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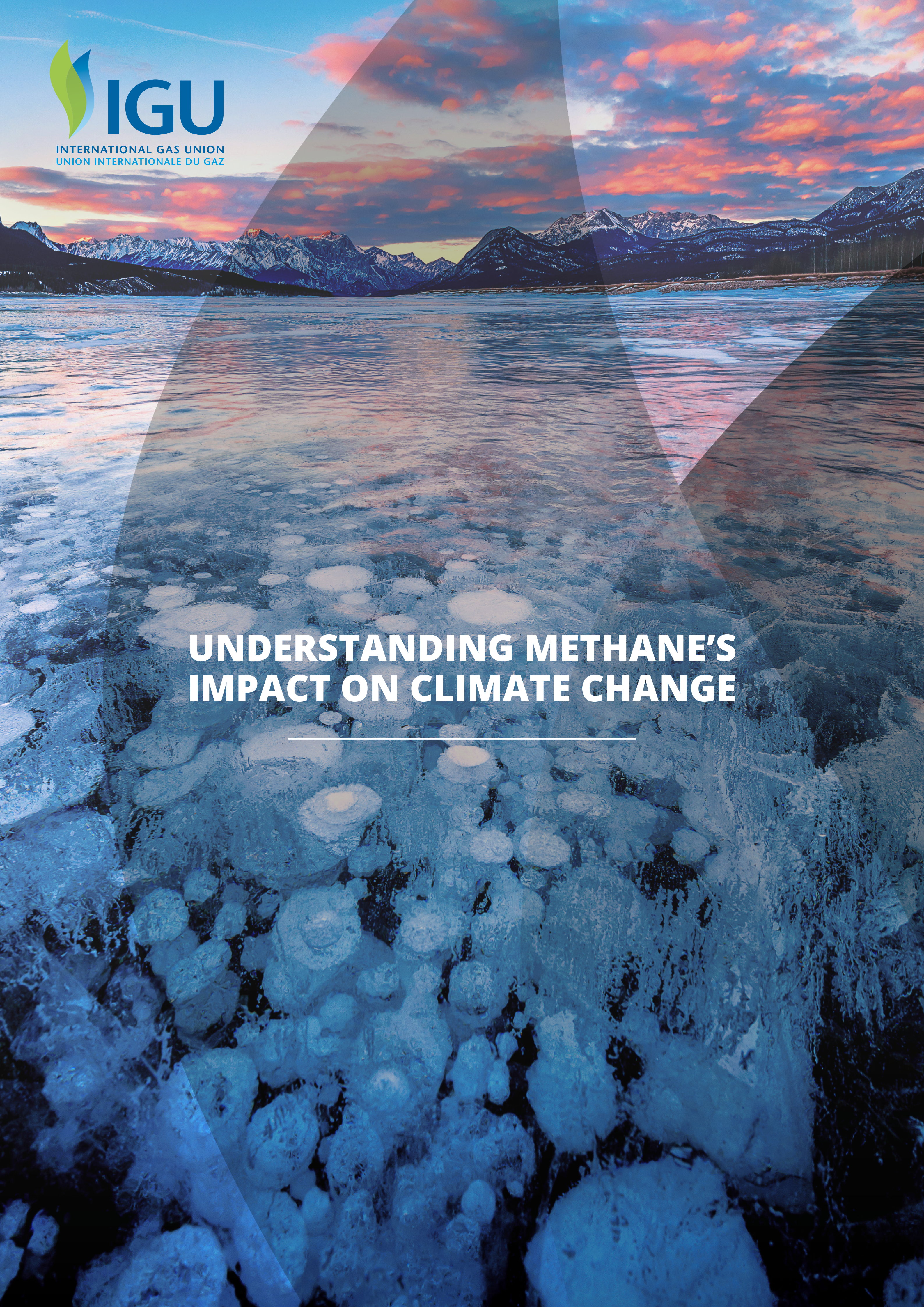


