



# INSIGHTS ON THE FIRST 29 LONG-TERM CLIMATE STRATEGIES SUBMITTED TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

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## EXECUTIVE SUMMARY

### Highlights

- Parties to the Paris Agreement are invited to communicate “long-term low greenhouse gas (GHG) emission development strategies” (long-term strategies or LTSs), laying out detailed plans for reaching midcentury climate and development objectives.
- By the end of June 2021, 29 parties had formally submitted an LTS to the United Nations Framework Convention on Climate Change (UNFCCC), representing 42 countries and 28 percent of global GHG emissions.
- This paper surveys these 29 LTSs, identifying common trends and transformations these parties envisage across all sectors of the economy.
- We also share our overall reflections on the strategies, describing how parties’ approaches to the LTS have evolved over time.

### Context

**Under the Paris Agreement, all parties are invited to communicate “long-term low greenhouse gas (GHG) emission development strategies” (long-term strategies or LTSs).** These strategies lay out the necessary transformations, opportunities, and challenges associated with reaching parties’ midcentury climate and development objectives.

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**By the end of June 2021, 29 parties had formally submitted an LTS to the UNFCCC, representing 42 countries and 28 percent of global GHG emissions.** These strategies cover a diverse array of parties—from large, developed economies such as the United States, the European Union (EU), Japan, and Canada, to major emerging economies like South Africa, to highly vulnerable nations and small island states, such as Benin, Fiji, and the Marshall Islands.

## About This Paper

**The aim of this paper is to provide insights on key elements of LTSs.** We survey the midcentury visions established by parties, the actions they propose to drive immediate action, how they plan to facilitate the transition, and how they aim to ensure their strategies remain relevant and useful over the next 30 years. We also share our overall reflections on the strategies, describing how parties' approaches to them have evolved over time.

## Key Takeaways

**All LTSs set a long-term vision for climate action, covering areas of mitigation, adaptation, and/or development.** All LTSs set quantified midcentury mitigation goals, with many of the more recent strategies (i.e., from 2018 onward) embracing net-zero GHG commitments<sup>1</sup>—a trend seemingly independent of emissions size or stage of economic development. Some strategies also include midcentury goals for adaptation, aiming to avert the worst impacts of climate change by building long-term resilience. LTSs are often framed within a development context, with parties highlighting the links between climate action and sustainable development and reduced poverty and inequality, much in line with the spirit of the Paris Agreement.

**Most LTSs present results of mitigation modeling exercises, illustrating different pathways for achieving parties' long-term visions.** The scenarios often also include information about required emission removals, through both natural sinks and carbon removal technologies. Several economic models also present quantitative data about projected costs and societal cobenefits. The mitigation scenarios included in LTSs vary widely, reflecting national situations and starting points.

**All LTSs envisage fundamental shifts across all sectors of the economy.** In the energy sector, for example, areas of convergence in the LTSs are increased renewable energy usage, including commitments for 100

percent clean electricity, as well as significant improvements in energy efficiency. In the land sector, parties recognize the crucial role for significant abatement as well as natural carbon removal, including enhancing food security and preventing land degradation and encroachment. The requirement for technical carbon removal solutions to balance residual emissions is also often noted across these envisioned sectoral transformations.

**Most LTSs include economy-wide and sector-specific near-term targets, milestones, and action plans. And there are also early indications that LTSs are increasingly informing parties' revised nationally determined contributions (NDCs).** Indeed, NDCs are ideally the shorter-term accountability mechanism for the LTS, providing a stepping-stone toward the midcentury vision. Some recent updated NDCs note either that they align with the long-term target in the party's LTS or that they will need to be updated to achieve this alignment.

**Most LTSs mention the importance of a just transition, recognizing that the future transformations will disproportionately affect those whose livelihoods are tied to a high-carbon economy.** In most strategies, a just transition is notionally addressed, but some parties do provide supplementary details including a phasing approach to the transition, intentions to retrain workers and change school curricula, and a description of means by which to finance the transition. Some parties also describe new job opportunities as well as risks to jobs in sectors that are most vulnerable, and occasionally quantify those impacts.

**All LTSs recognize the impacts of future climatic changes on all sectors of the economy and describe the environmental, social, human, and economic risks from inaction.** However, the level of detail on adaptation in the strategies varies widely. Most LTSs provide high-level narrative or lightly touch on adaptation measures and refer to other national adaptation planning strategies and documents. A few LTSs lead with (or give equal weight to) adaptation, incorporating detailed goals to enhance adaptive capacity, strengthen resilience, and reduce vulnerability.

**All LTSs suggest a commitment to ensure their relevance and longevity.** The strategies often include monitoring and evaluation (M&E) plans to support course corrections when required. Most parties also commit to regularly reviewing and updating their strategies—often in sync with the five-year cycles of the Paris Agreement—to

keep up with the latest science and market developments.

**All LTSs describe how key stakeholders have been and will be consulted in the development and implementation of the strategies.** Some LTSs also recognize the importance of engaging marginalized groups, and several highlight direct consultations with communities that are most impacted by climate change.

**Although LTSs submitted to the UNFCCC are not legally binding themselves, some are bolstered by formal laws.** In some cases, there is a specific legislative mandate to develop an LTS. In other cases, parties' long-term mitigation targets, as communicated by their LTSs, are enshrined in laws. Another set of parties have legislation under development.

**Overall, the tenor of the LTSs has shifted in the last five years.** LTSs are increasingly going beyond a presentation of mitigation modeling results, to further detailing the fundamental economic, technological, and societal shifts that will be required to meet the Paris Agreement goals and national development objectives. Parties are also becoming increasingly frank in their strategies about the challenges (technical, societal, financial) associated with the transition toward low-emissions and climate-resilient development—and the resulting gaps within their strategies, pointing to areas requiring more work.

**There is also a significant and growing movement toward “net-zero” strategies, regardless of emissions size or stage of economic development.** In the last three years, 17 LTSs have included goals for reaching net-zero emissions;<sup>2</sup> 12 of these strategies have been submitted since 2020. Looking ahead—and given the growing momentum for net-zero targets—the number of net-zero strategies is likely to continue to grow quickly.

## 1. INTRODUCTION

Under the Paris Agreement, all parties are invited to communicate “long-term low GHG emission development strategies,” (long-term strategies or LTSs). The accompanying decision text qualifies these strategies to be over a midcentury time frame and to be communicated by 2020 (Decision 1/CP.21, Paragraph 35) (UNFCCC 2015). Due to the COVID-19 pandemic and the resulting delay to United Nations Climate Change Conference of the Parties (COP26), however, many parties have delayed their submission to the end of 2021, if not even later.

LTSs can play an important role in achieving the long-term goal of limiting warming to well below 2°C, or 1.5°C, as these strategies begin to reveal the scale of transformation needed to bring national climate action in line with global ambition. In particular, these strategies can provide a long-term guiding vision to inform near-term decisions, helping to avoid investments that are incompatible with a low-emissions and climate-resilient future.

The aim of this paper is to shed light on the LTSs that have been communicated by parties to the United Nations Framework Convention on Climate Change (UNFCCC) by the end of June 2021. The paper brings out insights about how these parties plan to reorient their economies toward low emissions (and sometimes net-zero) development. Its findings are aimed at policymakers responsible for designing or updating LTSs, who might be interested in how other parties—and particularly regional collaborators or trade partners—are envisioning a low-emissions and climate-resilient future, and the means by which they can get there. The paper is also aimed at members of the international community—nongovernmental organizations (NGOs), multilateral development banks, global coalitions, and so forth—that are working to support the development and implementation of ambitious and robust LTSs.

The paper begins with a high-level overview of the parties that have communicated an LTS and a brief summary about what each strategy contains (Section 2).

The paper then transitions to a deeper examination of the topic areas that are generally found in LTSs. Here, we look across all the strategies, identifying common themes and trends. The topic areas we examine include the following:

- Setting a long-term vision (targets, models, sectoral transitions) (Section 3)
- Guiding near-term action, including links with nationally determined contributions (NDCs) (Section 4)
- Facilitating the transition (just transition, adaptation, international cooperation, and finance) (Section 5)
- Ensuring the longevity of LTSs (governance, engagement, monitoring plans, revision plans) (Section 6)

The paper concludes with a section on reflections, sharing what we are learning about LTSs and how these strategies are changing over time (Section 7).

All information presented in the paper is sourced directly from the LTSs available on the UNFCCC website (UNFCCC 2021) unless otherwise noted. We also take the strategies at face value, presenting information here that is directly communicated within the LTS, recognizing that domestic policies may have changed since a strategy’s submission.

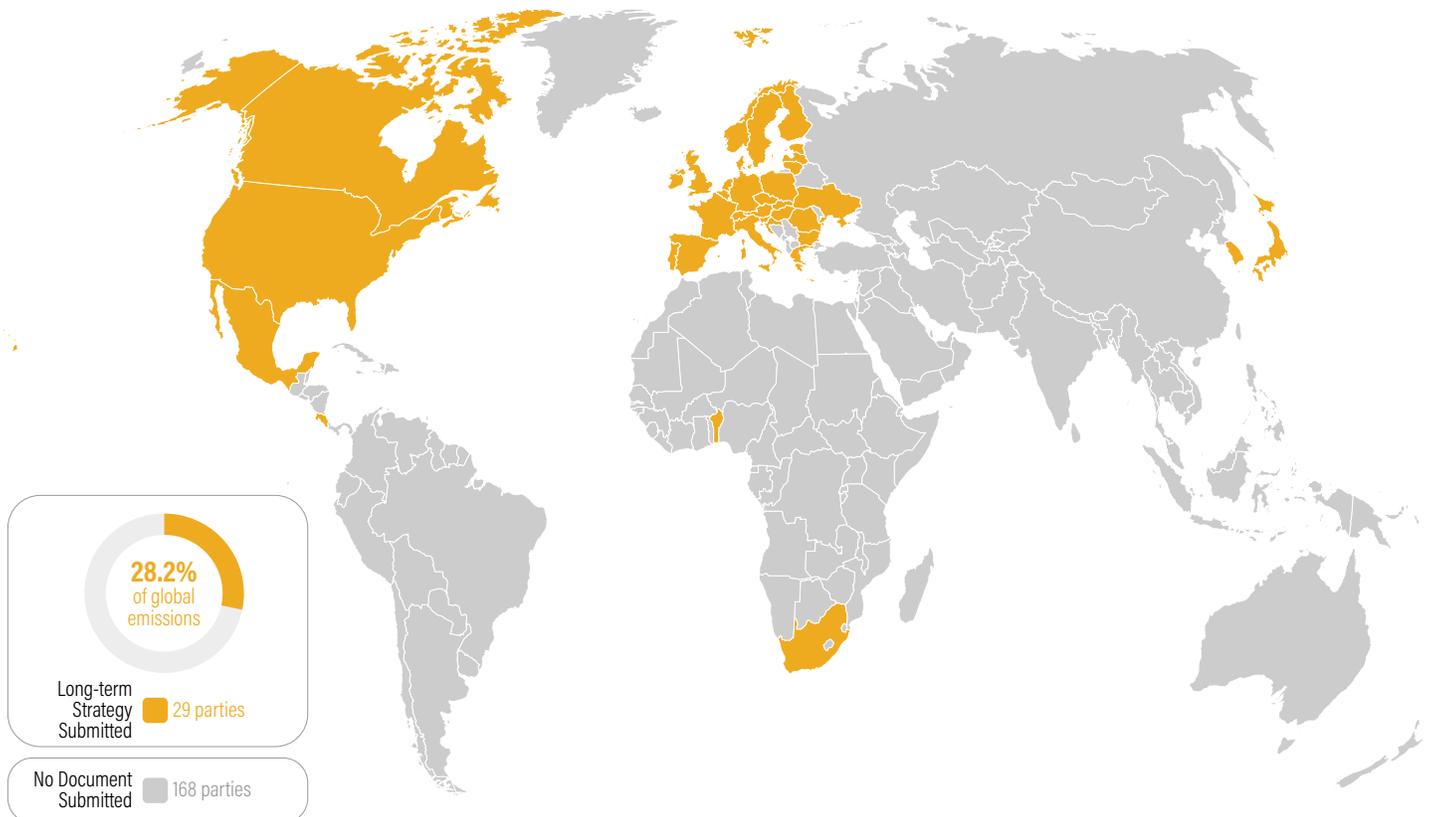
This paper does not offer guidance or recommendations on “best practices” for LTSs. Rather, the paper presents a factual account of the contents of the LTS submitted by end June 2021. If readers are interested in approaches for designing and implementing ambitious and robust LTSs, please refer to guidance from the “Long-term Strategies Project,” as well as the work of other NGOs, coalitions, and initiatives such as the 2050 Pathways Platform. For continued real-time tracking and analysis of LTSs, please visit Climate Watch’s long-term strategy tracker.

## 2. THE BIG PICTURE

By the end of June 2021, 29 parties had formally submitted an LTS to the UNFCCC, representing 28 percent of global GHG emissions (Figure 1). Germany was the first party to communicate an LTS in 2016, followed quickly by Mexico, the United States, Canada, France, and Benin, which also submitted LTSs in the same year. After that, 23 more parties communicated LTSs to the UNFCCC between 2017 and June 2021 (Figure 2). Two parties—France and Germany—have also updated and resubmitted their strategies to the UNFCCC. The majority of LTSs are from high-income or upper-middle-income countries, with several European Union (EU) countries incentivized to do so as part of the EU’s long-term climate and energy planning processes; however, major emerging economies like South Africa, as well as highly vulnerable nations and small island states, such as Benin, Fiji, and the Marshall Islands, have also submitted LTSs.

