Climate change: a summary for policy-makers

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Climate change: a summary for policymakers

- How rising atmospheric CO_2 causes global warming
- How global temperatures and sea level respond
- Quantifying human influence on climate and weather
- The fate of CO_2 and other anthropogenic emissions
- Global impact functions and the social cost of carbon
- Mitigation costs and pathways
- Policy options from carbon pricing to geo-engineering
- Capstone activity: design a robust climate policy

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Climate change: a summary for policymakers

- How rising atmospheric CO_2 causes global warming
- How global temperatures and sea level respond
- Quantifying human influence on climate and weather
- Should we all go vegan to address climate change?
- Global impact functions and the social cost of carbon
- Mitigation costs and pathways
- Policy options from carbon pricing to geo-engineering
- Capstone activity: design a robust climate policy

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What do these two have in common?

Alexandria Ocasio-Cortez
Brooklyn US Congresswoman

Darren Woods, CEO of Exxon-Mobil

- They've both expressed some unhelpfully short-term views about climate change

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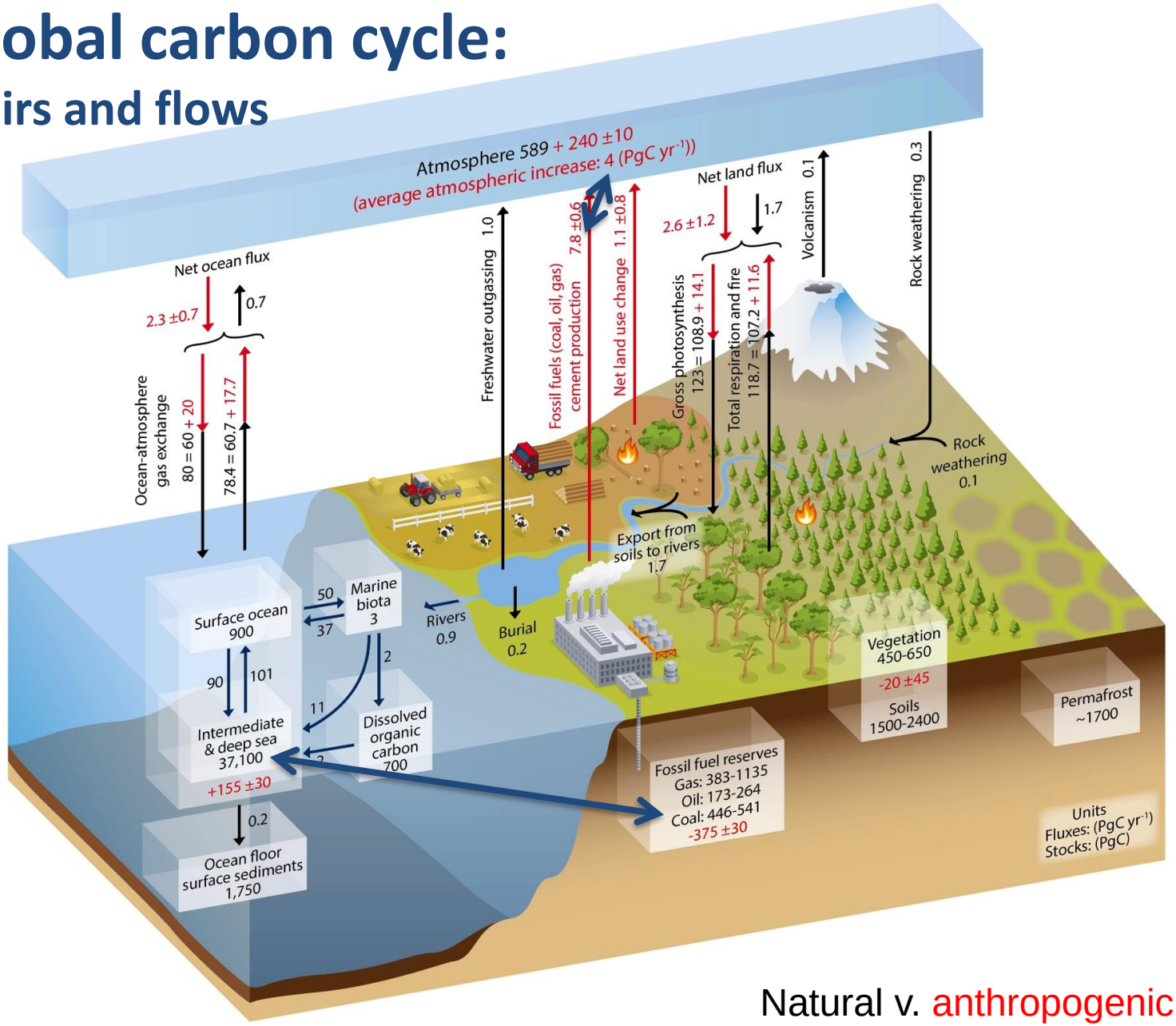
The global carbon cycle:

Reservoirs and flows



Natural v. anthropogenic

stocks and flows: 1 GtC/PgC = 3.7 $GtCO_2$

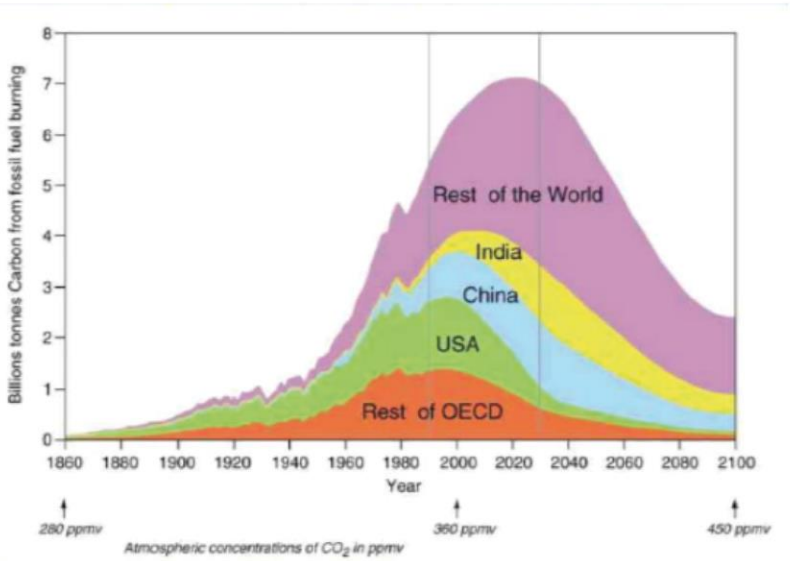
A seductive argument

- Land and oceans are currently taking up carbon at a rate of about 20 $GtCO_2$ (billion tonnes of CO_2) per year.
- Anthropogenic emissions from fossil fuels and industry + land use change = 41 $GtCO_2$.
- Oceans contain 10x as much dissolved inorganic carbon as total available fossil fuels: an inexhaustible sink?
- So if we reduce emissions by 50%, atmospheric concentrations will stop rising, yes?
- Sadly, no.

This matters: “contraction and convergence” model of climate change mitigation policy

3 Solution – contraction and convergence

First advocated in 1990 by Aubrey Meyer



“Long-term convergence of per capita emissions is … the only equitable basis for a global compact on climate change”

Manmohan Singh, 30 June 2008

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Why CO_2 concentrations don't revert to pre-industrial after emissions cease: the Revelle Factor

- Inorganic carbon in the oceans takes three forms:
  - Dissolved CO_2 = 0.5%
  - Bicarbonate ions HCO_3^- = 89%
  - Carbonate ions CO_3^{2-} = 10.5%
- On multi-century timescales, these are in equilibrium.
- So if we dissolve 1000 additional molecules of CO_2, 995 of them are converted to two forms of carbonate ion:

  $CO_2 + H_2O \Leftrightarrow HCO_3^- + H^+$

  $HCO_3^- \Leftrightarrow CO_3^{2-} + H^+$
- Ocean "buffer" keeps pH roughly constant, but every extra molecule of CO_2 "uses up" a carbonate CO_3^{2-} ion.
- Since only 10% of the carbon in the ocean is carbonate, the ocean "reservoir" is 10x smaller than it appears.

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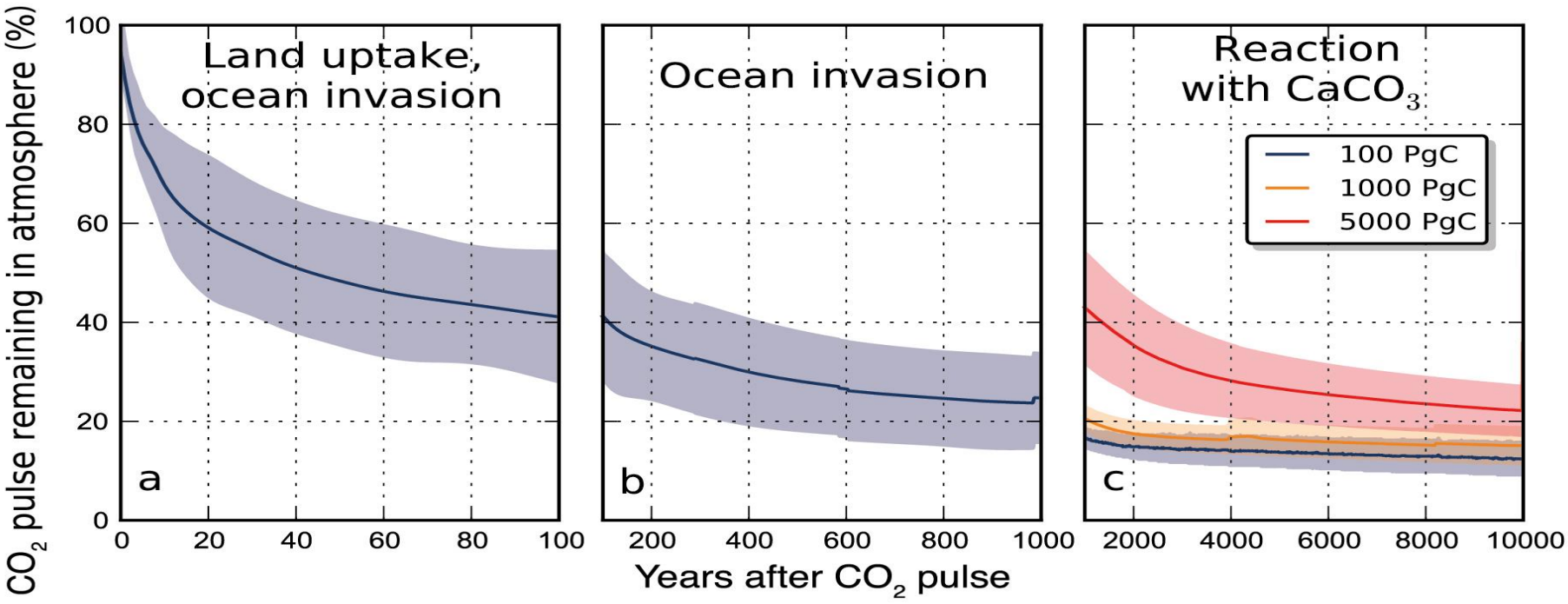
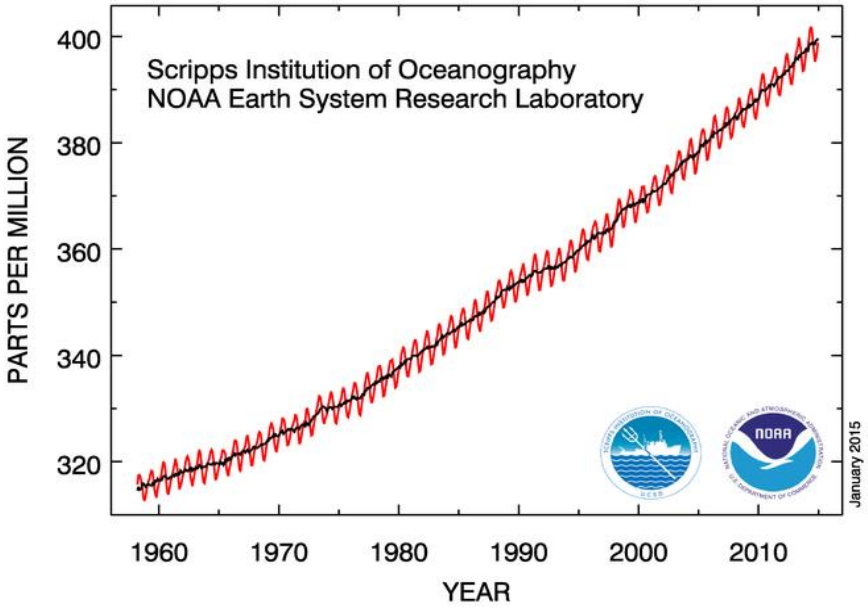
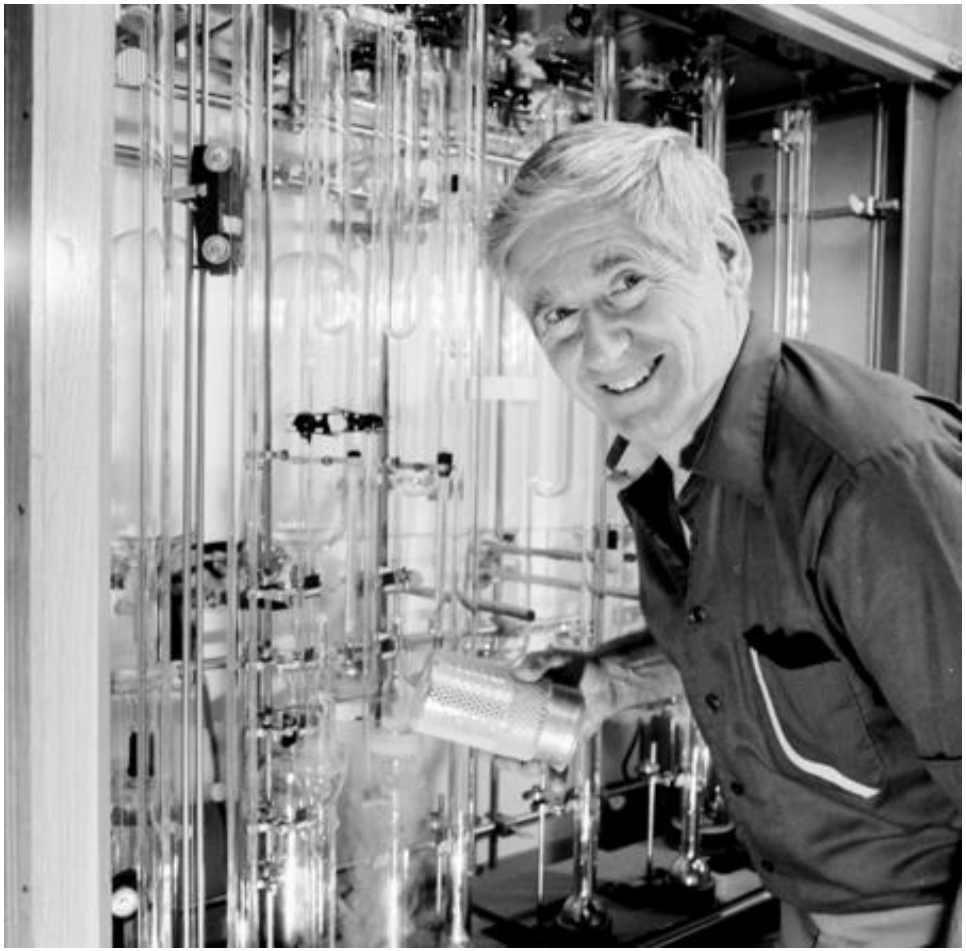
So we can expect the impact of CO_2 emissions to persist for a remarkably long time



