Wave of net zero greenhouse gas emission targets opens window on meeting the Paris Agreement

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Abstract

The wave of national net zero CO_2 and greenhouse gas emission targets could, if fully implemented, reduce best estimates of projected global average temperature increase to 2.0–2.4°C by 2100 and could bring achievement of the Paris Agreement within reach. 131 countries are discussing, have announced, or have adopted net zero targets, which together cover 72% of global emissions. Together, these net zero targets could significantly lower projected global warming compared to currently implemented policies (2.9 to 3.2°C) or to the pledges submitted to the Paris Agreement (2.4 to 2.9°C).

Main

Analyses of current promises and actions by countries to limit climate change have concluded that they are by far insufficient to meet the goal of the Paris Agreement to limit global temperature increase to well below 2°C, while pursuing efforts to limit it to 1.5°C (refs. [1–5]).

Specific policies employed to reduce emissions in line with the Paris Agreement may differ from country to country. However, a chief requirement of collective action is codified in Article 4.1 of the Paris Agreement (Article 4.1, UNFCCC, 2015): emissions need to peak as soon as possible and anthropogenic emissions must be balanced by removals in the second half of the century. In other words, global emissions must reach a net zero level. The idea to include a global net zero target in the Paris Agreement was put forward in the run up to its adoption in 2015.[7,8] Pathways to meet this goal have been evaluated in the literature subsequently[9].

At the time the Paris Agreement was adopted in 2015, only very few countries had net zero emissions reduction targets in place, for example, Costa Rica, Bhutan, and Sweden. In the five years since the adoption of the Paris Agreement, an increasing number of countries have adopted similar targets, with a wave of net zero target announcements from major emitters in recent months. The United Kingdom and small island states got the wave rolling just after Paris and in response to the publication of the IPCC Special Report on Global Warming of 1.5°C.[9] Then, the EU as a whole followed with a proposal to include climate neutrality in their climate law in March 2020.[10] The announcement of China in September 2020 to achieve carbon neutrality before 2060 [11] was a breakthrough moment, which was quickly followed by announcements of South Africa, Japan, South Korea and Canada[12–15]. China has not yet translated this announcement into its five-year planning. The election campaign of President Joe Biden also included an economy-wide 2050 net-zero emissions target which was codified in an executive order signed in January of 2021.[16] Together, we count 131 countries with announcements of the intention to go to net zero greenhouse gas (GHG) emissions (based on ref. 17 as of May 2021, which together cover around 72% of global GHG emissions (emissions data for 2018 taken from ref. [18]).

Analysing the climate effect of net zero targets requires three key components: (1) a political-technical analysis to estimate future emissions resulting from existing pledges and country-specific policies; (2) an estimate of the emissions implied by the net zero targets at country and global scale; and finally (3), a temperature calculation resulting from the emissions assessment.

We undertake and compare two studies of varying complexity that assess the global warming implications of net zero target estimates: one from the UNEP emissions gap report[3] and one from the Climate Action Tracker[19,20]. Both studies rely on the same set of globally consistent CO_2, non-CO_2 GHG, and aerosol emissions pathways used and assessed by the IPCC[9,21]. But both studies estimate future emissions from net zero targets and the resulting global temperature using slightly different methods.

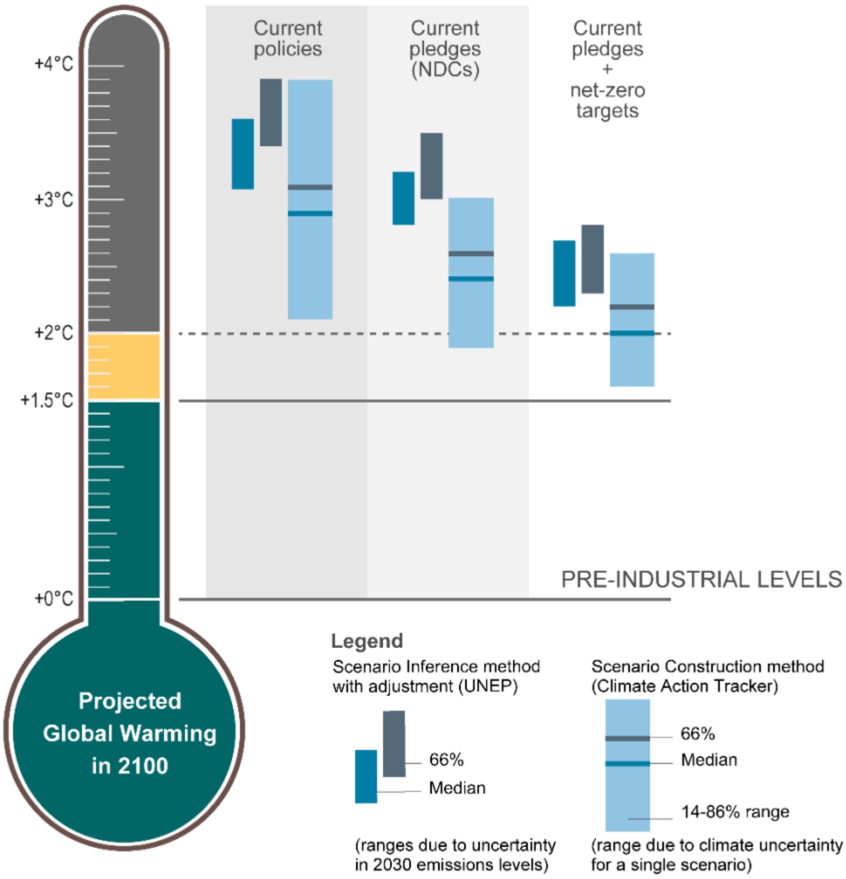
The UNEP Emissions Gap Report estimate uses the *Scenario Inference* method, which applies a functional relationship between 2030 emissions levels and warming in 2100 based on a large set of mitigation scenarios[1] and uses cumulative emissions savings from net zero targets after 2030 to determine warming in 2100 (see Methods). Utilizing this approach allows for swift quantification of new policies by directly imputing near-term emission levels with implied temperature levels. It is by its nature based on a multitude of models and scenarios and does not rely on a single model or scenario.

