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Working Paper

Metrics for methane emissions

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Summary

Methane is the most important anthropogenic greenhouse gas after CO_2. To meet ambitious climate change mitigation targets, it is crucial to effectively reduce the emissions of methane along with other greenhouse gases. The selection of mitigation measures depends on factors such as feasibility, costs and the amount of emission savings. When measures that target different greenhouse gases are compared, the climate impact of these different gases must be made comparable. For this purpose, metrics have been introduced.

The most common metric is the global warming potential over 100 years (GWP_{100}), which compares the warming effect of a gas over 100 years with the effect of CO_2. This metric is also used for greenhouse gas inventories under the United Nations Framework Convention on Climate Change and under the Paris Agreement.

In the current discussion, the global warming potential of methane over a period of 20 years (GWP_{20}) is sometimes used. In addition, other metrics for comparing the impact of different greenhouse gases have been proposed in the relevant literature. The contribution of various greenhouse gases to total emissions, and thus the need to reduce emissions, can change substantially depending on the choice of metric.

A comparison of various metrics shows that GWP_{100} is well suited to prioritising measures as it is designed for the long term and has a robust scientific foundation. If metrics with a shorter time horizon – such as GWP_{20} – are used, the long-term effect of greenhouse gases beyond the 20-year period is not taken into account. This would limit the informative value of total emissions for the periods under consideration, such as the middle of the century.

Another metric, the global temperature change potential (GTP), addresses the effect of a greenhouse gas on temperature at the end of a defined time period. It is associated with higher uncertainties than GWP; when using this metric, it is important to align the chosen time horizon with that of the temperature target.

A variation of the global warming potential, which is referred to as the GWP*, focuses on the change in emissions of short-lived substances compared to historical emissions. Negative GWP* values represent a reduction in emissions compared to the past. However, even with negative GWP*, there may be significant greenhouse gas emissions. This makes it difficult to use this metric in planning climate change mitigation.

Overall, GWP_{100} constitutes a good choice for prioritising climate change mitigation measures. The use of other metrics can be useful for various issues, but it should be made clear when quantifications of greenhouse gas emissions differ from those set out in the Paris Agreement, and what sectors or parties involved would benefit from what metrics.

Zusammenfassung: Metriken für Methan-Emissionen

Methan ist nach CO_2 das bedeutendste anthropogene Treibhausgas. Für die Einhaltung ambitionierter Klimaschutzziele ist es entscheidend, die Emissionen von Methan zusammen mit anderen Treibhausgasen wirksam zu reduzieren. Die Auswahl von Minderungsmaßnahmen hängt von Faktoren wie Machbarkeit, Kosten und Höhe der Emissionseinsparung ab. Werden Maßnahmen einander gegenübergestellt, die auf unterschiedliche Treibhausgase abzielen, so muss die Klimawirkung dieser unterschiedlichen Gase vergleichbar gemacht werden. Zu diesem Zweck wurden Metriken eingeführt.

Die gebräuchlichste Metrik ist das Treibhauspotenzial über einen Zeitraum von 100 Jahren (GWP_{100}), das die Erwärmungswirkung eines Gases über 100 Jahre mit der Wirkung von CO_2 vergleicht. Diese Metrik wird auch für Treibhausgasinventare unter der Klimarahmenkonvention und unter dem Übereinkommen von Paris verwendet.

In der aktuellen Diskussion wird in manchen Fällen das Treibhauspotenzial von Methan über einen Zeitraum von 20 Jahren (GWP_{20}) angegeben. Außerdem wurden in der wissenschaftlichen Literatur weitere Metriken vorgeschlagen, um die Wirkung unterschiedlicher Treibhausgase zu vergleichen. Der Beitrag unterschiedlicher Treibhausgase zu den Gesamtemissionen und damit die Notwendigkeit zur Emissionsminderung kann sich durch die Wahl der Metrik deutlich verändern.

Ein Vergleich unterschiedlicher Metriken zeigt, dass das Treibhauspotential GWP_{100} für die Priorisierung von Maßnahmen gut geeignet ist, da es langfristig ausgelegt ist und auf einer robusten wissenschaftlichen Grundlage basiert. Werden Metriken mit einem kürzeren Zeithorizont – wie etwa das GWP_{20} – verwendet, so bleibt die langfristige Wirkung von Treibhausgasen über den Zeitraum von 20 Jahren hinaus unberücksichtigt. Die Aussagekraft der Gesamtemissionen für Betrachtungszeiträume wie die Mitte des Jahrhunderts würde dadurch eingeschränkt.

Eine weitere Metrik, das globale Temperaturänderungs-Potenzial (GTP), betrachtet die Wirkung eines Treibhausgases auf die Temperatur am Ende eines definierten Zeitraums. Es ist mit höheren Unsicherheiten als das GWP verbunden, und bei seiner Verwendung ist es wichtig, den gewählten Zeithorizont an jenen des Temperaturziels anzupassen.

Eine Abwandlung des Treibhauspotenzials, das sogenannte GWP*, fokussiert auf die Änderung der Emissionen kurzlebiger Substanzen im Vergleich zu historischen Emissionen. Negative GWP*-Werte stellen eine Emissionsreduktion im Vergleich zur Vergangenheit dar; selbst bei negativem GWP* können jedoch bedeutende Treibhausgas-Emissionen verbleiben. Dies erschwert eine Verwendung dieser Metrik für die Klimaschutzplanung.

Insgesamt stellt das Treibhauspotenzial GWP_{100} für die Priorisierung von Klimaschutzmaßnahmen eine gute Wahl dar. Die Anwendung weiterer Metriken kann für verschiedene Fragestellungen nützlich sein, allerdings sollte jeweils deutlich gemacht werden, wenn Quantifizierungen der Treibhausgasemissionen von den Festlegungen unter dem Übereinkommen von Paris abweichen, und es sollte auch dargestellt werden, für welche Sektoren oder Akteure welche Metriken vorteilhaft sind.

Table of contents

List of figures

List of tables

1 Introduction

Methane (CH_4) is one of the most important anthropogenic greenhouse gases, along with carbon dioxide (CO_2), nitrous oxide (N_2O) and fluorinated gases. In Germany, methane is the second most important greenhouse gas after CO_2. It contributes approx. 7 % to total anthropogenic greenhouse gas emissions[1] (UBA 2022). The most important source of methane emissions in Germany is agriculture (62 %), followed by the energy sector (17 %) and the waste sector (13 %) (UBA 2022). Within the energy sector, fugitive emissions from fuels (especially natural gas) are the most important source. Imported fossil fuels (natural gas, oil and coal) generate significant additional methane emissions from mining and transport.

In order to identify ways in which methane emissions could be reduced in different sectors, the EU Commission in 2020 published a Methane Strategy (EC - European Commission 2020). Currently, the Methane Regulation is being negotiated at EU level, based on the EU Commission's 2021 proposal (EC - European Commission 2021). This regulation focuses on the energy sector and includes the measurement, reporting and reduction of emissions within the EU as well as transparency instruments for emissions that occur outside the EU. At the international level, under the Global Methane Pledge, over 150 countries have pledged to reduce their methane emissions by 30 % by 2030 compared to 2020.[2]

1.1 Different properties of methane and CO_2

Methane differs in its physical properties from carbon dioxide primarily in that it absorbs infrared radiation comparatively more strongly per molecule and thus has a higher global warming potential. However, it has a much shorter atmospheric residence time, which at about 12 years is considerably lower than the value for carbon dioxide, which once emitted can remain in the atmosphere for several hundred years (IPCC 2001). Methane is therefore classified as a short-lived greenhouse gas.

1.2 Metrics for converting methane into CO_2 equivalents

To achieve the temperature goal of the Paris Agreement, there must be huge reductions in the emissions of all greenhouse gases. Reduction targets for 2030 have been agreed at national and EU level, and both Germany and the EU are committed to greenhouse gas neutrality in the long term. In order to be able to verify compliance with these targets, the emissions of various greenhouse gases and the uptake of CO_2 by sinks are recorded in national greenhouse gas inventories.

