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METHANE REDUCTIONS, 'CLIMATE NEUTRALITY', AND CHOOSING THE ADEQUATE METRIC FOR EMISSIONS ACCOUNTING UNDER THE PARIS AGREEMENT

SUMMARY

Achieving the Paris Agreement goal of limiting global warming to 1.5°C requires deep and sustained emission reductions in all greenhouse gases (GHGs) and a balance in emissions and removals resulting in net zero emissions. Frequently, the term "climate neutrality" is used when referring to net zero goals. While the term is ambiguous and can be used in misleading ways, it is best understood as net zero GHGs as by the Paris Agreement. As GHGs differ in how they impact the climate and temperature change, scientists and policymakers use simple accounting measures called metrics to compare and aggregate their effects. In international and national climate policy, the metric must be consistent with the choice that informed the Paris Agreement: the Global Warming Potential over a time horizon of 100 years (GWP100).

This briefing provides an overview of the non-CO2 GHG reductions needed, relevant definitions under the Paris Agreement and issues with the "climate neutrality" concept, as well as the implications of different metrics to relate non-CO2 GHGs to CO2.

Rapid reductions in all greenhouse gases including methane are needed

The latest IPCC Sixth Assessment Report (AR6) of Working Group I (WGI) is clear that "*limiting human-induced global warming to a specific level requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 emissions, along with strong reductions in other greenhouse gas emissions*" (IPCC 2021b). GHGs differ in their effect on the climate, as they remain in the atmosphere for different periods of time and affect temperatures with different magnitudes: Carbon dioxide (CO_2) and nitrous oxide (N_2O) are long-lived GHGs with atmospheric lifetimes of centuries to millennia. Methane (CH_4) is a short-lived GHG that remains in the atmosphere for less than 20 years, but generally causes higher warming (Chen et al. 2021, Forster et al. 2021). Furthermore, changes in short-lived aerosols generally contribute to cooling and partly mask the warming effect of GHGs (IPCC, 2021b).

The latest AR6 WGI report also states that "*[s]trong, rapid and sustained reductions in CH_4 emissions would also limit the warming effect resulting from declining aerosol pollution and would improve air quality*" (IPCC 2021b). In the context of stringent mitigation pathways coming not only with declining methane but also declining aerosol emissions, the resulting reduced cooling effect from aerosols would be compensated by the reduced warming from CH_4. Both aerosols and methane are short-lived climate forcers. These reductions in short-lived climate forcers as a whole would therefore not lead to a net cooling.

The Paris Agreement temperature and mitigation goals and "climate neutrality"

The Paris Agreement establishes "*[h]olding the increase in the global average temperature to well below 2°C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels*" as its long-term temperature goal (LTTG) in its Article 2.1(a) (UNFCCC

2015). The LTTG does not specify whether a constant level (i.e. a stabilisation) of temperatures would be sufficient to significantly reduce climate risks and impacts or whether a decline would be required (Schleussner et al. 2019).

Article 4.1 of the Paris Agreement then goes on to establish "*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*" to achieve the LTTG as the mitigation goal (UNFCCC 2015). Whilst the LTTG sets the objective of the Paris Agreement and establishes 1.5°C as the long-term warming limit, Article 4.1 is designed to operationalise this goal in terms of a global emissions pathway based upon the best available science. The elements of the Mitigation Goal are to peak emissions as soon as possible, rapidly reduce thereafter and achieve net zero greenhouse gas emissions in the second half of the century. The timing and rate of reductions are to be achieved based on the best available science consistent with meeting the LTTG. While the statement on "balance" leaves room for interpretation, it is generally understood as achieving "net zero" GHG emissions (Fuglestvedt et al. 2018).

In addition to "net zero", the concept "climate neutrality" is sometimes used in the context of qualifying required GHG emission reductions. If applied as a "concept of a state in which human activities result in no net effect on the climate system" it is however ambiguous and scientifically not well defined[1].

