ENHANCING GLOBAL AMBITION FOR 2035:

ASSESSMENT OF HIGH-AMBITION COUNTRY PATHWAYS

CENTER FOR GLOBAL SUSTAINABILITY

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Summary for Policymakers

Global emissions continued to grow after COVID and reached a new record high in 2023, and the window of opportunity to meet the climate goal of limiting warming to 1.5°C is rapidly closing. Worldwide, green technologies have become cost-effective and green investments have begun to propel the economy, boosting confidence for enhanced action. As countries are developing and submitting new national climate targets (the Nationally Determined Contributions NDC 3.0) for 2035 over the coming months, it is critical that the updated targets reflect the highest ambition possible in different country contexts with absolute emissions reduction targets that cover all greenhouse gases from all sectors of the economy.

An effective NDC target needs to be high ambition and aligned with global climate goals; and at the same time, it needs to be plausible with concrete transition pathways and implementable in a domestic policy context. It therefore requires a combination of top-down and bottom-up approaches to assess the global ambition held by enhanced, robust national targets for 2035.

Using an open-source global integrated assessment model, we develop economy-wide pathways through 2035 and beyond for key emitting countries following either *High Ambition* or *Delayed Transition* scenarios, identify the key policy opportunities for rapid emissions reductions including with subnational actors, and assess the aggregate global emissions and temperature outcomes. This bottom-up approach allows a deeper understanding of country specific and global aggregate mitigation potential that reflects high ambition with near-term practicality, providing important complementary information to the top-down ambition assessments.

Key Findings

- Globally, the *High Ambition* country pathways can deliver a 35% reduction in total GHG emissions by 2035 from the 2023 level, compared to a 7% reduction in 2030 with existing country NDCs, and a 12% reduction by 2035 if countries follow the *Delayed Transition* pathways.
- Following the *High Ambition* pathways to net-zero CO_2 emissions with targeted non-CO_2 abatement leads to a peak temperature of 1.7°C with median likelihood; the additional CO_2 emissions from *High Ambition* to *Delayed Transition* alone would increase the peak temperature to 1.8°C, even with a very optimistic post-2030 trajectory after the delay to net zero.
- Drawing down the temperature overshoot and returning to 1.5°C is a massive challenge with uncertain feasibility in both technological and geophysical aspects of negative emissions, and adding a tenth of a degree °C makes the return nearly impossible.
- Across sectors, electricity generation contributes to be the largest CO_2 emissions reduction for most countries through 2035, globally increasing wind and solar capacity by tenfold and more than halving unabated fossil power generation from the 2020 levels. Contributions from industry, transport, buildings, and land sectors vary across countries based on existing emissions profiles.

- Targeted methane abatement in oil and gas, coal, and waste sectors can drive down global methane emissions by 35% from 2020, which accounts for nearly 40% of total GHG reductions between 2020 and 2035 if measured in its 20-year global warming potential.
- Key emitting countries are categorized into three groups, based on current emission trends, existing targets, and the potential to mitigate under the *High Ambition* pathways.
  - Group A countries with already decreasing emissions, existing 2030 commitments on absolute reductions from a base year and net-zero emissions by 2050 can deliver about 60 to 70% reduction in total GHG emissions from the NDC base year (or around 50% from 2023) by 2035;
  - Group B countries with recent or immediate peak emissions before 2025 can deliver 30 to 40% reduction by 2035 from the peak level; and
  - Group C countries with still growing emissions need to limit the growth and can deliver 10 to 20% reduction by 2035 from the estimated peak in a future year.
- Moving from the *High Ambition* pathways to *Delayed Transition*, majority (nearly 85%) of the increased cumulative emissions between 2023 and net zero occur in Group B and Group C countries; with further delay of emissions reductions in Group B countries and emissions peak in Group C countries beyond 2030, even larger peak temperatures exceeding 1.8°C would become inevitable.
- Despite different climate governance and institutional structures across countries, subnational actors have large potential and can make important contributions to enhance and deliver national ambition. With policy authorities in key areas (such as land, waste, transportation), subnational actors can innovate and implement solutions and build broader partnerships to drive action and deliver social and economic benefits to the local communities.

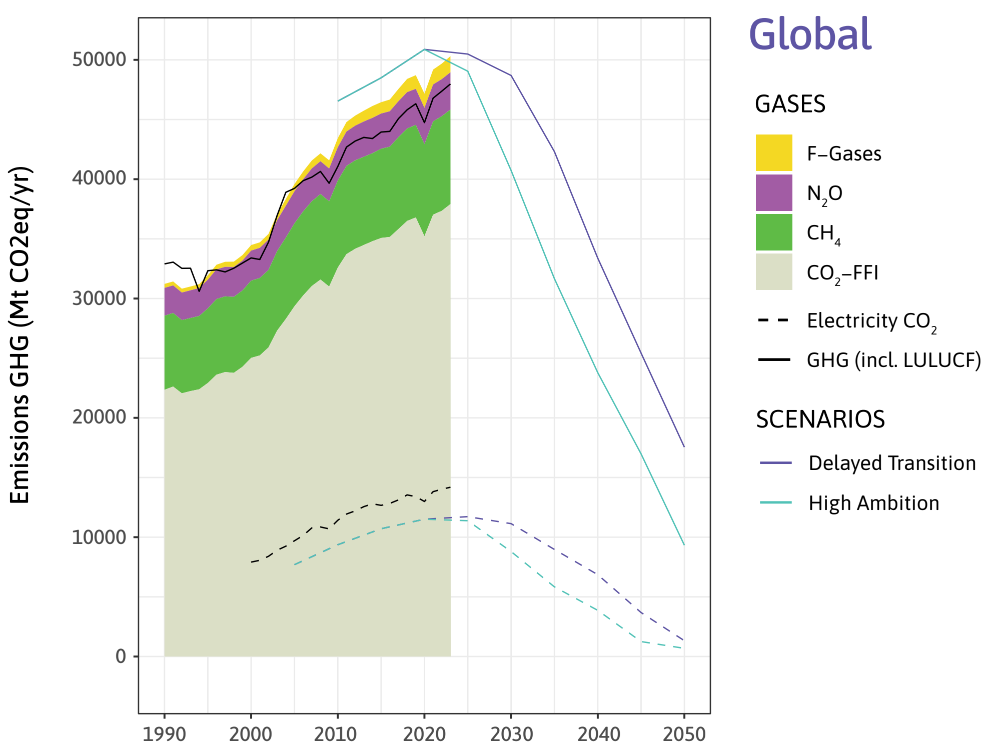

Figure SPM. Global GHG including LULUCF emission pathways across scenarios. World's GHG including LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist (solid black line for total GHG, include LULUCF), EMBER (dashed black line for electricity supply GHG emissions), and CEDS (colored breakdown of historic GHG emissions, without F-Gases). Pathways data includes LULUCF emissions and is an aggregation of the regional scenarios presented in this report.

1. Introduction

The first Global Stocktake concluded that the world is not on track to reach the climate goal of limiting warming to 1.5°C. Global emissions of greenhouse gases (GHGs) have resumed increasing after the 2020 COVID dip, reaching an all-time high in 2023.[1] The largest contributor, CO_2 emissions from industrial processes and fossil fuel energy, as well as the share caused by power generation, have also increased and reached record levels in 2023. To keep the global climate goal within reach, there is a real urgency to stop and revert the global emissions growth immediately and deliver meaningful emissions reductions over the next decade.

We now have an important policy window globally to advance country ambitions through the new cycle of national climate targets set under the Paris Agreement. Over the coming months, countries are developing and submitting their new Nationally Determined Contributions (NDCs) for 2035. The Paris process has acknowledged and empowered individual countries to drive climate policies and actions, respecting their own conditions and priorities; at the same time, it leverages the international process to provide a transparent platform for open assessment and discussion. Through the first two cycles of ambition ratchet, it is evident that the aggregate global ambition has largely improved from the 1st round of NDCs submissions to the 2nd,[2,3] demonstrating the alue of the Paris structure and process; however, existing national targets vary substantially in target type, coverage, level of stringency, and room for uncertainty, and there remains a large ambition gap to meeting global climate goals.[4]

With rapidly declining costs of renewables, battery storage, and electric vehicles, green technologies are proven cost-effective at large scale across the world.[5,6,7] Moreover, green investment and green industries have become the new engine of economic growth, bringing in tremendous social and economic benefits.[8,9,10] These new trends can help largely boost the confidence of countries to enhance ambition in NDCs 3.0 for 2035, which is almost halfway toward the net-zero emissions goals around mid-century and requires fundamental changes to start for deep decarbonization globally. Leveraging the rapidly advancing technology, policy, and economic landscape, the updated national climate targets should aim to reflect the highest ambition possible in each country's context with absolute emissions reduction targets that cover all GHG emissions from all sectors of the economy.

An effective NDC target needs to be high ambition and aligned with global climate goals; and at the same time, it needs to be plausible with concrete transition pathways and implementable in a domestic policy context. It therefore requires a combination of top-down and bottom-up approach to assess global ambition held by enhanced, robust national targets for 2035. Using an open-source, field-leading global integrated assessment model, we develop plausible, high-ambition economy-wide pathways through 2035 and beyond for key emitting countries (see Box 1 for more detail about the two modeled scenarios in the analysis), identify the key policy opportunities across sectors for rapid emissions reductions, and assess the aggregate global emissions and temperature outcomes. This bottom-up approach with in-depth country assessment allows a better understanding of high ambition with near-term practicality, providing important complementary information to the top-down ambition assessments.

Our analysis also highlights how non-state actors may contribute to enhanced ambition and implementation across different sectors and GHGs, especially in the identified key priority areas. Globally, non-state actors (states/provinces, cities, businesses, etc.) show increasing leadership in policy development and implementation that can drive large emissions reductions. In addition, enhancing all-of-society climate action can drive sustained economic growth and broad societal benefits, which makes the emissions reduction strategies more robust. A critical element of the improved strategy for NDCs 3.0 is to mobilize and integrate diverse non-state actors into national decarbonization strategies through an all-of-society approach, leveraging powers and strengths from different actors to maximize and reinforce the combined outcomes.

The report includes a global chapter that assesses the aggregate emissions pathways with 2035 national climate targets for the G20 countries. Key emitting countries are categorized into three groups based on their recent emissions trends and reduction potential under the *High Ambition* pathways through 2035. The global chapter also explores different ambition levels across country groups and the potential impacts on peak temperature. In addition, the report also includes in-depth assessments of ten countries, representing the three different groups, which provides a more comprehensive picture of the country's current national strategies, the *High Ambition* pathways for 2035, key opportunities for priority sectoral transition, and potential contributions from subnational actors.

Box 1. Two modeled scenarios in this analysis

Using an open-source global integrated assess ment model, the Global Change Analysis Model (GCAM-6.0-CGS), we develop two different transition pathways–*High Ambition* and *Delayed Transition*–for most countries and regions, largely based on the (global) Net Zero 2050 and Delayed Transition scenarios, respectively, from the NGFS Phase V 2024,[11,12] with additional country-specific adjustments. For the United States and China, we developed a different set of two scenarios with detailed sectoral policy modeling.[13,14] See Technical Appendix for more details about country scenarios. For India and Indonesia, we developed pathways based on the NGFS narratives and announced net zero pledges, while accounting for latest near-term dynamics not yet reflected in the global NGFS scenarios. Specifically,

> The *High Ambition* scenario assumes decisive accelerated action from current trends in each country in terms of energy transition, especially in decarbonizing electricity generation, halting deforestation, and targeted methane and other non-CO_2 gases reductions in energy and waste.
>
> The *Delayed Transition* scenario shows a delayed increase of policy implementation and uptake of low-carbon technologies through 2030, followed by very ambitious trajectories post-2030 after the delay, mostly in parallel to the *High Ambition* pathways to country net-zero targets.

The emission trajectories show total greenhouse gas emissions with AR4* global warming potentials (GWP), including CO_2 emissions from land-use, land-use change and forestry (LULUCF). Indirect emissions[15] that are included in national inventories but not represented in models are added from the country-level downscaled dataset of the NGFS scenarios. Furthermore, the scenario results (but not the historical data) additionally include emissions from international aviation and shipping. Not including these increases 2035 reduction numbers by up to a few percentage points.

*Fourth Assessment Report, Intergovernmental Panel on Climate

2. Aggregate Global Pathways

2.1 Overall emissions and peak temperature

Based on the *High Ambition* country pathways with decisive accelerated policy action in the near future, global total emissions stabilize and are a few percent below the peak level in the modeled 2025 timestep (which represents the average of the 2023-2027 period). This is consistent with other assessments that emissions in 2024 could plateau, and the world thus is entering the peaking stage (*The World Energy Outlook*, 2024). This is essential to prepare for very fast emission reductions over the coming decade. Overall, the *High Ambition* country pathways can deliver a 15% reduction in global total GHG emissions from 2023 to 2030 and a 35% reduction by 2035 (Figure 2.1), an improvement from the 7% reduction that can be delivered by 2030 under existing NDCs.[16]

In comparison, under the *Delayed Transition* country pathways, global total GHG emissions instead of declining remain at the peak level for longer with a small increase from 2023 to 2030. Given inertia in the energy system, this would also limit the ability to reduce emissions in 2035, so that even with much accelerated policies starting post-2030, only a 12% reduction would be achieved by 2035 (Figure 2.1).

The contrast between these two global emission trajectories shows the difference between very decisive accelerated action now, versus a delayed increase of policy implementation and uptake of low-carbon technologies. Such a delay has profound implications for the temperature increases and thus impacts that human systems will have to adapt to and cope with.

The temperature response to human emissions can broadly be split into two different mechanisms. On the one hand, the temperature increase is mostly proportional to the cumulative amount of emissions of long-lived greenhouse gases, mostly CO_2 (but also N_2O and some of the F-Gases, each with atmospheric lifetimes >100 years). On top of this comes the warming from methane emissions, but due to the shorter atmospheric lifetime of little over 10 years, it's mostly the methane emissions in the two decades prior that matter for the temperature effect in any given year.

Achieving the Paris Agreement goal of limiting warming to well below 2°C requires a peak of temperatures around mid-century. The peak is reached when CO_2 emissions reach net-zero. And while both the *High Ambition* and the *Delayed Transition* country pathways can lead to global net-zero emissions eventually, the delay results in a very distinct increase of the unavoidable further temperature increase, and thus increase of climate impacts.

The *High Ambition* country pathways can lead to a peak temperature at 1.7°C with median likelihood, including immediate targeted reductions of methane emissions from oil and gas, coal, and waste. In comparison, contribution from the increased CO_2 emissions under the *Delayed Transition* country pathways alone adds at least a tenth of a degree °C to peak temperature from 1.7°C to 1.8°C with median likelihood, even in the most optimistic case that very ambitious trajectories mostly in parallel to the *High Ambition* trajectories can be achieved after the delay until 2030.

The *High Ambition* country pathways are thus the only option to keep realistic chances alive to bring back temperatures to 1.5°C after the peak. Even drawing down 0.2°C is a massive challenge with uncertain feasibility in both technological and geophysical aspects of negative emissions.[17] Increasing the overshoot by 50% to 0.3°C would be all but giving up on the 1.5°C target altogether.[18] It demonstrates the importance of early actions to hedge against later hurdles in full decarbonization.

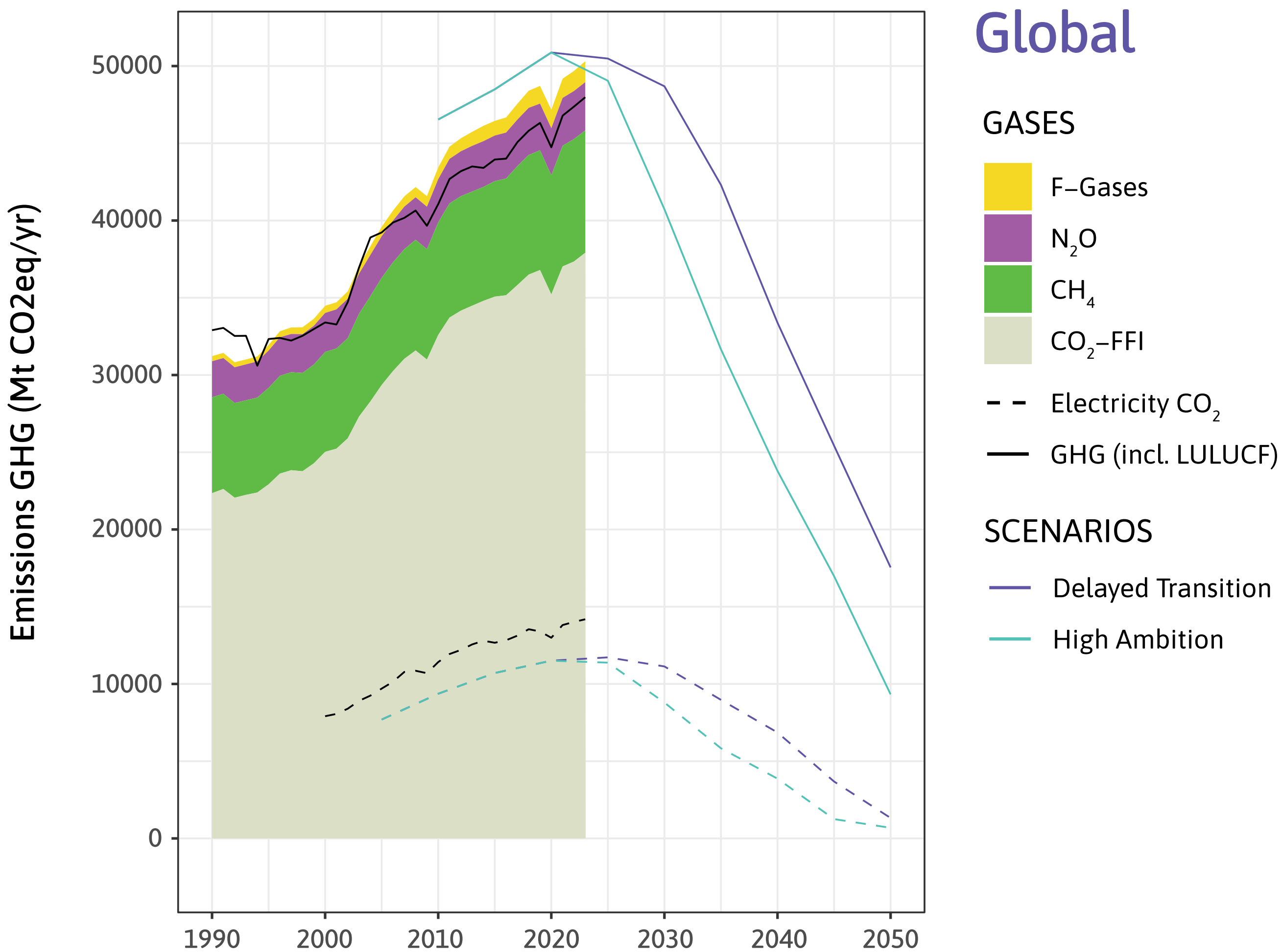

Figure 2.1. Global GHG including LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[19] (solid black line for total GHG, include LULUCF), EMBER[20] (dashed black line for electricity supply GHG emissions), and CEDS[21] (colored breakdown of historic GHG emissions, without F-Gases). Pathways data includes LULUCF emissions and is an aggregation of the regional scenarios presented in this report.[22]

2.2 Sectoral contributions

The *High Ambition* country pathways require mitigation contributions from all sectors and across all greenhouse gases. Globally, as well as in most countries, the power sector contributes the largest single component to overall emission reductions through 2035, by accelerated renewable deployment and fossil phaseout. Decarbonized power generation, which in many countries is largely achieved in the *High Ambition* scenario by 2035, provides the foundation of decarbonization of the end-use sectors such as transport, buildings, and industry, through direct and indirect electrification.

The contribution of emission reductions from the three energy end-use sectors are largely determined by their respective readiness for direct electrification to substitute fossil energy. Direct electrification, the direct use of electricity either from the grid or through batteries, is the preferred option in all processes where possible. It has a higher efficiency compared to indirect electrification in which the electricity gets converted to gaseous fuels like hydrogen or even liquid fuels like in e-kerosene. Due to the higher efficiency, direct electrification can already contribute to emission reductions through 2035, whereas indirect electrification only yields real reductions once electricity generation is mostly decarbonized. Therefore, while direct electrification through electric vehicles (EVs) and heat pumps scales up notably until 2035, most indirect electrification options need to be brought to mass markets for later up-scaling, particularly in the hard-to-electrify processes and sectors. In addition, demand dynamics illustrate how fast potential emission increases would have been without decarbonization—are also a critical determinant of mitigation potentials in the end-use sectors, which tends to vary more substantially across countries over the next decade due to different development stages, economic structures, consumer behaviors, and other factors.

Another key contribution to emission reductions through 2035 is the elimination of CO_2 emissions from land-use change, mostly deforestation. Globally, land use, land-use change, and forestry (LULUCF) emissions averaged at 4.7 Gt CO_2 per year between 2013 and 2022, with deforestation acting as the largest source and Brazil, Indonesia, and the Democratic Republic of the Congo contributing over 50% of global LULUCF emissions by 2023.[23] Carbon sequestration via re- and afforestation offset around two-thirds of deforestation emissions. In addition, the land linkages with certain decarbonization strategies, bioenergy in particular, and potentially growing mining activities of critical minerals, require comprehensive policy strategies to avoid additional deforestation.[24]

Last but not least, the reductions of non-CO_2 emissions, particularly CH_4, are critical for limiting the peak temperature as discussed above.[25] In particular, CH_4 emissions from waste and the energy sector offer important near-term opportunities for Gt CO_2eq sizes of emission reductions to achieve the *High Ambition* pathways, while CH_4 emissions from agriculture due to continued increases of demand for agricultural products can probably only be stabilized or moderately reduced via altered production practices and efficiency. In terms of relative reduction from 2020, CH_4 from the oil and gas sector can decrease by 73% by 2035, and CH_4 from landfills decreases by 50%, leading to a 35% reduction in total

CH_4 emissions by 2035. If measured in its 20-year global warming potential (GWP20), CH_4 reduction under the High Ambition pathways accounts for 38% of total GHG reductions between 2020 and 2035, compared to 18% if measured in the 100-year global warming potential (GWP100). As explained above, however, the reduction of CO_2 and CH_4 have their own distinct implications for temperature, and both are needed to minimize peak temperature, so any metric that tries to compare these inherently distinct contributions is imperfect.

2.3 Regional emissions and peak temperature

By taking the bottom-up approach, we develop the *High Ambition* country pathways that reflect specific contexts and circumstances of delivering decisive accelerated action from current trends. Largely, current trends of each country resulted from a combination of historical emissions, development stage, economic structure, resource endowment, technological and institutional capacity, and other country-specific conditions that have strong impacts on their mitigation potential over the coming decade. Our approach aims to balance the near-term practicality (starting with the current trends) and the high ambition possible (breaking the trends assertively) in each country's context, which is one way to reflect the common but differentiated responsibilities for the joint global target.

Based on individual countries' current emissions, existing climate targets, and the potential to mitigate under the *High Ambition* country pathways, we categorize the major economies into three groups of countries and summarize the 2035 emissions targets for the G20 countries under the *High Ambition* pathways (Table 2.1).

The first group of countries (Group A) is characterized by already declining emissions, having a 2030 NDC target that requires an absolute reduction in total GHG emissions from their current level, and having a net-zero target for 2050 regardless of the varying levels of scope and implementation. Group A countries include, for example, the United States, the United Kingdom, the European Union, Australia, Canada, Japan, South Korea, and others. For most of these countries, a high ambition 2035 target implies around 50% reduction from the 2023 levels, which translates into larger (60-70%) reductions relative to the country-specific NDC base years (usually around the emissions peak). The linear interpolation between 2030 and 2050 targets should be seen as the absolute minimum ambition and therefore in many cases is lower than the 2035 potential under the *High Ambition* scenario. Achieving faster than linear reductions in Group A countries by 2035 is critical in lowering the contribution to peak temperature; it also matches the observed characteristics of technology adoption curves, where fastest speed is achieved in the mid-transition period, as the 2035 period for these countries.

The second group of countries (Group B) were still growing in emissions during the announcement of the existing NDCs and thus had only committed to targets relative to a baseline, or intensity targets, but have since progressed in their decarbonization such that a peak of emissions can reasonably be achieved now, if not already, under the *High Ambition* pathways. Group B countries include, for example, China, South Africa, Argentina, Mexico, and others. While these countries have not yet committed to absolute emission reductions in their existing NDCs, the 2035 target should aim to include meaningful emissions reductions relative to a base year. As shown in our *High Ambition* pathways, Group B countries can deliver 30-40% reduction from the peak levels, mostly before 2025 (Table 2.1). Achieving meaningful emissions reductions in Group B countries by 2035 is critical in keeping ambitious global peak temperature targets within reach.

The last group of countries (Group C) still has structurally increasing emissions, either because the uptake of low-carbon technologies has not yet started, or because demand growth still strongly outpaces the addition of low-carbon technologies. Therefore, these countries can reasonably argue that it is still too early for them to clearly know whether they will be able to peak emissions soon; however, with the rapid cost declines and upscaling in low-carbon technologies, all of them should aim to peak emissions as soon as possible before 2030 and start to reduce emissions after. Group C countries include, for example, India, Indonesia (emissions excluding LULUCF to peak around 2025 driving down total emissions declining already), and others. As shown in our *High Ambition* pathways, these countries can deliver at least coming back to the 2023 levels of emissions or deliver up to 20% reduction from the peak by 2035 after potentially a few more years of emission increases (Table 2.1). Avoiding continued emissions growth in Group C countries now is critical in keeping ambitious global peak temperature targets within reach.

To better understand how the global peak temperature might be affected by different country decisions in NDCs 3.0, we further explore several alternative scenarios with different combinations of country ambitions for 2035 and beyond. The peak temperature is mostly determined by cumulative CO_2 emissions and an additional component due to non-CO_2 emissions. In this exercise, we therefore use carbon budgets until global net-zero CO_2 emissions as the linkage to peak temperatures, assuming ambitious reductions in non-CO_2 emissions.[26]

In the first scenario (*Uniform 2050*), we assume all countries would equally reduce CO_2 emissions from 2023 linearly towards net-zero in 2050; as a result, the cumulative emissions would amount to 13.5 times the level of 2023 emissions at 530 Gt of CO_2 by 2050, leading to <50% chance of peak temperature at 1.6°C (dash line in Figure 2.2). In this scenario, the three country groups would contribute towards the future cumulative carbon emissions at the share they have in 2023, with 28%, 34%, and 37% respectively (Figure 2.3). The assumption of uniform linear reduction trajectories for all countries however is of course unrealistic, given that some countries are already on a declining trajectory (some even with a slope roughly in line with such a trajectory), while others have increasing emissions. Furthermore, this assumption runs counter to pledged net-zero target years by countries. Given that most countries' net-zero targets are for total greenhouse gases (GHG), we do not exactly know when net-zero CO_2 is most likely to be expected, but there is a general consensus that net-zero CO_2 would precede net-zero GHG by 5-10 years.

In the second scenario (*Mild Differentiation*), we assume that countries with 2050 net-zero targets follow a linear trajectory towards net-zero CO_2 in 2045, which reduces the global cumulative emissions of this group until 2045 by 28 Gt CO_2. We further assume that countries with 2060 and 2070 targets

Table 2.1. Total GHG Emissions Reductions by 2035 for the G20 Countries and Globally Under the High Ambition Pathways

Country	NDC Base Year or Estimated Peak Year	Including LULUCF	Excluding LULUCF	
		Relative to base year or estimated peak year	Relative to base year or estimated peak year	Relative to 2023
Brazil	2005	-74%	-34%	-44%
Japan	2013	-64%	-66%	-55%
Republic of Korea	2018	-58%	-60%	-55%
United Kingdom	1990	-80%	-80%	-59%
EU27BX	1990	-69%	-70%	-54%
United States	2005	-67%	-58%	-49%
Australia	2005	-71%	-58%	-57%
Canada	2005	-60%	-50%	-45%
Argentina	2007*	-43%	-29%	-33%
South Africa	2012*	-49%	-49%	-40%
China	2023**	-33%	-32%	-32%
Mexico	2025**	-38%	-38%	-39%
Saudi Arabia	2019	-36%	-36%	-36%
Turkey	2021*	-43%	-42%	-41%
Russia	1990	-70%	-60%	-44%
Indonesia	2025**	-58%	-26%	-23%
India	2030**	-10%	-10%	+5%
World	2023	-35%	-34%	-34%

*Estimated peak year based on PRIMAP-hist historical data, total GHG emissions excluding LULUCF.

**Estimated peak year based on the *High Ambition* scenario, total GHG emissions excluding LULUCF.

reach net-zero CO_2 in 2055 and 2060 and that countries without net-zero targets also achieve 2060 net-zero CO_2, and that they all follow linear trajectories from 2023 until the respective net-zero year to reach those. This adds 34 Gt CO_2 emitted for group B, and 73 Gt CO_2 for group C, so 79 Gt CO_2 globally. In this scenario, the shares of groups A, B, and C towards future cumulative CO_2 emissions make up 20%, 35%, and 44%, respectively (Figure 2.3).

The modeled *High Ambition* pathways follow a similar trajectory than the back-of-the-envelope linear assumptions in the Mild Differentiation scenario, only with slightly higher differentiation mainly due to the convex decarbonization in Group A. The shares across country groups toward cumulative net positive emissions are 18%, 40%, and 41%, respectively.

Going from the *High Ambition* to the *Delayed Transition* pathways implies roughly 250 Gt additional cumulative CO_2 emissions until the point of net-zero, leading to ~50% chance of peak temperature at 1.8°C (Figure 2.2). Most of the emissions increase occurs in Groups B and C countries, with only 40 Gt CO_2 occurring in Group A countries, leading to cumulative emissions shares by 13%, 42%, and 45%, respectively, across the three country groups (Figure 2.3). Moreover, with further delay of emissions reductions in Group B countries and emissions peak in Group C countries beyond 2030, the likelihood of keeping well below 2°C falls below 75% (Figure 2.2).

