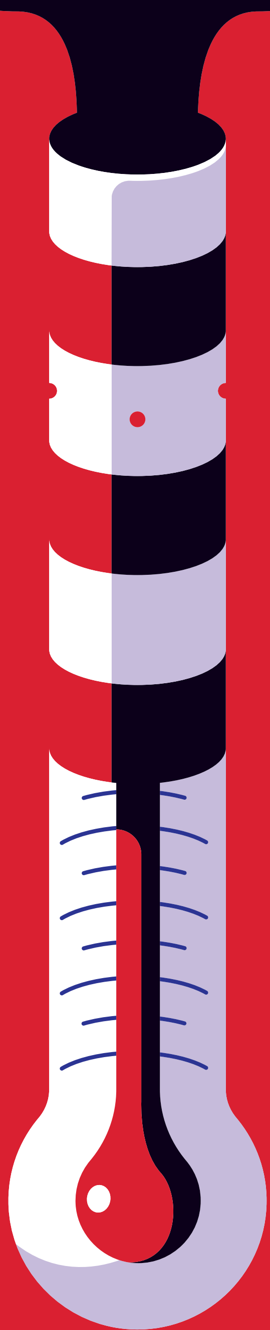
The Heat Is On

A world of climate promises not yet delivered



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Emissions Gap Report 2021

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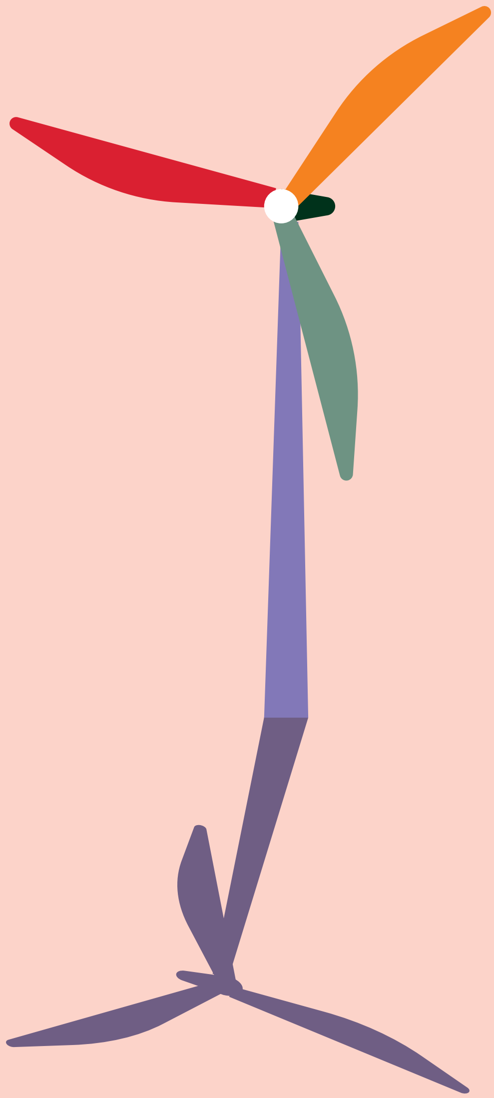
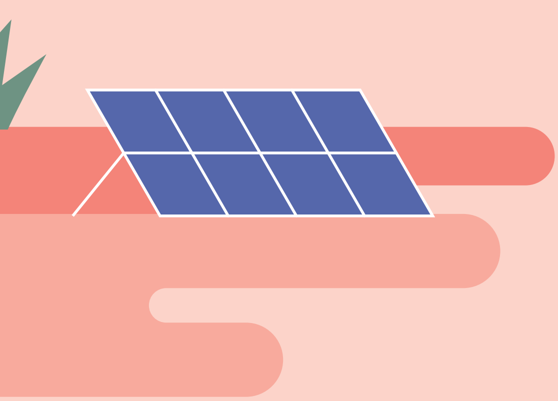




Glossary

This glossary is compiled according to the Lead Authors of the Report drawing on glossaries and other resources available on the websites of the following organizations, networks and projects: Intergovernmental Panel on Climate Change, United Nations Environment Programme, United Nations Framework Convention on Climate Change and World Resources Institute.

Anthropogenic methane: Methane emissions derived from human activities. Anthropogenic emission sources include coal mining, agricultural practices, wastewater treatment, certain industrial processes and oil and gas systems, among others.

Baseline/reference: The state against which change is measured. In the context of climate change transformation pathways, the term 'baseline scenarios' refers to scenarios that are based on the assumption that no mitigation policies or measures will be implemented beyond those that are already in force and/or are legislated or planned to be adopted. Baseline scenarios are not intended to be predictions of the future, but rather counterfactual constructions that can serve to highlight the level of emissions that would occur without further policy effort. Typically, baseline scenarios are compared to mitigation scenarios that are constructed to meet different goals for greenhouse gas emissions, atmospheric concentrations or temperature change. The term 'baseline scenario' is used interchangeably with 'reference scenario' and 'no policy scenario' In much of the literature, the term is also synonymous with the term 'business as usual (BAU) scenario', although the term 'BAU' has fallen out of favour because the idea of 'business as usual' in century-long socioeconomic projections is hard to fathom.

Carbon border adjustment mechanisms: Mechanisms that act to equalize the price of carbon between domestic products and imports to eliminate financial incentives in order to relocate production outside of regions with strong climate controls.

Carbon dioxide emission budget (or carbon budget): For a given temperature rise limit, for example a 1.5°C or 2°C long-term limit, the corresponding carbon budget reflects the total amount of carbon emissions that can be emitted for temperatures to stay below that limit. Stated differently, a carbon budget is the area under a carbon dioxide (CO_2) emission trajectory that satisfies assumptions about limits on cumulative emissions estimated to avoid a certain level of global mean surface temperature rise.

Carbon dioxide equivalent (CO_2e): A way to place emissions of various radiative forcing agents on a common footing by accounting for their effect on climate. It describes, for a given mixture and amount of greenhouse gases, the amount of CO_2 that would have the same global warming ability, when measured over a specified time period. For the purpose of this report, greenhouse gas emissions (unless otherwise specified) are the sum of the basket of greenhouse gases listed in Annex A to the Kyoto Protocol, expressed as CO_2e assuming a 100-year global warming potential.

Carbon markets: A term for a carbon trading system through which countries may buy or sell units of greenhouse gas emissions in an effort to meet their national limits on emissions, either under the Kyoto Protocol or other agreements, such as that among member states of the European Union. The term comes from the fact that CO_2 is the predominant greenhouse gas, and other gases are measured in units called carbon dioxide equivalent.

Carbon neutrality: This is achieved when an actor's net contribution to global CO_2 emissions is zero. Any CO_2 emissions attributable to an actor's activities are fully compensated by CO_2 reductions or removals exclusively claimed by the actor, irrespective of the time period or the relative magnitude of emissions and removals involved.

Carbon offset: See Offset.

Carbon price: The price for avoided or released CO_2 or CO_2e emissions. This may refer to the rate of a carbon tax or the price of emission permits. In many models that are used to assess the economic costs of mitigation, carbon prices are used as a proxy to represent the level of effort in mitigation policies.

Clean development mechanism (CDM): A mechanism under the Kyoto Protocol, the purpose of which, in accordance with article 12 of the Protocol, is to assist non-Annex I parties in achieving sustainable development and in contributing to the ultimate objective of the United Nations Framework Convention on Climate Change, and to assist Annex I parties in achieving compliance with their quantified emissions limitation and reduction commitments under article 3 of the Protocol.

Conditional nationally determined contribution (NDC): An NDC proposed by some countries that are contingent on a range of possible conditions, such as the ability of national legislatures to enact the necessary laws, ambitious action from other countries, realization of finance and technical support, or other factors.

Conference of the Parties (COP): The supreme body of the United Nations Framework Convention on Climate Change. It currently meets once a year to review the Convention's progress.

Double counting: Double counting involves two countries taking credit for the same emissions reductions, thereby giving the impression that the world has reduced emissions more than it actually has. For example, emissions reduction credits from one country might be sold to another country, but the reductions may still be counted towards the achievement of the NDC of the country where the credits originated.

Emission pathway: The trajectory of annual greenhouse gas emissions over time.

Emissions trading: One of the three Kyoto mechanisms, by which an Annex I party may transfer Kyoto Protocol units to, or acquire units from, another Annex I party. An Annex I party must meet specific eligibility requirements to participate in emissions trading.

EU Emissions Trading System (ETS): The EU ETS is a trading system for carbon emissions and the first international emissions trading system in the world. The EU ETS covers the following sectors and gases: electricity and heat generation, energy-intensive industry sectors (including oil refineries, steel works and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals, commercial aviation within the European Economic Area), nitrous oxide from production of nitric, adipic and glyoxylic acids and glyoxal, and perfluorocarbons from production of aluminium.

Global warming potential: An index representing the combined effect of the differing times greenhouse gases remain in the atmosphere and their relative effectiveness in absorbing outgoing infrared radiation.

Greenhouse gases: The atmospheric gases responsible for causing global warming and climatic change. The major greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Less prevalent, but very powerful, GHGs are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

Greenhouse gas removal: Withdrawal of a greenhouse gas and/or a precursor from the atmosphere by a sink.

Integrated assessment models: Models that seek to combine knowledge from multiple disciplines in the form of equations and/or algorithms in order to explore complex environmental problems. As such, they describe the full chain of climate change, from production of greenhouse gases to atmospheric responses. This necessarily includes relevant links and feedbacks between socioeconomic and biophysical processes.

Intended nationally determined contribution (INDC): INDCs are submissions from countries describing the national actions that they intend to take to reach the Paris Agreement's long-term temperature goal of limiting warming to well below 2°C. Once a country has ratified the Paris Agreement, its INDC is automatically converted to its NDC, unless it chooses to further update it.

Katowice Climate Package: The Katowice Climate Package, also known as 'the Katowice outcome ', is a complex package containing operational guidance on information provision, communication and rules for the functioning of the climate transparency framework, the global stocktaking of overall progress and the evaluation of progress, and the provision of prior information on financial assistance. The package sets out the essential procedures and mechanisms that operationalized the Paris Agreement. The guidelines of the package aim to build greater trust and strengthen international cooperation.

Kyoto Protocol: An international agreement, standing on its own, and requiring separate ratification by governments, but linked to the United Nations Framework Convention on Climate Change. The Kyoto Protocol, among other things, sets binding targets for the reduction of greenhouse gas emissions by industrialized countries.

Land use, land-use change and forestry (LULUCF): A greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land-use change and forestry activities.

Leakage: A phenomenon whereby the reduction in emissions (relative to a baseline) in a jurisdiction/sector associated with the implementation of mitigation policy is offset to some degree by an increase outside the jurisdiction/sector through induced changes in consumption, production, prices, land use and/or trade across the jurisdictions/sectors. Leakage can occur at a number of levels: project, state, province, nation or world region.

Least-cost pathway: Such scenarios identify the least expensive combination of mitigation options to fulfil a specific climate target. A least-cost scenario is based on the premise that, if an overarching climate objective is set, society wants to achieve this at the lowest possible costs over time. It also assumes that global actions start at the base year of model simulations (usually close to the current year) and are implemented following a cost-optimal (cost-efficient) sharing of the mitigation burden between current and future generations depending on the social discount rate.

Likely chance: A likelihood greater than 66 per cent chance. Used in this assessment to convey the probabilities of meeting temperature limits.

Mitigation: In the context of climate change, mitigation relates to a human intervention to reduce the sources, or enhance the sinks of greenhouse gases. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings and expanding forests and other 'sinks' to remove greater amounts of CO_2 from the atmosphere.

Nationally determined contribution (NDC): Submissions by countries that have ratified the Paris Agreement which presents their national efforts to reach the Paris Agreement's long-term temperature goal of limiting warming to well below 2°C. New or updated NDCs were expected to be submitted in 2020 and should be submitted every five years thereafter. NDCs thus represent a country's current ambition/target for reducing emissions nationally.

Offset (in climate policy): A unit of CO_2e emissions that is reduced, avoided or sequestered to compensate for emissions occurring elsewhere.

Recovery-type measure: Fiscal, monetary or regulatory intervention by a government to reinvigorate economic activity in response to a crisis.

Rescue-type measure: Immediate fiscal, monetary or regulatory intervention by a government to protect citizens' lives and socioeconomic well-being and/or to provide emergency support to businesses and the economy in response to a crisis.

Scenario: A description of how the future may unfold based on 'if-then' propositions. Scenarios typically include an initial socioeconomic situation and a description of the key driving forces and future changes in emissions, temperature or other climate change-related variables.

Shared Socioeconomic Pathways (SSP): Scenarios of projected socioeconomic global changes up to 2100. They are used to derive greenhouse gas emissions scenarios associated with different climate policies scenarios.

Source: Any process, activity or mechanism that releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol into the atmosphere.

Foreword

Climate change is no longer a future problem. It is a 'now' problem. As we saw this year, devastating impacts are spreading across the globe and growing ever stronger. The Intergovernmental Panel on Climate Change told us a few months ago that we have a 50 per cent chance of exceeding a 1.5°C temperature threshold within the next few decades.

Climate action so far has been characterized by weak promises, not yet delivered. As the Emissions Gap Report 2021 shows, the updated nationally determined contributions (NDCs) under the Paris Agreement fall into the same trap. These pledges only take 7.5 per cent off predicted 2030 emissions, compared to the previous round of commitments. This is far from adequate. Reductions of 30 per cent are needed to stay on the least-cost pathway for 2°C and 55 per cent for 1.5°C.

If nations only implement unconditional NDCs as they stand, we are likely to hit global warming of about 2.7°C by the end of the century. Current net-zero pledges could cut another 0.5°C off global warming – but these pledges are still ambiguous, delayed in many cases and not folded into NDCs. At the same time, this year's Emissions Gap Report shows that the opportunity to use pandemic recovery spending to reduce emissions has been largely missed.

To get on track to limit global warming to 1.5°C, the world needs to take an additional 28 gigatons of carbon dioxide equivalent ($GtCO_2e$) off annual emissions by 2030, over and above what is promised in updated unconditional NDCs. For the 2°C Paris Agreement target, the additional need is lower: a drop in annual emissions of 13 $GtCO_2e$ by 2030. To be clear: we have eight years to make the plans, put in place the policies, implement them and ultimately deliver the cuts. The clock is ticking loudly.

Nations must put in place the policies to meet their new commitments and start implementing them immediately. Then they must zero in on net zero, ensuring these long-term commitments are linked to the NDCs, and that action is brought forward. It is time to get the policies in place to back the raised ambitions and, again, start implementing them. This cannot happen in five years. Or in three years. This needs to start happening now.

We can still do it. As this year's Emissions Gap Report shows, there is huge potential for large cuts in methane emissions from the oil and gas, waste and agriculture sectors. Carbon markets could help to accelerate action by decreasing mitigation costs. COVID-19 recovery funding can still be greened. And as previous UNEP Emissions Gap Reports show, there is potential in nature-based solutions, renewables, energy efficiency and so much more.

We should not despair. We have already shown that climate action can make a difference. In 11 years, from 2010 to 2021, we have put in place policies that will lower annual emissions by 11 $GtCO_2e$ in 2030 compared to what would have happened without these policies. But we need to make the difference, not a difference. We cannot keep doing the same things and expect a better result.

The world has to wake up to the imminent peril we face as a species. We need to go firm. We need to go fast. And we need to start doing it now.

Inger Andersen

Executive Director
United Nations Environment Programme

Executive summary

Introduction

This twelfth edition of the United Nations Environment Programme (UNEP) Emissions Gap Report comes during a year of constant reminders that climate change is not in the distant future. Extreme weather events around the world – including flooding, droughts, wildfires, hurricanes and heatwaves – have continuously hit the news headlines. Thousands of people have been killed or displaced and economic losses are measured in the trillions. Bearing witness to the increasingly clear signs of climate change, the Intergovernmental Panel on Climate Change (IPCC) published the first report in its Sixth Assessment cycle addressing the "Physical Science Basis" in August 2021. Dubbed a "code red for humanity" by the United Nations Secretary-General, the IPCC report documents in far greater detail and with higher certainty than previous assessments how climate change and extreme events can be attributed to the build-up of anthropogenic greenhouse gas (GHG) emissions in the atmosphere. There is a fifty-fifty chance that global warming will exceed 1.5°C in the next two decades, and unless there are immediate, rapid and large-scale reductions in GHG emissions, limiting warming to 1.5°C or even 2°C by the end of the century will be beyond reach.

Building on the new evidence from the IPCC, the twenty-sixth United Nations Climate Change Conference of the Parties (COP26) is charged with the growing urgency of accelerating global ambition and action on both mitigation and adaptation. This year, the spotlight is on the new and updated nationally determined contributions (NDCs) that countries were requested to submit in advance of COP26. As the September 2021 version of the NDC Synthesis Report published by the United Nations Framework Convention on Climate Change (UNFCCC) illustrates, the new and updated NDCs are insufficient to achieve the temperature goal of the Paris Agreement.

This Emissions Gap Report confirms the findings of the UNFCCC report. It expands the assessment to consider announced mitigation pledges for 2030 in addition to the new and updated NDCs. The report shows that new or updated NDCs and announced pledges for 2030 have only limited impact on global emissions and the emissions gap in 2030, reducing projected 2030 emissions by only 7.5 per cent, compared with previous unconditional NDCs, whereas 30 per cent is needed to limit warming to 2°C and 55 per cent is needed for 1.5°C. If continued throughout this century, they would result in warming of 2.7°C. The achievement of the net-zero pledges that an increasing number of countries are committing to would improve the situation, limiting warming to about 2.2°C by the end of the century. However, the 2030 commitments do not yet set G20 members (accounting for close to 80 per cent of GHG emissions) on a clear path towards net zero.

Moreover, G20 members as a group do not have policies in place to achieve even the NDCs, much less net zero. Turning to some of the opportunities for bridging the emissions gap and getting on track to net zero, the report assesses the extent to which COVID-19 fiscal recovery measures are used to accelerate a green transition. It examines the scope for reducing emissions from methane, the second-most-important GHG in terms of current anthropogenic climate forcing, to bridge the gap and get on track to net zero. Finally, the report looks into a key negotiation issue for COP26: reaching agreement on how to move forward with article 6 of the Paris Agreement dealing with cooperative approaches and market mechanisms. A large number of countries have included the use of market mechanisms in their NDC implementation plans and are waiting for the modalities to be agreed. At the same time, the use of markets and offsets in meeting net-zero emission goals is often unclear.

As in previous years, the 2021 Emissions Gap Report has been guided by an experienced steering committee and prepared by an international team of leading scientists, assessing all available information, including that published in the context of the IPCC reports, as well as in other recent scientific literature. The assessment process has been transparent and participatory. The assessment methodology and preliminary findings were made available to the governments of the countries specifically mentioned in the report to give them an opportunity to comment on the findings.

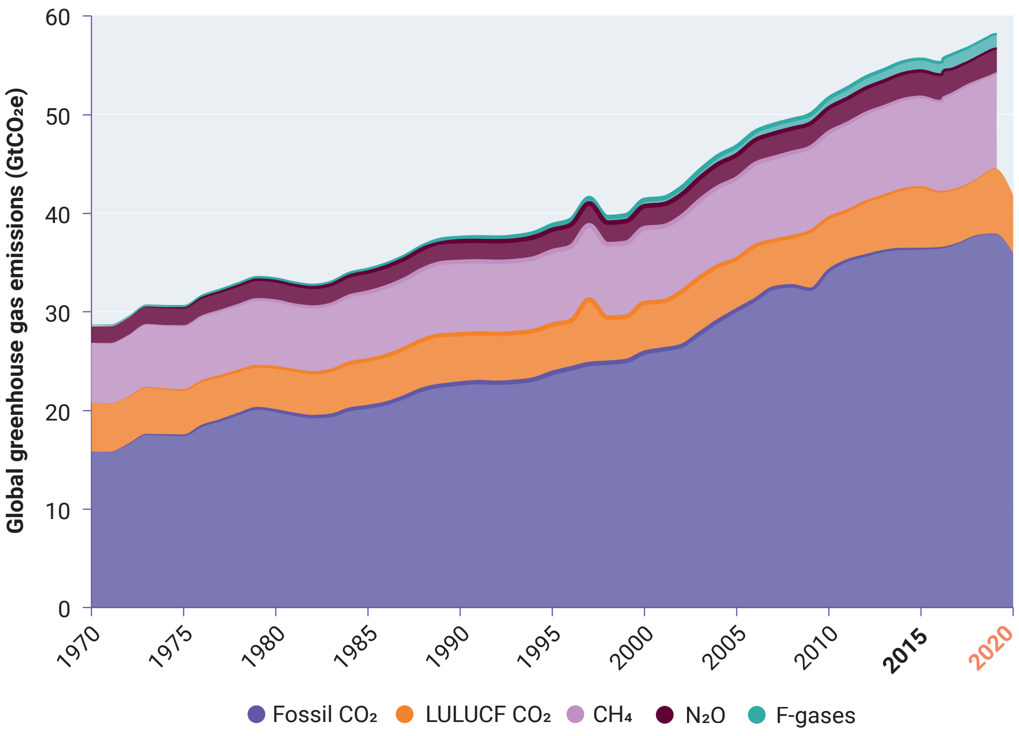
1. Following an unprecedented drop of 5.4 per cent in 2020, global carbon dioxide emissions are bouncing back to pre-COVID levels, and concentrations of GHGs in the atmosphere continue to rise.

- The COVID-19 pandemic led to an unprecedented 5.4 per cent drop in global fossil carbon dioxide (CO_2) emissions in 2020 (figure ES.1). Data are not yet available for all GHG emissions in 2020, but the drop in total global GHG emissions is anticipated to be smaller than the drop in fossil CO_2 emissions.

- A strong rebound in emissions is expected in 2021. Preliminary estimates suggest fossil energy CO_2 emissions could grow by 4.8 per cent in 2021 (excluding cement), and global emissions in 2021 are expected to be only slightly lower than the record level of 2019.

- Despite the large decline in CO_2 emissions in 2020, the concentration of CO_2 in the atmosphere grew by around 2.3 parts per million, in line with recent trends. It is unlikely that the reductions in emissions in 2020 will be detectible in the atmospheric growth rate, as the natural variability of around one part per million is far greater than the effect of a 5.4 per cent reduction in CO_2 emissions in a single year. Solving the climate problem requires rapid and sustained reductions in emissions.

Figure ES.1. Global greenhouse gas emissions from all sources, 1970–2020

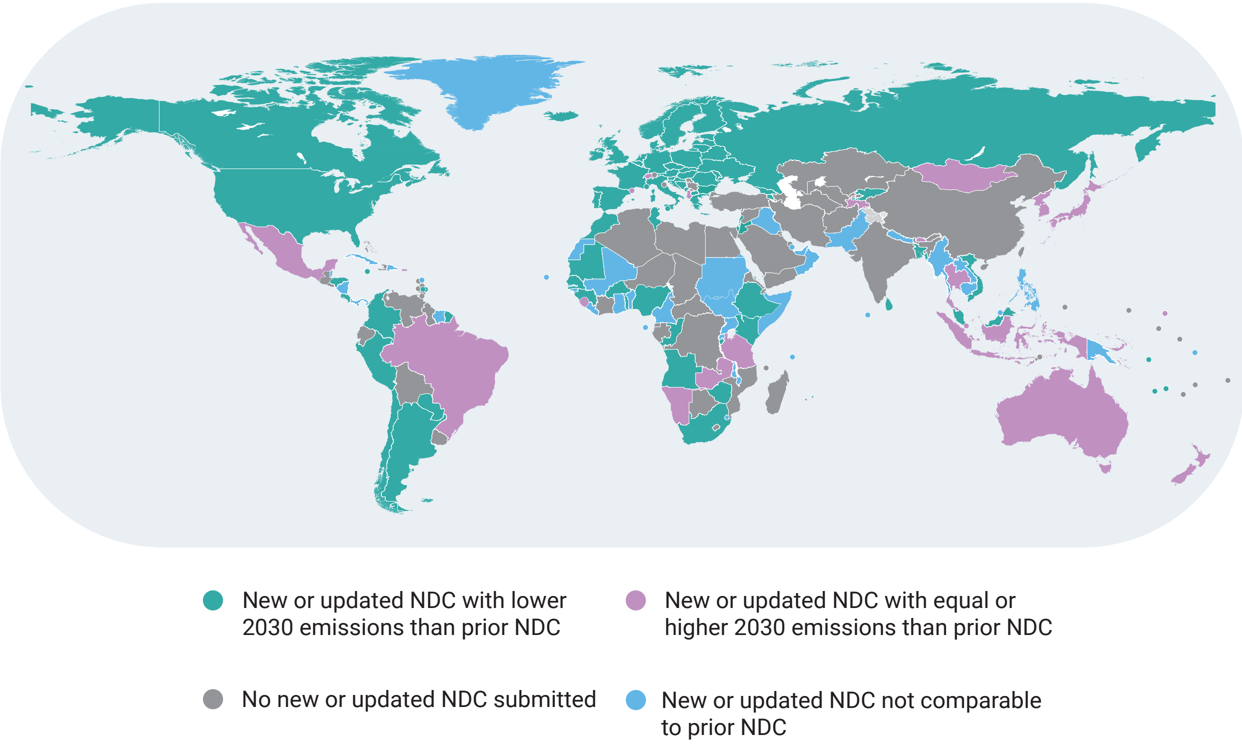


2. New mitigation pledges for 2030 show some progress, but their aggregate effect on global emissions is insufficient.

- As at 30 September 2021, 120 countries (121 parties, including the European Union and its 27 member states) representing just over half of global GHG emissions, have communicated new or updated NDCs. This year's assessment considers the new or updated NDCs communicated to the UNFCCC as well as announcements of new mitigation pledges for 2030 by China, Japan and the Republic of Korea not submitted as NDCs by 30 September.

- Just under half (49 per cent) of the new or updated NDCs submitted (from countries accounting for 32 per cent of global emissions) result in lower 2030 emissions than the previous NDC. Around 18 per cent of the NDCs (from countries accounting for 13 per cent of global emissions) will not reduce 2030 emissions relative to the previous NDC. The remaining 33 per cent of NDCs (from countries accounting for 7 per cent of global emissions) contain insufficient detail to assess their impact on emissions relative to the previous NDC (figure ES.2). Typically, this is due to a lack of information in the previous NDC, rather than the current one; the current NDCs are more transparent.

Figure ES.2. Effect of new or updated nationally determined contributions on 2030 greenhouse gas emissions relative to previous nationally determined contributions



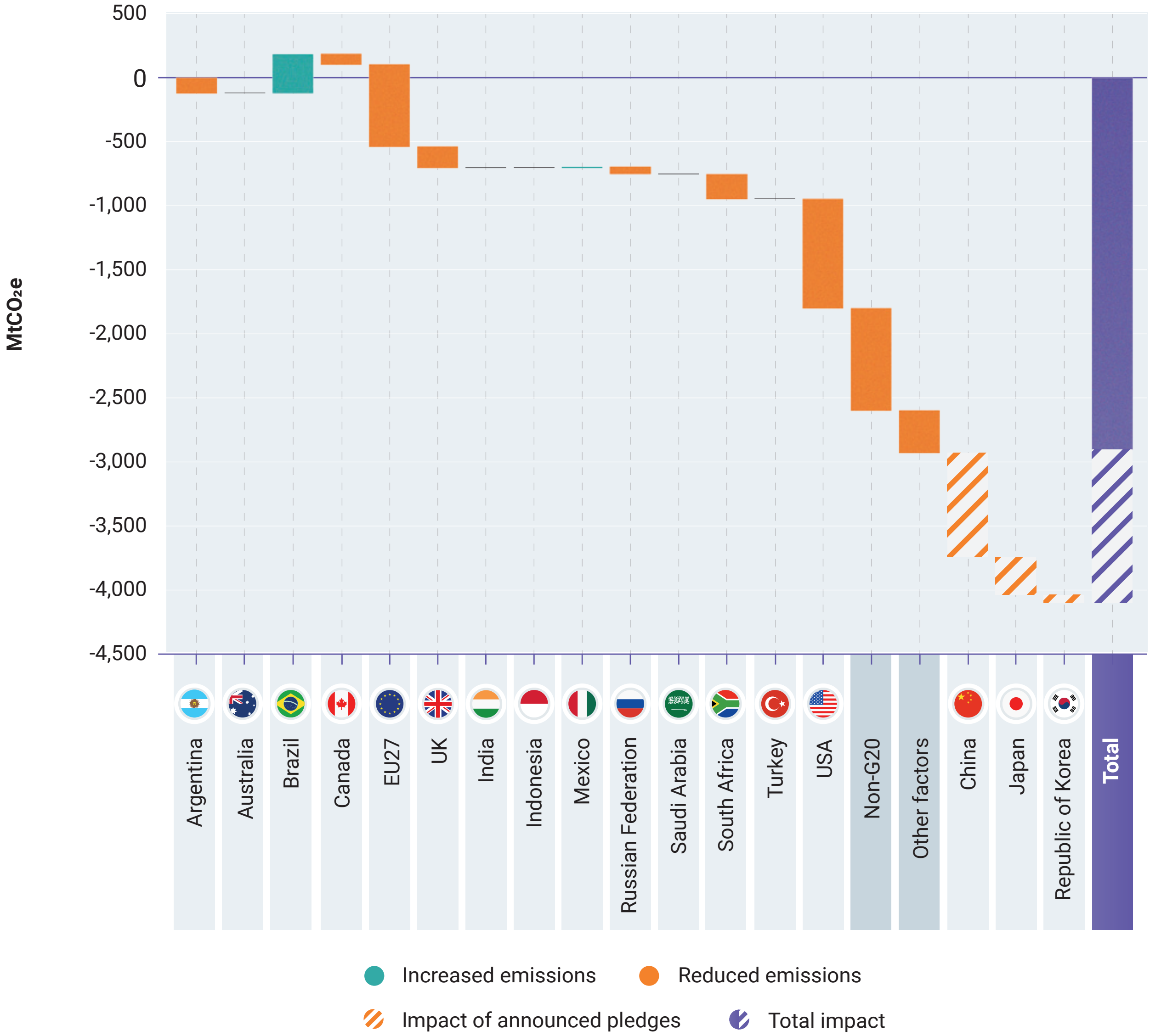
- Of the countries that have submitted new or updated NDCs, more (89 per cent) have GHG targets than before (75 per cent). However, these targets are only marginally more comprehensive in terms of sector and gas coverage. The share of new or updated NDCs that are completely unconditional has increased from 24 per cent to 26 per cent, while the share of NDCs that are completely conditional has dropped from 31 per cent to 18 per cent.

- The **aggregate impact of the new or updated NDCs** formally submitted is limited: new or updated unconditional NDCs are estimated to lead to a total reduction in 2030 global GHG emissions of about 2.9 gigatons of CO_2 equivalent ($GtCO_2e$), compared with the previous NDCs (figure ES.3). This estimate includes reductions of around 0.3 $GtCO_2e$ resulting from **other factors**, including lower projections of international aviation and shipping emissions, and adjustments of countries that are projected to overachieve their NDC targets. If the announced pledges of China, Japan and the Republic of Korea are also included, this aggregate reduction increases to just over 4 $GtCO_2e$. The impact of conditional targets is of similar magnitude.

- Taking a closer look at the **G20 members**, the combined impact of submitted NDCs and announced GHG reduction targets for 2030 is an annual reduction of about 3 $GtCO_2e$ compared with the previous NDCs. Six G20 members have formally submitted updated NDCs with enhanced GHG mitigation pledges: Argentina, Canada, the EU27 (counting the EU27 and its three individual G20 member states France, Germany and Italy as one), South Africa, the United Kingdom and the United States of America – all of which entail reduced emissions in 2030 of about 2.1 $GtCO_2e$ compared with previous NDCs. Two G20 members (Brazil and Mexico) have submitted targets that lead to an increase in emissions of 0.3 $GtCO_2e$, bringing the net reduction in global GHG emissions of new or updated NDCs submitted by G20 members to 1.8 $GtCO_2e$ annually by 2030. In addition, China, Japan and the Republic of Korea have announced enhanced pledges that result in annual reductions of about 1.2 $GtCO_2e$, but have not yet formally communicated them to the UNFCCC.

- The largest reductions come from the United States of America, the EU27, the United Kingdom, Argentina and Canada (submitted) and China and Japan (announced). Two G20 members (Australia and Indonesia) have submitted NDC targets, which are assessed not to lead to additional reduction relative to the previous NDCs. One G20 member (the Russian Federation) has submitted an NDC that improves upon its previous NDC, but still does not go beyond its current policies and another three G20 members (India, Saudi Arabia and Turkey) have not yet submitted a new or updated NDC.

Figure ES.3. Impact of 2030 pledges (nationally determined contributions and other announced pledges) on 2030 global emissions compared with previous nationally determined contribution submissions



- In comparison, the aggregate impact of the new or updated NDC submissions for the **non-G20 members** is an annual reduction of 0.8 $GtCO_2e$ by 2030.

3. As a group, G20 members are not on track to achieve either their original or new 2030 pledges. Ten G20 members are on track to achieve their previous NDCs, while seven are off track.

- When considering the impact of new pledges, it should be noted that collectively the G20 members are not yet on track to achieve their previous NDCs. If current policy projections are used for those countries where policy projections are lower than what NDCs would deliver, the G20 members as a group are projected to fall short of achieving their unconditional NDCs by 1.1 $GtCO_2e$ annually.

- Only 10 G20 members (Argentina, China, EU27, India, Japan, the Russian Federation, Saudi Arabia, South Africa, Turkey and the United Kingdom) are likely to achieve their original unconditional NDC targets under current policies. Among them, three members (India, the Russian Federation and Turkey) are projected to reduce their emissions to levels at least 15 per cent lower than their previous unconditional NDC emissions target levels under current policies, indicating that these countries have significant room for raising their NDC ambition. As at 30 September 2021, India and Turkey have not yet submitted a new or updated NDC, while the Russian Federation has submitted a new NDC that reduces emissions, but still results in higher emissions than implied by current policies.

Australia, Brazil, Canada, Mexico, the Republic of Korea and the United States of America are all assessed to require stronger policies to achieve prior NDCs, while there is insufficient information to assess the progress of Indonesia.

- G20 members have adopted a range of policies in recent years. While there are many positive developments, there are also negative examples, such as fossil fuel extraction projects and coal-fired power plant construction plans moving forward as well as rollback of environmental regulations during the COVID-19 pandemic. Based on the central estimates of independent studies, a large number of G20 members (Argentina, Brazil, China, India, Indonesia, Mexico, the Russian Federation and Saudi Arabia) are expected to emit more in 2030 under implemented policies than they did in 2010.

- Collectively, the G20 members are projected to fall short of their new or updated unconditional NDCs and other announced mitigation pledges for 2030. This is to be expected and it would indicate a lack of enhanced ambition if the new 2030 pledges were projected to be achieved with currently implemented policies. It is worth noting that Canada and the United States of America have submitted strengthened NDC targets, while independent studies suggest that they are not on track to meet their previous NDC targets with currently implemented policies. These two countries therefore need to make significant additional efforts to meet their new NDC targets.

4. A promising development is the announcement of long-term net-zero emissions pledges by 52 parties, covering more than half of global emissions. However, these pledges show large ambiguities.

- Net-zero emissions is a state where the sum of all anthropogenic emissions and removals is zero. Net-zero emissions targets are being defined in a variety of ways – the most important aspect from a global geophysical perspective being whether they cover all GHGs or CO_2 only. Global net-zero CO_2 emissions stabilize global warming, whereas net-zero GHG emissions result in a peak then a decline in global warming. To align with a 1.5°C limit, global CO_2 emissions must reach net zero around 2050, with global GHG emissions reaching net zero 15–20 years later. A delay of 15–20 years in either net-zero CO_2 or net-zero GHGs implies limiting warming to 2°C rather than 1.5°C.

- Globally, 51 countries and one party (the EU27 in addition to the net-zero pledges made by its individual member states) have pledged a net-zero emissions target that is stated in national legislation, in a policy document or in a public announcement by the government or a high-level government official. These pledges cover more than half of current global domestic GHG emissions, over half of gross domestic product (GDP) and one third of the global population. Thirteen targets covering 12 per cent of global emissions are enshrined in law.

- By number, the majority of these targets (40) are for 2050, coincident with the mid-century timescale for global CO_2 emissions indicated by the IPCC as necessary for limiting warming to 1.5°C. Eight targets are aimed at earlier years (2030–2045) and four at later years. In terms of emissions, however, the targets are split almost entirely and equally between 2050 (due to the European Union and United States of America pledges) and 2060 (due to China's pledge).

