Updated nationally determined contributions collectively raise ambition levels but need strengthening further to keep Paris goals within reach

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Abstract

By September 2021, 120 countries had submitted new or updated Nationally Determined Contributions (NDCs) to the UNFCCC in the context of the Paris Agreement. This study analyses the greenhouse gas (GHG) emissions and macroeconomic impacts of the new NDCs. The total impact of the updated NDCs of these countries on global emission levels by 2030 is an additional reduction of about 3.7 $GtCO_2e$, compared to the previously submitted NDCs. This increases to about 4.1 $GtCO_2e$, if also the lower projected emissions of the other countries are included. However, this total reduction needs to be four times greater to be consistent with keeping global temperature increase to well below 2 °C, and even eight times greater for 1.5 °C. Seven G20 economies have pledged stronger emission reduction targets for 2030 in their updated NDCs, leading to additional aggregated GHG emission reductions of about 3.1 $GtCO_2e$, compared to those in the previous NDCs. The socio-economic impacts of the updated NDCs are limited in major economies, while structural shifts occur away from fossil fuel supply sectors and towards renewable electricity. However, two G20 economies have submitted new targets that will lead to an increase in emissions of about 0.3 $GtCO_2e$, compared to their previous NDCs. The updated NDCs of non-G20 economies contain further net reductions. We conclude that countries should strongly increase the ambition levels of their updated NDC submissions to keep the climate goals of the Paris Agreement within reach.

1. Introduction

In the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC), governments agreed to the long-term target of keeping the increase in global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C (UNFCCC, 2015). Before and during the Paris conference, countries submitted comprehensive NDCs to the UNFCCC that outlined their self-determined post-2020 targets. This previous round of submitted NDCs would deliver only half of the emission reductions needed by 2030 to be on a global least-cost pathway towards keeping warming levels well below 2 °C, in comparison to a no policy baseline (Höhne et al., 2020; Rogelj et al., 2016).

Under the Paris Agreement, countries agreed to periodically update their contributions, over time, by an iterative process in 5-year intervals, informed by reviews of the status of contributions (global stocktake) (UNFCCC, 2015). Countries are expected to formulate and submit their updated NDCs and long-term development strategies well in advance of COP26 in 2021. By the end of September 2021, 120 countries (including 27 EU Member States) had updated their NDC submissions (UNFCCC, 2021a). These countries represent 49% of global GHG emissions, including those from land use in 2019 (FAOSTAT, 2020; Olivier and Peters, 2020), which means that from many countries, new submissions are still lacking.

Building on an earlier study (den Elzen et al., 2016), for this study, we analysed the GHG emissions and macroeconomic impacts of the second round of NDC submissions for on both the global level and the G20 economies. More specifically, we analysed the likely impact of fully implemented NDCs of 144

countries[1] (representing about 95% of global emissions in 2019, including the international bunker emissions, Supplementary Text 2) on global GHG emission levels up to 2030, and additional reductions included in the new or updated NDCs, compared to the projections based on the previous NDCs (October 2020). [2] Section 2 presents the NDCs of the G20 economies. Section 3 describes the used methodology. In Section 4 results are subsequently compared to emission projections based on current policies and to the projected global emission levels that need to be achieved by 2030 in order to meet the climate goals of the Paris Agreement. Section 5 compares the NDC targets with GHG emission projections against current domestic climate policies up to 2030. In addition, it shows how the NDCs of the G20 countries affect important emission indicators for comparing the ambition levels of these countries. Section 6 analyses the impact of emissions and removals from land use, land-use change and forestry (LULUCF) on achieving the NDCs. Finally, Section 7 analyses the macroeconomic impacts of the new or updated NDCs for 2030, and Section 8 concludes.

[1] Including 72 countries with updated NDCs, and for the other countries previous NDCs were used.
[2] An interactive tool showing emissions per country, emissions per capita, and emissions per unit of income, resulting from the current policies and NDCs, is available at: www.pbl.nl/ndc

2. Overview Of New Ndc Submissions

The European Union has submitted a more stringent NDC target, aiming for a reduction in domestic net GHG emissions of at least 55% below 1990 levels, by 2030. This target has been put into legislation as part of the European Climate Law, and proposals for measures to achieve the target were published under the Fit-For-55 policy package in July 2021 (European Commission, 2021). In December 2020, China announced that it intends to lower its carbon dioxide emissions per unit of GDP by over 65% from 2005 levels, by 2030. Additionally, by 2030, China intends to increase the share of non-fossil fuel energy in primary energy consumption to around 25% and total wind and solar generation capacity to over 1200 gigawatts. This announcement is an enhancement compared to the targets of their previous NDC (Table 1). At the US Leaders Summit on Climate on 22 April 2021, the US Federal Government presented its updated NDC, including a net GHG emission target of 50%–52% below 2005 levels, by 2030. Japan and Republic of Korea also announced stronger GHG reduction targets, but have not yet formally communicated them to the UNFCCC. Other G20 economies, China, India, Saudi Arabia and Turkey, have not officially revised their NDC targets, whereas Australia resubmitted their first NDC targets in 2020. Table 1 presents an overview of the previous and updated NDC submissions of all G20 economies, including the announcements, representing three quarters of global GHG emissions in 2019 (for all countries, see Supplementary Text 1 and Text 2).

3. Methods

Based on the new and updated NDC submissions, this study presents GHG emissions in CO_2 equivalent terms[3], excluding and including the LULUCF sector. Here, it outlines how the emission projections were derived and how, within this context, contributions to mitigation ambitions of countries from the LULUCF sector were accounted for. This is followed by a description of the methodological approach for comparing the emission projections from the NDC commitments to current policies scenarios and assessing the macroeconomic implications of NDCs.

3.1 Emission projections (excluding those from LULUCF) for the NDCs

This section provides the methodology used for calculating the emission projections (excluding the emissions and removals from LULUCF) for the NDC targets of the G20 and non-G20 economies. As the G20 countries, together, accounted for about 75% of global GHG emissions in 2019 based on the EDGAR database (GHG emissions excluding those from LULUCF) (Olivier et al., 2020) and FAOSTAT (2020) (LULUCF emissions), their NDCs were analysed in more detail than those from other countries.

G20 economies: The target emission values by 2030, provided in absolute terms, are based on the NDC submissions (UNFCCC, 2021a). In case the target could not directly be obtained from the NDC, national inventories or communications were used to derive the historical emission data or business-as-usual (BAU) projections, depending on how the NDC reduction targets were defined. More specifically, national inventories were used for calculating the absolute NDC emission targets of Australia, Canada, the EU-27 and the United Kingdom, Japan, Republic of Korea, the Russian Federation and the United States. The targets were directly derived from the NDCs for Argentina, Brazil, Indonesia, Mexico and Turkey. Supplementary Text 3 quantifies the mitigation components of the previous NDCs and the updated or new NDCs, if available, submitted by G20 members, showing their emission reduction targets, the base year relative to which these targets are defined, and the calculated absolute emission targets for 2030.

For China and India, the quantification of NDC target emission levels is more complicated, because they proposed a combination of targets that include non-fossil energy targets, timing of CO_2 emissions peak (China only), forest targets, and emission intensity reduction targets. Therefore, the calculated emissions highly depend on the assumptions applied. The starting point for the calculations for China is the current policies scenario of IMAGE. For China, the following targets of the original NDC and announcement are all well achieved in this current policies scenario: the peak of CO_2 emissions is before 2030, the reduction of the CO_2 intensity reaches 65% by 2030 and the non-fossil share in energy consumption reaches 25% by 2030. However, the announced increase in wind and solar capacity at 1200 GW is not reached (809 GW is achieved in the current policies scenario). Given these considerations, in this study, the current policies scenario is assumed to be equal to the NDC scenario, which is consistent with the scenarios developed by two national models for China (PECE V2.0 and IPAC), as presented in Fragkos et al. (2021b) and the COMMIT scenario database (van Soest et al., 2021a). For India, we calculated the combined

effect of intensity targets and the non-fossil target using the TIMER energy model of IMAGE (den Elzen et al., 2016).

Non-G20 economies: A total of 103 non-G20 countries are covered in the NDC analysis (17% of emissions by 2019). For 27 non-G20 countries, the NDCs are defined by reduction targets relative to a historical base year and can easily be translated into absolute levels (see Supplementary Text 2). For about 66 countries, NDCs are defined as a reduction target relative to business-as-usual (BAU) emission projections, which is mostly given in the NDC submissions (see UNFCCC website). Four countries provide intensity targets, and the remaining countries have NDCs defined as reduction actions for land-use emissions (Section 3.2). The emission levels of countries that are not included in the analysis follow the downscaled IMAGE current policies scenario (Section 3.3).

3.2 LULUCF emission projections in the NDCs

LULUCF accounting: Most of the G20 economies report emission target levels that include emissions and their removals related to mitigation options in the LULUCF sector, such as afforestation and reforestation. Although there are uncertainties concerning the accounting approaches and methodologies used by countries to account for LULUCF-related emissions and emission removal, we assume that all countries, unless otherwise stated in their NDC, will apply the net–net accounting approach for all carbon pools and LULUCF sub-sectors. This means that emissions from land use are included in the same way as those from the other sectors (see Supplementary Text 4 and Table S.3).

LULUCF emission projections: NDC scenario projections of LULUCF emissions and their removal were developed based on the NDCs that were submitted (UNFCCC, 2021a). In cases where no quantitative information about LULUCF sector developments in line with NDC targets could be derived from the NDCs, National Communications, we also analysed Biennial Update Reports (BUR) and national supporting documents. Thereafter, the projections were compared to the projections of LULUCF-related emissions developed based on the previous NDCs as documented by Forsell et al. (2016), to evaluate which countries have pledged higher emission reduction targets for the LULUCF sector. In terms of the G20 countries, NDC scenario projections for Argentina, Japan and Mexico were derived from their updated NDC submissions (UNFCCC, 2021a). For Australia, Canada and the EU-27, projections were derived from supporting documents (European Commission, 2020; UNFCCC, 2021b). In the case where LULUCF projections could not be derived from the updated NDCs, nor from support documents, we used projections from Forsell et al. (2016). The resulting LULUCF emissions and their removal in 2030, according to the NDC scenarios, are show in Table S.4. Supplementary Text 6 provides further information concerning the NDCs; the scenario projections were harmonised with the emission projections excluding LULUCF.

