"Methane is 80x worse than CO_2"

And Other Methane Myths

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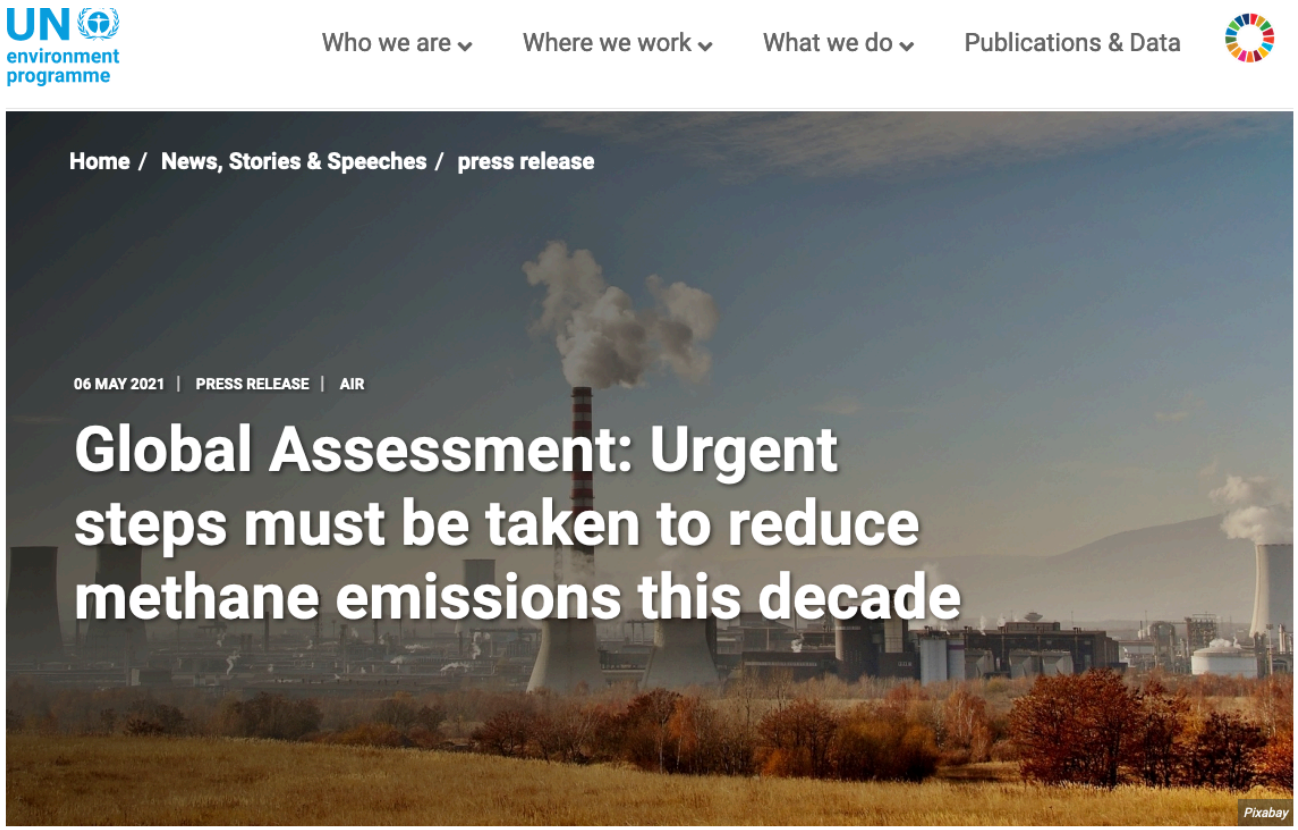
Aggressive push for early, urgent methane abatement



One example among many

Overview

What gases are we talking about

- CH_4 (12 year lifetime) gets most of the attention,
- Issues are the same for other GHG with decadal lifetimes (e.g. HFC's), but because of different nature of sources and different mitigation opportunities, HFC's offer policy responses different from CH_4
- N_2O, with a centennial lifetime, is in a policy grey area.

Radiative forcing and the Greenhouse effect

- Energy In from the Sun must be balanced by Energy Lost to Space by Infrared Radiation
- Infrared Radiation to space increases with Earth's temperature
- When additional greenhouse gas is added to the atmosphere, the rate of energy loss by Infrared goes down
- The planet must then warm up until balance is restored
- The reduction in Infrared Energy Loss by a given increase in a greenhouse gas is called *Radiative Forcing*
- More *Radiative Forcing* $\rightarrow$ more warming

Characterizing greenhouse gases: Linearized Radiative Efficiency

- a_{rad} is the rate at which radiative forcing changes with respect to atmospheric concentration of the gas in question, starting from a given baseline concentration. Usually expressed in $\mathrm{W/m^2/ppb}$
- 1 $\mathrm{W/m^2}$ of RF corresponds roughly to .75C warming
- a_{rad} decreases as the baseline concentration increases (cf. logarithmic behavior of RF for CO_2)...
- ... Hence, gases present initially at low concentrations tend to have high radiative efficiency