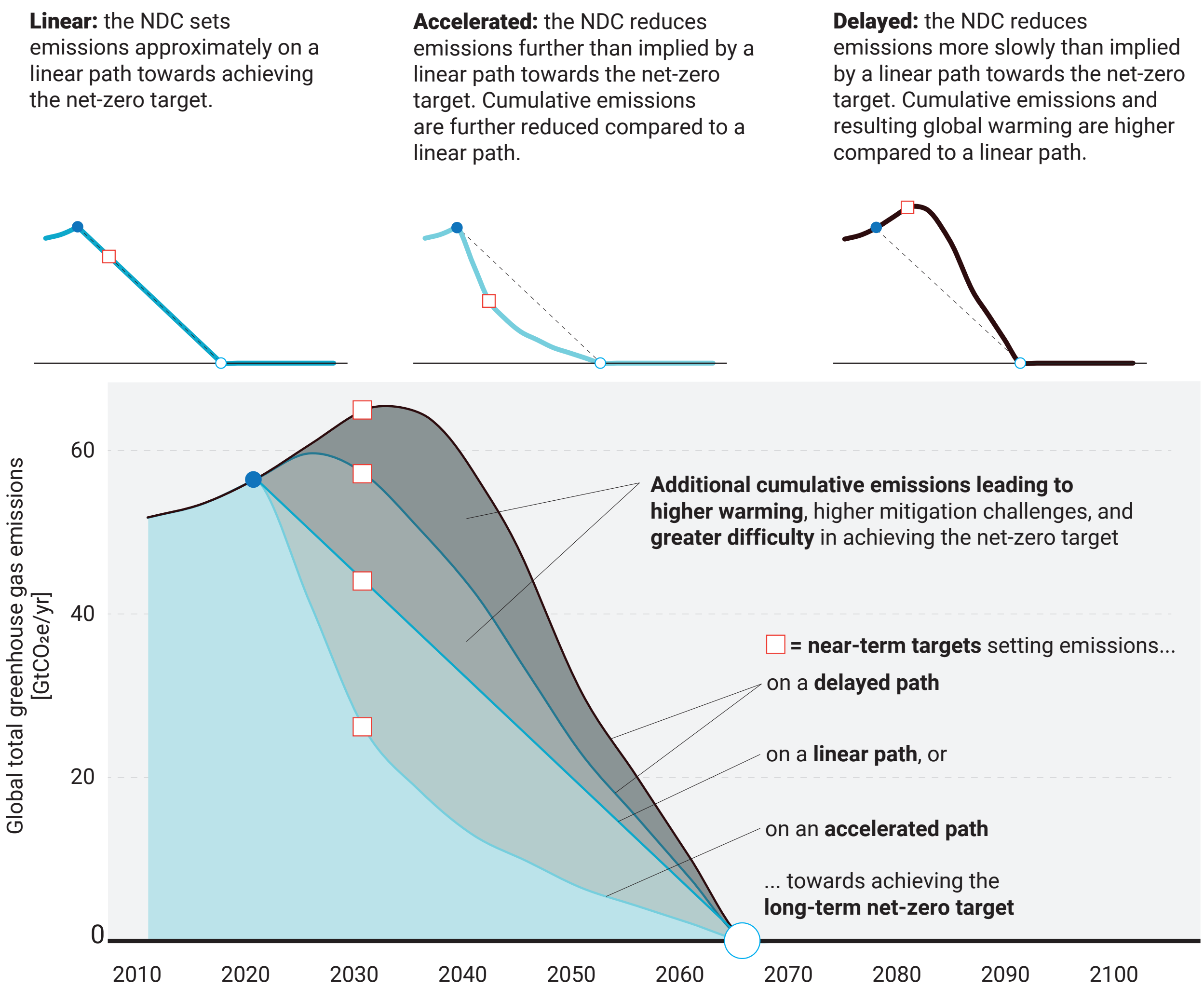
- Existing targets show variations in scope and large ambiguities with respect to the inclusion of sectors and GHGs. The majority are furthermore unclear or undecided on the inclusion of emissions from international aviation and shipping and the use of international offsets.

5. Few of the G20 members' NDC targets put emissions on a clear path towards net-zero pledges. There is an urgent need to back these pledges up with near-term targets and actions that give confidence that net-zero emissions can ultimately be achieved and the remaining carbon budget kept.

- Twelve G20 members covering just over half of global domestic GHG emissions have currently pledged a net-zero target, of which six are in law, two are in policy documents and four are government announcements. All are for the year 2050, with the exception of China's 2060 target and Germany's target for 2045. The remaining eight G20 members have so far not set net-zero targets, but three of them have communicated long-term low GHG emission development strategies to the UNFCCC (Indonesia, Mexico and South Africa).

- G20 pledges also show ambiguity. Most targets are unclear or undecided on the inclusion of offsets and of international aviation and shipping emissions. Lack of clarity is also notable on coverage of sectors and gases, but pledges that are clear show

Figure ES.4. Near-term targets are critical to set global emissions on a clear path towards achieving long-term net-zero targets and stringent climate goals



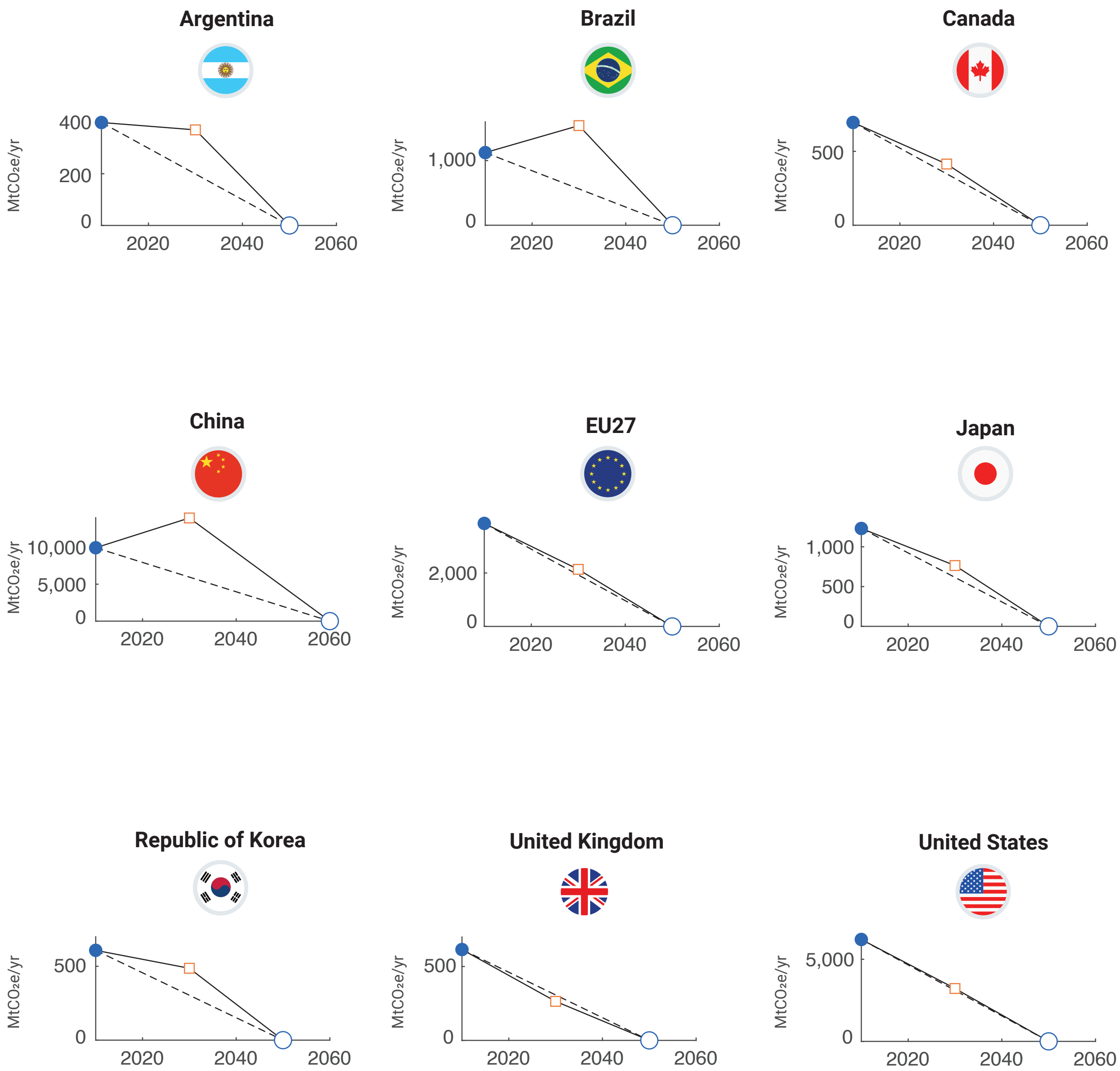
a tendency for comprehensive coverage. However, most show a lack of transparency regarding the approach taken to fairness, the plans for achievement (including on use of removals), and progress reporting and review. Only Canada, the European Union, France, Germany and the Republic of Korea have published their plans at the time of completing this report, and only these countries plus the United Kingdom have accountable processes for reviewing their targets.

- The pathway to net zero counts: the path followed from today until net-zero CO_2 emissions are reached determines the total amount of emitted CO_2 and thereby the total carbon budget used (see bullet below). Whether a linear, an accelerated, or a delayed path is followed will affect the climate outcome (figure ES.4).

- Global warming is close to linearly proportional to the total net amount of CO_2 that has ever been emitted in the atmosphere as a result of human activities. Therefore, limiting global warming to a specified level requires that the total amount of CO_2 emissions ever emitted be kept within a finite carbon budget. New IPCC estimates put the remaining carbon budget to limit warming to 1.5°C relative to pre-industrial levels, with 66 per cent chance, at 400 $GtCO_2$. For 2°C, the estimate is 1,150 $GtCO_2$. Current annual global CO_2 emissions are above 40 $GtCO_2$/year, meaning that urgent and deep emissions reductions over the next decade are required to stay within the remaining budgets.

- As an indication of the consistency between nearer-term actions and net-zero targets, figure ES.5 plots the emissions paths for a subgroup of G20 members implied by their current NDCs and

Figure ES.5. Overview of net-zero pathways implied by climate pledges by selected G20 members



Note: Only G20 members with net zero targets are included. Member states of the European Union have no separate assessment of their path to net zero, because their NDC is not assessed separately as part of this report.

their net-zero target. Of the nine G20 members for which an emissions path can be estimated based on their net-zero target and their NDC, none have NDC targets that put them on an accelerated path towards their net-zero emissions targets. Five of these nine members, accounting for about one fifth of global domestic GHG emissions, have NDC targets that put the country's domestic emissions onto a linear path towards achieving their net-zero targets. In the other four cases, the NDCs lead to emissions in 2030 that are about 25 per cent to 95 per cent higher than a linear path towards their net-zero targets would imply. Recognizing that countries face very different circumstances, these countries urgently need strengthened and more ambitious near-term climate plans for their net-zero targets to remain achievable.

- There is an urgent need for (i) more G20 members – and indeed all countries – to pledge net-zero emissions, (ii) all countries to increase the robustness of their net-zero pledges, and (iii) all net-zero targets to be backed up by near-term actions that give confidence that the net-zero targets can ultimately be achieved.

6. The emissions gap remains large: compared to previous unconditional NDCs, the new pledges for 2030 reduce projected 2030 emissions by only 7.5 per cent, whereas 30 per cent is needed for 2°C and 55 per cent is needed for 1.5°C.

- As in previous reports, the emissions gap for 2030 is defined as the difference between total global GHG emissions from least-cost scenarios that keep global warming to 2°C, 1.8°C or 1.5°C with varying levels of likelihood and the estimated total global GHG emissions resulting from the full implementation of the NDCs.

- This year, the NDC scenario has been expanded to include all the most recent NDCs (new or updated NDCs if submitted, and previous NDCs otherwise) as well as all officially announced climate change mitigation pledges for 2030 with a cut-off date of 30 August 2021. The three least-cost scenarios consistent with the Paris Agreement have been updated and their temperature outcomes re-assessed based on the Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. As a result, global emissions in 2030 consistent with keeping global warming below 2.0°C with a 66 per cent chance are now estimated at 39 $GtCO_2e$, which is about 2 $GtCO_2e$ lower than in earlier reports. Similarly, the estimate for 1.8°C is about 2 $GtCO_2e$ lower than the 1.8°C estimate of previous reports. There are no changes to the 1.5°C estimate (table ES.1). This implies that while the aggregate effect on global emissions in 2030 of new or updated NDCs and announced pledges is estimated at 4 $GtCO_2e$ (see point two of this summary), the gap with respect to 2°C is only reduced by 2 $GtCO_2e$ compared with last year.

- The updated current policies scenario is estimated to reduce global GHG emissions in 2030 to about 55 $GtCO_2e$ (range: 52–58 $GtCO_2e$) in 2030, which is 4 $GtCO_2e$ lower than the median estimate of the 2020 Emissions Gap Report and 9 $GtCO_2e$ lower than the 2010-policies scenario (table ES.1). Around half of the decrease between the 2020 and 2021 Reports reflects climate policy progress in the countries, while the other half is because of the general slowdown of economies due to the COVID-19 pandemic.

- Collectively, countries are falling short of meeting their new or updated NDCs and announced pledges with current policies. This implementation gap in 2030 is 3 $GtCO_2e$ for unconditional NDCs and 5 $GtCO_2e$ for conditional NDCs.

- Compared to last year, the emissions gap is only slightly narrowed by the new or updated NDCs and announced mitigation pledges. By 2030, annual emissions need to be 13 $GtCO_2e$ (range: 10–16 $GtCO_2e$) lower than current unconditional NDCs imply for the 2°C goal, and 28 $GtCO_2e$ (range: 25–30 $GtCO_2e$) lower for the 1.5°C goal. Both estimates are for a 66 per cent chance of staying below the stated temperature limit. If conditional NDCs are also considered, these gaps are reduced by around 2 $GtCO_2e$ and 3 $GtCO_2e$ respectively (figure ES.6, table ES.1).

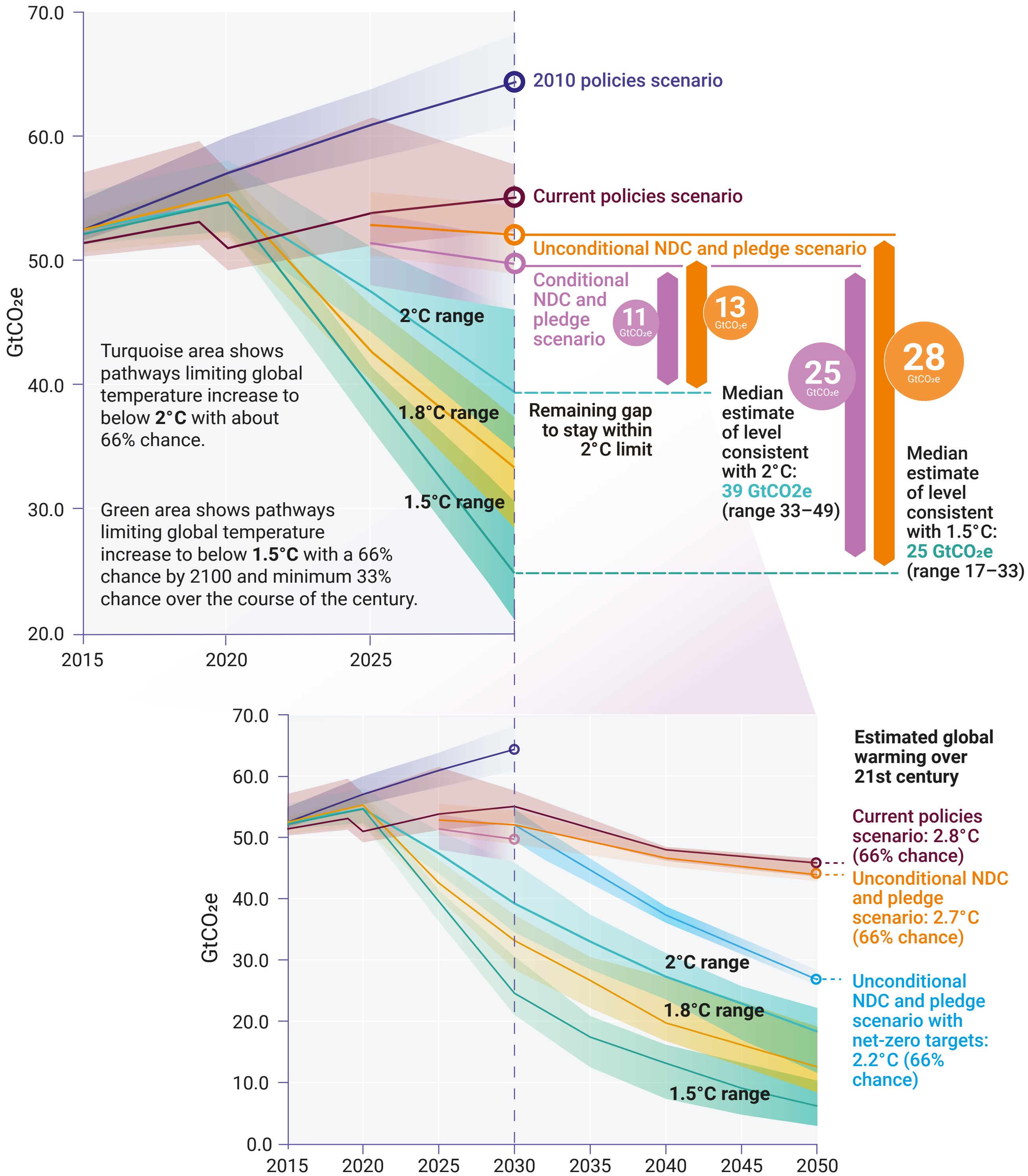
Table ES.1. Total global greenhouse gas emissions in 2030 under different scenarios, temperature implications, and the resulting emissions gap

Scenario (rounded to the nearest gigaton)	Number of scenarios in set	Global total emissions in 2030 [$GtCO_2e$]	Estimated temperature outcomes			Closest corresponding IPCC SR1.5 scenario class	Emissions gap in 2030 [$GtCO_2e$]		
			50% chance	66% chance	90% chance		Below 2.0°C	Below 1.8°C	Below 1.5°C
Year 2010 policies	6	64 (60–68)							
Current policies	9	55 (52–58)					15 (12–18)	22 (19–25)	30 (28–33)
Unconditional NDCs (updated NDCs and announcements)	8	52 (49–55)					13 (10–16)	19 (16–22)	28 (25–30)
Conditional NDCs (updated NDCs and announcements)	8	50 (46–52)					11 (7–13)	17 (13–19)	25 (22–28)
Below 2.0°C (66% chance)	71	39 (33–49)	Peak: 1.7–1.8°C In 2100: 1.3–1.7°C	Peak: 1.8–2.0°C In 2100: 1.5–1.9°C	Peak: 2.2–2.4°C In 2100: 1.9–2.4°C	Higher-2°C pathways			
Below 1.8°C (66% chance)	23	33 (27–41)	Peak: 1.6–1.7°C In 2100: 1.2–1.6°C	Peak: 1.7–1.8°C In 2100: 1.4–1.8°C	Peak: 2.0–2.2°C In 2100: 1.8–2.2°C	Lower-2°C pathways			
Below 1.5°C (66% chance in 2100 with no or limited overshoot)	26	25 (17–33)	Peak: 1.5–1.6°C In 2100: 1.0–1.3°C	Peak: 1.6–1.7°C In 2100: 1.2–1.5°C	Peak: 1.9–2.1°C In 2100: 1.5–1.9°C	1.5°C with no or limited overshoot			

7. Global warming at the end of the century is estimated at 2.7°C if all unconditional 2030 pledges are fully implemented and 2.6°C if all conditional pledges are also implemented. If the net-zero emissions pledges are additionally fully implemented, this estimate is lowered to around 2.2°C.

▶ To estimate the global warming implications at the end of this century, estimated emissions for the year 2030 are projected out to 2100, and their climate outcomes assessed using a climate model. This approach assumes a continuation of climate action beyond 2030, without further strengthening. Extrapolations until the end of the century are inherently uncertain and subject to scenario assumptions, such as the level at which climate action continues or technology costs. This uncertainty is currently of the order of ±0.5°C around the best-estimate 2.7°C projection, but is reduced to ±0.3°C when taking into account countries' net-zero targets. Furthermore, it should be noted that this year's estimates are based on improved methods and the latest climate assessment of Working Group I in the IPCC Sixth Assessment Report (AR6). These methodological updates alone lower temperature projections for unconditional NDCs by about 0.2°C compared to last year's estimates.

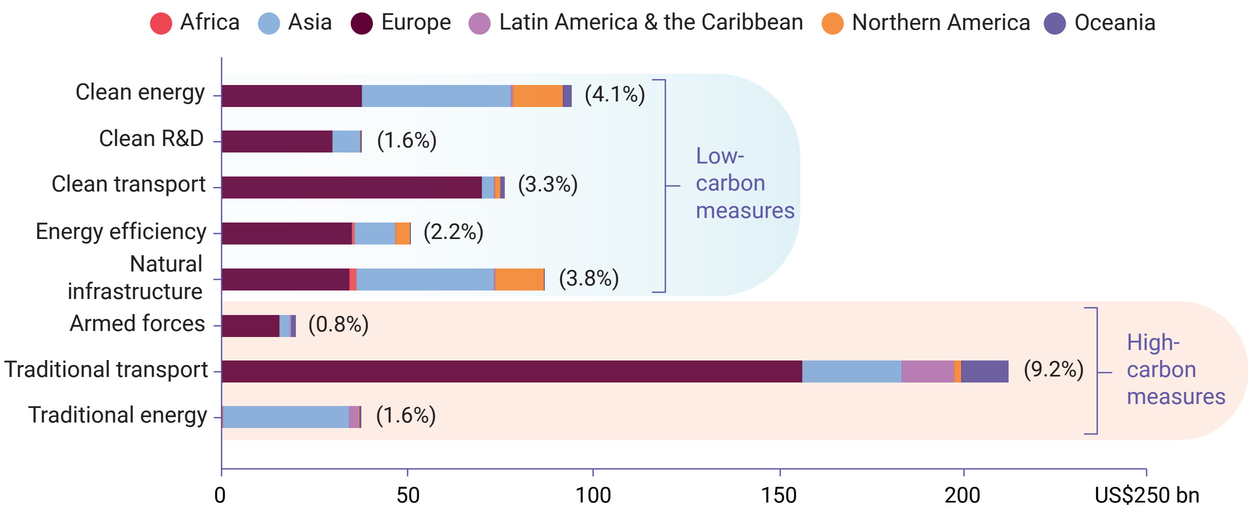
Figure ES.6. Global greenhouse gas emissions under different scenarios and the emissions gap in 2030 (median estimate and tenth to ninetieth percentile range)



- Acknowledging these caveats, a continuation of the new or updated unconditional NDCs and pledge announcements is estimated to limit warming to 2.7°C (range: 2.2–3.2°C) by the end of the century with a 66 per cent chance. If conditional pledges are also fully implemented, these estimates are lowered to 2.6°C (range: 2.1–3.1°C). By contrast, a continuation of current policies, which are insufficient to meet the 2030 pledges, is estimated to limit warming to 2.8°C (range 2.3–3.3°C).

- The full implementation of the net-zero pledges, in addition to new or updated unconditional NDCs and announced pledges, further lower these temperature estimates markedly to 2.2°C (range 2.0–2.5°C) with 66 per cent chance. Even under this scenario, there is still more than 15 per cent chance that global warming will exceed 2.5°C by the end of the century, and just short of 5 per cent chance that it will exceed 3°C. Finally, these estimated improvements from net-zero targets should be caveated by the fact that only a few current NDCs set countries' emissions on a linear path towards reaching longer-term net-zero targets.

Figure ES.7. Global recovery spending as at May 2021 across sectors by region (US$ billion). Low-carbon initiatives (top) and high-carbon initiatives (bottom)



Note: R&D stands for research and development.

8. The opportunity to use COVID-19 fiscal rescue and recovery spending to stimulate the economy while fostering a low-carbon transformation has been missed in most countries so far. Poor and vulnerable countries are being left behind.

- The COVID-19 pandemic has precipitated an enormous increase in public expenditure, in the form of: (i) short-term rescue spending, to keep businesses and people alive; (ii) longer-term recovery investment, to reinvigorate the economy; and (iii) reinforcement spending, to embed new economic trajectories into long-term development plans. Low-carbon rescue spending has incentivized decarbonization through green conditionalities attached to short-term business support. Low-carbon recovery investment has set out to accelerate the low-carbon transition directly by supporting green projects and indirectly by incorporating green incentives into traditional investment. Green reinforcement initiatives deliver long-term support to the projects and sectors targeted by green recovery investment.

- Approximately US$16.7 trillion was spent to May 2021 on COVID-19-related rescue and recovery packages (excluding unallocated European Union funds). However, most resources have been for immediate rescue spending, mostly on unemployment and worker support programmes, pandemic management, and health-care

Figure ES.8. COVID-19-related spending per capita across development categories (US$)

services. US$2.25 trillion is considered recovery spending. Of this, only around 17–19 per cent (US$390–440 billion) is likely to reduce GHG emissions.

- Low-carbon fiscal spending has covered a wide range of sectors. Over 500 green rescue and recovery measures have been introduced globally. Policies have covered most emerging and established green industries (figure ES.7). The range of spending has been notably wider in advanced economies, with emerging market and developing economies focusing their green recovery funds on clean energy generation and natural capital investments.

- International disparities are large in terms of both total spending and low-carbon spending. Almost 90 per cent of recovery spending is accounted for by seven countries: the Republic of Korea, Spain, Germany, the United Kingdom, China, France and Japan. The Global Recovery Observatory finds that, up to May 2021, France, Germany, Canada, Finland, Norway and Denmark can be classified as 'leaders' on green recovery, with green spending as a share of recovery spending ranging from 39 per cent to 75 per cent. The United Kingdom, Spain and Sweden also rank highly, according to Vivid Economics' Greenness of Stimulus Index.

- Vulnerable nations are being left behind. COVID-19 spending has been far lower in low-income economies (~US$60 per person) than advanced economies (~US$11,800 per person) (figure ES.8). Less diversified economies, rising debt as a percentage of GDP, and corresponding limited fiscal space have constrained the ability of emerging economies and low-income countries to mobilize resources.

- Without a substantial increase in foreign aid, the difference in spending between advanced economies and emerging markets and developing economies will exacerbate gaps in development and restrict progress against climate change. Additionally, without significantly increased climate finance, emerging markets and developing economies are likely to become the world's top GHG emitters, all while disproportionately suffering the burden of climate change, which has historically been caused primarily by high-income nations.

9. Reduction of methane emissions from the fossil fuel, waste and agriculture sectors can contribute significantly to closing the emissions gap and reduce warming in the short term.

- Methane is the second-most-important GHG in terms of current anthropogenic climate forcing, and global anthropogenic methane emissions continue to increase.

- With a lifetime of about 12 years, and a global warming potential (GWP) of approximately 82 over a 20-year period and 29 over a 100-year period, reducing methane emissions represents an important opportunity to slow down the rate of warming in the short term, reduce peak warming during this century and help bridge the emissions gap between current trajectories and those consistent with the 2°C or 1.5°C temperature goals.

- Strong abatement potential exists at net-negative and low costs (<US$600/$tCH_4$; <~US$20/tCO_2e using GWP100), especially in the fossil fuel sector, even without accounting for the avoided costs of environmental damages. Abatement potential via technical measures is also large in the waste sector and to a lesser extent in agriculture, where it will be difficult to greatly mitigate emissions without changing diets at the global or regional levels.

- Available net-negative or low-cost technical mitigation measures alone could reduce anthropogenic methane emissions by approximately 20 per cent by 2030, whereas all targeted measures could reduce emissions by about one third. Additional measures, such as switching from natural gas to renewables, dietary changes and food waste reduction could add 15 per cent to the 2030 mitigation potential. This is consistent with methane reductions in most 2°C and 1.5°C pathways, which are approximately 34 per cent and 44 per cent, respectively, at the global level in 2030 compared to 2015.

- Current NDCs cover only about one third of the methane reduction required to be consistent with a 2°C temperature goal, and only about 23 per cent of what is needed for the 1.5°C goal. There are, however, excellent opportunities to include additional methane reduction measures in NDCs, as several countries are already demonstrating, for example through actions such as upstream leak detection and repair in oil and gas systems, elimination of gas flaring, energy recovery from landfill gas, and reducing food waste and loss.

- Action is often hampered by the fact that reported methane emissions are highly uncertain given the large number and complexity of emission sources and the uncertainty over emission factors. Recent developments in measurement capabilities enable total emissions rates to be monitored, including at the facility scale for larger emission sources. Although these measurements will provide a much better basis for decisive actions, they need to be used systematically and to become a key element in preparing national policies.

10. Carbon markets can deliver real emissions abatement and drive ambition, but only when rules are clearly defined, designed to ensure that transactions reflect actual reductions in emissions, and supported by arrangements to track progress and provide transparency.

- Article 6 of the Paris Agreement and international markets are not a direct source of ambition but can function as a lever for implementing and unlocking greater ambition. Markets can provide an opportunity for countries, companies and other actors to achieve their emission reduction goals at lower costs and thereby create room to enhance their ambition in both the near- and long term. Particularly, participants with hard-to-abate emissions would be enabled to meet their mitigation goals at lower costs.

- From a market-integrity perspective, the optimal situation would be for NDCs to come with comprehensive GHG coverage, clearly quantifiable mitigation goals, and robust accounting, but NDCs are currently very heterogeneous. This creates challenges for developing a robust international market. The agreed rules need to ensure environmental integrity and encourage enhanced ambition. A global market system would best facilitate progress towards meeting the Paris goals, if countries are not allowed to capture the benefits of lower cost without raising ambition, or if countries that are selling off cheap mitigation options subsequently ensure delivery on the costlier ones.

- The use of market mechanisms could have important implications for both mitigation and sustainable development pathways. In addition to potentially lowering the cost of additional ambition everywhere, markets could lead to a shift in capital investment towards selling regions, and in this way affect metrics such as local air quality, employment and sustainability, and shift costs. Nevertheless, there is a risk that this could lead to reduced incentives for technological innovation in buying regions.

- Global modelling studies estimate that if all NDCs were transformed into tradable emissions abatement and all countries had economy-wide targets, around 4–5 $GtCO_2e$ could be traded per year by 2030. If the savings from more cost-effective global implementation of NDCs were redeployed towards increased ambition, the emissions reductions planned in current NDCs could be roughly doubled over the next decade at no added cost to parties, compared to parties acting alone to implement their commitments.

- These studies indicate the significant theoretical potential of carbon markets. For this potential to be realized, these theoretical findings need to be translated into real-world policy changes. The challenge for COP26 negotiations is to decide on the necessary guidance for article 6 that can launch a global market that is able to gradually expand and improve as pledges evolve and experiences are gained.

- The number of countries that in their new or updated NDCs have indicated the planned or possible use of voluntary cooperative approaches has almost doubled compared to the previous NDCs, indicating significantly increased interest.

- For markets to play a role in the process towards net-zero emissions, NDCs should cover all sectors and gases and have economy-wide quantitative goals. With narrowing cost differences over time, the volume of trading would likely diminish, while the transactional value would increase. The market would increasingly focus on CO_2 removal from the atmosphere.

1 Introduction

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1.1 Context of the Emissions Gap Report 2021

This twelfth edition of the United Nations Environment Programme (UNEP) Emissions Gap Report comes during a year of constant reminders that climate change is not in the distant future. Extreme weather events around the world – including flooding, droughts, wildfires, hurricanes and heatwaves – have continuously hit the news headlines. Thousands of people have been killed or displaced and economic losses are measured in the trillions. Bearing witness to the increasingly clear signs of climate change, the Intergovernmental Panel on Climate Change (IPCC) published the first report in its Sixth Assessment cycle addressing the "Physical Science Basis" in August 2021. Dubbed a "code red for humanity" by the United Nations Secretary-General, the IPCC report documents in far greater detail and with higher certainty than previous assessments how climate change and extreme events can be attributed to the build-up of anthropogenic greenhouse gas (GHG) emissions in the atmosphere. There is a fifty-fifty chance that global warming will exceed 1.5°C in the next two decades, and unless there are immediate, rapid and large-scale reductions in GHG emissions, limiting warming to 1.5°C or even 2°C by the end of the century will be beyond reach.

Building on the new evidence from the IPCC, the twenty-sixth United Nations Climate Change Conference of the Parties (COP26) is charged with the growing urgency of accelerating global ambition and action on both mitigation and adaptation. This coincides with an important milestone in the five-year ambition-raising cycle of the Paris Agreement, whereby countries were requested to submit new or updated nationally determined contributions (NDCs) that represent a progression compared with previous NDCs before COP26. There is therefore a special focus both in the international discussions and in this year's Emissions Gap Report on the ambition level in the new and updated NDCs.

As the September 2021 version of the NDC Synthesis Report published by the United Nations Framework Convention on Climate Change (UNFCCC) illustrates, the new and updated NDCs are insufficient to achieve the temperature goal of the Paris Agreement (United Nations Framework Convention on Climate Change 2021). This Emissions Gap Report confirms the findings of the UNFCCC report. It expands the analysis to consider new or updated NDCs and mitigation pledges that have been announced for 2030 and assesses the impacts of these on global emissions, the emissions gap and projected global warming at the end of the century. Furthermore, it provides an in-depth assessment of the net-zero pledges that an increasing number of countries are committing to, including whether 2030 plans set countries on a clear path towards their longer-term net-zero pledges.

1.2 Focus, approach and structure of the report

Each year, the Emissions Gap Report provides an updated assessment of the gap between i) estimated future global GHG emissions if countries implement their climate mitigation pledges and ii) the global emission levels from least-cost pathways that are aligned with achieving the Paris Agreement goal of limiting global warming to well below 2°C and pursuing 1.5°C. This difference between where we will likely be and where we need to be is now well known as the 'emissions gap'. This year, the new or updated NDCs as well as officially announced mitigation pledges for 2030, with a cut-off date of 30 September 2021, are included in the assessment.

One of the United Kingdom's key goals for its COP26 presidency is to secure global net zero by mid-century and keep 1.5°C within reach (United Nations and United Kingdom undated). To date, 49 countries (50 parties, including the European Union) have firmly pledged net-zero emission goals by around mid-century, and a large number of non-state actors have joined the High-Level Climate Champions in the Race To Zero campaign that aims to elevate ambition and mobilize credible climate action among cities, regions, businesses and investors. Given the increasing importance of and attention to net-zero emission pledges, the report includes a special chapter on net zero which assesses the trends in and robustness of these goals, including whether 2030 commitments set countries on a clear path towards their longer-term net-zero pledges.

The report also includes three chapters on opportunities to bridge the emissions gap that are pertinent to the current global situation and the COP negotiations. First, an updated assessment is provided on the extent to which COVID-19 fiscal recovery measures are used to accelerate a green transition. Second, the scope for reducing emissions from methane, the second largest GHG, to bridge the gap and get on track towards net zero is examined. Finally, the report looks into a key negotiation issue for COP26: reaching agreement on how to move forward with article 6 of the Paris Agreement dealing with cooperative approaches and market mechanisms. A large number of countries have included the use of market mechanisms in their NDC implementation plans and are waiting for the modalities to be agreed.

As in previous years, this 2021 Emissions Gap Report has been prepared by an international team consisting of 78 leading scientists from 44 expert institutions across 24 countries, assessing all available information, including that published in the context of the IPCC reports, as well as in other recent scientific studies. The transparent and participatory assessment process has been overseen by an experienced steering committee. All chapters have undergone external review and the assessment methodology and preliminary findings were made available to the governments of the countries specifically mentioned in the report in order to provide them with the opportunity to comment on the findings.

The report is organized into seven chapters, including this introduction. Chapter 2 assesses the trends in global GHG emissions and how they are affected by COVID-19, and provides a global and G20-member-specific overview of new, updated and announced NDCs. Chapter 3 provides an assessment of net-zero emission pledges. Chapter 4 updates the assessment of the likely emissions gap in 2030, based on new or updated NDCs as well as officially announced mitigation pledges for 2030. The chapter then looks at the implications of the emissions gap on the feasibility of achieving the long-term temperature goal of the Paris Agreement. Chapter 5 assesses the extent to which COVID-19 fiscal rescue and recovery measures to date can support low-carbon or high-carbon development. It also looks at the disparities between high-income and developing countries. Chapter 6 assesses the role of methane in the NDCs and in bridging the emissions gap, and considers options for cost-effective reductions of the otherwise growing emissions of methane. Finally, chapter 7 looks at the potential role of market mechanisms in implementing NDCs and enhancing future ambitions, and discusses what is required to make the use of markets environmentally effective, transparent and credible.

2 Trends in global emissions, new pledges for 2030 and G20 status and outlook

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2.1 Introduction

This chapter reviews the current status of global greenhouse gas (GHG) emissions as well as the outlook for 2030 emissions under new or updated nationally determined contributions (NDCs) and announced mitigation pledges. It also reviews progress towards implementing 2030 pledges, with a special focus on G20 members.[1]

Section 2.2 provides an overview of current trends in total global GHG emissions and global carbon dioxide (CO_2) emissions from fossil fuel use and industry-related sources, considering the impact of COVID-19 on 2020 and 2021 emissions. Section 2.3 presents new or updated NDCs communicated under the Paris Agreement, as well as additional pledges for 2030 that are yet to be formally submitted as NDCs. It discusses the characteristics of these pledges (in aggregate) and assesses their impact on global and G20 2030 emissions. Section 2.4 presents G20 members' pledges, assessing whether and how they have been updated, along with progress towards their implementation. The assessment covers all individual G20 members and regions, except European Union member states.[2] The cut-off date for the assessments of new or updated NDCs was set as 30 September 2021.

For this Emissions Gap Report, progress towards achieving the Cancun Pledges has not been assessed, due to the large uncertainty around 2020 emissions as a result of the COVID-19 pandemic. A more comprehensive assessment on the achievement of the Cancun Pledges is expected in the Emissions Gap Report 2022.

All GHG emission figures in this report are expressed using the 100-year global warming potentials (GWPs) from the Intergovernmental Panel on Climate Change (IPCC)

1 The members of the G20 are: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, the Republic of Korea, the Russian Federation, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States of America and the European Union.

2 The United Kingdom has left the European Union but was in a transition period until the end of 2020, during which the European Union's NDC still applied to the country.

Fourth Assessment Report,[3] unless otherwise noted. In terms of historical emissions data, section 2.2 uses globally consistent and independent data sets rather than officially reported United Nations Framework Convention on Climate Change (UNFCCC) inventory reports, whereas sections 2.3 and 2.4 use UNFCCC inventory reports when comparing historical emissions to individual G20 members' NDC targets.

The methodology and preliminary findings of this chapter were made available to the governments of the countries specifically mentioned to provide them with the opportunity to comment on the findings.

