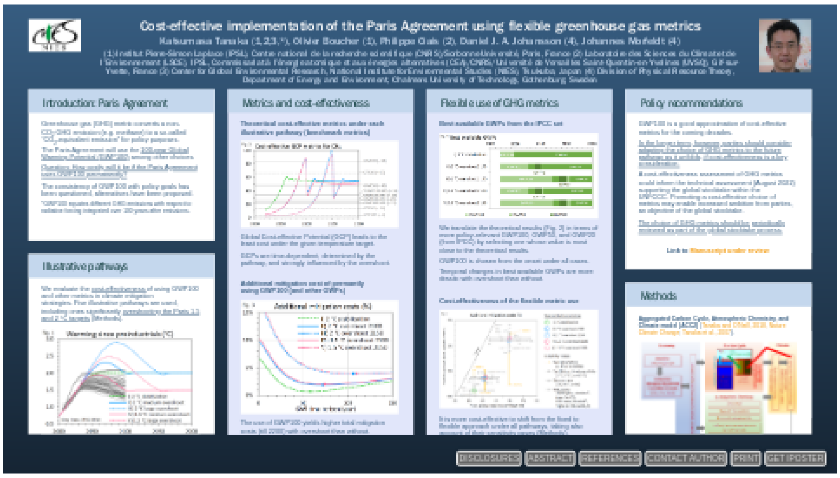
Cost-effective implementation of the Paris Agreement using flexible greenhouse gas metrics



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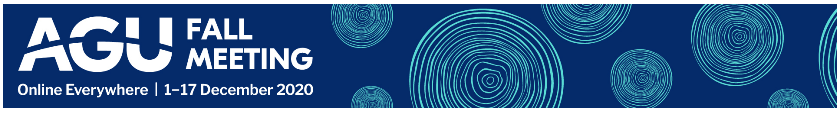


INTRODUCTION: PARIS AGREEMENT

Greenhouse gas (GHG) metric converts a non-CO_2 GHG emission (e.g. methane) to a so-called "CO_2-equivalent emission" for policy purposes.

The Paris Agreement has adopted the 100-year Global Warming Potential (GWP100) as a default choice among other choices.

The consistency of GWP100 with policy goals has been questioned, alternatives have been proposed.

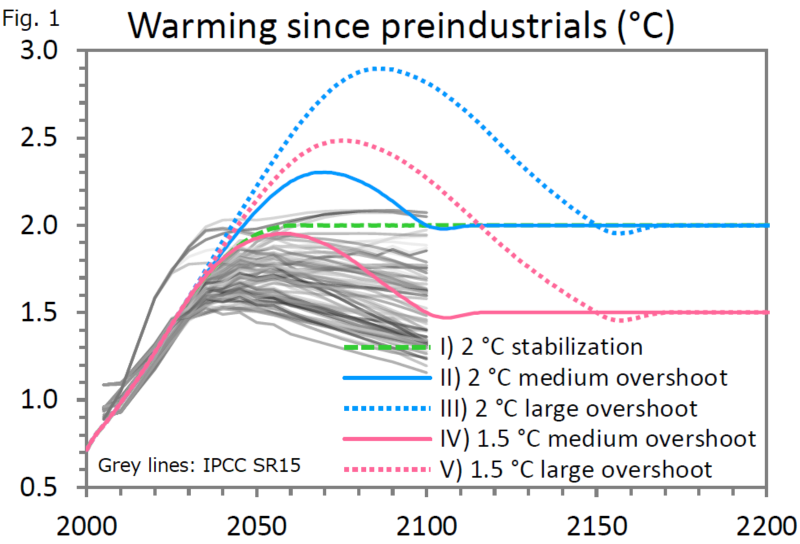
Question: How costly will it be if the Paris Agreement uses GWP100 *permanently*?

*GWP100 equates different GHG emissions with respect to radiative forcing integrated over 100 years after emissions.

ILLUSTRATIVE PATHWAYS

We evaluate the cost-effectiveness of using GWP100 and other metrics in climate mitigation strategies. Five illustrative pathways are used, including ones significantly overshooting the Paris 1.5 and 2 °C targets (Methods).

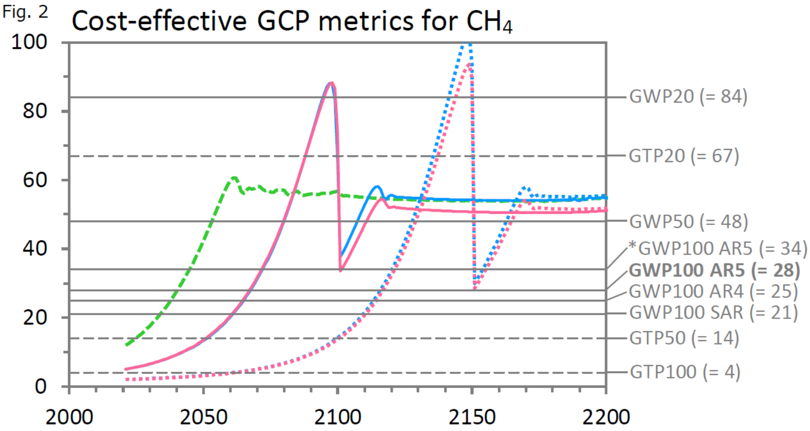
Fig. 1



METRICS AND COST-EFFECTIVENESS

Theoretical cost-effective metrics under each illustrative pathway (benchmark metrics)