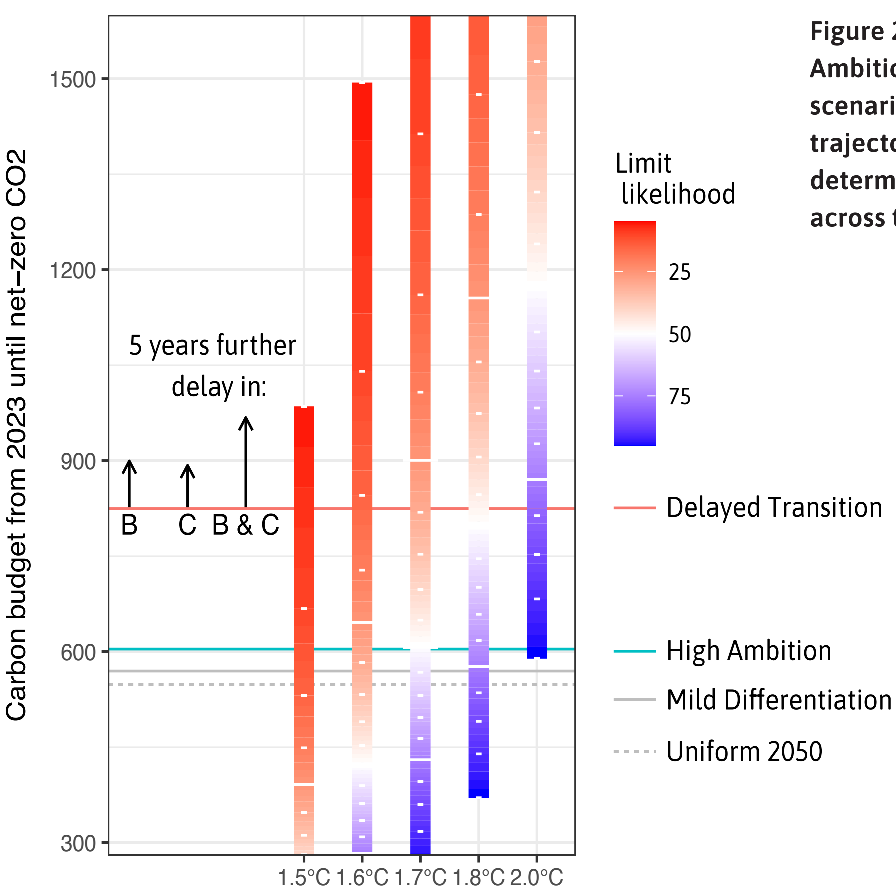

Figure 2.2. CO_2 emissions in the High Ambition and Delayed Transition scenarios compared to simple linear trajectories toward net zero, illustrating determinants of peak temperatures across the three different regions.

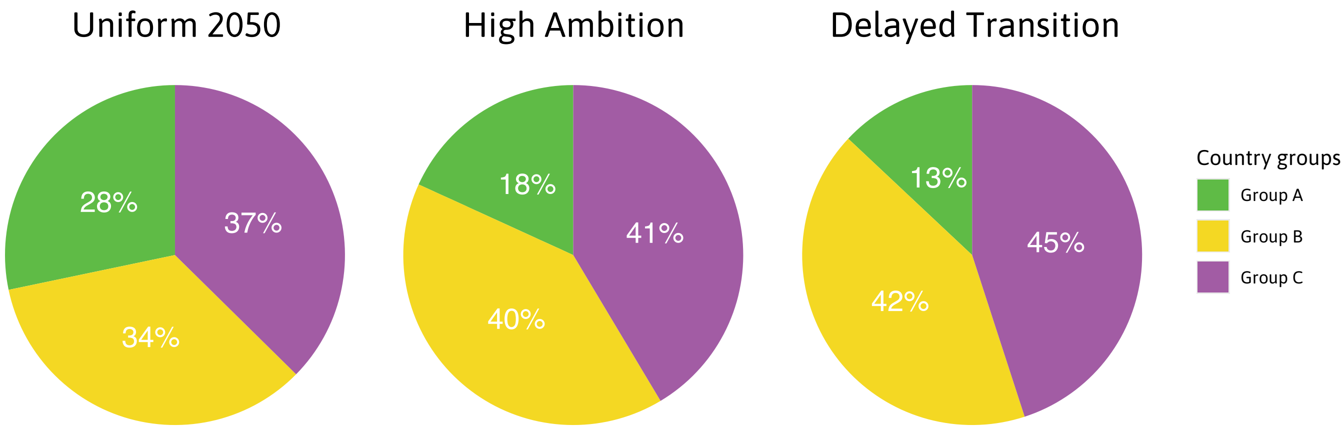

Figure 2.3. Share of Cumulative Global Carbon Emissions by Three Country Groups from 2023 to Net-Zero under Different Scenarios: Uniform 2050 (left), High Ambition (middle), and Delayed Transition (right).

3.1 Australia

Summary

- Australia's total GHG emissions peaked in 2006 and declined by 32% in 2023 from the peak level; emissions from electricity decreased by 15% during this period but remained the largest share of total emissions (31%) in 2022.
- Delivering the 2030 NDC target of reducing GHG emissions, including LULUCF, by 43% from 2005 requires increasing the average annual emissions reduction rate from 2% between 2007 and 2023 to 3% through 2030; Australia has also committed to net-zero GHG emissions by 2050.
- An important portion of emissions reductions and delivery of the NDC is achieved through the change of LULUCF from a substantial emissions source in the base year (12% of total) to a major sink, suggesting less emissions abatement delivered in the energy system.
- Australia's electricity generation is dominated by fossil energy (46% from coal and 17% from gas); with accelerated solar deployment, especially from distributed systems, Australia aims to generate 82% of its electricity from renewable sources by 2030.
- The fossil fuels industry contributes largely to Australia's economy and is expected to continue to grow with new infrastructure being developed for production and export.
- A high-ambition 2035 target for Australia includes a 63%-72% reduction in total GHG emissions, or 57%-69% excluding LULUCF, from the 2005 levels.
- Key strategies include a nearly 100% clean power system by 2035 with coal power phaseout and doubled to tripled annual solar and wind buildout, expansion of methane mitigation strategies in the agricultural and fossil fuel production sectors, and strengthened EV policies focused on EV adoption, infrastructure buildout, and national EV targets.
- Australia's climate governance follows a "compensatory federalism" model, where states enact climate policies in key areas like land management and transportation to offset the conservative national government, with local coal-fired power plant retirement and state-level EV charging infrastructure promotion serving as promising areas for subnational climate action.

EMISSIONS PROFILE. Australia's GHG emissions, including LULUCF, peaked in 2006 and by 2023 had decreased by 32%, reaching their lowest level in almost 30 years.[27] Roughly a third of all emissions come from the power sector (31% of GHG emissions, excluding LULUCF, as of 2022), followed by the methane and transport sectors (18% and 16%, respectively). While the LULUCF sector has historically been a source of emissions, the sector was a net sink of 88.5 $MtCO_2e$ in 2022, according to Australia's 2022 National Inventory Report.[28] However, other models estimate that the LULUCF sink is smaller, around 15 $MtCO_2$, or that emissions could even be positive, reaching up to 5 $MtCO_2$ in 2022.[29]

2030 NDC. Australia's 2022 NDC commits to reducing GHG emissions, including LULUCF, by 43% of 2005 levels by 2030, as well as achieving net-zero GHG emissions by 2050.[30] Continuing the emissions reduction rate between 2007 and 2022 is insufficient to meet its 2030 NDC. To achieve its NDC targets, Australia needs to accelerate its average annual emissions reduction rate from approximately 2%

between 2007 to 2022, including LULUCF, to 3% per year for 2022 to 2030 (Table 3.1.1 and Figure 3.1). Moreover, Australia's emissions reduction progress has been mixed with revisions in land use emissions. The 2030 NDC target is based on the 2005 baseline when land use emissions were a substantial share (>12%) of the total emissions and a net source. Recent official estimates of the historical trend and future projections now categorize land use as a major sink, reducing the other direct emissions abatement required to meet NDC targets.[31,32,33] This adjustment on the land sink has increased overall reduction that may delay action and transition in other sectors.

NATIONAL STRATEGIES. The National Energy Transformation Partnership serves as the overarching framework for integrated action on emissions reduction across sectors and levels of government, while the Climate Change Act 2022 legislates Australia's 2030 NDC. Key transition strategies include The Renewable Energy Target Mechanism, which incentivizes an annual growth of 33 TWh/year of renewable generation, including distributed generators, and the Annual Climate Change Statement (2023) that aims to generate 82% of the country's electricity from renewable sources by 2030.

The Australian Carbon Credit Unit (ACCU) system designed to reward emissions reductions and CCS projects. The ACCU is complemented by the Safeguard Mechanism, which sets emissions limits for large scale emitters but allows for unlimited domestic and international offsets.[34,35,36] There are 33 available offset methods as outlined by the Emissions Reductions Assurance Committee, nine of which target land use emissions, and all offsets are required to be additional, measurable, verifiable, eligible, and conservative.[37] However, offsets have been criticized as disincentivizing investment in long-term emissions reductions strategies.[38] In response, the government commissioned an independent review of the ACCU scheme, which, while recommending updates and improvements to the system, concluded that the ACCU and offset systems are robust.[39] This has again been disputed by research claiming that there is limited efficacy of offset projects, especially native forest regeneration, within Australia, and that offset schemes have limited potential for abatement more broadly.[40]

The fossil fuels industry contributes largely to Australia's economy and is expected to continue to grow. In 2021, the country was the third-largest fossil fuel exporter globally, accounting for over half of the world's metallurgical coal exports.[41] From 2015 to 2020, Australia doubled its liquefied natural gas (LNG) export capacity, with 80% of its gas production being exported.[42] Fossil fuel exports are expected to remain at similar levels until at least 2035, supported by federal government policies and the approval of new coal and gas export projects.[43] With 114 fossil fuel projects in the pipeline, including 69 coal mining projects, Australia has the highest levels within the OECD.[44] In addition, Australia lacks a national coal phase-out plan, and over two-thirds of the operating fleet do not have scheduled plans for retirement before 2030.[45] The country also seeks to develop a hydrogen supply chain and aims to become a major producer of electrolyzers through the Hydrogen Headstart Program, but intends to continue deploying fossil fuels within the current definition of "clean" hydrogen.[46] The ongoing reliance on fossil fuels, the promotion of carbon sequestration projects operated by the fossil fuel industry, and the allowance of international offsets make it more challenging to achieve actual domestic mitigation goals.[47]

2035 PATHWAYS. Our modeling analysis shows that a high-ambition 2035 target for Australia implies a 63%-72% reduction in total GHG emissions, or 57%-69% excluding LULUCF, from 2005 levels. We compare a few scenarios (Table 3.1.1 and Figure 3.1), including:

- *A **Delayed Transition*** where GHG including LULUCF emissions decline gradually through 2030, with a faster decline after 2030, achieving 25% and 51% of emissions reductions by 2030 and 2035, respectively.

- *A **High Ambition** pathway* where GHG emissions, including LULUCF, are projected to decline more rapidly from 2025 to 2030, with a slight decline in the annual reduction rate after 2030, ultimately reaching negative emissions by 2050. Emissions are expected to decrease by 56% by 2030 and by 71% by 2035.

- In comparison, the linear pathway from 2030 NDC to net-zero (NDC to Net-Zero Trend) implies a 63% reduction in total GHG emissions by 2035, continuing the reduction trend from today to meeting 2030 NDC afterwards (Today to NDC Trend) leads to a 72% reduction.

Table 3.1.1. Summary of GHG emissions reductions in 2030 and 2035, relative to NDC base-year (2005).

Scenario Name		**GHG emissions including LULUCF % change from 2005**		**GHG emissions excluding LULUCF % change from 2005**	
		2030	**2035**	**2030**	**2035**
Official NDC Target		-43%	TBD		
Delayed Transition*		-25%	-51%	-15%	-38%
High Ambition	***GCAM-6.0-CGS****	-56%	-71%	-43%	-58%
	NDC to Net-Zero Trend*	Meets NDC by design	-63%	Meets NDC by design	-57%
	Today to NDC Trend**		-72%		-69%

Notes: *Based on the scenarios developed using GCAM-6.0-CGS for the NGFS Phase V; **assume linear reduction from the 2030 NDC target to net-zero 2050; ***assume continuing the reduction trend between 2022 emissions level to 2030 NDC target for the post-2030 period.

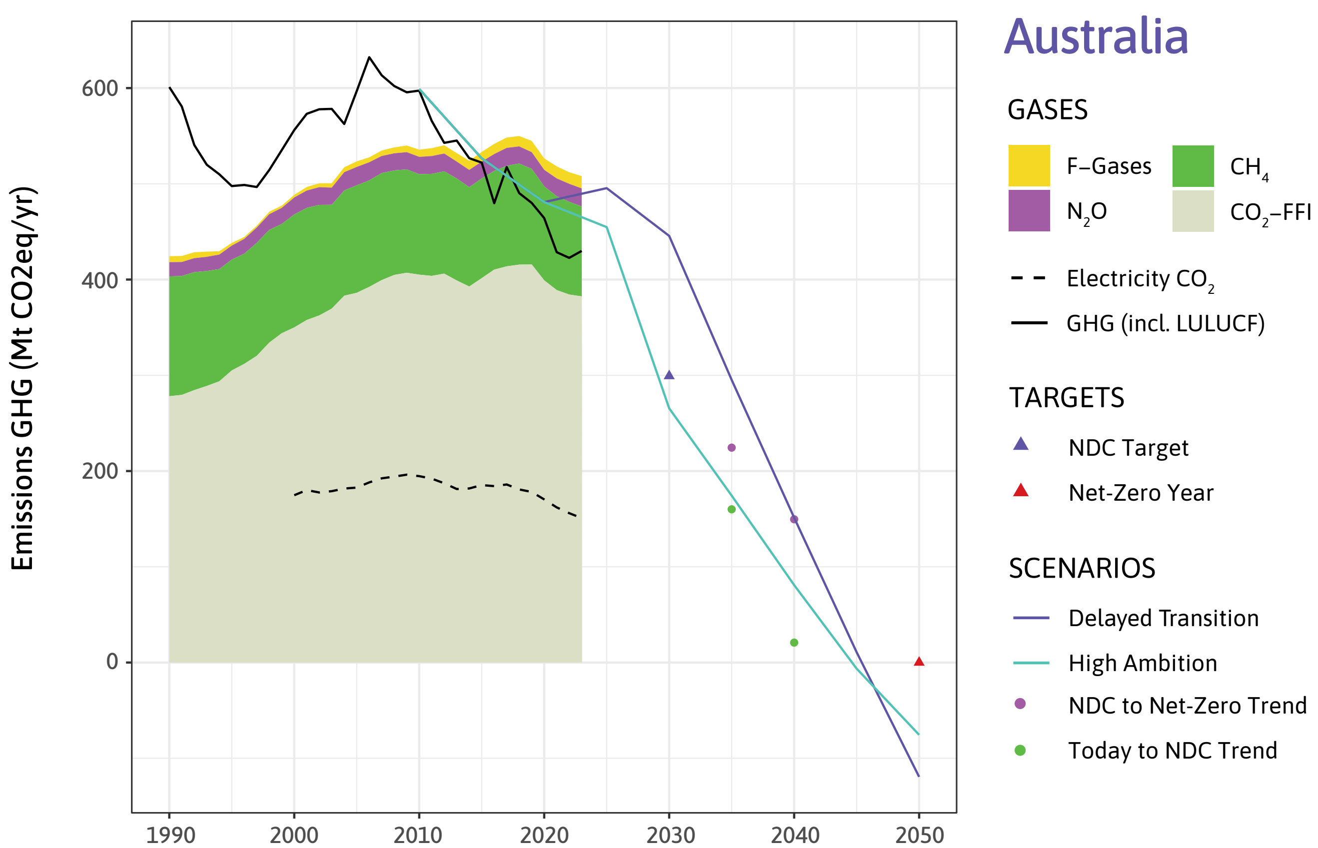

Figure 3.1. Australia's GHG including LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[48] (solid black line for total GHG, include LULUCF), EMBER[49] (dashed black line for electricity supply GHG emissions), and CEDS[50] (colored breakdown of historic GHG emissions, without F-Gases). Colored triangles mark the official 2030 NDC and Net-zero targets. Colored dots mark possible values for 2035 and 2040, based on extrapolation of the 2022-2030 linear trajectory ("Today to NDC Trend"), interpolation between the 2030 and net-zero 2050 targets ("NDC to Net-Zero Trend"). Pathways data includes LULUCF emissions and is from the downscaled scenarios based on the Australia_NZ region of the GCAM model from the NGFS Phase V scenarios.[51]

PRIORITY POLICY ACTIONS. To achieve the *High Ambition* pathways, policy actions in Australia can focus on the following areas to deliver meaningful emissions reductions through 2035:

- Taking into account the land sink adjustments from base year when setting the new climate target to ensure accelerated transition and abatement across sectors.
- **Power sector:** Accelerating solar and wind deployment with wind and solar contributing to over 74% of total generation by 2030 and 80% by 2035; reaching coal phase out by 2030 and reducing gas generation by 85% by 2035 from 2030 levels.
- **Methane:** Implementing technology standards, leak detection, and a ban on non-emergency flaring in fossil fuel production, and scale up the adoption of methane reduction technologies in the agricultural sector.

- **Transportation:** Strengthening fuel efficiency standards, accelerate EV adoption by setting national EV sale targets, and accelerate charging infrastructure buildout.

Power sector. Reducing Australia's reliance on fossil fuels for electricity generation is crucial for achieving high-ambition emissions reductions and avoiding future energy crises.[52] In 2023, Australia's electricity generation was predominantly fueled by fossil sources, with coal accounting for 46% and gas contributing 17%. Renewables make up 35% of total generation, with 16% from solar, 12% from wind, and 6% from hydro.[53] While renewable energy generation has tripled over the past decade, largely driven by distributed solar PV[54]—which can now meet 51.3% of demand during peak hours[55]—further efforts are required to enhance climate ambition and accelerate the clean energy transition. Key actions include expanding the transmission grid, incentivizing domestic production in the renewable supply chain, developing a national coal phase-out strategy, and simplifying the approval process for renewable projects.

Under the *High Ambition* scenario, Australia's power generation mix is 98% renewable by 2035, with accelerated solar and wind buildout, reduced gas generation and near total phase-out of coal by 2035 (Table 3.1.2). Specifically, power sector transitions under the *High Ambition* pathway include:

- Increasing the share of solar and wind from 29% in 2023 to 73% by 2030 and 80% by 2035, with an average buildout of 7 GW/year from 2020 to 2025, 12 GW/year from 2025 to 2030, and 9 GW/year from 2030 to 2035.
- Decreasing the share of coal generation by 94% by 2030 and 97% by 2035 from 2023 levels, and canceling coal projects in pre-construction stages (945 MW).[56]
- Reducing gas generation by 46% by 2030 and 85% by 2035 from 2023 levels and preventing new gas expansion.

Table 3.1.2. Key power sector metrics across scenarios.

Year/ Scenario	Solar + Wind % of total elec generation (Installed capacity, GW)		Coal % of total elec generation (Installed capacity, GW*)		Gas % of total elec generation (Installed capacity, GW*)	
	Delayed Transition	High ambition	Delayed Transition	High Ambition	Delayed Transition	High Ambition
2023	29% (45 GW)	29% (45 GW)	46% (23 GW)	46% (23 GW)	16% (11 GW)	16% (11 GW)
2025	37% (50 GW)	40% (55 GW)	34% (25 GW)	30% (23 GW)	12% (11 GW)	12% (11 GW)
2030[57,58]	54% (84 GW)	73% (115 GW)	19% (16 GW)	2% (1 GW)	11% (11 GW)	6% (5 GW)
2035	74% (139 GW)	80% (158 GW)	3% (3 GW)	1% (0.5 GW)	6% (6 GW)	1% (1 GW)

Note: Based on GCAM Australia_NZ results. *Capacity values of coal and gas plants denote the total capacity with constant operating hours at today's level in the respective categories. The same emissions reductions can also be achieved through reduced utilization of coal and gas plants to support the integration of increasing penetration of solar and wind, which results in higher capacity.

Methane. Australia is a signatory to the Global Methane Pledge, but it has no national methane emissions reduction targets, despite methane being the second largest source of emissions.[59] As of 2022, the agriculture sector generated 54% of all methane emissions, followed by fossil fuel production (30%) and waste (12%). Key methane abatement policy includes the Australian carbon trading system, which incorporates methane emissions from livestock and wastewater as Australian Carbon Credit Units (ACCUs).[60]

To achieve higher ambition, underreported fugitive emissions from fossil production and high levels of enteric fermentation must be addressed. Independent estimates of fugitive coal, oil and gas methane emissions are nearly twice that of national reporting.[61,62] Nearly half of all oil and gas methane emissions could be avoided with the implementation of technology standards, leak detection and reporting mandates, and a ban on non-emergency flaring and venting.[63] Feed supplements have the potential to reduce ruminant methane emissions by up to 90%, but implementation must be accelerated via the expansion of initiatives like The Methane Emissions Reduction in Livestock (MERiL) program.[64]

Transportation. Australia's EV market is substantially behind that of other advanced economies, with the share of new sales reaching just 2% compared to an average of 9% across similar economies.[65] Unlike the US and the EU, Australia did not impose heavy tariffs on EVs from China, and the current Australia-China Free Trade Agreement stipulates that EVs are accessible to Australian consumers, which resulted in a 120% recent increase in EV sales over 2023.[66,67] Tesla dominates Australia's EV market with a 53% share, while a non-premium Chinese automaker BYD entered the market in 2022 and grew its share to 14%, expanding its lineup to six models and targeting the mainstream market with plans to open 30 more dealerships. SAIC's MG and incumbents like Toyota and Ford also seek to increase their EV and hybrid offerings.[68]

Without intervention, the transport sector is on track to become Australia's largest source of emissions by 2030.[69] While recent legislation amended the lack of fuel efficiency standards, the New Vehicle Efficiency Standard relaxes regulations for the most popular SUVs and uses a vehicle test that underestimates emissions and fuel consumption.[70] Additionally, despite a large feedstock supply, Australia does not have any federal biofuel mandates or tax credits.

To achieve decarbonization in the transport sector, Australia can strengthen its fuel efficiency standard by reclassifying all SUVs as passenger vehicles and updating the vehicle test in line with international standards, stimulate the supply of EVs by setting strong uptake targets and a regularly updated federal fuel economy standard, improve coordination between subnational subsidy programs, accelerate charging infrastructure buildout, and develop biofuels for hard-to-decarbonize transport sectors like aviation.[71,72]

SUBNATIONAL ACTION

Australia's climate governance operates under "compensatory federalism," where states implement climate policies to counterbalance a conservative-dominated national government. States hold authority over key areas like land management, transportation, and environmental regulation, while the Commonwealth controls the power sector.[73] The balance of power between the Commonwealth and the states shifts with the ruling party's stance, as Labor tends to support state-led initiatives, while the Liberals align with Commonwealth authority.

Australia's climate governance provides significant flexibility for states to define their own policies, leading to noticeable gaps between state and Commonwealth climate goals. These gaps can be effectively addressed through state-level initiatives within their areas of authority, particularly in the renewable energy deployment in power sector and transportation sectors. While the power sector is largely under Commonwealth control, successful renewable energy deployment requires state-Commonwealth cooperation, especially in permitting and siting.[74] Furthermore, the absence of a national quantitative EV adoption target in the National Electric Vehicle Strategy presents an opportunity for states to implement detailed, practical EV policies, backed by Commonwealth support.[75,76]

Just transition of coal mining regions. Coal is often credited for Australia's wealth. The Australian Coal Association, the Mineral Council of Australia, and the Australian Trade and Industry Alliance form a coal lobby pushing for keeping the coal and mining industry supported by the Commonwealth, especially in the states of New South Wales and Queensland.[77] Given the projected decline in earnings for coal mining communities in Australia due to lower foreign demand, both the Liberal and the Labor parties have been forced to provide additional financial support to their coal-dependent constituencies to keep the coal mining jobs in place.[78,79] There is currently a dilemma of supporting the mining workers either through letting the industry expand in the short run or through a longer-term policy of facilitating just energy and economic transition.[80]

Power sector. Some regions in Australia are leaders in RE deployment, such as the Capital Territory and Tasmania with 100% renewable energy-based electricity and Victoria and Queensland with high RE deployment targets (65% by 2030 and 50% by 2030, respectively).[81,82] The only regions that were able to retire coal plants are the ACT, Tasmania, and South Australia, owing to high reliance on wind, hydro, and solar resources, as well as the Northern Territory, owing to high reliance on LNG, which in turn poses additional challenges in terms of the gas industry sustainability.[83] Other coal states have targets for phasing out coal by 2030 or later. The Australian states and territories have significant opportunities to accelerate the retirement of local coal plants and mines and to facilitate just energy and economic transition through the promotion of low emissions technologies onsite and new RE projects relying on abundant solar, wind, and hydro resources, as well as creating green power jobs in the coal-dominated regions. The areas with already 100% renewable energy generation could aim for exporting their energy to their neighboring regions.[84]

Transportation. While missing national EV sales target, many states in Australia have adopted their own targets, including New South Wales of 52% new EV sales by 2030, Queensland of 50% new ZEV sales by 2030, Victoria of 50% new light-duty ZEVs sales by 2030, and ACT of 80-90% ZEVs sales by 2030.[85,86,87,88] Tasmania has set a 2030 100% ZEVs target only for the Tasmanian Government's fleet, and Western Australia and the Northern Territory have expressed support for ZEVs transition but did not specify their EV sales targets.[89,90,91]

Nationwide, Australia is behind in terms of EV charging infrastructure. The ratio of charging stations to electric cars is 1:10 on the global average, but the ratio is only 1:35 in Australia.[92] New South Wales is believed to be the most EV-friendly state with approximately 497 public charging sites, while Victoria and South Australia have around more than 430 public charging sites each.[93] The diverse mosaic of EV targets and policy approaches across different states and territories suggests that additional inter-regional cooperation could enhance each of the state's potential in EV adoption through knowledge sharing and innovation diffusion. A reliable network of public EV chargers would target long commutes and allow for the geographic expansion of EVs further from the major coastal urban areas.

3.2 Brazil

Summary

- Brazil's total GHG emissions are contributed relatively equally by CH_4, LULUCF CO_2, and energy CO_2 (about 30% each) as of 2022, while the remaining 10% comes from N_2O.
- Total GHG emissions declined by 42% from a high peak level in 2005 to 2023, mostly driven by reduced deforestation through 2010; non-LULUCF emissions started to decline only after 2015, but recently reached a new peak with a large post-COVID rebound in 2021.
- Brazil's current NDC includes a 48% reduction in total GHG emissions by 2025 and a 53% reduction by 2030 from 2005 levels; achieving the 2025 target requires accelerated reverting from recent growth.
- The strong bioenergy industry has promoted biofuel deployment and emissions reductions in industry and transport and has the potential to help transition the petrochemical economy; however, at the same time, it has delayed electrification, missing the opportunity of leveraging its largely clean electricity.
- A high-ambition 2035 target for Brazil includes a 64-77% reduction in total GHG emissions, or 6%-41% excluding LULUCF, from 2005 levels.
- This is achieved by completely halting illegal deforestation, increasing afforestation and reforestation, accelerated end-use electrification with targeted bioenergy application in hard-to-electrify sectors, pioneering technologies and policies to reduce methane, especially in agriculture, and scaling up wind and solar generation to phase out fossil electricity.
- Due to the large contribution from non-CO_2 gases, especially enteric fermentation methane, in its overall emissions, meeting its 2050 net-zero GHG target requires faster and deeper reductions in CO_2 and potentially net-zero carbon emissions around 2040, which also incentivizes innovative solutions in abating livestock methane.
- Brazil's climate governance is characterized by shared responsibilities across federal, state, and municipal levels, with subnational action influenced by political and financial factors. Strong party polarization on the climate agenda is less pronounced on the subnational level, where local financing can focus on the tracking and enforcement policies for cattle and illegal deforestation, especially through the framework of the national Forest Code.

EMISSIONS PROFILE. Brazil's GHG emissions, including LULUCF, decreased by over 42% from 2005 to 2023.[94] Brazil's total GHG emissions have strongly declined from 2005 to 2010 (from around 2.6 to 1.3 Gt CO_2e) due to reductions in deforestation, and then gradually increased back to 1.8 Gt in 2020. Non-LULUCF CO_2 emissions increased steadily between 2005 and 2015 and started to decline until 2020, followed by a large post-COVID rebound in 2021 reaching a new peak. As of 2022, methane made up the largest share of Brazil's overall emissions (33%), followed by LULUCF CO_2 emissions (28%), transport (13%), N_2O (11%) and industry (8%).[95]

2030 NDC. Brazil's current NDC has committed to reduce its total emissions by 48% from 2005 levels by 2025, and by 53% by 2030.[96] These targets cover all greenhouse gas emissions from all sectors, including LULUCF. Additionally, Brazil has a net-zero GHG target for 2050. Brazil's 2025 NDC target implies a 5% reduction in total GHG emissions (including LULUCF) from 2023. The 2030 target implies a 14% reduction from 2023, which in comparison is relatively unambitious and would not require any reduction in other greenhouse gases if LULUCF CO_2 emissions are brought to zero. Stressing the requirement to reduce the emission components beyond LULUCF CO_2 emissions for 2030 is crucial to ensure proper preparation for later targets.

NATIONAL STRATEGIES. Brazil first established its National Policy on Climate Change in 2009 to unify government instruments for climate mitigation and adaptation based on its commitments to the UNFCCC, and as of October 2023 is updating the policy to incorporate sectoral strategies up to 2035.[97] Brazil's latest NDC places a strong emphasis on halting illegal deforestation, highlighting key initiatives such as the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) and the Permanent Interministerial Commission for the Prevention and Control of Deforestation. Additionally, President Lula's recent efforts to curb deforestation and promote sustainable livelihoods in the Amazon region are showing encouraging signs of progress.[98,99] However, deforestation still remains higher than in the early 2010s and illegal deforestation, especially outside of the Amazon, remains an issue.[100] Moreover, the extent of continued legal deforestation is uncertain due to a lack of clear measures and quantified targets.

Brazil has a relatively clean energy sector due to abundant hydropower, which can deliver immediate emissions reductions through end-use electrification, but at the same time still requires policy effort to phase out fossil energy and be fully decarbonized. Meanwhile, Brazil has already developed a strong biofuel industry and emphasizes fuel switching as an important decarbonization strategy for transport and industries in its national biofuel policy (RenovaBio). Given its potential land implication and available cost-competitive alternatives, biofuels need to be deployed strategically in complement with electrification, especially focusing on the hard-to-electrify sectors, such as non-road transport. Moreover, with an increasing contribution of the biofuel industry to its economy, Brazil, as a large oil exporter since 2015 with expanded production from offshore fields, has the opportunity to transition its petrochemical sector more proactively.