2.2 Current global emissions: status and trends

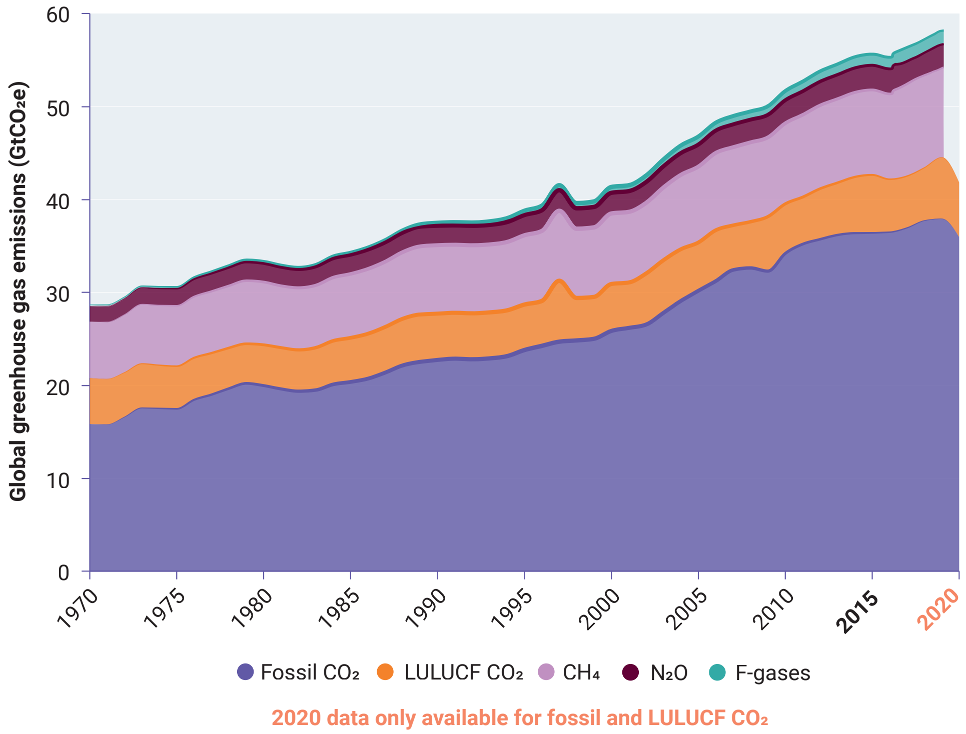
At present, there are no estimates available of total global GHG emissions for 2020. However, the COVID-19 pandemic led to an unprecedented 5.4 per cent drop in CO_2 emissions in 2020 (figure 2.1), with a smaller drop in total GHG emissions expected for the year. From 2010 to 2019, GHG emissions grew by 1.3 per cent per year on average, both with and without land-use change (LUC). GHG emissions reached a record high of 51.5 gigatons of CO_2 equivalent ($GtCO_2e$) in 2019 without LUC emissions and 58.1 $GtCO_2e$ when including LUC[4] (figure 2.1). These 2019 estimates of global GHG emissions have been downward adjusted compared with the Emissions Gap Report 2020, as more complete data have become available.

Different GHGs play different roles in the changes in total GHG emissions (figure 2.1). Fossil CO_2 emissions dominate total GHG emissions including LUC (66 per cent since 2010), as well as the growth in GHG emissions. Fossil CO_2 emissions reached a record 37.9 $GtCO_2$ in 2019, but dropped to 36.0 $GtCO_2$ in 2020. CO_2 emissions from LUC have constituted 10 per cent of cumulative GHG emissions since 2010, and can change significantly from year to year due to climate conditions (Friedlingstein *et al.* 2020; Canadell *et al.* 2021). Estimates in this chapter only consider the direct effects of LUC and represent the average of three bookkeeping models (Friedlingstein *et al.* 2020). Furthermore, the estimates assume that 2020 emissions are similar to the 2010–2019 average, based on preliminary estimates of fire data. No preliminary estimates are available for the growth of non-CO_2 emissions in 2020.

3 This change was made to be more in line with the decisions of the twenty-fourth United Nations Climate Change Conference of the Parties (COP24) held in Katowice, where parties agreed to use GWPs from the IPCC Fifth Assessment Report for reporting reasons. However, a full switch to using Fifth Assessment Report GWPs in this report is not yet possible as the literature is still not up to date on this decision.

4 The GHG emissions data in this report are based on the Emissions Database for Global Atmospheric Research (EDGAR; Crippa *et al.* 2021), PBL Netherlands Environmental Assessment Agency (Olivier and Peters 2021) and LUC from the Global Carbon Project (Friedlingstein *et al.* 2020). EDGAR data are available until 2020 for CO_2, but only until 2018 for non-CO_2 emissions. Non-CO_2 emissions were extrapolated to 2019 based on the Emissions Gap Report 2020. GWPs were used from the IPCC Fourth Assessment Report. All estimates for 2019 and 2020 should be considered preliminary.

Figure 2.1. Global greenhouse gas emissions from all sources, 1970–2020

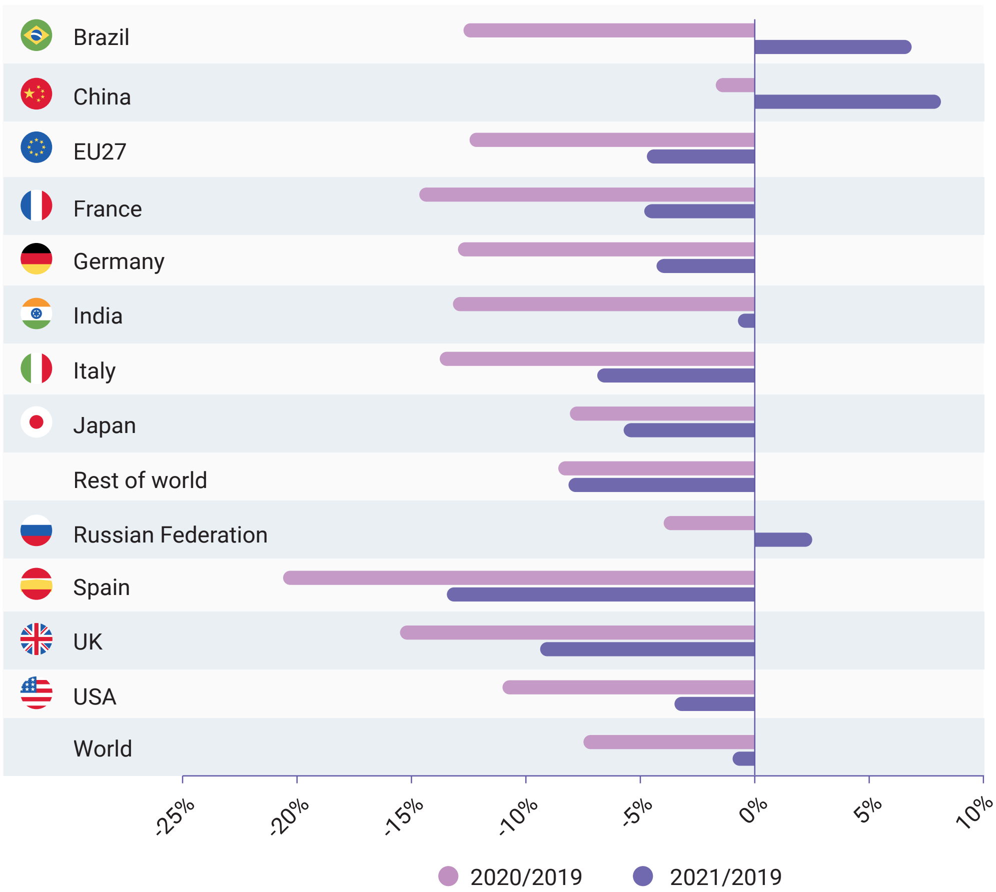


Notes: LULUCF – land use, land-use change and forestry. EDGAR data were used until 2018 for methane, nitrous oxide and fluorinated gases, but were extrapolated to 2019 using growth rates from the previous version of EDGAR (published in the Emissions Gap Report 2019).
Sources: EDGAR – Crippa *et al.* (2021); Olivier and Peters (2021); LUC – Friedlingstein *et al.* (2020)

As mentioned previously, the COVID-19 pandemic led to an unprecedented decline in fossil CO_2 emissions in 2020, both in relative and absolute terms. Global fossil CO_2 emissions fell 5.4 per cent according to this report's data set, with other estimates suggesting declines of 5.8 per cent (Global Carbon Project, updated based on Friedlingstein *et al.* 2020), 5.8 per cent (excluding cement) (International Energy Agency [IEA] 2021) and 6.3 per cent (BP 2021, excluding cement). The change in fossil CO_2 emissions varied across countries. Despite the pandemic, Chinese fossil CO_2 emissions grew 1.3 per cent in 2020, though most other major emitters saw a decline in emissions, including the United States of America (10 per cent), the EU27 (10 per cent), India (6.2 per cent), with international transportation (shipping and aviation) dropping by 20 per cent.

A strong rebound in emissions is expected in 2021 (figure 2.2). In April 2021, the International Energy Agency (IEA) estimated a 4.8 per cent increase in emissions in 2021, after the 5.8 per cent decline in 2020 (IEA 2021). Carbon Monitor (Liu *et al.* 2020) estimates near real-time estimates of daily CO_2 emissions, and based on data from January to July 2021, global fossil CO_2 emissions are only slightly lower (1 per cent) than the same period in 2019. Of the major emitters, only Brazil, China and the Russian Federation show an increase in emissions from January to July 2021 relative to 2019. Based on the IEA and Carbon Monitor data, fossil CO_2 emissions are expected to have a near full recovery in 2021, with emission levels only slightly lower than the record high in 2019.

Figure 2.2. Change in emissions in 2020 and 2021, both relative to 2019 levels due to COVID-19 lockdowns



Source: Liu *et al.* (2020)

Despite the large decline in CO_2 emissions in 2020, the concentration of CO_2 in the atmosphere grew by around 2.3 parts per million, in line with recent trends. It is unlikely that the reductions in emissions in 2020 will be detectible in the atmospheric growth rate for three reasons. First, although emission levels declined, they were still high and around the same levels as those seen in the early 2010s, meaning the amount of CO_2 remaining in the atmosphere is expected to be only marginally less than if emissions grew. Second, CO_2 is a cumulative pollutant with a long lifetime, so sustained emission reductions are needed to see a change in the atmospheric signal. Finally, the natural variability of around one part per million is far greater than the effect of a 5.4 per cent reduction in emissions. Similar factors mean that methane and nitrous oxide concentrations also continued to grow in line with trends, with the increase in these concentrations in 2020 the highest ever recorded. The lack of change in atmospheric concentrations despite a record drop in emissions highlights that solving the climate problem requires rapid and sustained reductions in emissions.

2.3 Trends and implications of the new or updated NDCs and other announced mitigation pledges for 2030

2.3.1 Global summary of trends in the new or updated NDCs

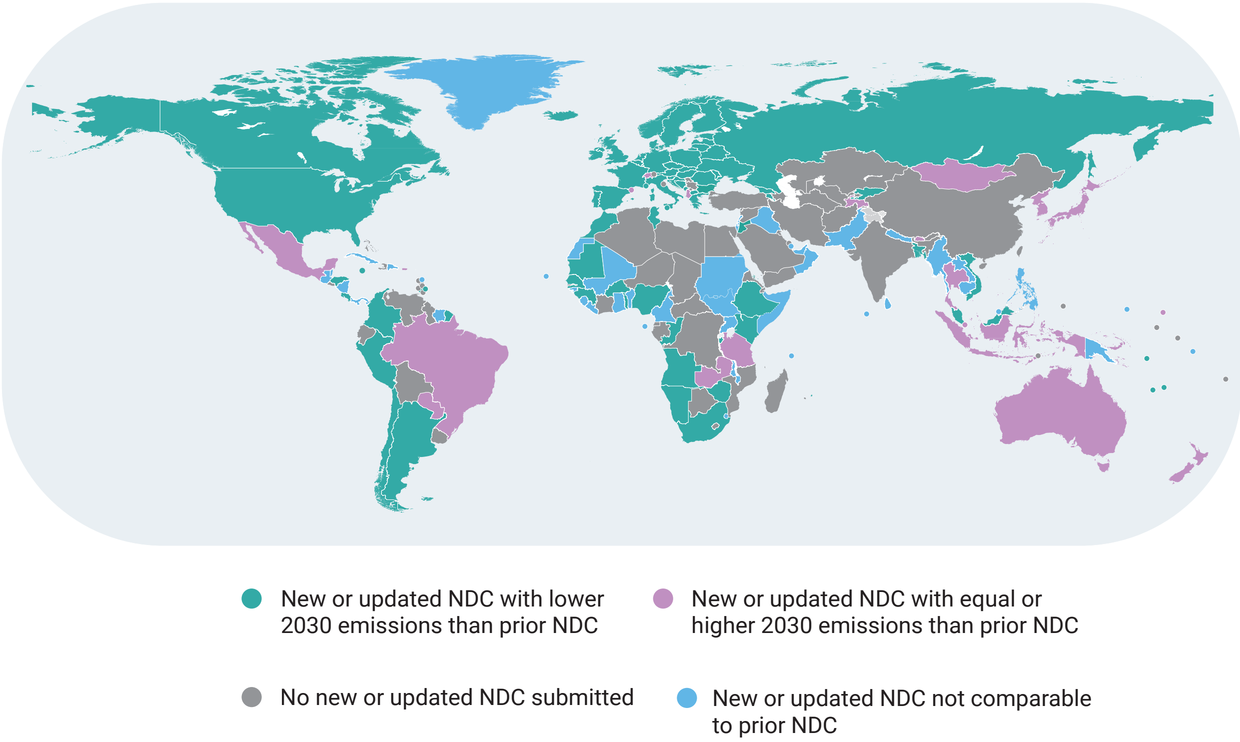
The decision text that accompanied the Paris Agreement (1/CP.21) requested that parties whose intended nationally determined contributions (INDCs) contained a time frame up to 2025 communicate a new NDC, and that parties whose INDC contained a time frame up to 2030 communicate or update that contribution by 2020. As at 30 September 2021,[5] 121 parties (including the European Union and its 27 member states, which submit a single NDC), representing around 52 per cent of 2018 global domestic GHG emissions (Climate Watch 2021), had submitted 94 new or updated NDCs. The NDCs communicated thus far reflect emerging trends related to the ambition, form, coverage and

5 All figures presented in section 2.3 reflect new or updated NDCs submitted until 30 September 2021.

conditionality of GHG mitigation pledges, as well as the expected use of market mechanisms in their achievement.

Effect on 2030 emissions: Of the 94 new or updated NDCs, just under half (46 NDCs from countries representing 32 per cent of global GHG emissions) would result in lower 2030 emissions relative to the previous NDCs (figure 2.3). Eighteen per cent (17 NDCs from countries representing 13 per cent of global GHG emissions) had communicated a new or updated NDC that would not reduce 2030 emissions relative to the previous NDCs. Thirty-four per cent (32 NDCs from countries representing 7 per cent of global emissions) could not be compared with the previous NDCs in terms of 2030 emissions, typically due to insufficient information in the previous NDCs, as transparency has improved in the current NDCs.

Figure 2.3. Effect of new or updated nationally determined contributions on 2030 greenhouse gas emissions relative to previous nationally determined contributions



Source: Climate Watch (2021)

Pledge form: Of the new or updated NDCs, more (89 per cent) have GHG targets than before (75 per cent).[6] These comprise several types of GHG targets, including base-year targets (commitments to reduce or control the increase in emissions by a specified amount relative to a base year) and baseline scenario targets (commitments to reduce emissions by a specified amount relative to a projected emissions baseline scenario), among other formulations. Base-year targets typically (though not always) result in emissions decreasing over time relative to historical levels, whereas baseline scenario targets are typically (though not always) formulated to allow absolute emissions to continue to grow. The form of GHG targets in new or updated NDCs evolved relative to the previous round, with a slightly larger share of NDCs now setting base-year targets (from 19 per cent to 28 per cent of NDCs). Most countries adopting a GHG target for the first time in their new or updated NDC adopted a baseline scenario target.

Sector and gas coverage: GHG targets can be formulated to cover a country's entire economy or only a subset of it. Targets with full coverage include the energy, industrial process and product use, waste and land sectors, as well as CO_2, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorochemicals (PFCs), sulfur hexafluoride and nitrogen trifluoride. The GHG targets in the current round of NDCs are only marginally more comprehensive in terms of sector and gas coverage than in the previous round. Of the new or updated NDCs, 19 per cent had full sector and gas coverage, up from 14 per cent in those countries' first NDCs. While

6 These figures include only those countries that have submitted new or updated NDCs.

seven countries improved their NDCs from partial coverage to full or nearly full coverage, three countries downgraded their NDCs from nearly full coverage to partial coverage.

Conditionality: Some parties have submitted NDCs that are entirely or partially conditional on factors such as international support (e.g. finance or technology transfer), while others have submitted NDCs that are not conditional. This round of NDCs includes more unconditional elements than the last round, with 26 per cent completely unconditional, up from 24 per cent in countries' first contributions. This was largely due to countries making any mixed conditional and unconditional elements completely unconditional in their new or updated NDCs. Likewise, the share of completely conditional NDCs fell from 31 per cent to 18 per cent.

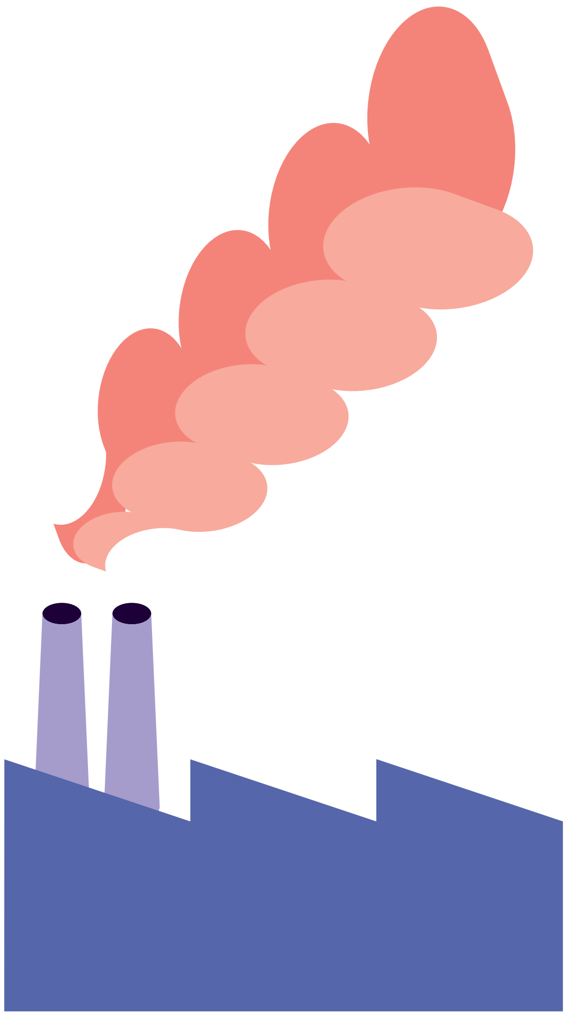
Finally, parties are increasingly recognizing gender integration as a means to enhance the ambition and effectiveness of their climate action in their new or updated NDCs (United Nations Framework Convention on Climate Change [UNFCCC] 2021).

2.3.2 Impacts on GHG emissions by 2030 at the global and G20 levels, considering new or updated NDCs and announced mitigation pledges

This section quantifies the impacts of the new or updated NDCs and announced mitigation pledges on global 2030 emissions, relative to the previous NDCs. The analysis is based on the difference in projected GHG emissions by 2030 under the full implementation of the new or updated NDC submissions and announced pledges compared with the previous NDCs. The data are from five model groups and two open-source tools.[7],[8]

Aggregate impact on global GHG emissions in 2030

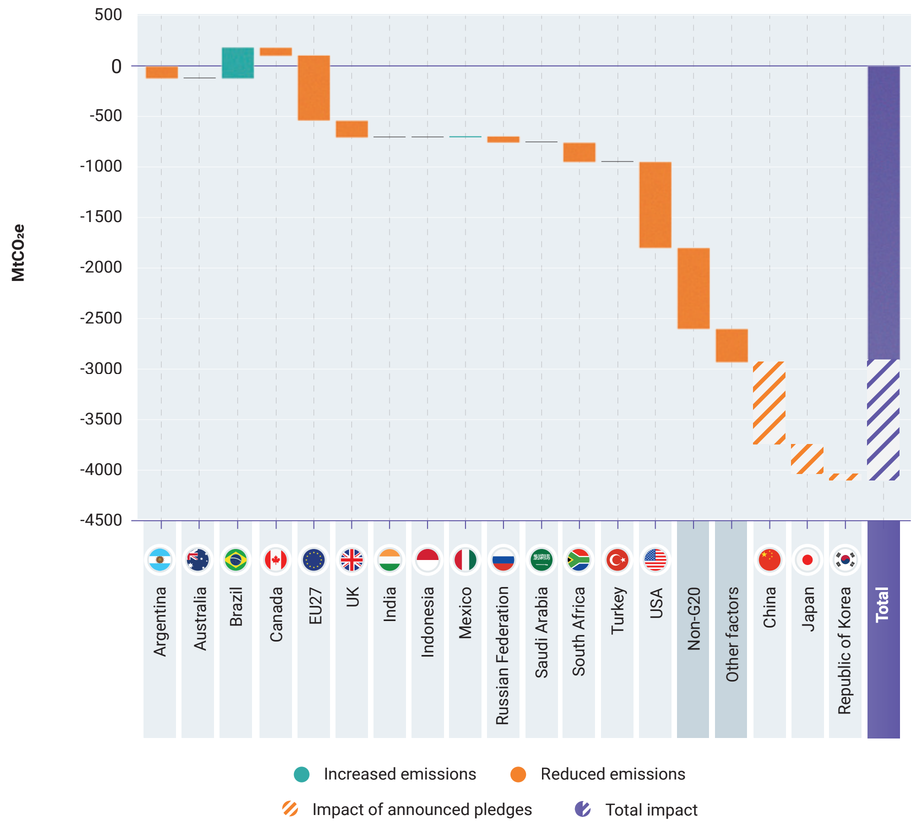
The analysis shows that the aggregate impact of the new or updated unconditional NDCs is estimated to lead to a reduction in 2030 global GHG emissions of about **2.9 $GtCO_2e$**, compared with the previous NDCs (figure 2.4). This estimate includes reductions of around 0.3 $GtCO_2e$ resulting from **other factors**, including lower projections of international aviation and shipping emissions, and adjustments of countries that are projected to overachieve their NDC targets. If the announced pledges of China, Japan and the Republic of Korea are included, this reduction increases to **4.1 $GtCO_2e$**. For the conditional targets, these reductions are **2.8 $GtCO_2e$** and **4.0 $GtCO_2e$**, respectively.



7 Climate Action Tracker (2021a; 2021b); Joint Research Centre with the Prospective Outlook on Long-term Energy Systems (POLES) model (Joint Research Centre 2021); PBL Netherlands Environmental Assessment Agency with the Integrated Model to Assess the Global Environment (IMAGE) model (den Elzen *et al.* 2021, in preparation; Nascimento *et al.* 2021). The two open-source tools that provide NDC emissions projections for many countries are: Climate Resource (Meinshausen *et al.* 2021) and the World Resources Institute's Climate Watch (2021). All GHG emissions projections of the Climate Action Tracker and Climate Resource exclude LULUCF.

8 The following data sources have been used to assess announced pledges that have not yet been formally submitted: Climate Action Tracker, PBL and the Joint Research Centre. Climate Action Tracker accounts for the impact of the announcements of China and Japan, Joint Research Centre for China and Japan, and PBL for the impact of China, Japan and the Republic of Korea.

Figure 2.4. Impact of 2030 pledges (nationally determined contributions and other announced pledges as at 30 September 2021) on 2030 global emissions compared with previous nationally determined contribution submissions



G20 members

Taking a closer look at the G20 members, the combined impact of submitted NDCs and announced GHG reduction targets for 2030 is an annual reduction of about 3 $GtCO_2e$ compared with the previous NDCs. Six G20 members have formally submitted updated NDCs with enhanced GHG mitigation pledges: Argentina, Canada, the EU27 (counting the EU27 and its three individual G20 member states France, Germany and Italy as one), South Africa, the United Kingdom and the United States of America – all of which entail reduced emissions in 2030 of about 2.1 $GtCO_2e$ compared with previous NDCs. Two G20 members (Brazil and Mexico) have submitted targets that lead to an increase in emissions of 0.3 $GtCO_2e$, bringing the net reduction in global GHG emissions of new or updated NDCs submitted by G20 members to 1.8 $GtCO_2e$ annually by 2030. In addition, China, Japan and the Republic of Korea have announced enhanced pledges that result in annual reductions of about 1.2 $GtCO_2e$, but have not yet formally communicated them to the UNFCCC. The largest reductions come from the United States of America, the EU27, the United Kingdom, Argentina and Canada (submitted), and China and Japan (announced). Two G20 members (Australia and Indonesia) have submitted NDC targets, which are assessed not to lead to an additional reduction relative to the previous NDCs. One G20 member (the Russian Federation) has submitted an NDC that improves upon its previous NDC, but still does not go beyond its current policies and another three G20 members (India, Saudi Arabia and Turkey) have not yet submitted a new or updated NDC (table 2.1).

Non-G20 members

In comparison, the aggregate impact of the new or updated NDC submissions for the non-G20 members is an annual reduction of about 0.8 $GtCO_2e$ by 2030.

Other factors

Finally, additional reductions of around 0.3 $GtCO_2e$ come from the decreased international aviation and shipping emissions projections, and from countries that are projected to overachieve their NDC targets. As explained previously, for some countries, NDC emission levels are expected to be above the estimated current policies scenario, with the projections of the current policies scenario assumed for the global emissions estimate. Due to the impact on COVID-19 on GHG emissions projections under the current policies scenario, the emissions projections of many countries have lowered. This means that a larger number of countries are expected to overachieve their NDC targets, in particular India, the Russian Federation and Turkey, which lowers global GHG emissions. In addition, the methodology of the underlying models may have also been updated, which could lead to changes in global emissions estimates between scenarios.

Table 2.1. Summary of greenhouse gas mitigation pledges in previous and new or updated nationally determined contributions by G20 members

G20 member	Original NDC	New or updated 2030 pledge	Change in 2030 emissions relative to original NDC Based on modelling studies (median and range)
G20 members that have submitted new or updated NDCs			
Argentina	Cap 2030 net emissions at 483 megatons of CO_2 equivalent ($MtCO_2e$) (unconditional) and 369 $MtCO_2e$ (conditional)	Cap 2030 net emissions at 359 $MtCO_2e$ (unconditional)	-0.12 $GtCO_2e$ (range: -0.11 – -0.13)
Australia	Reduce GHG emissions by 26–28 per cent from 2005 levels by 2030*	Reduce GHG emissions by 26–28 per cent from 2005 levels by 2030*	No change
Brazil	Reduce GHG emissions by 37 per cent from 2005 levels by 2025 and (indicatively) 43 per cent from 2005 levels by 2030	Reduce GHG emissions by 43 per cent from 2005 levels by 2030[9]	0.3 $GtCO_2e$ (range: 0.15–0.4)
Canada	Reduce GHG emissions by 30 per cent from 2005 levels by 2030	Emissions 40–45 per cent below 2005 levels by 2030	-0.09 $GtCO_2e$ (range: -0.08 – -0.1)
EU27	Reduce GHG emissions by at least 40 per cent from 1990 levels by 2030 (applied originally to EU28 collectively)	Reduce net GHG emissions by at least 55 per cent from 1990 levels by 2030	-0.6 $GtCO_2e$ (range: -0.5 – -0.7)
Indonesia	Reduce GHG emissions by 29 per cent (unconditional) and 41 per cent (conditional) relative to business as usual (BAU) by 2030	Reduce GHG emissions by 29 per cent (unconditional) and 41 per cent (conditional) relative to BAU by 2030	No change
Mexico	Reduce GHG emissions by 22 per cent (unconditional) and 36 per cent (conditional) from BAU by 2030	Reduce GHG emissions by 22 per cent (unconditional) and 36 per cent (conditional) from BAU by 2030	Marginal increase due to change in BAU scenario
Russian Federation	Limit 2030 emissions to 70–75 per cent of 1990 level	Limit 2030 emissions to 70 per cent of 1990 levels	Reduced, but the target still results in higher emissions than the current policy projection
South Africa	Limit 2025–2030 emissions to 398– 614 $MtCO_2e$	Limit 2030 emissions to 350–420 $MtCO_2e$	Reduced

9 The updated NDC leads to an absolute increase in emissions. Both NDCs present the same reduction target of 43 per cent by 2030 below 2005 emission levels. Brazil's NDC emissions (and therefore the absolute emissions in the NDC scenario) vary a great deal due to revisions of the 2005 base year. The country's second and third inventory reports and Fourth National Communication (its latest) give different values. The first NDC refers to the second inventory report, while the updated NDC cites the 2005 base year emissions of the third inventory report (Fifth Assessment Review metrics), but also specifies that "information on emissions in 2005 and reference values may be updated and recalculated due to methodological improvements applicable to the inventories" (Brazil 2020).

United Kingdom	Contribution to EU28-wide emissions target: reduction target of at least 40 per cent	Reduce GHG emissions by at least 68 per cent from 1990 levels by 2030	-0.17 $GtCO_2e$ (range: -0.1 – -0.2)
United States of America	Reduce GHG emissions by 26–28 per cent from 2005 levels by 2025[10]	Reduce GHG emissions by 50–52 per cent from 2005 levels by 2030	-0.85 $GtCO_2e$ (range: -0.8 – -0.9)[11]
G20 members that have announced mitigation pledges for 2030			
China	Peak CO_2 emissions around 2030 Reduce CO_2/gross domestic product (GDP) by 60–65 per cent from 2005 levels by 2030 Increase the share of non-fossil fuels in primary energy consumption to around 20 per cent by 2030 Increase forest stock volume by around 4.5 billion m3 by 2030	Peak CO_2 emissions before 2030 Reduce CO_2/GDP by 65 per cent from 2005 levels by 2030 Increase the share of non-fossil fuels in primary energy consumption to around 25 per cent by 2030 Increase forest stock volume by around 6 billion cubic metres in 2030 Increase the installed capacity of wind and solar power to 1,200 GW by 2030	-0.8 $GtCO_2e$ (range: -0.5 – -1.2)
Japan	Reduce GHG emissions by 26 per cent from 2013 levels by 2030	Reduce GHG emissions by 46 per cent from fiscal year 2013 levels by fiscal year 2030, with efforts to reduce by 50 per cent	-0.27 $GtCO_2e$ (range: -0.17 – -0.32)
Republic of Korea	Reduce GHG emissions by 37 per cent from BAU by 2030	Reduce GHG emissions by 35 per cent from 2018 levels by 2030**	Reduced**
G20 members that have not yet submitted new or updated NDCs or announced pledges			
India	Reduce emissions/GDP by 33–35 per cent from 2005 levels by 2030 Increase the share of non-fossil fuels in primary electricity production to 40 per cent (conditional)	N/A	N/A
Saudi Arabia	Annually abate up to 130 $MtCO_2e$ by 2030	N/A	N/A
Turkey	Reduce GHG emissions by up to 21 per cent from BAU by 2030	N/A	N/A

Notes: *Australia's original NDC was 'to be developed into an emissions budget' over the 2021–2030 period. The updated NDC of December 2020 provided an indicative emissions budget of 4,832–4,764 $MtCO_2e$.

**On 31 August 2021, the National Assembly passed the Framework Act on Carbon Neutrality, which outlines the new 2030 target (Republic of Korea, Ministry of Environment 2021). There is no study available yet that compares the ambition of the new 2030 target with the previous NDC.

Sources: Climate Watch (2021)

10 For comparison with the updated NDC, modelling studies interpolate the previous 2025 and 2050 targets (80 per cent from 2005 levels).

11 Climate Action Tracker (2021a) also reports the calculated impact relative to the current policies scenario. As the withdrawal of the United States of America from the Paris Agreement took effect on 4 November 2020, the country no longer had an official NDC in 2020. The calculated impact of the updated NDC relative to the current policies scenario would therefore be a reduction of about 2.0 $GtCO_2e$.

2.4 Assessment of G20 members' progress towards NDCs and mitigation pledges for 2030

This section assesses the progress of G20 members towards their previous NDC targets and indicates progress towards new, updated or announced 2030 targets based on emissions projections. GHG emissions projections were compiled and reviewed to assess the emission levels expected for G20 members under existing policies, i.e. the current policies scenario,[12] and whether members are likely to meet their respective emission reduction targets for 2030. Projections of the current policies scenario assume that no additional mitigation policies and measures are taken beyond those adopted and/or implemented as of a certain cut-off date (den Elzen *et al.* 2019). This report's assessment is based on 'point-in-time' emissions projections in the NDC target year.

2.4.1 Methods and limitations

Current policies scenario projections were compared against the original unconditional NDCs at the time of publication of the Emissions Gap Report 2020 (November 2020), as presented in table 2.1. This assessment follows the methodology of den Elzen *et al.* (2019) to enable a robust comparison of projections published by independent research institutions. European Union member states are assessed as the EU27 (and not individually), with the United Kingdom now assessed separately. Official assessments published by national governments were compared with independent assessments. All data sources are presented in appendix A (available online). Policy cut-off dates ranged from 2017 to 2021 across studies. The progress assessment was based on emissions figures including land use, land-use change and forestry (LULUCF; see appendix A on how the emissions projections excluding LULUCF were adjusted).

Recently published emissions projections for the current policies scenario and NDC scenario were collected from independent studies and considered. As at October 2021, only a few of the institutions regularly publishing national-level CO_2 and GHG emissions projections for the current policies scenario had released updates that considered the potential impact of COVID-19. Annually published global studies, such as Climate Action Tracker (2021b), Joint Research Centre of the European Commission (Joint Research Centre 2021) and PBL Netherlands Environmental Assessment Agency (Nascimento *et al.* 2021; PBL Netherlands Environmental Assessment Agency 2021), as well as national studies, such as the Rhodium Group study for the United States of America (Pitt *et al.* 2021), all include the impact of COVID-19 and recent policies. For these studies, the progress assessment used NDC target emission estimates from their previous updates (used in the Emissions Gap Report 2020).

Other recent studies included several new national model scenarios from Fragkos *et al.* (2021) and the COMMIT[13] scenario database (International Institute for Applied Systems Analysis [IIASA] 2021; van Soest *et al.* 2021) for Australia, China (two national studies), the EU27 and the United States of America. These studies updated some 2020 national model scenario projections from the European Horizon 2020 Linking Climate and Development Policies – Leveraging International Networks and Knowledge Sharing (CD-LINKS) project (Roelfsema *et al.* 2020). However, it should be noted that these scenarios did not include the impact of COVID-19. After examining the projections from the studies collected, a number of pre-2020 studies were excluded whose 2020 emission estimates were more than 10 per cent higher than the highest estimates of the three studies published in 2021 that considered the impact of COVID-19 and recent policies (Climate Action Tracker 2021b; Joint Research Centre 2021; Nascimento *et al.* 2021).

Up-to-date official emissions projections published since November 2020 were collected from various sources, including countries' recently published national communications and biennial update reports, and other national government reports (see appendix A). Such information included annually updated projections made by the Australian and Canadian governments (Australia, Department of Industry, Science, Energy and Resources 2020; Canada, Environment and Climate Change Canada 2021).

The most important limitation for the 2021 assessment is the impact of the COVID-19 pandemic on the current policies scenario projections. As at September 2021, several recent projections had either been published or prepared prior to the pandemic, and therefore did not account for its potentially significant impact on emission trends in 2020 and 2021, and in the period until 2030. Other important limitations are similar to those of previous Emissions Gap Reports (see appendix A).

2.4.2 G20 progress towards previous NDC targets and indications of progress towards new, updated or announced targets for 2030

Collectively, the G20 members are projected to fall short of their new or updated unconditional NDCs and other announced mitigation pledges for 2030. Similarly, G20 members are projected to collectively fall short of their previous unconditional NDCs (as at November 2020) by 1.1 $GtCO_2e$ per year, if the unconditional NDCs of the three G20 members that are projected to significantly overachieve

12 Current policy scenario projections assume that no additional mitigation action is taken beyond current policies, even if it results in NDC targets not being achieved or being overachieved (United Nations Environment Programme [UNEP] 2015; den Elzen *et al.* 2019). Current policies scenario projections reflect all adopted and implemented policies, which for the purpose of this report are defined as legislative decisions, executive orders or their equivalent. This implies that officially announced plans or strategies alone would not qualify, while individual executive orders to implement such plans or strategies would qualify.

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their targets (India, the Russian Federation and Turkey; see table 2.2) are substituted with current policies scenario projections. However, the G20 members are collectively expected to slightly overachieve their previous unconditional NDCs by about 0.3 $GtCO_2e$ per year by 2030, based on scenario projections by independent studies.

Table 2.2 shows the progress of G20 members towards their previous NDC targets as of November 2020, organized by the status and assessment of their new or updated NDC targets and other announced 2030 targets submitted or announced thereafter. Ten of 17[14] G20 members are likely to achieve their unconditional NDC targets based on previous or first NDC submissions under current policies (i.e. Argentina, China, the EU27, India, Japan, the Russian Federation, Saudi Arabia, South Africa, Turkey and the United Kingdom – as a former European Union member state; see table 2.2). Three G20 members (India, the Russian Federation and Turkey) are projected to be at least 15 per cent lower than their previous unconditional emission target levels and therefore have significant room to increase the ambition of their NDCs (figure 2.5). Central estimates of emissions projections for 2030 under current policies were lower than those of the Emissions Gap Report 2020 for all previously mentioned G20 members, with the exception of Argentina, whose estimate remained largely unchanged. For example, for the EU27 and South Africa, current projections are roughly 10 per cent and 20 per cent lower than the projections of last year's assessment, respectively, due to enhanced policies and the impact of COVID-19.

