Greenhouse gas removal

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Reducing the large short-lived impact of methane emissions with temporary carbon removals

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We consider potential non-permanence of carbon removal not as an obstacle but as a feature to focus on the compensation for the short-term warming of methane emissions. This could re-open climate finance for nature-based solutions and provide an immediate reduction in temperature stress.

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The policy problem

Carbon removal via nature-based solutions is frequently criticized for being impermanent, risky and non-additional. Over-crediting has occurred in the voluntary carbon market where, in particular, forest carbon credits are used to offset the virtually permanent effect of carbon emissions on temperatures. This credibility crisis in the voluntary carbon market threatens the flow of climate finance towards nature-based solutions for climate change, which, in principle, are cost-effective ways of removing carbon compared with the more permanent technological fixes such as direct air capture and carbon storage (DACCS). At the same time, public support for climate policy requires immediate action to mitigate climate change, including reducing emissions of other greenhouse gases, particularly methane (CH_4). Since not all CH_4 emissions can be avoided immediately, smart compensation is needed to achieve short-term temperature reduction benefits.

The findings

CH_4 emissions cause a large but short-lived (30–40 year) spike in temperature, whereas carbon dioxide (CO_2) emissions deliver a small but essentially long-term effect. Offsetting the temperature effect of CH_4 with permanent CO_2 removal using a 100-year time horizon leaves a short-term temperature spike compensated by a small reduction in temperatures over the long term (Fig. 1). Therefore, an intergenerational transfer of well-being occurs. Under this approach, 28 tonnes of permanent CO_2 removal are welfare equivalent, meaning economic damages are offset, to 1 tonne of CH_4. Using shorter time-horizons and therefore potentially temporary CO_2 removals to offset CH_4 allows to even out temperature fluctuations. We find that 87 1-tonne 30-year CO_2 removals are welfare equivalent to 1 tonne of CH_4. Welfare equivalence is established for all time horizons, but 30-year removals typically minimize intertemporal transfers compared with permanent removals and require more easily monitored short-term contracts.

The study

We use welfare equivalence to establish the appropriate equivalence of CO_2 to CH_4, which ensures that the present value of the damages associated with CH_4 are offset by equivalent climate benefits of lower temperature via removed CO_2. This overcomes the limitations of global warming potential, such as arbitrary time horizons and non-transparent assumptions on intergenerational fairness. We developed the CH_4 component of the FAIR 2.0.0 model to measure the temperature effect of CH_4 in different scenarios. We establish equivalence for different durations, Representative Concentration Pathway (RCP) emissions scenarios and discount rates. We calculate the duration of removals that minimizes the intertemporal transfers: the net fluctuations in temperature that arise from the emission-offset policy, and find that 30-year contracts are typically the best. The approach is a generally applicable accounting approach, yet whether the implied investment is cost effective depends on the relative prices of different temporary emissions reductions technologies.

Recommendations for policy

- Meeting the goals of the Paris Agreement requires short-term temperature reductions as well as long-term ones
- The credibility crisis for nature-based carbon removals could be addressed by using temporary CO_2 removals to offset the short-lived effect of CH_4 on temperatures
- Eighty-seven 1-tonne 30-year CO_2 removals are equivalent in terms of economic damages avoided to 1 tonne of CH_4, ensure short-term temperature reductions and reduce intertemporal transfers of well-being
- Using equivalent temporary CO_2 removals to offset CH_4 will guide the inclusion of the agricultural sector in emissions trading schemes

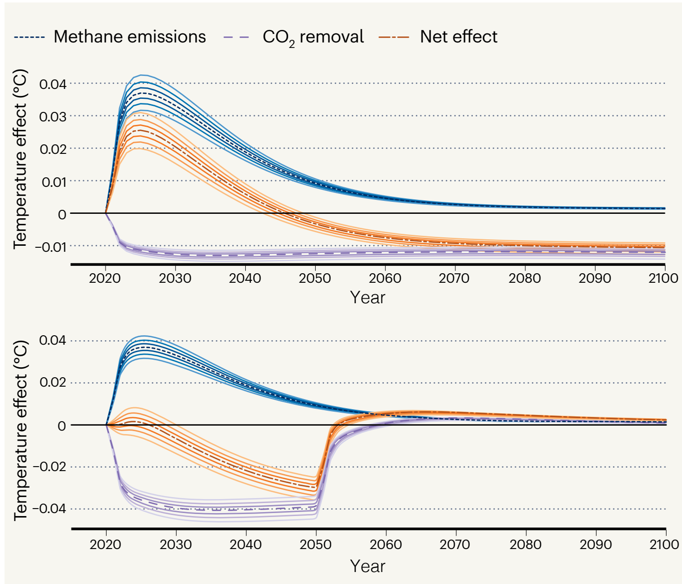

Fig. 1 | The temperature effect of CH_4 emissions offset by 25 100-year CO_2 removals and by 80 30-year CO_2 removals. The effects on temperature are estimated using the FAIR 2.0.0 model. The central dotted blue line is the impulse response function for 1 Mt of CH_4 emissions. The central dashed purple line reflects the effect of the temporary CO_2 removals. The dash-dotted red line charts the temperature change when the CH_4 emissions are offset by 25 100-year CO_2 removals (top) or by 80 30-year removals (bottom, global warming potential equivalence ratio for RCP 2.6, including forcing effects after the end of the offset). The surrounding lines in each case represent deciles reflecting physical uncertainty regarding gas forcing, absorption and decay dynamics. Figure adapted from F. Venmans et al. *Nat. Clim. Change* https://doi.org/10.1038/s41558-025-02487-8 (2025), Springer Nature Limited.

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Further reading

1. West, T. A. P. et al. Action needed to make carbon offsets from forest conservation work for climate change mitigation. *Science* **381**, 873–877 (2023).
   This paper provides insights on the credibility and impermanence crisis of the nature-based and, in particular, forest-based carbon removal market.
2. Open letter on Article 6.4. (IETA, 2025); https://go.nature.com/4oCO8TB
   This open letter provides insights on the relevance of nature-based carbon removal for climate change mitigation and the need for appropriate mechanisms to include them into international removal trading.
3. Groom, B. & Venmans, F. The social value of offsets. *Nature* **619**, 768–773 (2023).
   This paper provides insights on assessing the welfare implications of non-permanent carbon removal.
4. Leach, N. J. et al. FaIRv2.0.0: a generalized impulse response model for climate uncertainty and future scenario exploration. *Geosci. Model Dev.* **14**, 3007–3036 (2021).
   This paper provides insights on how to calculate the temperature impacts of different greenhouse gas emissions over time.

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Competing interests

The authors declare no competing interests