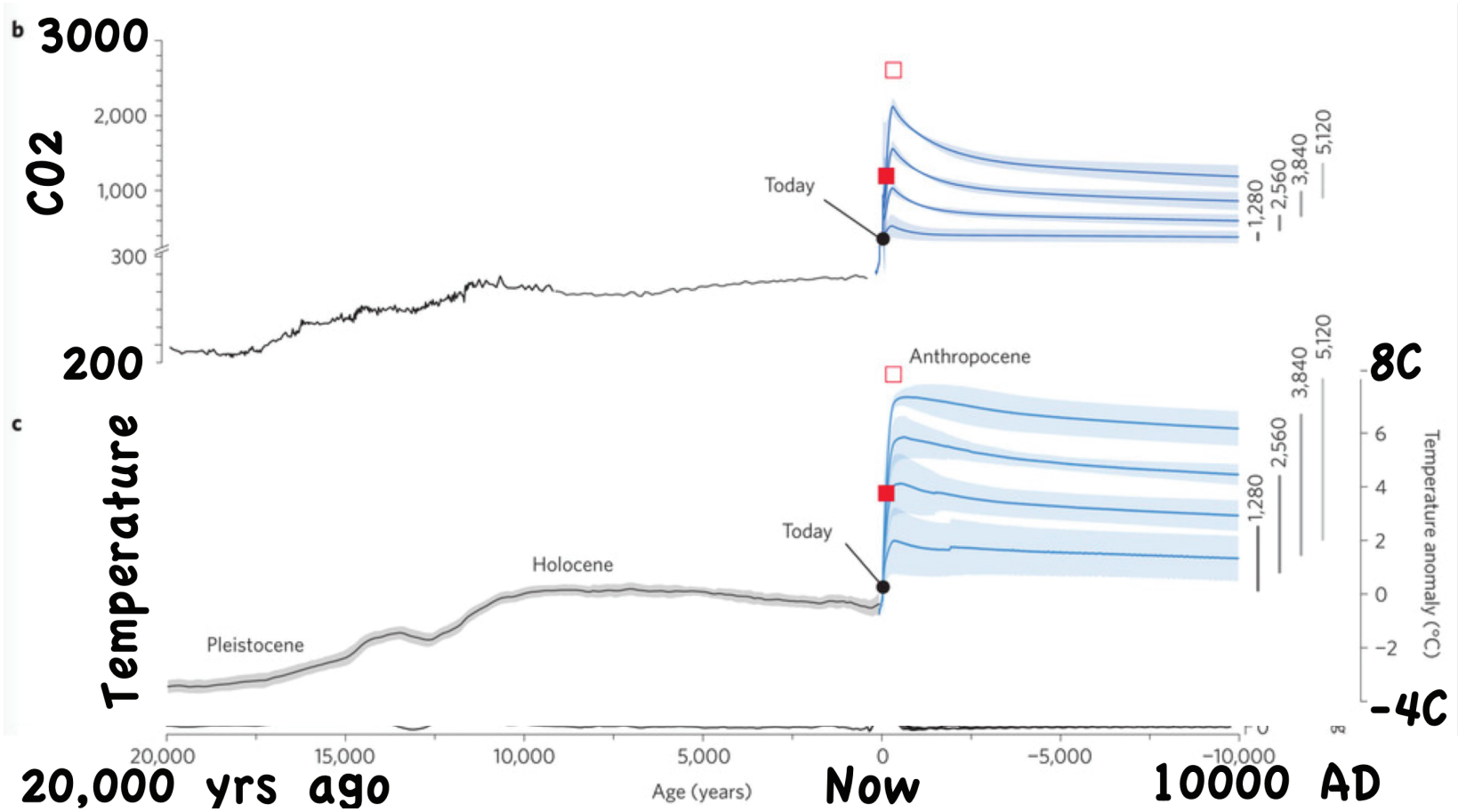
Low concentration $\rightarrow$ high radiative efficiency

- HFC: Tens of parts per trillion, $a_{rad} = .15$
- Methane: A few parts per million, $a_{rad} = 3.63 \times 10^{-4}$ (from today's baseline)
- CO_2: A few hundred parts per million, $a_{rad} = 1.37 \times 10^{-5}$ (from today's baseline) (from today's baseline)