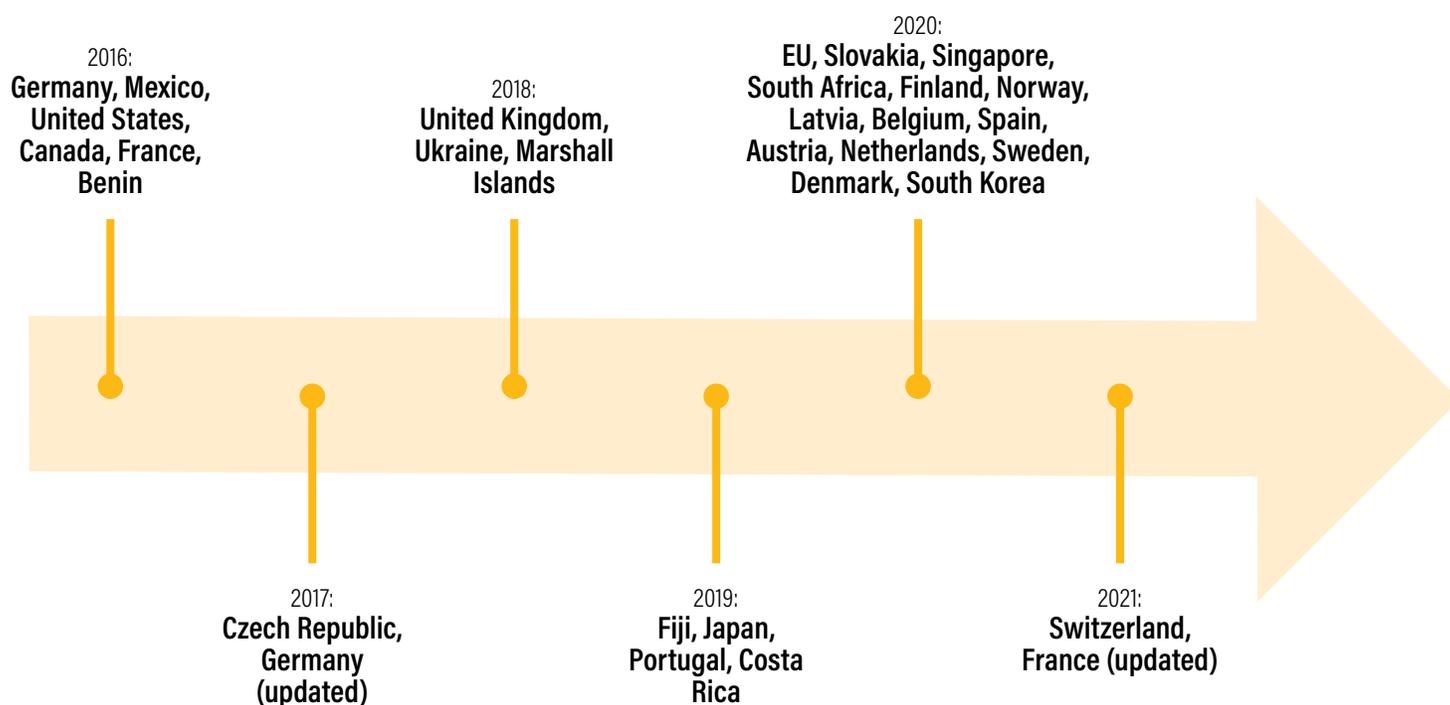
Figure 1 | **Parties That Have Communicated a Long-term Strategy to the UNFCCC, as of June 2021**

**29** Parties had submitted a long-term strategy by June 2021, representing **42** countries



Source: Climate Watch 2021.

Figure 2 | **Time Line of Long-term Strategy Submissions**



*Note:* Ordered by date of submission.  
*Source:* Authors.

Table 1 presents a summary of the contents of the 29 LTSs. Here we look at the elements that are typically covered in an LTS—the long-term vision, near-term implementation, means of facilitating the transition, and processes for ensuring the longevity of the strategies—and mark them according to coverage. A full circle indicates full coverage, a semicircle indicates partial coverage, and an empty circle indicates little or no coverage. Since LTSs are tailored to

national circumstances, some categories may be better covered than others, depending on the strategy. Importantly, these coverage markings are not value judgments or rankings—rather they present a bird’s eye view of the areas of focus on each LTS. We base this summary on the LTS documents alone; this table is not a comprehensive review of all supporting policies.

Table 1 | Summary of the Contents of the Long-term Strategies

● Full coverage    ◐ Partial coverage    ○ Little or no coverage

PARTY	LONG-TERM VISION				NEAR-TERM IMPLEMENTATION		
	EMISSIONS REDUCTION TARGET	MODELED PATHWAYS	SECTORAL TRANSITIONS	TECHNOLOGICAL CARBON REMOVAL INCLUSION	ECONOMY-WIDE GHG MILESTONES	QUANTITATIVE, SECTOR-SPECIFIC MILESTONES	QUALITATIVE PRIORITIES FOR ACTION
Austria	Climate neutrality by no later than 2050	Yes	●	Yes	●	○	●
Belgium	There is no federal-level reduction target in percentage terms, since all Belgian GHG emissions are covered by the emissions of the regions, each of which contains its own substrategy <sup>b</sup>	No	●	Yes	●	●	●
Benin	Avoidance of at least 12 MtCO <sub>2</sub> e and sequestration of 163 MtCO <sub>2</sub> e by 2030	No	●	No	○	○	●
Canada	80% reduction from a 2005 baseline by 2050	Yes	●	Yes	◐	◐	●
Costa Rica	Net-zero emissions by 2050	Yes	●	No	●	●	●
Czech Republic	80% reduction from a 1990 baseline by 2050	Yes	●	No	●	○	●
Denmark	Climate neutrality by no later than 2050	No	●	Yes	●	●	●
European Union (EU)	Climate neutrality by 2050	No	○	No	○	○	○
Fiji	Net-zero emissions by 2050	Yes	●	No	●	●	●
Finland	Carbon neutrality by 2035 and net-negative emissions thereafter	Yes	●	Yes	●	●	●
France	Carbon neutrality by 2050	Yes	●	Yes	●	●	●
Germany	Extensive GHG neutrality by 2050	No	●	No	●	●	●
Japan	80% reduction by 2050 and “a decarbonized society as early as possible in the second half of this century”	No	●	Yes	○	○	●

Full coverage
  Partial coverage
  Little or no coverage

PARTY	FACILITATING THE TRANSITION			PROCESSES TO ENSURE LONGEVITY OF STRATEGIES				
	ADAPTATION	INTERNATIONAL COOPERATION	JUST TRANSITION STRATEGY	INSTITUTIONAL ARRANGEMENTS	LEGAL BACKING <sup>a</sup>	STAKEHOLDER ENGAGEMENT	MONITORING & EVALUATION PLANS	REVIEW & REVISION PLANS
Austria				Yes		Yes	Yes	Yes
Belgium				Yes		Yes	No	Yes
Benin				Yes		Yes	Yes	Yes
Canada				Yes		Yes	No	Yes
Costa Rica				Yes		Yes	Yes	Yes
Czech Republic				Yes		Yes	Yes	Yes
Denmark				Yes		Yes	No	No
European Union (EU)				Yes		Yes	No	Yes
Fiji				Yes		Yes	Yes	Yes
Finland				Yes		Yes	Yes	No
France				Yes		Yes	Yes	Yes
Germany				Yes		Yes	Yes	Yes
Japan				No		Yes	No	Yes

Table 1 | Summary of the Contents of the Long-term Strategies (Cont'd)

PARTY	LONG-TERM VISION				NEAR-TERM IMPLEMENTATION		
	EMISSIONS REDUCTION TARGET	MODELED PATHWAYS	SECTORAL TRANSITIONS	TECHNOLOGICAL CARBON REMOVAL INCLUSION	ECONOMY-WIDE GHG MILESTONES	QUANTITATIVE, SECTOR-SPECIFIC MILESTONES	QUALITATIVE PRIORITIES FOR ACTION
Latvia	Climate neutrality by 2050	Yes	●	No	●	○	●
Marshall Islands	Net-zero emissions by 2050	Yes	●	No	●	◐	●
Mexico	50% reduction by 2050 relative to 2000	Yes	◐	No	●	●	●
Netherlands	95% reduction from a 1990 baseline by 2050	No	◐	Yes	●	●	○
Norway	80–95% reduction from a 1990 baseline by 2050	No	◐	Yes	●	●	●
Portugal	Carbon neutrality by 2050	Yes	●	No	●	◐	●
Singapore	Net-zero emissions "as soon as viable in the second half of the century"	No	●	Yes	○	◐	●
Slovakia	Climate neutrality by 2050	Yes	●	No	●	◐	●
South Africa	212–428 MtCO <sub>2</sub> e in 2050 <sup>c</sup>	No	●	No	●	○	●
South Korea	Carbon neutrality by 2050	No	●	Yes	○	◐	●
Spain	Climate neutrality by 2050	Yes	●	No	●	●	●
Sweden	Net-zero emissions by 2045	Yes	●	Yes	●	●	●
Switzerland	Net-zero emissions by 2050	Yes	●	Yes	●	●	●
Ukraine	31–34% reduction from a 1990 baseline by 2050	Yes	●	No	●	●	●
United Kingdom	80% reduction from a 1990 baseline by 2050	No	●	Yes	●	●	●
United States	80% or more reduction from a 2005 baseline by 2050	Yes	●	Yes	●	●	●

<sup>a</sup> For "legal backing," a full circle means that the long-term target and the development of the LTS are mandated by law; a semicircle means one of the two; and an empty circle means neither.

<sup>b</sup> Belgium's LTS is composed of three separate regional strategies (Wallonia, Flemish, and Bruxelles-Capitale), which collectively cover the entire party's emissions profile. The Wallonia strategy "aims to achieve carbon neutrality by 2050"; the Flemish strategy "aims to reduce greenhouse gas emissions from sectors not covered by [the Emissions Trading System] ETS (so-called non-ETS sectors) by 85% [from a 2005 baseline] by 2050, with the ambition to evolve towards total climate neutrality"; and the Bruxelles-Capitale strategy aims to "[get] closer [to] the European objective of carbon neutrality by 2050." This table was completed based on a review of Belgium's three strategies, which are presented as part of a single document submission to the UNFCCC.

Full coverage
  Partial coverage
  Little or no coverage

PARTY	FACILITATING THE TRANSITION			PROCESSES TO ENSURE LONGEVITY OF STRATEGIES				
	ADAPTATION	INTERNATIONAL COOPERATION	JUST TRANSITION STRATEGY	INSTITUTIONAL ARRANGEMENTS	LEGAL BACKING <sup>a</sup>	STAKEHOLDER ENGAGEMENT	MONITORING & EVALUATION PLANS	REVIEW & REVISION PLANS
Latvia				Yes		Yes	Yes	Yes
Marshall Islands				Yes		Yes	Yes	Yes
Mexico				Yes		Yes	Yes	Yes
Netherlands				Yes		Yes	Yes	No
Norway				No		Yes	Yes	Yes
Portugal				Yes		Yes	Yes	Yes
Singapore				Yes		Yes	No	Yes
Slovakia				Yes		Yes	No	Yes
South Africa				No		Yes	Yes	Yes
South Korea				Yes		Yes	No	Yes
Spain				Yes		Yes	Yes	Yes
Sweden				Yes		Yes	Yes	Yes
Switzerland				Yes		Yes	No	No
Ukraine				Yes		Yes	Yes	Yes
United Kingdom				Yes		Yes	Yes	Yes
United States				No		Yes	Yes	Yes

<sup>a</sup> According to South Africa's LTS, "in the absence of an agreed quantitative articulation of the vision, the national GHG emissions trajectory, as reflected in the National Climate Change Response Policy ... is used as the benchmark against which the performance of [the strategy] will be measured. ... From 2036 onwards, emissions will decline in absolute terms to a range with a lower limit of 212 MtCO<sub>2</sub>e and an upper limit of 428 MtCO<sub>2</sub>e by 2050."

Source: Authors.

### 3. SETTING A LONG-TERM VISION

Setting a long-term vision—a critical component of all LTSs—is a process of looking ahead, envisioning a prosperous midcentury society, and then developing pathways that can be followed to achieve that future. Accordingly, this section examines parties’ midcentury goals, the models they use to envisage pathways for achieving these targets, and the proposed sectoral transitions they cite as critical for achieving their long-term vision.

#### Midcentury Targets

Midcentury targets<sup>3</sup>—including both quantitative and qualitative aspirations—are the backbone of parties’ LTSs, essential for guiding decisions and framing policy priorities. Midcentury targets in the LTSs often include GHG reduction targets as well as qualitative development aspirations, depicting a vision of a thriving, sustainable, and equitable future.

The following trends emerge across the 29 LTSs submitted:

**Parties are increasingly setting net-zero targets<sup>4</sup> in their LTSs, typically for around 2050.** Of the 29 LTSs submitted to date, 17<sup>5</sup> contain an explicit midcentury net-zero target. Twelve of these net-zero targets were submitted in 2020 and 2021 alone, indicating growing global momentum for these types of targets, which is likely to continue in the coming years. (Some parties have also communicated net-zero targets since submitting their LTSs<sup>6</sup>—these are not described further in our analysis, which specifically focuses on the content and targets within existing LTSs.)

**Some midcentury targets cover all GHGs, while some parties exclude certain fluorinated GHGs (F-gases) from their LTSs.** While 15 strategies note that all UNFCCC GHGs—carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF<sub>6</sub>), and nitrogen trifluoride (NF<sub>3</sub>)—are included under their target, others exclude certain F-gases (HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub>) from their coverage. The parties that exclude one or more F-gases from coverage under their midcentury targets are Costa Rica, Denmark, Fiji, the Marshall Islands, Norway, South Africa, South Korea, Sweden, Ukraine, the United Kingdom, and the United States (see Appendix A, Table A2).

**Many parties’ midcentury targets also contain qualitative aspirations for sustaining economic development, reducing poverty, and ensuring decent work and quality jobs.** For many parties, an LTS represents not just a chance to outline a vision for climate change mitigation, but also an opportunity to rethink and improve economic structure. Indeed, Article 2.1 of the Paris Agreement embeds climate action in the context of sustainable development and efforts to eradicate poverty, recognizing that action on climate change and broader progress toward sustainable development are interdependent and mutually reinforcing. In this context, many parties emphasize the ways in which mitigation and development, poverty reduction, and creating a more equitable society go hand in hand. South Korea’s LTS, for instance, views its midcentury target as a stimulus to “open up broader discussions around fair burden-sharing necessary to achieve the ultimate goal of sustainable economic and social prosperity where economic and environmental benefits go hand in hand.” In Fiji, the LTS is seen as an opportunity to deliver “improved livelihoods and quality of life for the poor, decent jobs, enhanced human and social capital, and increased equality.”

