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Understanding Countries' Net-Zero Emissions Targets

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Abstract

This paper analyses net-zero emissions targets adopted in law, proposed in legislation, or reflected in policy documents in 51 countries and the EU to better understand their characteristics, similarities and differences. It examines countries' experiences with translating net-zero targets into near-term plans and analyses four case studies to show how countries develop and implement different pathways to net-zero. This paper also explores the potential role and associated risks, both for individual countries and globally, of using international carbon markets to help achieve countries' net-zero targets. The paper concludes that countries are adopting diverse approaches to their net-zero targets and many details are currently unclear, including the balance between emission reductions, removals and the use of international carbon markets in reaching countries' net-zero targets, and how this may change over the next few decades. The paper concludes that greater clarity on the scope, coverage and detail, in particular how countries plan to meet their net-zero commitments, is important to improve understanding of countries' net-zero targets, how they interact with each other, and their overall implications for achieving the global temperature goal of the Paris Agreement.

JEL classifications: Q54, Q56, Q58, F53

Keywords: Climate change, Paris Agreement, net-zero, NDCs, LT-LEDS, carbon markets

Résumé

Le présent document analyse, afin d'en mieux comprendre les caractéristiques, les ressemblances et les différences, les objectifs de neutralité carbone que 51 pays et l'UE ont adoptés dans leur législation, se proposent d'adopter ou mentionnent dans leurs documents de politique générale. Il examine comment les pays ont entrepris de traduire ces objectifs en plans d'action à court terme et, à travers quatre études de cas, montre comment les pays se fixent différentes trajectoires vers la neutralité carbone et s'y engagent. Il étudie aussi le rôle possible et les risques associés, à l'échelon national comme à l'échelle internationale, du recours aux marchés internationaux du carbone pour aider à la réalisation des objectifs nationaux de neutralité carbone. Il conclut que les approches qu'adoptent les pays pour viser la neutralité carbone sont diverses, et qu'il reste de nombreux points à éclaircir, concernant notamment l'équilibre entre réduction des émissions, absorption du carbone et recours aux marchés internationaux du carbone, et la façon dont cet équilibre pourrait évoluer au cours des prochaines décennies. En conclusion finale, il note qu'il importe de clarifier la portée, le champ d'application et le détail des plans d'action, en particulier s'agissant de la façon dont les pays prévoient de respecter leurs engagements en matière de neutralité carbone, afin de mieux comprendre les objectifs nationaux de neutralité carbone, leurs interactions, et leurs conséquences globales sur la réalisation de l'objectif de limitation de la hausse de la température mondiale de l'Accord de Paris.

Classifications JEL: Q54, Q56, Q58, F53

Mots-Clés : changement climatique, Accord de Paris, neutralité carbone, CDN, LT-LEDS, marchés du carbone

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List of acronyms

AR	Afforestation/reforestation
BECCS	Bioenergy With Carbon Capture And Storage
CCS	Carbon Capture And Storage Technologies
CDM	Clean Development Mechanism
CDR	Carbon Dioxide Removal
DACCS	Direct Air Carbon Capture And Storage
ETS	Emission Trading System
ESR	Effort Sharing Regulation
EW	Enhanced Weathering
IPCC	Intergovernmental Panel on Climate Change
GHGs	Greenhouse gases
GWP	Global Warming Potential
LT-LEDS	Long Term Low Emission Development Strategy
LULUCF	Land use, Land-Use Change and Forestry
MRV	Monitoring, Reporting And Verification Systems
NBS	Nature-Based Solutions
NDCs	Nationally Determined Contributions
TRL	Technology Readiness Level
UNFCCC	United Nations Framework Convention on Climate Change

List of ISO country codes

AND	Andorra
ATG	Antigua and Barbuda
ARG	Argentina
AUT	Austria
BEL	Belgium
BGR	Bulgaria
BRA	Brazil
CPV	Cabo Verde
CAN	Canada
CHL	Chile
CHN	China (People's Republic of)
COL	Colombia
CRI	Costa Rica
HRV	Croatia
CYP	Cyprus
CZE	Czech Republic
DNK	Denmark
DOM	Dominican Republic
EST	Estonia
FJI	Fiji
FIN	Finland
FRA	France
DEU	Germany
GRC	Greece
GRD	Grenada
HUN	Hungary
ISL	Iceland
IDN	Indonesia
IRL	Ireland
ITA	Italy

JPN	Japan
KOR	Korea (Republic of)
LAO	Lao People's Democratic Republic
LVA	Latvia
LBR	Liberia
LTU	Lithuania
LUX	Luxembourg
MDV	Maldives
MLT	Malta
MHL	Marshall Islands
MCO	Monaco
NAM	Namibia
NPL	Nepal
NLD	Netherlands
NZL	New Zealand
PAN	Panama
PNG	Papua New Guinea
POL	Poland
PRT	Portugal
ROU	Romania
SYC	Seychelles
SGP	Singapore
SVK	Slovak Republic
SVN	Slovenia
SLB	Solomon Islands
ZAF	South Africa
ESP	Spain
LKA	Sri Lanka
SWE	Sweden
CHE	Switzerland
UKR	Ukraine
GBR	United Kingdom
USA	United States

Glossary

NB: The terms **bolded in blue** throughout the paper contain a definition in this glossary. To ease reading, terms are only **bolded in blue** when they appear for the first time in the main body of the paper.

Term	Definition
Carbon budget	Refers to different concepts and can be used at different geographical levels. At the global level, the term "global carbon budget" refers to an assessment of carbon cycle sources and sinks on a global level and the resulting change in the concentration of atmospheric CO_2. The term "total carbon budget" is used to refer to the maximum amount of cumulative net global anthropogenic CO_2 emissions, starting from the pre-industrial period, that would result in limiting global surface temperature to a given level with a given probability, taking into account the effect of other anthropogenic climate forcers. See also "Remaining carbon budget to net-zero" below. At the national or sub-national level, the term "carbon budget" refers to the setting of GHG emission caps for different sectors or sources for successive, pre-defined periods (i.e. 5 years) or an overall limit on GHGs to be emitted over a specified period (i.e. between 2020-2030) in order to reach a longer-term emission reduction target. .
Carbon dioxide capture and storage (CCS)	A process in which a relatively pure stream of carbon dioxide (CO_2) from industrial and energy-related sources is separated (captured), conditioned, compressed and transported to a storage location for long-term isolation from the atmosphere. Sometimes referred to as Carbon capture and storage.
Climate neutrality	Concept of a state in which human activities result in no net effect on the climate system. Achieving such a state would require balancing of residual emissions with emission (carbon dioxide) removal as well as accounting for regional or local bio geophysical effects of human activities that, for example, affect surface albedo or local climate.
Direct air carbon dioxide capture and storage (DACCS)	Chemical process by which CO_2 is captured directly from the ambient air, with subsequent storage. Also known as direct air capture and storage (DACS).
Negative emissions	Removal of greenhouse gases (GHGs) from the atmosphere by deliberate human activities, i.e., in addition to the removal that would occur via natural carbon cycle processes.
Net-negative greenhouse gas emissions	A situation of net negative emissions is achieved when, as result of human activities, more greenhouse gases are removed from the atmosphere than are emitted into it. Where multiple greenhouse gases are involved, the quantification of negative emissions depends on the climate metric chosen to compare emissions of different gases as well as the chosen time horizon.
Net-zero CO_2 emissions	Net-zero carbon dioxide (CO_2) emissions are achieved when anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period. Net-zero CO_2 emissions and carbon neutrality are overlapping concepts and can be applied at different levels.
Net-zero greenhouse gas emissions	Net zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period. Where multiple greenhouse gases are involved, the quantification of net zero emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential, and others), as well as the chosen time horizon. Net-zero GHG emissions and GHG neutrality are overlapping concepts and can be applied at different levels.
Remaining carbon budget to net-zero	Estimated cumulative net global anthropogenic CO_2 emissions from the start of a particular year to the time that anthropogenic CO_2 emissions reach net-zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions.

Sources: Authors, based on (IPCC, 2018) and (IPCC, 2021[1]).

Executive Summary

To reach the long-term temperature goal of the Paris Agreement, Parties aim to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (UNFCCC, 2016[2]). The case for reaching net-zero emissions was further supported by the subsequent 2018 Intergovernmental Panel on Climate Change (IPCC) Special Report (IPCC, 2018[3]) and reiterated in the 2021 Working Group I contribution to the IPCC's Sixth Assessment Report (IPCC, 2021[4]).

The last few years have seen a considerable increase in the number of net-zero targets put forward by countries and non-state actors. The momentum behind net-zero has continued despite the COVID-19 pandemic. At the same time, there remains a gap between net-zero commitments and actions being implemented in the near-term (see for example, (OECD, 2021[5]), (Buckle et al., 2020[6])); and a discrepancy between these long-term ambitions and countries' near-term plans (see for example, (UNFCCC, 2021[7]), (United Nations Environment Programme, 2020[8])).

There are a number of open questions, including what net-zero means, how net-zero targets by different actors relate to each other, and - crucially - what plans, policies, and transformations are needed to reach net-zero globally by around 2050. There are also different pathways to reaching net-zero with different associated risks and uncertainties, for example related to future technologies and land availability, as well as varying challenges and opportunities for different sectors and countries in reaching net-zero.

This paper explores countries' net-zero emissions targets that have been adopted in law, proposed in legislation, or reflected in national policy documents to better understand their characteristics, similarities and differences. As of 1 October 2021, these targets cover 51 countries and the EU. This paper examines experiences with translating net-zero targets into near-term plans and analyses four case studies to show how countries develop and implement different pathways to net-zero. This paper also explores the role of international carbon markets as a potential tool for reaching countries' net-zero targets, including the changing market dynamics for buyers and sellers, and the potential risks both for individual countries and globally.

This analysis finds that countries are adopting diverse approaches across key dimensions of their net-zero targets. Some of the main areas of distinction include:

- The legal status of net-zero targets, with 17 enshrined in law, 4 in proposed legislation, and 31 reflected in a national policy document, including NDCs and LT-LEDS.
- The terminology used (e.g. net-zero, climate neutrality, GHG neutrality, carbon neutrality) which in some cases is misleading (e.g. carbon neutrality used for a target that covers all GHGs) or confusing (e.g. different terms used interchangeably in the same document).
- In terms of coverage, most net-zero targets analysed cover all GHG emissions, certain targets exclude specific GHGs (e.g. biogenic methane in New Zealand) and in some cases there is ambiguity on the scope of GHG emissions covered (e.g. for certain carbon neutrality targets).

- In terms of sectoral scope, most targets analysed are economy-wide, however some targets exclude specific sectors (e.g. LULUCF in Sweden), and most targets exclude emissions from international aviation and shipping, with a few exceptions (e.g. UK).
- In terms of timeframe, most countries analysed aim to achieve net-zero by 2050, although some countries have earlier (e.g. Austria, Finland, Iceland, Maldives) or later (e.g. Brazil[1], People's Republic of China (hereafter 'China'), Indonesia) targets.
- Some countries have also adopted commitments post-net-zero, i.e. to maintain net-zero (e.g. New Zealand), or to achieve negative emissions (e.g. Finland, Iceland, EU, Germany, Sweden).
- There is currently limited detail available on countries preference or goal when it comes to emission reductions, removals and use of international carbon markets in meeting their net-zero targets. While a few countries specify shares or limits on emission reductions and/or emission removals in their net-zero target (e.g. Sweden, EU), there is limited detail provided in other cases.

When it comes to governance mechanisms and institutional arrangements around net-zero targets, this analysis finds that there are many similarities between countries. For example:

- A number of countries have set up regular reporting cycles for their net-zero targets, with some cycles linked to annual financial budget discussions (e.g. Denmark, Sweden) and some linked to processes under the Paris Agreement (e.g. EU, Fiji).
- Several countries have established independent expert bodies to provide advice on and/or evaluate progress towards their net-zero (and other climate) targets.
- Some countries have set up (high-level) committees or councils to provide guidance and/or to co-ordinate efforts to reach net-zero and support implementation (e.g. China, Japan, and the Republic of Korea (hereafter 'Korea')).
- In some countries, dedicated groups have also been set up to engage with different stakeholders, including business and youth, in designing implementation plans for their net-zero targets (e.g. Denmark, Luxembourg, and New Zealand).
- Some countries have established citizen climate assemblies to discuss and recommend specific climate policies (e.g. Denmark, France, Ireland, and the UK). Such governance mechanisms institutional arrangements and stakeholder engagement processes can help to enhance transparency and galvanise domestic support behind countries' net-zero targets.

While a diversity in approaches to net-zero targets is understandable given national circumstances and starting points, such differences make it difficult to compare countries' targets by merely looking at headline figures and descriptions. Greater clarity on the scope, coverage and detail of countries' net-zero targets, in particular how countries plan to meet their net-zero commitments, is important to better understand countries' net-zero targets, how they interact with each other, and their overall implications for reaching net-zero at the global level. Further analysis of the interplay between net-zero targets by countries and non-state actors could help to improve consistency and coherence across different targets, identify potential gaps and ensure the sum of these various parts adds up to a whole concerted effort in line with the global temperature goal of the Paris Agreement.

Many countries are now turning to the task of translating their net-zero targets into near-term policies and plans. Several countries analysed in this paper have established interim targets as milestones along their pathway to net-zero. Interim targets are usually set 5-10 years ahead and can be either economy-wide or sectoral. Of the countries analysed, at least 22 have plans to periodically review progress towards their net-zero target. NDCs could be a useful tool to periodically set or adjust interim targets along the pathway

[1] For the purposes of analysis in this paper, Brazil's timeline for reaching climate neutrality is considered to be 2060 as announcements suggesting Brazil will bring forward its target date to 2050 have not been clarified in a policy document as of 1 October 2021.

to net-zero. The second round of countries' NDCs show an improved alignment between net-zero commitments and mid-term targets, with the EU and 49 countries analysed in this paper mentioning their net-zero goal in their second NDC. Furthermore, 2030 or 2035 targets included in the mitigation component of countries' second NDCs are now usually aligned with interim targets set by the country for achieving their net-zero commitment, which represents an improvement compared to the first NDC cycle.

To support the implementation of long-term climate targets, including net-zero commitments, some countries have developed long-term low GHG emission development strategies (LT-LEDS). As of 1 October 2021, 32 countries and the EU have submitted a LT-LEDS to the UNFCCC secretariat. In some cases, these are complemented with specific sectoral plans and implementation roadmaps. While the process of planning and implementing net-zero targets varies by country, there are some emerging insights from experiences which could be useful to other countries. For example, the UK shows how establishing an independent expert body can be helpful in providing a scientific evidence base and advice to inform the setting of a net-zero target and feed into subsequent policy decisions. Experience in Costa Rica provides an example of how nesting different types of policies (i.e. national, sectoral and sub-sectoral; short- and long-term) can support implementation of net-zero commitments and how inclusive stakeholder engagement processes can help to build domestic support. The case of South Africa shows how a focus on social dialogue and consensus, with a strong emphasis on a just transition, could facilitate the adoption of a long-term strategy to net-zero and help to strengthen links between company and country net-zero targets. Finally, the case of Fiji provides insights for countries particularly vulnerable to climate change, for which a focus on adaptation is important as they move towards net-zero and the importance of aligning investment plans with implementation roadmaps.

Reaching net-zero emissions will likely entail a balance between different approaches and may also involve the use of international carbon markets, at least in the short term as a transitional measure on the pathway to net-zero. The majority of countries analysed in this paper do not specify if and how they intend to use international carbon markets to achieve their net-zero targets, while those that do take different approaches. France and Finland explicitly rule out the use of international carbon markets in their net-zero plans, Switzerland indicates its intention to use such markets as part of its net-zero plan, while. Sweden specifies an upper limit to the potential use of international carbon markets in reaching its net-zero target. Some countries are waiting for agreed rules on Article 6 to define their strategies. To improve understanding of the role of international carbon markets as a potential tool for reaching countries' net-zero targets, more countries could clarify their position on certain aspects such as whether they will participate as a seller and/or buyer country; over which timeframe; the level of crediting from international carbon markets to be used for reaching their net-zero target; and if purchased credits will be accounted towards their net-zero target or used in addition to domestic mitigation action.

International carbon markets could potentially help countries enhance the ambition of their climate commitments and achieve their net-zero targets with greater economic efficiency, complementing domestic emission reduction efforts while providing other sustainable development co-benefits. In particular, international carbon markets could be useful for countries that are not able to achieve net-zero emissions through domestic mitigation actions alone. However, given the deep decarbonisation needed to reach net-zero, if all countries rely heavily on international carbon markets to achieve their own net-zero target, this could put at risk the achievement of net-zero globally. It would thus be important for individual countries to carefully assess their use of international carbon markets as part of their net-zero implementation plans, and for any such use to be accompanied in parallel by rapid and deep domestic decarbonisation to reduce the absolute level of demand for international credits over time.

The scale of emission reductions and removals needed to reach net-zero globally is likely to alter the dynamics of international carbon markets. On the supply side, selling "low-hanging fruit" mitigation opportunities internationally (e.g. cheap emission reduction options) would raise the total cost for the seller country of meeting its national climate mitigation target. As such, it would be in the interest of seller countries to reserve cheaper mitigation options for domestic use and sell "high-hanging fruit" mitigation

opportunities (i.e. higher-cost abatement options from less deployed technologies with high mitigation potential, mitigation measures with high sustainable development co-benefits, demand-side measures with high mitigation potential). On the demand side, buyer countries could use international carbon markets not only as a means to reach their net-zero target, including in a less costly manner, but also as an opportunity to raise their own climate ambition.

There are opportunities and risks associated with using different types of carbon credits to reach countries' net-zero targets. Not all types of mitigation activities are equally suitable for issuing credits in international carbon markets in a net-zero context. For instance, crediting from emission avoidance activities (e.g. non-exploitation of fossil fuel reserves, avoided deforestation) may not be aligned with net-zero pathways as these activities are highly vulnerable to the risk of non-permanence of stored emissions (i.e. where emissions removed by an activity are later reversed and re-emitted in the atmosphere). Crediting from emission reduction activities (e.g. energy efficiency, Carbon Capture and Storage (CCS) installation on a fossil-fuel power plant) could over time gradually veer towards activities that imply an absolute GHG emission reduction and with storage, rather than activities which increase absolute GHG emissions at a slower rate than a counterfactual baseline. Removal credits from technology-based CDR approaches (e.g. Direct Air Carbon Capture and Storage (DACCS), Bioenergy With Carbon Capture And Storage (BECCS), Enhanced Weathering) could play an increasingly important role in the future on the pathway to net-zero, but their availability would be limited by global removal capacity, and domestic land and land-based storage site constraints. The literature is divided on the potential role of nature-based solutions (e.g. afforestation and reforestation activities) to generate removal credits in the pathway to net-zero as these activities have a high risk of non-permanence of stored emissions.