Characterizing greenhouse gases: Atmospheric lifetime

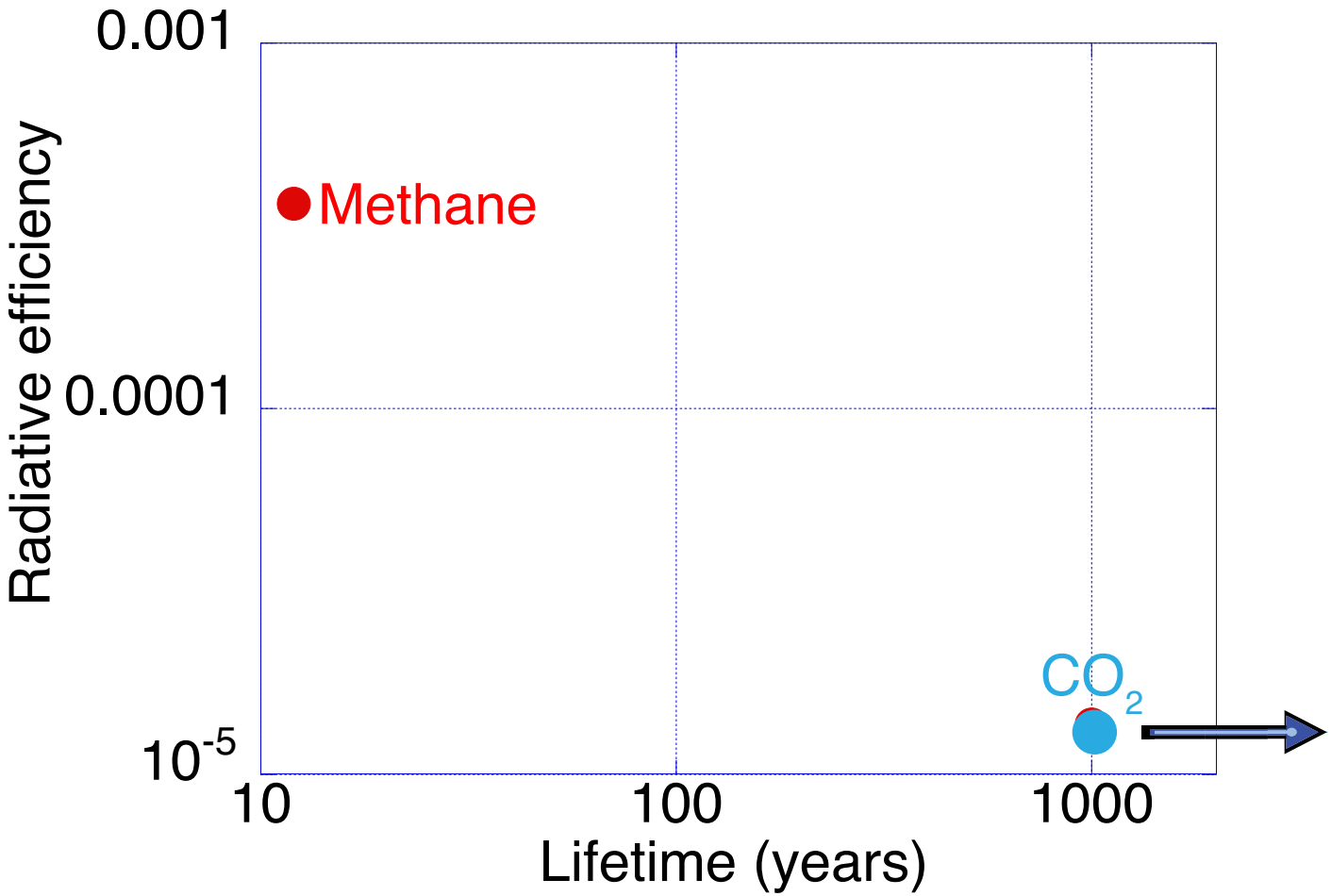
- The time constant (τ) for exponential decay of atmospheric concentration of the gas, following addition of a quantity to the atmosphere.
- Not all gases can be characterized by a single decay constant, but CO_2 is the only emission-controlled gas that poses a serious problem in this regard. CO_2 sinks are also nonlinear in concentration.