2035 PATHWAYS. Our modeling analysis shows that a high-ambition 2035 target for Brazil implies 64%-77% reduction in total GHG emissions, or 6%-41% reduction excluding LULUCF, from 2005 levels, including LULUCF (Table 3.2.1 and Figure 3.2).

- *A **Delayed Transition*** would miss both the 2025 and 2030 targets, as GHG emission excluding LULUCF would stagnate, while LULUCF would only slowly decrease, leading to 61% reduction in 2035 compared to 2005 (29% relative to 2023).

- A ***High Ambition*** *pathway* where the 2025 target is slightly missed, but the 2030 target is exceeded, and achieving a 74% reduction from 2005 levels in 2035 through reduction of emissions from all sectors. Land-use CO_2 emissions reach zero in 2035 and turn negative after that, and remaining GHG emissions also approach zero towards 2050, as carbon dioxide removal in the energy sector, made possible by Brazil's large bioenergy potentials, offsets remaining N_2O and CH_4 emissions.

Table 3.2.1. Summary of GHG emissions reductions in 2030 and 2035, relative to NDC base year (2005).

Scenario Name		GHG emissions including LULUCF % change from 2005		GHG emissions excluding LULUCF % change from 2005	
		2030	**2035**	**2030**	**2035**
Delayed Transition*		-43%	-61%	+20%	-10%
High Ambition	***GCAM-6.0-CGS****	-61%	-74%	-12%	-34%
	NDC to Net-Zero Trend**	Meets NDC by design	-64%	Meets NDC by design	-6%
	Today to NDC Trend***		-77%		-41%

Notes: *Based on the scenarios developed using GCAM-6.0-CGS for the NGFS Phase V. **assume linear reduction from the 2030 NDC target to net-zero 2050; ***assume continuing the reduction trend between 2022 emissions level to 2030 NDC target for the post-2030 period.

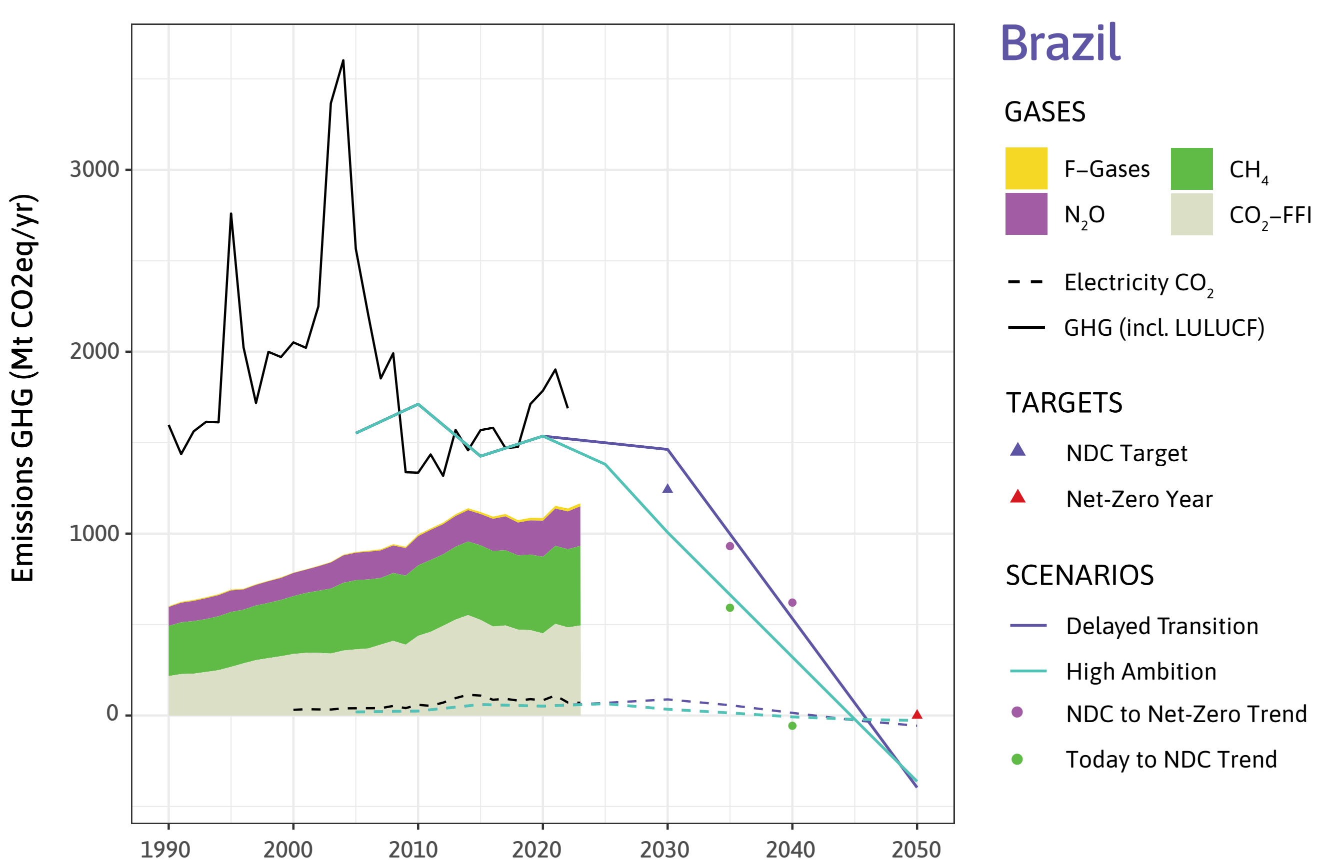

Figure 3.2. (above) Brazil's GHG including LULUCF emission pathways across scenarios. Historical data is from MICT[101] until 2020, SEEG[102] for 2021 and 2022, PRIMAP-hist[103] for 2023 (solid black lines for total GHG including LULUCF), EMBER[104] (dashed black line for electricity supply GHG emissions), and CEDS[105] (colored breakdown of historic GHG emissions, without F-Gases). Colored triangles mark the official 2030 NDC and Net-zero target. Colored dots mark possible values for 2035 and 2040, based on extrapolation of the 2022-2030 linear trajectory ("Today to NDC Trend"), interpolation between the 2030 and net-zero 2050 targets ("NDC to Net-Zero Trend"). Pathways data includes LULUCF emissions and is based on the scenarios developed using the GCAM IAM for the NGFS Phase V.[106]

PRIORITY POLICY ACTIONS. Brazil's unique emissions structure provides different opportunities for action. Due to the large contribution from non-CO_2 gases, especially enteric fermentation methane, meeting net-zero GHG emissions in Brazil requires faster and deeper reductions in CO_2 and potentially net-zero carbon emissions around 2040. Low-carbon electricity from abundant hydro power, along with the potential for negative emissions through land-based strategies, make deep decarbonization possible. At the same time, Brazil has the incentives to lead innovative solutions for reducing methane emissions in agriculture. In this context, prioritizing policy actions through 2035 include:

- **Land:** Fully stopping illegal deforestation and significantly reducing and limiting legal deforestation, as well as enhancing carbon uptake through reforestation and afforestation and soil carbon enhancements is the first priority for Brazil.
- **Methane:** Reducing methane emissions from agriculture via adjusted practices and improving the waste sector's landfill management and biogas utilization. Given the large share of methane emissions, Brazil can have an important role in pioneering and demonstrating low-methane agricultural practices.
- **Transportation and industry:** Significantly reducing the use of fossil fuels by making use of large bioenergy potentials prioritized for subsectors where direct electrification is not easily viable, and by increasing electrification and thereby leveraging the already mostly low-carbon electricity generation.
- **Power sector:** Increasing widely available, but so far underexploited, solar and wind resources to complement existing hydro generation, phasing out fossil generation, and providing for increased demand due to electrification.

Land. In 2023, Brazil saw a 36% reduction in primary forest loss compared to 2022, reaching its lowest level since 2015. However, the country still accounted for 30% of the total primary forest loss in the tropics that year.[107] The main causes of deforestation in Brazil include commodity-driven deforestation and shifting agriculture.[108] The goal of stopping illegal deforestation has been formulated multiple times, but its implementation remains unclear. Moreover, the extent of continued legal deforestation is also uncertain due to a lack of clear measures and quantified targets.

To achieve the accelerated pathway, it is crucial to stop illegal deforestation by 2028 as pledged at COP 26, which, given that almost all deforestation occurring in the country is classified as illegal, will result in significant emissions reductions.[109] Additional strategies include enhancing Indigenous land rights and creating protected areas within the Amazon, updating rural land taxes and agriculture subsidies, strengthening forest law enforcement via satellite monitoring, regulations, and an improved mapping and land registration system, and promoting reforestation and afforestation through robust regulations, well-defined property rights and technical and logistical assistance.[110,111]

Methane. Brazil is the 5th largest emitter of CH_4 in the world, contributing 5.5% of global methane.[112] As of 2022, enteric fermentation generated 62% of methane emissions, followed by wastewater (17%) and solid waste (11%).[113] Given current management practices and emission trends, agricultural emissions are on track to increase 5.6% by 2030.[114] Reducing methane emissions is, after LULUCF CO_2, the second largest climate mitigation challenge for Brazil. Methane abatement has been targeted in Brazil's Sectoral Plan for Adaptation and Low Carbon Emissions in Agriculture (ABC+), the National Zero Methane Program, and the Arrudas WTTP project, which incorporate strategies like intensive fishing, nitrogen fixation, animal waste management, and biomethane and biogas development.[115]

To further reduce emissions under the *High Ambition* pathway, Brazil can implement strategies to reduce methane in the agricultural sector like diet changes, genetic modification of cattle, and more efficient livestock management practices.[116,117] Waste methane can be mitigated by implementing biogas and methane technology in wastewater facilities, improving landfill management, and increasing composting and flattening.[118] Successful carbon credit schemes like the CAXIA Landfill Program can be expanded.[119] Catalyzing public and private financing for the development of methane technology is also key.[120]

Transportation. Emissions from transport account for the largest share of energy-related CO_2 emissions in Brazil, despite a relatively large use of bio-based fuels in the sector. The RenovaBio program is targeting transportation sector emissions through a biofuel blending mandate and decarbonization credits.[121] Electric and hybrid vehicles represent 3.85% of the Brazilian fleet[122] and Brazil has a mandatory blend ratio of 27% ethanol in gasoline and a 12% biodiesel in diesel.[123]

To accelerate near-term decarbonization in the transportation sector, Brazil can adopt stronger EV production and adoption policy, especially for light-duty vehicles, in complementary to biofuel development and deployment in hard-to-electrify sectors. As of 2023, Brazil was the only G20 country without a national plan for electric mobility. To incentivize EV deployment, the country needs legislation and regulations that promote EV production, and adoption.[124] Additionally, Brazil can move forward in the development and buildout of EV charging infrastructure, where it is estimated the country will require 150,000 charging stations by 2035.[125] Shifting the freight modal split can also deliver emissions reductions, as while approximately 60% of freight is transported by road in Brazil, similarly sized countries only have a 42% share of freight transport, with railways representing 43% and waterways 15%.[126]

Industry. Between 2005 and 2022, industrial CO_2 emissions increased by 5%. In 2022, cement production accounted for 23% of industrial CO_2 emissions, followed by iron and steel at 22%, and the agro-industry at 15%.[127] Emissions reductions from the industrial sectors under the *High Ambition* scenario are mostly driven by decreasing energy use in iron and steel sectors. By 2035, accelerated coal phase-down results in higher electrification, and thus slightly larger emissions reductions

As efforts to decarbonize Brazil's industry may require investments of US$21 billion, stimulating climate finance is crucial to achieving *High Ambition* emissions reductions.[128] Identifying cost-effective technologies and strategies is also key. Some solutions under analysis include energy and material efficiency, renewable energy, low-carbon fuels, and carbon capture, utilization, and storage (CCUS).[129] Additionally, Brazil can improve energy efficiency and create incentives for the use of cogeneration technologies, waste heat recovery, training and capacity building, energy management, and innovation.[130]

SUBNATIONAL ACTION

Brazil's climate governance is distinct within its federative system, where environmental protection responsibilities are shared among federal, state, and municipal levels. Since the 1990s, municipal governments have engaged in paradiplomatic processes, despite the absence of a clear framework for national and global collaboration. Subnational authority to act on broader political stages depends largely on political influence and financial capacity. Additionally, strong party polarization contributes to inconsistencies and limited follow-through on long-term climate goals, particularly regarding LULUCF and methane reduction.

Brazil's federal government structure operates under a presidential system, operating largely at a national level, with 26 states and one federal district. The country's climate policies are highly politicized, influenced by sharp ideological changes between successive presidential administrations. Polarization may be compensated for on the subnational level, as Brazilian subnational governments tend to prioritize the implementation of locally relevant climate policies, and some have engaged in participatory democracy to give citizens direct access to decision-making processes. However, there significant gaps in access to funding for climate policies on the subnational level remain, suggesting a need for heightened coordination between subnational and national climate governance actors.

Within Brazil's climate governance structure, the cattle and timber industries present both challenges and opportunities for subnational emissions reduction, as they are major contributors to deforestation. Given the direct link between cattle ranching, timber activities, and deforestation, policies addressing methane emissions from cattle align closely with deforestation reduction efforts. States like Pará and Mato Grosso could strengthen tracking, licensing, and Forest Code enforcement, while promoting efficient land-use practices like cattle tracking to support sustainable management.

Land. 2020 estimates suggest that 44% to 68% of deforestation in Brazil takes place illegally.[131] Between 2022 and 2023, illegal deforestation in the Amazon grew by 19%, from 106,000 ha to 126,000 ha.[132] Of this, 71% of illegal deforestation in Brazil takes place on private rural properties.[133] Out of all deforestation, both legal and illegal, private properties accounted for 28% of the entire deforested area in the Amazon from 2012 to 2021.[134] Based on this, a vast majority of identification information about perpetrators of illegal deforestation and their properties are available within municipal and state registers.[135] Therefore, halting illegal deforestation taking place on private properties relies on subnational efforts. Any lack of policy action regarding private landowners likely stems largely from burdens of cost and coordination on the local level.

The Forest Code, also known as the Native Vegetation Protection Law, is an existing federal law targeted at deforestation on private properties that is designed to be enforced on the state level. Under the Forest Code, states carry the vast responsibility of enforcing the Law on private properties, as they are responsible for their local environmental licensing processes.[136] The federal government works in coordination with the states and can provide additional financing. States such as Para and Mato Grosso can scale up their tracking, licensing, and enforcement of the Forest Code. This is likely one of the most cost-effective methods, as it does not require the creation of a new policy framework on the state or municipal level. As for the 16% of illegal deforestation occurring on Indigenous Territories (ITs), strategies in line with the methodology of deploying the Forest Code can be applied. Further, states and municipalities can engage in open discourse and communication with ITs.

Methane. Cattle-specific policies may include efficient land-use practices, such as cattle tracking. The Pará Cattle Integrity and Development Program marked the first environment-focused mandatory cattle traceability policy for individuals in Brazil. The Program is designed to track over 24 million cattle across more than 295,000 farms. Stakeholder groups, such as The Nature Conservancy, are pushing for accelerated deployment of the Program around ITs.[137] The Program aims to increase transparency of the cattle supply, demonstrate sustainable livestock farming practices, improve compliance by increasing disincentives for poor practices, and improve the livelihoods of farmers and cattle-based communities.[138] All cattle transported in the state will be tracked by December 2025, and all 24 million cattle are projected to be tracked by December 2026.[139] Upon success of this program, other states can follow suit to decrease cattle-based methane emissions across the country.

3.3 Canada

Summary

- Canada's overall emissions peaked in 2007 but have achieved limited reduction over the past 25 years, where total GHG emissions (excluding LULUCF) have decreased by less than 10% from the peak level to 2023.
- With existing progress and policies, Canada is not on track to deliver its 2030 NDC of reducing GHG emissions by 40-45% below 2005 levels.
- As a major oil and gas exporter, Canada's emissions (both CO_2 and CH_4) from oil and gas production have been increasing as production reached record high levels in 2023; the economic dependence on the oil and gas industry, especially in a few regions, underscores the need for a proactive energy and economic transition without expanding new fossil infrastructure.
- With abundant hydropower, Canada's electricity sector is fairly clean; however, coal power phasedown over the past two decades has been largely achieved by increasing gas generation, where wind and solar deployment is slow.
- A high-ambition 2035 target for Canada includes a 60%-68% reduction in total GHG emissions from the 2005 level.
- This is achieved by limiting oil and gas infrastructure expansion and heavily reducing its methane emissions, achieving 100% clean electricity through wind and solar scale-up, accelerating EV deployment, and implementing industrial decarbonization strategies.
- While Canada has committed to phasing out coal power by 2030, an enhanced target of 100% clean electricity by 2035 is critical for achieving near-term climate targets while decarbonizing the rest of the economy.
- Canada's decentralized climate governance, based on "executive federalism," grants provinces significant autonomy and constitutional authority over key sectors, enabling regionally tailored climate actions that are influenced by economic specialization and political alignment, with inter-provincial cooperation offering pathways to ensure just transition for oil & gas production regions, improve energy justice in off-grid rural communities and increase provincial preparedness for EV switch through transmission updates and buildouts.

EMISSIONS PROFILE. Canada's GHG emissions excluding LULUCF have decreased by about 10% from its peak in 2007 until 2023, with emissions experiencing a sharp drop in 2020 but resuming an upward trend the following years.[140] While power sector emissions have decreased in that time period, other fossil fuel emissions, especially both CO_2 and CH_4 emissions from the oil and gas sector, have increased. As of 2022, the transport sector, fossil fuel supply CO_2, and industry contributed 21%, 20%, and 17% of total GHG emissions (excluding LULUCF), respectively.[141] According to Canada's 2024 GHG Inventory, LULUCF emissions were a net emissions source of 51 $MtCO_2$ in 2022 (7% of total GHG emissions).[142]

2030 NDC. Canada's 2021 NDC commits to reducing GHG emissions by 40%-45% below 2005 levels by 2030.[143] The 2005 baseline emissions exclude LULUCF, but the 2030 emissions reduction target includes emissions and removals from LULUCF. Canada has also committed to reaching net-zero GHG emissions by 2050.[144] The 2030 NDC target of 40% - 45% reduction from 2005 implies a 35% - 41% reduction in emissions from 2022 to 2030, excluding LULUCF, with an average annual emissions reduction rate of 5% - 6%. Achieving this target will require a substantial acceleration of emissions decline, considering that the average annual emissions reduction from 2007 to 2022 was just 0.6%, and most recent data suggests emissions trends are increasing in recent years.[145]

NATIONAL STRATEGIES. Canada's most recent climate change plan was released in March of 2022, but many of the measures have yet to be implemented, nor are they sufficient to meet Canada's existing NDC target.[146] Key sectoral targets include achieving a 35% reduction in methane emissions by 2030, 100% LDV sales by 2035, and a net-zero electricity grid by 2035.[147]

The upcoming federal elections, set to take place in 2025, could significantly impact Canada's ability to meet its climate targets. Recent polling heavily favors the Conservative Party, which has made eliminating the consumer carbon tax a central part of its campaign platform.[148,149] Given that the legislated policies of the current government are already insufficient for net-zero achievement, the potential for rollback of emissions reduction policy will make achieving Canada's climate targets increasingly difficult.[150]

The oil and gas industry plays a significant role in Canada's economy. In 2022, it accounted for 3.2% of GDP and 20% of national exports, while also serving as an important source of revenue for both provincial and federal governments and providing job opportunities for 900,000 people. The Province of Alberta is home to most of Canada's oil and gas production, with the Provinces of British Columbia, Newfoundland and Labrador, and Saskatchewan making up a smaller share of the national total. The economic dependence of communities in those regions on the oil and gas industry underscores the need for a proactive energy and economic transition that doesn't leave those communities behind. Beyond energy transition, there is a large near-term potential of targeted methane abatement in the oil and gas sector given with mature technologies. Canada has pledged to reduce oil and gas methane emissions by 75% from 2012 levels by 2030.[151,152]

The political and economic impacts of decarbonization in Canada vary across regions, potentially hindering the country's efforts to meet its climate goals. National policies that balance cost-effectiveness, competitiveness, and fairness across provinces, building national consensus and enabling the pursuit of higher climate ambition, are needed.[153]

2035 PATHWAYS. Our modeling analysis shows that a high-ambition 2035 target for Canada implies a 60%-68% reduction from 2005 levels (Table 3.3.1 and Figure 3.3).

- *A **Delayed Transition*** where total GHG emissions decline gradually through 2030, with a slower decline after 2030, achieving 32% and 41% of emissions reductions by 2030 and 2035, respectively.

- A ***High Ambition*** *pathway* where total GHG emissions decline faster after 2025, reaching net zero emissions by 2050, leading to a 46% reduction in 2030 and a 60% reduction by 2035 from 2005, or a 54% reduction from 2023.

- In comparison, the linear pathway from the 2030 NDC to net-zero (NDC to Net-Zero Trend) suggests a 60% reduction in total GHG emissions by 2035 (55% from 2023). Continuing the current reduction trend to meet the 2030 NDC target (Today to NDC Trend) would lead to a 68% reduction by 2035 (63% from 2023).

Table 3.3.1. Summary of GHG emissions reductions (including LULUCF) in 2030 and 2035, relative to NDC base-year (2005).

Scenario Name		2030 emissions % change from 2005	2035 emissions % change from 2005
Official NDC target		-40%- -45%	TBD
Delayed Transition*		-32%	-41%
High Ambition	***GCAM-6.0-CGS****	-46%	-60%
	NDC to Net-Zero*	Meets NDC by design	-60%
	Today to NDC**		-68%

Notes: *Based on the scenarios developed using GCAM-6.0-CGS for the NGFS Phase V; **assume linear reduction from the 2030 NDC target to net-zero 2050; ***assume continuing the reduction trend between 2022 emissions level to 2030 NDC target for the post-2030 period.

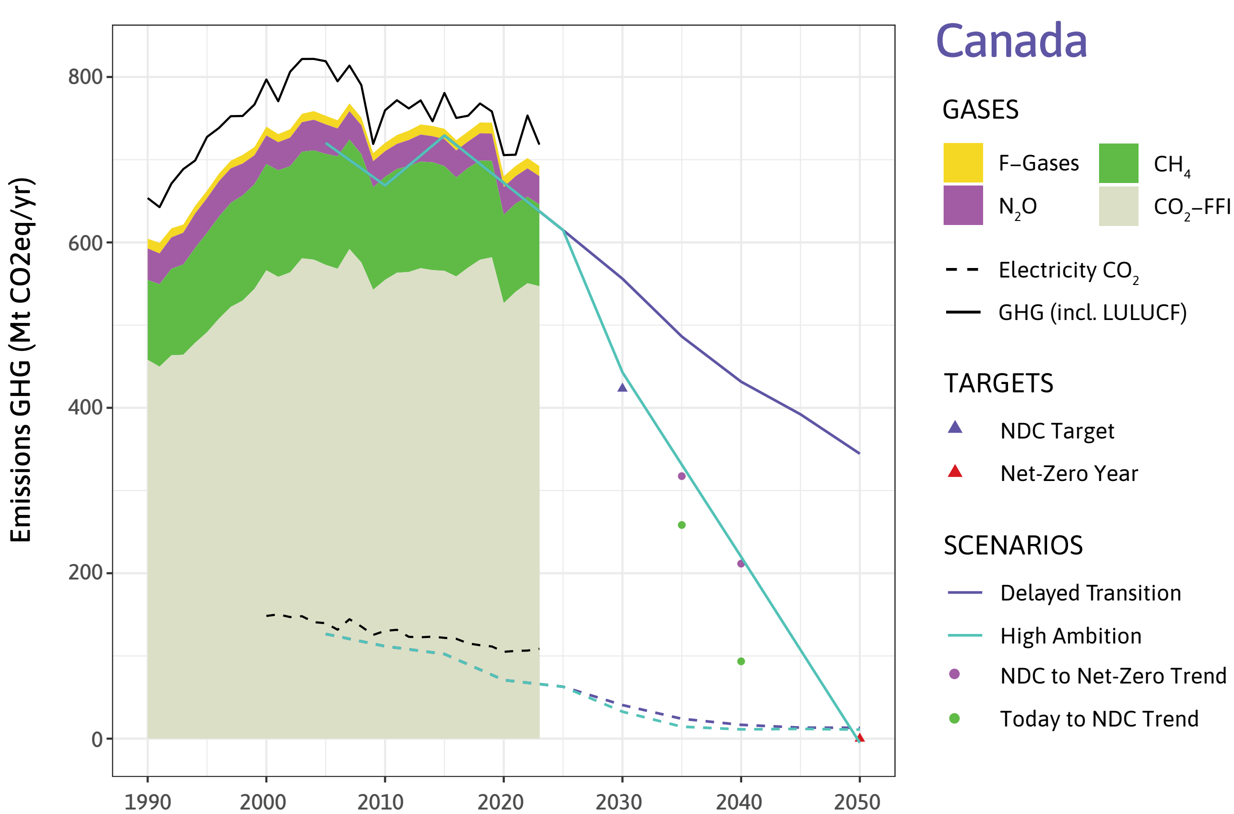

Figure 3.3. (above) Canada's GHG including LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[154] (solid black line for total GHG, include LULUCF), EMBER[155] (dashed black line for electricity supply GHG emissions), and CEDS[156] (colored breakdown of historic GHG emissions, without F-Gases). Colored triangles mark the official 2030 NDC and Net-zero targets. Colored dots mark possible values for 2035 and 2040, based on extrapolation of the 2022-2030 linear trajectory ("Today to NDC Trend"), interpolation between the 2030 and net-zero 2050 targets ("NDC to Net-Zero Trend"). Pathways data includes LULUCF emissions and is based on the scenarios developed using the GCAM IAM for the NGFS Phase V.[157]

PRIORITY POLICY ACTIONS. Priority policy actions can deliver meaningful emissions reductions in the power sector, fossil fuel production, transportation, and industry through 2035, including:

- **Oil and gas industry:** Adopting stringent policies for targeted methane reduction in the near term and stopping new infrastructure expansion to proactively transition away from the fossil industry and economy that minimizes negative impacts on fossil-dependent communities.
- **Power sector:** Achieving 100% clean electricity by 2035 with solar and wind scale-up and grid infrastructure expansion.
- **Transportation:** Increasing the electrification of medium and heavy vehicles, and supporting the deployment of charging infrastructure.
- **Industry**: Establishing industrial decarbonization strategies and promoting innovation and research in clean technologies, especially in mining, which is the only subsector with positive emissions growth in recent years.

Oil and gas industry: To achieve this target and align the sector more broadly with climate goals, Canada could focus its policy efforts on transitioning away from oil and gas by stopping fossil infrastructure expansion as well as abating methane emissions in existing oil and gas operations. While methane contributes just a fifth of the fossil production sectors' total GHG emissions, it presents clear opportunities for reductions. Strict regulations can cut or eliminate non-emergency flaring as well as prevent leaks by improving fugitive emissions monitoring and frequency.[158] Facilities can also adopt technological innovations like optimized venting, emissions capture, and non-emitting pumps and controllers to achieve further reductions.

Ending domestic public finance for fossil fuel projects, to stop the buildout of new fossil infrastructure, plays an important role in Canada's energy transition.[159] Promoting economic diversification to reduce reliance on fossil fuel exports will also aid in the transition. Additionally, Canada can provide financial support and tax incentives such as the CCUS Investment Tax Credit[160] as well as finalize and enforce the forthcoming GHG emissions cap for the oil and gas sector, which will complement existing measures and provide considerable opportunity for reductions in Canada's highest emitting sector.[161] Other mitigation measures in line with the *High Ambition* scenario include establishing additional mechanisms to incentivize the adoption of decarbonization strategies, such as the electrification of transport and low-temperature processes, steam displacement using solvents in in-situ oil sands production, replacing petroleum coke boilers with natural gas or hydrogen, and improving energy efficiency through equipment upgrades and automation.[162]

Power sector. Canada's power generation is fairly clean. As of 2023, 80% of electricity came from non-fossil sources, with hydro accounting for 58%, nuclear for 14%, and wind and solar for 7%. Fossil fuels made up the remaining 20%, with gas contributing 15% and coal 4%.[163] Further decarbonizing the power sector could lead to additional emission reductions in Canada in the short term. Under a *High Ambition* scenario, accelerating wind and solar deployment from an average of 2 GW/year to approximately 17 GW annually could increase non-fossil generation to 97% by 2030 and 98% by 2035, while phasing out coal by 2030 and reducing gas generation by 81% from 2023 levels by 2035. Key strategies to support this transition include adopting clean electricity standards, modernizing the wholesale market, compensating flexibility services, investing in grid infrastructure, and developing comprehensive electrification strategies for buildings and industry.[164]

Transportation: Considering that Canada aims to achieve a 100% EV sales target for LDVs by 2035, greater investment is needed to support the development and deployment of charging stations and related infrastructure. Additionally, Canada can focus efforts on setting ambitious infrastructure targets, standardizing protocols and defining the roles of utilities, as well as promoting capacity building and training for the workforce.[165]

To achieve ambitious reductions, Canada can implement policies that effectively reduce emissions from medium- and heavy-duty vehicles. This includes setting zero-emission standards across different subclasses, providing financial support for the replacement of existing vehicles, defining differentiated procurement mandates for public and private fleets, procuring a skilled workforce, enhancing capacity to support the supply chain, and strengthening emissions regulations for fossil fuel vehicles.[166]

Industry: While emissions from almost all subsectors of heavy industry decreased between 2005-2021, mining emissions increased over 20% between 2005-2021.[167] Emissions reductions were smallest in the iron and steel industries. Additionally, the emissions intensity of the mining and pulp and paper sectors increased. Canada is lagging behind other G7 countries in development and demonstration of clean industrial technologies due to a lack of industrial R&D spending.[168] Additionally, the country has yet to develop specific decarbonization policies for industries, except for cement. To meet G7 commitments, potential strategies include creating decarbonization roadmaps for various industries, promoting collaboration between researchers and companies to drive climate innovation, adopting green procurement practices, and establishing codes and standards that prioritize low- or zero-emission materials.[169]

SUBNATIONAL ACTION

As a decentralized federation, Canada's climate governance is structured around federal-provincial and interprovincial cooperation and consensus. Canadian provinces have constitutional authority over development of natural resources, including oil and gas, but the federal government has jurisdiction over taxation, works connecting provinces, regulation of trade and commerce, and holds residuary powers over matters not explicitly assigned to the provinces. Given that climate policy is impacted by areas of jurisdiction overseen by both federal and provincial governments, jurisdiction over climate policy is shared between the two levels of government. Consequently, regional economic specialization and political partisanship heavily influence subnational climate policy. For this reason, a strengthened just transition in oil and gas-producing regions, along with accelerated renewable energy deployment and EV adoption could be strategically advanced through greater federal-provincial and interprovincial cooperation.

