SMALL WORLD CONSULTING

GWP*: Applications & Misapplications

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Abstract

This paper has been written primarily for food, farming and land management organisations. It explores the different behaviour of CO_2 and methane and the different ways in which they contribute to global heating. We look at the problems with the standard GWP_{100} metric and hence the emergence of GWP* as well as the arguments for using GWP_{20} or reporting CO_2 and methane separately. We highlight the dangers of misuse of GWP* which can result in spuriously underplaying the need for methane reductions whereas, if properly used, GWP* has the effect of emphasising, much more so than GWP_{100}, the need for rapid methane reductions. We also highlight that other factors such as land use and water footprints need to be considered alongside CO_2 and methane emissions when setting targets for agriculture.

CO_2 and methane reductions consistent with limiting warming to 1.5°C

- The two most important greenhouse gases (GHGs) in the atmosphere responsible for anthropogenic global heating are carbon dioxide (CO_2) and methane (CH_4). Anthropogenic CO_2 emissions are mainly caused by the combustion of fossil fuels, although a small but significant proportion is attributable to food supply chains. The largest sources of anthropogenic methane are fossil fuel extraction (40%), livestock (30%), and landfill and agricultural waste (19%)[1,2]. Nitrous oxide (N_2O) emissions, which arise largely from agricultural practices, also have an important role in global heating.
- According to the recent Sixth Assessment Report (AR6) by IPCC, to keep global temperature rise below the "safer" 1.5°C limit, global emissions of both CO_2 and methane must decrease rapidly relative to present-day levels[3] (Figure 1).
- CO_2 emissions must reach net zero by 2050s and turn into a strong carbon sink afterwards. Methane emissions must reduce rapidly and settle on around 40% of present-day levels from 2050s onwards (Figure 1).
- The near-term reductions for both CO_2 and methane must be particularly fast during 2020s if we are to avoid overshooting the 1.5°C target considerably (Figure 1). The world is completely off-track in delivering such reductions[4].
- Delays in methane mitigation will result in a considerable overshoot of the global 1.5°C limit even if CO_2 mitigation efforts follow the required early reductions compatible with this temperature target (Figure 2).

[1] https://www.iea.org/reports/methane-tracker-2020.
[2] https://royalsocietypublishing.org/doi/10.1098/rsta.2020.0451.
[3] https://www.ipcc.ch/report/sixth-assessment-report-cycle/.
[4] https://iopscience.iop.org/article/10.1088/1748-9326/ac55b6/meta.

