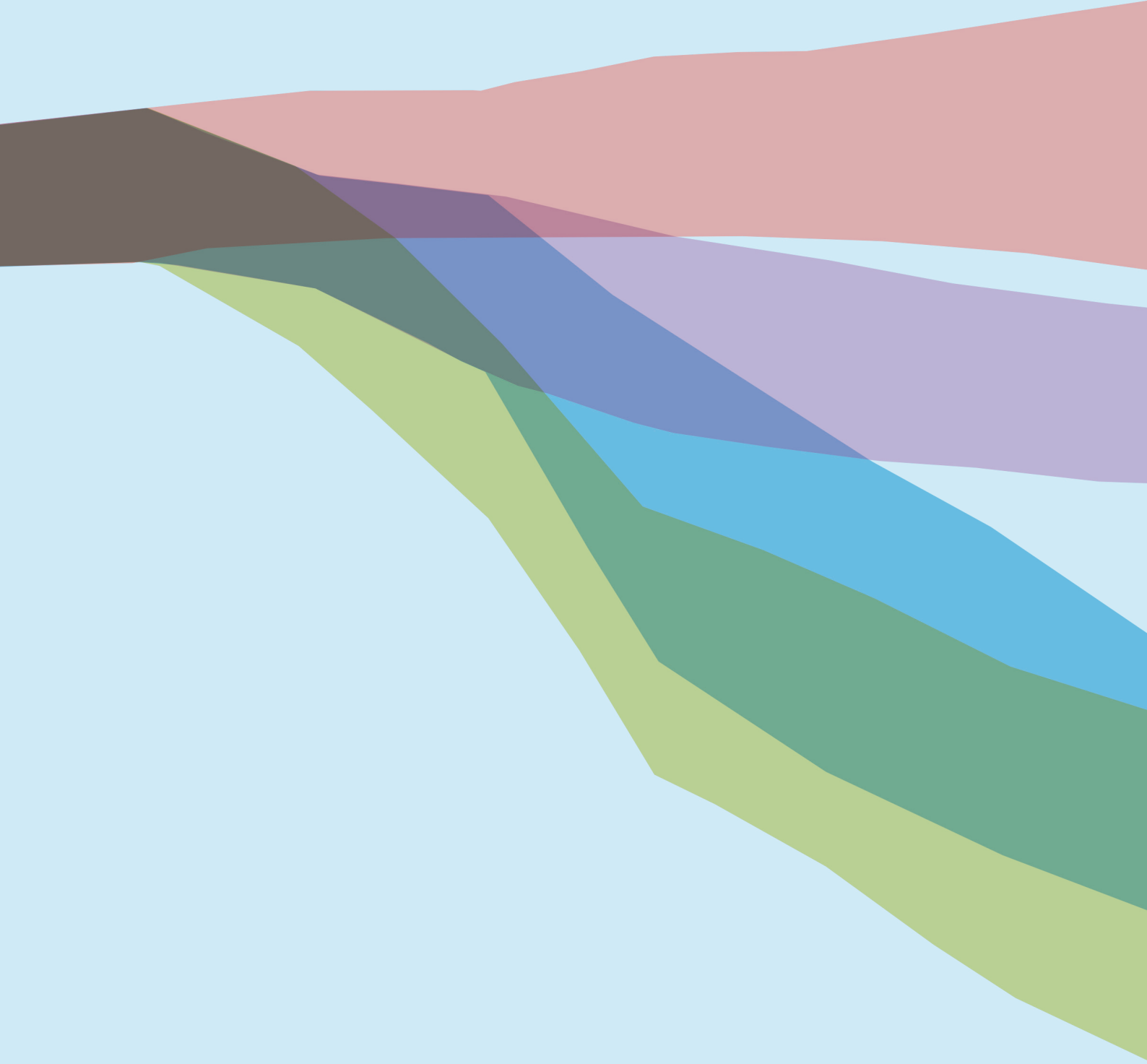

Assessing the Gap

Annual Net-Zero Report 2023

ELEVATE
supporting international climate policy

PBL Netherlands Environmental Assessment Agency

PBL Netherlands Environmental
Assessment Agency

PBL Netherlands Environmental Assessment Agency is the national institute in the Netherlands for strategic policy analysis in the fields of environment, nature and spatial planning. PBL plays an important role in international assessment of global environmental change. The team involved in the Integrated Model to Assess the Global Environment (IMAGE) produces scenarios of climate policy and climate change in terms of energy and land use and emissions of greenhouse gases. The IMAGE team has been involved in several European research projects and plays a key role in the development of scenarios for climate change assessment. PBL researchers play an active role in various international assessments, including those of the Intergovernmental Panel on Climate Change (IPCC), UNEP's Global Environmental Outlook (GEO), and the Global Land Outlook. PBL is part of many relevant scientific networks, including the Integrated Assessment Modelling Consortium (IAMC), the Global Carbon Project (GCP) and the Energy Modelling Forum (EMF). The organisation has extensive experience on advising policymakers on climate policy, including the European Commission and the government of the Netherlands.

Glossary

Current Policies

Current policies are defined as legislative decisions, executive orders, or their equivalent in order to mitigate greenhouse gas emissions. This does not include publicly announced plans or strategies (e.g. Nationally Determined Contributions – NDCs), but includes officially implemented polices to achieve such plans or strategies. The Current Policies (CPs) scenario in this work reflects the implementation of current policies at the national level as included in climate policy modeling protocol developed for the ELEVATE project.

Nationally Determined Contributions (NDCs)

Nationally Determined Contributions (NDCs) is the term adopted by the United Nations Framework Convention on Climate Change (UNFCCC) where countries that have joined the Paris Agreement outline their plans for reducing their greenhouse gas emissions. Each country is responsible for preparing, communicating and maintaining the successive NDCs that it intends to achieve. The NDCs scenario in this work reflects the implementation of countries' conditional NDCs (i.e. pledges that are dependent on a range of possible conditions (UNEP, 2023)).

Net-Zero Emissions and Long-Term Strategies

According to the Intergovernmental Panel on Climate Change (IPCC), ' net-zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period' (IPCC, 2018). In this work, the Long-Term Strategies (LTS) scenario reflects the implementation of the net-zero pledges that have been announced since the Conference of Parties (COP26) in Glasgow in 2021.

Abbreviations

AR6	6th IPCC Assessment Report
CDR	Carbon Dioxide Removal
CO_2e	CO_2 equivalents
COP	Conference of Parties
CPs	Current Policies
GHGs	Greenhouse gases
GWP	Global Warming Potential
IAMs	Integrated Assessment Models
IMAGE	Integrated Model to Assess the Global Environment
IPCC	Intergovernmental Panel on Climate Change
IRA	Inflation Reduction Act
LTS	Long-Term Strategy
NDCs	Nationally Determined Contribution
UNEP	United Nations Environment Programme
UNFCCC	United National Framework Convention on Climate Change