3.3 Current policies and NDC scenarios

Current policies scenario: The impact of adopted and implemented policies on GHG emissions in all sectors up to 2030 has been projected using the IMAGE modelling framework (Stehfest et al., 2014), which includes the TIMER energy model. The starting point for the calculations of the impact of climate policies is the updated SSP2 (no climate policy) baseline, as implemented in the IMAGE model (Roelfsema et al., 2020; Van Vuuren et al., 2017). Current climate and energy policies in the G20 economies, as identified in the public database on climate policies[4] and the ENGAGE project and policy overview updates (Kuramochi et al., 2019; 2021), were added to that IMAGE SSP2 baseline (Roelfsema et al., 2020) (Supplementary Text 5).[5] The current policies scenarios also take into account the short-term (2020–2025) economic projections that were updated to include the implications of the COVID-19 pandemic, including changes in sectoral activity (Dafnomilis et al., 2021). To ensure full consistency between the modelling frameworks, the GEM-E3 Current Policies scenario is fully consistent with the IMAGE scenario, as they assume the same climate and energy policies (Kuramochi et al., 2021).

The IMAGE calculations are supplemented for 12 major emitting non-G20 countries[6] by baseline scenarios taken from national governments and international organisations used as the basis to develop current policies scenario projections, as described in Kuramochi et al. (2021) with updates of Nascimento et al. (2021).

The LULUCF CO_2 emissions and their removal were calculated using the global GLOBIOM and G4M land-use models (Havlík et al., 2014). The starting point for the LULUCF-related calculations of the impact of climate policies is also the latest SSP2 baseline as implemented in the GLOBIOM and G4M models (Fricko et al., 2017). Current LULUCF policies as implemented in major emitting countries, were added to that baseline (Kuramochi et al., 2019).

NDC scenario: The NDC scenario assumes full implementation of the NDCs, using the updated NDCs if available. Several countries have distinguished unconditional and conditional targets in their NDCs, which is why we introduce both a unconditional and conditional NDC scenario. For countries whose NDCs include unconditional targets only, emission levels are assumed to be the same in both scenarios. For countries with only conditional NDC targets, the emissions levels of the current policies scenario for the unconditional NDC scenario is assumed. For the calculation of the global GHG emissions estimate for the NDC scenario, we assume that if countries are overachieving its NDC targets under current policies, the emissions level of the current policies is used.

Global: For both the NDC scenarios and current policies scenario, total global emissions were calculated by adding the following emissions to the NDC and current policies emissions levels of the G20 and non-G20 economies: emissions from international aviation and international shipping, which, together, is about 1.7 $GtCO_2e$ by 2030, based on the current policies scenario; and remaining LULUCF emissions based on various sources (including FAOSTAT, national communication and model projections) for the countries which NDC did not address LULUCF, which is together about 0.8 $GtCO_2e$ by 2030.

3.4 Macroeconomic impacts

The implementation of climate policies and NDCs affects the economy in multiple ways, as they impact the demand for goods and services, sectoral production, labour markets, income levels and bilateral trade. Here, we used the Computable General Equilibrium model GEM-E3-FIT (Paroussos et al., 2020) to quantify macroeconomic, trade, employment and distributional impacts of the new NDCs of G20 economies. We introduce the calculated NDC targets for G20 economies in the form of specific emission targets or emission-intensity targets for 2030 (excluding the emissions and removals from LULUCF) in GEM-E3 that act as constraints in model equations and lead to increased economy-wide regional and country-specific carbon prices, depending on the NDC ambition level. Carbon prices represent a general metric for the intensity of CO_2 reduction policies. GEM-E3 uses the same NDC emission targets up to 2030, as described in Section 3.1, ensuring full consistency with the detailed emission calculations presented in Table 1.

[3] All GHG emission figures are expressed using the 100-year global warming potential (GWPs) from the IPCC Fourth Assessment Report.
[4] www.climatepolicydatabase.org
[5] For countries that are part of a larger IMAGE region (Australia, Kazakhstan, Republic of Korea, Russian Federation, and Ukraine), emission projections were scaled down, using the country's share in the region's 2015 emissions as a constant scaling factor.
[6] Chile, Colombia, Egypt, Ethiopia, Iran, Kazakhstan, Morocco, the Philippines, Thailand, Ukraine, United Arab Emirates, Vietnam

4. Impact Of Ndcs On Global And National Emissions

This section analyses the impact of the new or updated NDCs on the global and national emission projections, compared to the earlier NDC submissions and current policies scenario projections, for 2030.

4.1 Impact of new NDCs on global emissions

All unconditional updated NDCs are estimated to have an aggregated impact on global GHG emissions of about 3.7 (2.0–4.3) $GtCO_2e$ by 2030, compared to that of the previous NDCs, if all unconditional NDC targets would be fully implemented (Figure 1). For the conditional targets, this additional reduction would be 3.4 (2.0–4.1) $GtCO_2e$.

Seven *G20 economies* with updated NDCs have pledged more stringent GHG reduction targets by 2030, leading to total additional reductions of 3.3 (1.8–3.8) $GtCO_2e$, compared to those in the previous NDCs (Figure 1). The largest additional contributions come from the United States, China, the EU-27, Japan, the United Kingdom, Argentina and Canada. For the United States, the impact of the updated NDC of -0.85 $GtCO_2e$ is calculated relative to the emission target for 2030, which was estimated by extrapolating the

2025 emission level (previous NDC) to the 2050 emission level, as based on the national long-term target (83% below 2005 levels, by 2050). For China, the impact of the announced climate targets is calculated relative to the current policies projections, accounting for recently adopted policies. The impact of the announcement is a reduction of 0.8 (0–1.2) $GtCO_2e$ relative to current policies projection of about 14.5 (12.1–14.5) $GtCO_2e$[7], which is mainly due to the impact of the announced increase in the installed capacity of wind and solar power, as the other announced NDC targets are met under the current policies (Section 3.1). The uncertainty range represents the uncertainty around the implementation of the additional renewables capacity.

There are also a number of *non-G20 economies* with new NDC targets with more stringent reduction targets (higher coverage of sectors and larger reduction targets), with a total impact of 0.8 $GtCO_2e$, with major contributions from Chile, Colombia, Nigeria and Ukraine with stronger reductions targets and/or reduced BAU emission projections for 2030. For the conditional NDCs, this would be 0.2 $GtCO_2e$ lower.

The enhanced ambition level of these countries with more stringent reduction targets leads to projected aggregated emission reductions in global emissions of about 4.1 (2.4–4.5) $GtCO_2e$ (see Figure 1). However, about 0.35 (0.2–0.5) $GtCO_2e$ of the additional emission reduction is counterbalanced by the higher emissions from a group of countries with lower ambition levels than in their previous NDCs. There are two reasons for higher emission levels: (1) changes in the historical reference period (e.g. Brazil) and (2) changes in the projected BAU baseline. More specifically:

(1) For Brazil**,** the updated NDC leads to an absolute increase in emissions. The updated NDC presents the same relative reduction target in percentage, i.e., reduction of 37% and 43% by 2025 and 2030, respectively, compared to 2005 levels. However, the assessment metric of the updated NDC was revised. While the 1st NDC refers to the Second National Inventory Report (NIR), the updated NDC follows the Third NIR (AR5 metrics). Since about two thirds of Brazil's emissions are related to land use, the updated methane GWP (from 21 to 34) has a large impact on emissions. Thus, the baseline year emissions move from 2.1 to 2.8 $GtCO_2e$[8], which increases the updated emission target in 2030 from 1.2 to 1.6 $GtCO_2e$.

(2) For Mexico, the projected BAU baseline emissions have increased, whereas the reduction targets have not changed, which increases the emission target slightly. For some other non-G20 countries, such as Cambodia and Zambia, baseline emissions in the updated NDC submission have increased, as BAU emissions of the NDCs of 2016 did not include all sources, which leads to an increase of 0.1 $GtCO_2e$, which is accounted for the net reduction in all non-G20 economies.

The remaining G20 economies have NDC targets which lead to no additional reduction. Russian Federation's updated NDC did not strengthen the country's 2030 emission target. Although the new target rules out the lower range of emission reductions, the target emission level remains higher than current policies projections and today's emission level. Australia and Indonesia have submitted the same reduction targets in their updated NDC (not shown in Figure 1). A number of G20 economies still have not submitted their new or updated NDC (Table 1).

Finally, there are additional net reductions from countries that overachieve their NDC targets, which leads to a further reduction of 0.4 $GtCO_2e$, as will be further explained below. The combined impact of the updated NDCs and these additional reductions, lowers the global GHG emissions by about 4.1 (2.3–4.7) $GtCO_2e$ by 2030 for the unconditional NDC scenario. For the conditional NDC scenario this would be 0.3 $GtCO_2e$ lower.

[INSERT FIGURE 1]

4.2 Emission reduction projections of new NDCs compared with current policies

For the G20 economies, this section compares the NDC targets with GHG emission projections under current domestic climate policies up to 2030. The comparison with current domestic mitigation policies allows an assessment of the additional emission reductions needed to achieve the NDCs' reduction targets. Figure 2 shows that, collectively, countries will likely need to implement additional policies to further reduce global GHG emissions by about 4.5 $GtCO_2e$ to achieve the unconditional NDCs by 2030, and by about 6.2 $GtCO_2e$ to achieve the conditional NDCs. Only six economies are responsible for the largest share (about 70% for the unconditional NDCs and about 55% for the conditional NDCs) of the required reductions, namely the United States, China, Canada, EU-28, Japan and Brazil.

The emission target levels of several NDCs (among which India, Russian Federation, Saudi Arabia, Turkey, and several non-G20 members, such as Iran) are projected to be *above* the estimated current policies scenario levels. These countries are expected to overachieve their NDC targets with current policies (Figure 2, upper part). In our assessment, we assumed that these countries will follow their current policies emission trajectory.

