

# Short-lived promises and cumulative risks: setting climate priorities

MYLES ALLEN Environmental Change Institute, School of  
Geography and the Environment & Department of Physics  
University of Oxford

## 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

## The only equation you need for climate policy

Warming over a multi-decade period  $t_0$  to  $t_1$  is proportional to cumulative CO<sub>2</sub>-forcing-equivalent emissions (CO<sub>2</sub> emissions that give same radiative forcing as total emissions) over that period.

$$\Delta T = \text{TCRE} \times \sum_{t_0}^{t_1} E_{\text{CO}_2\text{-fe}}$$

TCRE = “Transient Climate Response to Emissions”

≈ 0.4°C per TtCO<sub>2</sub> (0.23-0.68°C IPCC AR5 “likely” range)

1 TtCO<sub>2</sub> = 1000 GtCO<sub>2</sub> = 1 trillion tonnes CO<sub>2</sub>

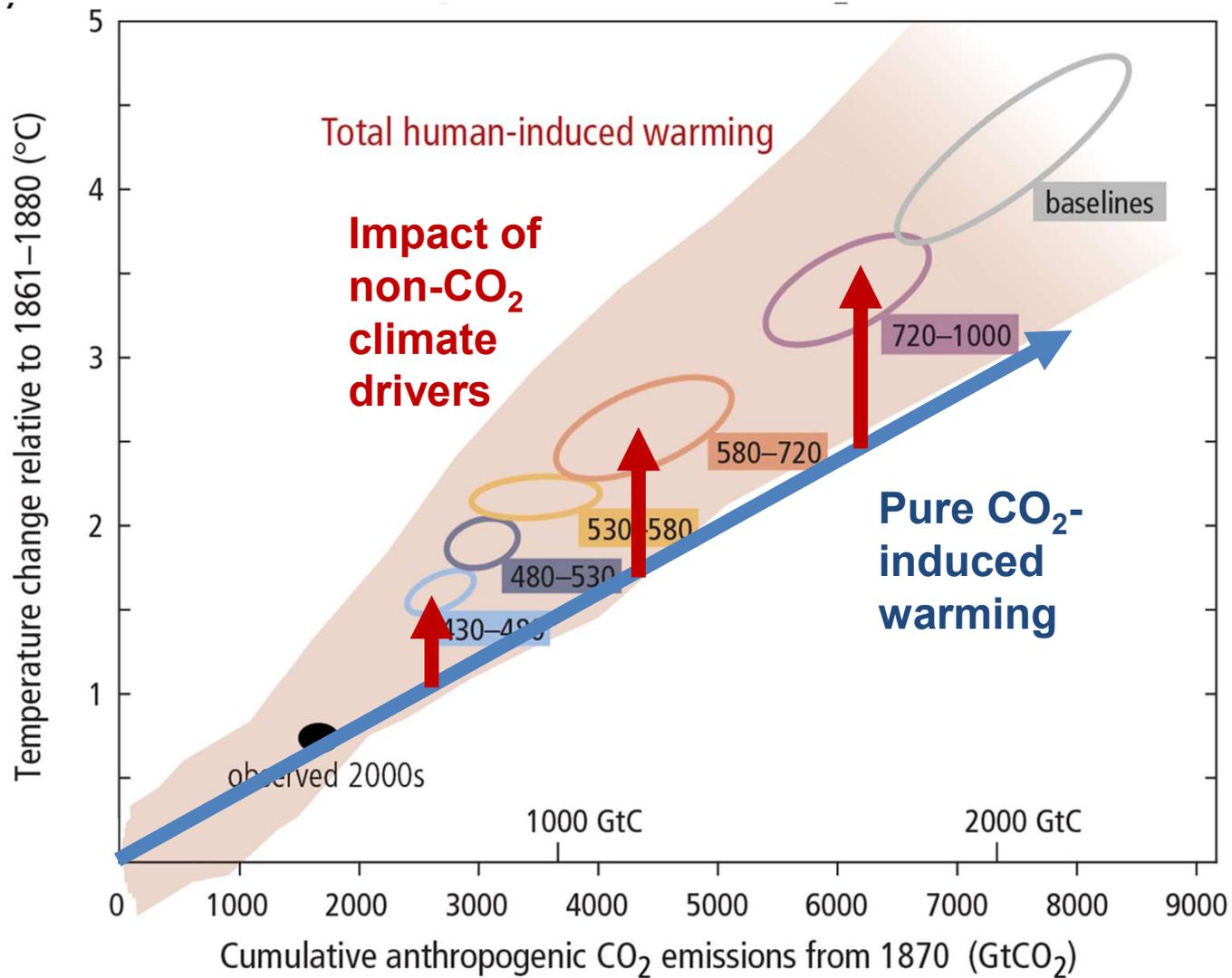
= 270 billion tonnes of carbon (GtC)

= 3000 billion barrels of oil

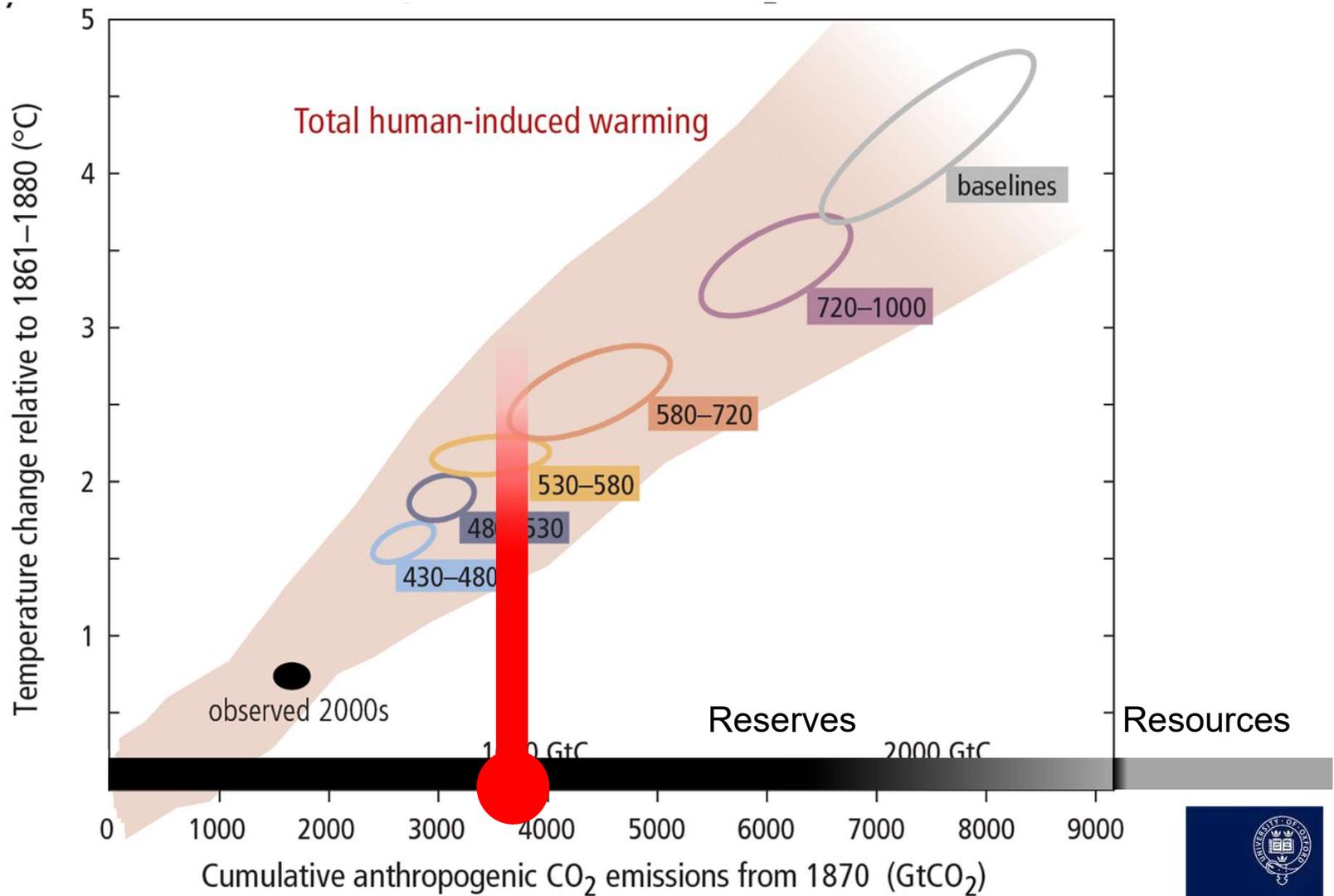
= 24 years of current CO<sub>2</sub> emissions