The discussion on net-zero has evolved rapidly in the last few years from a scientific concept to a central pillar of efforts to support the temperature goal of the Paris Agreement. The growing number of net-zero targets put forward by countries to date provide welcome signals of intent. However, as elaborated in this paper, countries' net-zero targets vary significantly in terms of their characteristics - which makes it difficult to compare countries' targets by merely looking at headline figures or descriptions. Moreover, many details are currently unclear, in particular the balance between emission reductions, removals and the use of international carbon markets in reaching countries' net-zero targets, and how this may change over the next few decades. The devil is in the details as the approach taken towards different dimensions of net-zero targets can lead to very different outcomes. Greater clarity on key dimensions of countries' net-zero targets, especially how countries plan to meet their commitments, is important to improve understanding of different net-zero targets, how they interact with each other, and their overall implications for achieving the global temperature goal. The moment of reckoning on net-zero is approaching as countries now turn to the more challenging task of translating their commitments into implementation. Concrete plans and actions taken over the next decade will be key to allow countries to get on track to net-zero.

1. Introduction

In the past few years, "net-zero" has been catapulted to a central pillar of efforts to support the long-term temperature goal of the Paris Agreement. The idea of achieving net-zero emissions was enshrined in Article 4.1 of the 2015 Paris Agreement (UNFCCC, 2016[2]). The rationale for reaching net-zero emissions was further supported by the subsequent 2018 Intergovernmental Panel on Climate Change (IPCC) Special Report (IPCC, 2018[3]) and is reiterated in the 2021 Working Group I contribution to the IPCC's Sixth Assessment Report (IPCC, 2021[4]). Net-zero targets have been adopted by a number of countries, including some advanced economies, emerging and developing countries, and regional groups, such as the European Union (EU). These efforts are supported by various international initiatives, such as the Climate Ambition Alliance (GCAP UNFCCC, n.d.[9]), and high-level commitments (see for example, (Group of Seven, 2021[10])). Countries are not alone in this endeavour, with a number of non-state actors putting forward their own net-zero commitments (UNFCCC, 2020[11]). The momentum behind net-zero has continued despite the COVID-19 pandemic.

At the same time, there is a growing gap between the various net-zero commitments put forward and concrete actions being implemented in the near-term (see for example, (OECD, 2021[5]) and (Buckle et al., 2020[6])). Moreover, even if all announced national net-zero pledges as of May 2021 are fully realised, global energy-related CO_2 emissions would still be around 22 gigatonnes (Gt) in 2050, and extending this trajectory would lead to a global average temperature rise of around 2.1°C by 2100, with a 50 per cent probability (IEA, 2021[12]). There are several open questions surrounding the concept of net-zero. This includes for example, what net-zero means, how different net-zero targets relate to each other, and what plans, policies, and sectoral transformations are needed to reach net-zero globally. Moreover, there are a number of assumptions, potential risks and uncertainties underlying net-zero commitments related to future technologies and land availability, as well as potential implications for equity and fairness (see for example, (La Hoz Theuer et al., 2021[13])).

The various net-zero commitments put forward to date provide welcome signals of intent. However, as currently formulated, net-zero targets vary significantly in their characteristics and there is limited detail available on the concrete pathway to reach these ambitions. The approach adopted by countries to their net-zero targets, for example the terminology used, greenhouse gases (GHGs) and sectors covered, timeframe, balance between emission reductions, removals, and use of international carbon markets to reach the country target, could lead to different outcomes and timelines for reaching net-zero globally. The devil is in the details, and without careful attention to such details, individual net-zero targets risk being too weak to achieve the global goal (Rogelj et al., 2021[14]).

This paper aims to unpack countries'[2] net-zero emissions targets[3] to better understand their characteristics, similarities and differences, and countries' experiences with translating net-zero targets into near-term plans. This paper focuses on net-zero targets in 51 countries and the EU that have been

[2] In this paper, the term "countries" is used to include regional economic organisations (e.g. the EU) when applicable.
[3] In this paper, the term "net-zero emissions targets" is used to refer to net-zero (GHG) emissions targets, climate neutrality targets and carbon neutrality targets.

adopted in law, proposed in legislation, or reflected in policy documents[4] as of 1 October 2021. This paper also explores the potential role, and associated risks, both for individual countries and globally, of using international carbon markets to help achieve countries' net-zero targets. It draws on available literature, country experiences, and insights; it does not undertake quantitative scenario analysis, but builds on relevant work by the OECD, IEA, and other organisations.

This paper is structured as follows. Section 2. provides a brief background and context, setting out some issues to keep in mind when discussing net-zero targets from the perspective of countries. Section 3. unpacks countries' net-zero targets across key dimensions and explores the extent to which net-zero targets are reflected in short and mid-term policy planning. Section 4. sets out insights from four country cases of planning and implementing net-zero targets. Section 5. explores the role, changes in dynamics and potential risks of using international carbon markets in net-zero emissions plans. Finally, Section 6. provides a synthesis of key findings and conclusions based on the analysis in this paper.

[4] This paper does not include countries' net-zero targets in political pledges or currently under discussion. For this reason, this analysis may differ from other assessments of net-zero targets which adopt a different approach (for example, see (Black et al., 2021[33]), (Climate Action 100+, 2021[169]), (World Resources Institute, 2020[46])).

2. Context and background

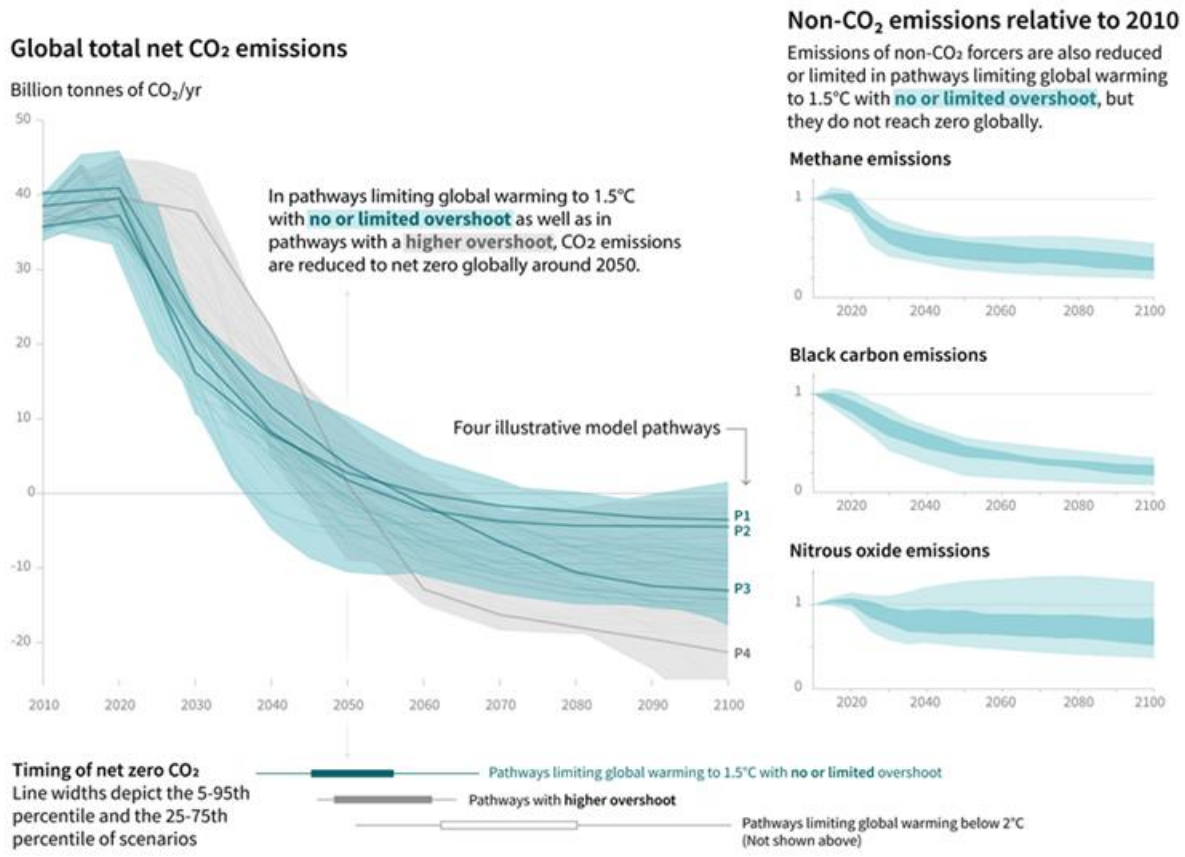
2.1. A brief rationale for net-zero and net-negative emissions

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) set an ultimate objective to achieve a "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC, 1992[15]). However, the 2021 Working Group I contribution to the Sixth Assessment Report of the IPCC indicates that human activities have unequivocally caused a continued increase in GHG concentrations in the atmosphere, with rapid and widespread changes across the climate system already affecting many weather and climate extremes in all regions across the globe (IPCC, 2021[4]).

The 2015 Paris Agreement set a goal of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognising that this would significantly reduce the risks and impacts of climate change" (UNFCCC, 2016[2]). Limiting global warming to 1.5°C is projected to lead to lower impacts and reduced climate-related risks compared to global warming of 2°C (IPCC, 2018[3]). However, the Working Group I contribution to the IPCC's Sixth Assessment Report finds that global warming will exceed 1.5°C and 2°C during the 21st century, unless deep and sustained reductions in CO_2 and other GHG emissions take place in the coming decades (IPCC, 2021[4]).

In the 2018 IPCC Special Report, modelled pathways that limit global warming to 1.5°C with no or limited overshoot see global net anthropogenic CO_2 emissions decline by about 45% from 2010 levels by 2030 (40–60% interquartile range) and reach **net-zero CO_2 emissions** by around 2050, with parallel reductions in non-CO_2 emissions – see Figure 2.1. **Net-zero GHG emissions** would only be reached around 2061–84 depending on the pathway (IPCC, 2018[3]). On a similar note, the first output of the Sixth IPCC Assessment Report notes that in scenarios that start in 2015 and have very low and low GHG emissions, limiting global warming to between 1°C to 2.4°C by 2100 requires CO_2 emissions to decline to net-zero around or after 2050, followed by varying levels of net-negative CO_2 emissions, alongside deep reductions in other GHG emissions, in particular methane emissions (IPCC, 2021[4]).

Figure 2.1. Global emissions pathways to limit global warming to 1.5C

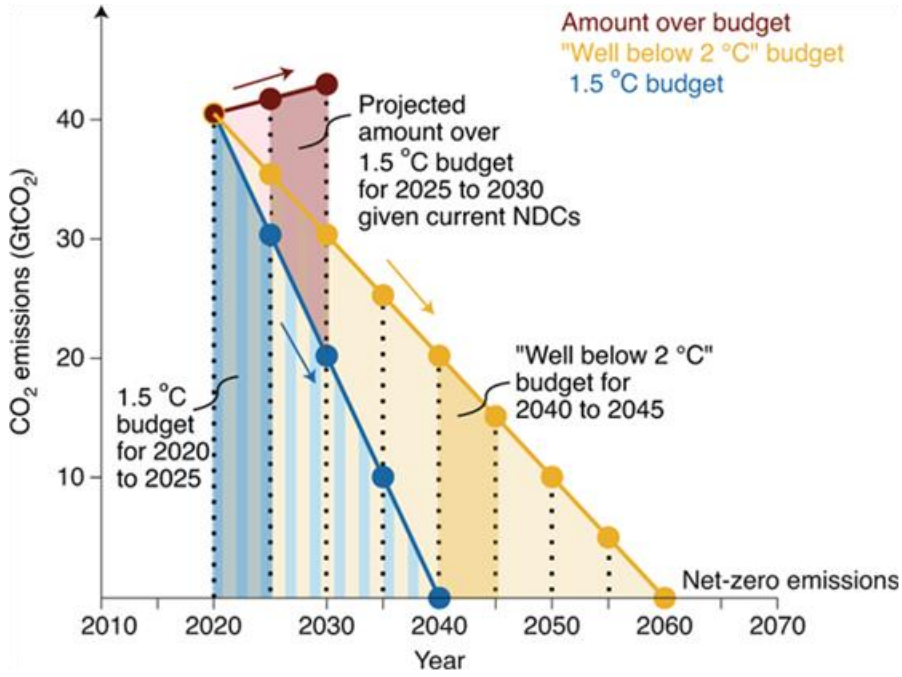


Note: The figure on the left shows global net anthropogenic CO_2 emissions in four illustrative pathways modelled by the IPCC (in the 2018 Special Report) that limit global warming to 1.5°C with no or limited overshoot and pathways with higher overshoot. P1 corresponds to the LED scenario (with particularly low energy demand), P2 to S1 (sustainability oriented scenario), P3 to S2 (middle-of-the-road scenario) and P4 to S5 (fossil-fuel intensive).
The figures on the right show the ranges of pathways for three compounds of non-CO_2 emissions. Shaded areas show the 5–95% (light shading) and interquartile (dark shading) ranges of pathways limiting global warming to 1.5°C with no or limited overshoot.
The box-whiskers at the bottom of the figure show the timing of pathways reaching global net-zero CO_2 emissions, and a comparison with pathways limiting global warming to 2°C with at least 66% probability.
Source: IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018[3]).

The 2021 Working Group I contribution to the IPCC's Sixth Assessment Report notes that "reaching net zero anthropogenic CO_2 emissions is a requirement to stabilize human-induced global temperature increase at any level, but that limiting global temperature increase to a specific level would imply limiting cumulative CO_2 emissions to within a **carbon budget**" (IPCC, 2021[4]). The 2018 IPCC Special Report estimates a **remaining carbon budget** of 420 $GtCO_2$ from 2018 onwards for a 66% chance of limiting global warming to 1.5°C. Staying within this budget implies reaching global carbon neutrality around 2040 (IPCC, 2018[3]). The 2021 Working Group I contribution to the IPCC's Sixth Assessment Report estimates a remaining carbon budget of 400 $GtCO_2$ from 2020 onwards for a 67% chance of limiting warming to 1.5°C, which can vary by 220 $GtCO_2$ or more depending on reductions in non-CO_2 emissions (IPCC, 2021[4]).

The remaining budget could be sliced/distributed in different ways by different actors including countries, corporates, investors and other non-state actors. An illustrative example of distributing the remaining carbon budget to reach net-zero CO_2 emissions by 2040 (consistent with 1.5°C warming) or by 2060 (consistent with "well below 2°C" warming) in contrast to emission projections from the first round of countries' NDCs is set out in Figure 2.2. Analysis by UNEP concludes that the first round of NDCs "fully deplete the carbon budget consistent with limiting warming to 1.5°C and strongly reduce the remaining budgets for limiting warming to well below 2°C, without making any progress towards bringing global CO_2 emissions closer to net zero" (United Nations Environment Programme, 2020[8]). Analysis by the UNFCCC concludes that based on NDCs submitted as of 30 July 2021, cumulative CO_2 emissions in 2020–2030 would likely use up 89 per cent of the remaining carbon budget consistent with a 50 per cent likelihood of limiting global warming to 1.5°C. This leaves a carbon budget after 2030 of around 55 Gt CO_2 which is equivalent to the average annual CO_2 emissions in the 2020–2030 period (UNFCCC, 2021[16]).

Figure 2.2. Illustrative example of distributing the remaining carbon budget to reach net-zero CO_2 emissions by 2040 or by 2060



Note: Years of net-zero CO_2 emissions in the figure are approximately consistent with estimates of the 67th percentile remaining carbon budgets from the 2018 IPCC Special Report (420 $GtCO_2$; area under blue line) and for an illustrative "well below 2°C" (800 $GtCO_2$; area under yellow line). The red shaded area indicates projected amounts over near-term carbon budgets based on the first round of NDCs.
Source: (Matthews et al., 2020[17]).

Moreover, while most current efforts focus on reaching net-zero emissions around mid-century, this is not an endpoint in itself, but rather a milestone to achieving **net-negative emissions** in the longer term (Rogelj et al., 2021[14]). This requires a long-term vision that looks at emissions trajectories once net-zero emissions are reached, for example to maintain net-zero or achieve net-negative emissions. Even if net-zero CO_2 emissions are reached around 2050, keeping temperatures below 1.5°C will depend on whether or not the geophysical response is towards the lower end of the uncertainty range currently estimated. On a longer timeframe, "sustained net negative global anthropogenic CO_2 emissions and/ or further reductions in non-CO_2 radiative forcing may still be required to prevent further warming due to Earth system feedbacks" (IPCC, 2018[3]).

2.2. What is net-zero?

There are currently different understandings of what net-zero is with nuances in the terminology used by different actors. In some cases, specific terms such as net-zero (GHG) emissions or carbon neutrality, are used to distinguish between different targets (e.g. in terms of the coverage of GHGs). In other cases, terms are used interchangeably and may lead to some confusion and lack of clarity (e.g. **climate neutrality** vs. carbon neutrality). Differences in terminology reflect different interpretations of the concept of net-zero and need to be kept in mind in a comparative analysis of net-zero targets. Some key terms relating to net-zero are provided in Box 2.1.

Box 2.1. Net-zero terminology

Net-zero greenhouse gas emissions is used when "anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period" (IPCC, 2018[3]). The quantification of net-zero emissions depends on the climate metric[1] chosen to compare emissions of different GHGs (i.e. global warming potential (GWP), global temperature change potential, etc.) and the time horizon (IPCC, 2018[3]). At a global scale, the terms net-zero GHG emissions and GHG neutrality are equivalent. However, at the regional, national and sub-national level, net-zero GHG emissions is usually applied to emissions and removals under direct responsibility of the reporting entity, while GHG neutrality usually includes anthropogenic emissions and anthropogenic removals within and beyond direct responsibility of the reporting entity (IPCC, 2021[1]).

Net-zero carbon dioxide (CO_2) emissions is used when "anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period" (IPCC, 2018[3]). Net-zero CO_2 emissions is also sometimes referred to as carbon neutrality and at a global scale, the two terms are equivalent. However, at regional, national and sub-national level, the term net-zero CO_2 emissions is generally applied to emissions and removals under direct responsibility of the reporting entity, whereas the term carbon neutrality generally includes emissions and removals within and beyond direct responsibility of the reporting entity (IPCC, 2021[1]).

Carbon neutrality refers to a condition where "anthropogenic CO_2 emissions associated with a subject are balanced by anthropogenic CO_2 removals. The subject can be an entity such as a country, an organisation, a district or a commodity, or an activity such as a service and an event. Carbon neutrality is often assessed over the life cycle including indirect ("scope 3") emissions, but can also be limited to the emissions and removals, over a specified period, for which the subject has direct control" (IPCC, 2021[1]).