Just transition in oil and gas producing provinces. Fossil fuels are credited for economic development and prosperity in oil and gas-producing provinces and have been incorporated by provincial conservative governments in the concept of Canada's national security.[170] Oil and gas account for 31% of Alberta's GDP, 25% of Newfoundland and Labrador's GDP, and 22% of Saskatchewan's GDP. [171,172] Workers in oil and gas, construction, professional services, manufacturing, accommodations, and food services sectors in oil rich provinces of Canada are heavily dependent on oil price fluctuations in their prosperity and employment.[173] Saskatchewan's Accelerated Site Closure Program (2020-2023) financed 9,823 well abandonments, 4,041 flowline abandonments, 66 facility decommissions, and 16,710 site remediation and reclamation activities and supported impacted businesses and Indigenous-owned service companies.[174] A comprehensive provincial energy transition strategy focused on supporting impacted workers could create 200,000 new jobs in Alberta by 2050, which would be 34,000 more jobs than existed in the oil and gas industry in 2014 at the height of Alberta's oil and gas investment boom.[175] To prevent job precarity in oil and gas-mining provinces, local governments could provide employment support to vulnerable workers in a form of urgent financial support, skill training, and business opening facilitation, expanding such programs from oil and gas workers to workers in other sectors dependent on commodity price fluctuations. These efforts could complement those being pursued by the federal government, including the Canadian Sustainable Jobs Act.[176]

Energy justice in rural Canada. Energy transition benefits are not equally spread across different communities. Around 200,000 people living in more than 280 rural communities in the North and in the Indigenous lands are not linked to the North American electricity grid or to the national gas distribution system, relying on expensive diesel- or unstable LNG-powered micro-grids, which is especially relevant for Yukon, Northwest Territories, and Nunavut with a high concentration of isolated electricity microgrids within these provinces and the overall isolation of their provincial grids from the national power system.[177,178] Major barriers to renewable energy in rural communities include the extreme level of intermittency for conventional renewable energy resources, such as solar and wind, in the North and the lack of indigenous perspectives in provincial policy-making.[179] The overarching national policies may not always fully address local needs, and subnational governments have substantial powers to ensure that rural off-grid communities are facilitated in ending diesel dependency, linked to stable grids, or provided with more stable, cleaner, and affordable energy generation equipment. Ontario's Wataynikaneyap project is aimed at building an additional transmission line through 21 First Nations settlements to end the communities' reliance on diesel by connecting them with provincial clean electricity grids, given that Ontario's electricity generation is 91% net-zero.[180,181] The other projects included installing wind turbines and a battery system to offset 35-50% of annual diesel consumption in Nain settlement (Labrador), building the largest solar farm in remote Canada of 2.2 MW to offset 25% of diesel consumption in Fort Chipewyan (Alberta), and installing energy-efficient technologies in households and public buildings in Gjoa Haven (Nunavut) to reduce annual diesel consumption by roughly 140,000 liters.[182]

Subnational transmission reforms. In addition to the federal iZEV program, British Columbia, New Brunswick, Nova Scotia, Newfoundland and Labrador, Prince Edward Island, Quebec, and Yukon provide provincial EV rebates as of 2024.[183] Quebec, one of the most attractive provinces for EV consumers in Canada, provides EV rebates of up to CAN $7,000 and has the lowest-in-the-country electricity rates owing to the high grid capacity of the province as a result of its reliance on hydro-power.[184] Given the varying energy profiles and high degree of autonomy of regional electricity grids, it is subnational governments who can ensure a timely transmission reform in anticipation of higher energy demand as more consumers purchase EVs, e.g. Site C Clean Energy Project in British Columbia will add 1.1 GW to the provincial hydroelectricity grid capacity, which would produce enough power to serve 1.7 million EVs annually.[185] Creating inter-provincial partnerships based on extra electricity grid capacity exports could also address the cross-country disparities in RE resource wealth and RE affordability, which would make an RE transition economically and socially easier in fossil fuels-dependent regions with delayed transmission reforms.

3.4 China

Summary

- After a long period of rapid emissions growth, China, the world's largest emitter, may have entered its emissions peaking stage, driven by world-leading green technology deployment and declining demand for energy-intensive materials and products due to economic slowdown and restructuring.
- China is on track to overachieve the 2030 carbon peaking target and has already exceeded the 1,200 GW wind and solar capacity target six years ahead. How quickly China can deliver meaningful emissions reductions after the peak will have a strong impact on global climate outcomes.
- China has started to observe economic benefits of the low-carbon transition, powered by investments and strong development in its green technology industries, particularly the "new three" of solar, electric vehicles, and batteries, which provides large potentials for rapid emissions reductions both domestically and for other developing countries.
- Electricity generation is expected to drive China's overall emissions in the coming decade; the most recent rapid coal power capacity expansion may not translate to growing emissions as long as coal plants are utilized at decreasing levels to prioritize renewable integration, despite large economic, technical, and safety challenges in using coal for dispatch.
- With recent policy development on methane and other non-CO_2 gases, China has committed to covering all GHGs from all sectors in its new NDC target with absolute reductions, despite an uncertain target base year.
- The *High Ambition* pathway for China implies emissions peak in 2023 and a 33% reduction in total GHG emissions by 2035 from the peak level, compared to a 15% reduction under the *Delayed Transition*.
- This is achieved by maintaining the high-speed deployment and integration of solar and wind while increasingly relying on non-fossil solutions for grid stability, continuing the economic restructure from energy-intensive growth, promoting energy conservation and efficiency improvements in end-uses, and prioritizing the reduction of non-CO_2 gases such as methane and N_2O across various sectors.
- China's "Tiao-Kuai" governance system combines a strong vertical hierarchy with horizontal coordination, enabling centrally defined climate policies to be implemented locally in a decentralized manner that accounts for local conditions and optimizes resource use. By granting subnational governments discretionary power to accelerate climate action and pilot innovative solutions, this system opens up key opportunities in the industrial sector and methane management at the subnational level, such as through small-scale circular economies like "zero-waste cities" and inter-provincial power imports.

EMISSIONS PROFILE. China exceeded the United States and became the world's largest emitter in 2006,[186] and contributed to about 30% of global total GHG emissions in 2023.[187] China's rapid emissions growth driven by strong economic development over the past two decades may soon, if not already, reach a turning point, due to rapid green technology deployment and declining demand for energy-intensive products with economic slowdown and restructuring. As of 2022, the majority of GHG emissions were from electricity and heat production (39%), industry (26%), and methane (9%).[188,189] Emissions from energy supply are still growing and driving the overall growth, where end-use emissions from industry and buildings have started decreasing, and transport emissions are expected to grow in the near term but remain at a small share.

2030 NDC. China's current 2030 NDC committed to carbon emissions peaking before 2030, a 65% reduction in carbon intensity from the 2005 level, and 1,200 GW total installed capacity for wind and solar.[190] China has also committed to achieving carbon neutrality before 2060.[191] The 2030 target does not cover non-CO_2 gases, and the carbon neutrality target does not specify coverage, but China has committed to include all GHGs in its 2035 NDC, which is an important improvement.

Overall, China is on track to overachieve its existing NDC targets. With recent trends, China is likely already entering its emissions peaking stage, with possible small fluctuations, on track to meet the carbon peak target. To peak earlier at lower levels can largely help the post-peaking transition to net zero and also has a critical implication to global peak temperature. Moreover, with its world-leading renewable buildout, China already met the solar and wind capacity target in September 2024, six years ahead of the schedule.[192] However, China is likely to miss the 2025 emissions intensity reduction target from a 2020 baseline, as specified in the 14th Five-Year Plan (FYP), unless substantial emissions reductions can be achieved in 2024 and 2025.[193]

NATIONAL STRATEGIES. China has made a number of major policy developments over the past two years, including the first methane action plan,[194] the coal power capacity payment reform,[195] the first national-level power spot market rules,[196] the action plan for low-carbon transformation of coal power,[197] and the work plan to accelerate the establishment of dual control system for carbon emissions,[198] which was seen as a soft launch of absolute emissions targets for the post-peaking period, setting up domestic policy structure for the new NDC.

In addition to policy progress, China has achieved tremendous success in developing its clean technology industries, especially the so-called "new three" of solar power, electric vehicles (EVs), and batteries, which have significantly driven down technology costs and promoted deployment worldwide. Investments continue to grow in green industries, which are beginning to drive China's economic growth.[199] The potential "overcapacity" question raises concerns for other countries' own green industrial development. With increasing challenges to enter the U.S. and E.U. markets, China has a strong interest in establishing new markets in other developing countries, creating opportunities for an accelerated energy transition.

Meanwhile, China, with its abundant coal reserves, remains at a heavy reliance on coal in its energy and economic systems. The strong political economy of coal involves powerful state-owned enterprises (SOEs) in the coal mining and coal power sectors, power grid SOEs, key industries, and local governments that depend on coal producers or consumers for employment and tax revenues. Although it is widely acknowledged that coal phaseout is essential for achieving carbon neutrality, near-term trends and policies seem to slow or divert progress on the transition, emphasizing coal as the "backbone" of the energy system and the principle of "establish before breaking."

China has consistently emphasized the role of coal power plants for ensuring resource adequacy and grid stability with increasing share of intermittent renewables. Due to the lack of gas resources, China is looking for coal plants to function as gas turbines in the power system, and has been pushing flexibility upgrades of coal plants to enhance the peaking-shaving and rapid load-following capabilities.[200] However, the challenges to continue upgrading the less preferable units will grow[201] with higher retrofit investment and maintenance costs, higher risks to plant and system operation safety, and higher per unit coal consumption, all of which reduce the technical performance and the economic feasibility of the upgrade.

Moreover, China continues to build a large amount of new coal plants, designed to have better dispatch capabilities for grid balancing. However, this approach tends to be more expensive compared to alternatives such as battery and other storage technologies, cross-region grid balancing, and demand-side resources.[202,203] Additionally, new policies such as the coal power capacity payment reform and the action plan for low-carbon transformation of coal power generation through biomass or ammonia co-firing and CCUS retrofits in selected plants are unlikely to deliver large-scale emissions reductions as intended, but may further incentivize new coal investments, slow down the retirement of inefficient coal plants, and preclude alternative options to supporting renewable integration, leading to uncertain emissions outcomes.

2035 PATHWAYS. Our modeling analysis shows that the 2035 target for China under the *High Ambition* pathway implies a 33% reduction from the peak level in 2023. We compare a few scenarios (Table 3.4.1 and Figure 3.4), including:

- A ***Delayed Transition*** where total GHG emissions decline by 8% in 2030 and by 15% in 2035 from the 2023 level, and or by 9% and 15%, respectively, excluding LULUCF (Table 3.4.1).
- A ***High Ambition*** *pathway* where China's overall GHG and CO_2 emissions peak before 2025; total GHG emissions decline by 12% in 2030 and by 33% in 2035 from the peak level, or 12% and 32% excluding LULUCF. There are uncertainties regarding land sink, where the *High Ambition* pathway assumes a constant land sink of 1 $GtCO_2$ through 2035.

Table 3.4.1. Summary of GHG emissions reductions in 2030 and 2035, relative to 2023.

Year/ Scenario	GHG including LULUCF % reduction from 2023		GHG excluding LULUCF % reduction from 2023	
	2030	2035	2030	2035
Delayed Transition*	8%	15%	9%	15%
High Ambition*	12%	33%	12%	32%

Note: *Based on the scenarios developed using GCAM-6.0-CGS.

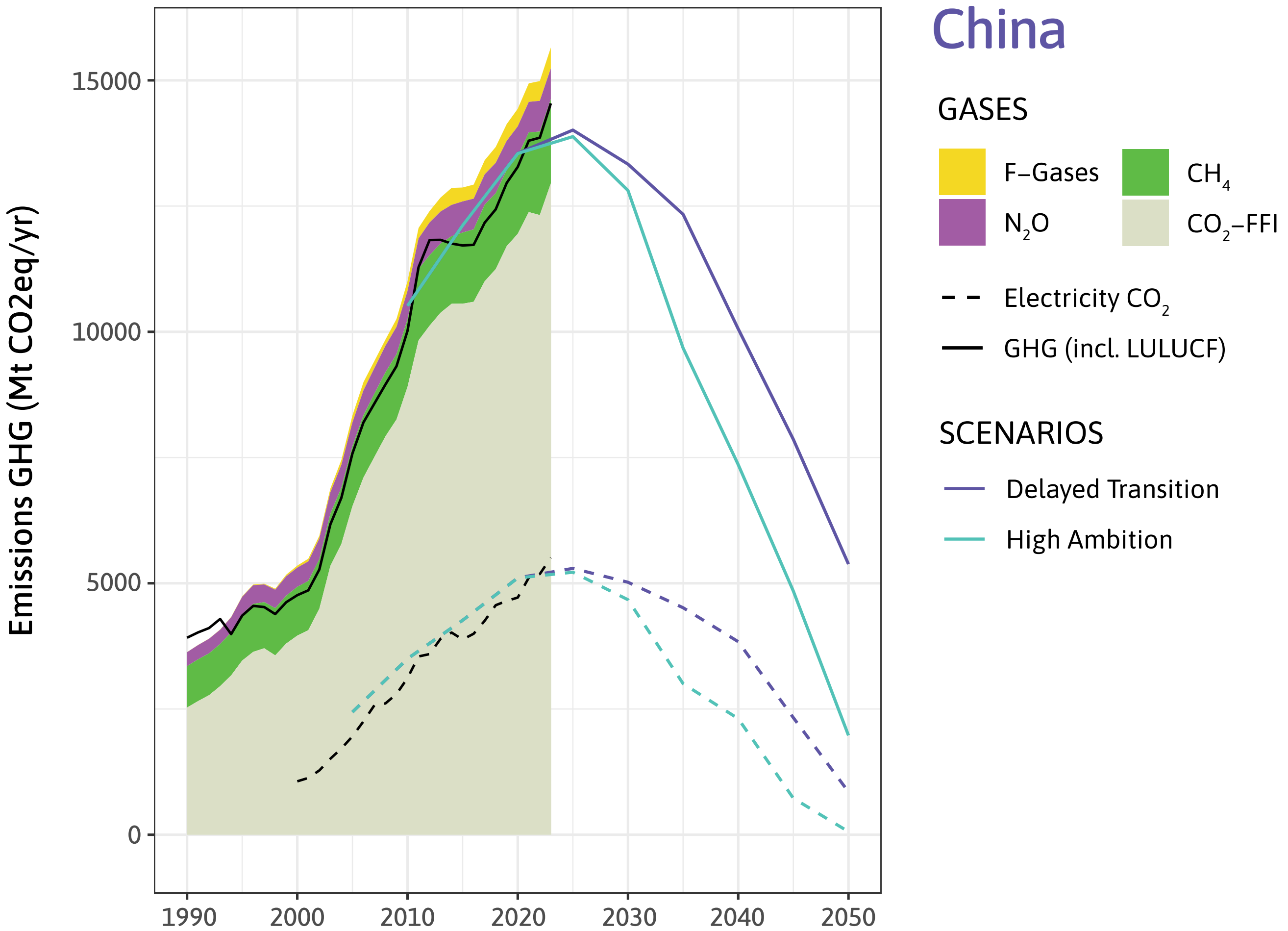

Figure 3.4. China's GHG including LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[204] (solid black line for total GHG, include LULUCF), EMBER[205] (dashed black line for electricity supply GHG emissions), and CEDS[206] (colored breakdown of historic GHG emissions, without F-Gases). Pathways data includes LULUCF emissions and is based on the scenarios developed using the GCAM IAM for the NGFS Phase V.[207]

PRIORITY POLICY ACTIONS. Electricity generation will likely drive China's overall emissions in the coming decade, as industry emissions are already on a declining trend due to economic structural change, and other end-use sectors continue to electrify. How quickly China can reduce its emissions during post peaking largely depends on key policy actions, including:

- **Power sector:** Maintaining high speed of solar and wind deployment at 300 GW per year with successful integration; canceling pre-construction new coal builds; targeted utilization of existing coal for dispatch; and adopting alternative grid balancing options.
- **Industry:** Continuing economic restructure, moving away from carbon-intensive growth; reducing coal use across sectors and in industrial parks, especially controlling the expansion of coal-to-chemicals sector; promoting the use of EAF and scrap metal in the steel sector; implementing low-cost N_2O abatement; connecting to circular economy goals, such as efficiency and waste and heat recovery to reduce energy demand.

- **Methane:** Enhancing policy efforts on targeted non-CO_2 abatement; setting an ambitious quantitative 2035 methane emissions target, especially in energy; integrating methane mitigation strategies with improving air quality and expanding circular economy; and improving monitoring and data management for key sectors.

Power sector. In 2023, China installed almost 300 GW of new solar and wind capacity, a large jump from the annual installation of 100-125 GW in the previous three consecutive years, and accounted for almost 80% of the total new capacity growth in 2023.[208] The buildout rate continues in 2024, with a total of 200 GW (161 GW solar and 39 GW wind) installed between January and September.[209]

Under the *High Ambition* pathway, rapid solar and wind deployments and integration are maintained at approximately 300 GW per year, starting to drive down coal power generation and thus electricity emissions (Table 3.4.2).

- Solar and wind deployment continues at the rate of 300 GW/year between 2023 and 2035, and contributes to 41% of total electricity generation in 2030 and 58% in 2035, increased from the 16% in 2023.[210]
- The share of coal in total generation declines from 58% in 2023 to 38% in 2030 and 22% in 2035.
- Assuming that only new projects under construction (~170 GW) are added, the average coal plant utilization declines to about 3,575 hours (41% of full capacity) in 2030 and 2,221 hours (25% of full capacity) in 2035.

Table 3.4.2. Key power sector metrics across the two scenarios.

Year/ Scenario	Solar + Wind % of total elec generation (Installed capacity, GW)		Coal % of total elec generation (avg utilization level, hours, %)	
	Delayed Transition	*High Ambition*	*Delayed Transition*	*High Ambition*
2023[211]	*16% (1,050 GW)*		*58% (4,592 hours, 52%)*	
2025	21% (1,384 GW)	25% (1,652 GW)	55% (4,250 hours, 49%)	52% (4,330 hours, 49%)
2030	37% (2,798 GW)	41% (3,198 GW)	42% (3,392 hours, 39%)	38% (3,575 hours, 41%)
2035	49% (4,078 GW)	58% (4,722 GW)	33% (2,942 hours, 34%)	22% (2,221 hours, 25%)

Note: Future average coal plant utilization levels are calculated based on continued coal builds (+400 GW through 2035) for the *Delayed Transition* and no new coal beyond construction (+170 GW through 2030) for the *High Ambition* pathway.

With continued electricity demand growth, China has been pursuing new coal capacity as a default option for resource adequacy with increasing penetration of intermittent renewables to meet increasing peak load demand. As of July 2024 the project pipeline includes 170 GW of new coal capacity under construction (76% of global total), and another 247 GW at pre-construction stages (66% of global total).[212] However, even without adding new coal capacity under the *High Ambition* pathway, existing coal plants will face significant decline in utilization level, from 58% in 2023 toward a 32%-41% capacity factor by 2030 and 20%-32% by 2035 across low and high total electricity demand scenarios; moreover, building all the 247 GW pre-construction projects will further lower the utilization to 28%-36% and 17%-28% by 2030 and 2035, respectively, placing significant economic impacts on existing and new coal plants. Instead, various alternative options are more cost-effective, including cross-region grid balancing, demand-side management, and investment in battery and other storage technologies, can be pursued to avoid further stranded assets.[213]

Industry. In 2022, the industrial sector accounted for 26% of overall GHG emissions in China, excluding LULUCF, with cement, iron and steel, and chemicals as the primary contributors.[214] Emissions have remained relatively stable, with a slight decline since 2014, driven by an economic shift away from infrastructure-driven growth. The construction sector is expected to see further decreases in 2024,[215] affecting the demand for building materials, particularly cement, which experienced a 7% drop in production in the second quarter of 2024 compared to 2023.[216] In steelmaking, a notable shift away from coal is emerging as demand peaks and scrap availability increases,[217] with no new coal-based projects approved in the first half of 2024, marking a significant change since China's dual carbon goals were announced in September 2020.[218] In contrast, emissions from the chemicals sector are rising due to falling coal prices, which have led to increased coal use in chemical production. This expansion of the coal-to-chemicals industry poses a challenge to China's overall emission reduction efforts.[219]

Our *High Ambition* scenario projects a 31% reduction in industry sector emissions by 2035 from 2020 levels, driven by an accelerated phase-down of coal due to increased electrification, particularly in the mining, construction, and agricultural energy sectors. To achieve this decarbonization pathway, several key policy actions include enhancing efficiency in the cement and steel sectors, promoting the use of electric arc furnaces (EAF) and scrap metal in steel production, replacing coal in the chemicals sector with alternative feedstocks, and strengthening China's circular economy strategies. Improving energy efficiency, recovering industrial waste and heat—especially in hard-to-abate sectors—and increasing the adoption of renewable energy in energy-intensive industries while developing renewable captive power plants are equally important. Further decarbonization of industrial parks, which contribute over 50% of China's industrial output and one-third of carbon emissions,[220] is necessary. Relocating energy-intensive industries to areas abundant in renewable energy resources, such as western and northern China, will facilitate a more sustainable industrial landscape.

Methane. Methane emissions account for 9% of China's total GHG emissions, excluding LULUCF, making the country one of the largest global emitters of methane.[221] Since 2005, methane emissions have risen by 37%, with the majority originating from the energy sector (50%, with 39% from coal), followed by agriculture (26%) and waste (23%).[222] To address this issue, China has initiated several actions aimed at accelerating methane emissions reduction. These include strengthening regulations on coalbed methane emissions through the Revised Emission Standard of Coalbed Methane/Coal Mine Methane, published in 2024, introducing the China Certified Emission Reduction (CCER) methodology to promote low-concentration methane extraction and utilization, reevaluating and updating emission factors based on detailed investigations to enhance the accuracy of methane inventories, and improving measurement, reporting, and verification (MRV) across all emission sectors.

In the *High Ambition* scenario, methane emissions decrease 35% from 2020 to 2035. To achieve this goal, key actions include strengthening monitoring and data management for methane emissions, enhancing efforts to address abandoned coal mines, orphan wells, and super emitters, and exploring the potential of a circular economy for methane mitigation. It is also important to tackle secondary emitting sources such as transportation, buildings, and industrial processes while encouraging technological innovation for methane reduction through market mechanisms and the establishment of green industrial parks. Additionally, integrating methane emissions reductions with national strategies focused on air pollution reduction, energy transition, and rural revitalization—particularly through sustainable agriculture and waste management—will be crucial.

SUBNATIONAL ACTION

China's governance structure is characterized as the "Tiao-Kuai" system, a two-dimensional approach featuring a strong vertical hierarchy in functional administration and horizontal coordination among territorially-based units at each governance level.[223] In climate governance, this means that while climate policy priorities are defined centrally by the national government, including the Ministry of Ecology and Environment, policy implementation is decentralized to account for local conditions and to optimize resource use.[224] This structure grants subnational governments sufficient discretionary power, allowing them to accelerate climate action and experiments with innovative solutions, often exemplified by pilot programs assigned to specific provinces or municipalities that have both economic resources and strong commitment to energy transition.[225,226]

China's structure for provincial-level implementation of national policies may allow for subnational actions to promote emissions reductions in industry and methane, with industry accounting for 26% of overall emissions in China, and methane accounting for 9%, 50% of which comes from coal. Industrial emissions reductions through waste reduction and reuse can be implemented almost entirely on the city level, with high financial return. Provincial governments have great influence in their portions of the national power grid, and therefore may control their shifts to make way for renewable energy—however this may require national support.

Industry: Small-scale circular economies can be deployed throughout provinces, particularly for the reuse of industrial waste products such as scrap metals, supplementary cementitious materials such as limestone and fly ash for cement clinker, and heat recovery for energy. China has already taken an interest in solid waste management in particular, with "zero-waste city" pilot programs implemented in 11 cities and five special areas since 2018. Within the 14th Five-Year Plan period, China is pursuing the construction in 113 cities and 8 special areas for this "zero-waste" program. This program puts forth an urban development model that aims to reduce the generation and promote the recycling of solid waste, reduce landfills, and promote overall green development, essentially maximizing the efficiency of industrial production processes.[227] One such city can be seen in Songjiang District, with an implementation plan that aims to have 90 "zero waste sites" by the end of 2024, including sites such as factories and offices. For example, the Shanghai Huanyi Waste Material Recycling Co Ltd plans to recycle approximately 15,000 tons of general industrial waste per annum.[228] Such zero-waste programs that emphasize circularity may also help with provincial coal phase-down and methane mitigation, as biogas derived from landfills, wastewater, and manure can be utilized to reduce methane emissions generated and to substitute as an energy source in place of fossil fuels to produce industrial heat and electrical power.[229]

Methane: The most significant source of methane emissions is coal, which is concentrated in the North, particularly in Shanxi, Inner Mongolia, and Shaanxi, which mine 70% of China's coal.[230] As mentioned above, in Shanxi and Inner Mongolia, coal accounts for 33.8 % of household energy consumption and for 51.5 % of energy production, despite the renewable resources wealth of the North and West of China.[231] However, due to economic concerns, other provinces have been building the most new coal projects. For example, the western province of Guizhou, which has high hydro power uptake rates, has planned the most coal-fired power projects in China in its provincial 14th Five-Year Plan.[232] This is largely due to provincial desires to generate their own power. Although there are two main federally-run grids, provinces tend to be the main operators. Therefore, for provincial shifts away from coal, provinces can adapt the way they operate their power grids and make space for imported renewable energy, such as from eastern China, where the vast majority of wind and solar production in China comes from. This however may require national support, as there is little financial incentive for provinces to stop generating their own power.[233]

3.5 India

Summary

- India's GHG emissions have been increasing rapidly, by over 62% from 2010 to 2023 (excluding LULUCF), primarily in the power and industrial sectors, driven by rapid population and economic growth.
- As India continues to experience speedy growth, the timing and level at which its emissions will peak remains uncertain. The current NDC target—aiming for a 45% reduction in carbon intensity from 2005 levels—allows for emissions to increase through 2030. A post-2030 emissions peak would leave less than 40 years to achieve the country's 2070 net-zero goal, and further delays would intensify the challenge.
- Although it is the world's fifth-largest economy, India's per capita GDP remains low, and development, industrialization, and urbanization for its fast-growing population continue to be a high priority; green growth and economic transformation provide opportunities.
- India is the only major economy outside China still building and planning for a large amount of new coal power capacity, despite already cost-competitive renewables; regulatory incentives and both explicit and implicit coal subsidies continue to favor coal investments over renewables, due to a strong political economy around coal mining and coal power.
- Our *High Ambition* pathway for India includes emissions peaking (excluding LULUCF) by 2030, followed by a 10% reduction from the peak level by 2035, or a 5% increase from 2023.
- This is achieved by accelerating annual solar and wind buildout to 5-6 times the current level, while canceling all pre-construction and some under-construction coal power projects, reducing heavy industry emissions through electrification and circular economy, expanding EV infrastructure and incentives for EV manufacturing, and reducing methane emissions through solid waste management improvement and limiting the expansion of underground coal mining.
- India's multi-level governance structure provides important opportunities for enhanced climate action through subnational leadership. Multiple states are now adopting their own roadmaps toward net-zero targets, some faster than the national goal. Key sectors, including industry through multi-level cooperation, transport through incentives, and agricultureal methane through promoting sustainable practices, show strong potential for impactful, state-led initiatives.

EMISSIONS PROFILE. India's GHG emissions excluding LULUCF increased by over 62% from 2010 to 2023,[234] primarily driven by growth in the power and industrial sectors, which accounted for 36% and 22% of total GHG emissions in 2022, respectively.[235] Methane emissions contributed 23% of total GHG emissions in 2022, although their levels have remained relatively stable, with agriculture accounting for about 61% of this share.[236]

2030 NDC. India's current NDC commits to reducing carbon intensity by 45% from 2005 levels by 2030.[237] India has also committed to achieving net-zero emissions by 2070.[238] However, the 2030 target excludes non-CO_2 gases and land-use change emissions (LULUCF), while the scope of the net-zero target remains unspecified. The 2030 NDC carbon intensity target will likely lead to 13-35% increase in total GHG emissions excluding LULUCF from 2022 (Table 3.5.1), allowing for continued emissions growth across a possible range of GDP growth rates (ranging from 6% to 8.9% per year). India is on track to meet its NDC before 2030, indicating there is potential for enhancing ambition.

While India's NDC balances development priorities with economic growth, the emissions intensity target tied to GDP growth does not specify a near-term emissions peak. By focusing on per capita emissions and equity based on historical responsibility,[239] India—currently the world's third-largest GHG emitter—can still grow emissions over this decade while adhering to its NDC commitments.

NATIONAL STRATEGIES. India is the fifth-largest economy in the world[240] with economic growth projected at 8.2% for 2023-2024, making it the fastest-growing major economy.[241] Despite its low per capita income, India aspires to achieve high middle-income status by 2047.[242] This growth is driven by significant investments in infrastructure along with a thriving manufacturing sector.[243] As India continues to prioritize development, industrialization, and urbanization for its fast-growing population, the focus on green growth and economic transformation presents key opportunities for sustainable progress.

India is the only major economy outside China still building and planning significant new coal power capacity, despite the availability of cost-competitive renewables. The current pipeline includes 29 GW of coal power plants under construction and 45 GW in pre-construction stages.[244] Regulatory incentives, along with explicit and implicit coal subsidies, continue to favor coal investments over renewables, largely due to the strong political economy surrounding coal mining and coal power.

In addition to the emission reduction targets outlined in its NDC, India has set key sectoral goals such as achieving 50% non-fossil power capacity by 2030,[245] producing 5 MMT of green hydrogen,[246] and reaching a 5% biofuel blending rate by that year.[247] At COP 26 in Glasgow, India announced its aim to install 500 GW of non-fossil power capacity and reduce up to 1 Gt of emissions by 2030, though no specific baseline for the emissions reduction target was provided.[248] These targets largely align with India's prior pledges and are not expected to lead to significant additional emissions reductions. India also mentioned a goal of enhancing its carbon sink by 2.5-3 Gt through additional forest and tree cover in its NDC,[249] but did not clarify the baseline or the approach for measuring progress.