= <10% of global fossil fuel reserves

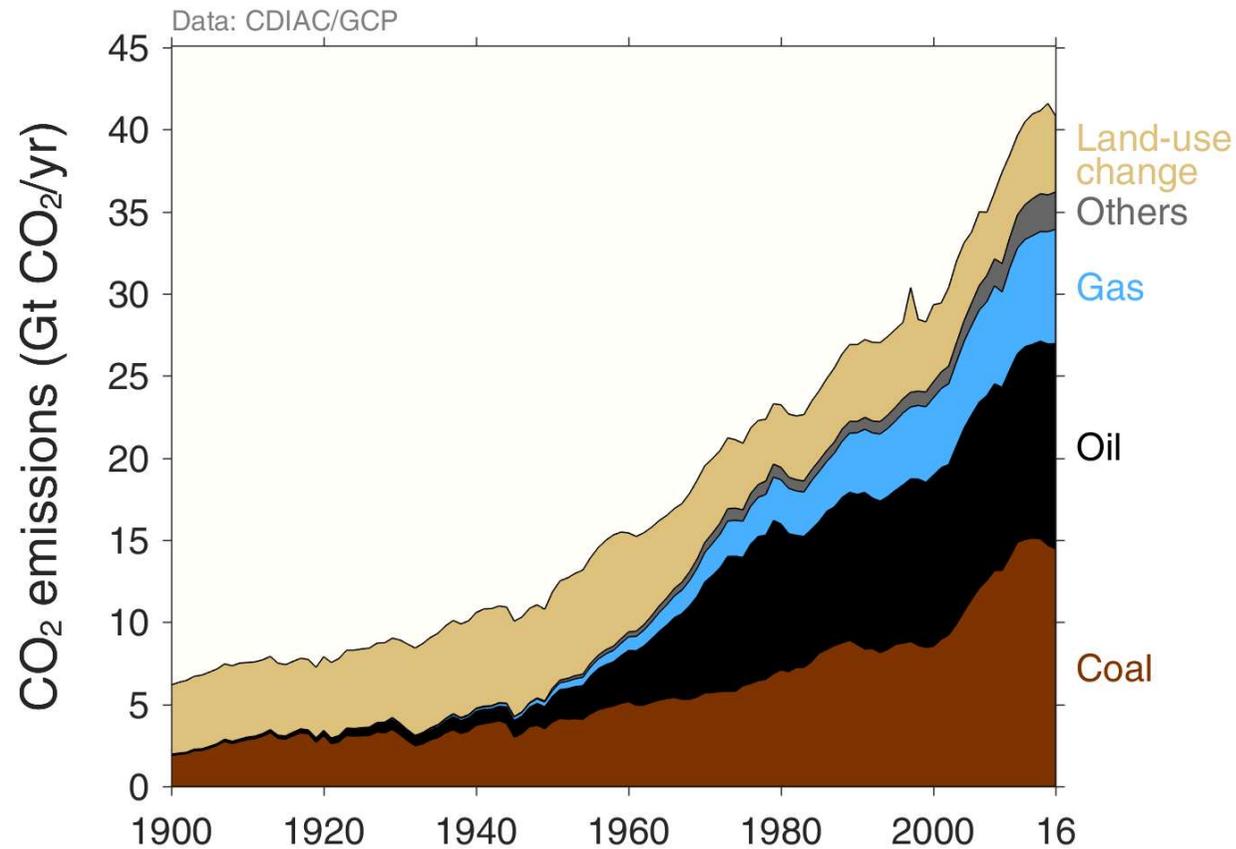
# Why this equation matters



# Why this equation matters

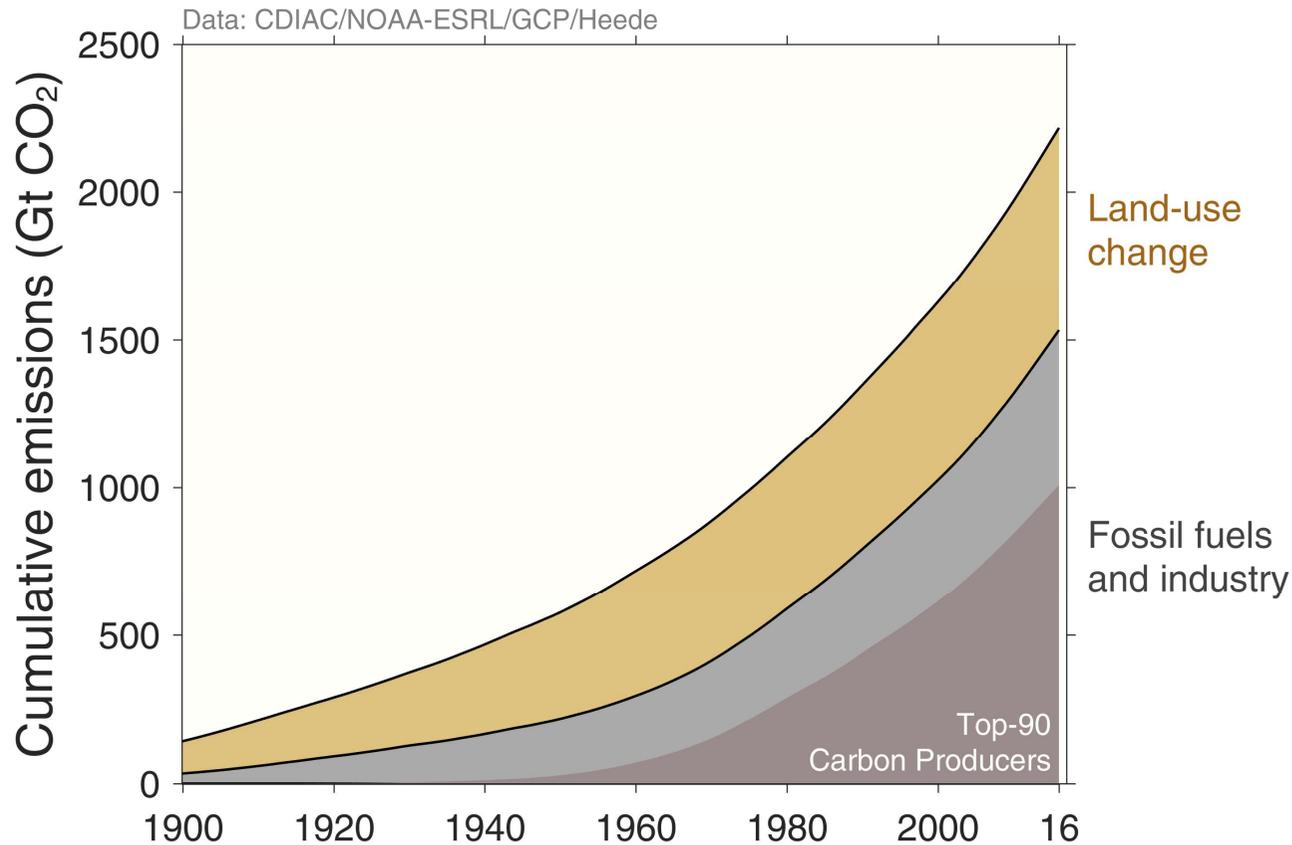


# Where is this carbon dioxide coming from? Annual CO<sub>2</sub> emissions since 1900



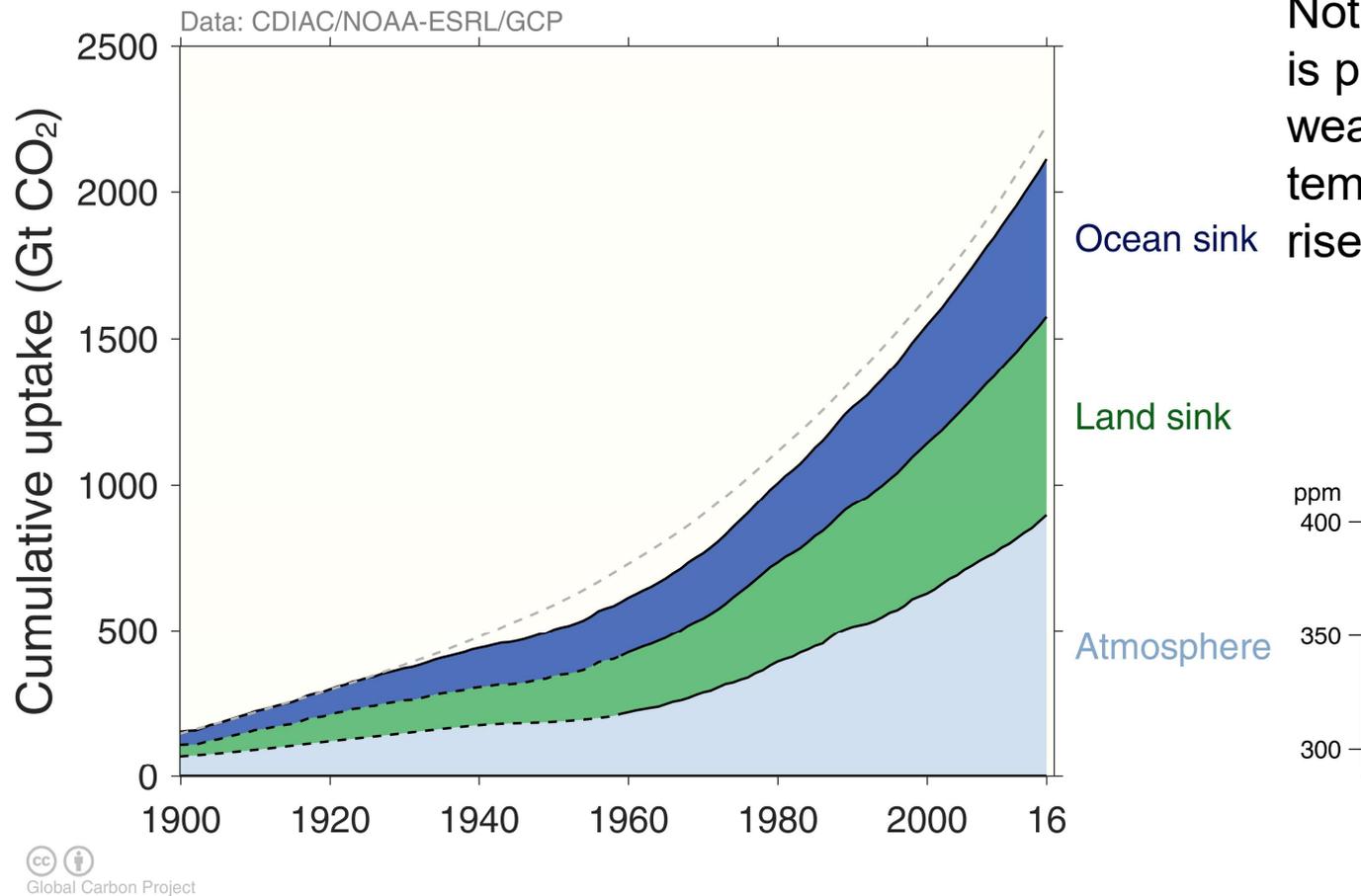
Global Carbon Project

# Where is this carbon dioxide coming from? Cumulative CO<sub>2</sub> emissions added up over time



CC BY  
Global Carbon Project

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



Note land sink is predicted to weaken as temperatures rise

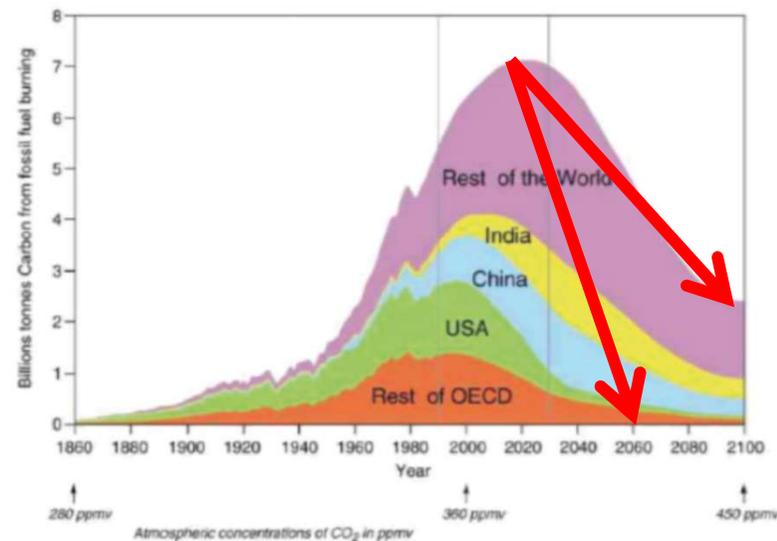
## A seductive argument

- About half the CO<sub>2</sub> we release into the atmosphere is taken up every year by the oceans and land biosphere.
- So if we halve emissions, atmospheric concentrations will stop rising, right?
- Sadly, wrong.
- Oceans and land “carbon pools” are filling up, just like the atmosphere.
- So if we halve emissions, concentrations keep rising, just half as fast as before.

# So what we 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

# 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

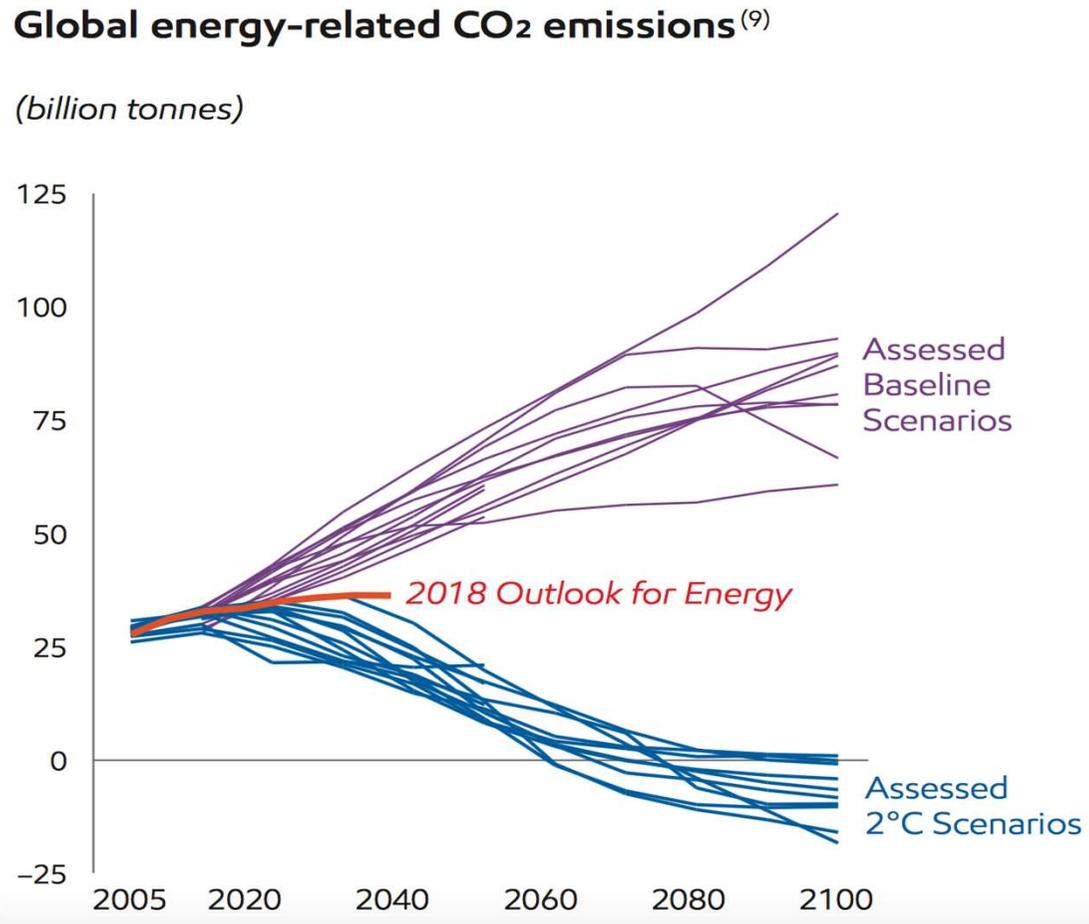
This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

- (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.

