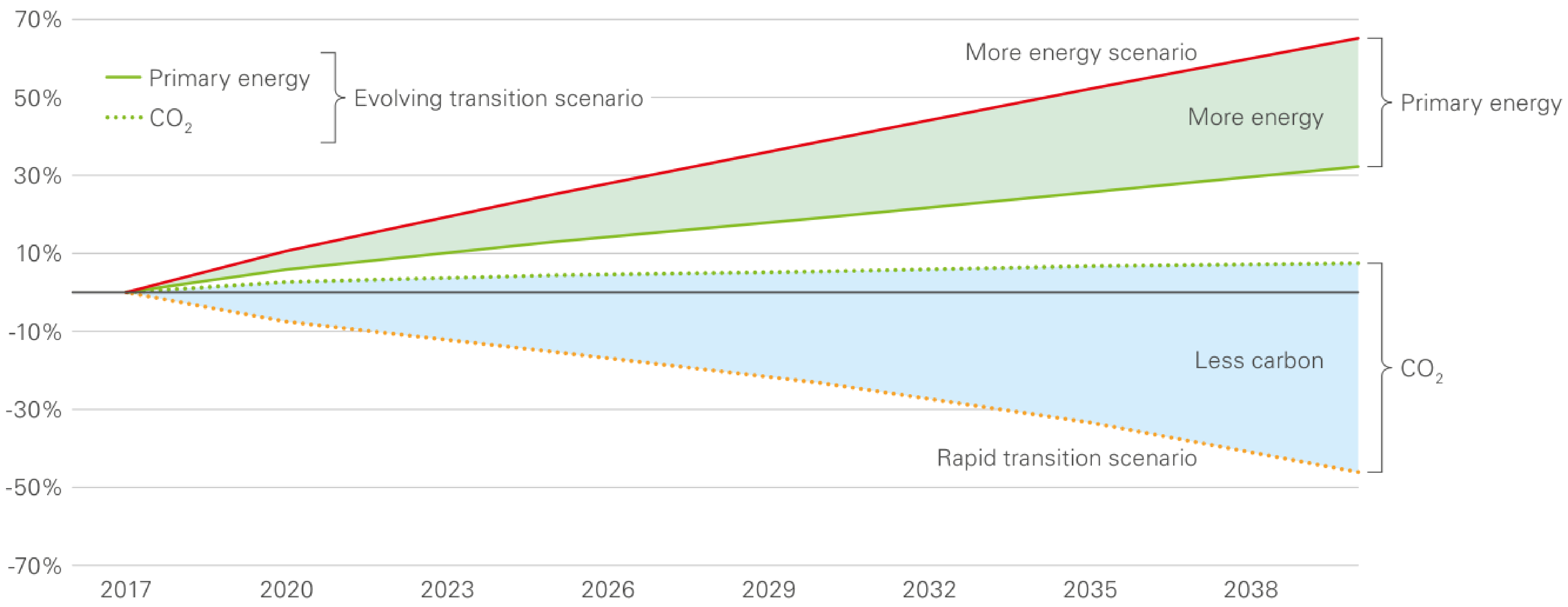
Tong et al. N*ature* **572**: 373–377 (2019)

The global energy system faces a dual challenge: the need for ‘more energy and less carbon’

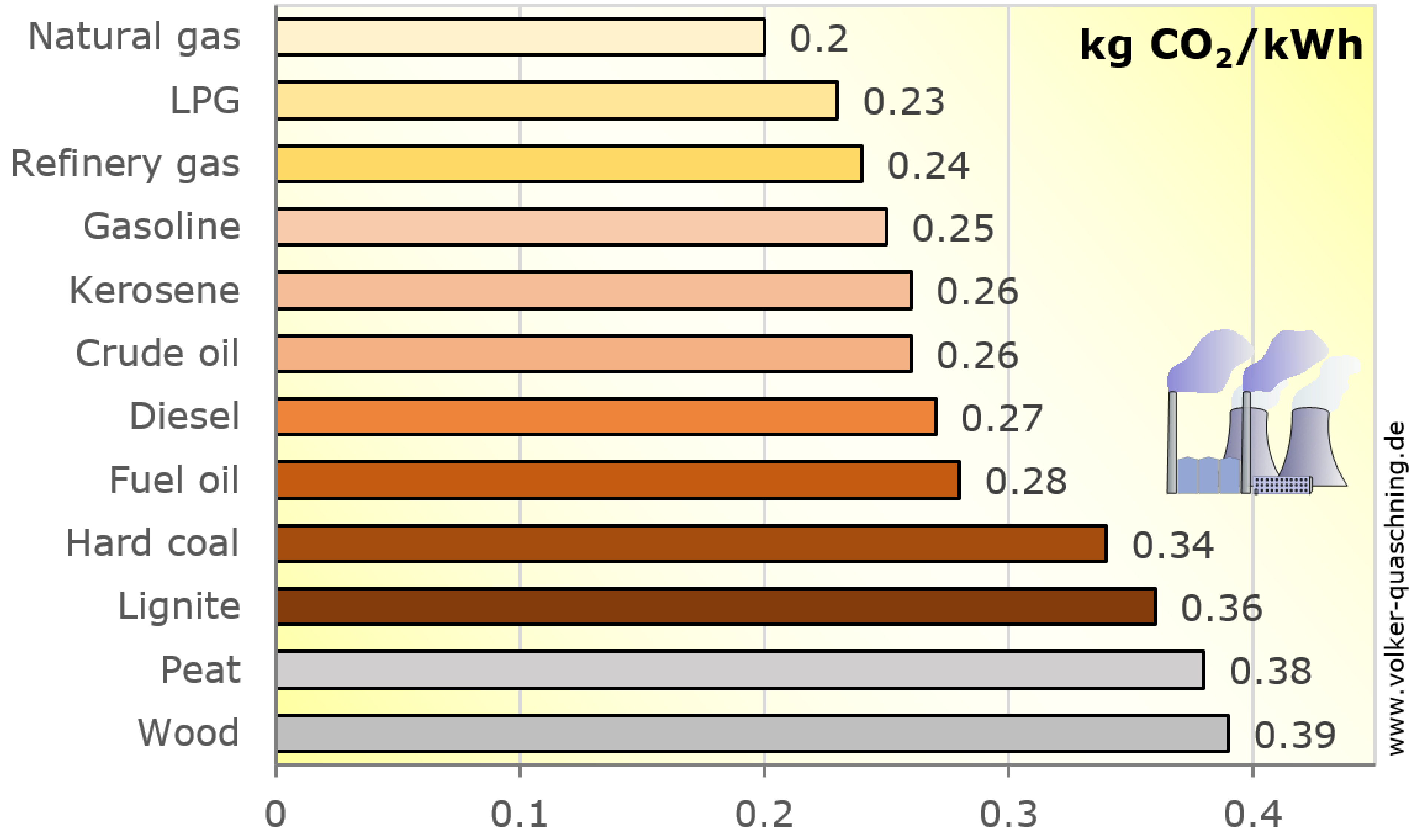
70 % of the demand will be covered by investing in fossil energy sources

Primary energy demand and carbon emissions

Cumulative growth rate, 2017 = 0%

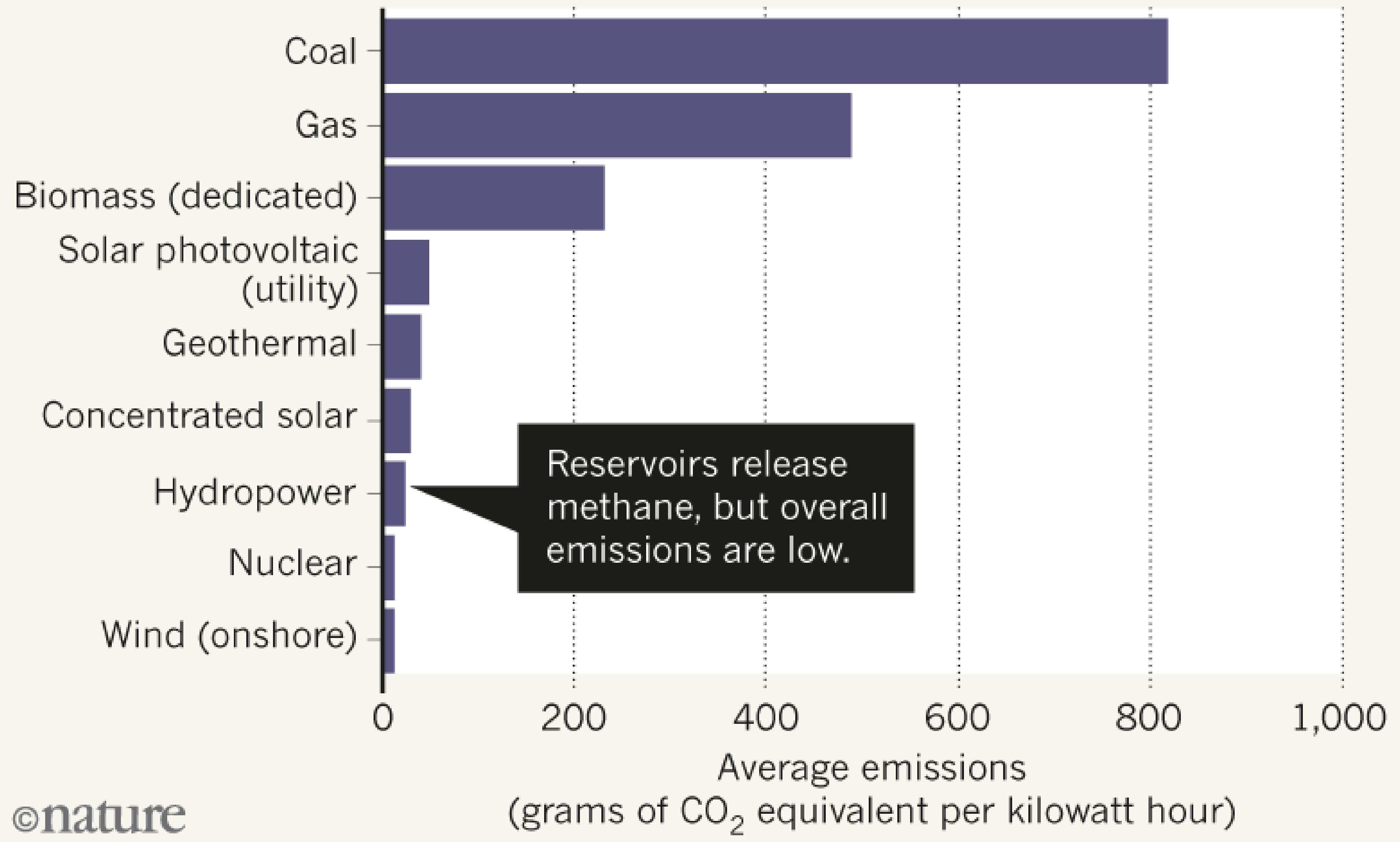


The Problem:
COAL


kg CO_2/kWh
Natural gas 0.2
LPG 0.23
Refinery gas 0.24
Gasoline 0.25
Kerosene 0.26
Crude oil 0.26
Diesel 0.27
Fuel oil 0.28
Hard coal 0.34
Lignite 0.36
Peat 0.38
Wood 0.39
0
0.1
0.2
0.3
0.4
www.volker-quaschning.de

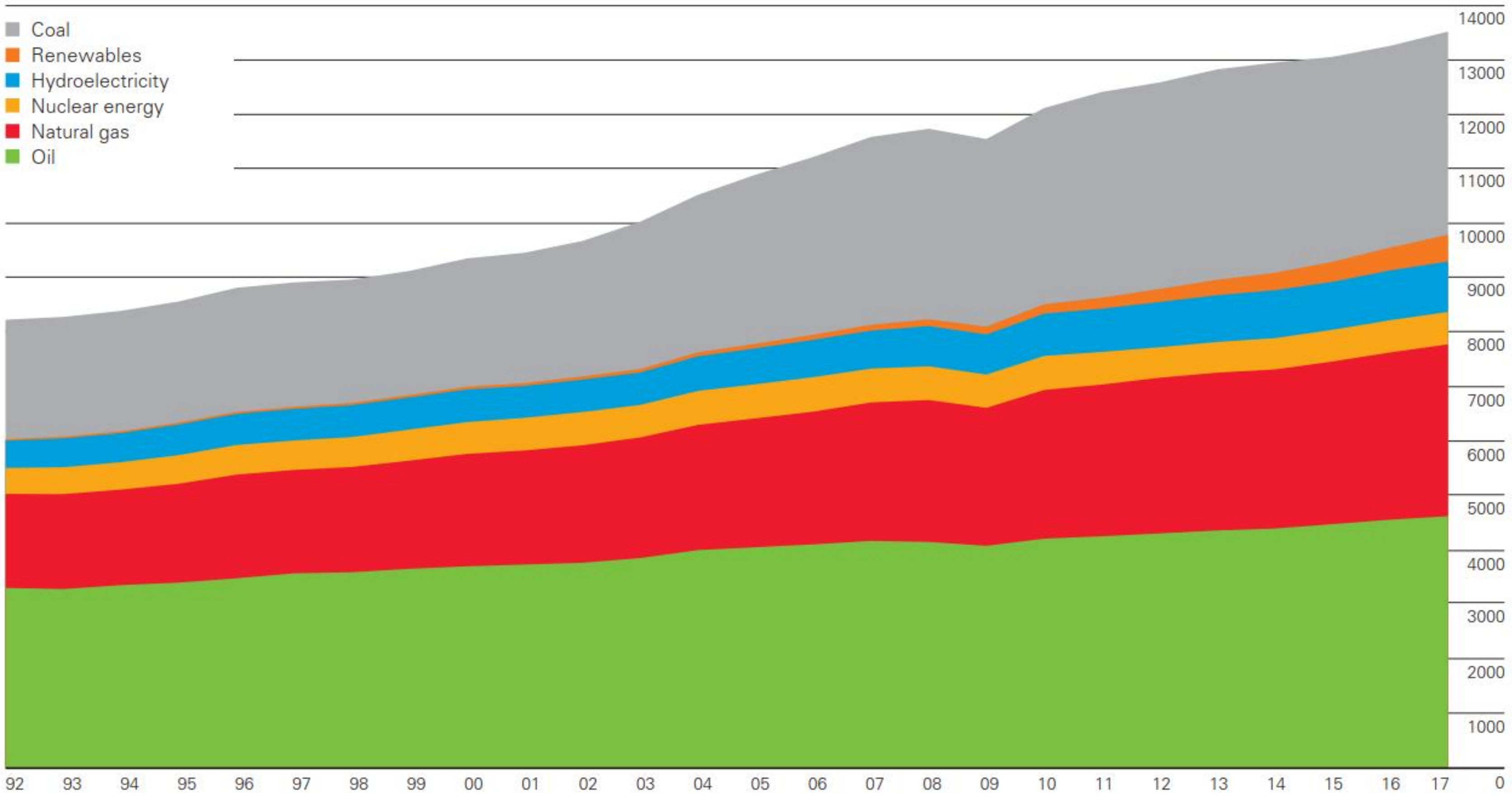
LIFE-CYCLE EMISSIONS

Over their working lives, electricity sources emit carbon emissions both directly and through infrastructure and supply chains.



