Technical Appendix
Enhancing Global Ambition for 2035: Assessment of High-Ambition Country Pathways

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Modeling method

Global Change Analysis Model (GCAM)

The Global Change Analysis Model (GCAM) is a global market equilibrium model that combines economic, energy, land use, and climate systems to analyze the interactions between human activities and global environmental changes. It is designed to assess the impacts of various policy scenarios and technology options on energy use, land use change, greenhouse gas emissions and climate change.[1] GCAM is a hierarchical market equilibrium model. The equilibrium in each period is solved by finding a set of market prices such that supplies and demands are equal in all simulated markets. As a dynamic recursive model, GCAM operates in 5-year time-increments till modeling year 2100, with each new period starting from the conditions that emerged in the last. After it solves each period, the model uses the resulting state of the world, including the consequences of decisions made in that period – such as resource depletion, capital stock retirements and installations, and changes to the landscape – and moves to the next time step and performs the same exercise. We use GCAM v.6.0 in this exercise. GCAM has previously been used to examine impacts of mitigation policies and technology deployment on greenhouse gas emissions.[2,3,4]

GCAM tracks emissions of 16 different species of GHGs and air pollutants from energy, agriculture, land use, and other industrial systems. In GCAM, the world is disaggregated into 32 economic regions, the resolution at which socioeconomics, energy, and market processes (including global trade) are modeled. Water flows and land use are modeled in more than 200 and 300 regions, respectively. The Earth system model (i.e., carbon-cycle climate module) Hector is the climate model within GCAM.[5]

Scenarios used in this analysis

1. Overall scenarios

[1] "GCAM v7.1 Documentation: Table of Contents," GitHub, 2024, https://jgcri.github.io/gcam-doc/toc.html.
[2] L. Clarke et al., "CO2 Emissions Mitigation and Technological Advance: An Updated Analysis of Advanced Technology Scenarios," *US Department of Energy & Pacific Northwest Laboratory*, 2008, https://www.pnnl.gov/science/pdf/PNNL18075.pdf.
[3] Jae Edmonds et al., "An Integrated Assessment of Climate Change and the Accelerated Introduction of Advanced Energy Technologies," *Mitigation and Adaptation Strategies for Global Change* 1, no. 4 (December 1, 1997): 311–39, https://doi.org/10.1007/BF00464886.
[4] Felipe Feijoo et al., "US Energy System Transitions under Cumulative Emissions Budgets," *Climatic Change* 162, no. 4 (October 1, 2020): 1947–63, https://doi.org/10.1007/s10584-020-02670-0.
[5] C. A. Hartin et al., "A Simple Object-Oriented and Open-Source Model for Scientific and Policy Analyses of the Global Climate System – Hector v1.0," *Geoscientific Model Development* 8, no. 4 (April 1, 2015): 939–55, https://doi.org/10.5194/gmd-8-939-2015.

We used the 1.5°C and delayed transition scenario from NGFS 2024 for high-ambition and low-ambitions scenarios. The NGFS scenarios are not forecasts, but aim at exploring the bookends of plausible futures.[6] The scenario narratives are regularly updated and expanded to reflect the most recent developments and technological ones (e.g. the availability of CDR), as well as delays in policy implementation within regions and globally. Most scenarios employ a top-down emissions constraint based on transition pathways at the regional level.[7]

- The net zero 2050 or 1.5°C scenario has a 50% chance of limiting average global warming to below 1.5°C by 2100, with an overshoot likely around mid-century. Global CO_2 emissions reach or approach zero in 2050 and countries with a political commitment to a net zero target meet the target in their respective target year (2050, 2060 or 2070). Some jurisdictions such as the US, EU, UK, Canada, Australia, and Japan reach net zero for all GHGs.
- The delayed transition scenario assumes countries stick to current policies until 2030 and experience a "fossil recovery", after which they transition such that the end-of-century temperature goal of 2°C warming is reached. Countries with net-zero policy target commitments are assumed to follow-through on 80% of them. Negative emissions are limited.

2. Specific scenarios and methodologies

For some countries, we used a different set of scenarios with detailed sectoral policy modeling or specific approaches to downscale GCAM results.

Australia:
Australia is not a standalone region in GCAM; therefore, we use downscaled scenario results for modeling. Australia is part of the Australia_NZ region in GCAM, where it largely dominates the outcomes, with New Zealand contributing only a small fraction.

Since global IAMs like GCAM provide projections at the level of world regions, the downscaled results are utilized from the approach developed by IIASA for the NGFS Consortium to capture the finer resolution required for regional or local analysis.[8] The downscaling tool provides country-level data for final, secondary, and primary energy variables as well as energy-related CO_2 emissions using regional input data from GCAM with population & GDP from baseline scenarios, and the energy-related historical data from IEA energy balances to initialize country variables at the base year. It generates two pathways (short-term projections consistent with historical data & GCAM results and long-term projections converging to regional results) to create a subset of key energy-system-related variables like emissions, primary energy and final energy have been downscaled to country level. The short- & long-term projection pathways are then harmonized, using linear interpolation between the base year and a future "time of convergence", which varies by underlying scenario storyline. Country-level pathways are developed using a weighted average of these projections, with weights adjusted for the longer term. Other databases for the power plant information, historical emissions and governance indicators and supply-cost curves for renewable energy potential are also employed.

[6] Ravi Menon and Livio Stracca, "NGFS Scenarios for Central Banks and Supervisors - Phase IV", Network for Greening the Financial System (NGFS), 2023, https://www.ngfs.net/en/ngfs-climate-scenarios-phase-iv-november-2023.
[7] Ravi Menon and Livio Stracca, "NGFS Scenarios for Central Banks and Supervisors - Phase IV", Network for Greening the Financial System (NGFS), 2023.
[8] Fabio Sferra, Bas van Ruijven, and Keywan Riahi, "Downscaling IAMs Results to the Country Level – a New Algorithm", (International Institute for Applied Systems Analysis (IIASA), 2021, https://pure.iiasa.ac.at/id/eprint/17501/1/NGFS_IIASA_report_2021_10_15_numbers.pdf.