Climate neutrality refers to a "state in which human activities result in no net effect on the climate system" which requires balancing residual emissions with emission removal and accounting for regional or local bio geophysical effects of human activities that affect local climate (IPCC, 2018[3]). Although climate neutrality is sometimes used interchangeably with the term net-zero emissions, there is a subtle difference between the terms. Net-zero emissions refers to balancing anthropogenic GHG emissions released into the atmosphere with removals of these emissions over a specified period whereas climate neutrality refers to the balancing of *residual* emissions with removals and takes into account wider bio-geophysical effects of human activities on the climate system overall (IPCC, 2018[3]).

Net-zero greenhouse gas emissions at the country level could be used to describe a situation where GHG emissions released to the atmosphere in the target year (minus the mitigation outcomes acquired from other countries) do not exceed the GHG emissions removed from the atmosphere by sinks within the country's territory in the target year (minus the mitigation outcomes transferred to other countries) [2] (Adapted from (Levin et al., 2020[18])).

Net-negative greenhouse gas emissions refers to a situation when "metric-weighted anthropogenic greenhouse gas (GHG) removals exceed metric-weighted anthropogenic GHG emissions". (IPCC, 2021[1]). Where multiple GHG are involved, the quantification of net emissions depends on the chosen metric to compare emissions of different gases and the time horizon.

[1] Defining net-zero targets using metrics other than the widely used GWP100 could shift the mitigation burden between different GHGs and thus between sectors and countries (Rogelj et al., 2021[14]). However, calculating the GWP of GHGs is not easy and there are some controversies in the academic literature (see for example (Allen et al., 2016[19]).

[2] This definition excludes GHG emissions from international air travel and shipping. These sectors are generally excluded from the scope of countries' net-zero targets with a few exceptions (e.g. the UK). However, emissions from international shipping and aviation will also need to be decarbonized by around 2050 in global CO_2 emission reduction pathways to limit global warming to 1.5°C (United Nations Environment Programme, 2020[8]).

Note: This paper uses the definition proposed by (Honegger, Burns and Morrow, 2021[20]), whereby "climate change mitigation" encompasses both concepts of emission reduction and emission removal.
Sources: (IPCC, 2018[3]); (IPCC, 2021[1]); (Allen et al., 2016[19]); (Rogelj et al., 2021[14]); (Levin et al., 2020[18]).

Countries adopt different terms in their net-zero commitments. Some countries refer to reaching net-zero emissions, others refer to climate neutrality or GHG neutrality. Some countries define their net-zero target in terms of carbon neutrality and there is some ambiguity and uncertainty on whether these targets refer to CO_2 only or if they encompass all GHG emissions. Table 2.1 provides an overview of different terminology used by selected countries in setting their net-zero commitments in law, proposed legislation or national policy documents. In some cases, net-zero terminology used can be misleading (e.g., "neutralité carbone" in French is sometimes used to refer to carbon neutrality and sometimes used to refer to net-zero GHG emissions) or used interchangeably (e.g. in the same policy document or in different policy documents).

Table 2.1. Net-zero terminology used in selected countries

Term used	Country
Net-zero (GHG) emissions	ATG, CAN, CPV, CRI, IDN, LAO, MHL, NAM, JPN, NPL, NZL, SYC, SGP, SLB, SWE, CHE, GBR, USA
Climate neutrality	AND, AUT, BRA, DNK, EU, HUN, IRL, ITA, LAT, LUX, SVK, ESP, UKR
GHG neutrality	CHL, DEU, DOM
Carbon neutrality	ARG, CHN*, COL, FIN, FRA, ISL, LBR, MCO, PAN, PNG, PRT, KOR, SVN, LKA
Net-zero carbon/CO2 emissions	FJI, GRD, MDV, ZAF

Note: Net-zero terminology in table is based on countries' legislative documents, legislative proposals or policy documents setting their net-zero commitment. For documents not available in English, the categorisation is based on an unofficial translation and interpretation by the authors.
* For China, policy documents refer to net-zero CO_2 emissions, however public announcements in July 2021 suggest the target could also cover other GHGs. As this has not been integrated in a policy document as of 1 October 2021, for the purposes of analysis in this paper, China's commitment is considered to cover CO_2 emissions.
Source: Authors.

This paper takes the following approaches:

- The term "net-zero emissions" is understood to cover all anthropogenic GHG emissions covered by the UNFCCC, unless otherwise specified in relevant country documents.
- "Net-zero emissions" targets are distinguished from "net-zero CO_2 emissions/carbon neutrality" targets which are understood to cover CO_2 emissions alone, unless otherwise specified in country documents.
- In some cases, countries use the term carbon neutrality to define their target (e.g. France), but national documents[5] specify this covers all GHG emissions and such cases are understood to cover net-zero GHG emissions in this paper.

[5] For example, in France, the 2019 Law on Energy and Climate uses the term "neutralité carbone" which in the document is understood as a balance between GHG emissions and removals (Government of France, 2019[43]).

2.3. Net-zero emissions and the Paris Agreement

The idea of reaching net-zero emissions was integrated in the final text of the Paris Agreement in Article 4.1 which states that "Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (UNFCCC, 2016[2]). The inclusion of this concept in the Paris Agreement, further supported by the subsequent 2018 IPCC Special Report and reiterated in the 2021 Working Group I contribution to the IPCC's Sixth Assessment Report, could be seen to provide a common foundation for the cascade of net-zero commitments put forward by countries and non-state actors in recent years.

In addition to supporting the long-term temperature goal of the Paris Agreement, net-zero emissions targets have links to and implications for other goals under Article 2 of the Paris Agreement. The adverse impacts of climate change could affect the ability to reach net-zero emissions, for example, through effects on the capacity/effectiveness of natural or technological solutions to reduce or remove emissions (see Box 2.2). These potential effects highlight the importance of considering climate resilience considerations in efforts to achieve net-zero emissions. Aligning finance flows with a net-zero emissions pathway will be critical for translating long-term mitigation commitments into concrete actions in the near- to medium-term. At a domestic level, net-zero emissions targets could also support country processes under the Paris Agreement, including for example the formulation and implementation of NDCs and LT-LEDS.

2.4. Potential issues and open questions relating to net-zero targets

Questions and issues relating to net zero targets vary depending on the perspective taken. This section discusses several of these from both a global and national perspective. At a global level, key questions concern how individual targets relate to reaching a global net-zero target, the timing of net-zero in different jurisdictions, as well as how to assess the overall impact of national and corporate targets with different accounting methods. Another key issue at the global level relates to uncertainties regarding how to balance emission reductions with emission removals. At the national level, key questions include among others how to translate net-zero targets into near-term plans and policies, and the interplay between national and sub-national efforts to reach net-zero emissions.

2.4.1. At the global level

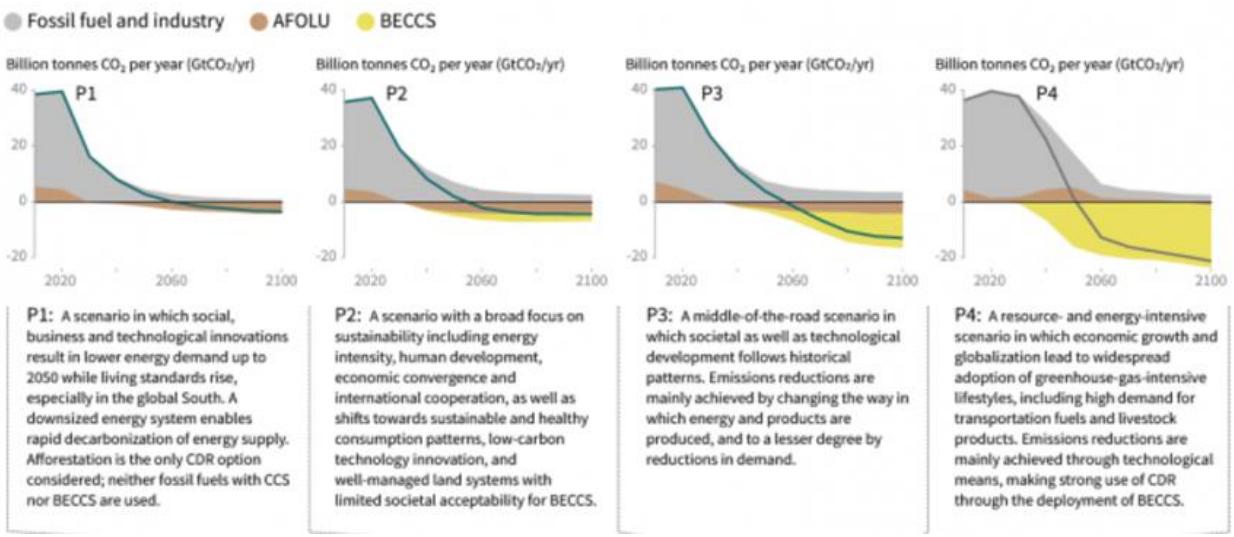
One potential issue concerns the **overall timeframe of achieving net-zero emissions** and differences between countries and across different sectors. Indeed, to reach global net-zero emissions, any net-positive emissions from one country will need to be balanced out by net-negative emissions in another country. Differences in timing in achieving net-zero reflect differences in the potential of different sectors as GHG emission sources/sinks, as well as the different opportunities of countries to contribute to reaching net-zero emissions. However, as noted by (Rogelj et al., 2021[14]) "emissions targets are a zero-sum game. If one country or company does less, others have to do more to achieve the same global temperature outcome", i.e. reducing emissions at a faster rate and eventually turning net-negative. In the IEA's 2050 Roadmap for the Global Energy Sector, advanced economies reach net-zero before emerging markets and developing economies, with emissions falling most rapidly in the power sector to reach net-zero before other sectors (IEA, 2021[12]). These different timeframes for reaching net-zero reflect different opportunities and challenges between sectors and countries.

The **interplay between different net-zero targets** by countries and non-state actors is another key issue. There has been limited effort to date to assess how the various net-zero targets adopted by countries and non-state actors relate to each other and potential issues relating to the different approaches adopted (e.g.

in terms of definitions, scope, coverage, etc.) by different actors. One particular issue concerns differences in accounting of emissions in national net-zero targets and in net-zero targets by non-state actors where there remain several open questions. For example, how do countries' net-zero targets (based on a national GHG inventory perspective) relate to net-zero targets by corporates (which widely use the Corporate GHG Protocol to account for their emissions)? What are the potential risks/uncertainties involved in these different approaches? (see for example (CPLC, 2021[21])). How do countries' net-zero targets take into account GHGs embodied in demand/consumption in a globalised economy? Further analysis of how individual net-zero targets interact with each other could help to improve consistency and coherence across different targets, identify potential gaps, and ensure the sum of these various parts adds up to a whole concerted effort in line with the global temperature goal.

Another key issue concerns the balance between emission reductions and removals and reliance on carbon dioxide removal (CDR) approaches such as bioenergy with carbon dioxide capture and storage (BECCS), direct air capture (DAC), afforestation/reforestation, and emerging approaches involving enhanced natural processes – see Box 2.2. As illustrated in Figure 2.3 delaying near-term emission reductions requires greater reliance on different CDR approaches - each of which has different potentials, risks, costs, co-benefits and trade-offs (IPCC, 2018[3]) as well as potential challenges related to food security, competing uses of land among others. The 2021 Working Group I contribution to the IPCC's Sixth Assessment Report notes that "CDR methods can have potentially wide-ranging effects on biogeochemical cycles and climate, which can either weaken or strengthen the potential of these methods to remove CO2 and reduce warming, and can also influence water availability and quality, food production and biodiversity" (IPCC, 2021[4]). Pushing mitigation action to the future also increases the need for removals to occur at greater scales, which could entail higher economic and social costs, lead to an intergenerational transfer of risks (Carton, Lund and Dooley, 2021[22]), has implications for intergenerational justice (see for example (Federal Constitutional Court of Germany, 2021[23])) and also increases the risks associated with unmitigated climate change (see for example (OECD, 2021[24]); (Honegger, 2020[25]). These risks and uncertainties need to be carefully planned and managed, for example through nationally appropriate CDR approaches (see for example (Honegger et al., 2021[26])).

Figure 2.3. Potential mitigation approaches in four model pathways to reach 1.5°C



Note: Characteristics of four illustrative model pathways to limit global warming to 1.5°C with no or limited overshoot in the 2018 IPCC Special Report
Source: (IPCC, 2018[3]).

Box 2.2. Potential role and constraints of carbon dioxide removal technologies for net-zero targets

CDR refers to capturing CO_2 from the atmosphere, directly or indirectly, and permanently storing it. In the 2018 IPCC Special Report, all pathways that limit global warming to 1.5°C with limited or no overshoot project the use of CDR in the order of 100–1000 $GtCO_2$ by 2100 (see Figure 2.3 and (IPCC, 2018[3])).

CDR approaches and technologies can play an important role in balancing out emissions in hard-to-abate sectors where direct mitigation may be extremely costly or technically difficult. In the long-term, CDR could also support net-negative emissions, which may be needed if near-term mitigation efforts are insufficient to keep future global temperature increases within targeted ranges.

CDR approaches can be based on technology or nature, or can involve enhanced natural processes:

- Technology-based CDR options include bioenergy with CCS (BECCS), which involves the capture and permanent storage of CO_2 from processes where biomass is converted to energy, and direct air capture (DAC) which involves the direct capture of CO_2 from the atmosphere using liquid solvents or solid sorbents.
- Nature-based solutions include afforestation/reforestation (AR) that repurposes land-use by growing forests (or any form of biomass) where there was none before or re-establishes a forest where there was one in the past.
- Emerging approaches involving enhanced natural processes include enhanced weathering (which artificially accelerate the natural process whereby acid rain dissolves minerals which then react with CO_2 to form carbonates), land-based approaches (such as biochar) and ocean-based approaches (such as ocean fertilisation or alkalinisation). Many of these approaches are in the research and development (R&D) phase and further studies are needed to understand their costs, risks and trade-offs.

Thirteen BECCS plants and fifteen DAC plants are in operation worldwide (IEA, 2020[27]), capturing around 2.6 $MtCO_2$/year, however many more plants are needed to reach net-zero targets. As noted in the 2018 IPCC Special Report, "CDR deployment of several hundreds of $GtCO_2$ is subject to multiple feasibility and sustainability constraints" (IPCC, 2018[3]). The role and potential of CDR approaches need to be assessed in the context of their carbon, land, water and resources footprint, the potential scale, feasibility and social acceptability of CDR deployment, technology readiness level (TRL), impact on the biosphere, cost and performance.

Another key consideration relates to the permanence of CO_2 removal from CDR approaches. Nature-based solutions and enhanced natural processes can be vulnerable to climate-related risks, fires, pests, diseases and forestry policy changes which could lead to reversals in CO_2 storage in the future. Well-managed geological storage sites will retain captured CO_2 for centuries and can be monitored for a period to verify permanent storage. However, these approaches are associated with higher costs than many nature-based solutions.

Critically, the availability of CDR options do not have to be considered as an alternative to cutting emissions today or as a reason for delayed mitigation action, but rather part of the portfolio of solutions to accelerate the pathway to net-zero (Budinis, 2020[28]).

Source: Box drafted by Sara Budinis (IEA).

2.4.2. At the national level

Achieving the pathways modelled in the 2018 IPCC Special Report to limit global warming to 1.5°C with no or limited overshoot would require far-reaching transitions across different sectors/systems and reliance on a wide portfolio of mitigation measures and approaches – see Box 2.3.

Box 2.3. Identifying transformational policies for net-zero systems by design

There are numerous types of pathways towards net-zero systems, and these depend, largely, upon policy prioritisation. The IPCC shows that pathways transforming systems so that these reduce energy and materials demand, can increase the chances of achieving stringent mitigation targets (IPCC, 2018[3]). Identifying which policies can lead to transformational pathways is fundamental. Policies that focus on redesigning systems can lead to such transformational pathways, while also improving wider well-being goals (Buckle et al., 2020[6]), (OECD Forthcoming, n.d.[29]).

The OECD's Well-Being Lens (OECD, 2021[30]) can support countries in identifying and prioritising policies that can lead to transformational pathways. The process has three steps: i) envision the outcomes a well-functioning system achieves; ii) understand why the functioning of the current system is not achieving such outcomes and how the system could be reorganised to lead to better results by design; and iii) identify actions and policies with the potential to change the systems' functioning towards a better one.

Applying the Well-Being Lens to different sectors can help identify policies that can lead to the transformational pathways needed to meet net-zero targets. For example, in the surface transport sector, policies with the potential to accelerate the transition towards net-zero transport systems by design include: the redesign of streets and improved management of public space; spatial planning aimed at increasing proximity; strengthening multi-modal and sustainable transport networks; changes in governance and monitoring frameworks, as well as innovations in systems and technologies.

Sources: Box drafted by Aimée Aguilar Jaber and Mariana Mirabile (OECD).

Beyond the initial step of setting a net-zero target, there is a **need for more clarity on how countries are planning to reach net-zero in practice.** Long-term goals need to be underpinned by interim targets for emission reductions and concrete implementation roadmaps to achieve stated ambitions (Rogelj et al., 2021[31]; Falduto and Rocha, 2020[32]). This includes for example setting interim milestones, aligning short- and medium-term plans, implementing policy measures to get on track, and adopting regular reporting and review mechanisms to assess progress and stay on track (Black et al., 2021[33]). There is also a need for further clarity on the approach to net-zero, including the balance between emission reduction, removals and use of international carbon markets to reaching net-zero, including understanding the potential role and constraints of CDR for achieving net-zero (see for example (Honegger et al., 2021[34])). See section 3.6 for further discussion on these issues and some insights from experiences in translating net-zero targets into near-term policies and planning.

In addition to national net-zero targets, a number of authorities at the sub-national level (municipalities, local governments) have also adopted net-zero commitments. In some cases, there is a close **interplay between national and sub-national efforts** with national governments focusing on sub-national action to support implementation of national net-zero commitments. For example in Japan, where over 250 local governments have committed to net-zero emissions by 2050, the national Government is supporting measures to expand the use of renewable energy at the regional level and has set up a Council for National and Local Decarbonisation to develop a 2050 decarbonisation roadmap ((Government of Japan, 2021[35]), (Grantham Research Institute on Climate Change and the Environment, 2021[36]). In Korea, cooperation between central and local governments is being enhanced for example with the preparation of a regional implementation system, expansion of regional GHG statistics and carbon neutrality support centres and a system of mutual cooperation through the Carbon Neutral Local Government Coalition for Practice (Government of the Republic Korea, 2021[37]). Similarly in Finland, proposed legislation aims to increase the involvement of municipalities in implementation of the carbon neutrality target given the impact of municipal decisions on climate change issues (Government of Finland, 2021[38]).