Charles David Keeling's first observations, 1958-60

- Unequivocal evidence that CO_2 concentrations are rising steadily





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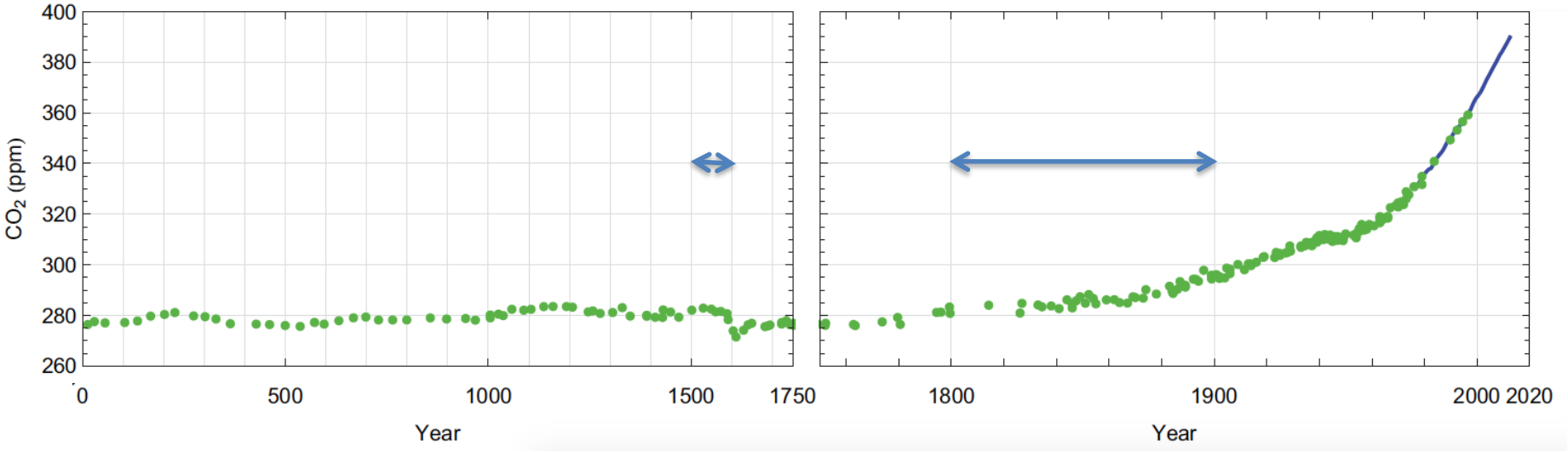
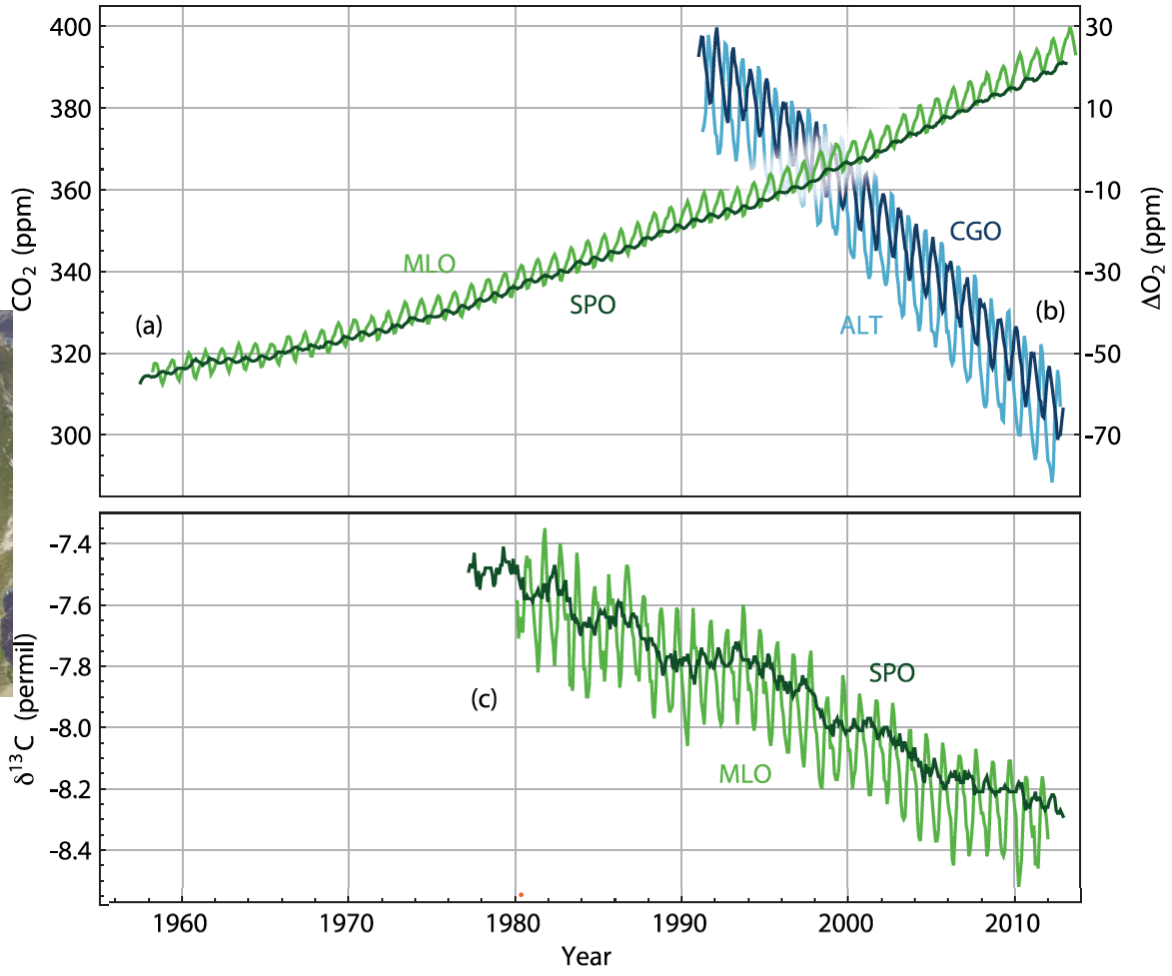
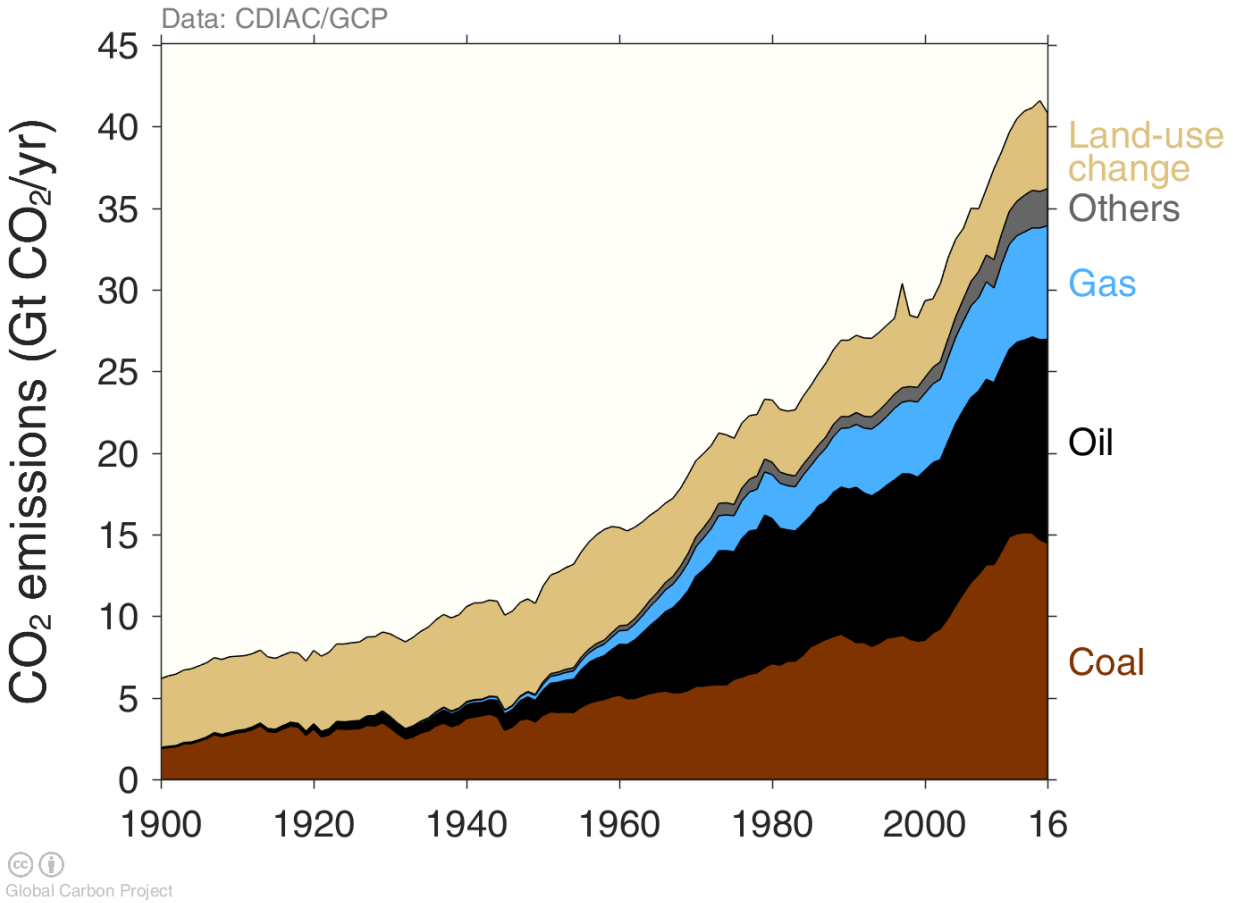
Carbon dioxide levels are rising to levels not seen in over 20 million years



