OXFORD MARTIN SCHOOL
BRIEFING NOVEMBER 2017

Climate metrics under ambitious mitigation

Key messages

- Combining emissions conventionally using GWP_{100} indicates warming instead of cooling associated with reductions in short-lived climate pollutants (SLCPs).

- This problem can be resolved by a new usage of GWP which equates a one-off permanent increase in methane emission rate with a one-off pulse emission of CO_2; and a one-off permanent decrease in methane emission rate with a one-off CO_2 removal.

- Combined in this way, total cumulative emissions predict temperature, with peak warming coinciding with net zero total emissions. Hence this is a better way than conventional GWP of monitoring progress to a long-term temperature goal.

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

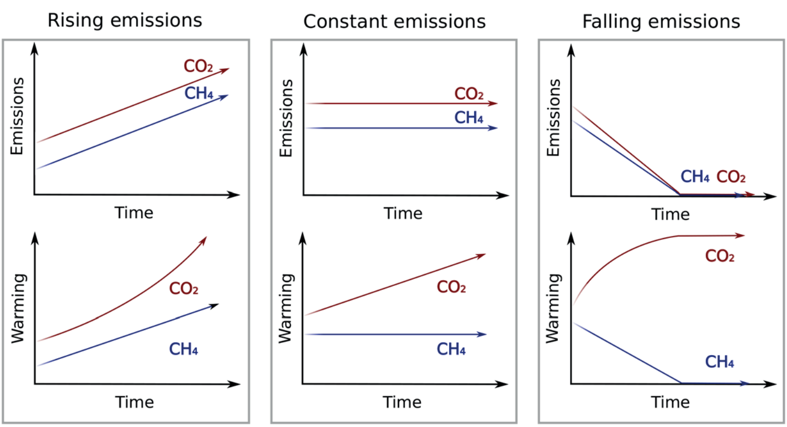
Surface temperature responds differently to carbon dioxide (CO_2) and methane (CH_4) emissions because CO_2 accumulates in the climate system, while methane is broken down by natural processes. Hence the warming caused by CO_2 is determined by total cumulative CO_2 emissions to date, while the warming 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 hold temperature at an elevated level but cause no further warming.

Temperature continues to rise in response to falling CO_2 emissions, as long as they remain above zero, but temperature falls in response to 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} that 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 an ambitious mitigation scenario

The conventional Global Warming Potential equates one tonne of methane with GWP_H tonnes of CO_2, calculated to have the same impact on the global energy budget over a time-horizon *H* if suddenly released into the atmosphere.

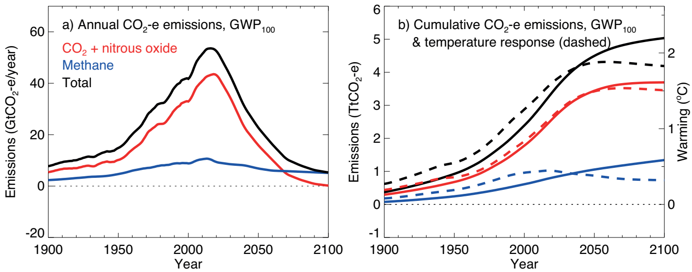


Figure a shows annual emission rates under an ambitious mitigation scenario, RCP2.6, of CO_2 and nitrous oxide (red), methane (blue) and their combination (black) expressed as “CO_2-equivalent” (CO_2-e) emissions using GWP_{100}. Figure b, solid lines, show cumulative emissions added up over time. Dashed lines and right axis show temperature responses to these emissions. The response to CO_2 and nitrous oxide is well approximated by cumulative CO_2-e emissions multiplied by the Transient Climate Response to Emissions (TCRE), but the response to methane is much closer to the annual rate of methane emissions in billion tonnes of CO_2-e per year (in a) multiplied by the TCRE times *H*. Total cumulative conventional CO_2-e emissions (b, black solid line) hence provide a poor indicator of the temperature response (dashed line), continuing to increase even after temperature has stabilised.

A new usage of Global Warming Potential, denoted by GWP*, equates a one-off permanent increase of one tonne per year in the rate of emission of a short-lived climate pollutant such as methane with a sudden release of *H* x GWP_H tonnes of CO_2, better reflecting their climate impact.

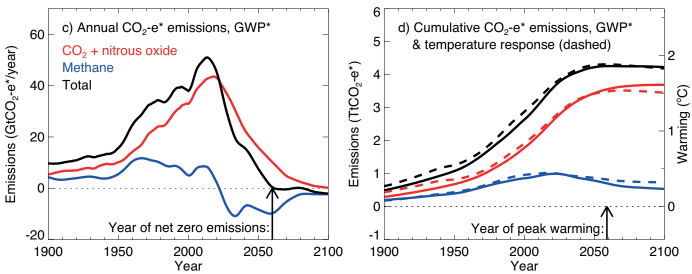


Figure c shows annual emissions in CO_2-e* under RCP2.6, with asterisks denoting this new usage. Emissions of CO_2 and nitrous oxide are unchanged, because they are not short-lived, but annual methane CO_2-e* emissions now track the rate of change of methane emissions, and hence become negative when methane emissions are falling. Total CO_2-e* emissions reach net zero in 2060. Figure d shows that cumulative CO_2-e* emissions closely track the temperature response to both individual and aggregate emissions. Temperature peaks when net annual CO_2-e* emissions reach zero, at a level determined by cumulative CO_2-e* emissions up to that date multiplied by the TCRE.

Summary

Many pollutants affect climate, including long-lived, or cumulative, pollutants such as CO_2 and nitrous oxide, and short-lived pollutants such as methane and aerosols. The method used to calculate aggregate total emissions is especially important under ambitious mitigation for two reasons:

- the relative importance of non-CO_2 pollutants increases as CO_2 emissions decline
- differences in temperature responses to cumulative and short-lived pollutants become more pronounced when emissions are falling (see box on page 2).

In this Programme Briefing, we show that the conventional Global Warming Potential (GWP) can be misleading, particularly under ambitious mitigation. A revised usage of GWP, denoted GWP*, which uses the same metric values but interpreted in a new way, provides a much more accurate indication of the net impact of all pollutants on global temperature over a broad range of timescales, and hence a better fit-for-purpose for monitoring progress to a long-term temperature goal.

Further reading:

For a more detailed treatment of metrics and SLCPs, see: Short Lived Promise? briefing paper by Myles Allen: http://www.oxfordmartin.ox.ac.uk/publications/view/1960

For a more detailed treatment of concepts in this briefing paper, see: Allen, M. R., Fuglestvedt, J. S., Shine, K. P., Reisinger, A., Pierrehumbert, R. T., & Forster, P. M. (2016). New use of global warming potentials to compare cumulative and short-lived climate pollutants. Nature Climate Change, 6(8), 773–776. http://doi.org/10.1038/nclimate2998

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