The downscaling approach is further detailed in the NGFS Consortium Technical Documentation.[9]

Canada:
This study designed two bespoke scenarios for Canada that are part of forthcoming analysis. Canada is assumed to fully implement existing federal climate policies (Table S1) across all sectors of the economy in the Delayed Transition scenario. In the High Ambition scenario, Canada is assumed to additionally achieve net-zero GHG emissions, economy-wide, by 2050. Net LULUCF emissions are exogenously assumed to reach -50 $MtCO_2$ and -100 $MtCO_2$ by 2050 in the Delayed Transition scenario and High Ambition scenario, respectively.

Table S1. Modeled Canadian federal climate policies.

Sector	Policies	
Economy-wide	- Fuel charge - Clean fuel regulations	- HFC phase-down - Natural climate solutions
Electricity	- Clean electricity regulations - Clean electricity ITC	- Coal phase-out
Transportation	- LDV emissions regulations - Freight truck emissions regulations - LDV ZEV sales mandate - Freight truck ZEV sales target	- Bus ZEV sales target - ZEV incentives - ZEV infrastructure program - Active transportation strategy
Buildings	- Green buildings strategy - Greener homes loan and grant programs	- Green and inclusive community buildings program
Industrial and other sectors	- Output-based pricing system - Oil and gas methane reduction target - Net-zero accelerator / Strategic innovation fund - CCUS ITC	- Clean technology ITC - Hydrogen production ITC - Agricultural clean technology program - Landfill methane reduction target

China:
This analysis developed two scenarios with different levels of near-term policy actions using a detailed, bottom-up policy modeling approach through 2035. Under the Cpol scenario, current policy efforts were reflected through 2030 and extended through 2035 based on policy levers in Table S2. In the Aclt scenario, accelerated policy actions across these same levers were modeled through 2035 (Table S2). After 2035, emissions constraints were implemented to evaluate long-term transition pathways. Both scenarios achieve net zero CO_2 emissions excluding LULUCF. For the Aclt scenario, methane emissions were calculated using a preliminary bottom-up approach to achieve 35% emissions reduction by 2035 from 2020 levels.

[9] Oliver Ritchers et al., "NGFS Phase 5 Scenario Explorer", International Institute for Applied Systems Analysis (IIASA), 2024, https://data.ene.iiasa.ac.at/ngfs/.

Table S2. Scenario policy assumptions table across key policy levers.

Sector	Key Policy Lever	Current Policies Scenario (Cpol)	Accelerated Action Scenario (Aclt)
Electricity	Wind + solar deployment	2025 target based on FYP provincial targets; 2030 and 2035 based on **continued** growth rate from FYP provincial targets.	2025 target based on FYP provincial targets; 2030 and 2035 based on **enhanced** growth rate from FYP provincial targets.
	Coal	Increasing coal capacity in line with all new builds in the pipeline (400 GW) through 2035.	Increasing coal capacity in line with projects under construction (150 GW) through 2030.
Industry	Sector emissions peaking and reduction	Emissions reduction in key industry subsectors **in line** with current trends.	Emissions reduction in key industry subsectors **beyond** current trends.
	Electrification	Increasing electrification **in line** with current trends.	Increasing electrification **beyond** current trends.
Buildings	Coal use	Remove scattered coal **according to** current policy trends, by 2035.	Remove scattered coal **earlier than** current policy trends, by 2030.
	Electrification	Increasing electrification **in line** with current trends.	Increasing electrification **beyond** current trends.
Transportation	Oil consumption peak	Oil demand peaks **in line** with current trends.	Oil demand peaks **earlier than** current trends.
	EV new sales target	EV sales increase **according to** announced policy targets.	EV sales increase according to current trends, **beyond** announced policy targets.
	Freight EV penetration	EV sales increase **according to** announced policy targets.	EV sales increase according to current trends, **beyond** announced policy targets.
Non-CO_2s	Methane emissions reduction	Reduce methane emissions according **to announced** policy targets.	Enhance methane emissions reductions **beyond** announced policy targets, to align with global goals.
Economy-wide carbon price	Price on FFI CO_2	Small carbon price through 2035	Triple 2035 price from 2025, still low

India:

This analysis established a high ambition scenario between the 2°C and delayed transition scenario from NGFS 2024 with additional adjustments in the power sector, demand, and methane (see below), weighing India's development context against the need for limiting mid-century warming and achieving mitigation in the near term. The NGFS 2°C scenario has a 67% chance of limiting global warming to below 2°C throughout 2100. It assumes a gradually increasing stringency in climate targets, but countries with net-zero goals achieve 80% of their target and others follow less ambitious trajectories. [10]

[10] "NGFS Scenarios Portal," Network for Greening the Financial System (NGFS), 2024, https://www.ngfs.net/ngfs-scenarios-portal/.

Since India has not specified any peaking year for emissions, we assume emissions - after small additional increases until 2025 to flatten and stay constant until 2030 and reduce linearly thereafter towards the country's net zero CO_2 emissions goal in 2070. We consider this to be a high ambition scenario which is achievable for India with ramping up of renewable energy capacity and rapid electrification of end use, especially industry. With no further addition of unabated fossil fuel generation, this scenario can limit the problem of potential stranded assets in the power sector.

Power sector: Adjustments were made to power sector output given the high level of electricity demand projected in initial modeled results. To identify reasonable but ambitious pathways, we developed several different scenarios using historical data from EMBER, government projections[11,12], and a range of demand and solar and wind growth assumptions. A baseline scenario was developed by calculating annual rate of change for generation and capacity across technology from 2023, 2027 and 2032 government projections and applying the latest EMBER historical data. Additional scenarios ambitious_RE scenarios that have increased solar and wind growth, as capacity added annually is doubled from government projections. Sensitivities were developed that adjusted demand growth in the ambitious_RE scenarios by 4%, 5% and 6% annually. Coal in these scenarios was calculated as the difference between the sum of all other technologies and total demand. Other technologies were not adjusted from government projections.

Mission LiFE: The Indian government started a program - Mission LiFE (Lifestyle For Environment)[13] as a panacea to rising emissions, suggesting that reduced demand and lifestyle changes embedded in the national traditions and behavioral changes can achieve enhanced reductions. While the program is widely promoted and mentioned in the NDC submissions, the actual reductions achieved are unclear, if any. Further, the strategies for scale up and application across sectors remain vague[14].

