PROVIDE

D1.1

Policy brief on assessment of GHG emissions implied by the latest round of NDCs under the Paris Agreement, their plausible temperature implications, and CDR deployment scales in associated pathways

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D1.1 Policy brief on assessment of GHG emissions implied by the latest round of NDCs under the Paris Agreement, their plausible temperature implications, and CDR deployment scales in associated pathways

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Abstract: A method to analyze the global warming implications of Nationally Determined Contributions (NDCs) and other long-term emissions reduction targets is described. In addition, a method to understand the potential Carbon Dioxide Removal (CDR) consequences of the implied emissions pathways is presented.

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Glossary

ABBREVIATION / ACRONYM	DESCRIPTION
AFOLU	Agriculture, Forestry and Other Land Use
CDR	Carbon-dioxide removal
GHG	Greenhouse gas
LTS	Long-Term Strategy
NDC	Nationally Determined Contribution
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

Since the adoption of the Paris Agreement in 2015, countries submit their national climate pledges, known as nationally determined contributions or NDCs, to the United Nations Framework Convention on Climate Change (UNFCCC). The initial round of NDCs fell woefully short of what is needed to limit global warming to the goal set out in the Paris Agreement. Besides NDCs with pledges for GHG emissions reductions to be achieved typically by 2030, countries have also come forward with longer term pledges. These pledges take the form of net-zero emissions targets.

Here we describe a new, improved method to project the global warming implications of NDCs and net zero targets by combining assessments of the credibility of NDC and net-zero target achievement. Current policies are projected to lead to about 2.6°C of median warming by the end of the century, and the inclusion of credible net-zero targets barely reduces this projection. However, if all NDCs and net-zero targets are taken at face value and believed, global warming in 2100 might be brought down to 1.6°C. This important discrepancy shows the importance of increasing the credibility of the achievement of long-term net-zero targets.

In addition, we also describe a method to understand the potential Carbon Dioxide Removal (CDR) consequences of the implied emissions pathways. We highlight the different roles CDR plays in achieving emissions reductions in line with the Paris Agreement. Given the emerging gap between available and required CO_2 removals for achieving pathways in line with the Paris Agreement – especially for novel technologies such as BECCS and DACCS – GHG emissions must be urgently reduced and simultaneously novel CDR and conventional removals should be scaled and expanded in sustainable ways.

1. Introduction

Since the adoption of the Paris Agreement in 2015, countries have been submitting their national climate pledges, known as nationally determined contributions or NDCs, to the United Nations Framework Convention on Climate Change (UNFCCC). The initial round of NDCs fell woefully short of what is needed to limit global warming to the goal set out in the Paris Agreement (Rogelj et al., 2016): to keep global warming well below 2°C and pursue limiting it to 1.5°C (UNFCCC, 2015). Since then, countries have been invited to update their pledges and come forward with revised and strengthened NDCs. By the 26th climate summit (known as Conference of the Parties or COP26) in 2021 in Glasgow in the UK, 86 new or updated NDCs were communicated to the UNFCCC (UNFCCC, 2021). Altogether, all NDCs by 2021 covered about 93 percent of global total greenhouse gas (GHG) emissions (UNFCCC, 2021).

Besides NDCs with pledges for GHG emissions reductions or other mitigation measures to be achieved over the next decade, typically by 2030, countries also came forward with longer term pledges. These pledges, which often take the form of net-zero emissions targets (Rogelj et al., 2021; World Resources Institute, 2022), aim to reach net zero GHG or CO_2 emissions by 2050 or later in the second half of the century (World Resources Institute, 2022).

Overall, many independent analysts assess NDCs to significantly fall short of what is required to limit global warming to the goal of the Paris Agreement (UNEP, 2021; IEA, 2022; Climate Action Tracker, 2022; Meinshausen et al., 2022). However, messaging around where we are heading and the levels of climate change that society should be preparing to adapt for are being muddled by the existence of long-term net-zero targets. When taken at face value, the achievement of these long-term net-zero targets brings global warming projections right down to below 2°C (Meinshausen et al., 2022; Höhne et al., 2021; Rogelj, Den Elzen & Portugal-Pereira, 2022). However, when only looking at policies that are currently on the books and being implemented, median global warming projections still end up North of 2.5°C (Climate Action Tracker, 2022; Rogelj, Den Elzen & Portugal-Pereira, 2022). This discrepancy between most optimistic and most conservative interpretations of how much global warming current climate policy is leading to is confusing.

This deliverable describes a new method to project the global warming implications of NDCs and net zero targets by combining assessments of the plausibility of NDC and net-zero target achievement. In addition, a method to understand the potential Carbon Dioxide Removal (CDR) consequences of the implied emissions pathways is presented.