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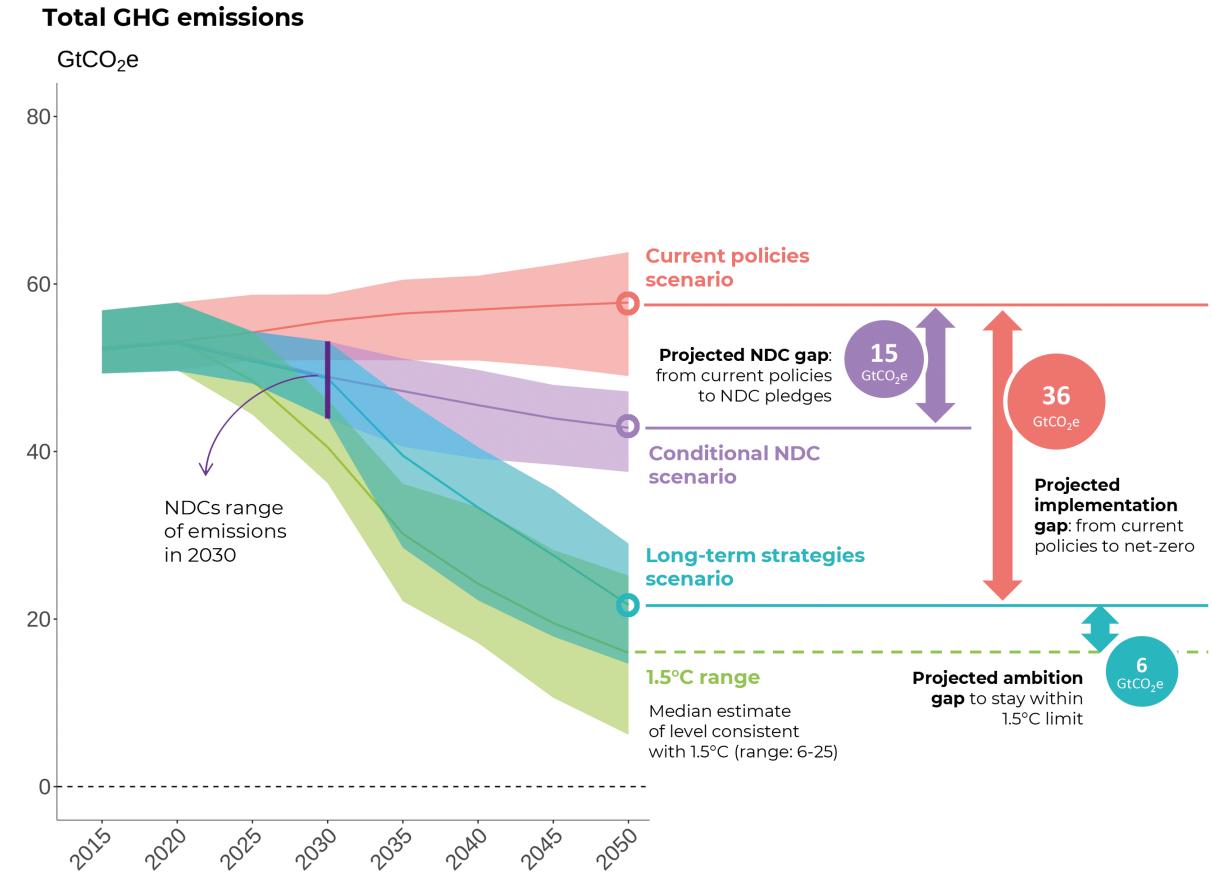
Main Findings



Global GHG emission pathways under various scenarios

This report evaluates the progress of implementing the climate goals of the Paris Agreement via the long-term goals. The figure above summarizes our main findings:

- If countries start implementing pathways towards the self-selected net-zero targets immediately, this would significantly reduce expected warming. However, an ambition gap of 6 $GtCO_2e$ to a 1.5 °C compatible pathway is projected by 2050, revealing that, on a global level, announced net-zero emission targets are not fully aligned with the collective Paris Agreement goals. In other words, further effort is still required.
- Implementation of current climate policies is not enough to achieve the net-zero targets on a global level — an implementation gap of 36 $GtCO_2e$ will remain by 2050. Countries need to increase their effort in implementing policies and underpinning their long-term goals, if they want to achieve their targets.
- Timing of net-zero is strongly dependent on the emission pathway towards and following the target year. This means that if emission levels are higher earlier in the century (such as in 2030), they will need to be compensated for by a more rapid transition towards net-zero, and/or more extensive net-negative emissions.
- Further clarity on net-zero targets is often needed. In many cases, their formulation is unclear in terms of the emission scope and the actual policies associated with them. As warming also depends on non-CO_2 emissions, it is important to specify action for both CO_2 and non-CO_2 (or all greenhouse gases). Net-zero CO_2 will typically be reached much earlier than net-zero GHGs.

1. Introduction

The increase of global mean surface temperature has already reached a level of around 1.2 °C above pre-industrial levels (IPCC, 2023). The numerous climate impacts, such as floods, heatwaves and wildfires, observed in recent years make it clear that anthropogenic climate change is happening and is affecting people all around the world. The IPCC AR6 report emphasizes that impacts will continue to intensify under further increases in global mean temperature. To prevent such increases, greenhouse gas emissions must be reduced to very low levels. However, so far, global greenhouse gas emissions are remaining at an all-time high (IPCC, 2023; UNEP, 2023).

The Paris Agreement was adopted in 2015 by 196 countries and aims to 'limit the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels' (UNFCCC, 2015). As climate science shows that there is a near-linear relationship between temperature increase and cumulative carbon dioxide emissions, limiting global warming requires net-zero carbon dioxide emissions, along with strong reductions in the emission of other greenhouse gases. This characteristic is also found in the scenarios assessed in the IPCC AR6 report consistent with the temperature goals of the Paris Agreement. To stay below 1.5 °C, emission scenarios reach net-zero carbon dioxide emissions in the early 2050s; scenarios consistent with peaking temperature around 1.7 °C do so in the early 2070s (Byers et al., 2022).

In the past decade, the concept of net-zero emissions has become central in climate policy. Net-zero describes the balance between emission sources and emission sinks — meaning that all emissions are either taken up by emission sinks or fully reduced to zero. The net-zero emission concept can be applied to carbon dioxide emissions but also to the total greenhouse gas emissions (expressed in carbon dioxide equivalent). The Paris Agreement refers to this in Article 4 by stating that 'to achieve this temperature goal, Parties aim to reach global peaking of greenhouse gas emissions (GHGs) as soon as possible, recognizing peaking will take longer for developing country Parties, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of the century' (UNFCCC, 2015).

Climate policy needs to be implemented at the national level. Countries have formulated both Nationally Determined Contribution (NDC) and Long-Term Strategies (LTS), that reflect their ambition and strategy on how to reduce national emissions in the short and long-term respectively. While some countries have presented detailed plans, others have not. Consistent with the need to go to net-zero emissions at the global level, many countries have formulated net-zero emission targets, as part of their NDCs or as separate LTS. Typically, these targets describe the year by which they intend to reach the net-zero level and to which gases it applies (either carbon dioxide or all greenhouse gas emissions). The current net-zero pledges (sometimes also communicated outside official documents) account for approximately 80% to 90% of global CO_2 emissions , depending on which pledges are included (UNFCCC, 2022). Nevertheless, not all pledges are underpinned by concrete policies and measures.