Methane policies: The Indian Council of Agricultural Research (ICAR) has established programs to enhance the resilience of Indian agriculture to climate change and climate vulnerability, and efforts include developing technologies with methane mitigation potential such as direct-seeded rice systems and crop diversification programs.[15]

- The New National Biogas and Organic Manure Programme (NNBOMP) and Galvanising Organic Bio-Agro Resources Dhan (GOBAR-Dahn) initiative promote biogas production from cattle manure and organic wastes.[16,17]
- India's National Dairy Development Board has been working on developing programs for reducing methane emissions from cattle, through changes in management and feeding

[11] India's Ministry of Power, "Press Release: Central Electricity Authority Notifies the National Electricity Plan for the Period of 2022-32," 2023, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1928750.
[12] Central Electricity Authority (CEA), Ministry of Power, "National Electricity Plan (Volume I)," 2023, https://mnre.gov.in/document/national-electricity-plan-volume-i-generation-by-cea/.
[13] Government of India, "LiFE - About," LiFE - Lifestyle for Environment, 2024, https://missionlife-moefcc.nic.in/aboutLiFE.php.
[14] Government of India, "LiFE - About," LiFE - Lifestyle for Environment, 2024.
[15] India's Ministry of Environment, Forest and Climate Change, "Measures to Reduce Methane Emissions," July 24, 2023, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1942106#:~:text=Feeding%20livestock%20with%20superior%20quality,reduce%20methane%20emissions%20from%20livestock.
[16] India's Ministry of New and Renewable Energy, "Methane Reduction Policies," 2021, https://www.globalmethane.org/challenge/mnre.html.
[17] Department of Drinking water and Sanitation, Ministry of Jal Shakti, "Galvanizing Organic Bio-Agro Resources Dhan (GOBARDhan)," National Portal of India, 2023, https://www.india.gov.in/spotlight/gobardhan-galvanizing-organic-bio-agro-resources-dhan.

practices.[18] The National Livestock Mission includes a strategy to improve livestock breeding and reduce etheric fermentation.[19]

- India has implemented the Cooling Action Plan, which in part focuses on expanding cooling throughout the food supply chain to reduce food waste.[20]

Indonesia:
In this analysis we used the 2°C and delayed transition scenario from NGFS 2024 for high-ambition and low-ambitions scenarios, with additional adjustments in methane, land-use change, and power sector (see below).[21] The 2°C scenario has a 67% likelihood of keeping global warming below 2°C through 2100. It assumes progressively stricter climate targets, with countries aiming for net-zero achieving 80% of their goals, while others pursue less ambitious paths.

Methane: Our high ambition scenario includes a 25% methane reduction in 2030 from 2020 and a 33% reduction in 2035, while the low ambition scenario assumes growing and then declining methane emissions to the 2020 level by 2035.

Land Use Change: We estimate land use and forestry emissions under the low-ambition and high-ambition scenarios through 2030, using the Existing Measures Scenario and Strengthen Measures Scenario from Wijaya, A., et al. (2017)[36], respectively. From 2030 to 2035, emissions were extrapolated assuming the same annual decline rate estimated for the period from 2022 to 2030. In the scenario, we used historical data from the GCB-Oscar model, as its historical values were closer to ones presented by the country in its NDC.

Power Sector: For the low ambition scenario we used the JETP scenario published in the Comprehensive Investment and Policy Plan (CIPP), adding captive expected emissions from the BAU scenario from Borrero et al, 2024. For the high ambition scenario we used the combined 1.5 aligned scenario from Borrero et al, 2024.[22]

United States:
We used the Current Policies and Enhanced Ambition scenarios from Zhao, et al. (2024).[23] The Current Policies scenario incorporates climate and energy measures from the Inflation Reduction Act (IRA), the Bipartisan Infrastructure Law (BIL), and various other federal and non-federal climate policies. The Enhanced Ambition scenario, meanwhile, models potential GHG emissions reductions through a comprehensive, society-wide climate strategy that expands on the policy framework in the Current Policies scenario with additional federal and non-federal action. In particular, it considers contributions from states, cities, and businesses, alongside strengthened federal regulatory measures, to achieve a

[18] National Dairy Development Board, "Methane Emission Reduction," 2017, https://www.nddb.coop/services/animalnutrition/climate-smart-dairying/methane-emission-reduction.
[19] Department of Animal Husbandry and Dairying, "National Livestock Mission," May 11, 2023, https://dahd.nic.in/schemes/programmes/national_livestock_mission.
[20] India's Ministry of Environment, Forest and Climate Change, "India Cooling Action Plan," 2019, https://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf.
[21] Networks for Greening the Financial System (NGFS), "NGFS Scenarios Portal," 2024.
[22] Maria A. Borrero et al., "1.5°C-Aligned Coal Power Transition Pathways in Indonesia: Additional Strategies Beyond the Comprehensive Investment and Policy Plan (CIPP)," 2024, https://cgs.umd.edu/sites/default/files/2024-06/Final_Indonesia%20Report_JETP_6.4.pdf.
[23] Alicia Zhao et al., "Forging a High-Ambition. U.S. Climate Pathway" (Center for Global Sustainability, University of Maryland, 2024), https://cgs.umd.edu/sites/default/files/2024-09/CGS_Toward%202035_Forging%20a%20High-Ambition%20US%20Climate%20Pathway_September%202024.pdf.

new ambitious emissions reduction target by 2035.[24] Further details are provided in the technical appendix to Zhao et al.[25]

Data

For both scenarios, emission results were calibrated through 2020 using PRIMPAP-hist GHG emissions data from 1990 to 2023 for all countries in the analysis.[26] Historical GHG emissions data (excluding LULUCF CO_2) by country and sector was sourced from the Community Emissions Data System (CEDS) to analyze sector-specific emissions.[27] Data on historical electricity generation and power capacity by country was obtained from EMBER's Electricity Data Explorer.[28] Information on coal- and gas-fired power plants used for power sector analysis in various countries came from the Global Energy Monitor.[29,30] Historical LULUCF data by country was sourced from the Global Carbon Budget and national inventories submitted to the UNFCCC in the Biennial Update Reports.[31,32] Data on EV sales and EV penetration used to analyze the transportation sector in some countries was sourced from the IEA Global EV Outlook.[33]

Additional figures and tables

Table S3. Total GHG Emissions Reductions by 2035 for the G20 Countries and Globally Under the *Delayed Transition* 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	-61%	-10%	-24%
Japan	2013	-46%	-48%	-32%
Republic of Korea	2018	-21%	-23%	-13%