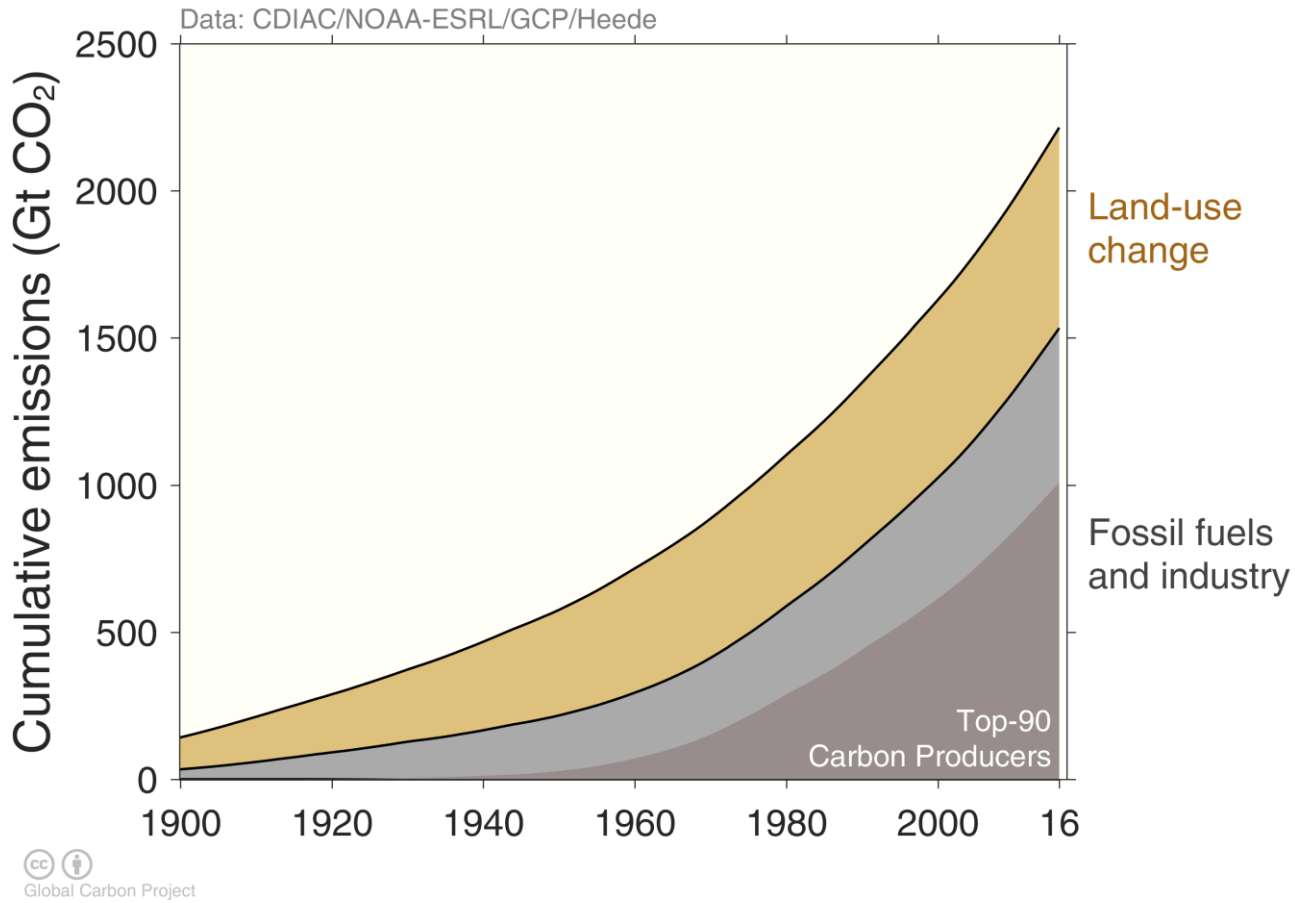
Atmospheric oxygen and carbon isotopes indicate recent CO_2 increase is created by combustion, not simply released from the oceans or by volcanism



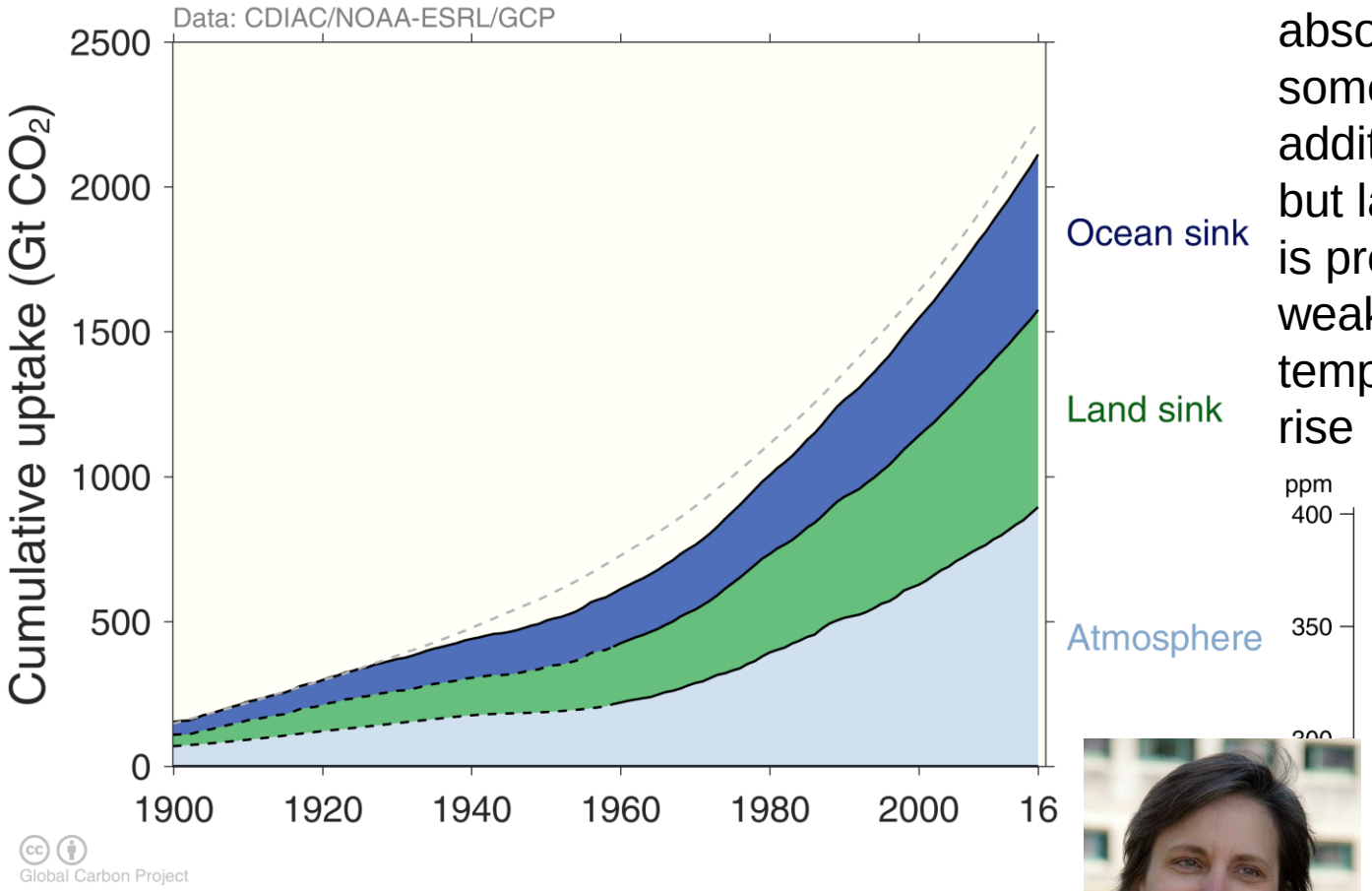
Where is this carbon dioxide coming from?



Cumulative CO_2 emissions added up over time



And where is it going? Atmospheric accumulation is more than half cumulative fossil fuel emissions



Plants and soils are absorbing some additional CO_2 but land sink is predicted to weaken as temperatures rise

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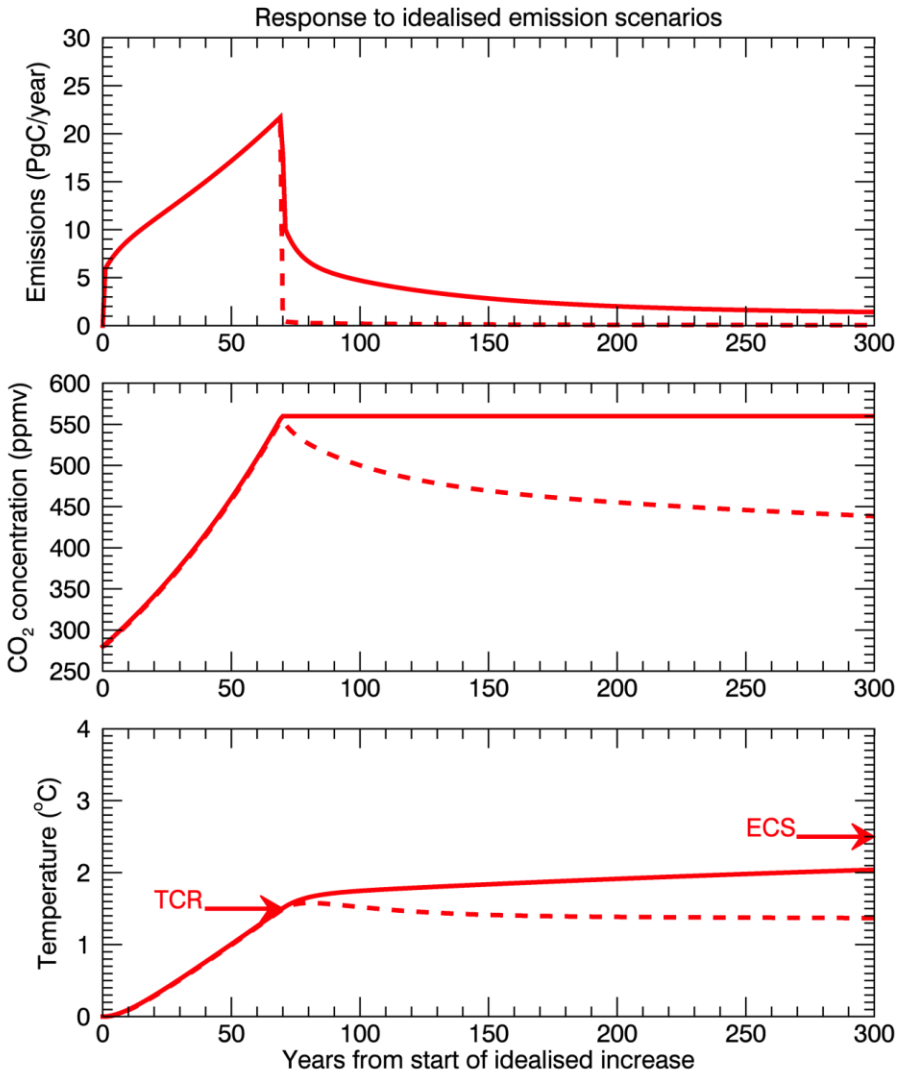
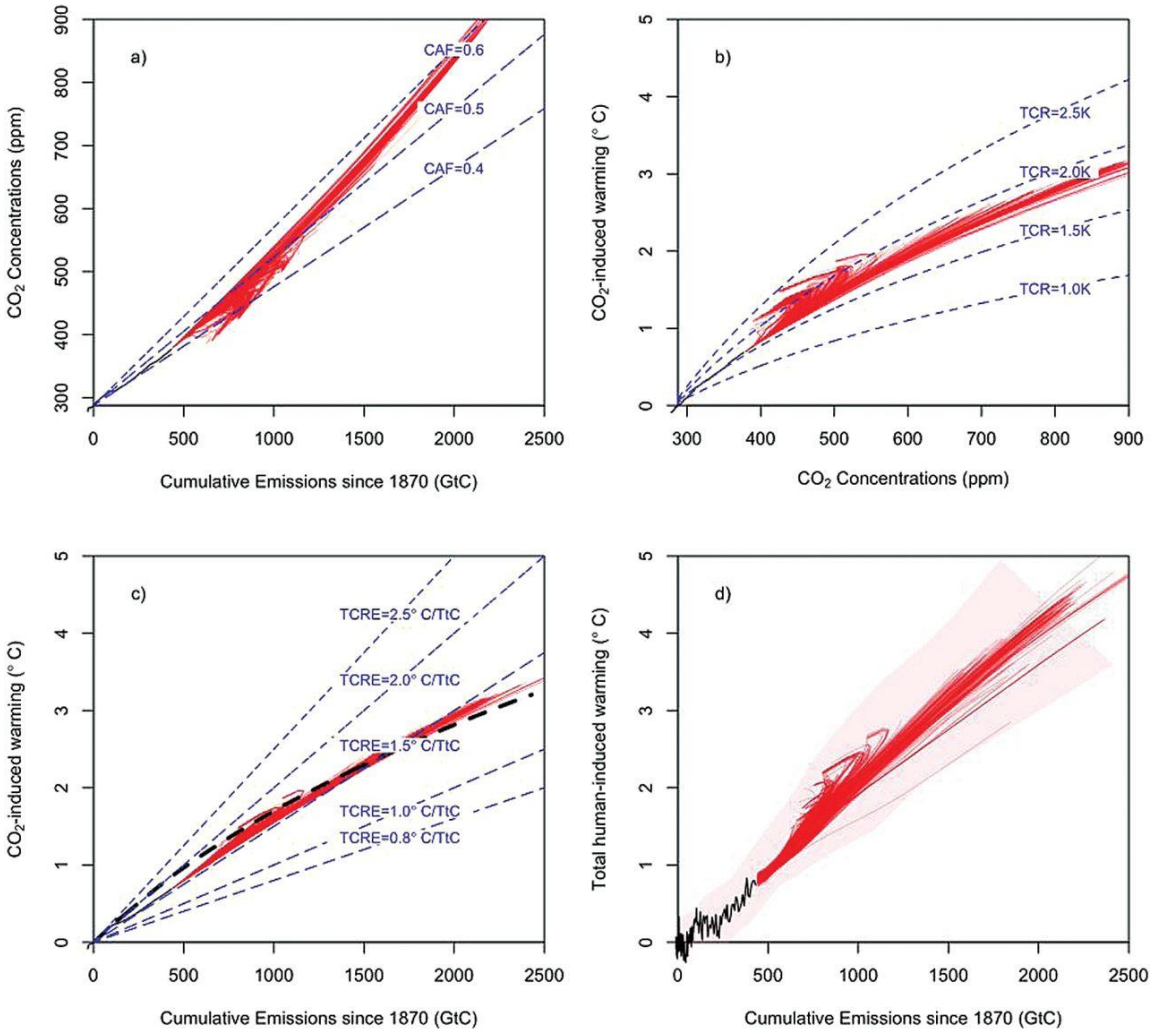
How CO_2 emissions affect concentrations and temperatures

- Stable concentrations mean some residual emissions and continued warming (solid lines).
- Net zero global emissions required to stop warming (dashed lines).
- "Airborne fraction" increases with warming, compensating for the logarithmic forcing-concentration relationship.