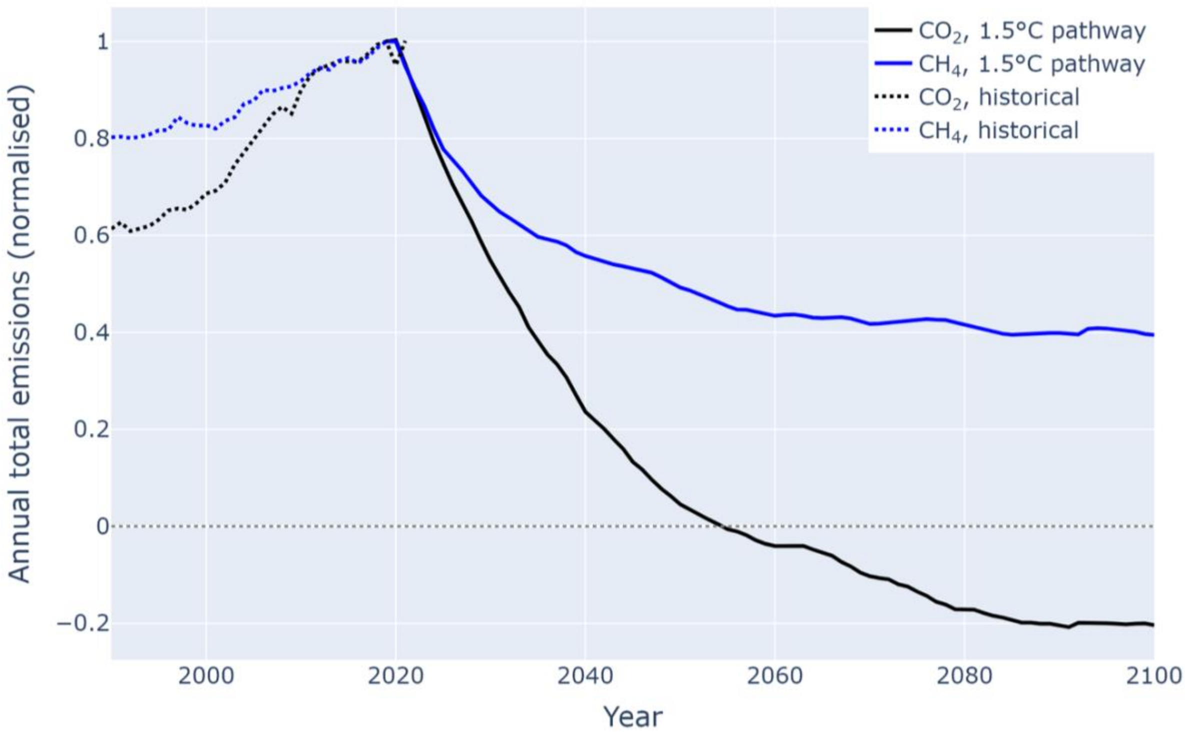

Figure 1. Historical global emissions of CO_2 and methane (CH_4) between 1990 and 2019, and future global reduction pathways for each of these gases consistent with the 1.5℃ target from the Paris Agreement (with low or no overshoot of the 1.5℃ limit). The data has been normalised to 2019. Source: IPCC AR6.

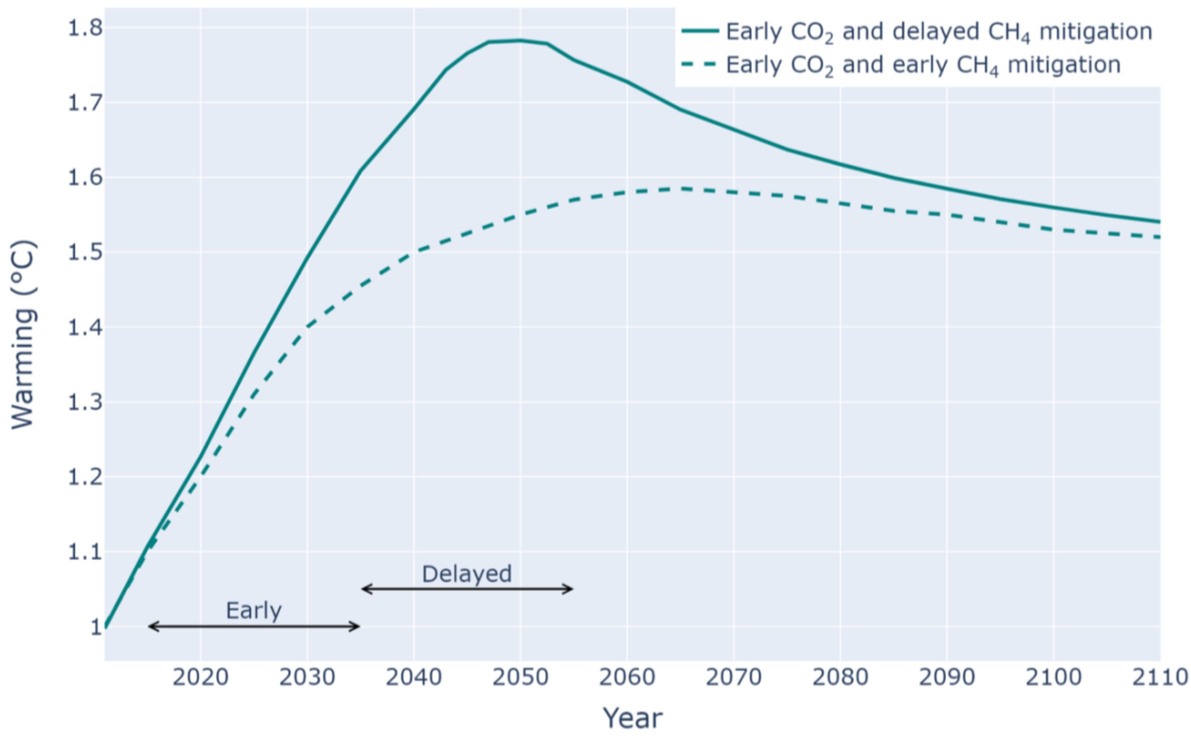

Figure 2. Global temperature projections under early cuts in CO_2 coupled with either early or delayed cuts in methane emissions. Adapted from Allen (2015)[5].