Some countries have **national and sub-national net-zero targets which complement/reinforce each other**. For example in the UK, devolved Administrations in Scotland and Wales have their own statutory emission reduction targets for 2050 which support the UK-wide net-zero emissions target (Government of the United Kingdom, 2020[39]). These sub-national targets were set following the advice of the UK Climate Change Committee (CCC) and "represent approximately equal effort in emissions reductions as in the UK as a whole and only differ from the UK wide target due to the differing opportunities and challenges for reducing emissions in the different nations" (Climate Change Committee, 2020[40]). There are also efforts in some countries to enhance dialogue between national and local authorities, including cities, to support a common net-zero goal (see Box 2.4).

Box 2.4. The case of Paris: Linking national and sub-national efforts towards net-zero

Cities are amongst the best-placed actors to contribute to the global transition to net-zero emissions given the close relationships between local administrations, institutions, residents, and businesses. Since 2018, momentum towards net-zero targets has grown considerably across cities and sub-national governments. As of 2020, 826 cities worldwide have put forward some form of net-zero target (NewClimate Institute & Data-Driven EnviroLab, 2020[41]).

In 2018, the City of Paris adopted a Climate Action Plan that sets two 2050 targets of attaining net-zero GHG emissions[1] and ensuring 100% of energy consumption in the City is derived from renewable energy (City of Paris, 2018[42]). These two long-term targets are broken down into more than 500 concrete measures and organised around interim milestones to 2020 and 2030.

The national regulatory and policy framework for climate action provides the broader framework within which cities and local governments take steps to implement net-zero aligned measures. In 2019, the French Government adopted a target to reach carbon neutrality by 2050 (Government of France, 2019[43]). The target is supported by the 2020 National Low-carbon Strategy (Stratégie nationale bas-carbone), which was also submitted to the UNFCCC as a LT-LEDS (Government of France, 2020[44]), and results from extensive consultations with, among others, local authorities.

While the Paris Climate Action Plan and the National Low-carbon Strategy do not directly reference each other, the need to ensure a link between different territorial scales is mentioned in both documents. The Paris Climate Action Plan recognises the need to coordinate with the national Government in key areas, e.g. to develop new regulatory standards for energy efficiency. The National Low-carbon Strategy recognises that the majority of its plans require active involvement of the territories and the national Government foresees the development of governance arrangements to facilitate implementation of the net-zero objective in territories (Government of France, 2020[45]). The national Government also plans to standardise data and methodologies to enable the regular production of comparable territorial data which could help compare local trajectories with the national trajectory (Government of France, 2020[45]). Enhanced dialogue between national and local authorities is currently enabled by the National Council for Ecological Transition. Such efforts can help enhance synergies between different levels towards the common goal of net-zero.

[1] The Climate Action Plan commits the City of Paris to achieving carbon neutrality which the document states "consists of attaining zero net greenhouse gas (or zero net carbon) emissions" (City of Paris, 2018[42]). For the purpose of this paper, this target is assumed to mean net-zero GHG emissions.

3. Understanding the landscape of countries' net-zero targets

This section unpacks countries' net-zero targets to identify some of the main similarities and differences across five key dimensions: (i) target status and distribution; (ii) timeframe; (iii) scope and coverage of GHG emissions and sectors; (iv) use of emission reductions, emission removals, and international carbon markets to reach net-zero; (v) governance mechanisms and stakeholder engagement processes. It also explores the extent to which countries' net-zero targets are reflected in short and near-term commitments, such as NDCs, and mid- and longer-term policy planning, such as long-term low GHG emission development strategies (LT-LEDS).

According to analysis for this paper, as of 1 October 2021, net-zero targets have been adopted by 51 countries and the EU in law, proposed in legislation or included in national policy documents[6] – see Figure 3.1. This is based on a screening of publicly-available documents and builds on recent analysis of countries' net-zero targets, related legislative and policy documents, including by (IEA, 2021[12]), (World Resources Institute, 2020[46]), (Black et al., 2021[33]) and (Grantham Research Institute on Climate Change and the Environment, 2021[36]).

This paper focuses primarily on the climate mitigation aspect of countries' net-zero emissions targets. While net-zero targets are intrinsically commitments towards climate change mitigation, they can also include considerations on and have implications for climate change adaptation. Independently from the extent to which countries will be able to cut GHG emissions in the future, some climate change impacts are already locked-in, and countries will need to take action to adapt to these impacts as they move towards achieving their net-zero ambitions (IPCC, 2018[3]). Some countries have already integrated or are beginning to integrate aspects of climate adaptation and resilience in their net-zero emissions targets and accompanying implementation plans (for example the Marshall Islands and Fiji – see section 4. for further discussion).

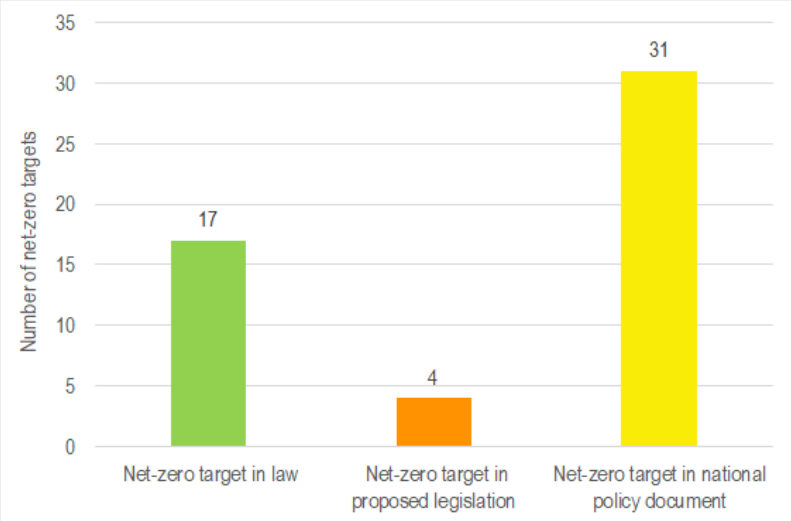
[6] This paper focuses on countries' net-zero targets that have been adopted in law, proposed in legislation, or reflected in policy documents as of 1 October 2021. It does not include net-zero targets set out in political pledges or announcements nor does it include targets under discussion at the national level. This paper also does not include targets that are long-term low-emissions goals (e.g. Norway's target to reduce emissions by 80–95% goal by 2050 (Government of Norway, 2020[170])); targets that are not economy-wide (e.g. Netherlands' target to achieve a 100% CO_2-neutral electricity supply by 2050 (Government of the Netherlands, 2019[171]) and the target in Barbados to become a 100% renewable energy and carbon neutral island state by 2030 (Government of Barbados, 2019[182])); and targets that are about maintaining rather than achieving net-zero emissions (e.g. Bhutan's commitment to remain carbon neutral (Royal Government of Bhutan, 2017[172]), Suriname's conditional commitment to maintain its forest carbon sink (Republic of Suriname, 2019[173]), or Sao Tome and Principe's commitment to remain climate neutral (Government of Sao Tome and Principe, 2021[174])). While such targets or commitments are important and can contribute to the global temperature goal, for the sake of consistency they are not analysed in this paper.

3.1. Target status and distribution

Net-zero emissions targets have been adopted by countries across different regions and from different income groups – see Figure 3.1. Of the 52 net-zero targets analysed in this paper, the majority (30) have been adopted by high-income countries as well as the EU. There are also a number of targets that have been adopted by upper-middle-income economies (13) as well as some lower-middle-income economies (8) and one low-income economy.[7]

As of 1 October 2021, 17 net-zero targets have been enshrined in law, 4 targets are in the process of being adopted in the national legislature and 31 targets are reflected in an official national policy document, including in countries' NDCs and LT-LEDS, and/or in other domestic policy documents (see Figure 3.1 and Annex A. In some cases, net-zero commitments are conditional on international support, e.g. Lao People's Democratic Republic (hereafter 'Lao PDR'), Maldives, and Solomon Islands. While the type of legal instrument used to set a net-zero target will depend on the national context and circumstances, having a net-zero target enshrined in law or integrated in a national policy document can provide long-term policy signals which can help drive changes in near-term decision-making and galvanise domestic support behind the target. Moreover, setting legally binding targets could provide an instrument for civil society to hold governments accountable for potential inaction on climate mitigation, as seen by the increasing number of climate change litigation cases in recent years (Setzer and Higham, 2021[47]).

Figure 3.1. Overview of countries with net-zero targets in law, in proposed legislation or in a national policy document, as of 1 October 2021



Note: The following categorisation is used in the figure to distinguish the status of countries' net-zero emissions targets:
Net-zero target in law covers countries where a bill including the net-zero emissions target has been passed into law.
Net-zero target in proposed legislation covers countries where a bill including the net-zero emissions target is currently under discussion in the national legislature of a country.
Net-zero target in policy document covers countries where a net-zero emissions target is included in an official national document, such as an NDC, in a strategy document such as a LT-LEDS, a domestic policy document, a national climate action plan etc.
Source: Authors.

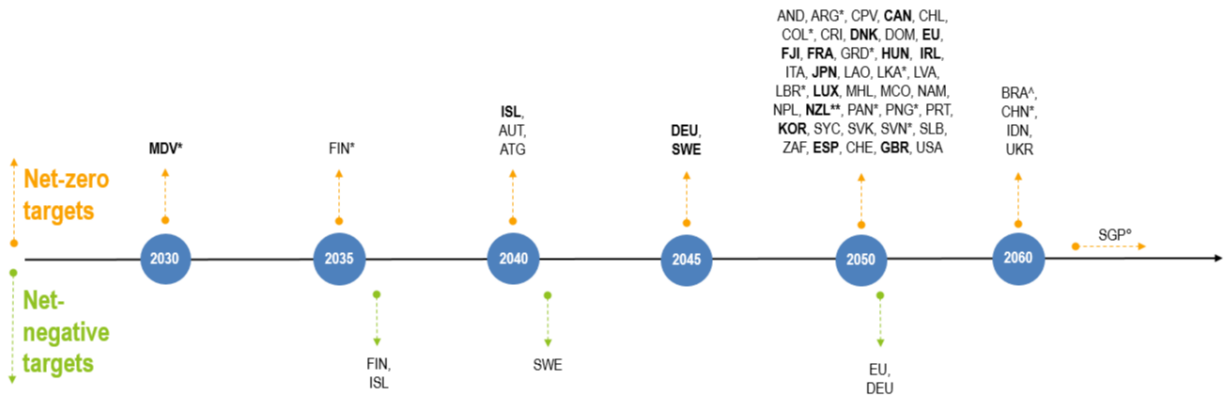
[7] Based on World Bank Country and Lending Groups, calculated using the World Bank Atlas method (World Bank, 2021[175]).

3.2. Timeframe

Most countries analysed in this paper aim to achieve their net-zero target by 2050, with only a few countries having committed to earlier targets (e.g. 2035, 2040, and 2045). Four countries have adopted targets beyond 2050, while some countries do not define a specific target year (e.g. Singapore). Figure 3.2 provides an overview of the net-zero target years set by countries analysed in this paper. As noted in Section 2, the timing of reaching net-zero is important with different timelines for achieving net-zero between countries, sectors and gases reflecting differences in the potential of different sectors as GHG emission sources/sinks as well as the different opportunities of countries to contribute to reaching net-zero emissions (see for example, (IEA, 2021[12])).

Some countries also indicate commitments after reaching net-zero such as committing to maintaining net-zero emissions after their net-zero target is reached as for example is the case with New Zealand (Government of New Zealand, 2019[48]). Some countries commit to achieving **negative emissions** after reaching their net-zero targets, for example Germany, Sweden and the EU. Such commitments recognise that net-zero emissions is not an endpoint in itself, but rather a milestone to achieving net-negative emissions in the longer term (Rogelj et al., 2021[49]).

Figure 3.2. Timeline of net-zero and net-negative targets in selected countries



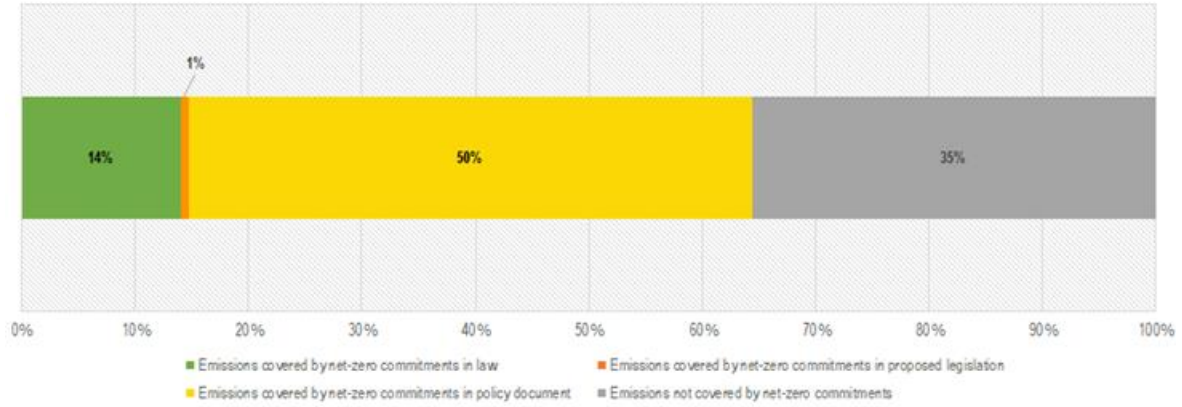
Note:
Targets marked in bold are legally binding.
* Indicates targets that only cover CO_2 emissions. In the case of China, policy documents refer to reaching net-zero CO_2 emissions by 2060. In July 2021, a public announcement by China's special envoy on climate change, Xie Zhenhua suggested the target also covers other GHGs. As this had not been clarified in a policy document as of 1 October 2021, for the purposes of analysis in this paper, China's commitment is considered to cover CO_2 emissions.
** New Zealand's target includes all GHGs except biogenic methane.
^In the case of Brazil, policy documents refer to reaching climate neutrality by 2060. In April 2021, an official announcement by the President of Brazil, Jair Messias Bolsonaro, suggested Brazil will achieve climate neutrality by 2050. As this had not been clarified in a policy document as of 1 October 2021, for the purposes of analysis in this paper, Brazil's timeline for reaching climate neutrality is considered to be 2060.
° Singapore aims to reach net-zero emissions "as soon as viable in the second half of the century".
Source: Authors.

3.3. Scope and coverage of GHG emissions and sectors

Of the 52 net-zero targets analysed in this paper, 40 are understood to cover all GHG emissions, 11 are understood to cover CO_2 emissions alone and one target excludes selected GHG emissions (i.e. New Zealand excludes emissions of biogenic methane, which are to be reduced by 24%-47% from 2017

emissions by 2050 (Government of New Zealand, 2019[48])**.** These 52 net-zero targets cover 65% of global CO_2 emissions (with 14% covered by targets in law, 1% covered by targets in proposed legislation, and 50% covered by targets in policy documents) – see Figure 3.3.

Figure 3.3. Share of global CO_2 emissions covered by net-zero commitments



Notes:
This figure illustrates the share of global CO_2 emissions covered by the 52 net-zero targets analysed in this paper. This figure uses economy-wide CO_2 emissions rather than GHG emissions to avoid a misrepresentation of net-zero targets for which the coverage of CO_2 emissions and/or GHG emissions is not clear.
Net CO_2 emission coverage of the EU is calculated by subtracting CO_2 emissions (2019) of EU member states with an individual net-zero target in law, in proposed legislation or in a policy document, from total EU emissions for 2019.
The share of global CO_2 emissions is calculated by dividing each country's territorial CO_2 emissions by the global CO_2 emissions.
Source: Authors based on 2019 economy-wide CO_2 emission data for individual countries and country groups (EU, The World) retrieved from http://www.globalcarbonatlas.org/en/CO2-emissions.

Available detail on the sectoral coverage of countries' net-zero targets varies. Of the targets analysed, the majority (38) are understood to be economy-wide while the sectoral scope of some targets (14) is currently unclear. Specific sectors are excluded from the scope of some net-zero targets, for example Sweden's net-zero target is economy-wide, however it does not include emissions and uptake from the land use, land-use change and forestry (LULUCF) sector[8] ((Government of Sweden, 2020[50]); (Swedish Environmental Protection Agency, n.d.[51])). International aviation and shipping are excluded in the net-zero targets of countries assessed, apart from some exceptions, e.g. the UK net-zero target (Government of the United Kingdom, 2019[52]). Some countries commit to reviewing this exclusion, e.g. New Zealand's Climate Change Commission is to advise by 2024 on whether the 2050 target should be revised to include international shipping and aviation (Government of New Zealand, 2019[48]).

[8] The LULUCF sector can only contribute to Sweden's net-zero target through additional measures to increase carbon sequestration in forests and land (Swedish Environmental Protection Agency, n.d.[51])

Table 3.1. Sectoral scope and GHG coverage of assessed net-zero targets

		All GHG Emissions	CO_2 emissions only	Exclude specific emissions
Sectoral coverage	Economy-wide	AND, AUT, CAN, CPV, CHL, CRI, DNK, ESP, EU, DOM, FJI, FRA, DEU, HUN, ISL, IRL, ITA, JPN, LVA, LUX, MHL, MCO, PRT, KOR, SGP, SVK, SWE^, ZAF, CHE, UKR	CHN*, FIN, LBR, MDV, PNG, SVN	NZL**
	Include international aviation and/or shipping	GBR		
	Sectoral scope unclear	ATG, BRA, IDN, LAO, NAM, NPL, SYC, SLB, USA	ARG, COL, GRD, PAN, LKA	

Notes:
* For China, policy documents refer to net-zero CO_2 emissions, however public announcements in July 2021 suggest the target could also cover other GHGs. As this has not been integrated in a policy document as of 1 October 2021, for the purposes of analysis in this paper, China's commitment is considered to cover CO_2 emissions.
** New Zealand's net-zero target excludes biogenic methane emissions which are to be reduced by 24%-47% from 2017 emissions by 2050.
^ Sweden's net-zero target does not include emissions and uptake from the LULUCF sector. The LULUCF sector can only contribute to Sweden's net-zero target through additional measures to increase carbon sequestration in forests and land.
Source: Authors.

