PROGRAMME BRIEFING

Oxford Martin Programme on Climate Pollutants
July 2022

CLIMATE METRICS FOR RUMINANT LIVESTOCK

KEY MESSAGES

- **Global methane emissions from livestock have a substantial impact on climate, albeit much smaller than the impact of fossil fuel emissions.**
- **Comparing greenhouse gases as "CO_2-equivalent" using the 100-year Global Warming Potential (GWP_{100}) misrepresents the warming impact of methane.**
- **Expressing methane emissions as "CO_2-warming-equivalent" reflects the actual impact of cattle and sheep farming on global temperatures much more accurately.**
- **Increasing methane emissions causes substantial warming, but reducing methane emissions faster than 3% per decade acts to reduce global temperatures.**
- **Setting a separate target for methane emissions helps clarify the implications of emission goals for global temperature.**

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 level of warming caused by CO_2 is determined by total cumulative CO_2 emissions to date, while the level of 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.

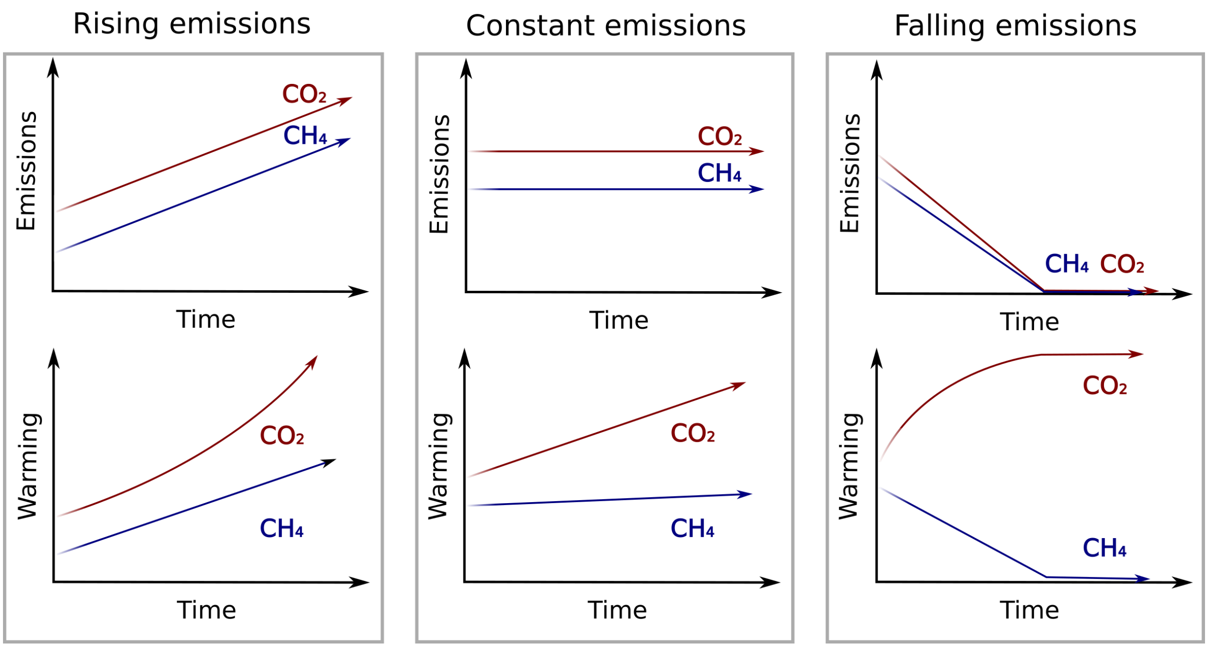
These differences matter because the world has set a target under the Paris Agreement to limit warming, limiting emissions is a means to this end. The below diagram contrasts the response to a long-lived, or cumulative, pollutant such as CO_2 (red) with a short-lived climate pollutant such as methane (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 very slow adjustment of the climate system over centuries to past methane emissions increases.

Temperature continues to rise in response to any remaining CO_2 emissions as long as they are greater than zero, even if they are falling rapidly. In contrast, temperature falls in response to methane emissions falling faster than about 3% per decade. When emissions reach net zero, the level of warming due to CO_2 remains constant for many decades, while the level of warming due to methane falls rapidly, halving within a couple of decades and continuing to decline thereafter, because of methane's short atmospheric lifetime.

