Written evidence from Oxford Net Zero (MET0041)

Question 11: What are the advantages and disadvantages of available metrics used to report and compare methane emissions?

Summary points

- There is broad agreement among scientists working on metrics that separate accounting for long-lived (e.g., CO2) and short-lived (e.g., methane) greenhouse gases will support clarity, transparency and understanding of mitigation plans and outcomes *(section I)*

- GWP100 is the most widely used metric and therefore provides consistency of comparison across different reports *(II)*

- GWP100 does not reflect how much methane emissions raise or lower global warming levels and can lead to perverse incentives or ambiguity in temperature outcomes if aggregating and offsetting using GWP100 for methane *(III)*

- Warming-equivalent metrics reflect the additional warming or cooling that follows a change in methane emissions *(IV)* and so can be used to evaluate impacts of different mitigation options *(VI).* GWP* is the simplest warming-equivalent metric.

- GWP* could be used to allow 'grandfathering' of emissions to historically high emitters, and penalise historically low emitters *(V)*

- Methane emissions reductions in the UK could be incentivised by introducing a penalty if UK methane causes additional warming (i.e., if country level methane emissions do not achieve 0.3% reductions year-on-year). Potentially, if reductions are faster than this, then a type of credit system could be devised to reward methane reductions. *(VI)*

I. Overview of Greenhouse Gas Metrics

Greenhouse gases (GHGs) differ in terms of their effect on the atmosphere's net energy budget and the number of years before they break down and therefore cease causing warming. Most metrics equate one GHG to another based on the relative value of some characteristic such as radiative forcing or temperature impact over a chosen time horizon. These metrics which consider a uniform time horizon across all GHGs are called 'stock metrics' because they are based on the 'stock' of emissions each year multiplied by a coefficient to convert the quantity into CO2-equivalents.

In recent years, scientists (including ourselves) have argued that equating long- and short lived GHGs on a common time horizon distorts their relative near-term impacts, thereby incentivising mitigation actions which may not be aligned with the goal to limit anthropogenic global warming. For this reason, there is agreement among the 33 authors of Allen et al. (2022) that short- and long-lived GHGs should be reported separately, and FAO (2023) recommend that GHGs are reported separately wherever possible. The proposed solution is to use 'warmingequivalent' methods which consider the rate-of-change (or flow) of short-lived pollutants rather than the stock. **This memo will provide an explanation of the key debates surrounding 'stock' and 'warming-equivalent' metrics in the context of the agriculture sector as an answer to Q11 and will offer a novel solution to reconcile the debate at a national level.**[1]

II. Advantages of Stock Metrics

The most common stock metric is Global Warming Potential on a 100-year time horizon (GWP100). GWP100 compares the radiative forcing of a pulse of a non-CO2 GHG integrated over 100 years to that of CO2. This calculation produces a single coefficient which can then be multiplied to annual rates of emissions. GWP is sometimes reported over 20 or 500-year time horizons. For the sake of this memo, we will focus only on GWP100 because it is most widely used and the disadvantages of GWP100 are common to all stock metrics.

The need to understand corporate and national contributions to climate change and interpret progress of mitigation across both time and space is paramount. The conventionalisation of GWP100 allows companies and countries alike to set targets which include all relevant GHGs and track their progress over time. The primary advantage of GWP100 is therefore that it provides a straightforward mechanism to compare, track, and report the total impact of CO2 and non-CO2 GHGs in a common unit.

Using GWP100, a tonne of CO2 only has the same warming impact as one tonne CO2equivalent of methane 40 years after the emission; the CO2 has less warming than the methane up to 40 years, and more warming after (Allen et al., 2016). While this may be a useful value to use, it's important to be aware of what it means (or does not mean) when using it to devise mitigation strategies.

III. Disadvantages of Stock Metrics

As mentioned in Section I, there is consensus that short-lived GHGs should be reported and targeted separately to long-lived because they affect climate differently. If the global objective as defined by the Paris Agreement is to avoid 1.5

[1] Note that 'stock' metrics are sometimes called 'pulse' metrics, such as in FAO (2023). 'Warming-equivalent' are the same as 'flow' metrics or 'step-pulse' metrics.

or 2 degrees C of warming, the use of stock metrics without separate reporting could incentivise the development of mitigation strategies which are not aligned with avoiding this temperature ceiling (Allen et al., 2021). This is because stock metrics allow for the ‘trading’ of long- and short-lived pollutants without acknowledging the timeframe during which they contribute to warming.

