

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

28 At the outset, it is important to outline what indeed *is* and *is not* included in RS19 as the
29 actual scope of the equity discussions in RS19 appears to be misunderstood by CCmt. RS19
30 provides a scientific critique of the potential ethical implications of applying GWP*-like
31 metrics at the country level with a focus on non-CO₂ emissions, and particularly methane.
32 RS19 neither discusses equity considerations in relation to (historic) CO₂ emissions, nor does
33 it aim to provide a comprehensive assessment of all ethical implications of the treatment of
34 different greenhouse gases in a common metric. The latter topic merits further exploration
35 and appears to be of major concern to CCmt. However, we do not consider the
36 misrepresentations by CCmt to provide a useful point of departure for this journey.

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

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

58 A second misrepresentation by CCmt is their suggestion that considering equity perspectives
59 for short-lived climate forcer mitigation across countries (as presented in RS19) would imply
60 a value judgement not *“to implement active CO₂ removal”*. As indicated above, RS19
61 highlights fundamental equity issues linked to the accounting and grandfathering of short-
62 lived (methane) warming when applying GWP* metrics at the level of single countries. It
63 highlights how contributions can be perceived very differently depending on the method
64 applied by countries to estimate CO₂-equivalent emissions. This implies neither that CO₂
65 should not be reduced, nor that it should not be reduced beyond zero. A scientific and policy
66 discourse around equity considerations in relation to CO₂ emissions and the (remaining)
67 carbon budget is indeed well established (e.g. see (4), (5), or (6) and (7)). RS19 references
68 this earlier literature to outline how some issues prevalent in the discourse on equity and
69 CO₂ emissions also apply to non-CO₂ emissions when metrics such as GWP* are being
70 applied to any but the global level. To conclude and as outlined above, RS19 is not a review
71 paper and hence does not aim to comprehensively discuss all relevant equity considerations
72 regarding the treatment of CO₂ and non-CO₂ gases in a common metric.

73 However, RS19 does highlight that perceived negative contributions under a grandfathering
74 GWP* metric could be used by countries to offset or not implement further CO₂ emission
75 reductions. This is a well-established understanding that RS19 and CCmt share, as members
76 of the CCmt author team have earlier written that *“[A] decline [of 24%] in methane
77 emissions [by 2050] would actually generate enough cooling to compensate for the warming
78 generated by all the non-methane greenhouse gases emitted by New Zealand as they
79 approach net zero. [...] [The reductions in New Zealand’s agricultural methane emissions]
80 would offset the warming impact of all the other emissions. New Zealand could declare itself
81 climate neutral almost immediately, well before 2050, and only because farmers were
82 reducing their methane emissions. That’s a free pass to all the other sectors, courtesy of New
83 Zealand’s farmers”* (8). There is thus a clear and acknowledged risk that negative GWP*
84 contributions that result from reductions of short-lived climate forcer emissions are
85 considered to compensate or as a *“free pass”* for CO₂ emissions in other sectors – a point for
86 which RS19 highlights that it would favour historic high emitters of methane (or other short-
87 lived greenhouse gases) when the grandfathering GWP* metric is applied. The above quote
88 also provides the precise context in which Cain (8) earlier referred to the cooling effect of

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

103 A third misrepresentation by CCmt is what they refer to as a “*fundamentally flawed*
104 *assumption*” in making no clear distinction between grandfathering of emissions and
105 grandfathering of warming. CCmt only seems to argue in terms of ethical principles that are
106 pegged to historical warming contributions and between various greenhouse gases, missing
107 the point made by RS19. RS19 highlights equity issues that are pegged to distributive justice
108 as part of on-going emissions of short-lived climate forcers between countries. These equity
109 issues are additional to historical warming considerations from long-lived greenhouse gases.
110 CCmt highlight that it is not evident to them why different ethical standards should be
111 applied to methane and CO₂, and construct a straw man argument misrepresenting RS19 by
112 suggesting that such an approach would be proposed. To be sure, RS19 does not suggest
113 that different ethical standards should be used if similar societal and ethical contexts apply.
114 Different ethical considerations exist, however, and are highlighted in RS19, including
115 considerations of burden-sharing and resource-sharing. Unfortunately, CCmt chose not to
116 engage with the question of distributional justice central to RS19.

117 Although not a part of the scope of RS19, considerations of the treatment of ongoing
118 emissions from short lived non-CO₂ gases such as methane and long-lived gases such as CO₂

119 exist. It is intuitive to understand that different equity implications can be identified for
120 warming caused by multi-decade-old emissions of long-lived greenhouse gases (emitted by a
121 cohort of the global population at a time when climate science was less robustly established
122 or widely understood and no clear low-carbon alternatives were available) compared to on-
123 going warming of short-lived climate forcers of which the effects and impacts are currently
124 well established and that could be reduced today with available technologies. Reflecting on
125 distributive versus corrective approaches to climate justice can further contribute to this
126 discussion (as has been done earlier for CO₂ (5)). No different ethical standards have hence
127 to be applied for different ethical implications to be applicable, and it is arguably not an
128 error or fundamentally flawed assumption as the comment by CCmt suggests.

