PROGRAMME BRIEFING
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OXFORD MARTIN SCHOOL

UNIVERSITY OF OXFORD

Climate metrics for ruminant livestock

Key messages

- **The new approach in this briefing note reflects the actual impact of cattle and sheep farming on global temperatures much more accurately than conventional methods, by correctly representing methane's warming effect.**
- Conventional interpretation of the "Global Warming Potential" of methane suggests that falling methane emissions would lead to continued global warming, while falling methane emissions would in fact lead to lower global temperatures.
- This misrepresentation can be overcome with a new usage that equates changes in methane emission rates with one-off emissions (or removals) of carbon dioxide.
- Gradually declining methane emissions (-0.3%/year) make no further contribution to warming. Faster cuts cause cooling, while any increase causes substantial warming.

How temperature responds differently to cumulative and short-lived climate pollutants

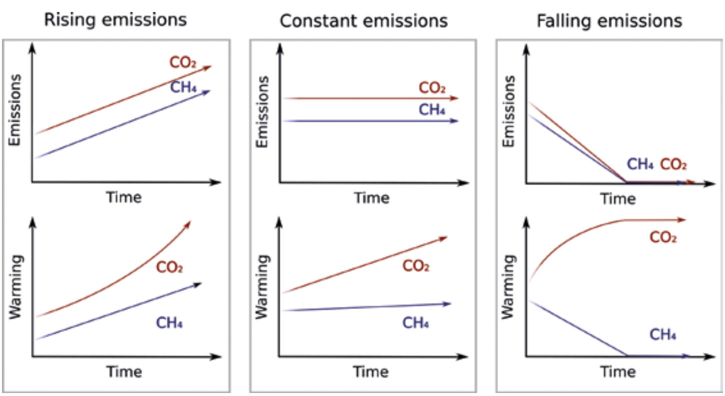
Surface temperature responds differently to carbon dioxide (CO_2) and methane (CH_4) emissions because CO_2 accumulates in the climate system, while methane is broken down by natural processes on a timescale of about 12 years. Hence the warming caused by CO_2 is determined by total cumulative CO_2 emissions to date, while the warming due to methane is determined more by the current rate of methane emissions in any given decade, and depends much less on historical methane emissions.

These differences matter most when emissions are falling towards zero. The schematic contrasts the response to a long-lived, or cumulative, pollutant such as CO_2 (red) with a short-lived climate pollutant such as methane (blue). Three cases are shown: emissions rising steadily, emissions constant, and emissions falling to zero, in all cases over several decades. Lower panels show the warming caused by these emissions.

When emissions are rising, CO_2 and methane both cause warming. Temperature continues to rise under constant emissions of CO_2, as CO_2 continues to accumulate. In contrast, constant methane emissions lead to constant methane concentrations in the atmosphere, which hold temperature at an elevated, but nearly stable, level, rising only very slowly due to continued multi-century adjustment of the climate system.

Temperature continues to rise in response to falling CO_2 emissions, as long as they remain above zero, but temperature falls in response to rapidly falling methane emissions. When emissions reach zero, the temperature response to CO_2 remains constant for many decades at whatever level it has reached due to cumulative CO_2 emissions over the entire industrial period, while the temperature response to methane declines to near zero within about a decade, because of its short lifetime.

Calculations of "CO_2-equivalent" emissions should account for these different behaviours. **Conventional metrics such as GWP_{100} or GWP_{20}, which equate one tonne of methane with a given number of tonnes of CO_2, would equate positive but falling methane emissions with positive CO_2 emissions, despite very different temperature responses.** A metric that reflects the equivalence between methane emission rates and cumulative emissions of CO_2 can overcome this problem.