If used without the explicit requirement of residual GHG emissions being balanced by emission removals (IPCC, 2018), the term "climate neutrality" may even tolerate a level of ambition that is not in line with the Paris Agreement at all. In such case, it may undermine efforts to stringently reduce emissions of all GHGs – by over-accounting natural emission sinks, for example. Therefore, "climate neutrality" can only be understood as global net zero anthropogenic GHG emissions if it is to be in line with the Paris Agreement. Only this would allow to achieve any long-term temperature target.

Metrics to relate different greenhouse gases

To quantify, compare and aggregate the effect of GHG emissions on climate change, there are simple measures available, called ***metrics***. Metrics can be used to place emissions of different GHGs on a common scale, usually CO_2 as the reference gas, thus expressing emissions as CO_2-equivalents (CO_2-eq) (Chen et al. 2021, Forster et al. 2021).

One of the most commonly used metrics is the Global Warming Potential (GWP) (Chen et al. 2021). GWP measures the climate effect resulting from emissions of a given GHG over a chosen time horizon, relative to the effect of emissions of the reference gas CO_2 (Chen et al. 2021, IPCC 2021a). As GHGs differ in how long they stay in the atmosphere, the choice of time horizon can strongly influence the metric value (Forster et al. 2021) and reflects a value judgement with respect to short- and long-term priorities of mitigation and warming targets. For example, fossil CH_4 has a lifetime of around 12 years and a GWP of around 30 over a time horizon of 100 years (GWP100), and a GWP of more than 80 over a much shorter period of 20 years (GWP20) (Forster et al. 2021).

A newer development is metrics that compare a sustained change in the rate of emission of a short-lived GHG like CH_4, to one-off emission of CO_2, for example the metric GWP* (Chen et al. 2021). These metrics make use of the fact that the climate effect of these sustained changes is more comparable to that of one-off emission of the long-lived CO_2 (Forster et al. 2021).

[1] https://climateanalytics.org/media/climate_neutrality.pdf

There is no recommended metric from a physical science perspective, as the choice depends on the purpose of application. The Paris Agreement itself allows for different interpretations with regard to the appropriate choice of metric (Forster et al. 2021). In practice, however, in the Paris Agreement Rulebook countries agreed to use GWP100 from the IPCC Fifth Assessment Report to report aggregate GHG emissions and removals, in Decision 18/CMA.1:

> *"Each Party shall use the 100-year time-horizon global warming potential (GWP) values from the IPCC Fifth Assessment Report, or 100-year time-horizon GWP values from a subsequent IPCC assessment report as agreed upon by the CMA, to report aggregate emissions and removals of GHGs, expressed in CO_2 eq. Each Party may in addition also use other metrics (e.g. global temperature potential) to report supplemental information on aggregate emissions and removals of GHGs, expressed in CO_2 eq. In such cases, the Party shall provide in the national inventory document information on the values of the metrics used and the IPCC assessment report they were sourced from."* (UNFCCC 2018)

While the choice of emission metric does not determine the physical temperature response, it does affect the timing of net zero GHG emissions (see Figure 1) as well as temperatures after the point in time when net zero is reached (IPCC 2021b).