Since the different greenhouse gases have different physical properties, the emissions of, for example, one tonne of methane does not have the same effect on global warming as the emission of one tonne of CO_2. Emissions of non-CO_2 gases are therefore converted into CO_2 equivalents using a metric.

A conversion metric for individual greenhouse gases is necessary to make them comparable in their effect and to be able to consider their overall effect. A conversion metric is particularly necessary for the following reasons:

[1] This value is derived by using the global warming potential GWP_{100} from the IPCC's Fourth Assessment Report.

[2] Global Methane Pledge, https://www.globalmethanepledge.org/

- to be able to aggregate the amount and impact of total greenhouse gas emissions in order to make statements about climate impacts or the effect of efforts to reduce greenhouse gases,
- to compare the impact of climate change mitigation measures and to prioritise measures,
- to develop mitigation measures and instruments that work across different greenhouse gases, and
- to be able to compare the polluters of emissions (companies, states, municipalities, etc.) and their reduction efforts with regard to the status of total emissions and reduction efforts.

In greenhouse gas inventories under the United Nations Framework Convention on Climate Change and under the Paris Agreement, the Global Warming Potential over a 100-year period (GWP_{100}) is used as a metric. The GWP_{100} of a substance indicates the cumulative warming effect over 100 years of emitting one kilogram of that substance compared to emitting one kilogram of CO_2. Table 1 provides an overview of the decisions in which the current GWPs were laid down for reporting purposes and the values for methane set.

Table 1: Regulations specifying the use of global warming potentials in inventories

Decision	Valid for	Valid until / from	GWP_{100} (methane)	Source
17/CP.8 (2002)[3]	Reports from developing countries under the Framework Convention on Climate Change	Until 2024	21	SAR
24/CP.19 (2013)[4]	Reports from developed countries under the Framework Convention on Climate Change	Until 2024	25	AR4
18/CMA.1 (2018)[5]	Biennial transparency reports under the Paris Agreement	From the end of 2024 at the latest	28	AR5
2020/1044 (Delegated Regulation of the EU Commission, 2020)[6]	Reports from EU Member States under the Governance Regulation	From 2023	28	AR5

[3] Decision 17/CP.8: Guidelines for the preparation of national communications from Parties not included in Annex I to the Convention, https://unfccc.int/documents/3217.

[4] Decision 24/CP.19: Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention, https://unfccc.int/documents/8105.

[5] Decision 18/CMA.1: Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement, https://unfccc.int/documents/193408.

[6] Commission Delegated Regulation (EU) 2020/1044 of 8 May 2020 supplementing Regulation (EU) 2018/1999 of the European Parliament and of the Council as regards global warming potential values and inventory guidelines and as regards the Union inventory system and repealing Commission Delegated Regulation (EU) No 666/2014, https://eur-lex.europa.eu/eli/reg_del/2020/1044/oj.

Decision	Valid for	Valid until / from	GWP_{100} (methane)	Source
6/CP.27 (2022)[7] (COP decision on reporting guidelines)	Inventory reports under the Framework Convention on Climate Change from developed countries that are not Parties to the Paris Agreement	From the end of 2024 at the latest	28	AR5
7/CP.27 (2022)[8] (COP decision on common metrics)	Reports under the Framework Convention on Climate Change from countries that are not parties to the Paris Agreement	From the end of 2024 at the latest	28	AR5

SAR: Second Assessment Report. AR4: IPCC Fourth Assessment Report. AR5: IPCC Fifth Assessment Report

The values of the individual metrics change over time due to new data and changes in the composition of the atmosphere. Current metrics are published in the assessment reports of the Intergovernmental Panel on Climate Change (IPCC). From 2024, the value from the IPCC Fifth Assessment Report (GWP_{100} = 28) applies uniformly under the Framework Convention on Climate Change, the Paris Agreement and the EU Governance Regulation (AR5, IPCC 2013).

In 2021, new global warming potentials were published in the IPCC Sixth Assessment Report (AR6, IPCC 2021). However, most countries have used the values from the Fifth Assessment Report to set their national targets for 2030 and are currently implementing measures to achieve these targets. For tracking their progress, these countries continue to use the GWPs from the Fifth Assessment Report. To ensure consistency between the tracking of progress and reporting in GHG inventories, it is important that GWPs do not change during the current NDC period from 2021 to 2030. Therefore, a change of the GWP values from AR5 to AR6 is not foreseen. The methane GWP values differ only slightly between AR5 and AR6. Table 4 in the Annex compares the most important metrics for methane from AR5 and AR6.

Metrics continue to be discussed even though the metrics for greenhouse gas inventories under the United Nations Framework Convention on Climate Change, under the Paris Agreement and for EU reporting are fixed for the years ahead. This is particularly the case as new metrics have been developed in recent years. In this paper, selected metrics are compared on the basis of various criteria.

1.3 Criteria for a metric

All metrics available for the conversion of greenhouse gases have both advantages and disadvantages. The importance of each criterion may differ depending on the issue, but the issues in international climate policy are clearly related to the comparability of greenhouse gases in terms of their contribution to climate change. The following criteria are relevant when choosing a metric:

- robust context for quantifying and comparing different greenhouse gases and their effect on climate change, with the context based on objective physical properties;

[7] Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention, https://unfccc.int/documents/626561.

[8] Common metrics to calculate the carbon dioxide equivalence of greenhouse gases, https://unfccc.int/documents/626561.

- compatibility with overarching goals under the United Nations Framework Convention on Climate Change and the Paris Agreement (e.g. temperature target);
- supports the setting of mitigation targets and the tracking of progress towards implementation in the time frames of the Paris Agreement;
- supports the prioritisation of mitigation strategies and the selection of mitigation actions that address multiple GHGs within the current time frames of countries;
- provides a robust basis for emissions trading in various greenhouse gases;
- there are recognised sources for reference values, i.e. values for the metric have been calculated by the IPCC, are published regularly and, if necessary, adjusted to the current state of research;
- values as stable as possible with little change over planning periods of approx. 50 years; and
- avoidance of unintended consequences.

2 Comparison of metrics

In the following, an overview of currently discussed metrics is provided. A distinction is made between Global Warming Potential (GWP), Global Temperature Change Potential (GTP), Combined-GTP and a variation of GWP (GWP*). There are variants for each of these metrics; in particular, they are calculated over different time horizons. Since the 20-year horizon has recently been brought up in discussions in addition to the 100-year horizon, they are considered separately. The chapter is therefore divided into six sections:

- GWP_{100},
- GWP_{20},
- GTP (different time horizons),
- combined GTP,
- GWP* and variants; and
- separate targets and metrics for short-lived and long-lived greenhouse gases.

For each of the metrics, the concept, scientific rationale, characteristics, advantages and disadvantages, influence on the weighting of methane in reporting and climate action, and the arguments advanced are discussed.

To compare the emissions of different gases, CO_2 is usually used as the reference gas, and the effects of the other gases are expressed relative to it in CO_2 equivalents (CO_2e). The effect of each greenhouse gas in the atmosphere depends on the following factors:

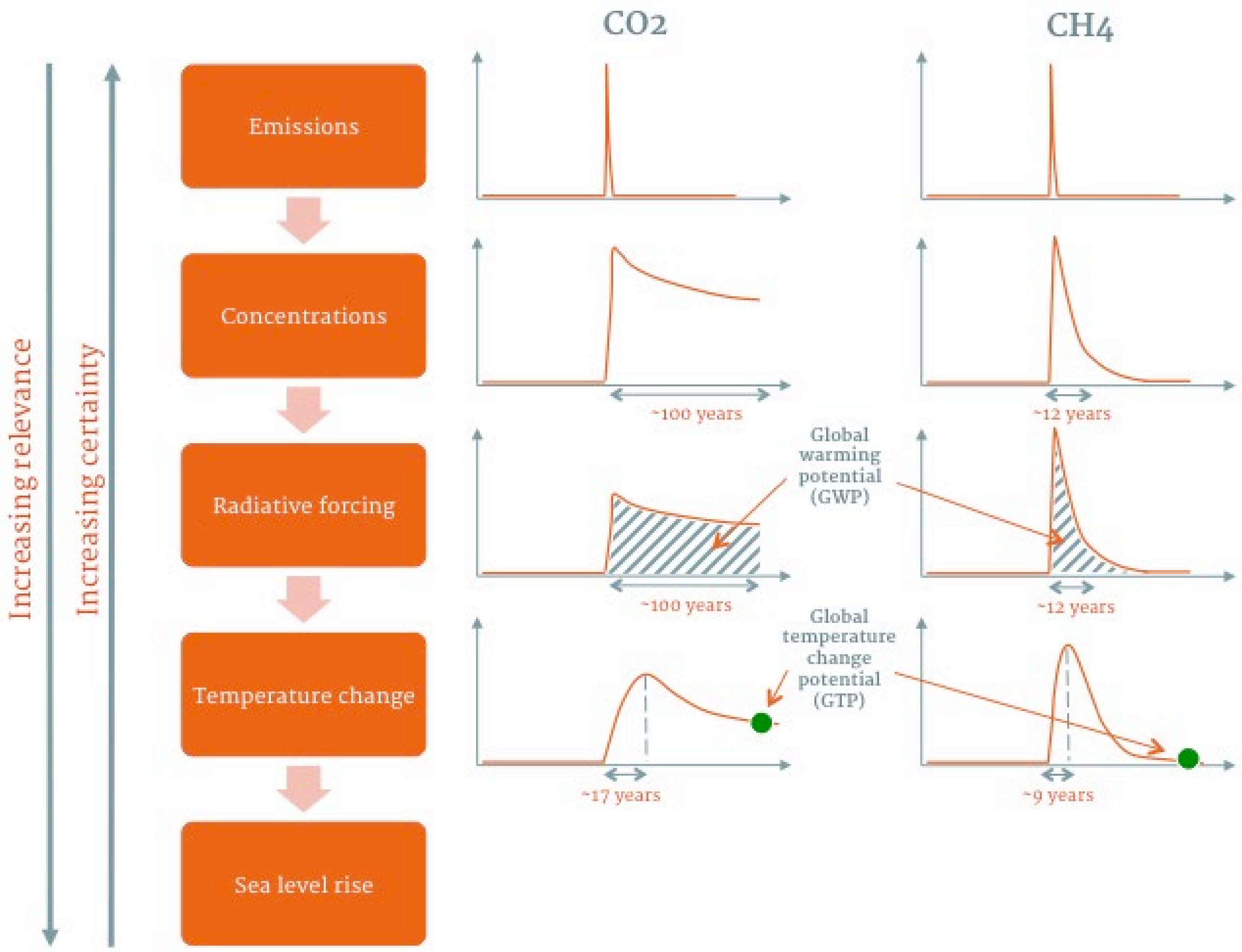
- How much of the respective gas is in the atmosphere?
- How long does the gas remain in the atmosphere?
- How much does the gas influence climate change?

The first two questions can be answered quite clearly based on measurements. The third question, i.e. the extent of a gas's impact on climate change, is more difficult to assess; different approximations and approaches have been used to compare the effects of different greenhouse gases. In terms of the climate impacts, the effects on surface temperature rise, precipitation or sea level rise need to be distinguished.

To understand the science behind the metrics, the "cause-effect chain" model of greenhouse gases in the atmosphere was used to explain the different concepts. Figure 1 shows the relationship between emissions and climate impacts such as sea level rise, using CO_2 as the reference gas:

An initial emission pulse increases the concentration of the gas in the atmosphere. As the gas decays in the atmosphere, the concentration then decreases again, with the rate of this decrease depending on the atmospheric lifetime of a gas. Radiative forcing is directly related to concentration and determines how much of the radiation in the atmosphere is converted to heat. The radiative forcing then leads to a change in temperature compared to the initial level. The temperature change associated with the initial emission pulse first increases, reaches its maximum and then decreases again. The temperature change subsequently leads to a rise in the sea level, altered precipitation and other climate impacts. The impacts of greenhouse gases can therefore be compared based on the different elements of this cause-effect chain, e.g. radiative forcing, temperature change or even direct impacts such as sea level rise, and metrics can be applied at these different levels.

Figure 1: Cause-effect chain of emissions with regard to sea level rise using the example of CO_2 and CH_4 to show GWPs and GTPs



Source: Höhne and Blok (2005)

2.1 Global Warming Potential GWP_{100}

2.1.1 Concept and scientific background

The Global Warming Potential (GWP) of a substance indicates the cumulative warming effect (cumulative radiative forcing) over a certain time horizon that results from the emission of one kilogram of this substance compared to the emission of one kilogram of the reference substance. The reference substance (reference gas) is usually CO_2; other substances can be converted into kg CO_2 equivalents by multiplying them by their global warming potential.

Global warming potentials can be determined for different time horizons. In the reports of the IPCC, most recently in the IPCC Sixth Assessment Report (IPCC 2021), global warming potentials are given for 20, 50 and 100 years. For national greenhouse gas inventories under the United Nations Framework Convention on Climate Change and under the Paris Agreement, the global warming potential over a 100-year period (GWP_{100}) is used. There are historical reasons for choosing a time horizon of 100 years: when the GWP was introduced by the IPCC, CO_2 was still assumed to have a lifetime of 100 years. The time horizon of 100 years was subsequently retained because the choice of a shorter time horizon would not take into account the long lifetime of many greenhouse gases and would thus greatly underestimate their long-term impact. The IPCC scenarios on the consequences of climate change are based, among other things, on assumed global effective radiative forcing up to 2100. This time horizon corresponds well with the time horizon of 100 years on which the GWP_{100} is based and also with the period in which current political and economic strategies primarily have an impact.

The metrics also differ in their mathematical function with regard to the time horizon: with GWP, an emission pulse is integrated over the time horizon and the effect is expressed during the entire time horizon, while endpoint metrics only look at what effect is left of an emission pulse after the period under consideration (see graphs to the right of “radiative forcing” and “temperature change" in Figure 1).

2.1.2 Characteristics, advantages and disadvantages

Global Warming Potential GWP_{100} is used for the reporting of greenhouse gas inventories, policies and measures and projections under the United Nations Framework Convention on Climate Change. This metric must also be used for reporting under the Paris Agreement; other metrics may be used additionally (UNFCCC 2018).

GWP_{100} thus has the advantage of being established for reporting under the UNFCCC. The continued use of this metric under the Paris Agreement is also assured. Similarly, GWP_{100} is used in the EU ETS and other national and international emissions trading systems. Finally, GWP_{100} has also been used by the IPCC as the basis for current mitigation scenarios.

The GWP values are revised by the IPCC over time because the radiative properties of the gases depend on the background gas concentration, which changes continuously. For previous reporting under the UNFCCC and under the Kyoto Protocol, the GWP_{100} from the IPCC Fourth Assessment Report was used; many developing countries still use the values from the IPCC Second Assessment Report. Under the Paris Agreement, the values from the IPCC Fifth Assessment Report are to be used (IPCC 2013).

Box 1. Climate-carbon feedback and methane oxidation

In the following, we consider two aspects that apply equally to all metrics discussed in this paper, not just GWP.

In the IPCC Fifth Assessment Report, carbon cycle feedbacks on emission metrics, so-called “climate-carbon feedbacks,” were considered. The “climate-carbon feedback" takes into account that the emission of greenhouse gases and the resulting warming lead to changes in the carbon cycle and thus to additional CO_2 emissions. Such feedback is included in the carbon cycle models for CO_2, but was neglected for non-CO_2 emissions until the IPCC Fifth Assessment Report was published. The inclusion of feedbacks for non-CO_2 emissions would represent the effects of these emissions more accurately. However, the calculation of climate-carbon feedback is subject to uncertainties, and values with climate-carbon feedback are not provided for all gases in the AR5. For the Sixth Assessment Report, climate-carbon feedback was consistently included in all metrics for all gases. Non-CO_2 emissions can also indirectly influence the carbon cycle. With methane, there are effects on the ozone and water vapour in the atmosphere; and the metrics are scaled with a factor accordingly.