# Short-termism 1: an excerpt from ExxonMobil's "Energy and Carbon Summary", 2018



# Short-termism 2: an excerpt from Alexandria Ocasio-Cortez's twitter feed



Alexandria Ocasio-Cortez

@AOC

Follow



For some reason GOP seems to think this is a gaffe, but it's actually a generational difference.

Young people understand that climate change is an existential threat: 3,000 Americans died in Hurricane María.

The UN says we've got 12 years left to fix it:  
[amp.theguardian.com/environment/20...](https://amp.theguardian.com/environment/20...)



Tom Elliott @tomselliott

.@AOC on millennials and social media: "We're, like, the world is going to end in 12 years if we don't address climate change"

Show this thread

6:43 AM - 22 Jan 2019

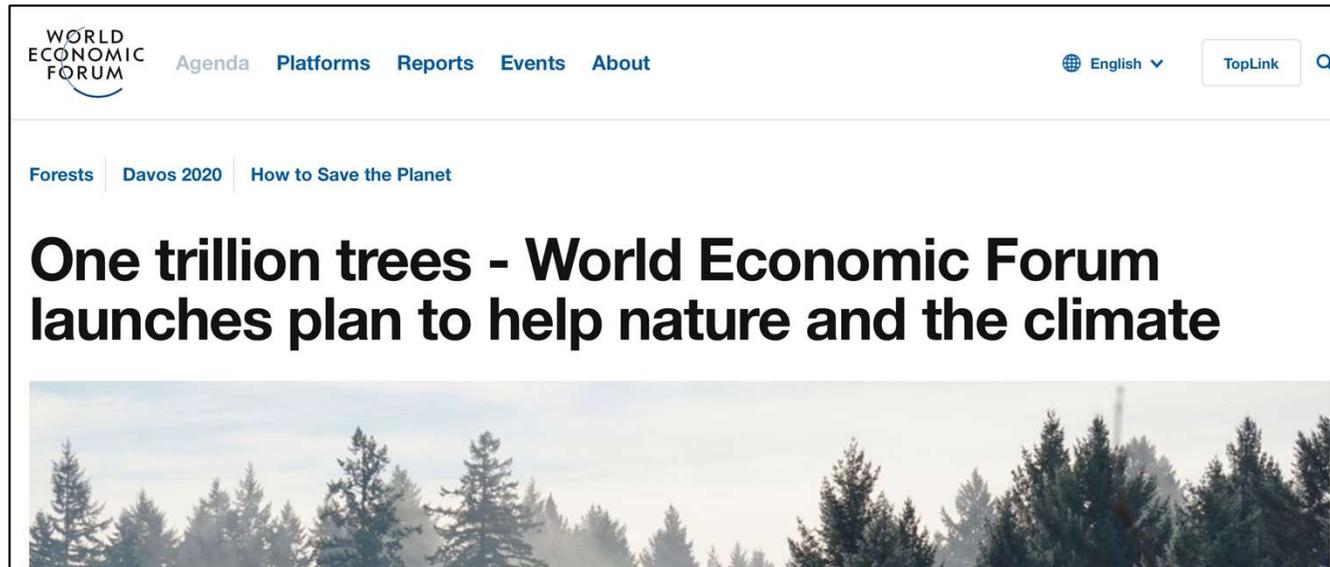
7,323 Retweets 33,166 Likes



## What they should have said:

- Alexandria OC: “Every decade’s delay in starting emission reductions either ratchets up global temperatures by another 0.2°C – or commits our kids to another \$80 trillion to clean it up.”
  - next week’s lecture.
- Darren Woods: “I’m sorry, I haven’t a clue.”

# Nature-based Climate Solutions?

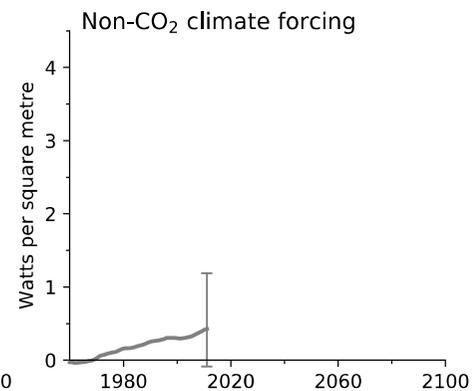
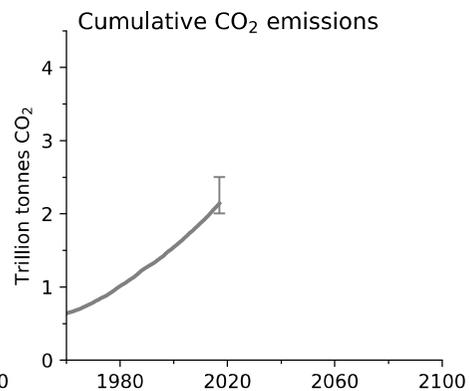
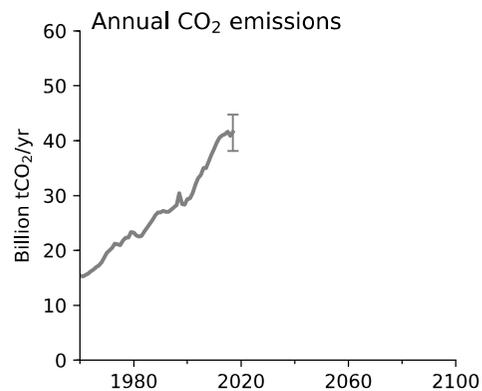
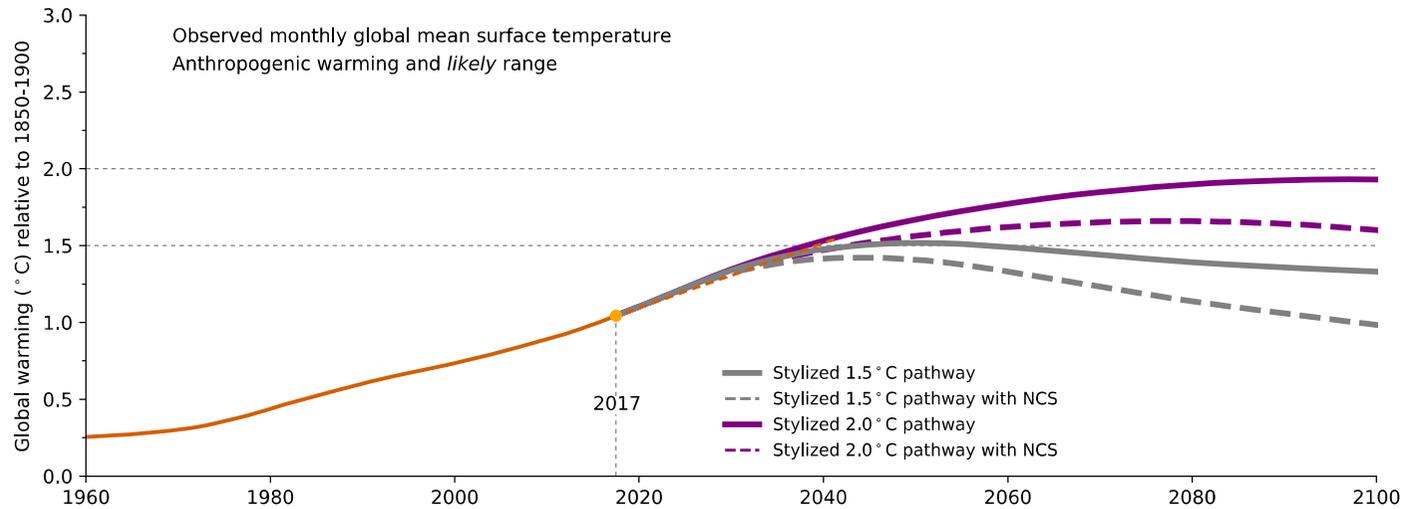


- "Nature-based solutions – locking-up carbon in the world’s forests, grasslands and wetlands – can provide up to one-third of the emissions reductions required by 2030 to meet the Paris Agreement targets," the Forum said.
- <https://www.theguardian.com/environment/2019/sep/19/greta-thunberg-we-are-ignoring-natural-climate-solutions>

## Why it helps to think a bit about the numbers

- Very optimistic estimates of Nature-based Climate Solutions potential estimate 10 GtCO<sub>2</sub> removal per year from the mid-2020s through afforestation, ecosystem restoration, “rewilding” etc.
- What impact would we expect this to have on global temperatures by 2050?

# Impact of 10 GtCO<sub>2</sub> per year CO<sub>2</sub> removal on global temperatures under 1.5°C and 2°C scenarios



## What about other greenhouse gases?

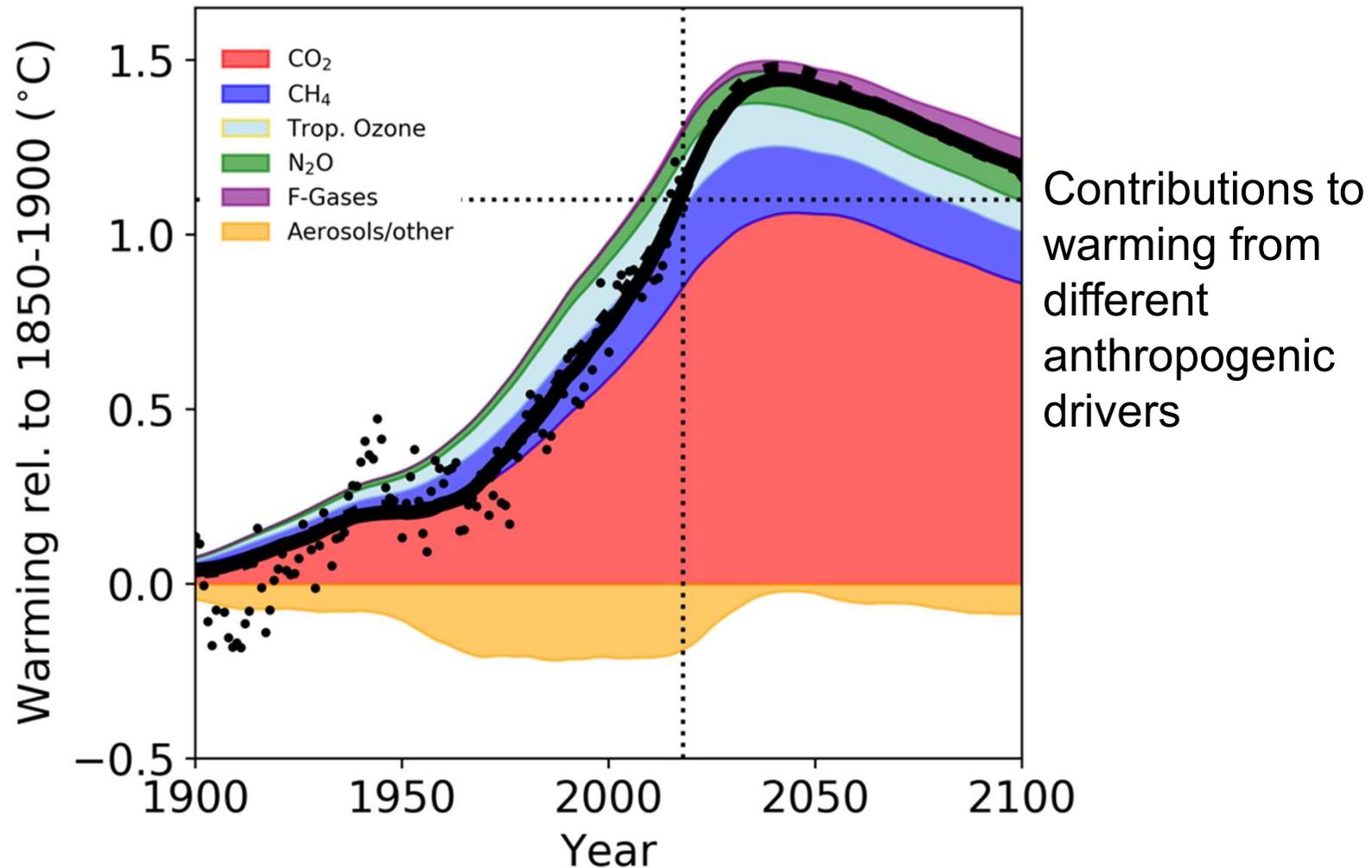


**We can stop  
Global Warming  
just by using one  
Simple Tool.**

If everyone switched to a vegan diet,  
we would immediately cut greenhouse gases in half  
(plus we'd eliminate most water pollution, rainforest destruction  
and species extinction, and we'd all live longer, healthier lives).