2. Global greenhouse gas (GHG) pathways implied by current pledges

2.1. Global GHG emissions in 2030 implied by current policies or promises

Under the Paris Agreement, countries are required to submit their intended contributions as Nationally Determined Contributions or NDCs. However, the pledged mitigation actions included in NDCs are not necessarily implemented. Therefore, many studies, including the UN Environment Programme's (UNEP) Emissions Gap Reports (UNEP, 2021), distinguish between emissions projections for current policies and current pledges. Current policy projections reflect the policies that are currently on the books and in the process of being implemented. NDCs reflect the pledges submitted by countries to the Paris Agreement, often taken at face value.

Estimating the level of global GHG emissions implied by current policies or NDCs is challenging due to a set of confounding factors, including uncertainties in emissions inventories, imprecision in the definition of targets, or the inclusion of conditionalities in the NDCs (Rogelj et al., 2017). The UNEP Emissions Gap Reports therefore provide an annual assessment of the potential range of global GHG emissions implied by current policies and the current NDCs (Rogelj, Den Elzen & Portugal-Pereira, 2022). We here use the latest authoritative UNEP assessment as starting point for understanding the implications for future GHG emissions and global warming.

Table 1: Estimated global GHG emissions in 2030 based on current policies and NDCs, as assessed by the 2022 UNEP Emissions Gap Report.

Case	Global GHG emissions in 2030 (GtCO2e/yr, AR6 GWP-100)
Current policies	58 (min-max: 52–60)
NDCs unconditional	55 (10–90%: 52–57)
NDCs conditional	52 (10–90%: 49–54)

2.2. Extending emissions beyond 2030

Beyond 2030, GHG emission estimates need to be extended. Two types of extensions are being considered. A first extension continues the level of climate action implied by the current policies or NDCs after 2030 and until 2100 (see Section 2.2.1). A second extension in addition takes into account long-term net-zero targets that have been announced by countries (see Section 2.2.2).

2.2.1. Global GHG emissions projections in absence of measures beyond 2030

The 2030 GHG emissions estimates are in this case extended by assuming that the carbon price implied to achieve the 2030 emissions reductions is continued in one of a few different ways, without taking account of net zero targets. We then consider the effects of taking into account net zero targets on greenhouse gasses, and then split up the Kyoto emissions basket.

Firstly, estimates for global 2030 emissions are harmonized to historic emissions. Historic data is obtained from the CMIP6 emissions database, which is based on a variety of literature sources (Gütschow, Jeffery & Gieseke, 2019; Hoesly et al., 2018; van Marle et al., 2017; Velders et al., 2015). The harmonization uses a multiplicative factor that starts at the value required to unify the data in 2015 to the historic value and tapers to 1 in 2050. Before 2015, historic values are applied.

Next, emissions are projected out to the end of the century. Several different approaches and assumptions are used to establish robust trends and quantify uncertainties. The implied GHG price is estimated by using the relationship between emissions and GHG prices in 2030 as modelled in a full ensemble (baseline to deepest possible mitigation) of middle-of-the-road SSP2 MESSAGE-GLOBIOM scenarios (Fricko et al., 2017; Rogelj et al., 2018a). To describe this relationship, we use a Piecewise Cubic Hermite Interpolating Polynomial (Pchip) interpolation to connect the price-emissions points described by these scenarios. We then assume a range of trends of price behaviour after that, either increasing exponentially at a rate between 0 and 5% per year, or at the rate prescribed by the GDP growth in the SSP2 baseline (which is taken as the central 'best-estimate' case). From all these price pathways, we can infer Kyoto-GHG emissions totals based on the SSP2 MESSAGE implementation, assuming a range of potential continuations of climate policy stringency post 2030. These three steps combined give us global Kyoto GHG emissions timeseries for the current policies and/or NDCs until the end of the century.

2.2.2. Global GHG emissions projections taking into account long-term targets

We then estimate the impact of including net-zero targets, at varying levels of certainty. This requires us to estimate what fraction of the expected emissions will be from We import country emissions from the CAIT database (WRI, 2015) and calculate regional sums of the countries corresponding to the 5 IAMC regions[1]. Although CAIT emissions sums differ from more recent historic global aggregate values, there is no need to harmonize because only emissions ratios are used. We then project the regional fraction of emissions of a given country by multiplying a country's fraction of CAIT emissions in the region in the most recent historic year by the ratio of NDCs in that year to 2030, divided by the ratio of regional emissions in that year to 2030 emissions (see equation below). We assume that if it were not for the net zero targets, this ratio would hold constant. With net zero targets, however, this fraction of emissions trends linearly to 0 in the net zero year. In the case of Mexico, they instead tend to a low but non-zero value (T). If regional emissions are expected to be lower than this value anyway, we do not change the emissions in that region. This change in emissions due to the imposition of a net zero target of T (generally zero) can be expressed arithmetically as