UNDERSTANDING METHANE'S IMPACT ON CLIMATE CHANGE

METHANE'S IMPACT ON CLIMATE CHANGE

SYNOPSIS

Climate change is a uniquely long-term problem, which can lead to potentially irreversible changes in the Earth's climate system.[1] The long-term climate impacts of unmitigated greenhouse gases (GHG) emissions are well-understood—thanks in a large part to the efforts by the UN IPCC[2] and the rest of the scientific community—and the confidence level in these long-term effects has risen over time.[3] The most devastating potential impacts of climate change—such as rising sea levels, ocean acidification, or the melting of ice sheets—play out over multiple decades, or even centuries.[4]

The risk of abrupt, non-linear changes in the climate system also likely increases with rising global temperature levels.[5] However, using only a very short timeframe for estimating climate impacts, like 20 years, would excessively weigh near-term impacts, understating the effect of long-term GHG accumulation on total warming by the end of the century, and thereafter.

The use of GWP[6] factor of 100 years yields a balanced approach to an effective outcome for climate policy, as MIT researchers put it:

> A 20-year GWP would emphasize the near-term impact of methane but ignore serious longer-term risks of climate change from GHG's that will remain in the atmosphere for hundreds to thousands of years, and the 500-year value would miss important effects over the current century. Methane is a more powerful GHG than CO_2, and its combination of potency and short life yields the 100-year GWP used in this study.[7]

1 Wagner and Weitzman (2015), p.9-10

2 Intergovernmental Panel on Climate Change (IPCC), a scientific and intergovernmental body under the auspices of the United Nations

3 https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf, p.8-26
https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf, p.694
Wagner and Weitzman (2015), p.50

4 Wagner and Weitzman (2015), p.10

5 https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full.pdf, p.73-74

6 Global Warming Potential

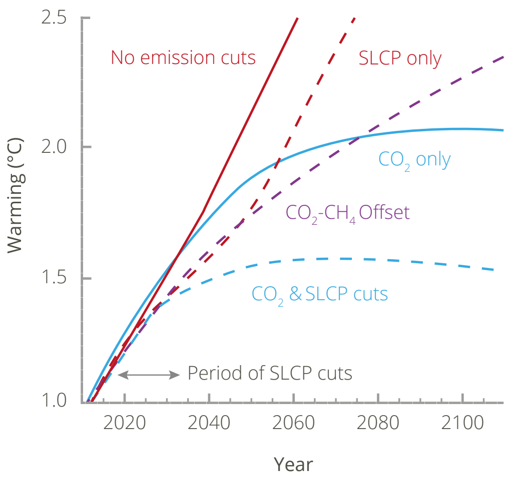
7 Moniz et al. (2011), Appendix 1A, p.19

The Policy Choice

The choice of time horizon for GWP metric is an expression of policy preference, and it reflects a particular view of the climate change problem we must solve. Focusing on a short time-period (e.g., 20 years) prioritizes the *rate* of climate change more than its long-term *magnitude*. It places greater emphasis on avoiding abrupt, non-linear climate responses (so-called "tipping points"), rather than the irreversible climate change over the long run.[8]

Policies aiming to avoid the long-term irreversible climate change and attain the 2°C target, which the international community agreed to in Paris, would need to be based on GWP_{100}. Using GWP_{20} would alter that aim, by shifting the focus onto mitigating the short-term rate of change, away from its long-term magnitude. That would smooth the short-term fluctuations, while missing the long-term temperature target, as CO_2 will continue to accumulate. This is illustrated by *the chart on the right,* comparing the impacts of CO_2 reductions to that of short-lived climate pollutants (SLCP) on global temperature.

Impact of CO_2 and SLCP cuts



Source: Myles, A. Short-lived Promise? The Science and Policy of Cumulative and Short-Lived Climate Pollutants. Oxford Martins Policy Paper, 2015.

In the long-term, the total amount of CO_2 emissions is the primary driver of the magnitude of climate change and the determinant of the peak warming point. Short-lived gases, like methane, affect the current rate of warming. If GHG emissions are eventually brought down consistent with global targets to limit climate change, today's methane emissions will have by then left the atmosphere and been converted to CO_2. The impact of methane on long-term climate change is thus largely explained by the amount of CO_2 that remains from methane, and thus rather small.