[5] https://www.oxfordmartin.ox.ac.uk/downloads/briefings/Short_Lived_Promise.pdf.

How CO_2 and methane each contribute to global heating

- CO_2 and methane behave in different ways in the atmosphere, where they contribute to the greenhouse effect alongside N_2O, water vapour and other GHGs.
- All GHGs act as a blanket and trap the Earth's heat, which is often referred to as "radiative forcing". Higher GHG concentrations lead to more heat being trapped, which results in higher mean global temperatures.
- Once emitted, CO_2 stays in the atmosphere until it is absorbed into terrestrial vegetation and soils, oceans, and rocks (rock weathering). While the processes are complex, as an approximation, CO_2 can be modelled as if a proportion of emitted gas remains in the atmosphere indefinitely. This has led to the widely adopted concept of cumulative CO_2 budgets for different global temperature change limits. These carbon budgets, however, are reliant on background assumptions about methane emissions.
- While in the atmosphere, each kilogram of methane leads to over 100 times more heat being trapped than the same mass of CO_2[6]. However, unlike CO_2, methane degrades over a relatively short period of time, with a half-life of around 12 years.
- Because of these different characteristics, **present-day global heating from CO_2 and methane** is largely dependent on ***cumulative*** **emissions of CO_2 to date** but on ***annual*** **emissions of methane over recent years**[7].
- Therefore, in terms of these two gases, the **climate impact of an individual, an organisation or a country** in a given year is largely determined by the **CO_2 emissions in that year** and by the ***change*** **in methane emissions** compared to the previous year.

Background to Global Warming Potential (GWP)

- A critical question for policymakers is **how best to share emission reductions between the world's countries and industries**. This includes agreeing the relative pace of reduction of CO_2 and methane, especially in the early years.
- The heating caused by global CO_2 and methane emissions is assessed using complex climate models, which capture the key properties of the global CO_2 and methane cycles in the biosphere. The scenarios in Figure 1, for example, are derived using such modelling.
- Global climate models, however, are not sensitive enough to resolve the climate impact of smaller emitters such as individuals, or most organisations or even countries. For this, some simpler, practical method is required, which accounts for the various GHGs.
- One such method, which has been widely adopted by academics, policymakers and businesses, is to use the concept of different Global Warming Potentials (GWPs) for different GHGs. The GWP method applies a scaling factor to each GHG based on how much radiative forcing emitting each tonne of that gas would cause over a certain timeframe, compared to emitting each tonne of CO_2[8].

[6] https://pubs.rsc.org/en/content/articlehtml/2018/em/c8em00414e.

[7] Because of these properties, CO_2 is referred to as a "stock" GHG while methane is referred to a "flow" GHG in climate science.

[8] See, for example, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials#:~:text=The%20Global%20Warming%20Potential%20(GWP,carbon%20dioxide%20(CO2.

- A timeframe of 100 years (GWP_{100}) was agreed as the standard metric by the United Nations Framework Convention on Climate Change at COP2 in 1996. This has since become a prevalent convention and, for example, is stipulated in the Paris Agreement as the metric for national reporting of greenhouse gases[9]. However, GWP can also be modelled over a shorter period of time of, say, 20 years (GWP_{20}) to better understand near-term impacts.
- For methane, GWP_{100} is around 28 and GWP_{20} is around 86. This means that on the timescales of 100 and 20 years, each tonne of methane emitted into the atmosphere exerts, respectively, 28 and 86 times more radiative forcing on the climate system compared to each tonne of CO_2.