The second aspect is that the AR5 and AR6 distinguish between biogenic and fossil methane. The value for fossil methane takes into account the additional warming effect of CO_2, which is produced when methane is broken down in the atmosphere (1 kg CH_4 is converted into 2.75 kg CO_2, i.e. a value of 2.75 is added for fossil CH_4). The inventories under the UNFCCC and under the Paris Agreement do not distinguish between fossil and biogenic methane. Whether the individual emission sources are of fossil or biogenic origin is known; however, when calculating the total emissions, all methane emissions are added together.

If the GWP for fossil methane is used throughout, it leads to overestimates in the sectors where biogenic methane is emitted, i.e. agriculture, LULUCF and waste. There are also overestimates for the emissions of fossil fuel combustion since the CO_2 emission factors are based on the assumption that 100% of the carbon is converted to CO_2 during combustion. If the GWP for biogenic methane is used throughout, it leads to underestimates for fugitive emissions and industrial processes, unless indirect emissions are considered separately in the inventory.

The metrics for methane from AR5 and AR6 are listed in Annex 1. The GWP_{100} (biogenic) is 28 according to AR5 and 27.0 according to AR6. The GWP_{100} value from the Fourth Assessment Report (IPCC 2007) which was previously used for the inventories of developed countries, is 25.

2.1.3 What influence does GWP_{100} have on the weighting of methane in climate change mitigation measures?

Due to the relatively short lifetime of methane, the use of GWP_{100} covers practically the entire time horizon of the warming effect of this gas, whereas for long-lived gases such as CO_2 the warming effect extends beyond the time horizon of 100 years and is therefore not fully covered by the time horizon. Methane is weighted higher than is the case when using GTP and lower than is the case when using GWP_{20}.

2.1.4 Arguments in favour of this metric

The arguments in favour of GWP_{100} are that the metric is an established one and that it is used in greenhouse gas inventories, in emissions trading systems and in the development of climate change targets (e.g. NDCs). A change in the metric that entails drastic changes in the importance of individual greenhouse gases could lead the public to question the robustness of and the sound scientific understanding of climate research as a whole. This is because the climate scenarios of the IPCC, which have been used for decades, are based on calculations that use GWP_{100}, meaning that these would then also be called into question or would have to be recalculated, thus also depriving the Paris Agreement of its methodological basis. It would be extremely difficult to communicate if, after 25 years of climate negotiations, methane was multiplied by a factor of 4 (GTP) or 84 (GWP_{20}) instead of 28. This situation would strongly support climate sceptics in their argument that a sufficient scientific basis for ambitious emission reductions is lacking. Moreover, such a process would invite numerous lobby groups with vested interests to demand changes to the metric that would reduce the significance of the respective emissions of these groups. One has to be aware of such interests in the current discussions.

GWP_{100} has lower uncertainties than other metrics and the values of GWP_{100} change relatively little over time and therefore provide a reliable basis for policy decisions and economic investments. It is also argued that a time horizon of 100 years appropriately takes into account long-term aspects.

It is necessary to keep the GWP_{100} metric in order to maintain the impact of existing policy instruments. Almost all countries have established their mitigation targets under the Paris Agreement based on GWP_{100}. Changing the metric would require updating all existing NDCs, which would be impractical. The EU's F-Gas Regulation mainly refers to HFCs, whose GTP equivalents would be significantly lower than the GWP emissions. In the case of a switch to GTP, the overall HFC policy both at the EU level and a proposed global HFC phase-down would result in substantially lower emission reductions (in terms of CO_2 equivalents).

2.2 Global Warming Potential GWP_{20}

2.2.1 Concept and scientific background

The concept of the global warming potential with a time horizon of 20 years (GWP_{20}) is the same as for GWP_{100}, with the difference that the cumulative warming effect over a period of 20 years is considered. The effect of the proportion of greenhouse gases that remain in the atmosphere for longer than 20 years is not considered and truncated. No scientific justifications for using GWP_{20} as a general metric can be found in the literature within the scope of the IPCC assessment reports.

2.2.2 Characteristics, advantages and disadvantages

By choosing a time horizon of 20 years for all greenhouse gases/substances, more weight is given to short-lived substances such as soot (black carbon) or methane, while substances with a long atmospheric residence time, especially CO_2, but also N_2O, PFCs and SF_6 are given considerably less weight and their greenhouse effect is underestimated. Figure 2 (taken from the IPCC Fourth Assessment Report) shows as an example the dimension of change for the global emissions of 2000, and CH_4 would clearly predominate in the climate impact. The mitigating effect of aerosols and black carbon on radiative forcing would suddenly be about as large as the increasing effect of CO_2 and false long-term options for action would result since the increase in the proportion of black carbon and aerosols would practically equal the CO_2 reduction in terms of quantitative effects.

With GWP_{20}, the share of long-lived greenhouse gases in radiative forcing would be significantly underestimated in the time periods underlying the assessments of the IPCC or the Paris Agreement, because the long-term effect after 20 years is not considered. It would also be illogical to use GWPs with a time horizon of 20 years for long-term climate targets that extend beyond the 20-year period, i.e. beyond 2040. GWP_{20} would not be suitable for long-term strategies, which usually extend to 2050.

The choice of this relatively short-term time horizon must therefore be seen as a disadvantage as it is not compatible with long-term climate change mitigation goals. Under the Paris Agreement, the aim is to stabilise global temperatures. This can only be achieved if the emissions of long-lived greenhouse gases (especially CO_2) are hugely reduced. The emissions of short-lived substances have a lower impact on this long-term goal.

Figure 2: Integrated radiative forcing for global emissions in 2000 for GWPs with time horizons of 100 years (top) and 20 years (bottom)

