Overview: Greenhouse gas metrics in IPCC reports

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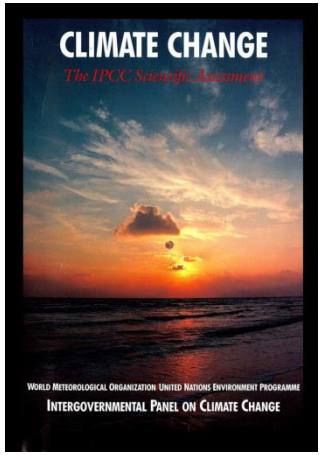
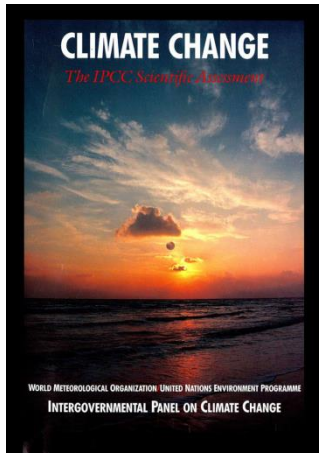
IPCC technical workshop on common metrics, 7 June 2023

UN Climate Change Conference
Bonn 5-15 June 2023



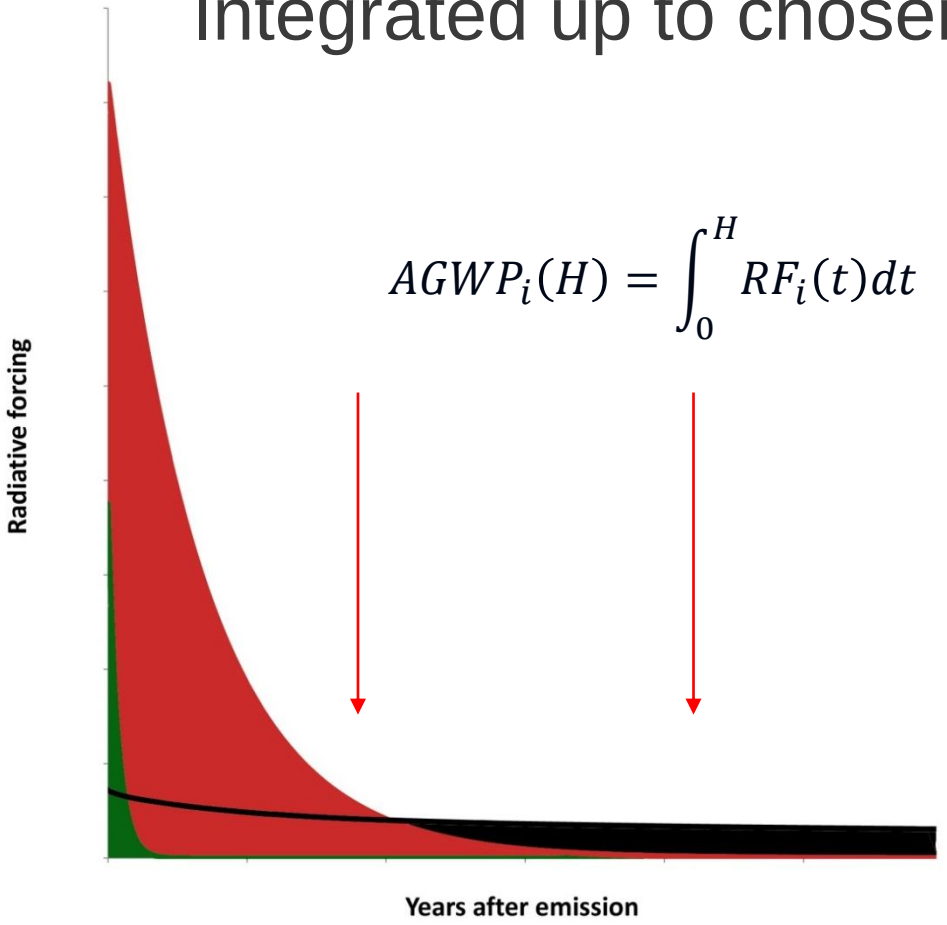
The view from IPCC's First Assessment Report

"It must be stressed that there is no universally accepted methodology for combining all the relevant factors into a single (metric) … A simple approach [i.e. the GWP] has been adopted here to illustrate the difficulties inherent in the concept …" (Section 2.2.7)



Global Warming Potential (GWP): Based on pulses of different gases

Integrated up to chosen time horizons (H)

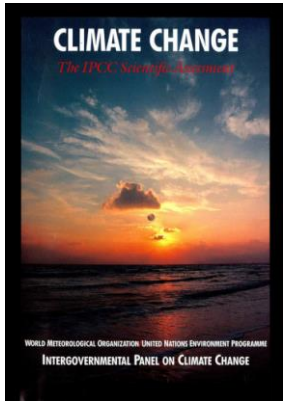


$$AGWP_i(H) = \int_0^H RF_i(t)dt$$

Then normalized to AGWP for CO_2:

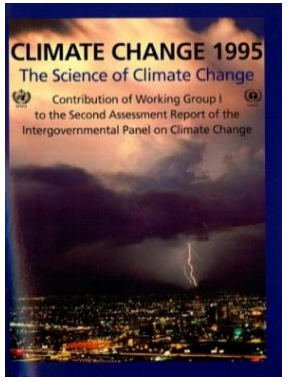
$$GWPi(H) = \frac{AGWP_i(H)}{AGWP_{CO_2}(H)} = \frac{\int_0^H RF_i(t)dt}{\int_0^H RF_{CO_2}(t)dt}$$

Time horizon



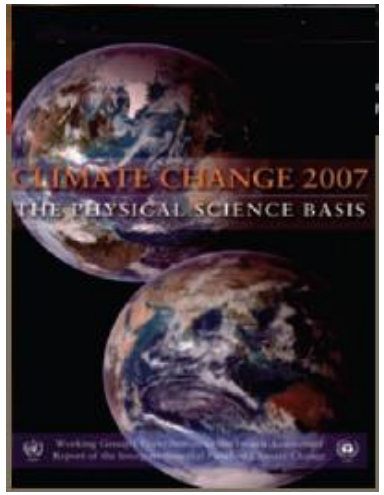
IPCC 1990 presented three time-horizons (20, 100 and 500 yr)

….'*as candidates for discussion [that] should not be considered as having any special significance*'



Kyoto Protocol: 100 years was chosen

SAR	GWP_{20}	**GWP_{100}**	GWP_{500}
CH_4	56	**21**	6.5

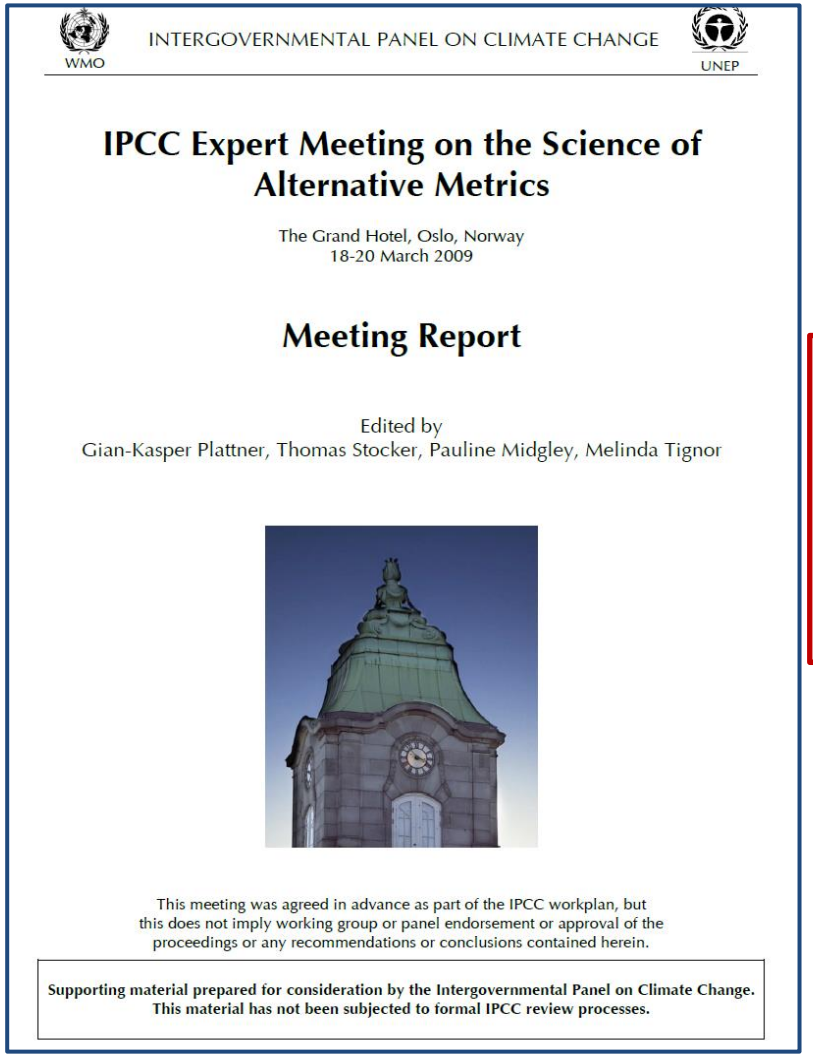


Statement on GWP in IPCC AR4

Although it has several known shortcomings, a multi-gas strategy using GWPs is very likely to have advantages over a CO_2-only strategy (O'Neill, 2003). Thus, GWPs remain the recommended metric to compare future climate impacts of emissions of long-lived climate gases.

Executive Summary

Key Conclusions and Recommendations to UNFCCC
Recommendations to the Scientific Community regarding Research Needs
Recommendations to the Scoping of IPCC Fifth Assessment Report (AR5)



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WMO UNEP

IPCC Expert Meeting on the Science of Alternative Metrics

The Grand Hotel, Oslo, Norway
18-20 March 2009

Meeting Report

Edited by
Gian-Kasper Plattner, Thomas Stocker, Pauline Midgley, Melinda Tignor

This meeting was agreed in advance as part of the IPCC workplan, but this does not imply working group or panel endorsement or approval of the proceedings or any recommendations or conclusions contained herein.