The policy dilemma is such that on one hand, efforts to deal with methane today may seem less important because they will matter little, unless CO_2 emissions are brought under control in the longer term. On the other, by the time CO_2 emissions are sharply reduced, warming will not be limited, unless methane emissions are also reduced. An overly aggressive focus on short-term climate impacts would undermine the importance of efforts to reduce CO_2, which is necessary to bring warming under control. Yet, ignoring short-term gases would not account for their impact on accelerating the rate of warming and on the potential for abrupt climate tipping points.[9] Thus, prudent policy should be mindful of this delicate balance, avoiding the temptation of short-term wins, at the expense of larger long-term failure to limit warming of the climate.

8 Fuglesvedt et al. (2003), p.292-294

9 Kopp et al. (2016), "Tipping elements and climate-economic shocks: Pathways toward integrated assessment," Earth's Future, August 2016, Vol. 4, Issue 8, p.346–372, http://onlinelibrary.wiley.com/doi/10.1002/2016EF000362/full

Global Warming Potential

Global Warming Potential (GWP) is an index, which allows to compare the global warming impact of a greenhouse gas, relative to the most prevalent of the greenhouse gases – CO_2.[10] In other words, GWP is an *exchange rate* for GHG's, converting them all to CO_2-equivalent units ($CO_{2\text{-}e}$).

Due to difference in chemical characteristics, each greenhouse gas traps different amounts of radiation, or heat, that is trying to escape back into space, a phenomenon known as *radiative forcing*. Radiative forcing is simply, *a measure of the difference between incoming solar energy absorbed by the Earth and the energy radiated back to space, caused by the presence of a given gas.*

Global Warming Potentials (GWP's) are calculated as the ratio of the radiative forcing that would result from the emission of 1 kg of a GHG to that from the emission of 1 kg of CO_2 over a fixed time period.[11] *

The time period most commonly used for calculating GWP's and aggregating CO_2-equivalent GHG emissions is 100 years, which was selected as a reasonable compromise between the shorter and longer possible time frames.[12] Earlier studies calculated GWP over 20, 100, and 500 years, so the IPCC chose 100 year timeframe as the compromise value.[13]

Some argue that this choice understates the climate change impact of short-lived gases like methane, and have thus argued for using 20 years, or perhaps both.[14] The choice of whether to use a shorter or longer timescale for estimating GWPs leads to a very different assessment of the climate change impact of methane relative to CO_2, as discussed below.

10 Ibid. p.710-714

* *It is extremely important to note that GWP factors are applied on the basis of mass and not units of volume.*

11 Fuglesvedt et al. (2003), "Metrics of Climate Change: Assessing Radiative Forcing and Emission Indices," *Climatic Change*, June 2003, Vol.58, Issue 3, p.276-277 https://www.scientificamerican.com/article/how-bad-of-a-greenhouse-gas-is-methane/

12 https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

13 Moniz et al. (2011), "The Future of Natural Gas: An Interdisciplinary MIT Study," Massachusetts Institute of Technology, MIT Energy Initiative, June 2011, Appendix 1A, p.19

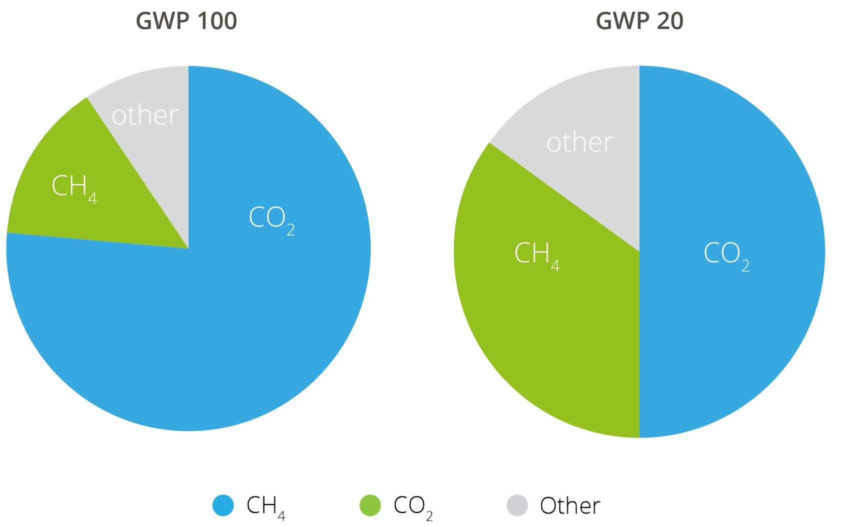
14 Ilissa B. Ocko et al. (2017), "Unmask temporal trade-offs in climate policy debates," *Science,* May 5, 2017, Vol.356, Issue 6337, p.492, http://science.sciencemag.org/content/356/6337/492