BP Statistical Review of World Energy 2018

World consumption
Million tonnes oil equivalent

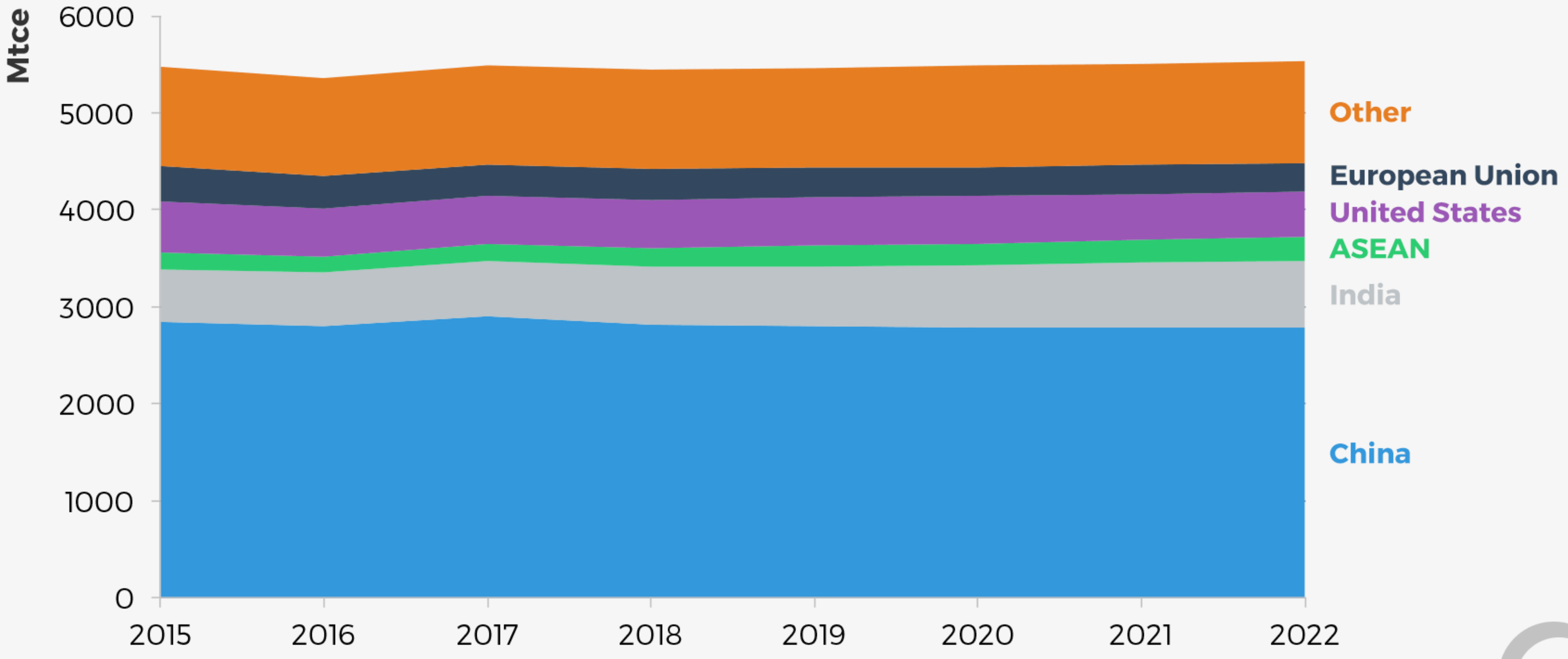


38 %

World primary energy consumption grew by 2.2% in 2017, up from 1.2% in 2016 and the highest since 2013. Growth was below average in Asia Pacific, the Middle East and S. & Cent. America but above average in other regions. All fuels except coal and hydroelectricity grew at above-average rates. Natural gas provided the largest increment to energy consumption at 83 million tonnes of oil equivalent (mtoe), followed by renewable power (69 mtoe) and oil (65 mtoe).

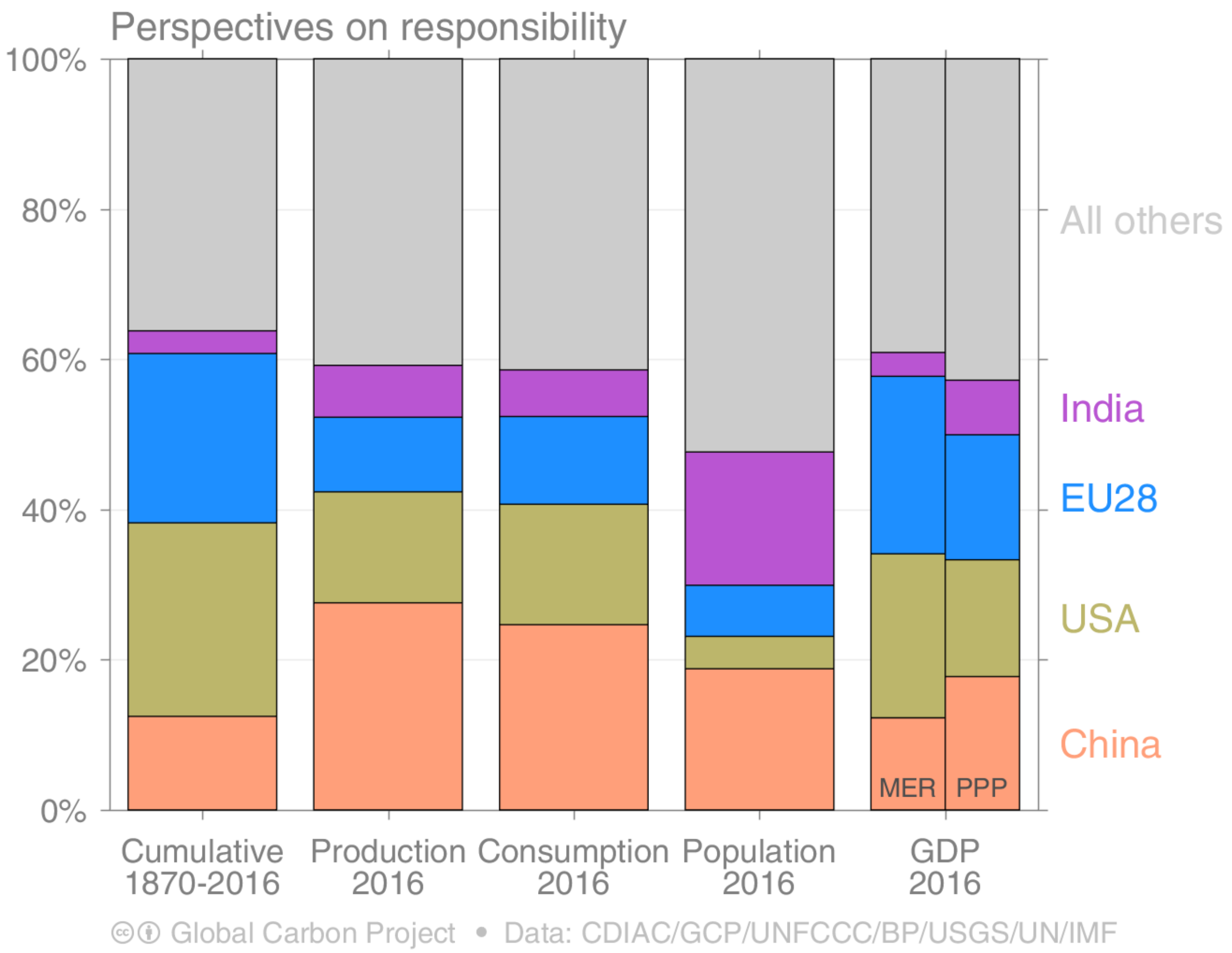
Global coal demand, 2015-2022

Coal 2017



Alternative rankings of countries

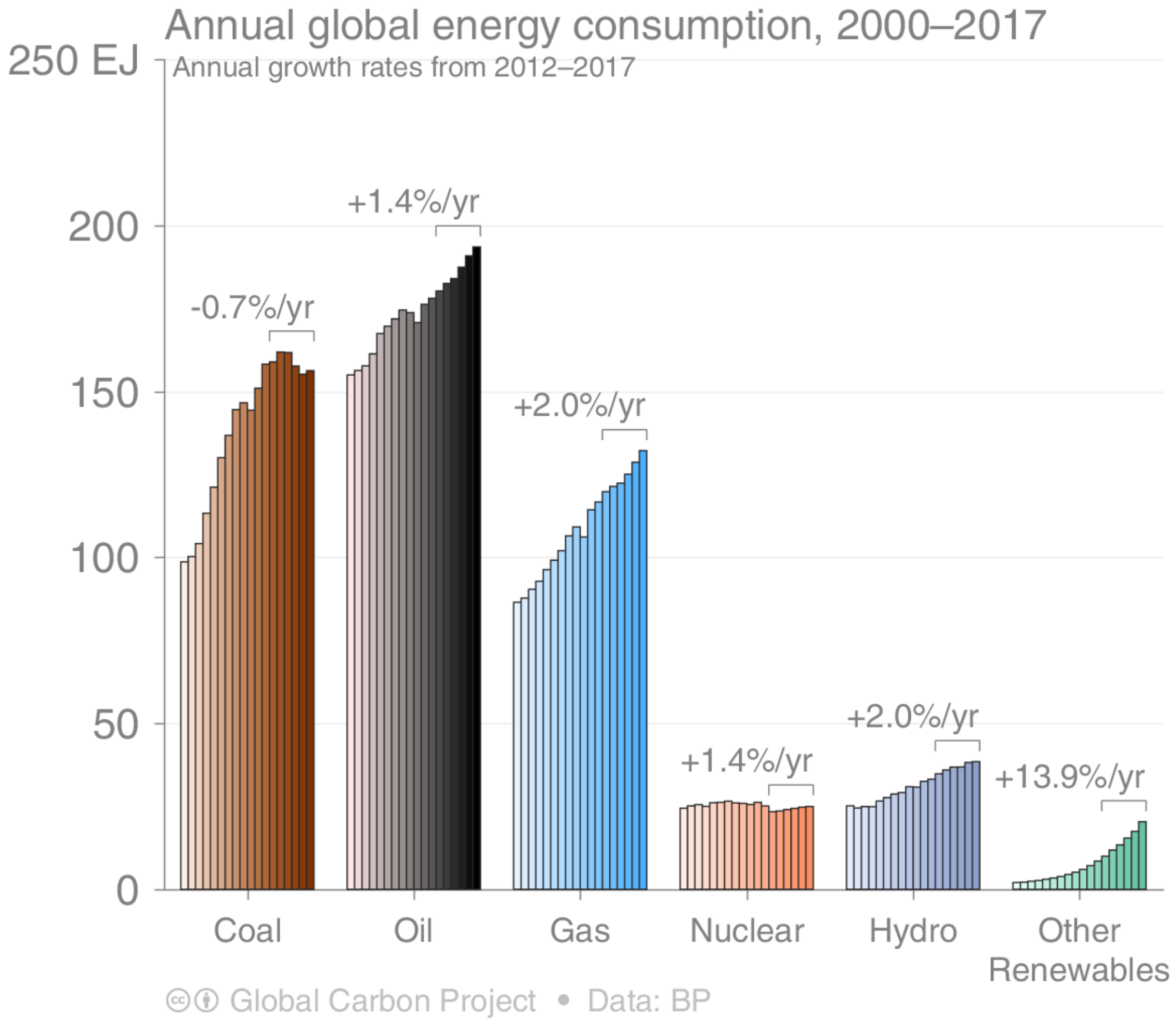
The responsibility of individual countries depends on perspective.
Bars indicate fossil CO_2 emissions, population, and GDP.



GDP: Gross Domestic Product in Market Exchange Rates (MER) and Purchasing Power Parity (PPP)
Source: CDIAC; United Nations; Le Quéré et al 2018; Global Carbon Budget 2018

Energy use by source

Energy consumption by fuel source from 2000 to 2017, with growth rates indicated for the more recent period of 2012 to 2017



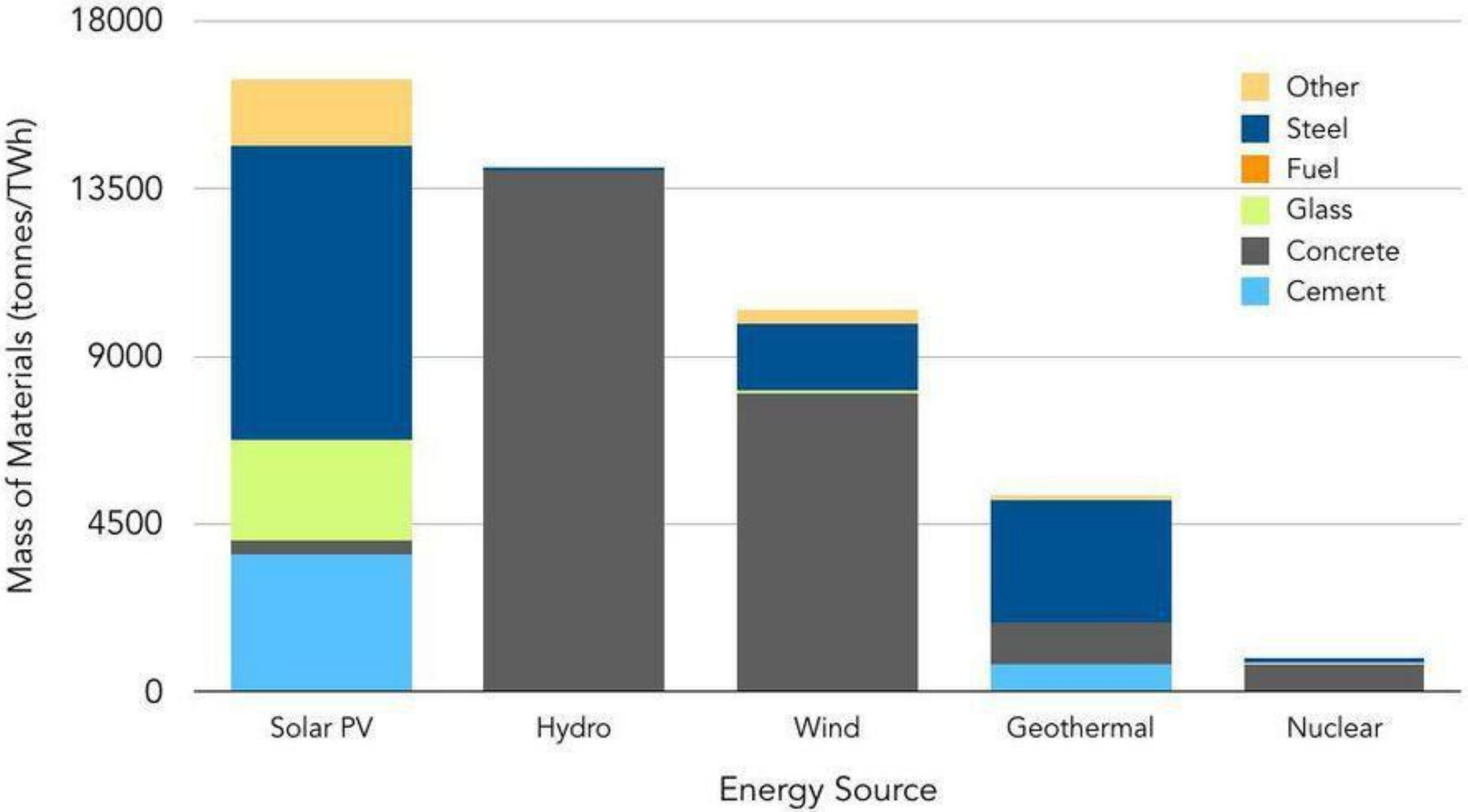
Source: BP 2018; Jackson et al 2018; Global Carbon Budget 2018

Power Density of Renewables

Miller & Keith 2018 ERL

- **Wind** power capacity factors are increasing, but that increase is associated with a decrease in capacity densities, so **power densities** (measured as W_e m^{-2}) **are stable or declining**. It seems likely that wind's power density will decrease as total wind generation increases.
- The transition to **wind or solar** power in the U.S. would require **five to 20 times more land** than previously thought, and, if such large-scale wind farms were built, would warm average surface temperatures over the continental U.S. by **0.24** degrees Celsius.
- **Solar** farms require generally up to **5,000 times more land per unit** of energy than **nuclear** plants because sunlight is energy-dilute and uranium is energy-dense.

