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 2.1–2.4°C by 2100 and could bring achievement of the Paris Agreement within reach. 127 countries are discussing, have announced or have adopted net zero targets, which together cover 63% 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 (2.6 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 (Höhne et al., 2020a; Rogelj et al., 2016; UNEP, 2019, 2020a).

Specific policies required to reduce emissions in line with the Paris Agreement may differ from country to country. However, at a global level a number of key characteristics can be defined (IPCC, 2018b). Chief among these is a requirement 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 COP 21, for instance in Haites, Yamin & Höhne (2013) and Rogelj et al. (2015).

At the time the Paris Agreement was adopted in 2015, only very few progressive 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, then the EU as a whole followed with a proposal to include climate neutrality in the climate law in March 2020 (European Commission, 2020). The announcement of China in September 2020 to achieve carbon neutrality by 2060 (Xinhua, 2020) was a breakthrough moment, which was quickly followed by announcements of South Africa, Japan, South Korea and Canada (Cha, 2020; Government of Canada, 2020; Lies, 2020; Republic of South Africa, 2020). The election campaign of President-elect Joe Biden also included the goal of carbon neutrality by 2050. Together we count 127 countries with announcements of the intention to go to net zero greenhouse gas (GHG) emissions (compilation based on ECIU (2020) as of 23 October 2020), which together cover around 63% of global GHG emissions (emissions data for 2017 taken from (EDGAR, 2019)). Excluding the USA, covered emissions amount to 51% of present-day levels.

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 both for the near (e.g., until 2030) and long-term (e.g., until 2100); and finally (3), a temperature calculation resulting from the emissions assessment.

We outline two approaches of varying complexity to assess the global warming implications of net zero target estimates: one based on *scenario inference* and another based on *scenario construction*. Both approaches rely on a set of globally consistent CO_2, non-CO_2 GHG, and aerosol emissions pathways that describe a plausible future space of global emissions and resulting warming – as used and assessed by the IPCC (IPCC, 2014, 2018a). Each approach places new net zero emission target estimates within this emissions space and derives potential temperature effects therefrom.

Scenario Inference analyses key scenario variables to create a functional relationship between 2030 emissions levels and warming in 2100 (Rogelj et al., 2016) or between cumulative emissions and 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. This approach was used in this year's UNEP Emissions Gap Report (UNEP, 2020b).

Scenario Construction seeks instead to develop a bespoke emission and temperature pathway. Emissions pathways are developed per country consistent with their current policies or pledges (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 (J Gütschow et al., 2018) (see Methods). These country level pathways are aggregated together for analysis by a reduced-complexity climate model (Meinshausen et al., 2011) to arrive at a temperature estimate. This approach was used by the Climate Action Tracker (CAT, 2020).

Using the Scenario Construction approach of Climate Action Tracker (CAT) we find that overall net zero targets resulted in likely (66% probability) warming of 2.3°C (2.1°C median estimate, Figure 1), down from 3.1°C (2.9°C median) achieved by current policies. Applying Scenario Inference used in the UNEP Gap report to a broad literature set of emission estimates for pledges, we find that net zero targets result in likely warming of 2.5 (range: 2.3–2.8°C) 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 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.

Despite the agreement between the two methods on the net effect of net zero targets, they differ in their absolute estimates. These differences can be easily understood. First, Climate Action Tracker estimates typically fall at the very low end of the set of literature estimates for 2030 emissions included in the UNEP range (56 to 65 $GtCO_2e$ for current policies). Accounting for this already resolves half of the reported difference in temperature projections. In addition, UNEP applies more conservative assumptions on the mitigation of non-CO_2 emissions and post-2030 policies compared to Climate Action Tracker, and consequentially its projections of temperature increase to 2100 are higher. Projecting emissions beyond 2030 is fraught with uncertainties (Jeffery et al., 2018). However, with no more than 0.1°C difference between the projected temperature outcomes including net zero targets, our results show the importance of net-zero targets in narrowing this uncertainty in projections of future climate change.

The two approaches largely agree on temperature reductions for individual country targets. Utilizing the Scenario Inference 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 Scenario Construction approach used by the CAT 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 assessments 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 estimates between the two approaches are largely due to differences in assessments of existing policies.

Consistent across each approach 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 varying 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 net zero emissions, because existing policies driving short-term action are currently not at all consistent with the net zero targets (den Elzen et al., 2019; Höhne et al., 2020b; Rogelj et al., 2016; UNEP, 2019, 2020b).

