

# Reply to Comment on: ‘Unintentional unfairness when applying new greenhouse gas emissions metrics at country level’

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*Reply to a comment by Cain et al. (1) with the title “Comment on: ‘Unintentional unfairness when applying new greenhouse gas emissions metrics at country level’”.*

A Comment was submitted (1) criticizing a recent paper with the original title of ‘Unintentional unfairness when applying new greenhouse gas emissions metrics at country level’. The original paper (2) presents a critique of and proposes a way forward for some of the ethical implications of applying a GWP\* metric at the country level. Henceforth, this original study (2) is referred to as RS19. The comment by Cain *et al.* (1) is referred to as CCmt. Some of the points in the submitted Comment might contribute to a constructive debate on this topic and warrant further clarification and nuance. A broader debate of the ethical implications of greenhouse gas metrics for inter- and intragenerational justice also continues to be timely. Unfortunately, the submitted Comment contains several statements that are misrepresentations of the original content of RS19. A selection of these misrepresentations is highlighted in this Reply in the hope that their merit, and the comment containing them, can be adequately reconsidered.

At the outset, it is important to outline what indeed *is* and *is not* included in RS19 as the actual scope of the equity discussions in RS19 appears to be misunderstood by CCmt. RS19 provides a scientific critique of the potential ethical implications of applying GWP\*-like metrics at the country level with a focus on non-CO<sub>2</sub> emissions, and particularly methane. RS19 neither discusses equity considerations in relation to (historic) CO<sub>2</sub> emissions, nor does it aim to provide a comprehensive assessment of all ethical implications of the treatment of different greenhouse gases in a common metric. The latter topic merits further exploration and appears to be of major concern to CCmt. However, we do not consider the misrepresentations by CCmt to provide a useful point of departure for this journey.

RS19 establishes that applying GWP\*-like metrics at any but the global level raises questions of how historic and on-going methane emissions in an atmosphere common to all are nationally accounted for in a fair and equitable manner. It further highlights various concepts of equity (burden sharing vs resource sharing (3)) and quantifies five different variants of GWP\* metrics that reflect these concepts in different ways. In particular, several variants keep *global* GWP\* emissions at exactly the same level as would be the case under the original GWP\* formulation, but redistribute (historic and other) reference emissions on a per capita basis to the level of individual countries, therewith exploring various possible interpretations of equity. Furthermore, RS19 also indicates that GWP\* emissions in a given year can vary by an order of magnitude because of methodological choices linked to such equity considerations, highlighting challenges for avoiding loopholes in international emissions trading if GWP\* metrics are applied by countries. Despite giving examples in its scientific critique of equity and fairness issues related to GWP\*, RS19 neither indicates a specific approach to be ethically superior nor does RS19 define what is or isn't fair in the context of a specific country.

A first misrepresentation of RS19 by CCmt is hence its "*principal objection*" that "*it is not up to scientists to determine what is fair based on their own interpretation of the interests of others*". As pointed out above, RS19 provides a scientific critique and five different perspectives that could be considered to account for continuing emissions of short-lived greenhouse gases at a national level. CCmt's "*principal objection*" is thus a straw man misrepresenting RS19.

A second misrepresentation by CCmt is their suggestion that considering equity perspectives for short-lived climate forcer mitigation across countries (as presented in RS19) would imply a value judgement not *“to implement active CO<sub>2</sub> removal”*. As indicated above, RS19 highlights fundamental equity issues linked to the accounting and grandfathering of short-lived (methane) warming when applying GWP\* metrics at the level of single countries. It highlights how contributions can be perceived very differently depending on the method applied by countries to estimate CO<sub>2</sub>-equivalent emissions. This implies neither that CO<sub>2</sub> should not be reduced, nor that it should not be reduced beyond zero. A scientific and policy discourse around equity considerations in relation to CO<sub>2</sub> emissions and the (remaining) carbon budget is indeed well established (e.g. see (4), (5), or (6) and (7)). RS19 references this earlier literature to outline how some issues prevalent in the discourse on equity and CO<sub>2</sub> emissions also apply to non-CO<sub>2</sub> emissions when metrics such as GWP\* are being applied to any but the global level. To conclude and as outlined above, RS19 is not a review paper and hence does not aim to comprehensively discuss all relevant equity considerations regarding the treatment of CO<sub>2</sub> and non-CO<sub>2</sub> gases in a common metric.