14 An assessment of individual European Union member states was not conducted.

Table 2.2. Assessment of progress towards achieving the previous unconditional nationally determined contribution targets for G20 members under current policies based on independent studies mainly published after the COVID-19 outbreak

		Projected progress towards the previous NDC target [*x* studies meet the target/out of *y* studies]		
		Achieve previous target (indicated by +, if overachieved by more than 15 per cent)	Miss previous target	Uncertain
Status of NDC or announced target	Submitted stronger target	Argentina [3/3], EU27 [in Emissions Gap Report 2020 for EU27+UK; 1/3, one within reach],[1,2] Russian Federation+ [4/5],[1] South Africa [3/3], UK (formerly part of the EU)	USA [0/5], Canada [1/3]	
	Announced stronger target	China [4/6], Japan [3/3]	Republic of Korea [0/3][3]	
	No new target submitted	India+ [4/6], Saudi Arabia [2/2], Turkey+ [3/3]		
	Submitted equivalent or weaker target		Australia [1/4], Brazil [1/4, one within reach], Mexico [0/3]	Indonesia [0/3, two within reach]

Notes: See appendix A for the list of studies reviewed. The number of independent studies that project a country to meet its previous or first NDC target were compared with the total number of studies and are indicated in square brackets. 'Within reach' indicates that only the lower bound estimate of the current policies scenario is within the NDC target range.

1. Current policies scenario projections were also examined from official publications. The number of official publications that projected countries would achieve their point-in-time NDC target were: Australia: 0 of 1, Canada: 0 of 1, EU27: 0 of 1, Russian Federation: 0 of 1 and the United Kingdom: 0 of 1.
2. The EU Reference Scenario was used for the EU27, which assumes full implementation of the national energy and climate plans by European Union member states and sees European Union emissions reduce by around 43 per cent below 1990 levels by 2030 (European Commission 2021). Including net removals from LULUCF increases the reduction to 45 per cent. This baseline scenario indicates that additional effort would be required to meet the European Union's current 2030 energy-efficiency target, though its current 2030 renewable energy target would be met. Additional measures for member states are being prepared to fully implement national energy and climate plans submitted in 2020 (European Commission 2020).
3. The Republic of Korea's Emissions Trading Scheme (K-ETS) is an instrument used to fully achieve the country's NDC target and covers about 70 per cent of its GHG emissions. Among the three independent studies, only one (PBL Netherlands Environmental Assessment Agency) explicitly quantified the impact of the K-ETS up to 2025 based on the Master Plans for K-ETS Phase III (2021–2025) and Phase IV (2026–2030) and the Phase III National Allowances Allocation Plan. This partially explains why the studies project that the Republic of Korea will miss its NDC target under current policies.

For **China**, four out of six independent studies projected that the country would achieve its original NDC target. However, since five of the six studies reviewed only provided a single NDC target value for 2030 – despite China's NDC containing multiple targets, which are partly dependent on GDP growth rates – it was not possible to analyse in detail which targets would likely be met or overachieved. The long-term impacts of COVID-19 on GHG emissions were also highly uncertain, especially given the fact that China's fossil CO_2 emissions rebounded strongly in the second half of 2020 and in 2021 (section 2.2). This stronger-than-expected rebound was not considered in China's latest emissions projections that estimated the impact of COVID-19 (Climate Action Tracker (2021b), Joint Research Centre (2021) and PBL Netherlands Environmental Assessment Agency (2021)).

Six G20 members' GHG emissions were projected to fall short and therefore require further action of varying degree to meet their previous (or original) unconditional NDC targets. These G20 members are Australia, Brazil, Canada, Mexico, the Republic of Korea and the United States of America.

- For **Australia**, official projections showed that it will fall short of achieving its point-in-time target of 26–28 per cent by 2030 with implemented measures. Australia is also projected to miss its emissions budget targets for 2021–2030 without relying on past overachievement (Australia, Department of Industry, Science, Energy and Resources 2020). However, the official projections also indicated that Australia would achieve its point-in-time NDC target if its Technology Investment Roadmap is fully implemented ('High technology' scenario) (Australia, Department of Industry, Science, Energy and Resources 2020).

- For **Canada**, official projections indicated that if its strengthened climate plan, A Healthy Environment and a Healthy Economy, introduced in December 2020, is fully implemented, its GHG emissions would be reduced by 31 per cent below 2005 levels, thus overachieving its previous NDC target of 30 per cent below 2005 levels (Canada, Environment and Climate Change Canada 2021).

- For **Mexico**, all three independent studies reviewed in this assessment showed a (minor) increase in 2030 emissions projections compared with previous assessments included in the Emissions Gap Report 2020, finding that the country would narrowly miss its original NDC target.

- The **United States of America** has returned to the Paris Agreement and reversed many policies of the Trump Administration that would have led to increased emissions. The central estimate for the country's 2030 emissions in this year's assessment decreased by about 0.5 $GtCO_2e$/year (about 10 per cent). The main reasons for this result include the exclusion of two projections developed with a 2017 cut-off date for policies (Chai *et al.* 2017; Roelfsema *et al.* 2020), which were replaced with one updated national model projection of the COMMIT scenario database, and the inclusion of projections that quantified the potential impact of the COVID-19 pandemic on emissions in 2020 and beyond, and to a lesser extent on the quantified impact of the reversal of the previous Administration's policies.

It is worth noting that **Canada** and the **United States of America** have strengthened their NDC targets, though independent studies suggest that they are not on track to meet their earlier NDC targets with implemented policies. Although positive trends have been observed as described previously, these two countries need to make significant additional efforts to meet their new NDC targets.

Independent studies either do not agree or are inconclusive on whether Indonesia is on track to meet its unconditional NDCs. This is mainly due to the uncertainty of LULUCF emissions projections as a result of peat fires. The central estimate for 2030 emissions in this year's assessment are higher than that of the 2020 assessment, partially due to the major revision of LULUCF emissions data and projections.

The aggregate emissions for G20 members in 2030 under current policies are projected to be about 2 $GtCO_2e$ lower than that of the 2020 assessment. Consideration of 2020 emission reductions and the long-term impact of COVID-19 on the global economy has contributed significantly to the lower emissions projections. Another key factor behind these estimated lower emissions is the impact of policies adopted by G20 members in recent years, which will affect their progress towards achieving their NDC targets.[15] A list of key policy measures that may have significant direct impacts on future GHG emissions adopted in 2020 and 2021 are presented in appendix A. Many of these policies were adopted after the publication of the scenario studies reviewed in this section. Although there have been many positive developments, there have also been several negative ones, such as the implementation of fossil fuel extraction projects and coal-fired power plant construction plans, as well as the rollback of environmental regulations during the pandemic. Based on the central estimates of independent studies, several G20 members, namely Argentina, Brazil, China, India, Indonesia, Mexico, the Russian Federation and Saudi Arabia, are expected to emit more emissions in 2030 than they did in 2010 under implemented policies. Figure 2.5 provides a more detailed overview of G20 members' projected GHG emissions under various scenarios, which are also compared with historical emissions.

15 There are several other factors for the lower emissions projections, including revisions in GHG inventory data and changes in emissions scenario methodologies, along with other underlying assumptions.

Figure 2.5. Greenhouse gas emissions (all gases and sectors, including land use, land-use change and forestry) of the G20 and its individual members by 2030 under the current policies scenario, previous nationally determined contributions and new, updated or announced pledges compared with historical emissions

Figure 2.5a.

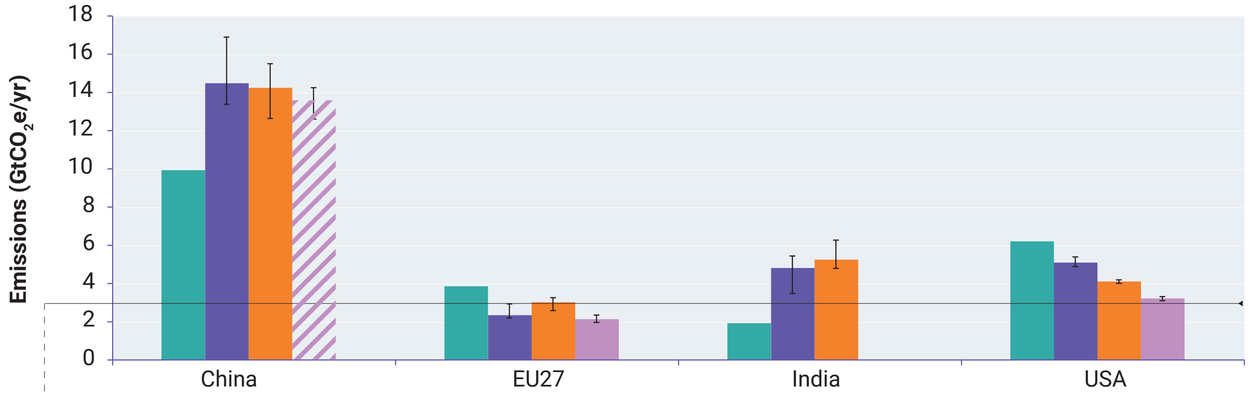
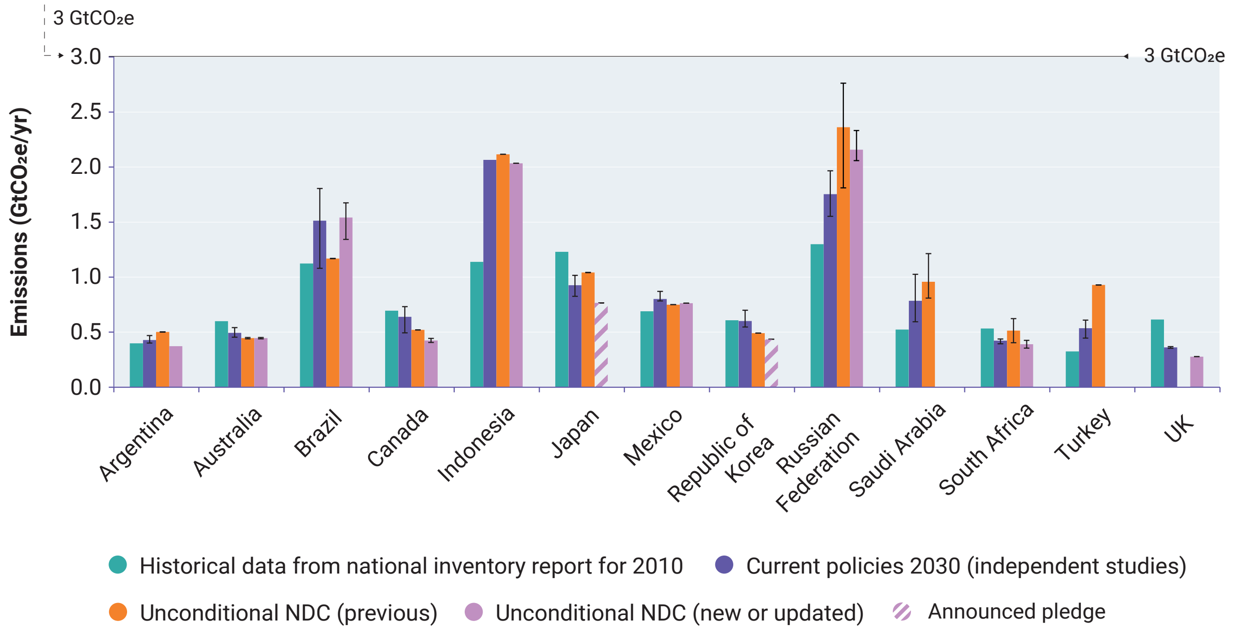


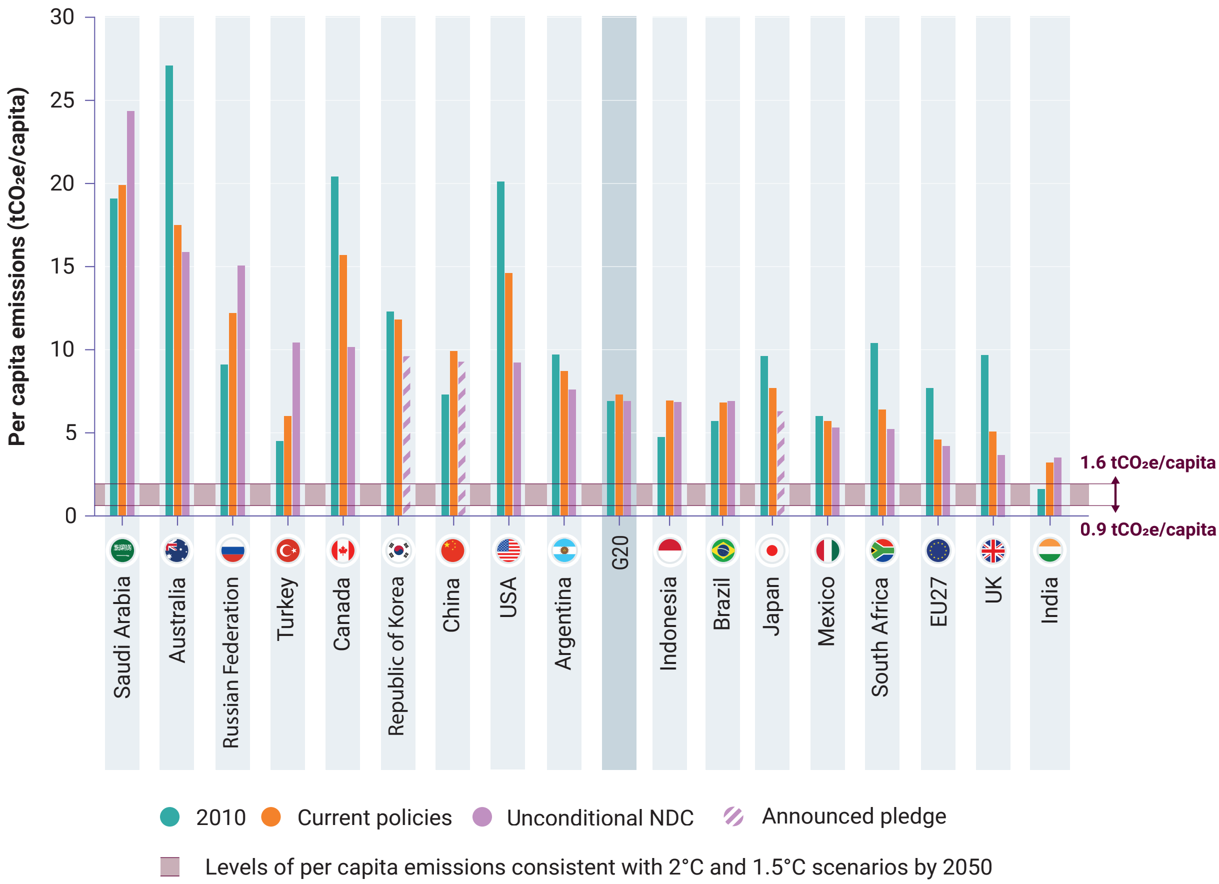
Figure 2.5b.



Notes: For current policies scenario projections, estimates based on independent studies are presented. For NDCs, official values (adjusted to Fourth Assessment Report GWPs) are presented where available. For reporting reasons, the emissions projections for China, the EU27, India and the United States of America are shown in figure 2.5a, and the other countries shown in figure 2.5b, using two different vertical axes. See appendix A for details. For the United States of America's previous NDC, the average of 2030 estimates from two studies are shown (Joint Research Centre 2021; Climate Action Tracker 2021b). For China and South Africa, the estimated emissions under the new 2030 announced targets are based on Climate Action Tracker and PBL Netherlands Environmental Assessment Agency studies (Nascimento *et al.* 2021; Climate Action Tracker 2021b). Estimates for China, Japan and the Republic of Korea use announced targets.

To supplement the findings presented above, figure 2.6 presents per capita GHG emissions under the current policies scenario, NDC targets and other announced 2030 pledges as at 30 September 2021, as well as the 2010 historical estimates for the 17 G20 members (counting the EU27 and its three individual G20 member states as one). In 2030, the average per capita emissions of G20 members under latest NDCs and other announced 2030 pledges are projected to be slightly lower (7 tCO_2e) than under the current policies scenario (7.4 tCO_2e) and the previous NDCs (7.2 tCO_2e). However, compared with 2010 levels, average emissions are not expected to be lower and as the figure illustrates they are still far off the median estimates consistent with 2°C and 1.5°C scenarios by 2050, which are 1.9 tCO_2e (tenth and ninetieth percentile range: 1.2–2.3 tCO_2e) and 0.6 tCO_2e (0.3–1.1 tCO_2e), respectively.[16] Per capita emissions vary significantly across G20 members, with India's emissions about half the G20 average for example, and Saudi Arabia's three times greater. The EU27 and the United Kingdom perform well in both absolute and per capita emission levels by 2030 and their reduction rates compared with 2010 levels. Australia and South Africa are also projected to reduce their per capita emissions by more than one third between 2010 and 2030 under current policies. Mexico also performs well in terms of its projected development of per capita emissions under both current policies and NDC scenarios. Per capita emissions under current unconditional NDC targets are projected to increase between 2010 and 2030 for seven G20 members.

Figure 2.6. Per capita greenhouse gas emissions of the G20 and its individual members by 2030 under nationally determined contributions and other announced 2030 pledges as at 30 September 2021, current policies scenario projections from independent studies mainly published after the COVID-19 outbreak, and 2010 historical levels



Notes: i) Figures include LULUCF. ii) Central estimates are a median value when five or more studies were available, otherwise they are average values. iii) Data on historical and projected (medium fertility variant) population per country are taken from the 2019 Revision of World Population Prospects (United Nations Department of Economics and Social Affairs [UN DESA], Population Division 2019). iv) The figures presented here may not exactly match official data due to the differences in data sources. v) G20 members are sorted in decreasing order of NDC emissions projections. vi) To estimate G20 total emissions for the NDC and announced 2030 pledges scenario, emissions projections under the current policies scenario were used for India, the Russian Federation and Turkey.

16 Estimated based on emission estimates from the IPCC Special Report on global warming of 1.5°C and United Nations population projections. The medium fertility variant was used (UN DESA, Population Division 2019).

3 Net-zero emissions targets

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3.1 Introduction

Achieving global net zero in line with the Paris Agreement requires rapid and deep reductions in global greenhouse gas (GHG) emissions, and the scaling-up of removals. Emissions reductions are essential to keep the challenge of halting global warming as manageable as possible. Removals are used to balance out emissions from activities for which we have not reduced emissions to zero – hence the concept of 'net zero' – as well as to deliver net-negative global emissions that can gradually reverse the warming already caused.

One promising development is the announcement of long-term net-zero emissions pledges by an increasing number of countries that currently account for more than half of global emissions. However, these pledges have large ambiguities and few of the latest nationally determined contributions (NDCs) put countries on a clear path towards their net-zero pledges. There is an urgent need to back net-zero pledges up with near-term targets and actions that give confidence that net-zero emissions can ultimately be achieved.

This chapter looks at how net-zero emissions targets have emerged from the scientific understanding of the climate system and the goals of the Paris Agreement (section 3.2). It sets out the considerations when translating net zero from a global scientific concept to national policy targets (section 3.3), and assesses current targets in terms of their ambition, scope, transparency and consistency with near-term plans and actions (sections 3.4 and 3.5).

3.2 The science of net-zero emissions targets

Net-zero emissions is a state where the sum of all anthropogenic emissions and removals is zero. Net-zero emissions targets are being defined in a variety of ways – the most important aspect from a global geophysical perspective being whether they cover all GHGs or carbon dioxide (CO_2) only (Rogelj *et al.* 2015). Net-zero GHG emissions are achieved when total aggregate GHG emissions over a given period are equal to an equivalent amount of aggregate GHG removal (Intergovernmental Panel on Climate Change [IPCC] 2021b). Net-zero CO_2 emissions are defined similarly but for CO_2 only.

Other terms such as 'carbon neutrality' and 'climate neutrality' are often used interchangeably for net-zero CO_2 and net-zero GHG emissions, respectively. However, as their meaning can differ depending on context and language, further specification is needed to avoid ambiguity (see glossary for various definitions of net-zero terms).

3.2.1 Net-zero CO_2 emissions stabilize global warming, whereas net-zero GHG emissions result in a peak and decline in global warming

As a concept, net-zero emissions were introduced well over a decade ago as a way of thinking about minimizing society's impact on the climate and the environment (United Nations Environment Programme [UNEP] 2008; Worth 2005). The concept gained traction after several scientific studies in the 2000s established a near-linear relationship between global warming and the total amount of net anthropogenic CO_2 emissions ever emitted.

Reaching net-zero CO_2 emissions results in CO_2 concentrations gradually declining over time towards a long-term equilibrium as part of the excess CO_2 in the atmosphere is redistributed by the uptake in the biosphere on land and in the ocean. As a result, CO_2-induced temperature stabilizes (Allen *et al.* 2009; Collins *et al.* 2013; Joos *et al.* 2013; Knutti and Rogelj 2015; Lee *et al.* 2021; MacDougall *et al.* 2020; Matthews *et al.* 2009; Matthews and Caldeira 2008; Meinshausen *et al.* 2009; Solomon *et al.* 2010; Zickfeld *et al.* 2009).

These insights were consolidated in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) where they were used to establish the geophysical requirements for halting global warming and to estimate carbon budgets consistent with preventing warming from exceeding specified levels (Collins *et al.* 2013; IPCC 2014, 2013; Stocker *et al.* 2013) (see box 3.1). The most recent IPCC assessment report (the Sixth Assessment Report, AR6) confirms that warming is expected to stabilize once global CO_2 emissions reach net-zero levels (IPCC 2021a; Lee *et al.* 2021).

For non-CO_2 emissions, the global temperature impact of achieving net-zero emissions depends on how long the GHG persists in the atmosphere (Pierrehumbert 2014; Solomon *et al.* 2010). Methane, currently the second-largest contributor to warming, has a much shorter lifetime than CO_2. Therefore, if methane emissions reduce to zero, concentrations fall faster, and their contribution to global temperature will decline. Achieving net-zero GHG emissions expressed with the default GWP-100 metric through a combination of low residual non-CO_2 emissions and CO_2 removal results in a peak then a decline in global warming (figure 3.1) (Forster *et al.* 2021; Fuglestvedt *et al.* 2018; IPCC 2021b; Rogelj *et al.* 2021). The magnitude of this decline depends on the minimum level to which non-CO_2 GHGs can be reduced, but could potentially be around 0.02–0.05°C/decade (Fuglestvedt *et al.* 2018).

At present, none of the available mitigation scenarios fully eliminate all CO_2 or other GHG emissions (Clarke *et al.* 2014; Gernaat *et al.* 2015; Rogelj *et al.* 2018; Smith *et al.* 2014). To reach net-zero emissions, residual emissions are thus balanced by removals from the atmosphere: hence the inclusion of 'net' in net-zero targets. The most scalable forms of GHG removal are CO_2 removal measures (Fuss *et al.* 2018; Nemet *et al.* 2018). This means that net-zero CO_2 emissions are achieved before net-zero GHG emissions. Reaching net-zero GHG emissions targets therefore involves at least two, and in most cases three, interlinked strategies: deep reductions in CO_2 emissions, the upscaling of CO_2 removal, and deep reductions in other GHG emissions (figure 3.1).

Box 3.1. Carbon budgets

Global warming is close to linearly proportional to the total net amount of CO_2 that has ever been emitted into the atmosphere as a result of human activities. Therefore, limiting global warming to a specified level requires that the total amount of CO_2 emissions ever emitted be kept within a finite carbon budget. Recently, AR6 published new estimates of the remaining carbon budget for limiting warming to 1.5°C or 2°C relative to pre-industrial levels (Canadell *et al.* 2021; IPCC 2021b). According to these, human activities resulted in about 2,390 $GtCO_2$ between 1850 and 2019, contributing around three quarters of the 1.07°C of human-induced warming from 1850-1900 to 2010-2019.

To limit warming to 1.5°C with a 66 per cent or 50 per cent chance, the remaining carbon budget is estimated at 400 and 500 $GtCO_2$, respectively. For 2°C, these estimates are 1,150 and 1,350 $GtCO_2$, respectively. Current annual global CO_2 emissions are above 40 $GtCO_2$/year, meaning that urgent and deep emissions reductions over the next decade are required to stay within the remaining budgets. AR6 clarifies that methodological improvements cause the estimates in the latest report to be markedly larger than in AR5 (Stocker *et al.* 2013), but very similar to those reported in the IPCC Special Report on global warming of 1.5°C (Rogelj *et al.* 2018) (see box 5.2 in Canadell *et al.* (2021) for more information).

Carbon budgets are not the only determinant of global warming. The warming that accompanies non-CO_2 emissions also plays a role. AR6 carbon budgets assume that non-CO_2 emissions are reduced following the median reductions from deep mitigation scenarios (Canadell *et al.* 2021; Rogelj *et al.* 2018). For methane, this implies at least a 30 per cent reduction in 2030 compared with 2010, and about a 50 per cent reduction in 2050. Remaining carbon budgets may vary by an estimated 220 $GtCO_2$ or more, depending on how deeply future non-carbon-dioxide emissions are reduced (Canadell *et al.* 2021). Chapter 6 assesses the role of methane in meeting these emissions reductions and bridging the emissions gap.

Total GHG emissions are aggregated in units of CO_2 equivalence. Although several different metrics for defining this equivalence exist (Myhre *et al.* 2013), under the Paris Agreement GHG emissions must be aggregated using the global warming potential over a 100-year time-horizon (GWP-100) metric[1] (United Nations Framework Convention on Climate Change [UNFCCC] 2018).

1 Parties to the Paris Agreement are mandated to report aggregated greenhouse gas emissions by using the GWP-100 metric, while additional information that uses other aggregations can also be provided. Note that in addition, emissions of the various GHGs also have to be reported individually.

Figure 3.1. Illustration of how net-zero carbon dioxide or net-zero greenhouse gas emissions are reached at a global level (top) and the typical global warming implications of reaching these respective targets (bottom)

Figure 3.1a. Global greenhouse gas (GHG) emissions and times of achieving net zero for an illustrative pathway that keeps warming well below 2°C

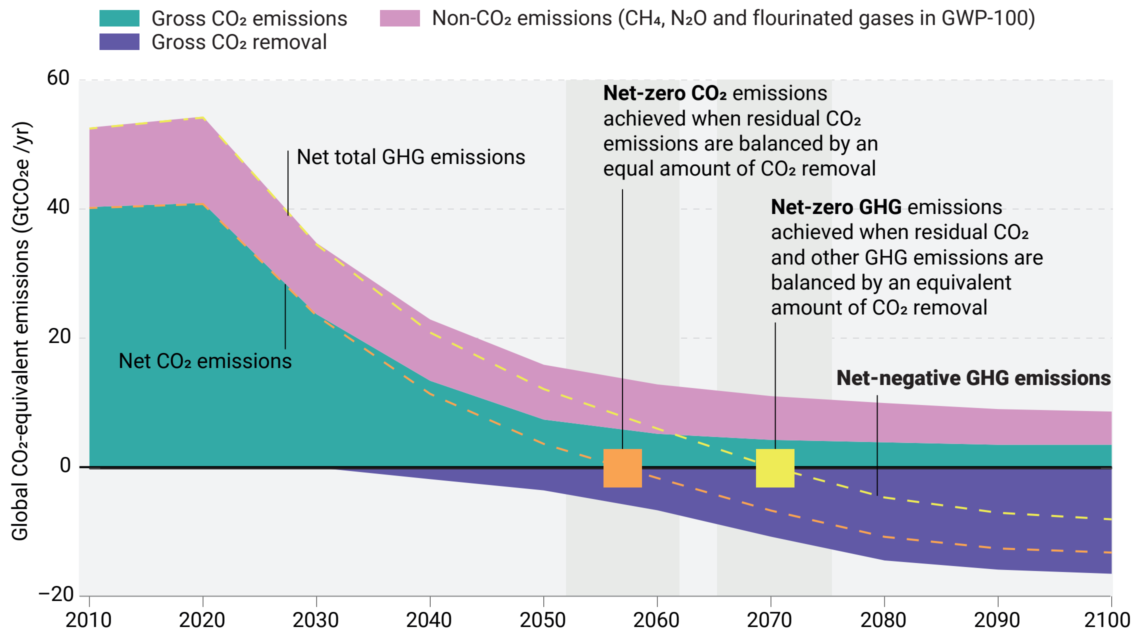
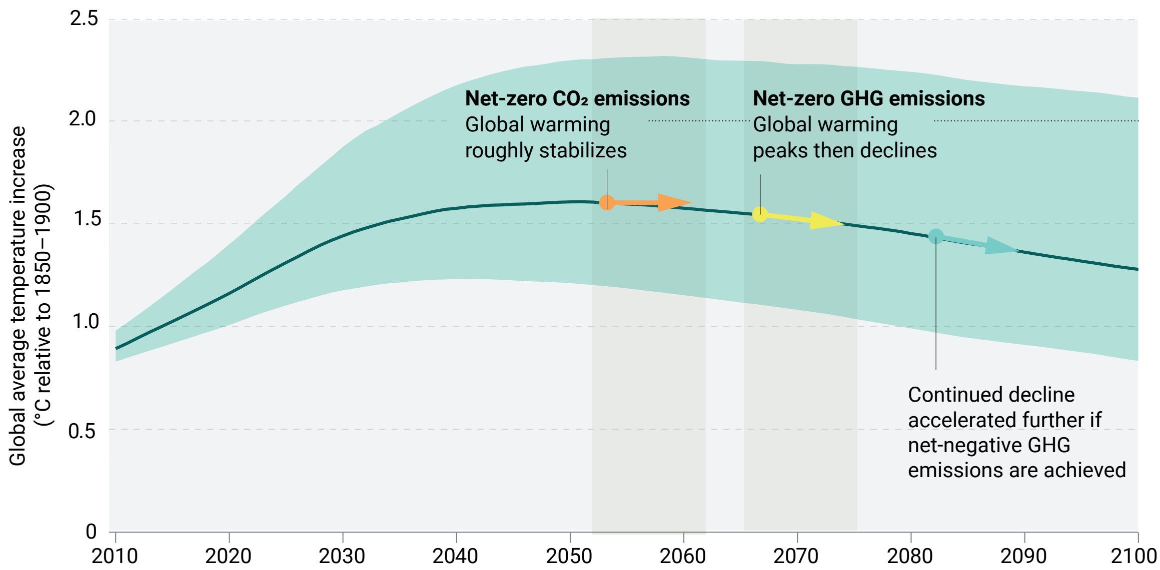


Figure 3.1b. Global warming implications



Note: GWP-100 stands for global warming potential over a 100-year time-horizon, and is the metric that is mandated to be used under the United Nations Framework Convention on Climate Change (UNFCCC) to report aggregated anthropogenic emissions and removals of GHGs. Reaching net-zero CO_2 emissions results in global warming stabilizing, provided that non-CO_2 forcing is also stabilized (Allen *et al.* 2018; IPCC 2018), while reaching net-zero GHG emissions defined with GWP-100 results in global warming peaking and subsequently gradually declining (Fuglestvedt *et al.* 2018). Figure adapted from Rogelj *et al.* (2021). Pathway taken from Huppmann et al. (2018a, 2018b) and climate outcome assessed using the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) (Meinshausen *et al.* 2011). Note that this figure shows one illustrative scenario in which the net-zero timings of CO_2 and total GHG emissions are not necessarily equal to the median estimates of the IPCC Special Report on global warming of 1.5°C (IPCC 2018).

3.2.2 The Paris Agreement and the timing of net-zero emissions

In the lead-up to the Paris Agreement, these geophysical concepts of carbon budgets and net-zero emissions were proposed as key elements for a legal architecture (Haites, Yamin and Höhne 2013), and studies proposed net-zero dates for global CO_2 and total GHG emissions in line with specific temperature limits (Rogelj *et al.* 2015). The Paris Agreement marked the incorporation of the net-zero concept into international policy, aiming to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty" (UNFCCC 2015). Subsequently, the IPCC Special Report on global warming of 1.5°C highlighted that to limit warming to 1.5°C above pre-industrial levels with no or limited overshoot, global CO_2 emissions should reach net zero around mid-century (IPCC 2018). The latter spurred a wave of net-zero target declarations.

Table 3.1 provides global net-zero timings from model pathways aligned with 1.5°C and 2°C limits. For 1.5°C, CO_2 emissions must reach net zero around 2050, with GHG emissions reaching net zero 15–20 years later. A delay of 15–20 years in either net-zero CO_2 or net-zero GHGs implies limiting warming to 2°C rather than 1.5°C.

Table 3.1. Global timing of net-zero carbon dioxide and net-zero greenhouse gas emissions. Median and interquartile range

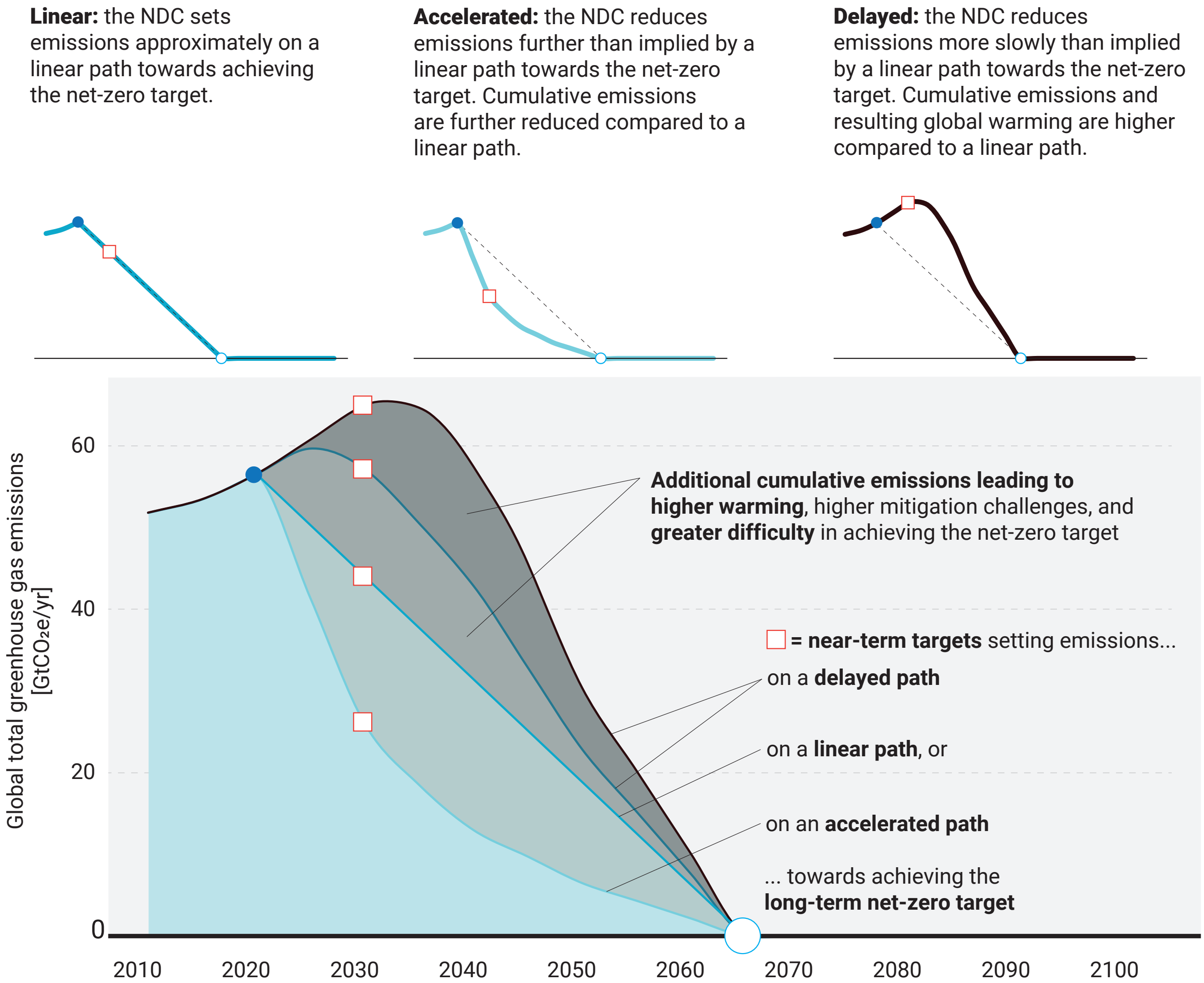
Pathway category	No. of scenarios	Timing of reaching net zero	
		Timing of reaching net zero Global CO_2 emissions	Global GHG emissions
SR1.5: 1.5°C with no or limited overshoot (50–66% chance in 2100 with maximum of 0.1°C overshoot until then)	42	2050 (2046, 2055)	2067 (2061, 2084)
SR1.5: Lower-2°C (66% chance)	54	2070 (2063, 2079)	Post-2100 (2090, post-2100)
1.5°C pathways (66% chance in 2100, and minimum 33% chance over the course of the century, chapter 4)	26	2054 (2049, 2059)	2071 (2058, post-2100)
1.8°C pathways (66% chance, chapter 4)	23	2067 (2057, 2083)	2086 (2068, post-2100)
2°C pathways (66% chance, chapter 4)	71	2069 (2059, 2089)	2090 (2077, post-2100)

Note: SR1.5 stands for IPCC Special Report on global warming of 1.5°C. IPCC estimates as reported in table 2.4 of SR1.5 (Rogelj *et al.* 2018). Values show the median and interquartile range across scenarios available in the SR1.5 scenario database (Huppmann *et al.* 2018a). In the pathway categories as used in chapter 4 of this report, pathways with emissions reductions before 2020 are excluded. The temperature outcomes of these pathways have also been reassessed based on the physical climate assessment of the IPCC AR6 – see cross-chapter box 7.1 in Forster *et al.* (2021).

3.2.3 The pathway to net-zero counts

Carbon budgets come with climate implications for net-zero targets: the path followed from today until net-zero CO_2 emissions are reached determines the total amount of emitted CO_2 and thereby the total carbon budget. Whether we follow a linear, an accelerated, or a delayed path impacts the climate outcome (figure 3.2). Following a delayed path compared to an accelerated path to net-zero GHG emissions by 2065 could lead to about 0.1°C more warming. At worst, a delay could result in a complete failure to achieve the net-zero target, resulting in higher warming. Near-term emissions reductions that sketch a linear or accelerated path towards a longer-term net-zero target therefore provide higher confidence that the net-zero target can ultimately be achieved.