Materials throughput by type of energy source



ENVIRONMENTAL PROGRESS

Sources: DOE Quadrennial Technology Review, Table 10.
Murray, R.L. and Holbert, K.E. 2015. Nuclear energy: an introduction to the concepts, systems, and applications of nuclear processes (7th ed.). Elsevier.

The International Renewable Energy Agency (IRENA) in 2016 estimated there was about 250,000 metric tonnes of solar panel waste in the world at the end of that year.

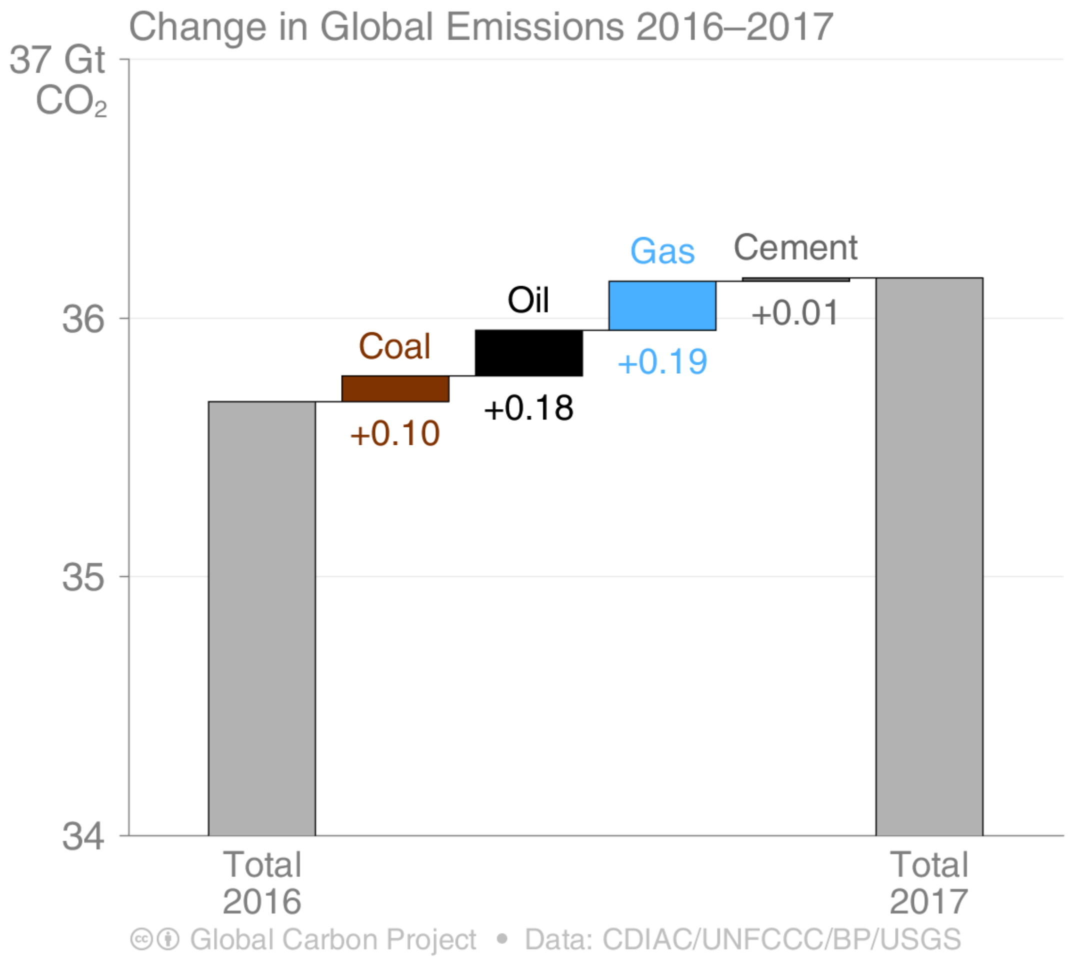
IRENA projected that this amount could reach 78 million metric tonnes by 2050.

Solar panels often contain lead, cadmium, antinomy and other toxic chemicals that cannot be removed without breaking apart the entire panel.

Approximately 90% of most PV modules are made up of glass, and this glass often cannot be recycled as float glass due to impurities.

Fossil CO_2 Emissions growth by source

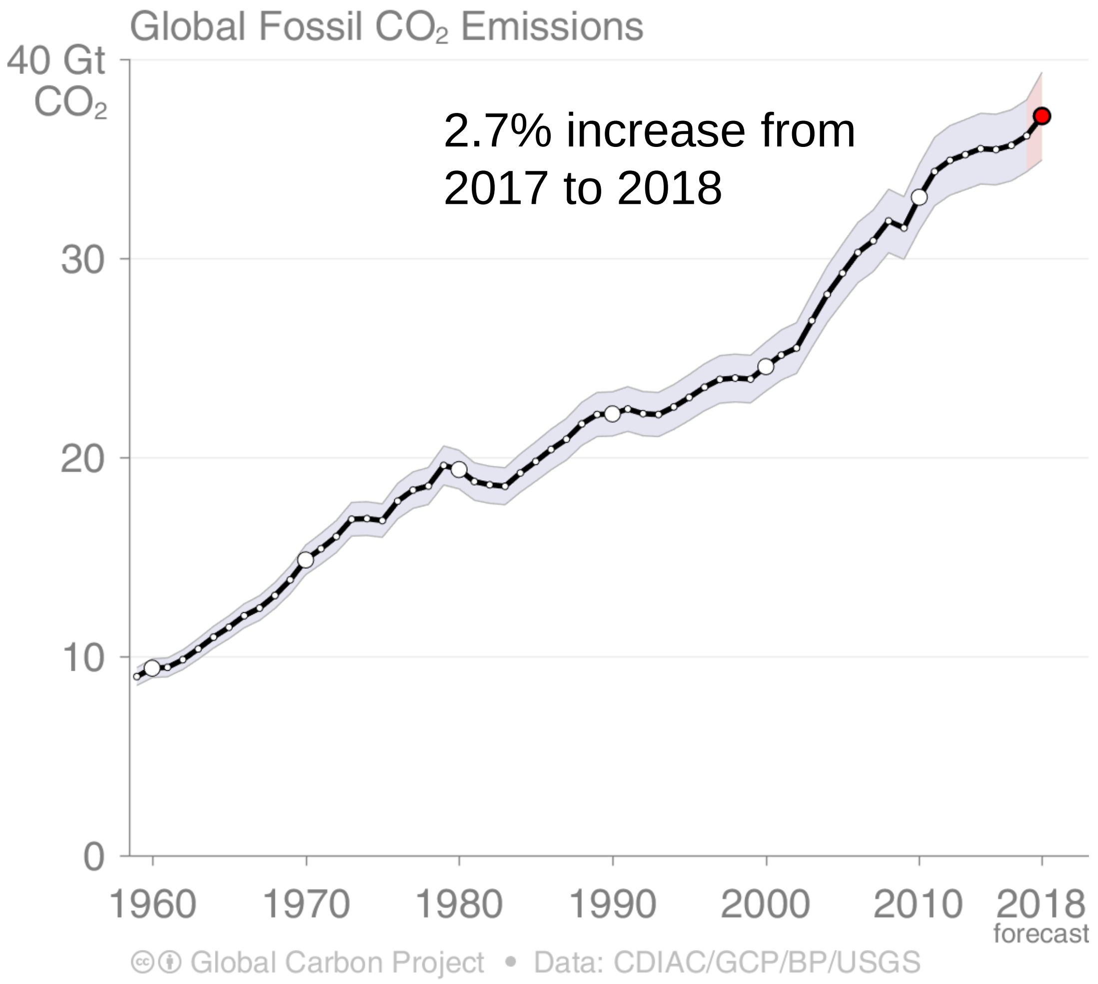
All fossil fuels contributed to the growth in fossil CO_2 emissions in 2017

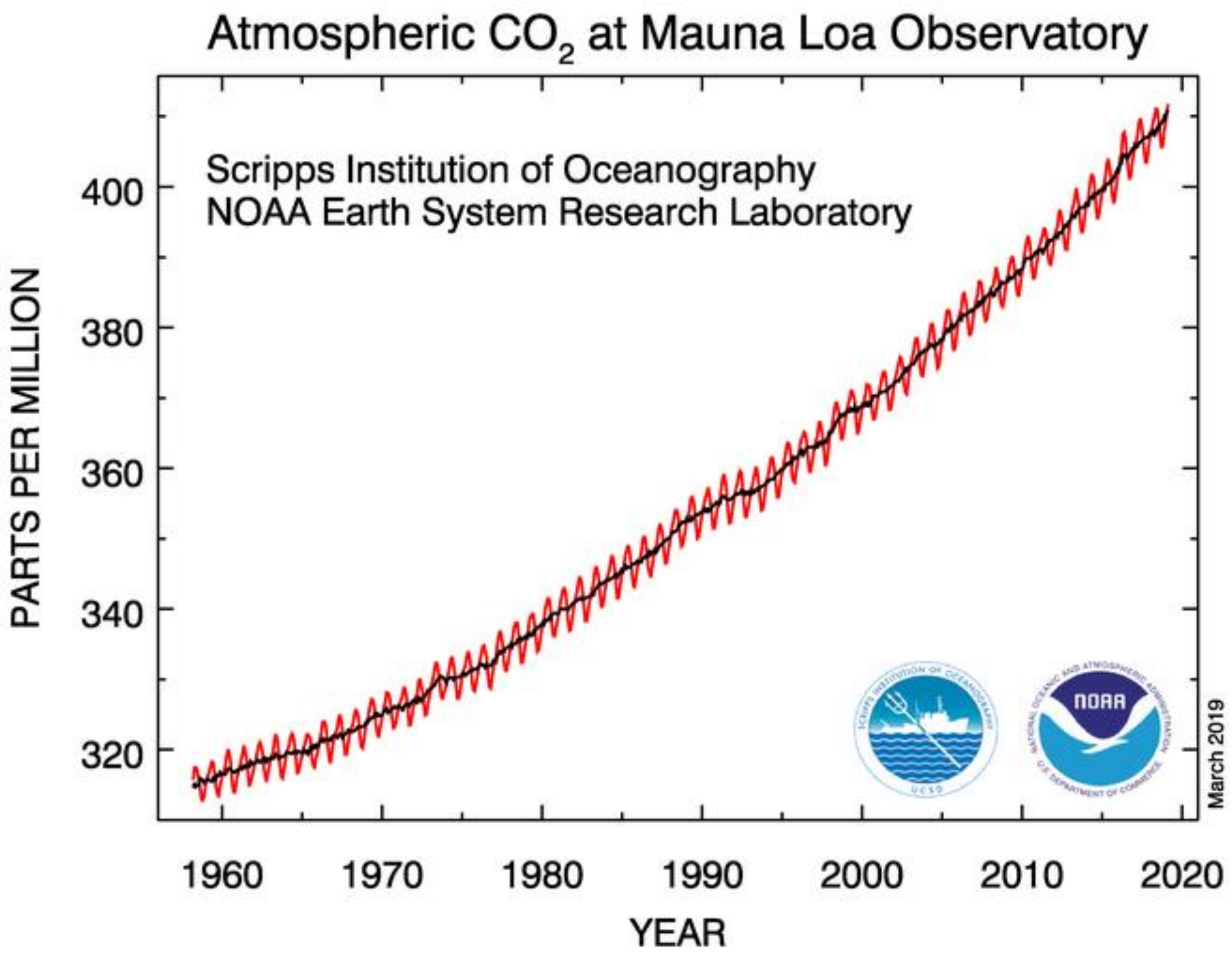


Source: CDIAC; Le Quéré et al 2018; Global Carbon Budget 2018

Global Fossil CO_2 Emissions

Global fossil CO_2 emissions have risen steadily over the last decades.
The peak in global emissions is not yet in sight.