The climate response to a broad range of emissions scenarios, demonstrating the importance of the cumulative carbon budget.

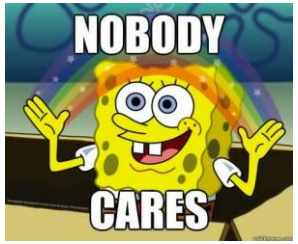


Richard Millar et al. Oxf Rev Econ Policy 2016;32:323-342

OXFORD REVIEW OF ECONOMIC POLICY

Now it's your turn

- Open OxfordSimpleIAM_2019_v0.xlsx
- Emissions->concentrations->forcing->temperature in a simple climate model (the one we saw last week, with a similar set of equations for emissions->concentrations)
- Shows RCP8.5 ("no-climate-policy") scenario
- Choose RCP3PD in the menu under EMS_SCEN
- Check emissions to forcing by ticking RCP DATA
- Check forcing to temperature by ticking CMIP5 scenario
- Note you'll need to increase ECS to match CMIP5



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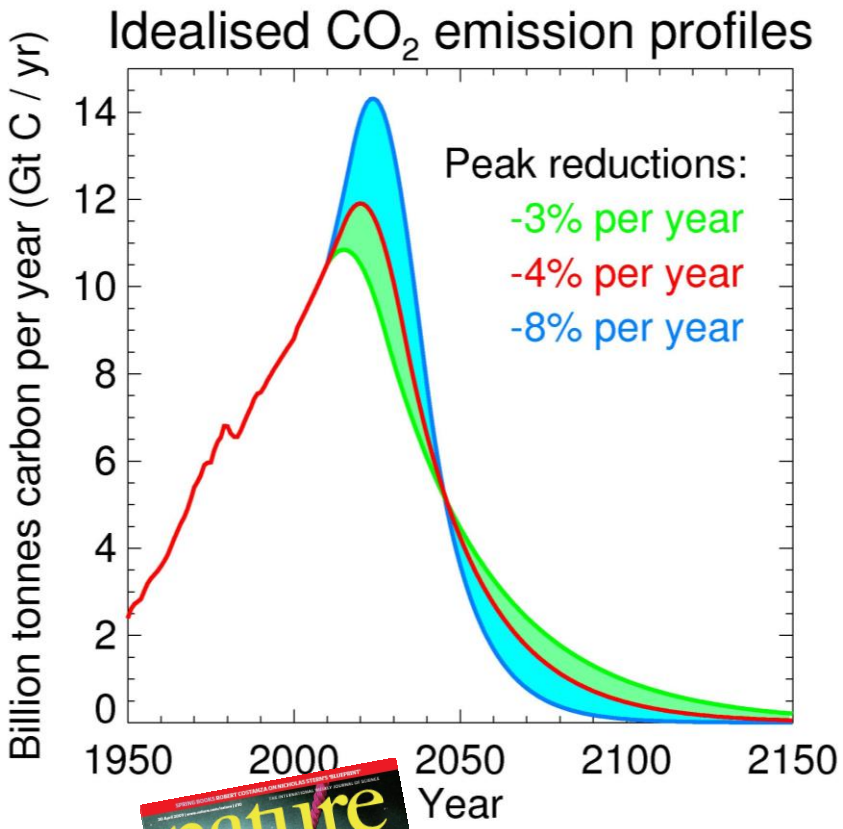
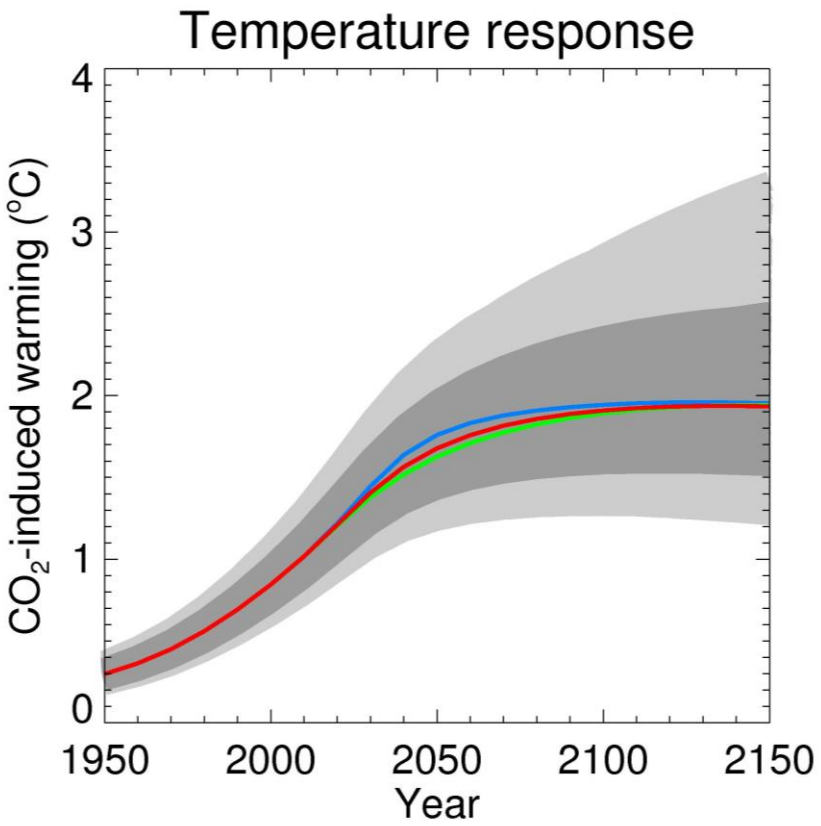
Cumulative emissions of carbon dioxide are the principal determinant of dangerous climate change





From Allen et al, *Nature*, 2009
& see also Meinshausen et al, *Nature*, 2009
& Solomon et al, *PNAS*, 2009

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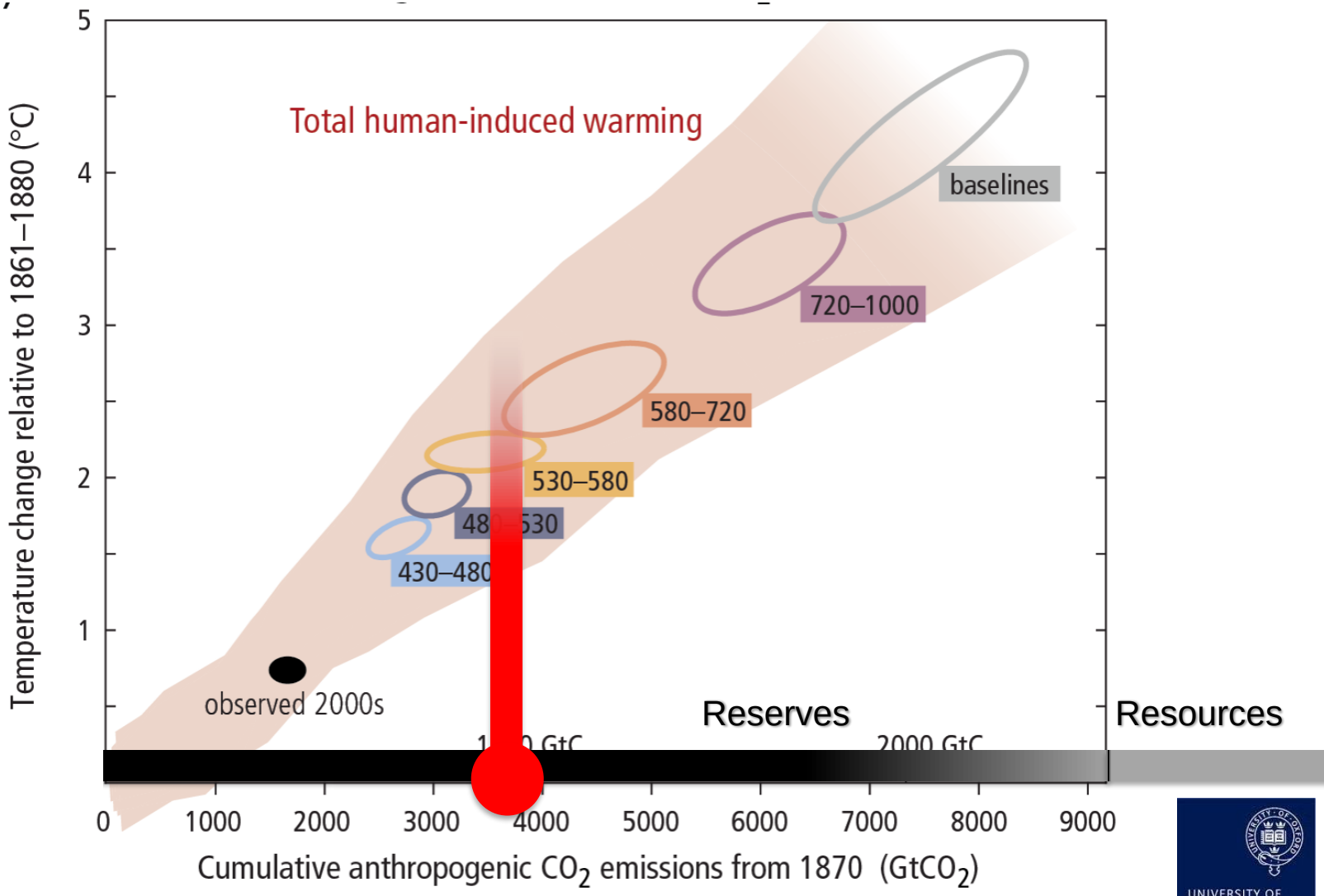
Why this matters



A remarkable achievement: the Paris Agreement

United Nations

Framework Convention on Climate Change

FCCC/CP/2015/L.9/Rev.1

Distr.: Limited
12 December 2015

Original: English

Article 2

This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

Article 4

In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

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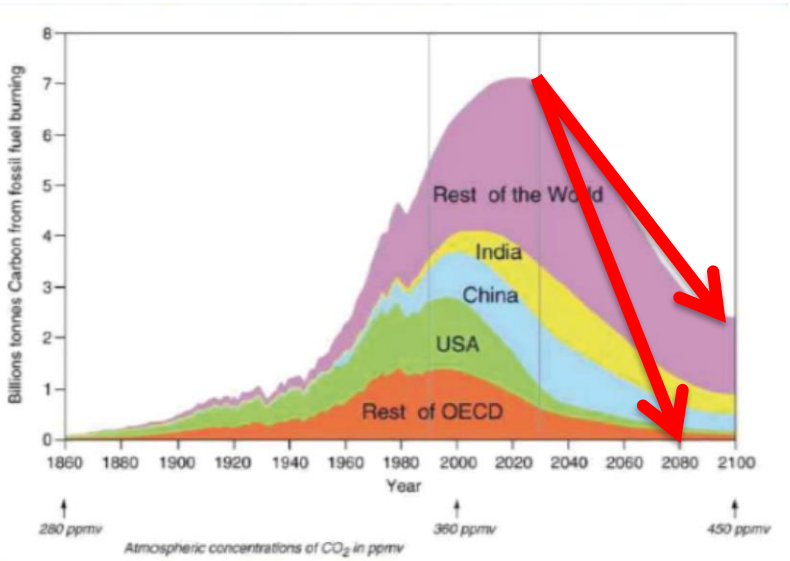
What they thought was needed to stop global warming, and what is actually needed

3 Solution – contraction and convergence

First advocated in 1990 by Aubrey Meyer



"Long-term convergence of per capita emissions is … the only equitable basis for a global compact on climate change"