Figure 3.2. Near-term targets are critical to set global emissions on a clear path towards achieving long-term net-zero targets and stringent climate goals



Global net-zero emissions targets in isolation set only a weak limit on the maximum level of global warming (Rogelj *et al.* 2015), as the maximum level of warming is largely defined by the cumulative amount of CO_2 emissions emitted until net zero (IPCC 2018).

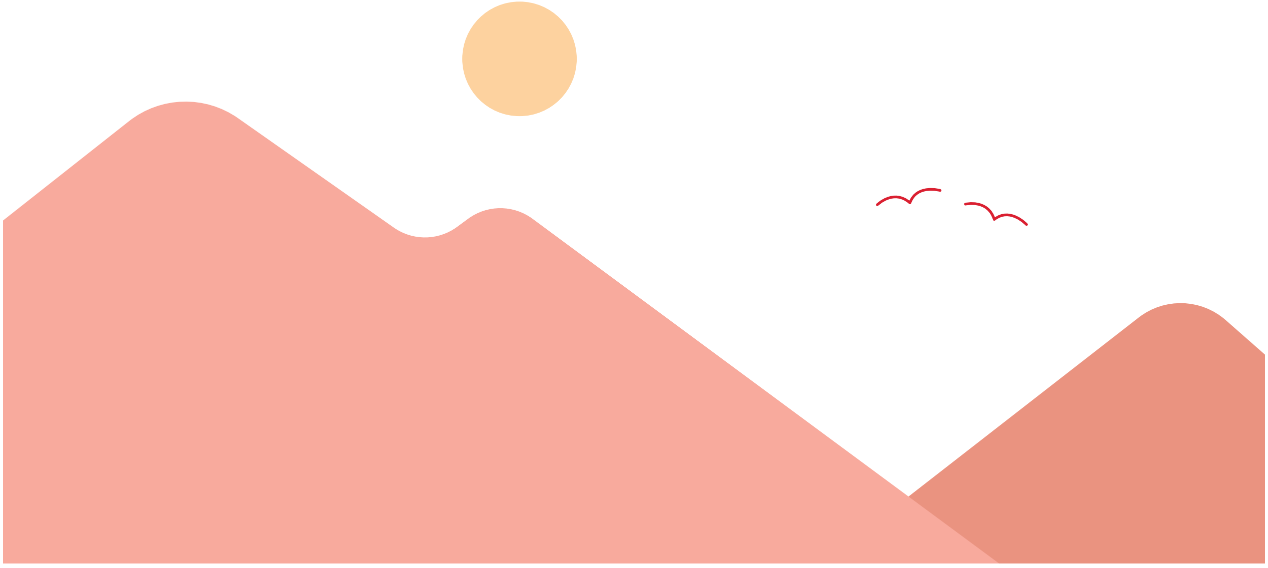
3.3 Net-zero at the national level

Setting net-zero emissions targets at the national level involves several steps in addition to the aforementioned global considerations. These steps represent both technical choices and normative decisions related to equity and fairness. Although this chapter focuses on countries, there are similar steps to translate global net-zero targets to sectors, companies, investment portfolios and other entities (see box 3.2).

First, at a technical level, the scope of emissions covered by a net-zero target needs defining (Levin *et al.* 2020; Rogelj *et al.* 2021). This includes defining the GHGs and activity sectors that are covered. For countries, the UNFCCC's requirement that parties report emissions and removals of a basket of GHGs on a territorial basis informs the scope of national targets. Countries could however exclude some gases or activities, include others such as international aviation and shipping, or take a different approach such as consumption-based accounting (Davis and Caldeira 2010; Munksgaard and Pedersen 2001; Wyckoff and Roop 1994).

A further choice in scope is the inclusion and use of carbon offsets, which are credits generated by projects carrying out emissions reduction or removal outside a country's (or other entity's) boundary. These credits are transferred to be accounted for within the boundary, often – but not always – by financial purchase through a market. Markets can allow entities to meet targets in a more economically efficient way (Grubb *et al.* 2011).

However, experience shows that international carbon markets can have pitfalls. Large numbers of credit-generating projects in the Clean Development Mechanism – the market operated under the Kyoto Protocol – were found not to fully represent additional carbon benefits



(Cames *et al.* 2016). The Paris Agreement anticipates a new international regime for carbon markets under article 6, the operation of which is still under negotiation. This will require clearly defined rules and robust accounting mechanisms to track progress, deliver real emissions reductions and drive ambition. Chapter 7 further discusses challenges and opportunities in using markets in achieving Paris Agreement targets in both the near-term and net-zero context.

Second, normative choices are required when translating global net-zero targets to the country level, involving questions of equity and fairness. A deadline for global net-zero emissions does not require all countries to achieve net zero at the same time (Robiou du Pont *et al.* 2016; Rogelj *et al.* 2021). Factors such as responsibility, capacity and level of development imply that some nations should achieve (and go beyond) net-zero emissions more quickly than others (Dubash *et al.* 2021; Rogelj *et al.* 2021). Furthermore, the costs of and potential for achieving emissions reductions and removals are geographically unevenly distributed. Reaching global net-zero emissions is therefore likely to involve a combination of positive and negative emissions contributions across countries and sectors, keeping in mind that the global potential for negative CO_2 emissions is limited because of technical, social and sustainability reasons (IPCC 2019, 2018). This variation between countries is illustrated by the different times at which regions (Rogelj 2018) or major emitting countries (van Soest *et al.* 2021) reach net-zero CO_2 or GHG emissions as part of a global least-cost transition, irrespective of additional equity or fairness considerations.

Aside from questions of equity and scope, debates have emerged over whether net-zero targets promote or hinder actions consistent with the Paris Agreement. Net-zero is seen as more actor-centred and effective than a temperature limit (Geden 2016). It also represents greater ambition than the current long-term pledges of most countries.[2]

Nevertheless, the concept of net-zero has faced criticism on the grounds that it may slow mitigation, either through over-reliance on carbon removal (McLaren *et al.* 2019) or on carbon credits (Stabinsky, Bhatnagar and Shaw 2021), or because an emphasis on long-term targets can distract from a lack of near-term actions. Other critics highlight that a narrow focus on net-zero targets can lose sight of differences in national climate politics, or the credibility of pledges, as well as equity (Dubash *et al.* 2021; Rogelj *et al.* 2021). Net-zero targets are not to be viewed in isolation as the sole policy mechanism for effecting change; they should be accompanied by near-term actions as well as detailed and transparent plans for delivery (Rogelj *et al.* 2021; Smith 2021). The Paris Agreement encourages these through the submission of NDCs and long-term strategies to the UNFCCC.

In response to these issues and criticisms, several recent studies have focused on identifying a set of criteria against which the robustness of net-zero pledges can be assessed (Black *et al.* 2021; Climate Action Tracker 2021; Levin *et al.* 2020; Rogelj *et al.* 2021). They share several common features, summarized in table 3.2.

2 See https://unfccc.int/process/the-paris-agreement/long-term-strategies.

Table 3.2. Overview of criteria used to assess national net-zero pledges

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="4">Studies</th></tr>
<tr><th>Climate Action Tracker (2021)</th><th>Energy & Climate Intelligence Unit – Oxford (Black et al. 2021)</th><th>Rogelj et al. (2021)</th><th>World Resources Institute (Levin et al. 2020)</th></tr>
<tr><td rowspan="6">Goal</td><td>Target year
When will net zero be achieved?</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Legal status
Is the target binding in domestic law, or what other form of commitment is it?</td><td>x</td><td>x</td><td></td><td>x</td></tr>
<tr><td>Global climate goal
What global temperature level is the target designed to contribute to?</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>Interim targets/action
What is the path to net zero?</td><td></td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Pathway after net zero
Is the intent to maintain net zero, or to reach net negative?</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>Reference to fairness
Has the target been justified as a fair and adequate contribution to the global goal? If so, how?</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td rowspan="4">Scope</td><td>Gas coverage
Does the target include all GHGs under the Paris Agreement, or a subset?</td><td rowspan="2">x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Sector coverage
Does the target include all domestic activities, or a subset?</td><td></td><td rowspan="2">x</td><td>x</td></tr>
<tr><td>Coverage of international aviation and shipping
Does the target include a share of international aviation and/ or shipping?</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Use of international offsets
Does the target allow such offsets to be counted towards the target?</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td rowspan="5">Transparency</td><td>Published plan
Has the government set out a plan of actions to achieve the target?</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Review process
Is there a regular, binding process for reviewing and revising the target?</td><td>x</td><td></td><td></td><td>x</td></tr>
<tr><td>Reporting of progress
Is there regular reporting of progress against the target?</td><td></td><td>x</td><td></td><td>x</td></tr>
<tr><td>Separate reductions and removals
Does the target include separate subtargets for emissions and removals?</td><td>x</td><td></td><td>x</td><td>x</td></tr>
<tr><td>Transparency on removals
Are assumptions about use of removal methods, both in the land and industry sectors, transparent?</td><td>x</td><td></td><td>x</td><td>x</td></tr>
<tr><td></td><td>Metric for aggregating emissions
If the target is for multiple GHGs, does it use the GWP-100 metric under the Paris Agreement? If not, why not?</td><td></td><td></td><td>x</td><td></td></tr>
</table>

Note: “x” indicates which criteria are included in each of the four published studies.

3.4 Tracking national net-zero targets globally

The number of national net-zero targets has grown rapidly over the last four years. By the broadest definition, as many as 136 countries covering more than half of global GHG emissions either have some form of commitment to such a target or are considering it (Climate Action Tracker 2021; Energy & Climate Intelligence Unit [ECIU] 2021; UNEP 2020; World Resources Institute 2020). This includes countries whose governments are merely discussing net-zero targets, and signatories to the Climate Ambition Alliance which cites working towards net-zero CO_2 emissions by 2050 among its aims (Climate Ambition Alliance 2019).

Here we define a net-zero target as a statement in national legislation, in a policy document (i.e. an NDC or long-term strategy communicated to the UNFCCC, or a similar document published by a national government), or a public announcement by the government or a high-level government official (e.g. Head of State). We include references to net-zero emissions, net-zero carbon, carbon neutral(ity), GHG neutral(ity), climate neutral(ity) and a decarbonized economy or society. Our analysis reflects developments up to 13 September 2021.

Using this classification, 52 parties (51 countries plus the European Union) have pledged a net-zero target. These cover around 57 per cent of current global domestic GHG emissions, 60 per cent of gross domestic product (GDP) and 34 per cent of the global population (Climate Watch 2021; World Resources Institute 2021). Thirteen targets are enshrined in law, covering 12 per cent of global emissions (table 3.3).

Table 3.3. Overview of current national net-zero pledges across all United Nations Framework Convention on Climate Change (UNFCCC) parties, by year and by legal status

	Parties	Emissions	GDP	Population
In law	13	12%	10%	3%
In policy document	24	15%	24%	7%
Government announcement	15	30%	26%	24%

Sources: Total coverage of current net-zero pledges by percentage of global domestic emissions in 2018 (World Resources Institute 2021), GDP (World Bank 2019, in purchasing power parity (PPP) constant international $ terms) and population (UN World Population Prospects 2019)

By number, the majority of these targets (40) are for 2050, coincident with the mid-century timescale for global CO_2 emissions indicated by the IPCC as necessary for limiting warming to 1.5°C. Eight targets are aimed at earlier years (2030–2045) and four at later years. In terms of emissions, however, the targets are split almost entirely and equally between 2050 (due to the pledges by the European Union and United States of America) and 2060 (due to China's pledge).

It is important to note that approaches to counting carbon sources and sinks can differ between global studies and national reporting. Some care is therefore needed when assigning net-zero status to countries, or interpreting claims by countries that 'carbon neutrality' has been achieved. In particular, national GHG inventories label all carbon uptake on managed land (including naturally occurring uptake) as anthropogenic, resulting in greater removal numbers than in the scientific modelling studies that form the basis for the global emissions pathways assessed in chapter 4 of this report (Grassi *et al.* 2021, 2018). However, one available study indicates that differences between the two approaches at the global level lead to a negligible difference in terms of timing of net-zero emissions (Grassi *et al.* 2021). Further in-depth studies are required to confirm this.

Existing net-zero targets show variations in scope, as well as large ambiguities (World Resources Institute 2020). Thirty-six are clear in including all sectors of domestic activity, while the remaining 16 are unclear or undecided. Regarding inclusion of GHGs, 17 targets are unclear or undecided, however those that are clear all include at least some non-CO_2 gases as well as CO_2. The majority (41) are unclear or undecided on inclusion of emissions from international aviation and shipping. However, three explicitly include them. Similarly, on use of offsets, five include them explicitly, eight rule them out and 39 are unclear or undecided.

As already explained, achieving net-zero emissions is key to halting or even gradually reversing global warming. With an increasing share of global emissions covered by net-zero targets, their impact on temperature projections is also increasingly important. Chapter 4 – which provides an overview of global warming implications of current policies, NDCs and net-zero targets – estimates that if fully achieved, net-zero targets could reduce global warming projections by about 0.5°C relative to projections that only take into account unconditional NDCs.

3.5 A closer look at net-zero targets in the G20

Twelve of the G20 members, covering 54 per cent of global domestic GHG emissions, currently have pledged a net-zero target, of which six are in law, two are in policy documents and four are government announcements. All are for the year 2050, with the exception of China's 2060 target and Germany's target for 2045.

Figure 3.3 provides an assessment of these targets against most of the criteria provided in table 3.3. Where information relevant to the criteria is available from countries, figure 3.3 highlights its existence rather than assessing its sufficiency. For instance, a plan may be published and it may refer to the fairness of its contribution to global efforts, however additional assessment is required to establish whether the plan is detailed enough and the fairness appropriate.

Similar to the global assessment of national net-zero targets, a notable feature of current net-zero targets of G20 members is their ambiguity. Regarding scope, most targets are unclear or undecided on inclusion of offsets and of international aviation and shipping emissions. Lack of clarity is also notable on coverage of sectors and gases, but those that are clear show a tendency for comprehensive coverage. Most show a lack of transparency regarding the approach taken to fairness, the plans for achievement (including on use of removals), and on reporting and reviewing progress. Only Canada, the European Union, France, Germany and the Republic of Korea have published their plans so far, and only these countries plus the United Kingdom have accountable processes for reviewing their targets.

As an indication of the consistency between nearer-term actions and net-zero targets, figure 3.3 also plots the emissions paths for G20 members implied by their most recent NDCs or announced mitigation pledge for 2030 and their net-zero target. As highlighted in section 3.2 and figure 3.2, near-term targets need to be aligned on a clear path towards achieving net-zero targets and limiting cumulative emissions. Indeed, the Emissions Gap Report 2020 (UNEP 2020) argued that the litmus test of net-zero pledges is the extent to which they are reflected in near-term policy action and in significantly more ambitious NDCs for the period to 2030. Near-term emissions reductions that follow a linear or accelerated path towards a net-zero target provide higher confidence that the net-zero target can be achieved.

To summarize, eight G20 members have so far not set net-zero targets, whereas 12 (covering 54 per cent of global domestic GHG emissions) have. Of the nine G20 members for which we can estimate an emissions path based on their net-zero target and their NDC, none have NDC targets that put them on an accelerated path towards their net-zero emissions targets. Five of these nine members (covering 21 per cent of global domestic GHG emissions) have NDC targets that put the country's domestic emissions onto a linear path towards achieving their net-zero targets. For four G20 members (covering 28 per cent of global domestic GHG emissions), the NDCs lead to emissions in 2030 that are about 25 per cent to 95 per cent higher than a linear path towards their net-zero targets would imply. These countries urgently need strengthened and more ambitious near-term climate plans for their net-zero targets to remain achievable.

There is an urgent need for (i) more G20 members – and indeed all countries – to pledge net-zero emissions, (ii) all countries to increase the robustness of their net-zero pledges, and (iii) all net-zero targets to be backed up by near-term actions that give confidence that the net-zero targets can ultimately be achieved.

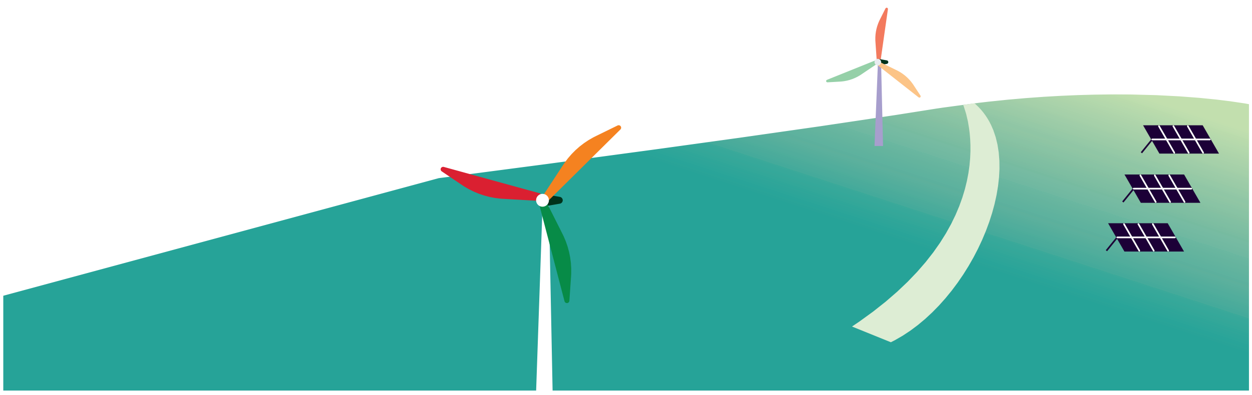
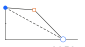
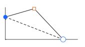
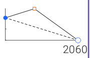
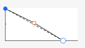
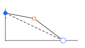
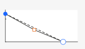
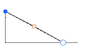
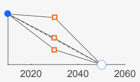


Figure 3.3. Analysis of current net-zero targets of G20 members

Country	Path to net zero	Year	Target status	Refers to fairness	All gases	All sectors	Int. aviation & shipping	Excludes offsets	Pub-lished plan	Review process	Reporting progress	Separate targets	Removals transparency
Argentina	 2050	2050	Government announcement	◌	?	?	?	?	◌	◌	◌	◌	◌
Brazil	 2050	2050	Government announcement	◌	?	●	?	?	◌	◌	◌	◌	◌
Canada	 2050	2050	In law	◌	●	●	?	?	●	●	Not annually	◌	◌
China	 2060	2060	Government announcement	◌	●	?	?	?	◌	◌	◌	◌	◌
European Union	 2050	2050	In law	◌	●	●	?	●	●	●	Not annually	◌	●
France		2050	In law	●	●	●	◌	●	●	●	Annually	●	●
Germany		2045	In law	◌	●	●	◌	◌	●	●	Annually	●	◌
Italy		2050	Government announcement	◌	?	?	?	?	◌	◌	◌	◌	◌
Japan	 2050	2050	In law	◌	●	●	?	?	◌	●	Not annually	◌	◌
Republic of Korea	 2050	2050	In policy document	◌	?	?	?	?	●	●	Not annually	◌	◌
UK	 2050	2050	In law	◌	●	●	●	◌	◌	●	Annually	◌	◌
USA	 2050	2050	In policy document	◌	●	●	?	?	◌	◌	◌	◌	◌

Key:



Schematic illustration of whether NDCs are putting national GHG emissions on a delayed, linear or accelerated path towards achieving the national net-zero target (see box 3.1)

● Yes ◌ No ? Unclear or undecided **Not annually** Not annually (reporting progress but less frequently than annually)

Note: Only G20 members with net zero targets are included. Member states of the European Union have no separate assessment of their path to net zero, because their NDC is not assessed separately as part of this report. Table 3.2 provides definitions of what is covered under the various headers.

Box 3.2. Non-state action on net zero

Businesses, cities, regions, investors, civil society groups, and other non-state and subnational actors (NSAs) play an increasingly important role in raising ambition and accelerating implementation. The Paris Agreement institutionalized the engagement of NSAs in achieving long-term climate goals and created an ongoing process to catalyse climate commitments made by NSAs, including net-zero targets (Chan, Ellinger and Widerberg 2018; Hale 2016; Hsu *et al*. 2018).

Efforts by NSAs towards global net-zero emissions are strengthening and broadening, which helps mobilize stakeholders to achieve net zero (Data-Driven EnviroLab and NewClimate Institute 2020; Hsu *et al*. 2020). The United Nations Race To Zero campaign rallies NSAs globally to take rigorous actions to reduce emissions by 50 per cent by 2030 and achieve net-zero carbon emissions by 2050 at the latest, vetting members via an independent expert group. More than 3,000 businesses, 730 cities, 170 investors, 30 regions and 600 universities have joined Race To Zero, together covering around 25 per cent of global CO_2 emissions and 50 per cent of GDP (Black *et al*. 2021; NewClimate Institute and Data-Driven EnviroLab 2020; Smit and Kuramochi 2020; UNFCCC 2021).

Actions taken by NSAs can also contribute to achieving net-zero targets set by governments, while at the same time creating more favourable conditions for governments to increase their ambition going forward. A recent study of major non-state actor initiatives found they had the potential to reduce 2030 emissions by 5–15 $GtCO_2e$ (Black *et al*. 2021; Hale *et al*. 2021; Hsu *et al*. 2019; NewClimate Institute and Data-Driven EnviroLab 2020; NewClimate Institute *et al*. 2021).

At the national level, NSAs are supporting implementation and enhancement of climate goals. For instance, America Is All In, a coalition of over 1,800 institutions representing 65 per cent of the United States of America's population and 70 per cent of its GDP, is an initiative to enhance non-state actions to cut the United States of America's GHG emissions by 50 per cent below 2005 levels by 2030 and put the country on a trajectory consistent with limiting global temperature rise to 1.5°C (Hultman *et al*. 2021). Meanwhile, the European Commission launched the European Climate Pact to mobilize NSAs and communities to participate in climate actions. The Japan Climate Initiative, made up of businesses and municipalities, has played a key role in supporting the government's new NDC.

However, the increase in NSA net-zero pledges needs to be treated with caution, because as they have proliferated, they have varied in robustness. The scope and coverage of net-zero targets; the existence of implementation plans, transparency and reporting to track progress; the alignment between near-term actions and long-term net-zero targets; and the robustness of carbon offsets are critical to credible net-zero targets (Black *et al*. 2021; Hale *et al*. 2021; Hsu *et al*. 2019; NewClimate Institute and Data-Driven EnviroLab 2020; NewClimate Institute *et al*. 2021). NSAs have started to take actions to address these issues. For example, the Taskforce on Scaling Voluntary Carbon Markets, a private-sector-led initiative, aims to develop a threshold standard to ensure high integrity offset credits and create robust and transparent markets.

4 The emissions gap

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4.1 Introduction

The emissions gap is estimated as the difference between projected global greenhouse gas (GHG) emissions assuming full implementation of the mitigation pledges that countries have made for 2030, and emissions under least-cost pathways consistent with the Paris Agreement's long-term goal of limiting global average temperature increase to "well-below 2°C" and pursing efforts to limit it to 1.5°C, compared with pre-industrial levels. This year, the update of the emissions gap is particularly interesting as it is the first time countries have submitted new or updated nationally determined contributions (NDCs) as part of the Paris Agreement's five-year ambition-raising cycle. Thus, the update of the emissions gap provides an indication of the extent to which the NDC process under the Paris Agreement is working and the progress made.

To estimate the emissions gap, updated scenarios that underlie its quantification are assessed (section 4.2). This year, the mitigation pledge scenarios include the latest available NDCs as well as announced mitigation pledges for 2030 with a cut-off date of 30 August 2021. Further, scenarios consider the repercussions of the COVID-19 pandemic and possible economic recovery paths. The emissions gap assessment for 2030 is presented in section 4.3, while the implications of failing to bridge the emissions gap for global temperature rise are discussed in section 4.4. In this context, the key questions assessed in this chapter are: What is our current best estimate of the emissions gap for 2030 taking into account the new or updated NDCs, announced pledges and the impact of the COVID-19 pandemic and associated recovery measures? What are the global warming implications over the course of the century?

4.2 Scenarios considered for the 2030 gap assessment

This section updates the eight scenarios considered for the 2030 emissions gap assessment. These scenarios comprise reference scenarios (4.2.1), NDC scenarios (4.2.2), and least-cost mitigation scenarios starting in 2020 consistent with specific temperature targets (4.2.3). Table 4.1 lists and describes all scenarios included in the assessment

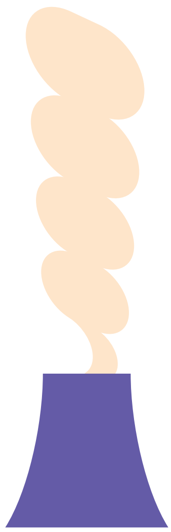


Table 4.1. Summary of assessed scenarios

Scenario		Cut-off year	Description
Reference	Year 2010 policies	2010	This scenario includes only climate polices implemented up to 2010 (no additional measures from 2010 onward).
	Current policies	2020/21	Current policies updated to reflect climate mitigation policies adopted and implemented as of 2020/21. Scenario also adjusted to reflect short- and midterm socioeconomic impacts from COVID-19.[1]
NDCs and announced mitigation pledges	Unconditional NDCs and announced mitigation pledges	2021	This scenario reflects new or updated NDCs as well as officially announced mitigation pledges for 2030 that have been indicated to be implemented without any explicit external support. (Cut-off date: 30 August 2021)
	Conditional NDC and announced mitigation pledges	2021	In addition to the unconditional pledges, this scenario considers new or updated NDCs as well as officially announced mitigation pledges for 2030 to be implemented conditional upon receiving international support (finance, technology transfer and/or capacity-building). (Cut-off date: 30 August 2021)
Mitigation scenarios consistent with the Paris Agreement	Below 2°C	Starting from 2020	Long-term least-cost pathway consistent with holding global warming below 2°C throughout the twenty-first century with at least 66 per cent chance.
	Below 1.8°C	Starting from 2020	Long-term least-cost pathway consistent with holding global warming below 1.8°C throughout the twenty-first century with at least 66 per cent chance.
	Below 1.5°C	Starting from 2020	Long-term least-cost pathway consistent with holding global warming below 1.5°C throughout the twenty-first century with limited or no overshooting. Global warming in 2100 is projected to be below 1.5°C with at least 66 per cent chance, while throughout the twenty-first century it is kept below 1.5°C with at least 33 per cent chance.

1 The updated current policy scenario adjusts original modelling studies to account for different policy cut-off dates, which range from 2017 to 2020, and varying consideration of the impact of the COVID-19 pandemic on socioeconomic drivers.

4.2.1 Reference scenarios and updates

Two reference scenarios are considered: the 'year 2010 policies' scenario and the 'updated current policies' scenario. Only the latter has changed compared to last year.

The **year 2010 policies scenario** assumes that no additional climate mitigation policies are implemented after 2010. As in previous gap reports, global GHG emissions in this scenario are based on the baseline projections of Shared Socioeconomic Pathway scenarios from six modelling studies assuming middle-of-the-road socioeconomic assumptions (SSP2) (Fricko *et al.* 2017) that also underpin the current policies scenario projections as of 2019 (McCollum *et al.* 2018; Roelfsema *et al.* 2020).[2]

The updated **current policies scenario** projects global GHG emissions assuming all currently adopted and implemented policies (defined as legislative decisions, executive orders, or equivalent) are realized and that no additional measures are undertaken. It also considers the impact of COVID-19. The data for this scenario are based on updates by four modelling studies[3] that include the impacts of COVID-19 and have a cut-off date of November 2020 and four international modelling groups.[4] The international modelling groups have 31 December 2016 as their cut-off date for current policies (Roelfsema *et al.* 2020) and do not include COVID-19 effects. They are included to ensure consistency of the data set and methodology across the Emissions Gap Reports. Their results were adjusted to reflect updates of policies until November 2020 by comparing them to the results of the four modelling studies that provide estimates for both cut-off dates (den Elzen, Höhne and Jiang 2017).

Following this approach, the median estimate of the impact of recent policies is a reduction in global GHG emissions of 1.5 gigatons of carbon dioxide equivalent ($GtCO_2e$) (range: 3.0–0.4). To capture the impact of COVID-19, the four international modelling groups' estimates were adjusted based on three of the four modelling studies (Climate Action Tracker, International Energy Agency [IEA] and PBL) that provide global GHG emissions projections based on consistent current policies scenarios, including as well as excluding the impact of the COVID-19 pandemic. Following this approach, the impact of COVID-19 is an estimated reduction in global GHG emissions of about 2.5 $GtCO_2e$ (range: 3.2–1.4) by 2030. Considering both of these impacts, the median estimate of global GHG emissions in 2030 for the updated current policies scenario becomes 55 $GtCO_2e$ (range of 52–58 $GtCO_2e$; see table 4.2) in 2030, which is 4 $GtCO_2e$ lower than the median estimate of the 2020 UNEP Emissions Gap Report.

It remains critically important to understand the potential structural changes of the COVID-19 pandemic and the post-COVID rescue and recovery packages on emission levels out to 2030 (see chapter 5). This is particularly important given the use of 2030 as a target year in many countries' NDC submissions and as a benchmark to gauge global climate action. Research is ongoing in this area, but not yet published in the peer-reviewed literature.

While understanding of energy-related GHG emissions trends during the COVID-19 pandemic is improving (Forster *et al.* 2020; Le Quéré *et al.* 2021, 2020; Liu *et al.* 2020), there is more uncertainty around trends in agriculture, forestry and other land-use (AFOLU)-based GHG emissions. However, these emissions seem to continue to increase. In 2020, agricultural activities had limited losses due to the COVID-19 pandemic and some commodities even increased their production (Food and Agriculture Organization of the United Nations [FAO] 2021a, 2021b; World Bank 2021). Further global deforestation rates increased significantly, resulting in a loss of tree cover by 25.2 Mha, 12 per cent more than in 2019 (Hansen *et al.* 2013; World Resources Institute [WRI] 2021).

Although near-term impacts on land-use dynamics are yet to be better known, as in the 2000s and 2010s, production of agricultural commodities (mainly beef, soy, and palm oil), illegal logging, mining extraction and wild fires were major drivers of deforestation (Curtis *et al.* 2018; FAO 2021c). The rising trend of prices for most food and metal commodities (FAO 2021a, 2021b; World Bank 2021), along with governmental stimulus into agribusiness activities, extractive industries, and development of road infrastructure in protected land regions drove deforestation and forest degradation, mainly in the tropics (Brancalion *et al.* 2020; Ferrante and Fearnside 2020). During the COVID-19 crisis and due to limited financing resources, some governments have also relaxed environmental laws and decreased their national budgets of regulatory mechanisms, which has reduced the enforcement of environmental protection laws (Amador-Jiménez *et al.* 2020; Vale *et al.* 2021). Furthermore, national lockdowns and disruption of non-forest economic activities have limited the income of forest-dependent communities,

2 From the CD-LINKS Scenario Database, version 1.0.

3 Climate Action Tracker (2021); Joint Research Centre's POLES model (Joint Research Centre, forthcoming); PBL Netherlands Environmental Assessment Agency's IMAGE model (Dafnomilis *et al.* 2021; den Elzen *et al.* in review; Nascimento *et al.* 2021) (see also: www.pbl.nl/ndc); and the stated policies scenario of the International Energy Agency [IEA]'s World Energy Outlook 2020 (IEA 2020). The more-optimistic stated policies scenario of the IEA World Energy Outlook 2020 that was used as a current policies scenario is not yet included. Furthermore, the energy-related CO_2 emissions of IEA were supplemented with the median estimates of the non-CO_2 GHG emissions and CO_2 land-use-related emissions of the current policies scenarios from the COMMIT database.

4 International Institute for Applied Systems Analysis (IIASA) with the MESSAGE–GLOBIOM model (Fricko *et al.* 2017); National Institute for Environmental Studies (NIES) with the AIM model (Fujimori *et al.* 2017); Potsdam Institute for Climate Impact Research (PIK) with the REMIND–MAgPIE model (Luderer *et al.* 2015) and COPPE, Universidade Federal do Rio de Janeiro (COPPE/UFRJ) with the COFFEE model (Rochedo *et al.* 2018).

thereby increasing pressure on forest products (Golar *et al.* 2020; Rahman *et al.* 2021).

Another issue related to land-use emissions is that about half of the global scenarios analyses and national GHG inventories use different definitions for anthropogenic removals in the land-use sector, resulting in different amounts of net land-use carbon dioxide (CO_2) emissions being reported, with a historic difference of up to 4 $GtCO_2e$/year between national GHG inventories and global emission pathway studies (Grassi *et al.* 2018). The solutions that have been published to account and correct for this discrepancy are integrated in these studies by applying a constant adjustment term over the 2010–2030 period.[5]

4.2.2 NDC and announced pledge scenarios and updates

The NDC and announced pledge scenarios include all the most recent NDCs (new or updated NDCs and previous NDCs for countries where no updates are available) as well as announced climate change mitigation pledges for 2030 that could be linked to updated NDCs and that focus on indicators or targets also included in their NDCs. The estimated impact of revised reduction targets in the new or updated unconditional NDC submissions and announcements lowers the emissions projection of the unconditional NDC scenario by about 4 $GtCO_2e$ (about 15 per cent) compared with the previous NDCs. For the conditional NDC scenario including announced pledges, a similar impact is found. This results in a median estimate of global GHG emissions of 52 $GtCO_2e$ and 50 $GtCO_2e$, if the unconditional and conditional NDCs are fully implemented. This is about 4 $GtCO_2e$ lower than last year's projections (based on previous NDCs, see figure 4.1).

The NDC and announced pledge scenario estimate is based on four model studies (Climate Action Tracker, PBL, JRC and Climate Resource) (Meinshausen *et al.* 2021),[6] all of which include the NDC updates (as at end of August 2021), while only the first three studies consider the impact of the announcements.[7,8] In addition, it is based on projections of four model groups (IIASA, the National Institute for Environmental Studies [NIES], the Potsdam Institute for Climate Impact Research [PIK] and Resources for the Future and Euro Mediterranean Center on Climate Change [RFF–CMCC]) that have been adjusted to reflect the impact of the new or updated NDCs and announced pledges.

4.2.3 Mitigation scenarios consistent with the Paris Agreement and updates

Emission projections of the latest NDCs and announced pledges scenarios, and updated current policies scenarios are compared to least-cost mitigation scenarios that meet specific temperature targets relative to pre-industrial levels. Here, we categorize emissions pathways from the literature based on their projected peak warming outcomes over the course of this century (Huppmann *et al.* 2018b, 2018a; Rogelj *et al.* 2018. See also chapter 3). We define three scenarios that differ in their estimated maximum warming over the course of this century (see table 4.1).

This year, the scenarios have been updated by re-assessing their temperature outcomes based on the Intergovernmental Panel on Climate Change (IPCC) Assessment Report 6 Working Group I assessment. The temperature outcome of the scenarios is assessed with the reduced-complexity carbon-cycle and climate model MAGICC (Meinshausen *et al.* 2011) in a set up that captures the uncertainties in radiative forcing as well as climate and carbon-cycle response (Nicholls *et al.* 2021) as assessed in cross-chapter box 7.1 of the IPCC Sixth Assessment Report (Forster *et al.* 2021).

As a result of the updates, global emissions in 2030 consistent with keeping global warming below 2.0°C with a 66 per cent chance are estimated at 39 $GtCO_2e$, which is about 2 $GtCO_2e$ lower than in earlier reports. Similarly, the estimate for 1.8°C is about 2 $GtCO_2e$ lower than the 1.8°C estimate of previous reports. There are no changes to the 1.5°C estimate (table 4.2). As pathways often assume net-negative CO_2 emissions in the second half of the century, the estimated global warming in the year 2100 is typically lower than the maximum warming over the course of the twenty-first century.

4.3 The emissions gap

The emissions gap for 2030 is defined as the difference between global total GHG emissions from least-cost scenarios that keep global warming to 2°C, 1.8°C or 1.5°C with varying levels of likelihood and the estimated global GHG emissions resulting from a full implementation of NDCs and announced reduction pledges. This section updates the gap based on the scenarios described in section 4.2.

5 This approach is consistent with the detailed adjustments calculated by Grassi *et al.* (2021), which are virtually constant until 2030 for emissions scenarios in line with updated current policies or NDCs scenarios. Previous reports already applied a similar adjustment method, when comparing model studies (such as the integrated assessment model studies) or in the emissions gap calculations. Although the literature now provides a more elaborate evidence base in support of this adjustment, this approach does not result in shifts in estimates of the global emissions gap.

6 Climate Action Tracker: https://climateactiontracker.org/global/cat-emissions-gaps/; PBL: www.pbl.nl/ndc; JRC: https://ec.europa.eu/jrc/en/geco.

7 The Climate Action Tracker accounts for the impact of the announcement of Japan and China, JRC for China and Japan, and PBL includes the impact of China, Japan and the Republic of Korea, and also includes the impact of the latest NDC of South Africa.

8 As these studies do not fully account for all announced pledges, the estimate is slightly lower than the estimate in chapter 2, but it has been rounded to avoid apparent inconsistencies.

Table 4.2 provides a full overview of 2030 emission levels for the eight scenarios considered, as well as the resulting emissions gap between the scenario and the 2°C, 1.8°C or 1.5°C pathways.