The Paris Agreement has designed a process to compare the national pledges to the overall objectives of the Paris Climate Agreement, i.e. the global stocktake. This process, however, is done only every five years and is thus too slow given the urgency of the climate problem. The UNEP-Gap report (2023) provides an annual overview, but focusses mostly on 2035. The process of aligning policy and scientific evidence requires the interdisciplinary exploration of possible strategies to strengthen climate action in order to reach net-zero emissions by mid-century. The aim of the ELEVATE Annual Net-Zero Report is to provide an assessment of how much progress countries have made on their way to net-zero emissions, based on findings from integrated assessment research, including scenario and

policy analysis, as well as behavioural and social sciences. A series of reports will be published annually as part of the ELEVATE project and will systematically address whether current climate policies seem sufficient to reach the net-zero goals and what emission gaps remain between the net-zero pledges and the overall global climate policy objectives (Chapter 2). Moreover, this first report shares insights into various formulations of existing net-zero targets and the influence of these formulations on the net-zero year (Chapter 3).

ELEVATE
supporting international climate policy

ELEVATE is funded by the European Union's Horizon Europe programme and brings together leading research institutes with the goal of supporting international climate policymaking. The aim of the project is to create the required scientific understanding of the impact of current climate policies and identifying opportunities to mitigate GHG emissions and support the preparation of NDCs and national policies focused on achieving net-zero emissions by mid-century, in line with the Paris Agreement.

Furthermore, the project aims at establishing strong interactions between researchers, policymakers and other stakeholders, bringing together global and national modelling teams and connecting the overall progress in achieving the Paris Agreement goals to the implementation of climate policies at the national level, including their alignment with other sustainable development goals.

More information about the ELEVATE project: www.elevate-climate.org

About the project

Grant Agreement ID: 101056873
Start: September 2022 | **End:** August 2026

Partners

PBL Netherlands Environmental Assessment Agency (Netherlands) – Project coordinator
PIK Potsdam Institute for Climate Impact Research (Germany)
COPPE/COPPETEC Graduate School of Engineering (Brazil)
UFRJ Universidade Federal do Rio de Janeiro (Brazil)
E3M E3-Modelling AE (Greece)
CMCC Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (Italy)
CS/SCS Climate Strategies (UK/Netherlands)
Aarhus University (Denmark)
TERI The Energy and Resources Institute (India)
IIASA International Institute for Applied Systems Analysis (Austria)
NewClimate Institute for Climate Policy and Global Sustainability (Germany)
MCC Mercator Research Institute on Global Commons and Climate Change (Germany)
Wageningen University & Research (Netherlands)
WiseEuropa Institute (Poland)
BJUT Beijing University of Technology (China)

External partners:

AFREC African Energy Commission (Africa)
Kyoto University (Japan)
UMD University of Maryland (United States)
KAPSARC King Abdullah Petroleum Studies and Research Center (Saudi Arabia)

2. Assessing the Gap

Since the Paris Agreement came into force, several studies have been assessing the gap between the emission reductions pledged by countries (in the form of the NDCs) and the emission reductions necessary to attain the climate goals outlined in the Paris Agreement. These studies consistently reveal that the currently adopted climate policies and the NDC pledges are not enough to achieve the Paris climate goals (den Elzen et al., 2022; IPCC, 2023; Rogelj et al., 2023; UNEP, 2023). As highlighted in the Emissions Gap Report 2023 of the United Nations Environment Programme (UNEP, 2023), average GHG emissions in the last decade were the highest on record, reaching approximately 57 $GtCO_2e$ in 2022, despite the impact of COVID-19.

In the last few years, countries have also formulated long-term strategies and net-zero targets. The formulation of net-zero targets raises a new crucial question: How do these targets and aspirations align with the climate goals established in the Paris Climate Agreement? And are the necessary policies being implemented to achieve these targets? Certainly, in the long-term, the question whether countries are implementing strategies

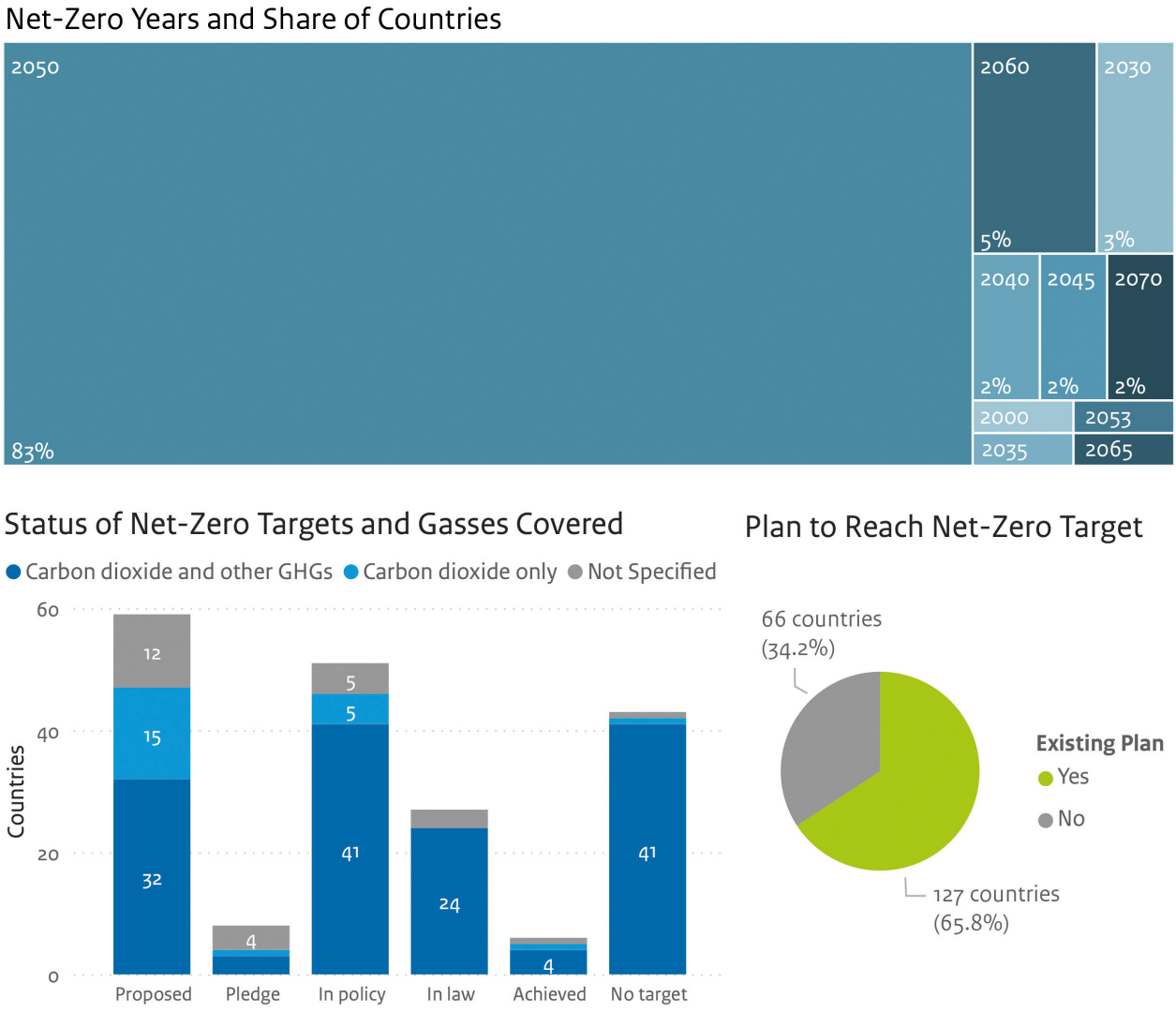


Figure 1: Status of announced net-zero targets, based on data from Net Zero Tracker (2023). Note: 'Proposed' net-zero targets refers to targets that have been proposed but are still discussed. 'Achieved' net-zero targets are self-declared.

to reduce emissions to zero might be even more critical than achieving the NDCs by 2030. This report, therefore, focuses not on the emission gap in 2030, but on the long-term emission trends and their alignment with the Paris climate goals. Just as for the 2030 emission gap, here, we introduce an 'implementation gap', measuring the alignment between current policies and long-term net-zero goals, and an 'ambition gap' measuring the alignment between the cumulative impact of all long-term net-zero goals and the 1.5 °C goal. This assessment is based on a multi-model intercomparison exercise conducted as part of the ENGAGE project[1], which explores how effective current climate policies, NDCs and long-term strategies will be in achieving the overall objectives of the Paris Agreement (Tagomori et al., 2023a; 2023b)[2].