Supporting material prepared for consideration by the Intergovernmental Panel on Climate Change. This material has not been subjected to formal IPCC review processes.

Key Conclusions and Recommendations to UNFCCC:

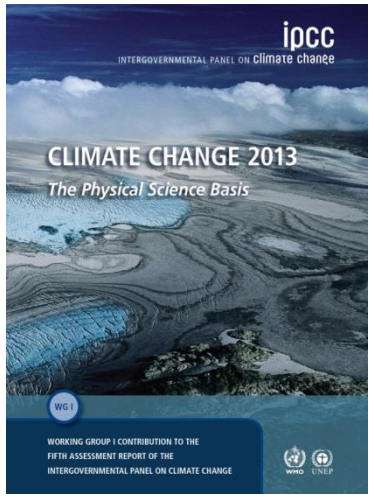
1. Global Warming Potential (GWP) is a well-defined metric based on radiative forcing that continues to be useful in a multi-gas approach. Shortcomings have been identified; however the scientific basis has not been fully established to address these shortcomings comprehensively in any currently discussed metric;

2. The effectiveness of the use of a given metric depends on the primary policy goal, for example to limit the long term temperature change, limit rates of change, avoid particular impacts, and balance costs and benefits. The GWP was not designed with a particular policy goal in mind. Depending on the specific policy goal or goals, alternative metrics may be preferable;

3. The GWP with the time horizon of 100 years is used in the Kyoto Protocol. The numerical value of the GWP can depend markedly on the choice of time horizon. The choice of any particular time horizon involves value judgments in terms of future commitment to radiative forcing;

4. Timely information on potential future policy goals would facilitate research on alternative metrics.

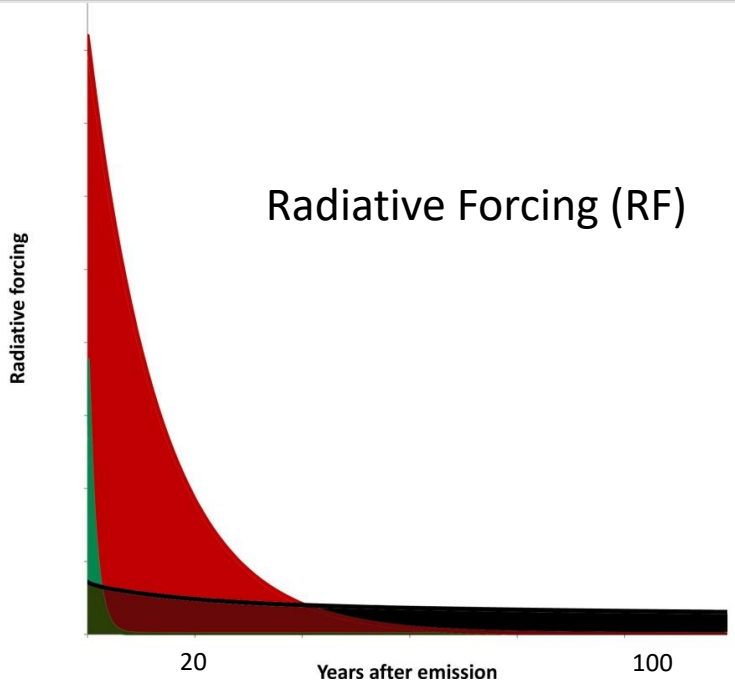
From the Summary for Policymakers:



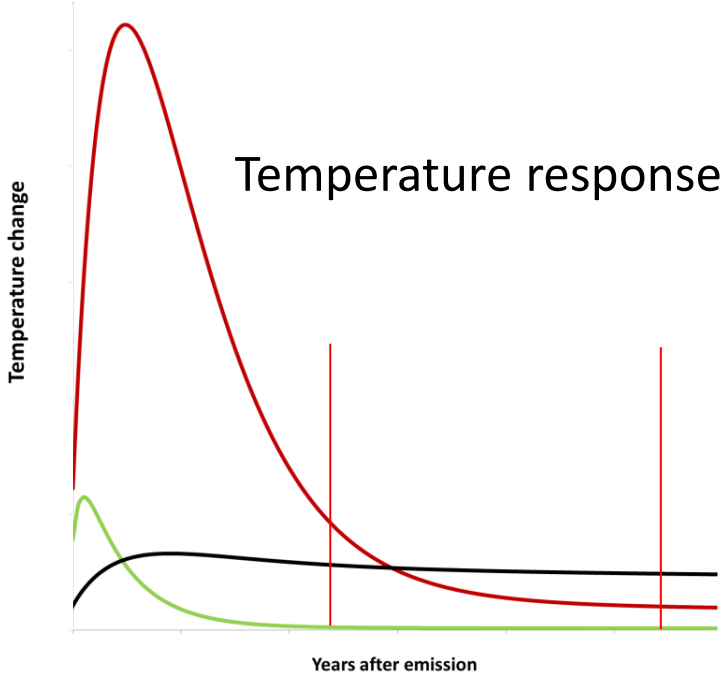
Emission metrics were addressed in Ch8

The most appropriate metric and time horizon will depend on which aspects of climate change are considered most important to a particular application.