CO_2 is forever

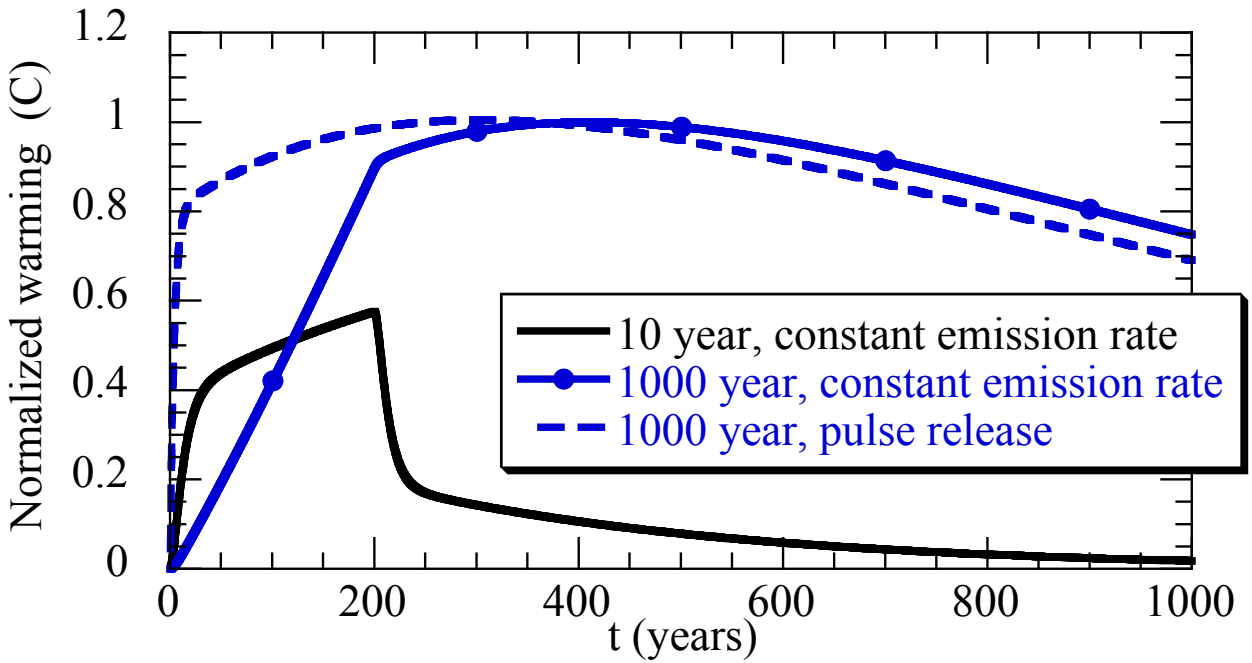


Clarke *et al.*, *Nature Climate* 2016

Methane is qualitatively different from CO_2

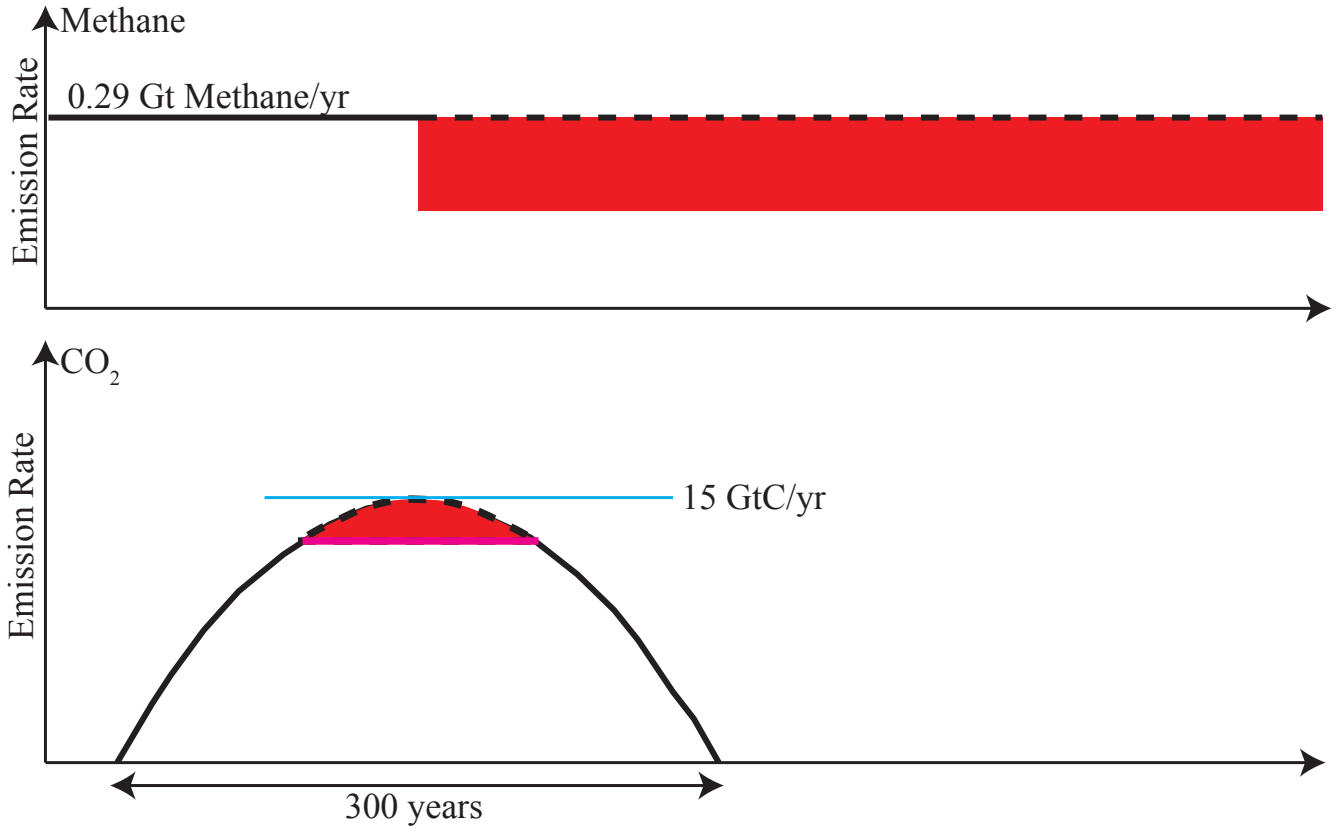


Climate effect of short-lived vs. long-lived GHG



Pierrehumbert, *AREPS* 2014

Warming-equivalent emissions scenarios



Pierrehumbert, *AREPS* 2014

The basic lesson

- The warming from CO_2 emissions depends on cumulative emissions over all past times.
- The warming from CH_4 (and other decadal gases) depends mainly on the emissions *rate*.
- CO_2 is a *stock* pollutant; CH_4 is (mostly) a *flow* pollutant.
- Decadal gases do have a small "stock pollutant" effect, through deep ocean heat storage.

Methane Myth: Net zero fallacies

e.g. "netZero doesn't mean zero sheep!

Methane Myth: Net zero fallacies vs. Some Truth

- For methane, and other short-lived gases, additional future warming comes (mainly) from increase in future emission *rate*.
- For CO_2 any continued amount of emission (even if rate is declining) leads to continued accumulation of CO_2 in the atmosphere, and continued warming.
- Unlike methane