[24] Alicia Zhao et al., "Technical Appendix Toward 2035: Forging a High Ambition U.S. Climate Pathway" (Center for Global Sustainability (CGS), University of Maryland, 2024), https://cgs.umd.edu/sites/default/files/2024-09/Technical%20Appendix_Toward%202035_Forging%20a%20High-Ambition%20U.S.%20Climate%20Pathway%20.pdf.
[25] Alicia Zhao et al., "Technical Appendix Toward 2035: Forging a High Ambition U.S. Climate Pathway" (Center for Global Sustainability (CGS), University of Maryland, 2024).
[26] Johannes Gütschow and Mika Pflüger, "The PRIMAP-Hist National Historical Emissions Time Series (1750-2022) v2.5", Zenodo, 2023, https://zenodo.org/records/10006301.
[27] Patrick R O'Rourke et al., "CEDS V_2021_02_05 Release Emissions Data", 2021, https://zenodo.org/records/4509372.
[28] Ember, "Electricity Data Explorer - Open Source Global Electricity Data," 2024, https://ember-climate.org/data/data-tools/data-explorer/.
[29] "Global Coal Plant Tracker," Global Energy Monitor, 2024, https://globalenergymonitor.org/projects/global-coal-plant-tracker/.
[30] "Global Oil and Gas Plant Tracker," Global Energy Monitor, 2024, https://globalenergymonitor.org/projects/global-oil-gas-plant-tracker/download-data/.
[31] Pierre Friedlingstein et al., "Global Carbon Budget 2023," *Earth System Science Data* 15, no. 12 (December 5, 2023): 5301–69, https://doi.org/10.5194/essd-15-5301-2023.
[32] "Biennial Update Report Submissions from Non-Annex I Parties," UNFCCC, 2019-2024, https://unfccc.int/BURs.
[33] IEA, Global EV Outlook 2024, International Energy Agency (IEA), 2024, https://www.iea.org/reports/global-ev-outlook-2024.

United Kingdom	1990	-63%	-64%	-26%
EU27BX	1990	-54%	-58%	-35%
United States	2005	-47%	-42%	-29%
Australia	2005	-51%	-38%	-36%
Canada	2005	-41%	-32%	-26%
Argentina	2007*	-26%	-6%	-12%
South Africa	2012*	-36%	-36%	-25%
China	2023**	-15%	-15%	-15%
Mexico	2025**	-16%	-16%	-14%
Saudi Arabia	2019	-13%	-13%	-14%
Turkey	2021*	-18%	-18%	-15%
Russia	1990	-53%	-44%	-21%
Indonesia	2025**	-23%	-8%	3%
India	2030**	-12%	-13%	12%
RoW	tba	tba	tba	tba
World	2023	-12%	-14%	-14%

*Estimated peak year based on Primap historical data, total GHG emissions excluding LULUCF.

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

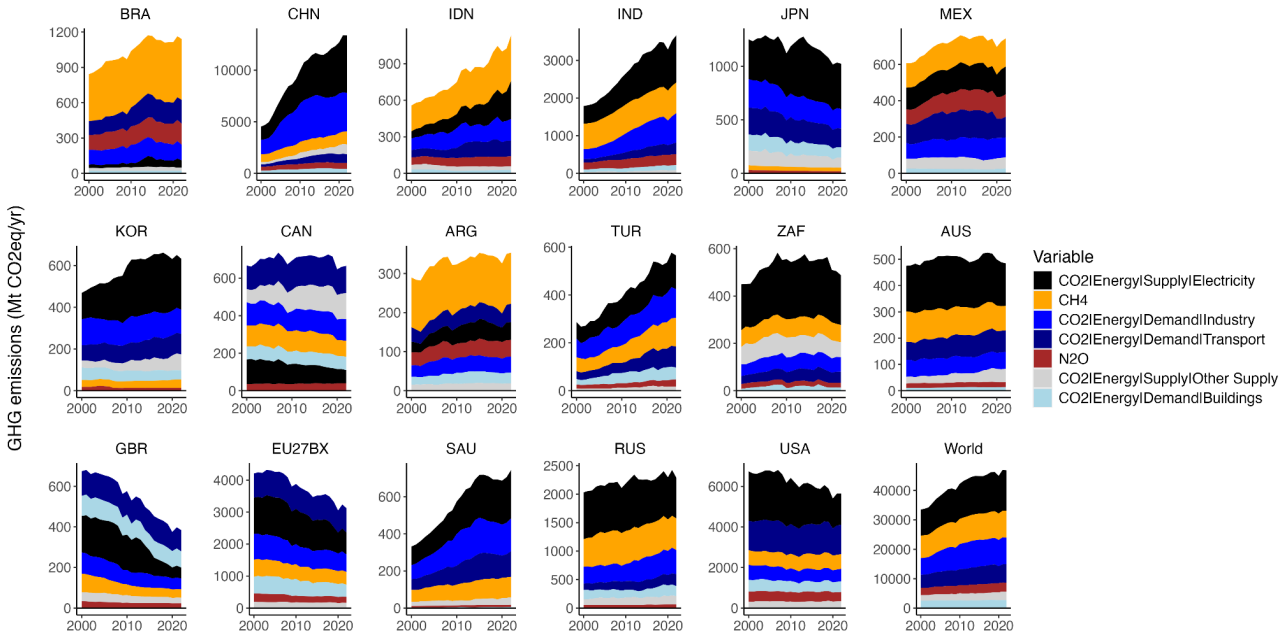

Figure S1. Historical GHG (excluding LULUCF CO_2) emissions by region and sector, sorted from largest to smallest in 2022.[34]