Subsequently, the report looks into the performance of five major emitters: the European Union, the United States of America, China, India and Brazil, based on the results from IMAGE (Integrated Model to Assess the Global Environment).

2.1. Current status of long-term strategies announcements (net-zero)

Figure 1 shows the current status of net-zero, in terms of net-zero year, legal status and established plans to achieve the target, as well as the emissions scope. The year 2050 is the net-zero year preferred by the vast majority of countries (83%). Most countries' net-zero targets cover CO_2 and other GHG emissions (75%). Finally, while many countries already have their net-zero targets enshrined in policy or law (40%), a considerable share lacks a plan to actually achieve these targets (34%).

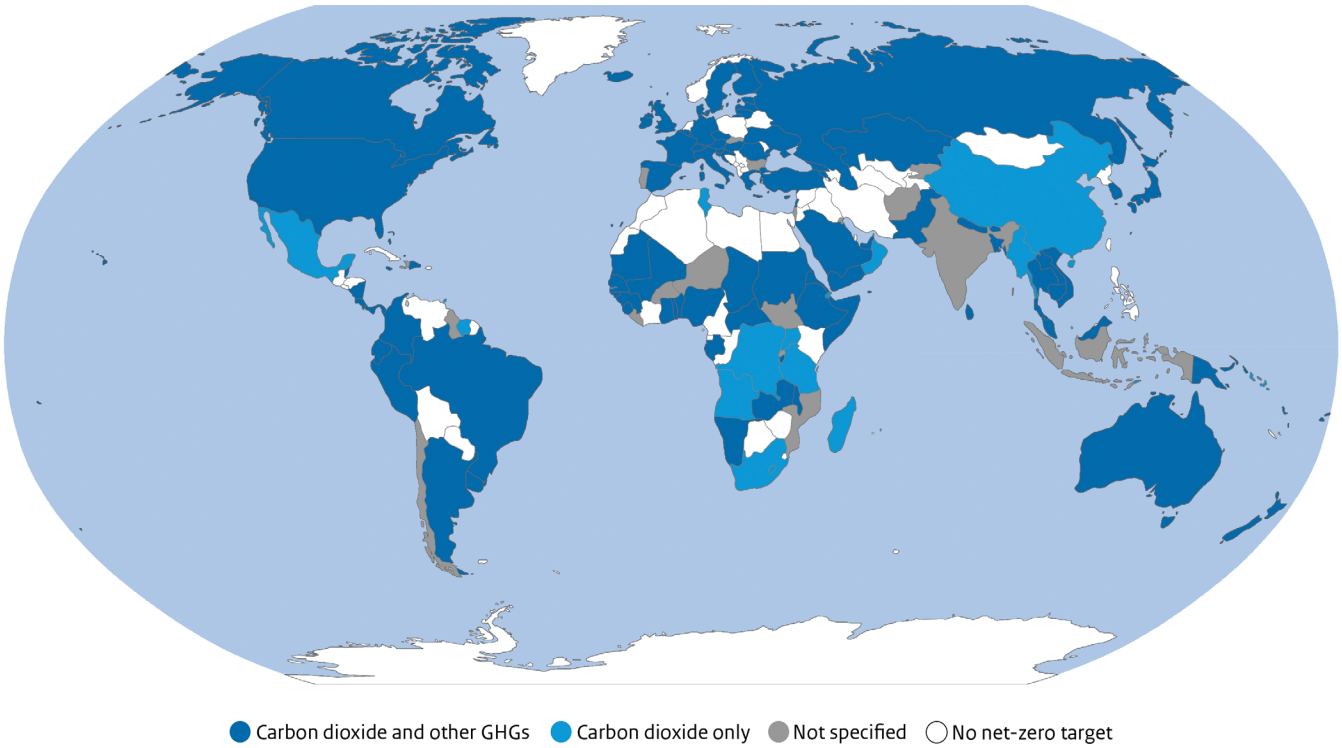


Figure 2: Emissions scope of the net-zero targets per country, based on data from Net Zero Tracker (2023)

1 ENGAGE (Exploring National and Global Actions to reduce Greenhouse gas Emissions) is a project funded by the European Union's Horizon 2020 Research and Innovation Programme. More information about ENGAGE can be found at: www.engage-climate.org.

2 The scenario range of emissions is based on the multi-model comparison of results from the following Integrated Assessment Models (IAMs): IMAGE, REMIND, MESSAGEix, GEM-E3, POLES, and WITCH. The full set of scenarios is publicly available on Zenodo (Tagomori et al., 2023a), and the documentation for all listed models can be found in the IAMC Model Documentation Wiki (www.iamcdocumentation.eu).

2.2. Mind the gap

Figure 3 presents the projected emission pathways for four different scenarios:

1. Current policies (CP) scenario: assumes all current adopted policies (legislated policies, executive orders) will be implemented until 2030; after 2030 it is assumed that policies will be implemented that involve a similar effort until the end of century[3].
2. NDCs scenario: assumes all NDCs pledges will be implemented until 2030; after 2030 it is assumed that policies will be implemented that involve a similar effort until the end of century.
3. Long-term strategies (LTS) scenario: assumes implementation of all NDCs pledges until 2030 and all announced net-zero pledges by each country's respective target year.
4. 1.5 °C scenario: cost-optimal scenario that limits global mean temperature increase to 1.5 °C by 2100.

2.2.1. Implementation gap

Figure 3 shows that the currently adopted climate policies are not sufficient to put individual countries and the world on a pathway consistent with the announced long-term emission reduction pledges. The current policy pathway in Figure 3 is based on a detailed assessment of adopted climate policies for many countries in the world. Most of these policies are formulated until 2030. Figure 3 shows their implementation leads to a slow increase in global emissions until 2030. In this analysis, a similar effort forward was projected, leading to a similar trend after 2030. The difference in emissions between the current policies pathway and a net-zero trajectory constitutes the implementation gap. The implementation gap for global GHG emissions is projected to reach 36 $GtCO_2e$ by 2050 (Figure 3). This reflects the need for countries to increase their ambition level by adopting and following up on additional policies and actions to achieve their announced long-term targets.

2.2.2. Ambition gap

While the implementation of national long-term strategies and the formulation of net-zero targets by many countries represents an important step forwards in reducing global emissions, the global ambition level still needs to increase. The collective net-zero ambition level of countries is not aligned with the emission levels that are required to put the world on a pathway compatible with the Paris Agreement goals. The difference in emissions between the net-zero trajectory and the estimated levels consistent with a 1.5 °C pathway constitutes the ambition gap. The ambition gap for global GHG emissions is projected at 6 $GtCO_2e$ by 2050 (Figure 3).