**Some parties’ midcentury targets also include goals for adaptation, aiming to avert the worst impacts of climate change by building long-term resilience.** Although the centerpiece of the LTS is typically its midcentury mitigation objective, some parties also acknowledge the role that adaptation and resilience-building must play in securing a prosperous future. Mexico, for example, emphasizes the LTS’ role in providing the “vision, principles, goals, and main lines of action [needed] to build a climate resilient society.” Sweden’s strategy notes “the Government’s objective for the adaptation of society to a change in climate is to develop a long-term sustainable and robust society that actively addresses climate change by reducing vulnerabilities and leveraging opportunities.” (See more on adaptation in Section 5.2).

For more information on midcentury targets, see Appendix A.

#### Modeling and Scenarios

Most LTSs present detailed modeling and scenarios, which illustrate pathways for achieving parties’ long-term visions. These pathways show different policy and technology combinations and trajectories and the associated

emissions through midcentury, shedding light on opportunities and trade-offs. The scenarios often also include information about required emissions removal, through both natural sinks (see Section 3.3.2) and carbon removal technologies (see Section 3.3.4.). Several models also present quantitative data about projected costs and societal cobenefits (e.g., job creation, improved health outcomes, etc.) (see Section 5.1). The mitigation scenarios included in LTSs vary widely, reflecting national situations and starting points.

The following trends emerge across the 29 LTSs submitted:

**The modeled scenarios included in LTSs—often depicting a range of different policy and technology pathways—are illustrative only, not intended to predict or prescribe exact future outcomes.**

Because LTSs are explicitly designed to be realized several decades from now, most parties note that their modeling scenarios are exploratory exercises, serving as examples of what is possible but not meant to predict or prescribe exact future outcomes. Nonetheless, these exercises are essential for providing a sense of the broad combination of measures that must be in place through midcentury and beyond, and for informing decision-makers of the policies and investments that must be made today to ensure the party is on track to reach its midcentury target. As the Czech LTS states, “the above-mentioned scenarios are intended to be illustrative . . . to show that the 2050 target cannot be achieved without the combination of many different measures. . . .”

**Nearly all LTSs that contain mitigation scenarios include a reference or benchmark scenario that projects midcentury emissions if the current policy trajectory does not change.** These scenarios give parties a sense of the urgency and importance of increased ambition by demonstrating how large their emissions would be in 2050 if no further changes from the policies already enacted were implemented, particularly in comparison to where they would need to be to meet the goals of the Paris Agreement.

**Many LTSs with net-zero midcentury targets intend to achieve such targets using significant GHG removal.** Indeed, many parties are projecting residual emissions in the middle of the century, for which they will compensate through GHG removals enabled by in-country natural carbon sinks (see Section 3.3.2) and

engineered removal technologies like carbon capture and storage (see Section 3.3.4). Costa Rica, for example, projects in its “Scenario 1.5°C” (see Appendix B, Table B2) that, in 2050, it will emit 5.5 MtCO<sub>2</sub>e and remove 5.5 MtCO<sub>2</sub>e (through natural sinks primarily). France’s “With Additional Measures” scenario provides another example, as it projects that France’s 80 MtCO<sub>2</sub>e of projected emissions will be balanced by 80 MtCO<sub>2</sub>e of removals to achieve neutrality by 2050.

**The models used to develop mitigation scenarios vary in type and in scope.** While some parties (Austria, Canada, Finland, Slovakia, Sweden, and the United States) design their own models to produce or contribute to the mitigation scenarios deployed within their LTSs, others have opted to tailor generic models to fit their specific national circumstances (see Appendix B, Table B2). One such generic model that is tailored and deployed across multiple LTSs (Austria, Costa Rica, Finland, Portugal, Spain, Sweden, and Ukraine) is the TIMES partial equilibrium model, which determines the energy system that will meet specified energy demands over a specified time horizon at the least cost (*Integrated MARKAL-EFOM System* 2014). Other generic models used in the LTSs submitted to date include, but are not limited to, the LEAP integrated assessment model, the EPPA computable general equilibrium model, and the GCAM integrated assessment model. It is worth noting here that parties frequently deploy multiple models—sometimes both jurisdiction-specific and generic—within their LTSs.

**Several parties acknowledge that they do not yet know how they will meet their midcentury targets.** Recognizing the uncertainty inherent in long-term planning and modeling, Austria, the Marshall Islands, and Slovakia explicitly acknowledge the gaps between their most ambitious emissions reductions and removals scenario and their midcentury target.<sup>7</sup> The Slovakian LTS, for example, notes that “if additional measures are not implemented beyond those used in [the strategy’s] models and scenarios, then Slovakia will not meet [its] climate neutrality target in 2050.” Despite these modeling challenges, all three parties put forward qualitative predictions for how these gaps will ultimately be resolved. All highlight the importance of developing further natural and technological carbon removal techniques; Austria also notes the additional possibility of reliance on renewable energy imports, and the Marshall Islands proposes supplemental dependence on international offsets.

**Parties that do not present detailed mitigation scenarios within their LTSs typically note the need to develop these scenarios soon.** Of the 29 LTSs, 12 do not present detailed modeled pathways for achieving their mitigation targets, but most do express an intention to develop these scenarios in the future. The South African strategy, for example, notes that “sectoral scenario analyses will be required to inform on the range of options,” and that “planning teams with analytical and sectoral expertise will engage in detailed scenario work to develop transformation pathways towards achieving [the] national targets.”

For more information on models and scenarios in LTSs, see Appendix B.

## Broad Sectoral Transitions Envisaged

While mitigation modeling and scenarios provide information about *the extent to which* parties will need to reduce their emissions/enhance their removals to achieve their midcentury targets, sectoral pathways contained within LTSs provide information about *how* such targets will be achieved. This component of the LTS offers guidance about key milestones, policies, technologies, and investments that should be championed to enable sectoral transformation. While not exhaustive of all the sectoral transitions envisaged by countries in the LTS, this section provides a flavor of the transitions that governments envisage in energy supply, land, and the “harder-to-abate” areas of the economy. It also explores the role of carbon removal.

## Energy

Energy production and use account for around two-thirds of global GHG emissions (IEA 2021) and, accordingly, this sector plays an outsized role in parties’ efforts to meet the goals of their LTSs. Moreover, because investment cycles for energy infrastructure are so long, decisions made today have long-term implications for both climate and development goals. Energy planning today which accounts for the long lifetime of infrastructure therefore increases the likelihood of both meeting climate goals and avoiding technology “lock-in,” which can result in substantial stranded assets and act as a drag on economic growth (Tong et al. 2019). The “energy sector,” for the purposes of this section, spans electric power generation, transportation, buildings (heating and cooling), and industry.

When looking across the LTSs submitted to date, common trends include, but are not limited to, the following:

**Most LTSs contain specific targets for the energy sector.** While the economy-wide midcentury target sets the overall vision of the LTS, sectoral and subsectoral targets are often included to provide more detailed guidance about what exactly needs to be done, and by when. Common milestones include, for example, time-stamped commitments to secure 100 percent renewably sourced electricity, phase out coal power plants, phase out internal combustion engines in transport, promote modal shifts in transport, engage in exclusively climate-neutral construction and building development, reduce the energy intensity of existing residential and service buildings, and set industrial emissions reduction targets for the production of glass, ceramics, chemical products, iron and steel, cement, pulp and paper, and other materials. Specific examples within LTSs are the following:

- The United Kingdom’s commitment to phase out unabated coal generation by 2025.
- Fiji’s commitment to achieve 100 percent renewable energy-based electricity by 2030.
- Singapore’s commitment to phase out all internal combustion engine vehicles by 2040.
- Portugal’s commitment to reduce energy-related industry emissions by 72–73 percent by 2050.

**Most LTSs cite the importance of energy efficiency measures across buildings, industry, and transport for reducing emissions and energy costs during the energy sector transition.** Germany’s LTS, for example, takes an “efficiency first” approach to transforming the energy sector, where energy efficiency “is a cross-cutting issue that plays an important role in *every* area of action.” Benin, too, highlights efficiency as its first priority. The United States’ LTS also highlights how energy efficiency benefits can accrue without paying a political cost: “Over the past several years, the United States has demonstrated that programs and standards to improve the energy efficiency of buildings, appliances and vehicles can cost-effectively cut carbon pollution and lower energy bills, while maintaining significant support from U.S. industry and consumers.”

**Most LTSs highlight key energy supply and decarbonization technologies that the party is already using or has plans to develop to achieve emissions cuts in the energy sector.** As shown in Appendix C, the most commonly cited technologies are solar (28 strategies), a combination of onshore and offshore wind (27 strategies), green hydrogen (27 strategies), and biomass/biofuel/bioenergy technologies (27 strategies). In addi-

tion to these technologies, parties have also noted their dependence on or interest in future development of hydropower (20 strategies), carbon capture and storage to clean fossil-based sources (18 strategies, with six more noting that they are researching the technology further before reaching a decision), geothermal (18 strategies), nuclear (16 strategies, with one more party noting that it is researching the technology further before reaching a decision), and wave/tidal (four strategies, with three more parties noting that they are researching the technology further before reaching a decision). While some of these technologies are already well diffused into the country's market, many parties are also acknowledging the role that research and development (R&D) investments will play in advancing further development of newer technologies (see Section 3.3.3).

**Most LTSs emphasize the importance of carbon pricing in facilitating the energy transition.** By placing a price on GHG emissions, a party can incentivize low-carbon energy sources by rendering green alternatives less expensive than their traditional carbon-intensive counterparts. Across the LTSs submitted to date, 20 reference domestic carbon pricing programs that have already been implemented (including the EU Emissions Trading System [ETS]), and 4 more note an intention to develop such a program. The prices associated with carbon pricing programs that have already been implemented range widely, with Singapore currently charging under US\$5/MtCO<sub>2</sub>e and Sweden charging close to US\$120/MtCO<sub>2</sub>e (The World Bank 2021). As a higher carbon price typically incentivizes greater emissions reductions, many parties indicate intention to ratchet up their carbon price over time (e.g., Singapore's LTS notes that the price will double by 2030).

**Parties commit to implementing several other policy instruments targeting their energy sector emissions.** Commonly cited instruments include, but are not limited to, vehicle emissions standards, feed-in tariffs, renewable portfolio standards, removal of fossil fuel subsidies, green labeling standards, regulatory mandates to reduce industrial emissions, and government-funded loan raising and equity financing for green entrepreneurs/companies.

**Most LTSs make mention of the expected cobenefits of energy sector decarbonization.** These benefits include, but are not limited to, job creation, reduced public health impacts from air pollution, economic growth from green exports, and increased energy access and security.

## Land

Transforming agriculture, forestry, and other land use (AFOLU, hereafter referred to as the "land sector") will be critical for meeting the goals of the Paris Agreement to hold the increase in global average temperature to well below 2°C, while promoting economic development. Indeed, while the world will need to feed nearly 10 billion people by 2050 and while agriculture will need to continue to contribute to poverty reduction and inclusive socioeconomic development, emissions from the sector today account for nearly a quarter of all human-caused emissions (Searchinger et al. 2019; Kissinger et al. 2012; (Henders, Persson, and Kastner 2015). At the same time, forests act as a critical carbon sink, soaking up one-third of fossil fuel emissions every year (Pan et al. 2011) but its size and location remain uncertain. Using forest inventory data and long-term ecosystem carbon studies, we estimate a total forest sink of 2.4 ± 0.4 petagrams of carbon per year. (Pg C year<sup>-1</sup>. Transforming the land sector therefore represents a multifold opportunity: it can contribute to both mitigating emissions and sequestering carbon from the atmosphere and storing it in vegetation and soils, while simultaneously safeguarding biodiversity and promoting global development.

The 29 LTSs submitted typically include milestones, policy objectives, and information about promising technologies that will enable land sector transformation to achieve climate and development objectives.

**Some LTSs contain quantified and/or time-bound land-related subsectoral targets, while others include more qualitative aspirations for the land sector transition.** From a quantitative perspective, Costa Rica, for example, commits to increasing forest cover to "at least 60% of the national territory by 2030" (without competing with agricultural needs); Denmark commits to restore or set aside "15,000 hectares of carbon-rich farmland" by 2030. Other LTSs take a more qualitative approach when describing their envisaged land sector transition, noting key shifts that must occur but avoiding hard quantitative targets and deadlines. Examples include Latvia's softer goals of managing all forests "in a sustainable manner" and the United States' intentions to "deliver carbon beneficial forms of biomass" that result in "net reductions of CO<sub>2</sub> emissions to the atmosphere" and "increase carbon sequestration on cropland and grazing lands."

**Most LTSs reference specific decarbonization policies and techniques that could reduce emis-**

**sions from the land sector.** Options that are explored to different extents across LTSs include both supply- and demand-side mitigation measures. Supply-side options include better forestry management (e.g., reducing or avoiding deforestation, reforestation and afforestation, peatland restoration, sustainable forest management) and climate-smart agricultural practices that raise productivity of crops, livestock, and aquaculture while reducing emissions and increasing resilience to climate change (e.g., rotational grazing and improved breeding). Demand-side options that are mentioned include reducing food loss and waste, shifting diets toward less emissions-intensive products (particularly in medium- and high-income countries), reducing demand for timber products, and reducing the amount of land dedicated to bioenergy production.

**Natural carbon removal policies and techniques are complementary to land sector–related decarbonization policies and techniques.** Most parties explicitly note in their LTSs that achievement of their midcentury targets will be contingent on some degree of GHG removals, and many strategies provide additional detail on in-country GHG absorption potential from their land sector.<sup>8</sup> The Portuguese LTS, for instance, notes that preserving and growing the land carbon sink “will have an extremely important impact on reducing the concentration of carbon dioxide in the atmosphere and on climate regulation.” Across the LTSs submitted to date, commonly referenced policies and techniques to promote natural carbon removal via the land sector include, but are not limited to, forest carbon management practices such as reducing the risk of catastrophic wildfire, reduced impact logging, active replanting postharvest; silvicultural practices that improve growth rates; reforestation of nonagricultural lands such as abandoned farmland, roadsides, parks, and urban areas; agricultural practices that boost yields and build soil carbon without shifting land uses; and integration of trees into agricultural lands while maintaining or increasing farm productivity (Mulligan et al. 2018).