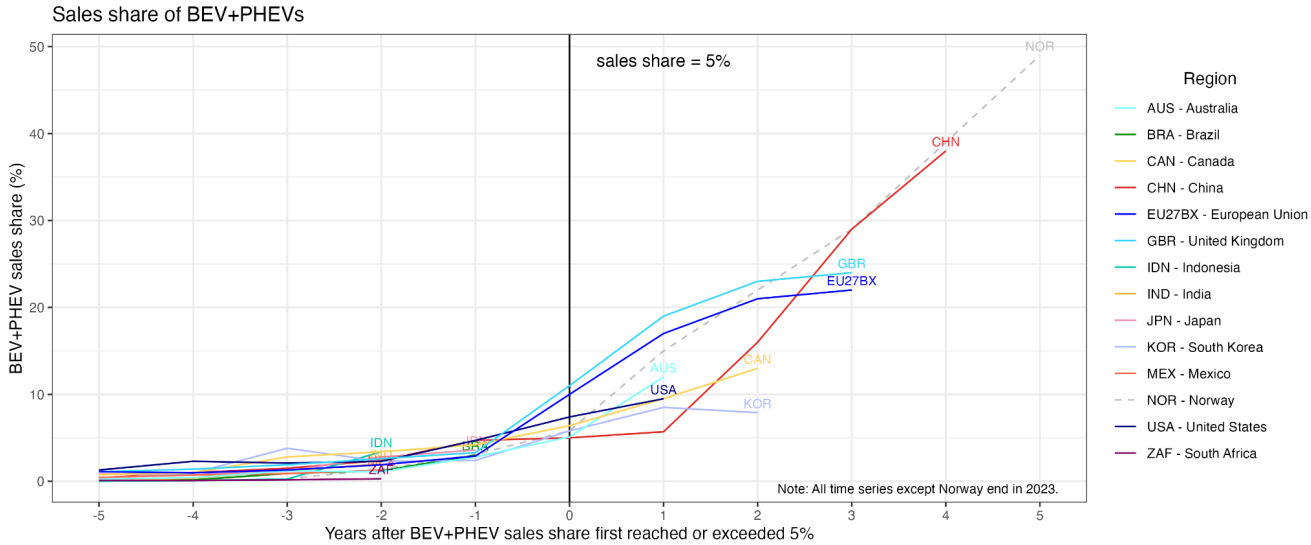

Figure S2. Sales share of combined BEVs (Battery Electric Vehicles) and PHEVs (Plug-in Hybrid Electric Vehicles) in different regions. The x-axis shows the years passed since the respective country first reached or exceeded 5%. All trajectories end in 2023, except for Norway, where the visible trajectory concludes in 2018 when the country achieved a 50% sales share. Since then, Norway's sales share has risen to 93% as of 2023. Source: IEA Global EV Outlook.[35]

[34] Patrick R O'Rourke et al., "CEDS V_2021_02_05 Release Emission Data", Zenodo, 2021.
[35] IEA, Global EV Outlook 2024, International Energy Agency (IEA), 2024.

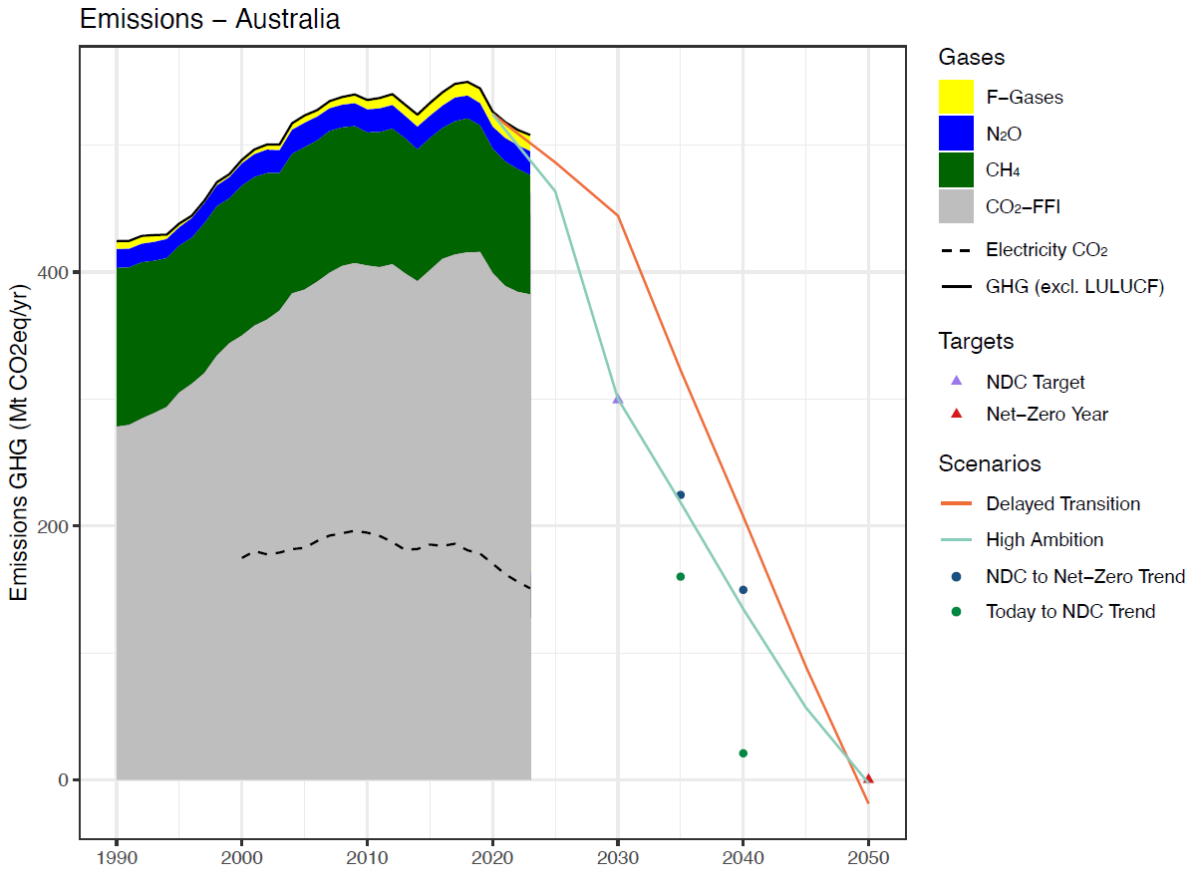

Figure S3. Australia's GHG excluding LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[36] (solid black line for total GHG, exclude LULUCF), Ember[37] (dashed black line for electricity supply GHG emissions), and CEDS[38] (colored breakdown of historic GHG emissions, without 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 excludes LULUCF emissions and is from downscaled scenarios based on the Australia_NZ region of the GCAM model from the NGFS Phase V scenarios.[39]

[36] Johannes Gütschow and Mika Pflüger, "The PRIMAP-Hist National Historical Emissions Time Series (1750-2022) v2.5", Zenodo, 2023.
[37] Ember, "Electricity Data Explorer - Open Source Global Electricity Data," 2024.
[38] Patrick R O'Rourke et al., "CEDS V_2021_02_05 Release Emissions Data", Zenodo, 2021.
[39] "NGFS Scenarios Portal," Network for Greening the Financial System (NGFS), accessed November 5, 2024.