The Climate Change Impact of Methane

The two main determinants of the global warming potential of different greenhouse gases are their respective abilities to absorb energy (i.e., their radiative efficiency) and their lifetime in the atmosphere. Carbon dioxide is a long-lived greenhouse gas, which means that much of our emissions today could remain in the climate system for millennia.[15] Methane, conversely, has a relatively short life—averaging about 12.4 years, according to the IPCC's latest assessment—but its ability to retain heat in the earth's surface is an order of magnitude higher than that of CO_2, during its relatively brief life in the atmosphere. At the end of its life, methane becomes oxidized and turns into CO_2.[16]

Given these starkly different characteristics, the GWP of 1 kg of methane relative to 1 kg of CO_2 will greatly depend on the time period over which the heating effects of these gases are compared. According to the IPCC's latest assessment report, the GWP of methane over the standard 100-year period is 28 to 34 times that of CO_2. If the time horizon is reduced to 20 years, then the GWP value for methane becomes much greater – 84 to 86 times that of CO_2.[17]

Recalibrating GHG impact estimates to 20-year GWP values, instead of 100-years, would give much greater weight to methane vis-à-vis CO_2—and the main methane emitting sectors like agriculture and energy—within the global GHG emission mix. Using the IPCC's latest 20-year GWP factors would reduce the share of CO_2 to just over 50% from 76% in the 2010 global GHG mix,[18] while the share of methane would increase to over 40% from the 2010 estimate of 16%, as illustrated below.



The selection of timescale dramatically redefines the climate problem. Using 20-year GWP values, instead of 100-year figures, puts a much greater emphasis on short-lived gases like methane, while sharply reducing the weight of long-lived gases, particularly CO_2.[19]

15 https://www.epa.gov/ghgemissions/understanding-global-warming-potentials
16 https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf, p.731
17 Ibid. p.714
18 https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/WGIIIAR5_SPM_TS_Volume.pdf, p.45
19 https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full.pdf, p.87-88

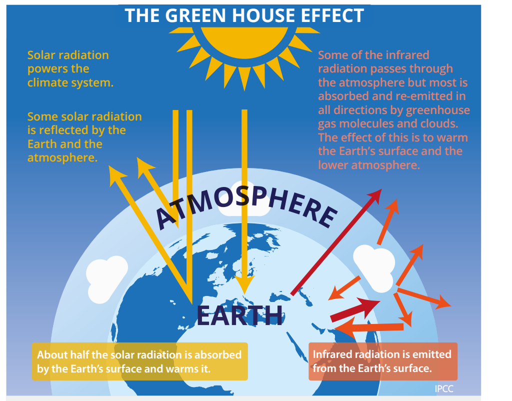
EXPLANATORY NOTE

GREENHOUSE GASES AND GLOBAL WARMING

The term greenhouse effect describes the warming of the Earth's surface, that results from the presence of greenhouse gases, which trap heat in the atmosphere.

Energy is constantly flowing into the Earth's atmosphere in the form of sunlight - about 30% of this energy is reflected back into space immediately, while the rest is absorbed by the planet.[20] As the Earth's surface, oceans, and the atmosphere warm up, they release heat back into space – as infrared thermal radiation. The outgoing thermal radiation has longer wavelength—and lower energy level—than the incoming radiation from the Sun. As a consequence, some of this weaker infrared outward radiation has difficulty passing through certain types of gas molecules ("greenhouse gases"), and—in the presence of sufficient quantities of such gases—the heat gets trapped in the atmosphere instead of escaping back to space. CO_2, CH_4, N_2O, and water vapour are the main greenhouse gases, responsible for creating the greenhouse effect.

