The implications of alternative warming metrics for national climate targets

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Abstract

Commonly-used greenhouse gas (GHG) accounting metrics do not correctly compare the relative warming impacts of short-lived gases, like methane, and long-lived gases, like carbon dioxide (CO_2). A new metric which corrects this shortcoming, GWP* (GWP-star), has been the subject of recent debate in the literature and has raised interest in policymakers. However, it has to date not been demonstrated for application to national GHG target-setting. Here we explore the implications of using GWP* in Ireland, which is the fourth highest per-capita emitter of agricultural methane globally and to date a "climate laggard". The government plans an acceleration in GHG mitigation efforts, setting the target of halving GHGs within the next decade, while also increasing agricultural outputs, particularly in dairy and beef production, while seeking to acknowledge the distinctive warming characteristics of biogenic methane. We examine the feasibility and consistency of these targets under GWP*. We find that with rising methane emissions, CO_2 emissions would need to fall to zero by 2030 to offset

the warming impact under GWP*. Furthermore, the incumbent metric under-represents the powerful mitigation lever that reducing methane emissions presents, leading to sub-optimal mitigation pathways. Finally, the mitigation pathways required for CO_2 under the incumbent and newly proposed metric are dramatically different, therefore scientific and global policy consensus is needed on GWP* before it can be practically applied at a national level.

Main text

With the urgency of limiting climate change and meeting the goals of the Paris Agreement, countries are setting more ambitious greenhouse-gas (GHG) abatement targets, and increasingly 'net-zero' emissions targets. These 'climate neutral' targets meet Article 4 of the Paris Agreement, which is to meet "*a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century*"[1].

Recently, studies have questioned the interpretation of Article 4 in the context of short-lived GHGs, including methane, highlighting the need for clarification to make this target operational within national climate frameworks[2]. A new metric, named GWP* (Gross Warming Potential, or GWP-star), has been developed to better compare the warming impact from methane and carbon-dioxide (CO_2)[3–5]. However, scientific debate remains on its consistency and equity when applied at the national level[6,7] and this study is the first to demonstrate its application to a concrete national case study.

The incumbent metric, GWP_{100}, calculates the 'CO_2-equivalence' (CO_2e) of non-CO_2 GHGs on the basis of difference in the integrated change in radiative forcing over 100 years following an emission pulse, relative to the same emissions of CO_2. GWP_{100} has been formally adopted in international climate policy and is the *de facto* standard for expressing GHG emissions, and the legal standard for national emissions accounts, scientific literature and in policy targets. However, despite its widespread use, GWP_{100} does not accurately reflect the relative warming impact of different GHGs, in particular the difference between long-lived gases, such as CO_2, which cumulates in the atmosphere for centuries, and short-lived gases, namely methane, which break down in the atmosphere within decades. This has raised questions about the consistency between the Paris Agreement Article 4 'climate neutrality' target and the Article 2 temperature stabilisation target when applied to methane emissions[2].

GWP* has been the subject of increasing interest in the scientific literature to addresses the shortcomings of GWP_{100}[2–7]. It relates the warming impact of a short-term change in methane emissions to the cumulative warming impact of CO_2 emissions in a way which reflects the warming impact of each gas, calculating the "warming equivalent" CO_2 for a given methane trend (CO_2-we). This metric is far more sensitive to the rate of change of methane, with even small absolute increases in the gas leading to a large warming impact relative to CO_2, and conversely, a small decline in methane equivalent to net-negative CO_2 emissions[5].

This paper illustrates the need for clarification on the warming attribution of methane and the interpretation of Article 4. Ireland, an important case study, has a large share of methane emissions from agriculture, and increasing GHG mitigation ambition. Furthermore, GWP* has achieved significant national attention as a means of setting a mitigation targets, an approach this paper explores.

Ireland has historically been a "climate laggard" in Europe and will fail to meet Effort Sharing Targets set by the European Union for 2020[8]. The government is currently developing legislation which will go beyond the EU's 2030 target and set into a law a rapid near-term decarbonisation target of halving GHG emissions by 2030 and a net-zero target by 2050, using five-year carbon budgets[9].

Agriculture in Ireland is responsible for substantial air, water and land-based pollution and environmental pressures, driven by the rapid expansion of activity and intensity, mainly ruminant dairy, beef and sheep[8]. Consequently, methane from agriculture represented 20% of total GHGs in 2018, the fourth-highest per-capita emissions in the world [*S1*], and by far the greatest share of any country in the EU, where the value averages 5% [*S2*].

Methane emissions have been growing since 2011 given the abolition of milk quotas in the EU. Ireland's climate is particularly suitable for grass-based livestock production. The agro-food industry is responsible for 7.7% of employment and 10% of exports, and 68% of the land are is used for agriculture, therefore the sector is very significant for the society, culture and the landscape as well as the economy.