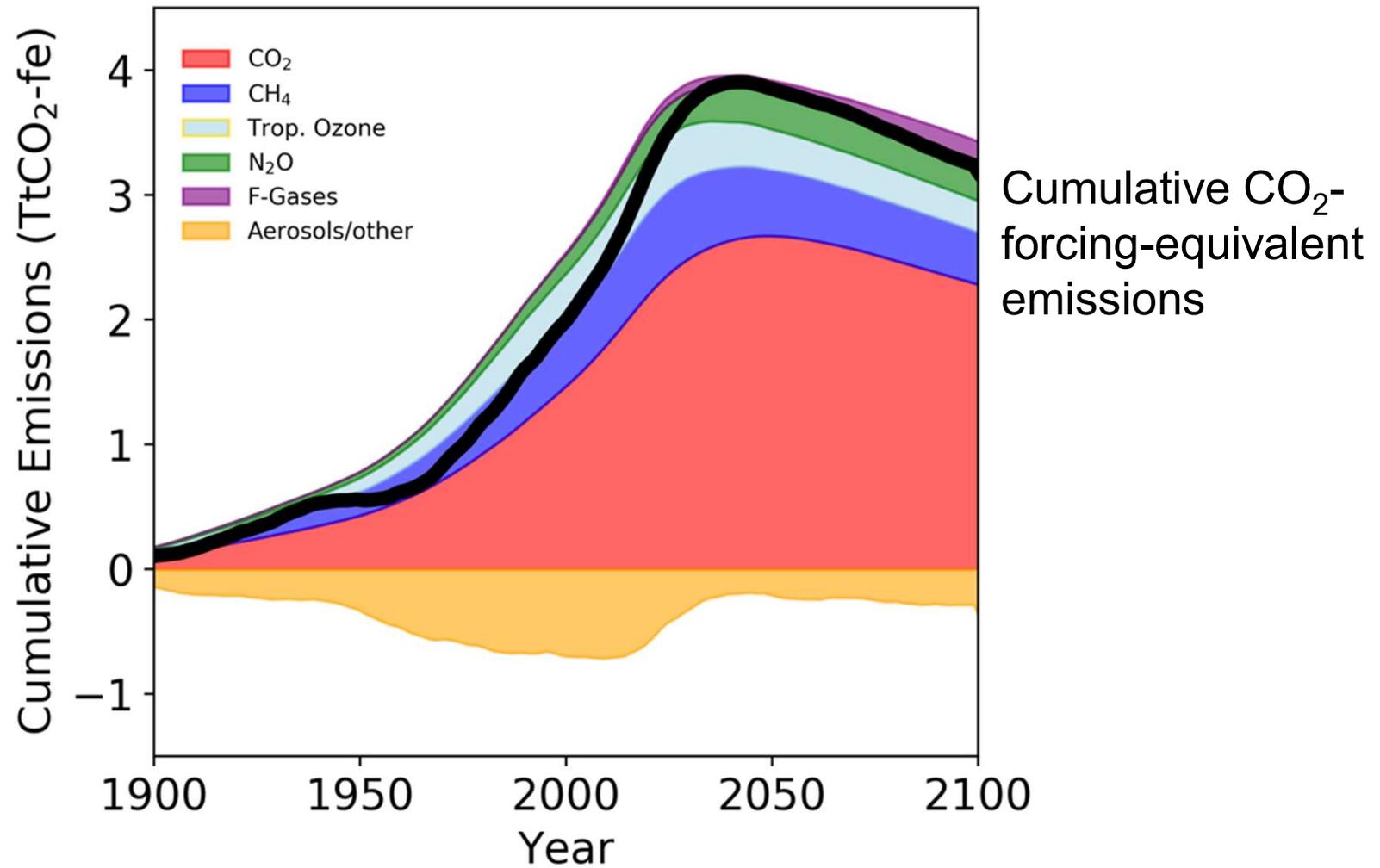
Source: Worldwatch Institute [VeganStreet.com](http://VeganStreet.com)

# Drivers of warming in a “1.5°C-consistent” scenario



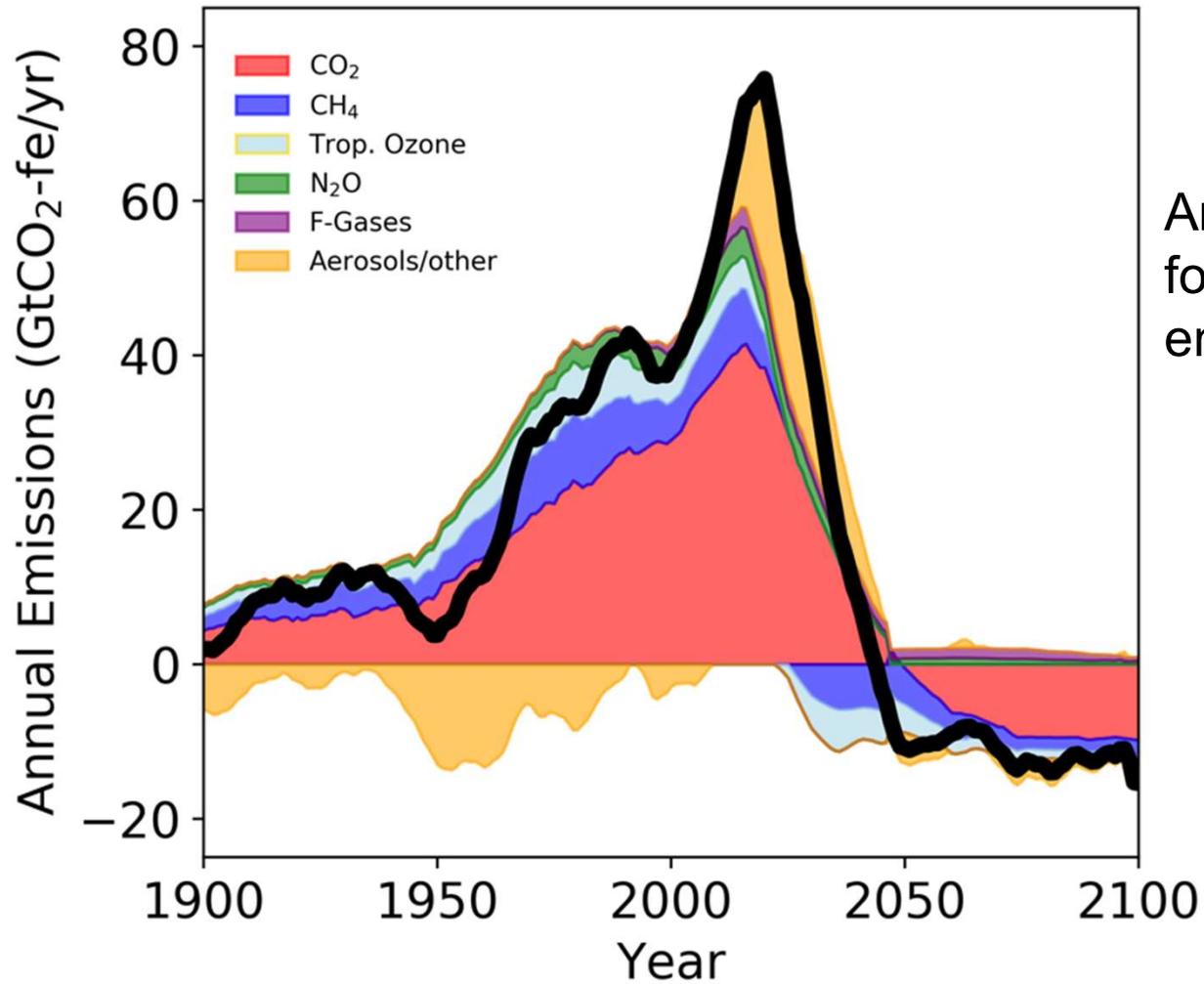
Contributions to observed warming to 2018, then following a typical very ambitious mitigation scenario that limits warming to 1.5°C

# Drivers of warming in a “1.5°C-consistent” scenario



CO<sub>2</sub>-forcing-equivalent emissions for driver X: CO<sub>2</sub> emissions that would have the same impact on global energy imbalance as X.