2.3. Tracking major emitters

This section presents the progress towards long-term targets (net-zero announcements) for five major emitters: the European Union, the United States, China, India and Brazil, based on the results of the IMAGE model. In addition, it provides an assessment of whether the countries' intermediate targets (NDCs) are aligned with each country's long-term goal. Targets differ in ambition level between the various countries. This report does not assess ambition levels and fairness of net-zero targets per country, but rather whether they are on track to achieve these targets under their respective climate policy status quo. Similarly, alignment of an NDC target with a net-zero target is no indication of whether a country is on track to achieve its long-term target, but rather whether a country's NDC and net-zero targets are aligned, meaning whether the NDC emission target puts the respective country on an emissions pathway to meet its net-zero goal (for the results presented in this chapter we do not consider equity approaches).

2.3.1. European Union (EU-27)

The EU-27 submitted its updated 2030 NDC target in 2020, increasing its ambition level from at least 40% to at least 55% emission reduction below 1990 levels — and has set a legal objective

3 The constant reduction effort after 2030 was implemented by extrapolating the equivalent carbon price (the value of carbon that would yield the same marginal emission reduction) in 2030, using the GDP growth rate in the regions in the various models up to 2100, following Dafnomilis et al. (2022) and van Soest et al. (2021). If a region has a zero carbon price while implementing policies or NDCs in 2030, a minimum carbon price of USD 1/tCO_2 was assumed.

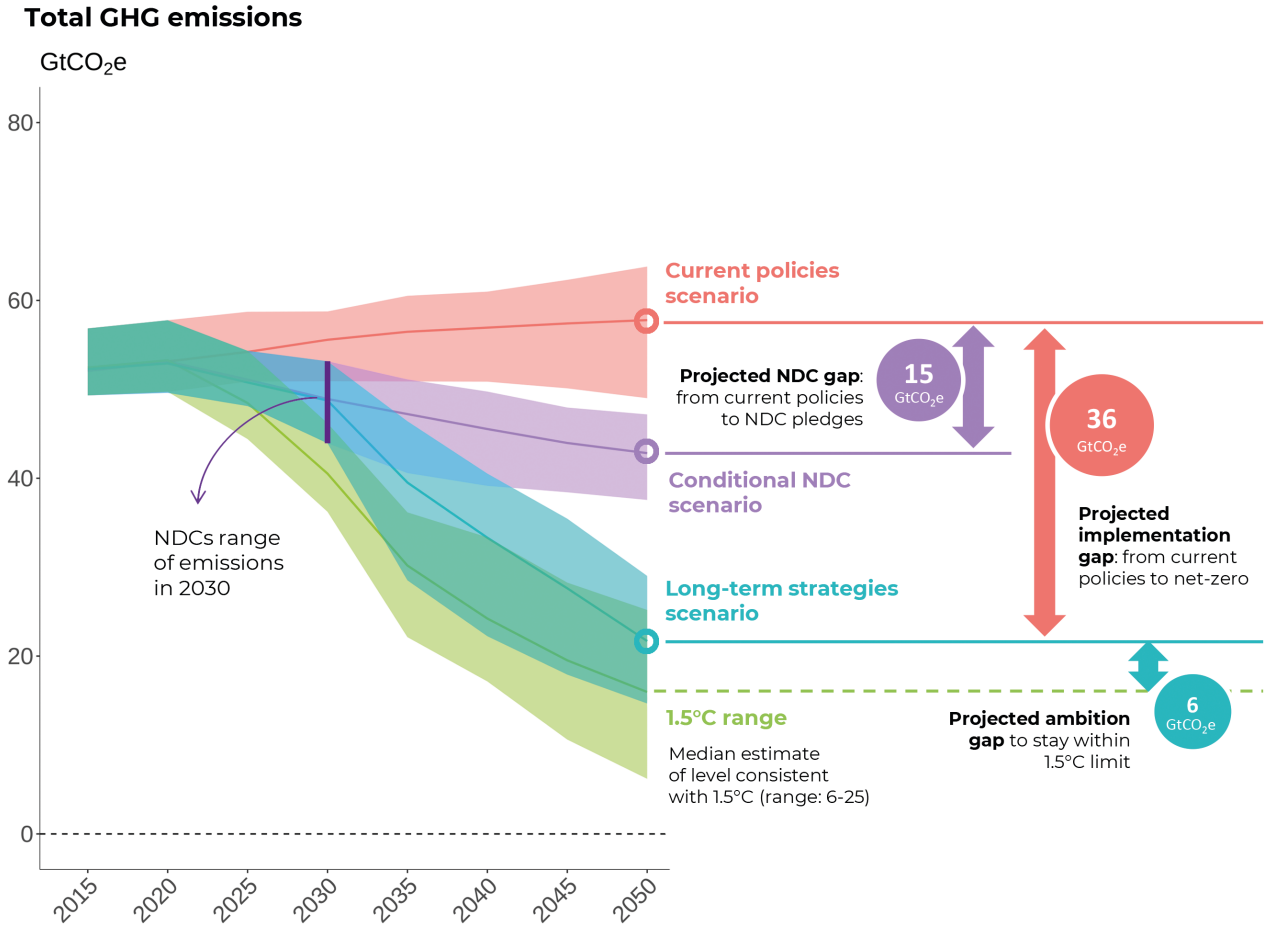


Figure 3: Global GHG emission pathways under various scenarios, and the projected implementation and ambition emission gaps by 2050

to become climate neutral (net-zero target for all greenhouse gases) by 2050, with a relatively clear structure, transparency and scope, and analysis supporting the target (European Commission, 2021b).

The implementation of the Fit-for-55 legislative proposal (European Commission, 2021a) and the REPowerEU Plan (European Commission, 2022), as well as other ambitious policies adopted on the EU level put the EU on track to achieve its 2050 net-zero target, and account for a substantial decrease in emissions by 2030 already. In addition, the NDC target for 2030 is well-aligned with the EU-27's net-zero target, meaning that continuation of the same level of effort after 2030 is likely sufficient to achieve GHG neutrality by 2050. However, it is important to note that the EU-27 being on track to achieve its targets stands true only if EU-27-level policies are considered. Under current Member State-level policies, emissions are expected to decrease by 38% by 2030 compared to 1990, not reaching the 55% target (Nascimento et al., 2023). This means that EU Member States need to adopt and implement more ambitious policies on a national level to be compatible with the EU-27's collective targets.

2.3.2. United States of America (USA)

After rejoining the Paris Agreement in 2021, the updated USA NDC is aimed at a reduction of 50% to 52% below 2005 emission levels, by 2030 (Government of the United States of America, 2021b). In November 2021, the country also published its long-term strategy, illustrating multiple pathways to reach net-zero GHG emissions by 2050, via investments in clean power, electrification of transportation and buildings, industrial transformation, reductions in methane and other potent non-CO_2 climate pollutants, and land-use sinks (Government of the United States of America, 2021a).

Under current policies, the country is projected to steadily decrease emissions until 2050, but there is uncertainty regarding the rate of decline. Quantification of the effect of the Inflation Reduction Act (IRA) is highly uncertain (Bistline et al., 2023). The IRA achieves significant emission reductions compared to previous policies but these will be insufficient to put the country on track to meet its net-zero target (Jenkins et al., 2022; Mahajan et al., 2022; Rhodium Group, 2022). However, the USA NDC target itself is aligned with the country's net-zero target — continuation of total GHG emission reductions at the same rate after 2030 will be enough to achieve the 2050 GHG neutrality target.