Take, for example, a company which emits both methane and carbon dioxide with a target to reduce emissions by 50% by 2030 and achieve net-zero GHGs by 2050. The use of stock metrics would hypothetically allow that company to meet their 2030 target by focusing on methane mitigation (which is valued at 28 tonnes of CO2 per tonne) while not reducing CO2 at all. This is problematic because methane persists only for a few decades while CO2 persists for millennia.

Figure 1 shows several scenarios which have the same total CO2-e emissions over time (left panel), which all have different temperature outcomes (right panel). This comes about because each coloured line shows a different mix of GHGs. If all emissions were methane (yellow), there is a higher peak temperature but a lower end point temperature, compared to CO2 (blue). That all of these temperature outcomes are from the same CO2-equivalent emissions shows why aggregating using GWP100 can cause ambiguity and could result in mitigation strategies which do not appropriately prioritise the mitigation of CO2.

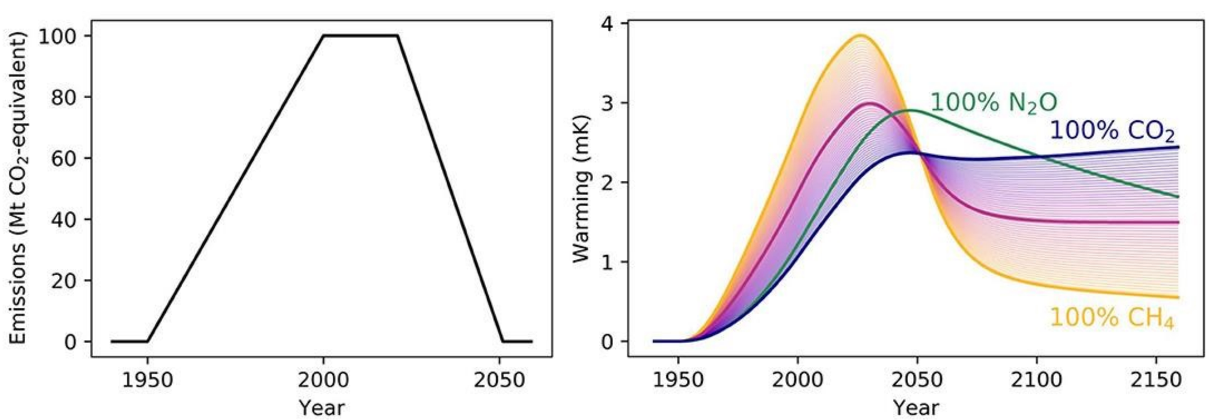

Figure 1: Reproduced from Lynch et al., 2021. A single emissions pathway (left) reported as CO2-equivalents using the 100-year Global Warming Potential (GWP100) can have very different impacts (right) depending on the gas-specific composition, illustrated by showing the warming contribution if the CO2-equivalent emissions are entirely nitrous oxide (green), entirely carbon dioxide (blue), entirely methane (orange), or various combinations of carbon dioxide and methane (blue-to-orange spectrum; 50% methane, 50% CO2 shown as stronger purple line).

Even if this hypothetical company reaches their 2030 target through methane reductions alone, they still must develop a strategy to achieve net zero. Unless they have fully eliminated methane emissions from their supply chain, any remaining emissions will have to be 'offset' somehow, and using GWP100 would result in ambiguous warming effects dependent on how much each gas is mitigated (Allen et al. 2021). Just as it is inappropriate to trade reductions in methane for emissions of CO2, it is equally as wrong to trade removals of CO2 for emissions of methane. For a further discussion of the principle of 'like-for-like' offsetting, refer to the Oxford Offsetting Principles' latest guidance (Axelsson et al. 2024). As a response to criticisms about the mischaracterisation of methane under GWP100, some have proposed the dual reporting of GWP100 and GWP20 (IGSD 2024). While GWP20 more accurately reflects the significant nearterm impact of methane, it nevertheless categorises methane as a cumulative GHG, which is inaccurate and exacerbates the discrepancies present in GWP100 if offsetting is used to achieve net zero emissions (Allen et al. 2021).

As GWP100 does not capture equivalence based on how much an emission warms the climate, this has implications for the outcomes of scenarios to reach net zero emissions. For example, the Committee on Climate Change scenario for reaching net zero in 2050 causes a peak and decline in the UK's contribution to global warming (CCC, 2019). This is a consequence of using GWP100, as continued methane emissions are offset by CO2 removals in the scenario using GWP100. The CO2 removal causes more cooling than the methane emissions do warming. The CCC performed climate modelling to show this, which demonstrates the necessity of using methods to explore the warming outcomes. This outcome would not be clear if only GWP100 based emissions were analysed. Indeed, if the aggregated CO2-e scenario is achieved using different methane cuts, then the temperature change would be different.