# Drivers of warming in a “1.5°C-consistent” scenario



Annual CO<sub>2</sub>-  
forcing-equivalent  
emissions

# Impact of non-CO<sub>2</sub> anthropogenic warming

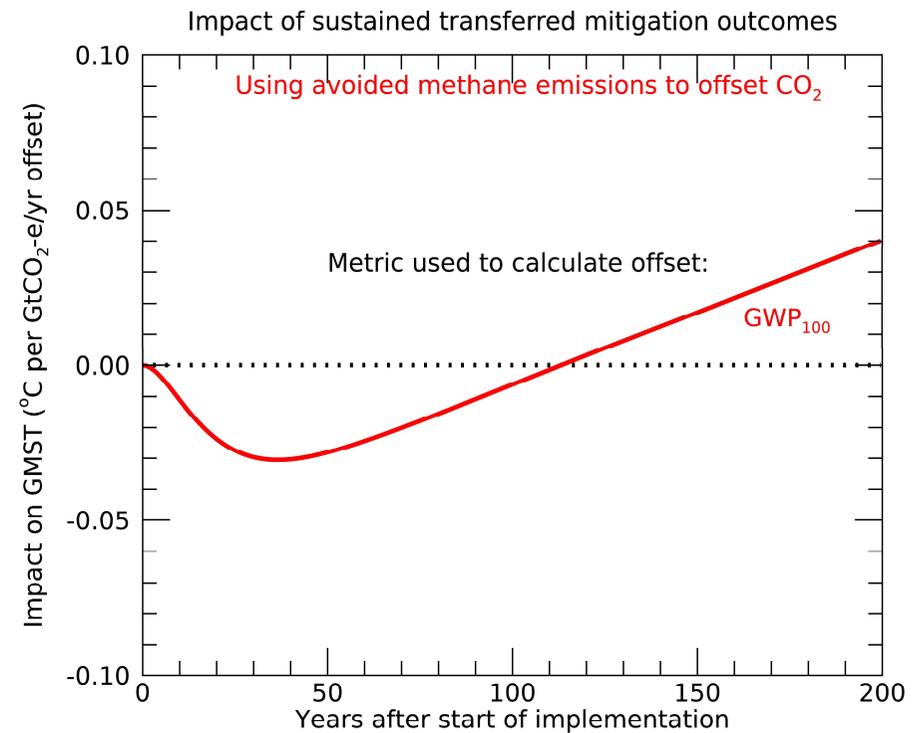
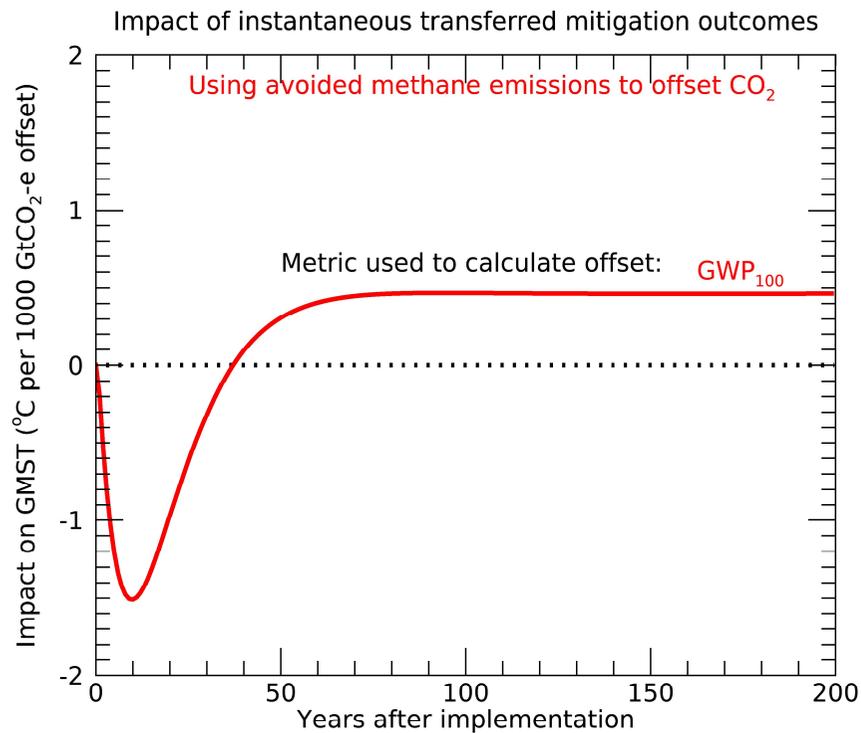
- Avoiding 1.5°C CO<sub>2</sub>-induced warming is a necessary, but not sufficient, condition for avoiding 1.5°C total warming.
- At present, methane, tropospheric ozone (linked to both methane and NO<sub>x</sub>), nitrous oxide (N<sub>2</sub>O) and industrial gases add ~0.4°C to CO<sub>2</sub>-induced warming, partly cancelled by ~0.2°C aerosol cooling.
- Aerosol cooling is rapidly reduced under most scenarios as aerosol precursors are cleaned up through improved air quality.
- So how do we set about reducing emissions of other (mostly shorter-lived) climate forcing agents?
- And how do we prioritize these against CO<sub>2</sub>?

# Conventional ways of dealing with different gases: “CO<sub>2</sub>-equivalent emissions” using a climate metric

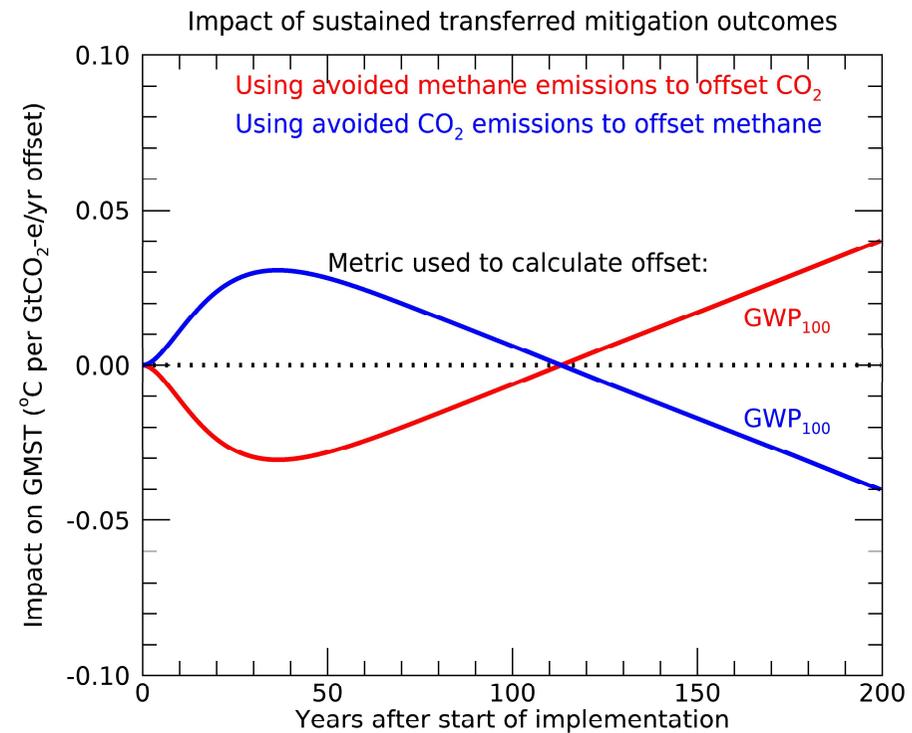
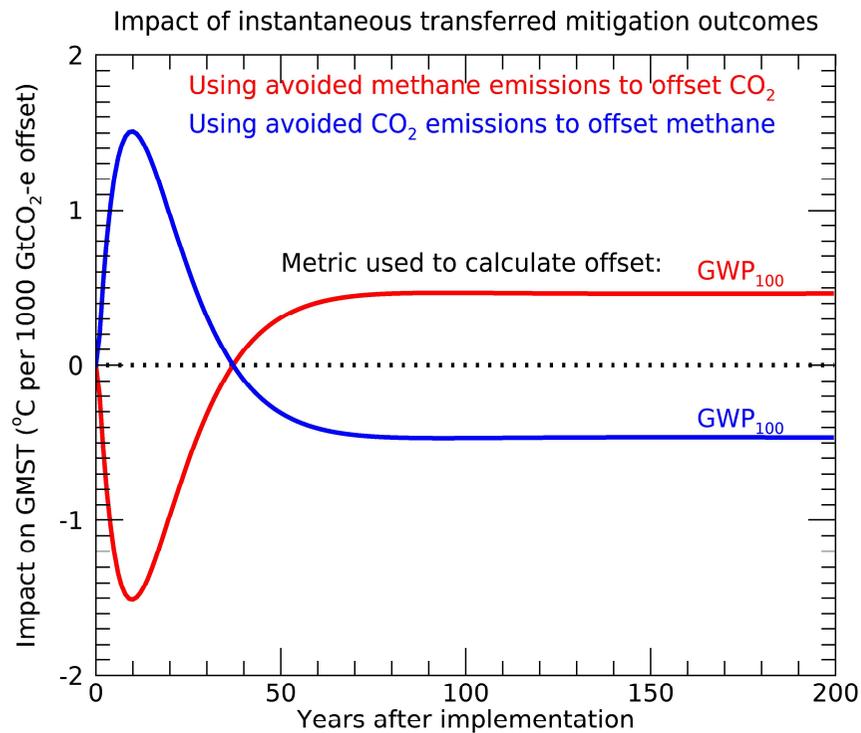
- Global Warming Potential (GWP<sub>H</sub>): integrated radiative forcing over a time-horizon H caused by a 1-tonne emission of a gas divided by that of 1 tonne of CO<sub>2</sub>.
  - Emissions (in tonnes) x GWP<sub>H</sub> = “CO<sub>2</sub>-equivalent” emissions, CO<sub>2</sub>-e.
- Global Temperature-change Potential (GTP<sub>H</sub>): temperature perturbation at the end of a time time-horizon H caused by a 1-tonne emission of a gas divided by that of 1 tonne of CO<sub>2</sub>.
- AR5 values (without carbon-cycle feedbacks):

Time horizon	20	100
Methane GWP	84	28
Methane GTP	67	4
Nitrous Oxide GWP	264	265
Nitrous Oxide GTP	277	234

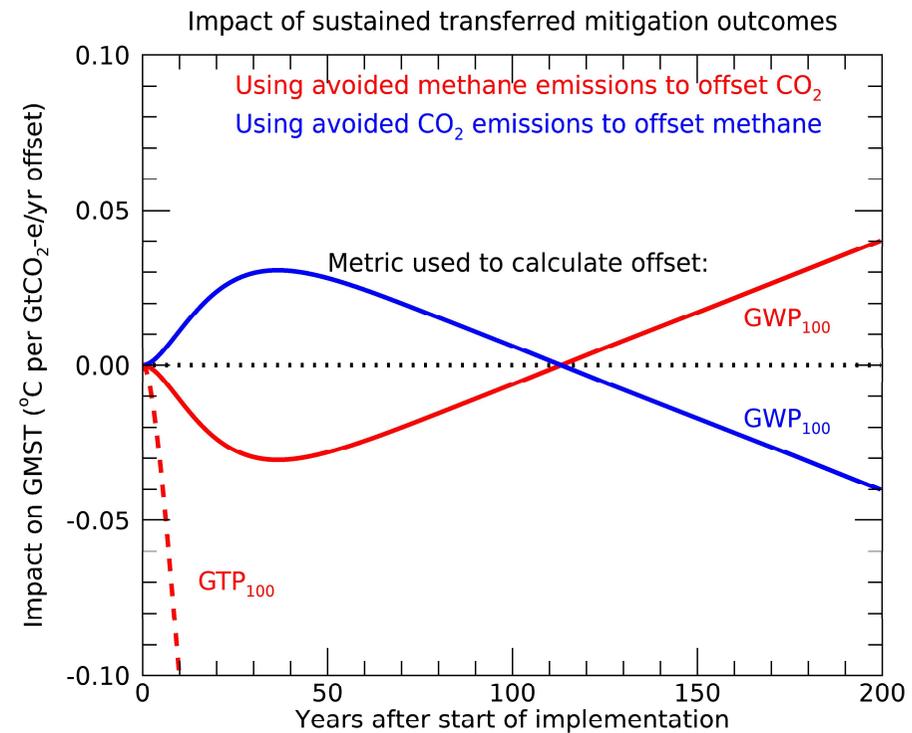
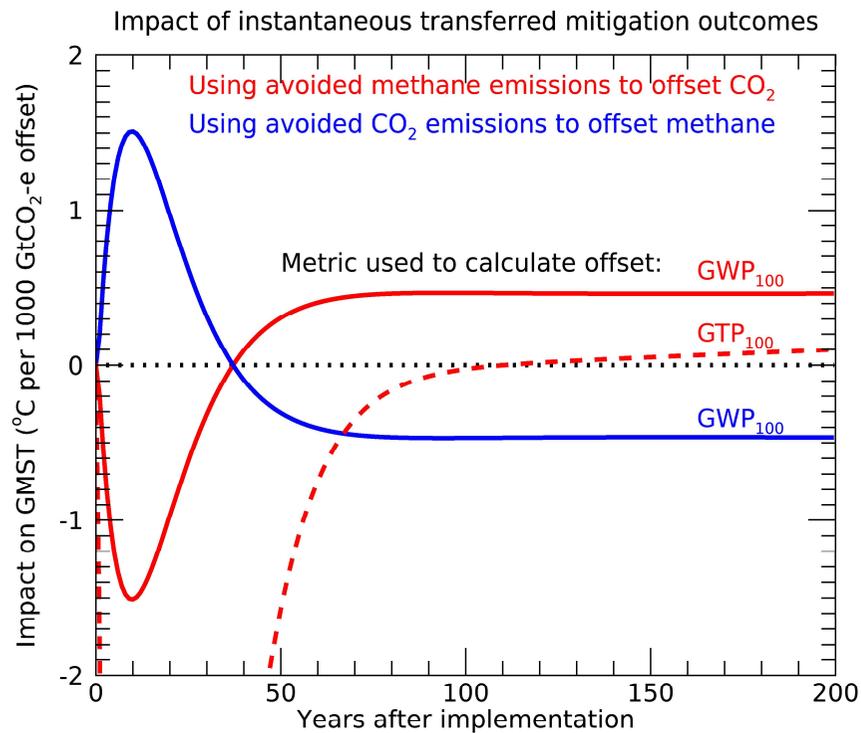
# The problem with climate metrics: CO<sub>2</sub>-equivalent emissions do not have equivalent impacts