Expressing methane emissions as CO_2-equivalent using the GWP_{100} metric, which equates one tonne of methane with 28 tonnes of CO_2, overstates the impact of a constant methane source on global temperature by a factor of 3 to 4 and understates the impact of a new methane source by a factor of 4 to 5 over the 20 years following the introduction of the new source[1].

So-called "warming-equivalent" metrics, such as GWP* or CGTP (Combined Global Temperature change Potential), can overcome this problem.



[1] Forster, P., T. Storelvmo, *et al*, 2021: *The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. In Climate Change 2021: The Physical Science Basis.* [Masson-Delmotte, V., P. Zhai, *et al* (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 923–1054, doi:10.1017/9781009157896.009

APPLICATION TO RUMINANT LIVESTOCK

Ruminant livestock emit large amounts of methane, generated as a by-product from enteric fermentation and from the anaerobic decomposition of organic material in their manures. Per molecule in the atmosphere, methane has a stronger global warming impact than CO_2. That is why methane from ruminant livestock has a warming impact on climate even though it is part of a natural carbon cycle.

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.

GWP* was developed to accurately represent the increased warming impact of each methane molecule while taking into account its short lifespan. To calculate CO_2-warming-equivalent emissions using GWP*, current methane emissions are multiplied by a factor of 8 and added to any net methane emissions increase or decrease over the previous 20 years multiplied by 120.

Warming-equivalent emissions reflect impact on global temperature: one tonne CO_2-warming-equivalent added or removed from the atmosphere increases or decreases global temperature by 0.45±0.18 trillionths of a degree Celsius.[1,2]

Implications of CO_2-warming-equivalent emissions:

- A constant methane emission of one tonne of methane per year established for longer than 20 years has approximately the same warming impact as an emission of 8 tonnes of CO_2 per year. This is 3½ times smaller than implied by GWP_{100}, and 10 times smaller than implied by GWP_{20}.

- A new emission source of one tonne of methane per year has the same warming impact as 128 (8+120) tonnes of CO_2 per year over the first 20 years after the introduction of the new source. This is 4½ times larger than implied by GWP_{100}, and 50% larger than implied by GWP_{20}.

- Any methane emission declining faster than 3% per decade (8/120 over 20 years), acts to reduce global temperatures: negative CO_2-warming-equivalent emissions have the same temperature impact as active removal of CO_2.

[2] The current rate of CO_2-warming-equivalent emissions for any other greenhouse gas with a lifetime less than 20 years can likewise be calculated by multiplying the current emission rate of that gas, expressed as CO_2-equivalent using GWP100, by 4.53 and subtracting the estimated rate of emissions 20 years ago multiplied by 4.25. Allen, M.R., Peters, G.P., Shine, K.P. et al. Indicate separate contributions of long-lived and short-lived greenhouse gases in emission targets. *npj Clim Atmos Sci* 5, 5 (2022). https://doi.org/10.1038/s41612-021-00226-2

SUMMARY

CO_2-warming-equivalent emissions, which can be calculated from CO_2-equivalent emissions using GWP*, provide a more accurate indication of the global temperature impact of emissions of methane and other greenhouse gases, and the impact of activities, decisions and practices that affect these emissions. There are various ways this information can be used depending on other considerations, including goals, values and priorities[3].

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

- Increasing methane emissions cause very substantial warming, but constant ongoing methane emissions cause relatively little additional warming. In contrast, every tonne of CO_2 emitted causes the same amount of warming whenever it occurs. In recent years, global methane emissions have increased, causing lots of warming.

- Gradually declining methane emissions of 10% over 30 years (equivalent to halving over about 200 years) cause no additional warming.

- Faster reductions in methane emissions lead to a lowering of global temperatures. In contrast, until net emissions of CO_2 and nitrous oxide are reduced to zero, they continue to increase global temperatures. Reducing methane to zero while continuing to emit CO_2 could delay, but not prevent, global temperatures rising.

Oxford Martin Programme on Climate Pollutants
Oxford Martin School
University of Oxford
34 Broad Street
Oxford OX1 3BD

Tel: +44 (0)1865 287430
Email: myles.allen@ouce.ox.ac.uk
Web: www.oxfordmartin.ox.ac.uk/pollutants/

Authored by: Myles Allen, John Lynch (University of Oxford), Michelle Cain (Cranfield University) and David Frame (University of Canterbury, New Zealand).
Published by the Oxford Martin Programme on Climate Pollutants

[3] Lynch, J., M. Cain, R. Pierrehumbert, and M. Allen, 2020: *Environmental Research Letters*, 15(4), 044023, doi:10.1088/1748-9326/ab6d7e