Beyond implemented policies, recent key policy trends in India include an increasing emphasis on economic transformation as a policy driver and expanding opportunities for multilevel governance. Indian policy makers at the national and state levels are increasingly conscious of the economic transformation required to deal with climate change and discussing impacts to economic growth can galvanize serious and urgent action to move towards the net-zero goal. Overall, the narrative of economic transformation over the previous discourse of co-benefits is gaining more traction.[250] The recent national elections have resulted in a weakened mandate for the union government, making it dependent on state-level allies. Since the major allies are based in regions with significant coal mining and thermal power generation capacity, enhanced ambition at scale may not be likely in the near term. However, existing commitments are unlikely to be scaled down and many states are increasingly proactive on renewable energy installation and economic transformation for net zero emissions, with some pursuing their own net-zero strategies.[251,252,253]

2035 PATHWAYS. Our analysis shows two pathways for India that lead to a 5%-12% increase in total GHG emissions excluding LULUCF by 2035 from 2023 (Table 3.5.1 and Figure 3.5).

- *A **Delayed Transition*** where emissions continue to grow through 2030 and decline thereafter. In this scenario, total emissions increase by 43% from 2023 levels by 2030 and by 25% by 2035, and decrease by 13% from the peak level in 2030 by 2035. Excluding LULUCF, emissions increase by 29% from 2023 levels by 2030 and by 12% by 2035.

- *A **High Ambition** pathway* where emissions remain constant between 2025 and 2030, then decline thereafter toward achieving net-zero CO_2 emissions by 2070. In this scenario, total emissions increase by 29% to the peak level in 2030 from 2023, and decline by 10% from the peak to 2035, or increase by 17% from 2023. Excluding LULUCF, emissions increase by 16% to the peak level in 2030 from 2023, and decline by 10% from the peak to 2035, or increase by 5% from 2023.

Land use change CO_2 emissions are relatively a minor contributor at approximately 1-3% of total CO_2 emissions, despite large variation across inventories.[254] Other analysis suggests that a high-ambition pathway for LULUCF may result in a net land sink of -250 $MtCO_2$/year in 2030.[255]

Table 3.5.1. Summary of changes in GHG emissions in 2030 and 2035, relative to 2023.

Year/ Scenario	GHG emissions including LULUCF % change from 2023		GHG emissions excluding LULUCF % change from 2023	
	2030	2035	2030	2035
NDC target			+13% to +35%	TBD
Delayed Transition*	+43%	+25%	+29%	+12%
High Ambition*	+29%	+17%	+16%	+5%

Note: *Based on the scenarios developed using GCAM-6.0-CGS for the NGFS Phase V.

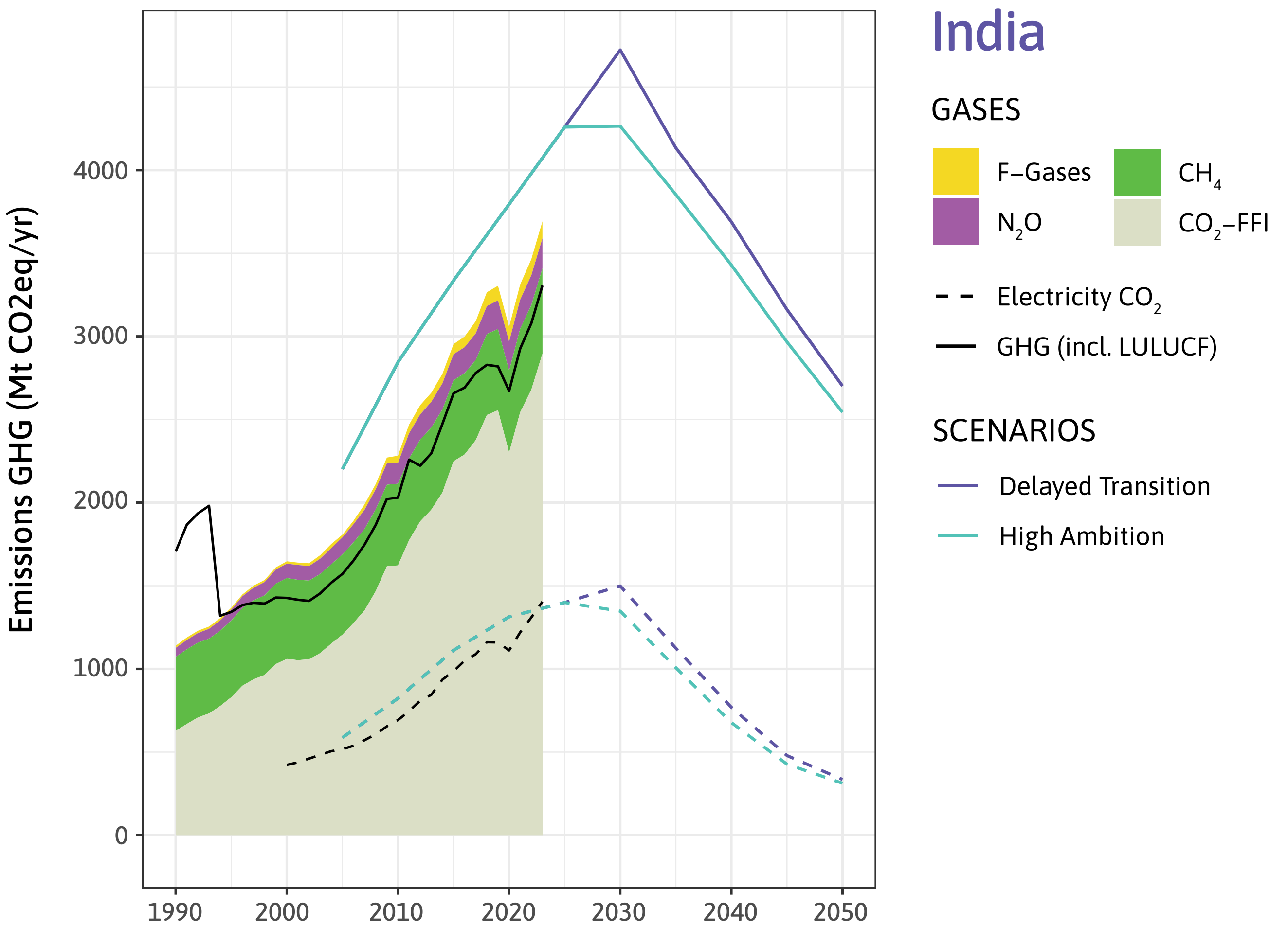

Figure 3.5. India's GHG including LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[256] (solid black line for total GHG, include LULUCF), EMBER[257] (dashed black line for electricity supply GHG emissions), and CEDS[258] (colored breakdown of historic GHG emissions, without F-Gases). Pathways data includes LULUCF emissions and is based on the scenarios developed using the GCAM IAM for the NGFS Phase V.[259]

PRIORITY POLICY ACTIONS. Detailed sectoral strategies should be developed to achieve the economy-wide targets. Priority policy actions to limit carbon emissions growth and drive reductions should focus on the power, industry, and transport sectors, as well as on waste and coal mining for methane reductions, including:

- **Power sector:** Maintaining sustainable electricity demand growth, ideally at less than 5% annually; accelerating the annual solar and wind buildout to 5-6 times the current level; achieving over 50% and 65% non-fossil generation by 2030 and 2035, respectively; and canceling pre-construction (45 GW) and some under-construction (29 GW) coal power projects.
- **Industry:** Shifting to low-carbon electric furnaces in the iron and steel industry and promoting the use of hydrogen or gas-reduced metallics, while connecting to a circular economy to reduce demand in certain sectors, such as petrochemicals.

- **Transportation:** Expanding EV infrastructure and incentives for EV manufacturing and developing value chains for critical components.
- **Methane:** Expanding opportunities for a circular economy in solid waste management, including biogas capture from landfills; improving emissions estimates for existing landfill and dump sites; and limiting the expansion of underground coal mining.

Power sector. Increasing coal consumption has largely driven the rise in power sector emissions in India, alongside growing demand in the residential and industrial sectors. As of 2023, coal accounted for 75% of total electricity generation, while renewables contributed 20%, with solar and wind providing 10% and hydro 8%.[260] Although the recent growth in wind and solar power installations, along with substantial existing hydro power generation, offers significant potential for transitioning away from coal, achieving meaningful emissions reductions will require a rapid expansion of renewables that exceeds the targets outlined in India's recent National Electricity Plan (NEP).[261]

Meaningful reductions in electricity emissions from India's power sector, targeting approximately 30% by 2035, are achievable if the following aspects are considered:

- Moderating demand growth below 5% annually through efficiency improvements and demand-side management.
- Increasing the share of non-fossil generation from 28% to over 50% by 2030 and to 65% by 2035.
- Accelerating the solar and wind buildout from the current level of 12-15 GW/year to about 74 GW/year (double the NEP) under low demand growth (4%) and to approximately 93 GW/year (2.5 times the existing government plan) under high demand growth (5%).
- Canceling 45 GW of coal power pre-construction projects and some of the 29 GW currently under construction, as these projects are already more expensive than solar electricity for meeting increasing demand.

Table 3.5.2. Percent change in coal power emissions in 2035 from 2023 under different solar and wind buildout rates and demand projections.

	Solar and Wind Buildout Rate			
Demand projections in 2035 (annual growth rate)	***National Electricity Plan (NEP) (37 GW/year)***	***1.5 times NEP rate (56 GW/year)***	***Double NEP rate (74 GW/year)***	***2.5 times NEP rate (93 GW/year)***
Low growth 3,311 TWh (4.0%)	+14.8%	-5.9%	-29.8%	-53.7%
Medium growth 3,714 TWh (5.0%)	n.a.	+19.5%	-4.3%	-28.2%
High growth 4,161 TWh (6.0%)	n.a.	+47.8%	+23.9%	+0.1%

Under a *High Ambition* scenario, no new coal capacity is needed under low to medium demand growth, and coal power generation can be reduced through a combination of targeted plant retirements, reduced utilization, and potentially biomass co-firing. However, additional coal capacity is required when electricity demand growth is high (6%), unless the solar and wind capacity buildout reaches 2.5 times the target outlined in the NEP.

While economic and technological factors play a significant role, they do not fully explain the current number of existing and planned coal power plants in India. Therefore, it is crucial to consider the political economy of coal in the country to limit further development. Addressing perceptions of coal's necessity for grid reliability and energy security, along with reconsidering regulatory incentives that favor coal investments and imports, is essential. Additionally, phasing out both implicit and explicit coal subsidies could discourage new private coal investments and potentially redirect financial flows toward renewable energy.

Industry. Reducing emissions amid economic development will be a key challenge for the industrial sector in India while creating jobs for its young population. As India aims to establish itself as a global manufacturing hub, the demand for energy-intensive building materials like steel and cement is expected to rise, driven by ongoing urbanization and industrialization. In 2022, India's industrial CO_2 emissions were predominantly generated by the iron and steel sector, which accounted for 29% of total emissions, closely followed by cement at 23%. Other significant contributors included manufacturing and non-metallic minerals.[262]

To achieve emission reductions consistent with the *High Ambition* pathway, several key policy actions are recommended. Establishing a functioning carbon market is crucial to encourage participation from various sectors, incentivizing the adoption of cleaner technologies and improvements in energy efficiency. In the iron and steel industry, transitioning to low-carbon electric furnaces and promoting the use of hydrogen or gas-reduced metallics will be essential.[263] Additionally, phasing out coal in cement production through the use of biomass or hydrogen, and gradually introducing carbon capture and storage (CCS) in cement kilns, are important steps.[264] Adopting circular economy principles can also help curb petrochemical demand, thus reducing emissions in this sector—such as by replacing coal-fired furnaces with low-carbon feedstocks like hydrogen or biomass.[265] Addressing the competitive impacts posed by the Carbon Border Adjustment Mechanism (CBAM) and integrating small enterprises into the global clean energy value chain will further enhance climate ambition.

Transportation. India is projected to experience the largest urban population increase in the world by 2050.[266] While the transport sector currently contributes a relatively small share of overall emissions, it is expected to undergo significant structural changes in the next decade. Near-term decisions regarding EV infrastructure can influence the emissions trajectory, especially when combined with the increasing share of renewable energy in the power sector.[267] In 2023, sales of EVs reached 2% of total new vehicle sales, marking a positive trend. Expanding EV adoption presents a viable pathway to mitigate both carbon emissions and air pollution from road transport, which has become an urgent concern for many Indian cities.[268]

To achieve ambitious emissions reductions, several key policy actions are essential. Given the anticipated rise in four-wheeler ownership due to increasing income levels,[269] prioritizing the development of infrastructure that supports the mass adoption of electric vehicles would be beneficial. Furthermore, continued investment in and promotion of sustainable public transportation options in growing urban areas could help alleviate congestion and reduce emissions. Encouraging domestic manufacturers to produce EVs will also play a crucial role in expanding access to and adoption of electric vehicles across the country.

Methane. Methane was the second-largest contributor to emissions in India in 2022, following the power sector. According to data from CEDS, over 60% of methane emissions originated from the agriculture sector (61%), with waste and energy contributing 23% and 15%, respectively.[270] Emissions across all sectors have been gradually increasing. India has not signed the Global Methane Pledge, leading to uncertainty about whether methane emissions will decline in the near term, as this will largely depend on policy choices in the waste and coal mining sectors.

In a *High Ambition* scenario, methane emissions would remain stable, with no increase from 2022 to 2030. Achieving this will require several key policy actions, including emphasizing a circular economy in solid waste management,[271] expanding biogas waste capture from organic waste and landfills,[272,273] and improving the understanding of emissions from landfill and non-landfill sources, such as dumpsites.[274,275] Additionally, to prevent further methane emissions from coal, it will be essential to limit the growth of underground mining activities and increase methane capture from surface mines.

SUBNATIONAL ACTION

India is a parliamentary democracy with both union and state governments. The 28 states exercise substantial autonomy, although the central government appoints governors for oversight and has a significant role in distribution of tax revenues.[276] State governments hold responsibility over critical climate-relevant policy areas, such as agriculture and the regulation of mines and mineral development. Local governance, managed by municipal corporations, includes climate-related responsibilities, notably through mining settlement authorities.[277]

India's climate governance structure highlights the potential of subnational actions to reduce emissions from agriculture and industry, with methane contributing 23% and industry 22% of the country's total emissions. Much of the methane emissions arise from agricultural practices regulated by state governments, while some mining and industrial activities operate at the state level, subject to the control of the Union, making way for subnational regulatory influence. Municipal level governments may have greater influence in urban development policies, including land use, building regulation, and transportation policies such as EV targets and public transportation.

Methane: The Agricultural Policy of India is a national tool for the subnational implementation of sustainable farming. The Policy's goal is to raise agricultural production, enhance farmers' living standards, address resource management and technology adoption, promote sustainable practices, and improve infrastructure.[278] Since states hold primary authority over agriculture under List-II[279] of the Constitution, subnational governments can prioritize the financing and promotion of sustainable farming practices.[280] Local governments can subsidize mitigation technologies on the farm-end that small farmers may not be able to afford and deploy advisors to educate farmers on efficient practices.[281] As for waste management, local governments can work towards rehabilitating landfills to include landfill gas capture, developing technical capacity and knowledge among waste servicers, and prioritizing efficient financing for organic waste management projects.[282] In addition to all of these approaches, circularity of end-of-life products on the state-level can be better managed to decrease the amount of waste entering into landfills.

Industry: Sector-wide collaboration, through incorporating non-state international cooperation and private actors, may be a promising approach for India's industrial sector and the subnational level. India already has a few of these multi-level partnerships. For example, the Leadership Group on Industry Transition which acts as a platform for correspondence of ideas between governments and the private sector for low-carbon business opportunities technology sharing, and sectoral roadmaps.[283] Furthermore, India co-chairs the Industrial Deep Decarbonization Institute, an international coalition of state and non-state organizations with the goal of leveraging demand for low carbon industrial materials. These types of collaborations can place pressure on private actors to move towards decarbonization, and state and municipal governments can join to share and push for their ideas and priorities. Pressure may be best received through an incentive-based approach, as smaller private actors may require additional upfront investment to keep pace with changing technologies and industrial decarbonization policies.[284] One way states may have potential to exercise incentives is through electricity prices for industry, as effective policies may make fuel shifts more attractive to industries. Further, states regulate pollution for all industries within their borders, so regulatory tools for emissions reductions may serve as a potential for linked reductions, so long as alternative technologies, such as those proposed in coalitions, are economically suitable.[285]

Transport: As of 2023, 26 states and union territories had published e-mobility strategies, with seven more in the draft stage.[286] The primary mode of transit in India is through personal vehicles. So far, most vehicle electrification has been seen in two- and three-wheelers and LCVs, with Delhi, Uttarakhand, and Goa leading the uptake.[287] Of the top 10 states for new EV registration, nine have notified EV policies, underscoring the importance of notified and quantified policy frameworks at the subnational level in driving EV adoption.[288] Beyond personal modes of transport, state and municipal authorities can prioritize public transportation infrastructure, such as for electrified buses and metro rail, as well as promote modal shifts. States also regulate pollution norms implementation as well as vehicle registration and scrappage, which could be utilized to enhance mitigation ambition. However, some of these infrastructure projects require significant upfront investment with federal support, and may therefore expand beyond purely subnational spheres.[289]

3.6 Indonesia

Summary

- Indonesia's GHG emissions, excluding LULUCF, increased by 61% from 2010 to 2023, driven largely by rapid growth in coal consumption for electricity generation and methane from coal production; LULUCF emissions have been the country's largest emissions source and increased by 30% from 2010 to 2022.
- Indonesia's current NDC includes a 32% (or 43% conditionally) GHG emissions reduction by 2030 from business-as-usual (BAU), which is likely non-binding, assuming overly optimistic LULUCF emissions reductions while allowing strong growth in other emissions. It also has a net-zero target by 2060.
- As a major coal producer and the world's largest coal exporter, Indonesia falls far behind in renewable deployment compared to other Southeast Asian countries, despite abundant solar resources. The Just Energy Transition Partnership (JETP) provides opportunities, but progress has been limited due to institutional and infrastructure barriers.
- National strategies and policies have pushed strong development of the nickel mining and processing and palm oil industries, which are connected to global decarbonization but have large emissions implications domestically through captive coal power and deforestation.
- The *High Ambition* pathway for Indonesia suggests that total GHG emissions began to decline after 2022, with non-LULUCF emissions peaking around 2025; and total GHG emissions achieve a 60% reduction by 2035 from the 2023 levels, or a 23% reduction excluding LULUCF.
- This requires both achieving a net land sink by 2035 and delivering meaningful reductions in energy emissions through accelerated renewable deployment, power infrastructure buildout, and end-use electrification. Due to the large share of LULUCF emissions, developing separate targets and strategies can ensure accelerated action in both the land and energy systems.
- While Indonesia's NDC target covers the non-CO_2 gases of CH_4 and N_2O, there are major policy gaps and thus a large potential for near-term methane abatement by expanding waste management services nationwide and restricting the expansion of underground coal mines.
- Subnational actors have a strong potential to enhance ambition in the critical sectors of renewable deployment, land use conflicts, and waste management, especially in major urban and tourist regions; it is also critical to engage key industry stakeholders like PLN, the mining industries, and the palm oil industry.

EMISSIONS PROFILE. Land use, land-use change, and forestry (LULUCF) has been the largest emissions source in Indonesia, accounting for 42% of total GHG emissions in 2022, and increased by 30% from 2010 to 2022.[290,291] Non-LULUCF emissions have increased even faster—by 61% from 2010 to 2023—and are dominated by methane and power generation, which were 19% and 16% of total GHG emissions in 2022, respectively.[292] The rapid growth is mainly driven by nearly doubled electricity emissions through a substantial increase in coal consumption and a 50% growth in methane emissions.

2030 NDC. Indonesia's current NDC has committed to reducing 2030 emissions by 32% (or 43% conditionally) from the business-as-usual (BAU) and achieving net-zero emissions by 2060. These targets cover CO_2, CH_4 and N_2O emissions from all sectors, leaving out other non-CO_2 gases.[293] The 2030 NDC targets are likely non-binding, especially on non-LULUCF emissions. The conditional target aims for a 17% reduction in total emissions, including LULUCF, from 2022, which requires a net land sink but allows a 42% increase in non-LULUCF GHG emissions. While the LULUCF target may be considered ambitious and presents significant challenges, the target for non-LULUCF emissions appears relatively modest, suggesting a faster emission growth rate of 4.5% annually from 2022 to 2030, compared to the 4%/year observed from 2010 to 2022. The unconditional target aims to keep total emissions stable by 2030 but allows for a 50% increase in non-LULUCF emissions.

NATIONAL STRATEGIES. Indonesia is a major coal producer and the world's largest coal exporter, with over two-thirds of its total coal production destined for export.[294] In 2023, both coal production and exports saw significant increases, reaching record highs.[295] Despite abundant RE resources, deployment of solar and wind is lagging far behind other Southeast Asian countries, notably Vietnam, the Philippines, and Malaysia.[296]

Policy efforts in Indonesia have focused on promoting land-use sink by 2030 and defining the investment plan for the Just Energy Transition Partnership (JETP). The Forest and Land Use Net Sink 2030 policy pledges to stop GHG emissions from forest management by 2030, by reducing the deforestation and degradation rate, establishing sustainable plantation forest, developing peatland management and fire prevention initiatives, and rehabilitating degraded land including mangroves, among others.[297] The JETP, aims to reach 34% renewable energy by 2030, peak power sector emissions by that year, and achieve net-zero emissions from the power sector by 2050.[298] However, one of the main challenges for its implementation is the increasing deployment of off-grid coal power generation that supports the industrial development of some sectors.[299]

To prepare for the global low-carbon transition away from coal, Indonesia has also pushed the development of "green industries", specifically nickel and palm oil, with strong policy support. However, both have large domestic emissions implications. While nickel mining and processing contribute to the global supply chain for batteries, these activities are energy- and carbon-intensive in Indonesia, and are currently planned to be largely powered by coal.[300] Palm oil, other biofuels, and biomass development to support industry are some of the reasons for Indonesia's deforestation and need to be integrated into land management.[301]

International investment and finance are crucial to Indonesia's energy and industrial development, with the U.S., China, Japan, and Korea being key partners.[302] Various financing mechanisms are being explored with these countries, either bilaterally or jointly, providing Indonesia with a broader set of opportunities, especially when challenges arise with a specific channel. Close monitoring of these engagements is essential to shift investments away from carbon-intensive projects and toward clean renewable energy.

2035 PATHWAYS. Considering Indonesia's historical emission trends and climate targets, our analysis presents two potential pathways for Indonesia's 2035 NDC, with the *High Ambition* pathway achieving a 33% reduction in total GHG emissions by 2030 from 2023, and up to 60% reductions by 2035 (Table 3.6.1 and Figure 3.6).

- *A **Delayed Transition*** increasing CO_2 emissions (excluding LULUCF) through 2025, limited reductions until 2030, followed by slower LULUCF reductions and minimal methane mitigation through 2035. In this scenario, total GHG emissions, including LULUCF, decrease by 20% from 2023 levels by 2035, while GHG emissions excluding LULUCF increase by 3% by 2035.

- *A **High Ambition** pathway* with immediate CO_2 reductions (excluding LULUCF) starting after 2025, achieving a net-zero land sink before 2035 (existing target is by 2030), and significant methane reductions through 2035. In this scenario, total GHG emissions decrease by 60% from 2023 levels by 2035, while GHG emissions excluding LULUCF decrease by 23% by 2035.

PRIORITY POLICY ACTIONS. Detailed sectoral strategies should be developed to achieve the economy-wide targets, particularly given the significance and large uncertainties surrounding land and methane emissions in Indonesia. Priority policy actions can deliver meaningful emissions reductions in power generation (both on-grid and captive), methane, and land use through 2035, including:

- **Land:** Extending the forest and peatland moratorium on oil palm and other crops, resolving land use conflicts by enhancing tools of the One Map Policy, and bolstering reforestation and rehabilitation targets through various financing mechanisms.
- **Power sector:** Canceling 2.6 GW of pre-construction captive coal power plants, increasing renewable power generation share to 46% by 2030 and 69% by 2035, reducing coal power (on-grid and captive) emissions by one-third between 2025 peak and 2035.
- **Methane:** Expanding waste collection services from major metropolitan areas to all cities and villages, increasing waste processing capacity by investing in treatment facilities, establishing a national dataset of MSW and wastewater treatment activities for improved emission estimates, and restricting underground coal mine expansion.

Table 3.6.1. Summary of changes in GHG emissions in 2030 and 2035, relative to 2023.

Year/ Scenario	GHG emissions including LULUCF % change from 2023		GHG emissions excluding LULUCF % change from 2023	
	2030	2035	2030	2035
Delayed Transition*	-4%	-20%	+14%	+3%
High Ambition*	-33%	-60%	-8%	-23%

Note: *Based on the scenarios developed using GCAM-6.0-CGS for the NGFS Phase V.

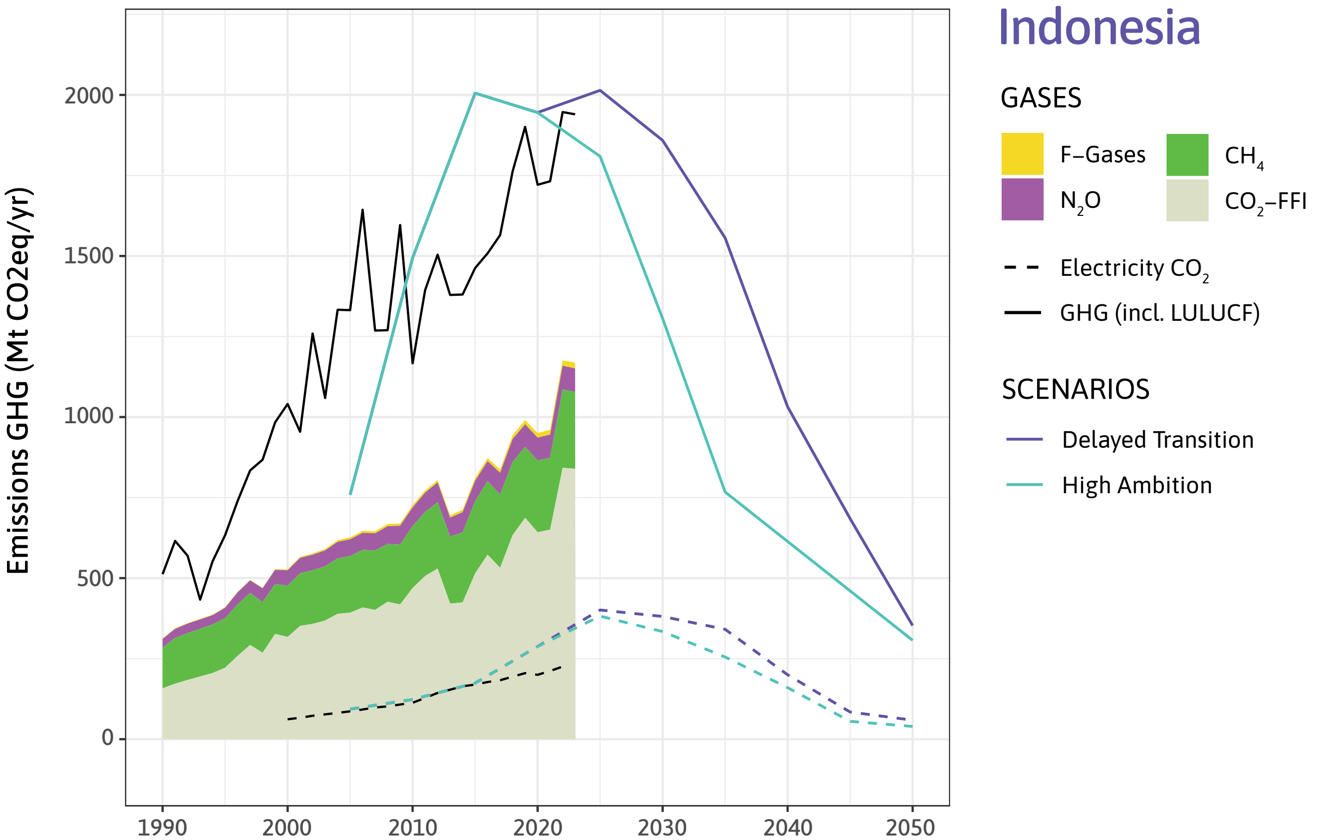

Figure 3.6. Indonesia's GHG including LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[303] (solid black line for total GHG, include LULUCF), EMBER[304] (dashed black line for electricity supply GHG emissions), and CEDS[305] (colored breakdown of historic GHG emissions, without F-Gases). Pathways data includes LULUCF emissions and is based on the scenarios developed using the GCAM IAM for the NGFS Phase V.[306]

Land. LULUCF has been the country's largest emissions source, accounting for over 40% of total GHG emissions in 2022. While forest loss had been decreasing since 2016, it rebounded by 27% in 2023,[307] largely driven by expansion of oil crops (palm oil), followed by growing timber plantations, other large-scale plantations, and small-scale agriculture.[308] Increasing mining activities might become another important driver moving forward. The recent policy target to achieve net-zero land sink by 2030[309] seems very challenging and highly uncertain, even with new enhanced measures. The land-energy linkage from palm oil and other biomass strategies does not appear to be fully assessed, and the NDC planning process is looking for additional expertise and capacity in these areas.

Indonesia's emission reduction potential was assessed using the Existing Measures and Strengthened Measures scenarios from Wijaya, A., et al. (2017).[310] Under the Strengthened Measures scenario, which assumes enhanced efforts in forest moratoriums and peat restoration, LULUCF emissions decrease by 72% by 2030 and by 116% by 2035, leading to negative emissions by 2034. To achieve these targets, extending the forest and peatland moratorium, enhancing transparency in land use licensing through the One Map Policy, and exploring financial incentives for conservation could be beneficial.[311] Additionally, reforestation efforts can be supported by green financing initiatives like the Indonesia Environment Fund, REDD+, and green bonds, alongside promoting carbon offsetting and seedling distribution. Strengthening agricultural value chains with legal frameworks for digital trade and improved market connectivity will also contribute to an enhanced ambition.[312]

Power sector. Increasing domestic coal consumption in power generation at both on-grid and captive plants has driven rapid growth in Indonesia's energy emissions. As of 2022, renewables account for 20% of total on-grid electricity generation, of which solar and wind contributed to less than 1%, while coal accounts for 62% and gas for 17%.[313] The main barriers to renewable deployment include limited policy support, insufficient financing mechanisms, inadequate grid infrastructure, and the dominant presence of a state-owned enterprise in the power sector (PLN). Additionally, rapidly growing captive coal capacity, driven by energy-intensive industry development (particularly nickel mining and processing), has become a major concern.