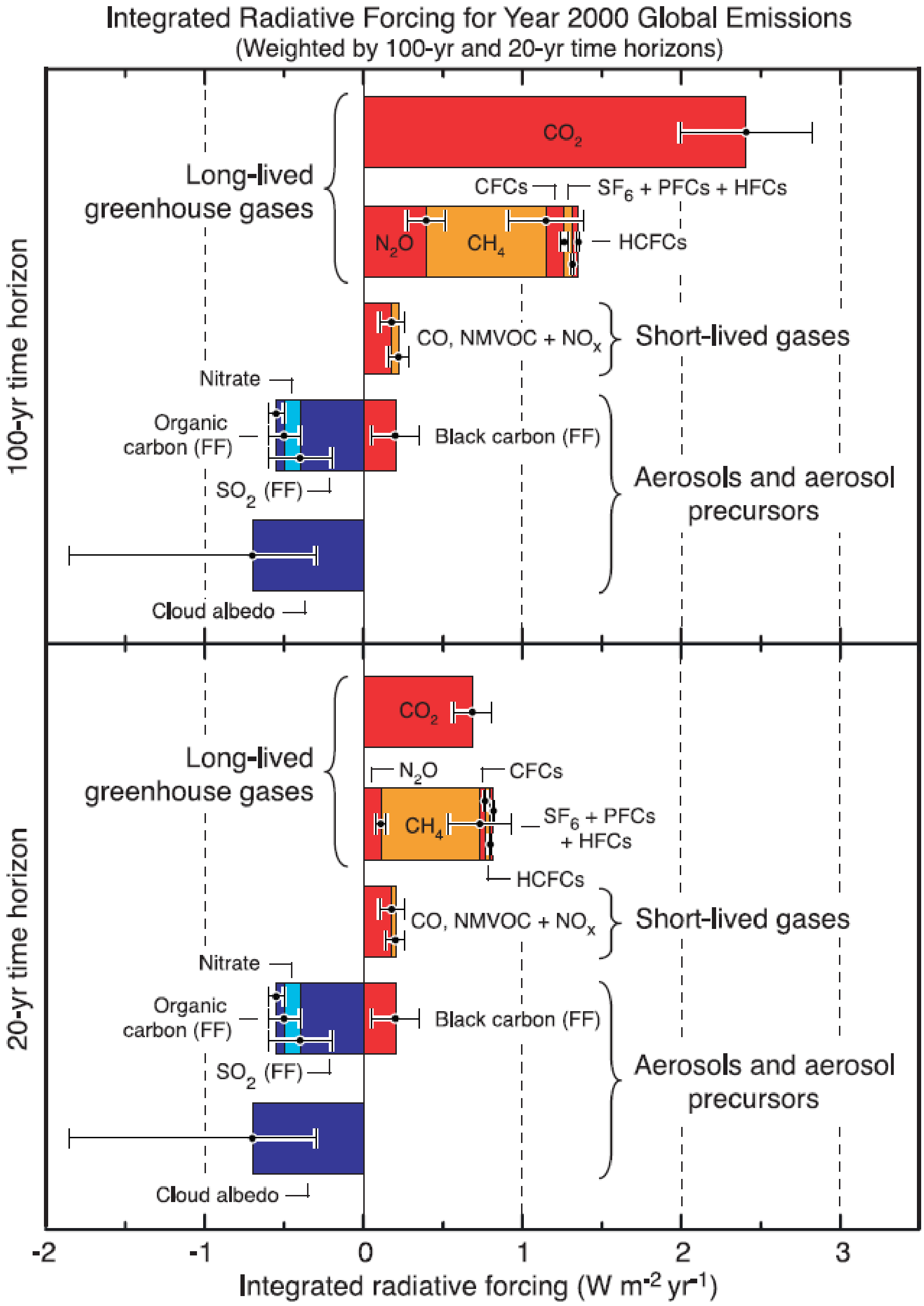


Figure 2.22. *Integrated RF of year 2000 emissions over two time horizons (20 and 100 years). The figure gives an indication of the future climate impact of current emissions. The values for aerosols and aerosol precursors are essentially equal for the two time horizons. It should be noted that the RFs of short-lived gases and aerosol depend critically on both when and where they are emitted; the values given in the figure apply only to total global annual emissions. For organic carbon and BC, both fossil fuel (FF) and biomass burning emissions are included. The uncertainty estimates are based on the uncertainties in emission sources, lifetime and radiative efficiency estimates.*

Source: Forster et al. (2007), IPCC (2013)

2.2.3 What influence does GWP_{20} have on the weighting of methane in climate change mitigation measures?

If GWP_{20} is used instead of GWP_{100} for prioritising mitigation measures, methane is weighted more heavily by a factor of approx. 3. In order to achieve a set emission reduction target, it is then more attractive to reduce methane emissions instead of implementing transformative measures to reduce CO_2 emissions. However, reducing methane instead of CO_2 emissions makes it more difficult to meet long-term climate targets, as CO_2 and other greenhouse gases remain in the atmosphere in the long term.

2.2.4 Arguments

The high potential of methane mitigation measures (e.g. for fugitive emissions) is put forward as an argument. This is undisputed, and many of these measures can be implemented at low cost. However, if GWP_{20} is applied when prioritising measures, there is a risk that methane emission reductions will take precedence over CO_2 emission reductions. This has a negative impact on meeting the long-term climate targets under the Paris Agreement.

Some environmental organisations have suggested that GWP_{20} is used in addition to GWP_{100} and that they could be jointly used in assessment and accounting (“dual accounting”). However, it is unclear how a joint assessment and accounting can be carried out. For prioritisation of measures or for comparison with reduction targets, a uniform measure is necessary. However, two conversion metrics cannot be used jointly and simultaneously for assessing the achievement of reduction targets or for emission allowances in emissions trading. This would be comparable to using two very different exchange rates for one currency.

Reference is made to tipping points in the global climate system that will already be reached in the next few decades. The danger of reaching tipping points more quickly in the next 20 years is considered much more important than the danger of global warming in the medium and long term. The IPCC has also been criticised for using GWP_{100} and for focusing too much on long-term climate change. When exactly tipping points are reached cannot be predicted, and no concrete examples have been given in the discussion. By focusing on short-lived greenhouse gases, warming would slow down somewhat in the next few decades, but it would be higher in the long term and could lead to more tipping points than a development more focused on CO_2 emission reductions.

A focus on short-lived greenhouse gases would not only have to consider CH_4, but also other relevant short-lived substances with a global warming potential such as nitrogen oxides (NO_x) or black carbon. According to the IPCC Fifth Assessment Report, nitrogen oxide emissions have a cooling effect in Europe corresponding to a GWP_{20} value of -39.4 and globally to -108, while the GWP_{100} values are only -15.6 and -31 respectively. The effect of black carbon, which is particularly relevant in short time periods, would then also have to be considered much more closely, because according to the IPCC the GWP_{20} value for black carbon is 3200, while the value for GWP_{100} is 900, i.e. there is no substantiation for only considering CH_4 when applying an approach that emphasises the effects of short-lived climate pollutants; rather, substances that are currently not even accounted for as indirect greenhouse gases also have to be considered.

2.2.5 What would it mean if GWP_{20} were used for policy discussion?

The choice of mitigation measures depends on many factors, including technical feasibility, costs and acceptance. The metric used can also play a role in the prioritisation of measures. If a metric with a high global warming potential for methane is used, it provides an additional incentive to reduce methane emissions in order to achieve a specific climate target.

If GWP_{20} is used instead of GWP_{100} in policy discussions, methane reduction measures are prioritised over CO_2 reduction measures and over the reduction of other long-lived greenhouse gases. A set reduction target could then be achieved with higher CO_2 emissions than when using GWP_{100}. These higher CO_2 emissions lead to greater warming in the long term and are counterproductive to meeting long-term climate targets.

Since the GWP_{100} metric is also used for the IPCC scenarios for the pathways to achieve the 1.5°C or 2°C temperature targets, the metric applied would no longer be consistent with the IPCC scenarios if GWP_{20} were used. In principle, the entire modelling work and factual reports of the IPCC would need to be revised to have a suitable scientific basis, which in turn would not be compatible with the time horizon of the IPCC modelling of global effective radiative forcing until 2100.

2.3 GTP (different time horizons)

2.3.1 Concept and scientific background

The Global Temperature Change Potential (GTP) indicates the effect of the emission of one kilogram of a substance on the mean global temperature at the end of a certain period of time, compared to the effect of the emission of one kilogram of a reference substance. CO_2 is normally used as the reference substance (reference gas); other substances can be converted into kg CO_2 equivalents by multiplying them by their GTP. The GTP concept goes one step further in the cause-effect chain and considers temperature change in addition to the radiation effect. GTPs can be determined for different time horizons. In the IPCC Fifth and Sixth Assessment Reports, GTPs are given over 50 and 100 years, among others. Since it is not the integral of the warming effect over a period of time that is considered, but the temperature change at the end point, the choice of the time horizon is much more crucial for the GTP than for GWP; the values change very strongly over the time horizons.

Since the GTP considers the effect of a single emission pulse on global temperature at the end of a given time period, greater weight is given to long-lived substances than to short-lived substances when periods of 50 or 100 years are considered. The effect of short-lived substances is not completely disregarded, but only that portion of the substance that remains in the atmosphere at the end of the time period is taken into account. Feedbacks can also be taken into account (e.g. the effect of short-term warming on the global carbon cycle and the resulting additional CO_2 emissions, as in the IPCC Sixth Assessment Report). However, using a time horizon go 50 or 100 years, there is practically nothing left of an emission pulse of CH_4 at a lifetime of about 12 years. Thus, the GTP values for CH_4 or other short-lived gases are also very low when time periods of 50 or 100 years are used.

2.3.2 Characteristics, advantages and disadvantages

As described above, the GTP concept goes one step further in the cause-effect chain and takes into account the temperature change in addition to the radiation effect. This further step in the cause-effect chain also increases, however, the uncertainty. For CH_4, the uncertainty of the GWP_{100} amounts to ± 40%, while that of the GTP_{100} amounts to ±60%. Appendix 1 shows the GTP_{20} and GTP_{100} values for methane from AR5 and AR6. As with GWP, values are available separately for fossil and biogenic methane. The table in the appendix shows that GTP_{100} for methane is significantly lower than GWP_{100}, since over a period of 100 years a large part of the methane decomposes in the atmosphere.