$$\Delta e_{cT}(y) = \max\left(\frac{e_r(y)}{e_r(y_1)} * \Delta e_{cp}(y1) - T, 0\right) * \min\left(1, \frac{y - y_1}{y_{nz} - y_1}\right)$$

$$\text{for } \Delta e_{cp}(y1) = \frac{e_{cp}(y_1)}{e_{cp}(y_0)} * \frac{e_{ca}(y_0)}{e_{ra}(y_0)} * e_r(y_0)$$

where $\Delta e_{cT}(y)$ is the change in emissions due to country c in year y (after 2030), e_r is the emissions estimate of that region, e_{cp} the country's NDC or current policy estimate, $e_{c(r)a}$ the country (region)'s emissions reported in the most recent reporting year y_0. y_1 is 2030 and y_{nz} is the year of the net zero (or T) target.

In some cases, it is unclear whether the net zero target applies to only CO_2 or to the GHG sum. We therefore run through two cases: one case where all unknown targets apply to all Kyoto GHGs and one where unknown targets apply only to the fraction of emissions

[1] See this webpage for the regional definitions: https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=10#regiondefs

that are expected to be CO_2. In all cases, this fraction is estimated by the regional fraction of Kyoto emissions corresponding to CO_2 in the MESSAGE-GLOBIOM SSP2-4.5 scenario.

Finally, not all long-term net-zero targets are equally credible. We assign a credibility score of *higher*, *lower*, or *very low* to a country's net zero targets as a function of whether their net-zero targets is legally binding, accompanied by an implementation plan, and if current policies are already sketching a downward path. This results in three emission projections, starting from the current policy projections and in line with the credibility of net-zero targets.

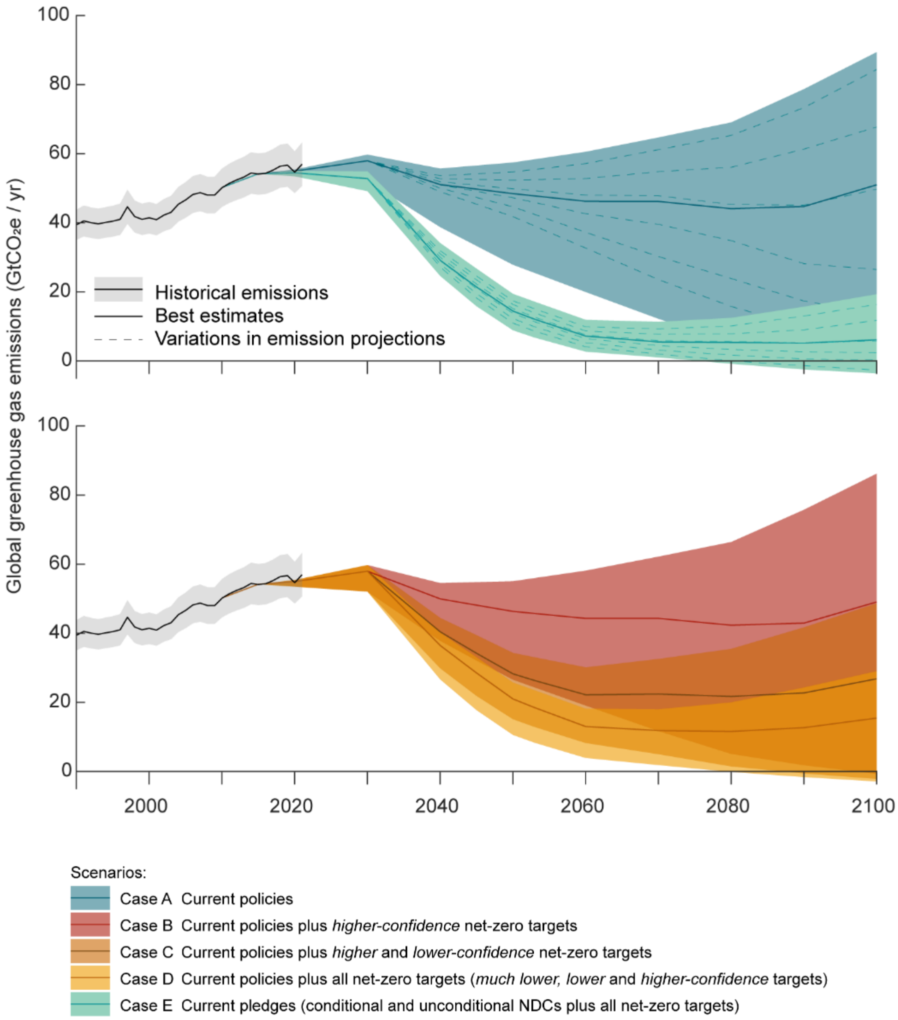

Figure 1: Global GHG emissions starting from either current policy projections (cases A–D) or current pledges (case E) in 2030, and extended taking into account a varying number of net-zero targets depending on their credibility.