**Some LTSs mention important cobenefits that will accrue from implementing measures to promote a transformation of the land sector.** For example, Canada’s LTS states that “changes in forest management practices could create cobenefits, including increased employment in the forest sector, reductions in black carbon emissions (where there is a reduction in slash burning), and increased adaptation efforts to improve the

resilience of forests.” Costa Rica’s LTS adds that investment in and stewardship of natural capital (e.g., land) has a critical role to play in protecting natural biodiversity.

**Although many LTSs emphasize the cobenefits associated with the land sector transition, some are frank about potential negative impacts on vulnerable populations.** France, Austria, and Finland are the most specific about how mitigation activities in the land sector could impact vulnerable populations. And France’s LTS, in particular, notes several mechanisms by which these negative impacts can be mitigated and/or compensated for, including through a focus on training and employment programs to support rural livelihoods.

### The “Hard-to-Abate” Areas of the Economy

While stringent mitigation measures must be applied across all sectors of the economy to reach the Paris Agreement goals, current technologies cannot eliminate all GHG emissions entirely.

**Most LTSs highlight the challenges of reducing emissions in the “harder-to-abate” areas of the economy.** The sectors highlighted by parties as the most challenging include agriculture, heavy industry, aviation, and shipping. Parties recognize that these “harder to abate” sectors of the economy will require more investment; coordinated efforts between government, industry, and consumers; significant innovation; and big technological breakthroughs to drive down emissions.

**Noting the need for increased technical and policy-oriented innovation to solve difficult decarbonization challenges, most LTSs reference commitments to accelerating public and private research and development (R&D) efforts.** Some parties simply emphasize the critical importance of R&D for both mitigation and economic development without providing further detail. For example, Belgium’s LTS, which comprises three subregional strategies, notes that “each strategy underlines the importance of innovation and R&D [in order to foster] the technological breakthroughs and innovations needed to achieve significant reductions in the long term.” Spain writes that R&D—both publicly and privately funded— “will improve the country’s entire value chain by creating business niches . . . and increasing the competitiveness of the economy as a whole.” Other parties’ LTSs put forward more concrete plans for how they intend to expand R&D efforts. Japan’s

LTS, for example, notes the country’s commitment to “hosting an international conference inviting leaders in science and technology from [the] G20 to create disruptive innovations in the clean energy technology field . . . enhancing alliances among R&D institutes with facilitation of international joint R&D activities.”

### The Role of Carbon Removal Technologies

While natural carbon removal (emissions absorbed by trees and soils) is an important part of the “removal” solution, the scale of removals required to tackle climate change is creating global momentum for developing and scaling supplementary carbon removal technologies.<sup>9</sup> Approaches to such technological carbon removal include bioenergy with carbon capture and storage (BECCS); direct air capture and storage (DACs); and frontier technologies such as biochar, plant breeding or engineering, enhanced weathering, and seawater capture. The intention of these technologies is to store CO<sub>2</sub> in plants, soils, and oceans, as well as nonbiologically in geological formations and products (e.g., building materials), augmenting the net transfer of carbon from the atmosphere that naturally takes place as part of the carbon cycle (Mulligan et al. 2018b).

**Of the 29 LTSs, 15 submitted to date note a present commitment or future intention to develop and scale human-developed carbon removal technologies to offset residual emissions.** BECCS is the most frequently mentioned carbon removal technology; however, several parties also note interest in investigating newer, frontier technologies for carbon removal. Japan’s LTS, for example, mentions a suite of technologies including “ocean fertilization to [fix] carbon in phytoplanktons and useful aquatic plants; promoting downwelling and upwelling; enhanced weathering . . . and carbon storage in cropland soil by using substances such as biochar,”<sup>10</sup> noting that social acceptance as well as international cooperation in development must be promoted. Ultimately, as Canada notes in its LTS, “negative CO<sub>2</sub> emissions are required . . . to offset hard-to-mitigate non-CO<sub>2</sub> emissions . . . to achieve net-zero global anthropogenic GHG emissions.” Multiple parties acknowledge that the deployment of human-developed carbon-removal technologies is critical to this effort.

## 4. GUIDING NEAR-TERM ACTION

One of the main benefits of the LTS, recognized by many parties, is to guide near-term action. Indeed, LTSs are often envisioned as a core element of a comprehensive climate policy package. They identify the transformative change needed over the coming decades to mitigate and adapt to climate change, while other elements of the policy package implement that change by establishing near-term targets, mandates, or incentives. By the same token, long-term GHG mitigation targets (including net-zero targets) are primarily useful insofar as they are used to steer these near-term targets, mandates, and incentives. In this section, we review the ways in which LTSs include near-term targets, milestones, and action plans, with a special focus on the relationship between LTSs and NDCs (the shorter-term action plans through 2030 under the Paris Agreement).

**Most LTSs include some form of economy-wide GHG milestones, metric, or pathway for years prior to 2050.** Within their LTSs, some parties (e.g., Austria, Denmark, Fiji, Mexico, and Spain) cite or elaborate on a 2025 or 2030 target from their NDC or from existing domestic policy. Some EU member states (e.g., Belgium and Sweden) include pre-2050 milestones for the share of the economy not covered by the EU Emissions Trading Scheme. And some parties (e.g., Fiji, Spain, and the United States) present a GHG time series from the near term through 2050 from modeling studies (sometimes in addition to 2025 or 2030 targets). It is not always clear whether these figures represent milestones the party intends to achieve, or whether they are rather intended to illustrate possible pathways.

**Most LTSs include sector-specific milestones, metrics, or pathways for years prior to 2050.** Some LTSs take a comprehensive approach to sector-specific milestones, including metrics for every sector in the economy, typically every five or ten years. Costa Rica and Germany are among the parties that take this approach. Other LTSs include targets or metrics only for select subsectors or technologies. For example, South Korea includes milestones for fuel cells, clean vehicles, and forest carbon removal. Norway mentions targets for transport, shipping, and agriculture. As for the economy-wide metrics described above, some LTSs (e.g., those of

Fiji, Finland, the Marshall Islands, and Spain) include sector-specific modeling results as time series through 2050, which may represent milestones the party intends to achieve or may represent illustrative pathways for the respective sectors.

**Almost every LTS includes a qualitative description of priority actions associated with implementing its long-term goals.** These qualitative descriptions vary widely in terms of their level of detail, including information regarding costing and funding (see more in Sections 3.3.1–3.3.2). Some LTSs (e.g., Canada’s) reference other existing or planned documents, which describe implementation plans in further detail.

**Several LTSs identify the use of carbon budgets in their LTSs.** France and the United Kingdom set multiple legally binding five-year carbon budgets, until the years 2033 and 2032, respectively. These budgets specify sector-specific emissions caps for each five-year period. South Africa mentions a first phase of voluntary, company-level carbon budgets for 2016–2020, with plans for subsequent, mandatory phases, pending approval of the Climate Change Bill. Norway mentions that some municipalities have established carbon budgets. No other countries identify the use of carbon budgets in their LTSs.

**According to the Paris Agreement, LTSs should inform NDCs.** Out of the 29 parties whose LTSs were evaluated for this paper, 14 are EU member states, which together submit a joint NDC under the Paris Agreement. Of the 15 remaining parties, 10 have submitted an updated or second NDC to date. The following points refer to these 10 parties plus the EU:

- Most NDCs (Costa Rica, European Union, Fiji, Marshall Islands, Mexico, Norway, South Korea, Switzerland, and the United Kingdom) explicitly refer to their parties’ LTSs and 2050 GHG targets contained therein.
- Some NDCs contain targets that are explicitly consistent with the interim milestones in the LTSs (e.g., Marshall Islands).
- Some NDCs contain targets that do not explicitly align with the interim milestones laid out in the LTSs.
- At least one NDC notes that it needs to be further strengthened in order to align with the interim goals laid out in the LTS (South Korea).

## 5. FACILITATING THE TRANSITION

The transition to low-emissions and climate-resilient development will require unprecedented changes across all sectors of the economy. This section unpacks the means of facilitating this transition, covering areas including a just transition, adaptation, international cooperation, and finance flows. Section 6.2 also discusses the ways in which parties are engaging stakeholders as part of the design and implementation of the LTS—critical for supporting a just and equitable transition.

### Just Transition

Governments and the international community have long recognized the moral, economic, and political imperatives of ensuring that action on climate change does not overlook hardships that may be imposed on their workers, their families, and their surrounding communities—and indeed, the preambular text of the Paris Agreement “takes into account the imperatives of a just transition of the workforce and the creation of decent work and quality jobs.”

**Most LTSs recognize that the transition toward low emissions and climate-resilient development will require fundamental transformation across all sectors of the economy, bringing changes in jobs and livelihoods.** Narratives cover the changes that lie ahead, recognizing that these will bring both opportunities for greener and more sustainable jobs but also challenges for the workers and communities that are strongly dependent on a fossil fuel–based economy. Norway, for example, highlights its endorsement of the Guidelines for a Just Transition adopted by the International Labour Organization (ILO). Spain references a separate Just Transition Strategy (as part of its national Energy and Climate Strategic Framework), which is aimed at promoting economic competitiveness and generating quality employment. South Africa presents a detailed and three-phased approach to implementing a just transition. Finland’s LTS, unusually, notes it “does not consider the transition to a low-emission society from the perspective of regional or social justice,” noting instead that the LTS is “based on the premise that emission reduction costs will be minimised across the country.”

**Some LTSs provide additional details about how their parties intend to retrain workers and change school curricula.** Austria, Germany, the Netherlands, and Norway plan to make investments in education and vocational training to actively address changes in the labor

market. France outlines a four-step plan for employment, training, and professional transitions linked to the energy transition and green growth. South Korea will develop a national standard for vocational skills and expand job training programs for the new low-carbon industry. Singapore offers subsidies to offset the costs of training in climate-friendly professions, such as energy efficiency technology development and installation.

**Some LTSs explain the impact on specific jobs or express intentions to quantify the impact of the transition on jobs.** Canada, Denmark, Fiji, Mexico, and the United Kingdom emphasize the new jobs that will be created as a result of a green transition, which are sometimes quantified on either a gross or net basis. Austria plans to undertake an in-depth analysis of the impact of the transformation and consequences of climate change on jobs and social aspects. Austria and Portugal expect to create additional new jobs in areas of renewable energy production, energy efficiency, automation and digitalization, construction, and logistics for shared and autonomous mobility. Sweden recognizes that its basic industry, heavy goods transport, and agricultural sectors may be particularly vulnerable in the transition, at least in the short term.

**A few LTSs discuss financing a just transition.** The European Union references a Just Transition Mechanism, including a proposal to facilitate €100 billion to support a “cost-effective, just, as well as socially balanced and fair transition,” which is also mentioned in some EU member LTSs. Costa Rica intends to create sector job plans and a funding strategy for those sectors most impacted by the transition.

## Adaptation

All LTSs recognize the impacts of future climate changes on the economy and describe the environmental, social, human, and economic risks of inaction. As climate patterns shift and extreme weather events become more frequent and intense, countries have little choice but to develop mechanisms to cope with the changes that are already locked in. Farsighted and transformational adaptation—instead of incremental and short-term action—is likely to be more cost-effective and less prone to unintended impacts or lock-in of ineffective measures over time.

**The level of detail on adaptation in the strategies, however, varies widely.** Some LTSs lightly touch on adaptation measures and refer to other national adap-

tation planning strategies and documents for further information. This is the case for Canada, Costa Rica, Czech Republic, Finland, France, Germany, the Marshall Islands, the Netherlands, Slovakia, South Africa, South Korea, and the United Kingdom. Other LTSs lead with (or give equal weight to) adaptation, incorporating detailed goals to enhance adaptive capacity, strengthen resilience, and reduce vulnerability—this is true in the case of Benin, the Marshall Islands, Mexico, and Singapore.

**Some LTSs highlight the importance of complementary mitigation and adaptation measures that address climate change and bring about broader societal benefits.** This is typically done as part of a high-level narrative, so in some instances would likely warrant further examination of how interactions among water, food, and energy are explicitly considered in the development of long-term pathways (IPCC 2018). France, Germany, Japan, and Spain state their intent to develop synergies between the party’s mitigation goals and adaptation strategy wherever possible. Fiji, Portugal, and the United States also identify some synergistic adaptation and mitigation measures.

**A few LTSs also note climate impacts on particularly vulnerable areas and sectors.** Belgium recognizes its agricultural sector; Canada references its northern regions; Spain recognizes its tourism, agriculture, livestock, and fishing sectors; Japan references the risks posed to its energy infrastructure; Singapore highlights the risks posed by flooding due to the island’s low-lying nature; and Fiji notes that it is one of the most vulnerable countries in the world to climate change due to its geographic location and the importance of natural resources to the economy.

## International Cooperation

All parties recognize that addressing climate change and achieving the goals set out in their LTSs will require significant international cooperation. This is particularly true in areas of finance for developing country parties, capacity-building, technology transfer, innovation, and knowledge-sharing. The level of detail regarding international cooperation is, however, generally quite limited in the LTSs communicated to date, with the bulk of each strategy focused on domestic issues and transitions.

**Some LTSs explicitly note the importance of international cooperation and partnerships in both the development and implementation of their LTSs.** Canada, the United States, and Mexico,

for example, worked closely together in 2016 to prepare their LTSs. In this vein, Mexico also references the North American Climate and Clean Energy Partnership, which is built to accelerate work on clean energy deployment, energy efficiency, methane, and short-lived climate pollutants reduction, as well as on protecting forests and sensitive ecosystems across the continent. And the United States highlights the benefits of working internationally to address climate change to minimize mitigation costs, maximize trade opportunities, accelerate innovation in the clean energy sector, and avoid emissions leakage.

**Some LTSs discuss the risks and opportunities that climate change presents vis-à-vis global trade, but specific details are often lacking.** The global transition toward low-emissions development will impact trade, changing how and where goods are produced, and the demand for those goods. From an energy perspective, for example, Canada sees opportunities to provide additional surplus hydropower to the United States, thus creating new market opportunities for Canadian electricity exports and increasing their profitability, while at the same time helping the United States to reduce fossil fuel-based power and meet its own domestic emissions reduction commitment. The United Kingdom is similarly devoting resources to increasing its export market and promoting manufacturing in wind power. On risks, Singapore notes its vulnerability to supply shocks in the global food market, and how that might worsen as a result of climate change.