Crucially, the government and industry strategy for agriculture is for continued growth and expansion and to promote the exports and image of Irish beef and dairy products abroad[10,11]. Recent draft legislation, which sets forth steps of setting 5-year carbon budgets, would require three factors related to agriculture to be considered when setting sectoral targets: i) the special economic and social role of agriculture; ii) the distinct characteristics of biogenic methane, and iii) the risk of carbon leakage[9].

These provisions could be taken together to argue for lower mitigation ambition in agriculture, requiring a greater mitigation effort from fossil fuels and land-use change, and that the short-lived but strong warming impact of methane emissions should be considered.

This analysis challenges whether this is consistent with national climate mitigation ambition.

Fig. 1 illustrates how the 2030 mitigation objective could be met. The required trajectory for CO_2 to meet the overall target (halving GHGs over 2020-30) is calculated under three trajectories for agricultural methane and two metrics, GWP100 and GWP*. In the first scenario, agricultural methane rises at 1.8% annually, the trend between 2011-18. The second scenario reflects one government proposal for stabilising methane emissions[11]. The third scenario reflects national projections for agricultural methane under "With Additional Measures" for mitigation[12].

Fig. 1 illustrates the findings from the six cases.

When volumetric methane is rising at the rate of 1.8% per annum, its warming-equivalent (using GWP*) rises 17.6% per annum. Given that GWP* is calculated on the basis of the growth of methane over a 20-year period, this also captures the impact of the growing emissions in the 2010s. CO_2 emissions need to fall to zero to meet the overall target under the GWP* methodology. A reduction of 13.2% per annum is needed annually under the GWP_{100} method (Fig. 1, 1(a) and 2(a)).

Where absolute CH_4 emissions are constant, CO_2 emissions need to fall by 12% per annum under GWP* and 11% per annum under GWP_{100} to meet the overall target (Fig 1, 1(b) and 2(b)).

When CH_4 emissions fall according to the EPA "With Additional Measures" scenario at 1.4% per annum, CO_2 emissions need to fall by 7% per annum under GWP* and 10% per annum under GWP_{100} ((Fig 1, 1(c) and 2(c)).

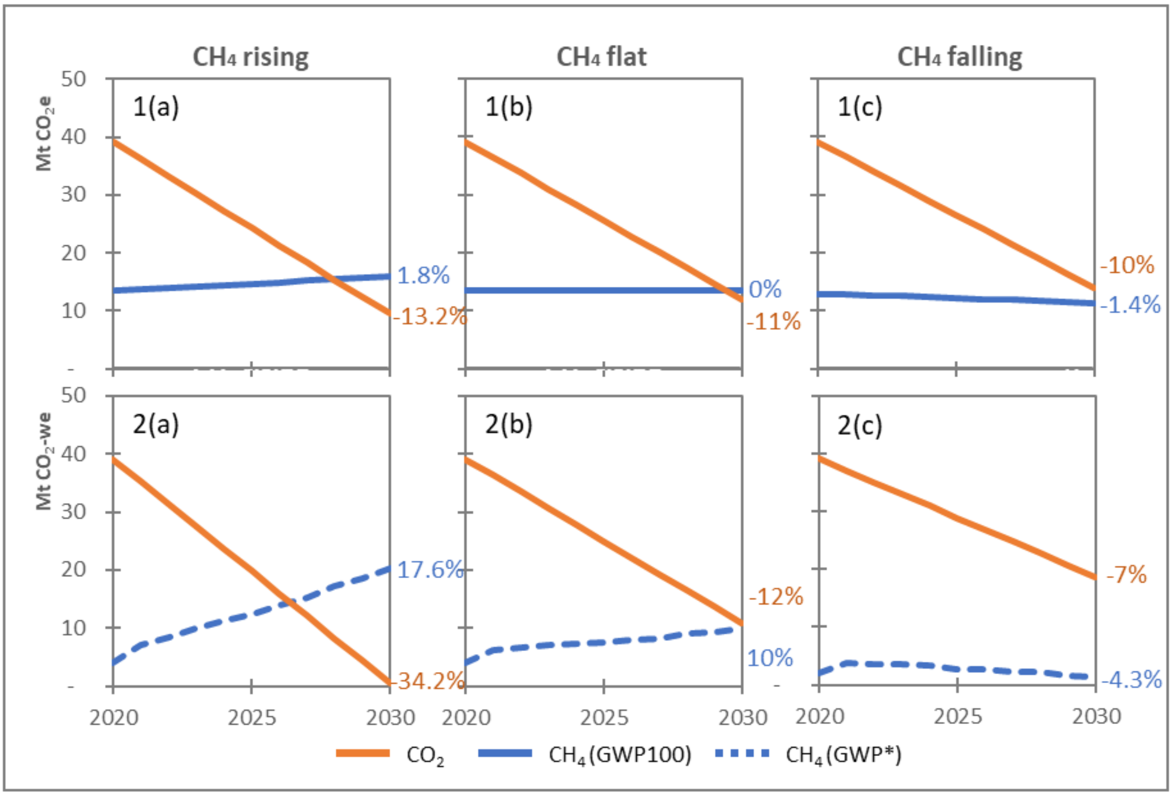

Figure 1: Illustrative scenarios for energy-related CO_2 emissions and agricultural methane (CH_4) emissions which would meet the Irish target of overall emissions falling by 50% between 2020-30, given two accounting frameworks – the current accounting framework, GWP100 (top panel) and a new framework equating the warming equivalence of the gases, GWP* (bottom panel). Percentage labels indicate the compound average annual growth rate of the gas over the decade.