2.3. Global Warming Implications

We now have projected Kyoto GHG aggregate emissions and wish to break this down into components. We do this using a specialised tool called Silicone (Lamboll et al., 2020) that infers relationships between different types of emissions in similar scenarios in a given database and works out the corresponding estimates for our scenarios. We also infill other emissions, and then run the results through a simple climate model.

The tool uses to split Kyoto GHGs up is called *SplitCollectionWithRemainderEmissions*, found in the python package called Silicone (Lamboll et al., 2020). This function estimates the emissions of the individual GHGs using the quantile rolling windows method with default settings, then attributes the difference between the sum of these emissions (in Mt CO_2-equivalent under AR6 GWP100 values) and the total emissions to CO_2 from energy and industry. The infiller database for this process is the SSP2 MESSAGE-GLOBIOM scenario set. However, for the breakdown of F-gases into individual components we use any scenarios in the SR1.5 database (Huppmann et al., 2018a, 2018b) that have all required F-gases for each stage, since many of these gases are not modelled in MESSAGE-GLOBIOM and few scenarios have a complete set. The breakdown of the F-gas total into components is done by first breaking down into total SF6, HFC and the two PFC emissions, after which the HFC emissions are broken down into individual components separately. These steps both happen via Silicone's *DecomposeCollectionTimeDepRatio* function.

Global mean surface temperature projections and their uncertainties are subsequently estimated for each modelled pathway using the FaIR simple climate model version 1.6.2. This is calibrated to match the radiative forcing and climate response uncertainty assessment of the IPCC Sixth Assessment Report (Smith et al., 2018; Smith, 2022; Nicholls et al., 2021). Table 2 provides an overview of the global warming projections for these scenarios.

Table 2: Global warming projections of various modelled cases. GHG = greenhouse gas; GDP = gross domestic product.

Scenario		**Global warming projection for 2100 (°C relative to 1850–1900)**		
Case	**Sub-case / extension variation**	**50th percentile**	**66th percentile**	**90th percentile**
Current policies	Best estimate (median 2030 GHG emission estimate and strengthening in line with GDP growth)	2.6	2.8	3.3
	Minimum 2030 GHG estimate and 5% strengthening rate	1.7	1.9	2.3
	Maximum 2030 GHG estimate and 0% strengthening rate	3.0	3.3	3.9
+ *higher* credibility net-zero targets	Best estimate (median 2030 GHG emission estimate and strengthening in line with GDP growth)	2.5	2.7	3.2
	Minimum 2030 GHG estimate and 5% strengthening rate	1.7	1.8	2.2
	Maximum 2030 GHG estimate and 0% strengthening rate	3.0	3.2	3.8
+ *higher* and *lower* credibility net-zero targets	Best estimate (median 2030 GHG emission estimate and strengthening in line with GDP growth)	2.1	2.2	2.6
	Minimum 2030 GHG estimate and 5% strengthening rate	1.5	1.6	2.0
	Maximum 2030 GHG estimate and 0% strengthening rate	2.3	2.5	3.0
+ *all* net-zero targets	Best estimate (median 2030 GHG emission estimate and strengthening in line with GDP growth)	1.8	2.0	2.3
	Minimum 2030 GHG estimate and 5% strengthening rate	1.4	1.6	1.9
	Maximum 2030 GHG estimate and 0% strengthening rate	2.0	2.2	2.6
Conditional NDCs with all net-zero targets	Best estimate (median 2030 GHG emission estimate and strengthening in line with GDP growth)	1.6	1.7	2.1
	Minimum 2030 GHG estimate and 5% strengthening rate	1.4	1.5	1.8
	Maximum 2030 GHG estimate and 0% strengthening rate	1.8	1.9	2.3

3. CDR implications of global pathways

3.1. Introduction and context

To limit global warming to well below 2°C or even 1.5°C, as agreed in the Paris Climate Agreement, only a very limited future CO_2 budget is available. This is an important insight from climate physics (IPCC, 2021). For example, in order to limit global warming to below 1.5°C with at least a 67% probability, the world was still allowed to emit approximately 400 billion tonnes of CO_2 from January 2020 onward. For the 2°C target, about 1,150 billion tonnes of CO_2 are still available (IPCC, 2021). With total annual global CO_2 emissions of about 40 ± 3.3 billion tonnes per year (Friedlingstein et al., 2022), this budget is quickly used up, in the case of the 1.5°C target in less than 10 years. From the existence of an absolute and strictly limited CO_2 budget for achieving the Paris climate goals, the three fundamental necessities of CO_2 removal in climate protection can be derived.