Table 4.2. Global total greenhouse gas emissions in 2030 under different scenarios, temperature implications, and the resulting emissions gap

Scenario (rounded to the nearest gigaton)	Number of scenarios in set	Global total emissions in 2030 [$GtCO_2e$]	Estimated temperature outcomes†			Closest corresponding IPCC SR1.5 scenario class	Emissions Gap in 2030 [$GtCO_2e$]		
			50% chance	66% chance	90% chance		Below 2.0°C	Below 1.8°C	Below 1.5°C
Year 2010 policies[i]	6	64 (60–68)							
Current policies[ii]	9	55 (52–58)					15 (12–18)	22 (19–25)	30 (28–33)
Unconditional NDCs (updated NDCs and announcements)	8	52 (49–55)					13 (10–16)	19 (16–22)	28 (25–30)
Conditional NDCs[iii] **(updated NDCs and announcements)**	8	50 (46–52)					11 (7–13)	17 (13–19)	25 (22–28)
Below 2.0°C (66% chance)**	71	39 (33–49)	Peak: 1.7–1.8°C In 2100: 1.3–1.7°C	Peak: 1.8–2.0°C In 2100: 1.5–1.9°C	Peak: 2.2–2.4°C In 2100: 1.9–2.4°C	Higher-2°C pathways			
Below 1.8°C (66% chance)**	23	33 (27–41)	Peak: 1.6–1.7°C In 2100: 1.2–1.6°C	Peak: 1.7–1.8°C In 2100: 1.4–1.8°C	Peak: 2.0–2.2°C In 2100: 1.8–2.2°C	Lower-2°C pathways			
Below 1.5°C (66% chance in 2100 with no or limited overshoot)	26	25 (17–33)	Peak: 1.5–1.6°C In 2100: 1.0–1.3°C	Peak: 1.6–1.7°C In 2100: 1.2–1.5°C	Peak: 1.9–2.1°C In 2100: 1.5–1.9°C	1.5°C with no or limited overshoot			

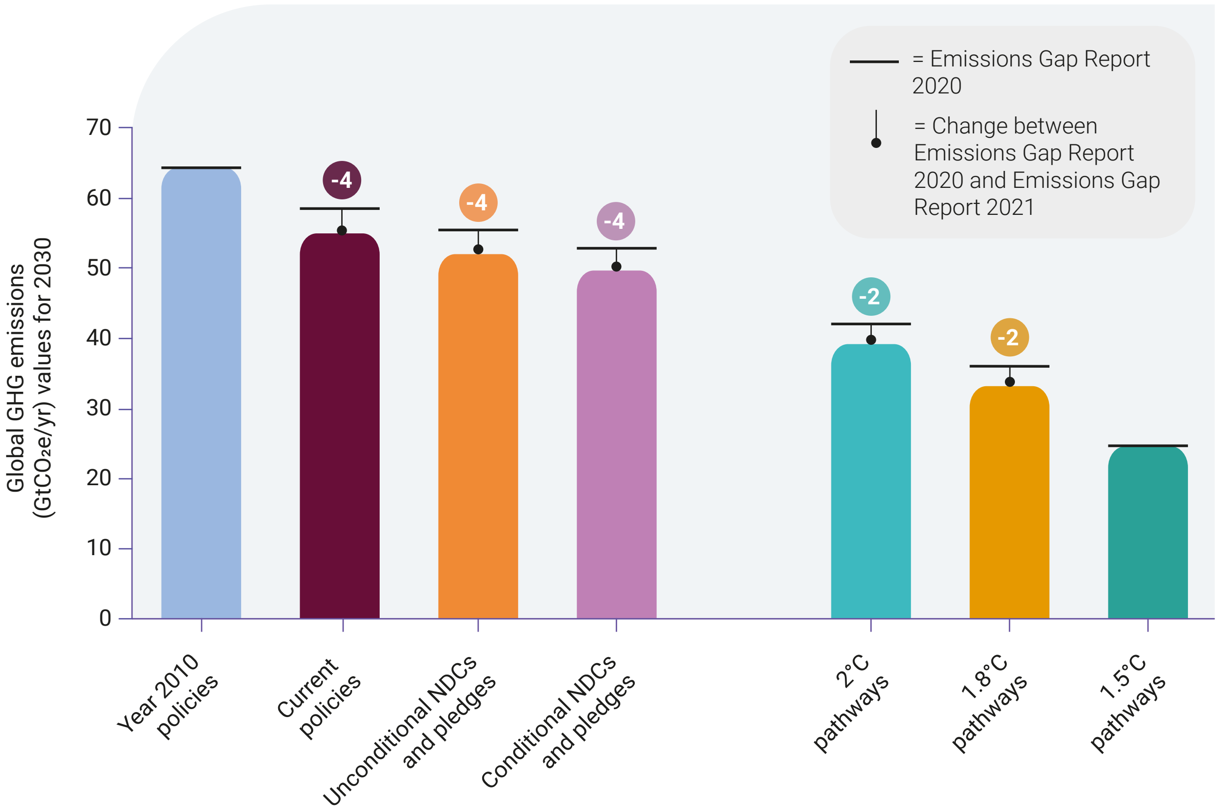
i All scenarios represent pre-COVID-19 estimates. Values represent the median and tenth to ninetieth percentile range across scenarios; ii All scenarios are adjusted to reflect the impact of COVID-19 and recent policies (cut-off date 2020). Values represent the median and tenth to ninetieth percentile range across scenarios; iii Values represent the median and tenth to ninetieth percentile range across scenarios.

† Temperature outcomes are estimated for global surface air temperature (GSAT) with the reduced-complexity carbon-cycle and climate model MAGICC (Meinshausen *et al.* 2011) in a set up that captures the uncertainties in radiative forcing as well as climate and carbon-cycle response (Nicholls *et al.* 2021).

** Values represent the median and tenth to ninetieth percentile range across scenarios. Probabilities ('chances') refer to peak warming at any time during the twenty-first century for the below-1.8°C and below-2.0°C scenarios. When deploying net-negative CO_2 emissions in the second half of the century, global warming can be further reduced from these peak warming characteristics. For the below-1.5°C scenario, it applies to the year 2100, while the "no or limited overshoot" characteristic is captured by ensuring projections do not exceed 1.5°C with at least 33 per cent chance over the course of the twenty-first century.

Note: The gap numbers and ranges are calculated based on the original numbers (without rounding), and these may differ from the rounded numbers (third column) in the table. Numbers are rounded to full $GtCO_2e$. GHG emissions have been aggregated with 100-year global warming potential (GWP) values of the IPCC AR4 (to be consistent with table 2.4 of IPCC Special Report on Global Warming of 1.5°C). IPCC SR1.5 refers to the IPCC Special Report on global warming of 1.5°C.

Figure 4.1. Overview of changes in greenhouse gas emissions projections for 2030 for different scenarios

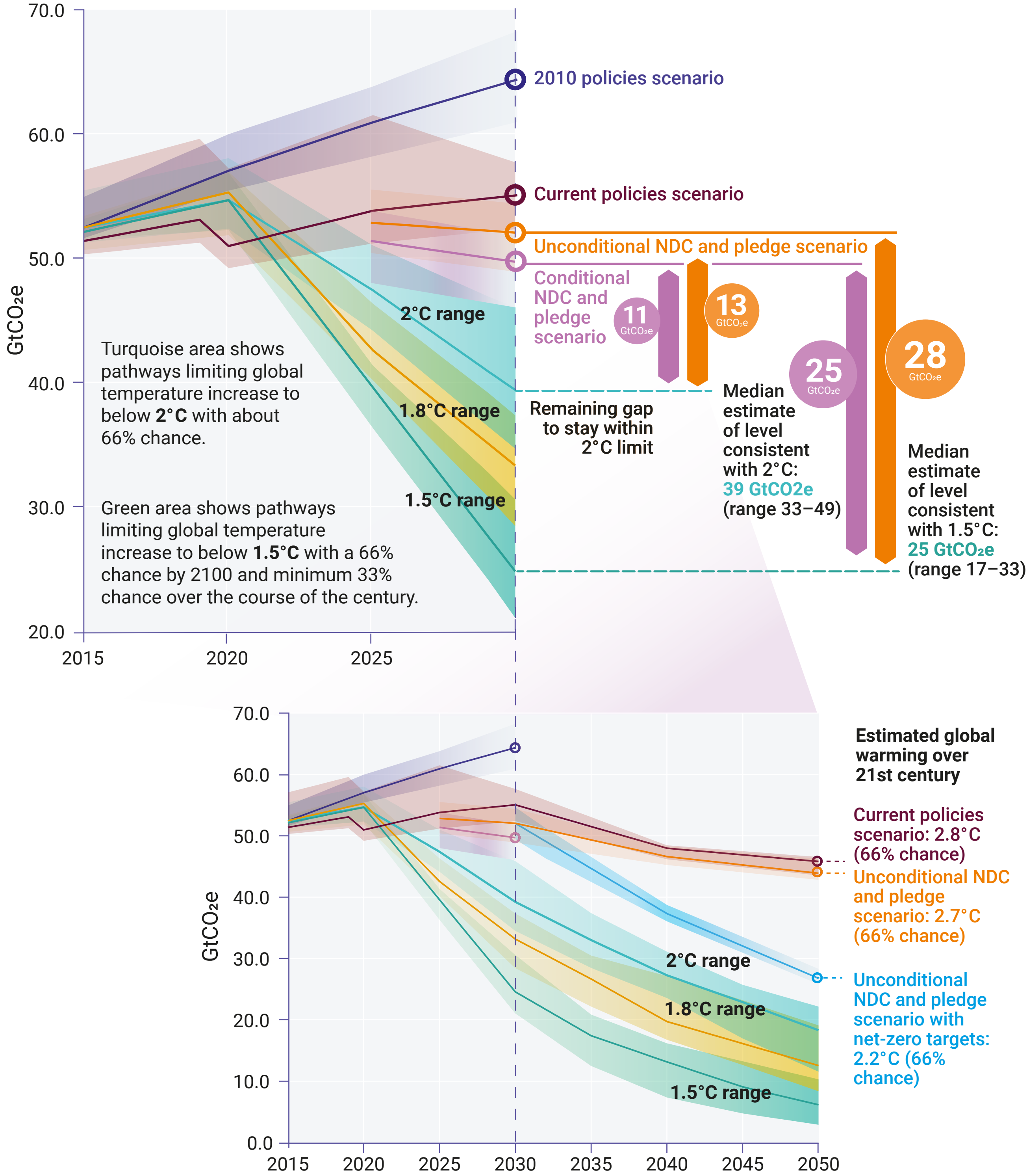


Note: Numbers in bubbles are rounded to nearest $GtCO_2e$.

The current policies scenario is estimated to reduce global GHG emissions in 2030 to about 55 $GtCO_2e$ (52–58), which is 9 $GtCO_2e$ lower than in the year 2010 policies scenario. It is also 4 $GtCO_2e$ lower than the median estimate of the current policies scenario of the 2020 UNEP Emissions Gap Report. The implementation gap, which is the difference between emissions expected under the current policies scenario and those needed to achieve the NDCs and announced reduction pledges, is estimated to be 3 $GtCO_2e$ and 5 $GtCO_2e$ for the unconditional and conditional NDCs and pledge scenarios respectively.

Figure 4.2 illustrates the emissions gap in 2030, highlighting that while the new and updated NDCs together with announced mitigation pledges narrow the gap slightly compared to previous NDCs, they are highly insufficient to bridge the gap. They take only 7.5 per cent off projected 2030 emissions, compared to earlier unconditional NDCs, whereas 30 per cent is needed for 2°C and 55 per cent is needed for 1.5°C. Figure 4.2 shows that full implementation of unconditional NDCs and announced reduction pledges is estimated to result in a gap to a 1.5°C pathway of 28 $GtCO_2e$ (range: 25–30). This is about 4 $GtCO_2e$ lower than the gap assessed in the 2020 report (United Nations Environment Programme [UNEP] 2020), due to the updated NDCs and announced reduction pledges. If the conditional NDCs and announced reduction pledges are also fully implemented, the emissions gap is further reduced by about 3 $GtCO_2e$. The emissions gap between unconditional NDCs and announced reduction pledges and below 2°C pathways is about 13 $GtCO_2e$ (range: 10–16 $GtCO_2e$), which is about 2 $GtCO_2e$ lower than last year. While NDC and announced mitigation pledges reduce global emissions by about 4 $GtCO_2e$ compared with previous NDCs, the updated 2°C scenario estimate for 2030 is about 2 $GtCO_2e$ lower than in previous Emissions Gap Reports (section 4.2.3), which means that the gap is only reduced by about 2 $GtCO_2e$.

Figure 4.2. Global greenhouse gas emissions under different scenarios and the emissions gap in 2030 (median estimate and tenth to ninetieth percentile range)

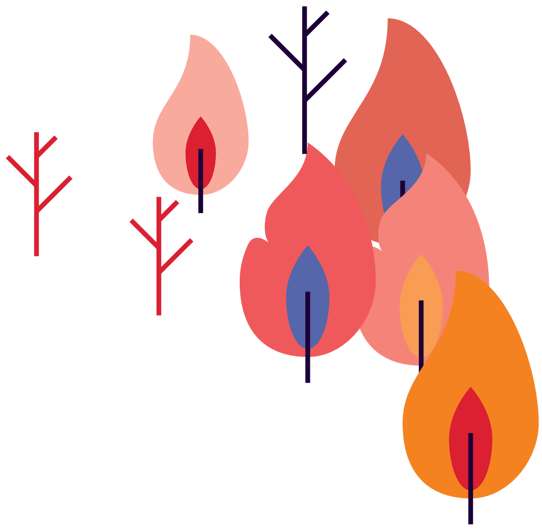


4.4 Temperature implications of the emissions gap

Neither current policies nor the latest NDCs and announced pledges are consistent with limiting warming to the goal of the Paris Agreement. To understand how far off the mark current policies and NDCs are, estimated emissions for the year 2030 for each of these scenarios are projected out to 2100, and their climate outcomes assessed with a climate model (see box 4.1). This approach assumes a continuation of climate action beyond 2030 without additional strengthening. Extrapolations until the end of the century are inherently uncertain and subject to scenario assumptions such as the level at which climate action continues or technology costs.

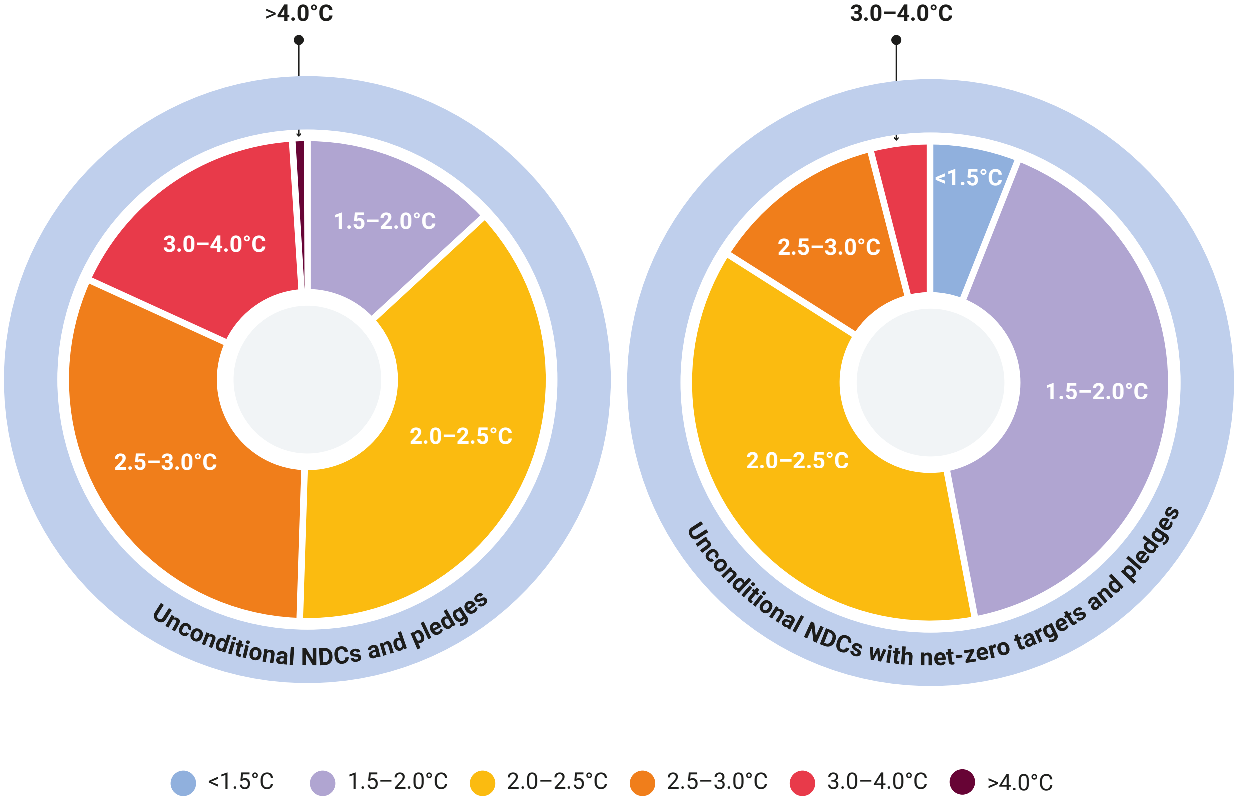
This year, the method to extend emissions to 2100 and the climate model set up used was updated based on improved methods and the latest climate assessment of IPCC AR6 Working Group I. These updates alone result in temperature projections that are about 0.2°C lower than in previous Emissions Gap Reports, which should be factored in when comparing the results below with previous estimates. A continuation of the effort implied by the latest unconditional NDCs and announced pledges is at present estimated to result in warming of about 2.7°C (range: 2.2–3.2°C) with a 66 per cent chance.[9] This implies a 50 per cent chance that warming is kept to 2.5°C (range: 2.0–2.9°C) by the end of the century and a 90 per cent chance that it is kept to 3.3°C (range: 2.7–3.9°C). A continuation of conditional NDCs and announced pledges lowers these estimates by about 0.1°C to 2.6°C (2.1–3.1°C), 2.4°C (1.9–2.8°C) and 3.2°C (2.6–3.8°C), respectively. By contrast, a continuation of current policies, which are insufficient to meet the 2030 pledges, increase the estimates by about 0.1°C to 2.8°C (range 2.3–3.3°C), 2.6°C (range 2.1–3.0°C) and 3.4°C (range 2.8–3.9°C), respectively.

Net-zero pledges, which have been announced by many countries (chapter 3), further lower these temperature estimates markedly by about 0.5°C, if fully implemented. Sixty-six per cent, 50 per cent and 90 per cent percentile global warming projections of pathways assuming unconditional NDCs and net-zero targets would then become 2.2°C (2.0–2.5°C), 2.0°C (1.8–2.3°C), and 2.7°C (2.3–3.1°C), respectively. Even with the implementation of current NDCs and all net-zero targets, there is still more than a 15 per cent chance that global warming will exceed 2.5°C by the end of the century, and a just short of 5 per cent chance that it will exceed 3°C (figure 4.3). Finally, these estimated improvements from net-zero targets should also be caveated by the fact that in many cases, current NDCs do not yet set countries' emissions on a direct path towards reaching longer-term net-zero targets (see chapter 3).



9 This range reflects the uncertainty due to extrapolation of GHG emissions after the year 2030 and is given for the central estimate of 2030 emissions implied by current policies, NDCs and/or other pledges. Taking the higher or lower end of the range surrounding the 2030 emissions estimates would lead to an additional increase or decrease in the temperature projections by about 0.1°C, respectively. Geophysical uncertainties in the climate response are reflected by the estimates for different warming percentiles (50 per cent, 66 per cent and 90 per cent).

Figure 4.3. Range of global warming outcomes projected if unconditional nationally determined contributions and announced pledges continue (left) and if additionally net-zero targets announced by countries are achieved (right)



Note: See box 4.1 for background.

Box 4.1. Estimating global warming implications of NDCs

A variety of methods exist to extend near-term emissions until the end of the century (Gütschow *et al.* 2018). We first estimate the global carbon price implied by the NDC emissions reductions in 2030 from a no-policies baseline. Here, we use the marker quantification of the second Shared Socioeconomic Pathway, called SSP2, which assumes a continuation of historical socioeconomic dynamics (Fricko *et al.* 2017; Riahi *et al.* 2017), to estimate the relationship between emission reductions and implied carbon prices in 2030. Subsequently, the carbon price implied by the global NDC reductions (e.g. globally about US$$20_{2010}$ in 2030 for unconditional NDCs) is extended out until the end of the century by applying the same annual growth rate as for projected global gross domestic product (GDP) under SSP2.

Based on the relationship between implied carbon prices and global GHG emissions levels over the course of the century, an emissions trajectory is estimated and divided into its constituting gases (Lamboll *et al.* 2020). Subsequently, the global warming outcome of each pathway is assessed with the reduced-complexity carbon-cycle and climate model MAGICC (Meinshausen *et al.* 2011) in a set up that captures the uncertainties in radiative forcing as well as climate and carbon-cycle response (Nicholls *et al.* 2021) as assessed in cross-chapter box 7.1 of the IPCC AR6 (Forster *et al.* 2021). Countries' net-zero targets, described and assessed in chapter 3, further bring down emissions projections over the course of this century (Höhne *et al.* 2021). The impact of this strengthening of climate action after 2030 is also estimated.

This approach is an update compared to previous reports, both in terms of the method used to extend emissions to 2100 and the climate model set up used. If the NDC estimates of this report are assessed using last year's methods, the temperature projections for unconditional NDCs would be about 0.2°C higher than this year's estimates.

5 Are COVID-19 fiscal recovery measures bridging or extending the emissions gap?

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5.1 Introduction

In response to COVID-19, government fiscal investment in climate change mitigation and adaptation can bolster long-term prosperity by creating jobs and accelerating economic growth while also meeting environmental, gender and social objectives. Academic evidence and political narratives support this approach (Barbier 2020; O'Callaghan and Murdock 2021). Countries that fail to capitalize on this opportunity for low-carbon and climate-resilient economic transformation risk their economic prosperity, environmental sustainability and long-term social cohesion.

Despite this, most governments have so far failed to prioritize a transformative low-carbon recovery, with the relatively insignificant low-carbon investment announced to date likely to maintain current unsustainable situations.[1] As at May 2021, only 2.5–12.1 per cent of US$16.7 trillion in total COVID-19 spending (excluding unallocated European Union spending) has been low-carbon or had mitigation co-benefits, while of a total US$2.25 trillion in announced COVID-19 'recovery' spending,[2] only 17–19 per cent has gone towards low-carbon spending, representing an insufficient commitment to align fiscal policies with the Paris Agreement (Andrijevic *et al.* 2020; O'Callaghan *et al.* 2021; Organisation for Economic Co-operation and Development [OECD] 2021; Vivid Economics 2021). A small number of wealthy economies account for the overwhelming majority of low-carbon spending,[3] with emerging market and developing economies in danger of being left behind. Although low-carbon recovery funds have supported a range of initiatives, they have so far been skewed towards clean energy and natural capital investments.

This chapter explores three questions:

1. How could COVID-19-related public spending bridge the emissions gap?

Section 5.2 summarizes key principles for low-carbon public spending in response to the pandemic. The section considers: (i) short-term rescue spending, to keep businesses and people alive; (ii) longer-term recovery investment, to reinvigorate the economy; and (iii) reinforcement processes, to embed new economic trajectories from recovery investment into long-term development plans. Targeted low-carbon rescue spending incentivizes the decarbonization of hard-to-abate sectors[4] by including low-carbon conditionalities or commitments in liquidity and other short-term business support and/or by sustaining the industries likely to foster low-carbon economic growth (Barbier 2020). Low-carbon recovery investment accelerates the low-carbon transition both directly and indirectly by incorporating low-carbon incentives into traditional investment. Low-carbon reinforcement initiatives build long-term support for the projects and sectors targeted by low-carbon recovery investment, aligning long-term development pathways with a low-carbon and climate-resilient transformation of the economy. At every stage, low-carbon spending and regulatory reforms should be

1 Low-carbon investment is defined in this chapter as spending that is likely to reduce net greenhouse gas (GHG) emissions.

2 Fiscal 'recovery' initiatives are defined in this chapter as taxation or expenditure measures that aim to reinvigorate economic growth. Recovery initiatives are distinct from 'rescue' initiatives, which act over the short term and aim to keep businesses and people alive in the face of immediate crisis.

3 China, France, Germany, the Republic of Korea, Spain and the United Kingdom together account for 77.4 per cent of total low-carbon spending (O'Callaghan, Bird and Murdock 2021a).

4 Hard-to-abate sectors are those in which low-carbon means of production are significantly more expensive or lacking in scalability than traditional means of production. Many of these sectors will require significant technological innovation to enable economically competitive GHG abatement without productivity loss.

considered in tandem, as successful implementation of the latter can amplify the impact of the former.

2. What are the characteristics of fiscal rescue and recovery spending to date and how may they impact the emissions gap?

Section 5.3 shows that low-carbon recovery measures have received only 17–19 per cent of fiscal investment and policy focus to date. Status quo policymaking risks a lock-in and possible expansion of high levels of greenhouse gas (GHG) emissions towards and beyond 2030. While examples of low-carbon investment are numerous and wide-ranging, they largely come from a small set of advanced economies. Long-term human capital development, including skills development, remains underprioritized. Without a substantial pivot towards higher low-carbon investment, countries risk lower economic and social returns, as well as a significant rebound in GHG emissions (United Nations Environment Programme [UNEP] 2020).

3. Do lower-income nations face greater barriers for low-carbon recovery spending? If so, what can be done?

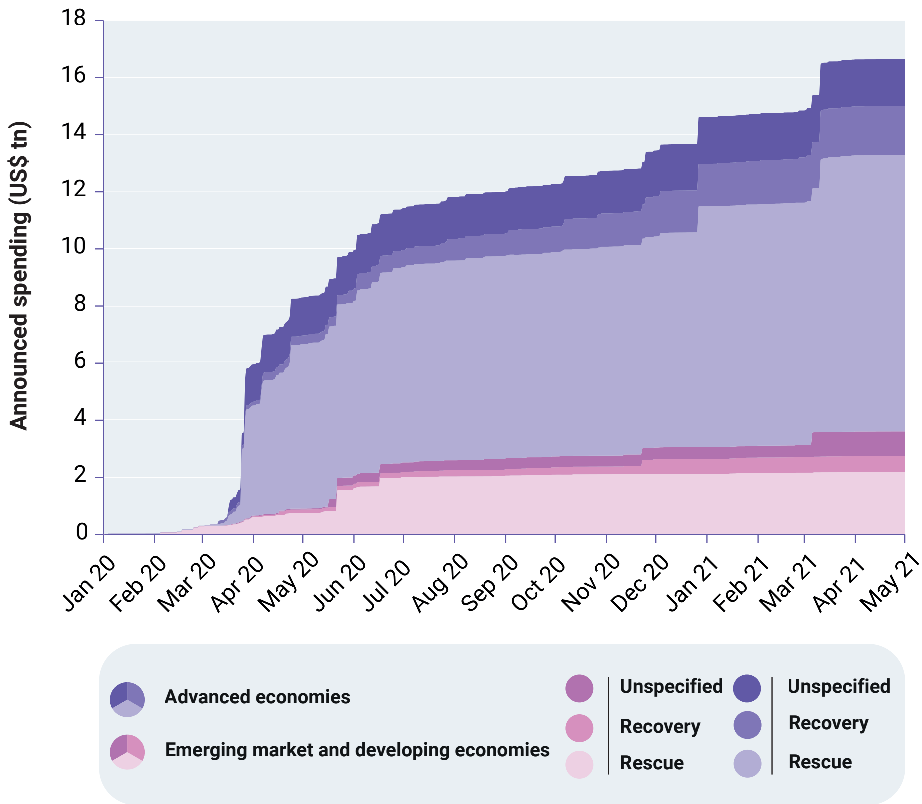
Section 5.4 indicates that although emerging market and developing economies have suffered disproportionately under the pandemic and are more exposed to climate risk, their recovery spending has been low, inhibited by restricted access to affordable finance. A global green recovery will require concessional finance, including direct grants, to vulnerable countries that are significantly above current proposals.[5]

5.2 How could COVID-19-related public spending bridge the emissions gap?

This section discusses trends in fiscal response towards recovery investment before asking why a low-carbon recovery should be pursued and what it should incorporate.

In the early stages of the pandemic, fiscal packages focused overwhelmingly on 'rescue' through the immediate protection of lives, livelihoods and business continuity. As death rates have gradually been controlled in many advanced economies, packages have slowly shifted to incorporate funds for reinvigorating the economy through 'recovery spending' (figure 5.1). However, recovery efforts continue to be inhibited by persistent COVID-19 outbreaks in many countries, particularly emerging market and developing economies (International Monetary Fund [IMF] 2020).

Figure 5.1. Announced rescue, recovery and unclear spending for advanced economies and emerging market and developing economies



Source: O'Callaghan *et al.* (2021)

5 Concessional finance refers to loans and other financial instruments that are extended on terms substantially more generous than market financial instruments.

Opportunities for rescue spending: Low-carbon rescue spending can ease industrial decarbonization, particularly in hard-to-abate sectors, through including green incentives in business liquidity support and other short-term support mechanisms (e.g. reduced taxation) and/or by directing support to industries likely to foster green growth (International Renewable Energy Agency [IRENA] 2020).[6] These programmes should empower businesses to make cost-efficient choices to transition to carbon neutrality without compromising jobs and livelihoods.

Opportunities for recovery spending: Growing evidence suggests that low-carbon investment can deliver stronger economic returns than conventional stimulus, while strengthening climate mitigation, adaptation, air pollution reduction, natural capital protection,[7] health outcomes, inequality reduction, human mobility and broad social progress and prosperity.[8] Carbon-intensive recovery packages that grow fossil fuel industries without conditions for a sustainable transition endanger economic returns as fossil fuel assets become devalued with reduced demand for their outputs (Mercure *et al.* 2018; Ansari and Holz 2020; van der Ploeg and Rezai 2020). An expert survey in Hepburn *et al.* (2020) identified traditional transport and energy infrastructure investment as the most harmful recovery policies for long-term GHG emissions, although this analysis did not consider armed forces infrastructure spending, which is also harmful compared with others (O'Callaghan, Murdock and Yau 2021).

Some of the most attractive recovery measures for reducing emissions – those which balance the potential to spur economic growth in a contractionary environment and the potential to mitigate emissions – include electric vehicle incentives and public transport modernization, clean energy infrastructure investments, energy efficiency upgrades, natural capital investments and clean research and development programmes (Barbier 2020; Garrett-Peltier 2017; United Kingdom, Climate Change Committee 2020; Hepburn *et al.* 2020). Continental unions and regional economic commissions of the United Nations have highlighted similar priorities (see appendix B.1). Although the accessibility of these options depends on the development of technological infrastructure and the availability of natural and human resources, input-output modelling indicates that low-carbon investment could generate significantly more jobs and greater economic value than traditional 'dirty' and 'neutral' alternatives.[9] This is true for both advanced economies and emerging market and developing economies.

Opportunities for reinforcement spending: The role of low-carbon reinforcement measures following recovery remains largely undiscussed in academic and professional literature. However, as COVID-19 spending becomes integrated intro regulatory budgetary processes, it becomes increasingly less distinguishable from normal 'peacetime' spending. Going forward, sustainability-proofing the entire budgetary process and increasing policy coherence across sectors and levels will be crucial to maximize the impact of a low-carbon recovery. This could be achieved through implementing green budget tagging processes (Eltokhy *et al.* forthcoming) or applying more advanced green public financial management frameworks.

Non-governmental and academic advisers collectively propose at least seven key principles for designing a low-carbon fiscal response to the pandemic, as summarized in figure 5.2. Consensus opinion suggests that policy design should be consultative, evidence-based and gender-sensitive, while ensuring prompt implementation that is considerate of pandemic realities. Importantly, fiscal action represents only one of several mechanisms available to advance climate action and stimulate economic growth following COVID-19. Regulatory and market interventions, among others, can play a key role.[10] Fiscal measures are also likely to prove most effective when combined with appropriate regulatory and market interventions (OECD 2020b).

6 Publicly-financed liquidity support and other short-term business support help businesses meet their immediate costs and continue operations, without the threat of expeditious liquidation. Low-carbon conditionalities may require businesses to take environmental commitments as a condition of receiving public funds (or having a lower temporary tax or expense load). Since these measures incentivize innovation, they may increase the economic impact of taxpayer spending while also delivering environmental and social benefits (O'Callaghan and Hepburn 2020).

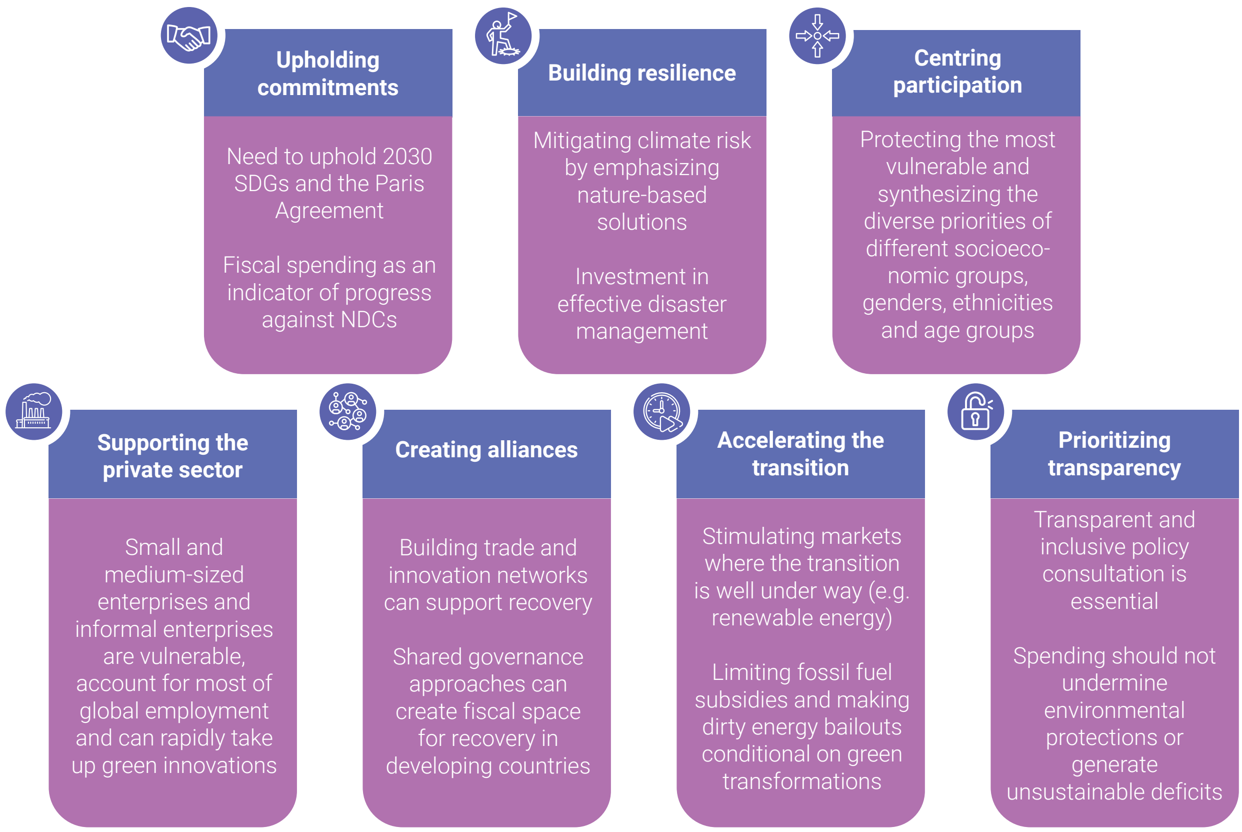
7 Natural capital refers to ecosystems, biodiverse habitats, clean water and air, productive soils and a stable and resilient climate.

8 Hepburn *et al.* (2020), OECD (2020a), Georgieva (2021), O'Callaghan and Murdock (2021) and United Nations Economic Commission for Africa [UNECA] (2021), among others, expand on existing evidence to support economic, environmental and social narratives for low-carbon public investment.

9 See International Energy Agency [IEA] (2020); Malliet *et al.* (2020); Pollitt *et al.* (2020); Vivid Economics modelling in O'Callaghan, Bird and Murdock (2021a); Vivid Economics modelling in O'Callaghan, Bird and Murdock (2021b); Kiss-Dobronyi *et al.* (2021); Schreiner and Madlener (2021). Ongoing initiatives to improve comparative modelling methods also present a similar finding (Batini *et al.* 2021).

10 For instance, in renewable energy generation, streamlined approval processes, contracts for difference models, and feed-in tariffs drastically accelerated uptake in pre-pandemic times (Haas *et al.* 2011; Schumacher 2019; Welisch and Poudineh 2020).

Figure 5.2. Principles for a green recovery



Sources: Synthesized from Butterworth (2020); C40 (2020); Corkal *et al.* (2020); Green Growth Knowledge Platform (2020); Partners for Inclusive Green Economies (2020); United Kingdom, Climate Change Committee (2020); Ocean Conservancy (2021); The Lancet COVID-19 Commission Task Force on Green Recovery (2021)

To support accountability and transparency, low-carbon recovery investment of all kinds should include appropriate management structures for monitoring, reporting and verifying the effective implementation and use of recovery funds (Agrawala *et al.* 2020), as well as designated funds and standards for ex-post impact assessment. Such measures may also improve understanding of the relative strengths of low-carbon fiscal investment over alternatives.[11] Oversight tools, such as the 'do no significant harm' principle included in the European Union's Recovery and Resilience Facility regulation, can counter measures that endanger environmental objectives (European Commission 2021).

5.3 What are the characteristics of fiscal rescue and recovery spending to date and how may they impact the emissions gap?

This section provides a high-level assessment of the characteristics of global COVID-19 rescue and recovery spending so far with respect to mitigation.

Across countries and data sources, several primary themes have emerged:

1) **Only 2.5 per cent of US$16.7 trillion in total COVID-19 fiscal spending (excluding unallocated European Union spending) has been low-carbon, with only 17–19 per cent of a total US$2.25 trillion in announced COVID-19 recovery spending likely to reduce GHG emissions** (O'Callaghan *et al.* 2021). Seven countries account for almost 90 per cent of this spending: China, France, Germany, Japan, the Republic of Korea, Spain and the United Kingdom (figure 5.3). The percentage of recovery spending that is low carbon has slowly increased since Emissions Gap Report 2020 (UNEP 2020), perhaps driven in part by a better understanding of the potential for low-carbon investments to deliver strong economic, environmental and social returns. High-carbon, neutral and unclear spending (87.9–97.5 per cent of total spending) either worsens or maintains the unsustainable status quo of the current global emissions trajectory (O'Callaghan *et al.* 2021; OECD 2021; Vivid Economics 2021).