However, RS19 does highlight that perceived negative contributions under a grandfathering GWP\* metric could be used by countries to offset or not implement further CO<sub>2</sub> emission reductions. This is a well-established understanding that RS19 and CCmt share, as members of the CCmt author team have earlier written that *“[A] decline [of 24%] in methane emissions [by 2050] would actually generate enough cooling to compensate for the warming generated by all the non-methane greenhouse gases emitted by New Zealand as they approach net zero. [...] [The reductions in New Zealand’s agricultural methane emissions] would offset the warming impact of all the other emissions. New Zealand could declare itself climate neutral almost immediately, well before 2050, and only because farmers were reducing their methane emissions. That’s a free pass to all the other sectors, courtesy of New Zealand’s farmers”* (8). There is thus a clear and acknowledged risk that negative GWP\* contributions that result from reductions of short-lived climate forcer emissions are considered to compensate or as a *“free pass”* for CO<sub>2</sub> emissions in other sectors – a point for which RS19 highlights that it would favour historic high emitters of methane (or other short-lived greenhouse gases) when the grandfathering GWP\* metric is applied. The above quote also provides the precise context in which Cain (8) earlier referred to the cooling effect of

methane reductions. RS19 indicated that such a statement would amount to a misunderstanding or misrepresentation. In making this statement, RS19 had to assume that the physics underlying the framing of the implications for New Zealand would equally apply at the global level – an uncontroversial assumption in our view. When the effects of lowering methane emissions are described exclusively as cooling (both in ref. (8) and by others before), historically accrued annual methane emissions are considered a fait accompli relative to which deviations should be expressed irrespective of the ethical consequences of that choice. Because methane warming is largely the effect of on-going emissions, an equally valid perspective is to describe this evolution merely as ‘less warming’. Both views are valid, and simply reflect different ethical choices about historical responsibility and time horizon. In context of the discussion about these ethical choices presented in RS19, failure to communicate the existence and implications of this choice remains a misrepresentation of the full picture. We thus consider the initial critique by RS19 to remain valid both at the national and the global level.

A third misrepresentation by CCmt is what they refer to as a “*fundamentally flawed assumption*” in making no clear distinction between grandfathering of emissions and grandfathering of warming. CCmt only seems to argue in terms of ethical principles that are pegged to historical warming contributions and between various greenhouse gases, missing the point made by RS19. RS19 highlights equity issues that are pegged to distributive justice as part of on-going emissions of short-lived climate forcers between countries. These equity issues are additional to historical warming considerations from long-lived greenhouse gases. CCmt highlight that it is not evident to them why different ethical standards should be applied to methane and CO<sub>2</sub>, and construct a straw man argument mispresenting RS19 by suggesting that such an approach would be proposed. To be sure, RS19 does not suggest that different ethical standards should be used if similar societal and ethical contexts apply. Different ethical considerations exist, however, and are highlighted in RS19, including considerations of burden-sharing and resource-sharing. Unfortunately, CCmt chose not to engage with the question of distributional justice central to RS19.

Although not a part of the scope of RS19, considerations of the treatment of ongoing emissions from short lived non-CO<sub>2</sub> gases such as methane and long-lived gases such as CO<sub>2</sub>

exist. It is intuitive to understand that different equity implications can be identified for warming caused by multi-decade-old emissions of long-lived greenhouse gases (emitted by a cohort of the global population at a time when climate science was less robustly established or widely understood and no clear low-carbon alternatives were available) compared to ongoing warming of short-lived climate forcers of which the effects and impacts are currently well established and that could be reduced today with available technologies. Reflecting on distributive versus corrective approaches to climate justice can further contribute to this discussion (as has been done earlier for CO<sub>2</sub> (5)). No different ethical standards have hence to be applied for different ethical implications to be applicable, and it is arguably not an error or fundamentally flawed assumption as the comment by CCmt suggests.

There are several further misrepresentations by CCmt, like the suggestion that an error was committed because RS19 failed to state that limitations or unintentional unfairness consequences would not be a characteristic of the metric itself, but of its application at the country level. It is hard to imagine how this could have been misunderstood by CCmt after a diligent reading of the RS19 manuscript. RS19's title is *"Unintentional unfairness when applying new greenhouse gas emissions metrics at country level"* and the *"limitation[s]"* highlighted by RS19 are immediately being followed in the text by a statement that clarifies that *"Applied at the global level they provide clear scientific merit with a more direct link between the representation of CO<sub>2</sub>-equivalent emissions and their warming impact. However, when applied at a national level they all suffer from the same implicit grandfathering bias, [...]"*. Without evidence in support of CCmt's implicit claim that specific policy frameworks would exist in which the application of GWP\* metrics at the country level would not result in unintended fairness consequences, the original statement by RS19 remains a valid and correct reflection of limitations of GWP\*-like metrics.

CCmt also discusses the use of novel metrics in a climate policy context including under the Paris Agreement. Missing out on the fact that the mitigation action architecture of the Paris Agreement encompasses more than just a temperature goal, CCmt claim that *"If a novel metric is more consistent with a particular policy context, then it is less, rather than more, problematic to use it"*. Analysis elsewhere (9) has shown that GWP\* cannot be considered directly *"consistent"* with the Paris Agreement. In fact, that study (9) shows that a plain

application of GWP\* could undermine the integrity of the mitigation architecture of the Agreement with extreme cases even failing to ensure that warming would be halted during this century.