  there is no "safe" level of continued CO_2 emissions

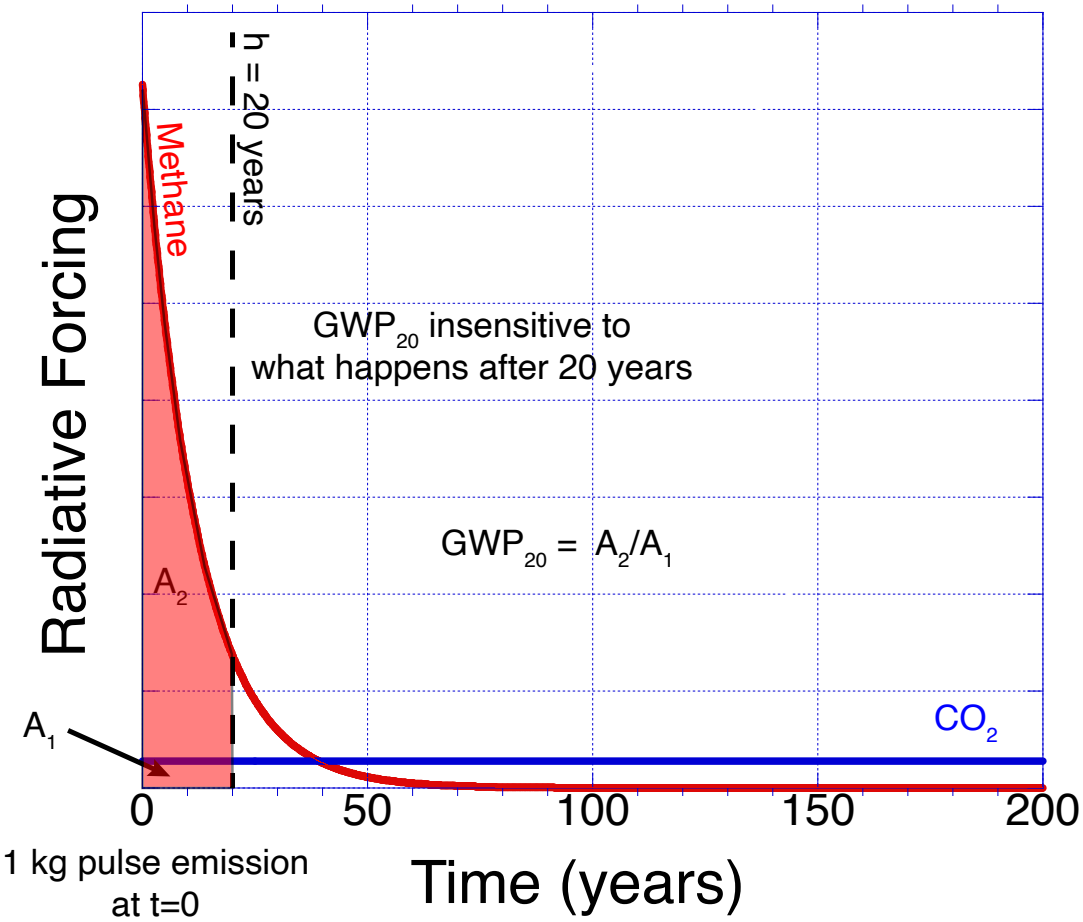
GHG metrics

- A GHG metric seeks to provide a way to aggregate emissions of multiple GHG's into a single number that measures their impact on climate.
- Since GHG's differ amongst each other in the two-dimensional space of radiative efficiency and lifetime, there is no way to do this without creating some bad policy guidance
- Still, if you must do it there are better and worse ways to do it.

GHG metrics

- The GWP metric (indeed most current metrics) are kg-for-kg metrics, as in
  "Emission of X kg of Gas A is equivalent to emission of 1kg of CO_2
- It is used to define quantities such as CO_{2e}
- The units of this conversion are not right for comparison of a short lived gas to a long-lived gas, because correct equivalence is between a sustained *rate* of emission of the short-lived gas (kg/yr) and a *mass* of the long-lived gas (kg).

GWP_h: A graphical explanation



Global warming potential for short-lived gases.

Assume:

- $h >> \tau$
- CO_2 doesn't decay appreciably over time h.