The IPCC clarifies that moving away from GWP100 should not be interpreted as a license to continue emitting methane. The IPCC's Sixth Assessment Report contains the following statement:

> *"By comparison expressing methane emissions as CO2 equivalent emissions using GWP-100 overstates the effect of constant methane emissions on global surface temperature by a factor of 3–4), while understating the effect of any new methane emission source by a factor of 4–5 over the 20 years following the introduction of the new source."(Forster et al., 2021)*

In other words, GWP100 does not accurately represent the magnitude of warming caused by an increase in methane emissions. If the global target is to avoid catastrophic warming and reach peak warming as soon as possible, it is crucial that we consider the effect that emissions and decisions today have on warming in the future.

IV. Advantages of Warming-equivalent Metrics

It is well-understood that anthropogenic warming is proportional to the cumulative emissions of long-lived GHGs and the rate-of-change of short-lived GHGs. In 2016, a group of scientists published the first version of GWP* (M. R. Allen et al. 2016) which introduced a flow-based method to account for the short-lived characteristics of methane and other non-cumulative GHGs. The formula looks at the rate-of-change of methane over a sliding 20-year window to equate emissions more directly with warming, resulting in 'warming-equivalent emissions.' A series of papers build on the original idea (M. R. Allen et al. 2016; 2018; Cain et al. 2019; Smith, Cain, and Allen 2021), to give a formula which reflects the impact of emissions today on temperatures in the future more accurately than stock metrics.[2] Thus, if used properly, we argue that this approach is a more helpful framework to inform mitigation decision-making to limit global warming. Emissions calculated using GWP* are termed 'CO2-warming-equivalent' to distinguish them from stock methods of CO2-equivalence. A lay explanation of GWP* and its advantages can be found in a briefing note by Allen et al., 2022b.

V. Disadvantages of Warming-equivalent Metrics

Since its inception, GWP* has been subject to a number of criticisms, and we use this section to discuss key points.

The use of GWP* at the sub-global level can incentivise the offshoring of methane emissions if one farm or country seeks to exploit the temporary 'cooling' effect which results from a negative rate-of-change of methane emissions by reducing their number of cattle. Without accompanying shifts in diets, this would simply result in increased methane emissions from a different farm or country to make up for the lost food production, and the contribution to warming (as well as pressures driving deforestation (Searchinger et al. 2019)) globally would not improve. Thus, the boundary of the farm and indeed the nation becomes hazy given the globalisation of the livestock industry and the UK's already-large offshore land and climate footprint from imported food. This is, however, an issue when any methane emissions are incentivised, no matter what the metric.

From a practical perspective, the data requirements to calculate warming-equivalent emissions may be an obstacle, as emissions data must be disaggregated by GHG, and short-lived emissions 20 years earlier are needed. While this is straightforward to obtain at the global (and sometimes country) level, this granularity of data is often not available at the farm-level. In Section VI, we propose a solution which focuses on *future,* rather than historical, trends. The 20year window should be seen as a way of capturing recent and future rate-of-change, which is what matters, rather than instantaneous value 20 years ago.

[2] See Smith, Cain and Allen (2021) for the most up to date equation which is cited in the IPCC's Sixth Assessment Report (Forster et al., 2021), showing that it reproduces historical temperatures more accurately than stock metrics.

It must be noted that reductions in methane emissions only equate to cooling so long as the rate-of-change of methane is negative. Because methane emissions cannot decline in perpetuity (either the maximum mitigation potential is met or methane emissions reach zero), this cooling effect is short-lived.

GWP* has been criticised for its dependence on a historical base year, which could be arbitrarily chosen to make the emitter look more favourable so long as methane emissions are not increasing (Cusworth et al. 2023; Carter and Urbancic 2023). For example, a developed country with stable methane emissions could choose a more recent base year and show they are no longer be contributing to warming (so long as emissions decrease by at least 0.3% per year), although they contributed to warming in the past. This has been characterised as 'grandfathering-in' historical methane emissions. On the other hand, developing countries whose methane emissions are increasing are more heavily penalised under GWP* in comparison to stock metrics over a longer time horizon. This contrast brings about valid questions of equitability in terms of who is responsible to reduce emissions, and at what spatial scale mitigation strategies should be considered. We believe GWP* opens up an opportunity to explore these questions based on both climate science and socio-political considerations.