First, limiting climate change to well below 2°C requires reaching net zero CO_2 emissions during the 21st century, and in the case of the 1.5°C target already at about mid-century. However, it will not be possible to simply reduce all CO_2 emissions to zero, and a certain amount of so-called residual emissions will therefore remain. These will have to be compensated for by removing an equal amount of CO_2 from the atmosphere. The compensation of residual emissions is the first important task of CO_2 removal in climate protection - an unavoidable one (Rogelj et al., 2018b; Hilaire et al., 2019; IPCC, 2022).

The second need for CO_2 removals arises from the very limited CO_2 budget still available to meet the Paris climate targets. In many climate protection scenarios, the available CO_2 budget is not sufficient to achieve the transformation to a net-zero CO_2 society in time. Therefore, it is temporarily exceeded, only to be compensated again later in the form of a net CO_2 withdrawal (Rogelj et al., 2018b; Hilaire et al., 2019; IPCC, 2022). In a sense, a loan is taken out on the atmosphere, which is then repaid in the form of net negative emissions.

It is important to distinguish between net emissions and gross emissions: Most figures usually show net emissions, but only if gross emissions are explicitly displayed, it quickly becomes clear that CO_2 will not only be removed in the second half of the century, but that emissions will already be partially offset in the next ten years with CO_2 removal technologies - this points to the third need for CO_2 removals: accelerating mitigation in the short to medium term (Rogelj et al., 2018b; Hilaire et al., 2019; IPCC, 2022). The total amount of CO_2 removals over the 21st century is thus much larger than the amount of net negative emissions in the second half of the century. This is important for creating national plans for scaling CO_2 removals as part of the overall climate change mitigation strategy.

Another concept that needs to be clarified is that of net zero CO_2 emissions as opposed to net zero greenhouse gas (GHG) emissions: If non-CO_2 GHGs such as methane and nitrous oxide, which are more potent, but also remain in the atmosphere for a shorter time than CO_2, are also included, then the point in time at which net zero emissions are achieved in order to reach the 2-degree target moves more than a decade into the future.

In order to achieve those CO_2 removals, there is an array of methods currently under discussion. This report uses the Intergovernmental Panel on Climate Change's current definition of CO_2 removals (Matthews et al., 2018). This includes “anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO_2 uptake not directly caused by human activities” (e.g. through increased CO_2 fertilisation).

In the pathways considered in this report, the dominant removal techniques are Bioenergy combined with Carbon Capture and Storage (BECCS) - where additionally grown biomass for bioenergy sequesters CO_2 via photosynthesis, which is not released but captured during the energy generation process and subsequently stored geologically – and afforestation and reforestation (ARR), which stores CO_2 in newly grown vegetation, also by means of photosynthesis. Several scenarios also include Direct Air Carbon Capture and Storage (DACCS), and to a lesser extent also Enhanced Weathering (EW) and "other" CDR, which is not further defined (Byers et al., 2022; Riahi et al., 2022; Strefler et al., 2021).

The rest of the Section will present the results of an analysis of the magnitudes of CDR deployment at the different levels of globally aggregate GHG emissions for current policy pledges as reported in Section 2.

3.2. Analysis of CDR implications of current policies and NDCs

To understand the potential CDR implications of current policy pledges, climate change mitigation pathways from the latest IPCC Assessment Report (AR6), aligning with estimated global GHG emissions of current policies and NDCs, were selected. The selection was based on the respective 2030 GHG emission ranges (see Section 2 for GHG emissions per policy pledge). These scenarios were then evaluated in terms of their implied CDR deployment volumes throughout the coming decades. In addition to current policies and NDCs, a group of "more ambitious" mitigation scenarios was introduced for comparison – represented by AR6 mitigation scenarios with 2030 GHG emissions lower than the GHG emission ranges of current policy pledges.