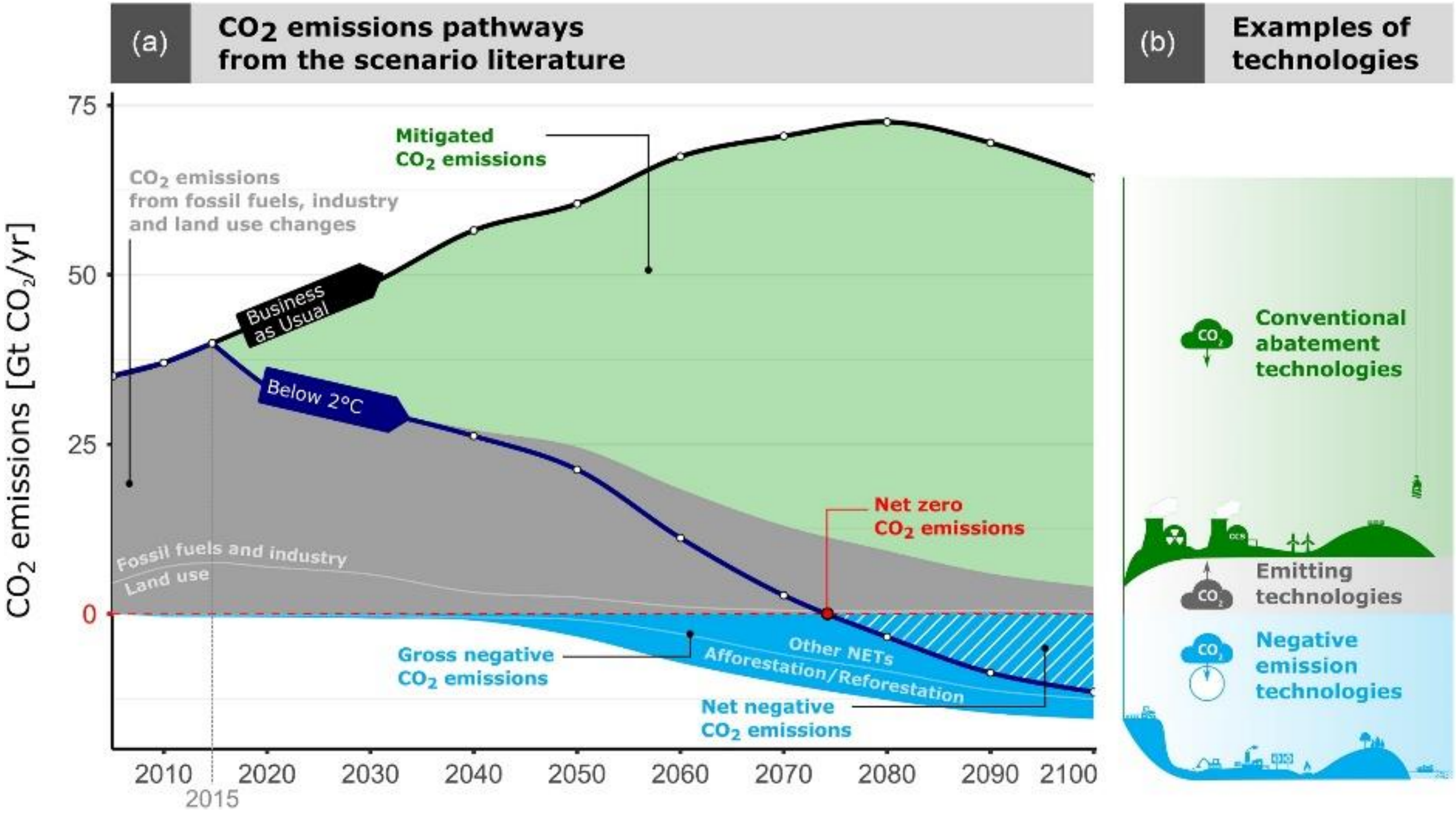


Estimates for 2015, 2016 and 2017 are preliminary ; 2018 is a projection based on partial data.
Source: [CDIAC](); [Le Quéré et al 2018](); [Global Carbon Budget 2018]()

So, what is needed?

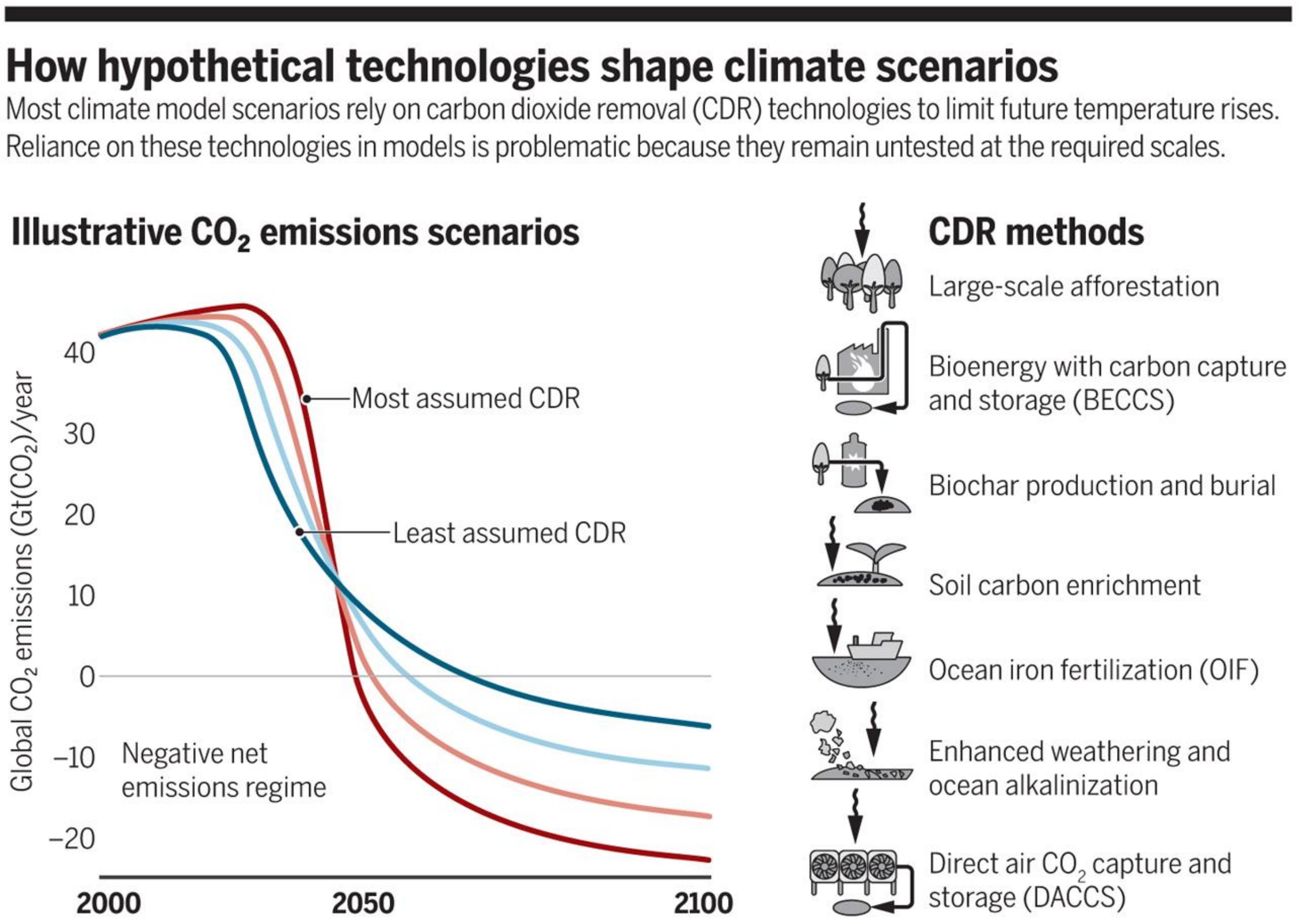
- Carbon Dioxide Removal (CDR) technologies, Natural Climate Solutions (NCS), Direct Air Capture (DAC) with Carbon Storage (DACCS)
- Complete mix of clean energy
- Poweful solutions to replace coal
  - Convertion of CO2 to usable form for current infrastucture
  - Hydrogen society
  - Fusion energy
- Focus on sectors that produce most warming
- Not only CO_2 – also short-lived climate pollutants (BC, methane…)
- Less energy, less consumption
- Circular economy
- Indirect solutions

Negative emission technologies (NETs) will be needed at very large scales



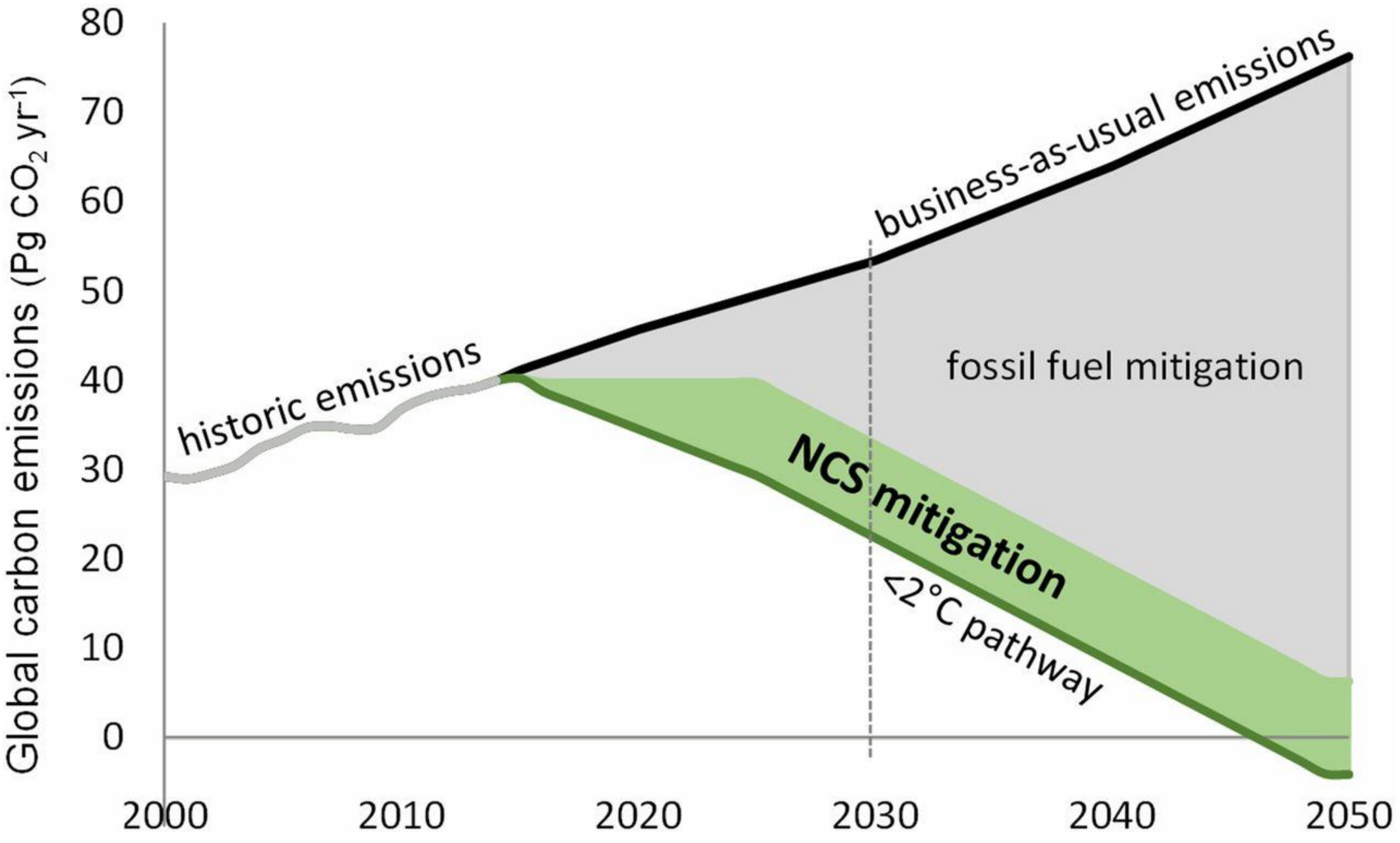
Fuss et al 2018 Environ. Res. Lett.

How hypothetical technologies shape climate scenarios



Mark G. Lawrence, and Stefan Schäfer Science 2019;364:829-830

Published by AAAS



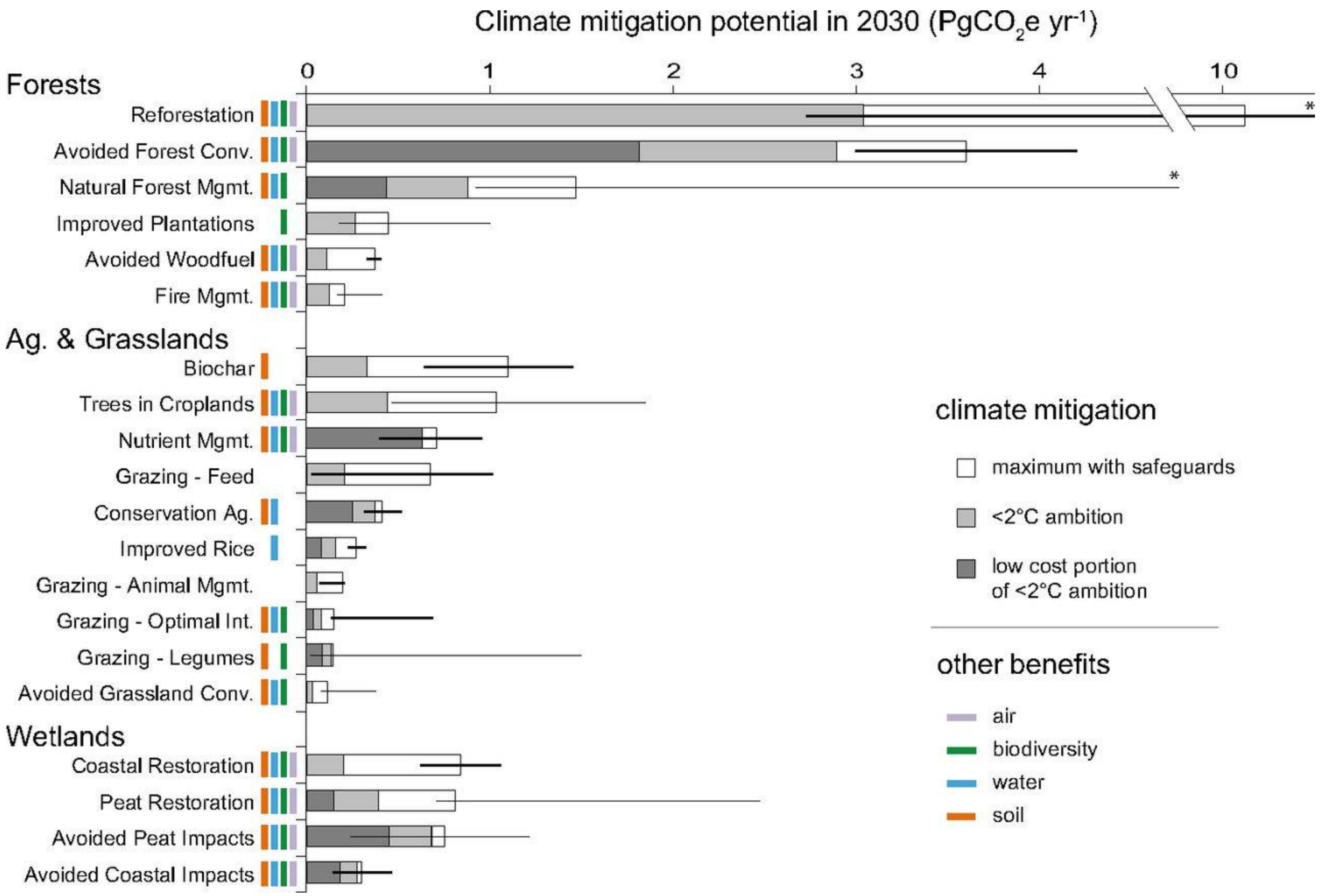
Natural Climate Solutions (NCS) has a maximum potential of **23.8** PgCO_2e y^{-1}

NCS provide **37**% of the necessary CO_2e mitigation between now and 2030 and **20**% between now and 2050

Bronson W. Griscom et al. PNAS 2017;114:44:11645-11650

PNAS

Climate mitigation potential of 20 natural pathways.