129 There are several further misrepresentations by CCmt, like the suggestion that an error was
130 committed because RS19 failed to state that limitations or unintentional unfairness
131 consequences would not be a characteristic of the metric itself, but of its application at the
132 country level. It is hard to imagine how this could have been misunderstood by CCmt after a
133 diligent reading of the RS19 manuscript. RS19's title is *"Unintentional unfairness when
134 applying new greenhouse gas emissions metrics at country level"* and the *"limitation[s]"*
135 highlighted by RS19 are immediately being followed in the text by a statement that clarifies
136 that *"Applied at the global level they provide clear scientific merit with a more direct link
137 between the representation of CO₂-equivalent emissions and their warming impact.
138 However, when applied at a national level they all suffer from the same implicit
139 grandfathering bias, [...]"*. Without evidence in support of CCmt's implicit claim that specific
140 policy frameworks would exist in which the application of GWP* metrics at the country level
141 would not result in unintended fairness consequences, the original statement by RS19
142 remains a valid and correct reflection of limitations of GWP*-like metrics.

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

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

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

169 A last misrepresentation highlighted here is CCmt's example of two countries Alpha and
170 Bravo, which suggests that RS19 implies all mitigation responsibility would fall on the
171 methane producing country Bravo in contrast to Alpha who has only emitted CO₂ in the past
172 and arguably currently has already achieved net zero CO₂ emissions. This example
173 misrepresents the discussion presented in RS19 by suggesting that the equity implications
174 presented in RS19 refer to CO₂ versus methane mitigation. This is incorrect as RS19 focusses
175 primarily on issues related to relative methane mitigation.

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

179 father was a farmer and so was his grandfather. Abraham lives a happy and fulfilled life with
180 his ten cows, and does not want to increase their number. Bethany is also 21 years old and
181 comes from a poorer family that historically was not able to afford cattle. However, through
182 a bank credit she was able to also buy ten cows. Also Bethany is happy with her ten cows,
183 and intends to keep her herd constant at that level. Finally, there is Chris, who is also 21
184 years old and comes from an established farming family. His father and grandfather had a
185 herd of 20 cows passed down over generations. Chris, however, has decided to downsize
186 and now also keeps a herd of just ten cows. Also Chris is happy. Abraham, Bethany, and
187 Chris thus have exactly the same number of cows, with the only difference between them
188 the number of cows their fathers owned. Following equation (1) in CCmt (published after
189 RS19, but with equivalent implications compared to the older metric description used in
190 RS19) this would nevertheless result in very different GWP*-based CO₂-equivalent emissions
191 for each of them over their adult farming lives (here assumed to be from about 21 to 70
192 years, and assuming that 10 cows emit about 1 tonne of methane per year):

- 193 ○ Abraham, keeping his cows at the level of his father and grandfathers, is
194 assigned 140 and 350 tCO₂*-equivalent methane emissions over the first 20
195 and 50 years, respectively.
- 196 ○ Bethany, who was able to buy 10 cows despite her parents not owning any, is
197 assigned 2240 and 2450 tCO₂*-equivalent methane emissions during the first
198 20 and 50 years, respectively.
- 199 ○ Chris, who kept half of the 20 cows of his father, is assigned negative 1960
200 and negative 1750 tCO₂*-equivalent methane emissions during the first 20
201 and 50 years, respectively.
- 202 ○ Globally (in this case, simply all three farmers together), methane emissions
203 would be estimated at 420 and 1050 tCO₂*-equivalent during the first 20 and
204 50 years, respectively. The latter global CO₂*-equivalent emissions reflect the
205 equivalent global warming impact of the on-going global methane emissions.
- 206 ○ Meanwhile, the dung produced by each farmer's herd was also responsible
207 for several additional tonnes (in CO₂-equivalence) of long-lived N₂O emissions
208 which are more similar to CO₂ in their climatic effect and are accounted for
209 identically under GWP and GWP*.

210 Despite Abraham, Bethany, and Chris having kept exactly the same number of cows for 50
211 years, their assigned CO₂-equivalent emissions under the applied version of a GWP* metric
212 vary both in sign and magnitude with the only reason for this variation being the number of
213 cows their fathers owned. This example does not provide a solution, but clearly illustrates
214 the potential fairness and equity issues as they are presented in RS19 and which surround
215 the application of a GWP*-based metric for policy at any but the global scale. The
216 contribution of RS19 is indeed to point to those issues as well as exploring the implications
217 of different considerations of equity including redistributing (historic) emissions allowances
218 per capita (and which would provide a level playing field for Abraham, Bethany, and Chris).

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

229 In an example in which CCmt use CO₂-e emissions estimated with the standard GWP-100
230 metric as indicators for warming, they highlight that *"it seems to us that one important form*
231 *of unfairness is to overstate the impact of the rice farm relative to the fracking operation via*
232 *the use of an inaccurate accounting rule"*. Irrespective of the merits of this example, this
233 example contradicts CCmt's principal objection of not second-guessing interests of others.

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

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

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

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

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

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

272 In RS19 Figure 3, and throughout the manuscript, a standard time interval of $\Delta T = 20$ years
273 was applied to estimate emissions under varying metrics for the year 2015. The figure
274 correctly shows how CO₂-equivalent methane emissions in the year 2015 can vary
275 depending on the type of GWP*-based metric that is used, following equations cited in the
276 manuscript. This suggestion by CCmt that an error in the rate of change contribution in the
277 GWP* equation was made in RS19 is thus unsubstantiated and invalid.

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

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