No single metric can accurately compare all consequences of different emissions, and all have limitations and uncertainties.



$$GWP_i(H) = \frac{\int_0^H RF_i(t)dt}{\int_0^H RF_{CO_2}(t)dt} = \frac{AGWP_i(H)}{AGWP_{CO_2}(H)}$$

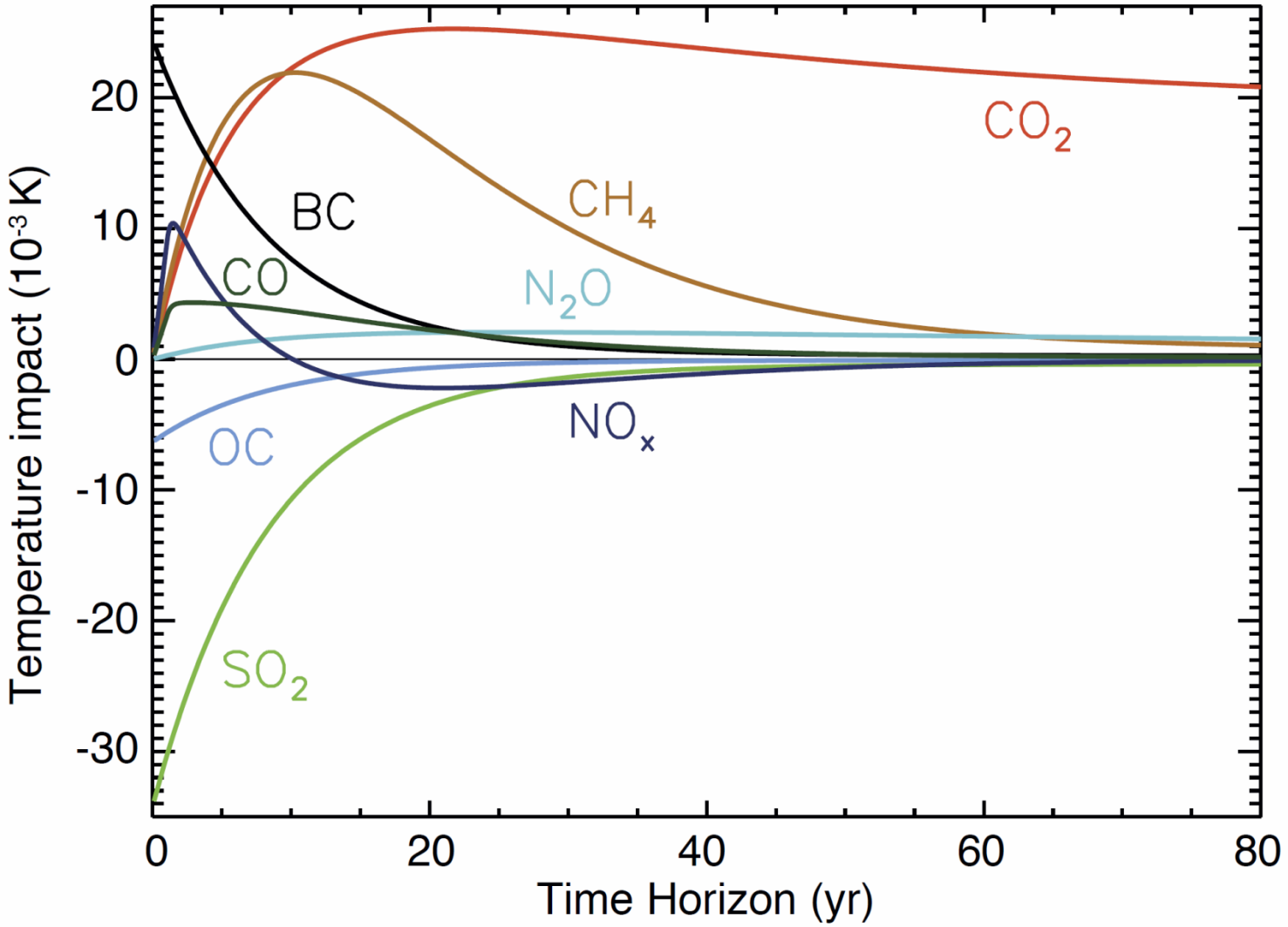


The Global temperature-change potential (GTP)

$$GTP_i(t) = \frac{AGTP(t)_i}{AGTP(t)_{CO_2}} = \frac{\Delta T(t)_i}{\Delta T(t)_{CO_2}}$$