The Climate Action Tracker estimate uses the *Scenario Construction* method*,* which seeks instead to develop a bespoke global emission pathway until 2100 and estimates the resulting warming with a simple climate model. Emission pathways are developed per country consistent with their current policies or pledges, including the net zero targets (e.g., until 2030 or 2050) and are extended until the end of the century assuming future policy action consistent with the emissions level of their last pledge or target[22] (see Methods). These country level pathways are aggregated together for analysis by a reduced-complexity climate model[23] to arrive at a temperature estimate.

Both studies start from a "current policies" scenario that assumes all currently adopted and implemented policies (defined as legislative decisions, executive orders, or equivalent) are realized and that no additional measures are undertaken and a "current pledges" scenario that takes into account the Nationally Determined Contributions (NDCs) of the countries (regardless if they are underpinned by national policies)[24]. The Climate Action Tracker estimate uses only one estimate for current policies and pledges, while the UNEP emissions gap report estimate uses a broad literature set of estimates.

With the method employed by Climate Action Tracker (CAT) we find that overall net zero targets keep warming below 2.2°C in 2100 with 66% probability (below 2.0°C with a 50% or median chance, Figure 1), down from 3.1°C (2.9°C median chance) achieved by current policies. After 2100, global warming still increases though. With the method used in the UNEP Emissions Gap Report, we find that net zero targets result in warming of 2.5 (range: 2.3–2.8°C) with a 66% probability as opposed to 3.5°C (range: 3.4–3.9°C) warming due to current policies. Both assessments estimate the net effect of new long-term targets to reduce warming by ~0.8-0.9°C compared to where emissions are heading today.

Figure 1. Estimates of temperature increase in 2100 above pre-industrial level as assessed by both the Scenario Inference and Scenario Construction Approaches. Temperature estimates are shown across probabilistic estimates and ranges of assessed policies in the case of Scenario Inference. Data underpinning this figure is provided in Table S1.



The differences in the two estimates can be easily understood: First, the Climate Action Tracker estimates for 2030 emissions for current policies are frequently revised to include latest developments and therefore typically fall at the very low end of the set of literature estimates included in the UNEP Emissions Gap Report range that also includes older studies (56 to 65 $GtCO_2e$/yr for current policies). Second, the isolated effect of the *Scenario Inference* versus the *Scenario Construction* method (using the same 2030 emission level as a starting point) result in ~0.1°C warmer estimate (median chance) resulting from current pledges for the *Scenario Inference* approach applied in the UNEP report (Supplementary Table S1). Finally, both approaches necessarily apply different methods to estimate the effect of net-zero targets (see Methods), resulting in an overall ~0.1°C stronger reduction from net-zero targets for the UNEP report estimate (Supplementary Table S2).

When both approaches are applied with the same input data, they are no more than 0.1°C different in the projected temperature level with net zero targets (2.0°C of the Climate Action Tracker using the *Scenario Construction* method and 1.9°C for the *Scenario Inference* method used in the UNEP Gap Report but using the same 2030 emission level as a basis and for a 50% likelihood, see Supplementary Table S2). This demonstrates that the inherent uncertainty of projected emissions beyond 2030 and associated future climate change[25] is reduced significantly if countries put forward credible long term net-zero targets.

The two estimates largely agree on temperature reductions for individual country targets. Utilizing the approach of the UNEP Gap Report, Chinese, EU, and US net zero targets result in net temperature reductions of 0.3–0.4°C, less than 0.1°C, and slightly more than 0.1°C, respectively. The approach used by the Climate Action Tracker similarly finds that Chinese, EU, and US net zero targets result in net temperature reductions of about 0.2-0.3°C, less than 0.1°C, and 0.1°C, respectively. The effect of countries' targets where the status is unclear or where it can only be traced to a subscription to a net zero initiative is below 0.1°C.

Both estimates provide plausible estimations of the end-of-century temperature outcomes based on newly announced net zero targets. The Scenario Inference approach used in UNEP provides a simple and straightforward method of assessing new and existing targets, whereas the Scenario Construction method used by the CAT provides a more detailed, but more complex, analytical framework. Differences in temperature estimates between the two assessments are largely due to differences in estimates of existing policies, which are inputs into both approaches.