CCmt correctly note that the GWP-100 metric has been agreed as the default greenhouse gas metric for the reporting aggregated national emissions and removals, and this is hence the only metric for which internally consistent information will be made available across all countries under the United Nations Framework Convention on Climate Change's (UNFCCC) Paris Agreement (10). Countries can also choose to apply other metrics to aggregate emissions in the context of their national targets, and hence the important warning that applying GWP\* metrics to national emission targets by countries with historically high methane emissions would lead to the unfairness issues highlighted in RS19. Moreover, applying GWP\* to net zero greenhouse targets as a proxy for the Paris Agreement's Article 4 would undermine the environmental integrity of the Paris Agreement mitigation architecture (9), as highlighted above. To be sure, this entire discussion only really applies to projected emissions reductions of countries as part of their pledged Nationally Determined Contributions (NDCs), which often are expressed in aggregated emissions terms. Historical and current greenhouse gas emissions are reported by countries for each greenhouse gas individually for the past two decades already. Scientifically, this represents the best and most transparent approach, which is also being discussed as part of the transparency guidelines for NDCs.

A last misrepresentation highlighted here is CCmt's example of two countries Alpha and Bravo, which suggests that RS19 implies all mitigation responsibility would fall on the methane producing country Bravo in contrast to Alpha who has only emitted CO<sub>2</sub> in the past and arguably currently has already achieved net zero CO<sub>2</sub> emissions. This example misrepresents the discussion presented in RS19 by suggesting that the equity implications presented in RS19 refer to CO<sub>2</sub> versus methane mitigation. This is incorrect as RS19 focusses primarily on issues related to relative methane mitigation.

An appropriate example for the issues that are identified in RS19 is the following. Imagine three farmers A, B, C who can be called Abraham, Bethany, and Chris – and can be used as analogues for three illustrative countries. Abraham is 21 years old and has ten cows. His

father was a farmer and so was his grandfather. Abraham lives a happy and fulfilled life with his ten cows, and does not want to increase their number. Bethany is also 21 years old and comes from a poorer family that historically was not able to afford cattle. However, through a bank credit she was able to also buy ten cows. Also Bethany is happy with her ten cows, and intends to keep her herd constant at that level. Finally, there is Chris, who is also 21 years old and comes from an established farming family. His father and grandfather had a herd of 20 cows passed down over generations. Chris, however, has decided to downsize and now also keeps a herd of just ten cows. Also Chris is happy. Abraham, Bethany, and Chris thus have exactly the same number of cows, with the only difference between them the number of cows their fathers owned. Following equation (1) in CCmt (published after RS19, but with equivalent implications compared to the older metric description used in RS19) this would nevertheless result in very different GWP\*-based CO<sub>2</sub>-equivalent emissions for each of them over their adult farming lives (here assumed to be from about 21 to 70 years, and assuming that 10 cows emit about 1 tonne of methane per year):

- Abraham, keeping his cows at the level of his father and grandfathers, is assigned 140 and 350 tCO<sub>2</sub>\*-equivalent methane emissions over the first 20 and 50 years, respectively.
- Bethany, who was able to buy 10 cows despite her parents not owning any, is assigned 2240 and 2450 tCO<sub>2</sub>\*-equivalent methane emissions during the first 20 and 50 years, respectively.
- Chris, who kept half of the 20 cows of his father, is assigned negative 1960 and negative 1750 tCO<sub>2</sub>\*-equivalent methane emissions during the first 20 and 50 years, respectively.
- Globally (in this case, simply all three farmers together), methane emissions would be estimated at 420 and 1050 tCO<sub>2</sub>\*-equivalent during the first 20 and 50 years, respectively. The latter global CO<sub>2</sub>\*-equivalent emissions reflect the equivalent global warming impact of the on-going global methane emissions.
- Meanwhile, the dung produced by each farmer's herd was also responsible for several additional tonnes (in CO<sub>2</sub>-equivalence) of long-lived N<sub>2</sub>O emissions which are more similar to CO<sub>2</sub> in their climatic effect and are accounted for identically under GWP and GWP\*.

Despite Abraham, Bethany, and Chris having kept exactly the same number of cows for 50 years, their assigned CO<sub>2</sub>-equivalent emissions under the applied version of a GWP\* metric vary both in sign and magnitude with the only reason for this variation being the number of cows their fathers owned. This example does not provide a solution, but clearly illustrates the potential fairness and equity issues as they are presented in RS19 and which surround the application of a GWP\*-based metric for policy at any but the global scale. The contribution of RS19 is indeed to point to those issues as well as exploring the implications of different considerations of equity including redistributing (historic) emissions allowances per capita (and which would provide a level playing field for Abraham, Bethany, and Chris).