2.3.3. China

China submitted its updated NDC in October 2021, revising its four separate NDC targets and adding a fifth target to increase renewable capacity. China also submitted its official long-term strategy in the same month, with a commitment to reach net-zero (CO_2) by 2060, although the document lacks details in bunker emission coverage, removal targets and other related sectors (Government of China, 2021).

Achieving its net-zero target will require additional effort. Emissions are projected to peak just before 2030, under current policies. However, the emission reduction rate post-peak will not be enough to put China on track to achieve its net-zero goal. In addition, given that China's long-term strategy only covers CO_2 emissions, the NDC target is not yet aligned with the country's net-zero target.

2.3.4. India

In August 2022, India submitted its updated NDC, which is aimed at decreasing the GHG emissions intensity by 45% below 2005 levels and at increasing the share of non-fossil energy capacity in the power sector to 50% by 2030 (Government of India, 2022b). India announced its net-zero target for 2070 during COP26 in Glasgow. The announced target is part of India's long-term strategy, submitted in 2022, but the gases it covers is still unclear. Policy guidance on how the government intends to achieve the targets beyond current policies and to what extent this will rely on the use of CCUS or carbon dioxide removal (CDR) technologies is still lacking (Government of India, 2022a).

GHG emissions in India, under current policies, are expected to steadily increase for the remainder of the century. Under current policies, the country is on track to meet, or even surpass, its NDC targets, but these targets do not drive further emission reductions (Climate Action Tracker, 2023b). Thus, the country's climate policies are not nearly ambitious enough to set India on its net-zero pathway. Accordingly, India's NDC is not aligned with its net-zero target (not for CO_2 only or all GHGs), as projections show a continuous increase in emissions. Alignment with the announced net-zero target would require immediate emission reduction efforts.

2.3.5. Brazil

Brazil submitted its updated NDC in October 2023, increasing its ambition level from 50% to 53.1% below 2005 levels by 2030. The update reiterates claims that it sets the country on a pathway compatible with climate neutrality by 2050. However, no further details or clarifications on the scope or pathway of said neutrality goal have been provided by the government (Climate Action Tracker, 2023a).

Brazil will likely fall short of its announced neutrality targets under existing policies. Emissions in the energy and industry sector will plateau or slightly increase at least until 2030. In addition, with the majority of the country's emissions coming from the land-use sector, achieving the net-zero target will highly depend on increasing the ambition level and enforcement of land-use related policies in the short-term. If Brazil manages to achieve an emission reduction trajectory that is consistent with its NDC, it will require a small amount of additional effort to achieve its net-zero target (CO_2 or GHG), as the NDC is not fully aligned with the country's long-term target.

Table 1: Progress of major emitters towards achieving their net-zero targets and assessment of countries' NDC alignment with net-zero targets

	Net-zero target	On track to achieve net-zero target	NDC target	NDC aligned with net-zero target
EU-27	Net-zero GHG by 2050	✓	Reduce GHG by 55% below 1990 levels by 2030	✓
USA	Net-zero GHG by 2050	✗	Reduce GHG by 50–52% below 2005 levels by 2030	✓
China	Carbon neutral before 2060 (CO_2 only)	✗	Peak CO_2 before 2030. Lower carbon intensity by over 65% by 2030 from 2005 levels and other targets	✗
India	Net zero by 2070 (type of gas not specified)	✗	Reduce GHG intensity by 45% below 2005 levels by 2030 and other targets	✗
Brazil	Climate neutral by 2050 (type of gas not specified)	✗	Reduce GHG by 53.1% below 2005 levels by 2030	✗

REPORTING LAND CO_2 FLUX

When comparing net-zero targets and emission scenarios it is important to note that different schemes are used to report land-use-related emissions. Most scientific studies (and the IPCC) define land-use-related carbon dioxide emissions on the basis of land-use change. In contrast, the UNFCCC also includes forest management in the anthropogenic net CO_2 fluxes related to land use. As a result, national inventories typically report lower figures for land-use-related carbon dioxide emissions than those in the emission scenarios (Grassi et al., 2018). The total difference (for all countries) is around 5 $GtCO_2$/year. In this report, managed forests are not included in anthropogenic land-use change. Currently, the modelling community is conducting a joint effort to align the assumptions in IAMs with the reporting from countries' inventories, to allow for comparison (Grassi et al., 2021). In the long-term, improvements are expected in both models and national GHGs inventories.

KEY FINDINGS

- Implementation of current climate policies is not enough to achieve the net-zero targets on a global level — an implementation gap of 36 $GtCO_2e$ will remain by 2050. Countries need to increase their ambition levels if they want to achieve their self-imposed targets.
- The ambition gap to a 1.5 oC compatible pathway is projected at 6 $GtCO_2e$ by 2050, revealing that, on a global level, announced net-zero emission projections are not fully aligned with the collective Paris Agreement goals — further effort is still required.
- Two of the five major emitters (EU-27 and USA) have an NDC that is aligned with their net-zero target, meaning that if they manage to achieve their NDC goals and maintain their level of effort, they could also achieve their long-term strategy.

3. Uncertainty of Net-Zero Formulations

Net-zero targets have become a commonly used climate policy pledge. The formulation of net-zero targets is critical because it reflects the technicalities behind the goal. This chapter discusses the uncertainties related to the formulation of net-zero targets and how they influence the timing of achieving them.

3.1. Various net-zero formulations

Currently, there is no international agreement on the criteria for formulating net-zero targets. In lack of a guideline, countries use a variety of formulations (UNFCCC, 2023). Therefore, direct comparison is difficult. For example, there is a crucial difference between whether a net-zero target refers to net-zero CO_2 or net-zero GHG emissions. There are also several underlying factors that can largely impact the time by which net-zero will be achieved, such as the conversion metrics, the temperature goal to which the net-zero pledge contributes, whether or not temperature overshoot is allowed, and whether or not there is a reliance on negative emissions. Understanding these factors is crucial for setting effective and realistic net-zero targets and policies (Wegh et al., 2023).

3.2. Largest influences on net-zero timing

In determining whether a net-zero year is in line with the overall climate objectives of the Paris Agreement, the first uncertainty is the range in the Paris temperature formulation. There is a large difference between scenarios that remain well-below 2 °C and 1.5 °C in the year by which net-zero will be achieved (with no or limited overshoot). Overshoot also plays a major role. The IPCC scenarios in category C1 (limit warming to 1.5 °C with low or limited overshoot), C2 (return warming to 1.5 ° after overshoot) and C3 (limited warming to 2 °C with a chance greater than 67%) can all be consistent with the Paris Agreement. An ex-post analysis of the net-zero targets was performed for different components of global net-zero: 1) the emission scope, 2) the conversion metrics, and 3) delayed action and net-negative emissions. Further information on the methods can be found in Wegh et al. (2023).