Manmohan Singh, 30 June 2008

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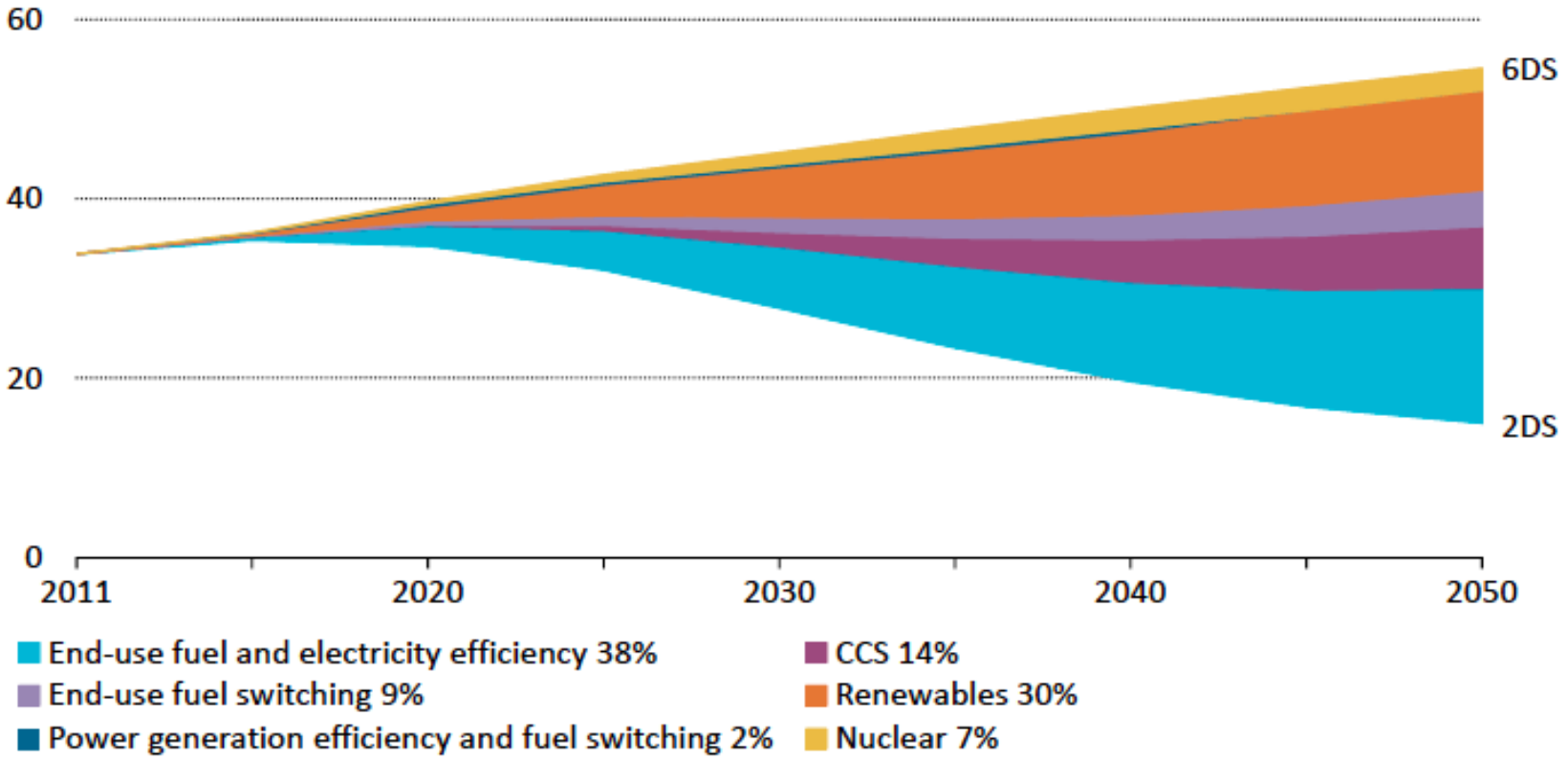
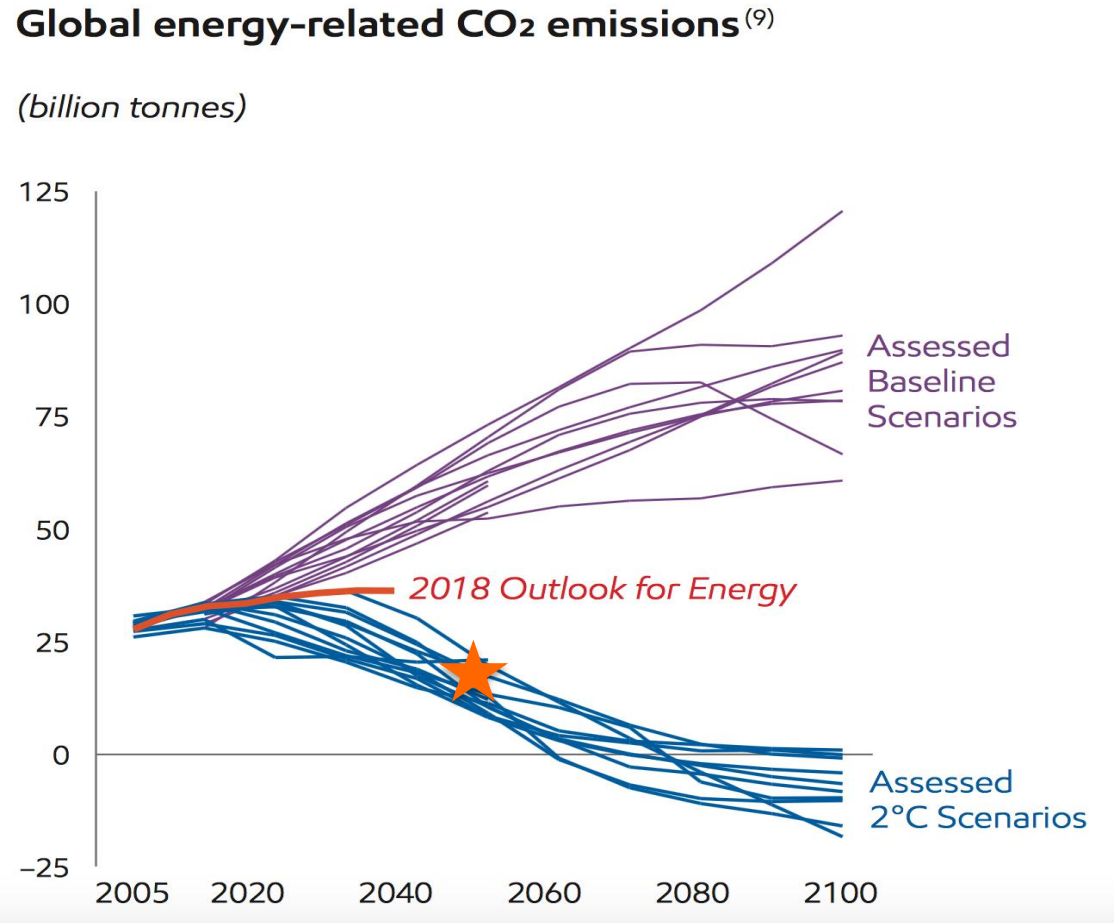
So 50% by 2050 is not enough



International Energy Agency “2DS” scenario

Short-termism matters: an excerpt from ExxonMobil "Energy and Carbon Summary", 2018



Short-termism matters: an excerpt from Alexandria Ocasio-Cortez's twitter feed

What this means for mitigation policy

- We need to limit cumulative emissions of CO_2.
- Total emissions of one trillion tonnes carbon (1 TtC) implies a likely range of warming of 0.8-2.5°C ("Transient Climate Response to Emissions", TCRE).
- Postponing emissions peak to 20xx does not "commit us to 2°C", it commits us to potentially unfeasible rates of emission reductions after 20xx if we are still to keep temperatures well below 2°C.
- "Sustainable" emissions after temperatures peak are indistinguishable from zero.
- What about 1.5° C?

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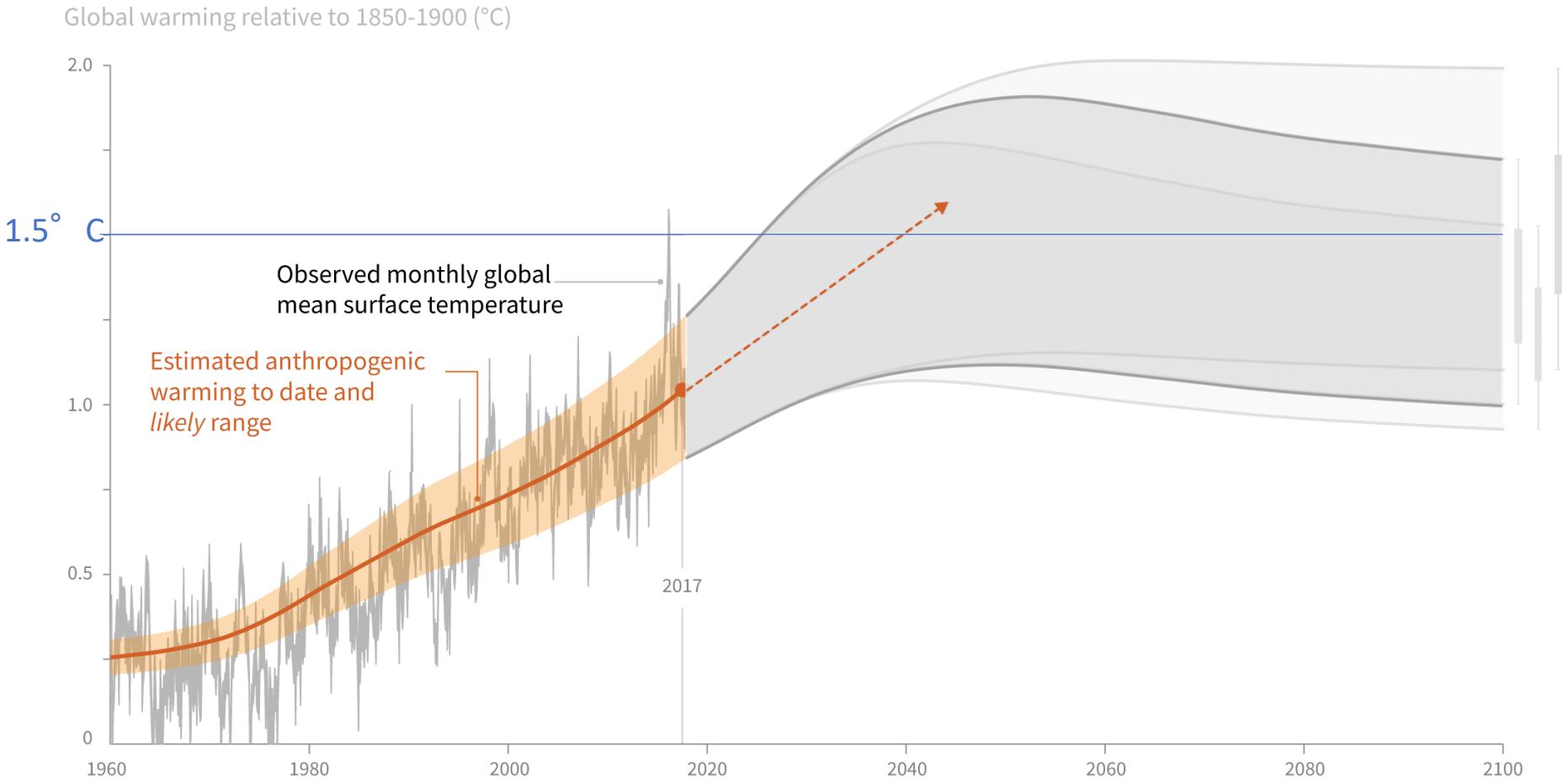
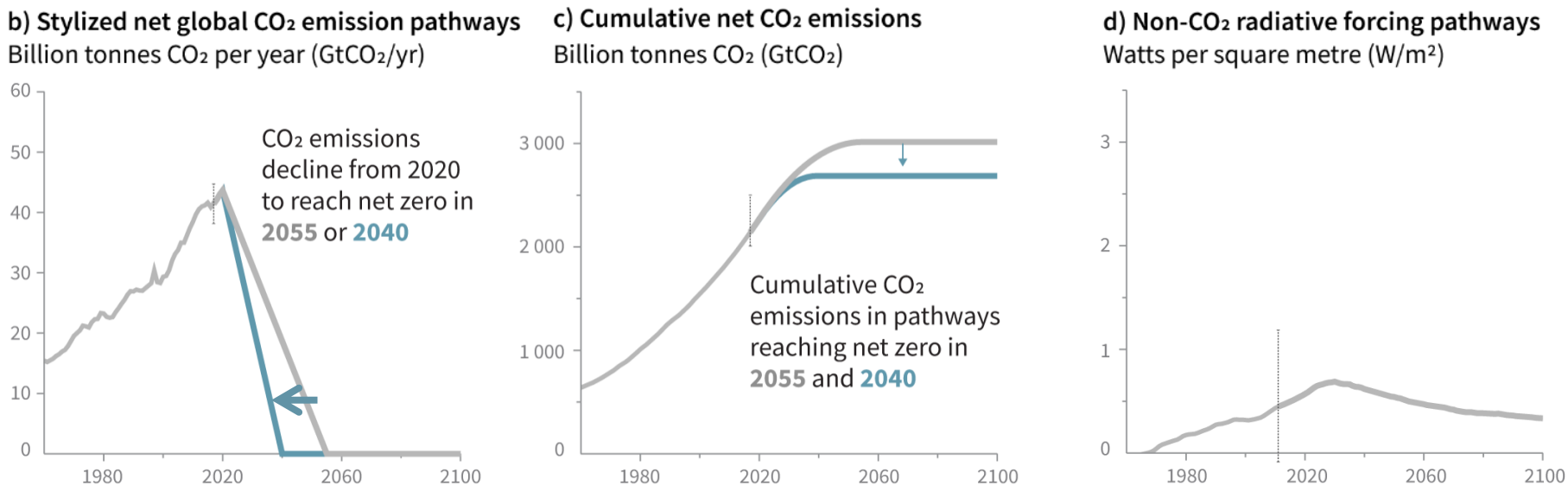
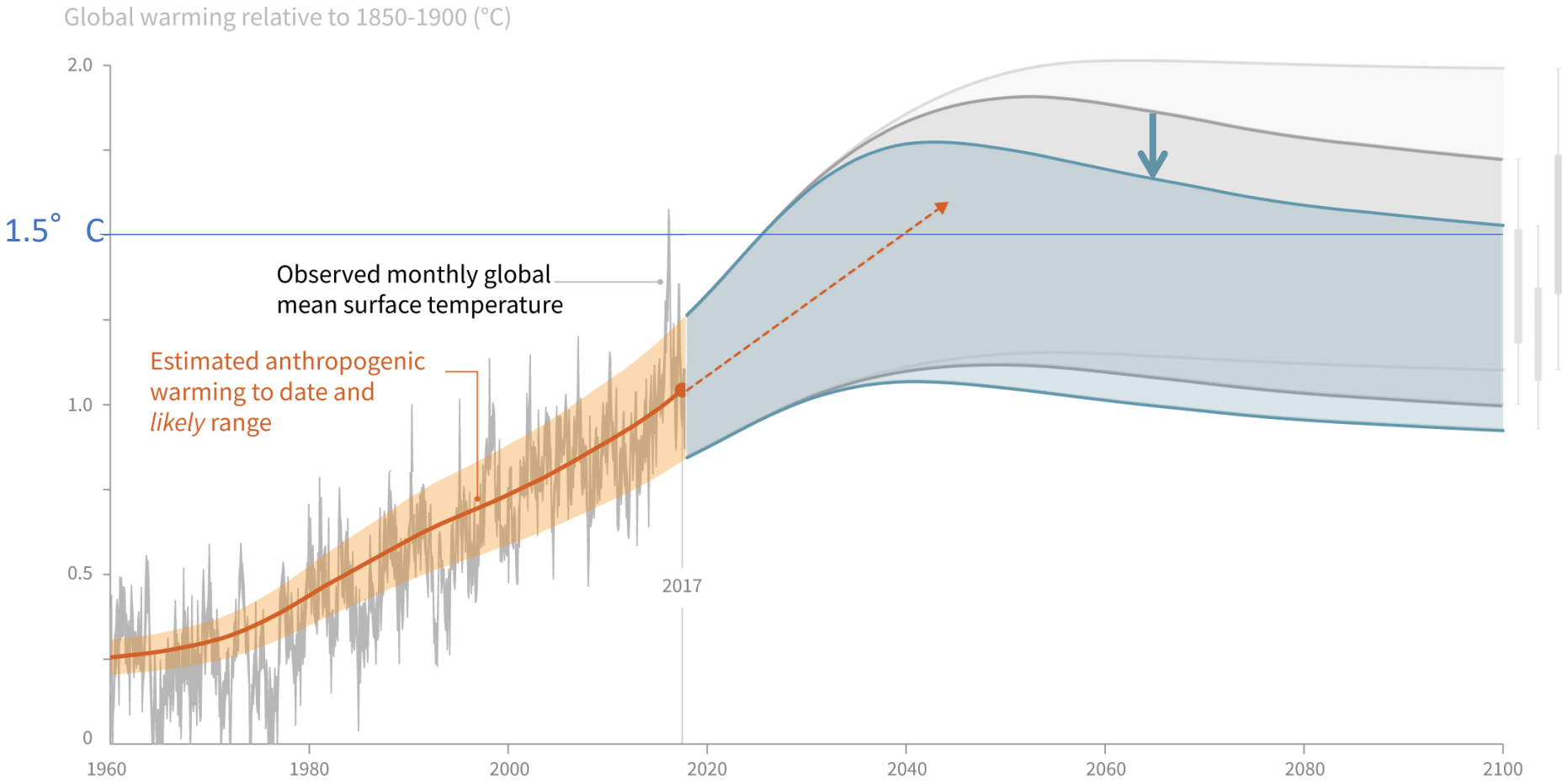
Warming response to stylized emissions pathway reaching net zero CO_2 emissions in 2055