then

$$GWP_h = \frac{a_1 \tau}{a_{CO2} h}$$

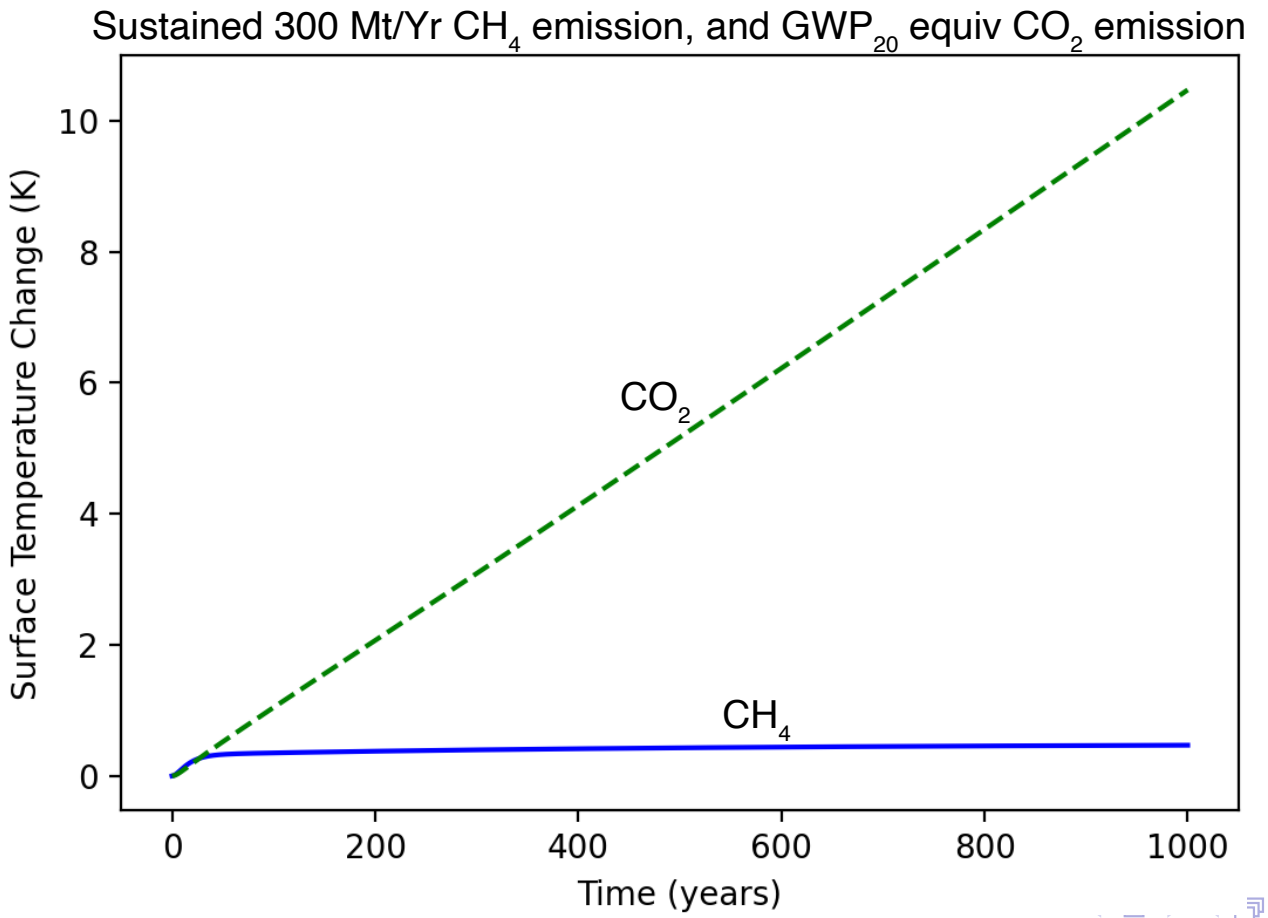
The chief Methane Myth

Methane is 80 times worse than carbon dioxide over a 20 year period.

(Based on GWP_{20})

Often the "20 year" qualification is even left out.

What this really means

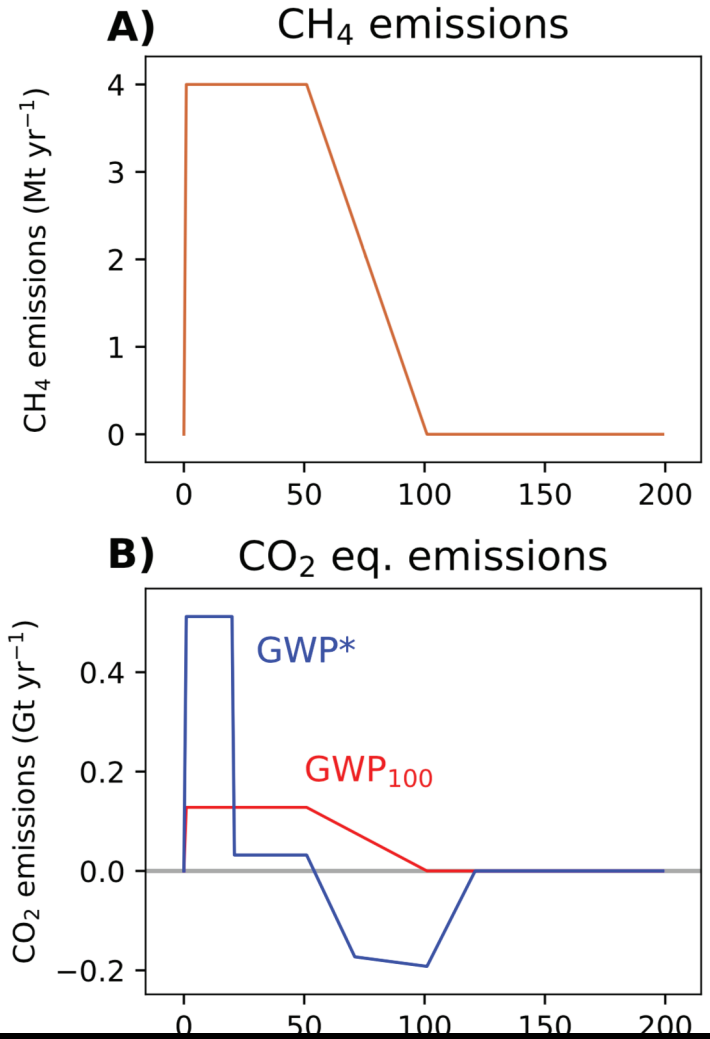


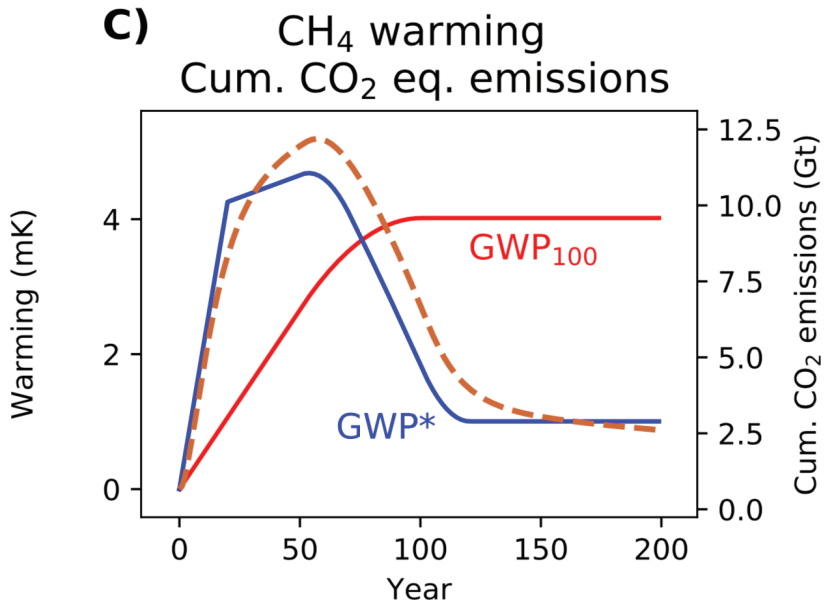
300 Mt/yr is approx. total current agricultural + fossil-fuel related methane emission