When it comes to achieving their net-zero targets, some countries propose to focus on specific sectors or areas in the context of implementing measures to reach their target. For example, Spain focuses on a number of areas including renewable energy, energy efficiency, low-emission vehicles, sustainable alternative fuels for air transport, and urban planning measures among others (Government of Spain, 2021[53]). Iceland's target is to be reached by reducing emissions across all sectors, and by increasing carbon removals from the atmosphere, including by restoration, revegetation, afforestation, and carbon capture and mineralization in rock formations (Government of Iceland, 2021[54]). Some countries set sectoral emissions limits or carbon budgets to meet their net-zero target. For example Germany has adopted annual reduction targets for key sectors (energy, industry, transport, buildings, agriculture, waste and others) in its pathway to reaching net-zero (Federal Government of Germany, 2021[55]) and Luxembourg has set annual emission reduction targets in key sectors (energy, manufacturing and construction, transport, buildings, agriculture and forestry, waste) (Government of Luxembourg, 2020[56]). For further discussion on implementation plans for net-zero, see sub-section 3.6 and section 4.

3.4. Use of emission reductions, emission removals and international carbon markets to reach net-zero

Achieving net-zero emissions targets will require a balance between emission reductions and removals, with the balance changing over time to reflect various factors such as market dynamics, changes in demand and technological innovations. Some countries might also use international carbon markets to reach their net-zero targets (see section 5.). Each approach has different implications. For example, emission removals today are still associated with many uncertainties and could entail risks for both natural solutions (e.g. direct and indirect impacts, permanence, long-term storage capacity) and engineered solutions (e.g. feasibility of large-scale deployment, costs, social acceptance) (Rogelj et al., 2021[14]) – see also Box 2.2).

Given the various uncertainties involved, there is currently limited detail available on countries preference or goal when it comes to the balance between emission reductions and removals, and the potential use of international carbon markets in meeting their net-zero targets. There are some exceptions, most notably Sweden which specifies the share of domestic GHG emission reductions in its overall net-zero target and sets a ceiling on the use of supplementary measures (i.e. emission removals, verified emission reductions,

and negative emission technologies) in meeting its interim targets towards net-zero (Government of Sweden, 2017[57]). The EU has set a limit on the contribution of net removals to its 2030 climate target (of 225 million tonnes of CO_2 equivalent) and aims to achieve a higher volume of its net carbon sink in 2030 in line with its 2050 climate neutrality goal (Official Journal of the European Union, 2021[58]). Some countries highlight the importance of domestic emission reductions (e.g. Denmark, France, UK) and/or of enhancing natural sinks to balance remaining GHG emissions (e.g. Costa Rica, Germany, Finland, Iceland, Indonesia, Portugal), with different emphasis and levels of detail provided in each case.

There has been much discussion in the literature on whether or not to aggregate GHG emission reduction and GHG removal targets (see for example, (Matthews and Caldeira, 2008[59]) (McLaren et al., 2019[60]), (Dorndorf, Jens and Carton, 2020[61]) and (Carton, Lund and Dooley, 2021[22])). Separating GHG emission reduction targets and emission removal targets (and timelines) could help to enhance transparency, including on the expected future contribution of emission removal technologies, provide direction in terms of the extent and pace of investment needed in different areas, and improve clarity on progress towards overall targets. Countries' experiences could provide insights on setting separate targets for emission reduction and removal to improve transparency and accountability. For example, in Sweden to achieve net-zero, domestic GHG emissions must be at least 85% lower in 2045, with the remaining 15% of emission reductions to be achieved through complementary measures which are a mix of domestic and international emission reductions, removals and offsets (Swedish Environmental Protection Agency, n.d.[51]). In the EU, to achieve climate-neutrality by 2050, domestic net GHG emissions (i.e. emissions after deduction of removals) are to be reduced by at least 55% by 2030 with the contribution of net removals to the EU-wide 2030 climate target to be limited to 225 million tonnes of CO_2 equivalent (Official Journal of the European Union, 2021[58]).

3.5. Governance mechanisms and stakeholder engagement processes

A number of countries analysed in this paper, in particular those with net-zero targets in law and in proposed legislation, have adopted reporting and review processes to assess progress towards their net-zero targets – see Table 3.2. A regular schedule for assessing, reviewing, and revising net-zero targets could help enhance transparency, enable accountability and support increased ambition (NewClimate Institute and DataDriven EnviroLab, 2020[62]). Some countries have set up reporting and review cycles for their net-zero targets linked to annual financial budget discussions (e.g., Denmark, Sweden), some review cycles are linked to the process of updating NDCs (e.g. Fiji) and some review cycles are linked to the Global Stocktake process under the Paris Agreement (e.g. EU).

Several countries have established independent bodies to provide advice on and/or evaluate progress towards their net-zero (and other climate) targets – see Table 3.2. Such independent expert bodies can help to review progress towards net-zero targets, strengthen accountability of the process and foster public debate. Some countries' net-zero targets have been set following the recommendations of such independent expert bodies (e.g. Finland, UK). In some cases, the government is required to publicly respond to the recommendations received from these bodies (e.g. Canada, Denmark, France, New Zealand, UK) or account for performance towards climate targets in front of a parliamentary committee (e.g. Ireland).

Table 3.2. Overview of governance mechanisms for net-zero targets in selected countries

	Reporting processes		Oversight mechanism		Other
	Reporting mechanism	Frequency	Independent expert body	Role	
Canada	✓	2 years before milestone years (of 2035, 2040, 2045) and 2050	✓	Provide advice, prepare annual reports	Federal Commissioner of Environment and Sustainable Development to report on implementation of climate mitigation measures at least once every 5 years
Chile	✓	Every 4 years	✓	Provide advice	
China (People's Republic of)	-	-	-	-	High-level climate leaders group to co-ordinate efforts
Denmark	✓	Annual	✓	Make recommendations	
EU	✓	Every 5 years	✓	Provide advice	Impact assessments of new proposals to consider climate neutrality objective
Fiji	✓	Every 5 years	✓	Make recommendations	
Finland	✓	Annual	✓	Provide advice	
France	✓	Every 5 years	✓	Prepare annual report, make recommendations	
Germany	✓	Annual	✓	Provide advice	
Ireland	✓	Annual	✓	Review progress, make recommendations	Ministers account for performance on sectoral targets before Parliament
Japan	✓	Annual	✓	Provide advice, consider policy directions	Council for national and local decarbonisation
Luxembourg	-	-	✓	Provide advice, Prepare annual report	Climate Platform to encourage dialogue and coordination
New Zealand	✓	Annual	✓	Prepare annual report, provide advice	
Korea (Republic of)	✓	-	-	-	Presidential 2050 Carbon Neutrality Committee to support implementation
Slovenia	✓	Annual	✓	For consultation	
Spain	✓	Periodically	✓	Prepare annual report	
Sweden	✓	Annual	✓	Assess action plans, evaluate progress	
UK	✓	Annual	✓	Provide advice, prepare progress reports	Two cabinet committees to drive transition

Note: "-" indicates information could not be found by the authors.
Source: Authors.

In some countries dedicated groups have also been set up to engage with different stakeholders in the process of designing implementation plans for their net-zero targets. For example, in New Zealand, the

Climate Leaders Coalition promotes domestic business leadership and collective, transparent action on climate change to support New Zealand's transition to a low emissions economy (Climate Leaders Coalition, n.d.[63]) Denmark has established 13 Climate Partnerships with private sector organizations and a Youth Council (Government of Denmark, 2020[64]). In Luxembourg, a Climate Platform has been created to provide a forum for dialogue on climate change issues, propose research studies, engage different stakeholders, provide input to draft policies etc. (Government of Luxembourg, 2020[56]). In the EU, the European Commission is to facilitate sector-specific climate dialogues and partnerships with key stakeholders to encourage the development of indicative voluntary roadmaps for the transition to climate neutrality (Official Journal of the European Union, 2021[58]).

Some countries have also established citizen climate assemblies to discuss and recommend specific climate policies (e.g. Denmark, France, Ireland, and UK). In some cases these processes have fed into the implementation plan for net-zero targets (e.g. France). Moreover, as discussed in section 2.4.2, some governments are engaging with sub-national authorities to support implementation of national net-zero commitments. In some countries different approaches have been adopted in parallel (e.g. independent expert body, coordinating committee, stakeholder groups, and citizen climate assembly). Such governance mechanisms, institutional arrangements and stakeholder engagement processes can help to enhance transparency and galvanise domestic support behind countries' net-zero targets.

3.6. Reflecting net-zero emissions targets in short- and mid-term policy planning

Setting interim short- and mid-term targets/milestones for emission reductions and concrete implementation roadmaps is an important ingredient in achieving a net-zero commitment both cost-effectively and sustainably (Rogelj et al., 2021[31]; Falduto and Rocha, 2020[32]; Vogt-Schilb and Hallegatte, 2014[65]; Fabert and Foussard, 2016[66]; del Río González, 2008[67]). A clear plan for the short- and mid-term is helpful to ensure continued momentum towards the long-term target and supports the implementation of necessary measures to achieve the target (Falduto and Rocha, 2020[32]). Short and mid-term planning and objectives are more easily aligned with business and political cycles governing policy-making and can provide concrete direction for actions. A shorter time horizon can more easily be translated into concrete measures and imply fewer uncertainties in, e.g., macroeconomic trends and future availability of technologies. Furthermore, interim targets make it easier to assess progress over time and provide opportunities to review and revise plans as needed to get back on track towards the long-term goal.

3.6.1. Timing and scope of milestone targets towards net-zero commitments

Analysis of 52 net-zero targets in this paper finds that 28 countries and the EU have set an interim target(s) as part of their net-zero commitment. Furthermore, 27 countries and the EU indicate their latest NDC is in line with their longer-term net-zero commitment and could be considered an interim target towards net-zero[9]. The year 2030 is the most commonly-used milestone, with 2025 and 2040 also used by some countries. Details on the interim targets are usually outlined in the legislation supporting the target or in the accompanying implementation plan. Some countries only specify their interim targets to net-zero in their NDC. For an overview of interim milestone targets set by selected countries, see Table 3.3 for further detail. This synthesis shows how interim targets put forward to date vary considerably across countries in terms of their timeline, scope and level of detail.

Interim targets do not necessarily have to be set at the time of making a net-zero commitment, and countries have established different mechanisms or processes for defining interim targets. Some countries,

[9] Canada, EU, Fiji, Chile, Colombia, Costa Rica, Marshall Islands, Papua New Guinea, New Zealand have an interim target in their net-zero commitment document and indicate their NDC target(s) is in line with their net-zero commitment. For the Maldives, their NDC target date and (conditional) net-zero target date is the same.

plan to set interim targets as they advance towards net-zero, following 5- or 10-year cycles. Countries that rely on their NDC to set interim targets will update and revise their interim targets regularly as part of the NDC revision cycle. Setting up regular programmes for reviewing progress towards a net-zero target can inform the adoption of new interim targets. For example, Denmark's net-zero target foresees two economy-wide emission reduction targets to 2025 and 2030, and the Government is mandated to set a new legally-binding target every 5 years, 10 years in advance, i.e. in 2025 a new target will be established for 2035 (Government of Denmark, 2020[68]). In Japan, the Plan for Global Warming Countermeasures sets out policies and measures to be implemented by different Ministries, local governments, businesses and citizens, to support mid-term (2030) and long-term (2050) GHG reduction targets. Progress is reviewed annually and the plan is revised every three years (Government of Japan, 2016[69]). The latest revision to the plan, to be released in 2022, is expected to include new 2030 targets and a pathway towards net-zero by 2050 (Personal communication, 2021).

An increasing number of countries are setting interim milestones using **carbon budgets.** Compared to single-year interim targets, carbon budgets offer flexibility in distributing yearly emission reductions over a set period. At the same time, given the flexibility they offer, carbon budgets may be difficult to enforce. This is because in the absence of quantified, single-year milestone target, there can be an incentive for policymakers to delay action and investments (Vogt-Schilb and Hallegatte, 2013[70]). The UK is among the first countries to have adopted a carbon-budget approach to guide their short- and mid-term policy planning. Carbon budgets were introduced in the UK in the Climate Change Act of 2008 and set legally-binding emission caps over successive five-year periods The UK's carbon budgets are set for 5 years and are legislated 12 years ahead of their implementation cycle. This ensures sufficient lead-time for the Government to develop and enact policies and for businesses to invest (Climate Change Committee, 2020[71]).The budgets are estimated to be consistent with a net-zero pathway (Government of the United Kingdom, 2019[52]; Government of the United Kingdom, 2008[72]). The level of each carbon budget is set based on advice from the UK Climate Change Committee.

Similarly, the Irish Climate Action and Low Carbon Development (Amendment) Bill introduces a legal requirement for the Government to implement three 5-year carbon budgets (Government of Ireland, 2021[73]). Interestingly, borrowing (and banking) is allowed between periods. For example, where total GHG emissions for a given budget are lower than that initially allocated; the surplus can be carried over to the next budget. Where total GHG emissions for a preceding budget period exceed the carbon budget for that period, excess GHG emissions are to be carried forward to the current budget period and the current carbon budget decreased by the amount of GHG emissions carried forward. France, Germany, Chile, and New Zealand also adopt carbon budgets as interim milestones towards their net-zero emissions targets.

Interim targets can be either economy-wide or sector-specific. Most countries include economy-wide emission reduction targets, often expressed in terms of percentage reductions compared to 1990 or 2005 levels. Examples include Denmark and Hungary. In contrast, some countries' interim targets are sector-specific. Sectoral targets can provide greater guidance to policymakers than economy-wide targets in developing implementation plans and can ensure greater accountability, as the responsibility for their achievement may be delegated to specific Ministries (Falduto and Rocha, 2020[32]; Nachmany and Mangan, 2018[74]). Furthermore, sectoral targets also offer more guidance to other stakeholders, such as businesses, who can set their own targets for emission reductions to reflect sectoral benchmarks (Nachmany and Mangan, 2018[74]). At the same time, to be able to set economy-wide targets, a country needs detailed information on emission projections (including the main emission drivers and sources) which may render the process of setting a sectoral target more costly in terms of the technical and economic resources required.

Luxembourg is among the countries that have established sectoral targets by allocating yearly emission allowances for the main polluting sectors (e.g., energy and manufacturing industries, transport, buildings, agriculture, forestry, and waste). This system allows for any surplus allowances to be carried over to the following year for the same sector and for the trading of allowances between sectors, provided that the

national foreseen emission reduction targets are met (Government of Luxembourg, 2020[56]). In contrast, Sweden has set a separate milestone target for domestic transport, excluding domestic flights, as the transport sector currently accounts for a third of Sweden's GHG emissions (Government of Sweden, 2020[50]).

A limited number of countries include milestones for critical measures deemed pivotal for the achievement of net-zero emissions. These include, e.g., France's interim target of phasing out coal-fired plants by 2022 and the EU's proposed target of net GHG removals in the LULUCF sector of 310 million tons of CO_2 equivalent by 2030 to enhance the EU's carbon sink in line with its climate neutrality objective (European Commission, 2021[75]). Such targets can support the implementation of major systemic transformations across different sectors and, if included in legislation or policy documents supporting the net-zero target, can send a strong political signal of the government's direction/intent in this regard.

Some emerging and developing economies with net-zero targets have set peak emissions as an interim target. A large number of countries that have set net-zero targets include developed economies, the large majority of which have already peaked their GHG emissions in the past two decades (WRI, 2017[76]). In contrast, a fundamental milestone on the net-zero pathway for emerging economies is that of establishing a year or timeframe where emissions would peak. For example, both China's net-zero commitment (Government of the People's Republic of China, 2021[77])and South Africa's GHG trajectory to net-zero identify a date by which their emissions will peak (Government of South Africa, 2020[78]).

Table 3.3. Overview of interim targets in selected countries

Country	Typologies of interim targets	Description of main interim targets	Mechanism for setting and/or reviewing interim targets
Brazil	GHG emission reductions; economy-wide	• 37% reduction in GHG emissions by 2025 (compared to 2005 levels) • 43% reduction in GHG emissions by 2030 (compared to 2005 levels)	Not specified; interim targets included in the country's NDC
Canada	GHG emission reductions; economy-wide	• 40-45% reduction in GHG emissions by 2030 (compared to 2005 levels)	Target established by Canada's Net-Zero Emissions Accountability Act. The Act also requires the Minister of Environment and Climate Change to set the subsequent 2035, 2040 and 2045 targets at least 10 years in advance. Progress towards achievement of the goal will be assessed regularly.
China	Emissions peak; economy-wide	• Peak CO2 emissions in 2030	Not specified
Denmark	GHG emission reductions; economy-wide	• 50-54% reduction in GHG emissions by 2025 (compared to 1990 levels) • 70% reduction in GHG emissions by 2030 (compared to 1990 levels)	Government to set a new legally binging target every 5 years, with a 10-year perspective (e.g. in 2025, new 2035 target will be set)
European Union	GHG emission reductions; economy-wide	• At least 55 % reduction in domestic GHG emissions by 2030 (compared to 1990 levels)	Within six months of the first global stocktake under the Paris Agreement, a proposal for a new EU-wide climate target for 2040 is to be put forward by the European Commission
Fiji	Total GHG emissions	• Total GHG emissions expressed in CO2eq in 2020, 2025, 2030, 2035 and 2040	Timeline of interim targets is set in coordination with NDC cycles. Progress towards achievement of the net-zero goal will be reviewed periodically and at least one year ahead of the submission of a new or updated NDC, so to inform and potentially adjust the new target.
France	Other types of quantitative targets, carbon budgets; sectoral	• Phasing out coal-fired plants by 2022 • 40% reduction in energy consumption by 2030 • 50% reduction in the share of nuclear power electricity by 2035 • 5-year carbon budgets (2019-2023; 2024-2028; 2029-2033)	Carbon budgets adopted by decree, in conjunction with the National Low Carbon Strategy. Carbon budgets are set and adopted every 5 years, upon revision of the strategy, and with a 10-year perspective.
Hungary	GHG emission reductions, other quantitative targets; economy-wide, sectoral	• 40% reduction in GHG emissions by 2030 (compared to 1990 levels) • 21% share of renewable energy sources in gross final energy consumption	Not specified
Luxembourg	GHG emission reductions, emission allowances; economy-wide, sectoral	• 55% emissions reductions by 2030 (compared to 2005 levels) • Annual emission allowances	National regulation sets annual sectoral emission allowances until 2029. Emission allowances are set every 10 years.