Application of AGTP – an example

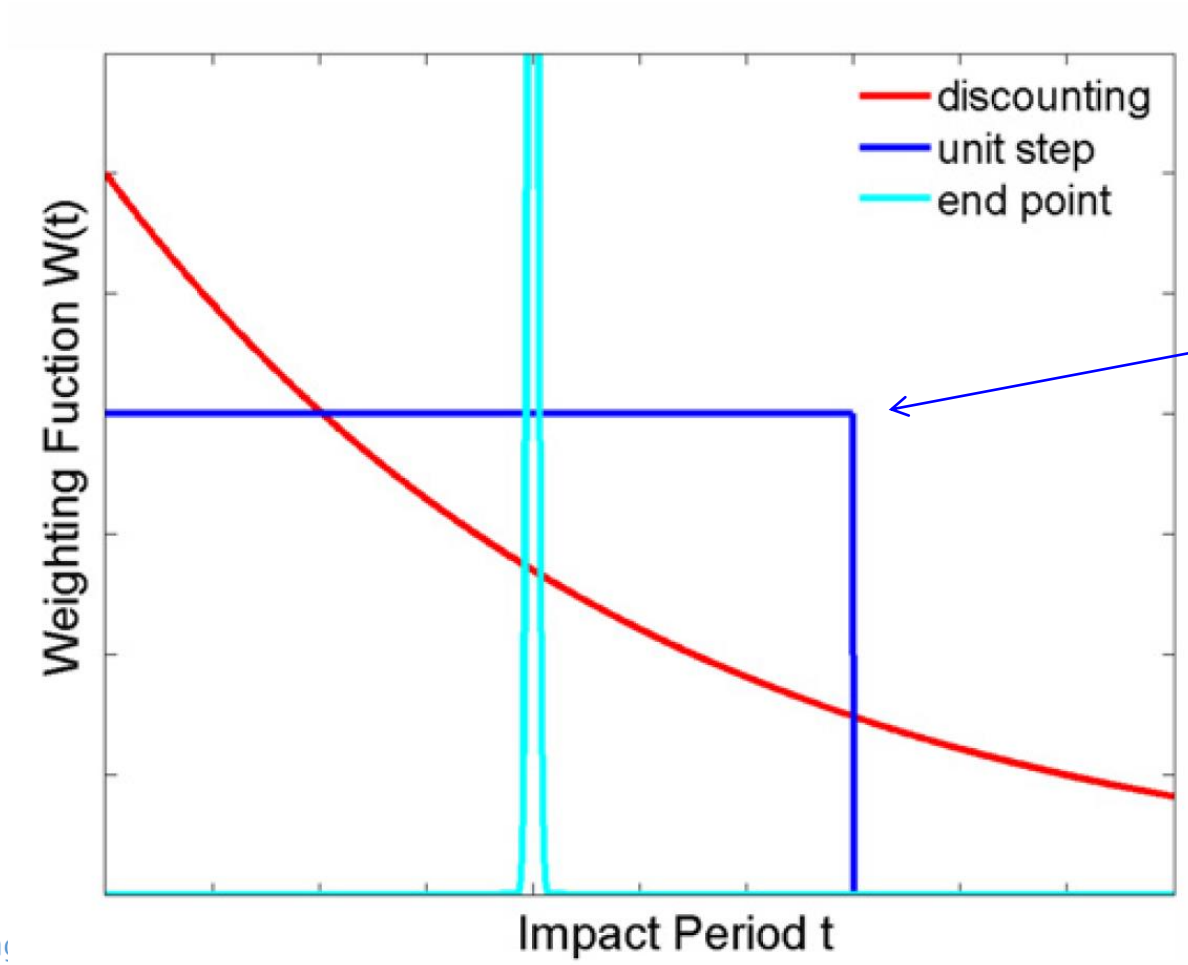
Temperature responses for total anthropogenic emissions for a one year emissions