Bronson W. Griscom et al. PNAS 2017;114:44:11645-11650

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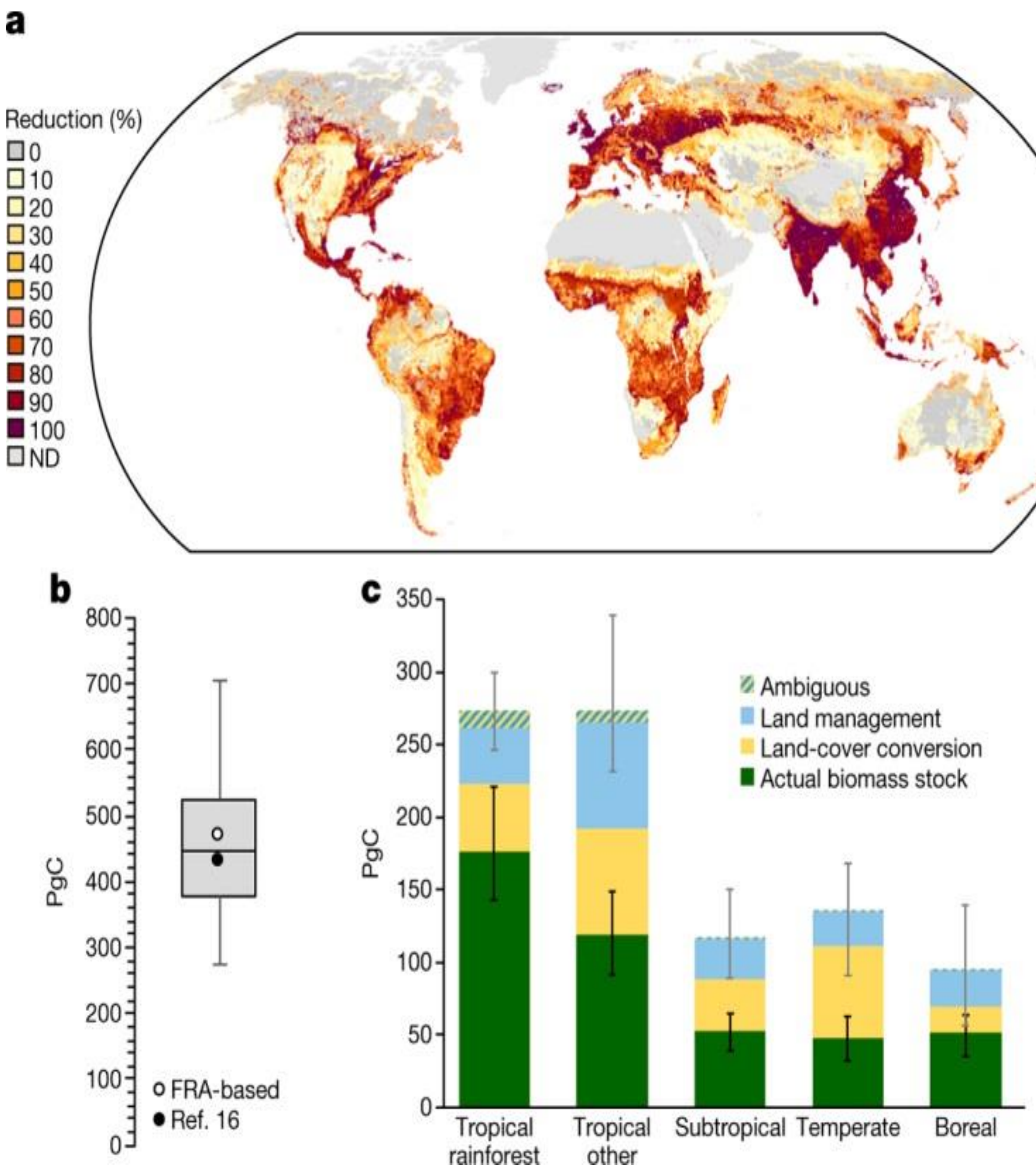
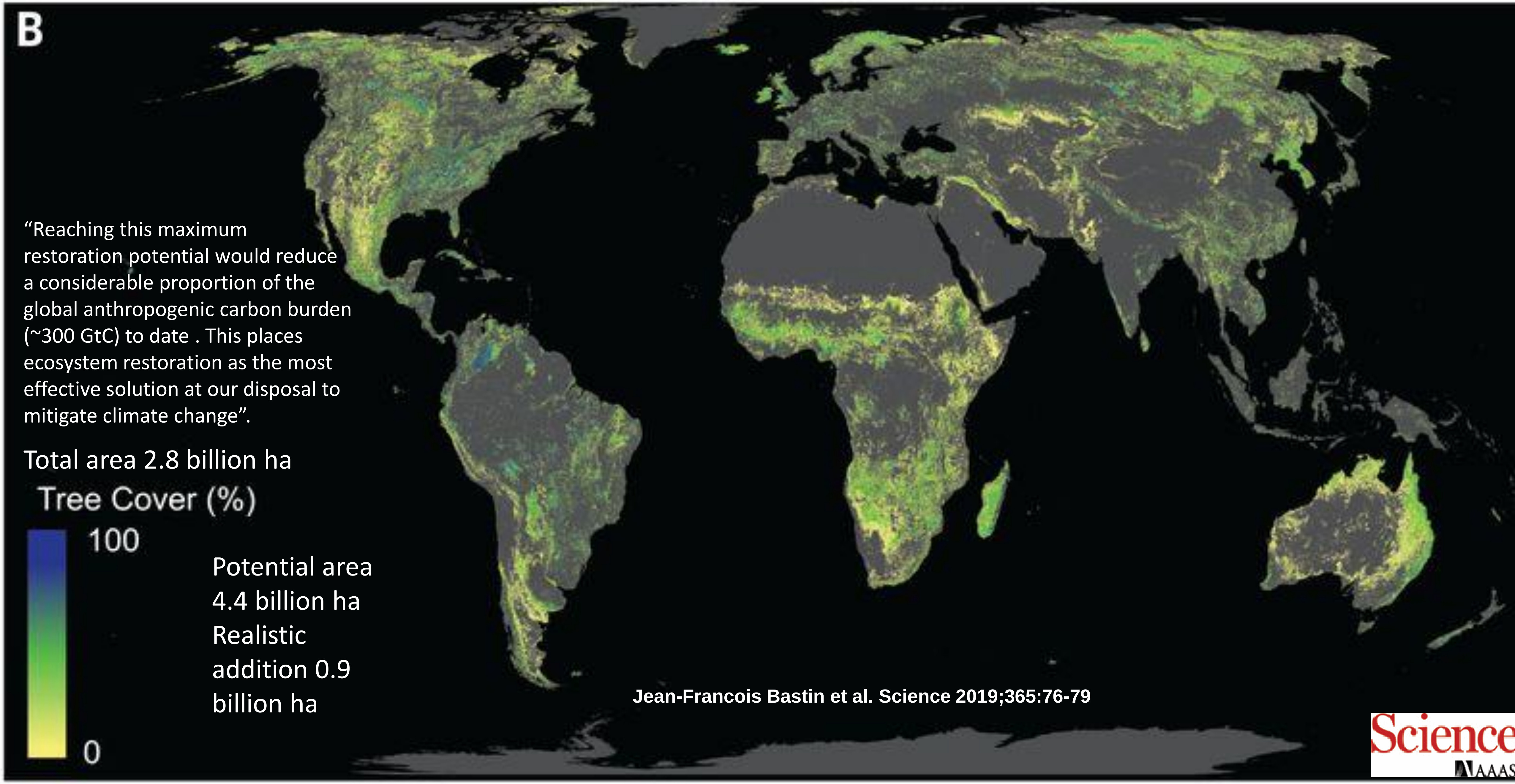
Differences in biomass stocks of potential and actual vegetation induced by land use



Vegetation currently stores around **450** Pg C.
In the hypothetical absence of land use, **potential vegetation** would store around **916** Pg C, under current climate conditions.
Deforestation and other land-cover changes are responsible for **53–58%** of the difference between current and potential biomass stocks. **Land management** effects contribute **42–47%**

K-H Erb *et al.* *Nature* **553,** 73–76 (2018) doi:10.1038/nature25138

nature



“Reaching this maximum restoration potential would reduce a considerable proportion of the global anthropogenic carbon burden (~300 GtC) to date . This places ecosystem restoration as the most effective solution at our disposal to mitigate climate change”.

Total area 2.8 billion ha

Potential area 4.4 billion ha
Realistic addition 0.9 billion ha

Jean-Francois Bastin et al. Science 2019;365:76-79

nature climate change

ARTICLES

https://doi.org/10.1038/s41558-018-0271-1

Latitudinal limits to the predicted increase of the peatland carbon sink with warming

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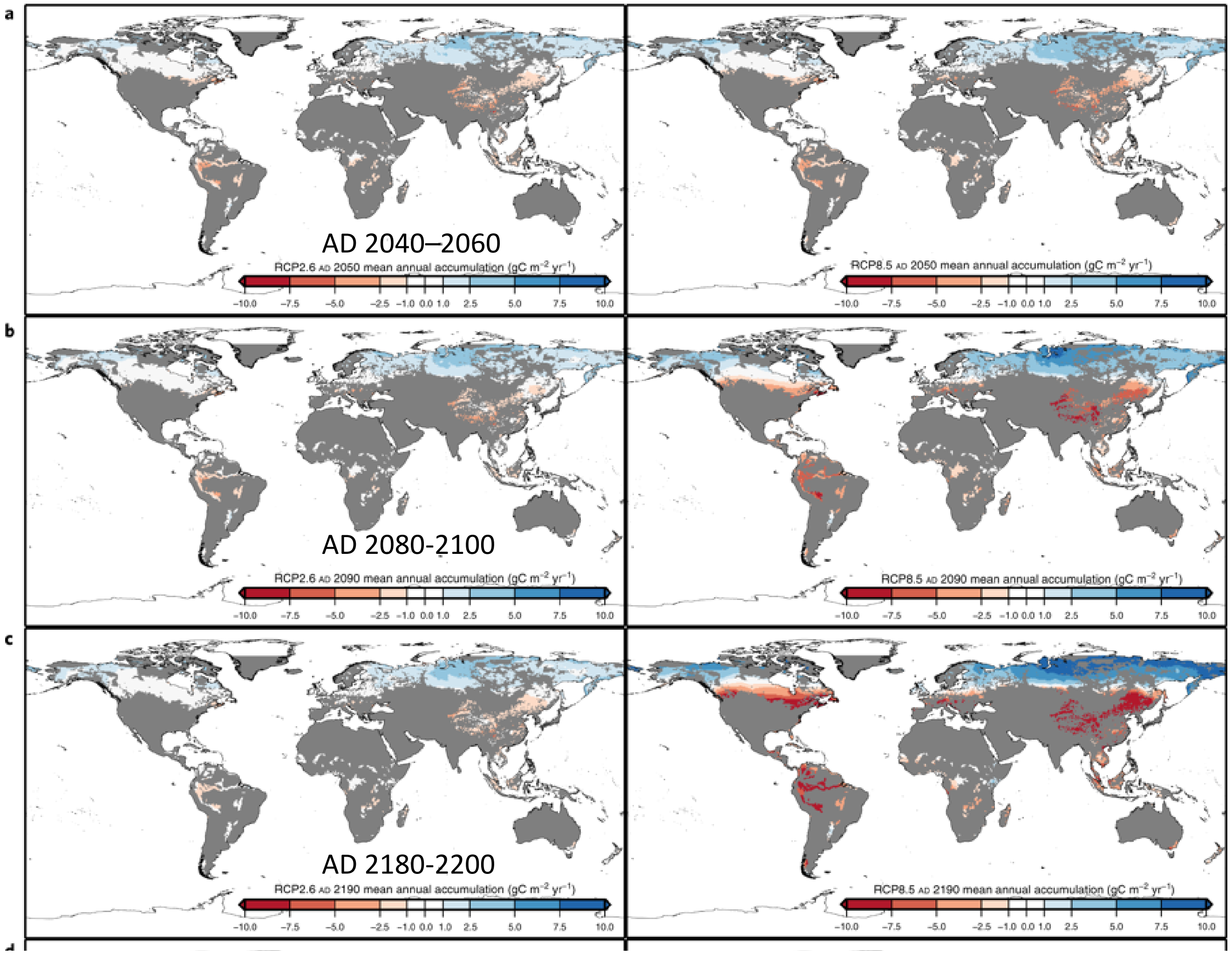
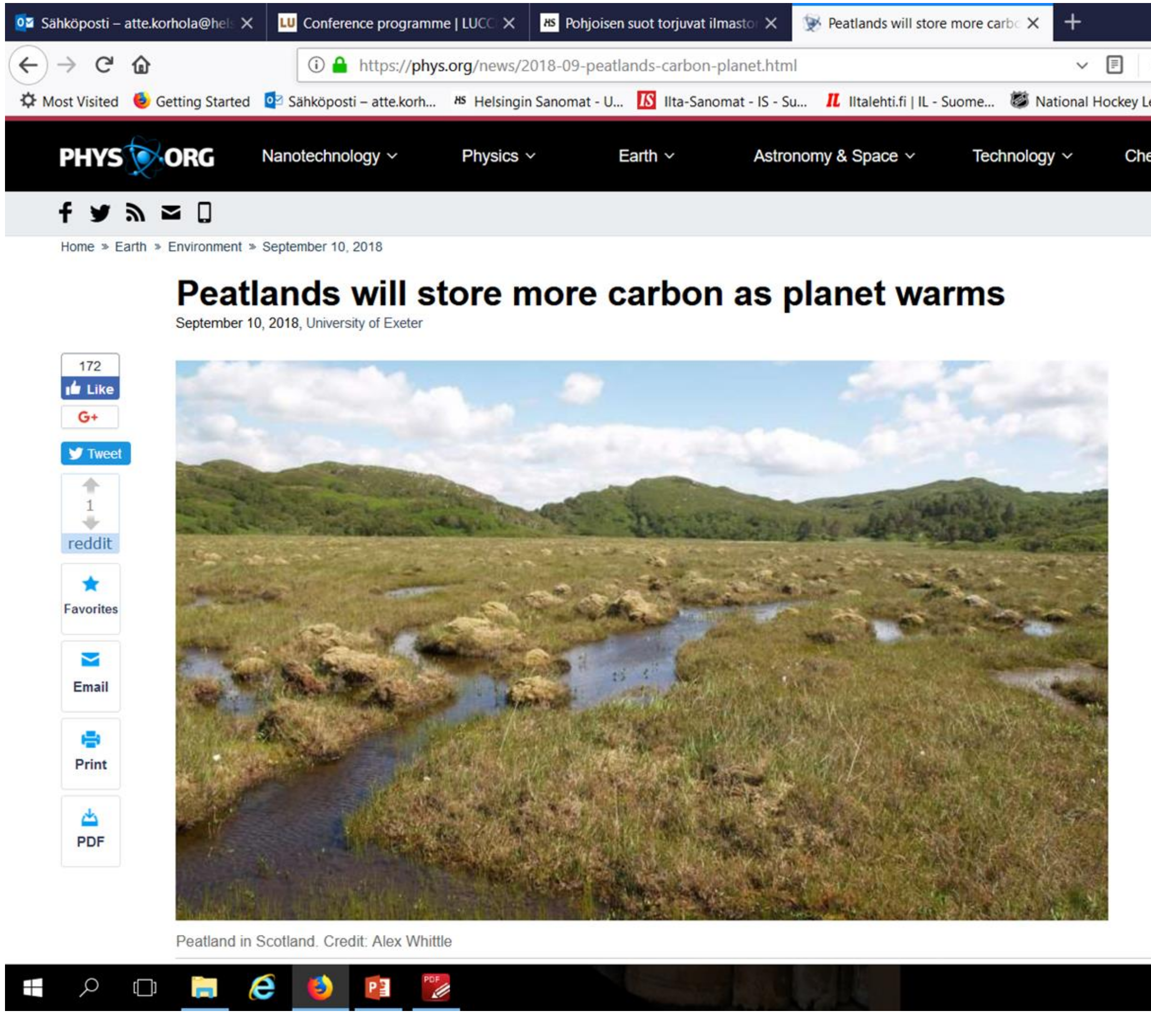
The carbon sink potential of peatlands depends on the balance of carbon uptake by plants and microbial decomposition. The rates of both these processes will increase with warming but it remains unclear which will dominate the global peatland response. Here we examine the global relationship between peatland carbon accumulation rates during the last millennium and planetary-scale climate space. A positive relationship is found between carbon accumulation and cumulative photosynthetically active radiation during the growing season for mid- to high-latitude peatlands in both hemispheres. However, this relationship reverses at lower latitudes, suggesting that carbon accumulation is lower under the warmest climate regimes. Projections under Representative Concentration Pathway (RCP)2.6 and RCP8.5 scenarios indicate that the present-day global sink will increase slightly until around AD 2100 but decline thereafter. Peatlands will remain a carbon sink in the future, but their response to warming switches from a negative to a positive climate feedback (decreased carbon sink with warming) at the end of the twenty-first century.