Marshall Islands	GHG emission reduction; economy-wide	• 32% reduction in GHG emissions by 2025 (compared to 2010 levels) • 45% reduction in GHG emissions by 2030 (compared to 2010 levels) • 45% reduction in GHG emissions by 2030 (compared to 2010 levels) • 58% reduction in GHG emissions by 2035 (compared to 2010 levels)	Long-term strategy, including the mid-term targets, reviewed and updated as necessary every 5 years.
New Zealand	Carbon budgets; economy-wide*	• Carbon budgets (yet to be set)	Starting on 31 December 2021, the Government is required to set a series of emission budgets to meet the 2050 net-zero target.
South Africa	Emissions peak; economy-wide	• Peak GHG emissions in 2020 – 2025 • Emissions start declining from 2036	Interim targets set in accordance with the GHG trajectory of the National Climate Change Response Policy. The Climate Change Bill makes provision for regular updates of this trajectory.
Spain	GHG emission reductions, other quantitative targets; economy-wide	• 20% reduction in GHG emissions by 2030 (compared to 1990 levels) • 35% renewable sources in total energy consumption by 2030 • 70% generation from renewable energies in electrical systems by 2030 • 35% reduction in primary energy consumption by at least 35% by 2030	A commission of experts on climate change and the energy transition will be established to evaluate progress towards milestone targets and make recommendations for improvement.
Sweden	GHG emission reductions; sectoral	• 40% reduction in GHG emissions by 2020 (compared to 1990 levels)** • 63% reduction in GHG emissions by 2030 (compared to 1990 levels)** • 75% reduction in GHG emissions by 2040 (compared to 1990 levels)** • 70% reduction in GHG emissions by 2030 for domestic transport (from 2010 levels)	Milestone targets were decided by the Swedish Parliament
United Kingdom	Carbon budgets; economy-wide	• 5-year carbon budgets (currently set budgets run until 2032)	The 2008 Climate Change Act establishes interim 5-year carbon budgets. The carbon budgets are set following the recommendation of the Committee on Climate Change (CCC).

Note:
*New Zealand's target excludes emissions of biogenic methane
** Interim targets cover GHG emissions in Effort Sharing Regulation (ESR) sectors (i.e. sectors that are not covered by the EU Emission Trading Scheme (EU ETS)) which include transport (excluding aviation); buildings (heating and cooling); agriculture (non-CO_2 emissions only); waste (solid waste disposal land, wastewater, waste incineration and any other waste management activity) (European Commission, 2021[79]). Interim targets do not include emissions and uptake from the LULUCF sector.
Source: Authors.

3.6.2. NDCs and net-zero targets

NDCs outline countries' targets towards achieving the collective goals of the Paris Agreement. The submission of NDCs is mandatory for all Parties under the Paris Agreement. NDCs typically cover a time horizon of 10-15 years (i.e. NDCs submitted in 2020 usually set targets to 2030 or 2035). The Paris Agreement provides for NDCs to be multiple steps of an *iterative* process. Starting in 2020, countries are requested to communicate new or updated NDCs every five years, with each successive NDC to represent a "progression" and "reflect its highest possible ambition" (Paris Agreement, 2015[80]).

NDCs represent an important tool to communicate countries' climate targets. Their 5-year cycles offer an ideal timeframe for the progressive definition of milestone targets towards net-zero commitments. However, assessments of the first cycle of NDCs, submitted in 2015, show that NDCs had not yet been able to effectively align short- and mid-term national efforts to the level of emission reductions needed in the long-term to achieve the goals of the Paris Agreement (UNEP, 2018[81]; UNEP, 2019[82]). The 2021 UNFCCC NDC synthesis report indicates that the total GHG emissions in 2030 from the implementation of countries' latest NDCs as of July 2021, is expected to be 16.3% above 2010 levels, far higher than the 45% reduction in emissions needed to be consistent with the IPCC's 1.5°C emission pathway (UNFCCC, 2021[83]).

Encouragingly, alignment of recently submitted NDCs with long-term net-zero targets has improved. Previous CCXG analysis showed that as of May 2020, only a limited number of countries explicitly linked their NDC targets to their respective long-term strategies or goals, including those of carbon or climate neutrality (Falduto and Rocha, 2020[32]). However, the 2021 Addendum to the UNFCCC NDC synthesis report highlights that 70 Parties provided quantitative considerations of long-term goals up to and beyond 2050, and the majority of these refer to "climate neutrality", "carbon neutrality", "GHG neutrality" or "net-zero emissions" (UNFCCC, 2021[84]).

The EU and 49 countries analysed in this paper reiterate their net-zero commitments in their new or updated NDCs. In some cases, when reference to net-zero emissions is made, it is to state that the quantitative target put forward by the NDC is compatible with or has been set, taking into consideration the long-term goal of achieving net-zero emissions or climate neutrality. For example, this is mentioned in the NDCs of the EU, Brazil, Cabo Verde, the United States, and Switzerland (European Union, 2020[85]); (Government of Brazil, 2020[86]; Government of Cabo Verde, 2021[87]; Government of the United States, 2021[88]; Government of Switzerland, 2020[89]). Of the countries analysed in this paper, as of 1 October 2021, only the NDCs of China and Singapore do not mention their net-zero commitment.

Several countries have a good level of consistency between the targets expressed in their NDC and the milestone targets included in their net-zero strategy or commitment. For example, the interim targets presented in the Marshall Islands' LT-LEDS to carbon neutrality correspond to those included in the country's NDC (Government of the Marshall Islands, 2018[90]; Government of the Marshall Islands, 2018[91]). Other countries, which may have recently formulated a net-zero target, express their intention to align future NDC submissions to long-term carbon or climate neutrality. For example, both China and the Republic of Korea (hereafter 'Korea') plan to update, before 2025, their current 2030 NDC target to raise ambition in line with their respective carbon neutrality targets (Climate Action Tracker, 2021[92]; Government of the Republic of Korea, 2020[93]).

4. Implementation plans and domestic roadmaps: insights from experience

Although many net-zero commitments were formulated or communicated in 2020-2021, several countries have already developed accompanying roadmaps that explore pathways to decarbonisation and outline crucial measures to be undertaken in the short- or medium-term to achieve net-zero emissions. As of 1 October 2021, 32 countries and the EU have submitted a LT-LEDS to the UNFCCC that sets out key steps in the next decades to achieve their long-term commitments. Overall, the roadmaps developed so far vary considerably in terms of the approaches adopted to achieve net-zero emissions and the level of detail provided in terms of policy planning. For example, Costa Rica's LT-LEDS identifies detailed, actionable measures, including milestone targets, for the short- medium- and long-term to achieve its net-zero commitment (Government of Costa Rica, 2019[94]). In contrast, the LT-LEDS prepared by Finland lays out emission reduction scenarios, noting that details on policies and measures to be implemented to achieve carbon neutrality will be outlined in other specific implementation tools and documents (Government of Finland, 2020[95]). It will be up to individual governments and countries to understand what approach would work better for them in light of their national circumstances and available resources. This section explores four cases of implementation strategies and practices adopted in selected countries to support their net-zero emissions commitments.

4.1. The case of the United Kingdom: Independent evidence-based advice to inform target setting and policy development

The UK's net-zero emission reduction target, set in the 2008 Climate Change Act (initially requiring at least an 80% reduction in emissions relative to 1990) was originally set based on advice by the independent Climate Change Committee (CCC). The target was made more stringent in 2019, to require at least 100% emission reduction below 1990 levels, again following the advice of the CCC. The presence of the CCC has helped provide a scientific, evidence–based approach to inform target setting and policy processes. Successive UK Governments (from across the political spectrum) have accepted the CCC's advised level of the carbon budget for the six legislated budgets to date (Climate Change Committee, 2020[71]) and have generally followed the advice of the CCC, for example to bring aviation and shipping emissions within UK carbon budgets (Climate Change Committee, 2021[96]).

The CCC is also responsible for assessing progress towards the UK's carbon budgets and long-term emissions goal, critically reviewing the Government's policies and progress towards the target and setting out detailed recommendations by Government department. Their reports are presented to the UK Parliament and the Government is required to produce a formal response to its findings (Climate Change Committee, 2020[97]). The latest report highlights that "credible policies for delivery currently cover only around 20% of the required reduction in emissions to meet the Sixth Carbon Budget" (Climate Change Committee, 2021[96]).

4.2. The case of Costa Rica: Nesting short-term actions within a comprehensive long-term net-zero strategy

Costa Rica's long-term strategy enshrines its commitment to reach net-zero emissions by 2050 (Government of Costa Rica, 2019[94]) and provides a framework for nesting policy developments across different levels (e.g. linking to national strategic frameworks and sub-sectoral plans) and timeframes. For example, the updated first NDC of Costa Rica, aligns short/medium-term climate commitments with the 2050 net-zero vision (Government of Costa Rica, 2020[98]). The process of developing the updated NDC entailed extensive consultations with stakeholders. Moving forward, the National Ambition Cycle seeks to establish a continuous, inclusive process that incorporates the views of vulnerable groups in the process of monitoring and updating Costa Rica's NDC and LTS to keep on track to net-zero (Government of Costa Rica, 2020[98])**.**

In its net-zero plan, the Government of Costa Rica outlines a detailed plan of action on 10 decarbonisation axes, which reflect mitigation priorities; three of the 10 focus on transformational change in the transport sector, given the large share of emissions from this sector (Government of Costa Rica, 2019[94]). The detailed actions outlined in the 10 axes are considered "initial actions being a part of the pathway that will be negotiated and deepened over time" (Government of Costa Rica, 2019[94]). The actions, also referred to as "policy packages", are presented for each axis over three stages: foundations (2018-2022), inflection (2023-2030) and massive deployment (2031-2050).

An interesting element of the action plan for each stage and axis is that it also contains actions to be avoided to reduce the risk of locking-in emissions for the decades to come. Examples of lock-in avoidance measures in the transport sector include avoiding infrastructure investments that favour private vehicle use over public transport. The net-zero strategy also has links to other plans such as efforts to disentangle Government revenues from fossil fuels through a green tax reform before promoting substantial electrification of the transport sector (Ministry of Finance of Costa Rica, 2020[99]).

4.3. The case of South Africa: Consulting with stakeholders to plan a just transition to net-zero

South Africa's Low-emission Development Strategy (LEDS) includes a commitment of "ultimately moving towards a goal of net-zero carbon emissions by 2050" (Government of South Africa, 2020[78]). How this goal will be achieved to ensure a just transition is to be communicated in future iterations of the strategy. Given the economic and social context of South Africa and the particular challenges faced, the approach to moving towards net-zero emissions has been strongly consultative, focused on social dialogue and on reaching consensus, with an emphasis on a just transition to avoid leaving anyone behind.

Between 2018 and 2021, the National Planning Commission engaged in extensive consultations with different stakeholders to develop a long-term national vision for a low carbon, climate-resilient economy and society. Based on this process, a Just Transition Plan is being prepared (Government of South Africa, 2021[100]). Just transition considerations are particularly important given the high unemployment, poverty, inequality, and other development challenges South Africa faces. These circumstances have led to an emphasis on carefully managing the transition to net-zero, taking into account social and economic costs of the transition for vulnerable groups, while ensuring economic opportunities are fairly distributed (Presidential Climate Commission, 2021[101]).

Detailed technical work is being undertaken to explore transformation pathways in key economic sectors and at the sub-sectoral level (Government of South Africa, 2020[78]). Consultative processes and technical work are also underway at different levels to take into account implications of the long-term net-zero emissions objective. South Africa's updated NDC recognises the work of the National Planning

Commission, the LEDS and the role of the Presidential Climate Commission in overseeing the just transition (Government of South Africa, 2021[100]). There are also initiatives and processes underway by non-state actors including business initiatives and efforts at the city level to plan for net-zero emissions. For example, following a modelling exercise by the National Business Initiative on pathways to achieve carbon neutrality, some of the country's largest emitters (including Eskom, Anglo American, Exxaro, SASOL) have made commitments or announcements that support the national 2050 net-zero goal (Presidential Climate Commission, 2021[101]). A growing number of company initiatives, such as Eskom's Just Energy Transition strategy to reach net-zero carbon emissions by 2050 and increase sustainable jobs, highlight the importance of drawing a link between net-zero targets at different levels, in particular in the context of monopolistic companies in key sectors, to support implementation of net-zero commitments.

4.4. The case of Fiji: Achieving net-zero focusing on adaptation and resilience

Fiji's LT-LEDS, submitted to the UNFCCC in 2019, establishes an economy-wide net-zero carbon emissions goal to 2050, that links national climate policy with development plans and sectoral planning processes and sets out a detailed implementation plan (Government of Fiji, 2018[102]). The net-zero goal is supported by the country's Climate Change Act 2021 (Government of Fiji, 2021[103]). The LT-LEDS has informed other processes including the NDC Implementation Roadmap (covering the period 2017-2030), the proposed NDC Investment Plan (Government of Fiji, 2021[104]) and has been translated into sectoral plans (e.g. the national energy policy). To reach its net-zero target, Fiji would need to transform its energy sector and decarbonise the transport sector. In addition, according to the LT-LEDS, the achievement of negative emissions could be possible through extensive afforestation measures and the promotion of sustainable forest plantations. The strategy includes five interim targets expressed in terms of total net emissions to be achieved in 2020, 2025, 2030, 2035, and 2040, respectively.

Fiji is amongst the most vulnerable countries to climate change. Its economy is strongly tied to agriculture and tourism, which may be severely affected by the consequences of climate change. For these reasons, adaptation and resilience are a critical component of Fiji's climate change strategy, and Fiji's commitment to net-zero emissions strongly focuses on aspects of resilience, adaptation and ECOSYSTEM restoration. To guide the development of mitigation strategies for decarbonisation designed with in-built climate resilience, the Government of Fiji identified key questions to integrate climate resilience in mitigation measures[10].

Considerations and measures for adaptation and resilience included in Fiji's net-zero strategy were further supported by an assessment on climate vulnerability (Government of Fiji, 2017[105]). Key outcomes from the assessment have been used to inform the development of mitigation strategies for decarbonisation, to ensure these are designed with in-built climate resilience. Table 4.1 provides an overview of the main mitigation measures envisaged by the LT-LEDS and respective adaptation and resilience considerations.

[10] The five key questions identified by the Government of Fiji that need to be addressed to integrate climate resilience in mitigation measures include: (i) Will the mitigation action or project be affected by predicted climate change risks?; (ii) How will the mitigation action be affected, and how can those risks be reduced or eliminated?; (iii) Will the climate change adaptation measure or project increase carbon emissions?; (iv) Is there a low or no-carbon alternative to the adaptation measure or project?; and (v) Are there adaptation actions that will increase the mitigation potential of the activity or project, or vice versa?

Table 4.1. Built-in adaptation and resilience components in Fiji's net-zero strategy

Mitigation sector	Built-in adaptation and resilience components
Infrastructure: Electricity and Other Energy Generation and Use	• Diversifying renewable energy generation to improve resilience; • Enhance insurance coverage of key energy assets • Increasing investments in rural mini-grids and solar home systems; • Working to optimise hydropower operations under new climate conditions; • Reviewing design and construction standards for energy facilities and solar home systems for climate resilience.
Infrastructure: Land, Maritime, and Air Transport	• Develop certification standards for climate-proofing transport infrastructure; • Promote institution strengthening and capacity building for integrated transport planning; • Work to renew and upgrade priority water crossings to withstand climate impacts
Infrastructure: Waste (including Water and Sanitation)	• Require national and sub-national governments to prepare and publish climate disaster management plans detailing how water and sanitation resources will be managed and protected; • Upgrade and develop new appropriate water and sanitation infrastructure; • Develop and implement new appropriate building codes, zoning, and construction codes for water and sanitation infrastructure.

Source: Authors, based on (Government of Fiji, 2018[102]).

5. Exploring the role of international carbon markets in achieving countries' net-zero targets

This section explores what role international carbon markets could play over time to help countries achieve their net-zero emissions targets. Unless otherwise stated, in this section "international carbon markets" refer to "carbon credit mechanisms"[11] that allow international transfers of carbon credits from one country to another. Discussions in this section focus on existing carbon crediting mechanisms, any potential future voluntary bilateral co-operation through Article 6.2 of the Paris Agreement that will involve crediting from mitigation activities, and future crediting from activities registered under the Article 6.4 mechanism.[12] This section first provides an overview of the type of credits issued to date in international carbon markets to help understand the role of these credits in achieving net-zero. It then discusses different approaches countries have taken in their proposed use of international carbon markets and the potential role of international carbon markets in achieving net-zero targets, both on the supply and demand side.

[11] A carbon crediting mechanism is a programme that registers mitigation activities and issues carbon credits corresponding to a defined quantity (generally, one tonne of CO_2-eq) of emission reductions or removals achieved by the activities, and it is also often referred to as "baseline and credit" mechanism (EDF, WWF-US and Oeko-Institut, 2020[132]) (Michaelowa et al., 2019[177]).

[12] This paper recognises that the rules for Article 6 are still under negotiation as of October 2021. Moreover, domestic carbon crediting mechanisms and voluntary / independent crediting schemes, are discussed because they share the same functioning principles as international carbon credit mechanisms, but they are not the primary focus of this section. Considerations on the role of other non-crediting domestic carbon market instruments, such as emission trading systems (ETS), in achieving net-zero are outside the scope of this paper, while acknowledging that linking of two ETS could potentially be framed as bilateral co-operation under Article 6.2 of the Paris Agreement.

5.1. Taxonomy of activities issuing credits in international carbon markets

While one carbon credit generally represents the mitigation of one tonne of CO_2-eq[13], regardless of the type of activity that generated it, the actual physical impact an activity issuing carbon credits has on the atmosphere can vary substantially depending on the type of activity.[14] The literature distinguishes between three categories of climate mitigation activities through which crediting mechanisms could allow the generation and issuance of carbon credits, namely: emission reduction, avoidance and removal activities. There is little agreement in the literature on the definition of certain categories, in particular for "emission reduction" and "emission avoidance" activities. In certain cases, the two terms are used interchangeably, or sometimes "emission avoidance" activities are considered a sub-category of "emission reduction" activities. For instance, (La Hoz Theuer et al., 2021[13]) and (Allen et al., 2020[106]) use the term "emission avoidance" to refer to activities that prevent an increase of future emissions below a baseline, such as the installation of new renewable energy activities displacing fossil fuel power generation in an electricity grid. In contrast, (Koeler and Michaelowa, 2014[107]) and (Asian Development Bank, 2020[108]), among others, use the term "emission avoidance" to refer to the prevention or halting of activities that might release stored carbon into the atmosphere, such as the non-exploitation of fossil fuel reserves.

Given the lack of an agreed definition, this paper uses the classification elaborated in Box 5.1 below and summarised in Table 5.1, which reflects the terminology used in recent informal UNFCCC discussions on international carbon markets. This classification is not intended to be prescriptive nor comprehensive, but it is elaborated here to provide a basis for the analysis in this paper.