The here considered climate change mitigation scenarios fall into the categories C2 and C3 of the IPCC. Scenarios in category C2 temporarily exceed global warming of 1.5 °C (P>67%) but then reverse warming and return to 1.5 °C by 2100 (P>50%) after a high overshoot. Scenarios in category C3 limit peak warming to no more than 2 °C (P>67%). Scenarios that are more ambitious than C2 and C3 were incompatible with the estimated GHG emissions of current policy pledges. However, for comparison, C1 scenarios were considered alongside C2 and C3 in the group of "more ambitious" mitigation scenarios, despite having 2030 GHG emissions that are below the projected ranges for current policies and NDCs. Scenarios in category C1 limit warming to 1.5 °C in 2100 (P>50%) with no or limited overshoot (Rogelj et al., 2018b; Guivarch et al., 2022).

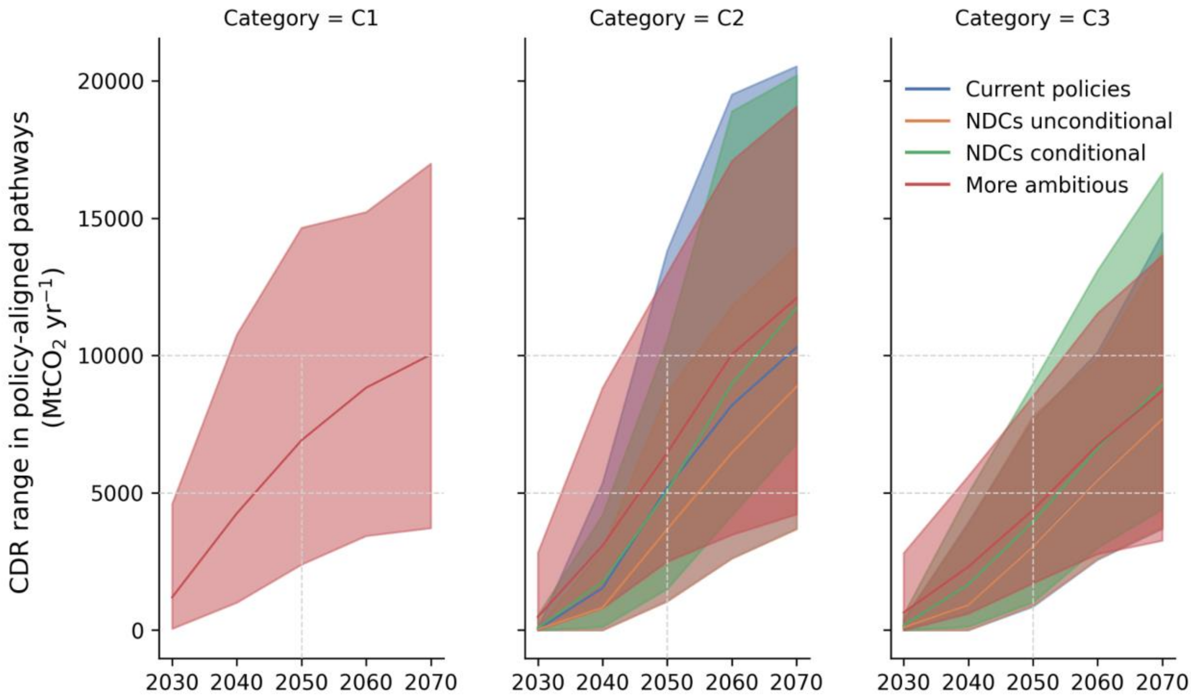

Figure 2: CDR deployment range across warming categories (C1-3) in policy-aligned mitigation pathways 2030-2070 (means and 5-95 percentile range).

Figure 2 shows CDR deployment ranges for the different policy pledges throughout the coming decades. The scale-up of CDR in the policy-aligned scenarios (C2-3) starts around 2030 and reaches annual mean removal rates of roughly 3-6 billion tonnes of CO_2 by mid-century. In the more ambitious scenarios of category C2, the upscaling of CDR removal occurs more rapidly, and more CDR is deployed than in scenarios of category C3. The difference between C2 and C3 scenarios in CDR deployment becomes even more apparent after mid-century. In the highly ambitious reference policy group (C1), the scale-up in CDR until mid-century happens even more rapidly, and higher volumes of CDR are implied than in C2 scenarios. However, the picture changes after mid-century, where C2 scenarios continue to upscale CDR to compensate for temporary overshoot, whereas in C1 scenarios, the CDR deployment curve starts to flatten. Table 3 further details the differences in CDR deployment until mid-century across scenarios of categories C2 and C3, aligning with current policy pledges.

The full range of potential CDR deployment is large, showing almost no CDR on the lower end – implying highly ambitious reductions of gross CO_2 and other non-CO_2 GHG emissions (Prütz et al., submitted), while other scenarios contain double-digit gigatonne-scale removal by mid-century. Figure 3 zooms into 2050 and presents a more detailed picture of implied CDR deployment volumes per policy pledge and scenario category by mid-century. While current policy pledges are still compatible with scenarios in categories C2 and C3, the number of scenarios that can be interpreted as consistent with the Paris Agreement strongly increases when shifting from current policies to the more ambitious reference group.