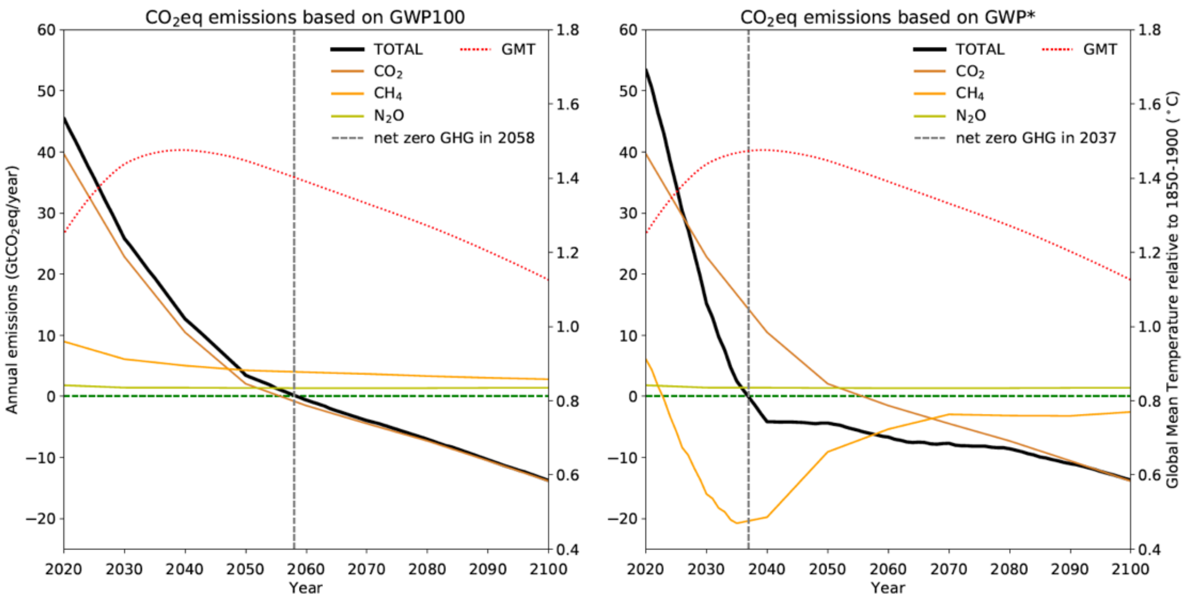

Figure 1: *CO_2-equivalent emissions based on GHG accounting under the Paris Agreement GWP100 (left panel) and using the GWP* metric (right panel) under the same illustrative greenhouse gas (GHG) emissions scenario designed to be consistent with the Paris Agreement. Respective net zero dates are indicated by dashed vertical line. Central estimate for global mean Temperature (GMT) relative to pre-industrial (1850-1900) as red dots.*

Due to the different treatment of short-lived GHGs between metrics, limiting warming to 1.5°C under GWP* would result in reaching net zero CO_2-eq emissions before 2050. Reaching net zero only around 2050 under GWP* would consequently lead to warming above 1.5°C. This is in contrast with achieving net zero under GWP100 around 2050, which would lead to limiting warming to close to 1.5°C (Schleussner et al. 2019) and declining temperatures thereafter. Using GWP* would lead to stabilising temperatures only (Forster et al. 2021). A stabilisation above 1.5°C would however not be in line with the Paris Agreement.

The GWP* allows to capture the direct and near-term temperature outcome of short-lived GHG emissions more accurately than GWP100, which represents a paradigm shift away from the focus on emissions. However, it comes with great risks when brought into the policy context:

When applied on any other but the global level, the metric choice has implications for equity and fairness between developed and developing countries – an explicit component of the Paris Agreement Article 4. GWP* does not account for past emissions. Therefore, applying it e.g. in the national context or to individual actors would benefit those with high historical emissions and put those with low historical emissions, like many developing countries, at a disadvantage (Rogelj and Schleussner 2019). Furthermore, as outlined above, applying GWP* would make net zero targets to limit warming to 1.5°C as set out in the Paris Agreement Articles 2 and 4 meaningless.

In short, it is crucial that the choice of metric for the international climate policy sphere under the UNFCCC is consistent with the Paris Agreement LTTG and mitigation goal, which GWP100 can deliver but GWP* cannot (Schleussner et al. 2019).

Regardless of the metric used, strong and sustained reductions in all GHGs including short-lived GHGs such as CH_4 are required in this and the coming decades to ensure reaching net zero CO_2 around mid-century and net zero GHGs shortly thereafter. It is the only way to limit and eventually reverse temperature increase and significantly reduce the risks and impacts of climate change as stipulated in the Paris Agreement.

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