Consistent across both estimates is the relative magnitude of the overall effect of net zero targets (i.e., reducing temperature by ~0.8-0.9°C). This is the single largest reduction in overall temperature estimations by either party since the inception of the Paris Agreement in 2015, and points toward countries' engagement with and enaction of climate policies that can enable meeting the goals of the Paris Agreement.

We assume here that the net-zero GHG gas targets are implemented in a way that maximize reductions of countries' own emissions and not through use of extra-territorial removals or offsets of low quality. Whether countries will follow such a strategy is unknown as countries generally have not specified how they plan to achieve the net zero targets.

Our analysis shows that there is significant momentum in target setting towards net zero GHG emissions which could bring the temperature limit of the Paris Agreement within reach. These good intentions must now propagate into short-term action immediately to put countries on a path towards meeting their net zero emission ambitions and to keep the goals of the Paris Agreement within reach. Existing policies and targets driving short-term action are currently not at all consistent with the announced net zero targets[1–4,24].

Methods

We calculated the global temperature increase with two independent approaches (see also supplementary information).

The UNEP Emissions Gap Report estimate used the *Scenario Inference* approach, we collected the global GHG emission level from countries' current NDCs and current policies for 2030 from a wide range of studies. 2100 warming is calculated using a functional relationship between 2030 emissions levels and warming in 2100.[1] For the impact on net zero targets, unconditional NDCs are taken as a point of departure for stable national emissions throughout the century. These emissions are compared to post-2030 pathways that achieve the net zero targets of the respective countries (see Supplementary Figure S1). Net zero targets are applied to CO_2 only, providing a conservative estimate of their effect compared to equivalent reductions in non-CO_2 GHGs. Finally, the resulting temperature reduction is estimated by combining the difference in cumulative CO_2 emissions with the transient climate response to cumulative emissions of CO_2 (TCRE) as assessed in the IPCC AR5[26].

The Climate Action Tracker estimate uses the Scenario Construction approach, where we derive individual emissions pathways per country. Emissions scenarios from the AR5 scenario dataset are first harmonized[27] and then downscaled to country-level assuming the similar regional emissions growth rates between countries based on the publicly available IPCC R5 regional emissions trajectories. We then place estimates of either current policies or country pledges from the Climate Action Tracker within that emissions space. We finally extend those emissions until 2100 using the Constant Quantile Extension method[22]. We separately estimated national emission pathways (excluding LULUCF) resulting from net zero targets for major emitting countries in detail (see supplementary material). For the remaining countries with net zero targets, we conservatively assumed a linear trajectory to zero in 2080, based on the assumption that these countries plan to achieve net zero CO2 emissions in their pledge target year, but reach net zero GHG emissions later in 2080, consistent with global pathways that limit warming to 1.5°C. For the countries without net zero targets, we use the existing pledge emissions estimate in 2030 and extended their trajectories as described above. Our temperature assessment is derived using MAGICC, a reduced complexity climate and carbon cycle model[23,28]. We construct emissions required by MAGICC by aggregating the country-level emissions to the IPCC R5 regional level and add global trajectories for land use emissions and international transport emissions. The resulting emission trajectory is run through MAGICC in probabilistic mode to arrive at a temperature distribution.

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Supplementary information

Supplementary Text 1: Like-for-like comparison between the two approaches in this study

To demonstrate the difference between the two approaches used in this study, we walk through both the current pledge (i.e., NDC) and net-zero target calculations. For simplicity and comparability, we assume GHG emissions in 2030 of 54.6 Gt CO_2-eq, consistent with current (unconditional) NDCs as assessed by the Climate Action Tracker in December 2020, with results shown in Table S1. The Scenario Inference approach then computes end-of-century global warming outcomes and cumulative CO_2 and GHG emissions estimates using a functional relationship keyed on global 2030 emissions and pathways from the scenario literature (Rogelj et al., 2016, Figure 2b,d), whereas the Scenario Construction approach constructs a full emissions pathway at the IPCC R5 regional level (Gütschow et al., 2018) which is evaluated by the reduced complexity climate and carbon cycle model, MAGICC (Meinshausen et al., 2011). Median temperature estimates differ by 0.2°C between the two approaches due to differences in climate assessment which is within tolerances provided in Rogelj et al. [1].

Table S1. Comparison of unconditional NDC estimates between both presented approaches

	2030 CO_2 Emissions (Gt CO_2)	2030 GHG Emissions (Gt CO_2-eq, AR4 GWP-100)	Cumulative CO_2 Emissions between 2000 and 2100 (Gt CO_2)	Cumulative GHG Emissions between 2000 and 2100 (Gt CO_2-eq, AR4 GWP-100)	Global-mean temperature rise in 2100 (66% chance)	Global-mean temperature rise in 2100 (median chance)
Scenario Inference (UNEP using CAT 2030 emission estimate)	38.6	49.5	2376	3626	2.8°C	2.5°C
Scenario Construction (CAT)	37.5		2679	3827	2.6°C	2.4°C

The approaches differ in their incorporation of net-zero pledges. The Scenario Inference approach calculates cumulative CO_2 emissions reductions implied by the net-zero pledges on a country-by-country basis and then computes the temperature differential implied by these reductions based on current estimates of the transient climate response to cumulative emissions of CO_2 (TCRE). The Scenario Construction approach instead constructs a total GHG pathway for each country with a net-zero pledge, resulting in new regional emissions pathways, which are again assessed using MAGICC. Results are displayed in Table S2.