Table 3.6.2. Key power sector results under the High Ambition scenario.

Year/ Scenario	Solar + Wind % of total elec generation (Installed capacity, GW)	On-grid coal			Captive coal	
		% of total elec generation (total capacity, GW)	Capacity for lower utilization (utilization, %)	Capacity with biomass co-firing	Total elec generation (total capacity, GW)	Capacity with biomass co-firing GW
2023[315,316]	*0.2% (0.5 GW)*	*62% (37 GW)*			*69 TWh (12 GW)*	
2025	1% (3 GW)	70% (39 GW)	8 GW (67%)	5 GW	92 TWh (21 GW)	11 GW
2030	14% (55 GW)	45% (40 GW)	8 GW (40%)	5 GW	90 TWh (20 GW)	13 GW
2035	40% (176 GW)	25% (30 GW)	8 GW (40%)	5 GW	71 TWh (19.5 GW)	12.5 GW

Note: On-grid renewable and coal share based on PLEXO model results. On-grid and captive coal capacity based on GEM 2023 and 2024, adjusted by decarbonization strategies from Borrero et al, 2024. See appendix for additional details.

Under the *High Ambition* scenario, power emissions peak at 382 $MTCO_2$ by 2025, then decrease by 13% by 2030, and by 33% in 2035 from 2025.[314] Specifically, power sector transitions under the *High Ambition* pathway include:

- Renewable share increases from 20% to 46% by 2030 and 69% by 2035.
- New 174 GW of solar capacity (~15 GW/year) are added between 2023 and 2035 through increased financial incentives and streamline regulatory processes.

- 2.6 GW of pre-construction captive coal power plants are canceled.
- 8 GW of on-grid coal power plants reduce their utilization to 40% by 2030 and 2035.
- Biomass co-firing is adopted at eligible captive (13 GW) and on-grid (5 GW) coal plants through 2035.
- 3.8 GW of low-hanging fruit plants with poor technical, economic, and environmental performance that are not eligible for biomass co-firing or flexibility services, plus another 0.7 GW identified in the CIPP for early retirement by 2035 are decommissioned.
- New grid infrastructure developments favor the replacement of captive coal plants, support renewable deployment and integration, and increase interconnectivity across islands.

Methane. According to global inventories, methane was the country's second-largest emissions source in 2022. While methane is covered by the existing NDC, specific policy and mitigation opportunities are largely missing from the current NDC planning process. Data uncertainty is extremely high.[317,318] Officially reported data may underestimate Indonesia's methane emissions.

Our *High Ambition* scenario includes a 25% methane reduction by 2030 from 2020 and a 33% reduction by 2035. Key strategies for achieving meaningful emissions reductions include strengthening the Monitoring, Reporting, and Verification (MRV) capacity of methane in coal mines, and restricting underground coal mine expansion.[319] Additionally, methane emissions in the waste sector can be reduced by expanding municipal waste collection services to all cities, investing in treatment facilities, and implementing community-based waste segregation and recycling programs. Building a comprehensive dataset, particularly at the district level, is essential to enhance the accuracy of emission estimates from the waste sector. Improved waste management also has strong co-benefits on poverty reduction, public health, and rural development. There is a large potential to engage and mobilize local governments and actors to support some of these actions in targeted geographies.

SUBNATIONAL ACTION

Indonesia, a quasi-federal state, has moved from centralization to decentralization and now leans toward re-centralization. The central government retains authority to override local laws and manage fiscal redistribution by population and poverty levels, yet the decentralized governance era of the 2000s and 2010s left a strong legacy of local political empowerment. Indonesia's climate governance is multi-level, with sector-specific authority. Forest management is centralized, while agricultural land control is local, often resulting in forest conversion and deforestation. Although decentralization fostered subnational initiatives, Indonesia still faces cross-level coordination challenges to balance land control across sectors.

Indonesia's climate governance structure, coupled with existing barriers in renewable energy deployment, land use, and solid waste management, highlights a need for stronger subnational policy support. Enhancing regional and local initiatives could significantly boost Indonesia's potential in these sectors. Key stakeholders, such as the state-owned monopolistic power company PLN, the palm oil industry, and major metropolitan and tourist areas, play essential roles in advancing these efforts.

Power sector. According to PLN's 2021-2030 Electricity Supply Business Plan (RUPTL), the company aims for renewables to account for 51.6% of its planned 40,575 MW power generation capacity by 2030, with an increased role for local independent power producers (IPPs).[320] Despite PLN's ambition, there is a lack of response to coal abatement at the local level in coal-mining regions. For example, South Kalimantan aims to increase the share of RE up to 24.7% by 2050, but coal is still to be prevalent in 2050 in the province.[321] Ensuring that RE targeting is more responsive to the local population may accelerate coal plants retirement—for example, Bali, which is not a coal-mining province, relied on participatory instruments in defining its RE targets, which resulted in adopting RE goals more ambitious than the national one.[322] De-monopolizing the power generation sector at the local level, providing additional grants to provinces and local districts for coal plant closures and renewable deployment, especially in East and South Kalimantan, Jambi, and South Sumatra, and relying on participatory approaches to developing local RE strategies could allow for accelerated RE deployment in Indonesia.

Land. Smallholders in Indonesia will be required to comply with the Indonesian Sustainable Palm Oil (ISPO) certification (introduced in 2011 to ensure sustainable and internationally compatible palm oil production) starting in November 2025, alongside companies and state-owned plantations. However, challenges such as land tenure issues, complex application processes, and high certification costs hinder smallholder participation.[323] Educating policymakers and farmers, enhancing collaboration with local stakeholders, and providing financial support could improve adoption, particularly in key palm oil-producing regions like Riau, North Sumatra, and West Kalimantan.[324,325,236]

Waste. Indonesia faces low recycling rates and relies heavily on informal waste management systems, including city or village waste pickers who lack adequate income and organization to facilitate recycling. Consequently, they often transport solid waste from residential areas to trash islands on the metropolitan outskirts, such as the Bantar Gebang trash island near Jakarta.[327] This reliance on informal networks stems from insufficient funding for waste management. Indonesian city governments allocate an average of only 2.5% of their municipal budgets to solid waste management, whereas a more effective allocation would be 5% or more.[328]

To address the problem of trash islands, President Joko Widodo signed a "Presidential Regulation No. 35" to accelerate the deployment of waste-to-energy facilities in 12 major cities including Jakarta, Tangerang, Bekasi, and Bandung, with the state-owned PLN being the sole government entity authorized to purchase power generated from these facilities.[329] Additionally, cities like Jakarta and Surabaya are taking steps to formalize solid waste management, streamline recycling efforts, and address the garbage islands by investing in municipal waste recovery facilities, introducing service-free trash collection, installing garbage bins, and banning single-use plastics.[330,331]

Enhancing these informal waste management systems could involve implementing policies that promote formalization. Potential formalization strategies range from building municipal trash collection infrastructure and ensuring the affordability of municipal services— which would help structure local waste management and improve data collection—to investing in waste-to-energy and other waste recovery facilities that could mitigate the growth of trash islands and boost recycling rates.

3.7 Japan

Summary

- Japan's overall GHG emissions peaked in 2013 and have declined steadily since then, reaching a 24% reduction in 2023 from the peak level; power generation remains the country's largest emissions source with 36% in 2022.
- Meeting Japan's 2030 NDC target of a 46% (or more) reduction from 2013 levels requires increasing the average 2013-2023 annual reduction rate of 2% to 6.5% through 2030. Japan also has a net-zero GHG target by 2050.
- As the third largest global economy and the only G7 country in Asia, Japan's energy system is heavily fossil-dependent and import-reliant; it has the lowest non-fossil share in power generation among all G7 countries and is the only one that built new coal power projects in recent years.
- Japan has laid out main transition strategies in the Green Transformation (GX) Policy and the Strategic Energy Plan, which aim to promote strong economic growth and energy security while reducing emissions, by advancing new technologies of hydrogen (plus ammonia), offshore wind, and carbon capture and storage for both domestic and global deployment.
- However, the deployment of cost-competitive technologies is delayed; solar and wind buildout has slowed down in recent years with the gradual restart and new builds of nuclear reactors and the plan to extend fossil plants' lifetime through ammonia co-firing; domestic passenger BEV adoption rates are extremely low compared to other advanced economies, and Japan's world-leading automobile companies are losing market share in EVs.
- The 2035 target for Japan under our *High Ambition* pathway implies a 64% reduction in total GHG emissions from the 2013 level.
- This is achieved by phasing out coal power generation, accelerating off-shore wind and solar deployment to 23 GW per year, decarbonizing the export-oriented industrial sector through electrification and coal phasedown, and increasing domestic EV production and deployment.
- Japan has strong economic and political influence in the Asia Pacific region and can impact other developing countries' transitions through its overseas investment.
- Japan's climate policy-making is highly centralized, led by national ministries with inputs from major industry stakeholders, though decentralization reforms have granted local entities limited administrative powers to pursue regionally aligned climate strategies, with power and transportation sectors showing potential to have local impacts.

EMISSIONS PROFILE. Japan's GHG emissions excluding LULUCF decreased by 24% from 2013 to 2023 Despite the resurgence of fossil fuels after Fukushima in 2011, growing renewable energy and declining energy demand have driven down emissions, along with the gradual restart of nuclear power in recent years. As of 2022, power sector emissions accounted for 36% of GHG emissions excluding LULUCF, followed by industry (16%) and transport (15%). Land use change CO_2 emissions are relatively a minor contributor at less than 2% of total GHG emissions.[332]

2030 NDC. Japan has committed to reduce its total GHG emissions by 46% or more (50%) from 2013 to 2030 and reach net-zero GHG by 2050. These targets cover all greenhouse gases from all sectors; however the 2013 base year does not include LULUCF emissions. Meeting the current 2030 NDC target of 46% reduction from 2013 requires Japan to more than triple the average emissions reduction rate from ~2%/year between 2013-2022 to 6.5% for 2023-2030.

NATIONAL STRATEGIES. As the third largest global economy and the only G7 country in Asia, Japan's energy system is heavily fossil dependent and relies on imports. It has the lowest non-fossil share in power generation among all G7 countries and is the only one actively developing new coal power projects in recent years.[333] Japan's solar development slowed down after 2020, and there is untapped off-shore wind potential.

Key policies highlight two main strategies for achieving Japan's climate goals while prioritizing energy security and industrial development: improving economic efficiency and extending the lifetime of fossil fuel plants through ammonia co-firing, driven by the growth of a new hydrogen economy. Japan's Green Transformation (GX) Decarbonization Power Supply Bill and the subsequent GX Basic Policy aim to transition the country from a fossil fuel-dependent economy to one centered on clean energy.[334] These policies focus on enhancing energy security and supporting Japan's NDC targets by transitioning fuel and feedstocks, expanding affordable renewable energy, increasing the use of nuclear power, and establishing competitive electricity and gas markets.

The GX plan also emphasizes the development of hydrogen and ammonia technologies, creating supply chains, and fostering international partnerships. However, the plan places limited emphasis on scaling up renewables and phasing out coal and gas. Instead, it prioritizes the construction and reactivation of nuclear power plants, along with the development and deployment of gray and blue hydrogen and ammonia.[335,336]

Industry and business actors are pivotal in advancing Japan's energy transition. However, Japan's leading global automobile companies are losing ground in the rapidly growing EV market, and domestic adoption of battery electric vehicles (BEVs) remains extremely low—only 2% of new sales in 2023 (Figure S2). The domestic automotive industry's focus on hydrogen vehicles, rather than BEVs, has contributed significantly to the slow uptake of electric vehicles.[337] Acknowledging the risks of this strategy sooner could accelerate progress in the sector and better position Japan to compete in the global transition to cleaner technologies.

2035 PATHWAYS. Our modeling analysis shows that the 2035 target under the *High Ambition* pathway for Japan implies a 64% reduction from 2013 levels (Table 3.7.1 and Figure 3.7).

- *A* ***Delayed Transition*** where total GHG emissions and power sector emissions decline only slightly through 2030 and more quickly after 2030 toward net-zero 2050. In this scenario, emissions decrease by 29% by 2030 and 46% by 2035 from 2013 levels.

- A ***High Ambition*** *pathway* where total GHG emissions decline more rapidly after 2025 toward net-zero 2050, decreasing by 45% from 2013 levels to 2030, and by 64% in 2035.

- In comparison, the linear pathway from the 2030 NDC to net-zero (NDC to Net-Zero Trend) suggests a 59% reduction in total GHG emissions by 2035; continuing the current reduction trend to meet the 2030 NDC target (Today to NDC Trend) would lead to a 64% reduction by 2035.

Table 3.7.1. Summary of GHG emissions reductions (including LULUCF) in 2030 and 2035, relative to NDC base year (2013).

Scenario Name		2030 emissions % change from 2013	2035 emissions % change from 2013
Official NDC Target		-46%	TBD
Delayed Transition*		-29%	-46%
High Ambition	***GCAM-6.0-CGS****	-45%	-64%
	NDC to Net-Zero Trend**	Meets NDC by design 46%	-59%
	Today to NDC Trend***		-64%

Notes: *Based on the scenarios developed using GCAM-6.0-CGS for the NGFS Phase V; **assume linear reduction from the 2030 NDC target to net-zero 2050; ***assume continuing the reduction trend between 2022 emissions level to 2030 NDC target for the post-2030 period.

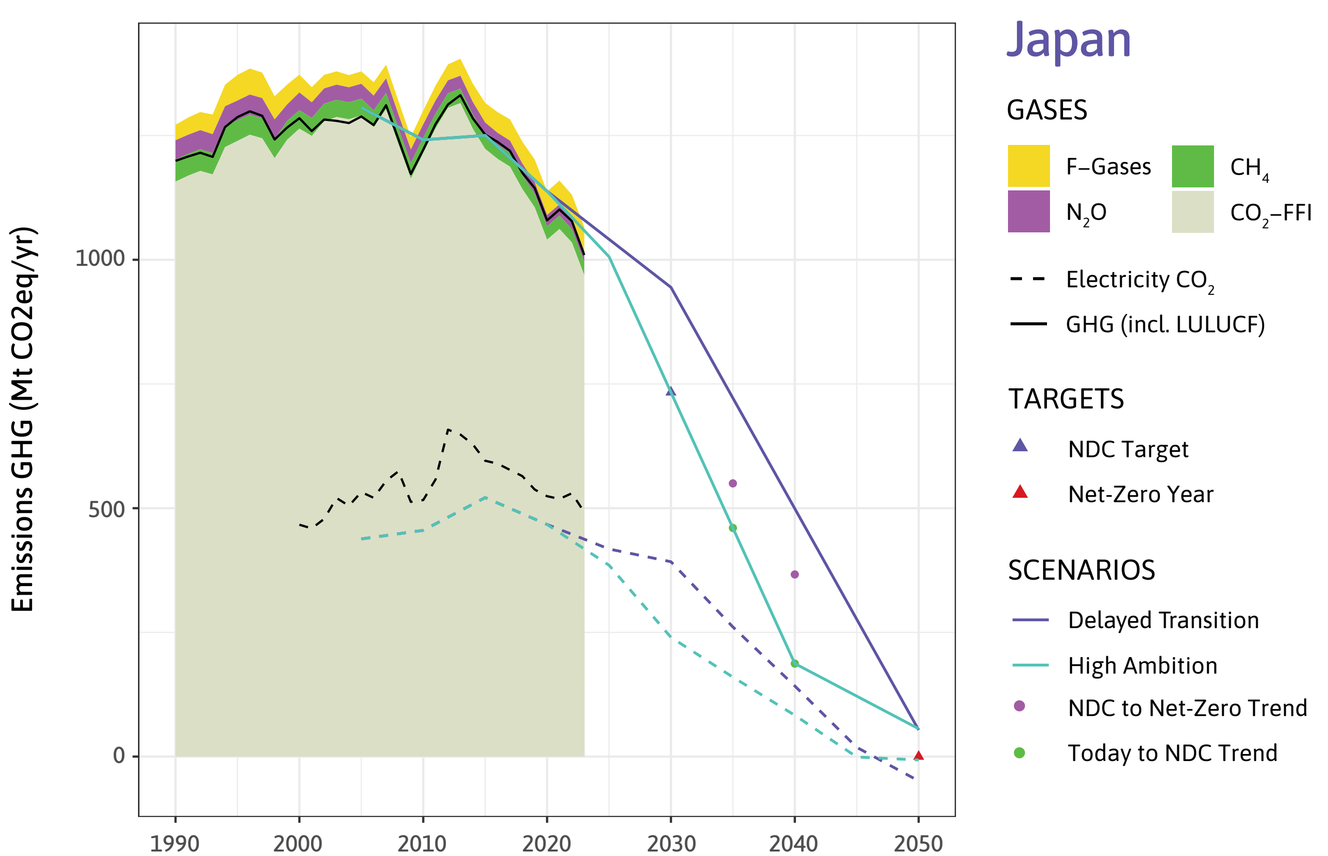

Figure 3.7. (above) Japan's GHG including LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[338] (solid black line for total GHG, include LULUCF), EMBER[339] (dashed black line for electricity supply GHG emissions), and CEDS[340] (colored breakdown of historic GHG emissions, without F-Gases). Colored triangles mark the official 2030 NDC and Net-zero targets. Colored dots mark possible values for 2035 and 2040, based on extrapolation of the 2022-2030 linear trajectory ("Today to NDC Trend"), interpolation between the 2030 and net-zero 2050 targets ("NDC to Net-Zero Trend"). Pathways data includes LULUCF emissions and is based on the scenarios developed using the GCAM IAM for the NGFS Phase V.[341]

PRIORITY POLICY ACTIONS. To achieve the *High Ambition* pathway, policy actions in Japan can focus on the following areas to deliver meaningful emissions reductions through 2035, including:

- **Power sector:** Expanding renewable generation, especially off-shore wind and solar, contributing to at least 50% of total generation by 2030 and 70% by 2035; canceling the 0.5 GW new coal power project at pre-construction stage; and phasing out coal before 2035.
- **Industry:** Reducing coal use in industry to less than 25% of total energy use in 2030; deploying electric arc furnaces in iron and steel; working with major industry actors to develop ambitious decarbonization plans.
- **Hydrogen:** Revisit the over-ambitious deployment plan for hydrogen and ammonia, assessing economic viability and environmental outcomes.
- **Transportation:** Increasing domestic battery EV production and deployment in addition to hybrid and fuel cell EV development; expanding charging infrastructure to facilitate EV adoption.

Power sector. In 2023, coal and gas accounted for over 32% and 33% of Japan's total electricity generation, respectively, while renewables contributed 24%, with solar and wind making up half of that total (12%).[342] Remaining renewable generation comes from biomass and hydropower.[343] Decarbonizing the electricity sector is critical, as it was the largest source of emissions in 2022.[344] Japan is one of the few OECD countries still increasing its coal power capacity. From 2020 to 2023, a total of 9.3 GW new coal power capacity was added, and the current pipeline includes 0.5 GW of coal power in pre-construction stages.[345] On the other hand, 12 GW of nuclear reactors have restarted operations and an additional 3 GW are under construction.[346] Floating offshore wind is particularly important for Japan to achieve its renewable target, given the limited availability of shallow seabed offshore.[347] However, by the end of 2023, only 0.15 GW offshore wind was operational in the country.[348]

Under the *High Ambition* pathway, emissions from electricity generation decrease 65% by 2035, compared to 2013 levels. Based on accelerated targets from recent trends, we look at an *Accelerated RE* scenario for the power sector that considered coal phaseout before 2035, accelerated gas phasedown, and accelerated RE deployment, including ambitious offshore wind installation.

Specifically, power sector transitions under the *High Ambition* and an *Accelerated RE* scenario include:

- Total renewable generation reaches 46% of total generation by 2030 (compared to the policy target of 36%-38%), and 54% by 2035. Under an *Accelerated RE* scenario, total renewable generation reaches 55% of total generation by 2030 and 75% by 2035.
- Average solar and wind buildout rate is about 23 GW per year, including an average of 6 GW per year of offshore wind.
- Share of coal generation decreases from 32% to 6% by 2030, and is phased out before 2035, while the share of gas generation declines from 33% in 2023 to 8% by 2035 and oil power generation is phased out by 2035.
- Reliance on technologies with uncertain emissions reduction potential, including ammonia and hydrogen, is limited.

Table 3.7.2. Key power sector metrics across the scenarios.

Year/ Scenario	Solar + Wind % of total elec generation (Installed capacity, GW)		Coal % of total elec generation (Installed capacity, GW*)		Gas % of total elec generation (Installed capacity, GW*)	
	High Ambition	***Accelerated RE***	***High Ambition***	***Accelerated RE***	***High Ambition***	***Accelerated RE***
2023	*12% (92 GW)*	*12% (92 GW)*	*32% (55 GW)*	*32% (55 GW)*	*33% (85 GW)*	*33% (85 GW)*
2025	20% (107 GW)	23% (145 GW)	23% (53 GW)	20% (47 GW)	33% (97 GW)	33% (97 GW)
2030	34% (180 GW)	43% (268 GW)	9% (21 GW)	6% (13 GW)	28% (81 GW)	25% (72 GW)
2035	44% (237 GW)	65% (380 GW)	3% (8 GW)	0% (0 GW)	21% (61 GW)	8% (23 GW)

Note: *Capacity values of coal and gas plants denote the total capacity with constant operating hours at today's level in the respective categories. The same emissions reductions can also be achieved through reduced utilization of coal and gas plants to support the integration of increasing penetration of solar and wind, which results in higher capacity.

Key policy actions to achieve a *High Ambition* and an *Accelerated RE* scenarios include halting the expansion of coal and nuclear capacity, as well as addressing barriers to solar and offshore wind deployment, such as complex siting and permitting processes.[349,350,351] Facilitating local and international supply chain partnerships, providing clear investment regulation guidelines, arranging additional R&D and workforce training, and collaborating with local communities to highlight the economic and social benefits of solar development can also help mitigate challenges related to supply chains, workforce, and land competition.[352,353]

Industry. The industry sector contributes about 16% of overall CO_2 emissions in 2022, with chemicals and iron and steel being the largest contributors. The main concern of the Japanese industries is that a rapid shift to decarbonization technologies can significantly increase the cost of production, which will consequently impede Japan's already slow economic growth and decrease its economic competitiveness.[354] Under our *High Ambition* scenario, industry emissions are reduced by 37% by 2035 compared to 2022 levels, largely driven by reductions in the steel industry, mainly via coal phaseout coupled with electrification and demand reductions.

To achieve the *High Ambition* pathway, Japan could signal stronger decarbonization intent and help direct near term investments in industry by enhancing the proposed carbon pricing regime and going beyond the voluntary participation in the envisaged emissions trading system (planned to be introduced in 2028 and fully rolled out in 2033).[355] Additionally, it is important to work with industrial actors to develop more ambitious decarbonization plans.[356,357,358] Existing plans have limited deployment of key technologies like electric arc furnaces, which are needed to meet the steel sector's tentative target of reducing emissions by 30% by 2030 compared to 2013.[359] For iron, expanding use of direct reduced iron (DRI) technology, which is limited in Japan, may help to reduce emissions in this sector. Additionally, encouraging earlier retirement can help pave the way for new technologies, as only 11% of currently operating coal-based blast furnaces are over retirement age.

Hydrogen. The 2023 Basic Hydrogen Plan sets a new target of 12 million tons of hydrogen per year by 2040, discusses planned investment in hydrogen supply chains and infrastructure, and outlines Japan's efforts to enhance relations with potential hydrogen resources.[360] Half of the hydrogen projects in Southeast Asia are sponsored by Japan, and Japan is interested in building a fleet for transporting liquid hydrogen over long distances.[361] Japan aims to use hydrogen for decarbonizing the power sector through co-firing and single-fired hydrogen/ammonia power generation, as well as in fuel cells development for export,[362] and direct use in steel and chemical production.[363]

However, analyses have shown the lack of economic competitiveness of hydrogen in many applications compared to the alternatives, except for in a few targeted applications in specific hard-to-abate sectors (i.e. freight transport, industrial feedstocks, etc.).[364,365] Additionally, expanding hydrogen use without expanding renewable power generation could lead to higher emissions.[366] The Basic Hydrogen Plan mentions that a carbon intensity target for low-carbon hydrogen will be set, but it does not yet include specific renewable energy or emissions targets for the production of low-carbon hydrogen and mentions using carbon capture and utilization and carbon recycling initiatives for producing hydrogen,[367] which may have associated emissions. As for ammonia, research suggests that ammonia combustion may not reduce GHG emissions due to its N_2O emissions and/or climatic impacts of H_2 slippage.[368]

Transportation. Japan is currently the third largest producer of motor vehicles, with around ⅔ of Japanese vehicles produced overseas.[369,370] However, current BEV shares in car sales in Japan are very low, only comprising around 2% of total new car sales in 2023 (Figure S2).

To achieve decarbonization in the transportation sector, Japan can shift developmental focus from hybrid and fuel-cell EVs to BEVs.[371] Japan's automotive companies targets for ZEVs include both battery and fuel cell EVs, and goals vary significantly across manufacturers.[372] Some overseas branches have expressed concerns about phase-out policies for ICE-powered vehicles in certain countries.[373] Expanding Japan's EV charging infrastructure could also support this shift—currently, the country has 30,000 charging connectors, or about one for every 4,000 EVs, which is less than a sixth of the density in the U.S. or Europe.[374] For harder-to-decarbonize sectors, such as freight, there may be opportunities to expand fuel-cell EV applications as an emissions reduction approach.

SUBNATIONAL ACTION

Japan is a unitary state with some minimum decentralization at the local level. Its climate policy-making process follows a top-down approach where decision-making authority is concentrated within the central government. Japan's multilevel governance structure emphasizes cross-sectional or intra-societal efforts led by national ministries, along with industry and academic representatives, with a secondary priority of communication with local governments and communities. While decentralization reforms in 1999 and from 2011 to 2014 transferred some administrative powers to local governments, substantial climate regulation authority still resides at the national level.

Subnational entities in Japan hold primarily administrative powers within the country's climate governance system, which provides an opportunity for tailoring the implementation of centrally determined overarching policies towards specific local needs. Regarding policy-making, the obligatory submission of local climate action plans is one of the few ways for local governments to design their own climate policies from the ground up.[375] Japan's subnational entities hold significant potential for advancing coal plant phase-outs and expanding EV charging infrastructure since local administrations possess enough administrative authority over infrastructure matters, a power initially granted by the central government to address local infrastructure challenges related to environmental adaptation and protection.[376]

Power sector. Japan's subnational action in the power sector can be divided into two main components: coal and renewable energy. For coal, Japan's current model emphasizes a partnership between the central government and fossil-fuel companies. The coal phase-out strategy primarily focuses on innovative coal technologies and energy efficiency, rather than an outright phase-out. The Tohoku region (North - North East) heavily relies on coal, which is especially topical for Akita, Aomori, Hokkaido, Fukushima, Iwate, and Miyagi prefectures due to the high energy demand for heating there.[377] JERA, the largest power generator owned by energy giants Tokyo Electric Power Company (TEPCO) and Chubu Electric Power, has worked on launching new coal-fired power plants in Taketoyo (Aichi prefecture, 1.07 GW), Kobe (Hyogo prefecture, 1.4 GW), Yokosuka (Kanagawa prefecture, 650 MW), etc., which is around 17 towns in total.[378,379,380] The new coal-fired power plants are expected to rely on coal innovative technologies and to have higher energy efficiency rates.[381,382] Meanwhile, Japan promised to shut down more than 100 old and inefficient coal-fired power plants by 2030 to phase out unabated coal.[383,384] The second component focuses on building partnerships at the subnational level between local administrations and renewable energy companies to further RE deployment. Initiatives such as public information campaigns and prioritizing RE in local contracts can build public trust in renewable energy and create a local market for small RE companies. For example, To push local energy provider Kansai Electric Power Company towards accelerated decarbonization, Kyoto City (Kansai prefecture) decided to require architects to explain the benefits of renewable energy to homeowners and potential buyers.[385] Similarly, the city of Yokohama (Kanagawa prefecture) launched energy consultancy services for its citizens to promote the benefits of RE.[386]

Transportation. Japan faces a domestic EV infrastructure barrier to widespread EV adoption, compounded by resistance from the strong domestic automotive sector. Japan's average EV charger capacity is around 50 kW, far below the 250-350 kW capacity needed.[387,388] For Japanese consumers, used to high-quality and cheap ICE vehicles, it is essential to have local reliable EV charging infrastructure to build the initial trust in EVs.[389] To support this transition, Tokyo authorities set a goal of 100% new EVs sales by 2030, and a Tokyo-based company Terra Motors decided to build more than 1,000 rapid chargers in the city by 2026, but the company was able to build only two rapid EV chargers in the first half of 2024 due to complicated permission procedures for high-voltage power access.[390,391] Tokyo also plans to build additional 150 hydrogen stations and to use promotion campaigns based on public-private partnerships.[392] Kashiwa-no-ha (Chiba prefecture) is testing wireless charging technology to address the issue of limited urban space and the need for speed EV charging infrastructure.[393] Given the primary administrative power of local governments in the road infrastructure and that the classic fiscal incentives such as EV subsidies and tax exemptions can be applied only by the central government, there is a significant potential for subnational action in building effective and accessible charging infrastructure, which could be done through setting up public rapid EV chargers, experimental policy-making, and public informational campaigns on EVs.[394]

3.8 Mexico

Summary

- Mexico's total GHG emissions increased by 15% from 2010 to 2023, mostly driven by increasing methane emissions in waste and agriculture sectors and rapid gas expansion in power generation.
- Mexico has committed to reducing total GHG emissions by 35% unconditionally or 40% conditionally from the business-as-usual (BAU) by 2030, which estimates to be a 19% reduction from 2023 with a 3% annual reduction rate unconditionally, or a 25% reduction with a 4% annual rate conditionally.
- Mexico is also one of the few major economies that has not committed to a net-zero emissions goal.
- Mexico's recent policy strategy to strengthen the oil and gas sector has restricted the deployment of renewables, increased reliance on gas imports, and led to a rise in the production of refined fuels.
- Opportunities are emerging with the new president to set ambitious renewable energy targets and advance the Emissions Trading System to help reduce industry emissions.
- The *High Ambition* pathway for Mexico includes an immediate emissions peak before 2025 and a 39% reduction in GHG emissions (excluding LULUCF) by 2035 from 2023, compared to a 14% reduction under *Delayed Transition*.
- Accelerated actions include tripling wind and solar deployment to phase out coal and limit gas power expansion, targeted abatement in methane waste and oil and gas methane, advancing the emissions trading scheme for key industries, and incentivizing EV adoption in transport.
- Given the significant share of non-CO_2 emissions, particularly from hard-to-abate sources like enteric fermentation, achieving net-zero GHG emissions in Mexico will likely require deeper CO_2 reductions, as well as advancing innovations to address agricultural methane and nitrous oxide (N_2O) emissions.
- As the subnational governments in Mexico practice relative autonomy in the development and implementation of climate policies, while still subordinate to the priorities on the federal level, they show potential to lead local emissions reductions in power, waste, and transportation by implementing local initiatives like solid waste plans, renewable energy auctions, and tax relief programs for EVs.