Besides the various instances of what seem to be key misrepresentations of RS19's arguments and positions, the comment by CCmt also displays some internal contradiction. In particular, CCmt state that their *"principal objection is more fundamental: it is not up to scientists to determine what is fair based on their own interpretation of the interests of others"*. We agree that it is not up to scientist to determine what is fair based on their own interpretation of the interests of others, and already pointed out above that we consider this *"objection"* to be a misrepresentation of the manner in which equity issues were laid out in RS19. However, in the examples and reasoning provided in their comment, CCmt proceed to doing exactly what they have principally objected to: basing fairness arguments on their own interpretation of the interests of others.

In an example in which CCmt use CO<sub>2</sub>-e emissions estimated with the standard GWP-100 metric as indicators for warming, they highlight that *"it seems to us that one important form of unfairness is to overstate the impact of the rice farm relative to the fracking operation via the use of an inaccurate accounting rule"*. Irrespective of the merits of this example, this example contradicts CCmt's principal objection of not second-guessing interests of others.

A second contradiction is found in CCmt's country example where CCmt *"disagree completely"* with the interpretation of equity in the illustrative case they present, and we consider a misrepresentation of the arguments made in RS19. CCmt clarify that in their view mitigation contributions *"ought to be discussed and negotiated over together"*, a position one can agree with. However, they subsequently continue to advocate their personal interpretation of interests of others by stating that under the Paris Agreement *"the*

*principles of justice ought to be applied to warming, and to emissions as they imply warming*". This Reply does not enter in the more fundamental discussion about interpretations and understanding of the Paris Agreement, but simply highlights that this argumentation directly contradicts CCmt's own principal position laid out at the onset of their Comment.

Finally, CCmt write in their comment that the choice of time interval  $\Delta T$  used to determine rates of change for GWP\*-like emission metrics does not "*strongly alter results*". This statement holds only in the highly idealized case considered by CCmt in which climate targets are expressed purely in terms of cumulative warming-equivalent emissions and under the stylized assumption that annual emissions change smoothly over time. Reality contrasts strongly with these simplifying assumptions.

As part of their NDCs (<https://www4.unfccc.int/sites/ndcstaging/>), countries are submitting *annual targets at five-yearly intervals* instead of the cumulative emissions targets assumed by CCmt. Furthermore, real-world methane emissions do not necessarily change smoothly over time (as illustrated by data in historical national emission inventories (11)) and these real-world emission features make estimated GWP\* emissions in a given year sensitive to the choice of time interval  $\Delta T$ . Annual GWP\* emission values for a given year are thus sensitive to time intervals that can potentially be arbitrarily picked to set and describe 'nationally determined' targets and can hence vary strongly from country to country and NDC to NDC. The ad-hoc application of GWP\* metrics at the country level thus opens a potential door to undermining emission accounting integrity and comparability across countries and over time.

For the eGWP\* metrics introduced in RS19, changes in the time interval  $\Delta T$  further affect the reference levels that are used to estimate per capita fair shares of global short-lived methane emissions (defined in Equation 3 in RS19). These shares are not just informed by individual countries' historic emissions, but also by emissions of other countries and population dynamics (see the orange line in RS19 Fig. 2b to see China's "per capita equitable emissions" changing over time). For the extreme 'Zero reference' case in RS19, the choice of time interval  $\Delta T$  has the strongest influence and becomes quite arbitrary. The choice of time interval  $\Delta T$  hence also remains an issue for the application of more equitable GWP\*-like

metrics like the ones explored and discussed in RS19. Robust guidance is required, but would be difficult to enforce as countries can pick and choose their preferred approach.

In RS19 Figure 3, and throughout the manuscript, a standard time interval of  $\Delta T = 20$  years was applied to estimate emissions under varying metrics for the year 2015. The figure correctly shows how CO<sub>2</sub>-equivalent methane emissions in the year 2015 can vary depending on the type of GWP\*-based metric that is used, following equations cited in the manuscript. This suggestion by CCmt that an error in the rate of change contribution in the GWP\* equation was made in RS19 is thus unsubstantiated and invalid.

In conclusion, we welcome CCmt's thoughts on this issue but struggle to engage constructively with a Comment that misrepresents the original position of RS19 in so many instances. Nevertheless, this debate highlights the difficulties to accurately communicate GWP\* because of different choices that are built into the metric and which are easily underappreciated or misunderstood by users. This debate furthermore also provides a good illustration of persistent interdisciplinary gaps in understanding as well as implicit and disciplinary biases that have to be addressed when translating insights from physics-oriented modelling exercises to policy and society. We conclude that this topic would benefit strongly from contributions by interdisciplinary, science-policy and climate ethics scholars.

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321