The GWP* metric has been used by the Irish farming industry to argue for more lenient targets applied to agriculture, and that the existing metric is "unfair and inefficient" for Ireland[13].

This analysis introduces more nuance to the debate, considering the implications of this metric where methane emissions are rising.

This analysis shines a light on how countries might set relative abatement targets for biogenic methane. GWP_{100} and GWP* lead to significantly different implications when setting targets for different GHGs; this difference is exacerbated with an increasing share of methane in national accounts. GWP* cannot be applied to set national policies without scientific consensus and alignment between national, EU and global rules, yet problems with GWP_{100} remain. Furthermore, GWP* not yet been demonstrated for single-year emissions or carbon footprint analysis, therefore is limited in its ability to compare CO_2 and methane impacts. Also, applying GWP* to constant methane results in low emissions-equivalent, which is often incorrectly interpreted as stabilised methane having no warming impact.

Biogenic methane reductions are a very powerful lever to reduce global warming. Fig. 2(c) shows that under GWP*, falling methane would take pressure off CO_2 abatement. Indeed, global agricultural methane emissions need to fall by 24-47% by mid-century in modelled pathways which limit global warming to 1.5°C with no or limited overshoot[14]. However, the powerful potential of this mitigation lever is not reflected with GWP_{100} and therefore not incentivised under national and EU GHG accounting frameworks, and furthermore Ireland could not meet its 2030 EU targets with the 2(c) scenario.

Any risk of an increasing methane emissions trend, is a credible outcome of the national position on agriculture, seriously undermines Ireland's goal to stabilise its warming impact. Offsetting rising methane with CO_2 reductions would require CO_2 to fall to zero, which is likely infeasible. Any lower ambition for methane would increase the mitigation cost in transport, heat and electricity, raising concerns about the fairness of protecting one industry in the interest in serving the global appetite for beef and dairy. Therefore methane and CO_2

are not directly fungible – permanently increasing carbon sinks would be needed to offset rising methane, while land-use is currently a carbon source in Ireland.

Draft climate legislation suggests that sectoral targets should be set considering the potential for carbon leakage, reflecting the frequent assertion that reducing Irish dairy and beef exports would lead to increased global consumption of food from more emissions-intensive systems. However, the scientific evidence on carbon leakage is weak[10]. Furthermore, a growing global diet based on ruminant agriculture is not consistent with the goals of the Paris Agreement[15]. Global atmospheric methane has been growing very strongly since 2014, a concerning trend requiring urgent action[16,17].

Prospects for offsetting rising agricultural activity through efficiency improvements in, for example, manure spreading, low fertiliser use and on-farm fossil fuel use[18] would need to directly tackle biogenic methane from enteric fermentation, for which there are currently no proven, cost-effective techniques. Therefore, it is very likely that the two national objectives of meaningful climate mitigation while increasing agricultural activity are contradictory.

GWP* has the potential to be a useful metric for policymakers to take into account methane's distinctive warming characteristics, however operationalising it remains very challenging given the differences with the existing accounting system. Scientific consensus and international harmonisation are necessary before it can be used by countries. Finally, GWP* is not a "get out of jail free card" for agriculture: the global food system is far from consistent with the goals of the Paris Agreement, an issue of the utmost urgency.

Methods

Each scenario meets the Irish Programme for Government (PfG) target of reducing GHG emissions by 50% by 2030. A base year of 2020 is taken for emissions, which are taken from national projections[12]. Only methane from agriculture and energy-related CO_2 emissions are modelled (79% of GHGs in the inventory in 2018). Three scenarios for volumetric methane emissions are modelled for the 2020-30 period: a) rising at 1.8% per year (the rate between 2011 and 2018), b) constant emissions at the 2018 level and c) falling by 1.4% per year, as per the EPA "With Additional Measures" scenario. The CO_2 warming-equivalence of these scenarios is calculated using Cain (2019)[3]:

$$E_{CO_2we} = \mathrm{GWP}_H \times \left[r \times \frac{\Delta E_{SLCP}}{\Delta t} \times H + s \times E_{\mathrm{SLCP}}\right] \quad (1)$$

Where GWP_H = 28 is the conventional global warming potential for a the short-lived climate pollutant (SLCP) methane over time-horizon H = 100, ΔE_{SLCP} the change in methane emission rate over the preceding Δt = 20 years, E_{SLCP} the methane emissions for that year, and r and s the weights assigned to the rate and stock contributions, respectively, where r = 0.75 and s = 0.25 (see SI for full dataset and calculations).

The CO_2 emissions trajectory needed to meet the PfG target given each methane trajectory under GWP100 and GWP* is calculated as the residual.

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