Similarly, the table also shows that GTP_{20} for methane is of the same order as GWP_{20}, i.e. the effect of an emission on the temperature increase over a 20-year period is about the same as the effect on warming over a 20-year period, each compared to CO_2.

GTP can be helpful in assessing the extent to which emission reductions contribute to meeting the temperature goal of the Paris Agreement. GTP_{20} and GTP_{50} are a measure of how much an emission will contribute to global temperature in 20 or 50 years, i.e. a period of time when the global temperature must approach a plateau in order to meet the Paris Agreement's temperature goal.

As GTP values are more dependent on the time horizon than GWP, it is much more difficult to choose the "right" GTP under the Paris Agreement with a view to the comparability of global mitigation targets. GTP_{100} values take into account what remains of an emission pulse in 100 years and therefore do not correspond to the current policy issues under the Paris Agreement, where the current NDCs mostly have a time horizon until 2030 and the long-term strategies until 2050. A comparison of GWP_{100} values with GTP_{100} values is misleading due to the differences in the mathematical calculation.

At a special IPCC session on metrics at the Subsidiary Bodies meeting in June 2014, researchers stated that the most appropriate choice of time horizon for GTPs was 40 to 60 years, in light of the goal of limiting global temperature increase to 2°C. In the contribution of Working Group III to the IPCC Sixth Assessment Report (2022, Chapter 2, cross-chapter box 2) a "dynamic GTP" has been discussed. This considers the temperature change in a specific future year, e.g. in the expected year of the maximum temperature for a specific temperature target. For emissions in 2020, for example, a GTP_{40} would correspond to a dynamic GTP for the year 2060. The WG III paper states that using the dynamic GTP instead of the GWP_{100} can reduce global mitigation costs in theory, but that this cost reduction depends on the temperature target, forward-looking policies and flexibility in the choice of measures.

It was stipulated under the UNFCCC and the Paris Agreement that GWP_{100} must be used for inventories. The current mitigation scenarios of the IPCC and various emissions trading systems are also based on GWP_{100}. As a result, a change of metric would be associated with great difficulties.

All metric values need to be updated over time due to changing atmospheric conditions and improved input data (IPCC 2014). However, dynamic GTP values will change more than GWPs. As the target year of the dynamic GTP (e.g. the global temperature maximum) approaches, short-lived substances will become more relevant to global temperature change and the dynamic GTP values for short-lived substances will then increase significantly. Metrics that show fluctuating "conversion rates" over time will pose challenges for policy makers, especially when designing long-term low emission strategies.

In addition to the GTP metric, the Integrated Global Temperature Potential metric (iGTP, Peters et al. 2011) has been proposed. This integrates the temperature change (in °C) over a certain period of time, similar to the GWP, which integrates the warming effect (in W/m^2) over a certain period of time. iGTP values are in most cases very similar to GWP values. The difference between the two concepts depends strongly on the underlying mathematical function and less on the fact that GTP relates directly to the temperature target.

2.3.3 What influence does GTP have on the weighting of methane in climate change mitigation measures?

Since GTP considers the warming effect at a certain point in the future and methane has a short lifetime in the atmosphere compared to CO_2, the weighting of methane becomes lower the longer the time horizon. Thus (according to AR5) the GTP_{100} value for methane is 4 compared to the GWP_{100} value of 28. As explained above, dynamic GTP values change strongly over time.

2.3.4 Arguments

It has been argued that GTP is an appropriate metric in the context of the temperature goal under the Paris Agreement since the effect of emissions on temperature change is relevant to meeting the temperature goal and this effect is better expressed by using GTP. It has also been argued that GWP_{100} overestimates the contribution of CH_4 and underestimates that of CO_2.

2.3.5 What would it mean if other metrics were used for policy discussion?

As described in section 2.2.5, the selection of mitigation measures depends on many factors. The metric used can also play a role in the prioritisation of measures. If GTP_{100} were used instead of GWP_{100} to prioritise measures, CO_2 reduction measures would be prioritised more than methane reduction measures. However, as described above, the time horizon of 100 years is not the adequate time horizon for the GTP under the Paris Agreement.

2.4 GWP* and variants

2.4.1 Concept and scientific background

In the IPCC report on the 1.5 °C goal (IPCC 2018), the GWP* concept was introduced, in which a permanent change in the emission level of a short-lived greenhouse gas is equated with a one-time pulse (emission increase or decrease) of CO_2. For example, if methane emissions in a given year are one tonne CO_2 equivalent lower than in the baseline year, this corresponds to a one-time emission saving of one tonne CO_2 in that year. The year t-20 is often used as the baseline year.

A modification has also been proposed for GWP* to reflect the impact of GHG emissions on the global average temperature (rather than on cumulative warming) (Cain et al. 2019). According to this approach, so-called "CO_2 warming equivalents" are calculated. A good explanation of the GWP* approach can be found in Lynch et al. (2020). In addition to the treatment of methane emissions, GWP* is also proposed for aviation emissions as the non-CO_2 effects and in particular cloud formation have a very short lifetime (Lee et al. 2021).

2.4.2 Characteristics, advantages and disadvantages

The GWP* concept provides a better understanding of the short-term impacts of emission changes on a global scale. According to the authors, GWP* more accurately indicates the effects of emissions of both long-lived and short-lived pollutants on radiative forcing and temperatures over a wide time frame than GWP or GTP, especially with ambitious mitigation. In long-term analyses, increasing methane emissions would result only in an additional temperature increase, as short-lived methane is degraded over a period of about 12 years and no longer increases temperature. Constant emissions lead to constant atmospheric concentration and thus a one-time temperature increase. Continuously constant CH_4 emissions would therefore not lead to a continuous additional temperature increase. In the GWP approach, however, constant methane emissions would be treated as long-lived gases and assessed as if they led to additional warming.

It should be noted that there are disadvantages in the long term and at the national level. If GWP* is used to calculate total emissions, negative emissions would be reported if methane emissions are reduced compared to the past. Ambitious reduction targets could thus be mathematically achieved without a reduction in CO_2 emissions. This is counterproductive for compliance with the long-term temperature goal: short-term changes in methane emissions compared to the past have little long-term impact on global temperature, while CO_2 emissions make it more difficult to comply with the temperature goal in the long term due to the long residence time of CO_2 in the atmosphere.

The application of GWP* at the national level has the disadvantage of favouring countries with historically high emissions and disadvantaging countries with historically low emissions. As Table 2 shows by way of example, countries in which methane emissions have increased over time (e.g. the Russian Federation, Brazil) have relatively high emissions (in CO_2 equivalent) per inhabitant. Countries that reduced their emissions over time have negative emissions. In the example in Table 2, Australia's emissions are 7 tonnes CO_2 equivalent lower per person if the GWP* approach is used instead of the GWP_{100} approach.

Table 2: Methane emissions in 2015 per inhabitant using GWP_{100} or GWP*

Country	Methane emissions per inhabitant in tonnes CO_2 equivalent	
	Using GWP_{100}	Using GWP*
Russian Federation	6.5	8.0
Australia	4.8	-2.2
USA	2.3	-1.8
Brazil	2.2	2.8

Selected baseline year: 1995 (t-20)

Source: Rogelj and Schleussner (2019)

Since GWP* compares current emission levels with those of 20 years ago, a long time series is necessary to calculate emissions. For developed countries that report complete inventories from 1990 under the UNFCCC, GWP* can be calculated for the period from 2010. However, many developing countries still do not have complete and consistent emission inventories from 1990 onwards, i.e. GWP* can only be calculated for a few years or even not at all. Many non-state actors that report their emissions and have set targets would also not be able to use the GWP* metric.

2.4.3 What influence does GWP* have on the weighting of methane in climate change mitigation measures?

The use of GWP* provides an incentive to reduce methane emissions compared to the past. Countries with historically high methane emissions can thus reduce their calculated greenhouse gas emissions (expressed in CO_2 equivalent according to GWP*) without having to reduce their CO_2 emissions.