EMISSIONS PROFILE. Mexico's total GHG emissions increased by 15% from 2010 to 2023, mostly driven by increasing methane emissions and emissions from the power sector.[395,396] Emissions have shown a consistent upward trend, with a brief dip during the COVID-19 pandemic in 2020, followed by a quick rebound. In 2022, methane emissions made up 19% of total GHG emissions excluding LULUCF, followed by the power sector at 18%, and the industry and transportation sectors at 14% each.[397] Land-use change emissions in Mexico are likely low and potentially negative, based on data from the country's latest Biennial Update Report (BUR) and Global Carbon Budget models.[398,399]

2030 NDC. Mexico has committed to reduce total GHG emissions by 35% unconditionally or 40% conditionally from BAU in 2030.[400] The NDC unconditional and conditional targets cover all GHG emissions from all sectors but there is ambiguity regarding how LULUCF emissions are counted. While only positive emissions from LULUCF are included in the 2030 BAU, it is unclear if land sinks will be accounted for in meeting the 2030 NDC target. To achieve Mexico's current NDC unconditional target, the country needs to reduce total emissions excluding LULUCF by 19% from 2022 to 2030, at an average emissions reduction rate of 3% annually. To reach the conditional target, emissions need to decrease by 25% by 2030, at an annual reduction rate of 4%.

NATIONAL STRATEGIES. Mexico is one of the few major economies that has not committed to any form of net-zero emissions target. In recent years, Mexico's policies have focused on strengthening the oil and gas sector by maintaining robust state-owned companies, given their significant contribution to public revenue and GDP. This focus has limited the role of private companies in deploying renewable power plants, increased dependency on gas imports, and led to a rise in the production of refined fuels.

First, the deployment of solar and wind capacity in Mexico has slowed significantly in recent years, dropping from over 4.5 GW in 2019 to only 1.4-1.6 GW in 2022 and 2023.[401] This decline is primarily attributed to government efforts to prioritize the dispatch of thermal power plants operated by the state-owned utility, Comisión Federal de Electricidad (CFE), over renewable power plants owned by private companies through a specific legislation.[402] Although the Supreme Court ruled against this law, lingering distrust in government policies continues to impact the transition of the power sector in the country.[403]

Second, Mexico's energy system is heavily dependent on fossil fuels and reliant on imports, with 54% of the gas consumed being imported—primarily through pipelines from the U.S.—while 46% is produced domestically.[404] Over the past decade, gas imports have steadily increased due to the abundant supply and low prices in the U.S., as well as growing demand from the power sector and limited domestic gas production in Mexico.[405,406] Gas power plants generate 58% of the country's total electricity and account for 60% of its total gas demand.[407,408] Transitioning away from imported fossil fuels to renewable energy in the power sector could enhance the country's energy security while reducing emissions from this sector.

Third, Mexico's energy security strategy has focused on increasing the production of refined fuels. Since 2019, the country has retrofitted six refineries, purchased an additional refinery in Texas, and is constructing a new refinery in Tabasco (Dos Bocas) through Pemex, the national oil company.[409] Although Pemex contributed 62% of public revenue and GDP from the oil and gas sector in 2023,[410] the company is facing financial difficulties and is regarded as the most indebted oil company in the world.[411] In addition to supporting investments in new refinery infrastructure, Pemex has significant financial commitments to its employees and relies on government support to continue its operations.[412] These circumstances could create opportunities to shift the company's interests toward favoring the energy transition.

Although there is uncertainty about how the government of President Claudia Sheinbaum will approach climate ambition, new opportunities arise with her leadership. Her emphasis on transitioning to renewable energy in the power sector during her campaign and her initial speeches as president suggest that solutions focused on energy security and active participation by state-owned companies in the energy transition could be promising.[413,414] Other key sectoral targets include achieving 39.9% non-fossil fuel generation by 2033[415], reaching 100% of light-duty and heavy-duty new sales of zero-emission vehicles by 2040,[416] reducing methane emissions by 30% by 2030,[417] and decreasing emissions from oil and gas production by 40-45% from 2013 levels by 2025.[418]

2035 PATHWAYS. Our modeling analysis shows that the 2035 target for Mexico under the *High Ambition* pathway implies a 39% reduction in GHG emissions excluding LULUCF, from 2023 levels. We compare a few scenarios (Table 3.8.1 and Figure 3.8), including:

- *A **Delayed Transition*** where GHG emissions remain stable through 2030, falling short of the 2030 NDC targets and delaying net-zero CO_2 emissions until after 2070, with only a 14% reduction achieved by 2035.

- *A **High Ambition** pathway* where GHG emissions peak before 2025, decline immediately to deliver the conditional NDC target by 2030, and are on track for a net-zero GHG target around 2060. In this scenario, GHG emissions, decrease by 28% from 2023 levels by 2030 and by 39% by 2035.

Table 3.8.1. Summary of GHG emissions reductions (excluding LULUCF) in 2030 and 2035, relative to 2023.

Scenario Name	2030 emissions % change from 2023	2035 emissions % change from 2023
Official NDC target	-35% unconditionally or -40% conditionally from 2030 BAU	n/a
Delayed Transition*	-2%	-14%
High Ambition*	-28%	-39%

Notes: *Based on the scenarios developed using GCAM-6.0-CGS for the NGFS Phase V. **assume continuing the reduction trend between 2022 emissions level to 2030 NDC target for the post-2030 period.

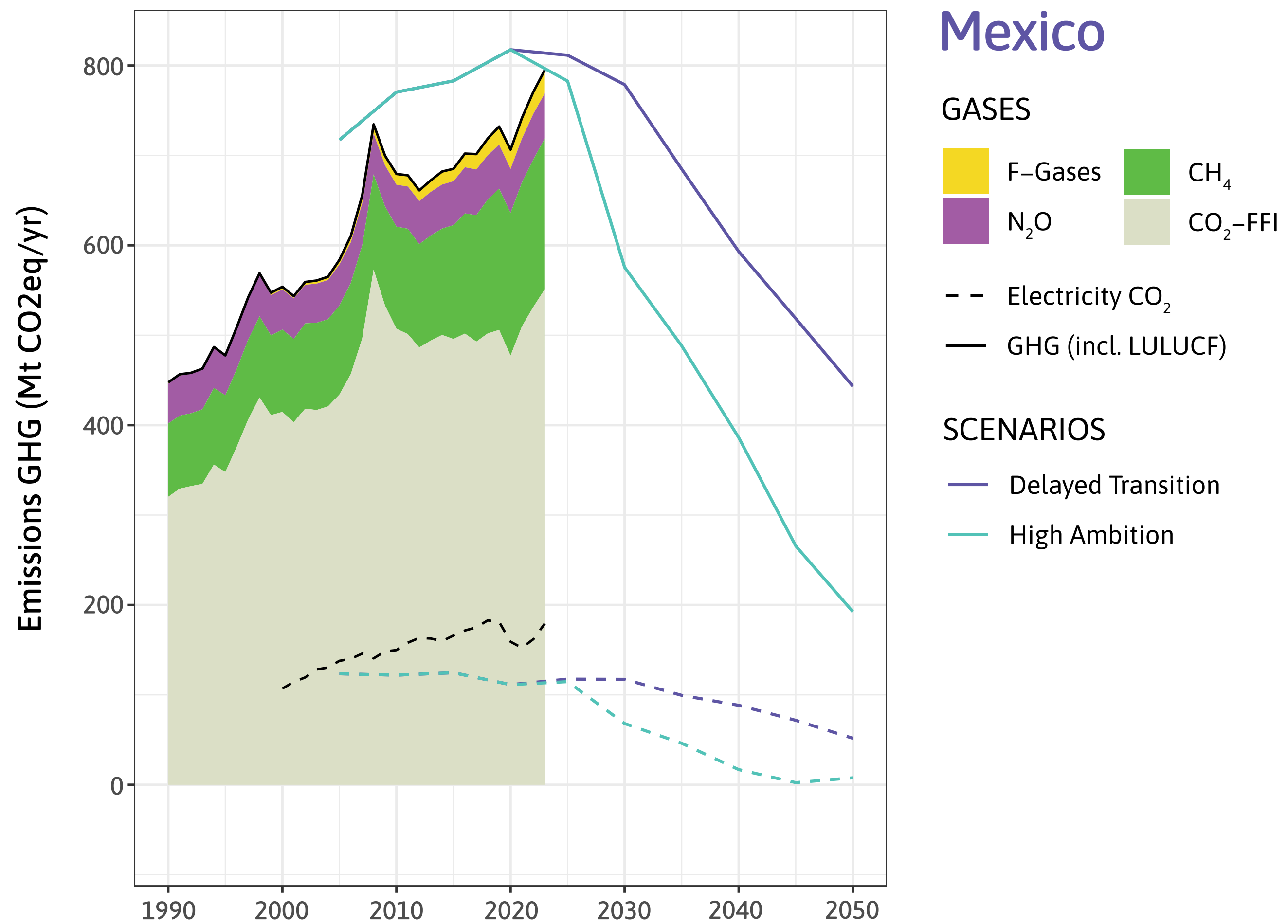

Figure 3.8. Mexico's GHG excluding LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[419] (dashed black line for total GHG, excluding LULUCF), EMBER[420] (dotted black line for electricity supply emissions), and CEDS[421] (colored breakdown of historic GHG emissions, without F-Gases). Pathways data excludes LULUCF emissions due to large discrepancy between historical and modeled values and is based on the NGFS Phase V[422] scenarios developed using GCAM. N_2O emissions are likely overestimated, as the data source differs significantly from historical values reported in national inventories.

PRIORITY POLICY ACTIONS. To achieve the *High Ambition* pathway, policy actions in Mexico can focus on the following areas to deliver meaningful emissions reductions through 2035, including:

- **Net-Zero Target:** Developing long-term climate goals with a net-zero emissions target.
- **Power sector:** Accelerating annual solar and wind deployment to three times the 2019 levels, aiming for 66% and 82% of non-fossil generation by 2030 and 2035, respectively. Phasing out unabated coal and oil power generation by 2030 and canceling 5 GW of pre-construction gas power plants.
- **Methane and other non-CO_2s:** Advancing solid waste management, adopting sustainable agricultural practices, and retrofitting oil and gas infrastructure to reduce methane emissions. Evaluating current subsidies for fertilizer use and production, and implementing catalytic processes in the fertilizer industry to reduce N_2O emissions.

- **Industry:** Accelerating electrification and promoting energy efficiency by providing technical and financial resources to manufacturing facilities. Implementing the Emission Trading System with more ambitious decarbonization goals and extending the carbon tax to include gas.
- **Transportation:** Incentivizing EV adoption through subsidies for vehicles and charging device installations, and expanding EV charging infrastructure throughout the country.

Power sector. As one of the largest sources of emissions in Mexico, with a significant share of fossil fuels, the electricity sector presents a substantial opportunity for low-cost decarbonization in the coming decade. As of 2023, coal and gas contributed 10% and 58%, respectively, to total electricity generation, while other fossil fuels accounted for 9% and nuclear for 3%. Renewables made up 20% of the total, with solar and wind contributing 12%.[423] Power sector emissions have increased by 8% since 2013,[424] driven by a rise in gas generation. Over the last decade, Mexico has deployed 16 GW of gas capacity, with an additional 7 GW of gas power currently under construction and 5 GW in pre-construction stages.[425] Almost half of the gas fleet in Mexico has been in operation for over 20 years, while 34% has been operating for less than 10 years.[426]

Under the *High Ambition* scenario, emissions from electricity generation decrease by 67% between 2022 and 2035, with accelerated solar and wind deployment, cancellation of new gas projects, and a coal phaseout by 2030 (Table 3.8.2). Specifically, power sector transitions under the *High Ambition* pathway include:

- Share of renewable energy generation (solar and wind) increases from 12% in 2023 to 53% by 2030 and 70% by 2035.
- Solar and wind installation triples from the highest annual rate in 2019 to 14 GW/year through 2035.
- Coal and oil generation phase out by 2030.
- Share of gas generation declines from 58% in 2023 to 15% by 2035, with no new gas expansion, by canceling 5 GW of pre-construction projects.

Table 3.8.2. Key power sector metrics across scenarios.

Year/ Scenario	Solar + Wind % of total elec generation (Installed capacity, GW)		Coal % of total elec generation (Installed capacity, GW*)		Gas % of total elec generation (Installed capacity, GW*)	
	Delayed Transition	***High Ambition***	***Delayed Transition***	***High Ambition***	***Delayed Transition***	***High Ambition***
2023[427]	*12% (18 GW)*	*12% (18 GW)*	*10% (5 GW)*	*10% (5 GW)*	*58% (45 GW)*	*58% (45 GW)*
2025	23% (35 GW)	25% (37 GW)	6% (5 GW)	7% (5 GW)	50% (53 GW)	48% (50 GW)
2030	38% (73 GW)	53% (97 GW)	4% (4 GW)	0% (0 GW)	41% (51 GW)	29% (35 GW)
2035	53% (125 GW)	70% (174 GW)	1% (2 GW)	0% (0 GW)	30% (43 GW)	15% (22 GW)

Note: *Capacity values of coal and gas plants denote the total capacity with constant operating hours at today's level in the respective categories. The same emissions reductions can also be achieved through reduced utilization of coal and gas plants to support the integration of increasing penetration of solar and wind, which results in higher capacity.

Methane. Methane was the largest contributor to Mexico's emissions in 2022.[428] Enteric fermentation accounted for 37% of the country's methane emissions, followed by solid waste at 32%, the oil and gas industry at 14%, and wastewater at 13%.[429] Recent research suggests that Mexico's methane inventory may be underestimated, likely due to emissions from the oil and gas sector.[430] Mexico is a signatory to the Global Methane Pledge (GMP), aiming to reduce methane emissions by 30% by 2030 compared to 2020 levels. The country also participates in the Lowering Organic Waste Methane Initiative, which seeks to reduce methane emissions from waste at the subnational level.[431]

Given the significant share of non-CO_2 emissions, particularly from hard-to-abate sources like enteric fermentation, achieving net-zero GHG emissions in Mexico will likely require deeper CO_2 reductions. In the near term, there is potential to reduce methane emissions from solid waste and the likely underestimated emissions from the oil and gas sector, as well as to promote technological and policy innovation to address agricultural methane and nitrous oxide (N_2O) emissions. Key strategies to further reduce emissions include strengthening monitoring and data management for methane emissions, advocating for equipment upgrades, implementing leak detection and repair programs, and capturing flared gas in the oil and gas sector. Additionally, efforts to enhance local initiatives that improve solid waste management by offering technical and financial assistance, developing waste management guidelines and protocols, and supporting agricultural practices that prevent methane emissions—such as substituting fertilizers and capturing and managing biogas—would be beneficial.

Industry. In 2022, cement production was responsible for nearly 20% of CO_2 emissions in the industrial sector.[432] To address this, the cement industry set a target to reduce emissions to 520 kg of CO_2 per ton of cement produced by 2030—a 17% decrease from 2016 levels.[433] Recent efforts have focused on lowering the clinker content in the cement mix, optimizing water usage, and enhancing recycling practices.[434] In 2024, Cemex, which holds 50% of the cement market in Mexico, announced that it had already exceeded the targets set by the sector.[435]

Oil and gas account for 44% of total final energy consumption in the industrial sector in Mexico.[436] To transition industrial production to cleaner technologies, Mexico established an Emissions Trading System (ETS) in 2018, which is set to begin operations in 2024. Under this system, companies in the industrial and energy sectors (including hydrocarbons and electricity) that emit more than 100,000 tons of CO_2 per year are required to participate.[437] The new government is expected to prioritize the development of the necessary regulations for the market to operate effectively. Additionally, states are working to align their policies with the national framework.[438]

To enhance mitigation efforts in the industrial sector, key strategies include strengthening the emissions trading system and aligning it with higher ambition goals, as well as applying the carbon tax to gas.[439]

Additional strategies involve improving energy efficiency by providing technical and financial assistance to manufacturing facilities across the country,[440] enhancing collaboration with major industry actors to pursue more ambitious commitments, and substituting fossil fuels with electricity in industrial activities wherever possible.[441]

Transportation. EV penetration in Mexico is currently low, accounting for only 0.26% of new car sales.[442] However, this share has been gradually increasing, reaching 0.45% from 2018 to 2022. The National Mobility Strategy aims to achieve a 50% share of hybrid or electric vehicles in the total vehicle stock by 2040 and a 100% share by 2050.[443] To meet these targets, the government plans for 50% of the cars produced in Mexico to be zero-emissions by 2050. This will be facilitated through the nationalization of lithium reserves and the establishment of new electric vehicle factories by companies such as BYD, Tesla, and Jetour, among others.[444,445]

To further reduce emissions from transportation, key policy actions include expanding EV charging infrastructure from 1,100 public charging stations in 2023 to at least 38,000 by 2040.[446] Additionally, Mexico can incentivize EV adoption through subsidies for vehicle purchases and home charging device installations, along with plans to phase out gasoline-powered vehicles.[447] Enhancing urban planning and promoting alternative transportation methods are also essential; this can be achieved by electrifying public transportation, improving efficiencies in urban areas, expanding and retrofitting railways, and encouraging modes of transport such as cycling and walking.

SUBNATIONAL ACTION

Mexico operates under a federal presidential system of governance, with 31 states and one federal district decentralized from the federal government, Mexico City. All states, including Mexico City, operate under relatively autonomous presidential systems as well. However, they are historically subordinate to the federal government and do not diverge from nationally-set policies.

On the subnational level, local governments have to develop and implement climate change policies, but they are still reliant on national and state governments for resources and investment, capacity, and prioritization of climate. Climate policy priorities at both the federal and state levels have varied with the political agendas of the governing administrations. However, the new President, Claudia Sheinbaum, has committed to restoring the energy transition efforts that were paused under her predecessor.

Power sector. Mexico's Power Sector Law allows states and regions to design and manage their own renewable power auctions. This provision enables state governments to play a key role in promoting the deployment of renewable energy projects across the country. Under current regulations, state governments can register as qualified users and, in partnership with the private sector, participate as buyers in these auctions.[448] States can also assist by identifying and securing land, as well as facilitating the pre-approval of project sites in line with environmental and social criteria. Moreover, they can work alongside technical experts and financial institutions to create the required market and funding structures.[449] Although grid transmission planning remains centralized in Mexico, auctions focused on locations with sufficient grid capacity could be initiated in the near future.[450]

Waste. Mexico's Waste Prevention and Management Law establishes that states and municipalities, in coordination with the federal government, must develop and implement local programs for the prevention and management of solid waste.[451] Within this framework, municipalities like Mexico City have established policies and programs that promote a circular economy while adopting the principles of extended responsibility, integrating the public and private sector, as well as civil organizations and citizens.[452] Following Mexico City's example, municipalities across the country can develop solid waste management plans that encourage responsible production and consumption, minimize the volume of waste disposed of in landfills and open dumps, improve collection practices and recycling, adopt clean technologies to capture emissions, and promote employment and inclusivity by identifying vulnerable sectors for training and skill development.[453]

Transportation. EV transportation in Mexico is already supported by several federal and state policies, which include tax reliefs, prioritized circulation, preferential parking, and differentiated toll tariff structures.[454] Municipal governments can further advance EV deployment by establishing standards, codes, and procedures to streamline the installation and maintenance of charging stations in collaboration with the national power utility (CFE).[455] Additional state measures could include allowing EVs to use high-occupancy vehicle lanes, offering financial incentives, and implementing a guaranteed loan program for electric public transportation options, such as taxis and buses. State governments could also equip key corridors between cities with EV infrastructure and pilot the electrification of vehicle fleets, including municipal vehicles, airport shuttles, and motorcycles.[456]

3.9 Republic of Korea

Summary

- Korea's total emissions peaked in 2018, and declined by 12% in 2023 from the peak level, mostly driven by reduced coal in power generation.
- The current NDC target commits to a 40% reduction in total GHG emissions from 2018 to 2030, with 35% to be achieved domestically and 5% through international offsets. Achieving the 2030 target without offsets would require doubling the average annual reduction rate since the emissions peak.
- Korea has laid out key transition strategies that heavily focus on technologies with high political, economic, or environmental uncertainties, including nuclear, ammonia, and hydrogen, while largely lagging behind in deploying renewables and electric vehicles (EVs), technologies that are widely proven cost-competitive.
- The *High Ambition* pathway for Korea includes fully meeting the 2030 target through domestic reductions, and reducing total GHG emissions by 58% in 2035 from the 2018 level; removing the use of uncertain international offsets can improve the credibility of its national targets.
- Domestic emissions reduction can be achieved through a complete coal power phaseout accompanied by accelerated solar and wind deployment, by enhancing mitigation efforts in the steelmaking, petrochemical, and cement industries, and prioritizing EV adoption and infrastructure support.
- Korea's provinces, despite having limited autonomy, still show potential to lead emissions reductions in power, industry, and transportation, implementing local initiatives such as siting policies, industrial park symbiosis in industrial hubs, and green transportation projects.

EMISSIONS PROFILE. The overall emissions of the Republic of Korea (henceforth "Korea") peaked in 2018, declined slowly thereafter, and reached a 12% reduction in total greenhouse gas (GHG) emissions (including LULUCF) in 2023.[457,458] This is mainly driven by faster reductions in the electricity sector (16% until 2022), due to declining coal power generation.[459] As of today, a large share of emissions still comes from electricity, with 36% of total GHG emissions in 2022. followed by industry (17%), and transport (15%).[460] Emissions from land use change in Korea are small, comprising around 1% of total GHG emissions.[461]

2030 NDC. Korea's current NDC target has committed to reduce its 2030 total GHG emissions by 40% from 2018 and reach net-zero GHG by 2050.[462] These targets cover all GHG emissions from all sectors (however, the 2018 base year does not include LULUCF emissions). To achieve its 2030 NDC, Korea aims to reduce 35% of the emissions domestically, with the remaining 5% coming from international offsets.[463] Continuing the emissions reduction rate between 2018 and 2022 is insufficient to meet its 2030 NDC. In order to fully achieve the NDC target without relying on international offsets, Korea would need to accelerate its average annual emissions reduction rate from approximately 2% per year between 2018 and 2022 to 4% per year for 2023-2030.

NATIONAL STRATEGIES. Korea has laid out transition strategies in several key policy documents, including the Framework Act on Carbon Neutrality (Carbon Neutrality Plan), Basic Plan on Electricity (Basic Electricity Plan (BEP)), and the Korea Emissions Trading Scheme (K-ETS). Several technologies are being emphasized, but they face uncertainties regarding political feasibility, economic competitiveness, and emissions outcomes. These include the expansion of nuclear power through the completion of four new reactors, an increased reliance on ammonia and hydrogen as 'carbon-free' power sources[464]—which may delay the phaseout of fossil fuels—and a roadmap for establishing a leading hydrogen economy to promote both domestic and overseas deployment and production.[465]

By contrast, the deployment of renewable energy and electric vehicles falls behind. Renewables contributed to only 6% of total power generation in 2023, where solar and wind deployment has slowed down in recent years, from over 4-5 GW per year in 2018-2020 to 3 GW per year in 2022-2023. The latest 11th Basic Energy Plan (BEP) still aims for relatively slow renewable expansion to only 22% of total generation by 2030, but instead heavily relies on the timely completion of additional nuclear reactors to reduce coal and LNG power generation. A slower pace of renewable energy deployment not only risks Korea missing its 2030 targets but may also limit the possibility of setting more ambitious targets for 2035.

Similarly, while new battery electric vehicle (BEV) sales have been increasing, the share reached only 7% in 2023, compared to 25% in China and 14% in Europe (Figure S2). However, existing policies place more emphasis on hybrid cars, as half of the new sales target for low emission vehicles (51% in 2025 and 83% in 2030) is expected to be met by hybrid cars, while 24% by EV and 9% by hydrogen vehicles.[466]

2035 PATHWAYS. Our modeling analysis shows that the 2035 target for Korea under the *High Ambition* pathway implies a 58% reduction from 2018, fully achieved domestically. We compare a few scenarios (Table 3.9.1 and Figure 3.9), including:

- *A* ***Delayed Transition*** where GHG emissions, including LULUCF, stagnate from 2018 to 2030 and then decline toward net-zero emissions by 2050, achieving a 21% reduction by 2035. This pathway is unlikely to happen given the continued reductions since 2018.

- *A* ***High Ambition*** *pathway* where GHG emissions, including LULUCF, decline to meet the NDC target of 40% reduction by 2030 fully domestically, and then continue the decline toward net-zero by 2050. In this scenario, GHG emissions, including LULUCF, decrease by 58% from 2018 levels by 2035, achieved entirely through domestic efforts.

- In comparison, the linear pathway from the 2030 NDC to net-zero (NDC to Net-Zero Trend) suggests a smaller 52% reduction in total GHG emissions by 2035; where continuing the current reduction trend to meet the 2030 NDC target (Today to NDC Trend) would lead to the 58% reduction by 2035.

Table 3.9.1. Summary of GHG emissions reductions (including LULUCF) in 2030 and 2035, relative to NDC base year (2018)

Scenario Name		2030 emissions % change from 2018	2035 emissions % change from 2018
Official NDC Target		-40% (35% domestic, and 5% international offsets)	TBD
Delayed Transition*		+1%	-21%
High Ambition	***GCAM-6.0-CGS****	-40%	-58%
	NDC to Net-Zero Trend**	Meets NDC by design	-52%
	Today to NDC Trend***		-58%

Notes: *Based on the scenarios developed using GCAM-6.0-CGS for the NGFS Phase V; **assume linear reduction from the 2030 NDC target to net-zero 2050; ***assume continuing the reduction trend between 2022 emissions level to 2030 NDC target for the post-2030 period.

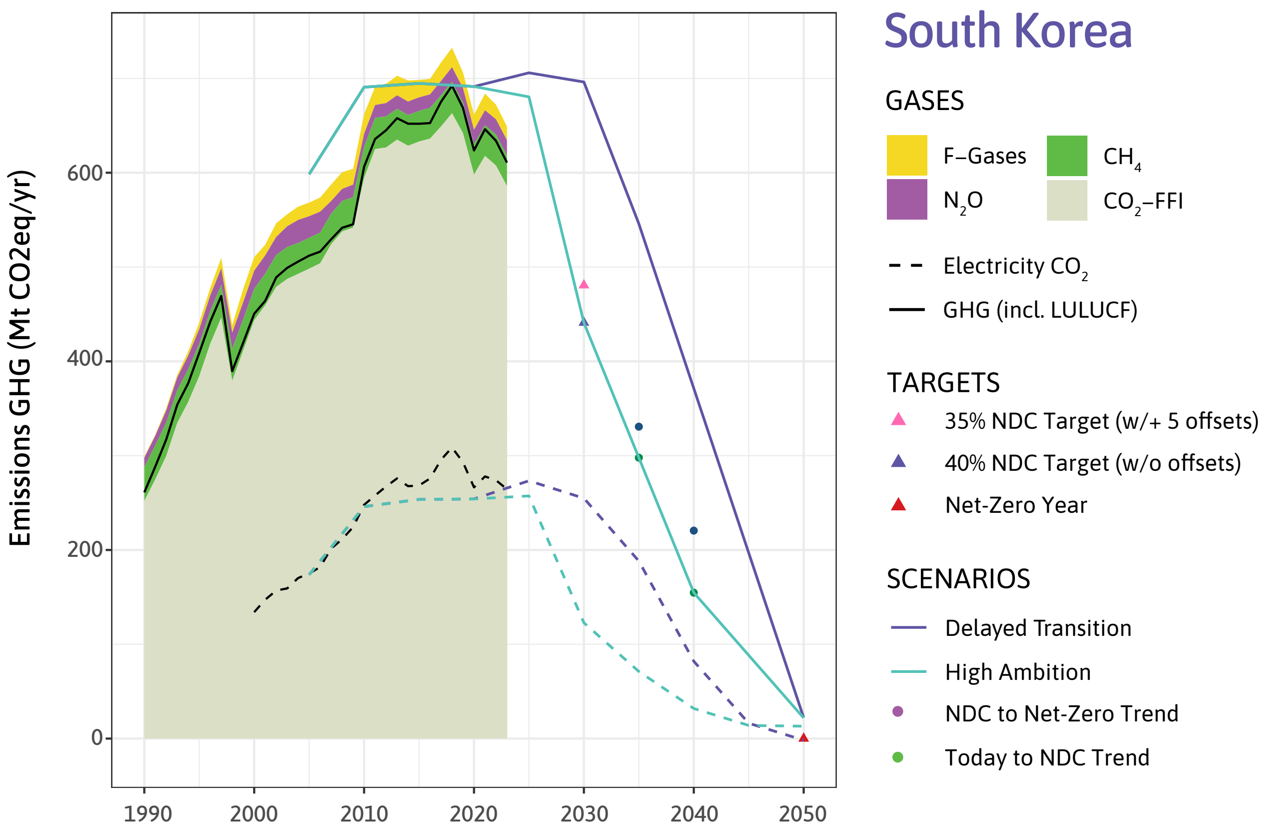

Figure 3.9. Korea GHG including LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[467] (dashed black line for total GHG, including LULUCF), EMBER[468] (solid black line for electricity supply GHG emissions), and CEDS[469] (colored breakdown of historic GHG emissions, without F-Gases). Colored triangles mark the official 2030 NDC and Net-zero targets. Colored dots mark possible values for 2035 and 2040, based on extrapolation of the 2022-2030 linear trajectory ("Today to NDC Trend"), interpolation between the 2030 and net-zero 2050 targets ("NDC to Net-Zero Trend"). Pathways data includes LULUCF emissions and is based on the NGFS Phase V[470] scenarios developed using GCAM.