GWP*

- A relatively recent development in greenhouse gas metrics has been the suggestion of GWP*, first introduced by Allen et al (2016)[10] and then in a revised form by Cain et al (2019)[11] and Smith et al (2021)[12]. GWP* attempts to reflect the different behaviours of CO_2 and methane in the atmosphere within a single measure.
- For methane, GWP* allocates the weight of 75% to the *changes* in annual emissions and only 25% to the actual annual emissions[13].
- The scientific value of GWP* compared to GWP_{100} for methane lies in being able to more accurately model the impact of today's emissions on future warming.
- Since the methane component of GWP* relates primarily to changes in emissions, unlike GWP_{100} and GWP_{20}, it requires a specified historical reference year upon which the results are highly dependent.

Practical implications of using GWP* for emissions targets

- If properly used, the insight offered by GWP* to all methane emitters is that, compared to GWP_{100}, it more fully and accurately reflects the near-term climate benefits of methane reductions. For example, it more fully emphasises the responsibilities of the food and agriculture industries for rapid methane reduction.
- The use of GWP* instead of GWP_{100} has the effect that increases in methane emissions appear to be more harmful, whereas reductions appear to be more beneficial. Therefore, while any new or growing emitters are penalised more heavily by GWP* than by GWP_{100}, existing methane emitters can achieve a very favourable GWP* score through only modest emission reductions[14].

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[9] https://www.sciencedirect.com/science/article/pii/S1462901122001204.
[10] https://www.nature.com/articles/nclimate2998.
[11] https://www.nature.com/articles/s41612-019-0086-4.
[12] https://www.nature.com/articles/s41612-021-00169-8.
[13] Allocating the entire 100% to annual methane emissions would result in GWP_{100}. The Smith et al (2021) method for GWP* also uses a more accurate weighting coefficient. The 25%-75% weights were chosen so that the corresponding cumulative CO_{2e} methane emissions evaluated using the revised GWP* closely match the associated global temperature responses, both during historic period and under future projections, as is the case for CO_2 emissions themselves.
[14] https://iopscience.iop.org/article/10.1088/1748-9326/ab4928/meta.

- The application of GWP* to emission reductions trajectories that have been developed for GWP_{100} or separately for CO_2 and methane (as in Figure 1) is not appropriate and could be highly misleading. One danger is that if this is done, it has the effect of shifting the burden of responsibility for climate mitigation away from methane and further onto CO_2 emissions (Figure 1).
- This is illustrated in Figure 3, where the CO_2 and methane trajectories from Figure 1 compatible with the 1.5°C global temperature target are projected to reach net zero tCO_2e emissions around the year of 2080 if GWP_{100} is used. Adopting GWP* instead of GWP_{100} brings the projected net zero year forward by over 40 years to 2035.
- Without adequate safeguards, GWP* can even lead to situations in which relatively small cuts in methane emissions could be claimed as an 'offset' for current CO_2 emissions.
- Since GWP* inadvertently favours existing methane emitters, most of whom are in wealthier countries, using it distorts the share of the remaining methane emissions consistent with the 1.5°C target (around 40% of the current levels) towards these emitters and countries. This raises basic questions about fairness[14].
- In view of the above, it is important for all methane emitters to resist and challenge the use of GWP* as an argument for failing to embrace the urgent shared responsibility for reducing emissions.