2.4.4 Arguments

It has been argued that using GWP_{100} overestimates the impact of methane emissions on long-term temperature increase and that GWP* is more appropriate for this purpose.

It should be noted that switching to GWP* would underestimate the impact of methane emissions compared to other metrics in many cases. Especially in countries with historically high methane emissions, this approach would have the consequence that both methane and CO_2 emissions would be reduced to a lesser extent than is the case when using other metrics. However, the authors of the concept also specifically address the situation of ambitious mitigation scenarios in which GWP and GTP no longer adequately reflect the role of short-lived gases in temperature increase.

It has also been argued that measures to reduce methane emissions lead to a “cooling” of the atmosphere. It should be made clear that the reduction of methane emissions can slow down the rise in global temperature in the short term. However, the global temperature rises more strongly in the long term if measures to reduce CO_2 are postponed in favour of measures to reduce methane.

2.4.5 What would it mean if GWP* is used in policy discussions?

When GWP* is used to prioritise measures, the focus is on reducing methane emissions from baseline levels. If methane emissions are reduced compared to the past, GWP* becomes negative. With a negative GWP*, emissions (expressed in CO_2 equivalent) could be mathematically set to zero, although absolute methane emissions and absolute CO_2 emissions remain. Measures that only minimise GWP* would neither achieve the goal of greenhouse gas neutrality nor the temperature goal under the Paris Agreement.

2.5 Combined GTP (CGTP)

2.5.1 Concept and scientific background

The Combined Global Temperature Change Potential (CGTP) is another possibility, besides GWP*, of making the effect of long-lived and short-lived greenhouse gases comparable. The CGTP is the absolute global temperature change potential (AGTP)[9] of an emission change divided by the AGTP of CO_2. Similarly to the GWP*, a change in the emission rate of a short-lived greenhouse gas is compared to an emission pulse of CO_2.

2.5.2 Characteristics, advantages and disadvantages

The CGTP shows smaller changes over time than the GTP. It can be calculated for any GHG, but is least dependent on the time horizon for GHGs that have a lifetime shorter than half the selected time horizon. Multiplying the emission rate of a short-lived greenhouse gas by its CGTP yields cumulative emissions in CO_2 equivalents.

2.5.3 What influence does CGTP have on the weighting of methane in climate change mitigation measures?

Similar to GWP*, CGTP provides the incentive to reduce methane emissions compared to past levels. Countries with historically high methane emissions can thus reduce their calculated greenhouse gas emissions (expressed in CO_2 equivalent according to CGTP) without having to reduce their CO_2 emissions.

2.5.4 Arguments

As with the GWP* metric, it can be argued that using GWP_{100} overestimates the impact of methane emissions on long-term temperature increase, and that CGTP is better suited for this purpose.

[9] Absolute Global Temperature Change Potential (AGTP): Change in mean global temperature at the end of a defined period of time based on the emission of one kilogram of a greenhouse gas.

2.5.5 What would it mean if CGTP is used for policy discussion?

The CGTP allows to compare the effect on global temperature of a long-term change in the emission level of methane with a short-term emission stimulus of CO_2. However, in policy discussions, the change in the emission level of methane ("measure A") is often compared to a change in the emission level of CO_2 ("measure B") over one year or a few years. The use of CGTP does not allow a direct comparison between the effect of these two measures.

2.6 Separate targets for long-lived and short-lived greenhouse gases

2.6.1 Concept and scientific background

In their statements, IPCC scientists emphasised several times that it is difficult to find a metric that appropriately takes into account both the contribution of short-lived gases and the contribution of long-lived greenhouse gases to the temperature increase. It was argued that the "basket approach" of the Kyoto Protocol, i.e. setting a reduction target for all anthropogenic greenhouse gas emissions, is the real problem. Therefore, it was recommended that either each greenhouse gas is treated separately or two different "baskets" of gases are used, one with short-lived greenhouse gases and a second with long-lived gases, and to use different metrics to calculate each basket.

2.6.2 Characteristics, advantages and disadvantages

The major disadvantage of this approach is that there would no longer be any easily understandable and comparable political climate targets that compare the outcome of the political actions of different countries. Clear political messages would be countered by a multitude of individual targets or at least two different targets for short- and long-lived gases. Furthermore, besides CH_4, a number of climate drivers such as NO_x and SO_2, black carbon and cloud formation from aviation, play a major role as short-lived substances and in some cases also have a cooling effect.

However, these effects are not necessarily distributed equally globally, but can occur regionally. In the political objective for the reduction of anthropogenic greenhouse gas emissions, the short-lived gases other than CH_4 currently play no role at all. A focus on a "basket" of short-lived substances would suddenly credit air pollutants such as SO_2 or NO_x with a positive climate impact, which could undermine reduction efforts for these substances as air pollutants. Important short-lived substances such as black carbon, which contribute to temperature increase, are currently not included by most countries in their greenhouse gas inventories because the relationships between emissions and effects are not clearly understood and the impact depends on other factors. CH_4 is therefore used in discussions as an indicator substance for a group of short-lived substances that currently play no particular role at all in discussions focused on climate policy. The different effects in Figure 3 also shows that it would be illusory to set a common target for all short-lived greenhouse gases as they behave in very different ways.

Figure 3: Temperature change due to emissions of different gases and black carbon (black carbon - BC)

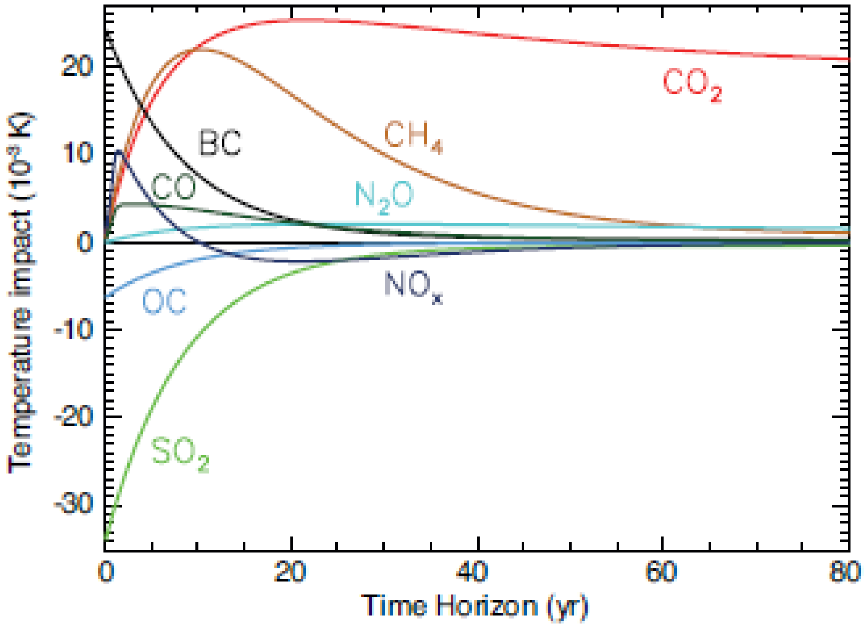


Figure 8.33 | Temperature response by component for total anthropogenic emissions for a 1-year pulse. Emission data for 2008 are taken from the EDGAR database and for BC and OC for 2005 from Shindell et al. (2012a). There are large uncertainties related to the AGTP values and consequentially also to the calculated temperature responses (see text).

Source: Myhre et al. (2013)

It is very difficult to communicate the scientific basis of such a differentiated approach to the general public. This could make the robustness of the scenarios contestable and would also, as described above, provide various lobby interests with leverage to prevent certain greenhouse gas sources from being included in mitigation strategies.

2.6.3 Arguments

The Montreal Protocol is leveraged in arguments about separate targets for long-lived and short-lived greenhouse gases; this Protocol regulates individual substances or substance groups, but does not combine them into one target. This leveraging is flawed, however, as the Montreal Protocol regulates man-made individual substances that have relatively few defined areas of application, for each of which substitutes are available. As a result, individual substances can be reduced in the respective areas of application and replaced by the substitute substances. It makes sense, however, to look at individual substances.