Projected anomalies (future – historic) of annual carbon accumulation rates for three time periods

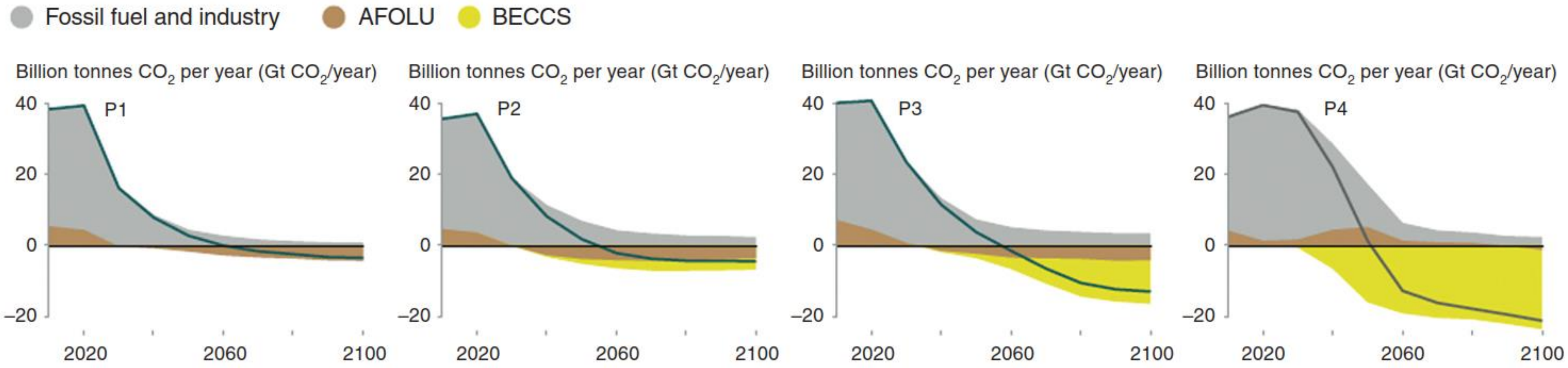
Gallego-Sala, A. et al. 2018.
Nature Climate Change

RCP2.6 | RCP8.5





Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business, and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A down-sized energy system enables rapid decarbonisation of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Figure 1. IPCC scenarios of four routes to achieving the Paris Agreement 1.5°C target.

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POLICY COMMENTARY

GLOBAL CHANGE BIOLOGY BIOENERGY WILEY

Serious mismatches continue between science and policy in forest bioenergy

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Abstract

In recent years, the production of pellets derived from forestry biomass to replace coal for electricity generation has been increasing, with over 10 million tonnes traded internationally—primarily between United States and Europe but with an increasing trend to Asia. Critical to this trade is the classification of woody biomass as 'renewable energy' and thus eligible for public subsidies. However, much scientific study on the net effect of this trend suggests that it is having the opposite effect to that ex-

Some points related to the use of forestry biomass to replace coal

Norton et al. 2019. GCB Energy

- Woody biomass contains **less energy** than coal (fresh wood 2-3; biomass pellets 9.6-12.2; coal 18.4-23.8 GJ/m3 respectively (Thrän et al. 2017)) and boiler temperatures are likely to be lower, reducing steam-cycle efficiency.
  - Replacing fossil fuels in electricity generation results in significant increases in emissions of CO2 per kilowatt hour generated.
- Burning forest biomass transmits the carbon from the forest stock to the atmosphere within minutes, and there is a '**carbon payback period**' between this initial release of carbon and its return to forest carbon stocks through regrowth. This payback period may be relatively short when burning forestry residues, but where whole trees are burnt, the payback periods depends on the species and conditions of regrowth which range from decades to centuries (e.g. Nabuurs et al. 2017; Sterman et al. 2018). In some scenarios, the carbon present in the original forest stock may never be recovered.
  - This means that the concept of carbon neutrality is both uncertain and highly time and context-dependent.
- Given that the IPCC (IPCC, 2018) projects that the 1.5C target is likely to be reached between 2030 and 2052 on current trends, payback periods of a decade or more increase the risks of **overshooting Paris goals**.
- A large amount of forest carbon is stored in the **soil**. Soils can hold up to twice as much carbon as the trees above, depending on the type of forest and amount of leaf litter and debris on the forest floor.
- The assumed greenhouse gas savings relative to fossil fuel commonly ignore the **supply chain** (from felling, transport, drying and pelleting, long-distance shipping) **emissions** as well as the carbon emissions from actually burning the wood.

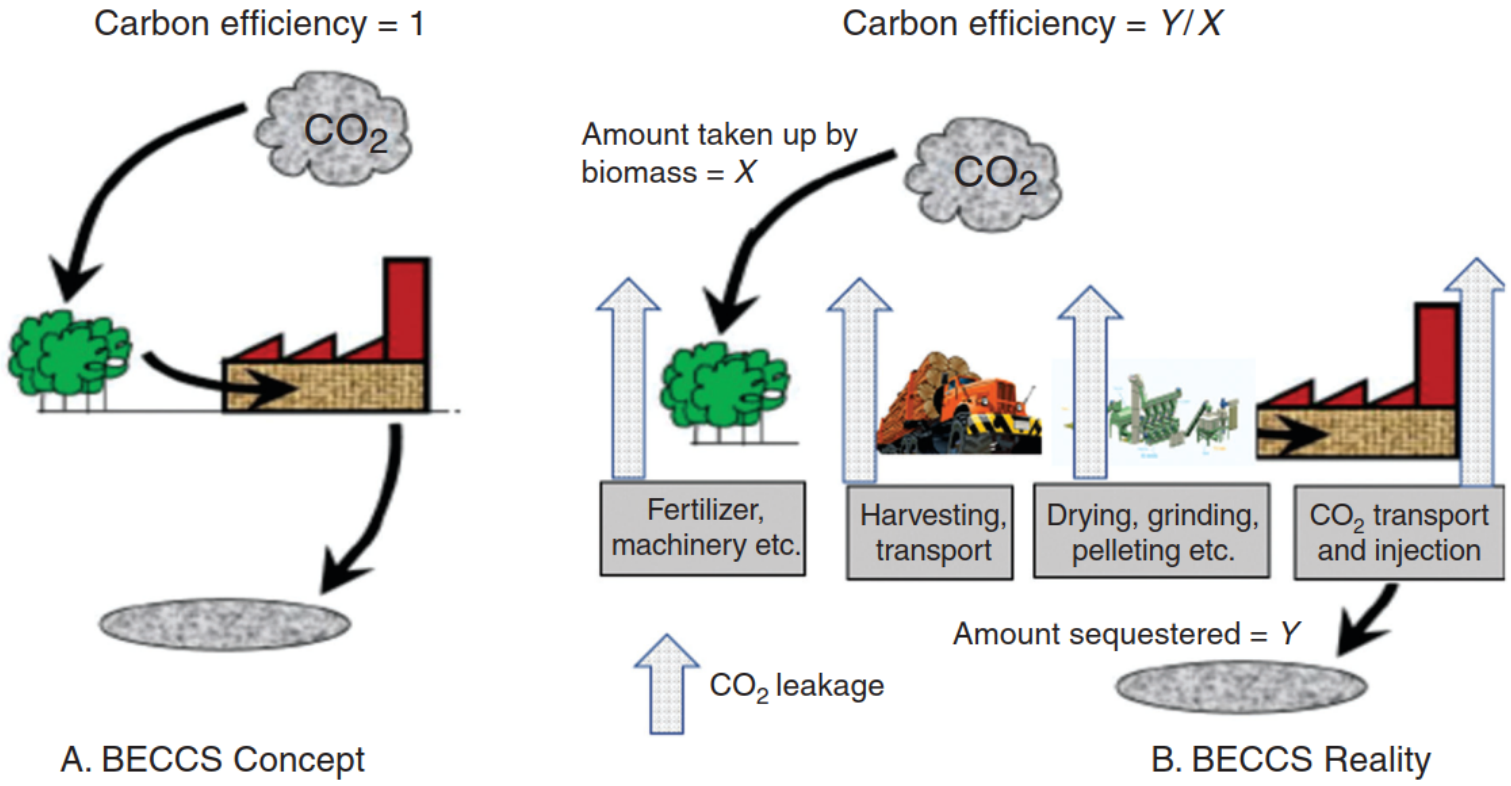

Figure 3. Simple BECCS concept and real life-cycle emission flows.

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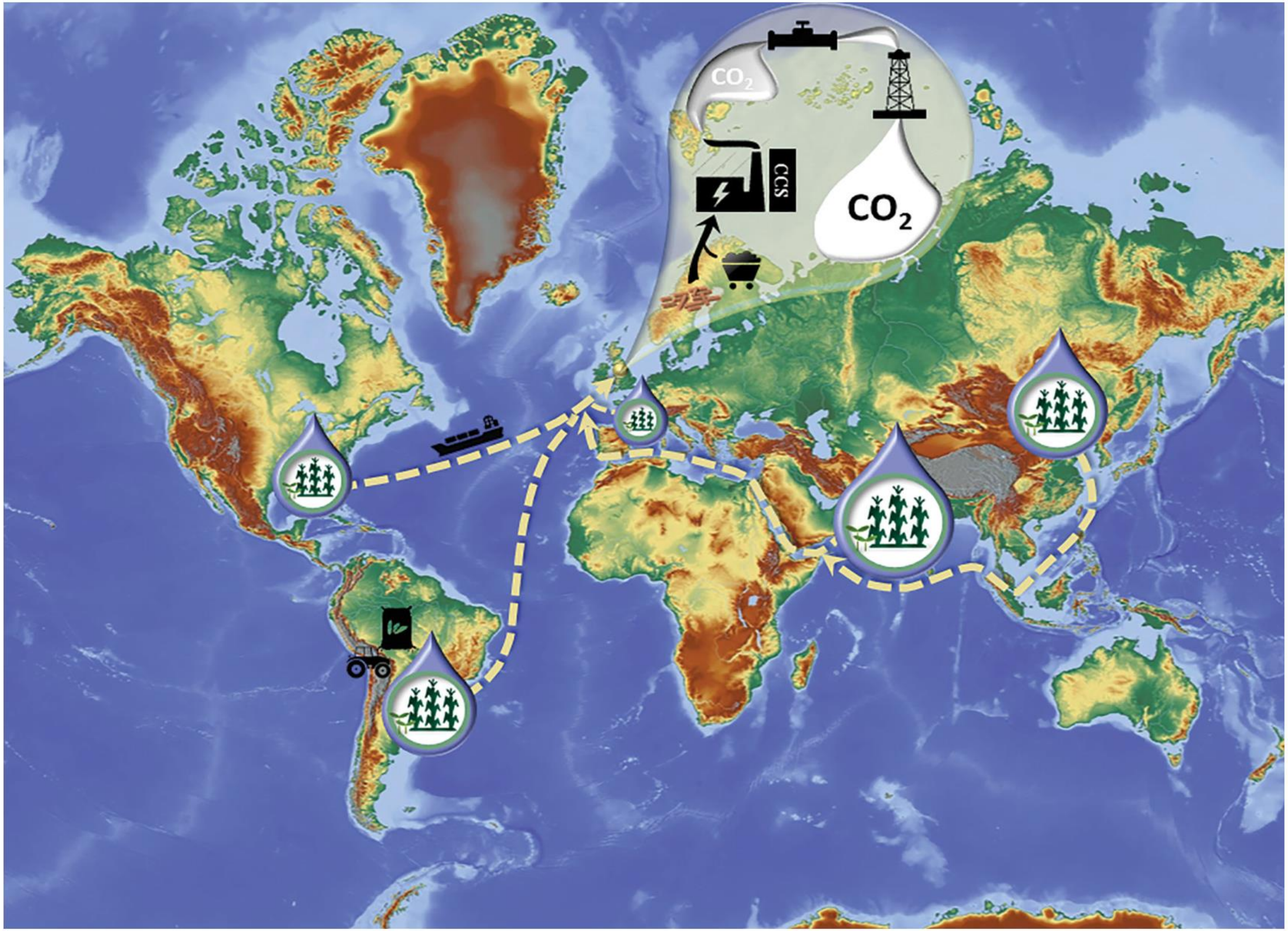
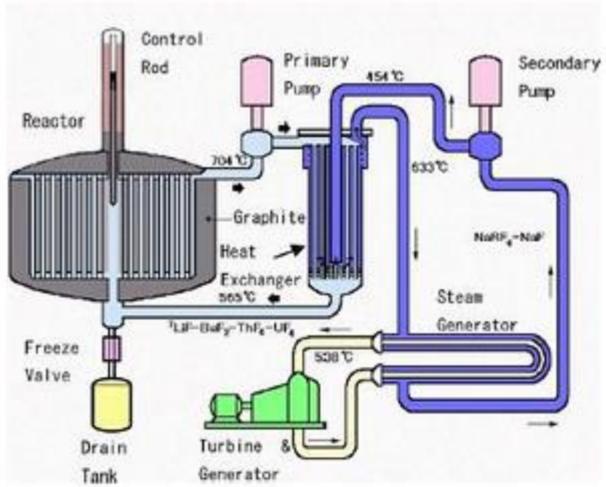