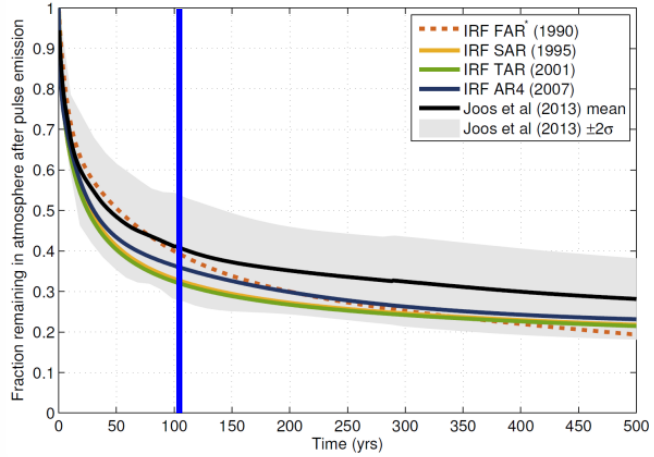
Myhre et al., 2013, AR5

Implicit value judgements in metrics

Weighting of effects over time



$$AGWP_i(H) = \int_0^H RF_i(t)\,dt$$



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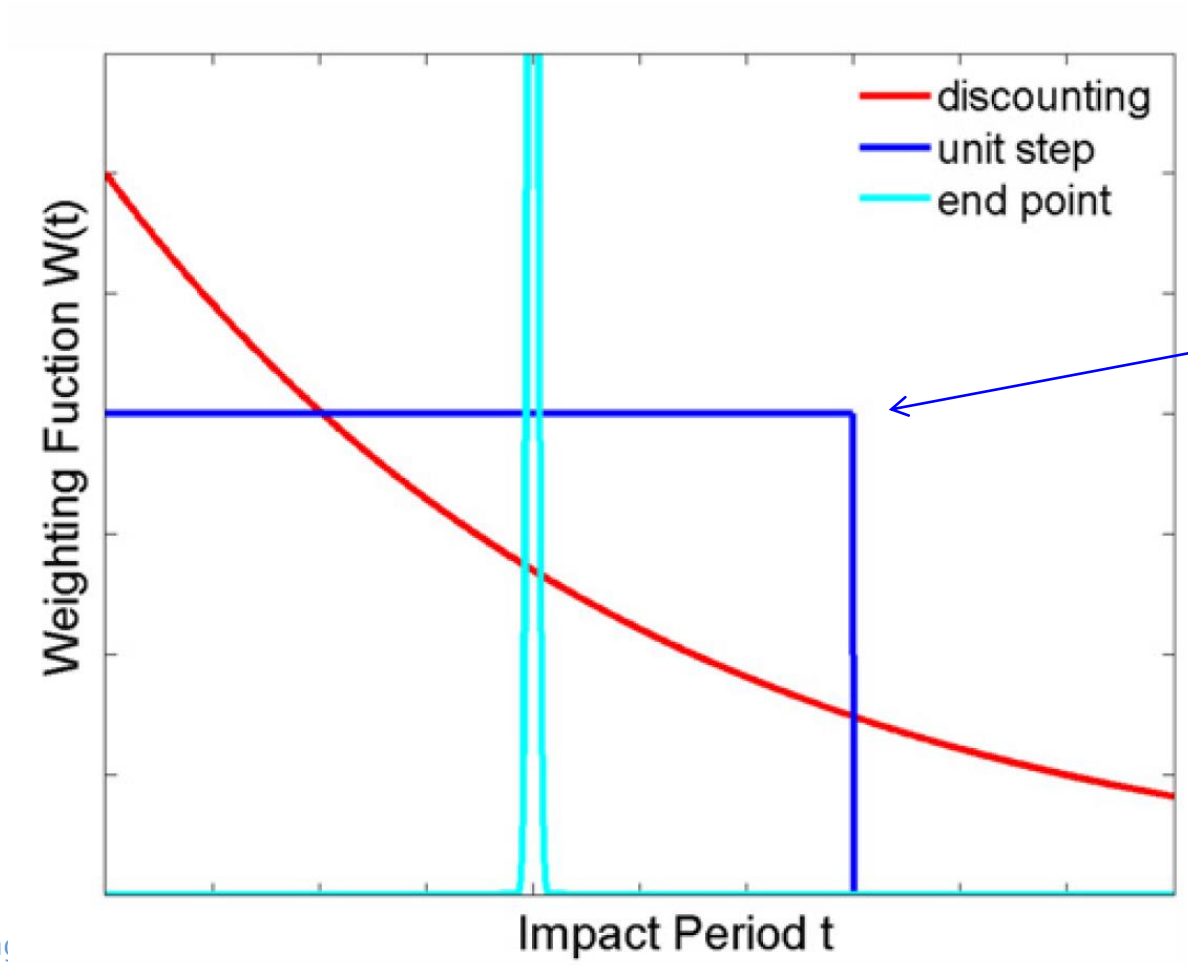

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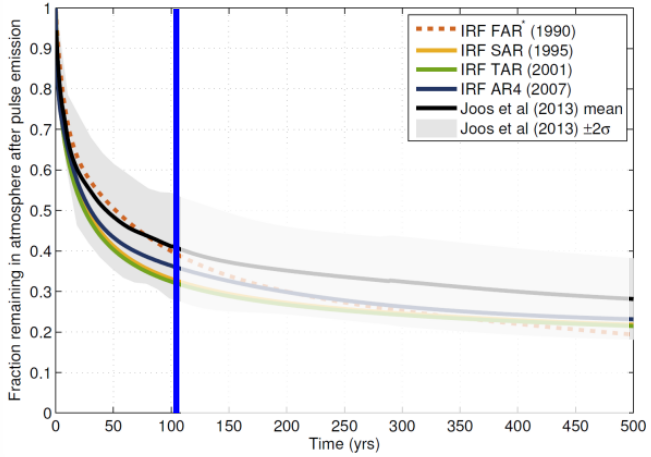
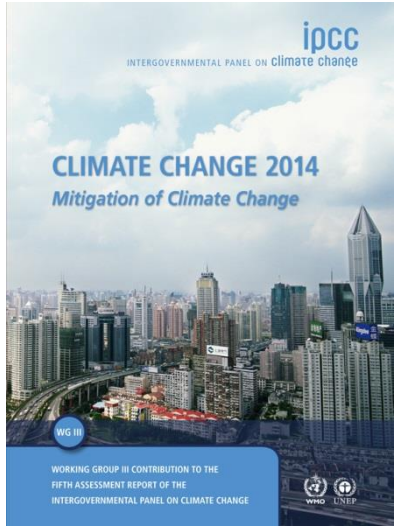