## Finance Flows

The Paris Agreement invites parties to develop their LTSs, “mindful of Article 2,” meaning that parties are encouraged to consider how their strategies can make finance flows consistent with a pathway toward low GHG emissions and climate-resilient development. To this end, most parties discuss finance and investment strategies within their LTS, although the level of detail varies. Indeed, financing this longer-term transition will ultimately require a multipronged approach tailored to national circumstances and priorities.

**Several developing countries highlight the need for additional international finance to address climate change adequately and reach long-term mitigation goals.** Mexico, for example, states that it needs “accessible, timely, and sufficient economic resources that allow for timely and decisive action on mitigation of and adaptation to climate change.” Benin also discusses the

financing mechanisms that will need to be mobilized to implement its LTS, which include the state budget, loans, grants, and donations, and to a lesser extent, private sector investment. The Marshall Islands intends to develop a long-term finance strategy of its own to help channel finance toward the small island state, recognizing that a “big barrier to implementing adaptation and resilience measures is long-term financing.”

**Several parties say that their LTSs will be used to guide future investments toward a cleaner and more sustainable future.** Germany and France, for example, recommend that climate objectives be considered in all public and private sector investment decisions. Canada and the United States view their strategies as a means to provide market signals to investors that economies are headed to a low-emissions future. The United Kingdom highlights its Green Finance Taskforce, working to provide recommendations for the delivery of public and private investment and to provide up to £20 million to support “a new clean technology early-stage investment fund,” among other initiatives. Spain includes a detailed annex that presents an evaluation of the investment needed to reach net-zero emissions. Costa Rica notes that the LTS will immediately contribute to the development of the National Development and Public Investments Plan. The Czech Republic also presents its aim of increasing climate finance to the level of other developed nations, per unit of gross domestic product (GDP).

## 6. ENSURING THE LONGEVITY OF LONG-TERM STRATEGIES

LTSs need to remain relevant and useful over their multi-decade implementation period. Accordingly, these strategies should have appropriate legal backing and be linked with national development policies. There should be adequate engagement with key stakeholders in the development and implementation of the strategies, particularly with vulnerable populations. And there should be plans to monitor and revise the strategies over time, keeping up with the latest science and market developments.

### Governance and Legal Elements

Laws are an important tool with which to insulate LTSs against shifts in the national political landscape (Elliott et al. 2019). Indeed, formal legal status, established through legislation mandating the establishment of LTSs, or formalizing quantitative targets may provide an important foundation through which to drive a coordinated govern-

ment response. Once legal backing for an LTS is in place, resources may be allocated and decisions may be made to carry out more effective implementation efforts. Moreover, businesses and other actors may be more inclined to act in alignment with the LTS.

**Several LTSs are underpinned by at least some degree of legal status.** In many cases, there is a clear legislative mandate to develop an LTS, which provides a formal space for these strategies in national climate policy frameworks. For example, all member countries of the EU are mandated under Regulation 2018/1999 of the European Parliament to prepare LTSs. Mexico’s Climate Change Law also mandates the development, evaluation, and revision of a national climate change strategy with long-term considerations.

**A few parties bolster the legal status of their LTSs by incorporating the quantitative targets within their LTSs into laws.** Denmark, France, the United Kingdom, and Mexico all have formal laws in place that set a national goal to meet the latest long-term quantitative targets in their strategies. In Sweden, the Swedish Climate Policy Framework<sup>11</sup> establishes the country’s 2045 goal, while the Climate Change Act—a national law—imposes an obligation on current and future governments to pursue policies based on these national climate goals. Several other parties have formal legislation under development, and some parties passed legislation after submitting LTSs, including Japan, Spain, and Canada (Canada’s legislation includes a more ambitious mitigation target than communicated in the initial LTS).

**Most LTSs identify the specific government entity(ies) that led the preparation of the strategy; a few also indicate the actors responsible for implementation of the strategy.** LTSs are not necessarily implementation plans. However, realization of the vision of the strategy will require a robust institutional framework, with clear responsibilities to implement climate policy aligned with the LTS’s long-term goals. Some strategies identify certain entities or groups responsible for implementation or describe a governance framework for transforming the strategy into action and creating a platform for delivery. In other cases, the strategy indicates that separate planning exercises will be undertaken to guide future implementation. In a few cases, no such information is provided.

## Stakeholder Consultation

A robust and transparent stakeholder involvement process during the design and implementation of the LTS is essential. Incorporating different voices from other government departments, technical groups, the private sector, civil society, academia, and vulnerable populations can inform the development and successful implementation of the vision of the strategy and ensure that it represents a broad constituency.

**All LTSs mention stakeholder consultation plans, with some strategies adding details on participants, frequency of meetings, and outcomes.** Mexico, for example, identifies the specific federal institutions and research centers that were involved in the consultation process, with details about how inputs were gathered. Canada lays out detailed information about ways of engagement, such as academic workshops and a web portal for public review, but does not state how many inputs were received.

**Most strategies note the engagement of stakeholders during the LTS planning and/or implementation period.** Costa Rica, the Czech Republic, Fiji, Finland, the Netherlands, Ukraine, and the United Kingdom, for example, focus their consultation on the planning process, often led by an interministerial working group, without specifying much information about stakeholder engagement during implementation. On the other hand, the Marshall Islands, Spain, Sweden, and Switzerland mention stakeholder consultation plans for the implementation of their strategies. Some strategies specify their stakeholder consultation plan for both the planning process and the implementation period—for example, South Africa lays out detailed information about current institutional arrangements to address climate change in different stages, as well as the stakeholder engagement plan to enhance institutional capacities in the future, with a strong focus on vulnerable groups and sectors. Japan plans to “widely disseminate the information that has been found and promote further initiatives by pursuing collaboration with the stakeholders and dialogue that includes younger generations, who will uphold the society over the long term.”

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**Some strategies recognize the importance of engaging marginalized groups, and several highlight direct consultations with communities that are most impacted by climate change.** Given their particular national circumstances, parties may place different focus on groups that are socially or economically marginalized. For example, Japan and Latvia recognize the importance of participation of younger generations and engage them in both planning and implementation of the strategy by highlighting youth movements and dialogues with younger generations; the Marshall Islands notes the stakeholder engagement plan from a gender perspective. Some parties such as Canada, France, Japan, the Marshall Islands, South Africa, and Spain highlight communities that are most impacted by climate change—for example, Canada prioritizes collaboration with indigenous peoples and territories that are vulnerable; South Africa has a strong focus on consultation with key sectors that are impacted by climate change.

## Monitoring and Evaluation

Most parties outline monitoring and evaluation (M&E) processes within their LTSs, often specifying clear details and responsibilities to ensure that the process is thorough. Such a process may define institutional responsibilities that specify the “what,” “when,” and “who” of monitoring and evaluation.

**Strategies, time lines, and responsibilities for M&E vary across the LTSs submitted to date.** The following examples demonstrate the breadth of how these M&E plans have been presented across several strategies:

*What:* Fiji’s LTS outlines a four-pronged approach to M&E, which tracks the implementation of policies and measures, the emission reductions achieved, the cobenefits attained, and progress on the means of implementation including capacity-building and finance.

*When:* Sweden’s LTS states that “the Government is to present a climate report in the Budget Bill each year,” monitoring and evaluating “the combined climate effects of all policy areas.”

*Who:* The United Kingdom’s LTS notes that “to maintain cross-government progress on clean growth, [the party] will reinstate a regular Clean Growth Inter-Ministerial Group, which will be responsible for monitoring the implementation of the [strategy] and driving ambitious clean growth policies.”

**Some LTSs acknowledge areas where M&E processes may be improved over time.** Fiji’s LTS, for example, acknowledges that “the data required to support various reporting processes will require improved systems for understanding and quantifying national assets and capital,” while South Africa’s LTS notes that further research will be required to develop a monitoring and evaluation system for sectors where robust data collection systems for tracking the long-term implications of policies and measures do not yet exist.

## Review and Revision

Most parties specify an intention to review and revise their LTSs. Indeed, review and revision based on results from monitoring and evaluation processes as well as other external pressures are important to ensure that the LTS keeps pace with new policy announcements and targets, innovation, shifting priorities and capacity, global market developments, and R&D advancement. For example, modeling assumptions can change in the space of a few years (e.g., based on new information and costs of new technologies), and new data availability may uncover untapped areas of mitigation potential. The review and revision process can also provide additional opportunities to engage stakeholders and accelerate support for climate action.

**Some parties simply note the importance of regular review, while others set clear deadlines for when revisions should be undertaken.** While some parties express non-time-bound intentions to review their strategies and revise them when appropriate (Austria, for example, notes that its strategy “must be reviewed and updated on a regular basis to ensure that the transformation process can adapt to changing conditions”), many are quite explicit about establishing specific intervals for regular review and revision. A five-year interval between reviews and revisions—in alignment with the periodic review cycles of other components of the Paris Agreement—is most common, with parties including France, Germany, the Marshall Islands, Norway, Slovakia, South Africa, Ukraine, the United Kingdom, and the United States committing to undertake review and revision of their strategies every half-decade. However, other time frames for review and revision are also articulated, ranging from a minimum of every four years to a maximum of every ten years.

**Two parties—Germany and France—have already once resubmitted revised versions of their first LTS.** In 2017, one year after its initial submission, Germany resubmitted its LTS to the UNFCCC, and, in 2021, France submitted an updated version of its first LTS, originally published in 2016. While Germany’s update consists primarily of small tweaks, France resubmitted its strategy after the party’s planned five-year review, with significant revisions and changes. Most notably, the party updated its midcentury target, increasing its ambition from a 75 percent emissions reduction by 2050 relative to 1990 (original submission) to achieving total neutrality by 2050 (revised submission). To support this enhanced ambition, updates to France’s strategy include, but are not limited to, modeling and mitigation scenario revisions and an exploration of the role that BECCS facilities can play in generating negative emissions. The updated French LTS also notes that its revision process included extensive stakeholder consultation.

## 7. FINAL REFLECTIONS

This paper examines trends across the 29 LTSs submitted to the UNFCCC by the end of June 2021. We have looked at how parties have established a midcentury vision, how they are using their strategies to drive immediate action, how they plan to facilitate the transition, and how they will ensure their strategies remain relevant and useful over the next 30 years.

In undertaking this review, we have also reflected on how these strategies are changing over time. Here are our main observations:

**LTSs are increasing in scope, going beyond mitigation-centric modeling exercises (which are still a key feature of most LTSs) and expanding to look at the fundamental economic, technological, and societal shifts that will be required to meet Paris Agreement goals and national development objectives.** The early submitted strategies were predominantly mitigation-centric (with the exception of Mexico and Benin), laying out detailed modeling results, which subsequently pointed to the policy changes that needed to be implemented (Ross and Fransen 2017). The later strategies follow this approach as well, but increasingly go further, including a broader development-focused narrative and exploring detailed societal transformations.

**There is a growing movement toward net-zero LTSs. Of the 29 strategies, 17 include net-zero targets, from developed and developing countries alike—a trend that may continue given increased net-zero commitments by national governments and subnational actors** (Climate Watch 2021; Race to Zero 2021). Some parties have also established net-zero targets since they submitted their first LTS, which will need to be reflected in updated strategies<sup>12</sup> and complemented with new modeling/sectoral pathways.

**As a result of the expanding scope of LTSs, and through the setting of more ambitious mitigation targets, parties are becoming increasingly frank about the challenges associated with the transition toward low-emissions and climate-resilient development. Parties are also highlighting gaps within their strategies, pointing to areas requiring more work.** The first strategies submitted in 2016 focus strongly on benefits of climate action, including positive impacts on economic growth, jobs, and taking leadership in the clean energy industries of the future. The later strategies, submitted from 2017 onward, acknowledge the challenges and difficulties associated with the transition, laying out unanswered questions and recognizing shortcomings where they exist. For example, the EU notes it will rely on citizens to close the emissions gap to reach net-zero emissions, particularly around aspects of behavior change. Finland notes that it can technically reach net-zero emissions but that its strategy “does not consider the transition to a low-emission society from the perspective of regional or social justice; instead, its underlying calculations are based on the premise that emission reduction costs will be minimised across the country.” Recognizing the uncertainty inherent in long-term planning and modeling, Austria, the Marshall Islands, and Slovakia explicitly acknowledge the gaps between their most ambitious emissions reductions/removals scenario and their midcentury target. South Africa is embarking on a pathway that starts with “doing no harm,” while further unpacking the necessary changes required across all sectors of the economy.

**There are early indications that LTSs are increasingly informing parties’ revised NDCs.** The first LTSs were communicated in 2016, only shortly after the first round of NDCs were announced. As parties update their NDCs as part of the first ambition cycle of the Paris Agreement, some recent NDCs note either that they align with the long-term target in the party’s LTS or that they will need to be updated in order to align.

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**Some aspects relating to the transitions that lie ahead are overlooked or touched upon lightly in the LTS.** The review and update of LTSs over time, which most parties are committed to doing, offers an opportunity for researchers and policymakers to tackle these (and any other) issues more deeply. For example, in current LTSs, there is generally less serious examination of the following:

- The ways in which goods and energy will flow across borders over the next three decades as a result of the global transition to low emissions, and, accordingly, how global trade may be affected. This also includes biomass that may be grown in one country and combusted in another, raising issues around double counting for midcentury targets.
- The ways longer-term development trajectories may be affected by climate risks over the next three decades. (This is distinct from the inclusion of adaptation in the LTSs, which is more common, but generally not addressed comprehensively, as noted in Section 5.2.)
- The significant challenges facing land sector transformation, including the following:
  - The need to balance future demand for commodities and food, while preserving and increasing the sequestration potential of the land sink.
  - How the poorest and most vulnerable may be impacted by transformations in the land sector, and accordingly, what safeguards must be implemented (including potentially developing programs where revenues from land sector credits or removals could be allocated toward protecting human rights).
- Detailed accounting for natural carbon removals (i.e., the national land sink) through 2050, since most parties are reliant on this sink to balance residual emissions.
- The role of international transferred mitigation outcomes in longer-term mitigation pathways—particularly if most countries are aiming to reach net-zero emissions, there will be limits on how many “net-negative” emissions can be traded post-midcentury.

**Despite the tremendous early progress on LTSs, only 29 parties submitted a strategy by the end of June 2021.** Notwithstanding COVID-19 and the delay to COP26, support requests from parties to NGOs, multilateral development banks, donors, and coalitions suggest that several still require additional capacity to develop and implement their LTSs. Having a clear sense of the challenges (or hesitations), as well as specific requirements for support, could help to relieve those barriers.