The Scenario Inference approach provides a higher estimate of cumulative CO_2 reduced through net-zero targets, because it assumes that in the regions for which net-zero targets have been announced, CO_2 emissions remain roughly constant after 2030 in the counterfactual NDC scenario without further strengthening. This is consistent with prior modeled scenarios (McCollum et al., 2018) in which NDCs are met, but no further climate action is pursued, resulting in flat-lining (e.g., in the OECD) or even growing emissions (e.g., in Asia). The Scenario Construction approach, however, assumes instead that trajectories follow scenarios with continued levels of effort as their NDC moving forward (Figure S1). The overall effect of this assumption is a ~50% larger reduction in cumulative CO_2 reductions in the Scenario Inference approach. This counteracts the difference in non-GHG warming between the approaches, resulting in a smaller total temperature differential (0.1°C) after accounting for net zero targets than in the case of the current pledge estimate (Table S1). A comparison across all estimated published temperature estimates is provided in Table S3.

Table S2. Comparison of net-zero estimates between both presented approaches

	Reductions in cumulative CO_2 due to Net-Zero Targets relative to assumed NDC pathway (Gt CO_2)	Cumulative CO_2 Emissions between 2000 and 2100 (Gt CO_2)	Cumulative GHG Emissions between 2000 and 2100 (Gt CO_2-eq)	Warming reduction in 2100 due to net zero targets (66%)	Warming reduction in 2100 due to net zero targets (median)	Warming in 2100 with net zero targets (66% chance)	Warming in 2100 with net zero targets (median chance)
Scenario Inference (UNEP using CAT 2030 emission estimate)	1253	1750	Not estimated	0.7°C	0.6°C	2.1°C (Implied)	1.9°C (Implied)
Scenario Constructio n (CAT)	518	21661	3177 Gt	0.5°C	0.4°C	2.2°C	2.0°C

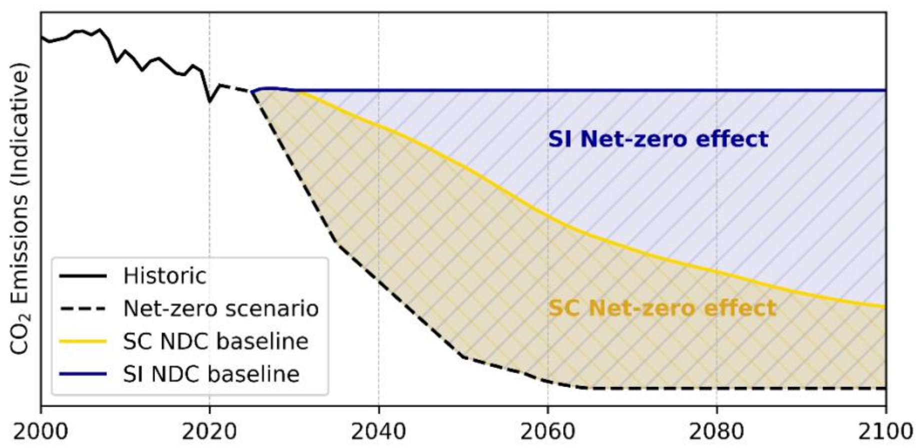


Figure S1. Graphical representation of country-level net-zero effect calculations in both methods on CO_2 emissions. The global net-zero effect is assessed by summing together all country-level emissions reductions. The figure represents an illustration of the relevant approaches and is not indicative of any specific country outcome. SI stands for Scenario Inference, while SC stands for Science Construction.

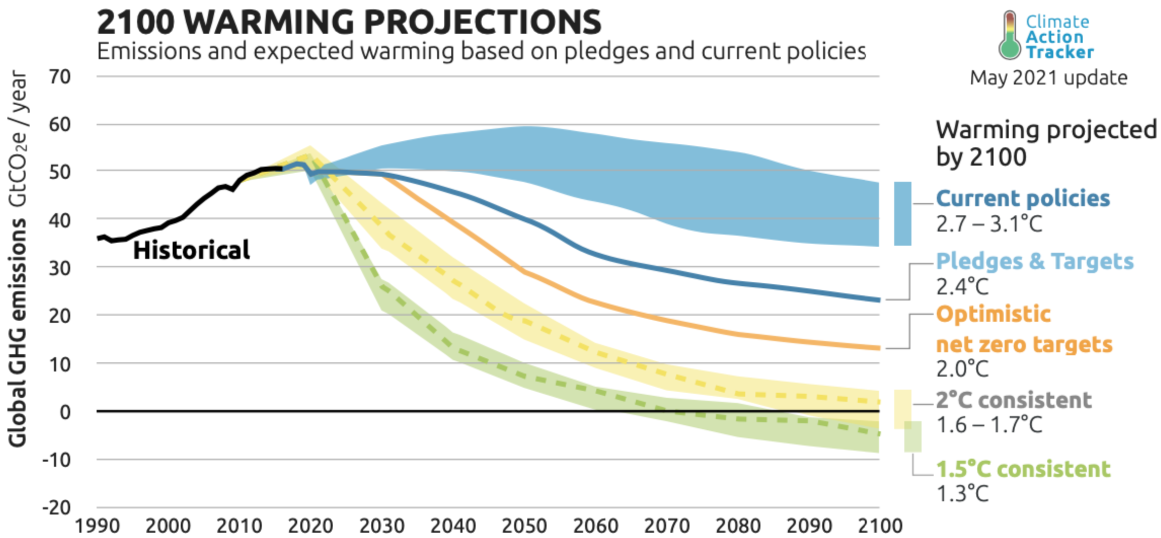
Table S3. End-of-century temperature delineated by probabilistic estimate and methodology. Ranges in the Scenario Inference approach are due to different assessments of 2030 emissions from polices and pledges[3].