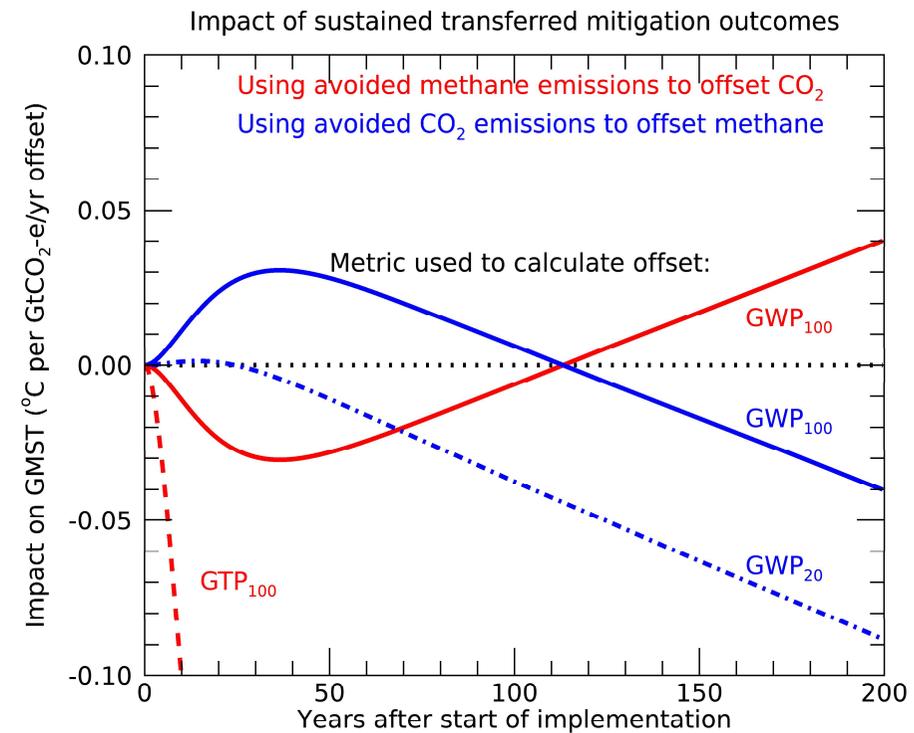
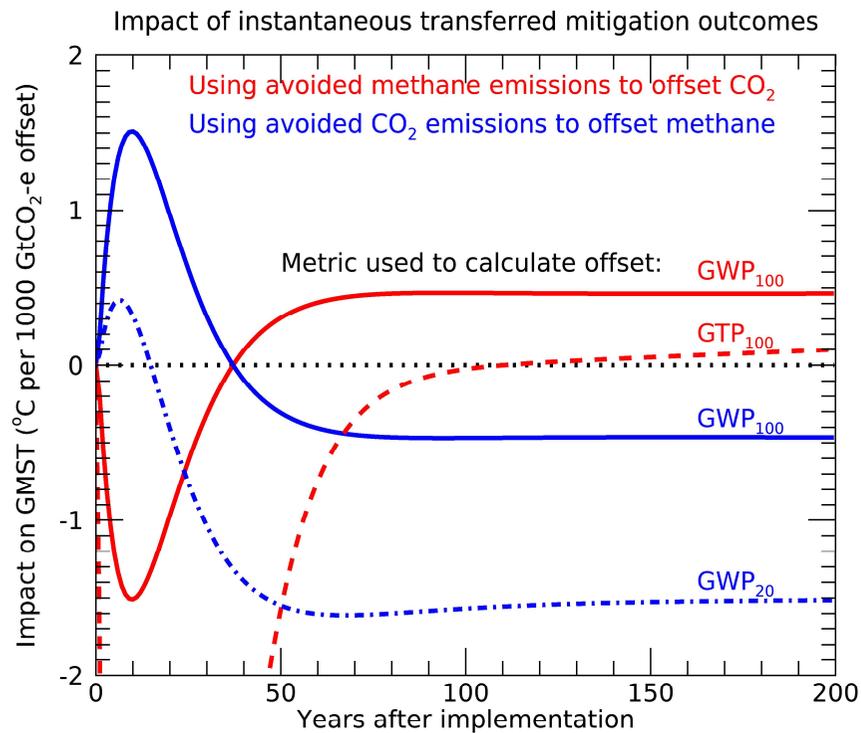
# The problem with climate metrics: CO<sub>2</sub>-equivalent emissions do not have equivalent impacts