In conclusion, the extent to which global temperature increase is held to 1.5–2°C will depend strongly on the implementation of the changes envisaged in parties’ LTSs, particularly from major emitters such as those in the G20. As more parties communicate their strategies and revise them over time, the international community should stand ready to support them—through financial and technical assistance programs, as well as lesson-sharing and best practices. Indeed, as noted in most LTSs, international cooperation will become increasingly important as more countries transition toward net-zero emissions while simultaneously pursuing their development objectives.

## APPENDIX A: MIDCENTURY TARGETS

This appendix presents the quantitative and qualitative midcentury goals in “long-term low greenhouse gas emission development strategies” (long-term strategies or LTSs). Table A1 provides definitions of the terminology associated with greenhouse gas (GHG) goals; Table A2 presents the results.

Table A1 | **Quantitative Components of the Midcentury Target**

QUANTITATIVE COMPONENT	DESCRIPTION
Emissions reduction goal	The emissions reduction goal under the target.
Target time frame	The year or range of years in which the target will be achieved.
Coverage of GHGs	The type of GHGs that must be reduced under the target. The UNFCCC GHGs (“all gases”) are CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O, HFCs, PFCs, SF <sub>6</sub> , and NF <sub>3</sub> .

Notes: GHG = Greenhouse gas; UNFCCC = United Nations Framework Convention on Climate Change; CO<sub>2</sub> = Carbon dioxide; CH<sub>4</sub> = Methane; N<sub>2</sub>O = Nitrous oxide; HFCs = Hydrofluorocarbons; PFCs = Perfluorocarbons; SF<sub>6</sub> = Sulfur hexafluoride; NF<sub>3</sub> = Nitrogen trifluoride.

Source: Authors.

Table A2 | **Quantitative and Qualitative Aspirations within Midcentury Targets**

QUANTITATIVE ASPIRATIONS				
Party	Emissions reduction target	Target time frame	Coverage of GHGs	Qualitative aspirations
Austria	Climate neutrality	No later than 2050	All gases	“A strategy that includes a comprehensive transformation of both our energy supply and our consumption patterns and that includes an adapted but competitive economic system goes far beyond . . . merely reducing greenhouse gas emissions. It must contain all three pillars of sustainability—economic, social, and environmental aspects—as this is the only way to achieve committing to far-reaching changes by the population.”
Belgium	Three separate regional strategies <sup>a</sup>	All refer to 2050	Not specified	With this LTS, Belgium “wishes to meet the expectations of the Paris and the European regulation on governance, and to provide a clear framework for its citizens and companies.” Each regional strategy “also addresses a number of relevant transversal points of attention for the long-term strategy,” including “a socially just transition,” “a secure and sufficient supply of sustainable and affordable energy,” “innovation and R&D,” “investments and financing,” and a “circular economy.”
Benin	Avoidance of at least 12 MtCO <sub>2</sub> e and sequestration of 163 MtCO <sub>2</sub> e	2030	All gases	“Benin is . . . a country whose development is resilient to climate change and low carbon intensity.”
Canada	80% reduction from 2005 levels	2050	All gases	“Canada is committed to creating a cleaner, more innovative economy that reduces emissions and protects the environment, while creating well-paying jobs and promoting robust economic growth.”
Costa Rica	Net-zero emissions	2050	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>2</sub> , HFCs)	“Costa Rica aspires to be a modern, green and emission-free economy—and to strengthen its leadership.”

Table A2 | **Quantitative and Qualitative Aspirations within Midcentury Targets (Cont'd)**

QUANTITATIVE ASPIRATIONS				
Party	Emissions reduction target	Target time frame	Coverage of GHGs	Qualitative aspirations
Czech Republic	80% reduction from 1990 levels, equivalent to 39.1 MtCO <sub>2</sub> e	2050	All gases	"The Climate Protection Policy of the Czech Republic specifies the objectives in the field of climate protection up to 2030 with an outlook up to 2050 and represents a long-term strategy of a low-emission development, which will lead to cost-effective achievement of the [specified] national targets."
Denmark	Climate neutrality	No later than 2050	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>2</sub> )	"The government want[s] to show how high climate ambitions can be translated into specific and concrete actions . . . how a green transition is carried through in a way that supports growth, welfare, just transition and development of green technological solutions that the world needs."
European Union (EU)	Climate neutrality	2050	Not specified	"The EU and its Member States aim to inspire global climate action and demonstrate that moving towards climate neutrality is not only imperative, but also feasible and desirable."
Fiji	Net-zero emissions	2050	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>2</sub> , HFCs)	"As the central goal of this low emission development strategy, Fiji aims to reach net zero carbon emissions by 2050 across all sectors of its economy. This is consistent and aligns directly with Fiji's objective stated above to ensure that net zero emissions are achieved globally by 2050."
Finland	Carbon neutrality by 2035 and net-negative emissions thereafter	n.a.	All gases	"Finland's long-term strategy lays out scenarios and impact assessments concerning the national carbon neutrality target set for 2035 and developments in greenhouse gas (GHG) emissions and removals by 2050."
France	Carbon neutrality	2050	All gases	"We must develop a new sustainable model of growth that creates jobs and wealth and improves wellbeing whilst building a circular economy for the future that is resilient to climate change."
Germany	Extensive GHG neutrality	2050	All gases	"This strategy must also take economic and social concerns into account: economic concerns because ultimately only economic success will make climate action an attractive proposition worldwide, and social concerns because one of the principles of climate action on a national as well as international level is that 'strong shoulders must carry more than weaker ones.'"
Japan	80% reduction by 2050 and "a decarbonized society as early as possible in the second half of this century"	n.a.	All gases	"Japan will achieve a virtuous cycle of environment and growth with disruptive innovation that is heretofore unconventional, thereby greatly reducing GHG emissions domestically. At the same time, Japan will contribute as much as possible to global emission reductions and achieve economic growth. . . . A decarbonized society for which this strategy aims should also be a bright society with hope for the future. It is important to create an environment to work voluntarily and actively by sharing the model of such a society with as many stakeholders as possible."
Latvia	Climate neutrality	2050	All gases	"The Strategy is a long-term policy planning document which has been developed to increase the economic competitiveness of [the] Latvian national economy, as well as to ensure a safe living environment for inhabitants of Latvia concurrently with the restriction and mitigation of climate change."

Table A2 | Quantitative and Qualitative Aspirations within Midcentury Targets (Cont'd)

QUANTITATIVE ASPIRATIONS				
Party	Emissions reduction target	Target time frame	Coverage of GHGs	Qualitative aspirations
Marshall Islands	Net-zero emissions	No later than 2050	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>2</sub> )	"The purpose of this 2050 Climate Strategy—which is [the Republic of the Marshall Islands'] long-term low greenhouse gas emission climate-resilient development strategy under the Paris Agreement—is to outline a long-term pathway for RMI to achieve its objectives for net zero emissions and 100% renewable energy, as well as to facilitate adaptation and climate resilience in a way that ensures the future protection and prosperity of the country and its women, men and youth."
Mexico	50% reduction from a 2000 baseline	2050	All gases and black carbon	"Mexico's mid-century climate change strategy provides the vision, principles, goals, and main lines of action to build a climate resilient society and transition towards a low emissions development."
Netherlands	95% reduction from a 1990 baseline	2050	Not specified	"The Climate Agreement emphatically targets an integrated approach to the climate challenge. The measures to be taken for the sectors depart from a vision of the future that encompasses more than CO <sub>2</sub> reduction alone. It is specifically linked to the transitions towards circular agriculture and a circular economy. Spatial integration, support and participation have been important considerations in the discussions about the measures to be taken. The wider social and economic perspective was also considered, in both the narrow and the broad sense."
Norway	80–95% reduction from a 1990 baseline	2050	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>2</sub> )	"[The LTS envisions a] low-emission society as one where greenhouse gas emissions, on the basis of the best available scientific knowledge, global emission trends and national circumstances, have been reduced in order to avert adverse impacts of global warming, as described in the Paris Agreement."
Portugal	Carbon neutrality	2050	All gases	"Achievement of the objective of carbon neutrality in 2050 is based on a strategic vision aimed at promoting decarbonisation of the economy and the energy transition towards carbon neutrality by 2050, as an opportunity for the country, based on a democratic and fair model of national cohesion that enhances the generation of wealth and the efficient use of resources."
Singapore	Net-zero emissions	"As soon as viable in the second half of the century"	All gases	"[The LTS] aims to facilitate long-term action to address the effects of climate change and to enable a well-managed transition to a low-carbon economy, while growing new sectors of our economy and creating jobs and opportunities."
Slovakia	Climate neutrality	2050	All gases	"The aim is to outline options for a comprehensive long-term (30-year) strategic roadmap for moving to a low-carbon economy, which will be completed by achieving climate neutrality by 2050."
South Africa	n.a. <sup>b</sup>	n.a.	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>2</sub> , HFCs, PFCs, SF <sub>6</sub> )	"South Africa follows a low-carbon growth trajectory while making a fair contribution to the global effort to limit the average temperature increase, while ensuring a just transition and building of the country's resilience to climate change."

Table A2 | Quantitative and Qualitative Aspirations within Midcentury Targets (Cont'd)

QUANTITATIVE ASPIRATIONS				
Party	Emissions reduction target	Target time frame	Coverage of GHGs	Qualitative aspirations
South Korea	Carbon neutrality	2050	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>2</sub> , HFCs, PFCs, SF <sub>6</sub> )	"The 2050 Vision in the Strategy will help develop a shared understanding that a fossil fuel-dependent economy and society will no longer be sustainable in the future. The Vision will open up broader discussions around fair burden-sharing necessary to achieve the ultimate goal of sustainable economic and social prosperity where economic and environmental benefits go hand in hand."
Spain	Climate neutrality	2050	All gases	"The objective of this long-term strategy . . . is to articulate a coherent and integrated response in the face of the climate crisis, taking advantage of opportunities for modernization and competitiveness [within] our economy and to be socially fair and inclusive."
Sweden	Net-zero emissions	2045	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>2</sub> , HFCs, PFCs, SF <sub>6</sub> )	"The climate policy framework's long-term climate goal establishes that, by 2045 at the latest, Sweden is to have zero net emissions of greenhouse gases into the atmosphere and should thereafter achieve negative emissions." "The Government's objective for the adaptation of society to a change in climate is to develop a long-term sustainable and robust society that actively addresses climate change by reducing vulnerabilities and leveraging opportunities."
Switzerland	Net-zero emissions	2050	All gases	The transition to net zero will be carried out in a socially acceptable way, [in an economically viable way], [and in a way that improves environmental quality]."
Ukraine	31–34% reduction from a 1990 baseline	2050	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O)	"It should be underscored, that a new development model should be green restoration, green growth, [and] green development, which is based on the inflow of investments into renewable sources of energy, environmentally safe production, and green technologies. . . . The LTS goal is to determine strategic directions for Ukraine's economy sustainable development based on national priorities accordant transition to low emission growth trajectory."
United Kingdom	80% reduction from a 1990 baseline	2050	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O)	"Clean growth means growing our national income while cutting greenhouse gas emissions. . . . It will increase our productivity, create good jobs, boost earning power for people right across the country, and help protect the climate and environment upon which we and future generations depend."
United States	80% or more reduction from a 2005 baseline	2050	Partial coverage (CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O)	"The mid-century strategy demonstrates how the United States can meet the growing demands on its energy system and lands while achieving a low-emissions pathway, maintaining a thriving economy, and ensuring a just transition for Americans whose livelihoods are connected to fossil fuel production and use."

Notes: MtCO<sub>2</sub>e = Million metric tons of carbon dioxide equivalent; GHG = Greenhouse gas; R&D = Research and development; n.a. = Not applicable; CO<sub>2</sub> = Carbon dioxide; CH<sub>4</sub> = Methane; N<sub>2</sub>O = Nitrous oxide

<sup>a</sup> Belgium's LTS is composed of three separate regional strategies (Walloon, Flemish, and Bruxelles-Capitale), which collectively cover the entire party's emissions profile. The Walloon strategy "aims to achieve carbon neutrality by 2050"; the Flemish strategy "aims to reduce greenhouse gas emissions from sectors not covered by ETS (so-called non-ETS sectors) by 85% [from a 2005 baseline] by 2050, with the ambition to evolve towards total climate neutrality"; and the Bruxelles-Capitale [strategy] aims to "[get] closer [to] the European objective of carbon neutrality by 2050."

<sup>b</sup> According to South Africa's LTS, "in the absence of an agreed quantitative articulation of the vision, the national GHG emissions trajectory, as reflected in the National Climate Change Response Policy . . . is used as the benchmark against which the performance of [the strategy] will be measured. . . . From 2036 onwards, emissions will decline in absolute terms to a range with a lower limit of 212 MtCO<sub>2</sub>e and an upper limit of 428 MtCO<sub>2</sub>e by 2050."

Source: Authors.

## APPENDIX B: MODELS AND SCENARIOS

This appendix presents more detail about the models and scenarios included in “long-term low greenhouse gas emission development strategies” (long-term strategies or LTSs). Table B1 provides definitions of the terminology associated with the models; Table B2 presents the results. Table B2 also identifies gaps between a party’s midcentury target and the most ambitious modeling scenario offered within the strategy.

Table B1 | **Terminology Associated with Models**

CRITERION	DESCRIPTION
Model name	The name(s) of the model(s) used to generate mitigation scenarios within an LTS.
Model type	The type(s) of model(s) used to generate mitigation scenarios within an LTS. The primary model types deployed within an LTS are <i>integrated assessment models (IAMs)</i> and <i>computable general equilibrium (CGE) models</i> . IAMs are policy-evaluation optimization tools that combine energy, climate, and economics modules. CGE models are tools that use economic data and theory to simulate the reaction of an economy to changes in policy, technology, or other factors. Some strategies also deploy <i>partial equilibrium models</i> (in which economic equilibrium is considered in only a subset of an economy) and <i>dynamic equilibrium models</i> (which account for evolution of an economy over time).
Model scope	The scope of model(s) used to generate mitigation scenarios within an LTS. Economic models used to envision mitigation scenarios within an LTS can be either <i>jurisdiction-specific</i> or <i>generic</i> . Jurisdiction-specific models are developed for specific countries or other jurisdictions to reflect their unique circumstances and are tailored to capture the complexities of the jurisdiction’s economic and energy systems. Generic models are designed to meet the needs of multiple users but can be customized to fit a user’s specific needs (Altamirano and Hennig 2021).