	Scenario Inference / UNEP				Scenario Construction / Climate Action Tracker			
Likelihood of being below…	**16%**	**50%**	**66%**	**84%**	**16%**	**50%**	**66%**	**84%**
Current policies	NA	3.2 (3.1-3.6)	3.5 (3.4-3.9)	NA	2.1	2.9	3.1	3.9
Pledges	NA	2.9 (2.8-3.2)	3.2 (3.0-3.5)	NA	1.9	2.4	2.6	3.0
Pledges plus net zero targets	NA	2.4 (2.2-2.7)	2.5 (2.3-2.8)	NA	1.6	2.0	2.2	2.6

Supplementary Text 2: Details of the Scenario Construction method by the Climate Action Tracker

The total emission trajectories of the Climate Action Tracker using Scenario Construction from the individual targets are provided in Figure S1. This scenario with net zero targets results at around 1700 GtCO2 from 2018 to 2100. The UNEP emissions gap report does not use an emissions scenario.

Figure S2. Resulting emission scenarios of the Climate Action Tracker estimate

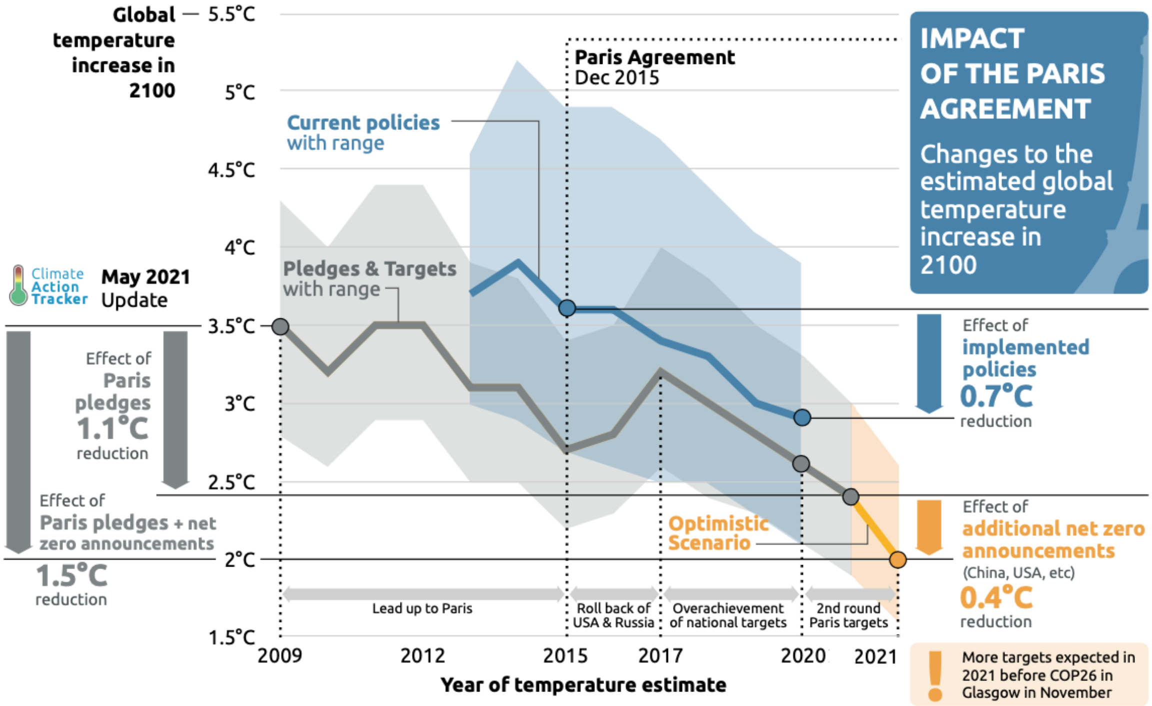


Comparison with previous temperature estimates

The Climate Action Tracker publishes a temperature estimate regularly since 2009 using the scenario construction method (Figure S2). The initial estimate of national pledges was 3.5°C (with considerable uncertainty), estimated in 2009 (with 50% likelihood). The most optimistic scenario with all net zero announcements is 2.0°C. A temperature estimate of current policies started at 3.7°C in 2013 and is today at 2.9°C.

The UNEP emissions gap report, using the scenario inference method started on 2016 with 2.9°C (50% likelihood) for the pledge scenario and is today still at 2.9°C. The UNEP report is the median over 10 studies and includes pledges only until 2030 (which are roughly unchanged since then) and not the long-term targets. the estimate for current policies is also still at 3.2°C today where it was in 2016.