CO2
CCS
CO2

Nuclear potentials

Cao et al. 2016. Science

- Small modular light-water reactors
- Molten salt reactors
- Gas-cooled reactors
- Liquid-metal–cooled reactors
- High-temperature gas reactors
- Thorium-fueled molten reactors
- Sodium-cooled fast reactors
- Accelerator-driven subcritical systems
- FUSION POWER



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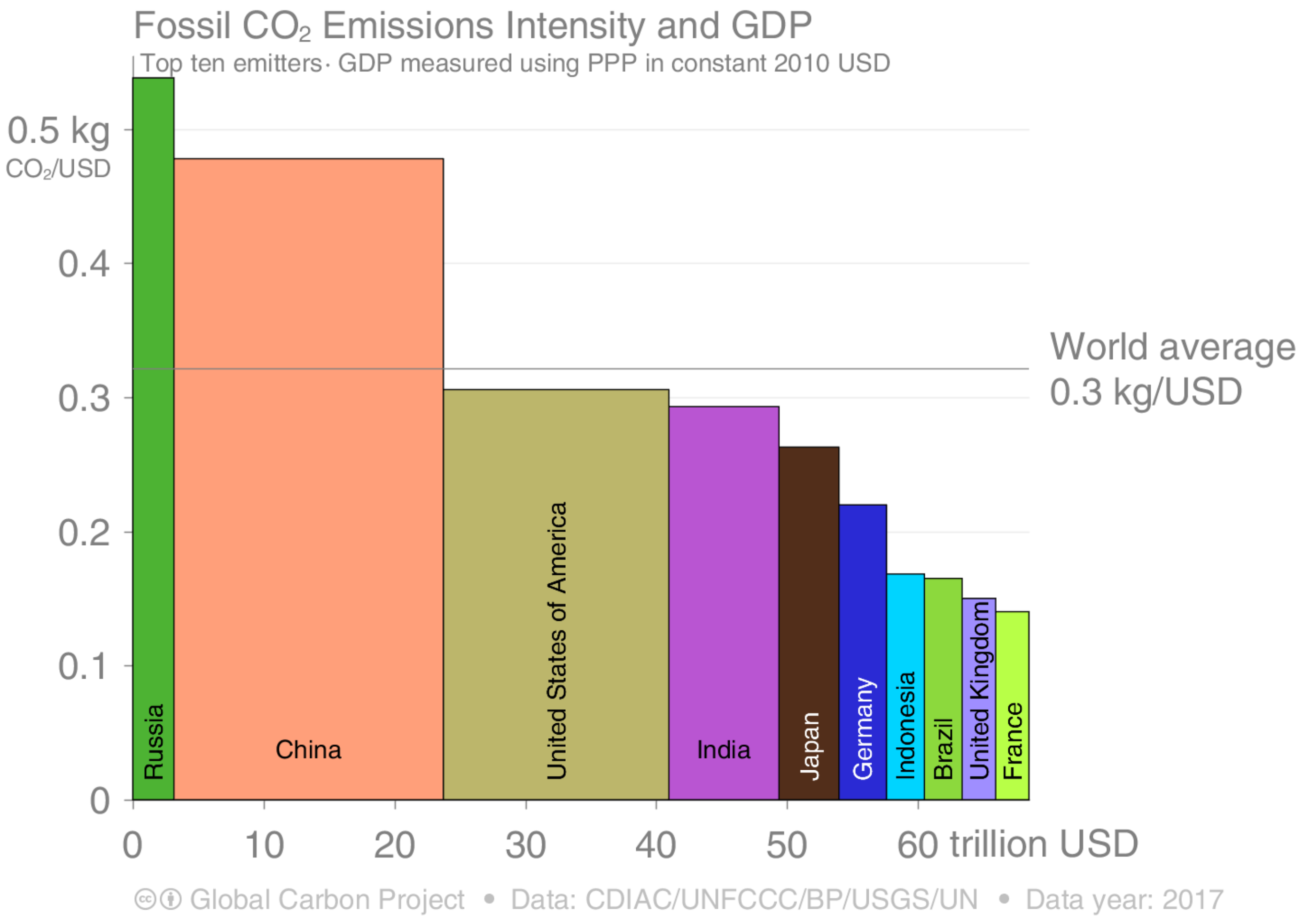
Fossil CO_2 emission intensity

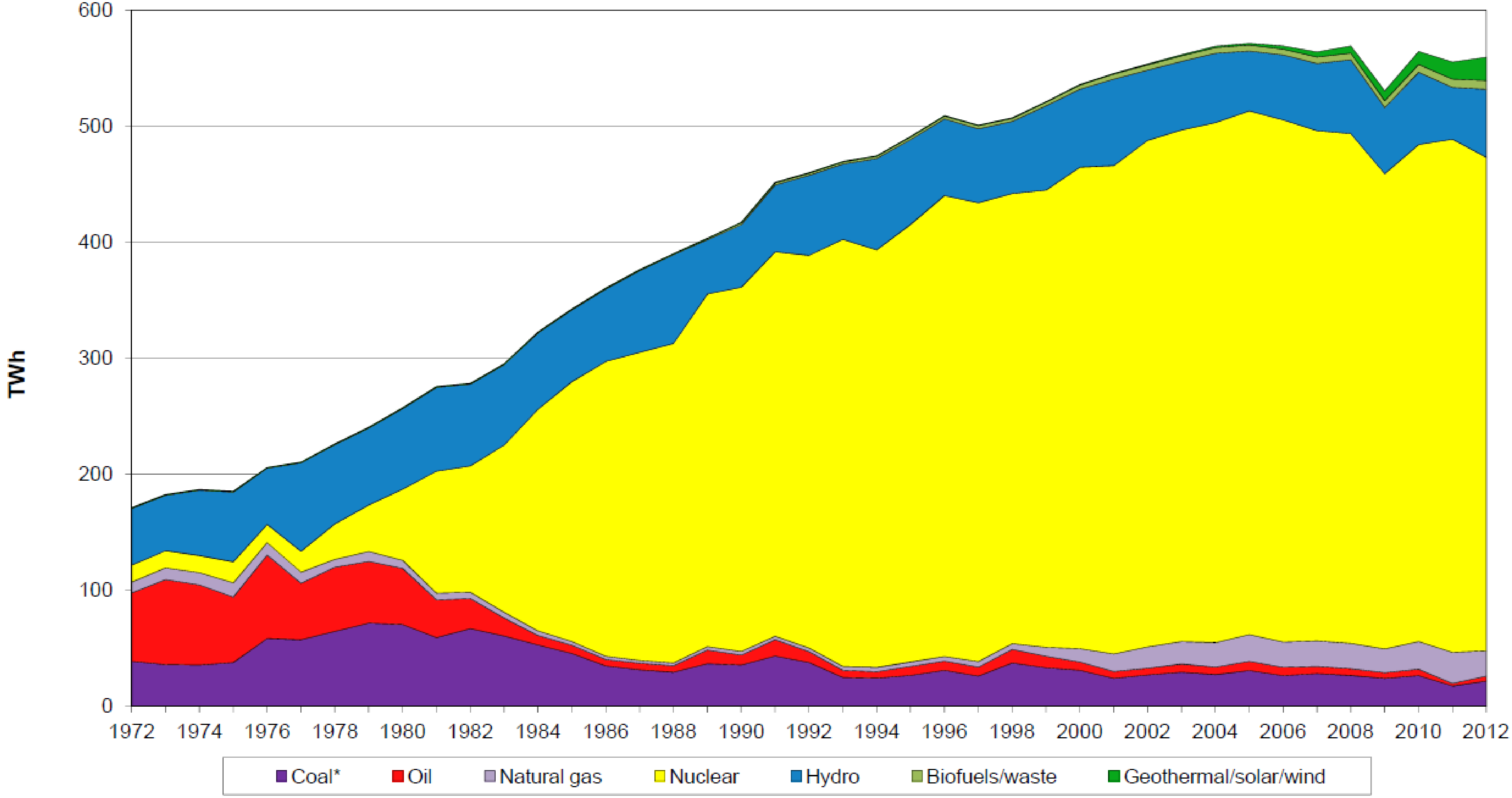
The 10 largest economies have a wide range of emission intensity of economic activity



Emission intensity: Fossil CO_2 emissions divided by Gross Domestic Product (GDP)
Source: Global Carbon Budget 2018

Electricity generation by fuel

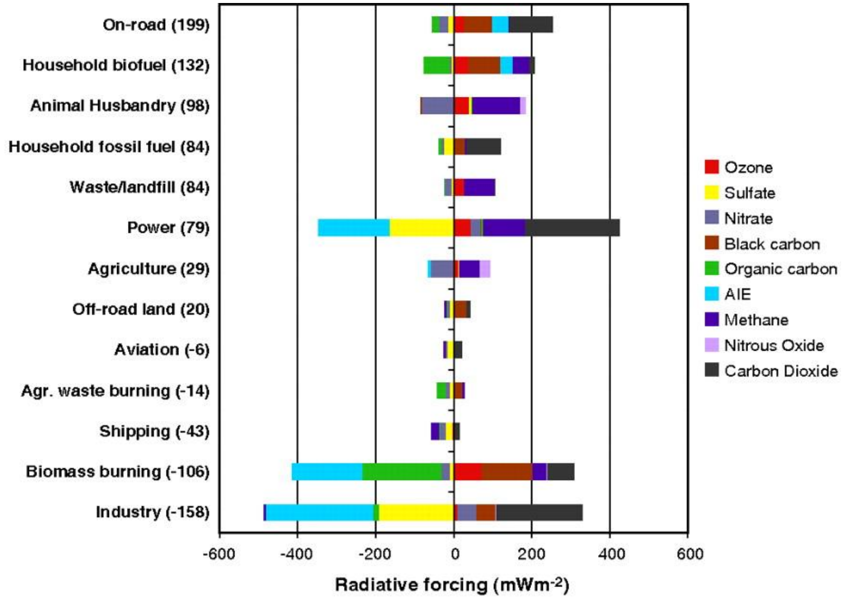
France



* In this graph, peat and oil shale are aggregated with coal, when relevant.

© OECD/IEA 2014

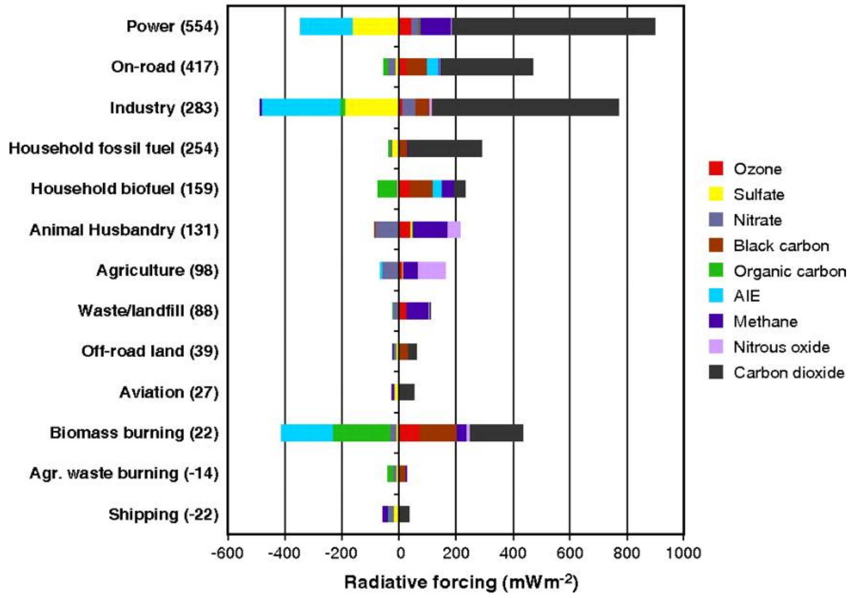
Radiative forcing due to perpetual constant year 2000 emissions grouped by sector at (a) 2020 (b) 2100 showing the contribution from each species.



2020

- On-road transportation
- Agriculture

Focus on sectors that produce most warming!



2100

- Power generation
- On-road transportation

Unger N et al. PNAS 2010;107:3382-3387

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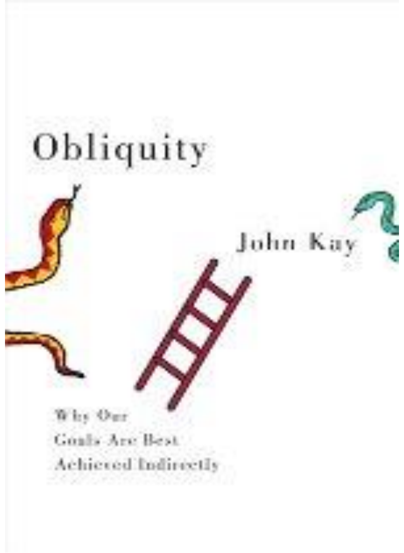
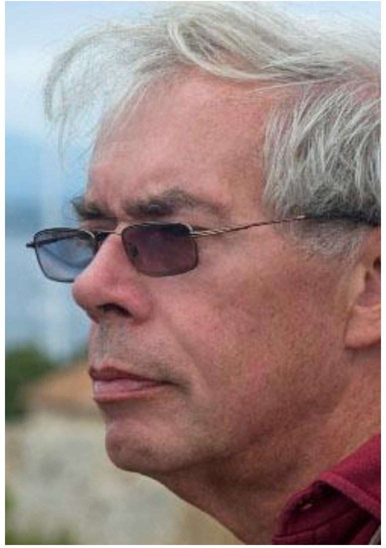
PNAS

Obliquity – why our goals are best achieved indirectly?