In the case of greenhouse gas emissions, there are a large number of emission sources influenced by humans which actually have natural processes as their cause and in which short-lived CH_4 and long-lived N_2O are emitted from the same natural reaction. These include, for example, manure management (CH_4 and N_2O emissions through decomposition processes), or emissions from agricultural soils. Although combustion processes mainly release CO_2 emissions, they also release

CH_4 and N_2O. It seems impractical to put the CH_4 emissions in a different “basket" of short-lived emissions with their own targets if the reduction applies to the same source.

2.6.4 What would it mean if separate targets were introduced for long-lived and short-lived greenhouse gases?

Separate targets for the different greenhouse gases, which include a large number of individual substances in the case of fluorinated gases, would be extremely complex for policy discussions and also for the international negotiation process. Particular interests in the form of special lobby groups would have much better points from which to start and would probably be much more effective, as hardly anyone would have an overview anymore. Certain activities (e.g. the combustion processes in power plants) that emit three different greenhouse gases would then be subject to three different targets that can no longer be flexibly balanced among each other, which would significantly increase the complexity for plant operators. It would also be unclear what metric should be used instead of GWP_{100} for the short-lived gases.

The IPCC Sixth Assessment Report (WG I, Box 7.3) points out that most NDCs specify an emissions target for 2030 in CO_2 equivalents without specifying which gases will contribute to the emissions by 2030. However, the long-term temperature change and thus compliance with the temperature goal depends on the ratio of short- and long-lived gases emitted. The IPCC therefore states that the impact of emission pathways on global warming could be presented more transparently by reporting emission pathways for individual gases separately, rather than solely as the sum of all gases in CO_2 equivalents using the GWP_{100}. Alternatively, cumulative emissions could be reported in CO_2 equivalents, provided that emissions of non-CO_2 gases are converted to CO_2 equivalents using the GWP* or CGTP (IPCC 2021).

2.7 Comparative overview

In the following table, the metrics are presented based on the criteria introduced in chapter 1.

Table 3: Comparison of metrics based on criteria

	GWP_{100}	GWP_{20}	GTP	GWP*	CGTP
Robust scientific basis	Yes	Yes	Yes, but higher uncertainty	Yes, but methodological adjustments are needed	Yes, but higher uncertainty
Compatibility with higher-level goals (e.g. temperature target)	Yes	Not applicable for long-term temperature target	Only applicable if time horizon of 40-60 years is chosen; not given if GTP_{100} is chosen	Not applicable for long-term temperature target	Only applicable if time horizon of 40-60 years is chosen
Supports the setting of mitigation targets and the tracking of progress towards implementation in the time periods of the Paris Agreement.	Yes	Not applicable	Only applicable if time horizon of 40-60 years is chosen; not applicable if GTP_{100} is chosen	Yes	Only applicable if time horizon of 40-60 years is chosen
Supports the prioritisation of mitigation strategies and the selection of measures	Yes	Not applicable	Only applicable if time horizon of 40-60 years is chosen; not applicable if GTP_{100} is chosen	Tends not to be applicable	Tends not to be applicable
Robust basis for emissions trading	Yes	No as not established	No as not established	No due to methodological difficulties, e.g. negative values for GWP*.	No as not established

	GWP_{100}	GWP_{20}	GTP	GWP*	CGTP
Recognised sources for reference values	Yes	Currently still applicable, in future probably no longer	Yes	Currently not applicable	Yes
As stable values as possible with little change over planning periods of approx. 25-50 years	Yes	Not applicable	Not applicable	Not applicable	Yes
Avoidance of unintended consequences	Yes	No. Risk that CO_2 emissions are not sufficiently reduced.	Yes	No. Risk that CO_2 emissions are not sufficiently reduced.	No. Risk that CO_2 emissions are not sufficiently reduced.

2.8 Conclusions from the comparison of the metrics

The comparison in Table 3 shows that the GWP_{100} best meets the criteria listed. This is due, among other things, to the fact that it is an established metric which has a robust scientific basis and which is already used in greenhouse gas inventories and emission trading systems. Furthermore, with a time horizon of 100 years, the GWP is suitable to support long-term climate change planning.

If metrics with a shorter time horizon - such as the GWP_{20} - are used, the long-term effect of greenhouse gases is not taken into account. This is problematic because various greenhouse gases, especially CO_2, have a long residence time in the atmosphere. Every additional emission of these gases makes it more difficult to stabilise the global temperature in the long term.

The GTP, which looks at the effect of a greenhouse gas on temperature at the end of a defined time period, is associated with higher uncertainties than the GWP. When using these metrics, it is important to align the chosen time horizon with the time horizon for the temperature goal. For example, to meet the temperature goal under the Paris Agreement, a maximum temperature must already be reached in the second half of this century. A time horizon of 100 years would not be suitable for this.

The metric GWP* focuses on the change in emissions of short-lived substances compared to historical emissions. If methane emissions are reduced in a country compared to the past, GWP* becomes negative. A negative GWP* would allow emissions (expressed in CO_2 equivalent) to be mathematically set to zero, although absolute methane emissions and absolute CO_2 emissions remain. This makes it difficult to use this metric in planning climate change mitigation.

The use of separate targets for different greenhouse gases would be complex for policy discussions, as individual activities would be subject to multiple targets. However, specifying emission pathways separately for individual gases could help to make the impact of pathways on global warming more transparent.

In summary, the global warming potential GWP_{100} fulfils the criteria for a metric well. For greenhouse gas inventories under the UNFCCC and under the Paris Agreement, GWP_{100} is the established metric. It is a good choice for prioritising action to meet climate change mitigation goals because it is long-term and has a robust scientific basis. The application of other metrics can be useful for specific questions but must be critically questioned in individual cases. When using metrics for quantifying GHG emissions that deviate from the specifications under the Paris Agreement, they should be clearly marked as such and it should also be shown for which sectors or actors the chosen alternative metrics are beneficial.

3 Outlook

With the decisions on greenhouse gas inventories and metrics at the climate conference in Sharm El-Sheikh in November 2022 (see Table 1), the Parties to the United Nations Framework Convention on Climate Change agreed for the first time on uniform metrics for the greenhouse gas inventories of all countries. The use of the GWP_{100} from the IPCC Fifth Assessment Report had already been established in 2018 for inventories under the Paris Agreement. By the end of 2024 at the latest, the same metrics will also apply to all greenhouse gas inventories under the Framework Convention on Climate Change.

Knowledge about metrics continues to evolve. In the IPCC Sixth Assessment Report, new values for the most important metrics were published. For methane, however, these differ only slightly from the values in the previous report. In the current NDC period 2021-2030, the current metrics will be retained in national reports. The rules for reporting under the Paris Agreement post-2030 will be reviewed and revised, if necessary, by the Subsidiary Body for Scientific and Technological Advice (SBSTA) no later than 2028 (UNFCCC 2018, para. 2).

Appendix: Overview of metrics for methane emissions

Table 4: Metrics for methane emissions in the IPCC Fifth and Sixth Assessment Reports

	IPCC Fifth Assessment Report (values take into account climate-carbon feedback for CO_2, but not for methane)		**IPCC Sixth Assessment Report** (values take into account climate-carbon feedback for CO_2 and methane)	
	Methane	**Fossil methane**	**Non-fossil methane**	**Fossil methane**
GWP_{100}	28	30	27.0	29.8
GWP_{20}	84	85	79.7	82.5
GTP_{100}	4	6	4.7	7.5
GTP_{50}	14	15	10.4	13.2
GTP_{20}	67	68	Not published in this report	
GWP*	No uniform values; dependent on historical emissions			

Source: IPCC (2013), Table 8.7; IPCC (2021), Table 7.15.

The value of 28 for the GWP_{100} of methane will be used for greenhouse gas inventories from 2023/2024 (see Table 1).

For background information on climate-carbon feedback and fossil methane, see Box 1 in Section 2.1.2.

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