[INSERT FIGURE 2]

4.3 Projected global GHG emission levels by 2030 if all NDCs are implemented

The resulting global GHG emission level in 2015 based on all data sources is estimated to be about 47.5 $GtCO_2e$, which is about 3.1 $GtCO_2e$ below the 2015 emission estimate from EDGAR and FAO. It is also about 3.5 $GtCO_2e$ below the 2015 emissions for the global least-cost emission pathways limiting global warming to below 2 °C and 1.5 °C, underlying the scenario database of IPCC Special Report on Global Warming of 1.5 °C (IPCC SR1.5; (Rogelj et al., 2018). Grassi et al. (2017; 2021) find an around 4 $GtCO_2e$/year difference in global LULUCF net emissions between country reports and scenarios studies (as reflected in IPCC report) mainly due to different definition of LULUCF emissions related to the 'anthropogenic forest sink'. This identified discrepancy can be accounted and corrected for, and solutions

has been analysed in Grassi et al. (2021). The analysis presented here corrects for the discrepancy in reported emissions between national GHG inventories and global emission pathway studies by applying a constant adjustment term of 3.7 $GtCO_2e$ over the 2010–2030 period.

As the projection that NDCs lead to emission reductions from the current policies scenario, global emissions are projected to peak by 2025, and reach about 2% above 2015 levels by 2030 if the unconditional NDCs are implemented, and return to 2015 levels if the conditional NDCs are implemented (Figure 3). This is well below the growth projected in the current policies scenario (15%). The projected global emission level in 2030 is about 52.5 (50–54) $GtCO_2e$ if all unconditional NDCs are implemented, and 51 (48.5–52) $GtCO_2e$ if the conditional NDCs are implemented (Supplementary Text 6), assuming that countries follow the current policies scenario, if they have no NDC or an NDC that would lead to higher emissions.

Our global emission projections for the NDC scenarios are surrounded with uncertainties, as uncertainty ranges account for the range in targets mentioned in the NDC. The largest uncertainty is related to the implementation of the mitigation targets of China and India, including the emission intensity targets, peaking ambition and non-fossil targets, and the final projected emission target levels strongly depend on future GDP trends, which are subject to large uncertainties (for further details, see Supplementary Text 3 and Text 6). The presented ranges try to quantify the above uncertainties.

4.4 What are the emission implications for staying well below 2˚C and 1.5˚C?

This section focuses on the global impact of NDCs and compares the resulting emission level with the level needed to meet the Paris climate goals. Global emission levels consistent with a 66% chance of staying below 2 °C and 1.5 °C are projected to be 41 (39–46) $GtCO_2e$ and 25 (22–31) $GtCO_2e$, respectively, for the year 2030 (median and 10th–90th percentile range), as presented in UNEP (2019) based on the IPCC SR1.5 scenario database. The full implementation of the unconditional NDCs is estimated to result in a gap in 2030 of 11 $GtCO_2e$ (range of 4–15) compared to cost-optimal 2 °C pathways. The emission gap between unconditional NDCs and below 1.5 °C pathways is about 28 $GtCO_2e$ (range of 19–31) (Figure 3). According to our projections, this gap will be 1.5 $GtCO_2e$ smaller if the conditional NDCs are implemented. The total impact of the NDC updates has reduced the 2030 gap from Current Policies to 2 °C by only 28% and to 1.5 °C by only 13%.

[INSERT FIGURE 3]

[7] The uncertainty range comes from the different current policies projections in Nascimento et al. (2021).
[8] The BUR gives a 2005 emissions of 2700 $MtCO_2e$ for GWP SAR, as can be seen in Figure III for BUR. For this analysis this estimate is corrected for GWP AR5, leading a base-year emissions of 2854 $MtCO_2e$,

which is also confirmed in Figure B.1 of BUR.

5. Comparing Indicators Between The G20 Countries

This section looks in more detail at country results regarding the effect of NDCs on the timing and level of GHG emission peaks, per capita emissions, and whether the NDCs are in line with 1.5 °C and 2 °C.

5.1 Timing and level of national GHG emission peaks

Full implementation of post-2020 NDCs is projected to lead to different national emission trajectories and emission peak years (Table 2). Among the G20 economies, the EU-27 was the first region where emissions peaked (around 1980). Before 1990, emissions in the Russian Federation and in the United Kingdom peaked.[9] By 2010, half of the G20 members (EU-27, Russia, Argentina, Australia, Brazil, Canada, the United Kingdom, and the United States) had peaked emissions. Emissions in Australia, Canada and the United States peaked with per capita emissions that were a factor two higher than the EU-27. By 2015, Japan had peaked. Another four G20 members' emissions will peak by 2020 (Republic of Korea), or by 2030 (China – CO_2 only – and Mexico) if commitments are achieved. Five G20 members' GHG emissions show no sign of peaking, given the full implementation of the current unconditional commitments (India, Indonesia, Saudi Arabia, South Africa and Turkey).

All countries, including those where emissions have already peaked, will need to accelerate the rate of emission reduction if long-term reductions close to the Paris targets are to be met. For instance, an 80% reduction in emissions between 2005 and 2050 requires an annual constant reduction rate of 3.5%/year for that period. By contrast, the six G20 members that have already peaked have shown annualised emission reduction rates ranging between 0.15%/year (Canada) to 1.6%/year (Australia) after peaking up to 2019 for all GHG emissions including those from LULUCF. Brazil's GHG emissions peaked in 2004 and showed an average 6.5%/year reduction between 2004 and 2018 due to the large reductions in LULUCF emissions. Brazil's GHG emissions from non-LULUCF sectors have increased, on average, by 1.5% per year.

[INSERT TABLE 2]

5.2 Projected per capita emissions for national NDCs

Emissions per capita are a useful indicator to see whether the NDCs are ambitious. Table 2 shows projected per capita GHG emissions under current policies and NDC targets in both absolute and relative terms (compared to 2010 levels) for all G20 members (excluding EU Member States). It shows that, for six G20 members, per capita emissions are projected to exceed 10 tCO_2e per year (the approximate levels of 2010, for EU-27 and Japan) in 2030, under current policies and four members could even emit these levels under unconditional NDC targets. Among OECD member countries[10], the EU-27 is projected to

have the lowest per capita emission levels in 2030. Mexico also performs well in terms of the projected development of per capita emissions under both current policies and NDC scenarios. As Table 2 shows, emissions per capita under the unconditional NDC targets are projected to decline between 2010 and 2030 in all G20 economies except China, India, Indonesia, the Russian Federation, Saudi Arabia and Turkey. There are also large differences in per capita emission levels. The per capita emissions of India and the European Union are about half the G20 average, whereas Saudi Arabia and Russian Federation reach three and two times the G20 average, respectively. The per capita emissions of China reach about 35% above G20 average levels, which is above the US levels, and more than two times the level of the EU-27. Per capita emissions in G20 as a group are projected to reduce with about 5% over the 2018–2030 period in their NDCs, whereas per capita emissions levels would need to be 29% and 58% lower than in 2018 to limit global warming to below 2˚C and 1.5°C respectively. This is based on reaching global average per capita emissions of 4.9 and 2.9 tCO_2e by 2030 for 2˚C and 1.5°C, respectively.[3]

5.3 Are national NDCs in line with 2 °C and 1.5 °C pathways?

On a global level, the emission reductions that would result from implementation of the submitted NDCs are insufficient to close the global emission gap to 2 °C and 1.5 °C (see Section 4.4). On an individual country level, however, NDCs may be consistent with least-costs pathways that limit global warming to 2 °C and 1.5 °C. Consistency with emission pathways that achieve the climate targets of 2 °C and 1.5 °C, on a national level, can be assessed by either considering effort-sharing or by assuming cost-optimal domestic implementation of climate policies.

In the first approach, emission allowances and reductions towards meeting the climate targets are distributed across countries based on alternative equity principles. Assessing whether the magnitude of change in GHG-emission-related indicators as a result of NDCs is ambitious and fair in the light of the Paris Agreement's long-term goals requires explicit benchmarking across alternative normative indicators of effort-sharing, which was beyond the scope of this study. However, a number of recent peer-reviewed studies have attempted this task, based on a range of effort-sharing considerations (Robiou du Pont et al., 2017; van den Berg et al., 2020).

The second approach focuses on global cost-optimal implementation of the Paris goals, where emission reductions are distributed across countries, sectors and greenhouse gases in such a way that the global costs of meeting the climate targets are minimised. Note that this approach refers to the cost-optimal geographical distribution of emission reductions, not to sharing the costs of mitigation. Without such funding, the cost-optimal approach would not be seen as a fair solution. Reductions would need to be partly funded internationally, regardless of their location, to make this an equitable approach. Developed countries could reduce their emissions by more than in the cost optimal pathway and/or provide capital flows to assist poorer countries in achieving the mitigation levels shown.

We compared the NDC reduction targets to projected 2030 GHG emission reductions for some major emitting countries, according to cost-optimal 2 °C and 1.5 °C scenarios developed with integrated

assessment models, based on van Soest et al. (2021b), as shown in Figure 4. Our analysis shows that only the NDCs submitted by Canada, the European Union and United Kingdom, and the United States are in line with a cost-optimal pathway to achieving the 1.5 °C climate target. The reduction target announced by Japan is in line with achieving the 2 °C emission pathways. The NDCs of the other countries, including China and India, are not in line with the least-cost 2 °C pathways (let alone those of 1.5 °C). For comparison, Figure 4 also includes the emissions reductions needed to meet the same world per capita emissions levels of 4.9 and 2.9 tCO_2e by 2030 for 2˚C and 1.5°C, respectively for all countries. It clearly shows the higher reductions needed for the countries with relatively high per capita emissions, such as Canada, Russian Federation and the United States, and the growth targets for India.

[INSERT FIGURE 4]

[9] Russia's emissions peaked prior to 1990. While Russia's commitments for 2020 and 2030 indicate an intended increase from recent emissions levels, Russia's future commitments do not propose to surpass 1990 emissions levels
[10] Australia, Canada, the EU, Japan, Mexico, Republic of Korea, Turkey, the United States.
[11] By 2030, global GHG emissions would need to be 25% and 55% lower than in 2018 to put the world on the least-cost pathway to limiting global warming to below 2˚C and 1.5°C respectively.