PRIORITY POLICY ACTIONS. To achieve the *High Ambition* pathway, policy actions in Korea can focus on the following areas to deliver meaningful emissions reductions through 2035, including:

- **Removing the use of uncertain international offsets** in 2030 and 2035 NDCs to improve the credibility of climate targets by focusing on domestic emissions reduction.
- **Hydrogen:** Re-evaluating the hydrogen deployment plan, assessing the uncertainties regarding the economic viability and emissions reduction potential of hydrogen and ammonia, and focusing on targeted applications in specific hard-to-abate sectors.
- **Power sector:** Accelerating renewable deployment with wind and solar contributing to over 40% of total generation by 2030 and nearly 60% by 2035; canceling new coal and gas projects; and phasing out coal by 2035.
- **Industry:** Reducing steel emissions through the deployment of hydrogen-based direct reduced iron (DRI) and electric arc furnaces (EAF); adopting fuel and material conversion in cement production; and using bio-naphtha as a feedstock for petrochemicals.
- **Transportation:** Focusing on EV and FCEV instead of hybrid cars in the new vehicle sales target with more policy incentives; accelerating bus electrification within cities; and updating building codes for high-rise buildings to include specific requirements for charging infrastructure.

Hydrogen. Given uncertainties about the economic viability and emissions reduction potential of hydrogen, it is important to assess the feasibility and impact of the country's ambitious hydrogen deployment strategy with wide applications in power generation, steel production, and transportation. Analyses have shown that hydrogen lacks economic competitiveness in many applications compared to readily-available and cost-effective alternative technologies, except for in a few targeted applications within hard-to-abate sectors (i.e. freight transport, industrial feedstocks). Additionally, research suggests that ammonia combustion may not significantly reduce the warming effect due to increased N_2O emissions and potential climatic impacts from hydrogen slippage.[471]

Power sector. Decarbonizing the power sector presents significant potential and is a key strategy for emissions reduction through 2035. Rapidly expanding renewables, particularly solar and wind, to complement nuclear buildout, would be a more robust approach to significantly reduce power sector emissions. To achieve this, it is essential to enhance renewable energy targets, eliminate bureaucratic hurdles, streamline planning and implementation processes, and provide stronger policy incentives. Additional measures include expediting the planned coal phaseout ahead of the 11th BEP schedule and halting the expansion of LNG infrastructure to avoid locking in fossil fuel infrastructure.

Under the *High Ambition* scenario, emissions from electricity generation decrease by 72% between 2020 and 2035, with accelerated solar and wind deployment, cancellation of new coal and gas projects, and a coal phaseout by 2035 (Table 3.9.2). Specifically, power sector transitions under the *High Ambition* pathway include:

- Share of renewable energy generation (solar and wind) increases from 6% in 2023 to 41% by 2030 and 59% by 2035, with an average of 14 GW solar and wind installations per year.
- Share of coal generation decreases from 33% in 2023 to 10% by 2030 and nearly phasing it out by 2035 (2%) and canceling the remaining 2 GW of under-construction coal projects.
- Share of gas generation declines from 28% in 2023 to 19% by 2035, with no new gas expansion, by canceling 14 GW of pre-construction projects.
- Other technologies with uncertain emissions reduction potential or economic viability, such as ammonia and hydrogen, are not deployed.

Table 3.9.2. Key power sector metrics across scenarios.

Year/ Scenario	Solar + Wind % of total elec generation (Installed capacity, GW)		Coal % of total elec generation (Installed capacity, GW*)		Gas % of total elec generation (Installed capacity, GW*)	
	11th BEP**	High Ambition	11th BEP**	High Ambition	11th BEP**	High Ambition
2023[472]	*5% (29 GW)*	*5% (29 GW)*	*33% (39 GW)*	*33% (39 GW)*	*28% (47 GW)*	*28% (47 GW)*
2025	n/a	17% (52 GW)	n/a	33% (44 GW)	n/a	25% (44 GW)
2030	21% (72 GW)	41% (123 GW)	17% (22 GW)	10% (13 GW)	25% (44 GW)	25% (41 GW)
2035	27% (99 GW)	59% (191 GW)	13% (17 GW)	2% (3 GW)	16% (31 GW)	19% (32 GW)

Note: *Capacity values of coal and gas plants denote the total capacity with constant operating hours at today's level in the respective categories. The same emissions reductions can also be achieved through reduced utilization of coal and gas plants to support the integration of increasing penetration of solar and wind, which results in higher capacity. **For the BEP, 2035 numbers are interpolated between 2030 and 2038, and capacity for gas and coal is estimated using BEP generation and the constant capacity factor at today's level, same as in the *High Ambition* scenario. The generation share from solar and wind power plants was estimated using the capacity and total electricity demand announced in the 11th BEP, applying the same capacity factor used in the *High Ambition* scenario.

Industry. Korea's industrial sector is the second-largest emitter[473] and the largest electricity consumer, playing a critical role in the country's economy.[474] Key industries such as steel and automobiles are export-oriented and thus are largely affected by new climate policies in importing regions (e.g., CBAM). Accelerating the deployment of decarbonization technologies, more efficient processes, and improved products can help these industries to remain competitive during the global low-carbon transition.[475,476]

Enhancing mitigation efforts in steelmaking, petrochemicals, and cement industries is crucial to achieving a higher ambition.[477] Near-term strategies include the adoption of technologies like hydrogen direct reduced iron (DRI) and electric arc furnaces (EAF) in steel production[478], fuel and material conversion (to waste synthetic resin, and from raw limestone to slag cement) for cement production,[479] and bio-naphtha as a feedstock for petrochemicals[480]. Additionally, enhancing collaboration with major industry actors, strengthening Korea's Emissions Trading System and energy efficiency standards, and eliminating the use of international offsets would further drive emission reductions.

Transportation. Korea aims to have 51% of new car sales be for low emissions vehicles, which include electric cars, hydrogen cars, and hybrid cars by 2025, increasing to 83% by 2030.[481] The roadmap accompanying this goal anticipates that in 2030, 50% of sales will come from hybrid vehicles, 24.4% from electric and 9% from hydrogen.[482] Given the growing share of BEV sales, which reached 7% in 2023, and assuming a similar growth rate to the one observed in China and Norway, the 2025 goal will likely be exceeded, especially as Korean manufacturers are expanding the availability of EV models.

To further reduce emissions from transportation, key strategies include prioritizing electric vehicles (EVs) and Fuel Cell Electric Vehicles (FCEVs) over hybrid cars in new sales targets, and accelerating bus electrification within cities.[483] Additional measures involve reducing car use by promoting public transportation, walking, and cycling,[484] as well as expanding green transportation by building more charging infrastructure, updating building codes for high-rise buildings specifically for charging infrastructure requirements, and providing incentives to favor the use of low-emission vehicles.[485]

SUBNATIONAL ACTION

Korea's centralized government operates primarily at the national level, with eight provinces and additional special administrative divisions. The country's climate policies are highly politicized, influenced by a cultural and economic focus on industrial strength. This emphasis shapes the approach to climate action under the Carbon Neutrality Framework Act, which mandates that subnational entities submit carbon-neutral growth and GHG reduction plans to the national government. However, significant gaps in the guidelines remain: they lack firm regulations on including the industrial and power sectors and clear GHG accounting methods, and they provide minimal incentives for subnational actors to pursue ambitious emissions reduction goals.

Given Korea's climate governance structure, provinces can still show potential to drive emissions reductions at the subnational level, especially in power, industry, and transportation. With limited autonomy, provinces and cities can operate with a degree of independence from national policy polarization, implementing measures like siting policies, policy incentives to support circular economy in industrial hubs, and green transportation initiatives at local and metropolitan levels.

Power sector. Regulatory constraints are the primary impediment to the widespread deployment of solar energy in Korea, reducing the market potential by 69.6%.[486] Data by the Korea Energy Economics Institute showed that in 2023 over 130 out of 226 Korean municipalities (>57.5%) specified minimum separation distances between solar equipment and designated roads, facilities, and other sites, reaching a maximum of 1,000 meters.[487] Such distance regulations can be amended by local governments without national-level guidance.[488]

Industry. Industrial park symbiosis would be both viable and effective at the subnational level in Korea through incentives and industrial forums. Korea had 973 industrial parks as of 2013[489], and piloted a national eco-industrial park program in 2003.[490] On the municipal level, sustainable supply chains and industrial park symbiosis can be pursued through information and material sharing, which can lead to an overall reduction of final waste and virgin materials, among other sustainable co-benefits. Korea's Ulsan Mipo and Onsan Industrial Park serves as a key example of the viability of eco-industrial parks, as it achieved $554 million in eco-related savings over the course of 10 years (2008-2018).[491,492,493] Due to the proven implementation and cost-saving processes within industrial park symbiosis, subnational actors such as Ulsan, Pohang, Daegu, Changwon, and Busan can take a stronger lead in pushing for industrial park symbiosis within existing industrial parks. Focus can be on renewable energy transmission to these parks, as well as virgin and waste product management and information networks.

Transportation. Subnational regions, especially cities, should transition to energy-efficient modes such as electrified railway, high-speed rail networks, and bus operation optimization.[494] Cities with major automotive industrial hubs, such as Daegu and Changwon, should act as leaders in the expansion of BEV or FCEV LDV vehicles (rather than hybrid) through policy incentives. All cities can expand charging infrastructure and update building codes for high-rise buildings to expand charger access and provide incentives to favor the use of lower-emission vehicles.[495]

3.10 South Africa

Summary

- South Africa's total emissions peaked in 2012 according to global inventory, and declined by 17% in 2023 from the peak level, mostly driven by reduction in the power sector.
- South Africa has established absolute GHG emissions targets in its existing NDCs of 398-510 $MtCO_2e$ by 2025 and 350-420 $MtCO_2e$ by 2030. These targets show a wide range of emission outcomes, implying annual emissions reductions of 1% to 3% through 2030, compared to the average 2% reduction rate post peaking. The country also aims to achieve net-zero GHG emissions by 2050.
- As the world's fifth-largest coal exporter, South Africa's coal mining sector plays a vital role in the economy, with significant downstream linkages. This makes the just transition a critical concern.
- The country has been grappling with an electricity supply crisis, compounded by Eskom's, the national power utility, ongoing financial challenges. These issues have delayed the decommissioning of a large number of old (>40 year) coal power plants and affected the implementation of the Just Energy Transition Partnership (JETP).
- The *High Ambition* pathway for South Africa includes delivering the lower emission range of its existing NDC targets in 2030, and a 38% reduction in total GHG emissions by 2035 from the 2023 levels.
- This is achieved by accelerating the deployment of renewable energy beyond existing targets to cancel and decommission coal and limit gas expansion; restricting coal mine expansion; targeting methane abatement in underground and abandoned coal mines as well as the waste sector through advanced disposal and treatment technologies and improved collection logistics.
- While provincial governments usually have a high conformity with the national government on climate issues, local governments, especially the eight metropolitan municipalities, offer a more promising outlook through their leadership in developing climate policies, strategies, and projects to transition to cleaner energy sources in the power sector and establish integrated waste management plans to address methane emissions

EMISSIONS PROFILE. South Africa's national inventory shows its overall GHG emissions, including LULUCF, peaked in 2008 and declined by 14% in 2023; other global inventory shows a later peak in 2012 with a 17% reduction by 2023 and a steady decline since 2019.[496] In 2022, the power sector accounted for nearly half (43%) of total GHG emissions, while methane contributed 15%, and industry and other energy supply made up 12%.[497] According to South Africa's latest National Inventory Report (NIR), LULUCF emissions were negative in 2020, acting as a sink of approximately 26 $MtCO_2$ (or 6% of total GHG emissions).[498]

2030 NDC. South Africa has committed to absolute GHG emissions targets (including LULUCF) of 398-510 $MtCO_2e$ by 2025 and 350-420 $MtCO_2e$ by 2030 in its current NDC.[499] Land sector emissions caused by natural disturbances are excluded from the targets.[500] The country also aims to achieve net-zero GHG emissions by 2050.[501] The existing NDC targets include a wide range of emission outcomes. The 2025 targets imply that total GHG emissions can either increase by 13% or decrease by 12% from 2023; and the 2030 targets imply a 7%-23% reduction from 2023 with a 1%–3% annual reduction rate. Compared to the average 2% annual reduction from peak emissions, the high end of the 2030 emissions target range lacks ambition but the low end shows accelerated transition.

NATIONAL STRATEGIES. As the largest emissions source, South Africa's electricity generation is dominated by coal, which accounts for 82% of total generation in 2023 with a large portion of both old (>40 years) and young (<10 years) coal plants. The country has committed to decommission 10 GW of coal power plants by 2030 as outlined in the Integrated Resource Plan (2019)—this, however, has been delayed due to an electricity supply crisis. South Africa has also committed to build 23 GW of new wind and solar capacity by 2030, but recent trends show gas power plants are being prioritized over renewables to address the energy shortfall.[502] Many questions also remain about regulatory oversight and enforcement, which could affect investor confidence in long-term clean energy investments.[503]

In response to these challenges, South Africa is implementing several reforms in the power sector aimed at stabilizing Eskom's finances, improving the availability of existing supply, and encouraging private investment in new generation capacity. These reforms also promote the procurement of new generation from renewables, gas, and battery storage, while empowering businesses and households to invest in rooftop solar.[504]

To support this transformation, the Just Energy Transition Partnership (JETP), led by the United States, United Kingdom, France, Germany, and the European Union, has committed $8.5 billion USD,[505] compared to the estimated $250 billion needed over the next three decades to support a clean energy transition.[506] However, only about 4% of this funding is allocated as grants, with the remainder comprising concessional and commercial loans, along with loan guarantees.[507,508] This funding structure adds to South Africa's existing public debt and Eskom's financial challenges.[509] The national power utility has been facing a financial crisis, limiting its ability to secure loans for transition investments such as expanding clean energy generation, upgrading transmission and distribution networks, and decommissioning or repurposing coal plants.[510]

As the fifth-largest coal exporter in the world, South Africa's coal mining sector, while not a significant contributor to GDP, has crucial downstream linkages to transportation, petrochemicals, and electricity generation.[511] Coal mining is predominantly concentrated in the Mpumalanga province, which contains 83% of the coal mines and accounts for 70% of coal production.[512] A just transition is a significant concern, as coal mining provides up to 20% of direct jobs in some municipalities in this region, impacting the majority of coal households (60%).[513] The Presidential Climate Commission adopted the Just Transition Framework in 2022 after extensive consultations,[514] although some local communities continue to express concerns.[515]

While South Africa is the first African country to adopt a carbon pricing policy, the current scheme includes exemptions, resulting in a low effective carbon tax rate.[516] Achieving its NDC targets will require raising this rate and strengthening the tax's implementation. Doing so could generate revenue to foster economic growth, support the green transition, and address the immediate impacts of economic transformation and other distributional effects. Despite these steps, emissions mitigation planning for high-emission sectors such as steel production and mining is still somewhat limited, although there is increasing interest in hydrogen as a possible solution.[517,518]

2035 PATHWAYS. Our modeling analysis shows that the 2035 target for South Africa under the *High Ambition* pathway implies a 38% reduction from 2023. We compare a few scenarios (Table 3.10.1 and Figure 3.10), including:

- *A **Delayed Transition*** where GHG emissions, including LULUCF, are expected to have a slower decline rate until 2030, with a net-zero target set for 2050. Emissions are projected to increase by 4% by 2030 and decrease 22% by 2035, compared to 2023 levels.

- *A **High Ambition** pathway* where GHG emissions, including LULUCF, decline faster to meet the NDC reduction target by 2030, followed by a slower decline toward net-zero by 2050. Emissions are expected to decrease by 17% by 2030 and 38% by 2035.

- Continuing the trend from the NDC to net-zero by 2050 could result in emissions reductions comparable to those in the *High Ambition* scenario. In contrast, the trend from today to the NDC (2022 to 2030) may lead to a lower (31%) emissions reduction.

Table 3.10.1. Summary of GHG emissions reductions (including LULUCF) in 2030 and 2035, relative to 2023.

<table>
<tr><th colspan="2">Scenario Name</th><th>2030 emissions
% change from 2023</th><th>2035 emissions
% change from 2023</th></tr>
<tr><td colspan="2">Official NDC target</td><td>-7% to -23%</td><td>TBD</td></tr>
<tr><td colspan="2">Delayed Transition*</td><td>+4%</td><td>-22%</td></tr>
<tr><td rowspan="3">High Ambition</td><td>GCAM-6.0-CGS*</td><td>-17%</td><td>-38%</td></tr>
<tr><td>NDC to Net-Zero**</td><td rowspan="2">Meets the upper reduction range of NDC by design</td><td>-38%</td></tr>
<tr><td>Today to NDC***</td><td>-31%</td></tr>
</table>

Notes: *Based on the scenarios developed using GCAM-6.0-CGS for the NGFS Phase V;**assume linear reduction from the 2030 NDC target to net-zero 2050; ***assume continuing the reduction trend between 2022 emissions level to 2030 NDC target for the post-2030 period.

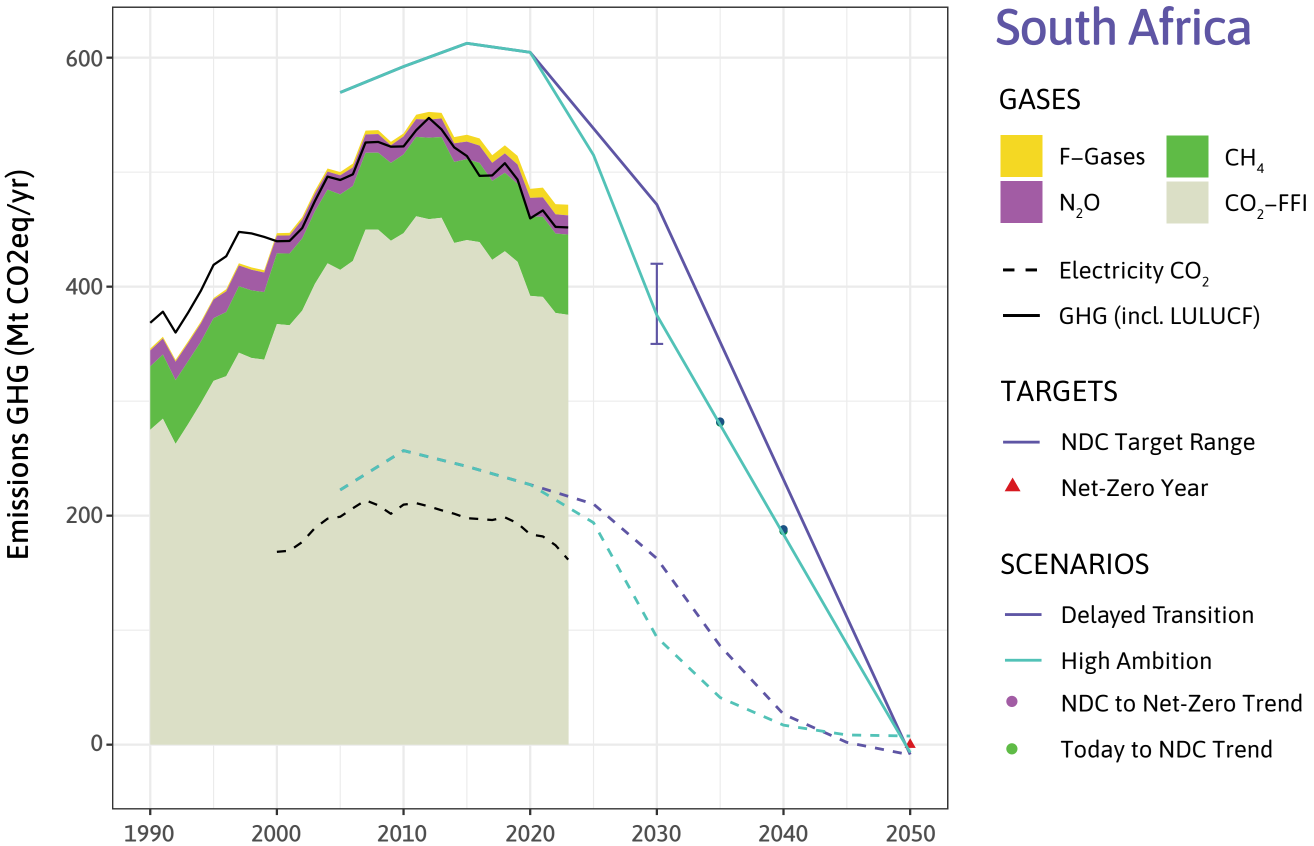

Figure 3.10. South Africa's GHG including LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[519] (solid black line for total GHG, include LULUCF), EMBER[520] (dashed black line for electricity supply GHG emissions), and CEDS[521] (colored breakdown of historic GHG emissions, without F-Gases). Colored triangles mark the official 2030 NDC and Net-zero targets. Colored dots mark possible values for 2035 and 2040, based on extrapolation of the 2022-2030 linear trajectory ("Today to NDC Trend"), interpolation between the 2030 and net-zero 2050 targets ("NDC to Net-Zero Trend"). Pathways data includes LULUCF emissions and is based on the scenarios developed using the GCAM IAM for the NGFS Phase V.[522]

PRIORITY POLICY ACTIONS. To achieve the *High Ambition* pathway, policy actions in South Africa can focus on the following areas to deliver meaningful emissions reductions through 2035, including:

- **Power sector:** Accelerating the deployment of renewable energy sources, with wind and solar expected to contribute over 67% of total generation by 2030 and 88% by 2035, while also decommissioning existing old (>40 years) coal plants and canceling new coal projects, as well as limiting gas expansion.
- **Methane:** Adopting best practices in monitoring, verification, and reporting (MVR), restricting coal mine expansion, and utilizing degasification systems in both underground and abandoned coal mines. Investing in advanced waste disposal technologies and wastewater treatment, enhancing waste collection logistics, and implementing training and awareness campaigns.

Power sector. South Africa's electricity generation is dominated by fossil fuels, with coal accounting for 82% and other fossil fuels contributing 2%. Renewables make up 13% of total generation (7% from solar and 5% from wind), while nuclear power accounts for 4%.[523] Notably, 34% of the coal capacity is over 40 years old, while newer coal plants, those less than 10 years old, account for 20% of total coal capacity. Currently, 0.8 GW of coal capacity is under construction, with an additional 3 GW in pre-construction stages.[524]

In the *High Ambition* scenario, solar and wind buildouts achieve 6 GW/year through 2025, 9 GW/year from 2025 to 2030, and 12 GW/year from 2030 to 2035, compared to the 6 GW/year JETP target for 2023 to 2027. As a result, solar and wind generation reaches 88% of total generation by 2035, where coal represents only 7% of total generation, declining by 84% from the 2023 levels (Table 3.10.2). It is therefore critical to cancel the 3 GW of coal power plants in pre-construction stages to avoid additional stranded assets.

Other key strategies for power sector transition include accelerating investment in transmission and distribution grids, and enhancing renewable deployment by creating a competitive power market, enabling power commercialization at the municipal level, and building value chains to support renewable energy growth.[525] Additionally, prioritizing the deployment of renewable power plants over gas plants will help mitigate the energy crisis, while strengthening regulation and enforcement could help build investor confidence in long-term clean energy investments.[526]

Table 3.10.2. Key power sector metrics across scenarios.

Year/ Scenario	Solar + Wind % of total elec generation (Installed capacity, GW)		Coal % of total elec generation (Installed capacity, GW*)	
	Delayed Transition	***High Ambition***	***Delayed Transition***	***High Ambition***
2023	*12% (10 GW)*	*12% (10 GW)*	*82% (46 GW)*	*82% (46 GW)*
2025	26% (29 GW)	31% (34 GW)	69% (41 GW)	64% (38 GW)
2030	47% (56 GW)	67% (77 GW)	48% (31 GW)	27% (17 GW)
2035	76% (113 GW)	88% (135 GW)	19% (15 GW)	7% (6 GW)

Note: *Capacity values of coal and gas plants denote the total capacity with constant operating hours at today's level in the respective categories. The same emissions reductions can also be achieved through reduced utilization of coal and gas plants to support the integration of increasing penetration of solar and wind, which results in higher capacity.

Methane. Methane is the second-largest source of greenhouse gas (GHG) emissions in South Africa. As of 2022, the coal supply sector was responsible for 44% of total methane emissions, followed by solid waste at 19% and wastewater at 12%.[527] Despite the significance of methane emissions, South Africa is not a signatory of the Global Methane Pledge nor has developed policies to address methane emissions.[528]

To prevent methane and other emissions from coal mines, key strategies include restricting underground coal mine expansion, adopting CMM emissions standards, implementing best practices for monitoring, verification, and reporting (MVR)—such as direct emissions measurement at the source—and utilizing satellite surveillance programs.[529] Additional measures to reduce emissions from underground and abandoned coal mines involve adopting degasification systems even after operations have ceased, on-site recovery and use of air methane for heating and coal drying, and thermal oxidation to eliminate ventilation air methane.[530]

In the waste sector, near-term strategies to further reduce methane emissions include improving waste management practices, investing in advanced waste disposal technologies and wastewater treatment, enhancing waste collection logistics, and implementing training and awareness campaigns.[531]

SUBNATIONAL ACTION

South Africa operates under a decentralized federal system of 'cooperative governance', with nine provinces and 257 municipalities (eight of which being metropolitan municipalities). The powers left exclusively to the national sphere of influence include matters such as land, regulating and policing mining industries and the energy sector, and distributing taxes among the three levels of government. Provincial governments have authority over agriculture, environment, trade, and health services, but do so within the national legislative framework, passing few provincial laws. Further, the constitution does not defer any significant revenue-raising powers to the provinces, so they are almost fully dependent on intergovernmental wealth transfers. Therefore, provinces play a limited role in climate governance.

However, local governments, especially the metropolitan municipalities, offer a far more promising outlook on subnational climate governance in deploying local climate response policies, strategies, and projects. For example, the City of Cape Town has made institutional changes in line with various strategies and policies, such as the Cape Town Energy 2040 Goal which commits the city to diversifying its energy supply and the 2021 Climate Change Strategy which plans for a climate neutral future.

South Africa relies heavily on coal-powered power generation, with a total of 18 operating across three provinces. Mpumalanga has 12 power stations, Gauteng has four, and Limpopo has two power stations.[532] In South Africa, the national government recognizes the necessity of coordinated and cooperative responses and acknowledges the significant roles that provincial and municipal governments can play to tackle the impacts of climate change.[533] While progress on subnational initiatives varies across provinces, there is a growing effort to address the impacts of climate change through strategic planning and implementation. But local governments struggle with limited expertise, financial resources, and institutional capacity to manage high-emitting activities in their areas.[534]

Power sector. South African provinces are increasingly focused on transitioning to cleaner energy sources as part of their climate strategies. The Western Cape province aims for net-zero emissions by 2050 by shifting from fossil fuel to renewable energy sources,[535] Gauteng's climate plans emphasize emissions reduction across sectors like energy supply and waste management while Mpumalanga province has made progress with a reported 3% reduction in emissions through its Climate Change Mitigation Strategy. However, many provinces still lack specific targets for clean energy adoption and require further investment and strategic development.[536] Provincial initiatives, such as in Gauteng, focus on reducing emissions through clean energy production but there is a significant gap due to lack of comprehensive strategies and legislative frameworks needed to achieve net-zero emissions.[537] City level initiatives are also available with various cities aiming to adopt and publish long-term climate action plans, ensuring alignment with national and provincial policies. In 2020, the Electricity Regulations on New Energy Generation Capacity of the Electricity Regulation Act (2006) was amended to enable municipalities with adequate finances to procure generation capacity in accordance with the national Integrated Resource Plan. The City of Cape Town, eThekwini, Johannesburg, Tshwane, and Ekurhuleni metropolitan municipalities have rolled out plans to procure energy from independent power producers, diversifying their power mix to include far more renewables.[538] Cape Town has committed to achieving carbon neutrality by 2050, including measures that explore electricity purchase from independent producers.[539]

Methane. To address methane emissions provinces have incorporated goals and objectives to ensure that producers capture and flare fugitive methane emissions within their climate change mitigation strategies and implementation plans.[540] Provinces have also established integrated waste management plans that promote recycling initiatives to reduce methane emissions from waste.[541] In their Vision 2050 report, Western Cape province identifies the need to manage methane and other short-lived emissions, but does not propose a specific action plan to address this issue.[542] Although such methane reduction targets are included in their climate initiative plans, they have not provided clear strategies, defined goals, and specific measures for implementation, which makes it difficult to assess their contributions to the NDCs. This highlights the need for comprehensive frameworks and strategies to effectively manage methane emissions.

4. Conclusion

Our bottom-up analysis shows that keeping the global 1.5°C goal will be an enormous challenge. With plausible, high-ambition country pathways, global aggregate GHG emissions decline by 35% by 2035 from the 2023 level, leading to a peak temperature of 1.7°C with median likelihood. These country pathways tend to reflect the highest ambition possible over the next decade, taking into consideration near-term, country-specific constraints and opportunities; however, rapidly advancing technologies, markets, policies, and consumer behaviors may further open up new space for faster emissions reductions. At the same time, institutions, infrastructure, trade, and global geopolitics may present additional implementation challenges and cause actions to fall short.

As for meeting global 1.5°C, there is no more room for delay. Immediate reversal of current trends and decisive accelerated actions are needed across all countries. One important strategy is to advance the all-of-society approach by mobilizing and integrating diverse non-state actors into national climate action. The all-of-society approach can leverage powers and strengths from different actors to maximize and reinforce the combined outcomes, as well as increase the robustness of transition to political uncertainty. Despite different climate governance or institutional structures across countries, subnational actors, such as states and provinces, cities, businesses, and civil society, have large potential and can make important contributions to enhance and deliver ambition.

The next steps of our research will focus on several aspects: first, maintain regular updates of the pathways to reflect latest technology, policy, and market trends; second, conduct and improve detailed policy modeling for other key emitting countries beyond the United States and China; third, develop analytical toolkits to explicitly represent subnational climate actions in the country pathways; and fourth, assess ambition implementation and the broad economic and societal outcomes at granular levels.

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