11 Proposed economic indicators include short- and long-term multiplier effects and labour impacts, environmental indicators, such as GHG emissions and air and water quality, and social indicators, such as cost-of-living, inequality, public health and gender equity impacts (Jotzo, Longden and Anjum 2020; World Bank 2020).

Figure 5.3. Non-exhaustive overview of total fiscal rescue and recovery measures of G20 members with high-carbon, neutral and low-carbon impacts as a share of 2020 gross domestic product[12]

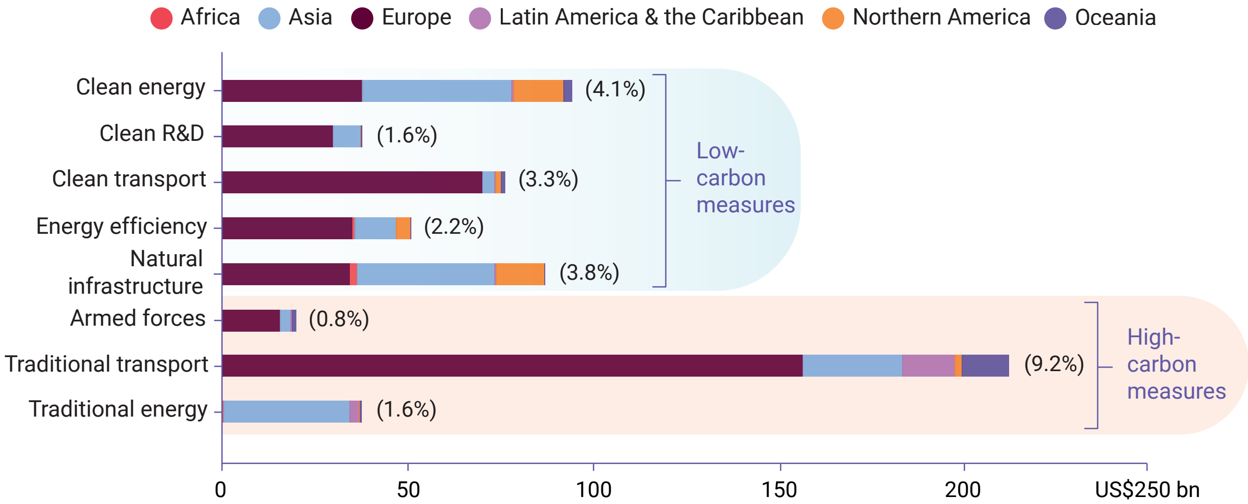
Notes: GRO – Global Recovery Observatory of the University of Oxford, UNEP, Green Fiscal Policy Network and United Nations Development Programme (UNDP); OECD – OECD Green Recovery Database; E3G – Green Recovery Tracker of Third Generation Environmentalism (E3G) and Wuppertal Institute.

12 Data for the overall spending bar are from the Global Recovery Observatory, as it is the only current tracker that accounts for 'neutral' measures. The International Monetary Fund (IMF) and Climate Action Tracker (CAT) have discontinued their trackers since the release of the 2020 Emissions Gap Report. The Greenness of Stimulus Index from Vivid Economics has changed its methodology, such that it no longer directly assesses policy-level climate impacts. Instead, the Greenness of Stimulus Index assigns a 'greenness value' (positive or negative) to each sector of every tracked country, with the final index for each country being an average of sectoral impact. As this methodology is not comparable with other trackers, Vivid Economics advised excluding the Greenness of Stimulus Index information from the figure. The IEA's Sustainable Recovery Tracker and the Energy Policy Tracker only cover energy spending and are therefore excluded from this analysis. Many discrepancies between the included trackers relate to key differences in methodology: for instance, the Green Recovery Tracker (E3G undated) does not include certain types of rescue spending, while the Global Recovery Observatory (O'Callaghan *et al.* 2021) accounts for all fiscal measures. Trackers also vary in their definitions of 'low-carbon': one measure may receive a low-carbon tag by one tracker and a neutral tag by another, resulting in substantial differences in spending recorded in either category. A comparison of trackers and their methodologies can be found in appendix B4.

2) **Low-carbon fiscal investment has covered a wide range of policy types.** Over 500 low-carbon rescue and recovery measures have been introduced worldwide, covering most emerging and established low-carbon industries (figure 5.4). The range of spending has been notably wider in advanced economies, with emerging market and developing economies focusing their low-carbon recovery funds on clean energy generation and natural capital investments. Spending on worker retraining initiatives remains low across countries, indicating an insufficient focus on long-term human capital development. A minor portion of investment in what have traditionally been considered 'neutral sectors' include accompanying low-carbon incentives (appendix B.2 lists a few examples of this type of investment).

3) **International disparities are significant in both total spending and low-carbon spending.** Some countries are already well into their economic recovery while others have been unable to act at all, constrained by low access to capital and continuing COVID-19 mobility restrictions. Of those who have spent significantly, some have integrated green priorities to a considerable degree, with others having failed to consider environmental concerns in any way. The Global Recovery Observatory has found that Canada, Denmark, Finland, France, Germany and Norway can be considered as 'leaders' in low-carbon recovery, with their low-carbon spending as a share of recovery spending ranging between 39 and 75 per cent. Spain, Sweden and the United Kingdom also rank highly according to Vivid Economics' Greenness of Stimulus Index.[13]

Figure 5.4. Global recovery spending as of May 2021 across sectors by region (US$ billions)



Note: Low-carbon initiatives (top) and high-carbon initiatives (bottom).
Source: O'Callaghan *et al.* (2021)

As chapter 2 shows, global emissions dropped in 2020, but are expected to bounce back in 2021. Studies on the impact of announced fiscal investment on global emissions suggest that decisions made so far will maintain the unsustainable trajectory of pre-pandemic economies (Forster *et al.* 2020; Malliet *et al.* 2020; Meles *et al.* 2020; Pollitt *et al.* 2020; IEA 2021; Shan *et al.* 2021). In line with the 2020 Emissions Gap Report, the studies suggest that a more carbon-intensive recovery would increase emissions substantially in the medium to long term, while a low-carbon recovery would significantly reduce emissions (see also appendix B.3).

5.4 Do lower-income nations face greater barriers for low-carbon recovery spending? If so, what can be done?

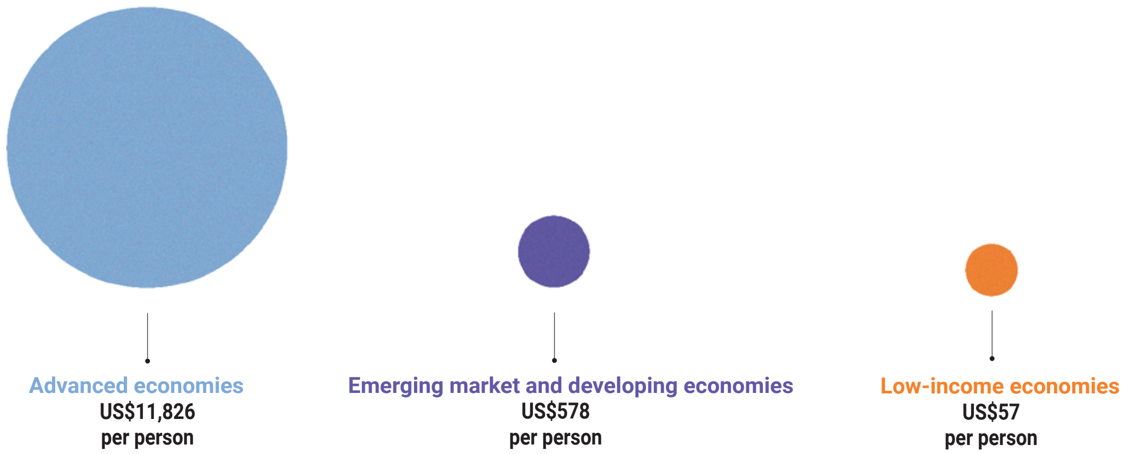
This section describes the disproportionately negative impacts of COVID-19 on vulnerable nations. It then discusses the need for significantly increased international aid to simultaneously support economic recovery, long-term economic development and climate priorities.

13 Leaders' are classified as having spent above 1 per cent of gross domestic product (GDP) on fiscal recovery and above 30 per cent of this on low-carbon measures (O'Callaghan and Murdock 2020). The Greenness of Stimulus Index score is calculated by combining the flow of stimulus into five key sectors with an indicator of each sector's environmental impact (Vivid Economics 2021).

5.4.1 Vulnerable nations are being left behind

The COVID-19 crisis has had an especially negative impact on vulnerable nations: global extreme poverty rose in 2020 for the first time in over 20 years, with an estimated 120 million additional people estimated to be living in poverty due to the pandemic (World Bank 2021a). Foreign direct investment fell by 8 per cent in developing countries in 2020 compared with 2019, driven by a 15.6 per cent decline in Africa and a 45.4 per cent decline in Latin America and the Caribbean (United Nations Conference on Trade and Development [UNCTAD] 2021).[14] Despite these trends, COVID-19 spending has been far lower in low-income economies (~US$60 per person) than advanced economies (~US$11,800 per person; see figure 5.5).

Figure 5.5. COVID-19-related spending per capita across development categories (US$)



Source: O'Callaghan *et al.* (2021)

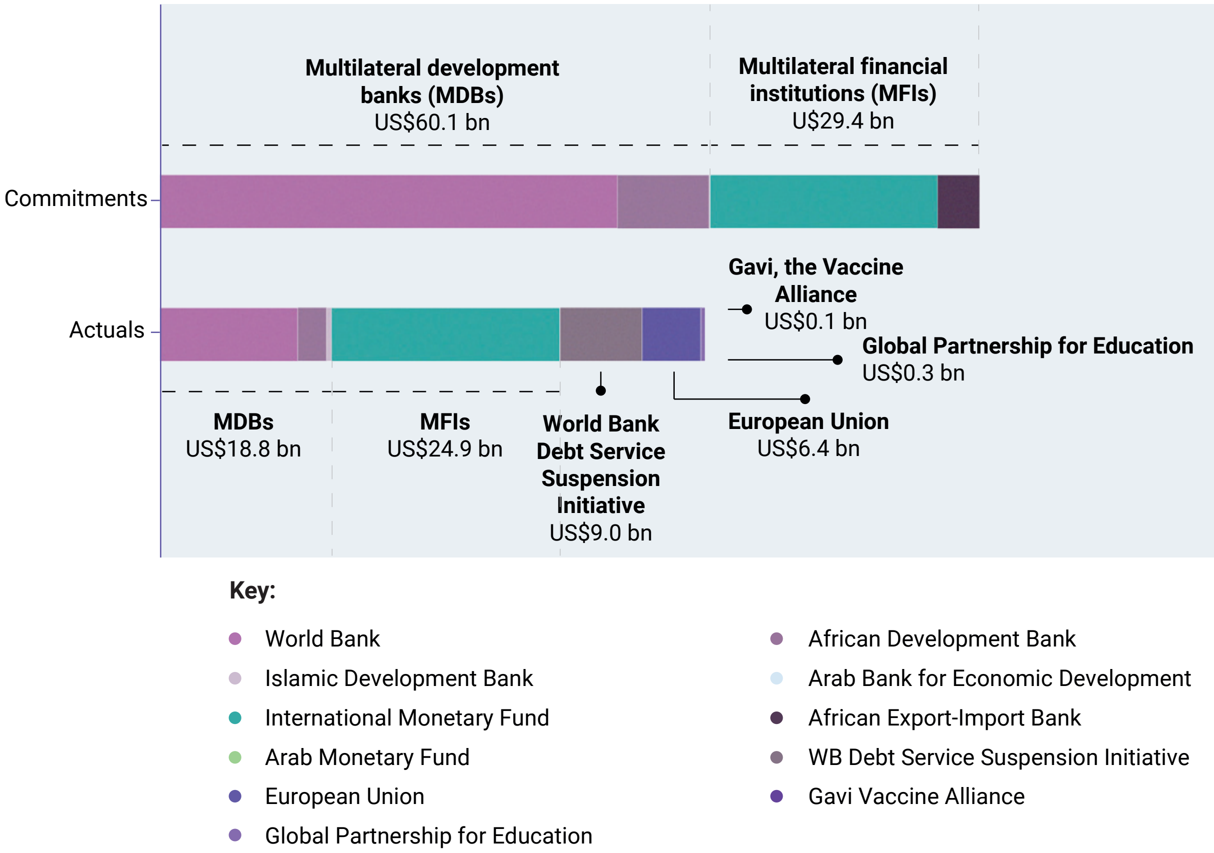
Unequal access to finance is a key driver of disparities in COVID-19 spending between high- and low-income nations (O'Callaghan and Murdock 2021).[15]

In 2020, development partners committed US$89.5 billion to support African nations in response to COVID-19, of which US$59.5 billion has been disbursed (figure 5.6). This represents just 0.4 per cent of total global COVID-19 spending. Without a substantial increase in foreign aid, the difference in spending between advanced economies and emerging market and developing economies will exacerbate gaps in development, while also restricting progress against climate change. Emerging market and developing economies are also likely to become the world's top GHG emitters if climate finance does not significantly increase (World Resources Institute undated), all while disproportionately suffering the burden of climate change, which has historically been caused by high-income economies (see IMF 2021a).

14 Foreign direct investment refers to cross-border investment where an investor establishes lasting financial interest in and influence over an enterprise domiciled in another economy.

15 Although many advanced countries have announced dramatic increases in expenditure at near- or below-zero financing costs (Blanchard 2019), the same is not true of most emerging market and developing economies. Severe pandemic-induced economic contractions in most emerging market and developing economies have caused a dramatic rise in debt-to-GDP ratios (IMF 2021b), temporarily increased credit default insurance premiums as measured by credit default swap spreads (Council on Foreign Relations [CFR] 2021) and reduced current account balances (World Bank 2021b), leaving emerging market and developing economies in the Latin America and the Caribbean, and Europe, the Middle East and Africa regions with historically low credit risk ratings (S&P 2021a; S&P 2021b). Across both advanced economies and emerging market and developing economies, climate change is likely to expose some forms of debt to even more risk, particularly debt to finance climate-exposed investments such as agriculture (Dibley, Wetzer and Hepburn 2021; European Central Bank 2021).

Figure 5.6. Funding commitments and disbursements to Africa by development partners in 2020–2021 (US$ billions)



Source: Non-public UNECA analysis (2021)

5.4.2 How to support vulnerable nations

As in advanced economies, low-carbon investment in emerging market and developing economies has the potential to shorten the duration of COVID-19 impacts, address climate concerns and set strong long-term development pathways. Natural resource endowments in many low-income nations make investments in renewable energy generation facilities and natural capital solutions particularly attractive (Kim 2020). By prioritizing local supply chains, long-term partnerships between emerging market and developing economies and high-income economies can enable sustainable growth and build future-proof infrastructure.

Wealthier economies could support vulnerable nations in several ways:

- **Debt forgiveness**

Based on IMF and World Bank debt sustainability analysis, debt treatments, including debt write-offs, must be considered for vulnerable countries. Debt relief programmes, including debt-for-climate swaps, could help support low-carbon recovery and a transition to low-carbon growth.[16] A haircut of 10 per cent in debt repayments could result in savings of US$100 billion for reinvestment in low-carbon recoveries (Jensen 2021). Debt restructuring, including private debt, through new bond issuances aligned with the Sustainable Development Goals (SDGs) and the Paris Agreement could help avert a 'lost decade' and provide fiscal resources for investment in a low-carbon recovery (Volz *et al.* 2021).

- **Direct grants and concessional finance**

New low-carbon and climate-resilient recovery investments can improve inclusion while advancing progress on the SDGs. Advanced economies can accelerate this by providing resources commensurate with the scale of the required transformation, i.e. significantly more than the commitments agreed at the sixteenth United Nations Climate Change Conference of the Parties (COP16) of US$100 billion per year

16 Debt for climate-resilience swaps exchange the cancellation of a developing country's public debt for increased investment in climate-related projects in that same country. These instruments offer a vehicle for generating low-carbon recovery investment in sectors that facilitate the transition to low-carbon growth.

(United Nations 2010). Disjointed interventions may widen further divergence.

- **Concessional finance for green and blue bonds**

The proceeds of green and blue bond issuances respectively finance environmentally-friendly projects and ocean conservation projects, often unlocking new finance to advance climate goals (Banga 2018; World Bank 2008). Green and blue debt markets are growing in emerging market and developing economies, yet several challenges remain, including only a small pricing benefit of green and blue bonds over regular bonds (Doran and Tanner 2019; Otek Ntsama *et al.* 2021).[17] Foreign monetary authorities and governments could commit to purchasing green and blue bonds at lower interest rates in emerging market and developing economies (Liaw 2020). Robust, standardized and stringent certification and monitoring systems could provide greater credibility for such issuances.

- **Guaranteeing private sector debt**

The impact of public investment in climate resilience and mitigation can be significantly improved by 'crowding-in' additional private sector resources. Blended finance and partial guarantees have a key role in supporting this for emerging market and developing economies, particularly following the pandemic-induced crash in international project finance and other forms of foreign direct investment (UNCTAD 2021).

- **Redistributing multilateral finance to vulnerable nations**

The proposed IMF issuance of US$650 billion in new special drawing rights could strongly support a low-carbon recovery if funds are directed to future-oriented low-carbon and climate-resilient investments. On-lending a substantial amount of such funds to the world's most vulnerable countries could significantly enhance the issuance. Without such an action, only 3.2 per cent of the issuance will be directed to low-income countries (The Economist 2021). While the current IMF call for US$100 billion to be on-lent is positive, it remains insufficient given the extreme disparity in fiscal space between advanced and vulnerable economies. Appendix B5 compares alternative approaches that could be implemented.

- **Considerations for carbon border adjustment mechanisms**[18]

Carbon border adjustment mechanisms, such as those proposed by the European Union, could provide highly effective trade-based regulations to drive down emissions and reward sustainable supply chains. However, although such mechanisms are primarily intended as protective environmental measures, their unequal trade implications and potentially high burden on vulnerable nations must be acknowledged. If carbon border adjustment mechanisms are implemented, standards and controls must be developed that both support global environmental needs and development priorities of vulnerable nations. These mechanisms (and their standards and controls) must be implemented with significant financial and technical resources to support capacity-building in vulnerable nations (see Gore 2021).

To ensure a successful sustainable and inclusive transition, emerging market and developing countries require significant technology transfer and capacity-building in addition to financial support, needs that should be reflected in updated nationally determined contributions (NDCs). Support for low-carbon recovery in emerging market and developing economies often relies directly on the nation's demonstrated interest to pursue public policy reforms that are consistent with the Paris Agreement goals, such as, for example, consideration of and action on carbon pricing, fossil fuel subsidies reform, green budgeting systems and regulations for financial sector greening.[19]

17 For example, Egypt's October 2020 issuance of a US$750 million green bond was broadly price aligned to its normal standard bond issuances (London Stock Exchange 2020).

18 Carbon border adjustment mechanisms act to "equalise the price of carbon between domestic products and imports" to eliminate financial incentives to relocate production outside of regions with strong climate controls (European Commission undated).

19 Emerging tools, such as the sustainable development and climate action green recovery screening tool (SCREEN, of the NewClimate Institute) can assist in identifying high-potential opportunities.

6 The role of anthropogenic methane emissions in bridging the emissions gap

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6.1 Introduction

Methane emissions are the second largest contributor to global warming to date after carbon dioxide (CO_2), accounting for about one third of the warming impact of all well-mixed greenhouse gas (GHG) emissions and 45 per cent of the net warming impact of all anthropogenic activities in 2019 (Intergovernmental Panel on Climate Change [IPCC] 2021). Along with black carbon, tropospheric ozone and some hydrofluorocarbons (HFCs), methane is a short-lived climate pollutant (SLCP), a class that has much greater warming impacts per ton than CO_2, but a much shorter atmospheric residence time. Methane accounts for more than half of the warming of all SLCPs.

Atmospheric observations show that emission growth rates have accelerated over the past 15 years, with methane atmospheric concentrations reaching 1,879 parts per billion in 2020 on annual average, which was 6 per cent higher than in 2000 (Dlugokencky undated) and 260 per cent higher than during pre-industrial times (World Meteorological Organization [WMO] 2020). Anthropogenic emissions account for roughly 60 per cent of total methane fluxes to the atmosphere, amounting to around 365±30 megatons of methane ($MtCH_4$)/year. Approximately 35 per cent come from fossil fuels (two thirds from oil and gas and one third from coal), 40 per cent from agriculture (three quarters from enteric fermentation and manure management and one quarter from rice) and 20 per cent from waste (mostly landfills and solid waste), with the remaining ~5 per cent emitted through biofuel and biomass burning (Saunois *et al.* 2020).

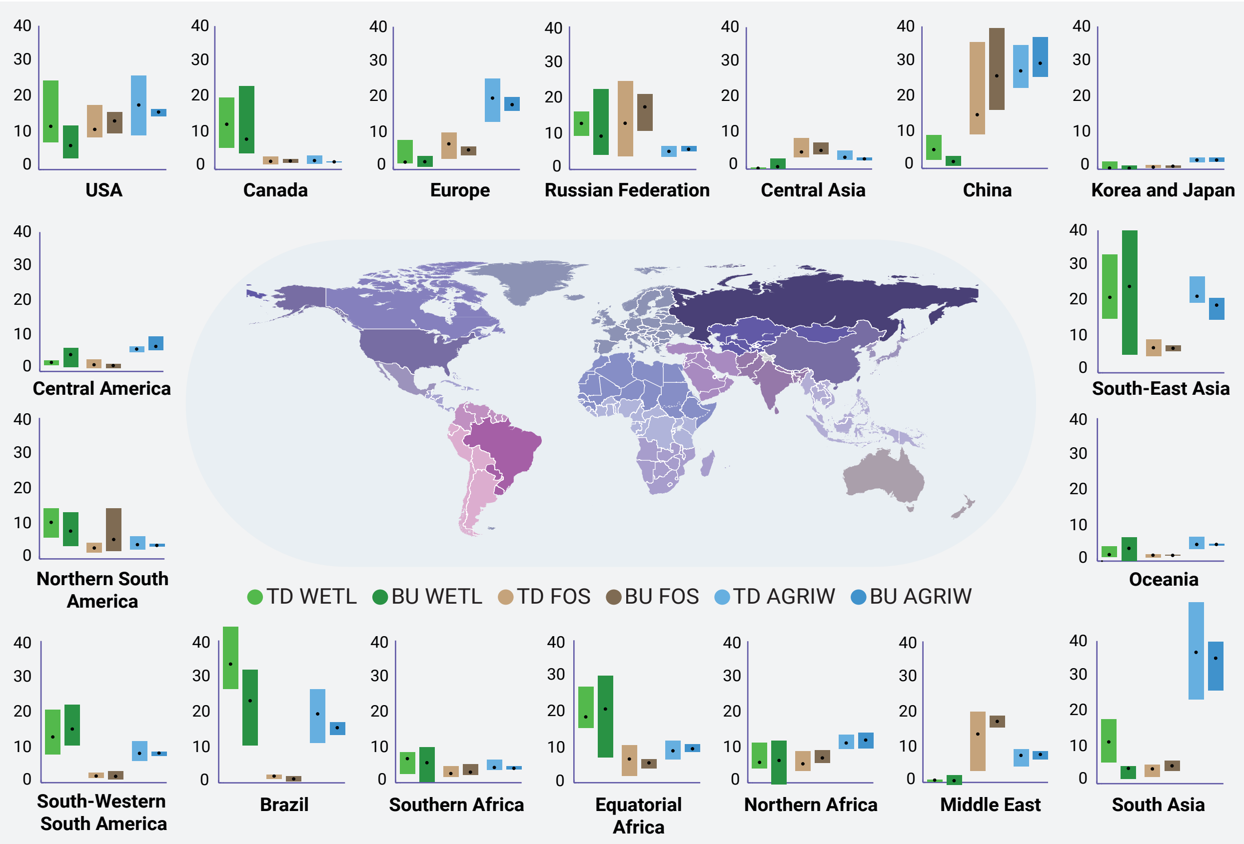
The remaining roughly 40 per cent of total methane emissions are generated by several natural sources: inland freshwaters (including wetlands, lakes, reservoirs and rivers), geological releases, wild animals, termites and permafrost. Sectoral partitioning of methane emissions varies greatly among countries/regions and large uncertainties remain in both anthropogenic and natural emissions (figure 6.1). Over the last two decades, the main cause of increasing atmospheric methane is likely increasing anthropogenic emissions, with hotspot contributions from agriculture and waste in South and South-East Asia, South America and Africa, and from fossil fuels in China, the Russian Federation and the United States of America (Jackson *et al.* 2020). Emissions from natural sources may also be increasing, as wetlands warm, tropical rainfall increases and permafrost thaws.

The size of methane sinks (mainly oxidation in the atmosphere), and how this varies over time, remain difficult to predict and study. Unlike CO_2, little attention has been given to capturing methane from the air, and further assessment of the feasibility of methane removal is therefore required (Jackson *et al.* 2019).

Although methane emission reductions are a necessary part of long-term mitigation strategies alongside CO_2 reductions (Rogelj *et al.* 2018), mitigating methane emissions would especially contribute to reducing climate change-related damages in the near term, while reducing the level of eventual temperature stabilization and decreasing peak warming during this century.

As a result, there has been increased focus in recent years on the immediate need and opportunity to reduce methane emissions. The United Nations Environment Programme (UNEP) and Climate and Clean Air Coalition (CCAC) released a Global Methane Assessment in May 2021, which analysed the benefits of reducing methane emissions, the policies and costs of mitigation actions and the reductions needed to meet Paris Agreement goals (United Nations Environment Programme [UNEP] and Climate and Clean Air Coalition [CCAC] 2021). Several groups have recently analysed abatement potentials for methane, while others have both examined mitigation and described the impacts of such mitigation on the ability to meet climate targets (Nisbet *et al.* 2020; Ocko *et al.* 2021; UNEP and CCAC 2021). The main findings of these studies are assessed below, with some elements highlighted and implications for nationally determined contributions (NDCs) explored.

Figure 6.1. Average methane emissions for 2008–2017 in $MtCH_4$/year for 18 continental regions



Note: Emissions are shown for three main emission categories: wetlands (WETL), fossil fuel-related (FOS) and agriculture and waste (AGRIW). Coloured bars represent the minimum and maximum range of available estimates from top-down (TD) and bottom-up (BU) approaches. Black dots show the average for each approach (based on Saunois *et al.* 2020 data sets). The colours in the map indicate regions only.

6.2 Optimizing methane emission reductions

The level of methane emissions (and other short-lived substances) at the time of reaching net zero for long-lived GHGs will play an important role in determining the level at which temperatures stabilize. Methane stabilization at a level greater than the pre-industrial level will mean a long-term commitment to warming relative to the pre-industrial level, whereas changes in methane emissions will contribute further to future temperature changes. As a GHG that does not accumulate semi-permanently in the atmosphere, achieving net-zero methane emissions is not required for climate stabilization, nor is it expected, in marked contrast to the sum of CO_2 and nitrous oxide (N_2O), for which net-zero emissions are required for stabilization (Rogelj *et al.* 2018; see also chapter 3).

Methane abatement would affect warming rates in the near term, resulting in benefits for ecosystems and the ability of humans to adapt. As a precursor of tropospheric ozone,[1] which can be toxic to both humans and plants, methane emissions affect public health and crop yields via air pollution. Defining the optimal path for methane emission reductions is therefore arguably more suited to a multiple-benefits analysis than other GHGs, rather than an analysis

1 The troposphere is the lowest level of the atmosphere, which includes surface air.

only defined by a climate metric (though other GHGs may also have co-benefits that affect air pollution and health). Captured methane has a clear use and market value as natural gas. As a result, many methane reduction measures have low or even negative costs, with many models examining least-cost pathways to meet low warming targets reducing methane sharply in the current decade (Harmsen *et al.* 2019a; UNEP and CCAC 2021), though such reductions are not yet occurring.

Depending on progress in mitigating emissions of long-lived GHGs, rapid reductions of methane are also likely to play a role in limiting peak warming (chapter 3). That role depends heavily on how quickly emissions of CO_2 are reduced, how much CO_2 removal is deployed, and on the emissions trajectories of other short-lived climate forcers.

6.3 Short- and long-term mitigation potentials

The UNEP and CCAC Global Methane Assessment assessed the methane mitigation potential and cost estimates produced by several teams. This assessment included sector-specific assumptions about technology turnover times, estimates for improvements in technology over time and the achievable pace of regulations. Costs include estimates for the future value of recovered gas as well as the discounting of future returns with rates of 4–10 per cent.

Implementation of readily available methane-targeted abatement measures alongside broader structural and behavioural measures could reduce methane emissions by approximately 180 Mt/year by 2030, which is equal to nearly 50 per cent of current methane emissions. Implementation of readily available methane-targeted measures alone (i.e. excluding structural and behavioural measures) could reduce 2030 methane emissions by around 30 per cent.

The fossil fuel sector shows the largest all-cost (i.e. not restricting the analysis to low or negative net emission control costs) absolute 2030 abatement potential in analyses by three teams (Harmsen *et al.* 2019b; United States Environmental Protection Agency [U.S. EPA] 2019; Höglund-Isaksson *et al.* 2020). Methane emissions from this sector could be reduced by approximately 75 Mt/year (~2.2 gigatons of CO_2 equivalent ($GtCO_2e$)/year using global warming potential over 100 years – GWP100) in the short-term (2030) using methane-specific emission abatement measures relative to ~130 Mt/year in projected 2030 business-as-usual (BAU) emissions. Within the sector, oil and gas has a substantially larger reduction potential than coal in two of the analyses and roughly equal potential in the third analysis. Based on the Global Methane Assessment, all-cost oil and gas emission mitigation potential is 25–58 Mt/year by 2030 and 35–95 Mt/year by 2050 (relative to projected BAU 2050 emissions of ~155 Mt/year). Averaged over all measures, abatement costs are quite similar for the coal subsector, but vary substantially for the oil and gas subsector. Restricting the analysis to low cost (< US\$600/tCH_4; < ~US\$20/tCO_2e using GWP100) measures only, ~17–32 Mt/year can be abated by 2030 in the oil and gas subsector, compared with ~8–24 Mt/year in the coal subsector. The largest and most cost-effective abatement potentials within the fossil fuel sector for 2030 are to prevent all venting of associated gas during oil and gas extraction (including from inefficient flaring), to install leak detection and repair programmes for natural gas infrastructure and to utilize ventilation air methane oxidation technology in coal mines (table 6.1).

Reducing methane emissions from waste and agriculture will be more challenging but is crucial to achieving low warming targets. For waste, the three analyses assessed in the Global Methane Assessment have very similar 2030 all-cost abatement potentials relative to projected 2030 BAU emissions (~28–32 Mt/year; ~30–35 per cent; ~0.9 $GtCO_2e$/year using GWP100), but with widely varying cost estimates (+US\$3 to -US\$200/tCO_2e using GWP100). The largest and most cost-effective abatement in the waste sector comes from municipal solid waste, typically either by diverting organic waste from the waste stream or capturing and utilizing landfill gas. More simply, covering landfills with soil is a very effective and low-cost measure, and reduces fires, odours and air pollution. This could be an attractive option for many tropical and subtropical megacities, which typically have extremely large and ill-managed landfills. Crop waste fires are widespread in the tropics, leading to significant air pollution and methane emissions from partial combustion. Such crop waste could instead be burned under controlled conditions to generate electricity or returned to the soil to provide nutrients.

All-cost abatement estimates for rice cultivation have similar abatement potentials (~7–10 Mt/year) but vary markedly in costs (roughly US\$3–100/tCO_2e using GWP100), whereas low-cost abatement potentials and costs are quite similar across analyses. Abatement within rice cultivation is possible through changes in agricultural production techniques, such as alternate wetting and drying of paddy fields, though the benefits can be undermined by increased N_2O emissions (table 6.1). In contrast, all-cost abatement potential estimates for the livestock sector have similar costs (~US\$13–30/tCO_2e using GWP100) but significantly varied abatement potentials (4 to > 40 Mt/year). These differences are largely attributable to assumptions about the feasibility of some countries being able to switch to higher-yielding livestock breeds. The average abatement potential is therefore smallest in the agriculture sector at ~20–25 per cent. Several less well-established abatement options are also under study for the livestock sector, including feed substitutes and methane inhibitors (UNEP and CCAC 2020; Ocko *et al.* 2021). At the same time, substantial mitigation of livestock-related methane could be achieved through widespread changes in human dietary choices, possibly reaching 30 Mt/year (~0.9 $GtCO_2e$/year using GWP100) by 2050, with additional CO_2 and N_2O reductions (Willett *et al.* 2019; UNEP and CCAC 2021).

For 2050, abatement potentials tend to increase moderately compared with 2030, with the exception of waste and oil and gas in one analysis that shows very large abatement increases. The average abatement potential for waste across the three estimates roughly doubles between 2030 and 2050. Similarly, the average all-cost abatement potential in oil and gas increases to ~80 per cent of the 2050 value, with roughly half of these emission controls available at low net cost. Targeted abatement estimates (without behavioural changes) increase only modestly in agriculture, which is expected to become the main anthropogenic source of emissions in low warming scenarios (e.g. Rogelj *et al.* 2018). Abatement costs also change, with some of the most noticeable shifts being that oil and gas abatement will become more expensive on average. Changes in livestock abatement costs vary significantly among analyses.

There are additional opportunities to reduce methane beyond methane-targeted abatement measures. These include fuel switching from natural gas to renewables in electricity generation and in buildings, and behavioural changes such as reduced consumption of cattle-based foods and reduced food waste and loss. Integrated assessment models show large ranges in potential methane mitigation due to these processes. On average, these models indicate that such actions could reduce methane emissions by another 15 per cent beyond the targeted measures, for a total 2030 reduction under 1.5°C scenarios of 45 per cent relative to BAU (UNEP and CCAC 2021). Both the Global Methane Assessment and Ocko *et al.* (2021) emphasize that fast methane action, as opposed to slower or delayed action, can contribute greatly to reducing midterm (2050) temperatures, i.e. peak warming if long-lived GHG emissions are also controlled. Fast action to reduce methane to a trajectory consistent with 1.5°C scenarios was found to be able to reduce both 2050 and 2100 global mean temperatures, by 0.2–0.4°C and 0.4–0.8°C, respectively, compared with a broad set of potential baseline scenarios (UNEP and CCAC 2021).

Table 6.1. Global annual abatement potential in 2030 and 2050 ($MtCH_4$ and $MtCO_2e$)

Sector	Technical abatement measure	2030 $MtCH_4$	2030 $MtCO_2e$	2050 $MtCH_4$	2050 $MtCO_2e$
Livestock	Manure anaerobic digestion with biogas recovery on large farms >100 livestock units	1.2	35	2.6	77
	Breeding for improved productivity, longevity and reproduction	1.2	36	12.2	354
	Feed management and feed additives	1.8	54	9.5	274
Rice cultivation	Improved water management, use of alternative hybrids and soil amendments	6.1	177	3.9	112
Burning of agricultural waste residuals	Ban and enforcement of bans	1.8	52	3.1	89
Coal mining	Pre-mining degasification	4.4	128	17.7	513
	Ventilation air methane oxidation	6.0	173	16.8	488
	Flooding of abandoned coal mines	1.7	50	8.0	231
Oil production	Increased recovery of associated petroleum gas	14.8	429	12.6	366
	Leak detection and repair programmes	4.7	136	17.5	507
Gas production	Leak detection and repair programmes	9.4	274	14.4	416
Gas transmission pipelines	Leak detection and repair programmes	2.7	79	10.6	308
Gas distribution networks	Replacement of grey cast iron pipes and leak detection and repair	6.7	195	18.0	522
Food industry waste	Anaerobic digestion with biogas recovery	3.2	93	21.3	617
Paper, textile and wood industry waste	Recycling and incineration with energy recovery	1.8	53	5.1	147
Municipal solid waste	Source separation and anaerobic digestion with biogas recovery	6.1	177	11.8	341
	Source separation and recycling	5.9	170	14.1	410
	Source separation and incineration with energy recovery	3.7	109	13.3	385
Wastewater – industry	Two-stage anaerobic and aerobic treatment with biogas recovery	6.7	195	23.1	671
Wastewater – municipal	Upgrade of primary to secondary/tertiary with biogas recovery	1.2	35	5.8	169
All sectors		91	2,650	241	7,000

Source: Höglund-Isaksson *et al.* (2020)

6.4 Link between methane mitigation and paths to net-zero CO_2

There are important links between methane emissions and the path to net-zero CO_2. Scenarios with strong climate change mitigation policies include decarbonizing the economy, which would reduce methane leakage from fossil fuel systems due to reduced demand. However, decarbonization will lead to more abandoned oil and gas wells and coal mines, which would need targeted actions to reduce methane emissions that are distinct from direct decarbonization policies (e.g. Kholod *et al.* 2020). By 2050, methane abatement associated with decarbonization alone is only about 30 per cent of the methane abatement seen under a broad multi-pollutant, multi-policy 2°C scenario, emphasizing the large role played by methane-specific policies.

On a more fundamental physical level, the less methane is reduced, the smaller the available carbon budget will be that is consistent with a given target (e.g. Rogelj *et al.* 2018). Quantitatively, every ~100 Mt of methane emissions reduced and kept reduced increases the cumulative twenty-first century carbon budget by around 450 $GtCO_2$.

There are also many linkages between methane reduction actions and opportunities for decarbonization. For example, within land use, the abatement of livestock-related methane typically involves reduced demand for cattle, which then frees up pasture and feed lands for potential production of biofuels or afforestation. Methane-formed surface ozone is known to reduce the growth rate of many plants, affecting both crops (and therefore land use, as a greater area would be required to produce the same yield) and decreasing CO_2 uptake by forests (e.g. Sitch *et al.* 2007). Finally, using organic material from landfills as plastic substitutes could reduce the need for petroleum-based plastics, which could play a role in the transition away from fossil fuels (though likely a modest role), while reducing landfill-related methane emissions. As shown, several methane mitigation pathways also have the potential to contribute to CO_2 mitigation.