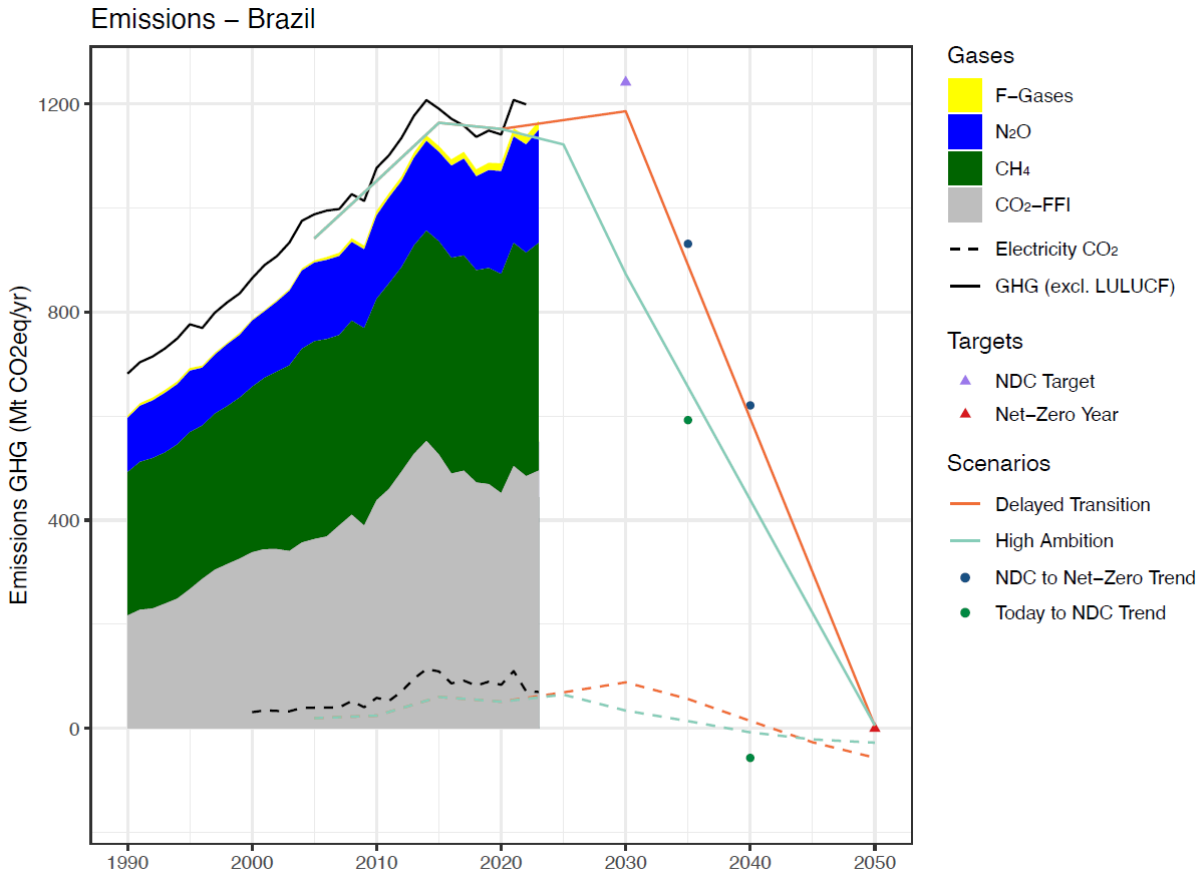

Figure S4. Brazil's GHG excluding LULUCF emission pathways across scenarios. Historical data is from MICT[40] until 2020, SEEG[41] for 2021 and 2022, PRIMAP-hist[42] for 2023 (solid black lines for total GHG excluding LULUCF), Ember[43] (dashed black line for electricity supply GHG emissions), and CEDS[44] (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 excludes LULUCF emissions and is based on the scenarios developed using the GCAM IAM for the NGFS Phase V.[45]

[40] Ministério da Ciência, Tecnologia e Inovação, "Emissões de GEE por Setor," 2023, https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene/emissoes/emissoes-de-gee-por-setor-1.
[41] Climate Observatory, "Sistema de Estimativa de Emissão de Gases (SEEG)," 2024, SEEG, https://plataforma.seeg.eco.br/?highlight=br-net-emissions-by-sector&_gl=1*wq3k9d*_ga*MTkxMTAyMDg2NS4xNzIxOTAxMjYx*_ga_XZWSWEJDWQ*MTcyMTkwMTI2MS4xLjEuMTcyMTkwMTMwNy4wLjAuMA.
[42] Johannes Gütschow and Mika Pflüger, "The PRIMAP-Hist National Historical Emissions Time Series (1750-2022) v2.5", Zenodo, 2023.
[43] Ember, "Electricity Data Explorer - Open Source Global Electricity Data," 2024.
[44] Patrick R O'Rourke et al., "CEDS V_2021_02_05 Release Emissions Data", 2021.
[45] Networks for Greening the Financial System, "NGFS Scenarios Portal," 2024.