Fig. 2

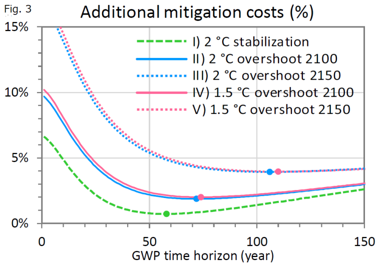


Global Cost-effective Potential (GCP) leads to the least cost under the given temperature target.

GCPs are time-dependent, determined by the pathway, and strongly influenced by the overshoot.

Additional mitigation cost of permantly using GWP100 (and other GWPs)

Fig. 3



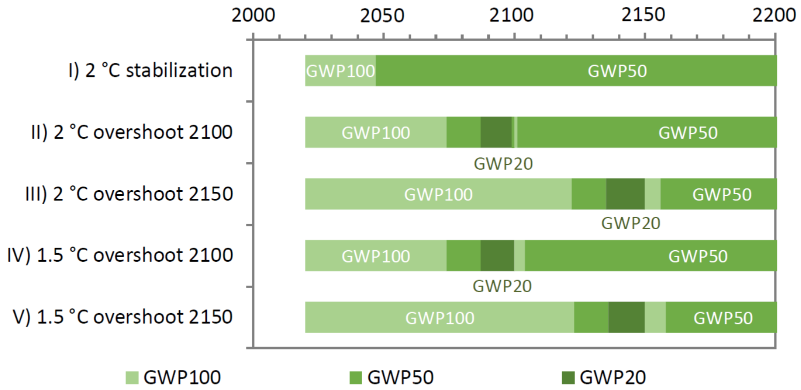
The use of GWP100 yields higher total mitigation costs (till 2200) with overshoot than without.

The additional costs remain more significant with overshoot under any fixed use of GWP.

FLEXIBLE USE OF GHG METRICS

Best available GWPs from the IPCC set

Fig. 4 Best available GWPs



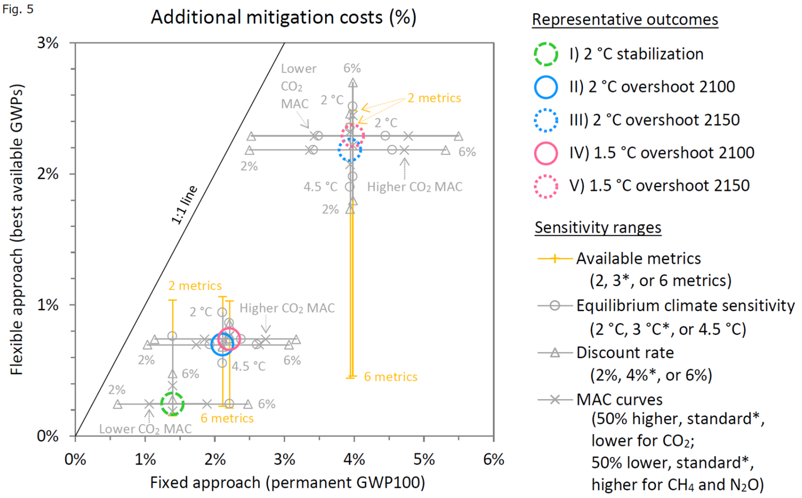
We translate the theoretical results (Fig. 2) in terms of more policy-relevant GWP100, GWP50, and GWP20 (from IPCC) by selecting one whose value is most close to the theoretical results.

GWP100 is chosen from the onset under all cases. After mid-century, the choice of metrics will change, depending on the pathway.

Overshoot pathways choose GWP20 with declining temperatures, reflecting the need to abate CH_4 strongly to decrease temperatures.

Cost-effectiveness of the flexible metric use

Fig. 5



It is more cost-effective to shift from the fixed to flexible approach under all pathways, taking also account of their sensitivity cases (Methods).

POLICY RECOMMENDATIONS

GWP100 is a good approximation of cost-effective metrics for the coming decades.

In the longer term, however, parties should consider adjusting the choice of GHG metrics to the evolving future pathway, if cost-effectiveness is a key consideration.