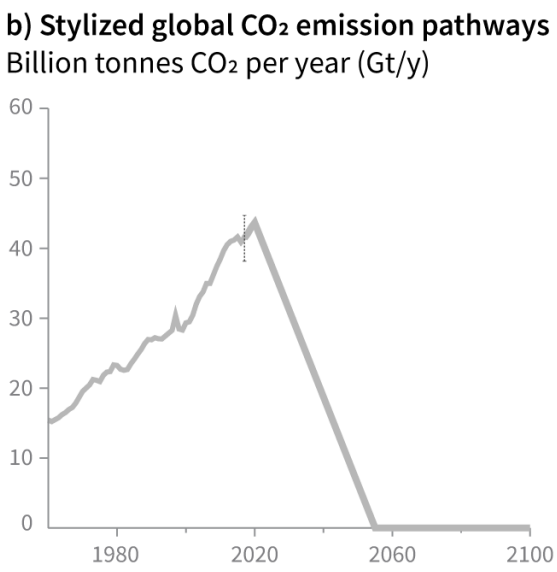
Faster immediate CO_2 reductions reaching net zero in 2040 reduce total cumulative CO_2 emissions

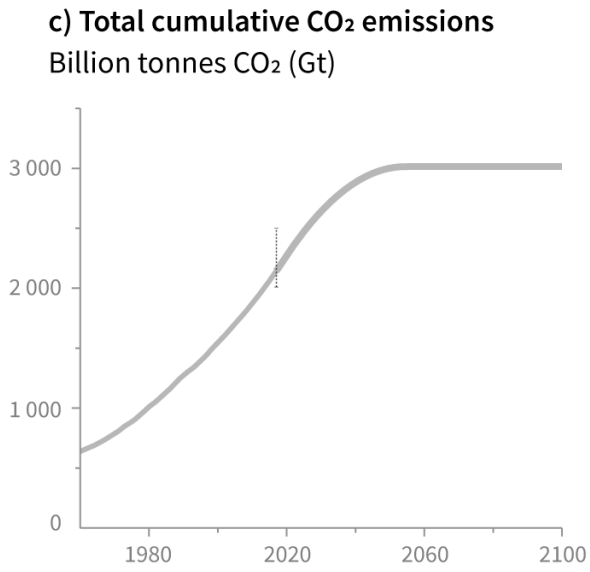


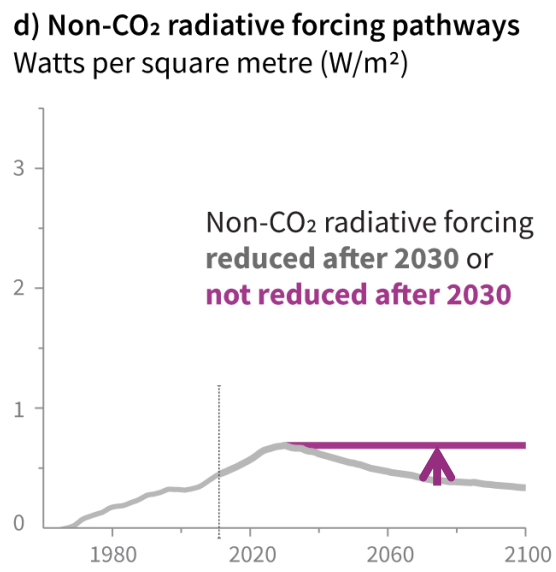
Faster immediate CO_2 reductions reaching net zero in 2040 result in a higher probability of limiting warming to 1.5°C



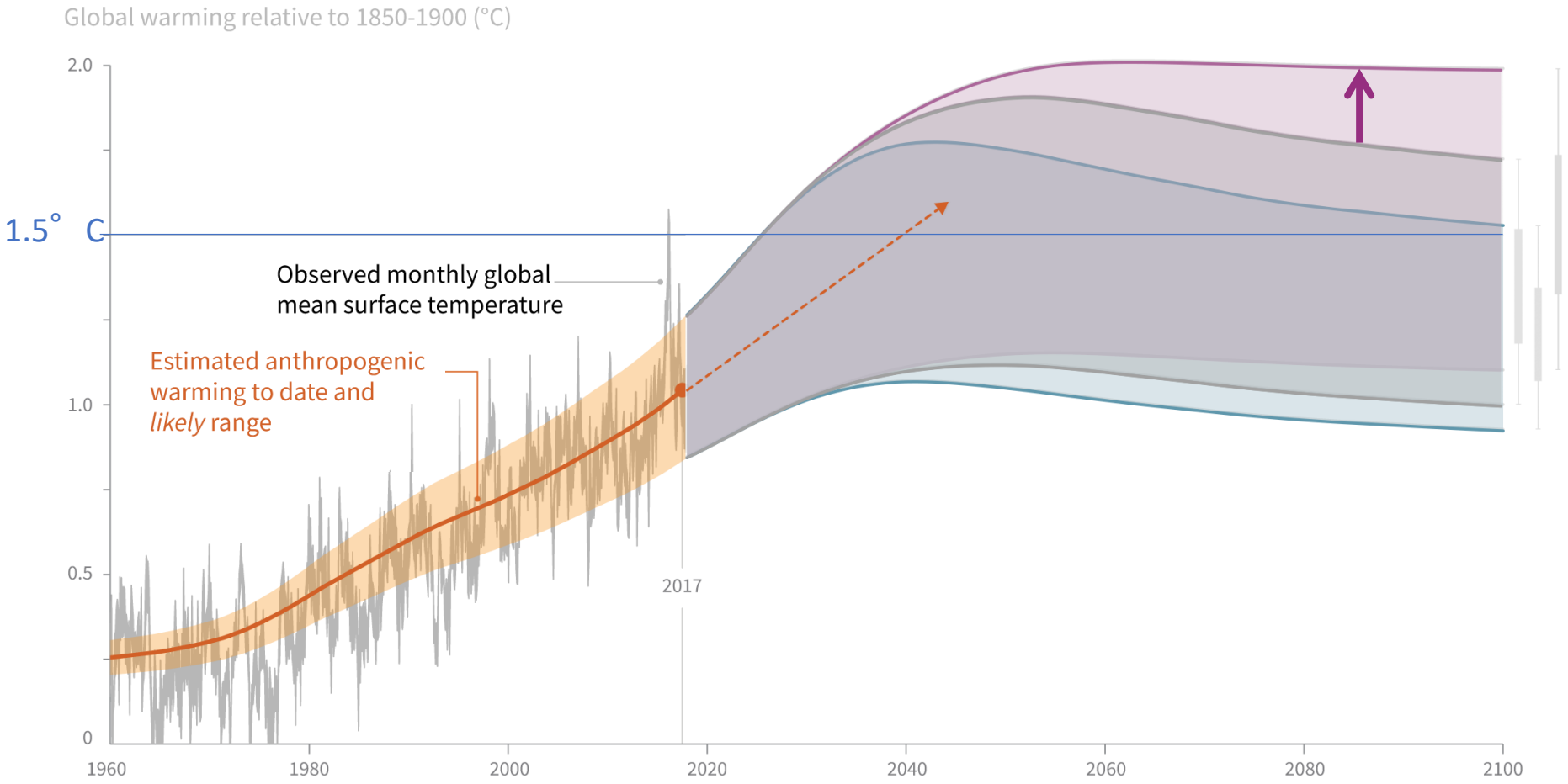
Future temperatures are also affected by radiative forcing due to methane, aerosols, nitrous oxide and other forcing agents







No reduction of non-CO_2 radiative forcing after 2030 results in a lower probability of limiting warming to 1.5°C



Impact of non-CO_2 anthropogenic warming

- At present, non-CO_2 greenhouse warming and sulphate cooling approximately cancel, but no longer do so in the future under most scenarios.
- Avoiding 2°C/1.5° C CO_2-induced warming is necessary, but not sufficient, condition for avoiding 2°C/1.5° C total warming.
- So how do we set about reducing emissions of other (mostly shorter-lived) climate forcing agents?
- And how do we prioritize these against CO_2?