Derivation of the simple form of GWP* equivalence

- Let ΔE_1 be the change in emission *rate* (e.g. tonnes/yr) of SLCP gas.
- Resulting radiative forcing after equilibration is $\Delta E_1 a_1 \tau$
- If β is climate sensitivity, resulting warming is $\beta \Delta E_1 a_1 \tau$
- Warming from emission of $\Delta \mathrm{CO}_2$ tonnes of CO_2 is $\beta a_{CO2} \Delta \mathrm{CO}_2$. (Note possibility we should let β be different).
- CO_2 emission to yield same warming is $\Delta \mathrm{CO}_{2\,equiv} = (a_1 \tau / a_{CO2}) \Delta E_1 = [h\mathrm{GWP_h}] \Delta E_1$
- Term in brackets is GWP*. It is *dimensional*, and has units of time. $h\mathrm{GWP_h} \approx$ const.

GWP* test with Ramp Decrease





Further remarks

- Additional examples in Lynch *et al ERL* 2020
- These examples were done with GWP_{100} but GWP_{20} yields even worse alignment with climate response.

Our reward for introducing GWP*

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Unintentional unfairness when applying new greenhouse gas emissions metrics at country level

Joeri Rogelj[1,2,3] and Carl-Friedrich Schleussner[4,5,6]

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Article PDF Article ePub

Our reward for introducing GWP*

Abstract

The 2015 Paris Agreement sets out that rapid reductions in greenhouse gas (GHG) emissions are needed to keep global warming to safe levels. A new approach (known as *GWP**) has been suggested to compare contributions of long- and short-lived GHGs, providing a close link between cumulative CO_2-equivalent emissions and total warming. However, comparison factors for non-CO_2 GHGs under the *GWP** metric depend on past emissions, and hence raise questions of equity and fairness when applied at any but the global level. The use of *GWP** would put most developing countries at a disadvantage compared to developed countries, because when using *GWP** countries with high historical emissions of short-lived GHGs are exempted from accounting for avoidable future warming that is caused by sustaining these emissions. We show that when various established

More accuracy = ethical breach???

GWP_{20} is gaining traction in climate policy

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For the purposes of this article the following terms shall have the following meanings:

1. "Allowance" means an authorization to emit, during a specified year, up to one ton of carbon dioxide equivalent.

2. "Carbon dioxide equivalent" means the amount of carbon dioxide by mass that would produce the same global warming impact as a given mass of another greenhouse gas over an integrated twenty-year time frame after emission.

False perception that retreating from GWP_{20} weakens climate goals

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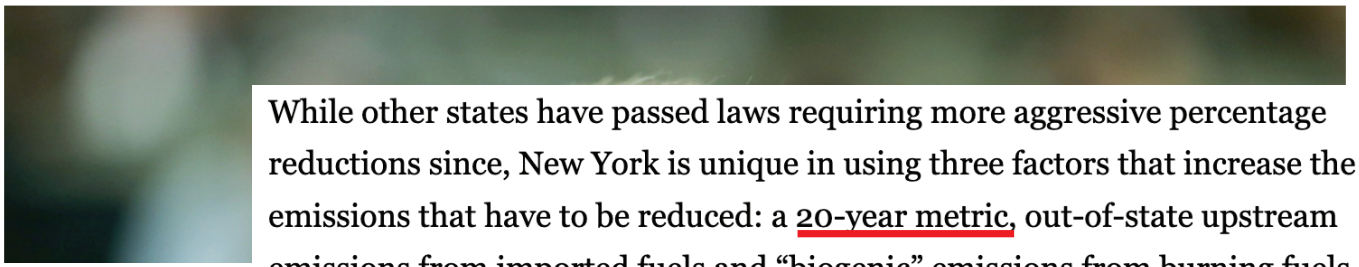
Hochul officials drop proposal to weaken climate law amid criticism

The major change is no longer a priority in budget negotiations.