Source: Authors.

Table B2 | **Models Used in Mitigation Scenarios**

PARTY	LIST OF MITIGATION SCENARIOS	MODEL DESCRIPTION (NAME, TYPE, SCOPE)	GAPS TO REACHING MIDCENTURY TARGET?
Austria	<b>1. Transition</b> , which depicts the greatest possible emissions reduction by 2050 (80% reduction from a 1990 baseline) based on domestically available resources and technologies, while taking lifestyle changes into account.	Name: DYNK, NEMO, KEX, GEORG, MARS, INVERT/EE-Lab, TIMES Type: CGE models, partial equilibrium model, others unknown Scope: Jurisdiction-specific and generic models	Yes. The midcentury target of reaching climate neutrality is not achieved in the Transition scenario. The LTS notes that this gap may be bridged via a combination of (1) capturing carbon in natural sinks; (2) importing additional energy from renewable sources; and (3) promoting permanent GHG sequestration in products, applications, and geological structures.
Belgium	The Wallonia strategy references mitigation scenarios used but does not provide detailed information about the outputs of these scenarios.	n.a.	n.a.
Benin	Mitigation scenarios are not provided in the strategy.	n.a.	n.a.

Table B2 | **Models Used in Mitigation Scenarios (Cont'd)**

PARTY	LIST OF MITIGATION SCENARIOS	MODEL DESCRIPTION (NAME, TYPE, SCOPE)	GAPS TO REACHING MIDCENTURY TARGET?
Canada	<p><b>1. High Ambition</b>, which achieves an 88% emissions reduction from a 2015 baseline by 2050 (excluding agriculture). This scenario projects 78 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>2. Current Tech</b>, which achieves a 65% reduction in energy sector emissions from a 2015 baseline by 2050.</p> <p><b>3. New Tech</b>, which also achieves a 65% reduction in energy sector emissions from a 2015 baseline by 2050.</p> <p><b>4. High Nuclear</b> (nonemitting electricity scenario), which is heavily dependent on nuclear electricity production, and achieves an 80% emissions reduction from a 2005 baseline by 2050.</p> <p><b>5. High Hydro</b> (nonemitting electricity scenario), which relies on a mix of hydro and wind to produce the majority of electricity, and achieves an 80% emissions reduction from a 2005 baseline by 2050.</p> <p><b>6. High Demand Response</b>, which achieves a net 80% GHG emissions reduction by 2050 relative to 2005 levels.</p>	<p>Name: CIMS, GEEM, NATEM, CanESS, GCAM</p> <p>Type: IAMs and CGE models</p> <p>Scope: Jurisdiction-specific and generic models</p>	<p>No. The midcentury target of achieving an 80% emissions reduction from a 2005 baseline is achieved in the High Nuclear, High Hydro, and High Demand Response scenarios.</p>
Costa Rica	<p><b>1. Business as Usual (BAU)</b>, which projects emissions without consideration of public policy interventions. This scenario projects 19 MtCO<sub>2</sub>e of emissions and 3 MtCO<sub>2</sub>e of removals in 2050, equaling a total of 16 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>2. Scenario 2°C</b>, which projects emissions with consideration of public policy interventions that are compatible with the NDC. This scenario projects 9 MtCO<sub>2</sub>e of emissions and 3 MtCO<sub>2</sub>e of removals in 2050, equaling a total of 6 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>3. Scenario 1.5°C</b>, which projects emissions with consideration of public policy interventions that are compatible with net-zero emissions in 2050. This scenario projects 5.5 MtCO<sub>2</sub>e of emissions and 5.5 MtCO<sub>2</sub>e of removals in 2050.</p>	<p>Name: TIMES-CR</p> <p>Type: Partial equilibrium model</p> <p>Scope: Generic model</p>	<p>No. The midcentury target of achieving net-zero emissions is achieved in Scenario 1.5°C.</p>
Czech Republic	<p><b>1. Reference</b>, which represents a BAU emissions trajectory. This scenario projects approximately 120 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>2. Extrapolation</b>, which mimics the scenario presented within the country's State Energy Concept, prepared by the Ministry of Industry and Trade. This scenario does not meet the 80% emissions reduction target by 2050.</p> <p><b>3. Nuclear</b>, which assumes an extension of the life of the Dukovany nuclear power plant to 2035, the construction of three new units with an output of 3x1,200 megawatts (MW), and the development of renewables, but does not meet the 80% emissions reduction target by 2050.</p> <p><b>4. Green</b>, which assumes high development of renewables, including wind, solar, biomass, and geothermal plants, but does not meet the 80% emissions reduction target by 2050.</p> <p><b>5. Economic Recession</b>, which simulates energy management with low fuel demand in all sectors during economic recession but does not meet the 80% emissions reduction target by 2050.</p> <p><b>6. With Electricity and Biomass Imports</b>, which mimics the Green scenario but allows for the import of electricity and biomass and does meet the 80% emissions reduction target by 2050.</p> <p><b>7. With CCS Development</b>, which mimics the Reference scenario but provides for the removal of 35 MtCO<sub>2</sub>e by 2050 with carbon capture and storage technology and does meet the 80% emissions reduction target by 2050.</p> <p><b>8. With Development of Renewable Energy Sources, Nuclear Energy, and Energy Savings</b>, which combines the Nuclear and Green scenarios, does not allow for electricity and biomass imports, and does meet the 80% emissions reduction target by 2050.</p>	<p>Name: ALADIN-CLIMATE/CZ, 2050 Pathways Calculator</p> <p>Type: IAMs, CGE model</p> <p>Scope: Generic models</p>	<p>No. The midcentury target of achieving an 80% emissions reduction from a 1990 baseline is achieved in the With Electricity and Biomass Imports; With CCS Development; and With Development of RES, Nuclear Energy, and Energy Savings scenarios.</p>
Denmark	<p>Mitigation scenarios are not provided in the strategy.</p>	<p>n.a.</p>	<p>n.a.</p>

Table B2 | **Models Used in Mitigation Scenarios (Cont'd)**

PARTY	LIST OF MITIGATION SCENARIOS	MODEL DESCRIPTION (NAME, TYPE, SCOPE)	GAPS TO REACHING MIDCENTURY TARGET?
European Union (EU)	Mitigation scenarios are not provided in the strategy.	n.a.	n.a.
Fiji	<p><b>1. BAU Unconditional</b>, which reflects the implementation of existing and official policies, targets, and technologies that are unconditional in the sense that Fiji would implement and finance them without reliance on external or international financing. This scenario projects 5 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>2. BAU Conditional</b>, which reflects the implementation of existing and official policies, targets, and technologies that are conditional in the sense that Fiji would rely on external or international financing to implement mitigation actions. This scenario projects 2 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>3. High Ambition</b>, which projects ambitions beyond those already specified in policies, relying on the adoption of new, more ambitious policies and technologies and availability of additional financing to implement mitigation actions, and achieves significant emissions reductions by 2050 compared with the BAU scenarios. This scenario projects 1 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>4. Very High Ambition</b>, which projects ambitions well beyond those already specified in policies, thus relying on the adoption of new, significantly more ambitious policies and availability of new technologies and additional financing to implement mitigation actions, in which most sectors achieve net-zero or negative emissions, by 2050. This scenario projects -0.8 MtCO<sub>2</sub>e of emissions in 2050.</p>	Name: LEAP tool Type: IAM Scope: Generic model	No. The midcentury target of achieving net-zero emissions is achieved in the Very High Ambition scenario.
Finland	<p><b>1. With Existing Measures (WEM)</b>, which is based on developments in line with existing policy measures that assume Finland will achieve its national energy and climate policy objectives for 2020 while extrapolating developments for the 2030–2050 period along the same trendline through to 2050. This scenario projects 27 MtCO<sub>2</sub>e in 2050.</p> <p><b>2. Continuous Growth</b>, which achieves carbon neutrality by 2035 and an 87.5% emissions reduction from a 1990 baseline by 2050 (net-negative emissions) by accelerated deployment of new technologies, including robust electrification, digitalization, and industrial renewal. CCS technologies will not be in use in this scenario.</p> <p><b>3. Savings</b>, which achieves carbon neutrality by 2035 and a 90% emissions reduction from a 1990 baseline by 2050 (net-negative emissions) by improving circular and sharing economies, increasing energy efficiency, and deploying CCS technologies.</p>	Name: TIMES-VTT, REMA, DREMFA, MELA software, FINAGE Type: Partial equilibrium models and CGE models Scope: Jurisdiction-specific and generic models	No. The midcentury targets of achieving carbon neutrality by 2035 and achieving net-negative emissions thereafter are achieved in the Continuous Growth and Savings scenarios.
France	<p><b>1. With Additional Measures (WAM)</b>, which details the public policy measures, including those already in place, which will allow France to meet its short-, medium-, and long-term climate and energy objectives (neutrality by 2050 is achieved). This scenario projects 80 MtCO<sub>2</sub>e of emissions and slightly more than 80 MtCO<sub>2</sub>e of removals in 2050</p>	Details not provided	No. The midcentury target of achieving carbon neutrality is achieved in the With Additional Measures scenario.
Germany	Mitigation scenarios are not provided in the strategy.	n.a.	n.a.
Japan	Mitigation scenarios are not provided in the strategy.	n.a.	n.a.
Latvia	<p><b>1. Base</b>, which projects current emissions in 2050 if there is no change in trajectory from current policy. This scenario projects 10 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>2. Target</b>, which achieves climate neutrality by 2050.</p>	Details not provided	No. The midcentury target of achieving climate neutrality is achieved in the Target scenario.
Marshall Islands	<p><b>1. Moderate</b>, which is an enhanced ambition scenario, reflecting technically and economically feasible targets. This scenario achieves a 56% reduction from a 2010 baseline by 2050.</p> <p><b>2. Significant</b>, which is an enhanced ambition scenario, equivalent to the Lighthouse scenario, but delayed by 15 years due to presumed lack of funding. This scenario achieves a 70% reduction from a 2010 baseline by 2050.</p> <p><b>3. Lighthouse</b>, which is an enhanced ambition scenario, which achieves an 87% emissions reduction from a 2010 baseline by 2050 by using technically feasible but more expensive solutions and without using any offsets.</p>	Details not provided	Yes. The midcentury target of reaching net-zero emissions is not achieved in the Lighthouse scenario. The LTS notes that this gap may be resolved through evaluating additional new technology options, carbon sinks, or offsetting options in future planning efforts.

Table B2 | **Models Used in Mitigation Scenarios (Cont'd)**

PARTY	LIST OF MITIGATION SCENARIOS	MODEL DESCRIPTION (NAME, TYPE, SCOPE)	GAPS TO REACHING MIDCENTURY TARGET?
Mexico	<p><b>1. Baseline</b>, which estimates the emissions trajectory without imposing climate or energy policy constraints. This scenario projects 1,236 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>2. NDC Policy</b>, which achieves a 22% emissions reduction from a 2000 baseline by 2030 (in line with Mexico's unconditional NDC target) and a 50% emissions reduction from a 2000 baseline by 2050. This scenario projects 311 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>3. NDC More Ambition</b>, which achieves a 36% emissions reduction from a 2000 baseline by 2030 (in line with Mexico's conditional NDC target) and a 50% emissions reduction from a 2000 baseline by 2050. This scenario projects 311 MtCO<sub>2</sub>e of emissions in 2050.</p>	<p>Name: EPPA</p> <p>Type: CGE model</p> <p>Scope: Generic model</p>	<p>No. The midcentury target of achieving a 50% emissions reduction from a 2000 baseline is achieved in the NDC Policy and NDC More Ambition scenarios.</p>
Netherlands	Mitigation scenarios are not provided in the strategy.	n.a.	n.a.
Norway	Mitigation scenarios are not provided in the strategy.	n.a.	n.a.
Portugal	<p><b>1. Off-Track</b>, which retains the essentials of the economic structure and current trends as well as the decarbonization policies already adopted or in force. Projected emissions generated by this scenario are not provided.</p> <p><b>2. Peloton</b>, which is compatible with carbon neutrality via the development and application of new technologies that, however, do not significantly change either the production structures or the population's lifestyles. This scenario foresees a modest incorporation of circular economy models and the maintenance of population concentration in metropolitan areas.</p> <p><b>3. Yellow Jersey</b>, which is compatible with carbon neutrality, characterized by a structural and transverse change in production chains, made possible by the combination of a series of technologies (associated with an "industrial revolution").</p>	<p>Name: TIMES_PT</p> <p>Type: Partial equilibrium model</p> <p>Scope: Generic model</p>	<p>No. The midcentury target of achieving carbon neutrality is achieved in the Peloton and Yellow Jersey scenarios.</p>
Singapore	Mitigation scenarios are not provided in the strategy.	n.a.	n.a.
Slovakia	<p><b>1. With Existing Measures (WEM)</b>, which models future emissions in Slovakia only if the measures in force at the time of modeling (2016–2018) are implemented. This scenario projects 43 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>2. With Additional Measures (WAM)</b>, which models future emissions in Slovakia if the country undertakes additional measures and invests in natural removal through the LULUCF sector and achieves a 90% emissions reduction from a 1990 baseline by 2050. This scenario projects 14 MtCO<sub>2</sub>e of emissions in 2050 and 7 MtCO<sub>2</sub>e of removals, leaving a gap of 7 MtCO<sub>2</sub>e of emissions.</p>	<p>Name: ENVISAGE-Slovakia, Compact Primes Slovakia, TREMOVE, COPERT IV</p> <p>Type: CGE model, partial equilibrium model</p> <p>Scope: Jurisdiction-specific and generic models</p>	<p>Yes. The midcentury target of reaching climate neutrality is not achieved in the WAM scenario. The LTS notes that this gap may be resolved through carbon removals in the land use, land-use change, and forestry (LULUCF) sector.</p>
South Africa	Mitigation scenarios are not provided in the strategy.	n.a.	n.a.
South Korea	Mitigation scenarios are not provided in the strategy.	n.a.	n.a.
Spain	<p><b>1. Trend</b>, which models emissions to 2050 if no additional measures beside what has already been committed to are implemented (current measures achieve a 23% emissions reduction from a 1990 baseline by 2030).</p> <p><b>2. Climate Neutrality</b>, which achieves a 90% emissions reduction from a 1990 baseline by 2050 and achieves the remaining reductions required to reach neutrality through absorption by sinks. This scenario projects 29 MtCO<sub>2</sub>e of emissions and up to 37 MtCO<sub>2</sub>e of removals in 2050.</p>	<p>Name: TIMES-Sinergia</p> <p>Type: Partial equilibrium model</p> <p>Scope: Generic model</p>	<p>No. The midcentury target of achieving climate neutrality is reached in the Climate Neutrality scenario.</p>
Sweden	<p><b>1. Decided Policy Instruments</b>, which projects emissions to 2050, given the policy instruments that have been implemented to June 2018. This scenario projects 45 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>2. Target</b>, which produces milestone targets for 2030 and 2040 and for the long-term target of net-zero emissions by 2045 by summing the total achievable emission reductions in each sector across the economy.</p>	<p>Name: TIMES-Sweden, unnamed energy model</p> <p>Type: Partial equilibrium model, CGE model</p> <p>Scope: Jurisdiction-specific and generic models</p>	<p>No. The midcentury target of achieving net-zero emissions is achieved in the Target scenario.</p>