[13] This paper uses the definition proposed by (Honegger, Burns and Morrow, 2021[20]), whereby "climate change mitigation" encompasses both concepts of emission reduction and emission removal. Moreover, in the context of Article 6 negotiations, this paper recognises that non-CO_2 metrics for Internationally Transferred Mitigation Outcomes (ITMOs) are being discussed. These discussions also acknowledge the need for a conversion from non-CO_2 metrics to CO_2-eq due to the requirement of a corresponding adjustment on ITMOs transfers. For simplification reasons, this paper uses CO_2-eq when referring to carbon credits, assuming that any credit generated in non-CO_2 metrics could be converted into the CO_2 metric by applying a specific conversion methodology, and acknowledging that there is no consensus in Article 6 negotiation on the definition and nature of ITMOs (e.g. some Parties argue that ITMOs should not be considered as the standard definition of "carbon credits", because they are not "issued").

[14] The term "activity" is used in this paper to encompass individual projects, programme of activities and policies that can generate carbon credits.

Box 5.1. Taxonomy of activities issuing credits in international carbon markets

- **Emission reduction activities** reduce the amount of GHG emissions added to the atmosphere compared to what would have been added in the absence of the activity. By this definition, emission reduction activities could reduce absolute GHG emission levels, lower the GHG emission intensity linked to the production or use of goods and services, or increase absolute GHG emissions at a slower rate than a counterfactual baseline.[15] Such activities could be further sub-categorised into:
  - Emission reduction activities without carbon storage, e.g. energy efficiency activities, methane or nitrous oxide abatement, installation of new renewable energy activities in a grid where fossil fuel activities were originally planned;
  - Emission reduction activities with carbon storage, e.g. installation of a CCS system on a fossil-fuel power plant or an industrial facility.
- **Emission avoidance activities** avoid potential sources of stored GHG emissions from being emitted to the atmosphere. Examples include the non-exploitation of fossil fuel reserves, maintaining land use and agricultural practices that retain already-stored carbon, and avoided deforestation. Such activities are vulnerable to the risk of non-permanence of stored emissions, e.g. fossil fuels could be kept in the ground (or deforestation could be avoided) for the time in which financial support from the sale of international credits is received, and subsequently extracted (or deforested, respectively) if conditions change, e.g. if the revenue stream from international carbon pricing halts.[16]
- **Emission removal activities** remove CO_2 from the atmosphere and store it.[17] Such activities could be further sub-categorised as follows:
  - Emission removal technologies which are CDR technologies with long-term storage, such as direct air carbon capture and storage (DACCS), bioenergy with carbon capture and storage (BECCS) or enhanced weathering (EW) (see Box 2.2). These activities allow for the removal of carbon from the atmosphere and storage in the order of centuries to millennia (Allen et al., 2020[106]). The risk of non-permanence[18] of stored emissions from these activities is very low, because carbon can be stored in geological reservoirs or mineralised into stable forms (Allen et al., 2020[106]).
  - Nature-based solutions (NBS) include CDR projects such as afforestation and reforestation, biochar and soil carbon sequestration. NBS are generally characterised by short-lived carbon storage (in the order of decades (Allen et al., 2020[106])). The risk of non-permanence of stored emissions from these activities is high, for instance due to forest fires or other natural phenomena (see Box 2.2).

Source: Authors

[15] This is because "emission reduction" activities can issue credits if the GHG emission of the implemented activities are lower than the emissions of a counterfactual business-as-usual scenario – this is how the term "emission reduction" activities is generally used in literature related to carbon credits and their issuance. This paper acknowledges that this definition is broad and could lead to counterintuitive results (e.g. absolute increase of emissions) given the range of possible outcomes.

Table 5.1. Categorisation and main characteristics of carbon credits issued in international carbon

Category of mitigation activities	Sub-category	Storage of emissions	Risk of non-permanence of stored emissions	Example of activities
Emission reduction	Emission reduction without storage	No	N/A (None)	Energy efficiency measures, methane or nitrous oxide abatement and the installation of new renewable energy activities in a grid where fossil fuel activities were originally planned instead
	Emission reduction with storage	Yes	Low	CCS installation on a fossil-fuel power plant or on an industrial facility
Emission avoidance	Emission avoidance	Yes	High	Non-exploitation of fossil fuel reserves, avoided deforestation
Emission removal	Emission removal technologies	Yes	Low	CDR technologies (DACCS, BECCS, EW)
	Nature-based solutions	Yes	High	A/R, biochar, soil carbon sequestration

Notes: N/A = not applicable; CCS = carbon capture and storage; CDR = carbon dioxide removal; DACCS = direct air carbon capture and storage, BECCS = bioenergy with carbon capture and storage; EW = enhanced weathering; A/R = afforestation and reforestation.
Source: Authors, based on (Allen et al., 2020[106]) (La Hoz Theuer et al., 2021[13]).

Activities issuing carbon credits can have significantly different impacts on the atmosphere. For example, installing a new renewable energy plant as an addition to the grid (an "emission reduction" activity) would *reduce* emissions that could have been emitted into the atmosphere if a fossil fuel plant was implemented instead. Such an activity would prevent additional future emissions from being emitted (thus preventing the addition of further GHGs to the current stock), but it would not *remove* GHGs from current concentration levels in the atmosphere. Conversely, technology-based CDR approaches (see Box 2.2) allow for the *removal* of emissions from the atmosphere, resulting in an absolute reduction of atmospheric GHG concentrations levels. This means that GHGs previously emitted in the atmosphere could technically be removed by CDR technologies and permanently stored.[19]

[16] This paper recognises that, based on CDM experience, there might, in theory, be another sub-category of emission avoidance activities consisting of those activities that could issue credits from avoiding the adoption of a more carbon-intensive process or practice compared to the baseline, e.g. issuance of credits for not switching from biomass-generated power to coal. However, since credit issuance from this type of activities has had very limited application (if at all) and their application would not be consistent with a net-zero pathway, these activities are not further discussed.

[17] "Emission removal" activities are often referred to as "carbon removal" activities because to date the majority of CDR technologies are able to only remove CO_2 emissions from the atmosphere. Removal technologies for other GHGs are still at very early development stages (La Hoz Theuer et al., 2021[13]).

[18] The risk of non-permanence of emission removals refers to the situation whereby emissions removed by a project activity are later reversed and re-emitted in the atmosphere. This can occur due to natural phenomena (e.g. a forest fire in A/R projects) or human mismanagement (e.g. in CDR projects).

[19] This focuses on a "static" view of the atmospheric emission concentration, and does not necessarily fully capture the "dynamic" flow of GHG emissions in the atmosphere.

5.2. The role of international carbon markets in achieving net-zero targets

The different types of activities that can issue carbon credits described in Box 5.1 and summarised in Table 5.1 are likely to have different impacts on countries' pathways to achieving net-zero emissions. This sub-section describes countries' approaches to the proposed use of international carbon markets in their net-zero plans, explores the possible dynamics of using international carbon markets to achieve net-zero targets, from both the supply and demand side, and why the role of international carbon markets will be increasingly limited over time.

5.2.1. Countries' approaches to using international carbon markets to meet their net-zero commitments

In documents setting out their net-zero targets, the majority of countries do not specify if and how they intend to use international carbon markets. As of 1 October 2021, 10 of the 51 countries and the EU analysed in this paper have indicated (either in the same pledge or in another policy document) a clear *intention* to use international carbon markets as part of their climate strategy to achieve their climate target. Some countries have also expressed the *possibility* of using international market mechanisms and co-operative approaches under Article 6 of the Paris Agreement to meet their NDCs, representing collectively (combined with those who expressed *intention*), 71% of new or updated NDCs as of July 2021 (UNFCCC, 2021[7]).

Countries are adopting different approaches to the use of international carbon markets in their plans to reach net-zero. Some countries have explicitly ruled out the use of international carbon markets to achieve their net-zero target, such as France (Government of France, 2020[45]) or Finland (Government of Finland, 2021[38]). Some countries, such as Sweden, allow the use of international carbon markets to support their net-zero target, but specify an upper limit to this use (Sweden's Ministry of Enviornment, 2021[109]).[20] Other countries, such as Switzerland (Federal Council of Switzerland, 2021[110])[21], indicate their intention to use international carbon markets to support their net-zero target without specifying any quantitative limits on use. In some countries such as the UK there is a lack of clarity on the Government's approach to the use of international carbon markets in reaching their net-zero target ((UK Government, 2019[111]) (UK Parliament, 2019[112])), although the CCC recommendation left the use of international carbon credits open in a way that would allow the UK to go beyond meeting domestic goals (Climate Change Committee, 2021[113]). In certain cases, the lack of agreed rules on Article 6 may prevent some countries from elaborating more definitive strategies.

To improve understanding of the role of international carbon markets as a potential tool for reaching countries' net-zero targets, more countries could clarify their position on certain aspects such as:

- **The timeframe in which countries intend to use international carbon markets**: i.e. as a short-term "transitional" tool to help decarbonise hard-to-abate sectors, or as a structural tool that will be used systematically until the target is reached and beyond;
- **Intended participation as buyers, sellers or both:** i.e. whether a country intends to host activities and sell credits, or purchase credits, or both. In some cases this role is implicitly defined in other documents. For instance, bilateral agreements Switzerland has stipulated with other countries for

[20] Sweden's climate policy framework stipulates that 15% of emission reductions of their 2045 net-zero emissions goal "can be achieved through supplementary measures such as increased carbon sequestration in forest and land, carbon capture and storage technologies (CCS) and emission reduction efforts outside of Sweden" (Sweden's Ministry of Enviornment, 2021[109]). The latter element refers to the use of international carbon markets.

[21] Switzerland's long-term strategy indicates that "internationally Switzerland advocates binding and effective rules on the allowability of reductions abroad (Article 6 of the Paris Agreement) and is already considering bilateral cooperation with various states" (Federal Council of Switzerland, 2021[110]).

implementing its commitments under the Paris Agreement suggest that it would participate as a buyer (Swiss Federal Office for the Environment, 2021[114]);

- **The level of crediting from international carbon markets to be used by the country for reaching its net-zero target**: i.e. the extent to which a country intends to participate in international carbon markets. Some countries, such as Sweden have set an upper limit to the level of carbon crediting that could be used to reach their net-zero target (Sweden's Ministry of Enviornment, 2021[109]). Other countries such as the Maldives, have indicated that it is not possible to determine their level of participation in international carbon markets without agreed rules on Article 6 (Ministry of Environment of the Maldives, 2020[115]).
- **The use of international carbon credits in a net-zero strategy:** e.g. if (and how) credits will be accounted towards their overall goal, or if credits will be used as an additional lever on top of domestic mitigation action (e.g. voluntarily cancelled).

5.2.2. Potential changes to international carbon market dynamics in a net-zero context

The significant levels of emission reductions and removals needed to reach global net-zero are likely to alter the dynamics of international carbon markets on both the supply and demand sides. Figure 2.1 in Section 2. illustrates some possible pathways to reducing global emissions to limit global warming to 1.5°C. All sectors will need to drastically reduce GHG emissions (IPCC, 2021[4]). However, some sectors are particularly hard to abate, such as heavy industry and long-distance transport (IEA, 2020[116]) (IEA, 2020[117]) (IEA, 2021[12]), or have process emissions that are difficult to avoid with currently-available processes or technologies, for instance methane emissions from livestock. This means that a certain level of annual residual emissions from these sectors is likely to remain and will need to be balanced by at least an equivalent amount of annual emission removals.[22] However, some countries might not have the opportunity to develop large-scale CDR activities within their geographical boundaries at the scale needed to balance their residual emissions. For these countries international co-operation, including through international carbon markets, could be essential to achieve their net-zero target. Moreover, given the time it will take to implement the deep transitions needed to reach net-zero, international carbon markets could be used in the short-term as a transitional measure, in parallel to deep domestic decarbonisation activities, to accelerate the global transition to net-zero.

It is important to distinguish between the need for certain types of activities to reach net zero globally (and how this will evolve over time), and their suitability to issue credits in international carbon markets. The types of activities (emission reduction, avoidance and removal) described in Box 5.1 are all essential to achieve global net-zero, though their relative levels are still debated in the literature (La Hoz Theuer et al., 2021[13]), and will need to be supported by a suite of policies and instruments, which could include international carbon markets. However, not all types of activities are suitable to being supported by international carbon markets in a net-zero context. For instance, emission avoidance activities will be less suitable to issuing credits through international carbon mechanisms because of their high vulnerability to the risk of non-permanence (see discussion in sub-section 5.2.3).

5.2.3. The supply side – the perspective of a seller country

In a pathway to net-zero, international carbon markets have the opportunity to become instruments to harness "high-hanging fruit" mitigation opportunities. To date, seller countries have mostly focused on

[22] This paper acknowledges that the future removal of 1 tCO_2-eq does not have the same cooling effect in the atmosphere as the warming effect of 1 tCO_2-eq already emitted (see (Keller et al., 2019[178])). This means that a simple equilibrium equation between emissions and removals (i.e. having the same amount of tCO_2-eq emitted and removed) in a certain year is likely not to be sufficient to achieve real net-zero.

supplying credits to meet demand for low-cost mitigation opportunities in order to optimise the overall economic efficiency of using international carbon markets to meet mitigation goals. As such, mitigation opportunities have been "low-hanging fruit", i.e. cheaper and easier to implement. This focus was possible because, under the Kyoto Protocol regime, only developed countries (buyers) had emission mitigation targets and there was no accounting obligation on the seller country under the Clean Development Mechanism (CDM).

Under the Paris Agreement, all countries have a mitigation commitment through their NDC. The framework for trading under the Paris Agreement will be further negotiated at COP26 and will also provide the requirements of those actors involved in ITMOs transfers. This could include explicit authorisation by seller country governments of the international transfers of ITMOs for use towards an NDC or for other international mitigation purposes (Lo Re and Ellis, 2021[118]). Article 6.2 of the Paris Agreement would also provide for the avoidance of double counting, which could mean i.a. that countries hosting mitigation activities cannot both sell credits from the emission reductions or removal activities and also use them domestically towards their NDC. Moreover, if a (seller) country A wants to transfer an ITMO to another (buyer) country B for use towards the NDC of country B, a corresponding adjustment will be applied to the NDC emission balance of the seller country A and of the buyer country B (Lo Re and Vaidyula, 2019[119]).[23] This means that if the seller country A sells its cheapest emission mitigation opportunities, this would raise the domestic costs of reaching its own NDC.

The host Party provisions within the framework of Article 6 (Lo Re and Ellis, 2021[118]) are expected to provide seller countries the opportunity to authorise the international transfer of ITMOs for certain types of "high-hanging fruit" mitigation activities, to take into account i.a. the constraints associated with meeting their own NDC emission targets. For technology-based mitigation actions, "high-hanging fruit" opportunities could include technologies that have a high mitigation potential and face large-scale deployment and cost barriers, for example crediting from technology-based CDR approaches, such as DACCS. A recent related example is the joint declaration of intent between Switzerland and Iceland, signed in July 2021, to co-operate on technology-based CDR approaches through Article 6 (Swiss Federal Office for the Environment and Ministry for the Environment and Natural Resources of Iceland, 2021[120]). For mitigation actions not based on technology, such as NBS, or that are small scale, such as the installation of more efficient cook stoves, sustainable development co-benefits could be another important criterion to consider when assessing "high-hanging fruit" activities. The co-benefits could vary substantially from activity to activity, e.g. from improved air quality to the protection of biodiversity. Far-reaching mitigation impacts could also be achieved through demand-side transformation activities, such as energy conservation, shifting diets or rethinking urban spaces. There is limited experience in issuing carbon credits from some of these demand-side activities, however some approaches are emerging (see for instance (Butzengeiger et al., 2021[121]).

Supply of different types of carbon credits in a net-zero context

The change of focus of the supply side of international carbon markets and the context of reaching net-zero emissions globally, will mean re-examining what role different types of carbon credits could play in achieving this goal. To date, the overwhelming majority of credits have been issued to international carbon markets by emission reduction activities without storage, and to a minor extent from NBS and emission avoidance activities (UNEP DTU Partnership, 2021[122]). In a pathway to net-zero, while all types of

[23] The paper acknowledges that there is currently no consensus among negotiating Parties on certain cases for the application of corresponding adjustments (e.g. accounting for Article 6.4 Emission Reductions from outside NDCs). The arguments presented in this paper are purely illustrative and without prejudice to the outcomes of negotiations at COP26.

activities (emission reduction, avoidance and removal) are needed, their suitability to issue credits in international carbon markets varies as elaborated below:

- **Carbon credits from emission reduction activities (with and without storage)** could be useful in the shorter-term to provide an extra revenue stream to emission reduction activities. International carbon markets could over time gradually veer towards crediting from activities that imply an absolute GHG emission reduction[24] and those with storage, rather than activities which increase absolute GHG emissions at a slower rate than a counterfactual baseline. At the same time, as governments reduce emissions and the cost of low-carbon technologies decrease, further reducing residual emissions is likely to become more costly and technically complicated over time.[25] For seller countries, this would mean that revenues from emission reduction credits might peak and decline before 2050, even as the price of carbon credits rise.
- **Credits issued from emission avoidance activities** might not be compatible with a net-zero emissions pathway and might have to be gradually discontinued from international carbon markets, as they are highly vulnerable to the risk of non-permanence of stored emissions. Such activities might be more suited for funding through other policy instruments.
- **Removal credits from technology-based CDR approaches** could play an increasingly important role in the future on the pathway to net-zero emissions ((Allen et al., 2020[106]); (La Hoz Theuer et al., 2021[13]); (Carrillo Pineda, Chang and Faria, 2020[123]); (IIGCC et al., 2021[124]); (World Bank, 2021[125])). International carbon credits could help scale-up the deployment of technology-based CDR approaches by generating an extra revenue stream to de-risk their investment and operations. The supply of removal credits issued by technology-based CDR approaches is likely to increase substantially closer to mid-century. The credits generated by these technologies, especially DACCS, could also have multiple advantages. For instance, while there is still limited experience with removal credits issued by CDR technologies, their monitoring, reporting and verification (MRV) systems and the methodologies to calculate emissions removed could be simplified compared to carbon credits issued from emission reduction or avoidance projects. This would also represent an opportunity to streamline transaction costs associated with the issuance of carbon credits. However, carbon crediting methodologies for technology-based CDR approaches are limited in terms of their technological scope and geographical application[26]. A number of actors have started addressing this issue, e.g. through the CCS+ initiative (CCS+ Initiative, 2021[126]). One important consideration is that the availability of removal credits issued by technology-based CDR approaches will be limited by the global removal capacity of these technologies, which could be constrained by several factors, including land and storage site availability (see Box 2.2).
- **Removal credits from NBS** could play a role in the pathway to net-zero although the literature is divided on this issue. Some argue that CO_2 absorption by NBS is land- and time-limited and will not be enough to compensate for the increasing rate of emissions in the atmosphere (Waring, 2021[127]) and that CDR technologies should rather be prioritised because of the lower risk of non-permanence compared to more vulnerable NBS (Allen et al., 2020[106]). Others argue that the risk of non-permanence associated with NBS can be methodologically addressed by using buffer accounts, which transfer the non-permanence risk from single NBS projects to a large pool of

[24] Potentially also including those emission reduction activities that lower the GHG emission intensity linked to the production or use of goods and services, if they lead to an absolute GHG emission reduction.