6. Impact Of Changes In Lulucf On Achieving Ndcs

The important role of nature-based solutions for mitigating climate change is increasingly being recognised, as these may bring other important co-benefits for biodiversity and ecosystem goods and services (Seddon et al., 2020). This is partially also reflected in the updated NDCs. As many as 118 of the 144 countries assessed explicitly state that LULUCF-related emissions and their removal are included in the mitigation component of their NDCs, compared to 108 in the previous NDCs.

Overall, the updated NDC submissions amount to an additional reduction in net LULUCF emissions of 330 $MtCO_2e$ by 2030, compared to the reduction commitments of the previous NDCs (Figure 5). The additional reductions largely arise from more stringent GHG reduction targets and commitments by non-Annex I countries, with Colombia in the lead with an additional emission reduction of 46 $MtCO_2e$ in the LULUCF sector. Countries that provide quantitative targets in their updated NDCs represent around 17% of the world's forest cover. However, most of the additional reductions in the LULUCF sector are not in the countries currently ranked globally in the top 10, in terms of forest area (FAOSTAT, 2021)[1]. Of these top 10 countries, only Indonesia and the EU-27 have provided updated NDCs that specify additional emission reductions in the LULUCF sector, while Australia has set a lower ambition level. Brazil did not provide transparent information on its targets for the LULUCF sector, which is why its contribution could not be clearly assessed. The target of 'realising zero illegal deforestation in Brazilian Amazonia by 2030', as stated in Brazil's previous NDC, is no longer included in the updated NDC. The United States is another example where the updated NDC does not provide specific targets for the LULUCF sector. As shown in Section 4, their updated NDC reduces overall emissions relative to their previous NDC target. As the US'

updated NDC provides no information about the expected contribution from the LULUCF sector, the country is not included in Figure 5.

The time sensitivity for mitigation actions applies particularly to the LULUCF sector. While readily available solutions are present, the promise of harnessing some LULUCF-based mitigation options may begin dissipating if no additional substantive measures are taken. As global warming increases, there is the risk of natural carbon sinks becoming sources, turning them from a solution into a problem. For example, there is evidence that, due to the combined effects of deforestation, environmental degradation and climate change, parts the Amazon are becoming an emission source (Gatti et al., 2021), reflecting concerns that a tipping point is being reached (Nobre et al., 2016).

[INSERT FIGURE 5]

[12] Russian Federation, Brazil, Canada, the Unites States, China, EU-27, Australia, Democratic Republic of Congo and Indonesia.

7. Macroeconomic Impacts Of Ndcs By 2030

Climate policies would impact the increase in economic activity in major emitting countries, as these policies affect household income, consumption of goods, trade patterns, labour markets and investment dynamics. As climate policies may have regressive distributional impacts posing a disproportionately high cost to vulnerable industries and low-income households, appropriate policies should be implemented to compensate the producers and consumers affected by decarbonisation policies, while carbon pricing itself could be used to fund these policies (Fragkos et al., 2021a). In our analysis, we did not assess compensatory schemes, as there is high uncertainty on their design and implementation, and we focused on the direct, indirect and induced socio-economic implications of implementing the new and updated NDCs by 2030[13], by quantifying the overall economic cost of emission abatement, without considering climate damages and potential co-benefits of climate policy for air quality and human health.

Energy system restructuring induced by the new and updated NDCs leads to a redirection of investments, driven by the replacement of fossil fuel-intensive technologies and infrastructure for low-carbon and energy-efficient technologies. Under the NDC scenario, investments in clean energy technologies increase, which puts pressure on the capital market, as capital resources are not assumed to be abundant in the CGE framework. This, in turn, will lead to ‘crowding-out effects’, as firms and households fund their clean energy investment by spending less on other, non-energy commodities and investment purposes[14] through a reallocation of their available resources.

The economy-wide effects are driven by the uptake of low-carbon technologies and energy efficiency, leading to increases in the cost of energy services, under the current policies (CurPol) scenario of the GEM-E3-FIT macroeconomic model. This induces an increase in the price of goods and services and a decline in the purchasing power of households, thus, reducing domestic demand. Full implementation of the NDC targets implies substituting fossil fuels (which are largely imported into the European Union,

Japan, China and India) with capital-intensive goods and services that are, to a certain extent, domestically produced. Spending on low-carbon technologies constrains the funds available for other investments and consumption purposes (crowding-out effect). The model-based analysis suggests that the new and updated NDCs will have only a limited impact on economic activity, with global GDP declining by 0.4% from CurPol levels, by 2030 (Table 3). This is in line with earlier macroeconomic assessments of the previous NDC submissions (i.e. Vandyck et al., (2016); Fragkos et al., (2018a), despite achieving larger emission reductions, as GEM-E3-FIT has integrated the declining costs of renewable energy technologies, in recent years. The economic costs that will emerge from the NDCs can be lower, if the benefits related to avoided climate impacts and air pollution are explicitly quantified (Rauner et al., 2020).

Macroeconomic impacts of NDCs differ between countries, largely depending on the emission reduction effort relative to CurPol, which is in line with the analysis presented above. Other country-level factors also influence mitigation costs, such as economic structure, fossil fuel resources, energy transformation, position in global energy trade, and technology costs. Overall, fossil fuel exporters face higher costs relative to importers, as a result of their reduced export revenues, while fossil fuel import savings reduce the mitigation costs for energy importers. GDP losses are found to be larger in the United States (0.8% of CurPol GDP in 2030) due to the higher ambition level of the new US NDC emission reduction target of 50%–52%. GDP impacts are marginal for countries whose NDCs do not lead to emission reductions from CurPol – excluding LULUCF emissions (e.g. India, Russian Federation, Argentina, Turkey, South Africa). The new, more ambitious NDC targets lead to limited GDP losses of around 0.5%, by 2030, in major developed economies, including the European Union, Japan, Canada, Republic of Korea and Australia, while China faces similar losses, mostly driven by the Chinese announcement (Table 1), as well as by the reduced exports to other economies due to lower global output. Overall, increases in investment costs of low-carbon technologies and infrastructure are to a large extent offset by fossil fuel savings, with a redirection of energy costs away from Operating Expenditures and towards Capital Expenditures. Businesses and consumers, instead of spending money on fossil fuel products, direct their spending towards low-carbon and energy-efficient investments. Our analysis shows that the new NDC targets are compatible with robust economic growth in all G20 economies, as GDP growth rates are found to remain very close to CurPol levels, with only marginal changes by 2030[15].

[INSERT TABLE 3]

The increased clean energy investment, under the NDC scenario, crowds out investment in other productive activities, as discussed above, leading to a small reduction in global investment, which declines by 0.2% from CurPol by 2030. The NDC impacts on investment are more limited than those on GDP (in all countries), due to increased investments in low-carbon technologies and energy efficiency, in line with Fragkos et al. (2021b) and European Commission (2020). On the other hand, private consumption decreases more than GDP (0.7% globally, between 0.1% and 1.2% in major economies), as production costs and prices increase due to carbon pricing, energy system restructuring and resource reallocation, compared to those under the CurPol scenario. The overall impact of the new NDCs on

employment is limited, with global employment declining by 0.2% from the level under the CurPol scenario by 2030, with deviations between countries ranging from -0.8% to +0.1%, which largely reflect the mitigation ambition level of the new NDCs. The NDC impacts on employment are projected to be more limited than those on GDP, as job impacts from reduced economic activity are largely counterbalanced by the creation of jobs in sectors related to low-carbon technologies and energy efficiency, as these sectors are commonly more labour-intensive than the fossil fuel sector (Fragkos et al., 2018b).

[13] The updated NDC of South Africa (submitted by 27 September 2021) was not included in the macro-economic analysis.
[14] Crowding-out effects can diminish in cases of favourable financing schemes, as assumed in Fragkos and Paroussos (2018b), who show that, if firms and households can borrow on capital markets without facing an increase in the related costs, the activity impacts of decarbonisation will be minimal or even positive (in the short term). In addition, neo-Keynesian assumptions do not include constraints in the financial capacity of agents and, thus, show no crowding-out effects as a result of decarbonisation policies, at least not in the short term.
[15] The global GDP annual growth rate marginally declines from 2.57% in CurPol to 2.53% in the NDC scenario over 2015–2030.

8. Conclusions

This paper analyses the emissions and macroeconomic impacts of the new and updated NDCs submitted between August 2019 and September 2021, where available and previous NDCs for others, within the context of the Paris Agreement. The following main conclusions can be drawn from the analysis.

The NDC updates – conditional and unconditional – have an aggregated impact on global GHG emissions of about -4.1 and -3.7 $GtCO_2e$ by 2030 respectively, compared to the previous NDCs. The total impact also includes that of lower emission projections from countries that overachieve their NDC targets. Seven G20 economies (United States, the EU-27, Japan, China, the United Kingdom, Argentina and Canada) have pledged higher emission reduction targets for 2030, in their updated NDCs, leading to additional aggregated GHG emission reductions of about 3.2 $GtCO_2e$, compared to the previous NDCs. About 0.3 $GtCO_2e$ will be counterbalanced by the higher emissions from a group of countries with a change in base year or BAU emissions, the most prominent of which being Brazil. The non-G20 economies with updated NDCs contribute a reduction of 0.8 $GtCO_2e$.

The collective ambition level of all submitted NDCs (also including the updates), falls short of what is needed to put global emissions on to a cost-effective pathway towards achieving the climate goals of the Paris Agreement. Global emissions are projected to peak by 2025 and reach about 52.5 (50–54) $GtCO_2e$, by 2030, if all unconditional NDCs are implemented, and 51 (48.5–52) $GtCO_2e$ if the conditional NDCs are implemented. The median estimates of unconditional NDCs for 2030 are 2% above 2015 emission levels.

By 2030, global emission levels need to be 11 (4–15) $GtCO_2e$ lower than current unconditional NDCs imply, in order to achieve the 2 °C goal, and 28 (19–31) $GtCO_2e$ lower for the 1.5 °C goal. Implementation of the conditional NDCs would reduce these estimates by about 1.5 $GtCO_2e$. While the NDCs are projected to be insufficient for closing the global emission gap, the NDCs of some G20 economies (i.e. Canada, the European Union and United States) are consistent with emission pathways below 2 °C and 1.5 °C, based on cost-optimal implementation.