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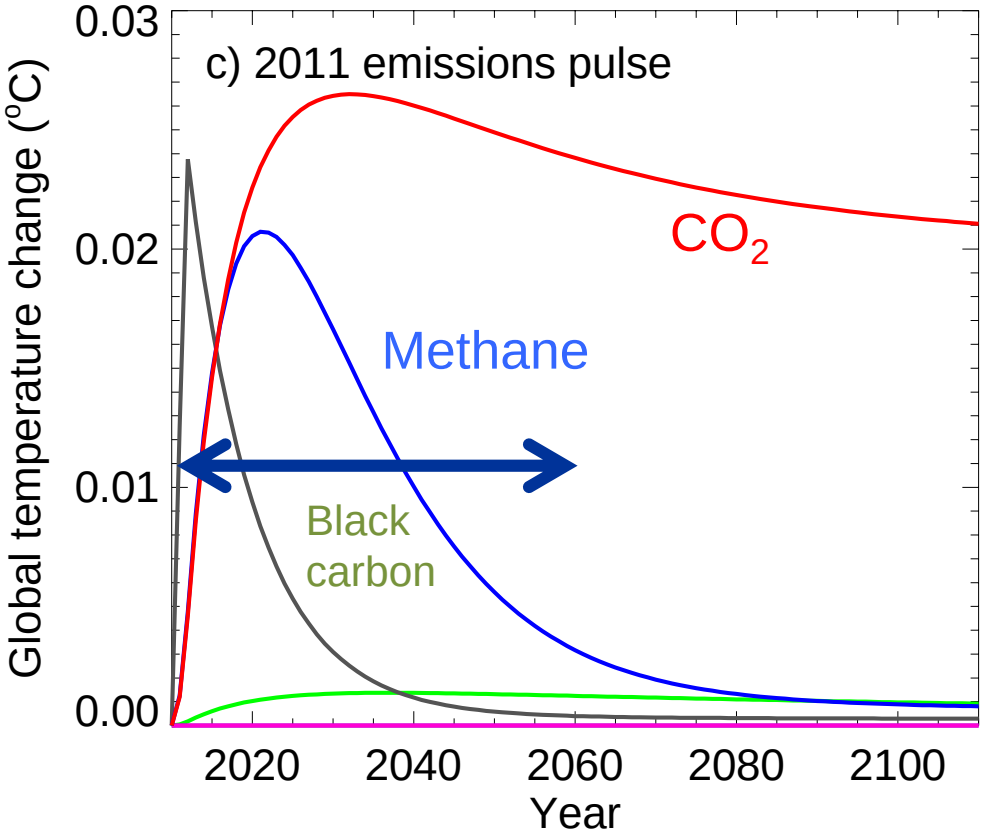
Is this true? Or helpful?

“All current greenhouse gas emissions [...] affect the rate and magnitude of climate change over the next few decades” AR5-SyR

Impact of 2011 emissions of different agents on future temperatures:

Current emissions of short-lived climate pollutants (methane and soot) mostly affect climate to mid-century



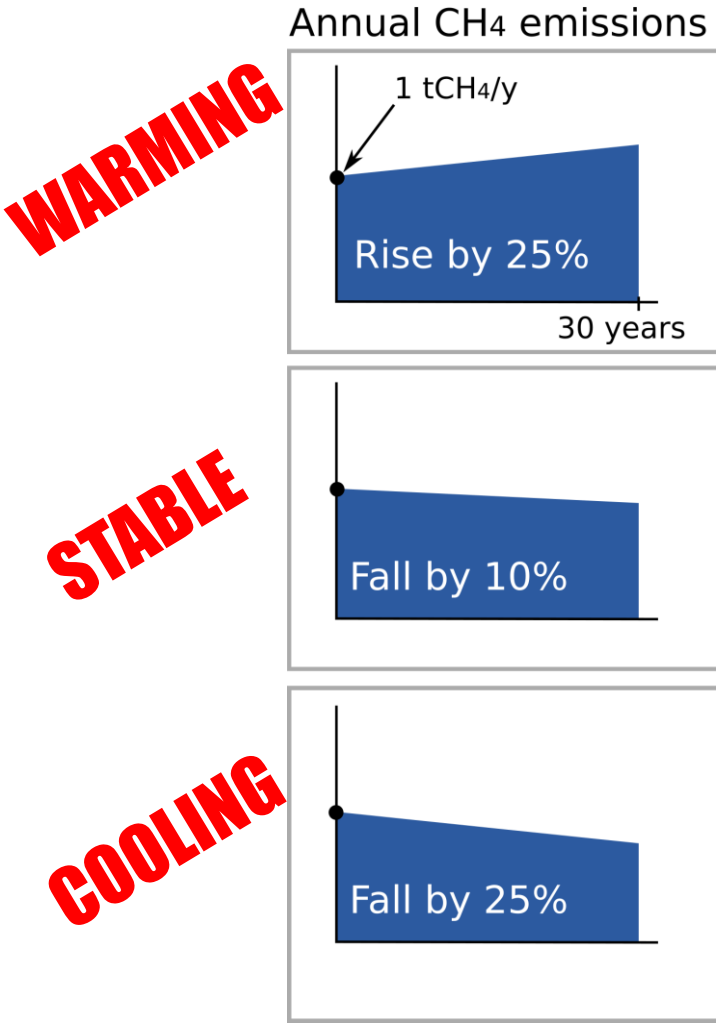
Your turn again

- On the spreadsheet OxfordSimpleIAM_2019_0.xlsx
  - Untick HadCRUT4 observations, RCP and CMIP5 data
  - Select Pulse_CO2 in the EMS_SCEN drop-down
  - Now try Pulse_CH4 and Pulse_N2O – how do they differ?
- Homework exercises:
  - Explore Step_CO2, Step_CH4 and Step_N2O
  - Try varying ECS and TCR (default setting of TCR preserves the ratio with ECS, but you can over-write it). Which aspects of the response to these various emissions scenarios do they affect?

Comparing emissions without a climate model: climate metrics

- Global Warming Potential (GWP): integrated radiative forcing perturbation over a specified time-horizon caused by a 1-tonne emission of gas, relative to a tonne of CO_2.
- Global Temperature Potential (GTP): temperature perturbation at the end of a specified timescale resulting from a 1-tonne emission of gas, relative to a tonne of CO_2.
- Revised Global Warming Potential (GWP*): for short-lived pollutants only, radiative forcing perturbation caused by a 1-tonne per year increase in *rate* of emission of gas, relative to integrated radiative forcing caused by a one-off 1-tonne emission of CO_2.

"Equivalent" emissions of CO_2 and methane have very different impacts on temperature



From Climate metrics for ruminant livestock, Oxford Martin Programme on Climate Pollutants briefing: https://www.oxfordmartin.ox.ac.uk/publications/view/2714

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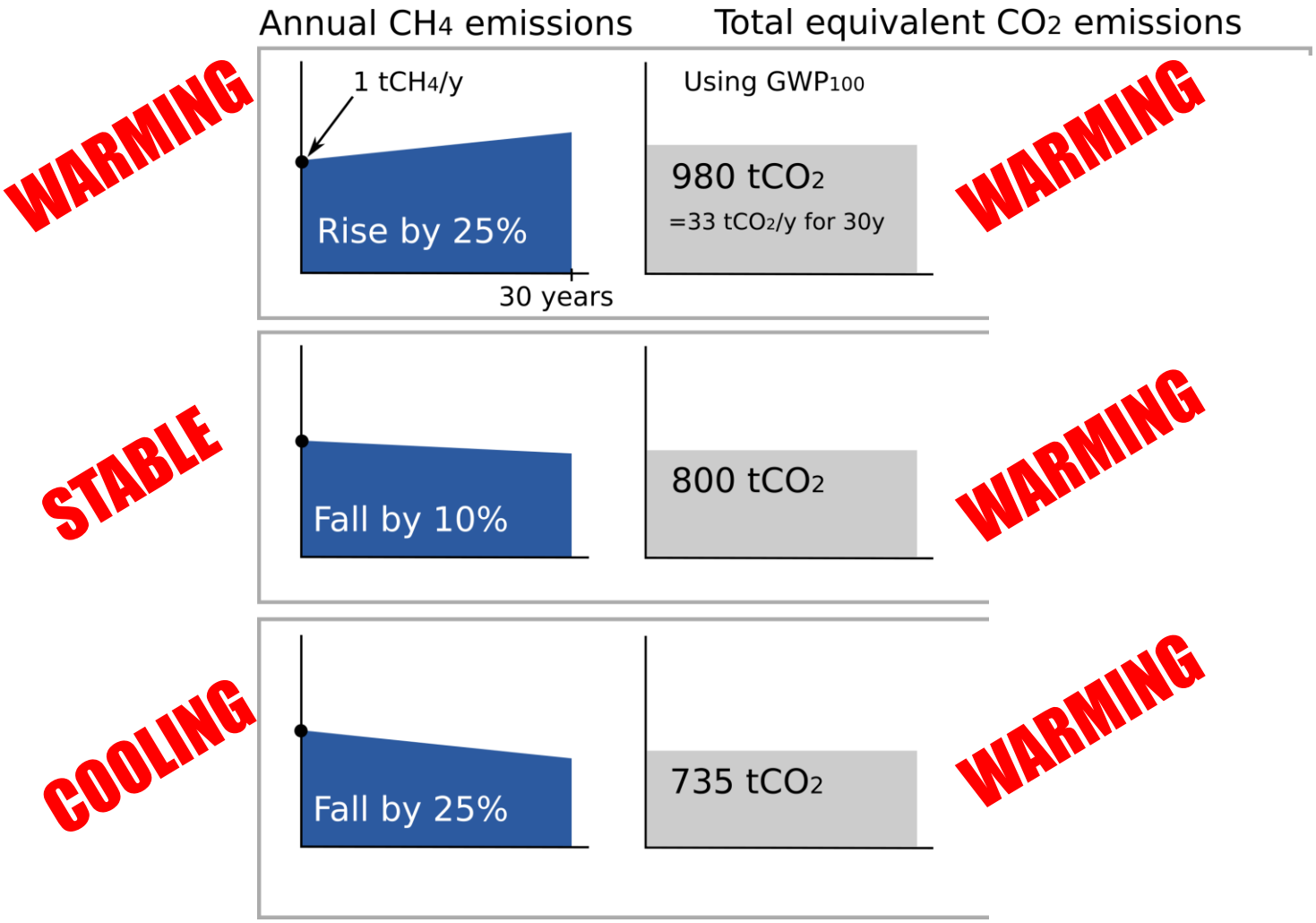

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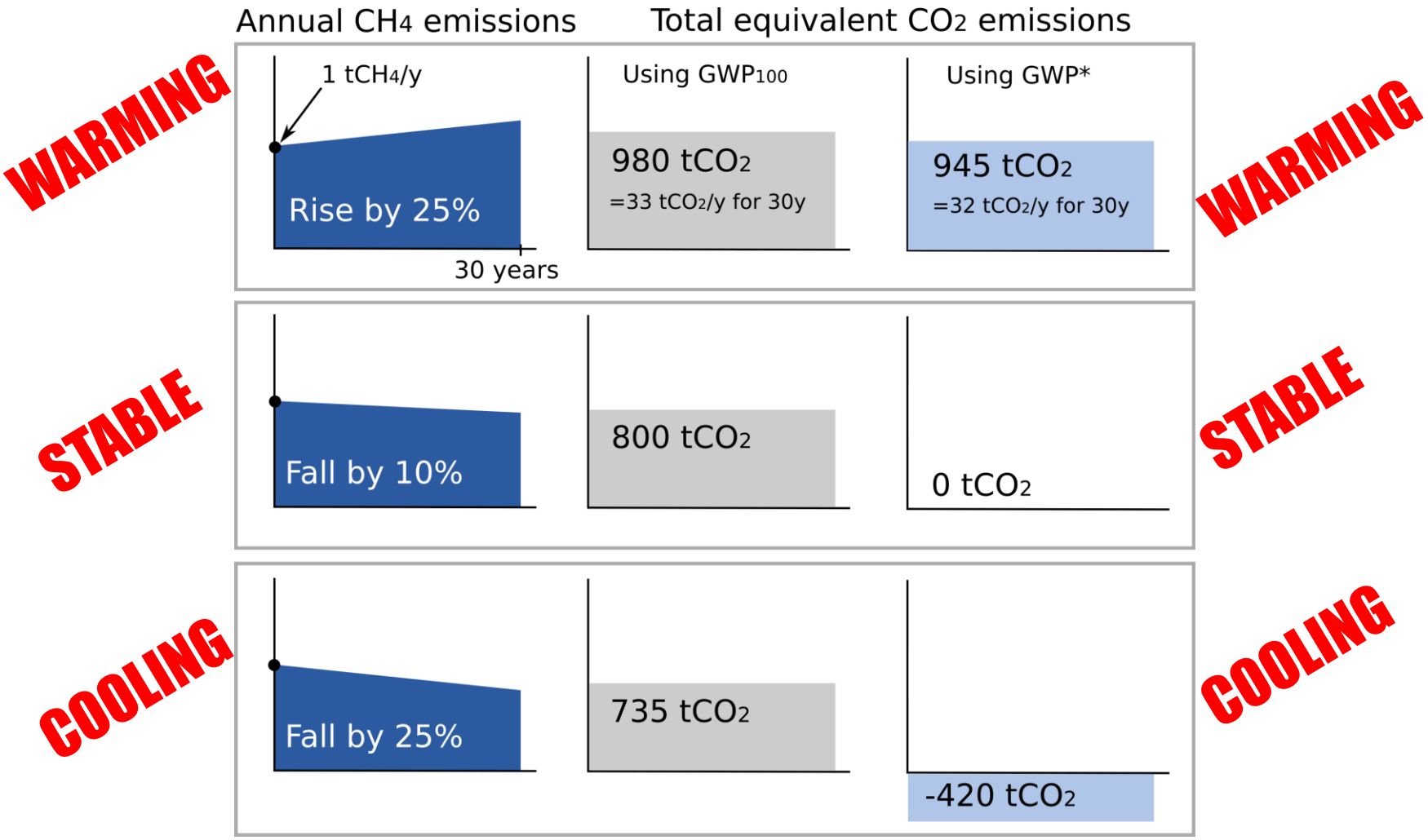
Equivalence of CH_4 and CO_2 – revisited