Figure S3. Temperature estimates of Climate action Tracker as they changed over time of estimation (Source: CAT 2021)



Net zero targets

For the Climate Action Tracker estimate using the *Scenario Construction* approach, we had to make several assumptions to assess the impact of net zero targets on the global temperature increase by 2100. These relate to (1) the emissions covered by the various targets, (2) land-use, land-use change and forestry (LULUCF) emissions by 2050, (3) the trajectory of non-CO_2 emissions and (4) the importance of 2030 targets.

Table S4 provides an overview of net zero targets assessed in detail for countries covered. Table S5 lists all 131 net zero targets included in the analysis.

Emissions covered: net zero CO_2 versus net zero GHG

While most countries have set net zero GHG targets, South Africa and South Korea explicitly committed to net zero CO_2 emissions. New Zealand committed to net zero GHG emissions, with the exception of methane (CH_4) from agriculture and waste. The scope of the Chinese, Japanese and US net zero target remain somewhat unclear. While President Xi Jinping spoke of "carbon neutrality" when he addressed the UN Assembly, national experts indicate this target could cover all GHG emissions [29]. Prime minister Suga of Japan has used the terms "carbon neutral" and "net zero GHG emissions" interchangeably; and president-elect Biden has used both "net zero GHG emissions" and "net zero carbon emissions". Based on communications with in-country experts, we assume that these three large emitters pledged net zero GHG emissions.

Land use, land-use change and forestry (LULUCF)

Net zero emissions imply that residual emissions can be balanced with removals, for example from LULUCF. We estimated the level of the LULUCF sink in the net zero target year for each country. Where available, we used national projections until 2050 (see Table S4). If only projections until 2030 were available, we assumed 2050 values to be equal to the 2030 value.

When no national projections were available, we assumed that future LULUCF emissions are equal to an historical average, based on most recent data. In our assessments of South Korea and Japan, whose LULUCF emissions have declined in the past decade, this approach led to a sink we considered unrealistically large. For those two countries, we extended the ten-year historical trend to 2030 and assumed that the 2050 value was equal to the 2030 value.

The total removals from LULUCF in 2050/2060 from the countries where we assessed it in detail amounts to 2GtCO2 per year.

Non-CO_2 emission projections

South Korea and South Africa have committed to net zero carbon emissions by 2050. We assumed that non-CO_2 emissions will decline at a linear rate between 2030 and 2070 (South Korea) or 2080 (South Africa). The IPCC SR1.5 found that pathways leading to a temperature increase of 1.5˚C above pre-industrial levels reach net zero GHG emissions between 2060 and 2080 [9]. We assumed that developed and developing countries that state net zero targets only for CO2 also reach net zero non-CO_2 emissions but only by 2070 and 2080, respectively.

To determine the amount of non-CO_2 emissions by 2030, we would ideally have used the breakdown as stated in the NDC. However, this information exists for neither South Africa nor South Korea, so we used the breakdown as projected by the current policy projection for 2030.

Importance of 2030 targets in the emission trajectory to net zero

The lower the 2030 value in the emissions trajectory, the lower global temperature increase will be. We assumed that countries achieve their most recent NDC target for 2030. Where countries have committed to an NDC range, we assumed the highest value.

Japan and South Africa are expected to overachieve their NDC targets. In this case, we have taken the maximum post-COVID current policy projection as the 2030 value.

The United States formally withdrew from the Paris Agreement in November 2020 and re-joined in February 2021 but no longer has an NDC target. We have taken the upper end of the USA post-COVID current policy projection in 2025 as the base year and assume that all GHG emissions will decline at a linear rate to net zero between 2025 and 2050, with all power sector CO_2 emissions already reaching zero by 2035 as proposed in the Biden Plan [30].

With the exception of Norway and Chile, none of the countries we analysed have submitted a stronger NDC target to the UNFCCC.[2] If countries commit to and achieve more ambitious NDC targets by 2030, global temperature increase could be further limited.

Table S4: List of net zero targets assessed in detail for countries covered in the Climate Action Tracker (CAT).

Country	Type of net zero target	Target year	Assumption on LULUCF	Assumptions on GHG emissions excluding LULUCF

[2] See the CAT's *Climate Target Update Tracker* for details available at: https://climateactiontracker.org/climate-target-update-tracker.