3.2.1. Emission scope

The emission scope of a net-zero target defines if it pursues a reduction in CO_2 emissions only or if other GHG emissions are also included. Some countries exclude specific greenhouse gases from

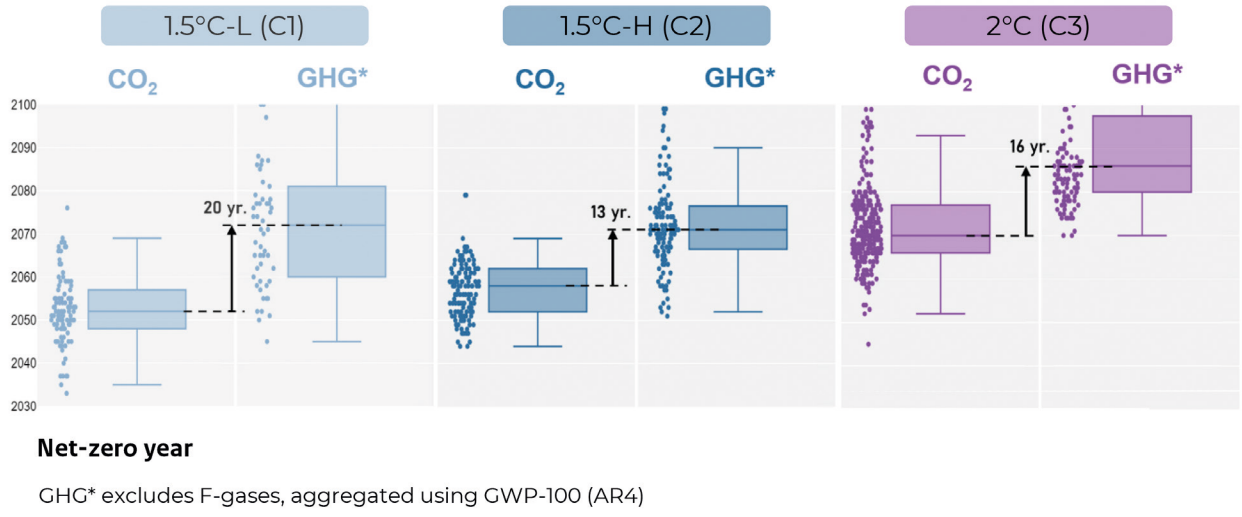


Figure 4: Net-zero CO_2 compared to net-zero GHG for scenarios with different temperature goals: C1 (1.5 °C-L), C2 (1.5 °C-H) and C3 (2 °C). Adapted from Wegh et al. (2023).

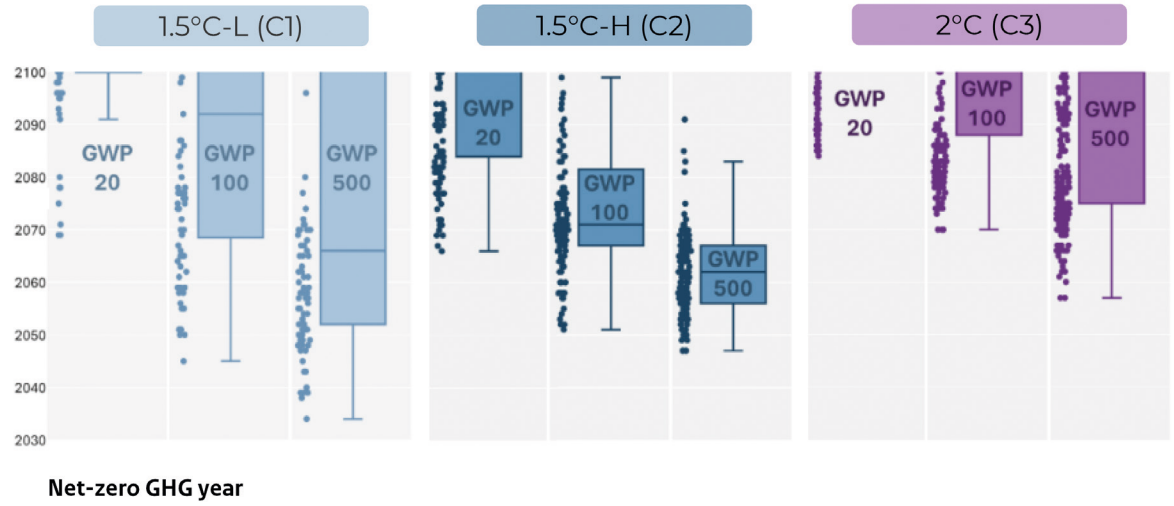


Figure 5: Timing of net-zero GHG for different GWPs (GWP-20, GWP-100 and GWP-500) for scenarios with different temperature goals: C1 (1.5 °C-L), C2 (1.5 °C-H) and C3 (2 °C). Adapted from Wegh et al. (2023).

their net-zero target. New Zealand, for example, has a separate target for biogenic methane and excluded it from their GHG net-zero pledge (International Energy Agency, 2021). Through an ex-post analysis of the contribution of the various non-CO_2 gases, Wegh et al. (2023) concluded that at the global scale, including CH_4 and N_2O in the net-zero target has a significant influence on the timing of net-zero GHG, while the influence of F-gases is found to be only minor.

Figure 4 compares the global net-zero year under scenarios with differing temperature goals, according to two different emission scopes: CO_2 and GHGs (excluding F-gases). The difference may be several decades, depending on the temperature goal. For example, for scenarios aimed at a maximum of 1.5 °C warming with low overshoot (C1), the difference between a net-zero CO_2 target and a net-zero GHGs target (excluding F-gases) is approximately 20 years. Comparison of country net-zero target thus needs to be done with this scope in mind.

3.2.2. Conversion metrics

Conversion metrics are used to compare GHGs by converting them into CO_2 equivalents (CO_2e). The choice of conversion metrics highly influences the timing of net-zero. A lower value reduces the difference between net-zero GHG and net-zero CO_2. A higher value results in a greater difference between net-zero GHG and net-zero CO_2, to the extent that net-zero GHG may not be achievable at all. Furthermore, the conversion metrics can also influence policy instruments and abatement costs, if the price of non-CO_2 gases is dependent on the CO_2 price (which is often the case in IAMs) (Van Den Berg et al., 2015).

The Global Warming Potential (GWP) is the most often used conversion metric. The larger the GWP, the higher the warming effect of a certain gas compared to CO_2 over a specific time period. The net-zero targets of countries are not always clear about the applied metric; but often might use GWPs based on the IPCC AR4 report (Van Den Berg et al., 2015). IPCC in its latest report used updated GWPs. The difference between these values is relatively small. We can illustrate the impact of different GWPs, however, by looking at GWPs over different time horizons: GWP over 20 years (GWP-20), 100 years (GWP-100) and 500 years (GWP-500). A shorter timeframe (e.g. GWP-20) attaches more weight to short-lived GHGs, emphasising short-term effects rather than long-term effects, delaying the achievement of net-zero GHG (Figure 5). A larger timeframe (e.g. GWP-500) attaches less weight to short-lived GHG and prioritises mitigation of long-term warming effects, which results in net-zero GHG

being achieved much earlier (Figure 5). GWP-100 is a compromise for these trade-offs, and is the most commonly used conversion metric.

3.2.3. Delayed action and net-negative emissions

Delayed climate action might also have consequences for the timing of net-zero. According to IPCC's AR6 (IPCC, 2023), under most 1.5 °C and 2 °C scenarios emissions peak between 2020 and 2025, followed by a rapid and sustained transition towards net-zero emissions. CO_2 emissions should be reduced by around 45% by 2030 (compared to 2010), to have a likely chance of limiting warming to 1.5 °C without overshoot. For limiting warming to 2 °C, the emission reduction should be around 25%. Following current NDC pledges, emissions will need to be reduced even more rapidly after 2030 to compensate for the delayed start and to reach 1.5 °C or 2 °C by 2100.