Table 3: CDR implied by policy-aligned mitigation pathways 2030-2050 (MtCO2 yr[1]).

		Below 1.5 with high overshoot (C2)			
		Current policies	NDCs unconditional	NDCs conditional	More ambitious
	Scenario count	29	21	31	87
	Mean	23	29	82	480
	Median	7	7	20	150
2030	5-95-percentile	0–69	0–75	0–539	4–2827
	Mean	1529	812	1747	3076
	Median	810	162	1282	1837
2040	5-95-percentile	0–5364	0–2956	115–4188	802–8827
	Mean	5175	3671	5056	6453
	Median	4425	1977	5160	5424
2050	5-95-percentile	1064–13822	1043–8668	1503–10548	2498–12988
		Likely below 2 °C (C3)			
		Current policies	NDCs unconditional	NDCs conditional	More ambitious
	Scenario count	65	54	75	216
	Mean	91	95	172	639
	Median	9	20	61	144
2030	5-95-percentile	0–366	0–428	0–565	0–2809
	Mean	914	910	1656	2304
	Median	299	299	1123	1646
2040	5-95-percentile	0–3921	0–3827	121–4985	606–5608
	Mean	3059	3041	3940	4367
	Median	1859	2089	3064	3874
2050	5-95-percentile	856–7653	904–7791	1014–8979	1709–8521

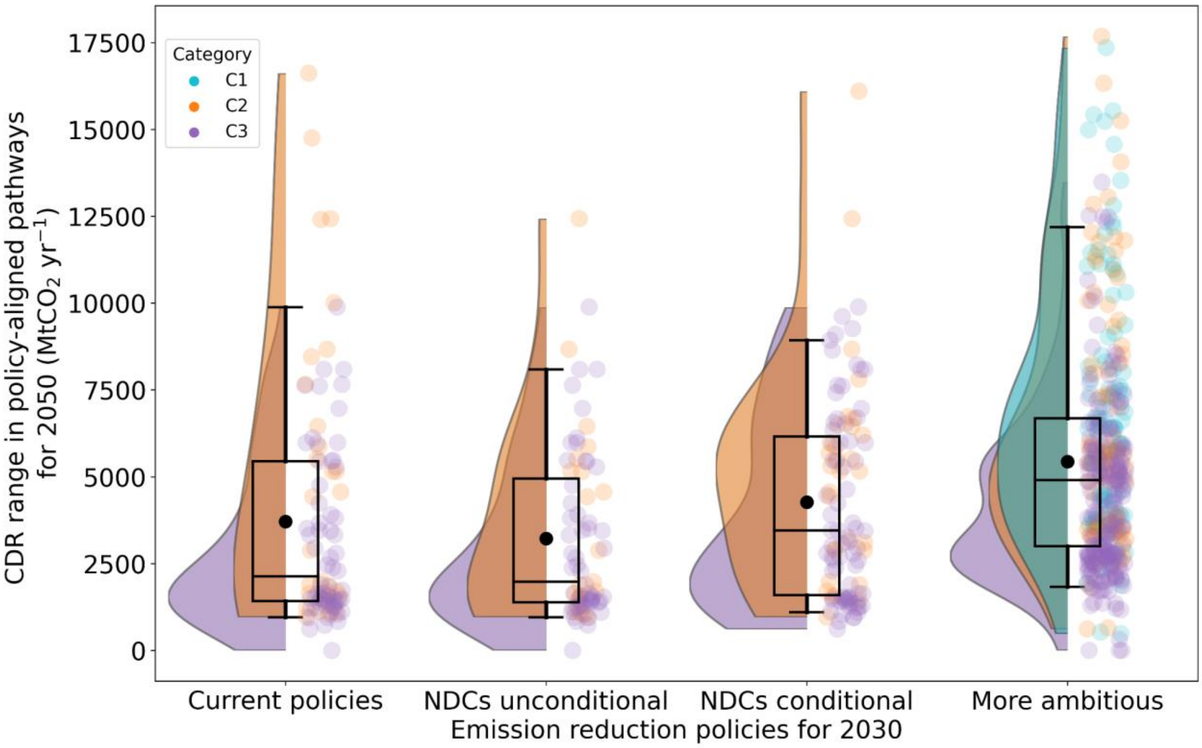

Figure 3: CDR deployment range in 2050 across warming categories (C1-3) in policy-aligned pathways (boxplots do not discriminate between warming categories; boxes show interquartile range and median; whiskers show 5-95 percentile range)

Figure 4 details policy-implied CO_2 removal by CDR option. Net-negative AFOLU CO_2 emissions were used as a (conservative) substitute for land use sequestration to account for missing data and different reporting methodologies across integrated assessment models (IAMs) (Warszawski et al., 2021; Schleussner et al., 2022). This applies to all CDR-related figures and tables in this report. BECCS and AFOLU-CDR dominate the CDR portfolios across all policy-aligned scenarios, regardless of the implied warming categories. Direct air capture is also implied by several scenarios, however, to a smaller extent than BECCS and AFOLU-CDR. CO_2 removal from enhanced weathering and other CDR options (not further defined) only play a marginal role in the scenarios assessed in this report.