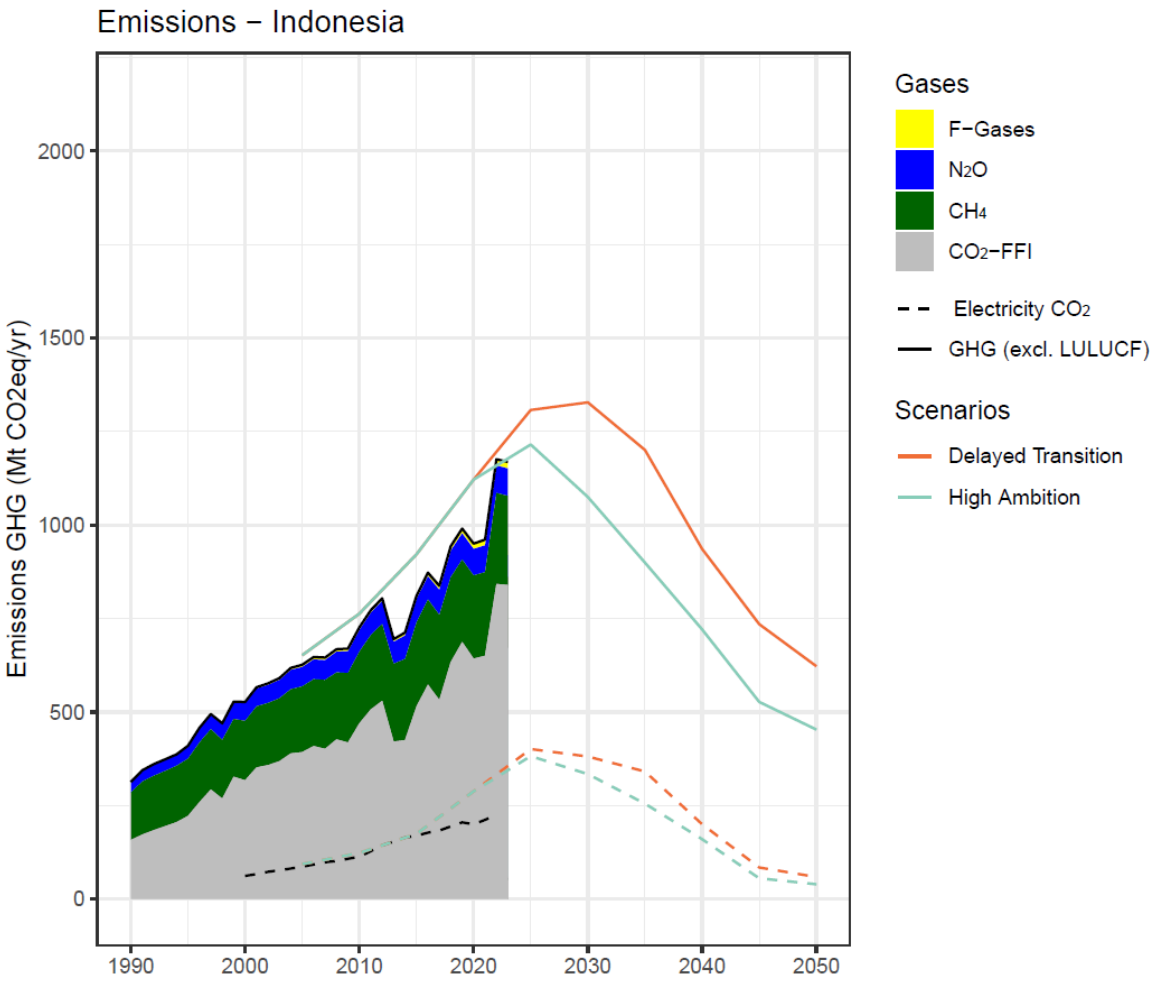

Figure S5. Indonesia's GHG excluding LULUCF emission pathways across scenarios. Historical data is from PRIMAP-hist[46] (solid black line for total GHG, exclude LULUCF), Ember[47] (dashed black line for electricity supply GHG emissions), and CEDS[48] (colored breakdown of historic GHG emissions, without F-Gases). Pathways data exclude LULUCF emissions and is based on the scenarios developed using the GCAM IAM for the NGFS Phase V.[49]

[46] Johannes Gütschow and Mika Pflüger, "The PRIMAP-Hist National Historical Emissions Time Series (1750-2022) v2.5", Zenodo, 2023.
[47] Ember, "Electricity Data Explorer - Open Source Global Electricity Data," 2024.
[48] Patrick R O'Rourke et al., "CEDS V_2021_02_05 Release Emissions Data", Zenodo, 2021.
[49] "NGFS Scenarios Portal," Network for Greening the Financial System (NGFS), accessed November 5, 2024.