# The problem with climate metrics: CO<sub>2</sub>-equivalent emissions do not have equivalent impacts

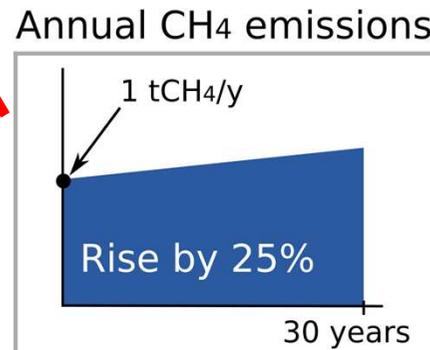


# The problem with climate metrics: CO<sub>2</sub>-equivalent emissions do not have equivalent impacts



# “Equivalent” emissions of CO<sub>2</sub> and methane have very different impacts on temperature

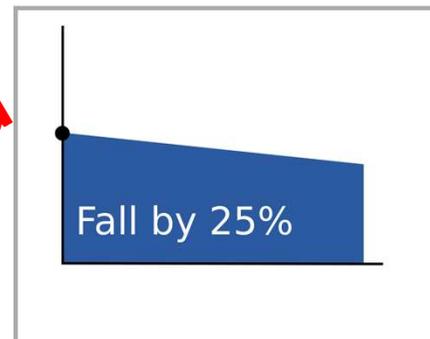
**WARMING**



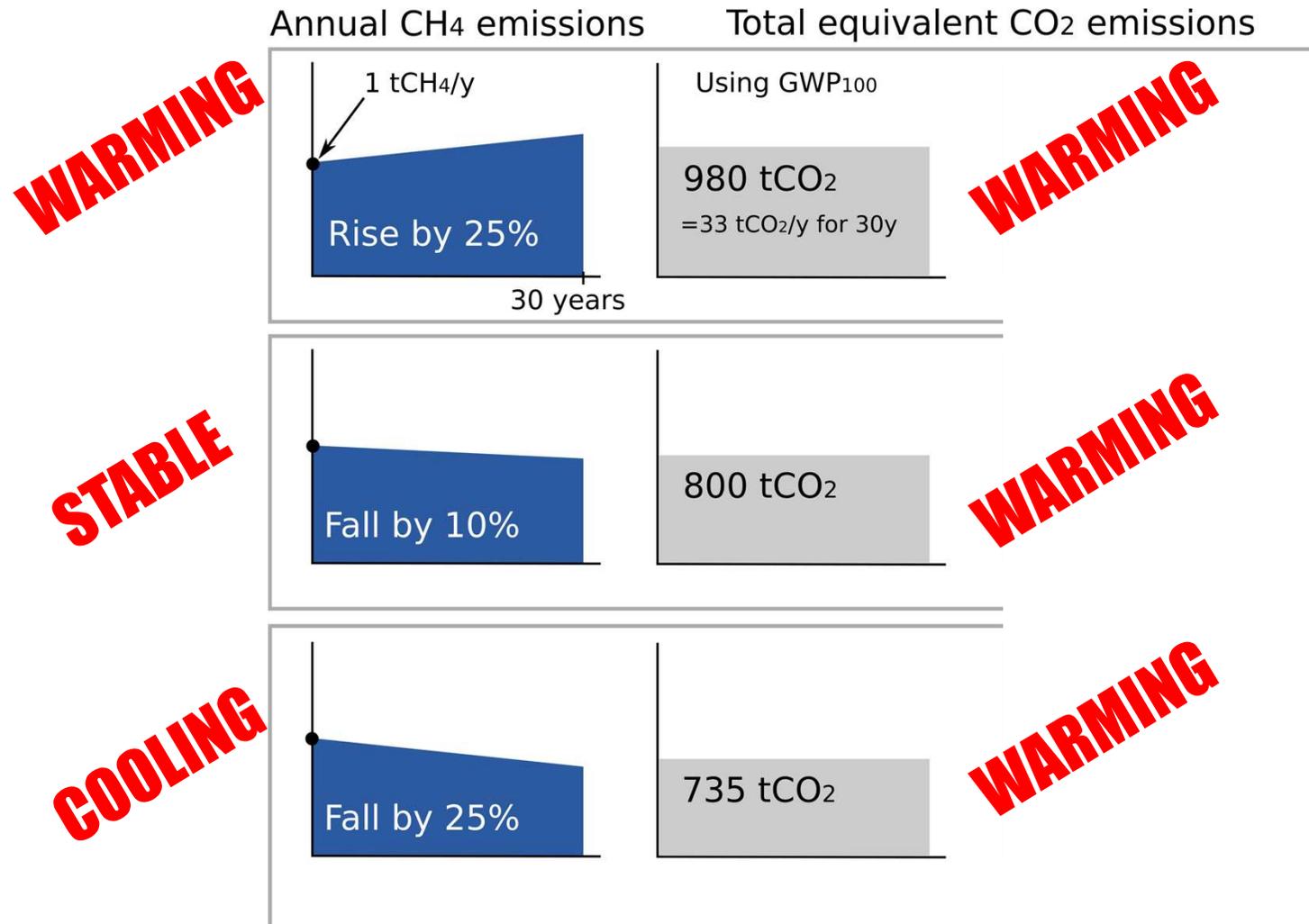
**STABLE**



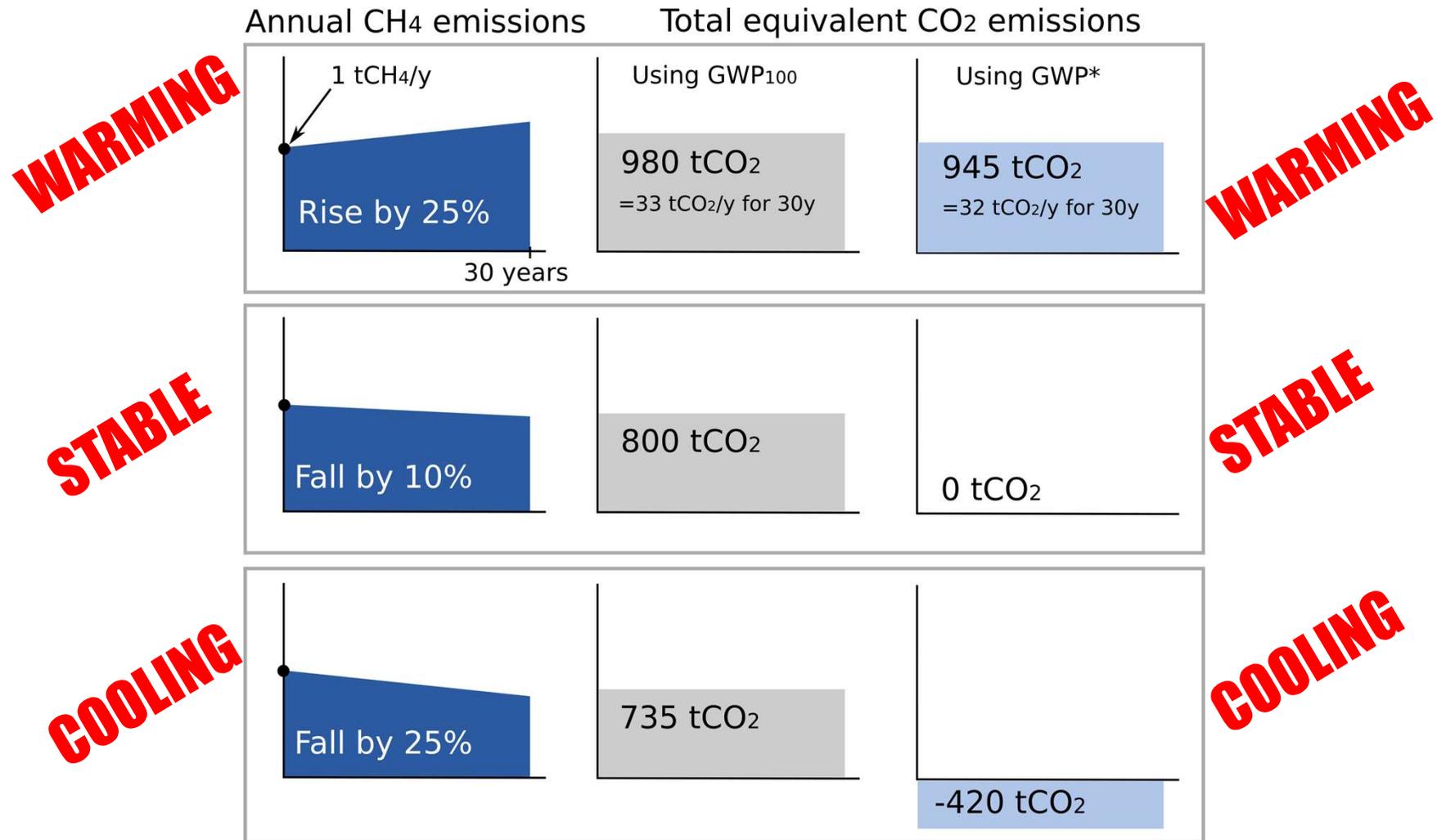
**COOLING**



# “Equivalent” emissions of CO<sub>2</sub> and methane have very different impacts on temperature



# Equivalence of CH<sub>4</sub> and CO<sub>2</sub> – revisited



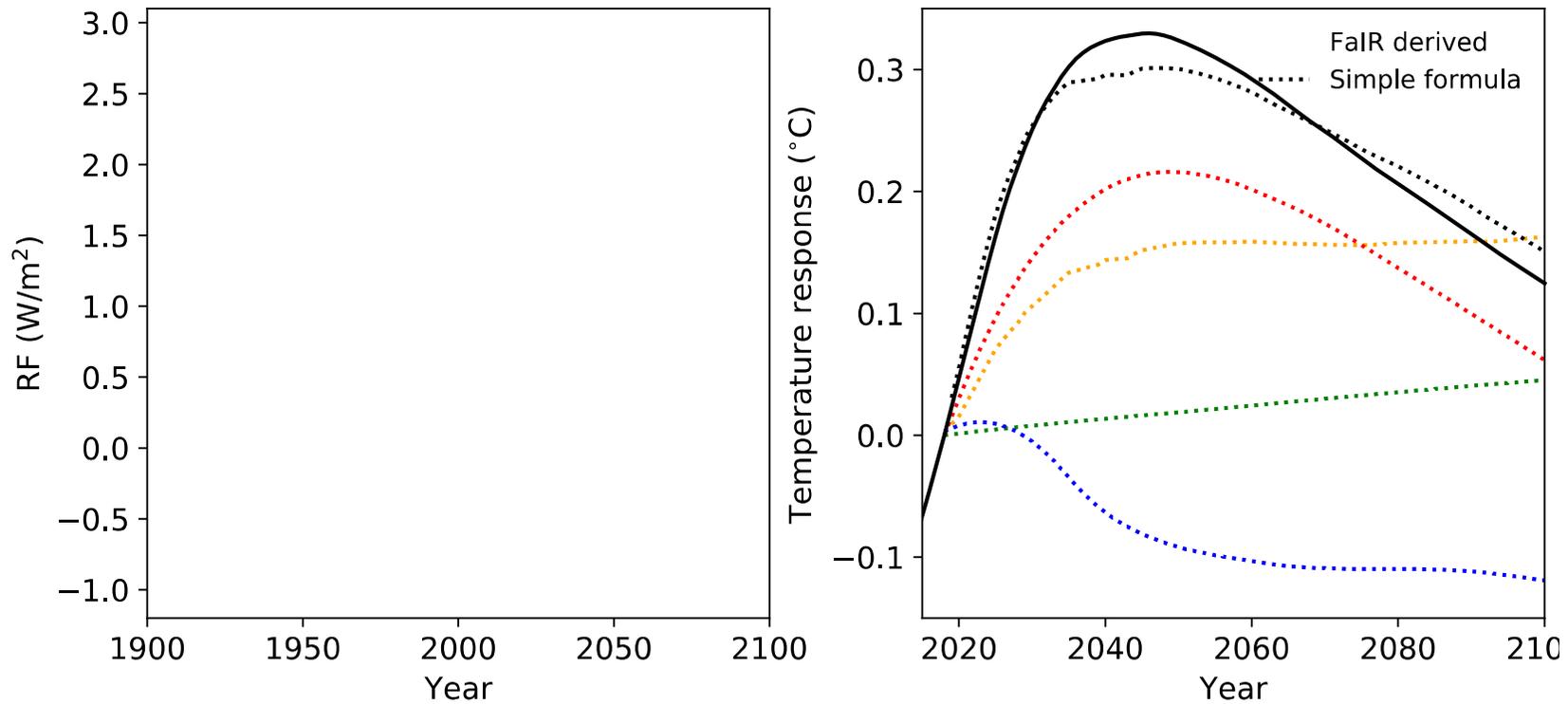
# A simple formula for calculating future warming from the three main greenhouse gases

- Warming from  $t_0$  to  $t_1$  is given by

$$\Delta T = \text{TCRE} \times \sum_{t_0}^{t_1} E_{\text{CO}_2}(t) + E_{\text{N}_2\text{O}}(t) + 4 \times E_{\text{CH}_4}(t) - 3.75 \times E_{\text{CH}_4}(t - 20)$$

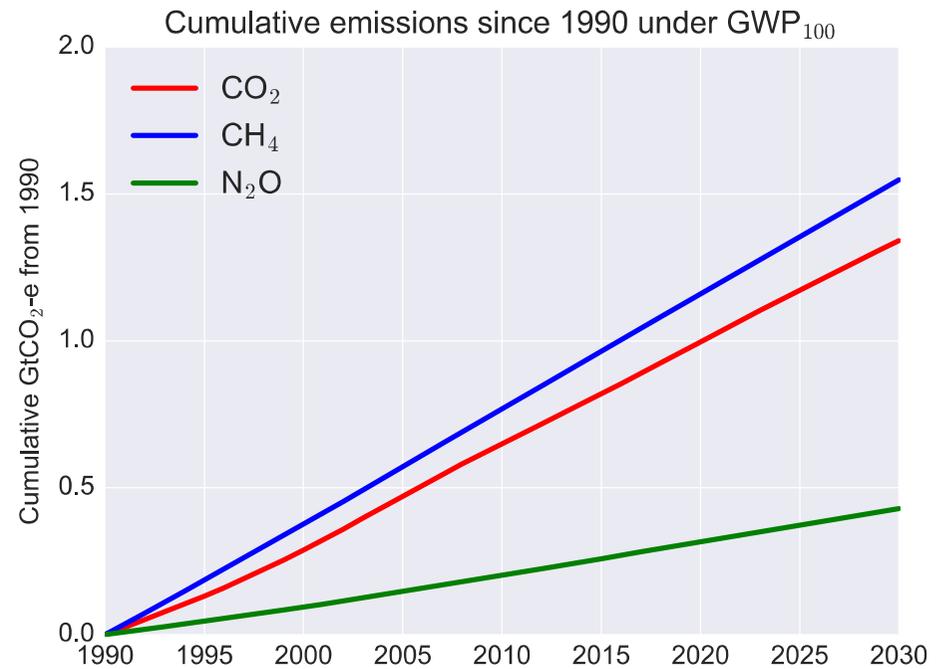
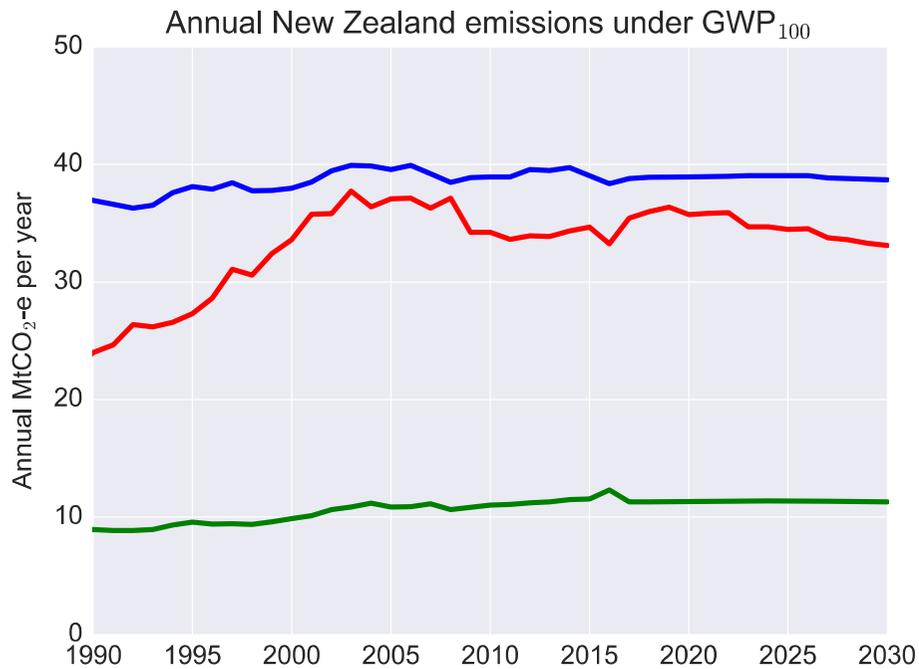
- $E_{\text{CO}_2}(t)$  =  $\text{CO}_2$  emissions in year  $t$
- $E_{\text{N}_2\text{O}}(t)$  =  $\text{CO}_2$ -e emissions of  $\text{N}_2\text{O}$  in year  $t$  using  $\text{GWP}_{100}$
- $E_{\text{CH}_4}(t)$  =  $\text{CO}_2$ -e emissions of methane in year  $t$  using  $\text{GWP}_{100}$
- Note that using conventional  $\text{CO}_2$ -e for methane alone
  - Undervalues new methane sources by a factor of 4
  - Overvalues established methane sources by a factor of 4
    - “Established source” = constant for more than 20 years