China	Net zero GHGs	2060	We used a ten-year historical average based on GHG inventory data from 2004 to 2014. The average of LULUCF emissions in those years is -783Mt, which we assumed as a value for 2050 and 2060. This estimate is consistent with the projections of Tsinghua University [29], which show a sink of 780Mt in those years.	We apply a linear interpolation of all GHG emission between 2030 and 2060 to balance LULUCF sinks in 2060. We use the average of the NDC non-fossil fuel and the NDC peaking pledge in 2030 as the starting point.
United States	Net zero GHGs	2050	We extrapolated the trend of 1990-2018 to 2050, which resulted in a sink of -643 $MtCO_2e$ in 2050.	We assume that power sector emissions fall linearly between 2025 and 2035, when these fall to zero, and apply a linear interpolation of all remaining GHG emissions between 2025 and 2050 to balance LULUCF sinks in 2050. We use the upper limited of the *Post-COVID Current Policy Projection* in 2025 as the starting point for both trajectories.
Canada	Net zero GHGs	2050	We used the 2030 projection from the 4th Biennial Report for the 2050 estimate and assumed emissions to be -10 $MtCO_2e$ [31].	We assumed a linear decline in total GHGs between 2030 and 2050 to balance LULUCF emissions in 2050.
Chile	Net zero GHGs	2050	We used national projections for 2050 presented in the updated NDC and Climate Neutrality Plan of 2020 and assumed LULUCF emissions to be -61 $MtCO_2e$ [32].	We used national projections for all GHG emission 2050 presented in the updated NDC and Climate Neutrality Plan of 2020 to balance LULUCF sinks in 2050 [32].
Costa Rica	Net zero GHGs	2050	We used national projections for 2050, as provided for in the 2018 Decarbonization Strategy and assumed LULUCF emissions to be –6Mt by 2050 [33].	We used national projections for 2050, as provided for in the 2018 Decarbonization Strategy, to balance LULUCF sinks in 2050 [33]. We use the upper limited of the NDC in 2030 as the starting point.
EU	Net zero GHGs	2050	The EU's projection for its 1.5LIFE scenario is a sink of -464 $MtCO_2$ in 2050 [34]	We used the EU's own projections for 2050 excluding LULUCF, from the 1.5LIFE scenario [34].
Japan	Net zero GHGs	2050	We extrapolated the 2009-2018 trend to 2030 resulting in -35 $MtCO_2e$ and assumed that the sink will be at 2030 levels by 2050.	We applied a linear interpolation of all GHG emission between 2030 and 2050 to balance LULUCF sinks in 2050. We used the upper limit of the Post-COVID Current Policy Projection in 2030 as the starting point.
South Korea	Net zero GHGs	2050	We extrapolated the 2008-2017 trend to 2030 resulting in -17 $MtCO_2e$ and assumed that the sink will be at 2030 levels by 2050.	We applied a linear interpolation of all GHG emission between 2030 and 2050 to balance LULUCF sinks in 2050. We assumed that non-CO_2 emissions will decrease at a linear rate to zero by 2070. We used the upper limit of the NDC in 2030 as the starting point.
South Africa	Net zero CO_2	2050	We used a ten-year historical average based on national inventory data from 2005-2015 resulting in -16 $MtCO_2e$.	We assumed that CO_2 emissions will decline at a linear rate between 2030 and 2050 to balance LULUCF sinks in 2050. We assume that non-

				CO_2 emissions will decline at a linear rate between 2030 and 2080 in line with the IPCC SR1.5 pathways. We use the upper limit of the *Post-COVID Current Policy Projection* in 2030 as the starting point.
Switzerland	Net zero GHGs	2050	We used the "with existing measures" projection for 2030 from the 4th Biennial Report (emissions of 1MtCO_2/yr) and assumed the same value for 2050 [35]	We assumed a linear decline in total GHGs between 2030 and 2050 to balance LULUCF emissions in 2050.
New Zealand	Net zero GHG, with the exception of CH4 from agriculture and waste	2050	We used national projection for 2050 [36], harmonised to historical data, giving a sink in 2050 of -31 MtCO_2.	We assume that GHG emissions excluding methane from agriculture and waste and LULUCF follow a linear decline from 2030 to 2050, to balance LULUCF removals in 2050. We take the upper end of New Zealand's target for biogenic methane (47% reduction from 2017 levels).
Norway	GHGs reduce by 90-95%, compared to 1990. We assumed that LULUCF emissions are included in this target.	2050	We used a projection from NIBIO, which gives a sink in 2050 of -20 MtCO_2 [37].	We assume a linear decline in GHG emissions excluding LULUCF between 2030 and 2050, such that total emissions in 2050 including LULUCF are 95% below 1990 levels.
Brazil	Net Zero CO2 emissions	2050	CO2 emissions in 2050 excluding LULUCF balance projected net removals from LULUCF taken from a decarbonisation strategy for Brazil produced by the Fórum Brasileiro de Mudança do Clima.	Non-CO2 emissions are assumed to fall linearly to zero in 2070.
Kazakhstan	Net zero GHGs	2060	We assumed that LULUCF sinks will contribute as much as the largest sink recorded in Kazakhstan's inventory data (i.e., Kazakhstan's GHG emissions in 2060 are assumed to equal the minimum LULUCF emissions between 1990 and 2018). This assumption was based on the reforestation plan as announced by the Kazakh government, accompanying their net-zero target.	We assume a linear decline in GHG emissions excluding LULUCF between 2030 and 20560, such that total emissions in 2050 including LULUCF are net zero.

Table S5: List of all net zero targets included in the Scenario Construction approach based on the ECIU [17] as of May 2021. Model run #1 is used as a basis. #2 and #3 are implemented to test the effect of countries with unclear implementation state and the effect of the USA.