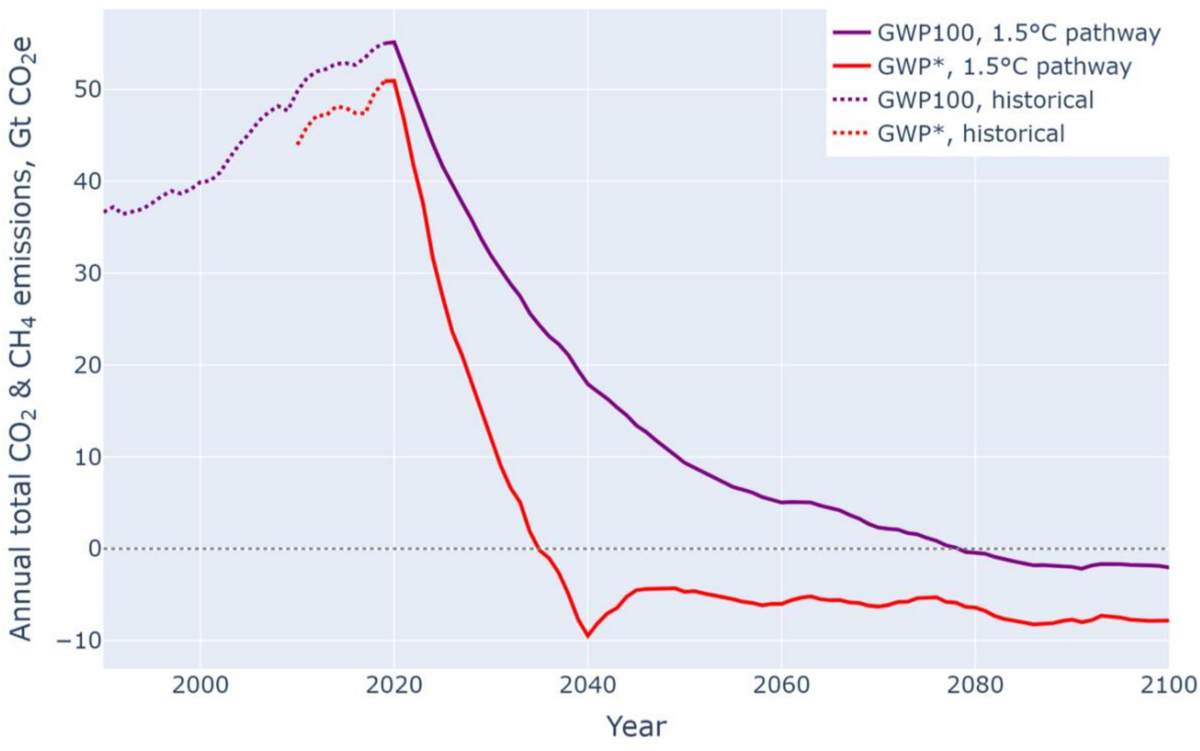

Figure 3. Historical global emissions and future reduction pathways for CO_2 and methane consistent with the 1.5℃ target from the Paris Agreement (with low or no overshoot of 1.5℃), which have been converted into a single tCO_2e metric using either GWP_{100} or GWP. The underlying CO_2 and methane emissions follow the individual pathways in Figure 1.*

Further considerations

- In the context of agriculture, it is equally important to consider, for example, the land use and water footprints of different production systems[15], as well as their impacts on biodiversity[16]. GHG emissions alone do not and cannot represent all the environmental impacts associated with agriculture and other anthropogenic land use, and they cannot be used as a sole basis for setting land use change targets.
- Another modelling improvement from GWP_{100} is the "two-basket approach"[17], which could involve reporting CO_2 and methane emissions separately without a GWP conversion. Reporting GWP_{20} alongside GWP_{100} is another option. As with the proper use of GWP*, these approaches have the effect of more accurately and fully emphasising the benefits of rapid reduction of methane emissions than is indicated by the more conventional GWP_{100} metric alone.

Case study: Implications of using GWP* and GWP_{100} for global pathways for agriculture and other land use consistent with limiting warming to 1.5°C