AR5 WGIII on metrics



Box on metrics in **Technical Summary**

Chapter 3: Social, Economic and Ethical Concepts and Methods

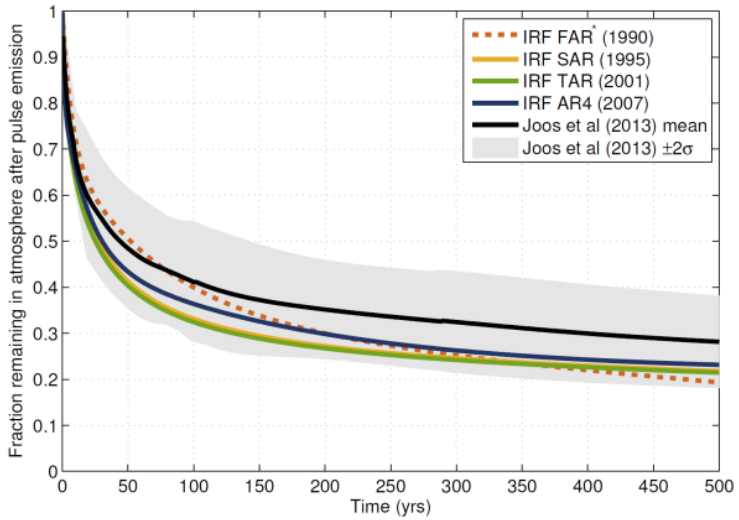
Conceptual overview and links between physical metrics and Global Damage Potential and Global Cost Potential (3.9.6)

Chapter 6: Assessing Transformation Pathways

Role of metrics in transformation pathways (6.3.2.5)

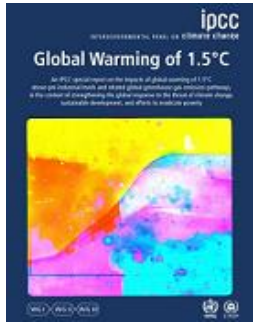
Key factors that change metric values between the assessments:

- Direct Radiative Forcing (RF) of the gas considered and CO_2 (reference)
- Changing background concentrations
- Lifetime of the gas considered
- Response time of the reference gas CO_2

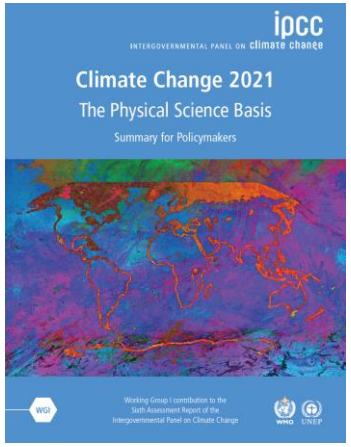


- Quantifictations of indirect effects (e.g., O_3 and stratospheric H_2O)
- Inclusion of climate-carbon cycle feedbacks

Where are emission metrics assessed in AR6?

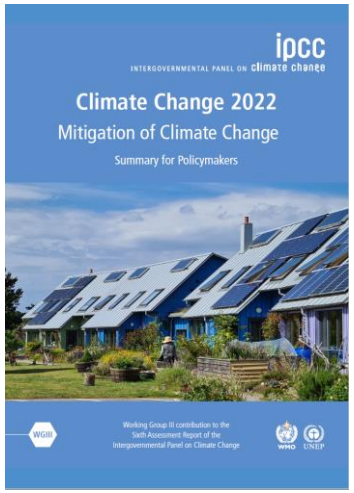


Discussed in **Cross-Chapter Box 2 | Measuring Progress to Net Zero Emissions Combining Long-Lived and Short-Lived Climate Forcers**



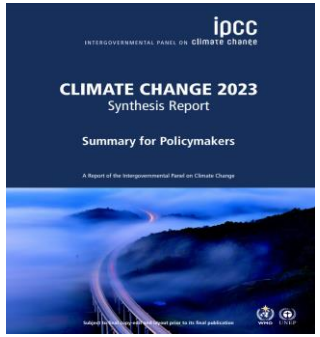
Discussed in Box in Ch1

Assessed in Ch7, and supplementary material



Cross-Chapter Box 2.2 in Ch2, and supplementary material

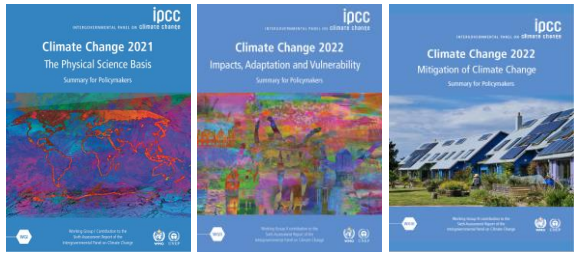
Both WGI and WGIII include assessment of new metric concepts since AR5



Footnote 9 in SPM and Section 2 of the Synthesis Report:

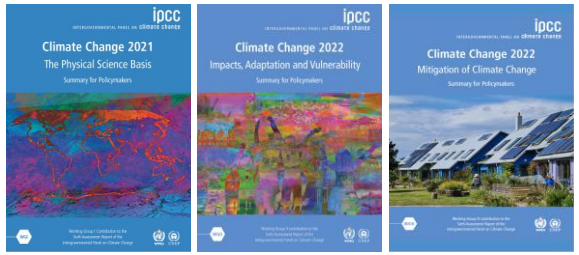
GHG emission metrics are used to express emissions of different greenhouse gases in a common unit. Aggregated GHG emissions in this report are stated in CO_2-equivalents (CO_2-eq) using the Global Warming Potential with a time horizon of 100 years (GWP100) with values based on the contribution of Working Group I to the AR6. The AR6 WGI and WGIII reports contain updated emission metric values, evaluations of different metrics with regard to mitigation objectives, and assess new approaches to aggregating gases. The choice of metric depends on the purpose of the analysis and all GHG emission metrics have limitations and uncertainties, given that they simplify the complexity of the physical climate system and its response to past and future GHG emissions. {2.1.1}

Increasing efforts made to report emissions and mitigations by gas where feasible, and use CO_2-eq only in addition.