Four G20 members are projected to emit more than 10 tCO_2e per capita, annually (2010 levels for EU-27 and Japan) by 2030, under unconditional NDCs. Emissions per capita, under the unconditional NDCs, are projected to decline between 2010 and 2030 in all G20 economies except China, India, Indonesia, the Russian Federation, Saudi Arabia and Turkey. There are also large differences in per-capita emission levels. The per-capita emissions in India and the European Union are about half the G20 average, whereas Saudi Arabia and the Russian Federation reach three and two times the G20 average, respectively.

The new NDCs will have a limited socio-economic impact in G20 economies, but induce an increase in clean energy investments. The new, updated NDCs will have only limited impact on economic output in major economies, but will induce a shift in investment patterns away from fossil fuels and towards low-carbon technologies and energy efficiency. The economic impact highly depends on the ambition level of NDC targets and on a country's trade position on global energy and other goods markets. The new NDCs will lead to a decline in global GDP of 0.4%, from current policies levels, while GDP losses in major economies by 2030 range between 0.0% (when NDCs do not imply climate efforts in addition to those under the Current Policies scenario) and 0.8% (in the United States, with its high mitigation effort and fossil fuel production), as businesses and consumers direct their spending towards investments in low-carbon technologies instead of fossil fuels.

The updated NDCs show a broader scope of mitigation efforts, with most countries providing cross-sectoral targets and a greater inclusion of the LULUCF sector. The updated NDC submissions show an increase in both mitigation scope and ambition level of the LULUCF-related measures. However, when taken together with mitigation actions across other sectors, the size and pace of nationally determined emission reductions currently will not meet the collective commitments required to achieve a pathway that aligns with the objectives of the Paris Agreement. This underlines the urgency of scaling up further actions, if a global warming limit of between 1.5 °C and 2 °C is to remain within the realm of possibilities. Further transparency and clear description of how much the LULUCF sector will contribute to the overall emission reduction target will help in recognising changes in scope and identifying entry points for action, particularly from key forest countries.

A continuous shortfall in collective ambition may foreclose some existing mitigation options, placing an additional burden on the future. Based on our assessment, the impact of the updated NDCs would need to be four times greater to be consistent with temperature increases of well below 2 °C, and about eight times greater for 1.5 °C. The urgency for scaling up the ambition level needs to be recognised in the context of the time sensitivity and, hence, also the need for prioritisation of mitigation options. With

further warming and increases in weather extremes, some of the mitigation options readily available today may no longer be viable at a later point in time. This may apply to forest sinks or the use of hydropower, in some regions. Hence, shortfalls in climate ambition levels today may translate into an additional demand for novel technologies and practices in the future, placing a further burden and challenges on future generations.

Declarations

Competing interests: Authors declare that they have no competing interests

Data and materials availability: An interactive tool showing emissions per country, emissions per capita, and emissions per unit of income, resulting from the current policies and NDCs, is available at: www.pbl.nl/ndc. All data of figures used in the analysis will be made available in a data repository upon publication.

References

Dafnomilis I, Chen H-H, den Elzen MGJ, Fragkos P, Chewpreecha U, van Soest HL,.. . van Vuuren DP (2021) Targeted green recovery measures in a post-COVID-19 world enable the energy transition. Nature Communications (submitted).

den Elzen M, Admiraal A, Roelfsema M, van Soest H, Hof AF, Forsell N (2016) Contribution of the G20 economies to the global impact of the Paris agreement climate proposals. Climatic Change 137:655–665.

European Commission (2020) Stepping up Europe's 2030 climate ambition. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the regions.

European Commission (2021) 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the regions, .

FAOSTAT (2020) Land use emissions. Food and Agricultural Organization of the United Nations (FAO), Rome, Italy, http://faostat3.fao.org/download/G2/*/E.

FAOSTAT (2021) Forests. Food and Agricultural Organization of the United Nations (FAO), Rome, Italy, http://www.fao.org/faostat/en/#data/GF.

Forsell N, Turkovska O, Gusti M, Obersteiner M, Den Elzen M, Havlik P (2016) Assessing the INDCs' land use, land use change, and forest emission projections. Carbon Balance and Management 11.

Fragkos P, Fragkiadakis K, Paroussos L, Pierfederici R, Vishwanathan SS, Köberle AC, . . . Oshiro K (2018a) Coupling national and global models to explore policy impacts of NDCs. Energy Policy 118:462–473.

Fragkos P, Fragkiadakis K, Sovacool B, Paroussos L, Vrontisi Z, Charalampidis I (2021a) Equity implications of climate policy: Assessing the social and distributional impacts of emission reduction targets in the European Union. Energy 237:121591.

Fragkos P, Laura van Soest H, Schaeffer R, Reedman L, Köberle AC, Macaluso N, . . . Iyer G (2021b) Energy system transitions and low-carbon pathways in Australia, Brazil, Canada, China, EU-28, India, Indonesia, Japan, Republic of Korea, Russia and the United States. Energy 216:119385.

Fragkos P, Paroussos L (2018b) Employment creation in EU related to renewables expansion. Applied Energy 230:935–945.

Gatti LV, Basso LS, Miller JB, Gloor M, Domingues LG, Cassol HL, . . . Peters W (2021) Amazonia as a carbon source linked to deforestation and climate change. Nature 595:388-393.

Grassi G, House J, Dentener F, Federici S, den Elzen M, Penman J (2017) The key role of forests in meeting climate targets requires science for credible mitigation. Nature Clim. Change 7:220-226.

Grassi G, Stehfest E, Rogelj J, van Vuuren D, Cescatti A, House J, . . . Popp A (2021) Critical adjustment of land mitigation pathways for assessing countries' climate progress. Nature Climate Change 11:425-434.

Havlík P, Valin H, Herrero M, Obersteiner M, Schmid E, Rufino MC, . . . Conant RT (2014) Climate change mitigation through livestock system transitions. Proceedings of the National Academy of Sciences 111:3709-3714.

Höhne N, den Elzen M, Rogelj J, Metz B, Fransen T, Kuramochi T, . . . Fu S (2020) Emissions: world has four times the work or one-third of the time. Nature Publishing Group.

Kuramochi T, Nascimento L, de Villafranca Casas MJ, Fekete H, de Vivero G, Lui S, . . . Gusti M (2019) Greenhouse gas mitigation scenarios for major emitting countries. Analysis of current climate policies and mitigation commitments: 2019 update, NewClimate Institute (Cologne, Germany), PBL (The Hague, the Netherlands), IIASA (Laxenburg, Austria), https://www.pbl.nl/en/publications/greenhouse-gas-mitigation-scenarios-for-major-emitting-countries-2019-update.

Kuramochi T, Nascimento L, Moisio M, den Elzen M, Forsell N, van Soest H, . . . Höhne N (2021) Greenhouse gas emission scenarios in nine key non-G20 countries: An assessment of progress toward 2030 climate targets. Environmental Science & Policy 123:67-81.

Ministry of Environment of the Republic of Korea (2021) Carbon Neutrality Act Passed by National Assembly Heralding Economic and Social Transition. Towards 2050 Carbon Neutrality. Available

at: http://eng.me.go.kr/eng/web/board/read.do;jsessionid=tfo02cAIR4Z9H5SPGX7HJr0g.mehome1?menuId=461&boardMasterId=522&boardId=1473610.

Nascimento L, Kuramochi T, de Villafranca Casas MJ, Fekete H, de Vivero G, Lui S, . . . Gusti M (2021) Greenhouse gas mitigation scenarios for major emitting countries. Analysis of current climate policies and mitigation commitments: 2019 update, NewClimate Institute (Cologne, Germany), PBL (The Hague, the Netherlands), IIASA (Austria), forthcoming.

Nobre CA, Sampaio G, Borma LS, Castilla-Rubio JC, Silva JS, Cardoso M (2016) Land-use and climate change risks in the Amazon and the need of a novel sustainable development paradigm. Proceedings of the National Academy of Sciences 113:10759–10768.

Olivier JGJ, Peters JAHW (2020) Trends in global emissions of CO2 and total greenhouse gases: 2020 Report. PBL Netherlands Environmental Assessment Agency, The Hague, the Netherlands.

Paroussos L, Fragkiadakis K, Fragkos P (2020) Macro-economic analysis of green growth policies: the role of finance and technical progress in Italian green growth. Climatic Change 160:591-608.

Rauner S, Hilaire J, Klein D, Strefler J, Luderer G (2020) Air quality co-benefits of ratcheting up the NDCs. Climatic Change 163:1481–1500.

Robiou du Pont Y, Jeffery L, Gutschow J, Rogelj J, Christoff P, Meinshausen M (2017) Equitable mitigation to achieve the Paris Agreement goals. Nature Clim. Change 7:38–43.

Roelfsema M, van Soest HL, Harmsen M, van Vuuren DP, Bertram C, den Elzen M, . . . Vishwanathan SS (2020) Taking stock of national climate policies to evaluate implementation of the Paris Agreement. Nature Communications 11:2096.

Rogelj J, Den Elzen M, Höhne N, Fransen T, Fekete H, Winkler H, . . . Meinshausen M (2016) Paris Agreement climate proposals need a boost to keep warming well below 2 °C. Nature 534:631–639.

Rogelj J, Shindell D, Jiang K, Fifita S, Forster P, Ginzburg V, . . . Kriegler E (2018) Mitigation pathways compatible with 1.5 C in the context of sustainable development. Global warming of 1.5° C. Intergovernmental Panel on Climate Change, pp. 93-174.

Seddon N, Chausson A, Berry P, Girardin CA, Smith A, Turner B (2020) Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B 375:20190120.

Stehfest E, Van Vuuren DP, Kram T, Bouwman L (2014) Integrated assessment of global environmental change with IMAGE 3.0. Model description and policy applications. PBL Netherlands Environmental Assessment Agency., The Hague.

UN (2017) Population Projections based on the World Population Prospects: The 2017 Revision. . United Nations, Department of Economic and Social Affairs, Population Division
DESA. http://esa.un.org/unpd/wpp/, New York, NY.