Obliquity is the principle that complex goals are best achieved *indirectly*. This book explains why the happiest people aren't necessarily those who focus on happiness, and how the most successful cities aren't planned (look at Paris versus Brasilia). And if a company announces shareholder return as its number one goal, perhaps we should beware: the most profit-orientated companies aren't usually the most profitable.





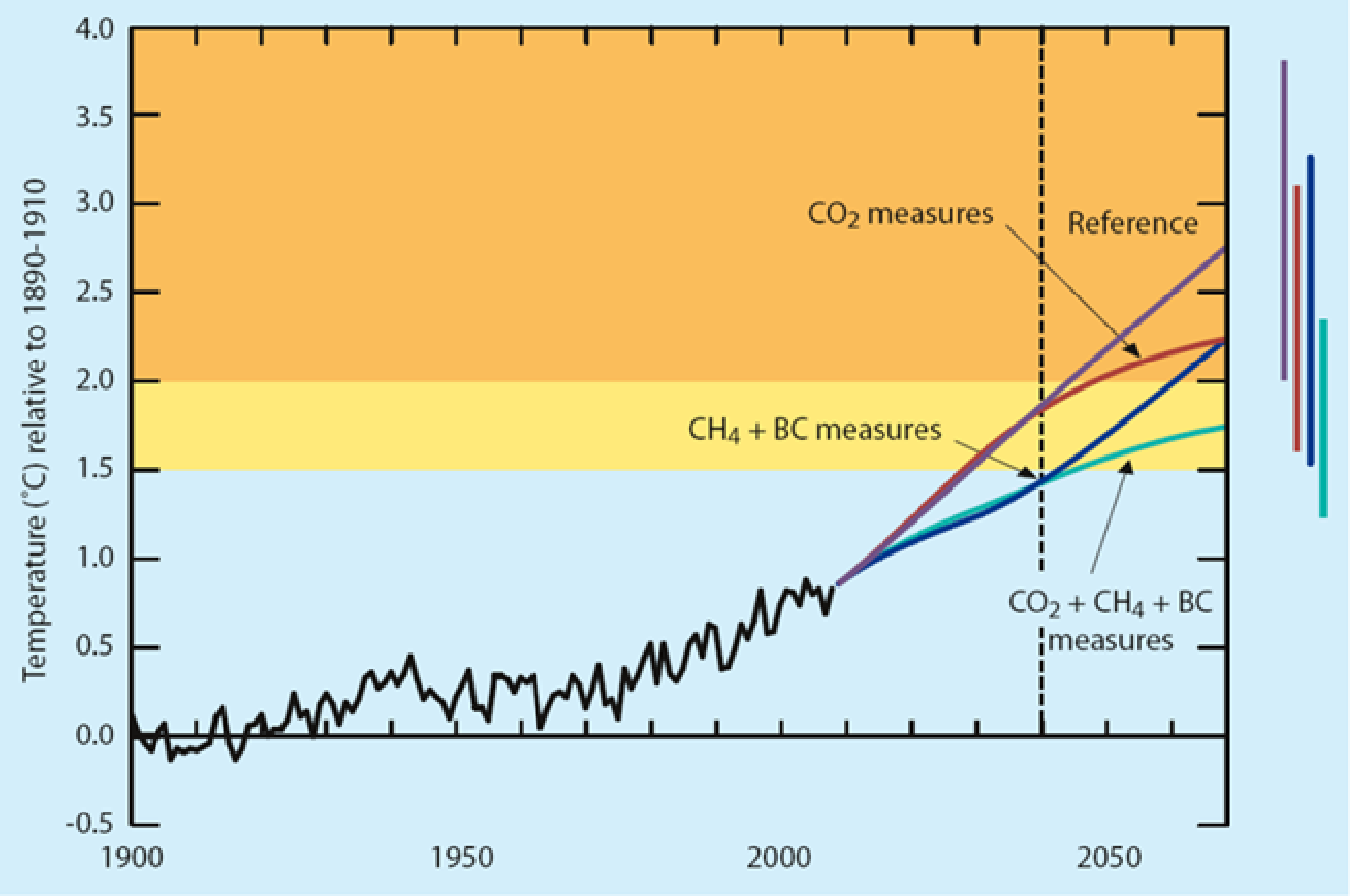
John Kay

Examples of indirect climate mitigation measures

- Improving people’s health by **reducing black carbon pollution** – this strategy avoids 0.7 to 4.7 million annual premature deaths!
- Increasing annual crop yields through **ozone reductions** – valued at $700 to $5000 per metric ton!
- Fighting against poverty through **preventing desertification** and reforestation – strengthtens cabon sinks!

Short-lived climate pollutants

Reductions of 30% for methane and 75% for BC would avoid up to **0.6°C of warming** by mid-century, while also slowing the rise in sea levels, the melting of glaciers, and the retreat of the Arctic ice cap.




50um
50um

We have several ways to fight climate change

Emissions reduction technologies

Energy
- Clean energy sources (wind, hydro, nuclear and solar)

Buildings
- More insulation/ refurbishment
- Using wooden materials

Industry
- Penetration of efficiency technologies

Transport
- Electric vehicles

Other
- Efficient fertilization in agriculture

Most essential methods - proven technologies

Emission neutral technologies

Carbon capture and storage (CCS)
- Capture and storage CO2 from fossil fuel combustion

Synthetic fuels
- Power-to-Liquid and Power-to-Gas technologies

Supporting technologies

Negative emission technologies (NETs)[1]

Trees and plants
- Forestation
- Natural forest management
- Wetland management

Soil
- Sustainable farming practices
- Enhanced agricultural methods
- Biochar
- Enhanced weathering

Ocean
- Ocean fertilization
- Seaweed / algae farming
- Enhanced weathering

Technology
- Direct air carbon capture and storage (DACCS)
- Bioenergy carbon capture and storage (BECCS)

Supporting technologies

1. NETs are defined as intentional efforts to remove CO2 emissions from atmosphere by increasing natural sinks or using chemical engineering to remove CO2

Source: BCG Economic Case for Combating Climate Change 2018; BCG analysis

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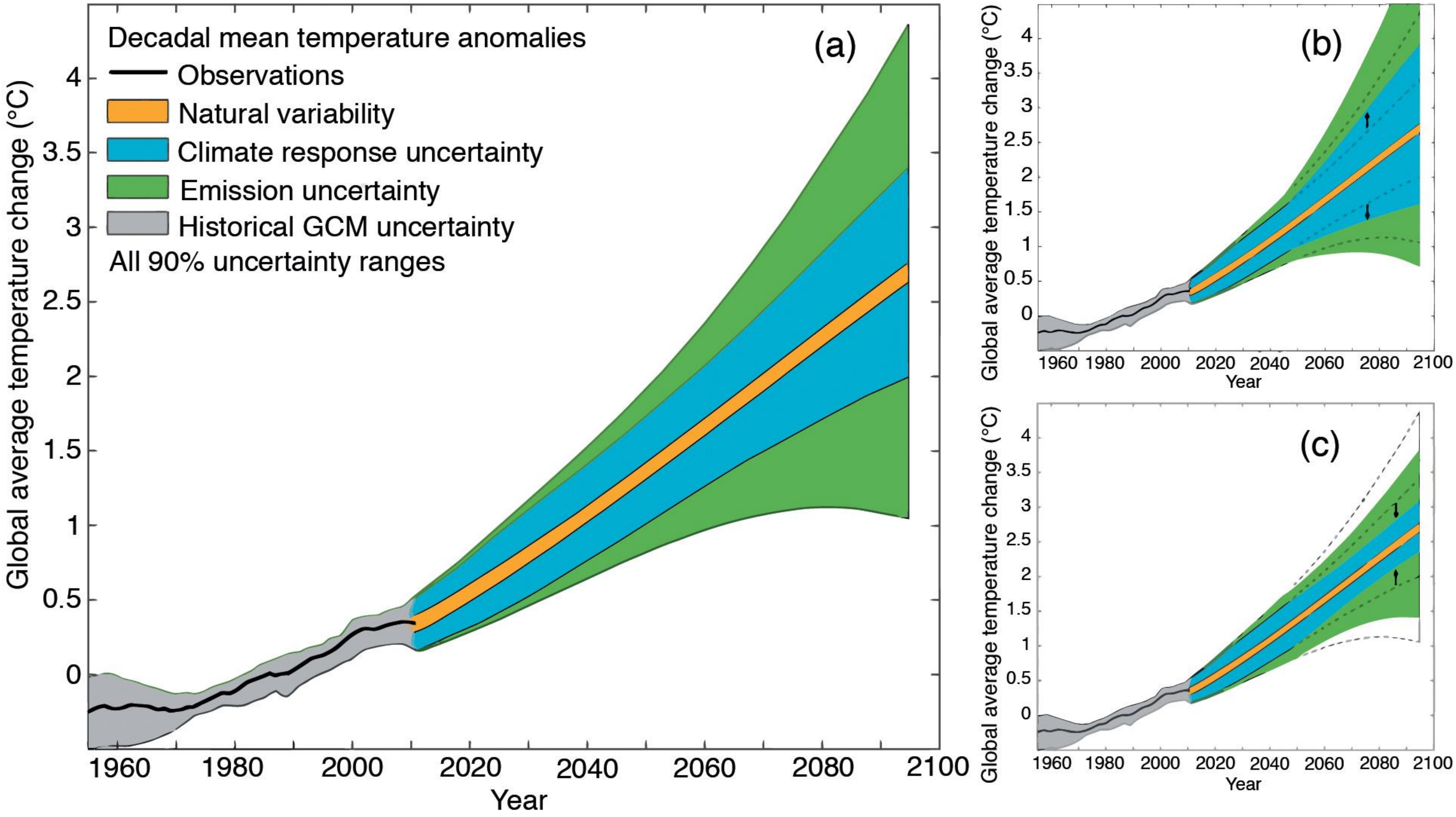
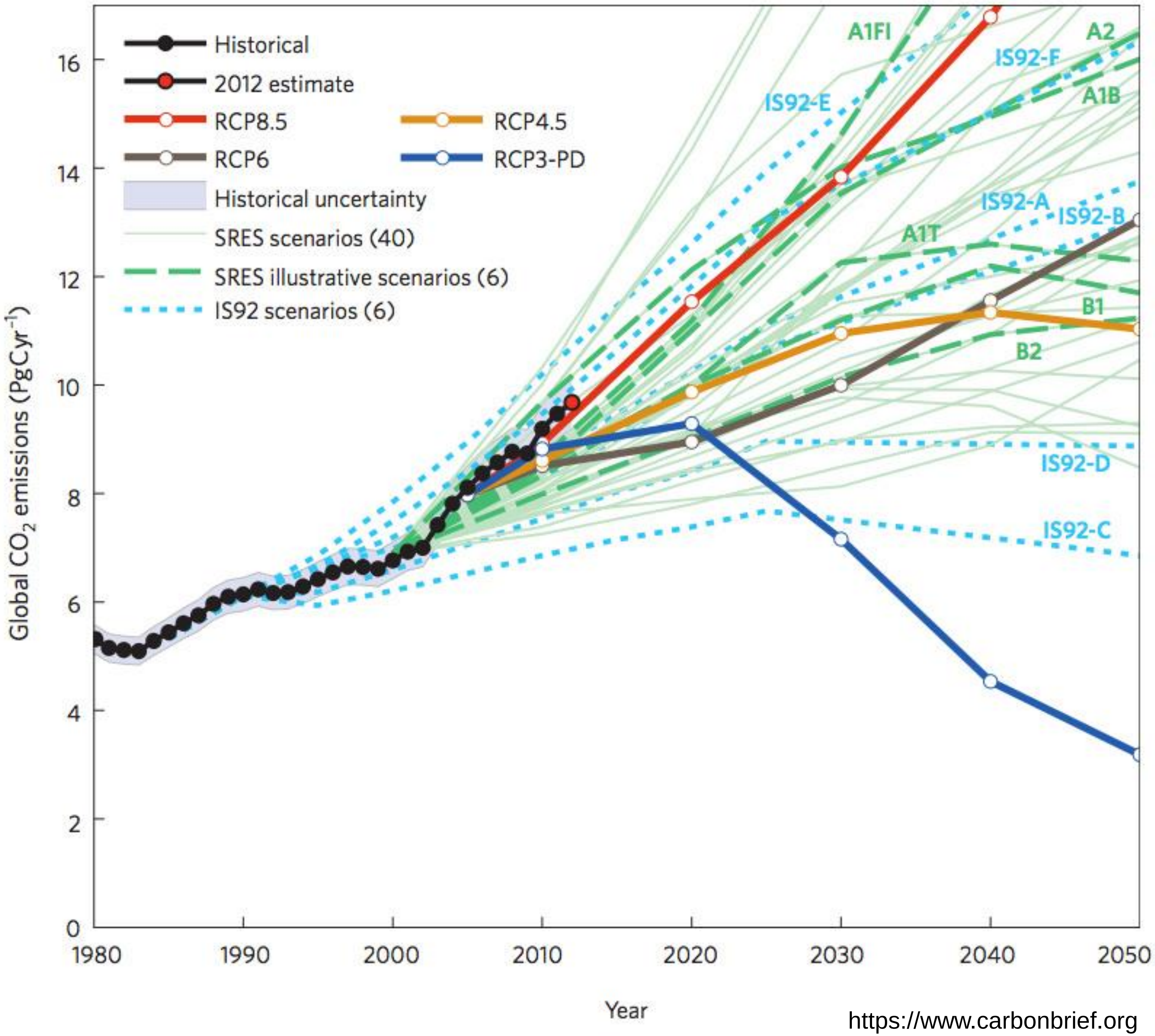


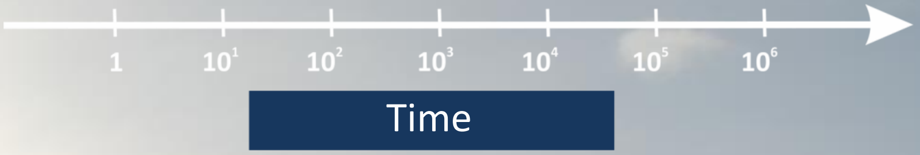
IPCC AR5 2013



https://www.carbonbrief.org

Environmental Change Research Unit (ECRU)

Atte Korhola
Leader of the Group



The central research themes in the ECRU are long-term Arctic environmental changes and their ecological and societal impacts. We are particularly interested in climate variability, carbon cycling, ecosystem feedbacks, black carbon deposition, freshwater, wetland and coastal ecology, biodiversity, lake optical environments, and climate mitigation and adaptation strategies.

http://www.helsinki.fi/bioscience/ecru/index.htm