This naturally occurring greenhouse effect keeps the Earth's surface temperature within a habitable range, and thus it is essential to sustain life on our planet.[21] However, human activities since the industrial revolution—particularly the burning of fossil fuels, agriculture and deforestation—have intensified the natural greenhouse effect[22], and contributed to rising global mean temperatures since 1750.[23] The emissions generated by these activities are known as anthropogenic, as opposed to those that occur naturally from wetlands, volcano eruptions, and other sources.



The Greenhouse Gas Effect

The heat-trapping potential of various gases in the atmosphere has been known to science for well-over a century. The so-called greenhouse effect—the warming of the Earth's surface in the presence of certain greenhouse gases—was first theorized by Joseph Fourier in 1824, proven in the lab by John Tyndall in 1859, and quantified by Svante Arrhenius in 1896. The greenhouse effect derives its name from a similar phenomenon observed in hothouses, where the glass walls prevent airflow and, as a result, the trapped hot air increases the temperature inside the greenhouse. In the case of the Earth's atmosphere, some of the energy from the sun is trapped by various gases, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and water vapour, and reflected back to the Earth, warming the planet's surface.

20 http://news.mit.edu/2010/explained-radforce-0309
21 https://www.livescience.com/37743-greenhouse-effect.html
22 https://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-3.html
23 https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf, p.661-663

THE RADIATIVE FORCING

Radiative forcing is a measure of the difference between incoming solar radiation absorbed by the Earth and the energy radiated back to space.[24] The degree of forcing is affected by the amount of greenhouse gases that are part of the Earth's atmosphere and the rate at which those gases absorb infrared energy. This balance between absorbed and radiated energy determines the average global temperature. At present, the Earth receives more incoming energy from sunlight than it radiates back into space, thanks to the greenhouse effect. This positive forcing warms the system, and thus the planet is warmer than it would be without an atmosphere containing excess greenhouse gases.[25]

In the regular assessment reports of the Intergovernmental Panel on Climate Change (IPCC), a scientific and intergovernmental body under the auspices of the United Nations, radiative forcing—measured in watts per square metre of surface—quantifies the impact of human activities (as well as natural forces, such as solar cycles and volcanic eruptions) on the Earth's radiation balance, since the start of the industrial revolution. Although the measure is subject to some uncertainties (particularly due to the ambiguous warming impact of aerosols in the atmosphere), radiative forcing is nevertheless a very useful metric, because it quantifies the impact various "forcing agents" have on the planet's energy balance on a common scale.[26]

According to the IPCC's latest (fifth) assessment report, greenhouse gas emissions from human activities are responsible for the vast majority of radiative forcing between 1750 and 2011.[27] Of all the greenhouse gases that the IPCC catalogues, rising CO_2 concentrations since 1750 have had by far the largest forcing effect.[28] Other natural and man-made forcing agents have had a much smaller and largely neutral impact, except for brief periods after major volcanic eruptions.[29]

MEASURING THE GLOBAL WARMING POTENTIAL (GWP)

Each greenhouse gas has a different capacity for trapping outgoing infrared radiation in the atmosphere, thereby contributing to radiative forcing. Global Warming Potential (GWP) is a relative index, which was developed to compare the global warming impact of a greenhouse gas relative to CO_2, the most prevalent of the greenhouse gases.[30] GWP builds on the radiative forcing concept by introducing a *temporal* dimension. Because some GHG's are potent but short-lived, radiative forcing as a function of time shows very different behaviour for different GHG's. And the choice of timeframe used to evaluate GWP thus matters greatly in comparing the climate change impact of different GHG's.

This common measurement unit enables the aggregation of emissions of various greenhouse gases, and allows economists, scientists and regulatory agencies to compare emission reduction options across a wide range of sectors and gases.[31] To be more precise, GWP compares the integrated radiative forcing over a specific time period from the emission of a unit mass of gas relative to the same mass of CO_2. GWPs are calculated as the ratio of the radiative forcing that would result from the emission of 1 kg of a GHG to that from the emission of 1 kg of CO_2 over a fixed time period.[32] It is extremely important to emphasize that GWP factors are applied on the basis of mass and not units of volume.