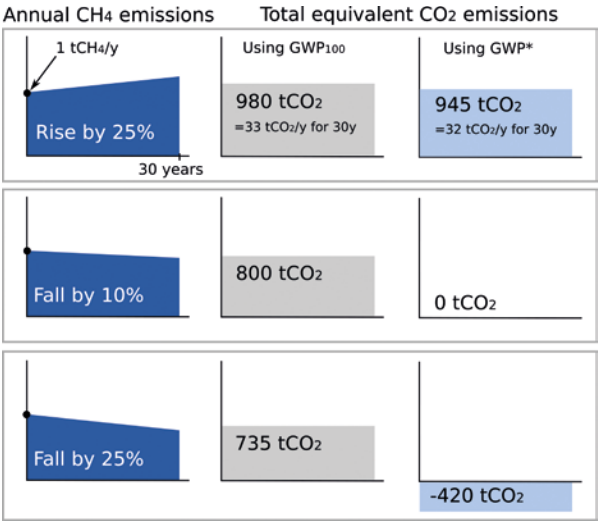


Application to ruminant livestock

Ruminant livestock are associated with high rates of methane (CH_4) emissions, generated as a by-product from enteric fermentation and from losses of organic material in their manures. Per molecule in the atmosphere, methane has a stronger global warming impact than carbon dioxide (CO_2). However, because of their very different lifetimes, the relationship between methane emissions and the concentration of methane in the atmosphere is very different to that of CO_2.

Emission comparisons are often based on GWP_{100} (the 100-year Global Warming Potential), which simply equates one tonne of methane (tCH_4) with 28 tonnes of CO_2 (tCO_2). GWP_{20} is sometimes used, which equates 1 tCH_4 with 84 tCO_2. However, neither GWP_{100} nor GWP_{20} accounts for the very different behaviour of methane and CO_2. Nitrous oxide, the other important greenhouse gas for agriculture, behaves much more like CO_2 and so is well represented by such conventional measures of GWP.

A new usage of GWP_{100}, denoted GWP*, captures methane's short-lived behaviour by equating a permanent increase of one tonne per year in the *rate* of emission of methane with a *one-off* release of 100 x GWP_{100} tonnes of CO_2. This better reflects its climate impact, shown on the previous page.



This new approach has a significant impact on activities where emissions are predominantly in the form of methane, such as ruminant livestock farming and rice production (as rice paddies provide anoxic conditions that suit methanogenic organisms).

The figure shows three scenarios, each starting from an emission rate of 1 tonne of methane per year, and either rising by 25%, falling by 10% or falling by 25% over the next 30 years. Conventional GWP_{100}, which ignores the impact of changing methane emission rates, would equate these to 980, 800 or 735 tonnes of CO_2 over that period, respectively (middle panels).

GWP* (right panels), which better represents the impact of methane emissions on global temperatures, would equate the rising emission scenario with 945 tCO_2 emitted over the same period, but 75% of this impact is due to the increasing rate, not the initial level, of methane emissions. A 10% decline in methane emission rate over 30 years is enough to fully compensate for its initial level, such that this scenario has the same impact on global temperature as zero CO_2 emissions over this period. A 25% decline would cause cooling equivalent to the active removal of 420 tCO_2 from the atmosphere.

Summary

The conventional Global Warming Potential (GWP) can be misleading when applied to methane emissions, particularly when these are being reduced. A revised usage of GWP, denoted GWP*, which uses the same metric values interpreted in a new way, provides a more accurate indication of the impact of short-lived pollutants on global temperature.

Of particular importance for ruminant livestock farming are the following observations:

- Past increases in methane emissions caused warming when they occurred, but constant methane emissions cause little additional warming. In contrast, every tonne of CO_2 emitted causes approximately the same amount of warming whenever it occurs.
- Gradually declining methane emissions of 10% over 30 years, equivalent to halving over about 200 years (e.g. through efficiency savings), cause no additional warming.
- Faster reductions in methane emissions lead to cooling, presenting an opportunity for agriculture to compensate for delays in reducing CO_2 emissions, although net emissions of CO_2 and nitrous oxide still ultimately need to be reduced to zero to stabilize global temperatures.
- Increasing methane emissions cause very substantial warming, equivalent to very large emissions of CO_2, but only while those increases are occurring.

Further reading:

A version of this briefing paper with a focus on scenarios for ambitious mitigation can be downloaded from: www.oxfordmartin.ox.ac.uk/publications/view/2601

For a more detailed treatment of concepts in this briefing paper, see: Allen, MR, Shine, KP, Fuglestvedt, JS, Millar, RJ, Cain, M, Frame, DJ, & Macey, AH: A solution to the misrepresentations of CO_2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. npj Climate and Atmospheric Science, 1(1), 16. https://doi.org/10.1038/s41612-018-0026-8 (2018).

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