- In this section, we apply different GWP metrics to the recommended CO_2, methane and N_2O emission reduction pathways for the global Agriculture, Forestry and Other Land Use sector (AFOLU), which are consistent with limiting global temperature rise to 1.5°C with no or little overshoot (Figure 4).
- Global AFOLU CO_2 emissions, primarily due to deforestation and soil degradation, need to reduce rapidly during the current decade and be replaced with strong carbon sequestration in new woodlands, restored soils and other recovered habitats from 2030s onwards. In absolute terms, the net sequestration needs to reach around 80% of the current net CO_2 emission levels in the latter part of the century.
- Global AFOLU methane emissions, primarily due to enteric fermentation in livestock, need to reduce to 75% of the current levels by 2040 and to 60% of the current levels by 2060.
- Global AFOLU N_2O emissions, primarily due to the use of synthetic fertilisers, need to reduce to 80% of the current levels by 2040 and to 75% of the current levels by the end of the century.
- When these emissions are combined into a single tCO_2e metric using GWP_{100}, the global AFOLU total needs to reduce from approximately 10 $GtCO_2e$ at present to around 1 $GtCO_2e$ by mid-2060s (Figure 5) and remain at that level for the remainder of the century.
- Using GWP* instead of GWP_{100}, however, means that the global AFOLU total measured in $GtCO_2e^*$ is projected to drop from around 10 $GtCO_2e^*$ at present to net zero by 2030 (Figure 5) and reach –6 $GtCO_2e^*$ by 2040 (i.e. net negative flux amounting to 60% of the current net emission levels in absolute terms).
- By simply replacing the GWP_{100} projections with the GWP* projections in Figure 5, one risks creating an impression that the proposed underlying reductions individually for each of the three main GHG associated with AFOLU (Figure 4), particularly for CO_2, may be unnecessary since they appear to result in a very early "net zero" date.
- Indeed, the widely adopted use of the term "net zero" and the associated policies are based on the GWP_{100} metric and cannot simply be extended to the GWP* metric. A separate "net zero*" term will need to be introduced if one wishes to work with the GWP* GHG accounting metric, and its own set of policies would need to be derived.

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[15] https://www.science.org/doi/abs/10.1126/science.aaq0216.

[16] https://www.ipbes.net/global-assessment.

[17] https://www.nature.com/articles/s41598-021-01639-y.

- Summing up, to avoid potential misinterpretation of climate policies, the best thing to do is to work with science-based reduction targets individually for CO_2, methane, N_2O and other GHGs, rather than use a single tCO_2e metric and the associated "net zero" targets based on either GWP_{100} or GWP*. This applies to all sectors (including AFOLU), countries, organisations, and individuals.