# This actually works rather well



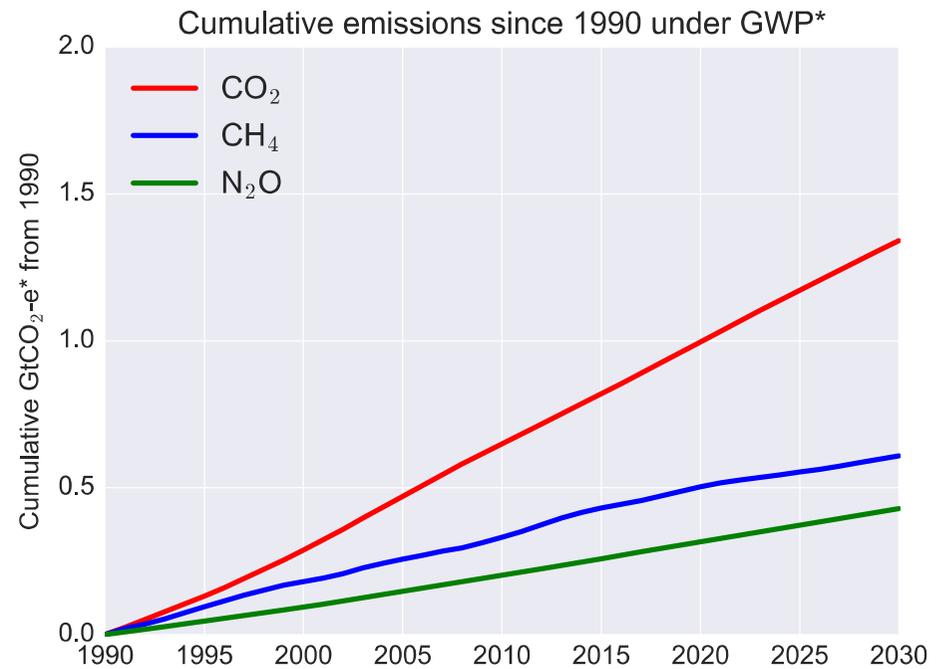
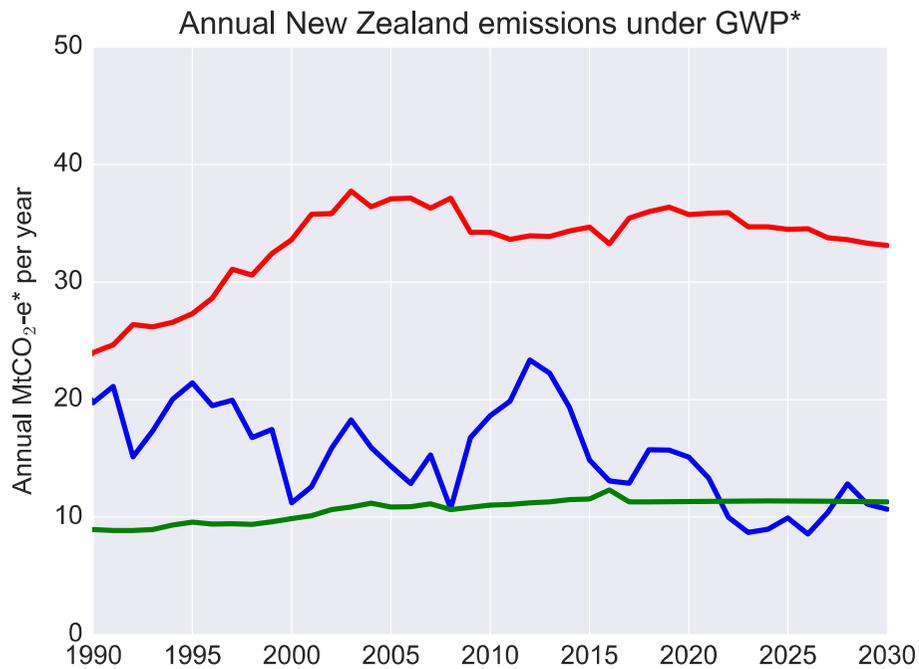
- $CO_2$
- $CH_4 + trop. Ozone$
- $N_2O$
- Aerosols
- Total
- Total (sum of component temps.)

# New Zealand emissions under GWP<sub>100</sub>: annual emission rates and cumulative emissions since 1990



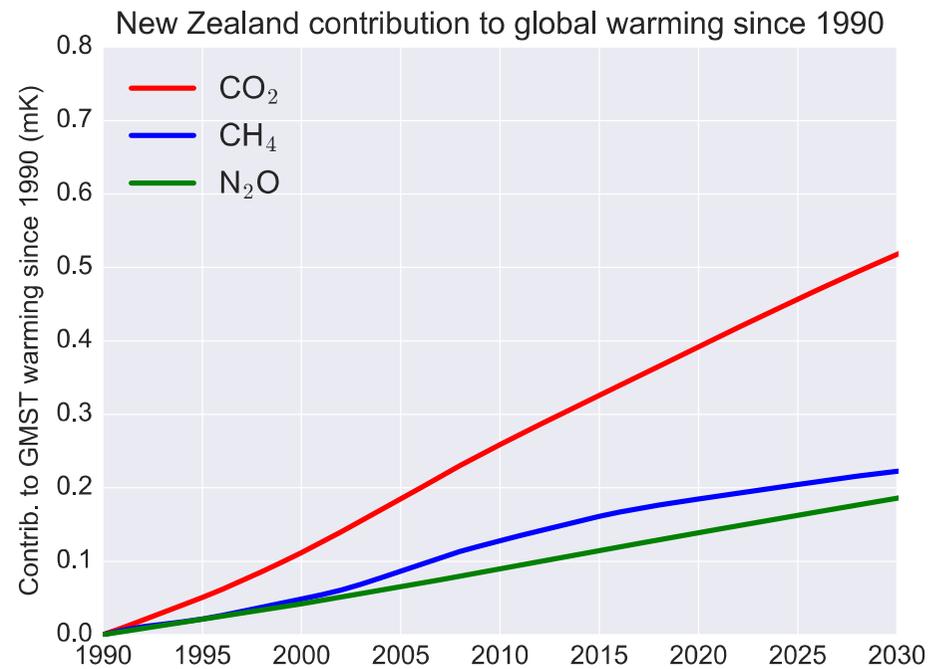
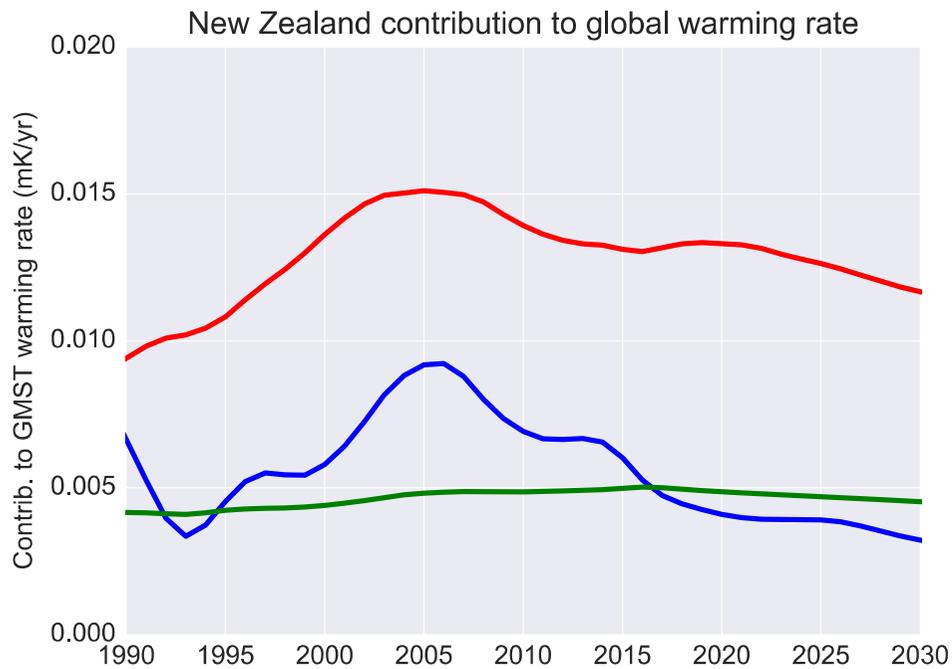
Nominal methane emissions under GWP<sub>100</sub> are higher than CO<sub>2</sub> emissions

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



Methane emissions under GWP\* are less than half CO<sub>2</sub> 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

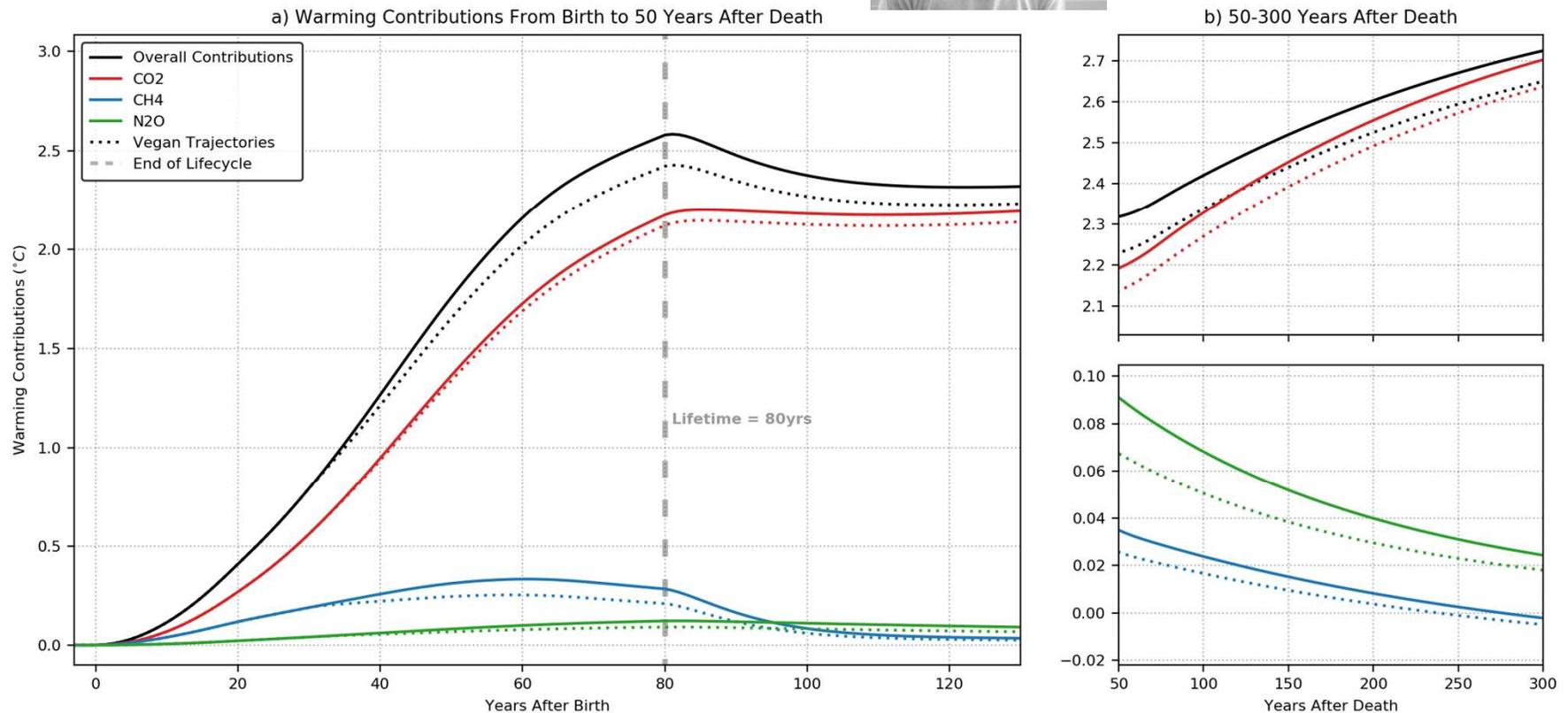
A gently declining (10% over 30 years) herd of cattle



## Summary

- Conventional greenhouse-gas metrics used by UNFCCC:
  - Undervalue the impact of increases and decreases in methane emission rates (e.g. new fracking projects).
  - Overvalue the impact of constant methane emission sources (e.g. established livestock or rice farms).
  - Would equate net-zero global emissions with a global cooling trend, assuming sustained methane emissions are balanced by CO<sub>2</sub> removals.
    - Is this what the Paris Agreement meant by “to pursue efforts to limit the temperature increase to 1.5°C”?

# And the all-important question, should Bill go vegan?



## Beware the Faustian bargain

20 years of  
low-cost  
methane  
mitigation...

So I can stop  
worrying about  
my carbon  
footprint?