UNEP (2018) The Emissions Gap Report 2018., United Nations Environment Programme (UNEP), Nairobi, https://www.unenvironment.org/resources/emissions-gap-report-2018.

UNEP (2019) The Emissions Gap Report 2019. United Nations Environment Programme (UNEP), Nairobi, https://www.unenvironment.org/resources/emissions-gap-report-2019.

UNFCCC (2015) FCCC/CP/2015/L.9/Rev.1: Adoption of the Paris Agreement. UNFCCC, Paris, France, pp. 1–32.

UNFCCC (2021a) NDC
registry, https://www4.unfccc.int/sites/NDCStaging/Pages/LatestSubmissions.aspx.

UNFCCC (2021b) Submitted National Communications from Annex I Parties, https://unfccc.int/NC7.

van den Berg NJ, van Soest HL, Hof AF, den Elzen MGJ, van Vuuren DP, Chen W, . . . Blok K (2020) Implications of various effort-sharing approaches for national carbon budgets and emission pathways. Climatic Change 162:1805–1822.

van Soest H, Reis LA, Baptista LB, Bertram C, Després J, Drouet L, . . . van Vuuren DP (2021a) Global roll-out of Comprehensive policy measures may aid in bridging emissions gap. Nature Communications https://doi.org/10.21203/rs.3.rs-126777/v1.

van Soest HL, den Elzen MG, van Vuuren DP (2021b) Net-zero emission targets for major emitting countries consistent with the Paris Agreement. Nature communications 12:1–9.

Van Vuuren DP, Stehfest E, Gernaat DE, Doelman JC, Van den Berg M, Harmsen M, . . . Edelenbosch OY (2017) Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm. Global Environmental Change 42:237–250.

Vandyck T, Keramidas K, Saveyn B, Kitous A, Vrontisi Z (2016) A global stocktake of the Paris pledges: Implications for energy systems and economy. Global Environmental Change 41:46-63.

Tables

Table 1: Summary of the GHG and non-GHG targets for 2030 of the NDCs and announcements by the G20 economies (except the EU Member States), as of 27 September 2021 (UNFCCC, 2021a). All target values are for 2030.

Country	Previous NDC	New or updated NDCs and other announced 2030 targets	Notes
Argentina	Cap 2030 net emissions at 483 $MtCO_2e$ (unconditional) and 369 $MtCO_2e$ (conditional)	Cap 2030 net emissions at 359 $MtCO_2e$ (unconditional)	
Australia	Reduce GHG emissions by 26%–28% from 2005 levels	Reduce GHG emissions by 26%–28% from 2005 levels. Updated NDC to be implemented as an emission budget.	
Brazil	Reduce GHG emissions by 37% from 2005 levels by 2025 and (indicatively) 43% from 2005 levels	Reduce GHG emissions by 43% from 2005 levels by 2030	Increased base year emissions
Canada	Reduce GHG emissions by 30% from 2005 levels	Reduce GHG emissions by 40%–45% from 2005 levels	
China	- Peak CO_2 emissions around 2030 - Reduce CO_2/GDP by 60%–65% from 2005 levels - Share of non-fossil fuels in primary energy consumption to around 20% - Increase forest stock volume by around 4.5 billion cubic metres	- Peak CO_2 emissions before 2030[i] - Reduce CO_2/GDP by 65% from 2005 levels[i] - Share of non-fossil fuels in primary energy consumption to 25% [i] - Increase forest stock volume by around 6 billion cubic metres[i] - Increase the installed capacity of wind and solar power to 1,200 GW[i]	
EU-27	Reduce GHG emissions by at least 40% from 1990 levels (for the EU-28)	Reduce net GHG emissions by at least 55% from 1990 levels [ii]	
India	- Reduce emissions/GDP by 33%–35% from 2005 levels - Increase in share of non-fossil fuel in primary electricity production to 40% (Conditional)	n/a	
Indonesia	Reduce GHG emissions by 26% (unconditional) and 29% (conditional) relative to business-as-usual (BAU)	Reduce GHG emissions by 26% (unconditional) and 29% (conditional) relative to BAU	
Japan	Reduce GHG emissions by 26% from 2013 levels (fiscal year)	Reduce GHG emissions by 46% from 2013 levels (fiscal year)[i]	
Mexico	Reduce GHG emissions by 22% (unconditional) and 36% (conditional) from BAU	Reduce GHG emissions by 22% (unconditional) and 36% (conditional) from BAU	Increased BAU
Russian Federation	Limit 2030 emissions to 70%–75% of 1990 level [iii]	Limit 2030 emissions to 70% of 1990 level [iii]	
Saudi Arabia	n/a	n/a	
South Africa	Limit 2025–2030 emissions to a range between 398 and 614 $MtCO_2e$	Limit 2025–2030 emissions to a range between 350 and 420 $MtCO_2e$	
Republic of Korea	Reduce GHG emissions by 37% from BAU	Reduce GHG emissions by 35% from 2018 levels [iv]	
Turkey [v]	Reduce GHG emissions by up to 21% from BAU (INDC)	n/a	
United Kingdom	(Part of EU-28)	Reduce GHG emissions by at least 68% from 1990 levels	

United States	Reduce GHG emissions by 26%–28% from 2005 levels by 2025	Reduce GHG emissions by 50%–52% from 2005 levels by 2030	

[i] These countries announced new pledges but not yet submitted them as updated NDCs. China announced climate targets at the 2020 Climate Summit. [ii] The new target is net GHG reduction (emissions after deduction for removed emissions must be 55% below their 1990 level). The former target included emissions from LULUCF, but not in the headline target — only the requirement that Member States balance emissions & their removal as per the LULUCF regulation. [iii] Taking into account the maximum possible absorptive capacity of forests; [iv] The national assembly just passed the new 2030 target (Ministry of Environment of the Republic of Korea, 2021); [v] Turkey has not ratified the Paris Agreement.

Table 2: Overview of G20 member status and progress, including on Cancun pledges and NDC targets, based on UNEP (2018).

Country	Share of global GHG emissions in 2019[1)]	Projected per capita GHG emissions in 2030 (tCO_2e/cap) and change rates from 2010 levels (in brackets) [3)]		Emission peaking	
		Unconditional NDCs	Current policies	Peaking year[4)]	Average annual growth after peaking[5)]
Argentina	0.8%	7.3 (-25%)	7.5 (-23%)	2007	-1.8%/yr (2006–2017)
Australia	1.5%	15.9 (-41%)	19.2 (-29%)	2006	-1.6%/yr (2006–2019)
Brazil	3.0%	6.7 (18%)	8.1 (40%)	2004	-6.5%/yr (2004–2018) (+1.5%/yr excl. LULUCF)
Canada	1.6%	9.5 (-54%)	17.5 (-20%)	2007	-0.15%/yr (2007–2019)
China	24.6%	9.4 (+29%)	9.9 (+37%)	Before 2030 (CO_2 only)	---
EU-27	6.7%	4.1 (-47%)	4.3 (-44%)	1990 or earlier	-1.1%/yr (1990–2019)
India	6.8%	3.3 (+114%)	2.3 (+48%)	No commitment to peak	---
Indonesia	3.8%	6.8 (+45%)	6.9 (+47%)	No commitment to peak	---
Japan	2.4%	6.3 (-34%)	8.4 (-12%)	2013	---
Mexico	1.5%	5.5 (-8%)	5.5 (-8%)	By 2030	---
Republic of Korea	1.2%	9.2 (-25%)	10.7 (-13%)	By 2020	---
Russian Federation	3.7%	15.1 (+66%)	12.0 (+32%)	1990 or earlier	-2.4%/yr (1990–2019) +0.7%/yr (2000–2019)
Saudi Arabia	1.3%	26.3 (+35%)	25.0 (+29%)	No commitment to peak	---
South Africa	1.1%	5.8 (-45%)	7.2 (-33%)	No commitment to peak	---
Turkey	1.1%	10.4 (+131%)	5.0 (+11%)	No commitment to peak	---
United Kingdom	0.9%	3.7 (-62%)	5.4 (-44%)	1990 or earlier	-1.1%/yr (1990–2019)
United States	11.8%	9.3 (-54%)	14.0 (-30%)	2007	-1.2%/yr (2007–2019)
G20	73.8%	7.1 (-1%)	7.1 (+3%)	2007	

Notes: 1) EDGAR (Olivier et al., 2020) and FAOSTAT (2020); 2) The population projections are based on the medium fertility variant of the UN Population Prospects 2017 edition (UN, 2017); 3) G20 average in 2015 was 7.5 tCO_2e/cap. Source: this study (based on national greenhouse inventories, and using the GHG trend of EDGAR, if emission data for the most recent years were missing). 4) Given the unconditional pledges. The column on peaking year of when countries are expected to peak in the future is based only on commitments that countries have made and assumes the achievement of such commitments. 5) Authors' calculations based on UNFCCC (2020) data (incl. LULUCF).

Table 3: Macroeconomic impacts of the new NDCs in major economies (as % changes from the CurPol scenario by 2030). Source: GEM-E3-FIT model.