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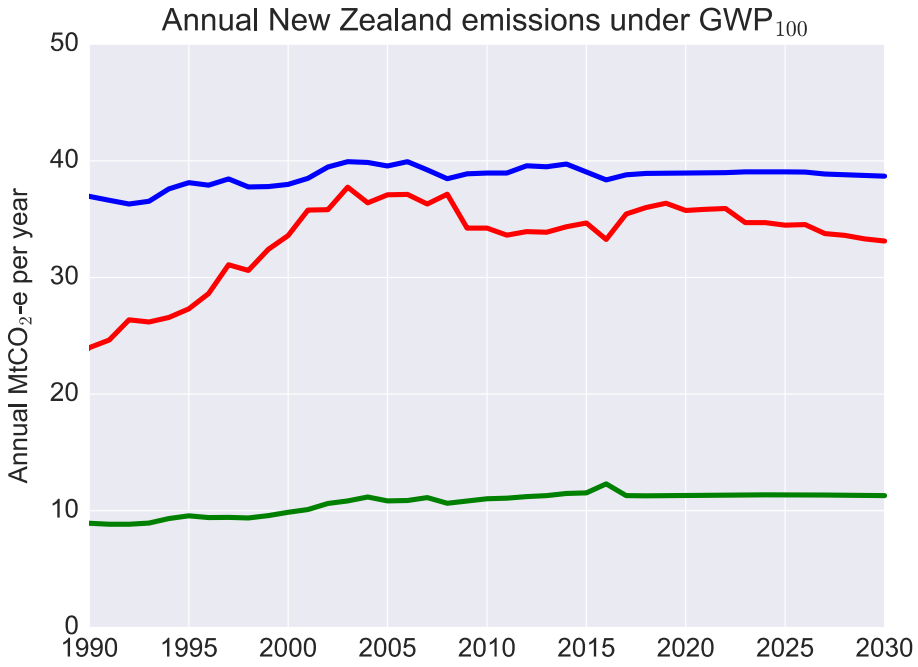
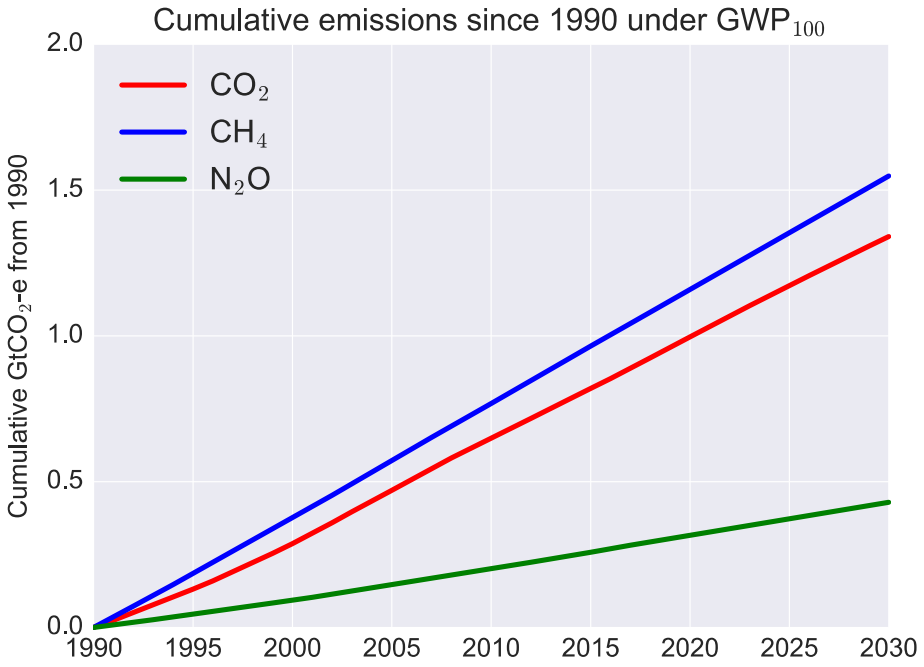
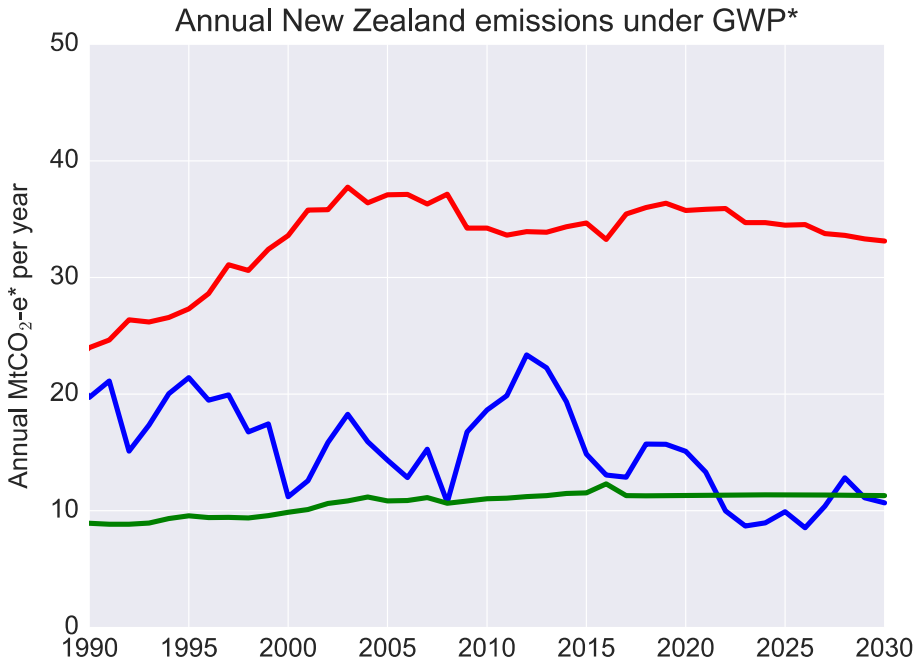
New Zealand emissions under GWP_{100}: annual rates and cumulative emissions since 1990

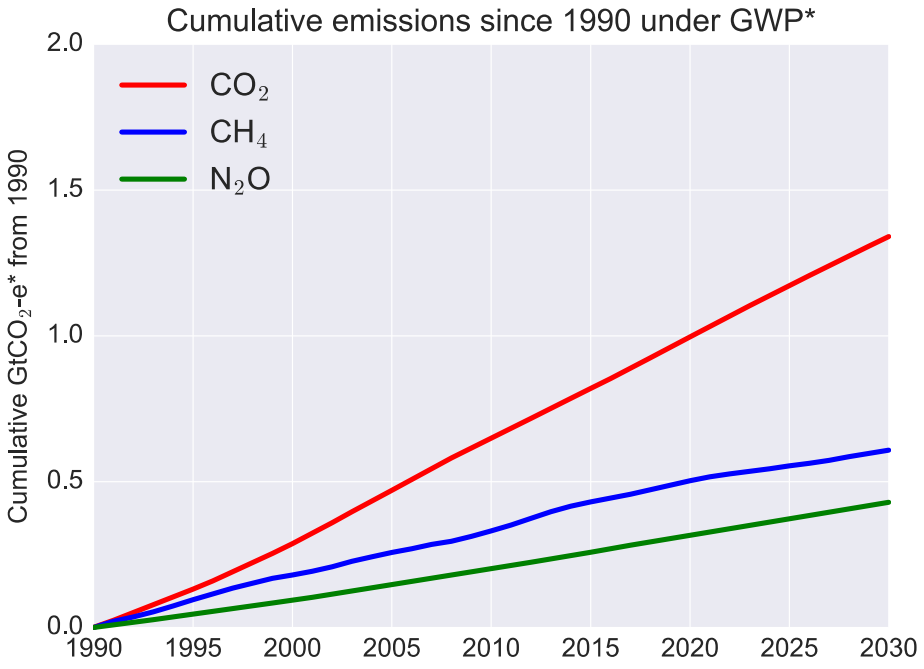




Nominal methane emissions under GWP_{100} are higher than CO_2 emissions

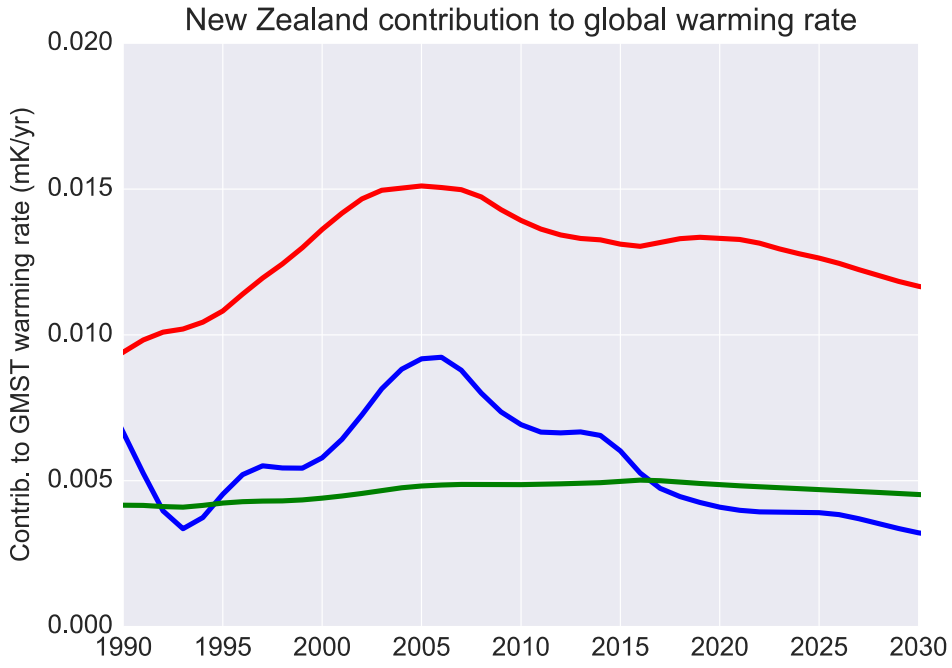
New Zealand emissions under GWP*: annual rates and cumulative emissions since 1990

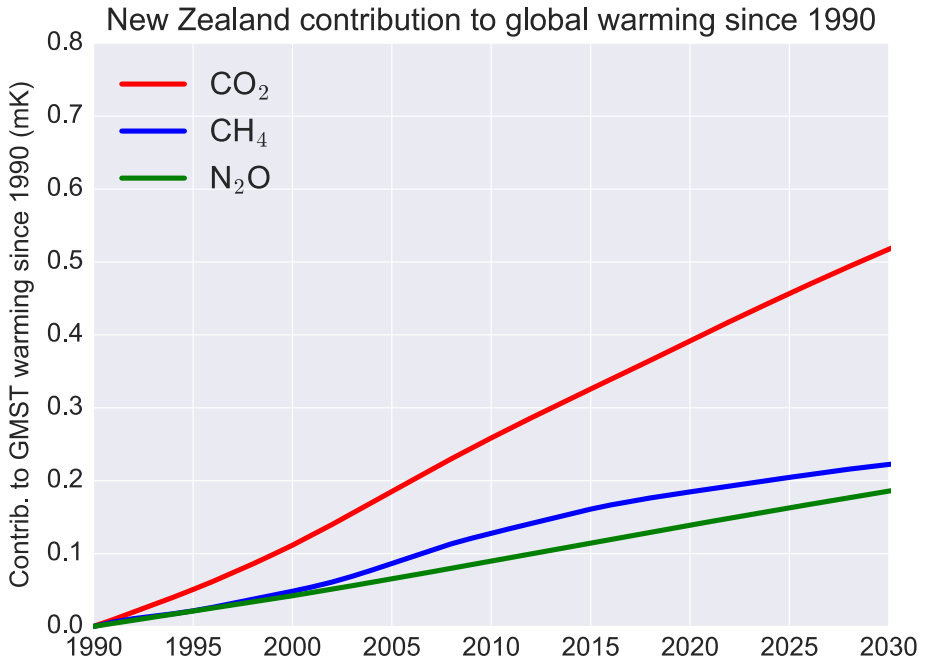




Methane emissions under GWP* are less than half CO_2 emissions

New Zealand's contributions to global warming since 1990 from different greenhouse gases





Methane emissions under GWP* more accurately reflect contributions to global temperature increase

Equivalent drivers of climate change: both caused warming in the past, but are no longer doing so

A closed power station

A gently declining (10% over 30 years) herd of cattle

Why short-termism matters

- It lets Exxon-Mobil say they fully support the Paris Agreement out to 2035 or so...
- It lets environmentalists claim we can solve climate change by adopting a plant-based diet
  - Methane reductions could compensate for CO_2-induced warming for a decade or maybe two, but then what?
- Conventional accounting rules used by UNFCCC:
  - Undervalue the short-term impact of methane reductions, and overvalue their long-term impact.
  - Would equate net-zero global emissions with a global cooling trend (consistent with Paris Agreement?).
  - Are demonstrably unfair on livestock farmers.

Beware the Faustian bargain