[25] This assumes that the "low-hanging fruit" mitigation action (e.g. low-cost, technologically mature) will be implemented first. This paper also recognises that each country has different starting points and will face unique pathways to net-zero, so this statement might not hold true for each specific countries' circumstances.

[26] See for instance the Carbon Dioxide Capture and Storage Working Group in the CDM (UNFCCC, 2021[179]).

projects[27], and that NBS can bring sustainable development co-benefits to local communities and biodiversity that CDR cannot (Ecosystem Marketplace, 2021[128]). Another important consideration for removal credits from NBS is that their availability will be limited by global removal capacity including land availability.

5.2.4. The demand side – the perspective of a buyer country

In the context of net-zero commitments, buyer countries could see international carbon markets as an opportunity to raise their climate ambition, and not just as a means to cost-effectively achieve their mitigation targets, as was the case under the Kyoto Protocol. Indeed, Article 6 of the Paris Agreement is intended to "allow for higher ambition" in countries' mitigation and adaptation actions (UNFCCC, 2016[129]). In this sense, the purpose of Article 6 is not only to allow buyer countries to reach their NDC targets in a more cost-effective way[28], but rather to "go above and beyond the fastest technically feasible decarbonisation pathway within a country's borders" (Kachi et al., 2019[130]).[29]

The rapid decarbonisation needed to reach net-zero (Masson-Delmotte et al., 2021[131]) would see emissions in many countries go into structural decline, requiring fewer credits to achieve net-zero targets closer to mid-century. Considering this and the supply dynamics mentioned in the previous sub-section, the global demand for international carbon credits to reach countries' net-zero goals is likely to peak and decline before 2050.

In a net-zero pathway, buyer countries could consider international carbon markets as a supplement to domestic mitigation action and a way to increase their overall climate mitigation target beyond their most ambitious domestic decarbonisation pathway. However, if international carbon credits are used as a substitute for domestic efforts, this could risk delaying or preventing investment in domestic mitigation measures which will make reaching net-zero more technically difficult and costly in the long-term. Another risk is that, if international carbon markets do not have robust environmental integrity, they could lead to an increase in both absolute GHG emissions and the cost of achieving climate targets (EDF, WWF-US and Oeko-Institut, 2020[132]). Other risks relate to non-issuance of carbon credits due to technology failure; lock-in of high-emitting technologies and infrastructure; the potential lack of emission reduction credits as the world decarbonises, and reputational risks (Kachi et al., 2019[130]).

Furthermore, new risks are emerging with the increasing interest in voluntary carbon markets such as the risk of double counting of emissions and emission reductions between corporates (which widely use the Corporate GHG Protocol) and governments (which report their emissions in GHG inventories) – an example of this risk is illustrated in (CPLC, 2021[21]). Voluntary carbon markets are heterogeneous and there is a lack of an agreed common standard (World Bank, 2021[125]), thus differing crediting activities follow different standards with varying levels of environmental integrity. Potential interactions between the future developments of voluntary carbon markets to reach corporate net-zero targets and international carbon markets for achieving countries' net-zero targets are still unclear and yet to be explored.

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[27] This concept consists of a risk mitigation strategy whereby in case of reversals of GHG emissions (e.g. due to forest fires or other natural phenomena) an equivalent amount of credits is cancelled from the pool, so that the reversed GHG emissions are taken into account and permanence is in theory mathematically ensured.

[28] A modelling exercise has shown that allowing countries to voluntarily co-operate through Article 6 of the Paris Agreement could reduce the total cost of implementing NDCs by approximately USD250 billion per year in 2030 (IETA, University of Maryland and CPLC, 2019[180])

[29] The same modelling study cited in the previous footnote also estimated that, if all the savings from NDC implementation were reinvested in further emission reductions, this would help close the ambition gap and the overall global reduction of GHG could be increased by around 5 billion tCO_2e per year in 2030 (IETA, University of Maryland and CPLC, 2019[180]).

Another risk could stem from the type of credits that buyer countries rely on over time to reach their net-zero target. (Allen et al., 2020[106]) argue that a portfolio of net-zero aligned credits would over time gradually phase out credits from emission avoidance activities, reduction activities without storage and NBS, in favour of credits from technology-based CDR approaches. These removal credits could help scale-up the deployment of technology-based CDR approaches. In theory, at the individual country level, this progression could align an individual buyer country's international credits portfolio with a global net-zero pathway. However, in practice, at the aggregate level, if many countries (and potentially other actors, such as corporates) rely on credits from technology-based CDR approaches to reach their net-zero targets, this might lead to a global shortage of these types of credits in the future as the availability of land and storage sites limit the global removal capacity of CDR approaches.

To avoid these risks, carefully assessing the demand for international carbon credits is an essential component of a well-planned net-zero strategy. The above points highlight that international carbon markets have the opportunity to help countries focus on the quality of mitigation actions exchanged (e.g. "high-hanging fruit" mitigation opportunities) rather than on the quantity (or volume) of credits issued and transferred from activities that are easier and less costly to implement.

6. Conclusions

To reach the global temperature goal of the Paris Agreement, Parties aim to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (UNFCCC, 2016[2]). The rationale for reaching net-zero emissions was further supported by the subsequent 2018 IPCC Special Report (IPCC, 2018[3]) and reiterated in the 2021 Working Group I contribution to the IPCC's Sixth Assessment Report, which notes that limiting global warming requires reaching at least net-zero CO_2 emissions, along with strong reductions in other GHG emissions. The timeline for reaching net-zero varies, for example in scenarios that start in 2015 and have very low and low GHG emissions, limiting global warming to between 1°C to 2.4°C by 2100 requires CO_2 emissions to reach net-zero around or after 2050 and then reach varying levels of net-negative CO_2 emissions (IPCC, 2021[4]).

Against this context, the last few years have seen a considerable rise in the number of net-zero commitments put forward by countries, sub-national governments and companies. According to analysis carried out for this paper, as of 1 October 2021, 51 countries and the EU have adopted net-zero emissions targets that are in law, proposed in legislation, or included in national policy documents. These targets cover around 65% of global CO_2 emissions. Many more countries are considering similar targets and over 4,500 non-state actors have joined the "Race to Zero" campaign (UNFCCC, 2020[11]).

Countries are adopting diverse approaches across key dimensions of their net-zero targets. Some key differences and similarities across countries' net-zero targets include the following:

- **Target status:** Countries have chosen different approaches to integrating net-zero commitments in their national policy frameworks. Of the 52 net-zero targets analysed, 17 have been enshrined in law, 4 are in the process of being adopted in the national legislature, and 31 are reflected in an official national policy document, including NDCs and LT-LEDS.
- **Terminology used:** Countries adopt different terms in defining their net-zero commitments (e.g. net-zero, climate neutrality, GHG neutrality, carbon neutrality) which in some cases is misleading (e.g. carbon neutrality used for a target that covers all GHGs) or confusing (e.g. different terms used interchangeably in the same policy document or in different documents).
- **Scope of GHG emissions:** While most net-zero targets analysed are understood to cover all GHG emissions, some countries exclude selected GHG emissions from the scope of their net-zero target (e.g. biogenic methane in New Zealand). In some cases there is ambiguity on the scope of GHG emissions covered (e.g. for certain carbon neutrality targets).
- **Sectoral coverage:** Most targets analysed in this paper are economy-wide. Some net-zero targets exclude certain sectors (e.g. Sweden's net-zero target excludes emissions and uptake from the LULUCF sector[30]). Emissions from international aviation and shipping are excluded in most countries' targets assessed in this paper, with a few exceptions (e.g. the UK). Some countries have committed to reviewing this exclusion at a future date (e.g. New Zealand).

[30] The LULUCF sector can only contribute to Sweden's net-zero target through additional measures to increase carbon sequestration in forests and land (Swedish Environmental Protection Agency, n.d.[51])

- **Timeframe:** While most countries analysed in this paper aim to achieve net-zero by 2050, some countries have adopted earlier targets (e.g. Austria, Finland, Maldives, Sweden, Germany) and others have adopted targets beyond 2050 (e.g. Brazil[31], China, Indonesia).
- **Commitments after net-zero:** Some countries have adopted commitments after reaching net-zero such as maintaining net-zero emissions (e.g. New Zealand) or achieving negative emissions (e.g. Finland, Iceland, EU, Germany, Sweden). These post-net-zero commitments recognise that net-zero emissions is not an endpoint in itself, but rather a milestone to achieving net-negative emissions in the longer term (Rogelj et al., 2021[49]).
- **Emission reductions, removals and use of international carbon markets:** There is currently limited detail available on countries preference or goal when it comes to emission reductions, removals and use of international carbon markets in meeting their net-zero targets. Some countries specify shares or limits on emission reductions and/or emission removals in their overall net-zero target and/or interim targets (e.g. Sweden, EU). Others note the importance of domestic emission reductions (e.g. Denmark, France, UK) and/or enhancing natural sinks to offset remaining GHG emissions (e.g. Costa Rica, Germany, Finland, Iceland, Indonesia, Portugal), with different emphasis and levels of detail provided. Separating emission reduction and removal targets could help enhance transparency, provide direction, and improve clarity on progress.
- **Institutional arrangements and reporting mechanisms:** A number of countries have set up regular reporting and review cycles for their net-zero targets, with some cycles linked to annual financial budget discussions (e.g., Denmark, Sweden) and others linked to processes under the Paris Agreement (e.g. EU, Fiji). A number of countries have established independent expert bodies to provide advice on and/or evaluate progress towards their net-zero (and other climate) targets. Some countries have established committees or councils to provide guidance or coordinate efforts between Government departments and across levels (e.g. with local or regional authorities).
- **Stakeholder engagement:** In some countries, dedicated groups have also been set up to engage with different stakeholders to support implementation of net-zero targets such as businesses and youth (e.g. in New Zealand and Luxembourg). Some countries have established citizen climate assemblies to discuss and recommend specific climate policies (e.g. Denmark, France, Ireland, and UK). In some cases, countries have adopted different approaches in parallel (e.g. an independent expert body, a citizen climate assembly, and stakeholder engagement groups).

Many countries are now turning to the task of translating their net-zero commitments into near-term action and exploring how to manage the transition. A clear plan for the short- and mid-term can help to ensure continued momentum towards a long-term target and support implementation of necessary measures (Falduto and Rocha, 2020[32]). Several countries analysed in this paper have established interim targets as milestones along their pathway to net-zero. Interim targets are usually set 5-10 years ahead and can be either economy-wide or sectoral. NDCs could be a useful tool to periodically set or adjust interim targets as countries progress towards their net-zero targets. The second round of countries' NDCs show an improved alignment between net-zero commitments and mid-term targets. Furthermore, 2030 or 2035 targets included in the mitigation component of countries' NDCs are usually aligned with the interim targets set by the country for achieving their net-zero commitment which represents an improvement compared to the first NDC cycle.

As of 1 October 2021, 32 countries and the EU have submitted a LT-LEDS to the UNFCCC secretariat. Some countries have complemented these documents with specific sectoral plans and implementation roadmaps. Although the process of designing and implementing net-zero targets will be unique to each

[31] For the purposes of analysis in this paper, Brazil's timeline for reaching climate neutrality is considered to be 2060 as public announcements suggesting Brazil will bring forward its target date to 2050 have not been clarified in a policy document as of 1 October 2021.

country, there are some emerging lessons from experiences which could be useful. Experiences in Costa Rica, Fiji, South Africa and the UK explored in this paper provide insights on different approaches to setting and reaching net-zero commitments, such as nesting different types of policies, aligning investment plans and implementation roadmaps, and linking company and country net-zero targets to support implementation; the importance of inclusive processes for buy-in; and the role of independent expert bodies alongside regular, transparent review processes in helping to keep on track to net-zero.

The majority of countries analysed in this paper have not yet specified if and how they intend to use international carbon markets in meeting their net-zero targets. The few countries that do, take different approaches. Some countries are waiting for agreed rules on Article 6 to define their strategies. To improve understanding of the role of international carbon markets as a potential tool for reaching countries' net-zero targets, more countries could clarify their position on certain aspects such as whether they will participate as a seller and/or buyer; over which timeframe; the extent to which they intend to use international carbon credits to reach their net-zero target; and if purchased credits will be accounted towards their net-zero target or used in addition to domestic mitigation action.

This paper highlighted that in a pathway to net-zero it would be in the interest of seller countries to sell "high-hanging fruit" mitigation opportunities (e.g. higher-cost abatement options from less deployed technologies with higher mitigation potential, mitigation measures with high levels of sustainable development co-benefits, or demand-side measures with high mitigation potential) and reserve "low-hanging fruit" mitigation opportunities (e.g. cheap abatement options) for the achievement of their domestic net-zero targets. Failing this, the seller country would risk being left with more expensive domestic mitigation options for the achievement of its own net-zero target. Buyer countries could see international carbon markets not only as a means to reach their net-zero goal in a less costly manner but also as an opportunity to raise their climate ambition.

There are opportunities and risks associated with using different types of carbon credits to reach countries' net-zero targets. Not all types of mitigation activities are equally suitable for issuing credits in international carbon markets in a net-zero context. For instance, crediting from emission avoidance activities (e.g. non-exploitation of fossil fuel reserves, avoided deforestation) may not be aligned with net-zero pathways as these activities are highly vulnerable to the risk of non-permanence of stored emissions. Conversely, removal credits by technology-based CDR approaches could play an increasingly important role in the future to achieve net-zero emissions, but their availability will be limited by global removal capacity and domestic land and land-based storage site constraints. Furthermore, given the deep decarbonisation needed to reach net-zero, if all countries rely heavily on international carbon markets to achieve their own net-zero target, this could put at risk the achievement of net-zero globally. It would thus be important for individual countries to carefully assess their use of international carbon markets as part of their net-zero implementation plans, and for any such use to be accompanied in parallel by rapid and deep domestic decarbonisation to reduce the absolute level of demand for international credits over time.

Analysis in this paper has shown how the conversation on net-zero has evolved in the last few years from a scientific concept to a central pillar of efforts to support the global temperature goal. The growing number of net-zero targets put forward by countries to date provide welcome signals of intent. However, as elaborated in this paper, countries' net-zero targets are diverse and difficult to compare. Moreover, many details are currently unclear, in particular how countries will meet their commitments and the balance between emission reductions, removals and the use of international carbon markets in reaching net-zero. The devil is in the details as the approach taken toward different dimensions of net-zero targets can have very different outcomes. Greater clarity on key dimensions of countries' net-zero targets is important to better understand net-zero targets, how they interact with each other, and their overall implications for achieving the temperature goal of the Paris Agreement.

Annex A. List of countries with net-zero targets

Table A.1. List of countries with net-zero targets in law, in proposed legislation or in a national policy document, as of 1 October 2021

Country / Regional organisation	Target status	Source
Andorra	In Policy Document	(Government of Andorra, 2020[133])
Antigua and Barbuda	In Policy Document	(Government of Antigua and Barbuda, 2021[134])
Argentina	In Policy Document	(Government of Argentina, 2020[135])
Austria	In Policy Document	(Government of the Republic of Austria, 2020[136])
Brazil	In Policy Document	(Government of Brazil, 2020[86])
Cabo Verde	In Policy Document	(Government of Cabo Verde, 2021[87])
Canada	In Law	(Government of Canada, 2021[137])
Chile	In Proposed Legislation	(Government of Chile, 2020[138])
China (People's Republic of)	In Policy Document	(Government of the People's Republic of China, 2021[77])
Colombia	In Proposed Legislation	(Government of Colombia, 2021[139])
Costa Rica	In Policy Document	(Government of Costa Rica, 2020[98])
Denmark	In Law	(Government of Denmark, 2020[68])
Dominican Republic	In Policy Document	(Government of the Dominican Republic, 2020[140])
European Union	In Law	(Official Journal of the European Union, 2021[58])
Fiji	In Law	(Government of Fiji, 2021[103])
Finland	In Proposed Legislation	(Government of Finland, 2021[38])
France	In Law	(Government of France, 2019[43])
Germany	In Law	(Government of the Federal Republic of Germany, 2021[141])
Grenada	In Policy Document	(Government of Grenada, 2020[142])
Hungary	In Law	(Government of Hungary, 2020[143])
Iceland	In Law	(Government of Iceland, 2021[144])
Indonesia	In Policy Document	(Government of Indonesia, 2021[145])
Ireland	In Law	(Government of Ireland, 2021[73])
Italy	In Policy Document	(Government of Italy, 2021[146])
Japan	In Law	(Government of Japan, 2021[147])
Korea (Republic of)	In Law	(Government of the Republic Korea, 2021[37])
Lao People's Democratic Republic	In Policy Document	(Government of Lao People's Democratic Republic, 2021[148])
Latvia	In Policy Document	(Government of Latvia, 2019[149])
Liberia	In Policy Document	(Government of Liberia, 2021[150])
Luxembourg	In Law	(Government of Luxembourg, 2020[56])
Maldives	In law	(Government of Maldives, 2021[151])
Marshall Islands	In Policy Document	(Government of the Marshall Islands, 2018[91])
Monaco	In Policy Document	(Govenrment of Monaco, 2020[152])
Namibia	In Policy Document	(Government of Namibia, n.d.[153])
Nepal	In Policy Document	(Government of Nepal, 2020[154])
New Zealand	In Law	(Government of New Zealand, 2019[48])
Panama	In Policy Document	(Government of Panama, 2020[155])
Papua New Guinea	In Policy Document	(Government of Papua New Guinea, 2020[156])
Portugal	In Policy Document	(Government of Portugal, 2019[157])
Seychelles	In Policy Document	(Government of Seychelles, 2021[158])

Singapore	In Policy Document	(Government of the Republic of Singapore, 2020[159])
Slovak Republic	In Policy Document	(Government of the Slovak Republic, 2019[160])
Slovenia	In Proposed Legislation	(Government of Slovenia, 2019[161])
Solomon Islands	In Policy Document	(Government of the Solomon Islands, 2021[162])
South Africa	In Policy Document	(Government of South Africa, 2020[78])
Spain	In Law	(Government of Spain, 2021[53])
Sri Lanka	In Policy Document	(Government of Sri Lanka, 2021[163])
Sweden	In Law	(Government of Sweden, 2017[57])
Switzerland	In Policy Document	(Government of Switzerland, 2020[89])
Ukraine	In Policy Document	(Government of Ukraine, 2021[164])
United Kingdom	In Law	(Government of the United Kingdom, 2019[52])
United States	In Policy Document	(Government of the United States, 2021[88])

Source: Authors.

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