	GDP	Investment	Consumption	Employment	% GHG emission reduction from CurPol in 2030
European Union	-0.5	0.3	-0.5	-0.5	-15%
United States	-0.8	-0.7	-1.8	-0.8	-29%
China	-0.5	-0.5	-1.1	-0.5	-7%
India	0.0	0.1	0.1	0.0	0%
Japan	-0.6	-0.5	-1.2	-0.7	-23%
Russian Federation	-0.1	-0.1	-0.1	0.1	0%
Canada	-0.6	-0.5	-0.9	-0.6	-25%
South Africa	0.1	0.2	0.2	0.2	0%
Republic of Korea	-0.5	-0.2	-0.9	-0.4	-21%
Mexico	-0.5	-0.9	-2.0	-0.4	-18%
Argentina	-0.1	0.1	0.0	0.0	-3%
Turkey	0.1	0.1	0.2	0.1	0%
Saudi Arabia	-0.6	0.0	-0.3	-0.2	0%
Australia	-0.6	-0.4	-1.0	-0.5	-15%
World	**-0.4**	**-0.2**	**-0.7**	**-0.2**	**-12%**

Figures

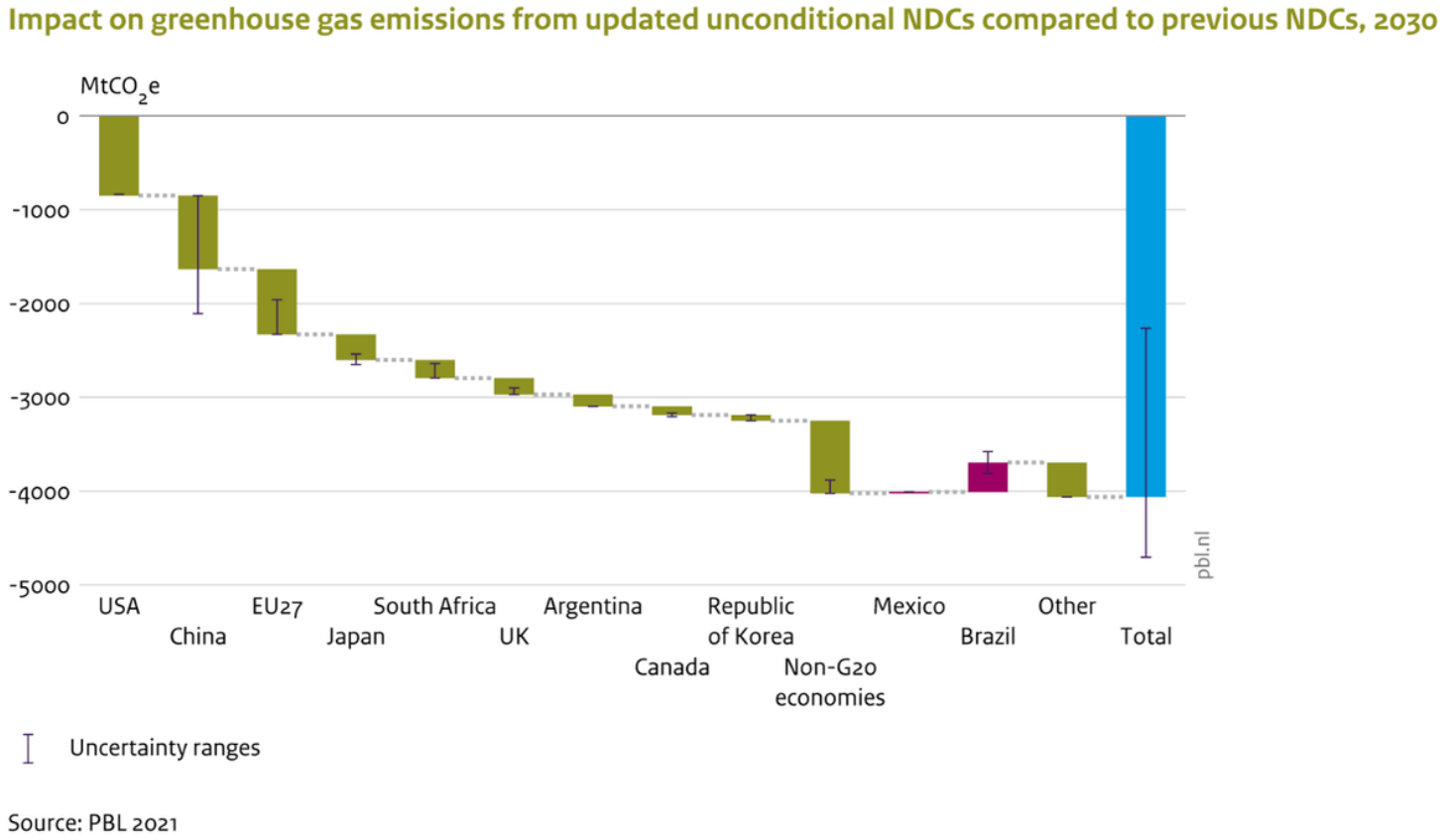

Figure 1

The contribution of the updated NDC targets of countries on total additional global emission reduction (as indicated in blue column) based on the full implementation of the unconditional NDC targets, compared to the previous NDCs. The green columns indicate additional reductions from individual G20 economies, the non-G20 countries as a group with their stronger NDC targets (compared to their previous NDCs), and the red columns indicate the increase in emissions from G20 economies with their weaker NDC targets. The uncertainty ranges represent the reductions relative to the current policies scenarios (such as for the EU-27), or other uncertainties related to the range in reduction targets (such as South Africa), or the uncertainties in the base-year emissions (Brazil). Some G20 economies are not shown as they have submitted the same reduction targets in their updated NDC, or have not yet submitted an updated NDC (see Table 1).

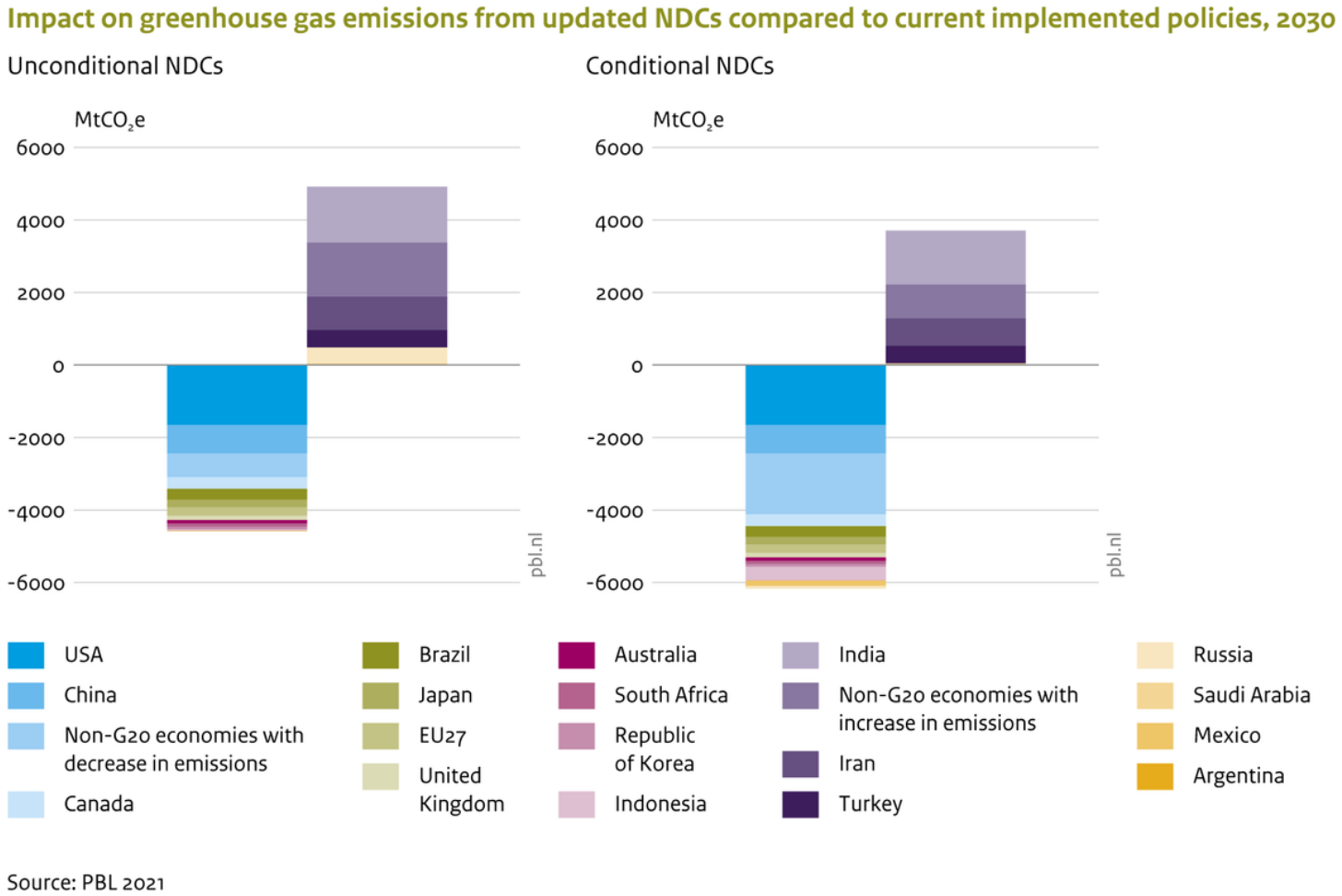

Figure 2

Projected absolute emission reductions relative to the current policies scenario in 2030 by the G20 countries and the non-G20 countries as a group based on their NDCs. For countries with a reduction target range, projected reductions were based on the average of the range.