The relationship between net-negative emissions and the net-zero year depends on the temperature overshoot. If the temperature overshoot is limited, there is a negative correlation between timing of the net-zero year and the amount of net-negative emissions. The required amount of net-negative emissions depends on the temperature goal of a given scenario, but generally speaking, if climate action is delayed, earlier net-zero years and lower warming are related to larger amounts of net-negative emissions (Figure 6).

Findings of this study are based on emissions on a global scale. Each country has its own amount of CO_2 and non-CO_2 emissions and, therefore, individual years of reaching net-zero will vary. Nevertheless, results can be used to guide the formulation of individual net-zero targets and to increase the accuracy of net-zero years by keeping the highlighted sensitivities in mind.

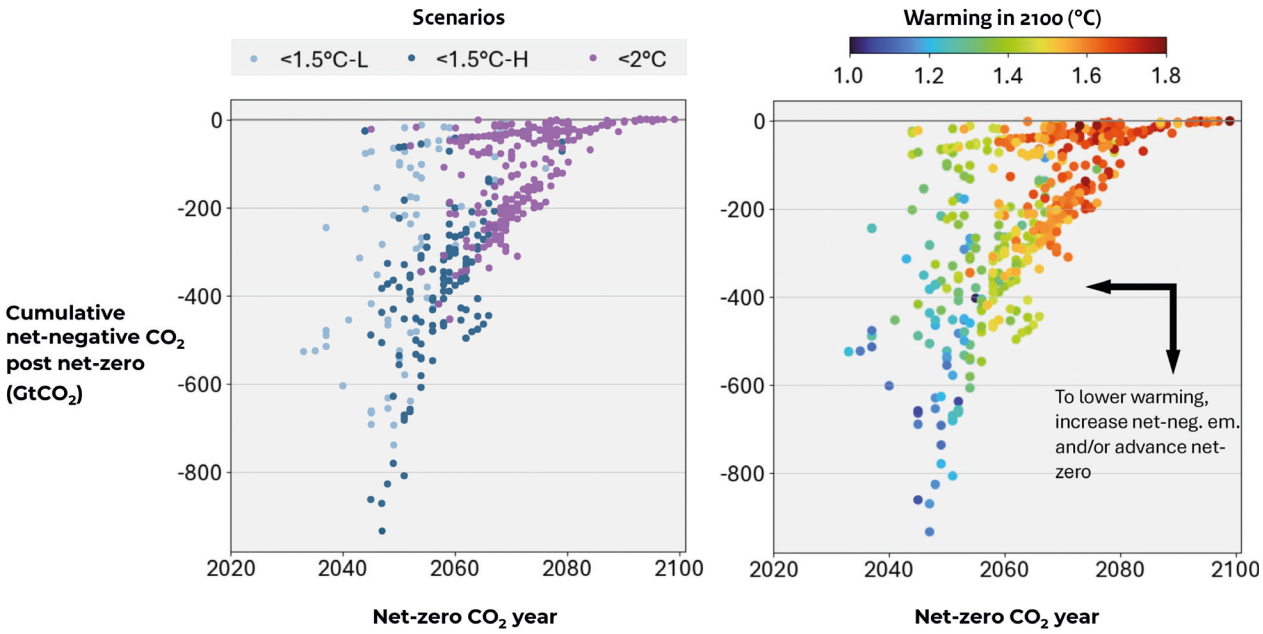


Figure 6: Correlation between cumulative net-negative CO_2 emissions post net-zero and warming levels to the timing of net-zero CO_2, for scenarios with different temperature goals: C1 (1.5 °C-L), C2 (1.5 °C-H) and C3 (2 °C). Adapted from Wegh et al. (2023).

KEY FINDINGS

- Net-zero CO_2 is often reached decades earlier than net-zero GHGs. For scenarios aiming for 1.5 °C, net-zero CO_2 will be achieved 13 to 20 years earlier than net-zero GHG, depending on the level of overshoot (13 years for high and 20 years for low overshoot). Therefore, net-zero pledges should clearly indicate their emission scope.
- The choice of conversion metrics can influence the timing of net-zero, but the impact is relatively small for the use of metrics of different IPCC reports. GWP-100 (Global Warming Potential over 100 years) is the most commonly used conversion metric. Choosing different time horizons (e.g., GWP-20 or GWP-500) may shift the net-zero year by decades, emphasising either shorter or longer term warming effects of GHGs.
- The range of warming levels in the Paris Agreement results in a range of net-zero years possibly consistent with the Agreement. A lower temperature goal generally requires reaching net-zero earlier. However, the relationship is also dependent on other parameters, such as when mitigation starts and the speed of the transition.
- Timing of net-zero is strongly dependent on the emission pathway towards and following the target year. This means that if emission levels are higher earlier in the century (such as in 2030), they will need to be compensated for by a more rapid transition towards net-zero, and/or more extensive net-negative emissions.

4. Future Vision: The Gap through an Equity Lens

As outlined in Chapters 2 and 3, current climate policies lack implementation and ambition, and net-zero pledges need uniform formulation. Clearly, global GHG emissions are not on track to achieve the goals of the Paris Agreement to stay well-below 2 °C or preferably below 1.5 °C warming. While NDC pledges are inherently bottom-up — as countries set the targets themselves — the ambition gap reflects the need for a collective discussion on how the burden of closing this gap could be shared.

At present, there is no agreed method within the UNFCCC for defining or measuring an equitable and ambitious contribution to mitigation, for each country (Pan et al., 2017). There are various scientific frameworks proposed for addressing the question of equity (Holz et al., 2018; Rajamani et al., 2021; Robiou Du Pont et al., 2017; Robiou du Pont & Meinshausen, 2018; van den Berg et al., 2020). They share a set of allocation principles. The first three are commonly considered as principles of fairness: (1) equality, associated with a per capita allocation, (2) responsibility, weighing historical emissions, and (3) capability, referring to the implementation of mitigation measures (related to wealth and institutions). For comparison, principles of (4) continuity, based on current emission levels, and (5) cost-optimality are added to the framework. These principles can be used in the formulation of effort-sharing rules: some are a direct reflection of the fairness principles (e.g., an immediate per capita method represents the equality principle), while others combine different methods (e.g., the framework of greenhouse development rights combines responsibility and capability).

Between countries, there are very large differences on what would constitute a fair goal. Fair-share computations act as a mirror to reflect on current NDCs and net-zero targets and whether these are indeed ambitious for a given country. The next edition of the ELEVATE Annual Net-Zero Report (to be released in October 2024) will dive further into the questions of fairness, discussing how justice and equity dimensions can be incorporated into modelling tools and scenarios, and will analyse how effort-sharing principles can be applied to close the emissions gap.

CARBON BUDGET EXPLORER

The 'Carbon Budget Explorer' is a free and open-source online dashboard that allows users to explore climate targets under different conditions around the globe, as well as various climate policy pathways and how differing views on fairness lead to different emission allocations for individual countries. It provides projections of emission pathways under current policies, NDCs and net-zero pledges and how they relate to various climate targets, allowing users to assess the different emission gaps and, given a carbon budget, to explore different effort-sharing methods. Stakeholders, policymakers and scientists are encouraged to navigate the dashboard to access detailed country-level data in an interactive and intuitive manner. The dashboard can be useful in negotiations and increases the accessibility to relevant policy data.

The "Carbon Budget Explorer" is developed by PBL in collaboration with the Netherlands eScience Center.

Website: www.carbonbudgetexplorer.eu

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