Methods

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

In a first approach the global greenhouse gas (GHG) emission level from countries' current Nationally Determined Contributions (NDCs) and current policies for 2030 is collected from a wide range of studies. 2100 warming is calculated using a functional relationship between 2030 emissions levels and warming in 2100 (Rogelj et al., 2016). For the impact on net zero targets, NDCs are taken as a point of departure for stable emissions throughout the century. These emissions are compared to post-2030 pathways that achieve the net zero targets of the respective countries. Net zero targets are applied to CO_2 only, providing a conservative estimate of their effect. The reduction in cumulative CO_2 emissions resulting from this decline is estimated from the historical CO_2 to total GHG emission fraction found in national GHG inventories (Johannes; Gütschow et al., 2019). Finally, the temperature reduction is estimated by combination with the transient climate response to cumulative emissions of CO_2 (TCRE) as assessed in the IPCC AR5 (IPCC, 2013).

In a second approach, we derive individual emissions pathways per country. We do so by first harmonizing (Gidden et al., 2018) and downscaling emissions scenarios from the AR5 scenario dataset 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 (J Gütschow et al., 2018).

We separately estimated national emission pathways (excluding LULUCF) resulting from net zero targets for 12 major emitting countries in detail (see supplementary material). For the remaining 115 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 (Meinshausen et al., 2011). We construct emissions required by MAGICC by aggregating the country-level emissions to the IPCC R5 regional level and add standard trajectories for LULUCF and bunkers. The resulting emission trajectory is run through MAGICC in probabilistic mode to arrive at a temperature distribution.

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Figures

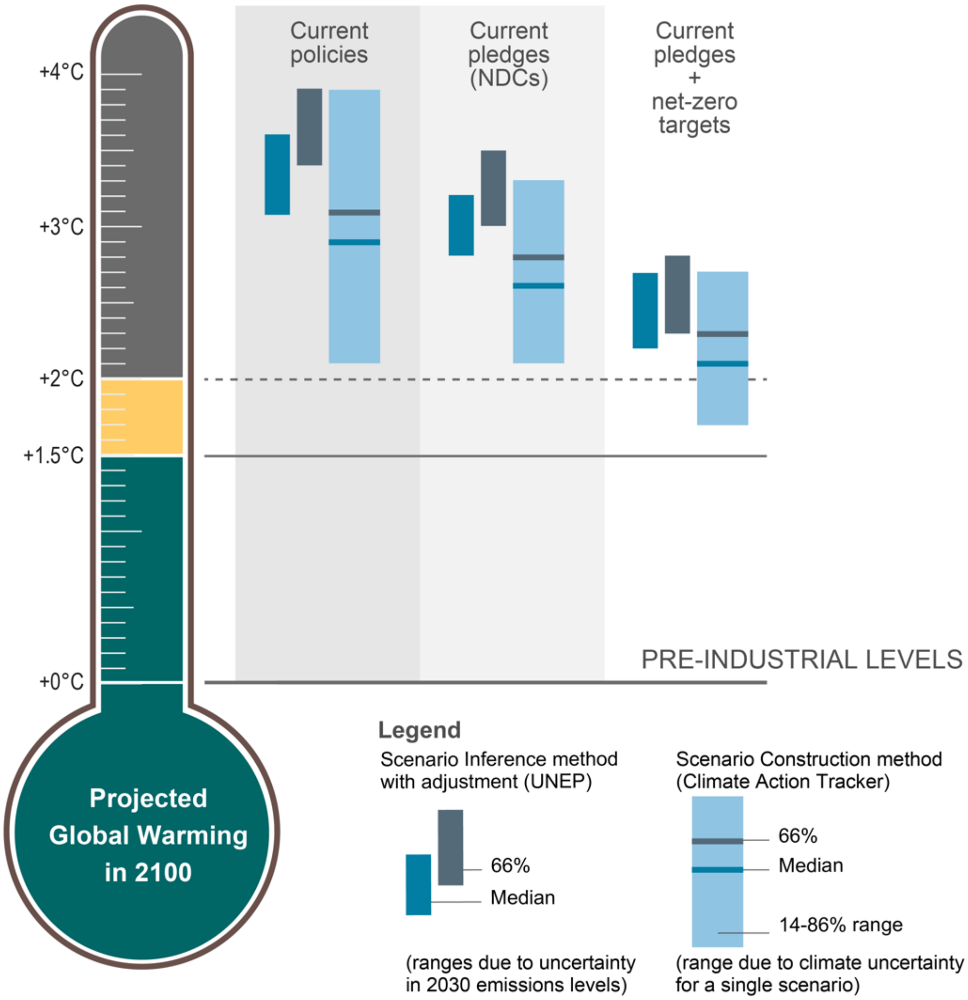

Figure 1

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.

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