From the common AR6 Glossary

Greenhouse gas emission metric A simplified relationship used to quantify the effect of emitting a unit mass of a given greenhouse gas (GHG) on a specified key measure of climate change. A relative GHG emission metric expresses the effect from one gas relative to the effect of emitting a unit mass of a reference GHG on the same measure of climate change. There are multiple emission metrics, and the most appropriate metric depends on the application. GHG emission metrics may differ with respect to:
(i) the key measure of climate change they consider;
(ii) whether they consider climate outcomes for a specified point in time or integrated over a specified time horizon;
(iii) the time horizon over which the metric is applied;
(iv) whether they apply to a single emission pulse, emissions sustained over a period of time, or a combination of both; and
(v) whether they consider the climate effect from an emission compared to the absence of that emission or compared to a reference emissions level or climate state.



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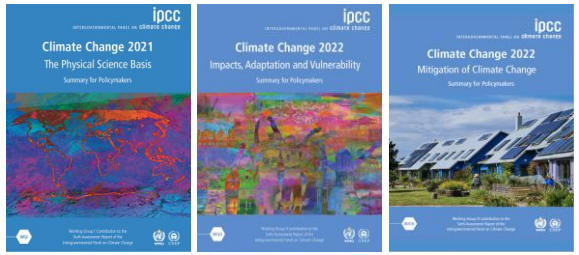

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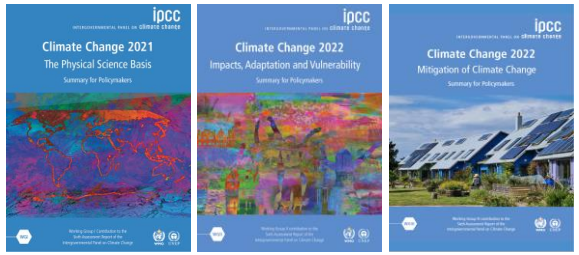
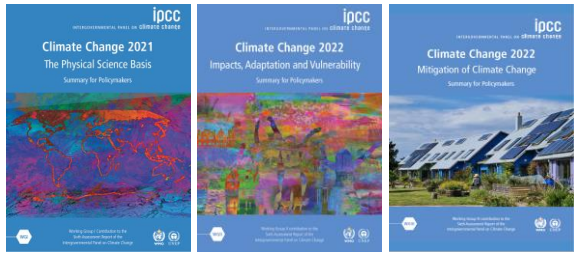


From the common AR6 Glossary

[**Note**: Most relative GHG emission metrics (such as the global warming potential (GWP), global temperature change potential (GTP), global damage potential, and GWP*), use carbon dioxide (CO_2) as the reference gas. Emissions of non-CO_2 gases, when expressed using such metrics, are often referred to as 'carbon dioxide equivalent' emissions. A metric that establishes equivalence regarding one key measure of the climate system response to emissions does not imply equivalence regarding other key measures. The choice of a metric, including its time horizon, should reflect the policy objectives for which the metric is applied.]



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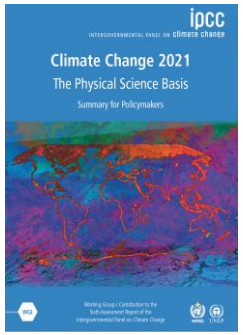
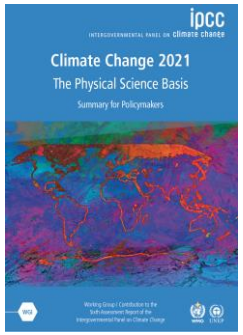
Net zero greenhouse gas emissions: Condition in which metric-weighted anthropogenic greenhouse gas (GHG) emissions are balanced by metric-weighted anthropogenic GHG removals over a specified period. The quantification of net zero GHG emissions depends on the GHG emission metric chosen to compare emissions and removals of different gases, as well as the time horizon chosen for that metric.



D.1.8 in WGI SPM:

Achieving global net zero CO_2 emissions, with anthropogenic CO_2 emissions balanced by anthropogenic removals of CO_2, is a requirement for stabilizing CO_2-induced global surface temperature increase. This is different from achieving net zero GHG emissions, where metric-weighted anthropogenic GHG emissions equal metric-weighted anthropogenic GHG removals. For a given GHG emissions pathway, the pathways of individual GHGs determine the resulting climate response,[46] whereas the choice of emissions metric[47] used to calculate aggregated emissions and removals of different GHGs affects what point in time the aggregated GHGs are calculated to be net zero. Emissions pathways that reach and sustain net zero GHG emissions defined by the 100-year global warming potential are projected to result in a decline in surface temperature after an earlier peak (high confidence). {4.6, 7.6, Box 7.3, TS.3.3}



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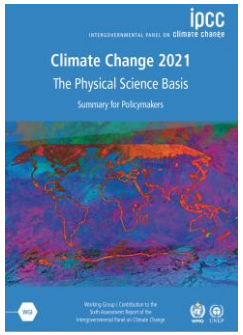

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More about ***net zero GHG*** in WGI and WGIII presentations