Table B2 | **Models Used in Mitigation Scenarios (Cont'd)**

PARTY	LIST OF MITIGATION SCENARIOS	MODEL DESCRIPTION (NAME, TYPE, SCOPE)	GAPS TO REACHING MIDCENTURY TARGET?
Switzerland	<p><b>1. Business as Usual (BAU)</b>, which reflects the measures and instruments of energy and climate policy in force up to the end of 2018 and projects them into the future without any further tightening of measures. This scenario projects 30 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>2. "Net Zero" (ZERO Basis)</b>, which describes development of the Swiss energy system and the resulting emissions on the path to the net-zero target by 2050.</p>	Details not provided	No. The midcentury target of achieving net-zero emissions is achieved in the ZERO Basis scenario.
Ukraine	<p><b>1. Baseline (Energy and Industrial Processes)</b>, which envisions that the characteristics for most of the technologies that households apply in their use and consumption of energy resources and those applied throughout all the stages of goods and services production remain unchanged up to 2050. This scenario projects 592 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>2. Baseline (Forests)</b>, which was developed based on expert modification of previous and modern trends in economic and social development. This scenario projects that by 2050 the annual GHG absorption level in Ukraine's forests will decrease by 26% compared to 2012 and will amount to about 44 MtCO<sub>2</sub>e per year.</p> <p><b>3. Energy Efficiency (Energy and Industrial Processes)</b>, which models emissions after the implementation of policies and measures that aim to increase efficiency in the use of energy resources, and energy savings accompanied with enhanced quality in energy services and energy resources supply. This scenario projects 448 MtCO<sub>2</sub>e of emissions in 2050.</p> <p><b>4. Energy Efficiency and Renewable Energy (Energy and Industrial Processes)</b>, which adds increases in output and consumption of electricity produced from renewable sources to the Energy Efficiency scenario. This scenario projects 278 MtCO<sub>2</sub>e in 2050.</p> <p><b>5. Energy Efficiency, Renewable Energy, Modernization and Innovation (Energy and Industrial Processes)</b>, which projects emissions after the implementation of business measures, regulatory and management practices at the national and sectoral levels, standards and codes, public outreach measures, development of education and science, and production of proprietary technologies. This scenario projects 285 MtCO<sub>2</sub>e in 2050.</p> <p><b>6. Energy Efficiency, Renewable Energy, Modernization and Innovation, Transformation of Market and Institutions (Energy and Industrial Processes)</b>, which builds on the former scenario by including emissions trading/taxation and other market transformation mechanisms. This scenario projects 261 MtCO<sub>2</sub>e in 2050.</p> <p><b>7. Forward Looking (Forests)</b>, which envisions achievement of forestry and nature protection targets in accordance with government-defined priorities and programs. This scenario projects that by 2050 the annual GHG absorption level will decrease by 15% compared to 2012 and will amount to about 50 MtCO<sub>2</sub>e per year.</p> <p><b>8. Forward Looking with Optimum Forest Cover (Forests)</b>, which adds parallel afforestation of 1.45 million hectares to the Forward Looking scenario to achieve 54 MtCO<sub>2</sub>e of GHG absorption by 2050.</p>	<p>Name: TIMES-Ukraine, unnamed dynamic general equilibrium model</p> <p>Type: Partial equilibrium model, dynamic equilibrium model</p> <p>Scope: Generic models</p>	No. The midcentury target of achieving a 31–34% emissions reduction from a 1990 baseline is achieved in the Energy Efficiency, Renewable Energy, Modernization and Innovation (34%); Energy Efficiency and Renewable Energy (33%); and the Energy Efficiency, Renewable Energy, Modernization and Innovation, Transformation of Market and Institutions (31%) scenarios.
United Kingdom	Mitigation scenarios (to 2050) are not provided in the strategy. <sup>a</sup>	n.a.	n.a.

Table B2 | **Models Used in Mitigation Scenarios (Cont'd)**

PARTY	LIST OF MITIGATION SCENARIOS	MODEL DESCRIPTION (NAME, TYPE, SCOPE)	GAPS TO REACHING MIDCENTURY TARGET?
United States	<p><b>1. Benchmark</b>, which serves as a starting point for the analysis and projects emissions based on the current policy trajectory of the country. This scenario leads to a 74% reduction in CO<sub>2</sub> emissions from fossil fuel combustion and industrial processes from a 2005 baseline by 2050.</p> <p><b>2. No CO<sub>2</sub> Removal Technology</b>, which assumes that engineered CO<sub>2</sub> removal technologies like bioenergy with carbon capture and storage (BECCS) are unavailable. This scenario leads to a 79% emissions reduction from a 2005 baseline by 2050.</p> <p><b>3. Limited Sink</b>, which assumes not only limited availability of CO<sub>2</sub> removal technologies but also limited success in maintaining and enhancing the land sink. This scenario leads to an 86% emissions reduction from a 2005 baseline by 2050.</p> <p><b>4. No CCUS</b>, which achieves 80% reductions by 2050 from a 2005 baseline without the use of CCS.</p> <p><b>5. Smart Growth</b>, which portrays a different pathway to decarbonization in the transportation and buildings sectors. This scenario leads to an 80% emissions reduction from a 2005 baseline by 2050.</p> <p><b>6. Limited Biomass</b>, which explores an alternative to the benchmark scenario with lower bioenergy consumption and no deployment of BECCS. This scenario leads to an 80% emissions reduction from a 2005 baseline by 2050.</p> <p><b>7. Beyond 80</b>, which assumes stronger global action to reduce emissions and more rapid advances in low-carbon technologies. This scenario leads to deeper emissions reduction by 2050 of greater than 80% below 2005 levels.</p>	<p>Name: GCAM, GTM, USFAS, NEMS, MAC</p> <p>Type: IAM, partial equilibrium model</p> <p>Scope: Jurisdiction-specific and generic models</p>	<p>No. The midcentury target of achieving an 80% emissions reduction from a 2005 baseline is achieved in the Limited Sink, No CCUS, Smart Growth, Limited Biomass, and Beyond 80 scenarios.</p>

Notes: CGE = Computable general equilibrium; IAMs = Integrated assessment models; MtCO<sub>2</sub>e = Million metric tons of carbon dioxide equivalent; GHG = Greenhouse gas; NDC = Nationally Determined Contribution; CCS = Carbon capture and storage; CCUS = Carbon capture, utilization, and storage; n.a. = Not applicable.

<sup>a</sup> The UK LTS contains modeling to 2032, which is the year the party is slated to meet its legislated carbon budget of reducing emissions to 58 MtCO<sub>2</sub>e. However, no modeling scenarios are presented to depict a pathway toward 80 percent emissions reduction from a 1990 baseline in 2050.

Source: Authors.

## APPENDIX C: ENERGY SECTOR TRANSITIONS

This appendix—supplemental to Section 3.3—provides an overview of energy supply and decarbonization technologies mentioned in the “long-term low greenhouse gas emission development strategies” (long-term strategies or LTSs) submitted to date (Table C1).

Table C1 | **Energy Supply and Decarbonization Technologies Envisioned as Part of the Energy Sector Transition**

PARTY	SOLAR	WIND	HYDROPOWER	HYDROGEN	NUCLEAR	GEOTHERMAL	BIOMASS/ BIOFUEL/ BIOENERGY	WAVE/TIDAL	CCS TO CLEAN FOSSIL SOURCES
Austria	✓	✓	✓	✓		✓	✓		Under consideration
Belgium	✓	✓		✓	✓ <sup>a</sup>	✓	✓		✓
Benin	✓	✓	✓				✓		
Canada	✓	✓	✓	✓	✓	✓	✓	✓	✓
Costa Rica	✓	✓	✓	✓		✓	✓		
Czech Republic	✓	✓	✓	✓	✓	✓	✓		✓
Denmark	✓	✓		✓			✓		Under consideration
European Union (EU)	Not stated <sup>b</sup>	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Fiji	✓	✓	✓	✓		✓	✓	✓	
Finland	✓	✓		✓	✓		✓		✓
France	✓	✓	✓	✓	✓	✓	✓		✓
Germany	✓	✓		✓	✓	✓	✓		✓
Japan	✓	✓	✓	✓	✓	✓	✓		✓
Latvia	✓	✓	✓	✓		✓	✓		Under consideration
Marshall Islands	✓	✓		✓			✓		
Mexico	✓	✓	✓	✓	Under consideration	✓	✓	Under consideration	Under consideration
Netherlands	✓	✓		✓	✓		✓		✓
Norway	✓	✓	✓	✓			✓		✓
Portugal	✓	✓	✓	✓		✓	✓		Under consideration
Singapore	✓			✓				Under consideration	✓
Slovakia	✓	✓	✓	✓	✓		✓		✓

Table C1 | **Energy Supply and Decarbonization Technologies Envisioned as Part of the Energy Sector Transition (Cont'd)**

PARTY	SOLAR	WIND	HYDROPOWER	HYDROGEN	NUCLEAR	GEOTHERMAL	BIOMASS/ BIOFUEL/ BIOENERGY	WAVE/TIDAL	CCS TO CLEAN FOSSIL SOURCES
South Africa	✓	✓	✓	✓	✓		✓		Under consideration
South Korea	✓	✓	✓	✓	✓	✓	✓		✓
Spain	✓	✓	✓	✓		✓	✓	✓	✓
Sweden	✓	✓	✓	✓	✓	✓	✓		✓
Switzerland	✓	✓	✓	✓	✓	✓	✓		✓
Ukraine	✓	✓	✓	✓	✓		✓		✓
United Kingdom	✓	✓		✓	✓	✓	✓	✓	✓
United States	✓	✓	✓	✓	✓	✓	✓	Under consideration	✓

Note: CCS = Carbon capture and storage.

<sup>a</sup> Belgium currently relies on a small amount of nuclear power but has committed to phasing out all nuclear power by 2025.

<sup>b</sup> According to the European Union's LTS, "The European Council acknowledges the need to ensure energy security and to respect the right of the member states to decide on their energy mix and to choose the most appropriate technologies."

Source: Authors.

## ENDNOTES

- When describing a goal to reach net-zero emissions by midcentury, governments have used different terminology to describe their targets. This includes "carbon neutrality," "climate neutrality," "net-zero emissions," "phase out," and/or "net-CO<sub>2</sub> removal." Some have used different terms intentionally to refer to different forms of targets (e.g., carbon neutrality may only refer to CO<sub>2</sub> gas coverage), whereas others have used the above terms interchangeably (Levin et al. 2020).
- The 17 LTSs that currently contain net-zero targets are Austria, Costa Rica, Denmark, the European Union, Fiji, Finland, France, Japan, Latvia, the Marshall Islands, Portugal, Singapore, Slovakia, South Korea, Spain, Sweden, and Switzerland.
- The intended purpose of parties' high-level mitigation objectives varies, with some parties setting binding targets through their LTSs and others describing aspirations or exploratory pathways that may evolve over time. This paper's use of the word "target" should not be construed as implying that all parties have set binding midcentury mitigation goals.
- When describing a goal to reach net-zero emissions by midcentury, governments have used different terminology to describe their targets. This includes "carbon neutrality," "climate neutrality," "net-zero emissions," "phase out," and/or "net-CO<sub>2</sub> removal." Some have used different terms intentionally to refer to different forms of targets (e.g., carbon neutrality may only refer to CO<sub>2</sub> gas coverage), whereas others have used the above terms interchangeably (Levin et al. 2020).
- The 17 LTSs that currently contain net-zero targets are Austria, Costa Rica, Denmark, the European Union, Fiji, Finland, France, Japan, Latvia, the Marshall Islands, Portugal, Singapore, Slovakia, South Korea, Spain, Sweden, and Switzerland.
- Three parties have communicated net-zero targets since publishing LTSs that contain different midcentury targets. These parties are Canada, the United Kingdom, and the United States.
- Gaps may occur in part because many parties deploy a "backcasting" methodology in modeling, wherein the long-term vision (e.g., net-zero emissions by 2050) is established first, and the necessary policy and technology interventions are identified thereafter.
- When modeling the natural carbon removal that can be achieved via the land sector and determining how much land is available to unlock this removal, parties and policymakers must also be cognizant of competing demands for land resources (e.g., the land that is needed to supply the food and commodities that parties' economies produce) (Searchinger et al. 2019).
- As in the case of natural emissions sinks, technological carbon removal techniques also depend on substantial land requirements, which must be balanced with competing demands for food and commodity production.
- LTSs are taken at face value for the purposes of this publication, and the authors do not comment on parties' self-determined actions. However, it is important to note here that the exact carbon benefits of certain removal technologies are still uncertain, though further research is underway.

11. In June 2017, Sweden's Riksdag decided by a large political majority to introduce a Climate Policy Framework with an accompanying Climate Change Act for Sweden. This framework is the most important climate reform in Sweden's history and begins the implementation process of the Paris Agreement in Sweden.
12. Parties that have established net-zero commitments since submitting their first LTSs are Canada, Japan, the United Kingdom, and the United States.

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