In a recent report for Beef + Lamb New Zealand (Barth et al. 2023), in which we explore the concept of a 'fair share' of mitigating contribution to warming, we describe a 'methane opportunity cost' which suggests that, while constant rates of methane emissions do not contribute to *further* warming, the planet would be cooler (for the next 20 years) if those emissions did not exist today. In other words, constant methane emissions 'hold up' temperatures higher than in their absence. In Section VI we will explore how, while the absolute impact on global warming of a farm or country may be ambiguous, this shouldn't prevent the projection of the impact on warming of an intervention or activity.

Some authors who have published on the potential problems with using GWP* (Rogelj and Schleussner 2019; Carter and Urbancic 2023) still see the value in using a warming-equivalent emissions accounting framework, as they have done so in their own pursuits to accurately convey the warming impact of emissions. A pre-printed article led by Rogelj proposes warmingbased allocation of climate mitigation responsibility using GWP* (Rogelj et al. 2024).

Additionally, the report, 'Seeing Stars', while criticising GWP*, proposes a flow-based method using GWP20 and the rate-of-change of methane over a 40-year time horizon which performs a similar function of warming equivalence to GWP* itself, just formulated slightly differently.

VI. A Path Forward

One representation of GWP* in the media is that it represents a 'get-out-of-jail' pass for livestock farmers in developed nations (Place, McCabe, and Mitloehner

2022; B+LNZ 2021), though for the reasons stated in the previous section, we find that this is a misrepresentation of the metric. However, given this reputation, it has attracted interest within the livestock industry. As such, farm emissions calculators have begun to implement GWP*, causing significant confusion because of the 20-year historical data requirement, which could be avoided entirely. What matters for the impact of farms on future temperatures is the current rate of emissions and how is it changing over time based on projected trends. If a farmer happens to have had a good year 20 years ago, making it appear their emissions have fallen, but they're planning to expand their operations, their 20-year historical trend is neither here nor there. Thus, we propose an alternative focus on forward rate of change.

We propose that, for the entire UK livestock sector, we establish a methane-specific target informed by warming impact, alongside existing net-zero targets for long-lived emissions. This would involve a threshold of constant methane reductions of 0.3% per year. If the sector fails to stay below the threshold, a 'super-levy' would be triggered causing all UK agricultural methane emissions to be valued according to their warming impact. This much higher value for methane could be used in farm carbon calculators and other sectoral data. This provides a significant penalty for warming but avoids anomalous results at the individual farm level which might arise through farm consolidation because the methane value is set at a national level.

If the sector were to achieve constant methane reductions of 0.3% per year the value of methane in such calculators and the wider supply chain, potentially including Scope 3 and the National Inventory, would be zero. If individual farm/producers were to significantly surpass this threshold through the adoption of known methane reducing practices/technologies (for example certified feed additives) it may be justifiable to devise some kind of methane credit/payment/grant which incentivises the development and adoption of such technology/practices

One stipulation of this incentive would be that farmers must focus on specific interventions which are known to reduce methane emissions *per kilogram of food,* rather than meeting targets simply by reducing output. Given the wide acceptance of split-gas reporting and the growing acknowledgement of the value of warming-based reporting, we conclude that actualising predetermined global outcomes matters more than the metric chosen to track progress towards those outcomes. Thus, accounting and reporting frameworks should be designed to incentivise progress towards the intended outcome as opposed to the other way around.

VII. Oxford Net Zero and Authors

Oxford Net Zero (ONZ) is an initiative within Oxford University which publishes academic research and policy guidance relating to emissions accounting, climate change mitigation, and what it means to achieve 'net zero.' Myles Allen, one of ONZ's three Principal Investigators, developed the metric known as GWP* as a mechanism to account for the fact that methane persists on a decadal time horizon in the atmosphere, whereas carbon dioxide persists for many centuries (or millennia). Michelle Cain worked with Professor Allen as a Senior Researcher and is now a Senior Lecturer at Cranfield University and UKRI Future Leaders Fellow, specialising in research on short-lived climate pollutants. Jessica Zionts is a Doctoral Student at Oxford University working under Professor Allen on the implications of metric selection as it relates to mitigation strategies in the UK's livestock sector. Andrew Loftus is a farmer in North Yorkshire, sits on the NFU National Livestock Board, and chairs the Beef and Lamb Net Zero Roadmap supported by AHDB.

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