6.5 Methane mitigation in the first NDCs

Many countries present their mitigation pledges for GHG emission reductions in various ways in their NDCs.[2] Some emissions targets are not quantitative, while most that are quantitative tend to be provided as aggregated GHGs, which makes it difficult to discern projections for individual gases (at present, individual gases are only reported in national communication submissions by Annex I countries for trajectories based on current policies). The emissions implications of many major emitters' first NDC commitments have been analysed as part of a large international research project. Using a suite of global and national models and informed by policy-specific input from national experts, the project developed a range of plausible implementation pathways to achieve the NDCs (Roelfsema *et al.* 2020). The project also examined a least-cost 2°C scenario (accounting for mitigation costs only, and excluding environmental costs), with reductions starting in 2020 and a 66 per cent chance of staying below 2°C.

According to those estimates, some countries have made pledges that would lead to substantial decreases in their methane emissions by 2030 (table 6.2). Extrapolating countries' NDCs reveals that most are projected to achieve substantially greater reductions by 2050 than 2030. Japan is the exception, showing a smaller reduction in 2050. A group of major emitting countries, including the United States of America, European Union nations, Japan and Canada, have NDCs that will likely result in reductions of ~80–88 per cent of those seen in 2°C least-cost pathways by 2030 compared with 2015, and ~69–77 per cent by 2050. However, most of the world is not yet as close to 2°C pathways, so at the global scale, NDCs are expected to deliver only about a third of 2030 methane reductions expected under 2°C scenarios. Among the major emitting countries analysed, China, the Russian Federation, India and Australia show the greatest emission gaps for methane, with their NDC reductions relative to their 2°C reductions less than the global mean for both 2030 and 2050. Methane reductions in 1.5°C least-cost pathways are 44 per cent at the global level by 2030 compared with 2015, rather than 34 per cent for 2°C. The NDCs are therefore projected to deliver only about one quarter of 2030 reductions in 1.5°C pathways. The International Institute for Applied Systems Analysis (IIASA) has also carried out analyses of the impact of NDCs on methane for the European Union, which show decreases of 21 per cent by 2030 and 34 per cent by 2050 (relative to 2015), results that are very similar to those shown in table 6.2.

2 The assessment in this chapter only considers the first round of NDCs. New or updated NDCs are not considered.

Table 6.2. Projected changes in methane emissions relative to 2015 under nationally determined contributions and under a 2°C scenario

	2030	2030	2030		2050	2050	2050
Country	**% decrease in NDC**	**% decrease in 2°C**	**NDC/2°C fraction**	**Country**	**% decrease in NDC**	**% decrease in 2°C**	**NDC/2°C fraction**
Republic of Korea	26	29	89	USA	44	57	77
USA	30	34	88	EU	37	50	74
Canada	44	51	87	Japan	39	55	71
Japan	46	54	86	Canada	50	72	69
EU	22	28	80	Indonesia	40	65	61
Indonesia	23	40	59	Brazil	21	38	56
Turkey	22	38	58	Republic of Korea	31	64	49
Brazil	11	23	48	Turkey	26	59	44
Global	11	34	34	Global	23	55	41
Rest of world	10	34	30	Rest of world	22	57	39
Australia	2	9	18	China	18	59	30
Russian Federation	5	35	16	Russian Federation	19	63	30
China	6	40	15	India	8	46	17
India	1	26	3	Australia	5	43	12

Note: Projections for both the NDCs and the 2°C scenario are based on Roelfsema *et al.* (2020) and PBL Netherlands Environmental Assessment Agency (undated). Although ranges across the models were not specified for methane alone, the tenth to ninetieth percentile range of the emissions gap between the NDCs and 2°C scenario for all GHGs was ~36 per cent at the global level and 30–55 per cent at the national level, indicating that a similar uncertainty range is appropriate for methane estimates. The assumptions and underlying data are described in Roelfsema *et al.* (2020).

Although there are signs that transformation is taking place in some parts of the world, more ambitious efforts are clearly needed if the world is to aim for 2°C or 1.5°C pathways. In countries or regions with large projected decreases in methane emissions, specific policies have been put into place to achieve such reductions. Examples include the 2016 North American Leaders' Summit agreement to reduce oil and gas methane emissions by 40–45 per cent by 2025 (relative to 2012) in Canada, Mexico and the United States of America, the European Union's 2020 strategy to reduce methane emissions (COM/2020/663 final) and the goals of Nigeria and Côte d'Ivoire to reduce oil and gas methane emissions by 60–75 per cent by 2030 as part of the UNEP and CCAC Global Methane Alliance. In September 2021, the United States of America and the European Union announced a Global Methane Pledge to reduce anthropogenic methane emissions by at least 30 per cent globally relative to 2020 levels by 2030. On 11 October 2021, they reported that more than 30 additional countries had committed to joining the Pledge, with coverage now including nine of the top 20 methane emitters globally, and urged others to sign on before the official launch at the twenty-sixth United Nations Climate Change Conference of the Parties (COP26). There is a clear need for increased ambition almost everywhere, with possible actions that policymakers could consider including increased efforts to build on growing momentum to monitor and address environmental impacts within the private investment community. More transparent data on sector-specific 'best practice' methane emissions would help support a market for both monitoring and mitigation services by facilitating the identification of the best-performing companies.

NDCs typically include more information about the energy sector than the agriculture or waste sectors. Every country emits GHGs from municipal waste, which is largely generated by the human population (Eggelston *et al*. 2006). In NDCs representing 174 countries, 137 included general waste sector mitigation commitments, with 67 citing specific mitigation actions (Powell *et al*. 2018). The most common mitigation action was improved landfilling, followed by converting waste into energy (e.g. incineration and conversion of landfill gas into energy). Improvements in waste management systems could provide public health co-benefits, such as reducing hazards associated with wastewater mismanagement, improving air quality and diminishing land and water contamination (Mittal *et al.* 2017; Cohen *et al.* 2021).

Agricultural methane emissions primarily derive from animal stocks and rice cultivation, as well as deliberate biomass burning, factors that vary widely from country to country (Food and Agriculture Organization of the United Nations [FAO] 2021). In their first NDCs, 32 countries referred to 'climate-smart agriculture', with aims to optimize agricultural systems to increase productivity and incomes, enhance resilience and reduce GHG emissions (Strohmaier *et al*. 2016). However, countries rarely included quantitative targets for reducing agricultural methane emissions (Hönle *et al.* 2019). In fact, of the top 46 countries that contribute to 90 per cent of global agricultural emissions, only a quarter included broadly-stated measures targeting emissions from ruminant livestock. This may be due to relatively high abatement costs and the impact such measures may have on economically important sectors such as beef and dairy. Mitigation measures such as sustainable intensification of rice cultivation were more likely to be included, in part because they present clear co-benefits for modernization or productivity (Hönle *et al.* 2019). The magnitude of agricultural methane emissions suggests that agriculture should receive more attention than it currently does in methane mitigation strategies, and that strategies that include changes in consumption through a food systems approach will need to be considered (Tubiello *et al.* 2021). Setting quantitative goals for cropland and livestock management, which could come in the form of targets for best practices, would help countries raise their ambition in this sector.

6.6 Measurement-based verification of uncertain emission reporting

In many cases, methane mitigation efforts are hampered by uncertainties relating to actual emission numbers, making it important to urgently improve approaches for measuring and reporting emissions. Improved monitoring at the facility level could serve to motivate action to reduce emissions and to verify the effectiveness of such action. This would open up opportunities for regulators to use flexible policy instruments that directly target measurable emission reductions compared with more prescriptive best available technology standards. Effectively prioritizing methane sources, reducing methane emissions and tracking mitigation progress necessitates a broad suite of measurement-based technologies that draw on the unique advantages of each.

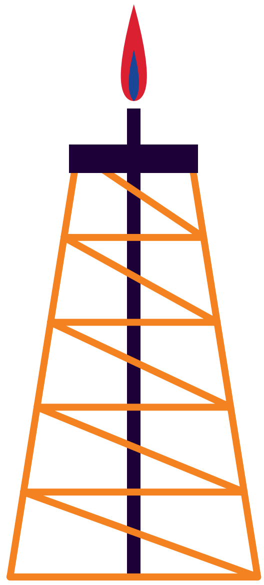
Traditional bottom-up approaches, based on source-specific emission factors combined with statistical activity data (for example, livestock numbers, amount of oil and gas extracted), have inherent uncertainties that can be large at the national/sectoral scale (figure 6.1), especially for non-Annex 1 countries with limited institutional capacity and data availability (Solazzo *et al.* 2021). Even in countries such as Germany and the United Kingdom, which have well-established emission reporting systems, methane inventories have been revised by up to 60 per cent between subsequent submissions (Bergamaschi *et al.* 2010).

New top-down approaches have been developed that use atmospheric observations (at the surface, airborne or from satellites), which when combined with atmospheric transport models, can be applied to determine emissions for a specific facility, sector, region or other aggregation. These top-down approaches have proven effective in correcting emission factors and in revising sectoral methane emissions in multiple geographies (e.g. Alvarez *et al.* 2018; Zavala-Araiza *et al.* 2021), and in this way have provided opportunities for identifying specific sources and mitigation opportunities (Lyon *et al.* 2016; Johnson *et al.* 2017).

Top-down approaches can also support the transparency of reporting processes, with the updated IPCC reporting guidelines recommending the application of such approaches as additional quality control (Bartram *et al.* 2019). However, at present, only Switzerland and the United Kingdom include top-down methane estimates in an annex to their national inventory reports (Manning *et al.* 2011; Henne *et al.* 2016).

New observational capabilities are revealing emission hotspots and facility- or city-scale emissions through measurements from cars, drones and aircraft, and satellite remote sensing, especially in remote world regions, which in at least a few cases has led to industry action to eliminate major emission point sources (Nisbet *et al.* 2020). However, at a larger scale, top-down methods depend highly on the density of observations and are challenged by the difficulty in disentangling different sources and separating natural emissions from anthropogenic emissions, which is crucial for many countries with large natural emissions. Compared with high-frequency in situ surface measurements, satellite observations have a broader coverage but less sensitivity to methane sources, and are limited by cloud coverage. Further deployment of mobile measurements and fixed stations should therefore be supported to better monitor methane concentrations, especially over tropical and boreal regions.

In the near future, wider use of top-down approaches will be facilitated by a new International Methane Emissions Observatory (IMEO) hosted by UNEP. The International Energy Agency (IEA) Methane Tracker (2020) already includes data on leaked methane of super emitters, which is detected by the TROPOspheric Monitoring Instrument (TROPOMI), with a new generation of satellites, such as GHGSat (Varon *et al.* 2020), being specifically designed to map and quantify point sources.



7 The role of market mechanisms in bridging the emissions gap

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7.1 Introduction: The role of carbon markets and current status

In the Paris Agreement, cooperation among countries is considered a way to both implement nationally determined contributions (NDCs) and promote greater ambition, while also fostering sustainable development and encouraging broad participation from the private and public sectors. Market mechanisms are therefore seen as an important component in collective action to achieve the long-term goals of the Paris Agreement. In principle, the role of markets within the context of the agreement is to enable all parties engaged in mitigation actions to implement these in a cost-effective manner, while simultaneously providing an opportunity to enhance their ambition.

Under article 6, the Paris Agreement provides for an international framework for market mechanisms to enable greater ambition in both mitigation and adaptation actions (Bodansky *et al.* 2016). It also allows countries to voluntarily cooperate to achieve their NDCs, "promote sustainable development and ensure environmental integrity and transparency" (article 6.2), so long as parties avoid double counting mitigation outcomes. The fact that 87 per cent of new and updated NDCs specify countries' intentions to possibly use voluntary cooperation under article 6 (United Nations Framework Convention on Climate Change [UNFCCC] 2021) confirms a significantly increased interest in this approach, compared with previous NDCs.

Although article 6 established these principles, the rules that facilitate their implementation in practice are still the subject of negotiations, including guidance for cooperative approaches (article 6.2), which covers all forms of international mitigation markets, the rules for a mechanism (article 6.4), and a framework and work programme to promote non-market cooperation (articles 6.8 and 6.9). These rules, modalities and procedures are an anticipated key outcome of the of twenty-sixth United Nations Climate Change Conference of the Parties (COP26).

There is already considerable experience in designing and implementing market mechanisms to control pollutants, including different forms of carbon markets (Schmalensee and Stavins 2017; Michaelowa *et al.* 2019a; World Bank 2021a). The current state of carbon markets is very diverse. Such markets include both voluntary and compliance-driven programmes, which are used both domestically and internationally to reduce emissions, and involve different types of allowances and credits and both public and private sector entities as buyers and sellers (box 1, figure 7.1).

Box 7.1. Current state of carbon markets

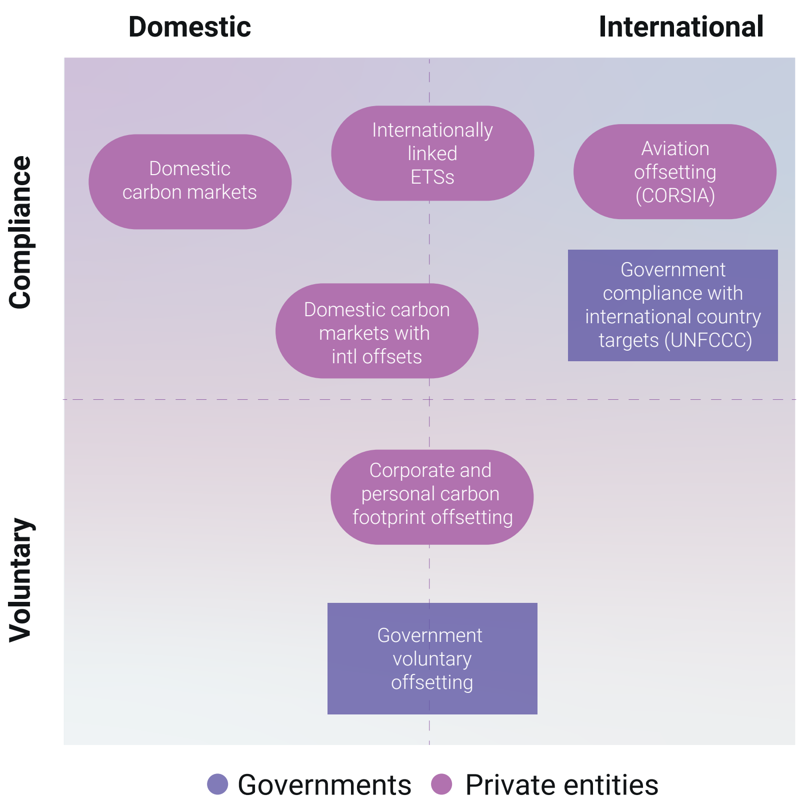
Compliance carbon markets are marketplaces in which participants act in response to an obligation established by a regulatory body. The most prominent examples of such markets are national or regional emissions trading systems. In national emissions trading systems, governments set a cap on the aggregate level of greenhouse gas (GHG) emissions that regulated entities can emit over a period of time. These entities are required to submit an emission permit (or allowance) for each ton of carbon dioxide equivalent (tCO_2e) they emit. Emissions trading systems can be restricted to domestic borders or may have international elements through links with other emissions trading systems (e.g. the European Union, the European Union-Swiss link and the California-Quebec link) and/or the acceptance of international offsets (e.g. the Republic of Korea's Emissions Trading Scheme – K-ETS).

In voluntary carbon markets, participants are under no formal obligation to achieve a specific target. Instead, companies, private entities and national governments seek to voluntarily offset their emissions, for example, as part of a social responsibility strategy. Voluntary buyers can procure domestic or international carbon credits from various different crediting programmes, as well as allowances from compliance markets (Doda *et al.* 2021).

Compliance carbon markets have historically generated more mitigation action and stronger incentives for decarbonization than voluntary carbon markets, though they may face more political opposition and entail higher regulatory burdens. Voluntary carbon markets can be an important tool to mobilize the private sector and expand the reach of carbon markets beyond sectors and regions subject to explicit climate regulation.

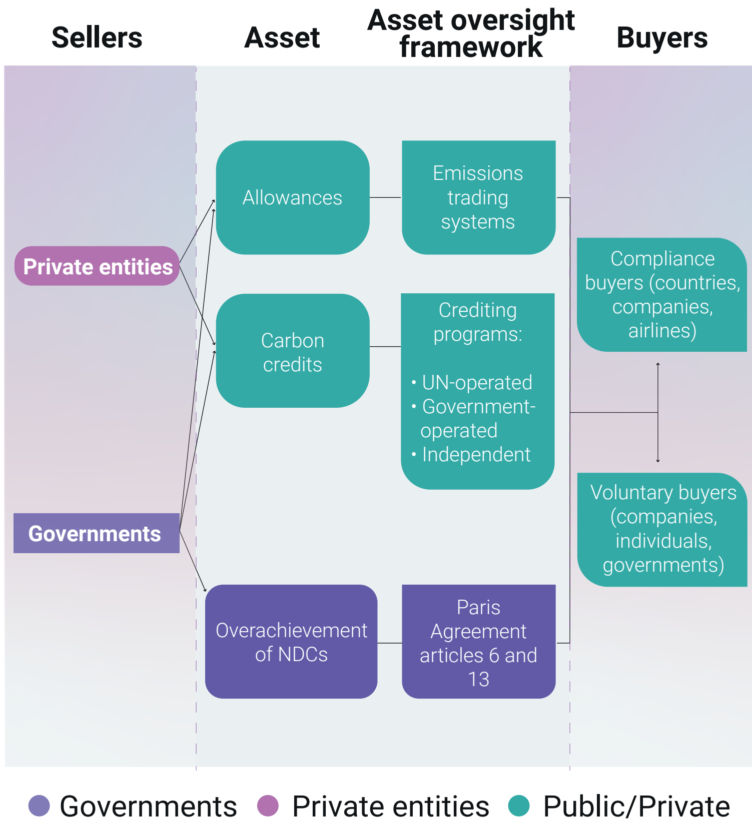
In terms of structure, domestic carbon markets have the advantage of normally allowing better oversight and control through full regulatory control by a relevant authority, with little risk of spillover effects from other systems or jurisdictions, and all mitigation benefits accrued domestically. Adding international elements to markets will increase their complexity, but also presents a significant advantage of potentially reducing compliance costs by making use of cheaper mitigation opportunities in other jurisdictions.

Figure 7.1a. Market typology



Source: Adapted from La Hoz Theuer (2021)

Figure 7.1b. Cross-border unit transfers



Source: Adapted from La Hoz Theuer (2021)

Experiences from these various markets and approaches provide important learnings for the design of new cooperative approaches. This chapter initially provides an assessment of the potential role of market mechanisms under the Paris Agreement in both the near term and in achieving long-term climate goals (section 7.2), then examines technical issues that have implications for the effective implementation of article 6 (section 7.3), and finally discusses actions that can be taken to unlock market potentials and enhance ambition (section 7.4).

7.2 The potential role of international carbon markets under the Paris Agreement: near-term versus net-zero implications

7.2.1 Near-term implications

NDCs define the mitigation contribution of each party to meeting the goals of the Paris Agreement. Countries have prepared their NDCs using different target types and metrics ranging from reductions in all greenhouse gas (GHG) emissions relative to a fixed emissions level (e.g. a 50 per cent reduction in all GHGs in 2030 relative to 2005), to specific actions such as planting a specific number of trees by a specific date, to conditional contributions that apply only if an additional condition is met (Hood and Soo 2017). The heterogenous nature of the current NDCs in this way creates challenges for both negotiating and establishing effective real-world markets, as well as the risks of double counting, emission leakages and unattainable targets.

There is growing interest from countries in using markets and voluntary cooperation to implement their NDCs. As of 30 July 2021, the share of parties that indicated an intention or possibility of using voluntary cooperation has nearly doubled, from 44 to 87 per cent in the new or updated NDCs, compared with previous NDCs. Moreover, the share of parties that have set qualitative limits on voluntary cooperation, such as using certain standards and guidelines to ensure additionality and avoid double counting, has increased from 19 to 39 per cent (UNFCCC 2021).

The existing quantitative literature that estimates the maximum potential gains from cooperation generally assumes that the heterogeneous NDCs could be translated into a common comprehensive, transferable emissions mitigation metric. This is evidently not something that is going to happen quickly, if at all, and the results must therefore be interpreted as estimates of **potential** gains from cooperation compared with independent implementation of the same targets. These studies do not include ancillary domestic benefits that may have motivated countries' choice of NDC target methods.

A relatively limited number of studies have so far provided quantification of the gains from cooperative implementation of NDC pledges (e.g. Fujimori *et al.* 2016; Hof *et al.* 2017; Edmonds *et al.* 2019; Böhringer *et al.* 2021; Edmonds *et al.*

2021). With the aim of achieving the current NDC ambition through global cooperation, most models estimate a global carbon price of US$9–38/t$CO_2$ between 2025 and 2030.[1] In contrast, the studies find that due to the varying stringency in NDCs, the shadow price of carbon for a country to independently and cost-effectively achieve its unconditional NDC pledge by 2030 ranges from US$0/t$CO_2$ to over US$250/t$CO_2$ across models and studies (with each study analysing then-current NDC pledges), highlighting the potential gains through international emissions trading. As a result, the estimated mitigation costs by 2030 in an ideal situation could be reduced by 40–60 per cent through the full use of market mechanisms (Aldy *et al.* 2016; Fujimori *et al.* 2016; Hof *et al.* 2017; Edmonds *et al.* 2019; Edmonds *et al.* 2021). Although there are uncertainties associated with economic modelling, results in all studies suggest significant potential cost reductions and economic gains from using market mechanisms. These results provide a strong incentive for countries to negotiate a credible agreement on article 6 and to move towards more compatible NDCs over time.

The modelling studies estimate that around 4–5 GtCO_2e could be traded per year by 2030 with a market volume of US$60–100 billion per year if NDCs are transformed into tradable emission mitigation actions (Fujimori *et al.* 2016; Edmonds *et al.* 2019; Edmonds *et al.* 2021). Net market transactions constitute balance-of-trade changes and therefore changes to participants' gross domestic product (GDP) and/or exchange rate position. For selling regions, this would represent a potentially significant new net export (Piris-Cabezas *et al.* 2019; Edmonds *et al.* 2021; Kachi *et al.* 2020). The extent to which this will actually occur is very uncertain, with many parties emphasizing domestic implementation and mentioning flexible mechanisms as an additionality in their NDCs.

Carbon markets shift both emission mitigation actions and emission mitigation investments from buyers to sellers. Provided that sellers are primarily developing countries, carbon markets have the potential to transfer emission mitigation-related capital towards developing economies, help prevent lock-ins to carbon-intensive infrastructure and contribute to capacity-building to further reduce emissions. Redistributing capital investments potentially carries implications for other sustainability metrics, such as local air quality, forest conservation, rural livelihoods, food prices, water quality and energy access, as well as for the regional distribution of incentives for technology development and innovation.

While increasing emission mitigation innovations in selling regions, carbon markets could reduce incentives in buying regions. In buying regions with greater capacity to develop capital-intensive emission mitigation technologies, the overall pace of technological change that favours emissions mitigation could be reduced if ambitions are not increased at the same time. However, under different policy designs, near-term flexibility facilitated by low-cost mitigation options, such as reducing tropical devastation, can free resources to boost investments into research and development and yield improved technologies in the longer term (Szolgayová, Golub and Fuss 2014; Koch *et al.* 2017).

Studies of potential emissions mitigation with international markets indicate that land-use emission mitigation opportunities are undertaken earlier than under independent NDC implementation (Edmonds *et al.* 2021). By valuing land-use change emissions, international carbon markets can also provide incentives to prevent deforestation and increase afforestation and reforestation (Lubowski and Rose 2013; Fujimori *et al.* 2016; Edmonds *et al.* 2019; Piris-Cabezas *et al.* 2019; Edmonds *et al.* 2021; Fuss, Lubowski and Gulub 2021).

The need for an interlinked implementation of climate goals and the Sustainable Development Goals (SDGs) is being increasingly recognized at the political level to enhance synergies and maximize co-benefits. However, tools and approaches to assess and report on sustainable development impacts of article 6 cooperative approaches are lacking and remain an unresolved topic in negotiations (Olsen, Arens and Mersmann 2018; Kachi and Mooldijk 2020). Similarly, there are unresolved issues about how the use of cooperative approaches can be designed to contribute to financing adaptation in vulnerable countries with limited potential for direct participation.

7.2.2 Net-zero implications

For climate change to stabilize, global anthropogenic net emissions must decline to zero (chapter 3). As of 13 September 2021, 50 parties to the United Nations Framework Convention on Climate Change (UNFCCC) have announced net-zero targets, of which five parties have explicitly indicated their intent to use international trading to achieve their net-zero pledges. In addition, a growing number of non-State and subnational actors have made net-zero pledges with trading considered.

When global net carbon emissions start to approach zero, carbon market conditions will be very different to how they are currently. Reducing global carbon emissions to net zero involves reducing carbon emissions to near zero in all sectors in all regions, with emissions that remain positive being offset by so-called negative emissions or carbon dioxide (CO_2) removal (see chapter 3). This suggests that the overall scope for transactions in physical (i.e. tons of CO_2 – tCO_2) will shift towards negative emissions over time.

1 The Asia-Pacific Integrated Model/Computable General Equilibrium (AIM/CGE) 2.0 ADVANCED analysis from the Intergovernmental Panel on Climate Change (IPCC) Special Report on global warming of 1.5°C database estimates a substantially higher value of carbon price (US$73/t$CO_2$) by 2030.

The marginal cost of removing the final tons of CO_2 from some hard-to-abate sectors and regions could become high, implying that transactions that occur could be very valuable.

As discussed in chapter 3, net-zero pledges across countries and organizations have different timings, sectoral coverage, gas coverage and legal statuses. In addition to the challenges discussed in section 5.3, ambiguity of net-zero targets creates additional barriers to using market mechanisms to achieve net-zero targets. Further complexity arises from uncertainty in how to treat the various forms of CO_2 removal (National Academies of Sciences, Engineering, and Medicine 2019) in carbon markets. Some carbon markets (Australia, Colombia, New Zealand and the Republic of Korea, and California, Alberta and China's regional systems) already recognize the role of nature-based removal credits and the long-term importance of bringing emission sources and sinks into a common market framework aimed at achieving net-zero emissions (La Hoz Theuer *et al.* 2021).

To reach global net-zero emissions, countries with emissions greater than zero may need to be balanced by countries with negative emissions. Almost all global net-zero scenarios assessed in the Intergovernmental Panel on Climate Change (IPCC) Special Report on global warming of 1.5°C and Fifth Assessment Report databases have similar marginal costs across world regions, which implicitly assume international cooperation to achieve global net-zero scenarios. Van Soest *et al.* (2021) examined cost-optimal emission phase-out years, without fairness considerations, for both 1.5°C and 2°C targets across six integrated assessment models. Their findings revealed significant variations in the timing in which countries reached net-zero emissions, which indicates that there is potential for using market mechanisms to achieve a global net-zero goal.

The magnitude, value and patterns of emissions trading to reach a global net-zero target are dynamic and depend on several factors, such as the use of CO_2 removal technologies and the timing of reaching net zero in each region (Yu *et al.* 2021). Market size, for example, reaches US$300–400 billion in 2030 and around US$1 trillion in 2050 in scenarios with different net-zero timings. Studies have found that land resources also play an important role (Intergovernmental Panel on Climate Change [IPCC] 2018; Yu *et al.* 2021). Removal credits by technology-based CO_2 removal approaches could play an increasingly important role to achieve net-zero emissions but will be limited by the global removal capacity of these technologies (Allen *et al.* 2020; La Hoz Theuer *et al.* 2021).

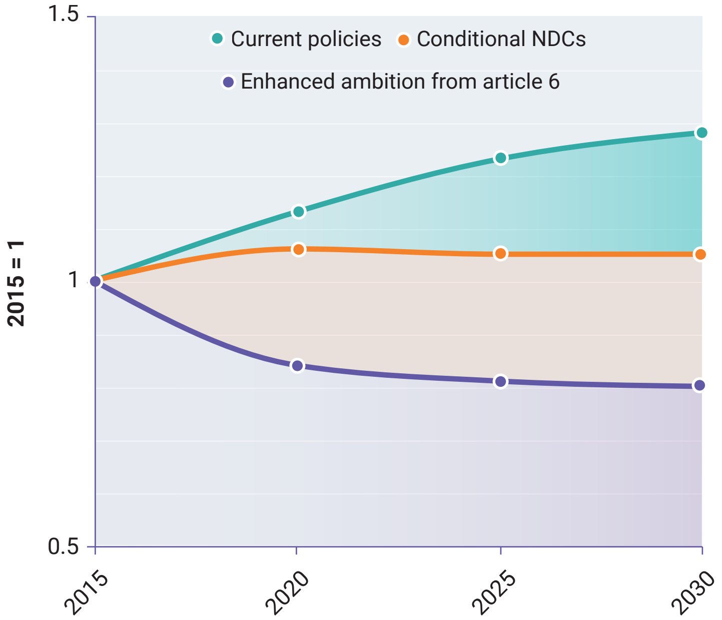
Box 7.2. Enhancing ambition through carbon markets

The main goal of article 6 of the Paris Agreement is to enable parties to increase their ambition towards achieving the agreement's long-term goals. Many researchers have documented that the initial nationally determined contributions (NDCs) are insufficient to be aligned with trajectories to reach the long-term Paris Agreement goals (Fawcett *et al.* 2015; United Nations Environment Programme [UNEP] 2020). However, recent studies by Piris-Cabezas *et al.* (2019) and Edmonds *et al.* (2021) have shown that if the savings from more cost-effective global implementation of NDCs were redeployed towards increased ambition, global emission reductions could be roughly doubled over the next decade at no added cost to parties compared with parties acting alone to implement their commitments (figure 7.2). A major part of the potential ambition increases derives from natural climate solutions, notably forests. Piris-Cabezas *et al.* (2019) estimate that this doubling of climate ambition provides about two thirds of the reductions necessary to get on a 2°C pathway through 2035, closing about half of the current gap without any added cost compared with parties acting independently. Although these calculations are evidently speculative, they highlight both the potential power of carbon markets and how far NDCs need to be enhanced to capture that potential.

Carbon markets do not create ambition for parties. Rather, they create conditions that make enhanced ambitions more attractive through the implicit incentive that emissions mitigation is cost-effective, thereby lowering political and stakeholder resistance to tightening targets and facilitating emission reductions and strengthened targets over time. Experience from the world's current major emissions trading systems supports this approach (Parker 2019). Emissions within trading systems have always fallen faster and at a lower cost than initially expected (Haites 2018). Periods of low prices have been followed by a period of policy reassessment and more ambitious targets, as seen under the European Union Emissions Trading System (EU ETS), the Regional Greenhouse Gas Initiative (RGGI) and California's cap-and-trade programme.

Various explicit mechanisms have been proposed to increase ambition. These include, for example, taxing or 'cancelling' a portion of emission mitigation trades. Under a fixed emissions budget, such schemes could increase overall emissions abatement in the near term. However, according to Piris-Cabezas *et al.* (2019), such an approach applied on a per transaction basis functions as a type of tariff on mitigation exports and hinders the ability of markets to deliver cost-effective mitigation. In the long term, this prevents markets from lowering costs and thereby from facilitating increases in ambition.

Figure 7.2. Increased ambition potentially available from economic efficiency savings available from the ideal implementation of article 6



Source: Adapted from Edmonds *et al.* (2021)

7.3 Using market mechanisms under article 6

Although there is potential for international carbon markets to reduce costs to achieve NDC goals and increase ambition, such potential will remain unknown until important details are determined under article 6. These include establishing robust rules to ensure environmental integrity, including the avoidance of double counting, capacity-building and the management of potential carbon leakages.

7.3.1 Getting the accounting right

To avoid double counting the same emission reductions/removals, the Paris Agreement requires parties participating in article 6.2 cooperative approaches to apply 'corresponding adjustments', i.e. adjusting the balance of their emissions or removals covered by their NDCs to reflect internationally transferred mitigation outcomes.

To ensure environmental integrity under article 6.4, parties are negotiating the application of corresponding adjustments, though their implementation is being complicated by the diverse scope and formulation of the parties' NDC pledges (Greiner *et al.* 2019; Asian Development Bank 2020). Parties have different views on how to define the scope of NDCs, for example, whether to define them in terms of sectors, gases and/or policies and measures. There is also disagreement over whether corresponding adjustments should be required for internationally transferred mitigation outcomes generated outside the scope of selling countries' NDCs.

Many NDCs only include single-year targets, such as 2025 or 2030, which raises the question of how to treat non-compliance years when accounting for internationally transferred mitigation outcomes. Several accounting methods have been put forward to address this challenge (Greiner *et al.* 2019; Lo Re and Vaidyula 2019; Asian Development Bank 2020).

7.3.2 Trade when the basic policy environment lacks a fixed emissions limit

Target setting in the NDCs is still very heterogeneous. Some NDC emission mitigation targets (Graichen, Cames and Schneider 2016; Vaidyula and Hood 2018; Schneider *et al.* 2019) are expressed in non-GHG terms, such as energy efficiency and forestry, while others are framed as intensity targets and/or targets relative to projected business-as-usual (BAU) emissions. Uncertainties in BAU emission projections may weaken the actual ambition of mitigation targets (Hood, Briner and Rocha 2014; Graichen, Cames and Schneider 2016; Hood and Soo 2017; Vaidyula and Hood 2018; and Rocha and Ellis 2020). The scope of NDCs also differ in terms of sectors and GHGs: some cover all sectors and all GHGs, some have more limited coverage and others are unclear and only include indicators, such as policies and measures.

The lack of a fixed emissions limit in many NDCs makes accounting complex. Some researchers have recommended the use of economy-wide absolute emission targets for all NDCs to facilitate robust accounting and reduce complexity

(Graichen, Cames and Schneider 2016; Schneider *et al.* 2019). Although this is not likely to happen anytime soon, parties could be requested to provide clearer and more transparent NDC targets as a potential short-term step. For this purpose, the Katowice Climate Package includes detailed provisions on how countries should describe or clarify the scope of their NCDs. However, some provisions of this package are only mandatory for second and subsequent NDCs or require countries to provide relevant information by 2024 (Schneider *et al.* 2020).

The treatment of mitigation outcomes generated outside the scope of NDCs is an important issue in negotiations. The main advantages of allowing emission reductions outside the scope of NDCs include the full utilization of mitigation potential, reduced mitigation costs, improved data quality of uncovered sectors and the facilitation of their inclusion into future NDCs (Spalding-Fecher 2017; Schneider *et al.* 2020). Disadvantages include disincentives to enhancing the scope of NDCs, a lack of fairness, scrutiny and quality assurance, and double-counting risks (Spalding-Fecher 2017; Howard 2018; Warnecke *et al.* 2018; Hood 2019; Michaelowa *et al.* 2019b; Schneider and La Hoz Theuer 2019; Schneider *et al.* 2020).

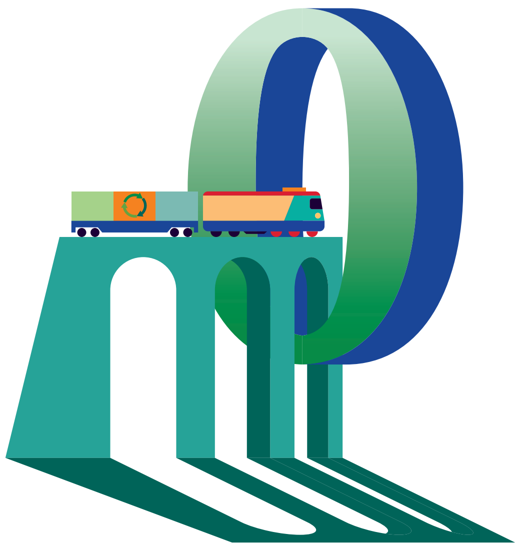
Many options have been raised to address the above cited concerns, such as applying corresponding adjustments regardless of NDC scope, bringing relevant sectors and GHGs into the scope of next NDCs, imposing international oversight on the quality of NDCs and restrictions on the number of and deadline for achieving internationally transferred mitigation outcomes, quantifying NDC targets in terms of GHG emissions and specifying the scope of NDCs (Marcu *et al.* 2017; Mizuno 2017; Spalding-Fecher 2017; Howard 2018; Greiner *et al.* 2019; Warnecke *et al.* 2018; Schneider and La Hoz Theuer 2019; Schneider *et al.* 2020). Care needs to be taken in framing such offset programmes so that macroscale outcomes deliver the intended aggregate emissions mitigation. Calvin *et al.* (2015) showed that well-intentioned offset programmes have the potential to inadvertently lower overall ambition.

Although some of the proposed options are ideal in theory, they may lack political feasibility. Many parties have been concerned by potential limitations on article 6 participation and threats to the bottom-up nature of NDCs.

7.4 The way forward

One possible outcome of COP26 is that initial article 6 rules will be agreed upon, with the intention that they be improved gradually over time and strengthened through other market arrangements. This has been the case for other parts of the Paris Agreement. The Clean Development Mechanism (CDM) could be a useful reference in this regard, as despite receiving many criticisms, it has played a crucial role in facilitating or enhancing many countries' mitigation efforts. In many developing countries, the capacities developed through participation in the CDM (e.g. to measure and verify emissions) have helped them prepare their initial NDCs. In some countries, such as China and the Republic of Korea, participation in the CDM provided valuable lessons and capacities for establishing domestic carbon markets.

Success of the Paris Agreement market arrangements will require the establishment of solid managerial, technical and institutional capacity. Parties participating in article 6.2 will need to jointly agree on a cooperative framework for emission reductions, decide how to establish domestic modalities and procedures to complete the authorization, quantification, monitoring, verification and reporting of internationally transferred mitigation outcomes and make corresponding adjustments after the transfer of these outcomes (World Bank 2021b). Participation in the article 6.4 mechanism will be more demanding for host parties than the CDM, as it will involve documenting transparent reductions, as well as showing additionality to their NDCs and supporting sustainable development.



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