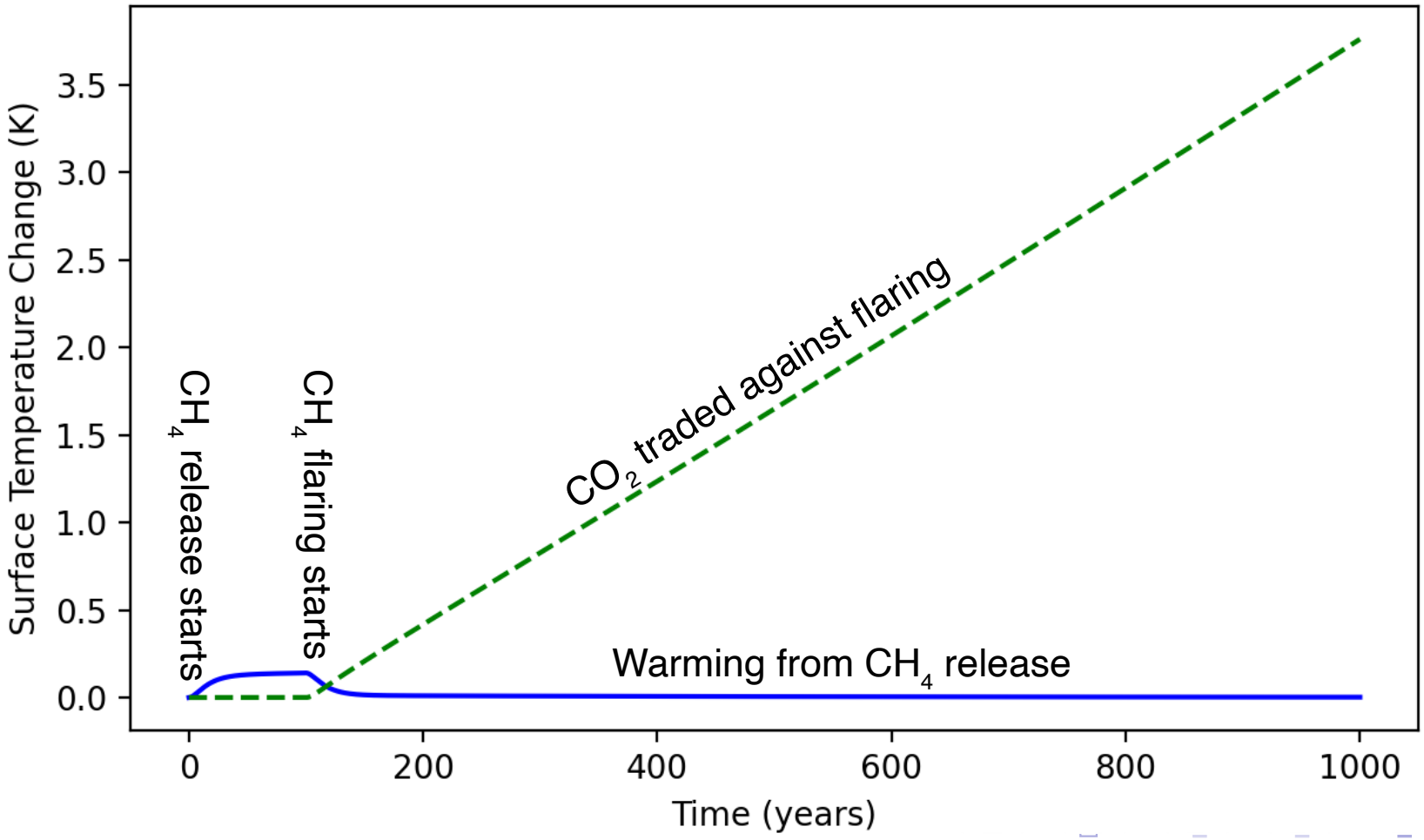
While other states have passed laws requiring more aggressive percentage reductions since, New York is unique in using three factors that increase the emissions that have to be reduced: a 20-year metric, out-of-state upstream emissions from imported fuels and "biogenic" emissions from burning fuels like wood and ethanol.

New York is the one of only two jurisdictions to use a 20-year time horizon to account for the damaging effects of planet-warming gasses instead of 100 years. Maryland's 2022 climate law also uses the 20-year metric.

Example: Methane flaring

- Suppose methane is traded against CO_2 on a kg-for-kg basis using GWP_{20}
- Suppose the fossil fuel industry collectively flares off the 120 Mt/yr current methane leakage ...
- ... and trades the resulting credits to allow a corresponding increase in CO_2 emissions.
- What are the consequences for climate?

Basically the same graph we have already seen



Methane Myths based on GWP_{20}

- "Natural gas is worse than coal" (Howarth)
- "Going vegan is the best thing you can do individually for climate"
- Blue hydrogen (H_2 from CH_4 with CCS) is worse than just burning the gas (Howarth again)

Equivalent cumulative carbon emissions for beef production

	CC_{eq} CH_4	CC_{eq} N_2O	CC_{eq} $N_2O + CH_4$	*CC*-deforest CO_2	1000yr *CC*-dir CO_2	CC_{eq} Total
Feedlot Midwest	587	873	1460	-	1429	2889
Pastured Midwest	756	1150	1906	?	1753	3659
Pastured Brazil	1150	550	1700	-	273	1973
Brazil w/deforestation	1150	550	1700	4750	273	6723
Ranch System Sweden	756	346	1102	?	270	1372
Sweden Average Beef	654	419	1073	-	950	2023

kg equiv. cum. emission per kg bone-free beef produced annually

Pierrehumbert and Eshel, *ERL* 2015

What about HFC's?

- Used in refrigeration and air conditioning
- Anticipated rapidly growing emissions under BAU $\rightarrow$ rapidly growing warming
- Hence, there is a strong case for abatement policy of some sort.
- For same reason as methane, shouldn't be traded against CO_2, though
- Climate (and ozone) friendly replacements are available ...
- ... and upgrades of refrigeration/a.c infrastructure to use them has considerable co-benefit in reducing energy usage (and hence CO_2 emissions).
- Probably best treated via direct regulation and standards, rather than emissions trading.

Conclusions

- This is not a "get out of jail" card for methane or HFC polluters. There are benefits in requiring low-cost or negative cost abatements, if they are done in such a way as to not allow or encourage substitution for for CO_2 mitigation.
- It could make sense to trade decadal SLCP against each other using GWP*, but any market based trading will be monetized, and if that happens the broader economy will allow trading against CO_2
- I think that for SLCP mitigation, direct regulation (e.g. of methane leakage from fossil fuel production) is probably the best option.

Additional take-home points

- GWP_h is not a suitable metric for climate policy, since it does not map accurately to warming targets.
- Because of its short lifetime, a delay in methane abatement is less harmful than a delay in CO_2 abatement
- Unless we get CO_2 to net zero, nothing we do with methane (or other short lived greenhouse gases) will matter much.
- Methane (and other short lived GHG's) should not be traded in any way against CO_2. Trading based on GWP_{20} leads to particularly adverse outcomes.