The time period most commonly used for calculating GWPs and aggregating CO_2-equivalent GHG emissions is 100 years.[33] Some argue that this choice understates the climate change impact of short-lived gases like methane, and have thus argued for using 20 years, or perhaps both.[34] The choice of whether to use a shorter or longer timescale for estimating GWPs leads to a very different assessment of the climate change impact of methane relative to CO_2.

GWP and Other Climate Metrics

This paper focuses on the GWP methodology for measuring the relative climate impacts of GHG's, largely because it is the one most widely accepted. Delving into the other climate change metrics is beyond this paper's scope.

However, it should be noted that GWP is just one of many factors that exist, and each one can dramatically change the importance of different gases vis-à-vis climate change. This serves as a reminder of the vast uncertainties that still remain in this complex area of climate science.

For example, another common contender for comparing different gases is the Global Temperature Change Potential (GTP).

"GTP is defined as the ratio between the global mean surface temperature change at a given future time horizon (TH) following an emission (pulse or sustained) of a compound x relative to a reference gas r (e.g., CO_2)" (IPCC, 2007). In other words, this GHG 'Exchange rate' equates gases to CO_2 based on their relative direct impact on the global temperature. GTP values are also impacted by the time horizon chosen.

24 http://news.mit.edu/2010/explained-radforce-0309
25 http://blogs.edf.org/climate411/2007/07/25/greenhouse_effect/
26 Radiative forcing values can be converted to mean global temperature change using another metric called climate sensitivity, which is an expression of surface air temperature change in response to a unit change in radiative forcing. Climate sensitivity is expressed in °C/(W/m2). For a description of radiative forcing, see for example https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf, p.664-665
27 https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf, p.678
28 Ibid. p.678
29 Ibid. p.662
30 Ibid. p.710-714
31 https://ecometrica.com/assets/Understanding-the-Changes-to-GWPs.pdf, p.2-3
32 Fuglesvedt et al. (2003), "Metrics of Climate Change: Assessing Radiative Forcing and Emission Indices," Climatic Change, June 2003, Vol.58, Issue 3, p.276-277
https://www.scientificamerican.com/article/how-bad-of-a-greenhouse-gas-is-methane/
33 https://www.epa.gov/ghgemissions/understanding-global-warming-potentials
34 Ilissa B. Ocko et al. (2017), "Unmask temporal trade-offs in climate policy debates," Science, May 5, 2017, Vol.356, Issue 6337, p.492, http://science.sciencemag.org/content/356/6337/492

The convention of using 100-year GWP values accounts for the long-term nature of the climate change problem, while also acknowledging the short-term impacts of potent GHG's on warming. For this reason, the choice of the 100-year GWP (GWP_{100}) has become the standard metric to convert GHG emissions to CO_2 equivalence. It was intended to provide "a balanced representation" of climate impacts between relatively short (i.e., 20-year) and extremely long (i.e., 500-year) time periods.[35] It dates back to the early days of global climate policy. The metric was first introduced in the IPCC's first assessment report in 1990,[36] and was later adopted in the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, as well as in the Kyoto Protocol in 1997.[37] Ever since the 1990s, the 100-year GWP has been used as the default metric to report national GHG inventories, set emission targets, and formulate various mitigation policies around the world.

Thus an additional consideration is that the current climate change discourse—including global, national, and sectoral emission estimates and climate change targets—is built around emission estimates using 100-year GWP values. Scientists, policy makers and a range of international organizations have invested substantial intellectual and political capital to build widespread policy and political acceptance for these commonly understood metrics and climate change goals. Shifting to 20-year GWP would not only discount the long-term nature of the climate change problem, but also disrupt the shared understanding on which current emission estimates, targets, and policies are based.

35 Fuglesvedt et al. (2003), p.293

36 https://www.ipcc.ch/ipccreports/far/wg_I/ipcc_far_wg_I_full_report.pdf, p.xxi

37 Fuglesvedt et al. (2003), p.267-271

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