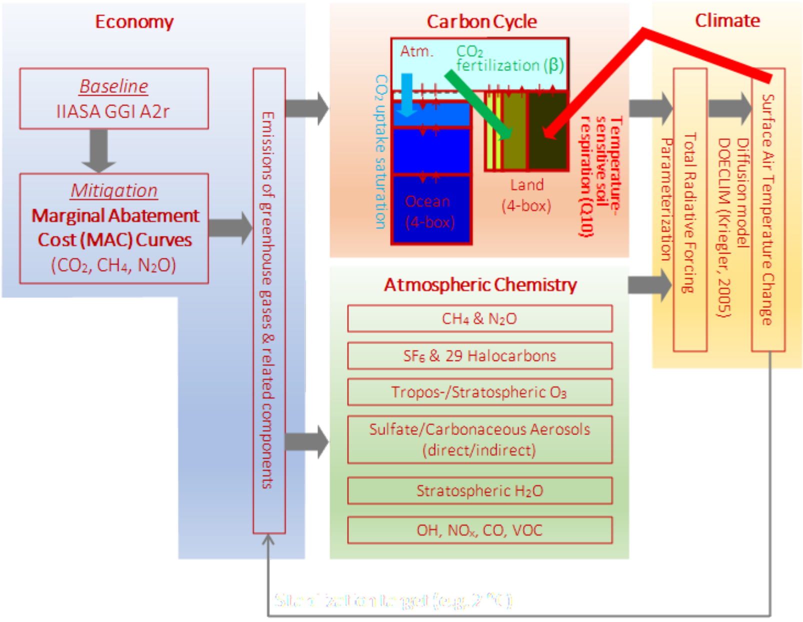
A cost-effectiveness assessment of GHG metrics could inform the technical assessment (August 2022) supporting the global stocktake within the UNFCCC. Promoting a cost-effective choice of metrics may enable increased ambition from parties, an objective of the global stocktake.

The choice of GHG metrics should be periodically reviewed as part of the global stocktake process.

Link to Manuscript under review (https://arxiv.org/abs/2006.01901)

METHODS

Aggregated Carbon Cycle, Atmospheric Chemistry, and Climate model (ACC2) (Tanaka and O'Neill, 2018, Nature Climate Change (https://www.nature.com/articles/s41558-018-0097-x); Tanaka et al., 2007 (https://pure.mpg.de/pubman/faces/ViewItemOverviewPage.jsp?itemId=item_994422)).



ACC2 is a simple Integrated Assessment Model (IAM) that consists of a global climate and carbon cycle model of reduced complexity combined with marginal abatement cost (MAC) curves for CO_2, CH_4, and N_2O.

This model allows us to generate cost-effective emission pathways for given temperature targets under this single modeling framework, unlike other more complex IAMs that are not dynamically coupled with a climate and carbon cycle model.

The model describes primarily global aspects, providing no details in regional and sectoral changes. The temporal resolution of the model is one year.

In generating illustrative temperature pathways, we assume two different overshoot levels by requiring the warming not to exceed the respective target after 2100 or 2150. The length and magnitude of temperature overshoot were therefore not externally set in our analysis but rather an outcome of our internal cost-effective pathway calculations.

The cost-effective GCP metrics for methane are calculated under each illustrative pathway, reflecting the ratio of the emission shadow prices between the two gases.

The economic costs of using a sub-optimal metric such as GWP100 can be calculated by imposing the metric in the pathway calculation, namely, on the ratios of the marginal abatement costs of associated gases at each point in time. Thus, the use of metrics poses additional constraints in the pathway calculation, giving rise to higher mitigation costs than those without the use of metrics. The cost increment as a result of the metric use, relative to the lowest costs without the use of metrics (or equivalently with the use of GCP), is analyzed as the “cost of metrics” in our study.

We explore the sensitivity of the outcome by varing the assumptions on the equilibrium climate sensitivity (2 °C and 4.5 °C, with 3 °C by default), the discount rate (2% and 6%, with 4% by default), and the MAC curves (one case assuming a 50% higher CO_2 MAC curve and 50% lower CH_4 and N_2O MAC curves than the respective standard MAC curves and the opposite case assuming a 50% lower CO_2 MAC curve and 50% higher CH_4 and N_2O MAC curves than the respective standard MAC curves). In the analysis of best available metrics (Figs. 4 and 5), we further consider the sensitivity of the assumed set of available metrics by testing cases with two time horizons (100 and 20 years) and six time horizons (500, 200, 100, 50, 20, and 10 years).

DISCLOSURES

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ABSTRACT

Greenhouse gas (GHG) emission metrics, that is, conversion factors to evaluate the emissions of non-CO_2 climate forcers on a common scale with CO_2, serve crucial functions upon the implementation of the Paris Agreement. While different metrics have been proposed, they have not been investigated under a range of pathways, including those significantly overshooting the temperature targets of the Paris Agreement. Here we show that cost-effective metrics that minimize the overall cost of climate mitigation are time-dependent, primarily determined by the period remaining before the eventual stabilization, and strongly influenced by temperature overshoot. Our study suggests that flexibility should be maintained to adapt the choice of metrics in time as the future unfolds, if cost-effectiveness is a key consideration for global climate policy, instead of hardwiring the 100-year Global Warming Potential (GWP100) as a permanent feature of the Paris Agreement implementation as is currently under negotiation.

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