References

1. "GCAM v7.1 Documentation: Table of Contents," GitHub, 2024, https://jgcri.github.io/gcam-doc/toc.html.
2. L. Clarke et al., "CO2 Emissions Mitigation and Technological Advance: An Updated Analysis of Advanced Technology Scenarios," *US Department of Energy & Pacific Northwest Laboratory*, 2008, https://www.pnnl.gov/science/pdf/PNNL18075.pdf.
3. Jae Edmonds et al., "An Integrated Assessment of Climate Change and the Accelerated Introduction of Advanced Energy Technologies," *Mitigation and Adaptation Strategies for Global Change* 1, no. 4 (December 1, 1997): 311–39, https://doi.org/10.1007/BF00464886.
4. Felipe Feijoo et al., "US Energy System Transitions under Cumulative Emissions Budgets," *Climatic Change* 162, no. 4 (October 1, 2020): 1947–63, https://doi.org/10.1007/s10584-020-02670-0.
5. C. A. Hartin et al., "A Simple Object-Oriented and Open-Source Model for Scientific and Policy Analyses of the Global Climate System – Hector v1.0," *Geoscientific Model Development* 8, no. 4 (April 1, 2015): 939–55, https://doi.org/10.5194/gmd-8-939-2015.
6. Ravi Menon and Livio Stracca, "NGFS Scenarios for Central Banks and Supervisors - Phase IV", Network for Greening the Financial System (NGFS), 2023, https://www.ngfs.net/en/ngfs-climate-scenarios-phase-iv-november-2023.
7. Ravi Menon and Livio Stracca, "NGFS Scenarios for Central Banks and Supervisors - Phase IV", Network for Greening the Financial System (NGFS), 2023.
8. Fabio Sferra, Bas van Ruijven, and Keywan Riahi, "Downscaling IAMs Results to the Country Level – a New Algorithm", (International Institute for Applied Systems Analysis (IIASA), 2021, https://pure.iiasa.ac.at/id/eprint/17501/1/NGFS_IIASA_report_2021_10_15_numbers.pdf.
9. Oliver Ritchers et al., "NGFS Phase 5 Scenario Explorer", International Institute for Applied Systems Analysis (IIASA), 2024, https://data.ene.iiasa.ac.at/ngfs/.
10. "NGFS Scenarios Portal," Network for Greening the Financial System (NGFS), 2024, https://www.ngfs.net/ngfs-scenarios-portal/.
11. India's Ministry of Power, "Press Release: Central Electricity Authority Notifies the National Electricity Plan for the Period of 2022-32," 2023, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1928750.
12. Central Electricity Authority (CEA), Ministry of Power, "National Electricity Plan (Volume I)," 2023, https://mnre.gov.in/document/national-electricity-plan-volume-i-generation-by-cea/.
13. Government of India, "LiFE - About," LiFE - Lifestyle for Environment, 2024, https://missionlife-moefcc.nic.in/aboutLiFE.php.
14. Government of India, "LiFE - About," LiFE - Lifestyle for Environment, 2024.
15. India's Ministry of Environment, Forest and Climate Change, "Measures to Reduce Methane Emissions," July 24, 2023, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1942106#:~:text=Feeding%20livestock%20with%20superior%20quality,reduce%20methane%20emissions%20from%20livestock.
16. India's Ministry of New and Renewable Energy, "Methane Reduction Policies," 2021, https://www.globalmethane.org/challenge/mnre.html.
17. Department of Drinking water and Sanitation, Ministry of Jal Shakti, "Galvanizing Organic Bio-Agro Resources Dhan (GOBARDhan)," National Portal of India, 2023, https://www.india.gov.in/spotlight/gobardhan-galvanizing-organic-bio-agro-resources-dhan.
18. National Dairy Development Board, "Methane Emission Reduction," 2017, https://www.nddb.coop/services/animalnutrition/climate-smart-dairying/methane-emission-reduction.
19. Department of Animal Husbandry and Dairying, "National Livestock Mission," May 11, 2023, https://dahd.nic.in/schemes/programmes/national_livestock_mission.
20. IIndia's Ministry of Environment, Forest and Climate Change, "India Cooling Action Plan," 2019, https://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf.
21. Networks for Greening the Financial System (NGFS), "NGFS Scenarios Portal," 2024.
22. Maria A. Borrero et al., "1.5°C-Aligned Coal Power Transition Pathways in Indonesia: Additional Strategies Beyond the Comprehensive Investment and Policy Plan (CIPP)," 2024, https://cgs.umd.edu/sites/default/files/2024-06/Final_Indonesia%20Report_JETP_6.4.pdf.
23. Alicia Zhao et al., "Forging a High-Ambition. U.S. Climate Pathway" (Center for Global Sustainability, University of Maryland, 2024), https://cgs.umd.edu/sites/default/files/2024-09/CGS_Toward%202035_Forging%20a%20High-Ambition%20US%20Climate%20Pathway_September%202024.pdf.
24. Alicia Zhao et al., "Technical Appendix Toward 2035: Forging a High Ambition U.S. Climate Pathway" (Center for Global Sustainability (CGS), University of Maryland, 2024), https://cgs.umd.edu/sites/default/files/2024-09/Technical%20Appendix_Toward%202035_Forging%20a%20High-Ambition%20U.S.%20Climate%20Pathway%20.pdf.
25. Alicia Zhao et al., "Technical Appendix Toward 2035: Forging a High Ambition U.S. Climate Pathway" (Center for Global Sustainability (CGS), University of Maryland, 2024).
26. Johannes Gütschow and Mika Pflüger, "The PRIMAP-Hist National Historical Emissions Time Series (1750-2022) v2.5", Zenodo, 2023, https://zenodo.org/records/10006301.
27. Patrick R O'Rourke et al., "CEDS V_2021_02_05 Release Emissions Data", 2021, https://zenodo.org/records/4509372.
28. Ember, "Electricity Data Explorer - Open Source Global Electricity Data," 2024, https://ember-climate.org/data/data-tools/data-explorer/.
29. "Global Coal Plant Tracker," Global Energy Monitor (GEM), 2024, https://globalenergymonitor.org/projects/global-coal-plant-tracker/.
30. "Global Oil and Gas Plant Tracker," Global Energy Monitor (GEM), 2024, https://globalenergymonitor.org/projects/global-oil-gas-plant-tracker/download-data/.
31. Pierre Friedlingstein et al., "Global Carbon Budget 2023," *Earth System Science Data* 15, no. 12 (December 5, 2023): 5301–69, https://doi.org/10.5194/essd-15-5301-2023.
32. "Biennial Update Report Submissions from Non-Annex I Parties," UNFCCC, 2019-2024, https://unfccc.int/BURs.
33. IEA, Global EV Outlook 2024, International Energy Agency (IEA), 2024, https://www.iea.org/reports/global-ev-outlook-2024.

34. Patrick R O'Rourke et al., "CEDS V_2021_02_05 Release Emission Data", Zenodo, 2021.
35. IEA, Global EV Outlook 2024, International Energy Agency (IEA), 2024.
36. Johannes Gütschow and Mika Pflüger, "The PRIMAP-Hist National Historical Emissions Time Series (1750-2022) v2.5", Zenodo, 2023.
37. Ember, "Electricity Data Explorer - Open Source Global Electricity Data," 2024.
38. Patrick R O'Rourke et al., "CEDS V_2021_02_05 Release Emissions Data", Zenodo, 2021.
39. "NGFS Scenarios Portal," Network for Greening the Financial System (NGFS), accessed November 5, 2024.
40. Ministério da Ciência, Tecnologia e Inovação, "Emissões de GEE por Setor," 2023, https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene/emissoes/emissoes-de-gee-por-setor-1.
41. Climate Observatory, "Sistema de Estimativa de Emissão de Gases (SEEG)," 2024, SEEG, https://plataforma.seeg.eco.br/?highlight=br-net-emissions-by-sector&_gl=1*wq3k9d*_ga*MTkxMTAyMDg2NS4xNzIxOTAxMjYx*_ga_XZWSWEJDWQ*MTcyMTkwMTI2MS4xLjEuMTcyMTkwMTMwNy4wLjAuMA.
42. Johannes Gütschow and Mika Pflüger, "The PRIMAP-Hist National Historical Emissions Time Series (1750-2022) v2.5", Zenodo, 2023.
43. Ember, "Electricity Data Explorer - Open Source Global Electricity Data," 2024.
44. Patrick R O'Rourke et al., "CEDS V_2021_02_05 Release Emissions Data", 2021.
45. Networks for Greening the Financial System, "NGFS Scenarios Portal," 2024.
46. Johannes Gütschow and Mika Pflüger, "The PRIMAP-Hist National Historical Emissions Time Series (1750-2022) v2.5", Zenodo, 2023.
47. Ember, "Electricity Data Explorer - Open Source Global Electricity Data," 2024.
48. Patrick R O'Rourke et al., "CEDS V_2021_02_05 Release Emissions Data", 2021.
49. "NGFS Scenarios Portal," Network for Greening the Financial System (NGFS), accessed November 5, 2024.