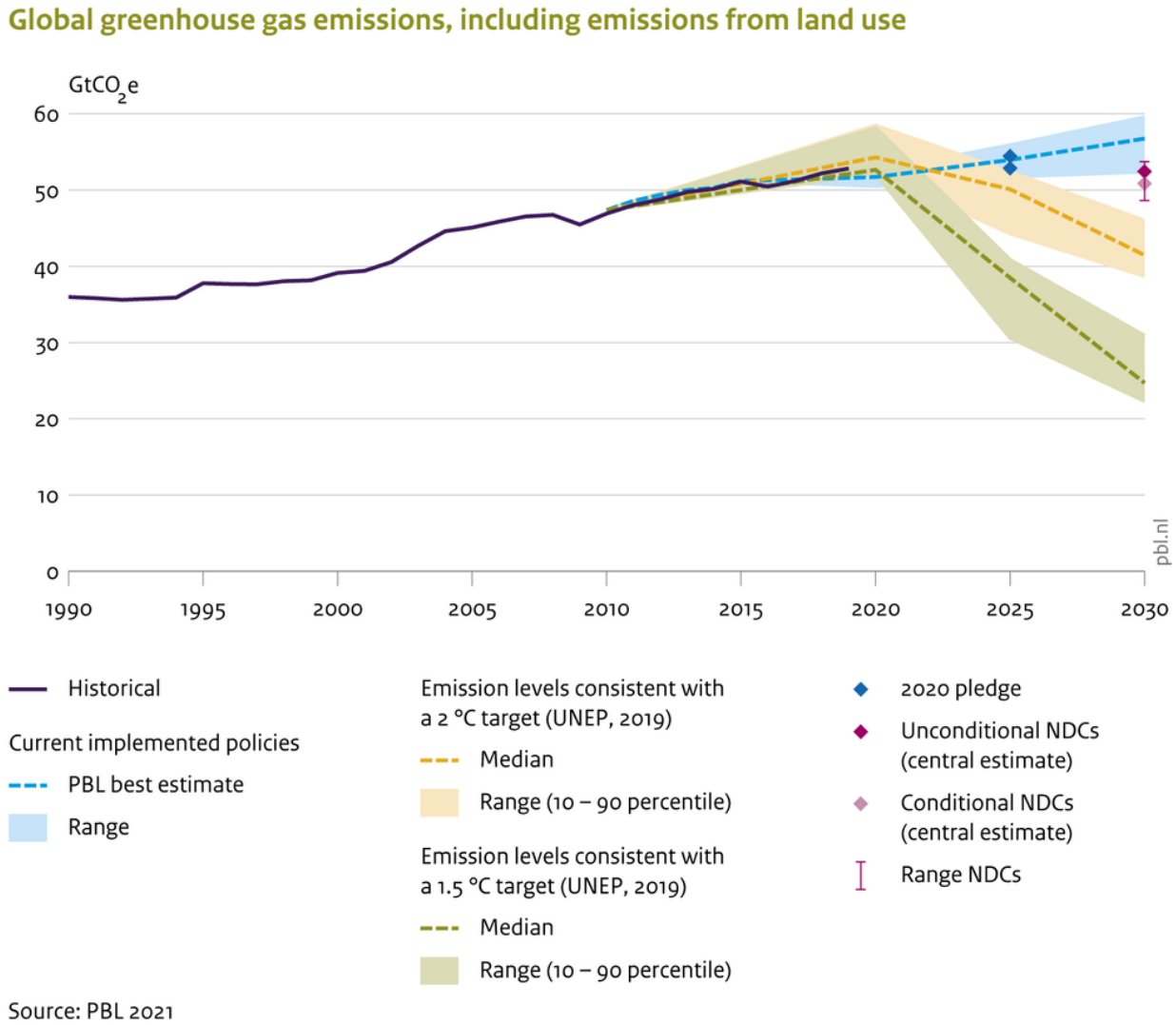

Figure 3

Impact of the implementation of the NDCs and current policies on greenhouse gas emission projections and on narrowing the emission gap in 2030.

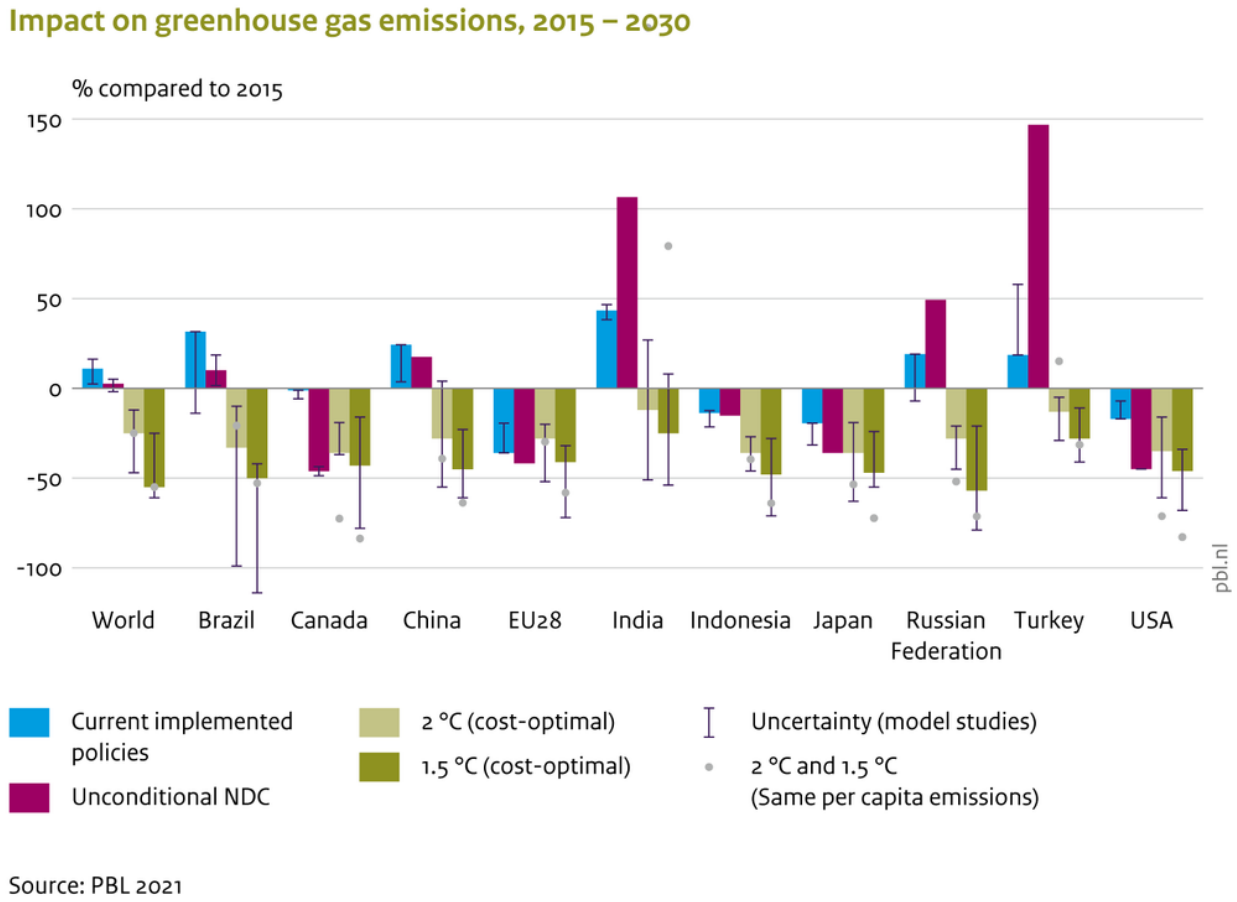

Figure 4

Kyoto greenhouse gas emissions by 2030, projected by models for cost-optimal 1.5 °C and 2 °C scenarios, compared to NDCs and current policies. Total emissions are shown in comparison to 2015 levels (%, with positive numbers indicating an increase in emissions). Dots represents the emissions reductions needed to meet the same world per capita emissions levels for 2˚C and 1.5°C. Solid NDC bars show the central estimate in this study, error bars present the range. There are three types of NDC ranges: the range for the reduction target mentioned in the NDCs themselves ('Target'; Canada, United States), the range resulting from unconditional targets, and the range resulting from various model studies ('Model Studies NDC'; India, China).

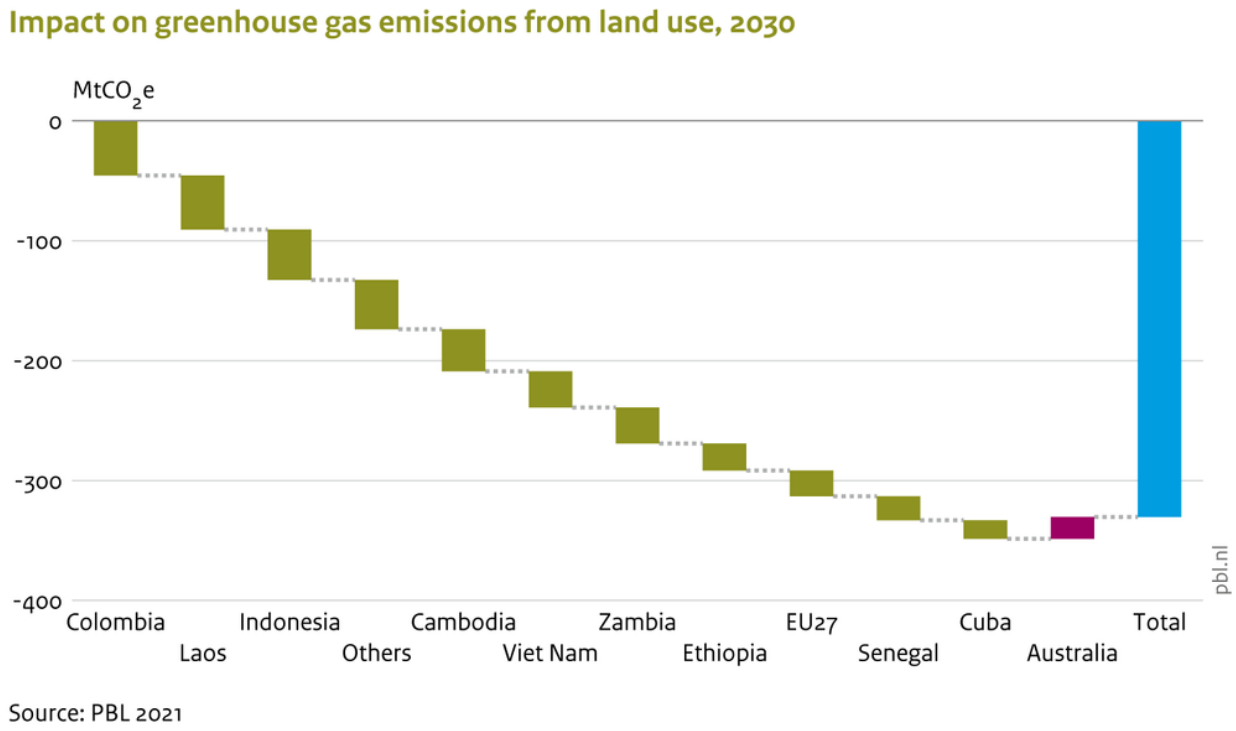

Figure 5

Impact of the emissions and their removal from the LULUCF sector by 2030. A negative estimate, here, reflects an enhancement of GHG commitments for the LULUCF sector within the updated NDCs, as compared to the previous NDCs. Others here shows the combined contribution for Mongolia, Papua New Guinea, Suriname, Chile, Mexico and Macedonia.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupInfoAnalysisimpactnewNDCs2October2021.docx