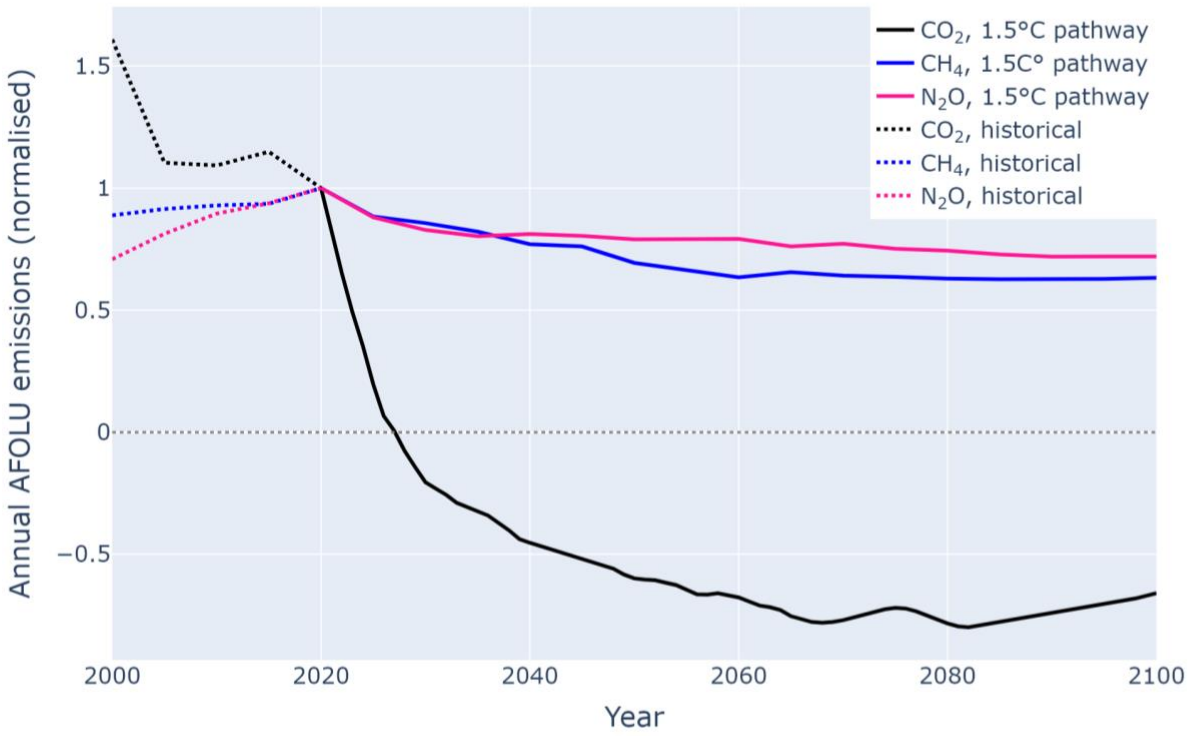

Figure 4. Historical emissions of CO_2, methane (CH_4) and N_2O associated with the global agriculture, forestry and other land use sector (AFOLU), and the corresponding future reduction pathways for each of these gases consistent with the 1.5 ℃ target from the Paris Agreement (with low or no overshoot of 1.5 ℃). The data has been normalised to 2019. Source: IPCC AR6.

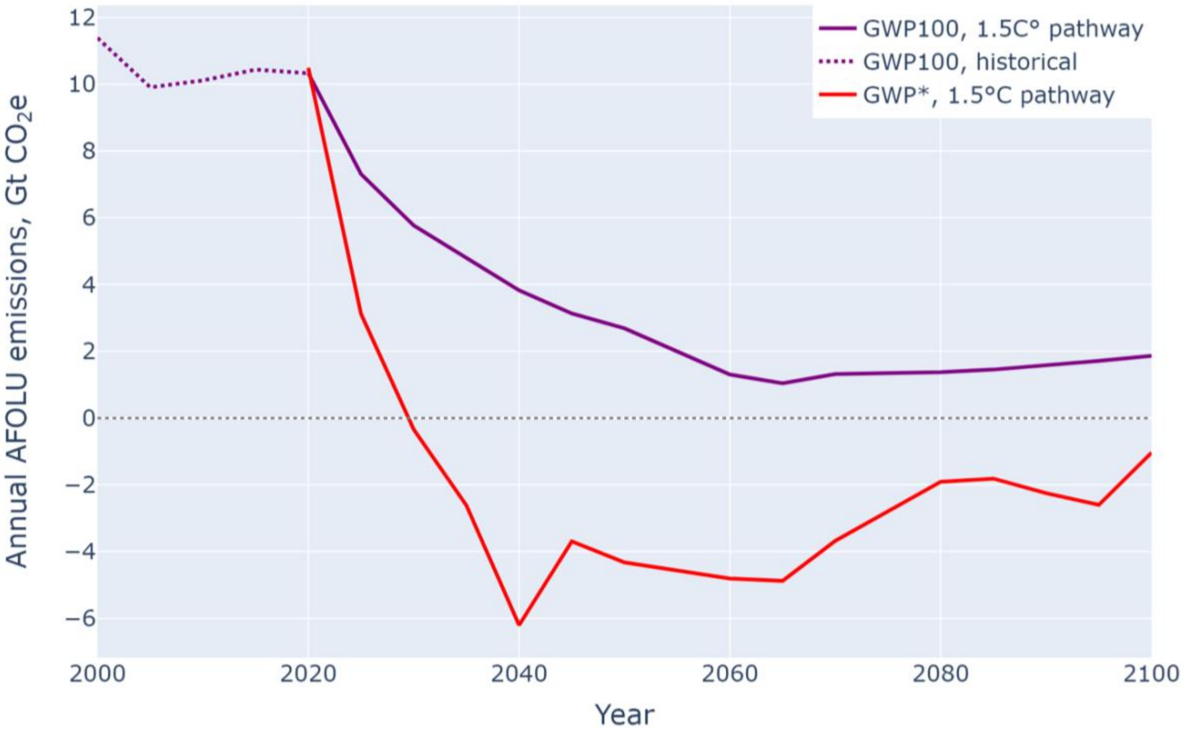

Figure 5. Historical (where available) and future reduction pathways for CO_2, methane and N_2O for the global AFOLU sector consistent with the 1.5℃ target from the Paris Agreement (with low or no overshoot of 1.5℃), which have been converted into a single tCO_2e metric using either GWP_{100} or GWP. The underlying CO_2, methane and N_2O emissions follow the individual pathways in Figure 4.*