****Note: All Member States of the EU27 and the United Kingdom are included in the modelling runs through EU28, not individually.***

Country	Status	Year
Afghanistan	Under Discussion	2050
Andorra	In Policy Document	2050
Angola	Under Discussion	2050
Antigua and Barbuda	Under Discussion	2050
Argentina	Under Discussion	2050
Armenia	Under Discussion	2050
Austria*	In Policy Document	2040
Bahamas (the)	Under Discussion	2050
Bangladesh	Under Discussion	2050
Barbados	Under Discussion	2050
Belgium*	Under Discussion	2050
Belize	Under Discussion	2050
Benin	Under Discussion	2050
Bhutan	Achieved	
Brazil	In Policy Document	2050
Bulgaria*	Under Discussion	2050
Burkina Faso	Under Discussion	2050
Burundi	Under Discussion	2050
Cabo Verde	Under Discussion	2050
Cambodia	Under Discussion	2050
Canada	Proposed legislation	2050
Central African Republic (the)	Under Discussion	2050
Chad	Under Discussion	2050
Chile	Proposed Legislation	2050
China	Under Discussion *(announcement by head of state)*	2060
Colombia	Under Discussion	2050
Comoros (the)	Under Discussion	2050
Congo (the Democratic Republic of the)	Under Discussion	2050
Cook Islands (the)	Under Discussion	2050
Costa Rica	In Policy Document	2050
Croatia*	Under Discussion	2050
Cyprus*	Under Discussion	2050
Czechia*	Under Discussion	2050

Denmark*	In Law	2050
Djibouti	Under Discussion	2050
Dominica	Under Discussion	2050
Dominican Republic (the)	Under Discussion	2050
Ecuador	Under Discussion	2050
Eritrea	Under Discussion	2050
Estonia*	Under Discussion	2050
Ethiopia	Under Discussion	2050
European Union	Proposed Legislation	2050
Fiji	Proposed Legislation	2050
Finland*	In Policy Document	2035
France*	In Law	2050
Gambia (the)	Under Discussion	2050
Germany*	In Policy Document	2050
Greece*	Under Discussion	2050
Grenada	Under Discussion	2050
Guinea	Under Discussion	2050
Guinea-Bissau	Under Discussion	2050
Guyana	Under Discussion	2050
Haiti	Under Discussion	2050
Hungary*	In Law	2050
Iceland	In Policy Document	2040
Ireland*	In Policy Document	2050
Italy*	Under Discussion	2050
Jamaica	Under Discussion	2050
Japan	Under Discussion *(announcement by head of state)*	2050
Kazakhstan	In Policy Document	2050
Kiribati	Under Discussion	2050
Korea (the Republic of)	Under Discussion *(announcement by head of state)*	2050
Lao People's Democratic Republic (the)	Under Discussion	2050
Latvia*	Under Discussion	2050
Lebanon	Under Discussion	2050
Lesotho	Under Discussion	2050
Liberia	Under Discussion	2050
Lithuania*	Under Discussion	2050
Luxembourg*	Under Discussion	2050
Madagascar	Under Discussion	2050
Malawi	Under Discussion	2050
Maldives	Under Discussion	2050
Mali	Under Discussion	2050
Malta*	Under Discussion	2050
Marshall Islands (the)	In Policy Document	2050

Mauritania	Under Discussion	2050
Mauritius	Under Discussion	2050
Mexico	Under Discussion	2050
Micronesia (Federated States of)	Under Discussion	2050
Monaco	Under Discussion	2050
Mozambique	Under Discussion	2050
Myanmar	Under Discussion	2050
Namibia	Under Discussion	2050
Nauru	Under Discussion	2050
Nepal	Under Discussion	2050
Netherlands (the)*	Under Discussion	2050
New Zealand	In Law	2050
Nicaragua	Under Discussion	2050
Niger (the)	Under Discussion	2050
Niue	Under Discussion	2050
Norway	In Policy Document	2050
Pakistan	Under Discussion	2050
Panama	In Policy Document	2050
Palau	Under Discussion	2050
Papua New Guinea	Under Discussion	2050
Peru	Under Discussion	2050
Portugal*	In Policy Document	2050
Romania*	Under Discussion	2050
Rwanda	Under Discussion	2050
Saint Kitts and Nevis	Under Discussion	2050
Saint Lucia	Under Discussion	2050
Saint Vincent and the Grenadines	Under Discussion	2050
Samoa	Under Discussion	2050
Sao Tome and Principe	Under Discussion	2050
Senegal	Under Discussion	2050
Seychelles	Under Discussion	2050
Sierra Leone	Under Discussion	2050
Slovakia*	Under Discussion	2050
Slovenia*	In Policy Document	2050
Solomon Islands	Under Discussion	2050
Somalia	Under Discussion	2050
South Africa	In Policy Document	2050
South Sudan	Under Discussion	2050
Spain*	Proposed Legislation	2050
Sudan (the)	Under Discussion	2050
Suriname	Achieved	
Sweden*	In Law	2045
Switzerland	In Policy Document	2050
Tanzania, United Republic of	Under Discussion	2050
Timor-Leste	Under Discussion	2050

Togo	Under Discussion	2050
Tonga	Under Discussion	2050
Trinidad and Tobago	Under Discussion	2050
Tuvalu	Under Discussion	2050
Uganda	Under Discussion	2050
United Kingdom of Great Britain and Northern Ireland (the)*	In Law	2050
United States of America (the)	Under Discussion	2050
Uruguay	Under Discussion	2030
Vanuatu	Under Discussion	2050
Yemen	Under Discussion	2050
Zambia	Under Discussion	2050