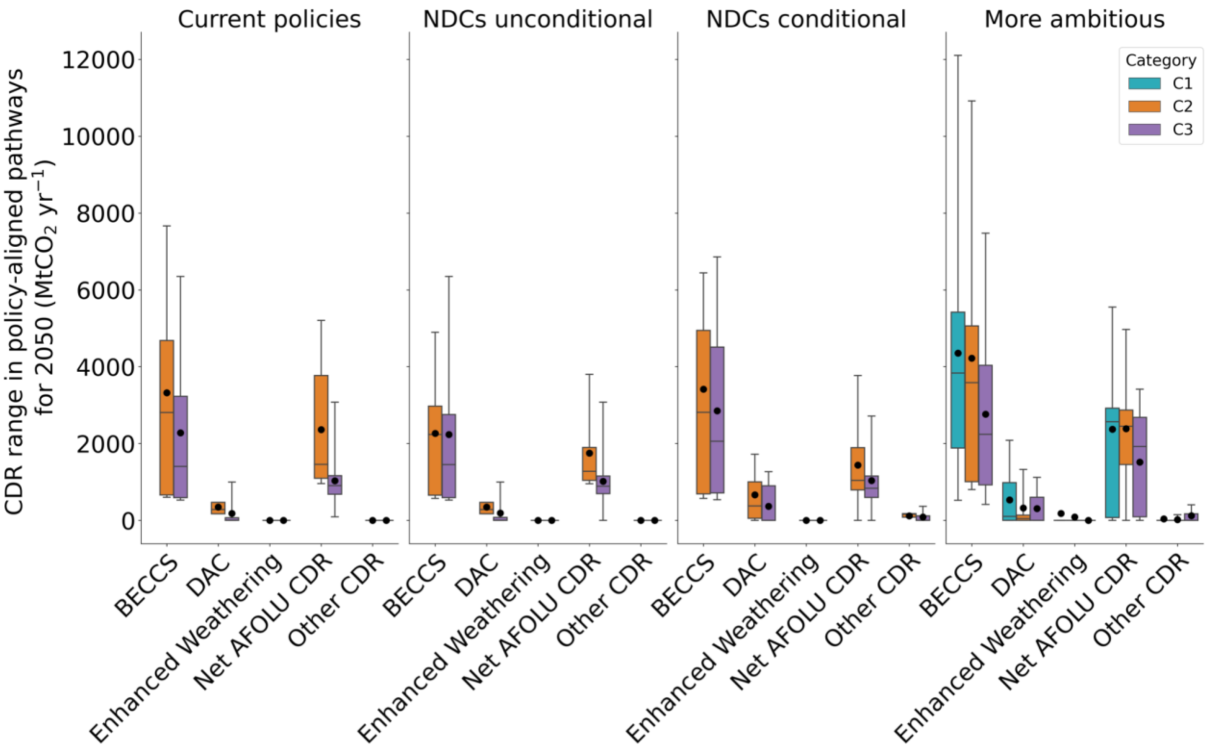

Figure 4: Disaggregated CDR deployment range in 2050 across warming categories (C1-3) in policy-aligned pathways (boxplots: boxes show interquartile range and median; means are represented by points; whiskers show 5-95 percentile range.

While the range of CDR implied across policy-aligned climate change mitigation pathways is large, it is clear that CO_2 removals play a vital role in climate action compatible with the Paris Agreement (Rogelj et al., 2018b; Riahi et al., 2022). To ensure the availability of annual gigatonne-scale CO_2 removals later this century, timely decisions to facilitate and organize CDR upscaling are required (Nemet et al., 2018; Fuss et al., 2018). A recent report on the current state of CDR found an already now emerging gap between available and required CO_2 removals – especially for novel technologies such as BECCS and DACCS, which feature prominently in the here evaluated climate change mitigation scenarios. To bridge this gap, we must urgently reduce GHG emissions and simultaneously scale novel CDR and expand conventional removals through carbon sequestration on land (Smith et al., 2023).

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